Socially Motivated Approach to Simulate Negotiation Process

SOCIALLY MOTIVATED APPROACH TO SIMULATE NEGOTIATION PROCESS

by

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Approval Signatures

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Abstract

Automated negotiation is treated as multi-disciplinary area of rigorous research consisting of Multi Agent Systems (MAS) such as optimization, decision support system, game theory and e-commerce. Thus, automated negotiations can be treated as a search space problem where different autonomous agents try to occupy their own utilities via finding the best possible option obtained from the search space. In this work, a comprehensive study was conducted on the negotiations' elements in order to model Agent Z. Cultural algorithms were used in the modeling as they offer a dual inheritance system between the belief space and population space. Agent Z was modeled to be compatible with General Environment for Negotiation with Intelligent multi-purpose Usage Simulator (GENIUS). Moreover, the simulator allows agent Z to negotiate with a human negotiator through a user interface window. Agent Z has three major improvements through its versions (V1.0, V2.0, and V3.0). In Agent Z–V1.0, the agent was modeled to deal with cooperating opponents. In this version, the population size was fixed and independent on the domain size. Moreover, the termination operator was time and utility dependent. In Agent Z-V2.0 the number of children was changed to a percentage of the domain size instead of a fixed number in version 1. Additionally, a memory was added to the agent to store best offers sent from the opponents. An important modification in V2.0 was the algorithm of producing the child generation from several parents unlike V1.0, which was produced from two parents only. An internal clock was added to V2.0 that divided the time into two phases. Lastly Agent Z-V3.0 was a hybrid agent that integrated V1.0 and V2.0 and a C factor was introduced. Agent Z is much more cooperative than other agents and tends to find win-win agreement rather than win a negotiation. It has been observed that when negotiators cooperate the time to reach an agreement is faster than competing agents. Finally Agent Z was found to perform well with time and utility dependent agents unlike utility only dependent agents who were forced to accept the best offer sent when time is about to finish.

Search Terms:

Negotiation, Negotiation Agent, Automated Negotiation, Negotiation Strategy, and Cultural Algorithm.

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Abbreviations

MAS	Multi Agent System
PDG	Prisoners' Dilemma Game
GA	Genetic Algorithm
CA	Cultural Algorithm
KDE	Kernel Density Estimation
GENIUS	General Environment for Negotiation with Intelligent multi-purpose Usage Simulation
BAI	Best Accepted Individual
MaxNTU	Maximum Normative Target Utility
MinNTU	Minimum Normative Target Utility
SKU	Situational Knowledge Utility
ANAC	Automated Negotiating Agent Competition

Chapter 1: Introduction

1.1. Background

In 1899, Gorge Eastman, the founder of Kodak Company, was interested in buying the full right of Velox, a photographic printing paper machine, from Leo Baekeland. Accordingly, Eastman invited Leo to come to Rochester, New York to negotiate the price. Baekeland planned to ask for $50,000 for his invention, and if worse comes to worse in negotiation, to take no less than $25,000 for it. However, Eastman spoke first and offered him one million dollar, which made Baekeland a millionaire at 35 years of age [**1**].

This short historical story motivated the research on negotiation and its process. It also highlighted the impact of uncertainty about the opponent's preferences on the negotiation outcome. Negotiation is an essential part of human activities, since each negotiator tries to achieve better individual payoffs, and tries to avoid the phenomenon of "leaving some money on the table" [**2**]. Negotiation has a great deal of application in business life. It plays a critical role in sales, marketing, procurement [**2**], human resource management [**3**], and business contracts.

1.2. Overview of Automated Negotiation

As the world is constrained with limited resources, negotiation has long been considered as a necessary activity. Negotiation is the act by which a group of parties try to reach an agreement over some matter [**4**]. The mutually beneficial agreement is reached through communication, compromising and modifying the local preferences between negotiating parties [**5**,**6**,**7**]. Generally, negotiation is referred to as the process of which bi-lateral or multi-lateral parties communicate through communication protocol, with each other, to reach a mutually accepted agreement over single or multiple issues. For instance, one can negotiate with a real estate developer on the price of a property (single-issue bi-lateral negotiation). Also, another scenario could be the negotiation with real estate developer on the price, payment plan and warranty of a property (multi-issue bi-lateral negotiation).

Automated negotiation is treated as a multi-disciplinary area of rigorous research consisting of MAS (Multi Agent Systems) such as optimization, decision support system, game theory and e-commerce. Researchers from different fields have different perceptions and views for automated negotiation and its possible applications. Some researchers have categorized it as a search problem and accordingly, automated negotiation can be treated as a search space problem where different autonomous agents try to occupy their own utilities via finding the best possible option obtained from the search space.

1.3. Automated Negotiation Elements

Automated negotiation models vary, and basically almost all of them consist of four elements [**8**,**9**]:

1. Negotiation Protocol
2. Strategies Space
3. Negotiation Environment
4. Negotiating Agent

The following subsections will explain briefly each elements of automated negotiation.

1.3.1. Negotiation Protocol

Negotiation protocol consists of a set of rules administering the communication between negotiating agents. Those rules include: allowed types of participants (e.g. negotiators, mediators or third party), state of negotiation and valid actions in a given state, such as “waiting for offer submission” or “termination” of negotiation session. Termination could be by “accepting the offer” or “failure”. Failure occurs when one of the parties withdraws from the negotiation or the negotiation session time is out [**10**].

There are different types of protocols such as Dutch auctions, offer/critique, offer/counteroffer, and augmentation-based negotiation. In this work, the author focused on one style: “alternating offers and counteroffers” protocol called the “*negotiation dance*” [**11**]. This refers to the feedback and response on a received proposal by an alternative proposal. Informally, Agent A requests Agent B to provide him with service or product X. Agent B responses that s/he is willing to provide Agent A with the service or product X, if Agent A provides him/her with service or product Y.

If actions of "*confirm*" and "*deny*" are introduced to the alternating offers protocol, then the model will be allowed to deal with one-to-many negotiation. For example, if a seller sends an offer to many buyers (e.g. buyer 1, 2, 3, etc.) and then they respond with acceptance, the seller here will need to "confirm" one of the offers and "deny" the rest as proposed in [**12**] and illustrated in Figure 1.

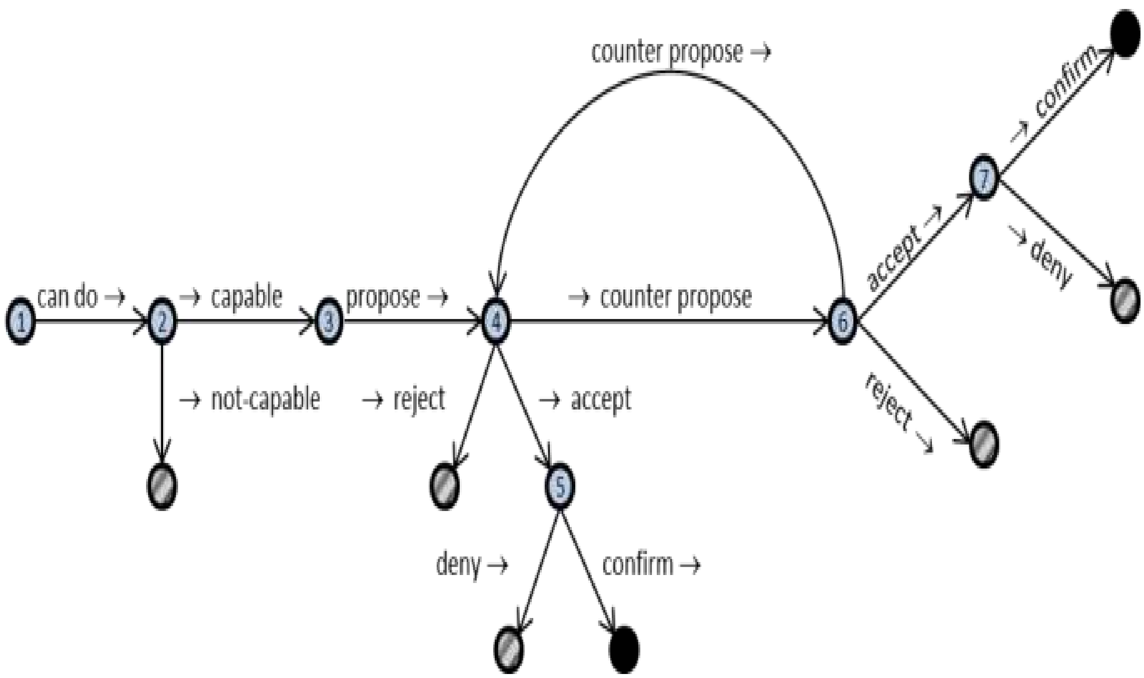

Figure 1 : ADEPTs Negotiation Protocol [12]

1.3.2. Strategies Space

Strategy is the second negotiation element and it is defined as the agent's plan of actions within the environment to reach a long-term or overall goal [**4**]. Generally, there will be a space of strategies or offers, in which each offer has different outcomes. The challenge is to search for the optimal strategy or offer that will produce a maximum outcome for the agent. The optimal strategy, if one exists, relies on the knowledge obtained about negotiation parameters [**9**].

1.3.3. Negotiation Environment

While environment is the third element in negotiation, it represents the factors contributing in the negotiation, such as the number of agents, issues or topics, actions, time pressure, and the nature of negotiation. Negotiation nature could be in two forms based on negotiators' behavior and attitude, either "cooperative" or "competitive" [**6**]. In cooperative or "integrated" negotiation, each party has its own preferences but with different weights. The aim here is not to win all the issues, but to maximize the ones with higher weight. Such negotiation generally results in higher satisfaction levels; since it promotes cooperation between parties to reach a mutually accepted agreement [**13**]. This agreement is usually referred to as "Nash Equilibrium" [**14**] in which both parties reach a win-win stage. On the other hand, the competitive negotiation or "distribution" is a zero sum game, in which the gain for one party is a loss for the other. Each party will try to maximize his/her own payoff individually through predicting his/her opponents' preferences, limitations and strategies. The process eventually will yield winners and committed losers. This kind of environment will encompass tactics to force the negotiator's opponent to be in a weaker position (e.g. lying or hiding information) and; thus, it usually results in low satisfaction level [**13**]. The best model to illustrate cooperation and competition results is the "Prisoners' Dilemma Game" as shown in Figure 2.

Figure 2 : The Prisoner's Dilemma [13]

Negotiation is normally associated with uncertainty and incomplete information about opponent's strategy, reserve price, deadline or limits; making the study of negotiation a challenging problem. It allows having multiple sequential equilibriums [**15**], requiring the existence of both the believe space and strategies of how an agent should behave or respond at each stage. Such an approach alerts researchers in the field of operation research to introduce utility functions in order to calculate Nash equilibrium [**14**].

Multi-issues negotiation environment is more complex than single issue due to the extra dimension, which makes finding the "*Pareto-efficient solution*" a challenging job. A change in strategy, action or allocation that makes one party better off without making others worse off is called "*Pareto Improvement*" [**9**]. The Pareto-efficient solution is achieved when all Pareto improvements are applied and no further improvement can be made. Multi-issues negotiation is treated in different ways. Issues can be negotiated as bulk or according to an agenda [**9**]. Moreover, time is an element in negotiation environment and has an effect on negotiating agents. The most common effects are time discounting and deadlines [**16**]. It plays a focal role in strategy selection. Some agents like to concede at early stages, while others like to concede just before time is out.

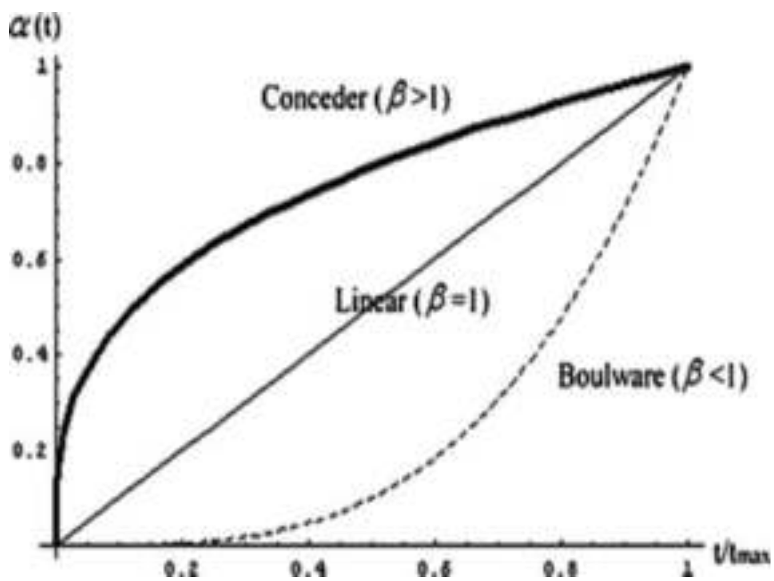

Figure 3 : Negotiators Types With Respect To Time [16]

1.3.4. Negotiating Agent

The fourth element in negotiation is the negotiator. Different factors contribute to the negotiating agent design, such as attitude (generous or self-interested), cognitive type (well-informed agent or memoryless agent), goals, beliefs, and the negotiator's knowledge and experience about the opponent. The negotiating agent design will be explained in detail in the following chapters.

1.4. Automated Negotiation Categories

Automated negotiation has no universal best technique or approach due to the variety of possibilities [**17**]. However, each approach has its own properties and performance physiognomies in a given negotiation context. The techniques can be divided into three categories: game theory models, heuristics and argumentation-based approaches. Those categories are briefly presented and overviewed to ease the understanding for following chapters and sections.

1.4.1. Game Theory Models

Game theory is a branch of economics which focuses on studying the interactions between self-interested parties in a given game such as chess. The origin of game theory goes back to the year 1944 for the work of Von Neumann [**18**]. Negotiation can be viewed as a game since the negotiating agents can be assumed to be self-interested. In such a game, the main question is 'what is the best or optimal action of an agent in a given situation?' To answer this question, assumptions are required of how the opponents might behave to optimize their outcome. Game theory models assume that the agent can select the optimal strategy from all the possible strategies by bearing in mind all types of interactions. However, this search has exponential growth and requires a great deal of computation, which cannot be feasible in polynomial time for large domains. If negotiation is standardized to fit game theory, it would result in optimal strategy and reach stability such as Nash equilibrium [**17**].

1.4.2. Heuristic Approaches

A heuristics approach is applied to overcome the limitation of game theory. Its goal is to find a good solution rather than an optimal one. It involves a set of procedures, interactions and reasonable assumptions to find this good solution. In heuristics negotiation models, the agents define evaluation for each option and alternatives for the negotiation objects and issues. It then applies the utility function to evaluate the welfare of the offers. Due to the approximate nature, the strategy space might not be tested in full, and a sub-optimal agreement is more likely to be reached [**19**]. Moreover, the feedback in heuristics models is by counteroffer which is another point in the strategy space. Thus, adding another issue or dimension in a given negotiation session is usually hard once the negotiation session is started [**17**]. The sophisticated nature of heuristics approach normally requires simulation, which will likely find a very good feasible solution for a negotiation session.

1.4.3. Argumentation-Based Approaches

The idea behind the argumentation-based approach is to add another dimension of knowledge and guide the negotiation to discover areas in the strategy space that have not been discovered by the opponent. This is done in human negotiation normally through explaining a proposal or criticizing a received offer from the opponent. It also includes modifying the preferences of the opponent by adding a threat or a reward to a given offer. Argumentation-based models exercise logic-based mechanisms to the search for critique or explanation for a strategy. Thus, applying it in automated negotiation is hard because other negotiation agents might not be modeled to accept such an approach. Moreover, it require a mechanism to verify the validity of a given critique or explanation [**17**].

1.5. Statement of the Problem

A negotiation mechanism consists of a specific protocol and a decision making model. In real life, negotiation is branded with multiple issues, agents and strategies. Negotiation is a complex and non-linear process, and most of the time a human negotiator achieves a sub-optimal rather than optimal solution [**11**]. Moreover, in complex computational situations, an automated negotiator is more efficient than human negotiator [**20**]. The automated negotiator should be autonomous, flexible and able to adopt and interact with the changes in the environment. A negotiation agent is desired to be "*effective*" and "*efficient*". By being effective, the agent will maximize their outcome and reach a win-win stage with the opponent. On the other hand, by being efficient, the process will be improved to consume minimum resources such as time and computational capabilities.

1.6. Research Objective

The goal of this research is to consider a realistic negotiation model, which focuses on bi-lateral agents, negotiating over single or multiple issues under complex negotiation spaces and environments. For the sake of reality, the negotiation process is assumed to be constrained by time, limited computational capabilities and uncertainty about the opponent's preferences. The system will define a deadline for the process and a discounting factor to encourage the agent to finish the negotiation without unnecessary delay. If the system reaches the deadline without reaching an agreement, the negotiation will end in failure.

In order to adopt real-world negotiation, the research objective is to design the negotiating agent as bounded rather than totally rational, in which the agent will look for a satisfactory outcome rather than an optimal one. The model should be sensitive to environmental pressure such as time pressure. Moreover, the model will be designed to execute negotiation under complete uncertainty about the opponent's preferences, and the agent will only know its own preferences and limitations.

To achieve this goal, the negotiation agent will be designed to adopt and deal with changes in the environment and use previous actions and reactions with the opponent in the negotiation process. The model will be capable to handle multi-issue negotiation with one side uncertainty. Since the choice of the agent may change over time and under pressure, the model will be designed to deal with such changes and update the agent's belief space.

1.7. Research Contribution

The focal contributions of this research consist of the following:

1. Adding a cultural algorithm model of the negotiation process to the automated negotiation literature.
2. Developing an automated negotiation agent which will be referred to throughout this work as Agent Z. The agent will be equipped with the

ability to observe the opponent’s actions and reactions and use the obtained knowledge in negotiation. It also will be able to adopt the changes in the negotiation environment such as time.

3. Developing a strategy selecting technique from the strategies space based on continuous evaluation of the offers received and proposed. This will result in updating the belief space with all possible or generated offers.
4. Developing a heuristic search technique to adopt the limited computational resources.

1.8. Research Methodology

The following steps are carried out to achieve the research objectives:

Step 1: Review the literature and previous work related to automated negotiation modeling with more focus on bi-lateral multi-issues negotiation.

Step 2: Benchmark problems proposed in the literature for computational comparison and analysis.

Step 3: Develop and code Agent Z, an automated negotiation agent for bi-lateral multi-issues closed negotiation.

Step 4: Validate and compare the proposed negotiating agent through simulation and computational experiments using the benchmarked problems

1.9. Structure of the Report

Thesis has been organized as follows; chapter one describes the Problem Definition, Objective, Motivation and Research Contribution. Chapter 2 is divided into two parts: the first part contains theoretical background describes the basics game approach, Heuristic approach, Fuzzy Logic, Meta Heuristic and Genetic Algorithm approach. While the second part contains literature review contains description of the research papers and other literature reviewed. Chapter 3 describes the algorithm used in modeling the negotiation. It highlights the algorithm’s main components and functions. Chapter 4 proposes the design of Agent Z and its 3 versions. Moreover it highlights the negotiation setting and the internal mechanism of the proposed negotiator. Furthermore, chapter 5 describes tools, technology and dataset details used for the experiments. Next, chapter 6 contains experimental results carried out and discussion based on the experiments. Then, chapter 7 concludes the work done and the implications for the study and future extension that can be done. Lastly, the Bibliography contains the list of reference.

Chapter 2: Literature Review

2.1. Review Concepts and Theories

There is vast research in game theory, economics and artificial intelligence that focus on modeling negotiation. Different models have been proposed with different approaches. For almost forty years, the game theory approach provided theoretical analysis of how to reach optimality and tried to predict unique equilibrium outcomes of negotiation with narrow success [**21**]. Others approached the problem as a fuzzy logical set to overcome the apparent game theory models' limitations from a heuristic perspective. Yet many of the apparent limitations of game theory were not adequately met by this approach. In recent literature, negotiations were modeled in Genetic Algorithm (GA) framework and argumentation-based approaches designed from a meta-heuristic perspective yet still show significant disadvantages to a general "cover-all" or paradigmatic model of automated negotiations. To this end this review is devoted.

In the following section, the pros and cons of the previously mentioned approaches will be summarized. The next chapter will introduce the proposed methodology to simulate the negotiation process in the automated negotiation agent. Given the voluminous abundance of research within the discipline, this chapter's defined scope is most relevant to the basic research thesis addressed in Chapter 1 and more adequately explored in Chapter 3. Obvious omissions are due to brevity of the discussion within the parameters of the research focus.

2.1.1. Game Theory

Game theory is a branch of economics which focuses on studying the interactions between self-interested parties in a given game such as chess. The origin of game theory goes back to the year 1944 in the work of Von Neumann and Morgenstern [**18**]. Classic game theory applications, particularly in the areas of negotiations and bargaining have used such "hierarchal and progressive choice" games as "Prisoner's Dilemma" and "Tit for Tat." In the past decade, it has been used extensively to study the interaction between self-interested computational agents by [22, 23]. Negotiation can be viewed as a game since the negotiating agents can be assumed to be self-interested. In such a game, the main question is ‘What is the best or optimal action of an agent in a given situation?’ To answer this question, assumptions are required of how the opponents might behave to optimize their outcome. Game theory models assume that the agent can select the optimal strategy from all the possible strategies by bearing in mind all types of interactions. Other assumptions are also quite evident in classic game theory. Agents, besides being viewed as fully rational, will attempt maximization of their outcome, accepting the highest payoffs, and knowing the "intrinsic" rules of the game. In addition, the number of agents in the game is "known," communication is highly controlled, limited, and not always relevant to the interaction itself. Decisions that are made are "maximally efficient" and intersect with the point which reaches Pareto optimal.

Thorough analysis of gaming strategy has been made in terms of identical agents in attempting optimization in pursuit of equilibrium [22, 23, 24]. The strategies, established by assumed payoffs, game rules, agent goals with no other knowledge except introspection, suggest that these methods can be made optimal. Supported by the assumptions of rational choice theory [**25**] , the agents, more or less behave rationally guiding the game theoretic design of the interaction itself. [26, 27]. That is, the agents possess a “bounded rationality” described by Rubinstein [**32**] as conforming to the theoretical parameters of the design itself limited and determined by “rational choices” within the bounds of negotiation. However, this model’s requirement for search has exponential growth and requires much computation, which cannot be feasible in polynomial time for large domains [**29**]. If negotiation is standardized to fit game theory, it would result in optimal strategy and reach stability such as in Nash’s conception of equilibrium [30, 31].

Nash [**14**], in his seminal work on bargaining theory, studied the relation of negotiation outcome and the situation properties. His Game Theory model argued that both players will gain, if they both reach a mutual agreement on a solution; otherwise, they will go back to status quo. In order to approach this system, Nash assumed a cooperative perfect information environment, in which all the entities know each other’s true tastes and preferences without lying or withholding information. He also assumed full rationality of agents that each continually evaluates his/her satisfaction. Another assumption he made to idealize the bargaining problem, is that all agents are equal in their power and negotiating skills. His model proposed that the solutions should be Pareto optimal and all the outcome's constrains should be satisfied.

The Nash bargaining model is considered to be static, timeless, and focused only on the outcome of negotiation, and not the procedures leading to that outcome. Figure 4 illustrates Nash's solution in a graphical model.

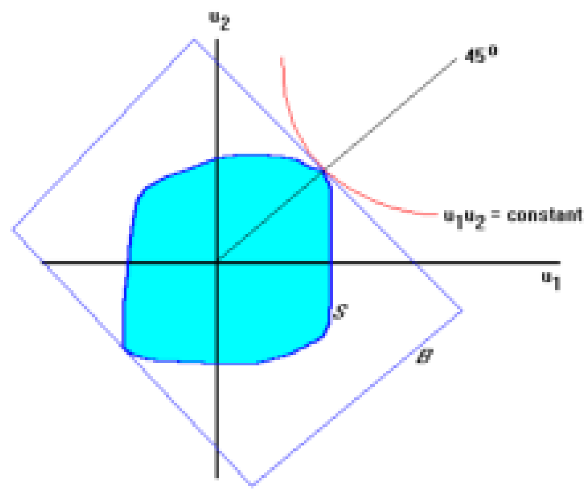

Figure 4 : Nash's Bargaining Solution [14]

Rubinstein [**10**] studied non cooperative negotiation, in which he proposed two players negotiating over a partition of a pie by alternating-offers in infinite horizon. He assumed that time is valuable, negotiating cost is fixed, discounting factors are fixed, and players are impatient and have perfect information ab out the opponent. The main proposition was that Nash equilibrium is a weak concept, and instead he used a perfect equilibrium concept. The focal finding defines conditions under which the game has a unique perfect equilibrium. Carmton [**32**], in his research, studied bargaining as a sequential direct revelation game, in which, it allows analyzing the learning process of players in a given situation. Still, this model of negotiation and bargaining is situational and based on the rationality of the interactive agents. In addition, search spaces are formed to a restrictive extent, which do not uncover agent values or motivations.

Game Theory assumes that agents are fully rational, while in reality this assumption is not valid. Agents often act irrationally according to some strategy. A heuristic search has commonly been used to find a likely solution. Research on designing negotiation agents includes often that the agent make some assumption about their opponent and the act of an agent is based on previous reaction. More detailed models were built to handle sophisticated bargaining agents [**12**]. The model proposes a function for counteroffers dependent on time, resources available and agent behavior. Time and resources are consumed during the negotiation, which introduce pressure power and have an effect over the agent's decision.

However, those models are believed to be rigid and cannot adopt real negotiation situations due to several reasons mentioned above. Also, a well-reviewed problem is the exponential growth of the search space of all possible strategies and interaction to reach equilibrium. To this end, computational complexity theory has extended game theoretic approaches devoted to the development of efficient (polynomial) algorithms for what seem to be intractable problems.

2.1.2. Heuristic & Fuzzy Logic

Common heuristic approaches are applied to overcome the limitation of game theory and extend its "either/or" simplicity to some extent. To this end it concerns "value." Its goal is to find a good solution rather than an optimal one. It involves a set of procedures, interactions and reasonable assumptions to find this good solution. In heuristics negotiation models, the agents define evaluation for each option and alternatives for the negotiation objects and issues. It then applies the utility function to evaluate the welfare of the offers. Due to the approximate nature, the strategy space might not be tested in full, and a sub-optimal agreement is more likely to be reached [**33**]. Moreover, the feedback in heuristics models is by counteroffer which is another point in the strategy space. Thus, adding another issue or dimension in a given negotiation session is usually hard once the negotiation session is started [**30**]. The sophisticated nature of the heuristics approach normally requires simulation, which will likely find a very good feasible solution for a negotiation session.

While game theoretic techniques work well in many cases, they also embody a number of assumptions that can be limiting for real-world applications. In particular, these models are often based on notions of perfect rationality (requiring the agent to be computationally unbounded and have full information of its own and its opponent's negotiation options) and they provide limited flexibility in cases where the designer cannot a priori impose a negotiation strategy upon the agent. In such cases, heuristic approaches are more suitable [34].

Heuristic approaches emerged to address some of the limitations of game theory. As mentioned earlier, heuristics provide "rule of thumb" valuations that produce sufficient (good enough) rather than optimal or maximized outcomes. These outcomes are produced most often in relation to agent rationality and rationality with more relaxed assumptions. Empirical testing and evaluation [28, 35] have supported particular heuristic approaches in alignment with offered approximations, as an extension of game theory, to the decisions made by the agents. The below are the key advantages of heuristic approach:

- The heuristic models are purely based on real assumptions; therefore they give more proximity for automation and hence, useful in a wide variety of real-life application domains.
- The designers of agents, who don't know the concept of game theory, can choose the heuristic approach as an alternative and less constrained method to design various distinct agent architectures.

A number of studies by Faratin, Sierra and Jennings [45, 46, 47] concentrated on agent decision making where functions are used to evaluate and generate offers and proposals (potential deals) in multi-attribute negotiation. Conforming to this heuristic model, a method of tradeoff generation was also produced which aided the creation of alternative offers during the bargaining process [39]. With the model's basis in distributed constraint satisfaction [40], decision procedures and protocol were also incorporated into the heuristic approach [40]. Later extensions to the heuristic model accommodated multiple concurrent negotiations [41], and were inclusive of "fuzzy" sets and constraints [42]. Fuzzy constraint satisfaction further reinforced the general heuristic approach [43], while Fatima, Wooldridge and Jennings [53, 54, 55] researched and augmented this model by focusing on the influence of time and information constraints on equilibrium.

While heuristic methods do indeed overcome some of the shortcomings of game-theoretic approaches, they also have a number of disadvantages [30]. Firstly, the models often lead to outcomes that are sub-optimal because they adopt an approximate notion of rationality and because they do not examine the full space of possible outcomes. Secondly, it is very difficult to predict precisely how the system and the constituent agents will behave. Consequently, the models need extensive evaluation through simulations and empirical analysis. But first let us consider some of the origins and special extensions of the heuristic approach.

In 1965, Zadeh [27] proposed “Fuzzy Logic” to deal with processes that are not fixed and exact. It uses “IF-THEN” rules to handle the uncertainty in the user nature and reasoning logic for his/her actions. Fuzzy logic doesn’t have “ELSE” rule and is considered weak in terms of not having an inherent pattern.

Wasfi and Hosni [26] introduced a multi-issue, two-party fuzzy logic model for negotiation. They integrated several negotiation theories and focused on the impression in the process. Their negotiation system was approached as fuzzy logic, assuming entities exchanging structural and communicative moves. They added time pressure and negotiators’ power as a dynamic set changing throughout the process to the fuzzy logic model. Figure 5 illustrates their model structure.

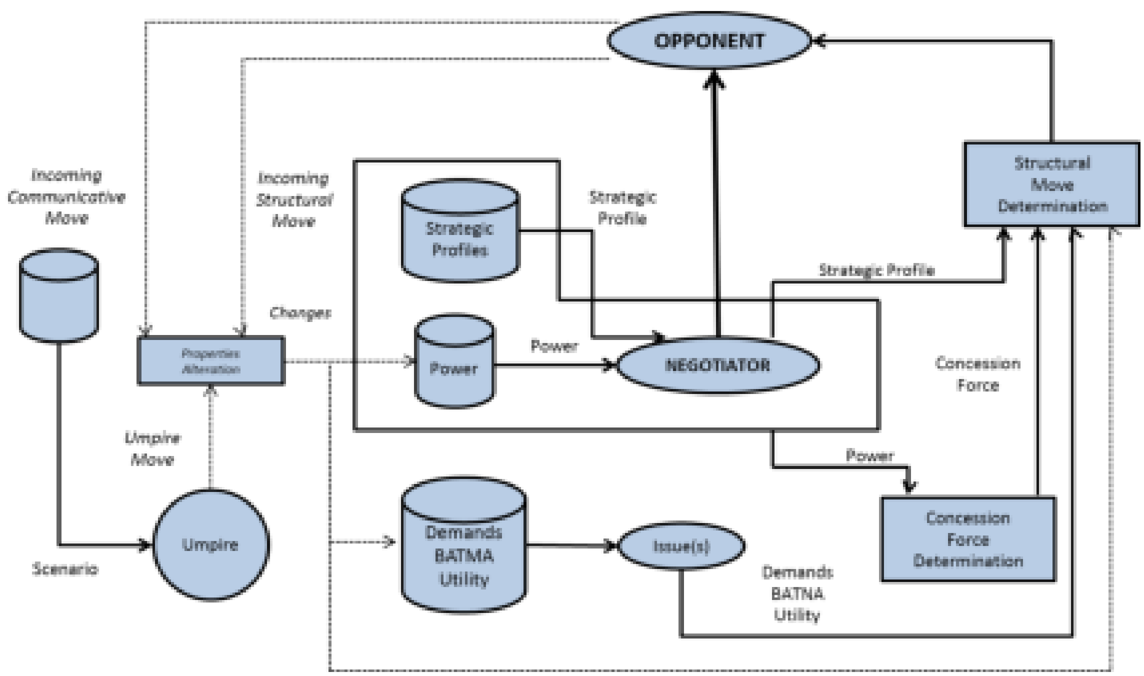

Figure 5 : Wasfi and Hosni Model for Two-Party Negotiation [26]

A prioritized fuzzy constraints model was developed for bi-lateral, multi-issue negotiation in semi-competitive environments [**52**]. The model is developed to handle the case when one of the parties has to relax his/her constraints to meet the other party's limitations, based on a set of fuzzy constraints with priority. For example, the buyer will define his set of constraints and associate a priority for each, and then s/he will submit them one by one to the seller, from the highest priority to the lowest. The seller afterword will either make an offer or will let the buyer relax his constraints till they reach a satisfactory offer for both parties. The authors argue that a Pareto optimal is guaranteed, if the participating agents reveal minimum amount of information about their constraints and preferences.

Major criticisms and or disadvantages thus far include a number of criteria. Although sophisticated systems highly suitable for a wide range of applications have been produced by game theoretic and heuristic approaches, they share some further limitations in addition to those mentioned above. Because agents exchange proposals, such as potential agreements or deals in both these models in a fixed evaluation based on preset criteria, there are limits of the two models. Thus an example, such as a promise to buy a product at a specific price in an English auction which a value assignment is given to multi-attributes in a multi-dimension [**50**], or a bargaining encounter which carries an alternate offer [**51**], the agents cannot exchange any further information other than what is expressed in the proposal. In essence, they are "proposal bound." This carries problems in contexts where agents have limited data concerning their environment or where their rational choices are equally dependent on the choices of other agents. In addition, a priori-type agent preferences or utilities, prior to the interaction itself, completely characterized and set in place, can pose limitations to conventional automated negotiations. This pre-conditioned assumption may work well when the negotiation object is financial in nature in which the agent mechanism can compare proposals based on monetary value, however when the negotiation object increases in complexity, agents of course will have incomplete information. Within this context, agents may lack information relevant to make comparisons between outcomes and may have limited resources to acquire the information needed. In addition, agents may lack time to process comparison and have other inconsistent, unformed, incoherent, and undetermined knowledge or preferences about the environment or the object of negotiation itself [**30**]. Finally, game theoretic heuristic models have the major assumption of rational utility and preference. These conditions are fixed: agents cannot influence each other's preferences or internal attitudes which fashion its preference model. Only new information would modify a given agent's preferences and traditional automated negotiations would not accommodate the reception and evaluation of this new information.

Against this background, argumentation-based approaches to negotiation attempt to overcome the above limitations by allowing agents to exchange additional information, or to ‘‘argue’’ about their beliefs and other mental attitudes during the negotiation process. This “valuation” was often sought in a sense of “bounded rationality” [**52**] or from a logical or syllogistic-based sequence of steps. Since these parameters positioned protocol on the basis of a higher level of evaluations, they were considered “meta-heuristic.” This thesis will focus on these approaches.

2.1.3. Meta-Heuristic and Genetic Algorithm

In general, heuristic models and methods did liberate some of the shortcomings of game theory models in an ad hoc fashion, but they also possessed some distinct disadvantages. The models had a tendency to select deals or outcomes which would be sub-optimal because of the adoption of approximate notions of rationality and the limited examination of the full territory of outcome possibilities. In addition, simulations and empirical analysis were needed to a higher degree of critical examination due to the factors of unpredictability of the agent behavior in protocol. Agents would have the tendencies to behave in inconsistent manners not often foreseen based on a "rational choice" type of design.

The general prospectus of automated negotiations from a basis of argumentation was to remove these limitations above by allowing additional information over and above the proposals to be exchanged. The information, in a variety of forms, all derived from arguments would explain the opinion of the agent involved in the exchange making the argument. Thus an agent, besides rejecting proposals could offer a meta-critique of the proposal essentially why the argument was rejected. This idea could possibly have the effect of opening up negotiation space within the negotiation strategies, in terms of what areas were not worth exploring by opponent agents. In addition, from a meta-perspective, an agent could also pair up a proposal with an argument why the other agent would or should accept the proposition changing regions of acceptability by preference alteration and by doing so the whole negotiation space itself. This ability to argue on "top of" or produce value concerning the worth of the object of negotiation would be tied to persuasive and human argumentation in general as a system of criteria which the afore mentioned models lacked. In this approach, threats, rewards, evaluations could provide a further level of negotiation strategy [**53**]. In addition, agents may not always be truthful in their argumentation agendas of which they generate so the agent would have the options and means of argument evaluation based on the "logic" of the argument, on its own merits, providing a dimension of "agent credibility" to which the other agent must evaluate and respond to.

By adding these dimensions of knowledge to guide the negotiations and discover "strategy space" not discovered by the opponent would offer new insights into agent behavior. By providing guiding or upper level criteria to assess and make judgments concerning the logic itself preferences could be modified from the argument-based model of automated negotiations [**52**]. Yet such an approach also has its limitations due to the scope of agent preferences involved. A given agent may not respond or accept the approach if it is not modeled to do so. In addition, the model requires validity mechanisms which are needed to verity an explanation or critique [**17**]. Adding to the Meta-Heuristic mix of models were genetic algorithms which focused on optimizing strategies. Inherent within this model were "learned" applications based on historic choices. These fine-tunings would be helpful in the design of automated negotiations but were complexity and cost-effectiveness would emerge as limiting issues. In addition, during research and study, several spaces of protocol would emerge as undiscovered which were later to be deemed more receptive to the cultural specifications of algorithmic applications which will help to summarize this chapter.

Genetic algorithms (GA) use the process of natural evolution (inheritance, mutation, selection, and crossover) to generate solutions for optimization and search problems such as the search for optimal strategy in the negotiation process [**54**]. Learning in negotiation helps the negotiator to build an idea about the opponent. Genetic algorithms were widely used in this aspect as a decision making tool to learn the best strategies. An empirical evaluation was proposed for a range of strategies and tactics in a variety of environments [**55**]. The authors of [**55**] took the negotiation parameters as genes, and tested the operational pros and cons of number of strategies. The authors argue that it is beneficial for the agent to use a cocktail of tactics and their combinations for single issue negotiation.

Dzeng and Lin [**2**] examined an automated system that could evaluate, negotiate and finalize a given bid using a coordinating agent, which can be seen in figure 6 below. They focused on common negotiation issues and options for construction material procurement. An agent-based system has been proposed and named “C-Negotiators”, which was enhanced with a genetic algorithm model to find the most beneficial solution for both contractors and suppliers. They used a weighted payoff function to represent the preferences of the human negotiators for each issue (e.g. price, delivery, payment terms, etc.). The experimental results showed improvement in the joint utility for both parties, ranging from 1.5% to 9.8% as compared with human negotiation.

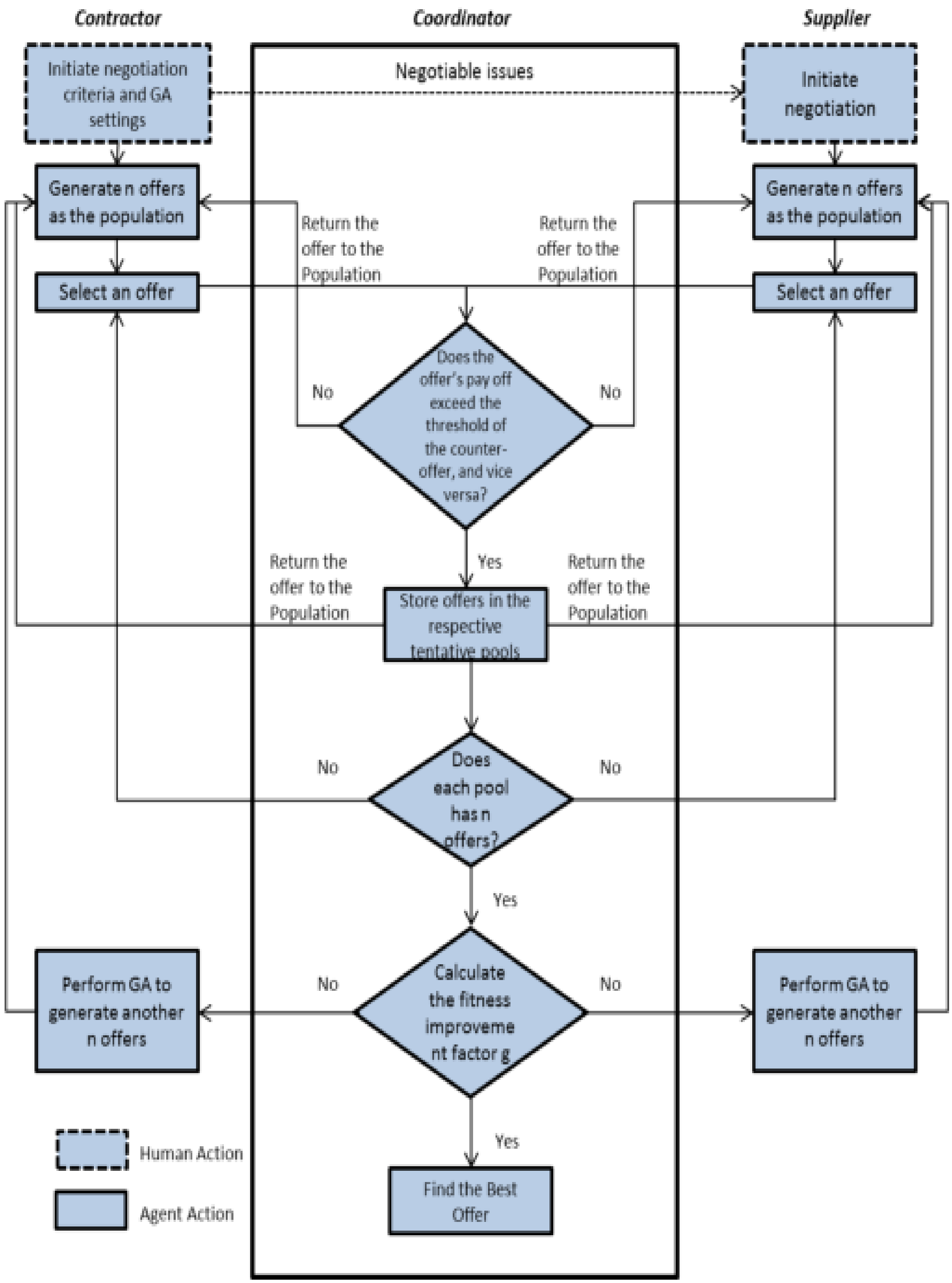

Figure 6 : Dzeng and Lin Computation Model for Negotiation Agents [2]

The main disadvantage of genetic algorithm models is the requirement of huge computational capabilities to achieve a good strategy at the end. The trails in literature vary from 20 generations as in [**56**], upwards to 4000 generations as in [**57**]. In addition, certain "cultural" spaces or macro maps can be un-noticed, undiscovered or not generated, to this idea extensions could be made to the model to bring about the dynamics of automated negotiations.

A dual inheritance system model of cultural algorithms would essentially open up a realization of spaces which many of the traditional models could or would overlook. While keeping an evolutionary model of "historic" memory and choice of agents, a cultural model would supplant this knowledge, practice and protocol with "belief spaces" categorized by types of "space knowledge" of which the agent would be aware of. Introduced in 1994 by Reynolds, cultural algorithms co-exist in a systemic dialectic of interactions where there is a population [60]. Because the model is entirely commensurable with genetic algorithms, it can be extended into agent population search spaces represented by the types of knowledge presented below [60, 61, 62]:

Cultural algorithm has several types of knowledge. The following briefly represents these types:

- Normative: A group of desired value ranges for agents within the population, parameters of acceptable behavior.
- Domain specific: Data concerning the specific domain referred to.
- Situational: important events, such as successful/unsuccessful solutions
- Temporal: History of the search space. The temporal patterns of the search.
- Spatial: Data concerning the geography and topography of the search space itself.

This discrete categorization of evolutionary "space" maps work on the macro-level and meta-heuristic modeling functions giving automated negotiations more distinct agent behavior based on contextual parameters, temporal and spatial information which can regulate any aberrant choices in the maximization process, and carry all the value and argument guidelines inherent within meta-heuristic approaches through situational, domain-specific and especially normative "search" spaces of knowledge, while keeping the micro-evolutionary exchanges intact.

2.2. Review Previous Research Findings

Different research papers have been reviewed during the semester, for the purpose of the survey, to understand the domain of problem and possible approaches to solve the problem and improvements suggested by different authors. This may be helpful to design a new approach which may solve problems and find some improvements. Thus, in this section the summary of different approaches, as well as problems associated with them, are discussed. Of significant relevance to the on-going discussion, and with considerable research interest in the past few years, are the foci of multi-issue negotiations. A continuing growing body of research is posed to ameliorate the outcomes of automated negotiation through efficacious strategy or through the discovery of the preferences of the opponent. Applications of a learning method have had a significant impact on the outcome of the negotiation [**62**]. Such applications have found that a learning method not only empowers agents to explore the preferences of the opponent [63, 64, 65, 66], but also enables agents to discover strategies of optimal interaction [**67**] and consideration of future agent moves [**66**]. In addition, through the application of a learning method, several attempts have been made to uncover the preferences of the opponent, such as the point of reservation [**64**] the priority or issues in terms of relative importance [64, 65] and the estimation of the importance of degrees over issues by the opponent [64, 68]. The approach also is inclusive of a learning application to attempt estimation of the degrees of importance of an opponent by the use of a genetic algorithm and set of constraints in the underlying form of fuzzy values.

Undoubtedly Bayesian learning is a very much used methodology to understand the behavior of an opponent in the discipline of automated negotiation, but it does have its limitations and drawbacks. A Priori information and data is needed by the agents concerning the likely outcome of the negotiation based on distribution of probability. Through historical data concerning previous negotiation encounters agents can draw some generalizations about probability concerning the behavior of the opponent.

Because of the privacy of information required to compute these probabilities, this is certainly a limitation of Bayesian learning. Attempts to use Bayesian learning in single issue price negotiation concerning the reservation point of the opponent revealing preferences and ultimately the outcome itself have been demonstrated by Zeng and Sycara [64], however this work focuses on multi-issue processes of the negotiation through an exploration of preferences of the opponents. To determine a class (using a Bayesian classifier) where the preference relation of the opponent is the most likely fit during the process of negotiation has been used by Buffett and Spencer [65] with success. The significance of their methodology is highly dependent on the prior class set determined by the use of k-mean method. The main assumption of the authors was that concession-based strategies were used by agents to bring about a reduction in their utility of their offers, thus reaching agreement. This approach was used in similar fashion to bring about concession-based results [68] through Bayesian learning. In this work, similar assumptions of concession are applied to form constraints to illuminate the utility boundaries of an opponent during the process of negotiation, yet contrary to Bayesian learning, the approach of the thesis does not rely on prior knowledge concerning the agent opponent which makes it more efficacious or pragmatic. By using Kernel Density Estimation (KDE) [66] as emulated by Coehoorn and Jennings, issue priorities of opponents can be illuminated. By using the history of previous encounters of negotiations in an offline mode estimations can be made concerning initial probability density functions over the importance degrees for issues of negotiation in the opponent. Then new data can be discerned and augmented by learning from the continuing negotiation online. The authors found that minimal errors in estimation concerning the weight of the opponent will not significantly lower the performance of the trade-off algorithm [**69**]. In this work, the approach assumption is, agents do not possess information about previous encounters with the other opponent. As a consequence, only through online learning can an agent learn of the preferences of the opponent. By a consideration of the weights (opponent's issue importance degrees) as fuzzy values, agents will learn preferences having minimum error based on some constraints and ultimately an estimation of the preferences of the opponent which can be used in trade-off [**64**].

In addition, as studied by Ros and Sierra [67] in relation to learning the order of issues degrees of importance, attempts were made to understand these degrees based on simple statistical analysis of the offers received. Issues having fewer changes, rather than more changes, were considered more important. Thus using this notion, Kersten, Vahidov, and Carbonneau [69] used the "weightings" for improvement in trade-off algorithms similar to the scope of the approach this work uses in online learning during the negotiation process. However, the intent and design of this research is not limited to learning the order of weights, but extended to forecast how the importance of issue degrees will empower an opponent or agent to more effectively generate offers. In line with this approach, constraint satisfaction problems have been researched and applied to the negotiation process [70, 71, 72, 73, 74]. In particular, developments of a fuzzy constraint model, as adapted by Luo, et al. [74] for bilateral multi-issues negotiations, are used in order to discover trade-offs within the extent of possible values of the actual negotiation issues which will make sure that agents will reach a fair agreement, amounting to Pareto-optimal. To this end, and in the model advocated within the scope of the research, constraints are used first to bound the opponent utility, then consequently explore the agent preferences by use of a genetic algorithm.

Due to the fact that agents possess incomplete and unclear data about their opponents and that perception of the opponent agent is unclear, this uncertainty and imperfect information has led to the application of fuzzy techniques in the research in automated negotiation. By using fuzzy similarity approach, presentations can be made concerning a trade-off strategy among decision variables (negotiation issues) by enabling the agent to make trade-offs based on the importance degrees of an opponent, as in the seminal work of Sierra, Jennings and Faratin [71]. The authors also claimed that negotiation quality will significantly decline if there is unclear or incomplete information about the agent's opponent. Similarly, the model presented in this study and complimentary to the model presented in the work of Faratin, Sierra and Jennings, uses a learning approach to examine the preferences of an opponent and application of strategies of trade-offs to increase the rate of negotiation success. Fuzzy scoring functions individual issues' utility has been evaluated in a context of limited time negotiation by looking at each individual issue in multilateral negotiations, as proposed by Teuteberg

[77]. This study has concluded that early compromise between agents, as in concessions by both seller and buyer agents can increase the negotiation success rate, while the approach advocated by this study uses fuzzy preferences to learn of the issues' weight in bilateral negotiation, by projecting the agent or opponent's utility value.

Modeled as a distributed fuzzy constraint satisfaction problem, a prototype in autonomous multi-issue negotiation considered as a distribution of the problematic of decision-making with the environment and presence of uncertain constraints and incomplete data, was used as a prototype by Kowalczyk and Bui [48]. However, the approach did not use an explicit learning method and was overly-complex and time-consuming through its use of search processes and search spaces to find mutual agreements. As an extension, the application of fuzzy Markov decision-making for adaptive strategies in single issue negotiations was presented by Richter [78]. In contrast, the model used within the scope of the research in this approach is an exploration of opponent preferences within multi-issue negotiations.

2.3. Summary

This chapter presented a summary of the literature that dealt with negotiation modeling and automated negotiators. The models are grouped into three categories: game theory models, fuzzy logic models and meta-heuristics models such as genetic algorithms. From this review, it is clear that the literature is missing negotiation models for designing a negotiating agent that uses dual inheritance systems such as cultural algorithms.

Chapter 3: Modeling Negotiation Using Cultural Algorithm

3.1. Overview of Cultural Algorithm

Cultural Algorithm (CA) is considered as a branch of evolutionary computation, and it is considered as an extension to traditional Genetic Algorithms [**77**]. It mimics the cultural evolution of humans by using more comprehensive learning between individuals. Cultural algorithms consist of two main components: belief space and population component. They interact with each other, through different functions, creating a system of dual inheritance.

Evolution in cultural algorithm is faster than simple biological evolution since cultural algorithms work at two different levels, the micro-evolution level and the macro-evolution level. The micro-evolution resides information and genetic materials inherit from the parents, while the macro-evolution resides the information adopted from the cultural through many generations. The fittest individual in the population is sent to the belief space to update it with its knowledge and experience about the environment, that information is accessible to all the individuals in the population. In return, the updated belief space will influence and guide the reproduction of the following populations. This algorithm is different from genetic algorithm, where evolution takes place at population level only. Figure 7 shows classic cultural algorithm diagram in term of its components and functions, while Figure 8, presents basic pseudo code of basic cultural algorithms.

3.2. Structure of the Algorithm

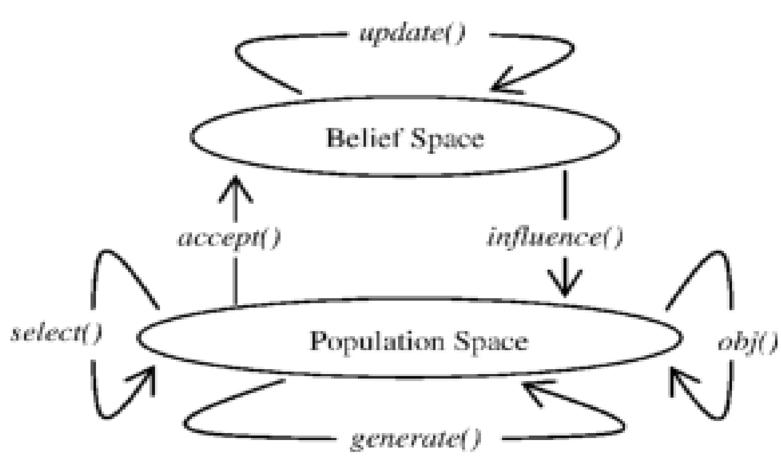

Figure 7 : Cultural Algorithm Diagram

3.3. Pseudo Code of the Algorithm

```
Begin
t=0;
Initialize Population POP(0);
Initialize Belief Network BLF(0);
Initialize Communication Channel CHL(0);
Evaluate (POP(0));
t=1;
Repeat
Communicate (POP(0), BLF(t));
Adjust (BLF(t));
Communicate (BLF(t), POP(t));
Modulate Fitness (BLF(t), POP(t));
t = t+1;
Select POP(t) from POP(t-1);
Evolve (POP(t));
Evaluate (POP(t));
until (termination condition)
End
```

Figure 8 : Basic Cultural Algorithm Pseudo Code

3.4. Main Elements and Functions of the Algorithm

This section will explain the knowledge chromosome and the three main parts of cultural algorithm in details and how it will be integrated in the negotiation process.

3.4.1. Knowledge Chromosome

The knowledge chromosome of cultural algorithm, used in negotiation, uses the binary representation (0 or 1) for the bids. To illustrate this, let’s consider an example negotiation with four issues where each issue has three options. Thus, an example of knowledge chromosome is provided in Figure 9 which represents the selection of option 1 from issue I, option 2 from issue II, option 1 from issue III and option 3 from issue IV.

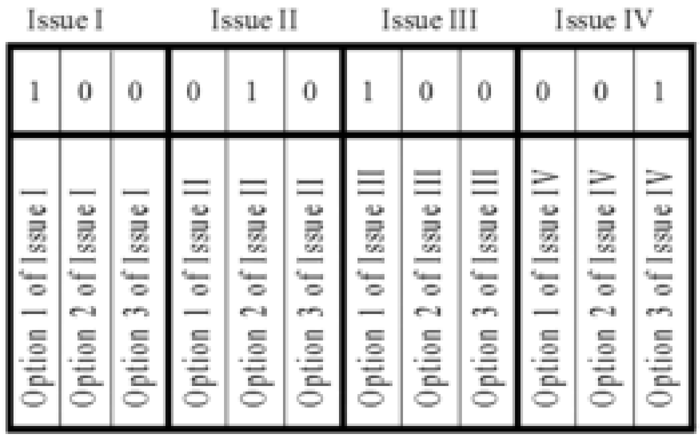

Figure 9 : An Example of Knowledge Chromosome

3.4.2. The Belief Space

The belief space is the place where information about the solution is stored and refined. It will also be shared with all the individuals and will help in influencing the reproduction in the population space for the following populations [**77**]. In this work, the belief space contains three parts:

- The Normative Knowledge
- The Situational Knowledge
- The Temporal Knowledge

The normative knowledge represents the pool of desirable value from the population space. In other words, it holds the desirable utility range that the negotiator has such as minimum offer to accept and maximum initial offer.

Moreover, situational knowledge contains important and special events, such as successful or unsuccessful offers, which will help influencing the next generation of population. Situational knowledge will be empty at t = 0.0 and it will be updated throughout the negotiation. The knowledge stored in this component will be used to guide the search for an agreement in the next generation.

Temporal knowledge represents the historical data and received offers from the opponent will be stored in the belief space and is to be used to track the opponent behavior during the negotiation.

3.4.3. The Population Space

Population space will contain all the possible strategies or bids generated based on the influence of the belief space. And the population space will select the best individual (solution) that will influence the belief space.

Initially, the first generation is created from random, representing a population of solution in the search space. Each individual (solution) is evaluated using fitness function, in which in negotiation we refer to as "utility function". This function will return the best individual solution, which will be used to influence and update the belief space once it's accepted by acceptance function.

3.4.4. Communication Protocol

Information passes between the two spaces through a system of communication protocol. This system contains functions for exchanging information. Some has been explained previously. However the following abstracts them again here:

1. Accept Function:

This function sends the data from the best accepted individual (BAI) to the belief space. The BAI is selected according to the following:

$$\boldsymbol{BAI} = \begin{cases} MaxNTU_t & ,pop = 1 \\ Max\ U(.) \neq MaxNTU_{t-1} & ,pop > 1 \end{cases} \tag{1}$$

Where, $\mathrm{MaxNTU_t}$ is maximum normative target utility at time t, $\mathrm{Max\ U(.)}$ is the maximum utility of an offer and pop is the population.

Once the negotiation session start, the population of all possible offers is generated. The first population will choose the individual (bid) that has the maximum normative target utility (MaxNTU) which was stored in the belief space and store it as the best accepted individual (BAI). Later, and for the following generations, the BAI will be the individual (bid) that has the maximum utility from the generation.

2. Update Function:

This function revises the new accepted information inside the belief space. The following illustrate the update for $\mathrm{MNTU_t}$

$$MaxNTU_t = \begin{cases} MaxNTU_t & , \quad t = 0 \\ BAI & , \quad t > 0 \end{cases} \tag{2}$$

In general, the Maximum Normative Target Utility (MaxNTU) will be updated with time with the Best Accepted Individual (BAI) founded in the search in the population space.

3. Influence Function:

This function is used to bias the next generation in the population space. The information inherited from the belief space is used in the variety function. The influence function will pass to the population the parents that they will use in the production of the following generation.

4. Utility (Fitness) Function:

This function (as presented in figure 10) is used to evaluate the fitness for each offer in term of its utility. The utility function has been discussed previously, and the following example illustrates the calculation for a sample knowledge chromosome in the solution space.

Issue	Laptop Brand			Hard Disk Drive			Monitor Size		
weight	0.3			0.6			0.1		
	1	0	0	0	1	0	0	0	1
Option	Hp	Dell	Mac	60GB	80GB	120GB	19"	20"	23"
Evaluation	1	3	2	3	2	1	2	1	3

Figure 10 : Utility Calculation for a Sample Knowledge Chromosome

$$U(O) = \sum_{i=1}^{n} \omega_i \frac{E(v_i)}{Max\,(E(v_i))} = \left(0.3 * \frac{1}{3}\right) + \left(0.6 * \frac{2}{3}\right) + \left(0.1 * \frac{3}{3}\right) = 0.6$$

5. Variety Function:

This function uses the belief space knowledge components as parents for producing the next generation using crossover and mutation. To produce children in the population, two parents are required. The first parent will always be the last offer sent to the opponent, while the other parent will be from the belief space from the situational knowledge component which stores the offer received from the opponent.

Chapter 4: Proposed Design of Agent Z in Automated Negotiation

The modeling of negotiating agent using Cultural Algorithm has been highlighted in the previous chapter and it was implemented in a negotiation agent who will be referred to throughout this work as Agent Z. The agent was modeled to negotiate with any automated negotiator that is compatible with GENIUS (General Environment for Negotiation with Intelligent multi-purpose Usage Simulation). Moreover, the simulator allows Agent Z to negotiate against human negotiators who can enter their offers through a user interface window.

Now, in order to present the cultural algorithm model for the automated negotiator, two elements need to be defined. First, the negotiation settings and parameters will be defined. Second, the internal mechanism of cultural algorithm in the negotiation agent will be exemplified.

4.1. Negotiation Setting

In this part, the negotiation settings and parameters for the cultural algorithm negotiation model is explained. The model considers alternating offers and counter offers protocol which were introduced by Rubinstein [**10**] for bilateral multi issues closed negotiation. Each negotiation scenario will include the negotiation settings and environment, the participating parties in the negotiation and the negotiation object.

Negotiating parties in a bilateral negotiation are referred to the two intelligent negotiating agents. Each negotiation agent negotiates on behalf of one side of the negotiation. Depending on the negotiation scenario, those two agents could be seller and buyer, product supplier and consumer or employee and employers. Throughout this work, *Agent a* and *Agent b* will represent the negotiators.

4.2. Negotiation Process Flow

The proposed methodology in handling the negotiation problem in a cultural framework is presented in Figure 11.

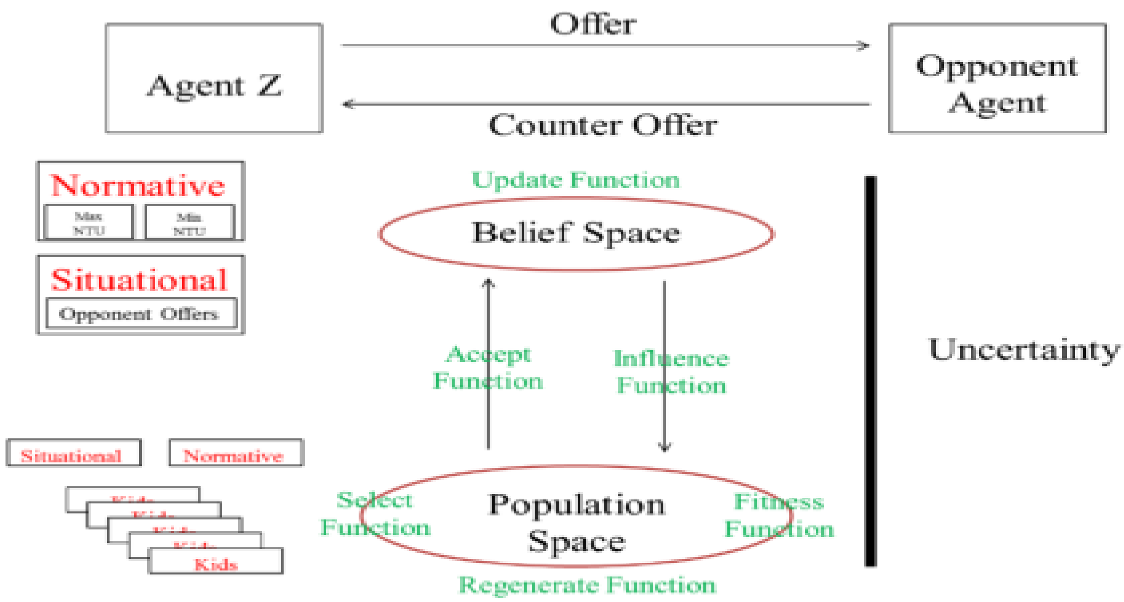

Figure 11 : The Proposed Cultural Algorithm Model for Negotiation Process

The negotiation agent will negotiate over the negotiating object, which refers to the set of the conflicting issues, to try to reach an agreement. Negotiation issues are dependent on the negotiation context, for instance, negotiation between provider and consumer in the supply chain could be on: product price, product warranty, lead time and consumer returns policy. In this work, the set of negotiation issues will be denoted as set A, $A = \{a_1, a_2, a_3 \ldots, a_n\}$, while for each issue $a_j \in A$, the negotiation agent will have a set of options o_n, such as each $a_j = \{o_1, o_2, o_3 \ldots, o_n\}$, those options are mutually exclusive, meaning that the negotiation agent is allowed to select only one option for each negotiation issue and reject the rest.

The preference profile refers to the importance of weight for each negotiation issue, and the evaluation of each option available for each issue. This profile is considered as private information in close negotiation, and it is not allowed to exchange that information prior or during the negotiation with the opponent. The preference profile for each negotiation agent will be defined prior to the start of the negotiation as well as the time available for negotiation. This information will initialize the belief space and the population space randomly within minimum and maximum target utility.

The importance of weight for negotiation issues will be denoted as a vector W and the sum of all the weights should equal to one.

$$W^i = <w^i_1, w^i_2, w^i_3, \ldots, w^i_n> \quad (3)$$

$$\sum_{i=1}^{n} W^i_j = 1 \quad (4)$$

Where i Є {a,b} , j Є A and n is the number of issues.

During the negotiation, Agent i will select a value for each issue, x_j, to make the complete bid, X = {$x_1, x_2, x_3, \ldots, x_n$} which its utility will be calculated using the utility function.

$$U(X) = \sum_{i=1}^{n} \omega_i \frac{E(o_i)}{Max\left(E(o_i)\right)} \quad (5)$$

Where U(.) is the utility of an offer X, representing a complete bundle that specifies the value for each issue a_j. Also, E(.) is the agent evaluation for an option in an issue a, n is the total number of issues, and ω_i is the weight for issue a_j.

The utility of an offer belongs to the interval between [0,1]. Thus, the reserve price for the negotiation agent is zero. In other words, if the negotiation is finished without an agreement, the agent will receive a utility equaling to its reserve price, which is in this case zero.

In the first version of Agent Z, no assumptions were made about the opponent's preferences or utility. However, it is left to evolve throughout the negotiation. However, in the following versions of Agent Z, a frequency model was used to draw an idea about the opponent preferences and to improve the quality of the offer sent to the opponent.

When the negotiation starts, the negotiating agent will generate the first population from random, but the following constraints should be satisfied for all the individuals in the first population:

$$U(O) \geq MinNTU \quad (6)$$

$$U(O) \leq MaxNTU \quad (7)$$

Consequently, the $MaxNTU$ will be selected as best fit and will be sent to believe space and then to the opponent as an offer. After that we have there possible actions:

$$Possible\ actions = \begin{cases} Agreement \\ Counter\ Offer \\ Termination \end{cases}$$

If the offer sent by Agent Z to the opponent got accepted, the utility is recorded and the negotiation session is ended. If the offer is rejected, the opponent might terminate the negotiation and then each agent will receive their own reserve price, or the opponent will propose a counter offer.

Agent Z would accept an offer received from the opponent, if the offer utility is higher than the aspiration level (ɒ) of the agent. The aspiration level is the utility level that the agent is looking to achieve during the negotiation. This aspiration level change during the negotiation based on the time, number of rounds and the opponent behavior during the negotiation (cooperating or competing). Agent Z might accept an offer, which has been rejected earlier because the aspiration level was lowered in later stage of the negotiation. At the start of the negotiation, the aspiration level is as high as the maximum utility of 1, and towards the end of the negotiation, it is as low as the minimum accepted utility.

Agent Z would propose a counter offer, if the proposed offer utility is lower than the aspiration level and the agent believes that an improvement can be achieved in the future. The internal mechanism of offer generation follows the following steps: Agent Z will receive the offer from the opponent, calculate its utility from its own preferences profile and store as Situational Knowledge Utility (SKU). The termination function is called, which will end the negotiation, with acceptance of the last offer received if one of the following conditions is satisfied:

$$\frac{t_{now}}{t_{max}} \geq 0.99 \tag{8}$$

$$\frac{SKU}{MaxNTU} \geq 0.99 \tag{9}$$

The first termination condition illustrates the situation when the time is about to finish and no agreement is reached yet. In this situation, Agent Z will prefer to accept the last offer received from the opponent which has a utility higher than the utility of the reserve price of zero. The second termination condition illustrates the situation when the opponent offers a bid with very close utility to the last bid proposed by Agent Z. Both termination conditions are implemented in Agent Z in order to make the agent time and utility dependent agent and to make the agent more rational.

If the termination conditions are not reached, the population space will be influenced by SKU and MaxNTU, which will be considered as parents to produce the following generation. After that, the utility (fitness) function will calculate the fitness for the entire space and return the best to the acceptance function. Once the offer is accepted, it will be sent to the belief space to update MaxNTU and send it to the opponent as a counteroffer.

On the other hand, the negotiation agent can terminate the negotiation at any point of time during the negotiation session. This action is possible in reality, especially when the opponent is not cooperating and the gap between the negotiating parties is large. Once the negotiation is terminated by either party, both agents will receive a utility equaling to zero. Thus, in automated negotiation, and for a rational agent, it is always better to negotiate more and to try to reach an agreement rather than terminating the session. That is because the utility of any agreement reached is definitely higher than the utility of the reserved value of zero.

As mentioned earlier, the negotiation session could also be terminated, if the total allowed time for the negotiation is finished ($t > t_{max}$), or the allowed number of rounds is reached without reaching an agreement with the opponent. For this reason, the aspiration level is lowered to the minimum accepted utility towards the end of the negotiation so the agent would accept the opponent offer rather than ending up with zero utility. It is assumed, in this work, that the negotiation is bounded by time only rather than the number of rounds, to allow the negotiation agent to exchange more bids. This will allow testing the negotiation agent behavior during the negotiation in term of cooperation and concession and how close are their offers to Pareto optimal frontier. An offer is called a Pareto optimal offer if it has higher utility for the opponent from all the other generated offers at a given aspiration level. Proposing an offer on the Pareto optimal frontier as shown in Figure 12, which is the frontier that connects all the Pareto optimal points, indicates that the agent is able to learn the opponent preferences effectively and can propose offers which increase the opponent's utility without reducing its own utility, which has a higher possibility to be accepted by the opponent. During the negotiation, the agents will try to learn more about the opponent preferences, due to the fact that having more information about the opponent preference would improve the quality of the offers and increase the probability of reaching an agreement by the end of the negotiation.

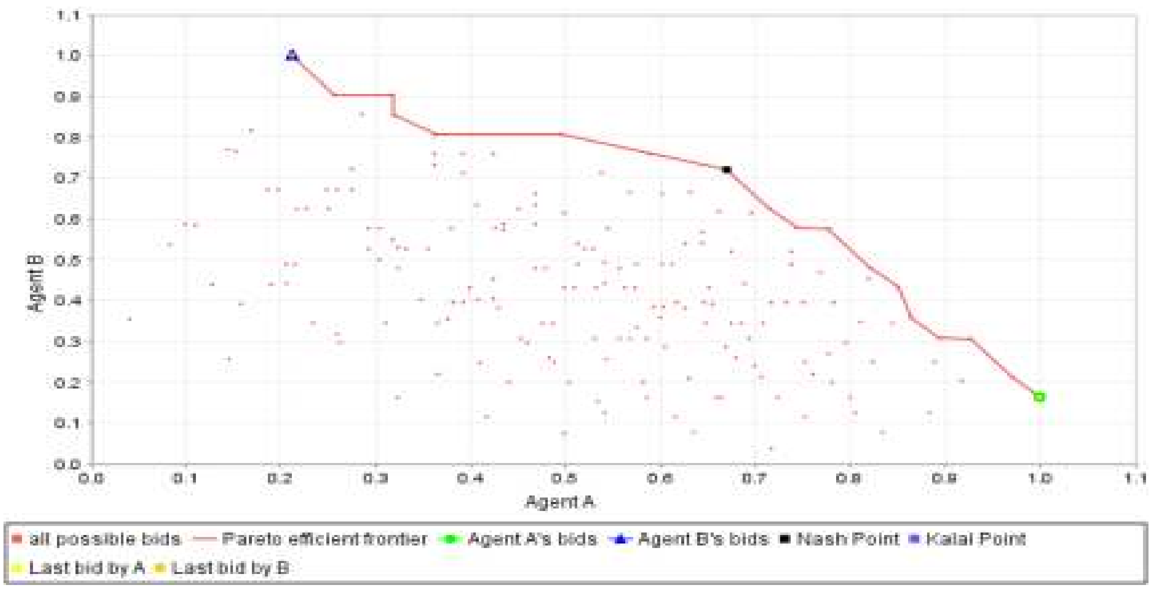

Figure 12 : Pareto Efficient Frontier in Sample Negotiation Domain

It is assumed that repeating the same offer many times without reaching the minimum normative target utility (MinNTU) is not desirable for both negotiators. A cooperative opponent would try to negotiate, discover the different areas in the solution space and learn the opponents' preferences by sending different offers to the opponent and observe the reaction behavior. On the other hand, a competitive negotiator would prefer to repeat his/her offers over and over to force the opponent to concede first in the negotiation. Agent Z is assumed to be a cooperative negotiator. S/he tries to search the solution space and find offers that are close to Pareto efficient frontier. Such offers have higher probabilities to be accepted since they optimize the opponent utility while not decreasing Agent Z's utility at a given utility level. To illustrate this, let's consider the possible offers around 0.55 to 0.65 utility to Agent B in Figure 13. There are 21 offers in this range and 3 offers only are located on the Pareto efficient frontier. If Agent B is to offer a bid from those 21 offers, which are indifferent to it since it all has almost the same utility, Agent A would have a higher probability of accepting the offers that are close to the frontier since its utility increases as the offers approach the frontier.

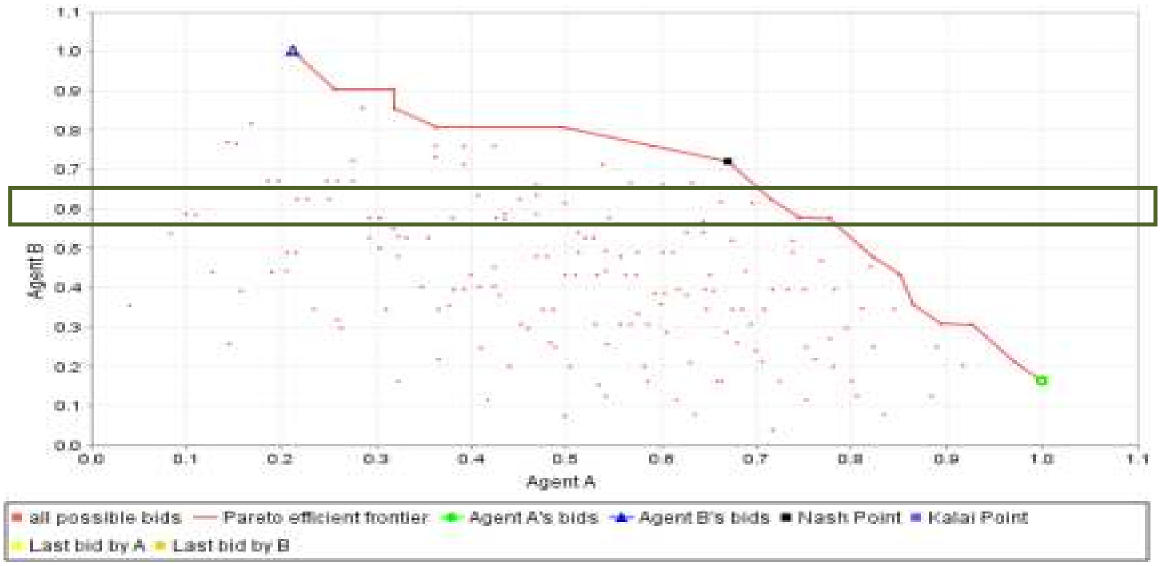

Figure 13 : Possible Offers Around 0.55 to 0.65 utility to Agent B

It is believed that if both agents cooperated in the negotiation, the probability to reach an agreement is higher. Thus, different strategies were used in different versions of Agent Z to increase the cooperation level of the opponent, such as:

1. Hold changing the proposed offer till the last quarter of the time available for negotiation, in order to add time pressure on the opponent to cooperate.
2. Sending different offers that are indifferent in utility for Agent Z at a given utility level.

The second action experimentally proved to be better in promoting cooperation and it shows higher level of responsiveness by the opponent because of the following:

1. It shows the opponent that Agent Z is willing to cooperate to find a mutually accepted agreement.
2. It allows saving time for further negotiation unlike the first strategy which put both negotiation parties under time pressure.
3. It allows learning about the opponent preference.

4.3. Agent Z – V1.0

The first version of Agent Z, was modeled to deal with cooperating opponents, assuming that if both parties agreed to cooperate during the negotiation, then the probability to reach an agreement is higher. Figure 14 illustrates the mechanism of exchanging offers and counter offers with the opponent.

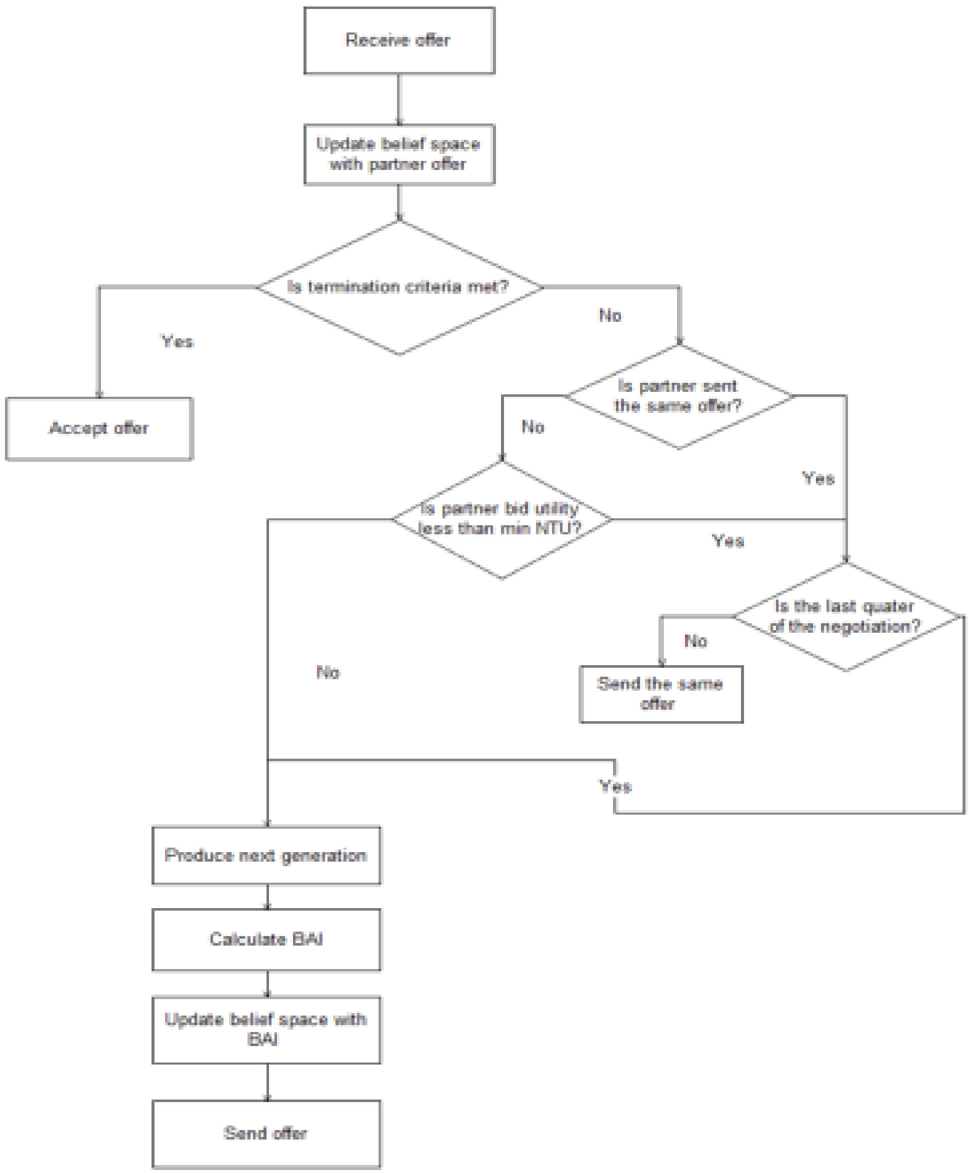

Figure 14 : Agent Z Offer Exchange Mechanism - Version 1

Before starting the negotiation the agent initializes the population. In this version of the agent the size of the population is fixed. It is being read from the settings file and does not depend on the domain size. The agent calculates the best bid and adds it to the population. Other population members (population size – 1) are being generated from random.

In case Agent Z is starting the negotiation it offers the best accepted individual from the population, which is the best bid calculated during the initialization of the population.

Let us take a detailed look on the process flow steps from receiving the opponent's offer through the decision making to the sending the offer to the opponent.

The agent receives the opponent's offer. From the code point of view it is a method *call* from GENIUS negotiation simulator. After receiving the offer the agent updates the situational knowledge utility (SKU) component of the Belief Space with the partner's bid.

Then the termination criterion is checked. In case it is satisfied, Agent Z accepts the opponent's offer. The termination criterion consists of 2 parts: the time part and the utility part. The satisfaction of either parts of the criterion is enough for the whole termination criterion to be satisfied. The time part checks whether the negotiation process is coming to end. This criterion is satisfied if the time passed since the start of the negotiation is more or equal to the 99% of the time dedicated to the whole negotiation process. The reason of adding such a criterion is to avoid the situation when the negotiation process is finished without finding the agreement. The second criterion is the utility criterion. It checks whether the opponent's offer utility is more or equal to the 99% of the maximum normative target utility. It means that if the opponent's offer is "good enough" to Agent Z it will be accepted. The 99% valued mentioned above could be alternated in the settings file.

Then the agent checks whether the opponent's bid is the same bid received on the previous round – send offer cycle iteration. This check is made in order to press the opponent to cooperate. If the opponent is sending the same offer again and again Agent Z also sends the same offer it has sent before. This could be done till the last quarter (25%)

of the negotiation. In the last quarter of the negotiation the agent is forced to search for the agreement and no longer presses the opponent. The 25% value could be changed in the settings file.

The next step is producing the next generation of the population. It is being done in the following way.

```
Bid parent1 = beliefSpace.getMaxNTUBid();
writer.write("First parent: " + parent1.toString());
writer.newLine();
Bid parent2 = beliefSpace.getSKUBid();
writer.write("Second parent: " + parent2.toString());
writer.newLine();
```

Figure 15 : Population Generation Code from Parents

Firstly, Agent Z selects two parents. The first parent is the bid with the maximum normative target utility (*MaxNTU*) from the existing population while the second parent is the opponent's bid. After that the code will go into the children generation loop in which the population size is taken from the xml settings file.

For example, let us assume that the size is set to 10 children. Then the code will need 5 iterations of the loop; since the code generates two children in every loop.

```
for (int i = 0; i < Settings.POPULATION_SIZE /2; i++) {
...
}
```

Figure 16 : Children Generation Loop

The next generation of the population is being produced from these two parents using the crossover and the mutation operations.

The crossover operation exchanges parts of the parents' chromosomes. It is a fixed 2-points crossover with the distance between points equal to the single issue. In other words, a single issue number will be selected and options for that issue will be exchanged between parents.

The follwoing is an example of the crossover:

Parent 1 : ***001,001,001***

Parent 2 : 010,010,010

Possible children : 010,***001***,***001*** and ***001***,010,010

or ***001***,010,***001*** and 010,***001***,010

or ***001***,***001***,010 and 010,010,***001***

```
int issueIndex =
random.nextInt(utilitySpace.getDomain().getIssues().size());
int issueNumber =
utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
Value tempOption = child1.getValue(issueNumber);
child1.setValue(issueNumber, child2.getValue(issueNumber));
child2.setValue(issueNumber, tempOption);
```

Figure 17 : Crossover Code

The mutation operation changes one random issue option of each child with a fixed 50% probability. The probability value will be configured in the xml setting file.

For example, in the child 01,01, the mutation operation could leave it unchanged with the 50% probability: 01,01. Or it could change it in one of the following ways with the equal 25% probability:

10, 01

01, 10

The following is the mutation code on child 1 and the same is applied on child 2.

```
if (random.nextDouble() < Settings.MUTATION_PROBABILITY) {
issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
issueNumber =
utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
IssueDiscrete issueDiscrete =
(IssueDiscrete)utilitySpace.getDomain().getIssue(issueIndex);
int issueValue = random.nextInt(issueDiscrete.getNumberOfValues());
child1.setValue(issueNumber, issueDiscrete.getValue(issueValue));
}
```

Figure 18 : Mutation Code of the First Child.

These crossover and mutation operations are being performed on a population size / 2 times, producing 2 children every time.

Then the best accepted individual from the population will be calculated using the fitness function. This function searches the bid with the maximum utility except for the bids with the utility that is equal to the previous maximum normative target utility. This is done in order to diversify the offers generated by the Agent.

In the final step the best accepted individual found on the previous step is being sent to the Belief space as the maximum normative target utility (*MaxNTU)* bid and being offered to the partner. From the code point of view the method returns the bid to the GENIUS negotiation simulator.

During the testing of the Agent Z – Version 1.0 against different agents and on different negotiation domains, few drawbacks were discovered:

1. When a time termination criterion was set to 95% and negotiation time comes to 95% , Agent Z accepts the last opponent's offer, though it could have lower utility than the one of the previous opponent's offers.

2. It behaves badly on big domains.

3. Sometimes agreement is not too close to the Pareto line.

A few significant improvements were proposed that were introduced in Agent Z – Version 2.0.

4.4. Agent Z – V2.0

The second version of Agent Z, was modified in term of the selection and mutation operators. It now uses several children from several parents. Figure 19 illustrates the mechanism of exchanging offers and counter offers with the opponent.

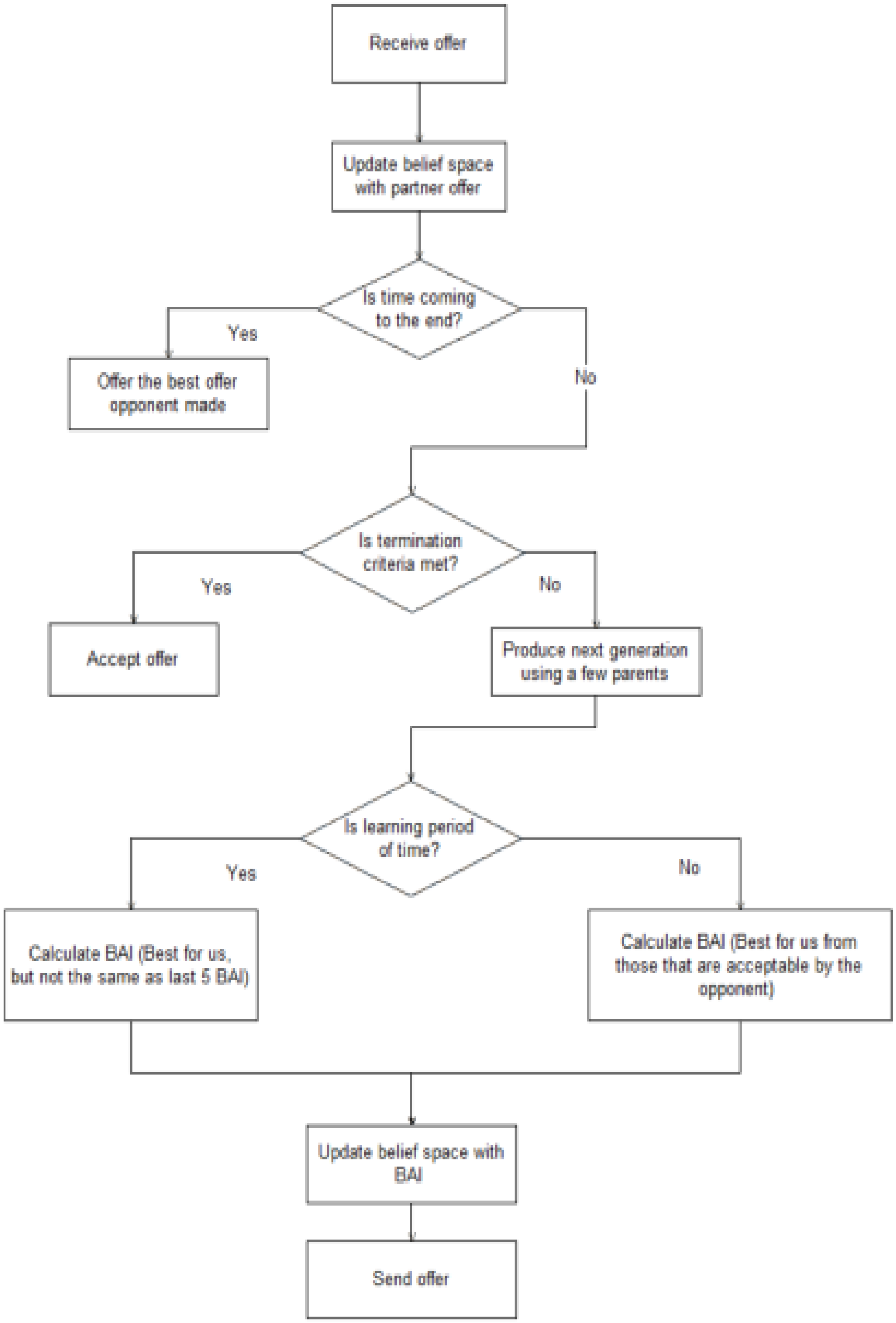

Figure 19 : Agent Z Offer Exchange Mechanism - Version 2

Let's have a detailed look on the process flow. Initially Agent Z – Version 2.0 works the same as the previous version. It generates the first population, receives the opponent's offer and updates the belief space with this offer, but there is a small but an important change. In the previous version the number of children in the population was fixed and did not depend on the domain size. It worked well on small domains, but for the large domains the number of children was not enough resulting in inability to find the good offers. In Agent Z – Version 2.0 the number of children is made a percentage of the domain size. This percentage value can be changed in the xml settings file.

Next, the termination criteria will be checked. Here the second main difference is introduced. The previous version of the agent accepts the last opponent's offer in case negotiation time is coming to the end. This is done in order to avoid the situation where agreement wasn't reached during the negotiation. But this approach appeared to be not very effective. Very often the last opponent's offer was not the best offer (offer with maximum utility) s/he made during the negotiation. And by accepting that offer we agree to the lower utility than the utility that we could possibly reach, assuming that if the opponent has made an offer before it is acceptable for him/her during the whole negotiation.

So, in this version Agent Z remembers previous opponent's bids and offers the best one from Agent Z's utility point of view to the opponent in case the negotiation time is coming to an end. The second termination criterion – utility criterion remains unchanged.

The third main difference is the algorithm of producing the child generation from parents. The previous version used 2 parents to produce the population: the bid with maximum normative target utility from the current generation and the last opponent's bid. The previous version was generating children in cycle from these 2 parents. Now it was decided to use different second parents on each cycle iteration. Agent Z – Version 2.0 uses 3 last opponent's bids in a round robin manner. It means that it uses the last opponent's bid on iterations 1, 4, 7, etc; the bid before last on iterations 2, 5, 8, etc and the third bid on iterations 3, 6, 9, etc. Agent Z – Version 2.0 introduces additional variety to the child generation and allows finding the agreement more quickly.

The fourth main difference is that Agent Z – Version 2.0 is trying to learn from the opponent about his preferences profile. Every opponent would first offer the bid that gives him a utility of 1, which means that is the most preferred options for the opponent. Then the opponent concedes to lower offers and that leads to the next opponent's preference. So we can guess the opponent's preferences profile and predict the opponent's utility. Thus when we make an offer we somehow have an idea of the utility for the opponent. If we could predict the opponent preference profile accurately, we can find the Pareto line and we can move on it towards an agreement. So at the end the target is to make a win-win agreement rather than winning the negotiation only.

It was decided to divide the negotiation time into 2 parts: learning and searching for the agreement. During the first phase of the negotiation Agent Z will learn from the opponent. It will use the fitness function that is very similar to the one used in the first version of the Agent Z. This function selects best bids, but not the bids that were selected the last 5 times before. So basically during the learning phase we offer what is best for us, but not repeat the last 5 offers. It is done in order to look at the opponent's reaction for the different offers and thus learning his/her preferences in a better way.

During the second phase Agent Z offers the bids that are rather good for us but are acceptable for the opponent too. This behavior is implemented in the new fitness function. Firstly, Agent Z finds the child with the maximum utility for the opponent. Then Agent Z calculates the minimal accepted opponent's utility by multiplying the maximum utility by the normalized time passed from the negotiation start (normalized time varies from 0 at the start of the negotiation to 1 at the end of the negotiation). As normalized time increases during the negotiation, the minimal accepted opponent's utility will increase too. Then Agent Z finds the best bid for us from the children acceptable for the opponent (bid utility > minimal accepted opponent's utility).

After the best accepted individual is selected using one of the 2 fitness functions described above, it is being set to the belief space and sent to the opponent.

4.5. Agent Z – V3.0

The third model of Agent Z is a hybrid agent which integrates the first and second version and introduced C factor which will indicate the level of partner's concession and affect the level of our concession.

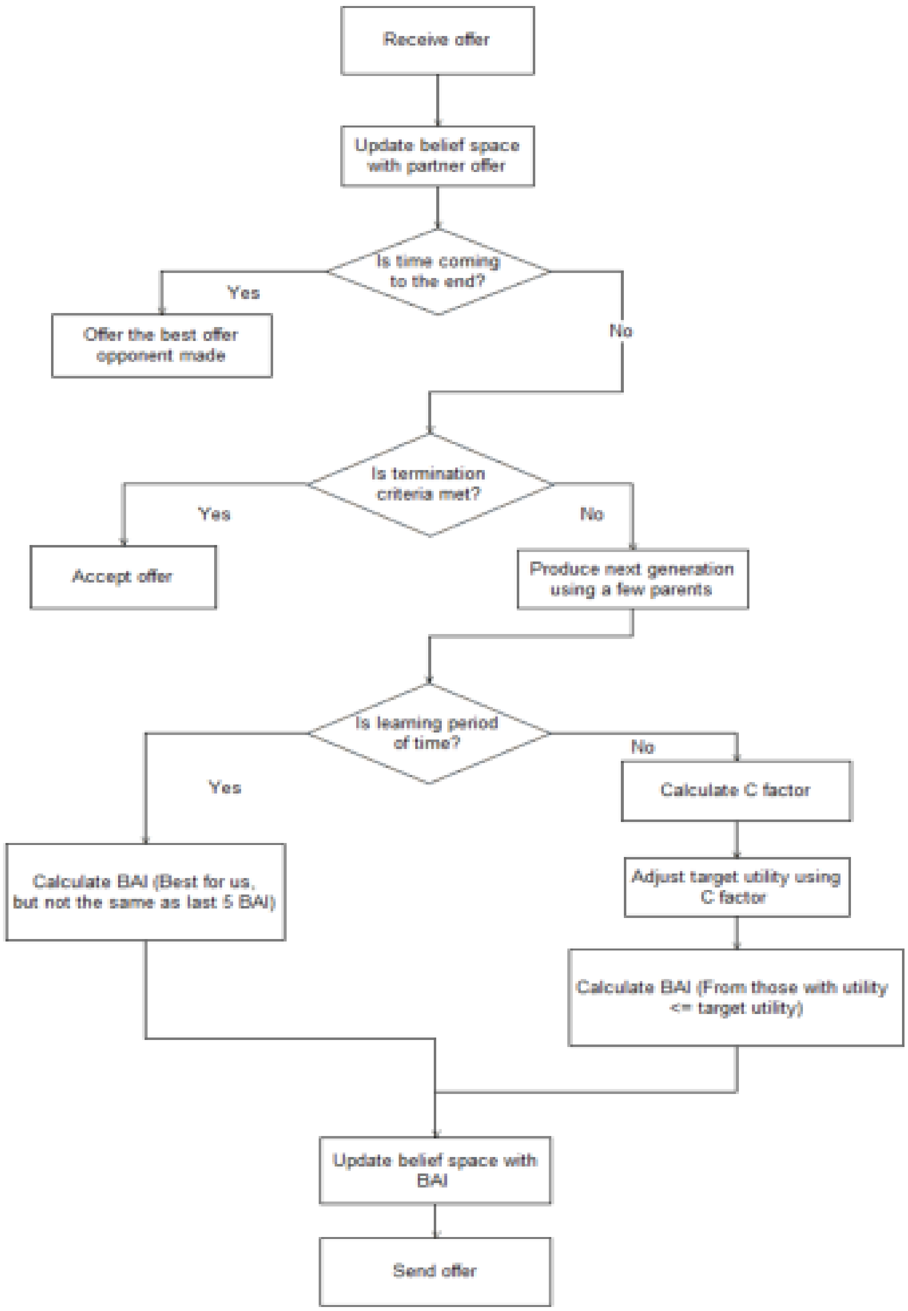

Figure 20 : Agent Z Offer Exchange Mechanism - Version 3

The process flow for Agent Z – Version 3.0 is the same as for the Version 2.0 except for the behavior during the second (searching for the agreement) phase.

During the second phase the C factor is calculated. It is equal to the utility of the last opponent's bid – utility of the opponent's bid before last. From the record of the opponent bids and its utility for us, if the opponent's bid is conceding, or in other words if offers of the opponent's bid are increasing out utility, then the opponent's bid cooperating and the C factor is lowered with the same difference, however if the opponent's bid does not concede then our utility will not change and C level will be very close to zero.

Then the target utility is adjusted by subtracting the C factor from the current target utility. After that in the new fitness function the best accepted individual is being selected using the following algorithm. Firstly, the bids are being filtered by the target utility and bids with a high utility are being ignored. Then from the rest of the bids the bid with the maximum opponent's utility will be selected. That bid is the best accepted individual. So our bids should be close to Pareto line.

Chapter 5: Implementation Details

5.1. Implementation Platform Details

The intelligent automated agent used in this thesis, Socially Motivated Approach to Simulate Negotiation Process in Automated Negotiating Agent, was tested and implemented on the platform provided in Table 1 below:

Table 1 : Testing System Specifications

Hardware Specification	
Processor	Intel I7 Q720 1.6 Ghz
RAM	6.00 GB
Hard Drive	600 GB
Software Specification	
Operating System	Windows 7 Home Premium
Java Environment	JDK 1.6, IntelliJ IDEA

5.2. General Environment for Negotiation with Intelligent Multi-Purpose Usage Simulation

The model validation is conducted using GENIUS (General Environment for Negotiation with Intelligent multi-purpose Usage Simulation), which is an open source simulator, shown below in Figure 21, offered by Lin et al. [**22**]. GENIUS is a negotiation environment that provides a test bed for automated negotiating agents, as well as offers a number of negotiation domains and analytical tools to evaluate the agent's performance. The author considered different problem domains to evaluate the performance of the proposed model.

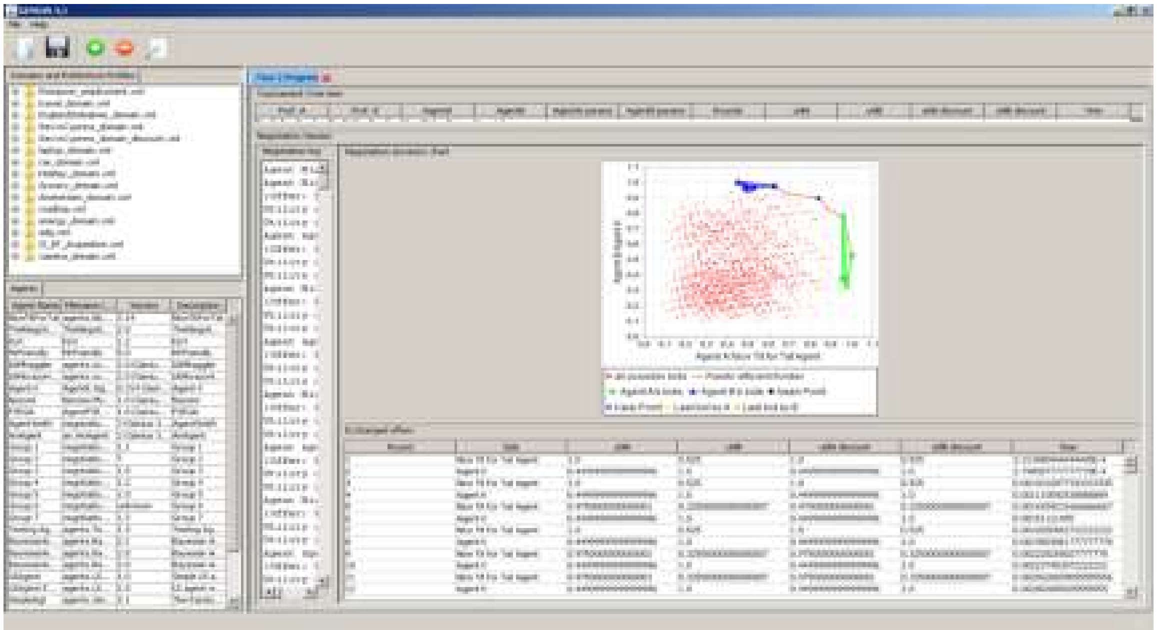

Figure 21 : GENIUS Simulator

5.3. Negotiation Domains

Negotiation domains can vary in the size depending on the number of issues and options for each issue. Figures 22 to 24 illustrate three samples domains: small, medium and large domain.

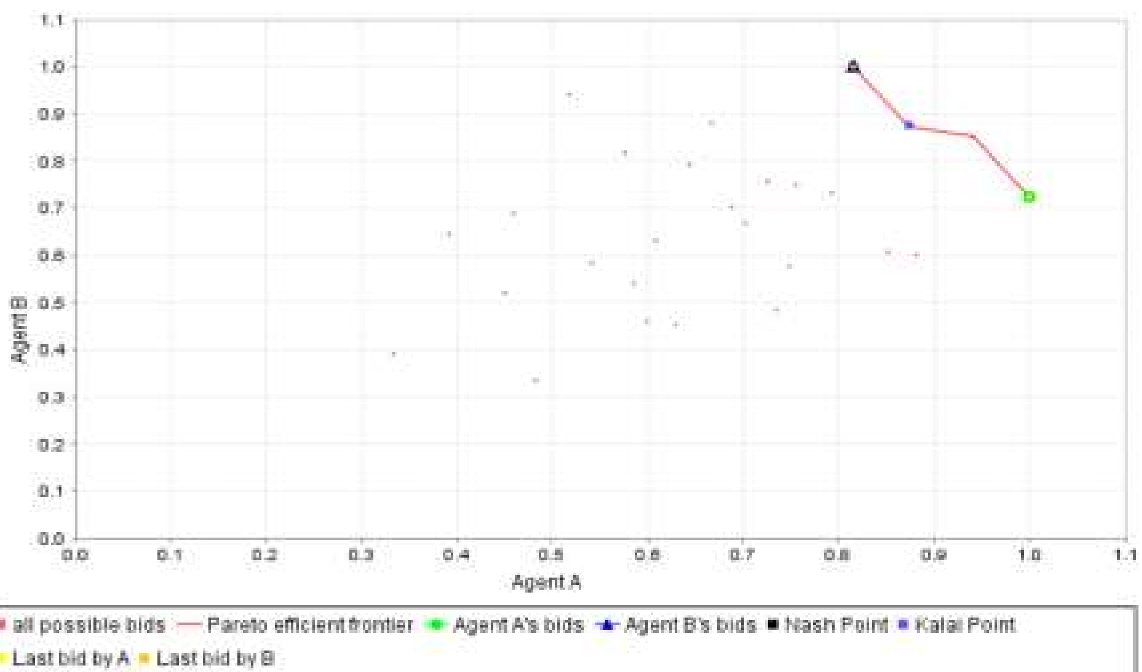

Figure 22 : Sample of Small Negotiation Domain

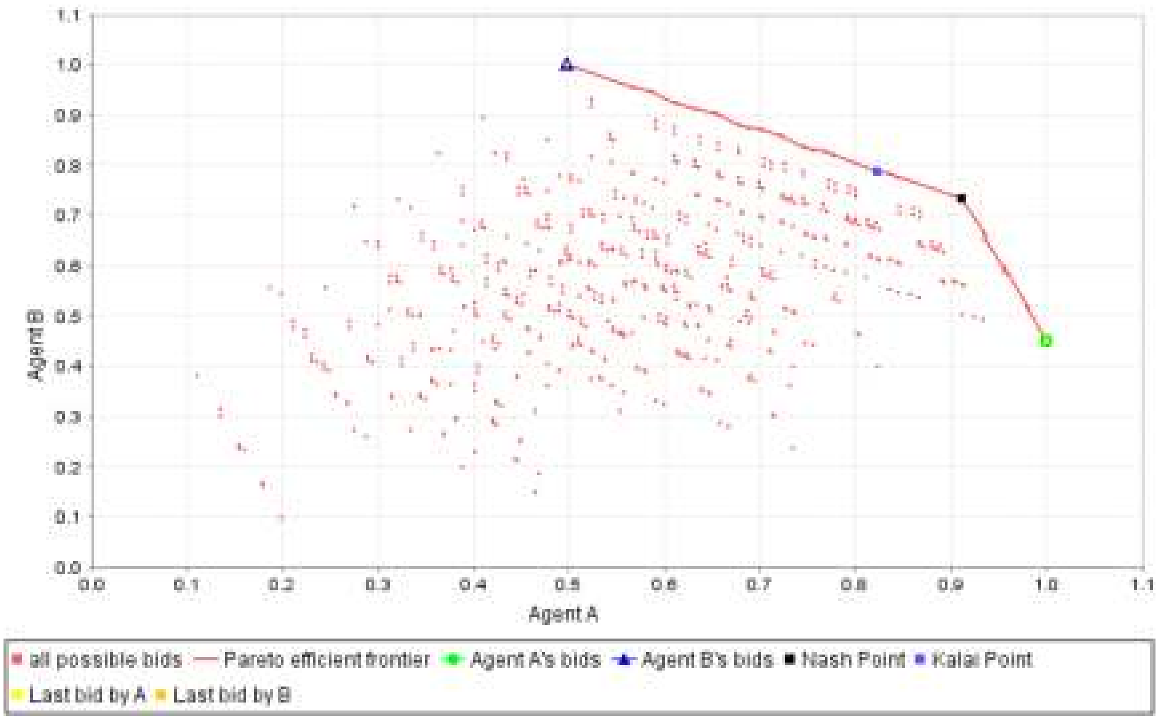

Figure 23 : Sample of Medium Negotiation Domain

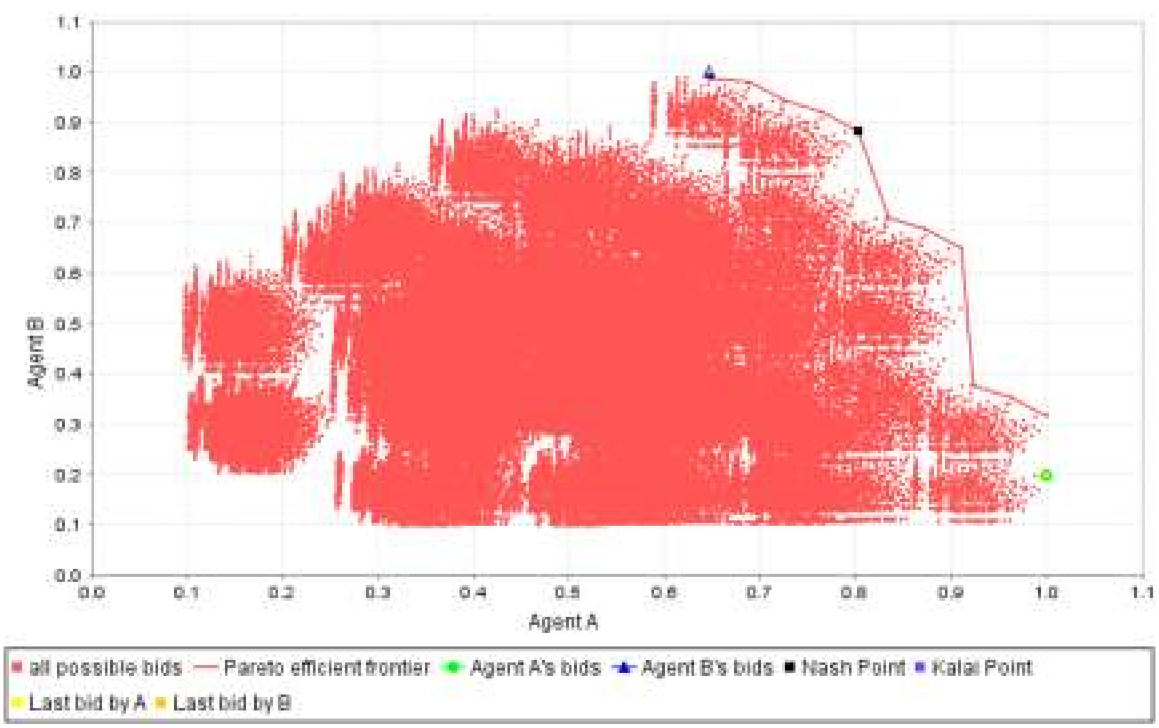

Figure 24 : Sample of Large Negotiation Domain

Chapter 6: Performance Study

6.1. Performance Comparison

After compiling the agent on the simulator, several tournaments have been run against several automated negotiation agents from the Automated Negotiating Agent Competition (ANAC) [**23**] listed in Table 2.

Table 2 : The Participating Agents of ANAC

Agent Name	Institution
IAMHaggler	University of Southampton
IAMcrazyHaggler	University of Southampton
Agent K	Nagoya Institute of Technology
Nozomi	Nagoya Institute of Technology
FSEGA	Babes Bolyai University
Agent Smith	TU Delft

The following section will give a brief description of each agent participating in the performance study. The strategy design in each agent is compared by highlighting the common and contrasting approaches. Overall, the following aspects are the most relative in the performance study:

1. Inner Proposal Behavior
2. Learning the Opponent Preferences
3. Time Monitoring

6.1.1. Opponent Negotiator Strategies

This section will give a brief of the basic internal mechanism of each agent, the way that the agent proposes and accepts offers. Moreover, the brief will include whether the agent is trying to learn his opponent preference profile from received offers and if the agent considers the remaining time for negotiation. Most of the negotiating agents are non-deterministic and select offers at certain scenarios randomly. In other words, the agents may offer different offers each time they negotiate with specific agent even on the same domain and preference profile.

Table 3 gives a summary of the participating agents in the study. It highlight whether the agent is time dependent and/or utility dependent. Moreover, it shows whether the agent is deterministic or non-deterministic and the agents' method in learning the opponent negotiator.

Table 3 : Strategies of Negotiation Agents

Agent Name	Time Dependent	Utility Dependent	Acceptance Criteria	Learning Method	Deterministic
IAM(Crazy)Haggler	✖	✔	U	None	✖
IAMHaggler	✔	✔	U	Bayesian	✖
Agent K	✔	✔	T/U	All proposals	✖
Nozomi	✔	✔	T/U	Compromises	✖
FSEGA	✔	✔	U	Bayesian	✔
Agent Smith	✔	✔	T/U	Weights	✔

6.1.1.1. IAM(crazy)Haggler

This agent is a very simple agent that consider only a "*take it or leave it*" strategy. IAM(crazy)Haggler keeps on sending random offers that are above certain utility level. Moreover, this agent doesn't care about negotiation time nor the opponents' moves.

6.1.1.2. IAMHaggler

This agent is the opposite of IAM(crazy)Haggler. IAMHaggler tries to learn the opponent negotiator using Bayesian learning. Normally IAMHaggler start with maximum utility offer of 1 and continuously IAMHaggler set a target utility. The target utility is based on the following:

1. Utility offered by the opponent
2. Negotiation Time
3. Predicted opponent profile

However, IAMHaggler considers only utility when accepting an offer. To explain that let's consider X to be the last offer received from the opponent. The offer will be accepted if any of the following is satisfied:

1. If X utility is at least 98% of IAMHaggler previous offer.
2. If X utility is at least 98% of maximum aspiration level.
3. If X utility is at least 98% of IAMHaggler upcoming offer.

6.1.1.3. Agent K

Agent K introduced “proposal target”. The previous offer received from the opponent and the time left for the negotiation. If Agent K receives an offer that is close to the proposal target, it will send the proposal target again to increase the probability of accepting it by the opponent. Otherwise, Agent K will search for offers that are at least as good as the proposal target. If nothing is found the proposal target is lowered slighting and so on.

The process of accepting offer is sophisticated in Agent K. It employs the mean, variance and the standard deviation of the offers received from the opponent. Agent K accepts an offer based on target utility and the probability of receiving better offers in the future.

6.1.1.4. Nozomi Agent

Nozomi Agent is the time and utility dependent agent. This Agent starts the negotiation with maximum utility of one. Nozomi Agent doesn’t try to predict the opponent preference. However, it measures the compromises that the opponent does and the gap in utility between Nozomi and its opponent negotiator. Nozomi divides the time into non equal 4 intervals from (0-50%) then (50% to 80%) then (80% to 90%) and (90% till the end of negotiation session). Nozomi accepts an offer based on the time left before the negotiation session comes to an end, previous offers received and the gap between the parties.

6.1.1.5. FSEGA Agent

FSEGA is like the Nozomi agent in splitting the negotiation time into intervals and following a different strategy in each one. In the first 85% of the time, the agent tries to obtain information about the opponent negotiator through the negotiator counter-offer. While in the following 10% of the negotiation time, FESGA does not make a lot of concession but relax some of the condition while trying to find an offer with high chances of being accepted by the opponent. In the last 5% of the negotiation time, the FESGA Agent applies an aggressive concession strategy to end up offering a proposal that is higher than its reservation vale.

The acceptance mechanism in the first interval in FESGA would accept any offer received which is 3% better than the last offer proposed. In later stages, the agent would accept any offer that is better than the FESGA's upcoming offers. Finally, this agent would accept any offer received when the agent can't find a better offer.

6.1.1.6. Agent Smith

Agent Smith tries to learn the opponent's preference profile thought a weight system. The system considers the importance and the preference for all the issues and its options. Agent Smith starts from maximum utility as first offer and concedes slowly towards the opponent's negotiation to close the gap between them.

The acceptance mechanism in Agent Smith works according to the following circumstances. When the negotiation is coming to an end and less than 10 seconds is left in the negotiation time, the agent offers the best offer received from the opponent negotiator, even if that offer is not good for Agent Smith. However, this strategy had a bug in the implementation since the agent was showing this behavior at an earlier stage, and this explained the poor performance of Agent Smith against other negotiation agents.

6.1.2. Testing Domains

Agent Z with all versions of Agent Z (V1.0, V2.0 and V3.0) was tested on a few different negotiation domains in terms of size and complexity as can be seen in Table 4. Basically, we have one large domain (Energy), 4 middle size domains (Amsterdam, Camera, Car, Grocery) and 1 small domain (Laptop).

Table 4 : Negotiation Domains

Domain	Number of issues	Domain size
Laptop	3	27
Grocery	5	1,600
Amsterdam Party	6	3,024
Camera	6	3,600
ADG Car Domain	6	15,625
Energy	8	390,625

For every negotiation domain a weight for each issue and preference were defined for each agent as private information. The maximum time allowed for the negotiation is set to 60 second, discounting the factor set to 1 with no limitation on the number of rounds. Moreover, the situational knowledge was set to zero, $MaxNTU$ to 1 and MinNTU to 0.5.

6.1.3. Laptop Domain

In this domain, two parties negotiate over 3 issues about buying a laptop. Table 5 presents the domain specifications and graph.

Table 5 : Laptop Domain Details

Sizes	
Issue Sizes	3, 3, 3
Domain Size	27
Pareto Frontier Size	4
Arithmetic Averaging	
K-S Point	0.87402429847838, 0.87402429847838
Max (K-S)	0.87402429847838
Mean	0.67276648590053
Mean/Max	0.76973430495214
Geometric Averaging	
Nash Point	1.0000518041718, 0.81510539516969
Max (Nash)	0.90285526028793
Mean	0.66673658347979
Mean/Max	0.73847560379408
Issue	**Options**
Laptop	Dell, Macintosh, HP
Hard Disk	60 Gb, 80 Gb, 120 Gb
External Monitor	19" LCD, 20" LCD, 23" LCD

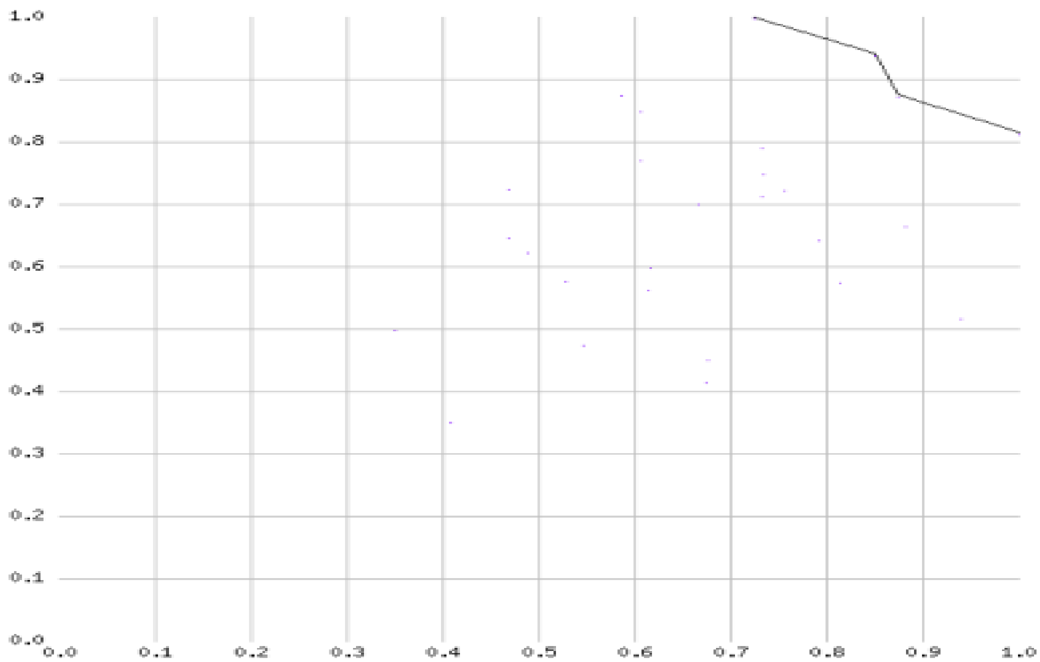

Figure 25 : Laptop Domain

6.1.1. Grocery Domain

Table 6 : Grocery Domain Details

Sizes	
Issue Sizes	4, 5, 4, 4, 5
Domain Size	1600
Pareto Frontier Size	7
Arithmetic Averaging	
K-S Point	0.84, 0.895
Max (K-S)	0.8675
Mean	0.44225
Mean/Max	0.50979827089337
Geometric Averaging	
Nash Point	0.84, 0.895
Max (Nash)	0.86706401147781
Mean	0.42530598380327
Mean/Max	0.49051278587654
Issue	**Options**
Bread type	Baguette, Crackers, Croissants, Plain bread
Fruit	Apples, Bananas, Cherries, Grapes, Pears
Snacks	Chocolate bars, Doughnuts, Nachos, Popcorn
Spreads	Cheese, Jam, Peanut butter, Sandwich spread
Vegetables	Beans, Broccoli, Leek, Potatoes, Spinach

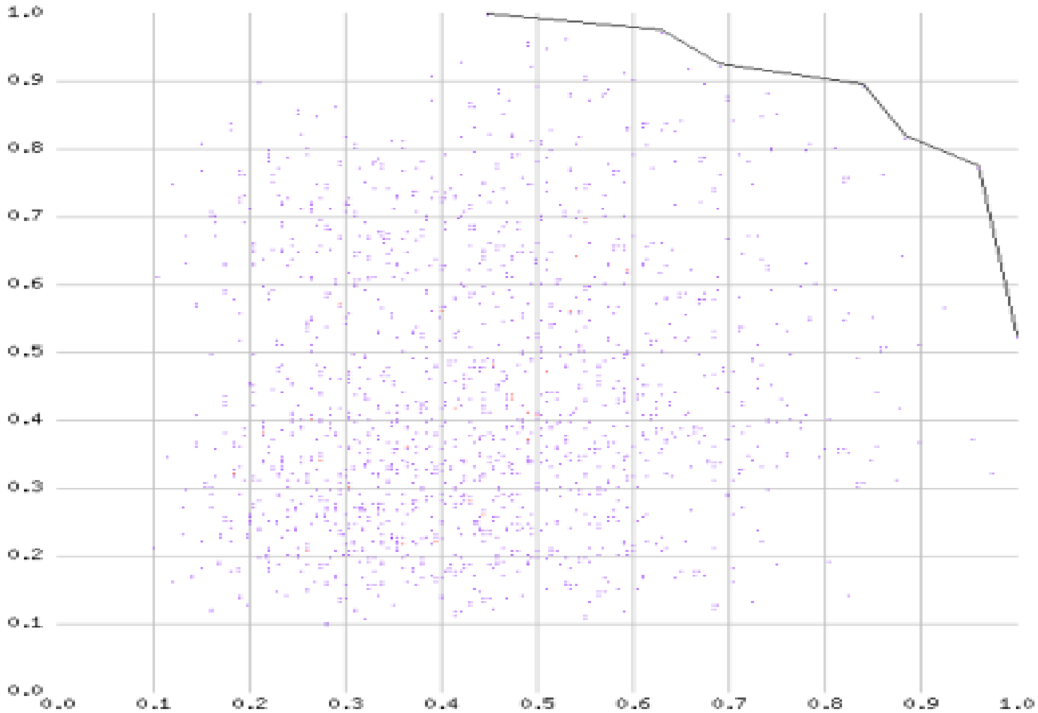

Figure 26 : Grocery Domain

6.1.2. The Amsterdam Party Domain

Table 7: Amsterdam Party Domain Details

Sizes	
Issue Sizes	4, 3, 7, 3, 3, 4
Domain Size	3024
Pareto Frontier Size	11
Arithmetic Averaging	
K-S Point	0.83, 0.855833333333333
Max (K-S)	0.84291666666667
Mean	0.62176587301587
Mean/Max	0.73763623096297
Geometric Averaging	
Nash Point	0.83, 0.855833333333333
Max (Nash)	0.84281769479922
Mean	0.61205332804818
Mean/Max	0.72619895361118
Issue	**Options**
Venue	Shopping, Museum, Dancing, Diner
Time of arrival	Morning, Afternoon, Evening
Day of the week	Mon, Tues, Weds, Thurs, Fri, Sat, Sun
Duration	One day, One night, One week
Transportation	Public transport, Car, Combination
Souvenirs	None, Tulips, Cheese, Water pipe

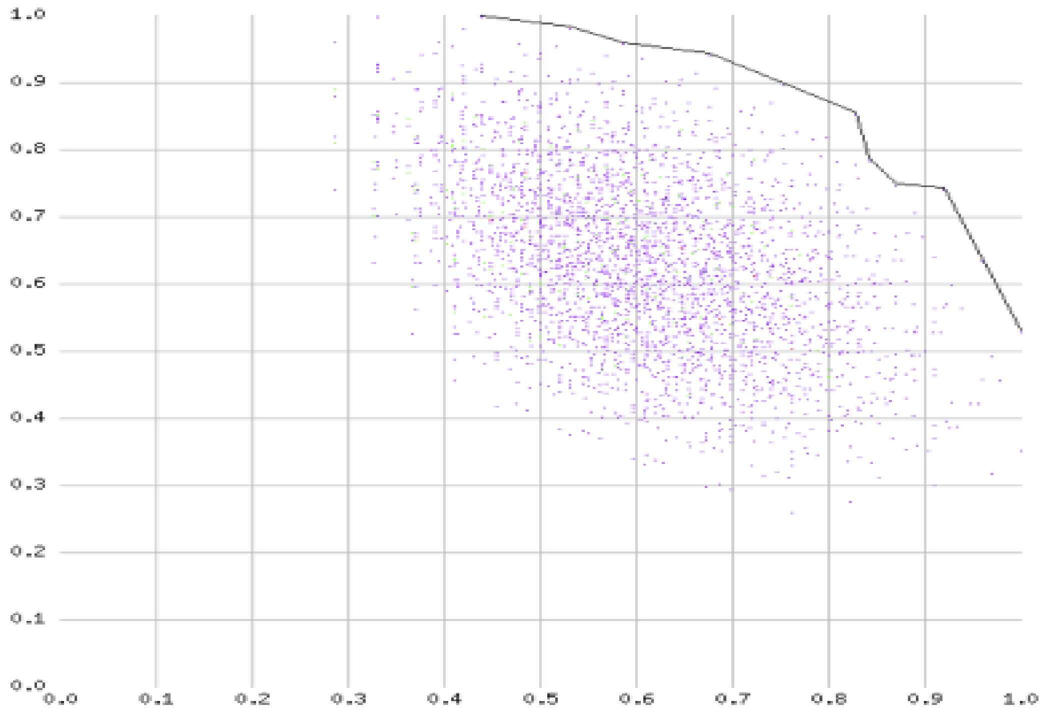

Figure 27 : Amsterdam Party Domain

6.1.3. Camera Domain

Table 8 : Camera Domain Details

Sizes	
Issue Sizes	5, 4, 3, 3, 5, 4
Domain Size	3600
Pareto Frontier Size	16
Arithmetic Averaging	
K-S Point	0.8294012605042, 0.81977142857143
Max (K-S)	0.82458634453782
Mean	0.42692323879552
Mean/Max	0.51774230997581
Geometric Averaging	
Nash Point	0.8106512605042, 0.8908
Max (Nash)	0.84978123235168
Mean	0.40342628318472
Mean/Max	0.47474134262565
Issue	**Options**
Maker	Canon, Nikon, Pentax, Sony, Panasonic
Body	Full size, APS-C, Micro Four Thirds, compact
Lens	High end model, Middle range model, Entry model
Tripod	GITZO, Manfrotto, Induro
Bag	Domke, Lowepro, Tamrac, National Geographic, Artizan&Artist
Accessory	Electronic Flash, Battery Grip, Memory, Strap

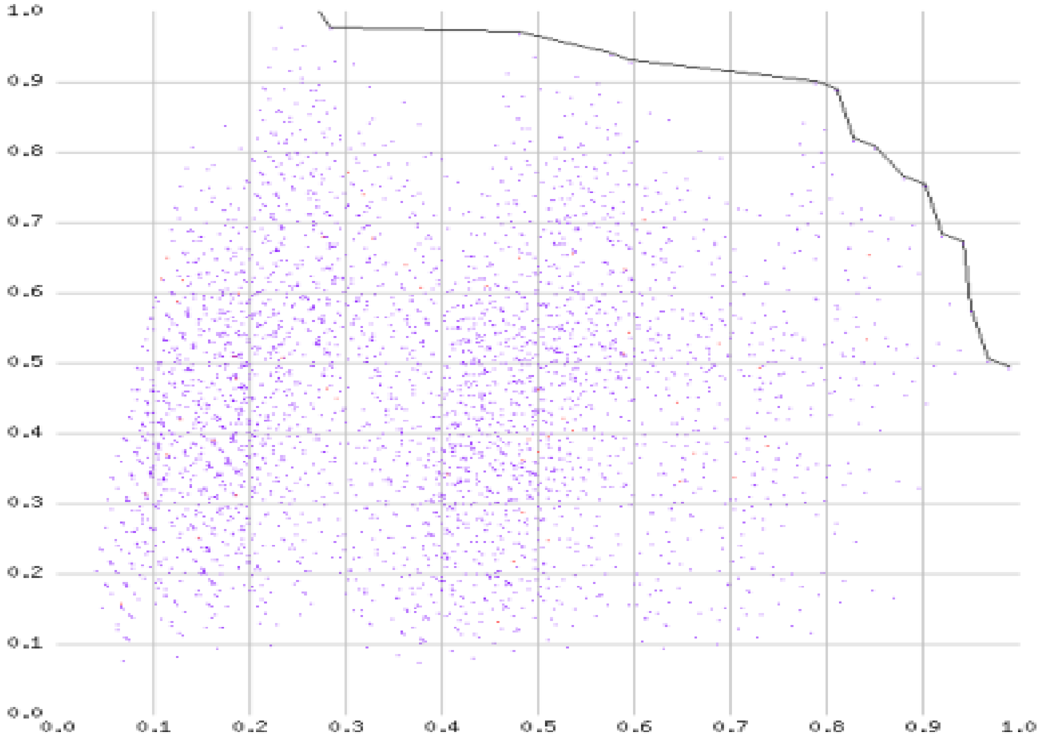

Figure 28 : Camera Domain

6.1.4. ADG Car Domain

Table 9 : ADG Car Domain Details

Sizes	
Issue Sizes	5, 5, 5, 5, 5, 5
Domain Size	15625
Pareto Frontier Size	75
Arithmetic Averaging	
K-S Point	0.9335, 0.9316
Max (K-S)	0.93255
Mean	0.74407
Mean/Max	0.7978875127339
Geometric Averaging	
Nash Point	0.9403, 0.9296
Max (Nash)	0.93493469290641
Mean	0.72834772986635
Mean/Max	0.77903594271612
Issue	**Options**
CD player	good, fairly good, standard, meager, none
Extra speakers	good, fairly good, standard, meager, none
Air conditioning	good, fairly good, standard, meager, none
Tow hedge	good, fairly good, standard, meager, none
Tow hedge2	good, fairly good, standard, meager, none
Tow hedge3	good, fairly good, standard, meager, none

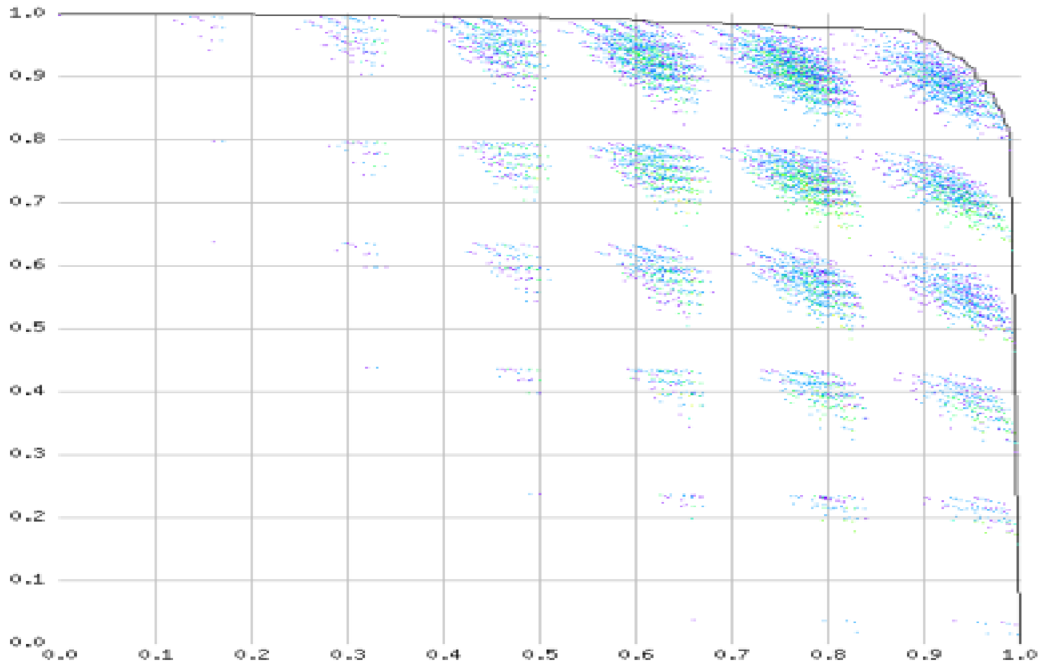

Figure 29 : ADG Car Domain

6.1.5. Energy Domain

Table 10 : Energy Domain Details

Sizes	
Issue Sizes	5, 5, 5, 5, 5, 5, 5, 5
Domain Size	390625
Pareto Frontier Size	211
Arithmetic Averaging	
K-S Point	0.6825, 0.684
Max (K-S)	0.68325
Mean	0.5625
Mean/Max	0.82327113062569
Geometric Averaging	
Nash Point	0.625, 0.75428571428571
Max (Nash)	0.6866065623256
Mean	0.54343658285431
Mean/Max	0.79148177817241
Issue	**Options**
0000-0300	0 kW, 25 kW, 50 kW, 75 kW, 100 kW
0300-0600	0 kW, 25 kW, 50 kW, 75 kW, 100 kW
0600-0900	0 kW, 25 kW, 50 kW, 75 kW, 100 kW
0900-1200	0 kW, 25 kW, 50 kW, 75 kW, 100 kW
1200-1500	0 kW, 25 kW, 50 kW, 75 kW, 100 kW
1500-1800	0 kW, 25 kW, 50 kW, 75 kW, 100 kW
1800-2100	0 kW, 25 kW, 50 kW, 75 kW, 100 kW
2100-0000	0 kW, 25 kW, 50 kW, 75 kW, 100 kW

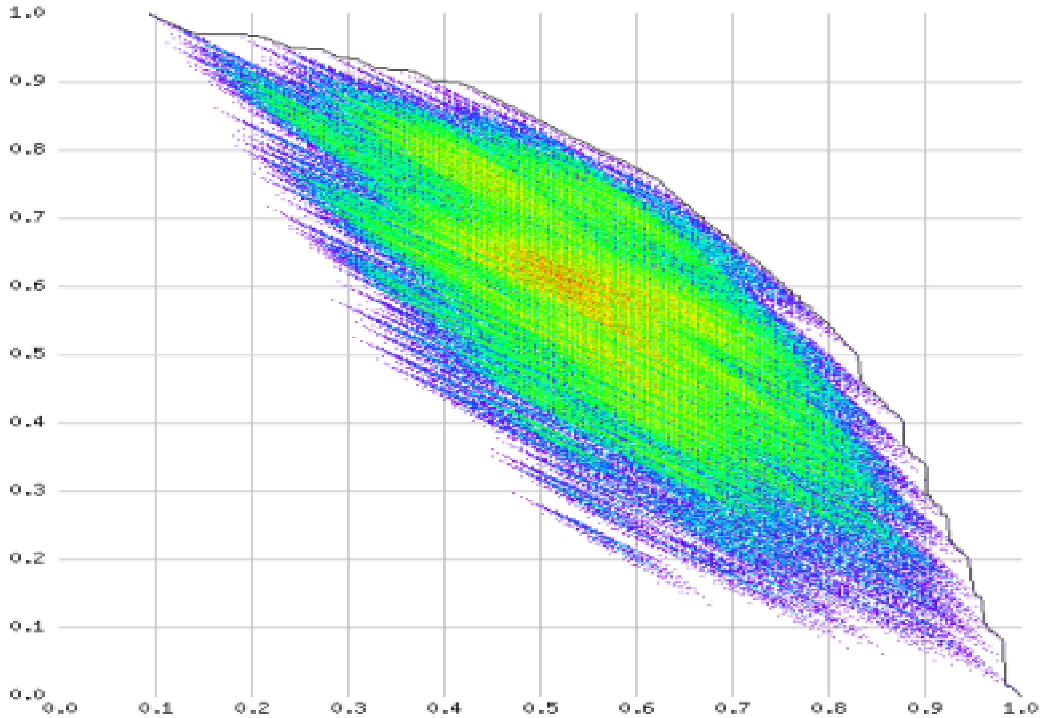

Figure 30 : Energey Domain

6.2. Experimental Negotiation Results and Discussion

Agent Z (V1.0, V2.0 and V3.0) was compiled of GEINUS 4.0 and tournaments were run on both sides, once Agent Z as Negotiator Agent A and the other as Negotiator Agent B. Each negotiation was run for 10 secessions to properly test the behavior of the agent since Agent Z is non-deterministic and chooses random values and some points.

6.2.1. Agent Z1.0 Run Resutls

Table 11 shows the tournament results for Agent Z1.0 vs the other six opponent negotiators. Agent Z1.0 negotiates 100 times with each opponent once as agent A and another as Agent B. Overall, Agent Z1.0 won 308 negotiations, lost 234 negotiations, withdrew from the negotiation 21 times and 37 negotiations were finished before reaching an agreement.

Table 11 : Agent Z1.0 Run Results vs Opponent

Agent Z		Opponent	Wins the Negotiation	Looses the Negotiation	Draws from Negotiation	Reached deadlines without agreement	Sum
Agent Z 1.0	vs	AgentFSEGA	29	40	5	26	100
Agent Z 1.0	vs	AgentK	75	19	6	0	100
Agent Z 1.0	vs	IAmHaggler	52	35	2	11	100
Agent Z 1.0	vs	IAmCrazyHaggler	15	80	5	0	100
Agent Z 1.0	vs	AgentSmith	94	4	2	0	100
Agent Z 1.0	Vs	Nozomi	43	56	1	0	100
Agent Z 1.0 Totals			308	234	21	37	600

Table 12 shows the results for Agent Z1.0 verses the opponent in regards to domains. The results show that Agent Z1.0 performs better on small domains like Laptop and Grocery domain while the performance was poor on other domains.

Table 12 : Agent Z1.0 Run Results on Different Domains

Agent Z		Domain	Wins the Negotiation	Looses the Negotiation	Draws from Negotiation	Reached deadlines without agreement.	Sum
Agent Z 1.0	on	Laptop	73	26	21	0	120
Agent Z 1.0	on	Grocery	79	41	0	0	120
Agent Z 1.0	on	Amsterdam	44	73	0	3	120
Agent Z 1.0	on	Camera	49	65	0	6	120
Agent Z 1.0	on	Car	63	29	0	28	120
Agent Z 1.0 Totals			308	234	21	37	600

Table 13 shows the quality of the results for Agent Z1.0 in terms of average Pareto, Nash and Kalai distances. Moreover, it shows the overall average social welfare. It is noticeable that the quality for solutions on small domains are much better in comparison with larger domains.

Table 13 : Agent Z1.0 Solution Quality

Agent Z		Domain	Pareto Distance	Nash Distance	Kalai Distance	Social Welfare
Agent Z 1.0	on	Laptop	0.001579	0.136222	0.076584	1.788503
Agent Z 1.0	on	Grocery	0.03679	0.213783	0.213783	1.600209
Agent Z 1.0	on	Amsterdam	0.097749	0.315012	0.315012	1.435159
Agent Z 1.0	on	Camera	0.086368	0.322098	0.304784	1.418569
Agent Z 1.0	on	Car	0.251486	0.602401	0.600027	1.167621
Agent Z 1.0 Totals			0.094795	0.317903	0.302038	1.482012

6.2.2. Agent Z2.0 Run Resutls

Table 14 shows the result for Agent Z2.0 verses the other negotiators. Agent Z2.0 won 253 times, lost 306 times, withdrew from the negotiations 14 times and the negotiation time finished before reaching an agreement 27 times. It is noticeable that Agent Z2.0 managed to reach agreement 559 times in comparison to Agent Z1.0 who reaced to agreements only 540 times.

Table 14 : Agent Z2.0 Run Results vs Opponent

Agent Z		Opponent	Wins the Negotiation	Looses the Negotiation	Draws from Negotiation	Reached deadlines without agreement.	Sum
Agent Z 2.0	Vs	AgentFSEGA	20	65	0	15	100
Agent Z 2.0	Vs	AgentK	63	37	0	0	100
Agent Z 2.0	Vs	IAmHaggler	54	33	1	12	100
Agent Z 2.0	Vs	IAmCrazyHaggler	9	83	8	0	100
Agent Z 2.0	Vs	AgentSmith	80	15	5	0	100
Agent Z 2.0	Vs	Nozomi	27	73	0	0	100
Agent Z 2.0 total			253	306	14	27	600

Table 15 shows the results for Agent Z2.0 verses the other opponent in regards to domains. The reults shows that Agent Z2.0 performs better on larger domains like the Car Domain.

Table 15 : Agent Z2.0 Run Results on Domains

Agent Z		Domain	Wins the Negotiation	Looses the Negotiation	Draws from Negotiation	Reached deadlines without agreement.	Sum
Agent Z 2.0	on	Laptop	17	89	14	0	120
Agent Z 2.0	on	Grocery	85	35	0	0	120
Agent Z 2.0	on	Amsterdam	46	71	0	3	120
Agent Z 2.0	on	Camera	45	75	0	0	120
Agent Z 2.0	on	Car	60	36	0	24	120
Agent Z 2.0 Totals			253	306	14	27	600

Table 16 shows the quality results for Agent Z2.0. It shows that Agent Z2.0's results were much better than Agent Z1.0 in terms of quality. The solutions were very close to Nash Point and most of the time was exactly a Nash point like on Laptop Domain.

Table 16 : Agent Z2.0 Solution Quality

Agent Z		Domain	Pareto Distance	Nash Distance	Kalai Distance	Social Welfare
Agent Z 2.0	on	Laptop	0	0.173394	0.120627	1.773365
Agent Z 2.0	on	Grocery	0.02047	0.15829	0.15829	1.634918
Agent Z 2.0	on	Amsterdam	0.086219	0.320344	0.320344	1.446444
Agent Z 2.0	on	Camera	0.046718	0.319301	0.295026	1.45482
Agent Z 2.0	on	Car	0.219542	0.575638	0.573468	1.214939
Agent Z 2.0 Totals			0.07459	0.309394	0.293551	1.504897

6.2.3. Agent Z3.0 Run Resutls

Table 17 shows the results for Agent Z3.0 verses the other negotiators. Agent Z3.0 won 186 negotiations and lost 362 negotiations. Morover, Agent Z3.0 withdrew from negotiations 16 times and ran out of time 36 times. An investigation was conducted on the negotiations with FSEGA and the opponent failed to send his/her last offer before negotiation deadtime. Otherwise, Agent Z3.0 could end up with reaching agreement 575 times out of 600 negotiations.

Table 17 : Agent Z3.0 Run Results vs Opponent

Agent Z		Opponent	Wins the Negotiation	Looses the Negotiation	Draws from Negotiation	Reached deadlines without agreement.	Sum
Agent Z 3.0	vs	AgentFSEGA	14	59	0	27	100
Agent Z 3.0	vs	AgentK	26	71	3	0	100
Agent Z 3.0	vs	IAmHaggler	53	38	0	9	100
Agent Z 3.0	vs	IAmCrazyHaggler	11	80	9	0	100
Agent Z 3.0	vs	AgentSmith	69	27	4	0	100
Agent Z 3.0	Vs	Nozomi	13	87	0	0	100
Agent Z 3.0 total			186	362	16	36	600

Table 18 shows the reults for Agent Z3.0 verses opponent in regards to domains. It is noticeable that cooperations approach for Agent Z3.0 was too good to reach solutions rather than winning the negotiations. The realier investigations shows that the opponent FSEGA had diffeculties in sending the last offer on Car domain which is a large domain.

Table 18 : Agent Z3.0 Run Results on Domains

Agent Z		Domain	Wins the Negotiation	Looses the Negotiation	Draws from Negotiation	Reached deadlines without agreement.	Sum
Agent Z 3.0	on	Laptop	29	75	16	0	120
Agent Z 3.0	on	Grocery	60	60	0	0	120
Agent Z 3.0	on	Amsterdam	35	81	0	4	120
Agent Z 3.0	on	Camera	22	94	0	4	120
Agent Z 3.0	on	Car	40	52	0	28	120
Agent Z 3.0 Totals			186	362	16	36	600

Table 19 shows the solution quality for the reached agreement for Agent Z3.0. It is noticeable that Agent Z3.0 had better solutions on Laptop, Amsterdam and Camera Doamin verses the previous domains. However, Agent Z2.0 had better overall solution qualities.

Table 19 : Agent Z3.0 Solution Quality

Agent Z		Domain	Pareto Distance	Nash Distance	Kalai Distance	Social Welfare
Agent Z 3.0	on	Laptop	0	0.151072	0.075438	1.790537
Agent Z 3.0	on	Grocery	0.030955	0.146519	0.146519	1.642125
Agent Z 3.0	on	Amsterdam	0.062732	0.234871	0.234871	1.517736
Agent Z 3.0	on	Camera	0.061218	0.209317	0.199346	1.515906
Agent Z 3.0	on	Car	0.264957	0.542767	0.539848	1.210163
Agent Z 3.0 Totals			0.083972	0.256909	0.239204	1.535293

6.3. Energy Domain

The Energy domain is a very big domain that is hardly handled by most of the agents even Agent Z1.0 and Agent Z2.0. To run the negotiation, tournament time was increased to 180 second and time termneation criteria was set to 0.95. The size of the domain leads to a significant number of operations to be done to make a decision. Hence one round takes more time than smaller domains. This leads to a small number of rounds that the agents are able to perform during the 180 seconds negotiation time. Some of the agents were not able to do any rounds at all and agreement was not reached as shown in Table 20.

Table 20 : Tournament Result for Energy Domain

Negotiation Session	Number of Rounds	Agent A	Agent B	Utility of Agent A	Utility of Agent B	Time to Agreement
1	9	Agent Z3.0	IAMHaggler	0.0	0.0	-
2	45	Agent Z3.0	IAMcrazyHaggler	0.23	0.85	0.97
3	47	Agent Z3.0	Agent K	0.43	0.80	0.95
4	47	Agent Z3.0	Nozomi	0.31	0.82	0.97
5	0	Agent Z3.0	FSEGA	0.0	0.0	-
6	3	Agent Z3.0	Agent Smith	0.0	0.0	-

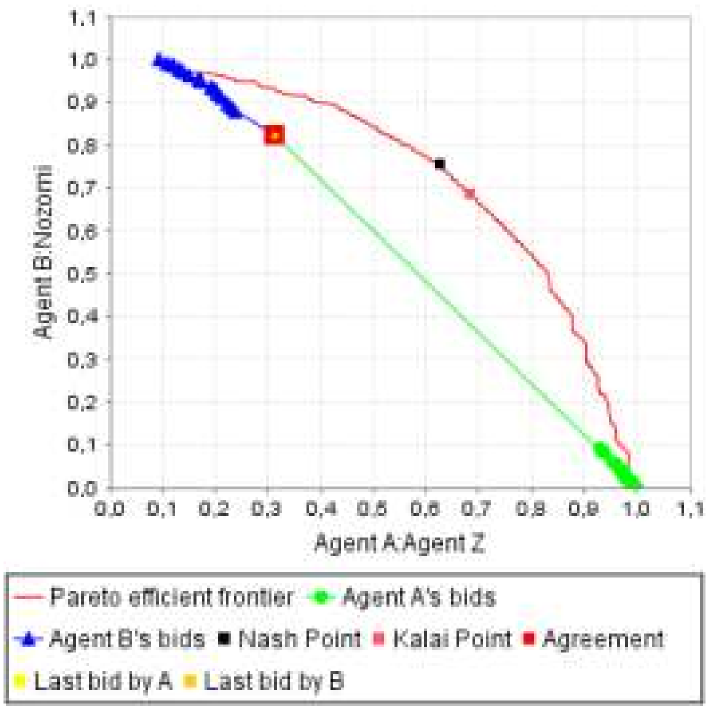

Figure 31 : Agent Z3.0 vs. Nozomi: Energy Domain

Both agents starts with 1.0 utility bids. During the negotiation Nozomi lowers his utility, so the C factor is raised and Agent Z3.0 cooperates. However, due to the large size of the domain the number of rounds is not enough to reach the agreement. Agent Z3.0 accepts the best opponent's bid when the negotiation time comes to 0.95 rather than ending up with 0 utility before deadtime.

6.4. Summary

Overall, the script to analyze GENISU log files obtained some interesting results. It turned out that Agent Z is not that bad in terms of winning the negotiations. Both Agent Z1.0 and Agent Z2.0 win Agent K, IAMhaggler and Agent Smith but loose to Agent FSEGA, IAMcrazyHaggler and Nozomi. Moreover, Agent Z3.0 wins IAMhaggler and Agent Smith but looses to the remaining 4 agents. What is interesting is that Agent Z1.0 wins more often than Agent Z2.0 and Agent Z3.0

A detailed look at the cases of deadline was also looked at in detail. They all happen with AgentFSEGA and IAmHaggler. They were all reached while it was opponent's time to make offer.

The motivation for moving from Agent Z1.0 to Agent Z2.0 and Agent Z3.0 was that the agents were not cooperative enough and agreements were not often close to the Pareto line. The results show that Agent Z2.0 and Agent Z3.0 are indeed more cooperative than Agent Z1.0. Moreover, Agent Z3.0 gives much better results in term of Nash distance, Kalai distance and overall social welfare. In conulusion, in this thesis, we succeeded in the development of cooperative agents that try to reach acceptable solutions for negotiators rather than being selfish and win all the negotiations.

Chapter 7: Conclusion and Implications of the Study

7.1. Conclusion and Possible Improvements

In this work, a novel model of negotiation in cultural algorithm framework is presented. Cultural algorithm is considered as a dual inheritance system. It evolves on two levels, the micro evolution level in the belief space and the macro evolution level in the population space. The experimental results show that the cultural algorithm model could adopt the nature of negotiation and it could improve the search for near optimal strategy with lower computational capabilities. Thus, the negotiation is considered as effective and efficient.

However, this model performs best when both agents are willing to cooperate to reach a win-win stage. On the other hand, if the opponent preferred to compete rather than to cooperate, the negotiation yields lower results for the negotiating agents. To solve this issue, number of tactics is proposed such as putting the opponent under time pressure by letting the negotiating agent hold his/her offer till the last quarter of the available time. This approach helped in forcing the opponent to cooperate and negotiate rather than repeating the same offer over and over. Moreover, the minimum normative target utility (MinNTU) is introduced as stopping criteria, in which the negotiating agent is not allowed to concede beyond this utility.

Agent Z succeeded in reaching an agreement in most of the negotiation sessions except for some sessions on the very large Energy domain. The following conclusions can be drawn from the results and Appendices:

1. Agent Z is much more cooperative than most of the other agents. Agent Z tends to find a win-win agreement rather than win a negotiation.
2. Many of the agreement reached are located on Pareto efficient frontier.
3. Many of the agreements reached were either Nash equilibrium point or close to it.
4. If the opponent is cooperative, like Agent Smith, reaching an agreement is much faster than with non-cooperative agents.

5. Agent Z performs well with time and utility dependent agents. However, it didn't perform well with utility only dependent agents, like IAMcrazyHaggler, and was forced to accept the best offer when the negotiation time passed 99%.

The following problems were discovered:

1. Sometimes Agent Z offers bids that have lower utility than the best opponent's bid. In order to solve this problem additional checks on the offers being made should be performed.

2. The constant 99% value of the time termination criterion is not always the best solution. Sometimes it is too low, and we could make a few more negotiation rounds before accepting the opponent's best offer. And sometimes on very large domains where one round could take more than 5% of the time, 95% is too much because negotiation could be terminated without finding an agreement and without Agent Z having a chance to accept the opponent's offer. So it will be better to make this 95% coefficient dependent on average or maximum opponent's response time.

7.2. Future Research

The future research directions include developing a better learning mechanism for the negotiating agent in order to predict the opponent's utility and preferences. It is believed that the more knowledge one has on the opponent, the better the outcomes and strategeies for the negotiation.

Moreover, the possibility of implementing the negotiation model should be investigated on real cases in engineering systems such as resources allocation problem, and team collation problem.

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Appendix A : Laptop Domain – Agent Z1.0

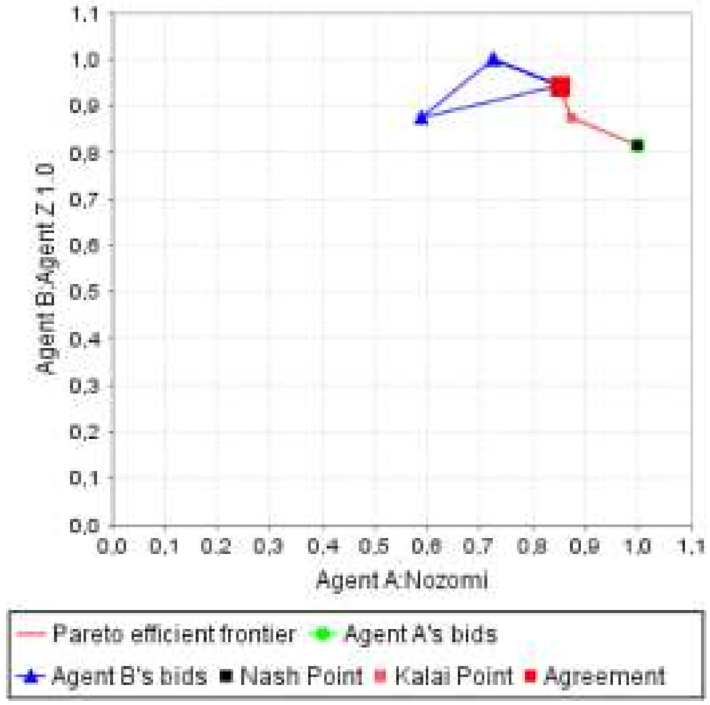

Figure 32 : Nozomi vs Agent Z1.0 - Laptop Domain

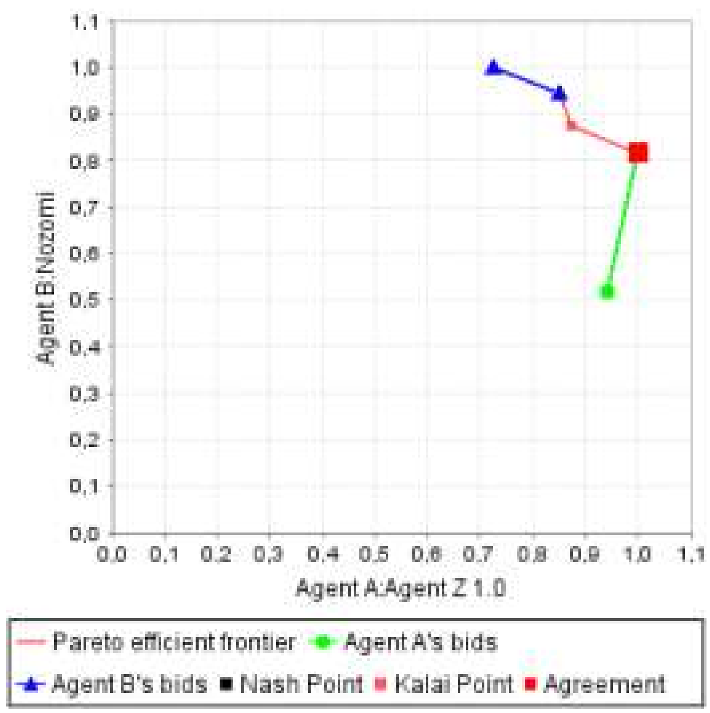

Figure 33 : Agent Z1.0 vs Nozomi - Laptop Domain

Table 21 : Agent Z1.0 vs Nozomin - Laptop Domain

Agent	Agent Z 1.0	Nozomi		Nozomi	Agent Z 1.0
Average time of agreement	0.540385441	0.540385441		0.81081231	0.81081231
Std time of agreement	0.362362494	0.362362494		0.004860432	0.004860432
Average time of end of negotiation	0.540385441	0.540385441		0.81081231	0.81081231
Std time of end of negotiation	0.362362494	0.362362494		0.004860432	0.004860432
Average rounds	216.5	216.5		322.8	322.8
Std rounds	143.6142001	143.6142001		1.932183566	1.932183566
Percentage of agreement	100	100		100	100
Average utility	0.927422141	0.873325676		0.851647612	0.941132901
Std utility	0.075536453	0.062827367		0	0
Average utility of agreements	0.927422141	0.873325676		0.851647612	0.941132901
Average discounted utility	0.600108921	0.585461331		0.425077025	0.469741203
Std discounted utility	0.155775573	0.227603944		0.001773768	0.001960144
Average discounted utility of agreements	0.600108921	0.585461331		0.425077025	0.469741203
Average nash distance	0.093358235	0.093358235		0.19465704	0.19465704
Average nash distance of agreements	0.093358235	0.093358235		0.19465704	0.19465704
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.099854073	0.099854073		0.07074094	0.07074094
Average kalai distance of agreements	0.099854073	0.099854073		0.07074094	0.07074094
Average social welfare	1.800747817	1.800747817		1.792780513	1.792780513
Average social welfare of agreements	1.800747817	1.800747817		1.792780513	1.792780513
Average exploration	0.084656085	0.082010582		0.037037037	0.096296296
Average joint exploration	0.166666667	0.166666667		0.122222222	0.122222222
Perc pareto bids	0.42704955	1		1	0.998125
Average unfortunate moves	0.039344891	0		0	0.001886792
Average fortunate moves	0.016179995	0		0	0.001886792
Average nice moves	0	0		0	0
Average selfish moves	0.000362582	0.009885162		0	0.014930271
Average concession moves	0.000899639	0.038153958		0	0.016817063
Average silent moves	0.943212894	0.951960881		1	0.964479081

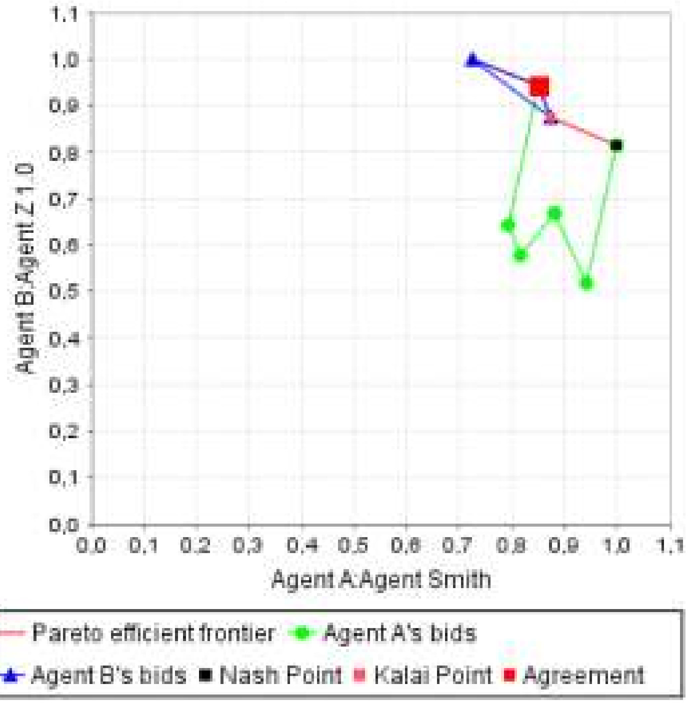

Figure 34 : Agent Smith vs Agent Z1.0 - Laptop Domain

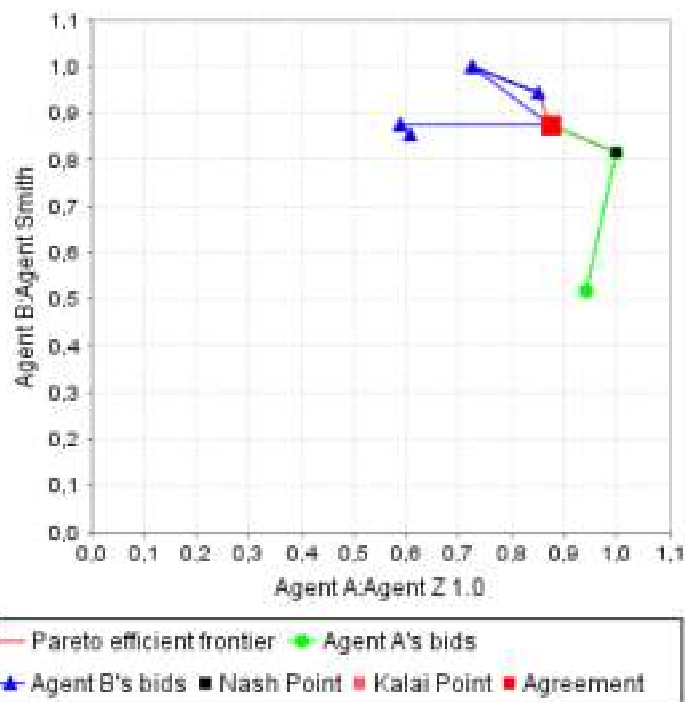

Figure 35 : Agent Z1.0 vs Agent Smith – Laptop Domain

Table 22 : Agent Z1.0 vs Agent Smith - Laptop Domain

Agent	Agent Z 1.0	Agent Smith		Agent Smith	Agent Z 1.0
Average time of agreement	0.025360407	0.025360407		0.037976	0.037976
Std time of agreement	0.016755179	0.016755179		0.002629	0.002629
Average time of end of negotiation	0.025360407	0.025360407		0.037976	0.037976
Std time of end of negotiation	0.016755179	0.016755179		0.002629	0.002629
Average rounds	11.4	11.4		15	15
Std rounds	6.095535707	6.095535707		1.054093	1.054093
Percentage of agreement	100	100		100	100
Average utility	0.928061475	0.871408288		0.853885	0.934422
Std utility	0.076122772	0.062630316		0.007076	0.021222
Average utility of agreements	0.928061475	0.871408288		0.853885	0.934422
Average discounted utility	0.907296177	0.853533226		0.826548	0.904486
Std discounted utility	0.062595165	0.073626972		0.007699	0.01998
Average discounted utility of agreements	0.907296177	0.853533226		0.826548	0.904486
Average nash distance	0.091770122	0.091770122		0.189099	0.189099
Average nash distance of agreements	0.091770122	0.091770122		0.189099	0.189099
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.097832903	0.097832903		0.063667	0.063667
Average kalai distance of agreements	0.097832903	0.097832903		0.063667	0.063667
Average social welfare	1.799469762	1.799469762		1.788307	1.788307
Average social welfare of agreements	1.799469762	1.799469762		1.788307	1.788307
Average exploration	0.111111111	0.174074074		0.203704	0.114815
Average joint exploration	0.285185185	0.285185185		0.311111	0.311111
Perc pareto bids	0.57281746	0.723809524		0.280357	0.95
Average unfortunate moves	0.430952381	0		0.309524	0.057143
Average fortunate moves	0.145238095	0		0.014286	0.057143
Average nice moves	0	0		0	0
Average selfish moves	0.026785714	0.244761905		0.140476	0.154762
Average concession moves	0.105952381	0.705238095		0.22619	0.111905
Average silent moves	0.291071429	0.05		0.309524	0.619048

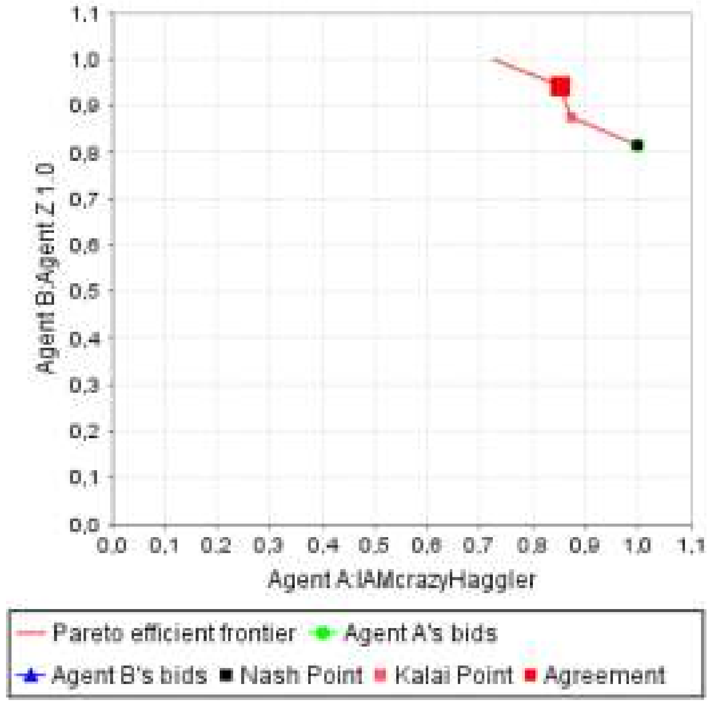

Figure 36 : IAMcrazyHaggler vs Agent Z1.0 – Laptop Domain

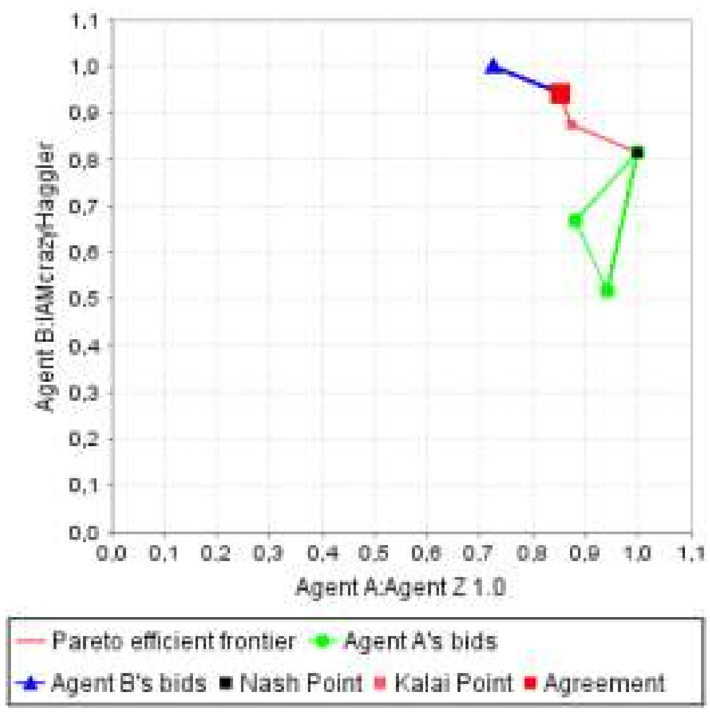

Figure 37 : Agent Z1.0 vs IAMcrazyHaggler – Laptop Domain

Table 23 : Agent Z1.0 vs IAMcrazyHaggler – Laptop Domain

Agent	Agent Z 1.0	IAMcrazy haggler		IAMcrazy haggler	Agent Z 1.0
Average time of agreement	0.276207	0.276207		0.005036	0.005036
Std time of agreement	0.311241	0.311241		7.51E-06	7.51E-06
Average time of end of negotiation	0.276207	0.276207		0.005036	0.005036
Std time of end of negotiation	0.311241	0.311241		7.51E-06	7.51E-06
Average rounds	111.1	111.1		2	2
Std rounds	123.2779	123.2779		0	0
Percentage of agreement	100	100		100	100
Average utility	0.862836	0.907579		0.851648	0.941133
Std utility	0.011794	0.035369		0	0
Average utility of agreements	0.862836	0.907579		0.851648	0.941133
Average discounted utility	0.700551	0.739311		0.847979	0.937079
Std discounted utility	0.160227	0.182713		5.46E-06	6.03E-06
Average discounted utility of agreements	0.700551	0.739311		0.847979	0.937079
Average nash distance	0.166865	0.166865		0.194657	0.194657
Average nash distance of agreements	0.166865	0.166865		0.194657	0.194657
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.03537	0.03537		0.070741	0.070741
Average kalai distance of agreements	0.03537	0.03537		0.070741	0.070741
Average social welfare	1.770415	1.770415		1.792781	1.792781
Average social welfare of agreements	1.770415	1.770415		1.792781	1.792781
Average exploration	0.111111	0.074074		0.037037	0.037037
Average joint exploration	0.185185	0.185185		0.074074	0.074074
Perc pareto bids	0.448251	1		0.5	1
Average unfortunate moves	0.170575	0		NaN	NaN
Average fortunate moves	0.115532	0		NaN	NaN
Average nice moves	0	0		NaN	NaN
Average selfish moves	0	0.273625		NaN	NaN
Average concession moves	0.050716	0.283348		NaN	NaN
Average silent moves	0.663177	0.443027		NaN	NaN

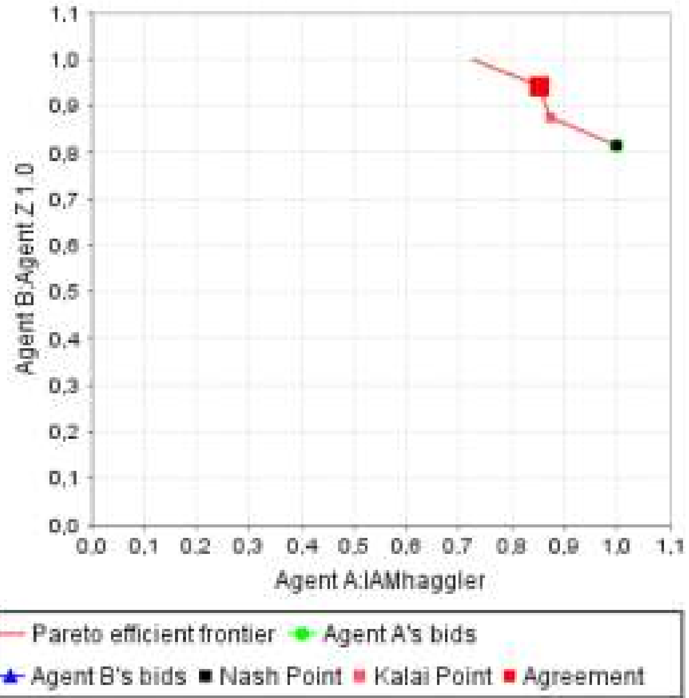

Figure 38 : IAMHaggler vs Agent Z1.0 – Laptop Domain

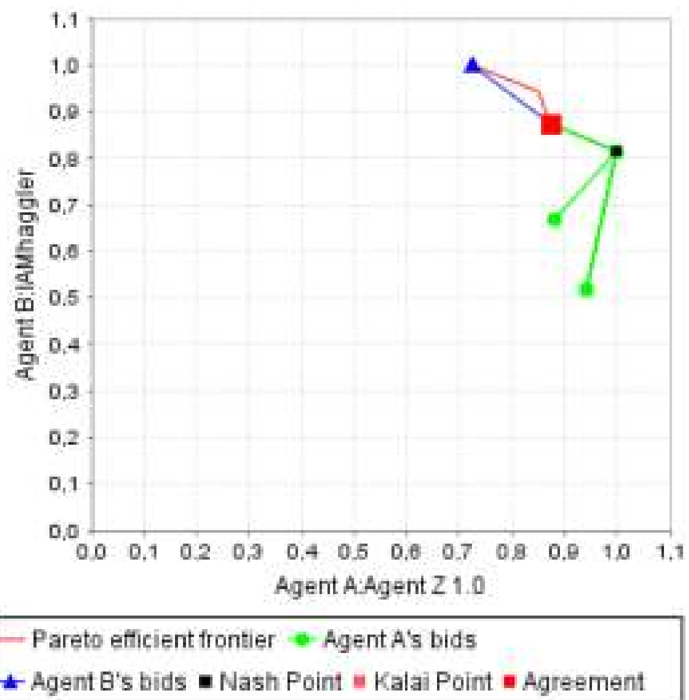

Figure 39 : Agent Z1.0 vs IAMHaggler – Laptop Domain

Table 24 : Agent Z1.0 vs IAMHaggler – Laptop Domain

Agent	Agent Z 1.0	IAMhaggler		IAMhaggler	Agent Z 1.0
Average time of agreement	0.821955	0.821955		0.00506	0.00506
Std time of agreement	0.08992	0.08992		1.33E-05	1.33E-05
Average time of end of negotiation	0.821955	0.821955		0.00506	0.00506
Std time of end of negotiation	0.08992	0.08992		1.33E-05	1.33E-05
Average rounds	328.8	328.8		2	2
Std rounds	35.41751	35.41751		0	0
Percentage of agreement	100	100		100	100
Average utility	0.974805	0.826889		0.851648	0.941133
Std utility	0.053116	0.024842		0	0
Average utility of agreements	0.974805	0.826889		0.851648	0.941133
Average discounted utility	0.484889	0.40904		0.847962	0.93706
Std discounted utility	0.058804	0.018829		9.7E-06	1.07E-05
Average discounted utility of agreements	0.484889	0.40904		0.847962	0.93706
Average nash distance	0.027815	0.027815		0.194657	0.194657
Average nash distance of agreements	0.027815	0.027815		0.194657	0.194657
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.111258	0.111258		0.070741	0.070741
Average kalai distance of agreements	0.111258	0.111258		0.070741	0.070741
Average social welfare	1.801694	1.801694		1.792781	1.792781
Average social welfare of agreements	1.801694	1.801694		1.792781	1.792781
Average exploration	0.111111	0.103704		0.037037	0.037037
Average joint exploration	0.203704	0.203704		0.074074	0.074074
Perc pareto bids	0.118415	0.997436		1	1
Average unfortunate moves	0.02149	0.00129		NaN	NaN
Average fortunate moves	0.015821	0		NaN	NaN
Average nice moves	0	0		NaN	NaN
Average selfish moves	0.003458	0		NaN	NaN
Average concession moves	0.001523	0.010047		NaN	NaN
Average silent moves	0.957708	0.988662		NaN	NaN

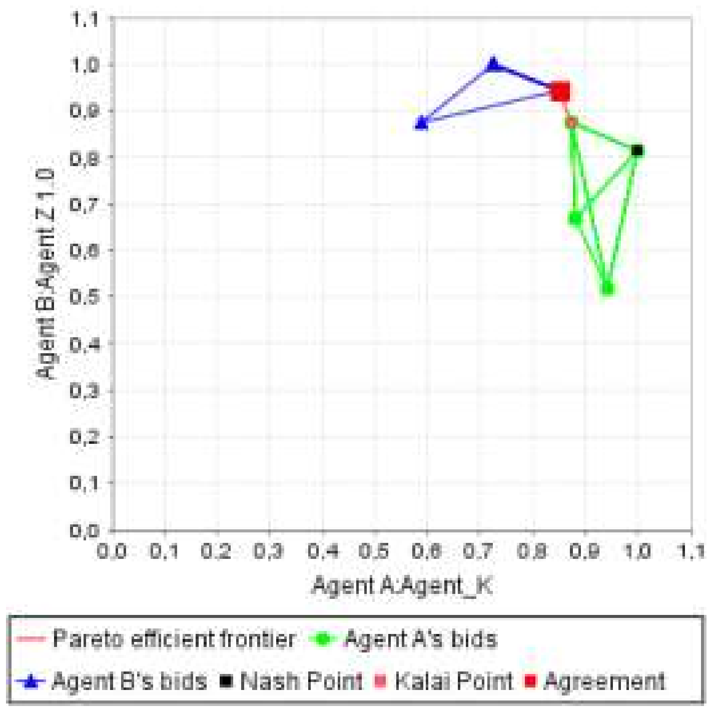

Figure 40 : Agent K vs Agent Z1.0 – Laptop Domain

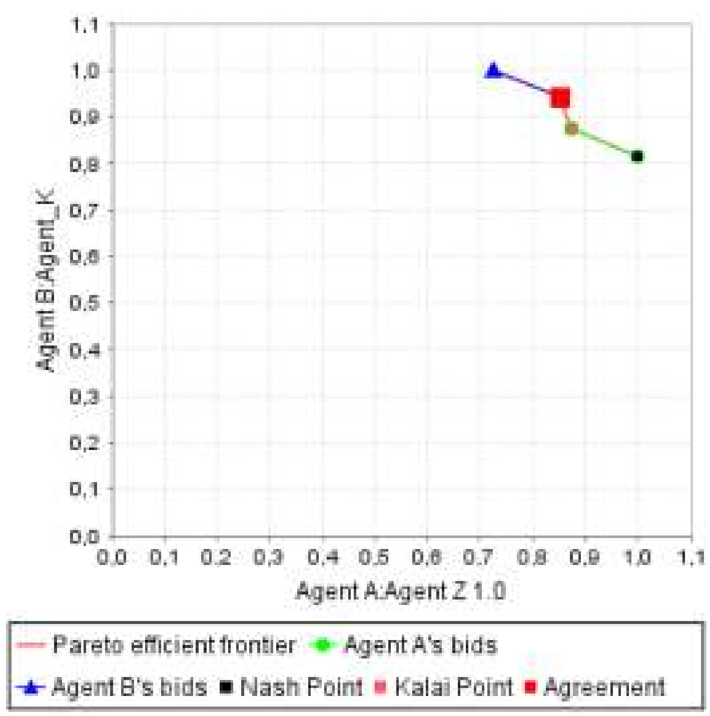

Figure 41 : Agent Z1.0 vs Agent K – Laptop Domain

Table 25 : Agent Z1.0 vs Agent K – Laptop Domain

Agent	Agent Z 1.0	Agent K		Agent K	Agent Z 1.0
Average time of agreement	0.733385	0.733385		0.926387	0.926387
Std time of agreement	0.054069	0.054069		0.056007	0.056007
Average time of end of negotiation	0.733385	0.733385		0.926387	0.926387
Std time of end of negotiation	0.054069	0.054069		0.056007	0.056007
Average rounds	293.5	293.5		369.1	369.1
Std rounds	21.01983	21.01983		22.01237	22.01237
Percentage of agreement	100	100		100	100
Average utility	0.896153	0.903325		0.897801	0.848219
Std utility	0.071661	0.060877		0.054421	0.072855
Average utility of agreements	0.896153	0.903325		0.897801	0.848219
Average discounted utility	0.47749	0.483069		0.406169	0.384296
Std discounted utility	0.02952	0.048671		0.02975	0.04141
Average discounted utility of agreements	0.47749	0.483069		0.406169	0.384296
Average nash distance	0.13626	0.13626		0.121856	0.121856
Average nash distance of agreements	0.13626	0.13626		0.121856	0.121856
Average pareto distance	0	0		0.018947	0.018947
Average pareto distance of agreements	0	0		0.018947	0.018947
Average kalai distance	0.091241	0.091241		0.055637	0.055637
Average kalai distance of agreements	0.091241	0.091241		0.055637	0.055637
Average social welfare	1.799478	1.799478		1.74602	1.74602
Average social welfare of agreements	1.799478	1.799478		1.74602	1.74602
Average exploration	0.092593	0.114815		0.196296	0.155556
Average joint exploration	0.207407	0.207407		0.32963	0.32963
Perc pareto bids	0.248138	0.993539		0.917068	0.989234
Average unfortunate moves	0.0166	0.00259		0.032056	0.008739
Average fortunate moves	0.01306	0.003222		0.030752	0.007637
Average nice moves	0	0		0	0
Average selfish moves	0.000613	0.019162		0.021841	0.039727
Average concession moves	0.002024	0.026028		0.026763	0.043599
Average silent moves	0.967702	0.948997		0.888588	0.900299

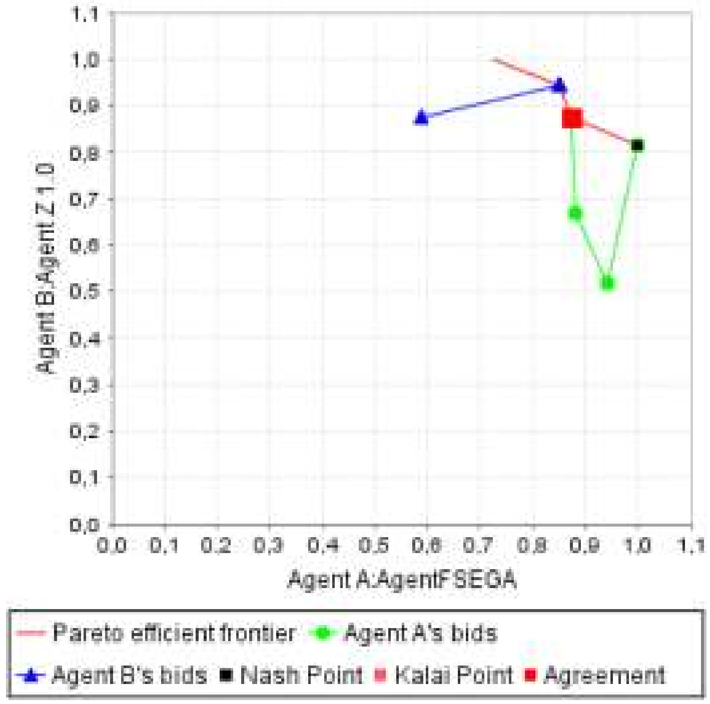

Figure 42 : Agent FSEGA vs Agent Z1.0 – Laptop Domain

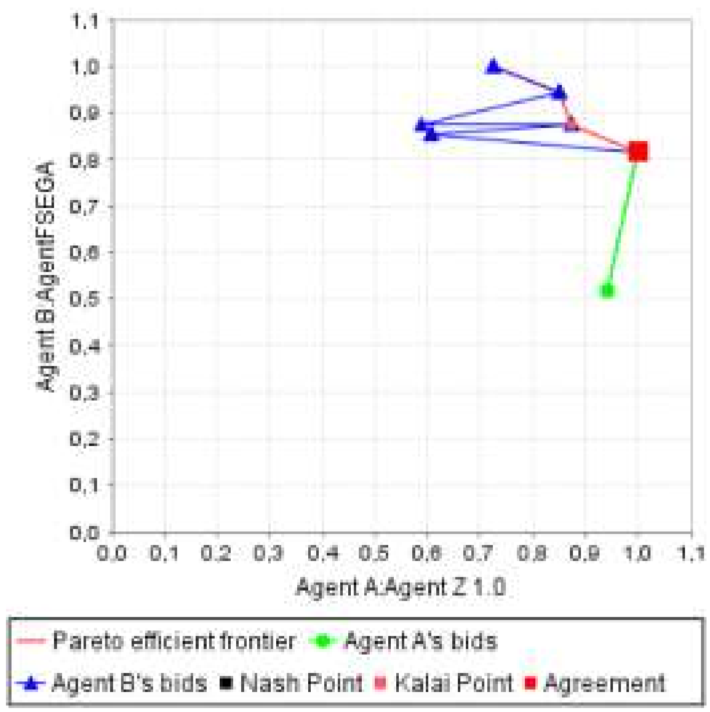

Figure 43 : Agent Z1.0 vs Agent FSEGA – Laptop Domain

Table 26 : Agent Z1.0 vs Agent FSEGA – Laptop Domain

Agent	Agent Z 1.0	FSEGA		FSEGA	Agent Z 1.0
Average time of agreement	0.261478	0.261478		0.199814	0.199814
Std time of agreement	0.070075	0.070075		0.025258	0.025258
Average time of end of negotiation	0.261478	0.261478		0.199814	0.199814
Std time of end of negotiation	0.070075	0.070075		0.025258	0.025258
Average rounds	99.2	99.2		73	73
Std rounds	27.82804	27.82804		9.60324	9.60324
Percentage of agreement	100	100		100	100
Average utility	0.985165	0.827708		0.862836	0.907579
Std utility	0.046913	0.039853		0.011794	0.035369
Average utility of agreements	0.985165	0.827708		0.862836	0.907579
Average discounted utility	0.786534	0.664524		0.727379	0.764319
Std discounted utility	0.007397	0.080065		0.025641	0.013523
Average discounted utility of agreements	0.786534	0.664524		0.727379	0.764319
Average nash distance	0.019466	0.019466		0.166865	0.166865
Average nash distance of agreements	0.019466	0.019466		0.166865	0.166865
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.13224	0.13224		0.03537	0.03537
Average kalai distance of agreements	0.13224	0.13224		0.03537	0.03537
Average social welfare	1.812873	1.812873		1.770415	1.770415
Average social welfare of agreements	1.812873	1.812873		1.770415	1.770415
Average exploration	0.096296	0.207407		0.162963	0.074074
Average joint exploration	0.303704	0.303704		0.218519	0.218519
Perc pareto bids	0.174815	0.764815		0.370724	0.9625
Average unfortunate moves	0.045073	0.033962		0.028448	0.012903
Average fortunate moves	0.016981	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0	0		0	0.0125
Average concession moves	0	0.062055		0.065948	0.015948
Average silent moves	0.937945	0.903983		0.905603	0.958648

Appendix B : Laptop Domain – Agent Z2.0

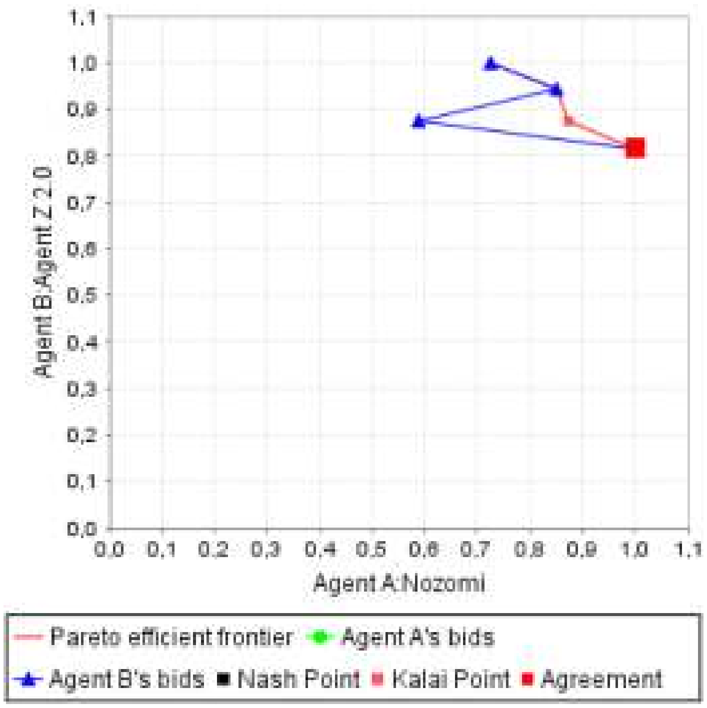

Figure 44 Agent Nozomi vs Agent Z2.0 – Laptop Domain

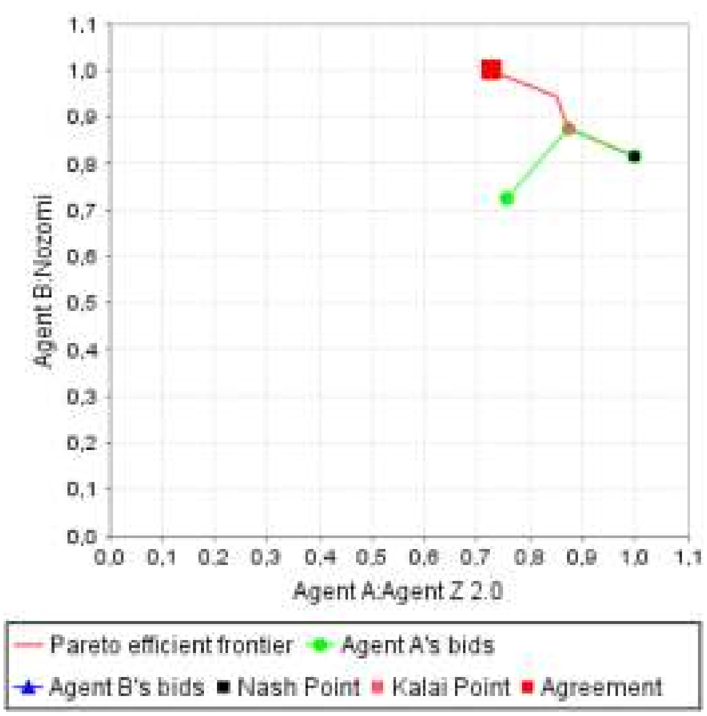

Figure 45 : Agent Z2.0 vs Nozomi – Laptop Domain

Table 27 : Agent Z2.0 vs Nozomi – Laptop Domain

Agent	Agent Z 2.0	Nozomi		Nozomi	Agent Z 2.0
Average time of agreement	0.013625	0.013625		0.015113	0.015113
Std time of agreement	0.004773	0.004773		0.004094	0.004094
Average time of end of negotiation	0.013625	0.013625		0.015113	0.015113
Std time of end of negotiation	0.004773	0.004773		0.004094	0.004094
Average rounds	6.8	6.8		6	6
Std rounds	1.988858	1.988858		1.632993	1.632993
Percentage of agreement	100	100		100	100
Average utility	0.72562	1		1	0.815105
Std utility	1.17E-16	0		0	0
Average utility of agreements	0.72562	1		1	0.815105
Average discounted utility	0.717202	0.988398		0.987137	0.80462
Std discounted utility	0.002926	0.004032		0.003464	0.002823
Average discounted utility of agreements	0.717202	0.988398		0.987137	0.80462
Average nash distance	0.330863	0.330863		0	0
Average nash distance of agreements	0.330863	0.330863		0	0
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.194663	0.194663		0.139073	0.139073
Average kalai distance of agreements	0.194663	0.194663		0.139073	0.139073
Average social welfare	1.72562	1.72562		1.815105	1.815105
Average social welfare of agreements	1.72562	1.72562		1.815105	1.815105
Average exploration	0.137037	0.037037		0.037037	0.111111
Average joint exploration	0.151852	0.151852		0.137037	0.137037
Perc pareto bids	0.808333	1		1	0.95
Average unfortunate moves	0.203333	0		0	0.066667
Average fortunate moves	0	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0.02	0		0	0
Average concession moves	0.776667	0		0	0.933333
Average silent moves	0	1		1	0

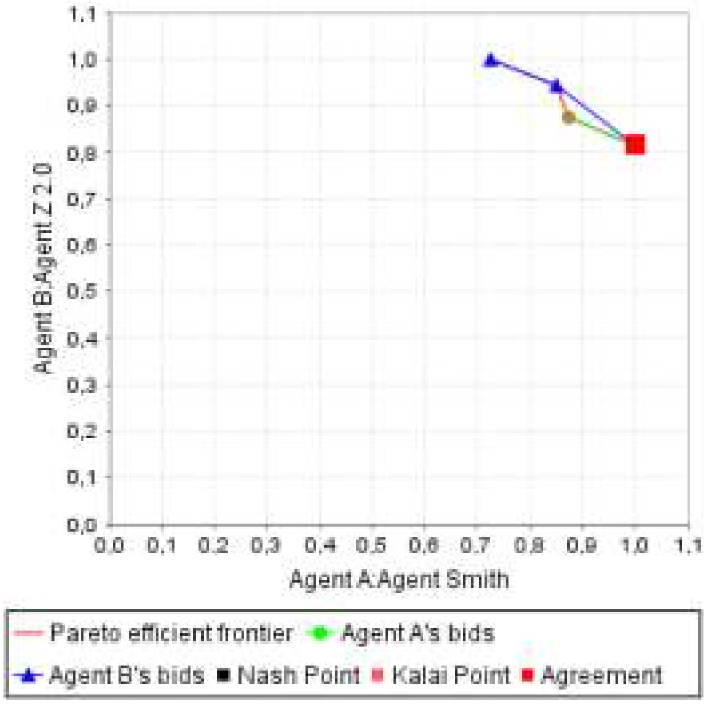

Figure 46 : Agent Smith vs Agent Z2.0 – Laptop Domain

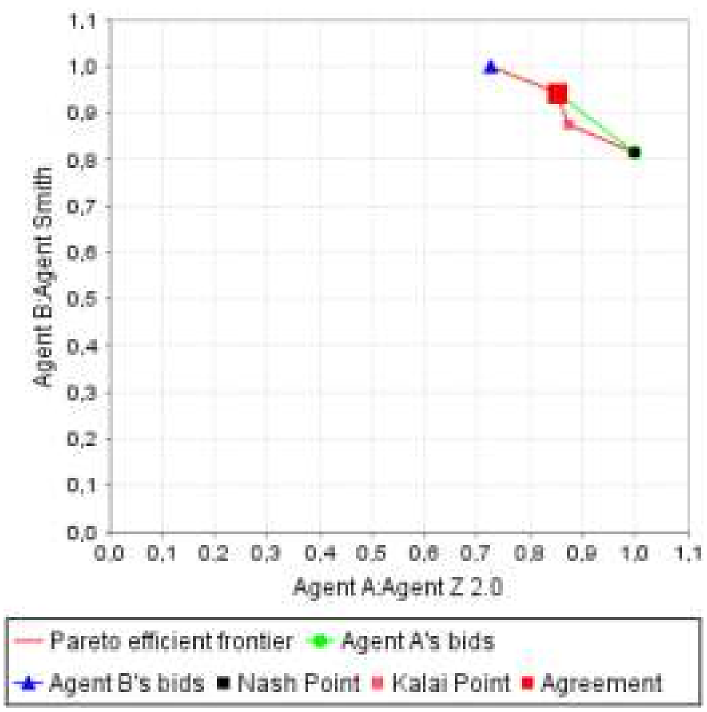

Figure 47 : Agent Z2.0 vs Agent Smith – Laptop Domain

Table 28 : Agent Z2.0 vs Agent Smith – Laptop Domain

Agent	Agent Z 2.0	Agent Smith		Agent Smith	Agent Z 2.0
Average time of agreement	0.009684	0.009684		0.01367	0.01367
Std time of agreement	0.001623	0.001623		0.002432	0.002432
Average time of end of negotiation	0.009684	0.009684		0.01367	0.01367
Std time of end of negotiation	0.001623	0.001623		0.002432	0.002432
Average rounds	5.4	5.4		5.5	5.5
Std rounds	0.966092	0.966092		0.849837	0.849837
Percentage of agreement	100	100		100	100
Average utility	0.839045	0.94702		0.937012	0.844565
Std utility	0.039853	0.018615		0.066395	0.031053
Average utility of agreements	0.839045	0.94702		0.937012	0.844565
Average discounted utility	0.832115	0.939191		0.926127	0.834717
Std discounted utility	0.039633	0.018384		0.066074	0.030355
Average discounted utility of agreements	0.832115	0.939191		0.926127	0.834717
Average nash distance	0.208278	0.208278		0.069537	0.069537
Average nash distance of agreements	0.208278	0.208278		0.069537	0.069537
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.083133	0.083133		0.069537	0.069537
Average kalai distance of agreements	0.083133	0.083133		0.069537	0.069537
Average social welfare	1.786064	1.786064		1.781577	1.781577
Average social welfare of agreements	1.786064	1.786064		1.781577	1.781577
Average exploration	0.107407	0.059259		0.066667	0.1
Average joint exploration	0.162963	0.162963		0.144444	0.144444
Perc pareto bids	0.8	1		1	0.95
Average unfortunate moves	0.333333	0		0	0.1
Average fortunate moves	0	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0	0		0	0
Average concession moves	0.666667	0.333333		0.4	0.9
Average silent moves	0	0.666667		0.6	0

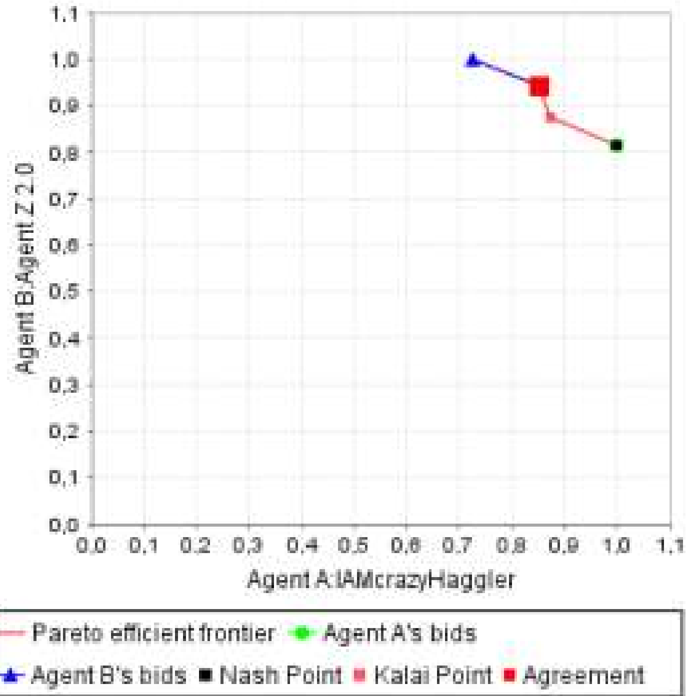

Figure 48 : IAMcrazyHaggler vs Agent Z2.0 – Laptop Domain

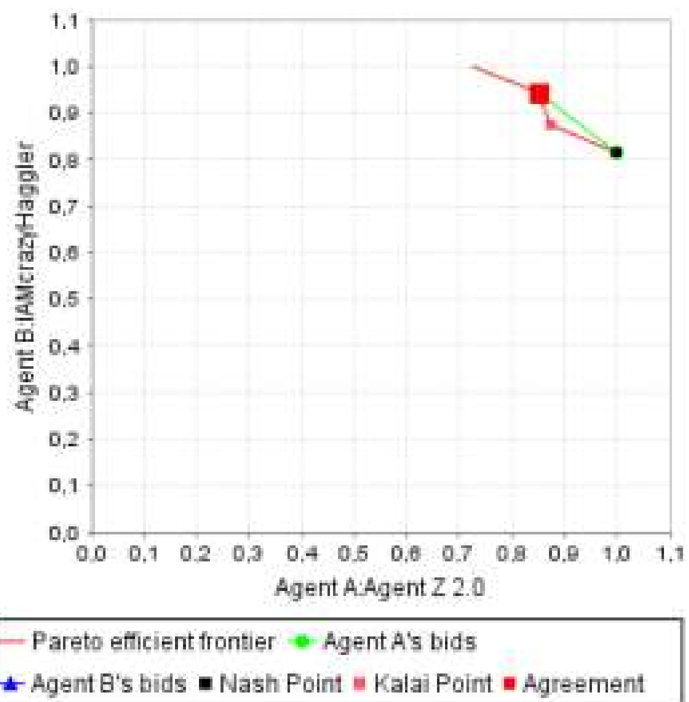

Figure 49 : Agent Z2.0 vs IAMcrazyHaggler – Laptop Domain

Table 29 : Agent Z2.0 vs IAMcrazyHaggler – Laptop Domain

Agent	Agent Z 2.0	IAMcrazyHaggler		IAMcrazyHaggler	Agent Z 2.0
Average time of agreement	0.005602	0.005602		0.007594	0.007594
Std time of agreement	0.00169	0.00169		0.002649	0.002649
Average time of end of negotiation	0.005602	0.005602		0.007594	0.007594
Std time of end of negotiation	0.00169	0.00169		0.002649	0.002649
Average rounds	3.4	3.4		3	3
Std rounds	0.966092	0.966092		1.054093	1.054093
Percentage of agreement	100	100		100	100
Average utility	0.852471	0.906754		0.856123	0.927711
Std utility	0.045802	0.045544		0.009435	0.028295
Average utility of agreements	0.852471	0.906754		0.856123	0.927711
Average discounted utility	0.848446	0.90237		0.85058	0.921666
Std discounted utility	0.046621	0.044321		0.010482	0.027179
Average discounted utility of agreements	0.848446	0.90237		0.85058	0.921666
Average nash distance	0.174927	0.174927		0.18354	0.18354
Average nash distance of agreements	0.174927	0.174927		0.18354	0.18354
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.040689	0.040689		0.056593	0.056593
Average kalai distance of agreements	0.040689	0.040689		0.056593	0.056593
Average social welfare	1.759225	1.759225		1.783834	1.783834
Average social welfare of agreements	1.759225	1.759225		1.783834	1.783834
Average exploration	0.077778	0.044444		0.044444	0.055556
Average joint exploration	0.114815	0.114815		0.1	0.1
Perc pareto bids	0.883333	1		0.6	1
Average unfortunate moves	0.75	0		0.4	0
Average fortunate moves	0	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0	0.25		0	0
Average concession moves	0.25	0.5		0	1
Average silent moves	0	0.25		0.6	0

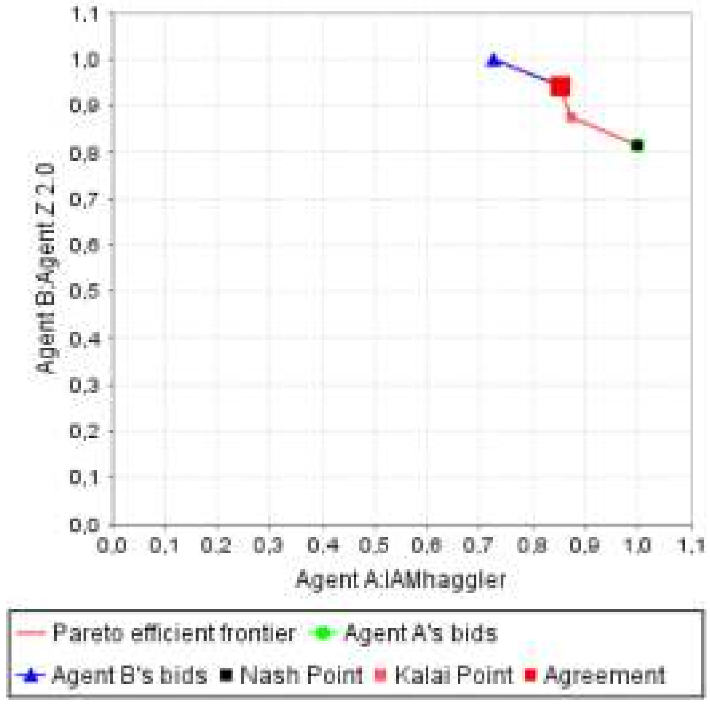

Figure 50 : IAMhaggler vs Agent Z2.0 – Laptop Domain

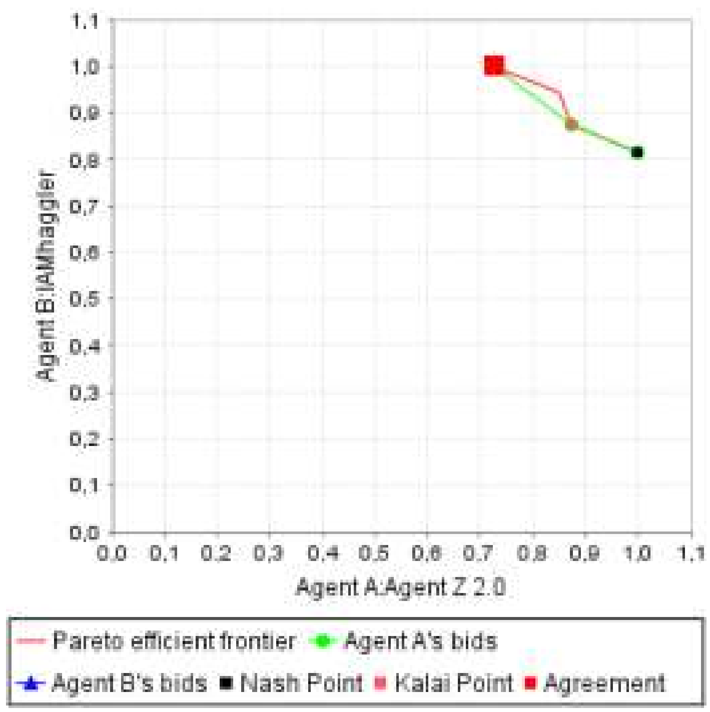

Figure 51 : Agent Z2.0 vs IAMhaggler – Laptop Domain

Table 30 : Agent Z2.0 vs IAMhaggler – Laptop Domain

Agent	Agent Z 2.0	IAMhaggler		IAMhaggler	Agent Z 2.0
Average time of agreement	0.012174	0.012174		0.008607	0.008607
Std time of agreement	0.003506	0.003506		0.002428	0.002428
Average time of end of negotiation	0.012174	0.012174		0.008607	0.008607
Std time of end of negotiation	0.003506	0.003506		0.002428	0.002428
Average rounds	5.8	5.8		3.4	3.4
Std rounds	1.398412	1.398412		0.966092	0.966092
Percentage of agreement	100	100		100	100
Average utility	0.788634	0.970566		0.853885	0.934422
Std utility	0.066422	0.031026		0.007076	0.021222
Average utility of agreements	0.788634	0.970566		0.853885	0.934422
Average discounted utility	0.780401	0.96052		0.847608	0.927565
Std discounted utility	0.065106	0.031645		0.006859	0.021538
Average discounted utility of agreements	0.780401	0.96052		0.847608	0.927565
Average nash distance	0.26276	0.26276		0.189099	0.189099
Average nash distance of agreements	0.26276	0.26276		0.189099	0.189099
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.132702	0.132702		0.063667	0.063667
Average kalai distance of agreements	0.132702	0.132702		0.063667	0.063667
Average social welfare	1.7592	1.7592		1.788307	1.788307
Average social welfare of agreements	1.7592	1.7592		1.788307	1.788307
Average exploration	0.125926	0.037037		0.037037	0.062963
Average joint exploration	0.144444	0.144444		0.1	0.1
Perc pareto bids	0.876667	1		1	1
Average unfortunate moves	0.141667	0		0	0
Average fortunate moves	0.025	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0	0		0	0
Average concession moves	0.833333	0		0	1
Average silent moves	0	1		1	0

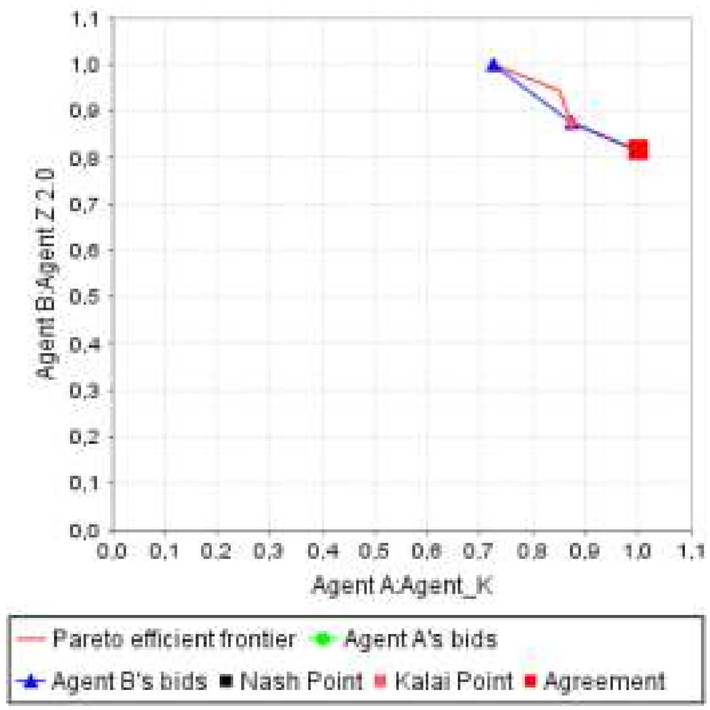

Figure 52 : Agent K vs Agent Z2.0 – Laptop Domain

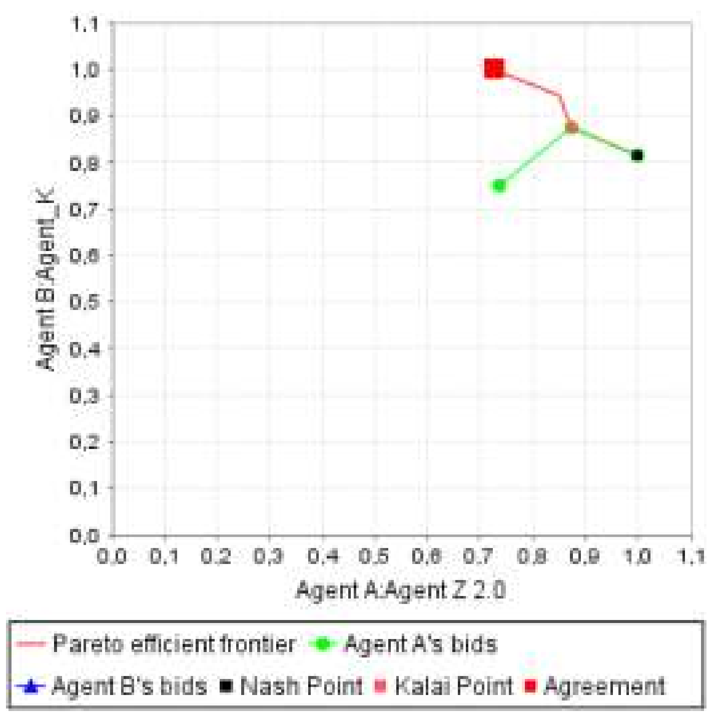

Figure 53 : Agent Z2.0 vs Agent K – Laptop Domain

Table 31 : Agent Z2.0 vs Agent K – Laptop Domain

Agent	Agent Z 2.0	Agent K		Agent K	Agent Z 2.0
Average time of agreement	0.015209	0.015209		0.015122	0.015122
Std time of agreement	0.00857	0.00857		0.00334	0.00334
Average time of end of negotiation	0.015209	0.015209		0.015122	0.015122
Std time of end of negotiation	0.00857	0.00857		0.00334	0.00334
Average rounds	7.9	7.9		7	7
Std rounds	3.478505	3.478505		1.333333	1.333333
Percentage of agreement	100	100		100	100
Average utility	0.72562	1		1	0.815105
Std utility	1.17E-16	0		0	0
Average utility of agreements	0.72562	1		1	0.815105
Average discounted utility	0.71624	0.987074		0.987127	0.804612
Std discounted utility	0.005232	0.007211		0.002826	0.002304
Average discounted utility of agreements	0.71624	0.987074		0.987127	0.804612
Average nash distance	0.330863	0.330863		0	0
Average nash distance of agreements	0.330863	0.330863		0	0
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.194663	0.194663		0.139073	0.139073
Average kalai distance of agreements	0.194663	0.194663		0.139073	0.139073
Average social welfare	1.72562	1.72562		1.815105	1.815105
Average social welfare of agreements	1.72562	1.72562		1.815105	1.815105
Average exploration	0.148148	0.037037		0.037037	0.111111
Average joint exploration	0.17037	0.17037		0.140741	0.140741
Perc pareto bids	0.725	1		1	1
Average unfortunate moves	0.312857	0		0	0
Average fortunate moves	0.014286	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0.048571	0		0	0.033333
Average concession moves	0.624286	0		0	0.966667
Average silent moves	0	1		1	0

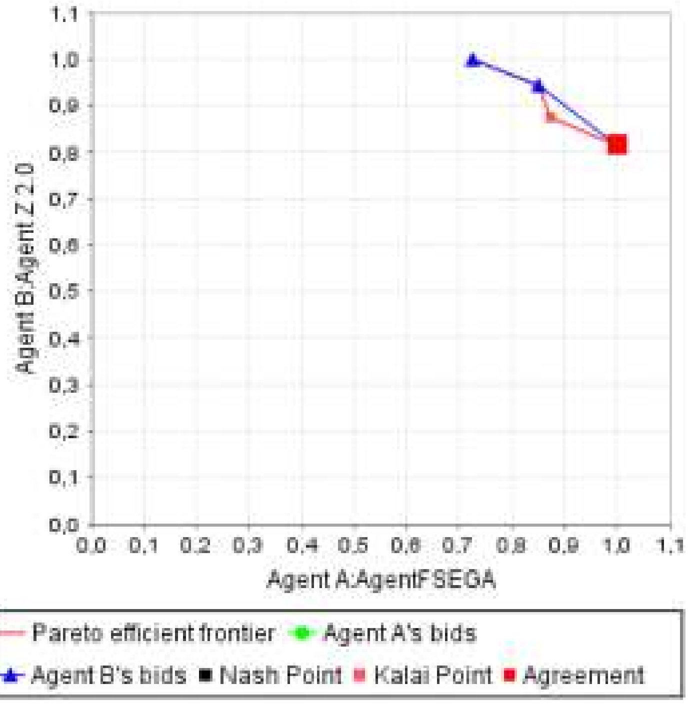

Figure 54 : Agent FSEGA vs Agent Z2.0 – Laptop Domain

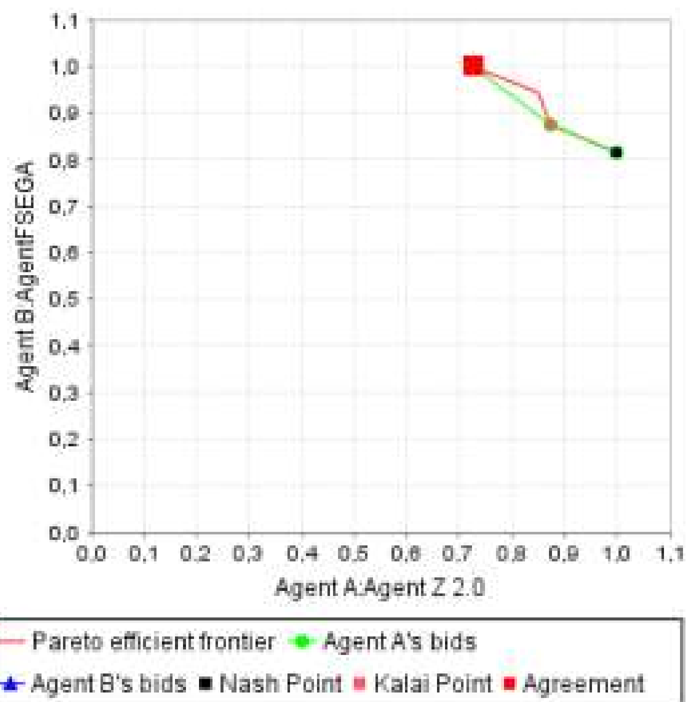

Figure 55 : Agent Z2.0 vs FSEGA – Laptop Domain

Table 32 : Agent Z2.0 vs FSEGA – Laptop Domain

Agent	Agent Z 2.0	FSEGA		FSEGA	Agent Z 2.0
Average time of agreement	0.033632	0.033632		0.033382	0.033382
Std time of agreement	0.006834	0.006834		0.003429	0.003429
Average time of end of negotiation	0.033632	0.033632		0.033382	0.033382
Std time of end of negotiation	0.006834	0.006834		0.003429	0.003429
Average rounds	8.2	8.2		6.6	6.6
Std rounds	2.485514	2.485514		1.349897	1.349897
Percentage of agreement	100	100		100	100
Average utility	0.72562	1		1	0.815105
Std utility	1.17E-16	0		0	0
Average utility of agreements	0.72562	1		1	0.815105
Average discounted utility	0.705014	0.971602		0.971799	0.792118
Std discounted utility	0.004127	0.005687		0.002858	0.002329
Average discounted utility of agreements	0.705014	0.971602		0.971799	0.792118
Average nash distance	0.330863	0.330863		0	0
Average nash distance of agreements	0.330863	0.330863		0	0
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.194663	0.194663		0.139073	0.139073
Average kalai distance of agreements	0.194663	0.194663		0.139073	0.139073
Average social welfare	1.72562	1.72562		1.815105	1.815105
Average social welfare of agreements	1.72562	1.72562		1.815105	1.815105
Average exploration	0.159259	0.037037		0.037037	0.122222
Average joint exploration	0.181481	0.181481		0.155556	0.155556
Perc pareto bids	0.643333	1		1	0.95
Average unfortunate moves	0.355	0		0	0.066667
Average fortunate moves	0.02	0		0	0.033333
Average nice moves	0	0		0	0
Average selfish moves	0.065	0		0	0.066667
Average concession moves	0.56	0		0	0.833333
Average silent moves	0	1		1	0

Appendix C : Laptop Domain – Agent Z3.0

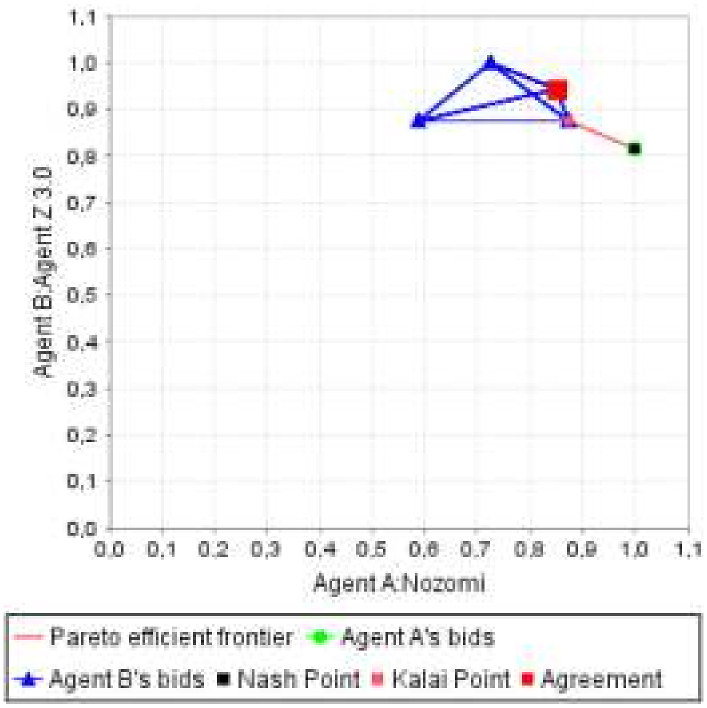

Figure 56 : Agent Nozomi vs Agent Z3.0 – Laptop Domain

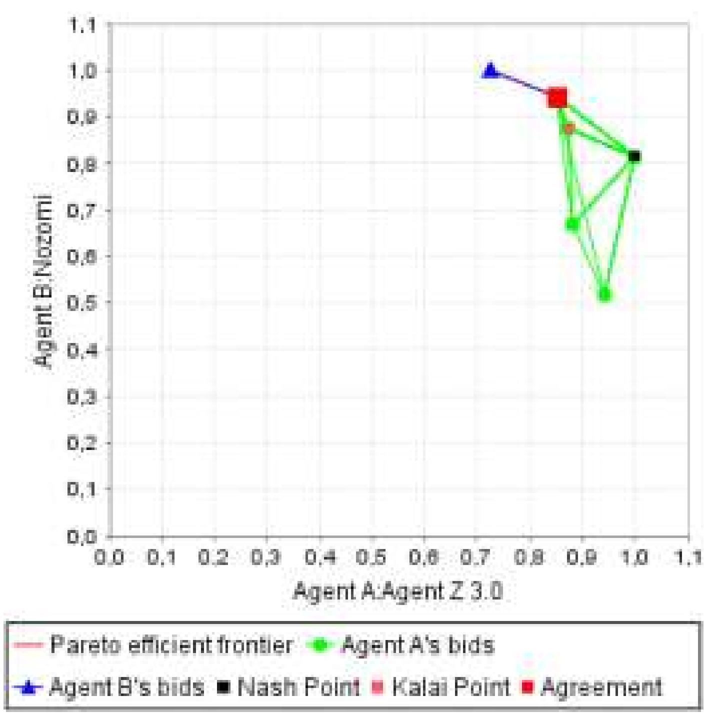

Figure 57 : Agent Z3.0 vs Agent Nozomi – Laptop Domain

Table 33 : Agent Z3.0 vs Agent Nozomi – Laptop Domain

Agent	Agent Z 3.0	Nozomi		Nozomi	Agent Z 3.0
Average time of agreement	0.921008	0.921008		0.536809	0.536809
Std time of agreement	0.008675	0.008675		0.273914	0.273914
Average time of end of negotiation	0.921008	0.921008		0.536809	0.536809
Std time of end of negotiation	0.008675	0.008675		0.273914	0.273914
Average rounds	366.6	366.6		214	214
Std rounds	3.50238	3.50238		108.7505	108.7505
Percentage of agreement	100	100		100	100
Average utility	0.851648	0.941133		0.940659	0.865516
Std utility	0	0		0.076609	0.06508
Average utility of agreements	0.851648	0.941133		0.940659	0.865516
Average discounted utility	0.386775	0.427415		0.61801	0.552938
Std discounted utility	0.002868	0.003169		0.191754	0.105788
Average discounted utility of agreements	0.386775	0.427415		0.61801	0.552938
Average nash distance	0.194657	0.194657		0.077863	0.077863
Average nash distance of agreements	0.194657	0.194657		0.077863	0.077863
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.070741	0.070741		0.11174	0.11174
Average kalai distance of agreements	0.070741	0.070741		0.11174	0.11174
Average social welfare	1.792781	1.792781		1.806175	1.806175
Average social welfare of agreements	1.792781	1.792781		1.806175	1.806175
Average exploration	0.303704	0.074074		0.040741	0.22963
Average joint exploration	0.340741	0.340741		0.237037	0.237037
Perc pareto bids	0.973875	1		0.998058	0.924856
Average unfortunate moves	0.023512	0		0.00098	0.072817
Average fortunate moves	0.012041	0		0.00098	0.065906
Average nice moves	0	0		0	0
Average selfish moves	0.16252	0		0	0.143367
Average concession moves	0.157578	0.005501		0	0.245577
Average silent moves	0.644349	0.994499		0.998039	0.472333

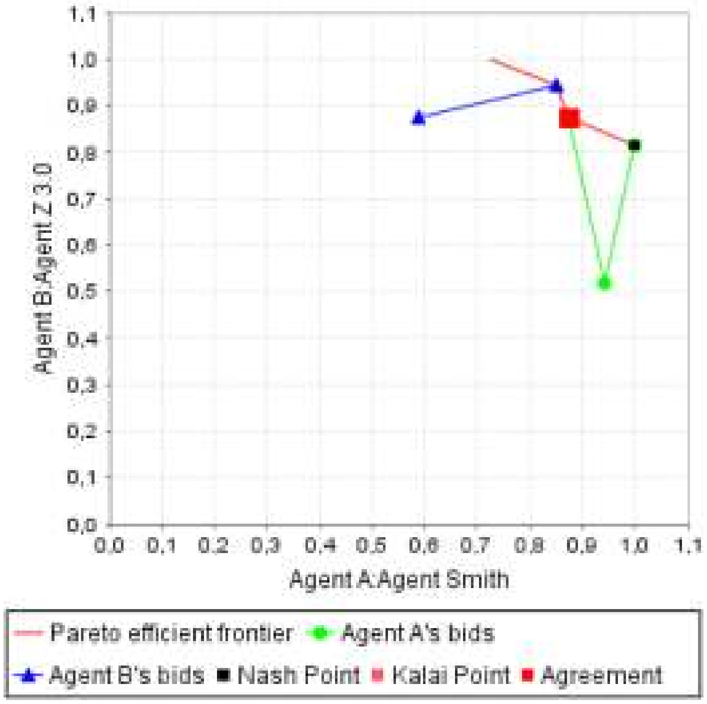

Figure 58 : Agent Smith vs Agent Z3.0 – Laptop Domain

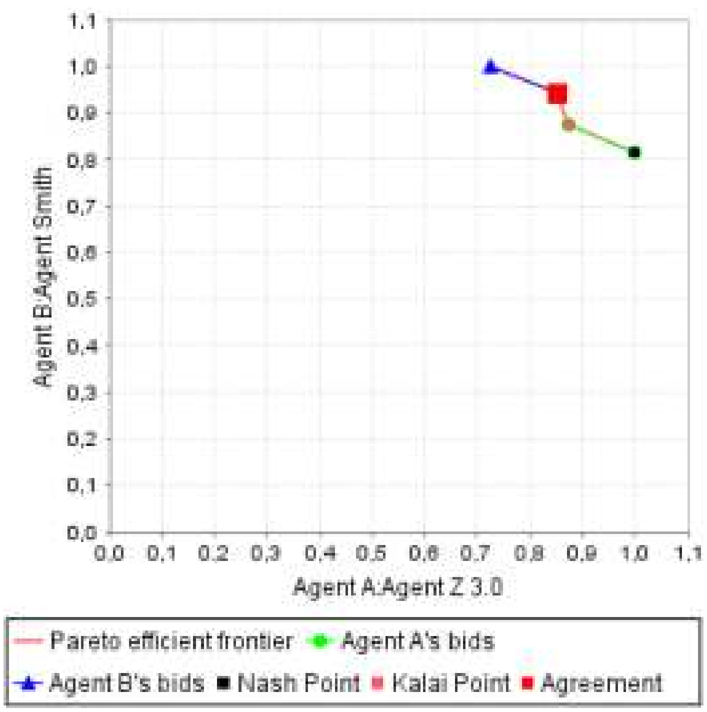

Figure 59 : Agent Z3.0 vs Agent Smith – Laptop Domain

Table 34 : Agent Z3.0 vs Agent Smith – Laptop Domain

Agent	Agent Z 3.0	Agent Smith		Agent Smith	Agent Z 3.0
Average time of agreement	0.010317	0.010317		0.022784	0.022784
Std time of agreement	0.002461	0.002461		0.008649	0.008649
Average time of end of negotiation	0.010317	0.010317		0.022784	0.022784
Std time of end of negotiation	0.002461	0.002461		0.008649	0.008649
Average rounds	5.5	5.5		9.6	9.6
Std rounds	1.080123	1.080123		3.134042	3.134042
Percentage of agreement	100	100		100	100
Average utility	0.851648	0.941133		0.860598	0.914289
Std utility	0	0		0.011555	0.034655
Average utility of agreements	0.851648	0.941133		0.860598	0.914289
Average discounted utility	0.844152	0.932849		0.843967	0.89666
Std discounted utility	0.001781	0.001968		0.012227	0.035431
Average discounted utility of agreements	0.844152	0.932849		0.843967	0.89666
Average nash distance	0.194657	0.194657		0.172423	0.172423
Average nash distance of agreements	0.194657	0.194657		0.172423	0.172423
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.070741	0.070741		0.042445	0.042445
Average kalai distance of agreements	0.070741	0.070741		0.042445	0.042445
Average social welfare	1.792781	1.792781		1.774888	1.774888
Average social welfare of agreements	1.792781	1.792781		1.774888	1.774888
Average exploration	0.1	0.059259		0.148148	0.118519
Average joint exploration	0.155556	0.155556		0.222222	0.222222
Perc pareto bids	0.9	1		0.703095	0.890714
Average unfortunate moves	0.166667	0		0.14	0.145
Average fortunate moves	0	0		0	0.025
Average nice moves	0	0		0	0
Average selfish moves	0.037037	0		0.128333	0.15
Average concession moves	0.685185	0.333333		0.433333	0.486667
Average silent moves	0.111111	0.666667		0.298333	0.193333

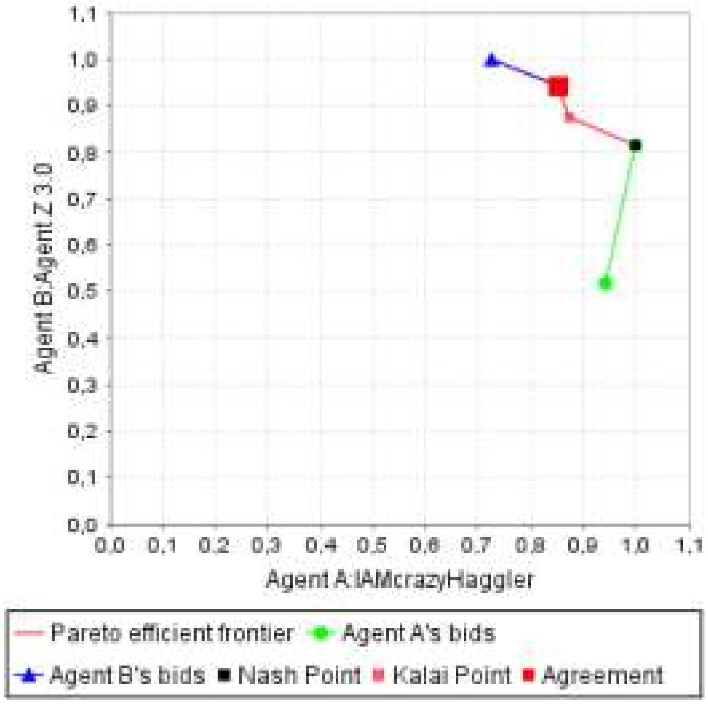

Figure 60 : IAMcrazyHaggler vs Agent Z3.0 – Laptop Domain

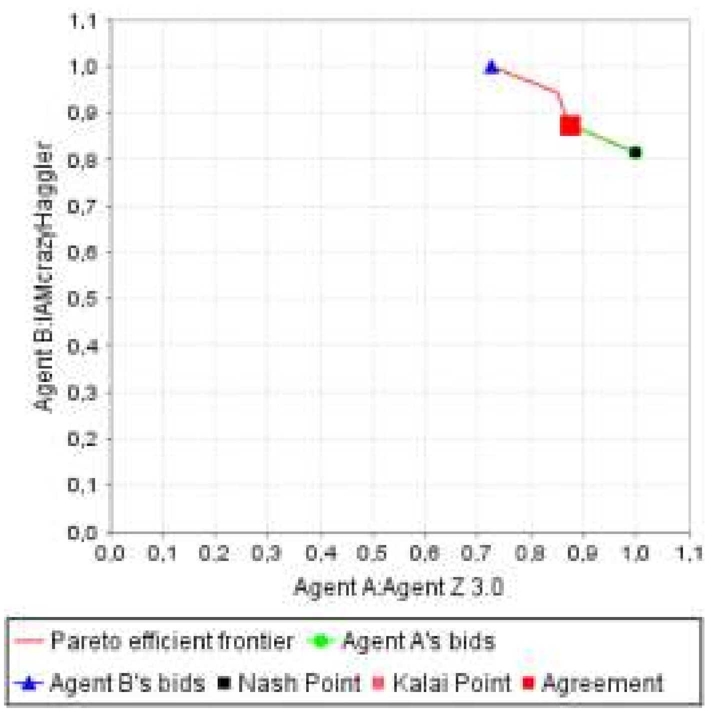

Figure 61 : Agent Z3.0 vs IAMcrazyHaggler – Laptop Domain

Table 35 : Agent Z3.0 vs IAMcrazyHaggler – Laptop Domain

Agent	Agent Z 3.0	IAMcrazyHaggler		IAMcrazyHaggler	Agent Z 3.0
Average time of agreement	0.006109	0.006109		0.006614	0.006614
Std time of agreement	0.002102	0.002102		0.002419	0.002419
Average time of end of negotiation	0.006109	0.006109		0.006614	0.006614
Std time of end of negotiation	0.002102	0.002102		0.002419	0.002419
Average rounds	3.4	3.4		2.6	2.6
Std rounds	0.843274	0.843274		0.966092	0.966092
Percentage of agreement	100	100		100	100
Average utility	0.869549	0.887446		0.853885	0.934422
Std utility	0.009435	0.028295		0.007076	0.021222
Average utility of agreements	0.869549	0.887446		0.853885	0.934422
Average discounted utility	0.865015	0.882796		0.849064	0.929134
Std discounted utility	0.010056	0.027574		0.007623	0.020792
Average discounted utility of agreements	0.865015	0.882796		0.849064	0.929134
Average nash distance	0.15019	0.15019		0.189099	0.189099
Average nash distance of agreements	0.15019	0.15019		0.189099	0.189099
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.014148	0.014148		0.063667	0.063667
Average kalai distance of agreements	0.014148	0.014148		0.063667	0.063667
Average social welfare	1.756995	1.756995		1.788307	1.788307
Average social welfare of agreements	1.756995	1.756995		1.788307	1.788307
Average exploration	0.081481	0.044444		0.040741	0.048148
Average joint exploration	0.118519	0.118519		0.088889	0.088889
Perc pareto bids	0.933333	1		0.35	1
Average unfortunate moves	0.5	0		0.333333	0
Average fortunate moves	0	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0	1		0	0
Average concession moves	0.5	0		0	1
Average silent moves	0	0		0.666667	0

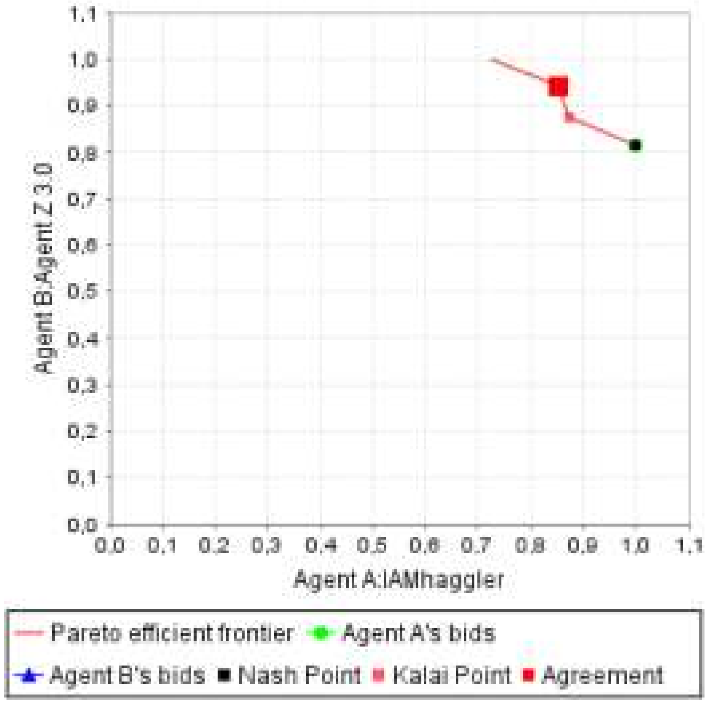

Figure 62 : IAMhaggler vs Agent Z3.0 – Laptop Domain

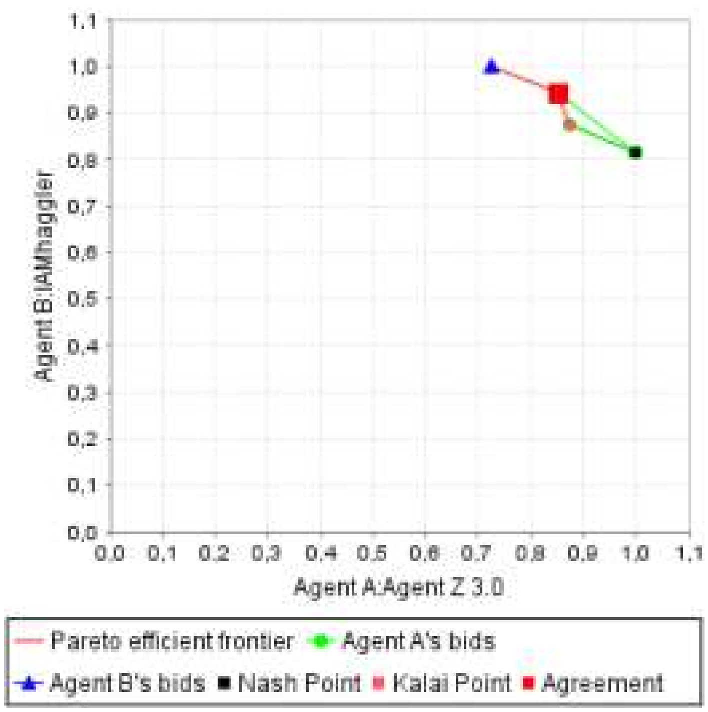

Figure 63 : Agent Z3.0 vs IAMhaggler – Laptop Domain

Table 36 : Agent Z3.0 vs IAMhaggler – Laptop Domain

Agent	Agent Z 3.0	IAMhaggler		IAMhaggler	Agent Z 3.0
Average time of agreement	0.022838	0.022838		0.009127	0.009127
Std time of agreement	0.023821	0.023821		0.002111	0.002111
Average time of end of negotiation	0.022838	0.022838		0.009127	0.009127
Std time of end of negotiation	0.023821	0.023821		0.002111	0.002111
Average rounds	10	10		3.6	3.6
Std rounds	9.486833	9.486833		0.843274	0.843274
Percentage of agreement	100	100		100	100
Average utility	0.851648	0.941133		0.851648	0.941133
Std utility	0	0		0	0
Average utility of agreements	0.851648	0.941133		0.851648	0.941133
Average discounted utility	0.835294	0.923061		0.845013	0.933801
Std discounted utility	0.016725	0.018483		0.001531	0.001692
Average discounted utility of agreements	0.835294	0.923061		0.845013	0.933801
Average nash distance	0.194657	0.194657		0.194657	0.194657
Average nash distance of agreements	0.194657	0.194657		0.194657	0.194657
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.070741	0.070741		0.070741	0.070741
Average kalai distance of agreements	0.070741	0.070741		0.070741	0.070741
Average social welfare	1.792781	1.792781		1.792781	1.792781
Average social welfare of agreements	1.792781	1.792781		1.792781	1.792781
Average exploration	0.111111	0.037037		0.037037	0.066667
Average joint exploration	0.148148	0.148148		0.103704	0.103704
Perc pareto bids	0.946667	1		1	1
Average unfortunate moves	0.09375	0		0	0
Average fortunate moves	0	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0.129377	0		0	0
Average concession moves	0.508754	0		0	1
Average silent moves	0.26812	1		1	0

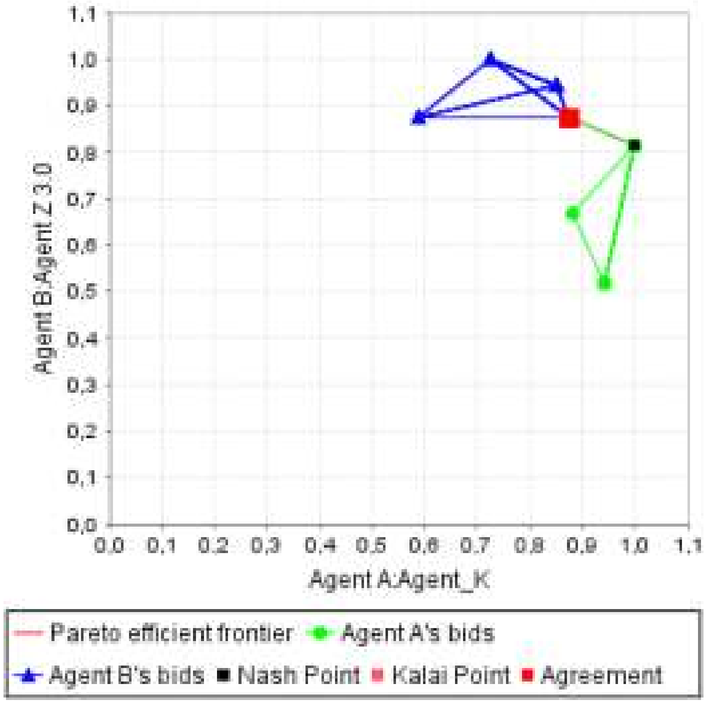

Figure 64 : Agent K vs Agent Z3.0 – Laptop Domain

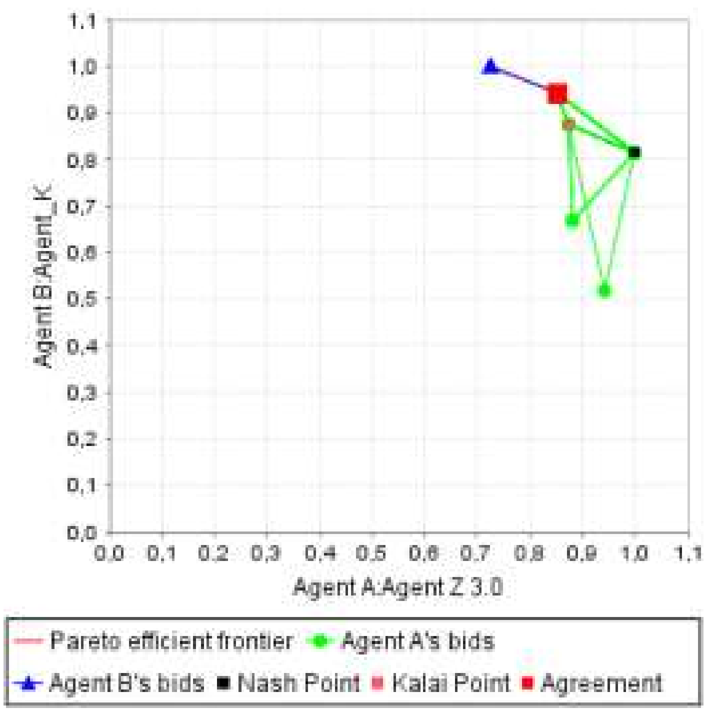

Figure 65 : Agent Z3.0 vs Agent K – Laptop Domain

Table 37 : Agent Z3.0 vs Agent K – Laptop Domain

Agent	Agent Z 3.0	Agent K		Agent K	Agent Z 3.0
Average time of agreement	0.690652	0.690652		0.452368	0.452368
Std time of agreement	0.158074	0.158074		0.280646	0.280646
Average time of end of negotiation	0.690652	0.690652		0.452368	0.452368
Std time of end of negotiation	0.158074	0.158074		0.280646	0.280646
Average rounds	276.4	276.4		181	181
Std rounds	62.74322	62.74322		111.6224	111.6224
Percentage of agreement	100	100		100	100
Average utility	0.839045	0.94702		0.962207	0.832781
Std utility	0.039853	0.018615		0.060852	0.028461
Average utility of agreements	0.839045	0.94702		0.962207	0.832781
Average discounted utility	0.465315	0.530321		0.677156	0.575632
Std discounted utility	0.04393	0.099454		0.18258	0.113436
Average discounted utility of agreements	0.465315	0.530321		0.677156	0.575632
Average nash distance	0.208278	0.208278		0.041722	0.041722
Average nash distance of agreements	0.208278	0.208278		0.041722	0.041722
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.083133	0.083133		0.097351	0.097351
Average kalai distance of agreements	0.083133	0.083133		0.097351	0.097351
Average social welfare	1.786064	1.786064		1.794988	1.794988
Average social welfare of agreements	1.786064	1.786064		1.794988	1.794988
Average exploration	0.340741	0.07037		0.066667	0.248148
Average joint exploration	0.377778	0.377778		0.277778	0.277778
Perc pareto bids	0.966876	1		0.984474	0.921967
Average unfortunate moves	0.031375	0		0.00961	0.074949
Average fortunate moves	0.013583	0		0.009004	0.056145
Average nice moves	0	0		0	0
Average selfish moves	0.176551	0.002027		0	0.172254
Average concession moves	0.172319	0.008145		0.002402	0.175019
Average silent moves	0.606172	0.989827		0.978984	0.521634

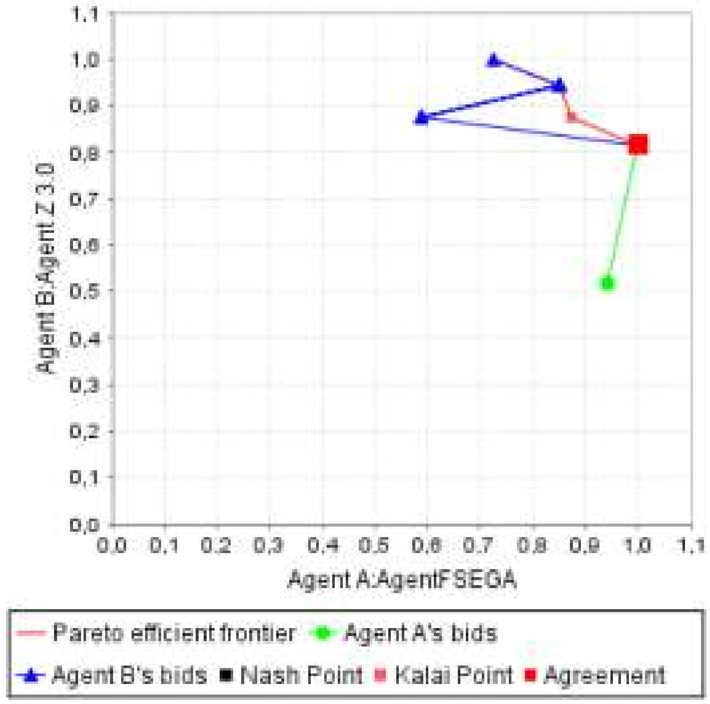

Figure 66 : FSEGA vs Agent Z3.0 – Laptop Domain

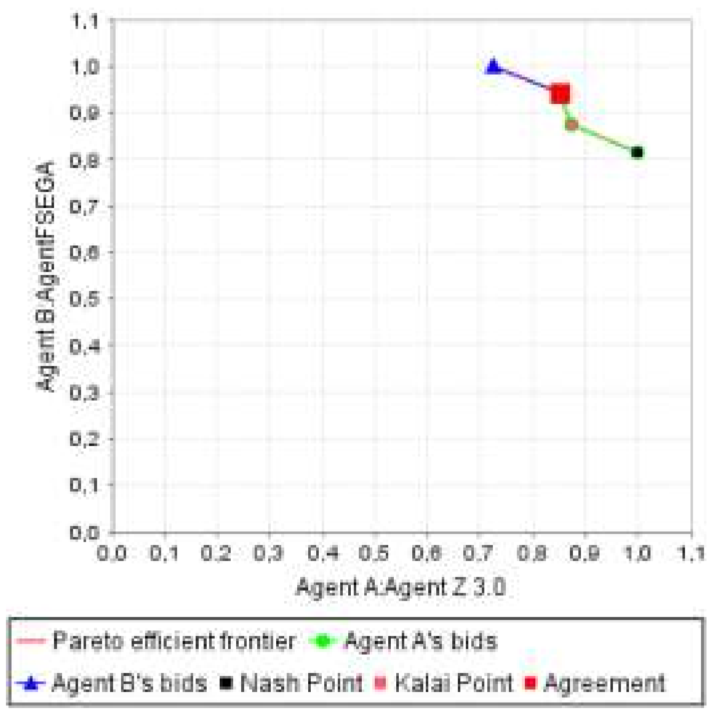

Figure 67 : Agent Z3.0 vs FSEGA – Laptop Domain

Table 38 : Agent Z3.0 vs FSEGA – Laptop Domain

Agent	Agent Z 3.0	FSEGA		FSEGA	Agent Z 3.0
Average time of agreement	0.063897	0.063897		0.100876	0.100876
Std time of agreement	0.002453	0.002453		0.027512	0.027512
Average time of end of negotiation	0.063897	0.063897		0.100876	0.100876
Std time of end of negotiation	0.002453	0.002453		0.027512	0.027512
Average rounds	20.5	20.5		33.4	33.4
Std rounds	0.849837	0.849837		10.91584	10.91584
Percentage of agreement	100	100		100	100
Average utility	0.851648	0.941133		1	0.815105
Std utility	0	0		0	0
Average utility of agreements	0.851648	0.941133		1	0.815105
Average discounted utility	0.806265	0.890981		0.917403	0.74778
Std discounted utility	0.001694	0.001871		0.021341	0.017395
Average discounted utility of agreements	0.806265	0.890981		0.917403	0.74778
Average nash distance	0.194657	0.194657		0	0
Average nash distance of agreements	0.194657	0.194657		0	0
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.070741	0.070741		0.139073	0.139073
Average kalai distance of agreements	0.070741	0.070741		0.139073	0.139073
Average social welfare	1.792781	1.792781		1.815105	1.815105
Average social welfare of agreements	1.792781	1.792781		1.815105	1.815105
Average exploration	0.151852	0.074074		0.074074	0.214815
Average joint exploration	0.196296	0.196296		0.288889	0.288889
Perc pareto bids	0.932727	1		0.582059	0.888703
Average unfortunate moves	0.063333	0		0.069455	0.102391
Average fortunate moves	0.01	0		0	0.07089
Average nice moves	0	0		0	0
Average selfish moves	0.16	0		0	0.114132
Average concession moves	0.214444	0.108889		0	0.232978
Average silent moves	0.552222	0.891111		0.930545	0.479608

Appendix D : Grocery Domain – Agent Z1.0

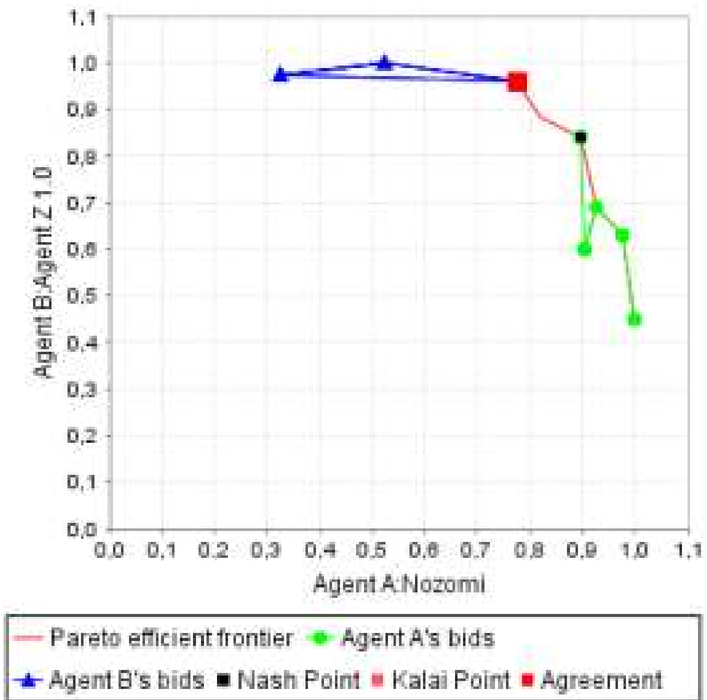

Figure 68 : Nozomi vs Agent Z1.0 – Grocery Domain

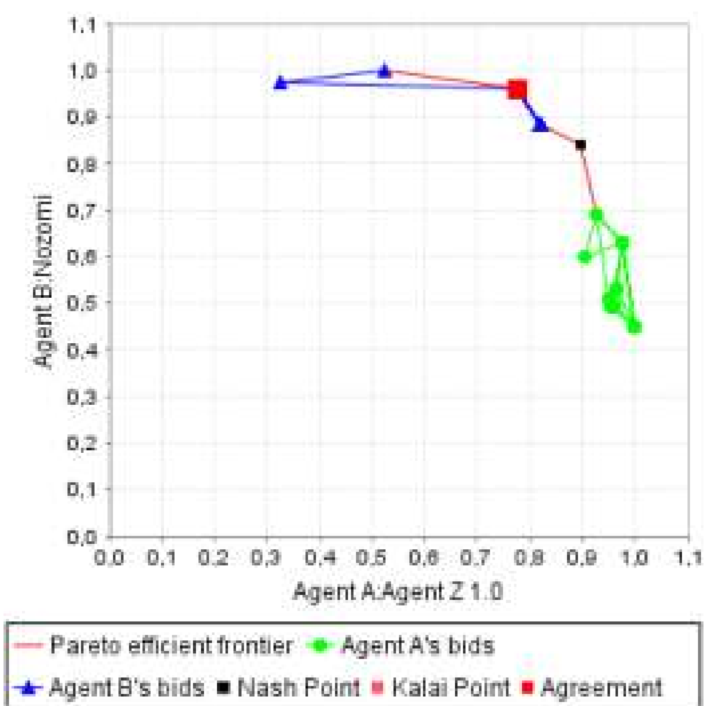

Figure 69 : Agent Z1.0 vs Nozomi – Grocery Domain

Table 39 : Agent Z1.0 vs Nozomi – Grocery Domain

Agent	Agent Z 1.0	Nozomi		Nozomi	Agent Z 1.0
Average time of agreement	0.993758	0.993758		0.928413	0.928413
Std time of agreement	0.001253	0.001253		0.086234	0.086234
Average time of end of negotiation	0.993758	0.993758		0.928413	0.928413
Std time of end of negotiation	0.001253	0.001253		0.086234	0.086234
Average rounds	395.8	395.8		368.2	368.2
Std rounds	0.632456	0.632456		34.18512	34.18512
Percentage of agreement	100	100		100	100
Average utility	0.8005	0.9255		0.859	0.828
Std utility	0.039402	0.046395		0.073212	0.127436
Average utility of agreements	0.8005	0.9255		0.859	0.828
Average discounted utility	0.645725	0.746552		0.70195	0.67898
Std discounted utility	0.031814	0.037359		0.048357	0.115408
Average discounted utility of agreements	0.645725	0.746552		0.70195	0.67898
Average nash distance	0.128063	0.128063		0.12907	0.12907
Average nash distance of agreements	0.128063	0.128063		0.12907	0.12907
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.128063	0.128063		0.12907	0.12907
Average kalai distance of agreements	0.128063	0.128063		0.12907	0.12907
Average social welfare	1.726	1.726		1.687	1.687
Average social welfare of agreements	1.726	1.726		1.687	1.687
Average exploration	0.005125	0.002313		0.002563	0.003125
Average joint exploration	0.007438	0.007438		0.00525	0.00525
Perc pareto bids	0.95805	0.986866		0.75969	0.575336
Average unfortunate moves	0.024381	0.005079		0.007817	0.031778
Average fortunate moves	0.011685	0		0.005379	0.032241
Average nice moves	0	0		0	0
Average selfish moves	0.050275	0.025381		0.057701	0.032072
Average concession moves	0.053323	0.032492		0.070583	0.036562
Average silent moves	0.860336	0.937048		0.85852	0.867346

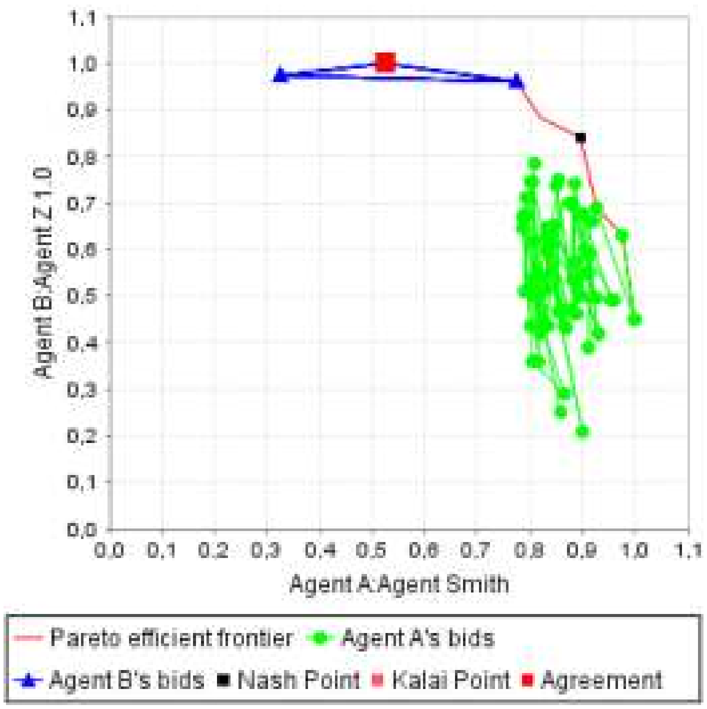

Figure 70 : Agent Smith vs Agent Z1.0 – Grocery Domain

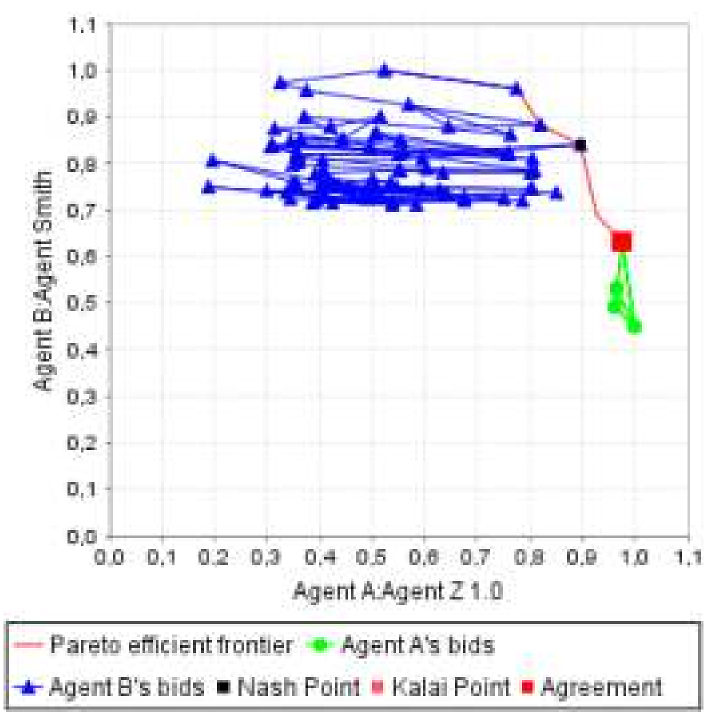

Figure 71 : Agent Z1.0 vs Agent Smith – Grocery Domain

Table 40 : Agent Z1.0 vs Agent Smith – Grocery Domain

Agent	Agent Z 1.0	Agent Smith		Agent Smith	Agent Z 1.0
Average time of agreement	0.615632	0.615632		0.59718	0.59718
Std time of agreement	0.001951	0.001951		0.039488	0.039488
Average time of end of negotiation	0.615632	0.615632		0.59718	0.59718
Std time of end of negotiation	0.001951	0.001951		0.039488	0.039488
Average rounds	181.4	181.4		148.2	148.2
Std rounds	2.458545	2.458545		8.664102	8.664102
Percentage of agreement	100	100		100	100
Average utility	0.9865	0.53		0.534	0.961
Std utility	0.014539	0.089443		0.205004	0.043128
Average utility of agreements	0.9865	0.53		0.534	0.961
Average discounted utility	0.863553	0.463948		0.470369	0.844357
Std discounted utility	0.012747	0.078314		0.184054	0.031884
Average discounted utility of agreements	0.863553	0.463948		0.470369	0.844357
Average nash distance	0.323613	0.323613		0.384384	0.384384
Average nash distance of agreements	0.323613	0.323613		0.384384	0.384384
Average pareto distance	0.008732	0.008732		0.076127	0.076127
Average pareto distance of agreements	0.008732	0.008732		0.076127	0.076127
Average kalai distance	0.323613	0.323613		0.384384	0.384384
Average kalai distance of agreements	0.323613	0.323613		0.384384	0.384384
Average social welfare	1.5165	1.5165		1.495	1.495
Average social welfare of agreements	1.5165	1.5165		1.495	1.495
Average exploration	0.004688	0.05275		0.042625	0.003563
Average joint exploration	0.057438	0.057438		0.045938	0.045938
Perc pareto bids	0.756852	0.053256		0.072984	0.641344
Average unfortunate moves	0.039969	0.265707		0.201679	0.076197
Average fortunate moves	0.032043	0.071847		0.011096	0.065193
Average nice moves	0	0.129968		0.1559	0
Average selfish moves	0.09088	0.192852		0.237769	0.095533
Average concession moves	0.094226	0.295985		0.334201	0.10832
Average silent moves	0.742882	0.04364		0.059356	0.654757

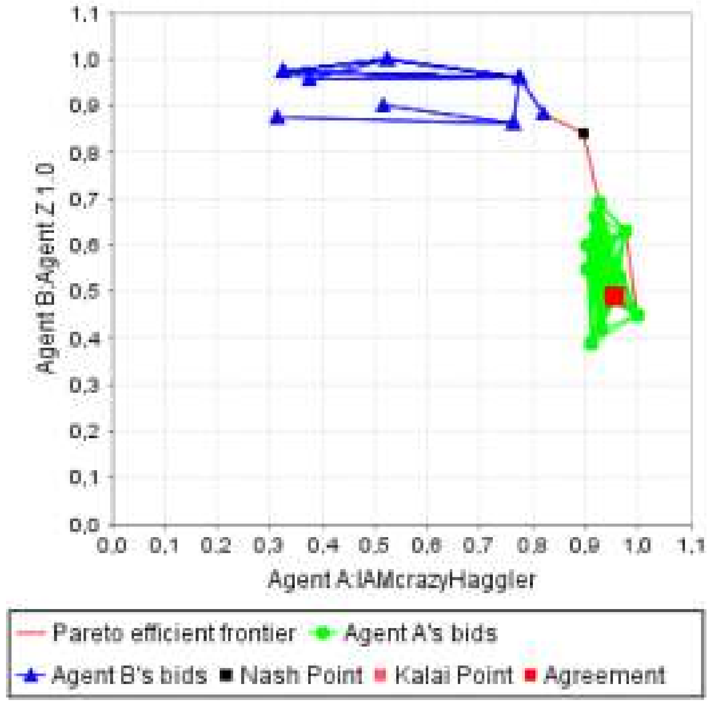

Figure 72 : IAMcrazyHaggler vs Agent Z1.0 – Grocery Domain

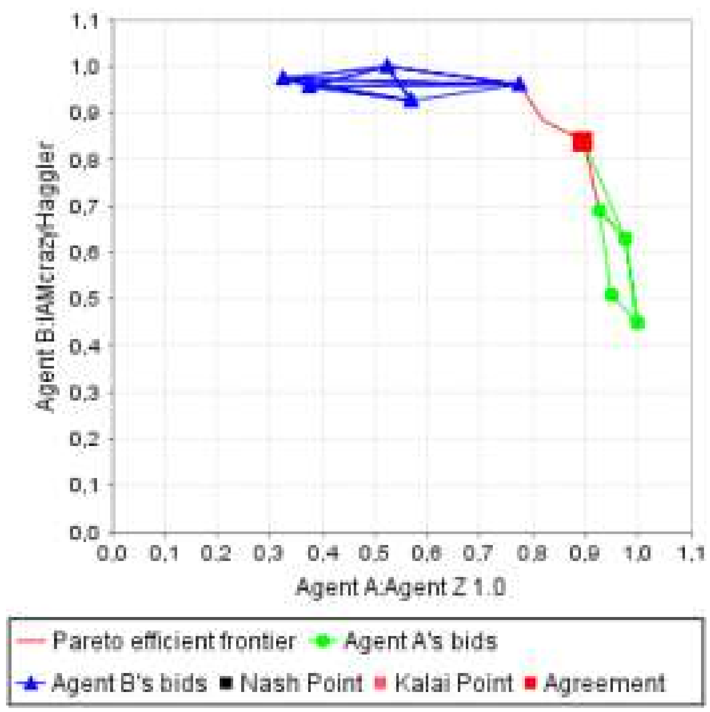

Figure 73 : Agent Z1.0 vs IAMcrazyHaggler – Grocery Domain

Table 41 : Agent Z1.0 vs IAMcrazyHaggler – Grocery Domain

Agent	Agent Z 1.0	IAMcrazyHag		IAMcrazyHag	Agent Z 1.0
Average time of agreement	0.745991	0.745991		0.887856	0.887856
Std time of agreement	0.366306	0.366306		0.216546	0.216546
Average time of end of negotiation	0.745991	0.745991		0.887856	0.887856
Std time of end of negotiation	0.366306	0.366306		0.216546	0.216546
Average rounds	293.3	293.3		349.9	349.9
Std rounds	143.6787	143.6787		85.42632	85.42632
Percentage of agreement	100	100		100	100
Average utility	0.685	0.9045		0.9125	0.6065
Std utility	0.252982	0.06918		0.019185	0.174643
Average utility of agreements	0.685	0.9045		0.9125	0.6065
Average discounted utility	0.594432	0.768998		0.753547	0.505561
Std discounted utility	0.247596	0.045503		0.031904	0.16667
Average discounted utility of agreements	0.594432	0.768998		0.753547	0.505561
Average nash distance	0.222372	0.222372		0.234392	0.234392
Average nash distance of agreements	0.222372	0.222372		0.234392	0.234392
Average pareto distance	0.051477	0.051477		0.058739	0.058739
Average pareto distance of agreements	0.051477	0.051477		0.058739	0.058739
Average kalai distance	0.222372	0.222372		0.234392	0.234392
Average kalai distance of agreements	0.222372	0.222372		0.234392	0.234392
Average social welfare	1.5895	1.5895		1.519	1.519
Average social welfare of agreements	1.5895	1.5895		1.519	1.519
Average exploration	0.008938	0.005938		0.049563	0.006875
Average joint exploration	0.013938	0.013938		0.055875	0.055875
Perc pareto bids	0.825015	0.391718		0.203969	0.658036
Average unfortunate moves	0.051381	0.152033		0.192957	0.078459
Average fortunate moves	0.02968	0.16221		0.181123	0.064937
Average nice moves	0	0		0.019289	0
Average selfish moves	0.099853	0.235805		0.271347	0.10588
Average concession moves	0.134164	0.237948		0.273752	0.117717
Average silent moves	0.684922	0.212004		0.061532	0.633008

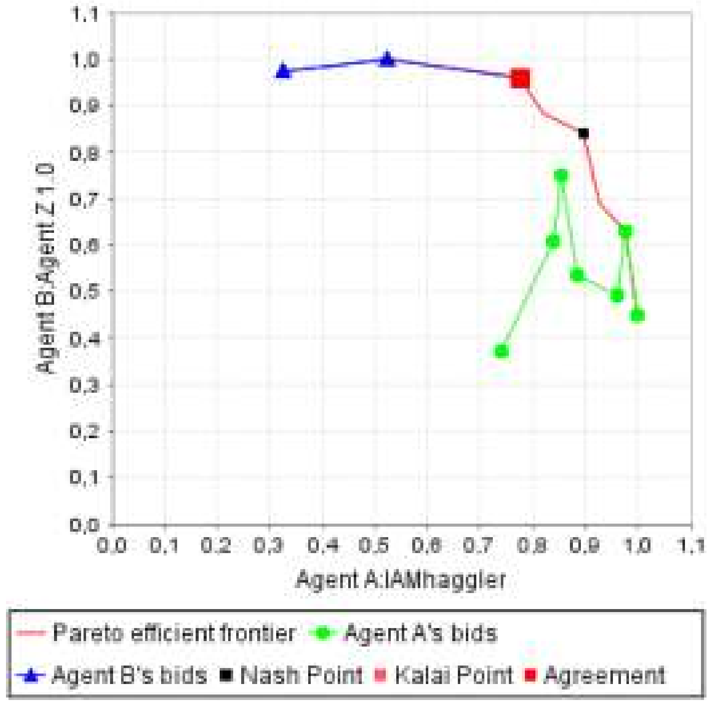

Figure 74 : IAMhaggler vs Agent Z1.0 – Grocery Domain

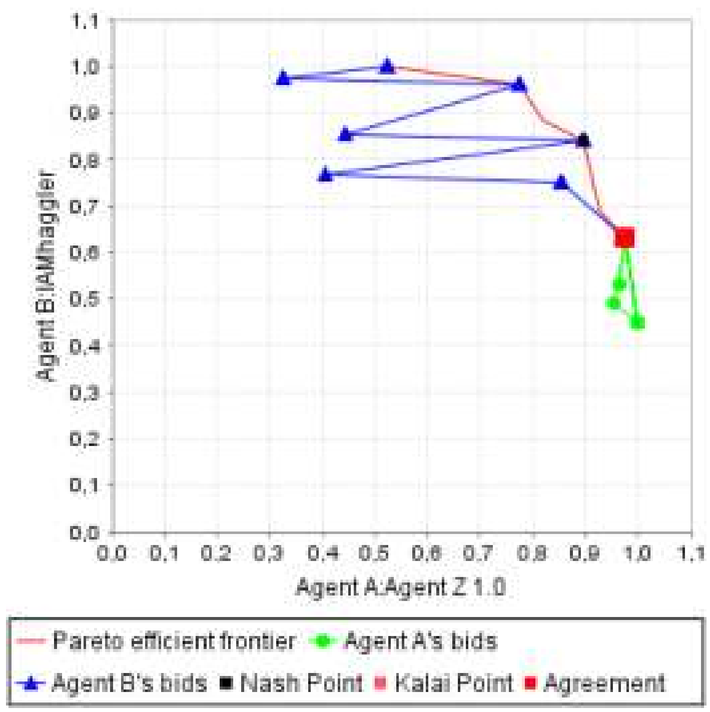

Figure 75 : Agent Z1.0 vs IAMhaggler – Grocery Domain

Table 42 : Agent Z1.0 vs IAMhaggler – Grocery Domain

Agent	Agent Z 1.0	IAMhaggler		IAMhaggler	Agent Z 1.0
Average time of agreement	0.838603	0.838603		0.570409	0.570409
Std time of agreement	0.018521	0.018521		0.212554	0.212554
Average time of end of negotiation	0.838603	0.838603		0.570409	0.570409
Std time of end of negotiation	0.018521	0.018521		0.212554	0.212554
Average rounds	285.1	285.1		193	193
Std rounds	6.556591	6.556591		71.00078	71.00078
Percentage of agreement	100	100		100	100
Average utility	0.959	0.642		0.775	0.96
Std utility	0.025798	0.020976		1.17E-16	2.34E-16
Average utility of agreements	0.959	0.642		0.775	0.96
Average discounted utility	0.799909	0.535603		0.685731	0.849421
Std discounted utility	0.018959	0.019732		0.031636	0.039188
Average discounted utility of agreements	0.799909	0.535603		0.685731	0.849421
Average nash distance	0.208948	0.208948		0.169706	0.169706
Average nash distance of agreements	0.208948	0.208948		0.169706	0.169706
Average pareto distance	0.006083	0.006083		0	0
Average pareto distance of agreements	0.006083	0.006083		0	0
Average kalai distance	0.208948	0.208948		0.169706	0.169706
Average kalai distance of agreements	0.208948	0.208948		0.169706	0.169706
Average social welfare	1.601	1.601		1.735	1.735
Average social welfare of agreements	1.601	1.601		1.735	1.735
Average exploration	0.002813	0.005813		0.00425	0.002
Average joint exploration	0.008625	0.008625		0.005813	0.005813
Perc pareto bids	0.946693	0.684262		0.527258	0.719795
Average unfortunate moves	0.007738	0.027632		0.026942	0.007555
Average fortunate moves	0.00561	0		0	0.01004
Average nice moves	0	0		0	0
Average selfish moves	0.028138	0.000699		0	0.00539
Average concession moves	0.032438	0.030344		0.043214	0.012181
Average silent moves	0.926076	0.941325		0.929844	0.964834

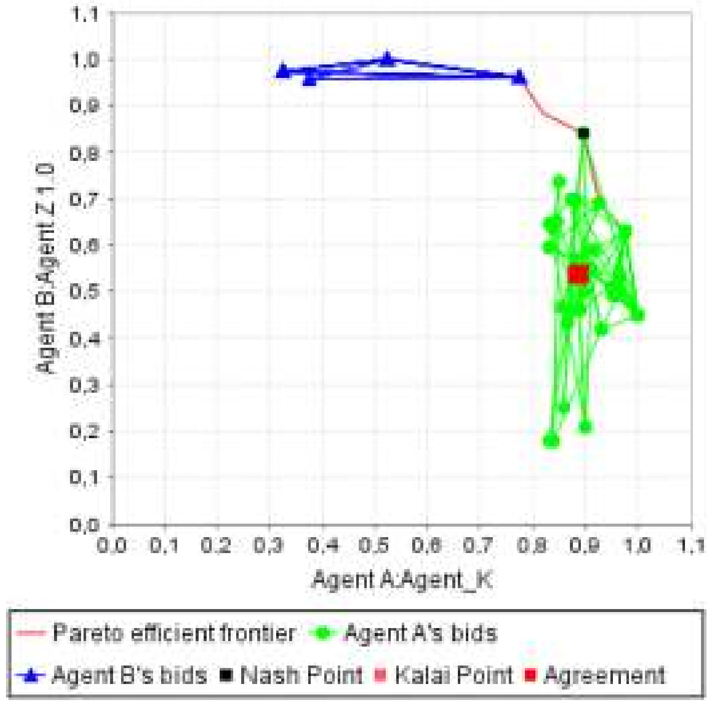

Figure 76 : Agent K vs Agent Z1.0 – Grocery Domain

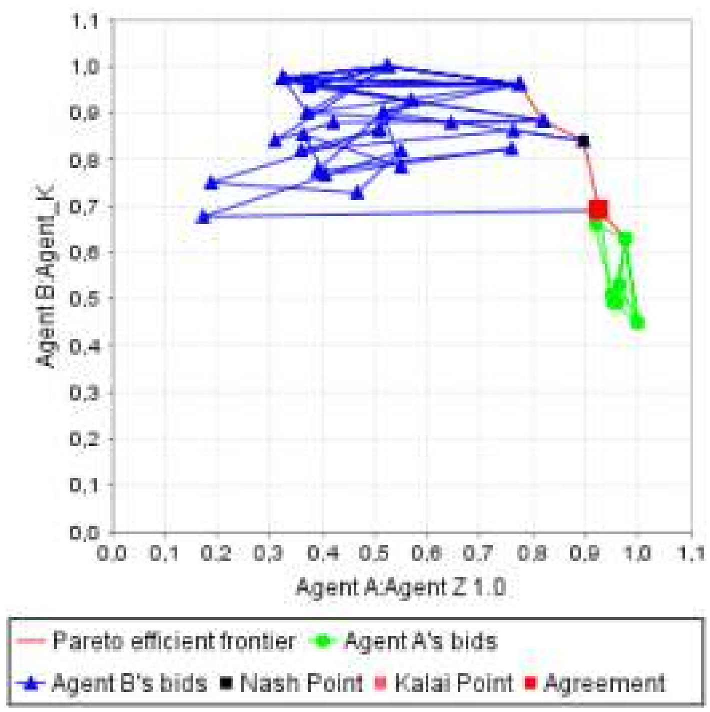

Figure 77 : Agent Z1.0 vs Agent K – Grocery Domain

Table 43 : Agent Z1.0 vs Agent K – Grocery Domain

Agent	Agent Z 1.0	Agent K		Agent K	Agent Z 1.0
Average time of agreement	0.924144	0.924144		0.926641	0.926641
Std time of agreement	0.05106	0.05106		0.087697	0.087697
Average time of end of negotiation	0.924144	0.924144		0.926641	0.926641
Std time of end of negotiation	0.05106	0.05106		0.087697	0.087697
Average rounds	360.1	360.1		361.3	361.3
Std rounds	19.85755	19.85755		33.93474	33.93474
Percentage of agreement	100	100		100	100
Average utility	0.891	0.738		0.8485	0.823
Std utility	0.077201	0.070993		0.051911	0.142443
Average utility of agreements	0.891	0.738		0.8485	0.823
Average discounted utility	0.730002	0.60418		0.694581	0.67432
Std discounted utility	0.067126	0.056213		0.044948	0.120182
Average discounted utility of agreements	0.730002	0.60418		0.694581	0.67432
Average nash distance	0.116842	0.116842		0.114718	0.114718
Average nash distance of agreements	0.116842	0.116842		0.114718	0.114718
Average pareto distance	0.021966	0.021966		0.020702	0.020702
Average pareto distance of agreements	0.021966	0.021966		0.020702	0.020702
Average kalai distance	0.116842	0.116842		0.114718	0.114718
Average kalai distance of agreements	0.116842	0.116842		0.114718	0.114718
Average social welfare	1.629	1.629		1.6715	1.6715
Average social welfare of agreements	1.629	1.629		1.6715	1.6715
Average exploration	0.008375	0.019188		0.023938	0.00525
Average joint exploration	0.026938	0.026938		0.0285	0.0285
Perc pareto bids	0.791164	0.609208		0.68059	0.644187
Average unfortunate moves	0.044925	0.198374		0.094209	0.047681
Average fortunate moves	0.02489	0.182682		0.088825	0.045528
Average nice moves	0	0.000575		0	0
Average selfish moves	0.085833	0.101982		0.226548	0.076846
Average concession moves	0.092638	0.117782		0.23393	0.082545
Average silent moves	0.751715	0.398605		0.356487	0.747401

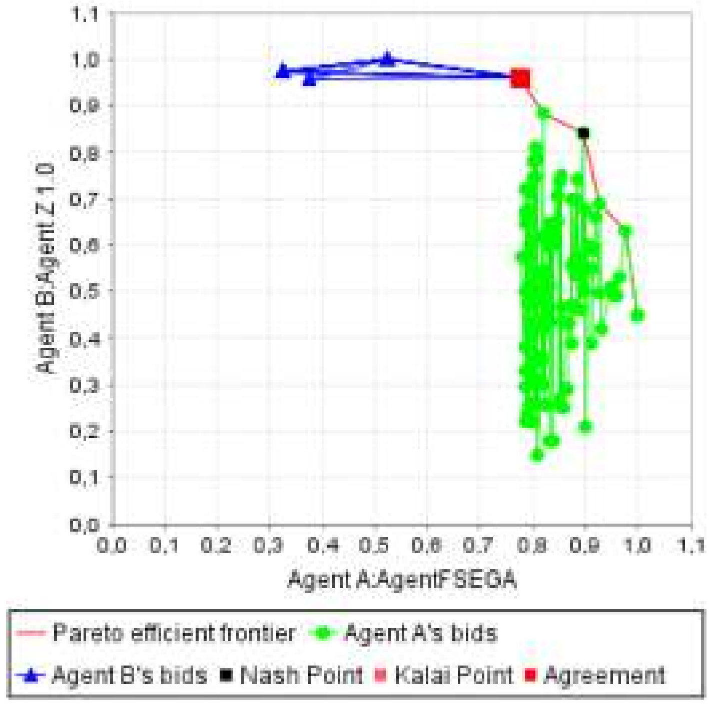

Figure 78 : FSEGA vs Agent Z1.0 – Grocery Domain

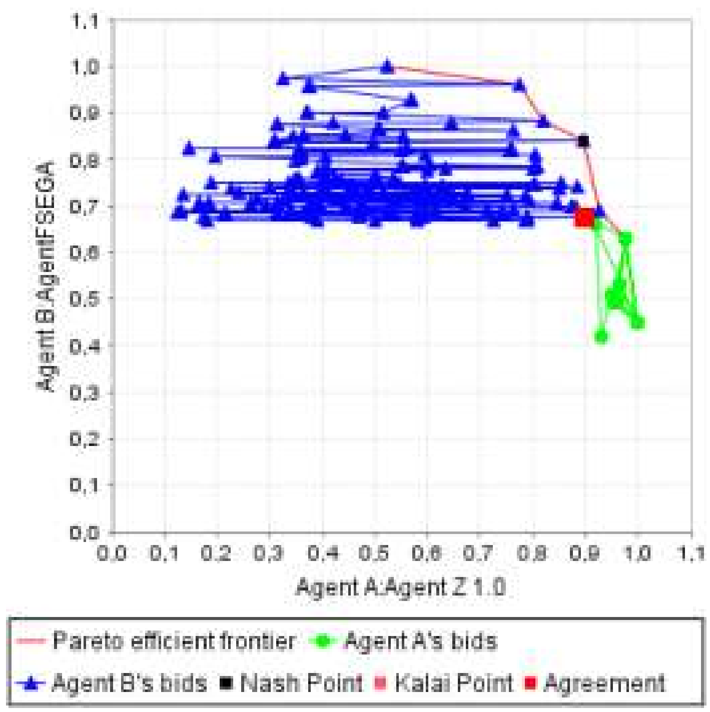

Figure 79 : Agent Z1.0 vs FSEGA – Grocery Domain

Table 44 : Agent Z1.0 vs FSEGA – Grocery Domain

Agent	Agent Z 1.0	FSEGA		FSEGA	Agent Z 1.0
Average time of agreement	0.907748	0.907748		0.51845	0.51845
Std time of agreement	0.102931	0.102931		0.073338	0.073338
Average time of end of negotiation	0.907748	0.907748		0.51845	0.51845
Std time of end of negotiation	0.102931	0.102931		0.073338	0.073338
Average rounds	347.6	347.6		191	191
Std rounds	40.93681	40.93681		28.87906	28.87906
Percentage of agreement	100	100		100	100
Average utility	0.6275	0.6735		0.7795	0.9525
Std utility	0.308412	0.014916		0.01423	0.023717
Average utility of agreements	0.6275	0.6735		0.7795	0.9525
Average discounted utility	0.52027	0.553838		0.697079	0.851326
Std discounted utility	0.26388	0.024486		0.02354	0.012146
Average discounted utility of agreements	0.52027	0.553838		0.697079	0.851326
Average nash distance	0.371805	0.371805		0.161481	0.161481
Average nash distance of agreements	0.371805	0.371805		0.161481	0.161481
Average pareto distance	0.197659	0.197659		0	0
Average pareto distance of agreements	0.197659	0.197659		0	0
Average kalai distance	0.371805	0.371805		0.161481	0.161481
Average kalai distance of agreements	0.371805	0.371805		0.161481	0.161481
Average social welfare	1.301	1.301		1.732	1.732
Average social welfare of agreements	1.301	1.301		1.732	1.732
Average exploration	0.0065	0.094438		0.056063	0.0035
Average joint exploration	0.100938	0.100938		0.059125	0.059125
Perc pareto bids	0.777653	0.039622		0.062927	0.61953
Average unfortunate moves	0.04454	0.437648		0.512806	0.072197
Average fortunate moves	0.035551	0		0	0.058257
Average nice moves	0	0.286846		0.278354	0
Average selfish moves	0.09659	0		0	0.070762
Average concession moves	0.099427	0.143556		0.145764	0.083666
Average silent moves	0.723892	0.13195		0.063076	0.715118

Appendix E : Grocery Domain – Agent Z2.0

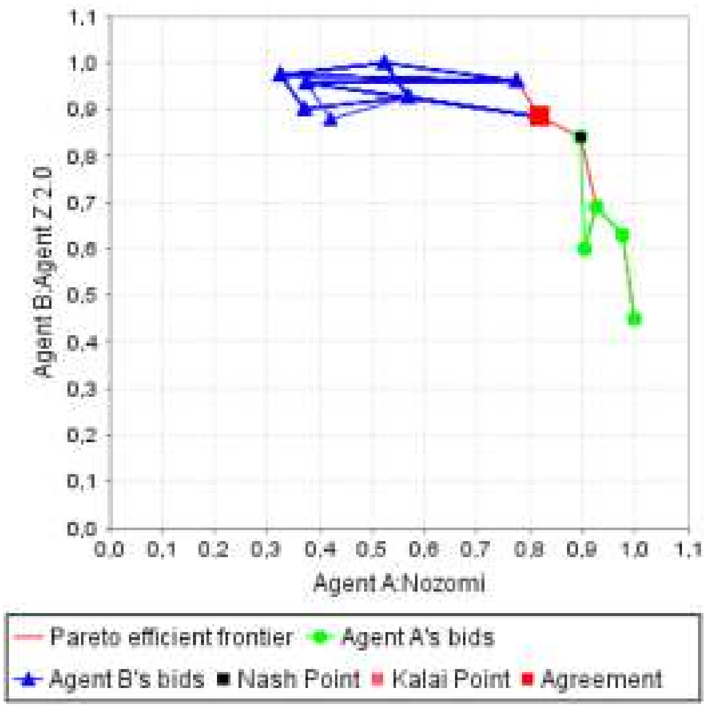

Figure 80 : Nozomi vs Agent Z2.0 – Grocery Domain

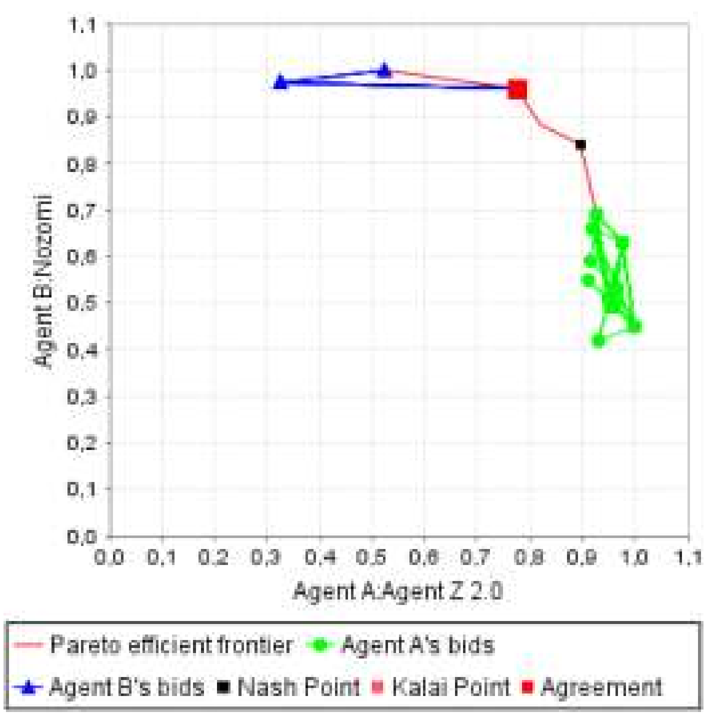

Figure 81 : Agent Z2.0 vs Nozomi – Grocery Domain

Table 45 : Agent Z2.0 vs Nozomi – Grocery Domain

Agent	Agent Z 2.0	Nozomi		Nozomi	Agent Z 2.0
Average time of agreement	0.992477	0.992477		0.921959	0.921959
Std time of agreement	0.001578	0.001578		0.046333	0.046333
Average time of end of negotiation	0.992477	0.992477		0.921959	0.921959
Std time of end of negotiation	0.001578	0.001578		0.046333	0.046333
Average rounds	367	367		338.3	338.3
Std rounds	1.699673	1.699673		16.86581	16.86581
Percentage of agreement	100	100		100	100
Average utility	0.775	0.96		0.821	0.861
Std utility	1.17E-16	2.34E-16		0.003162	0.075895
Average utility of agreements	0.775	0.96		0.821	0.861
Average discounted utility	0.625327	0.774599		0.672639	0.705718
Std discounted utility	0.000213	0.000264		0.005856	0.065365
Average discounted utility of agreements	0.625327	0.774599		0.672639	0.705718
Average nash distance	0.169706	0.169706		0.099273	0.099273
Average nash distance of agreements	0.169706	0.169706		0.099273	0.099273
Average pareto distance	0	0		0.010512	0.010512
Average pareto distance of agreements	0	0		0.010512	0.010512
Average kalai distance	0.169706	0.169706		0.099273	0.099273
Average kalai distance of agreements	0.169706	0.169706		0.099273	0.099273
Average social welfare	1.735	1.735		1.682	1.682
Average social welfare of agreements	1.735	1.735		1.682	1.682
Average exploration	0.0205	0.001875		0.003	0.016313
Average joint exploration	0.022375	0.022375		0.01775	0.01775
Perc pareto bids	0.431604	0.975442		0.982344	0.475636
Average unfortunate moves	0.268513	0.00986		0.005417	0.30272
Average fortunate moves	0.032946	0.004381		0.002476	0.03105
Average nice moves	0	0		0	0
Average selfish moves	0.282163	0.003846		0.077394	0.329446
Average concession moves	0.416378	0.009326		0.090001	0.336784
Average silent moves	0	0.972587		0.824713	0

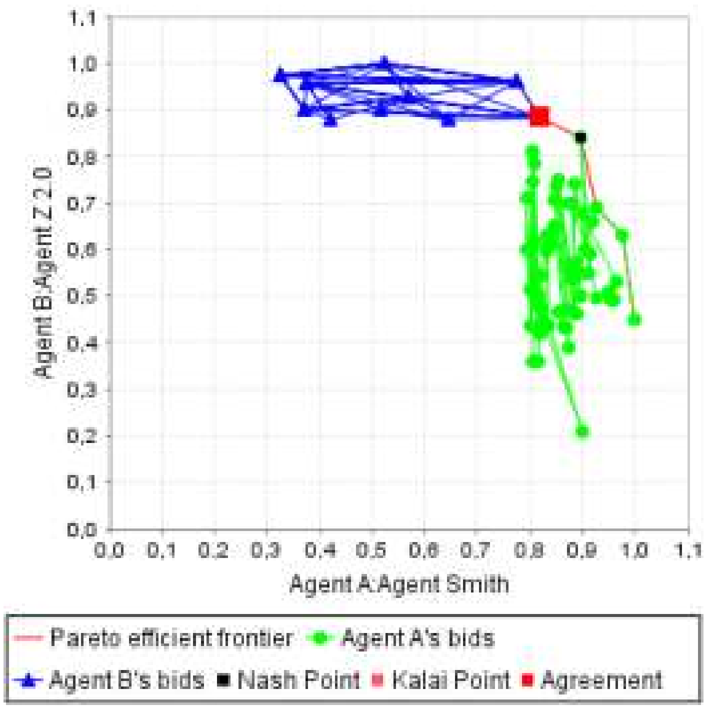

Figure 82 : Agent Smith vs Agent Z2.0 – Grocery Domain

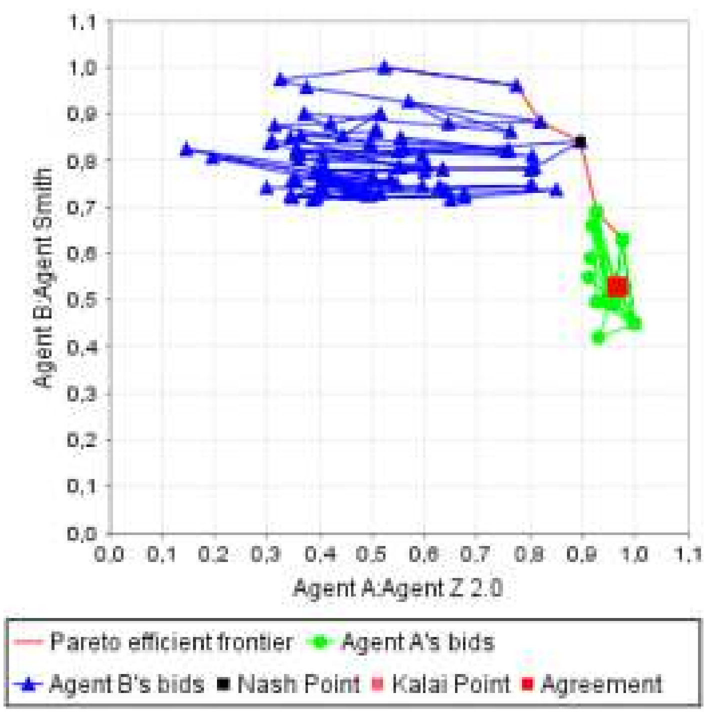

Figure 83 : Agent Z2.0 vs Agent Smith – Grocery Domain

Table 46 : Agent Z2.0 vs Agent Smith – Grocery Domain

Agent	Agent Z 2.0	Agent Smith		Agent Smith	Agent Z 2.0
Average time of agreement	0.491723	0.491723		0.553622	0.553622
Std time of agreement	0.163971	0.163971		0.061194	0.061194
Average time of end of negotiation	0.491723	0.491723		0.553622	0.553622
Std time of end of negotiation	0.163971	0.163971		0.061194	0.061194
Average rounds	140.7	140.7		134.7	134.7
Std rounds	42.85648	42.85648		13.44991	13.44991
Percentage of agreement	100	100		100	100
Average utility	0.9305	0.64		0.82	0.885
Std utility	0.030863	0.172498		1.17E-16	0
Average utility of agreements	0.9305	0.64		0.82	0.885
Average discounted utility	0.836266	0.580617		0.72755	0.785221
Std discounted utility	0.008073	0.17733		0.009693	0.010462
Average discounted utility of agreements	0.836266	0.580617		0.72755	0.785221
Average nash distance	0.203167	0.203167		0.087464	0.087464
Average nash distance of agreements	0.203167	0.203167		0.087464	0.087464
Average pareto distance	0.044204	0.044204		0	0
Average pareto distance of agreements	0.044204	0.044204		0	0
Average kalai distance	0.203167	0.203167		0.087464	0.087464
Average kalai distance of agreements	0.203167	0.203167		0.087464	0.087464
Average social welfare	1.5705	1.5705		1.705	1.705
Average social welfare of agreements	1.5705	1.5705		1.705	1.705
Average exploration	0.0195	0.041188		0.03725	0.016375
Average joint exploration	0.060688	0.060688		0.0525	0.0525
Perc pareto bids	0.366474	0.079528		0.096024	0.427294
Average unfortunate moves	0.313017	0.317832		0.183836	0.345312
Average fortunate moves	0.043861	0.062157		0.024876	0.08622
Average nice moves	0	0.093308		0.066016	0.001389
Average selfish moves	0.224208	0.188208		0.262846	0.25037
Average concession moves	0.418914	0.296053		0.364769	0.316709
Average silent moves	0	0.042443		0.097657	0

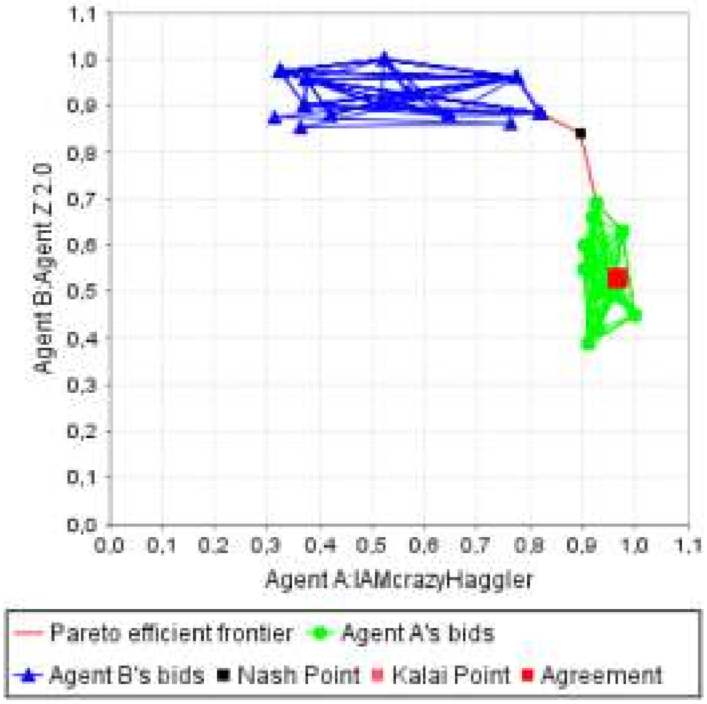

Figure 84 : IAMcrazyHaggler vs Agent Z2.0 – Grocery Domain

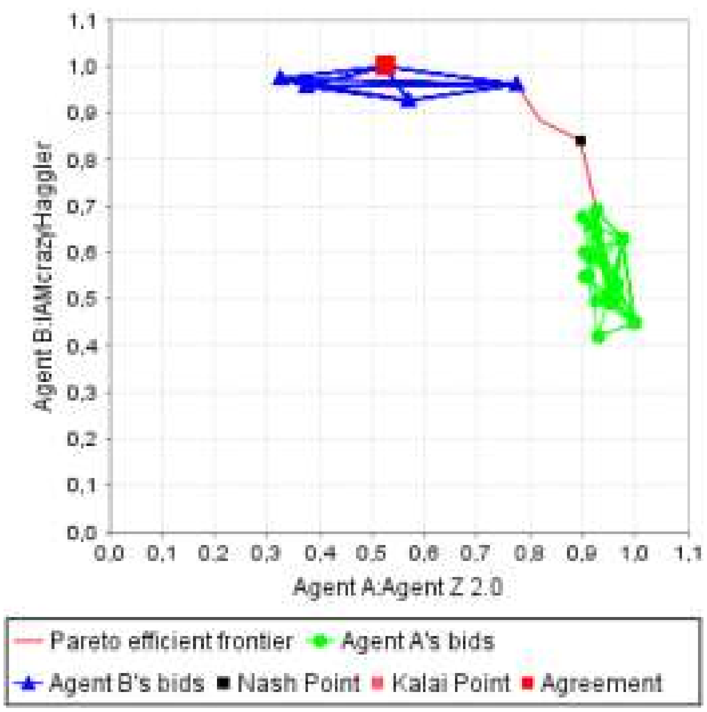

Figure 85 : Agent Z2.0 vs IAMcrazyHaggler – Grocery Domain

Table 47 : Agent Z2.0 vs IAMcrazyHaggler – Grocery Domain

Agent	Agent Z 2.0	IAMcrazyHag		IAMcrazyHag	Agent Z 2.0
Average time of agreement	0.984656	0.984656		0.992393	0.992393
Std time of agreement	0.021233	0.021233		0.001781	0.001781
Average time of end of negotiation	0.984656	0.984656		0.992393	0.992393
Std time of end of negotiation	0.021233	0.021233		0.001781	0.001781
Average rounds	359.9	359.9		363.9	363.9
Std rounds	8.849984	8.849984		1.37032	1.37032
Percentage of agreement	100	100		100	100
Average utility	0.546	0.9535		0.949	0.5335
Std utility	0.177651	0.048879		0.031252	0.085896
Average utility of agreements	0.546	0.9535		0.949	0.5335
Average discounted utility	0.441714	0.77053		0.765741	0.430476
Std discounted utility	0.1457	0.036939		0.025352	0.069314
Average discounted utility of agreements	0.441714	0.77053		0.765741	0.430476
Average nash distance	0.370181	0.370181		0.313034	0.313034
Average nash distance of agreements	0.370181	0.370181		0.313034	0.313034
Average pareto distance	0.068969	0.068969		0.055111	0.055111
Average pareto distance of agreements	0.068969	0.068969		0.055111	0.055111
Average kalai distance	0.370181	0.370181		0.313034	0.313034
Average kalai distance of agreements	0.370181	0.370181		0.313034	0.313034
Average social welfare	1.4995	1.4995		1.4825	1.4825
Average social welfare of agreements	1.4995	1.4995		1.4825	1.4825
Average exploration	0.033063	0.00625		0.049563	0.028938
Average joint exploration	0.0385	0.0385		0.075438	0.075438
Perc pareto bids	0.412217	0.383359		0.198467	0.428635
Average unfortunate moves	0.280321	0.155921		0.197348	0.273021
Average fortunate moves	0.046881	0.160234		0.190221	0.07927
Average nice moves	0	0		0.012103	0
Average selfish moves	0.266015	0.230918		0.276749	0.300855
Average concession moves	0.406783	0.242129		0.262402	0.346853
Average silent moves	0	0.210799		0.061178	0

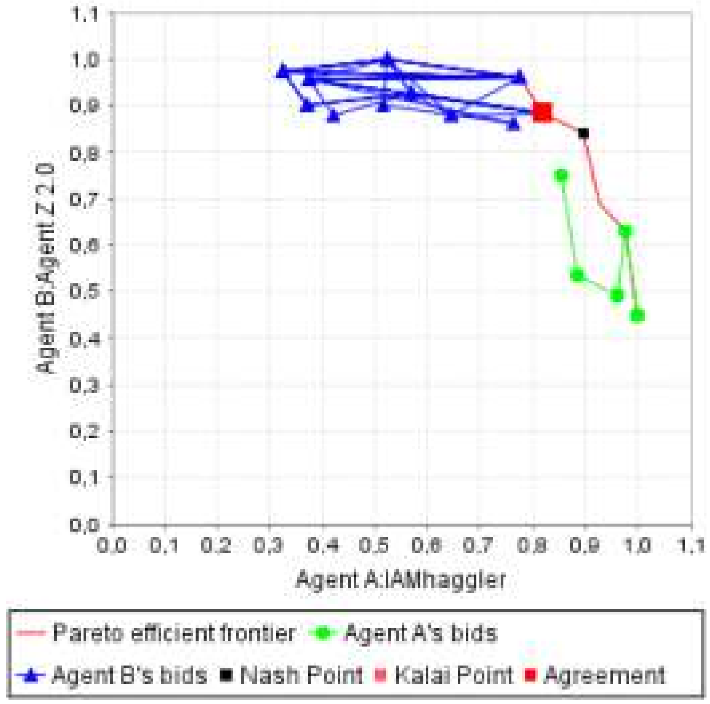

Figure 86 : IAMhaggler vs Agent Z2.0 – Grocery Domain

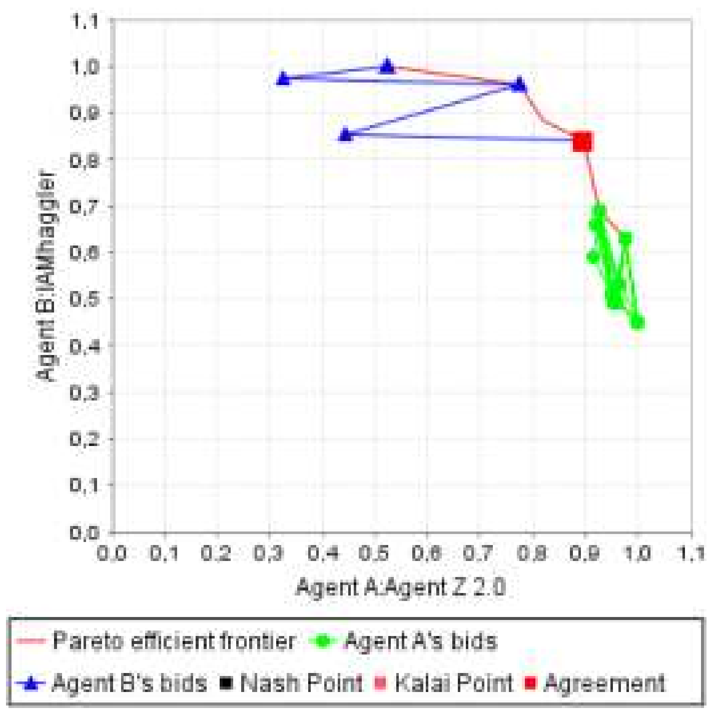

Figure 87 : Agent Z2.0 vs IAMhaggler – Grocery Domain

Table 48 : Agent Z2.0 vs IAMhaggler – Grocery Domain

Agent	Agent Z 2.0	IAMhaggler		IAMhaggler	Agent Z 2.0
Average time of agreement	0.322344	0.322344		0.315852	0.315852
Std time of agreement	0.009475	0.009475		0.008866	0.008866
Average time of end of negotiation	0.322344	0.322344		0.315852	0.315852
Std time of end of negotiation	0.009475	0.009475		0.008866	0.008866
Average rounds	107.8	107.8		105.1	105.1
Std rounds	2.740641	2.740641		3.665151	3.665151
Percentage of agreement	100	100		100	100
Average utility	0.895	0.84		0.82	0.885
Std utility	2.34E-16	0		1.17E-16	0
Average utility of agreements	0.895	0.84		0.82	0.885
Average discounted utility	0.834748	0.783451		0.765871	0.826581
Std discounted utility	0.001711	0.001605		0.001468	0.001584
Average discounted utility of agreements	0.834748	0.783451		0.765871	0.826581
Average nash distance	0	0		0.087464	0.087464
Average nash distance of agreements	0	0		0.087464	0.087464
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0	0		0.087464	0.087464
Average kalai distance of agreements	0	0		0.087464	0.087464
Average social welfare	1.735	1.735		1.705	1.705
Average social welfare of agreements	1.735	1.735		1.705	1.705
Average exploration	0.016063	0.003125		0.003813	0.015188
Average joint exploration	0.019188	0.019188		0.016813	0.016813
Perc pareto bids	0.417079	0.935081		0.731874	0.41858
Average unfortunate moves	0.274369	0.03783		0.023106	0.295609
Average fortunate moves	0.054195	0		0	0.097939
Average nice moves	0	0		0	0
Average selfish moves	0.264493	0		0	0.291523
Average concession moves	0.406943	0.03783		0.075015	0.314929
Average silent moves	0	0.92434		0.901879	0

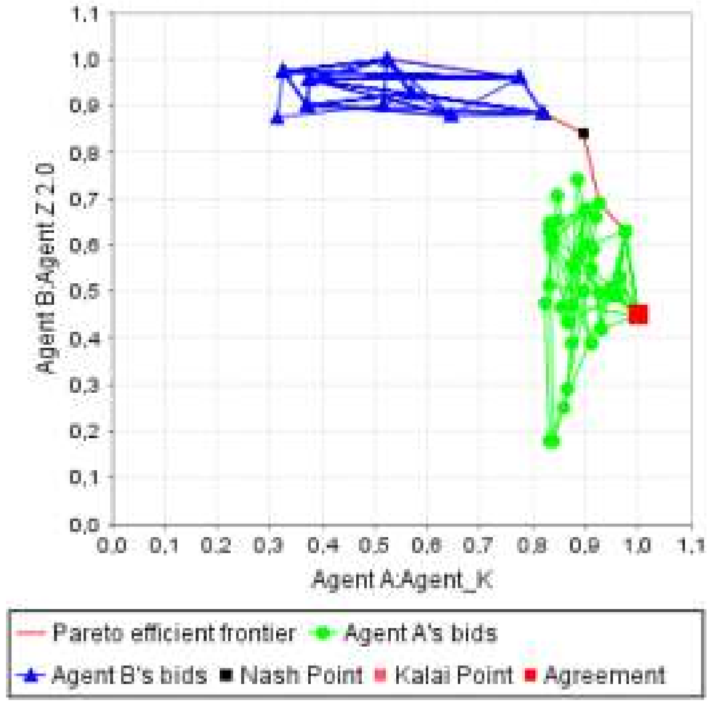

Figure 88 : Agent K vs Agent Z2.0 – Grocery Domain

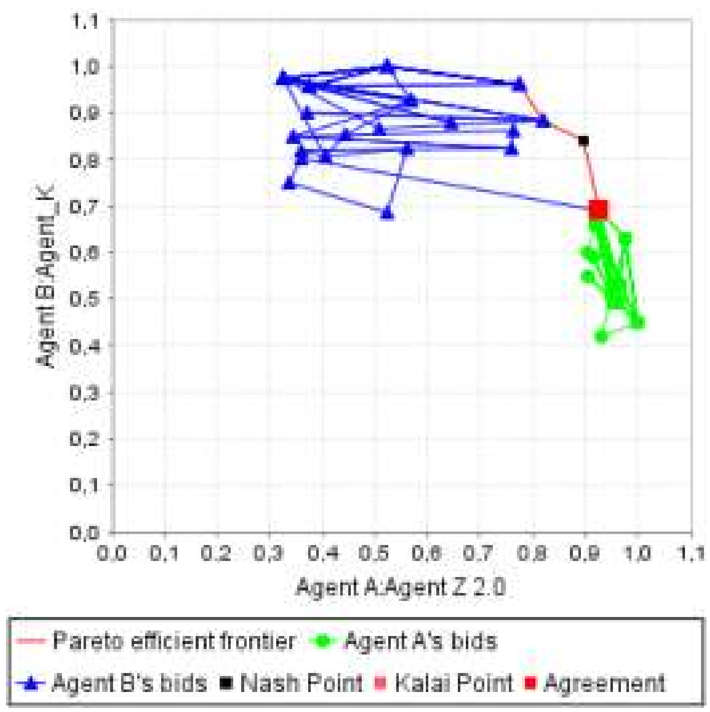

Figure 89 : Agent Z2.0 vs Agent K – Grocery Domain

Table 49 : Agent Z2.0 vs Agent K – Grocery Domain

Agent	Agent Z 2.0	Agent_K		Agent K	Agent Z 2.0
Average time of agreement	0.854685	0.854685		0.949351	0.949351
Std time of agreement	0.019209	0.019209		0.06706	0.06706
Average time of end of negotiation	0.854685	0.854685		0.949351	0.949351
Std time of end of negotiation	0.019209	0.019209		0.06706	0.06706
Average rounds	313.8	313.8		346.2	346.2
Std rounds	7.743097	7.743097		25.35438	25.35438
Percentage of agreement	100	100		100	100
Average utility	0.922	0.705		0.8615	0.6845
Std utility	0.009487	0.047434		0.0574	0.223873
Average utility of agreements	0.922	0.705		0.8615	0.6845
Average discounted utility	0.766414	0.586188		0.701384	0.559062
Std discounted utility	0.005217	0.04205		0.042129	0.187536
Average discounted utility of agreements	0.766414	0.586188		0.701384	0.559062
Average nash distance	0.137674	0.137674		0.223338	0.223338
Average nash distance of agreements	0.137674	0.137674		0.223338	0.223338
Average pareto distance	0	0		0.043023	0.043023
Average pareto distance of agreements	0	0		0.043023	0.043023
Average kalai distance	0.137674	0.137674		0.223338	0.223338
Average kalai distance of agreements	0.137674	0.137674		0.223338	0.223338
Average social welfare	1.627	1.627		1.546	1.546
Average social welfare of agreements	1.627	1.627		1.546	1.546
Average exploration	0.032813	0.016375		0.027688	0.028125
Average joint exploration	0.048688	0.048688		0.053625	0.053625
Perc pareto bids	0.39762	0.630217		0.616006	0.423211
Average unfortunate moves	0.266272	0.191355		0.111961	0.263822
Average fortunate moves	0.065813	0.182232		0.103143	0.096738
Average nice moves	0	0.001282		0.004609	0
Average selfish moves	0.26684	0.098755		0.220798	0.305846
Average concession moves	0.401075	0.110885		0.240714	0.333594
Average silent moves	0	0.41549		0.318776	0

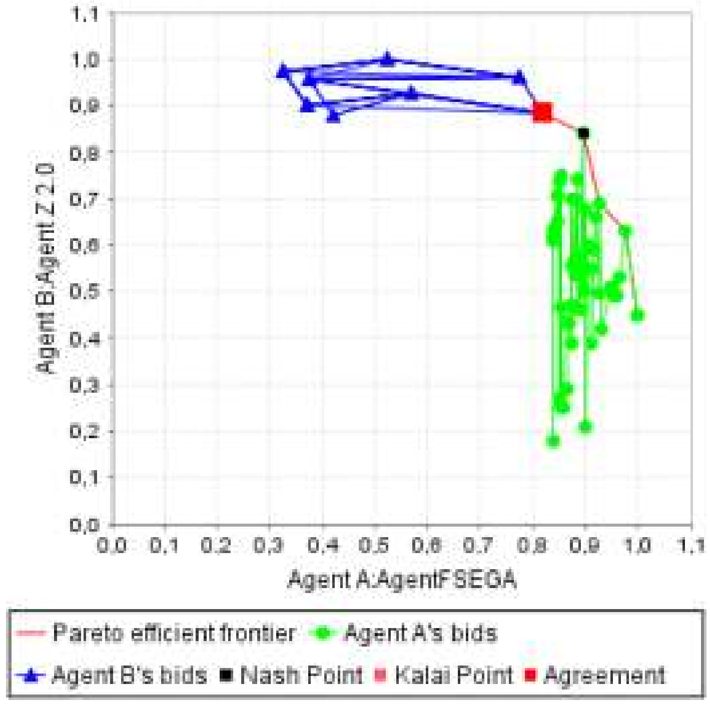

Figure 90 : FSEGA vs Agent Z2.0 – Grocery Domain

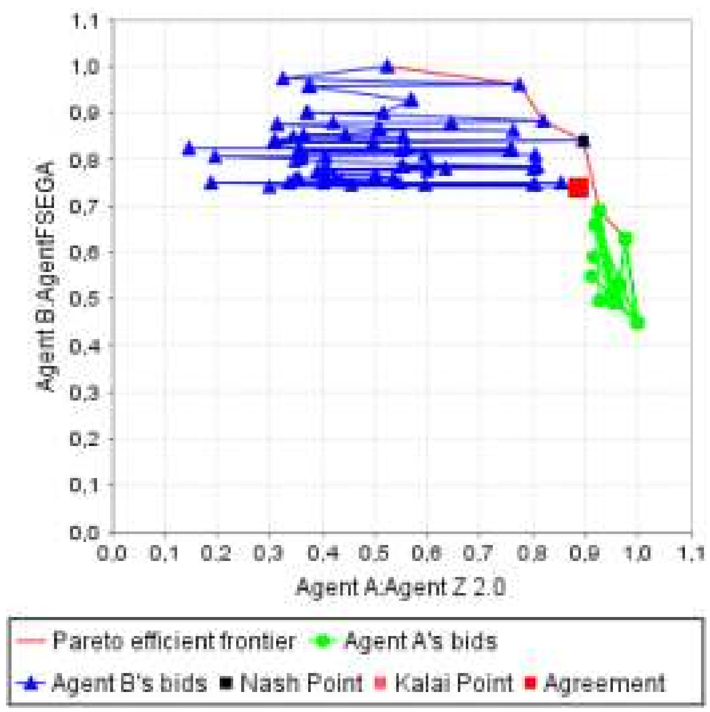

Figure 91 : Agent Z2.0 vs FSEGA – Grocery Domain

Table 50 : Agent Z2.0 vs FSEGA – Grocery Domain

Agent	Agent Z 2.0	FSEGA		FSEGA	Agent Z 2.0
Average time of agreement	0.609957	0.609957		0.325707	0.325707
Std time of agreement	0.166983	0.166983		0.011	0.011
Average time of end of negotiation	0.609957	0.609957		0.325707	0.325707
Std time of end of negotiation	0.166983	0.166983		0.011	0.011
Average rounds	215.3	215.3		108.8	108.8
Std rounds	60.87154	60.87154		3.910101	3.910101
Percentage of agreement	100	100		100	100
Average utility	0.9055	0.721		0.82	0.885
Std utility	0.020877	0.047714		1.17E-16	0
Average utility of agreements	0.9055	0.721		0.82	0.885
Average discounted utility	0.793764	0.633638		0.764242	0.824822
Std discounted utility	0.024349	0.066758		0.001815	0.001959
Average discounted utility of agreements	0.793764	0.633638		0.764242	0.824822
Average nash distance	0.120715	0.120715		0.087464	0.087464
Average nash distance of agreements	0.120715	0.120715		0.087464	0.087464
Average pareto distance	0.023819	0.023819		0	0
Average pareto distance of agreements	0.023819	0.023819		0	0
Average kalai distance	0.120715	0.120715		0.087464	0.087464
Average kalai distance of agreements	0.120715	0.120715		0.087464	0.087464
Average social welfare	1.6265	1.6265		1.705	1.705
Average social welfare of agreements	1.6265	1.6265		1.705	1.705
Average exploration	0.024063	0.054688		0.030875	0.016125
Average joint exploration	0.07875	0.07875		0.046063	0.046063
Perc pareto bids	0.384907	0.060492		0.092015	0.417344
Average unfortunate moves	0.316218	0.395295		0.46254	0.322827
Average fortunate moves	0.031978	0		0	0.102146
Average nice moves	0	0.215739		0.245216	0
Average selfish moves	0.231349	0		0	0.248721
Average concession moves	0.420454	0.176267		0.198502	0.326307
Average silent moves	0	0.212699		0.093742	0

Appendix F : Grocery Domain – Agent Z3.0

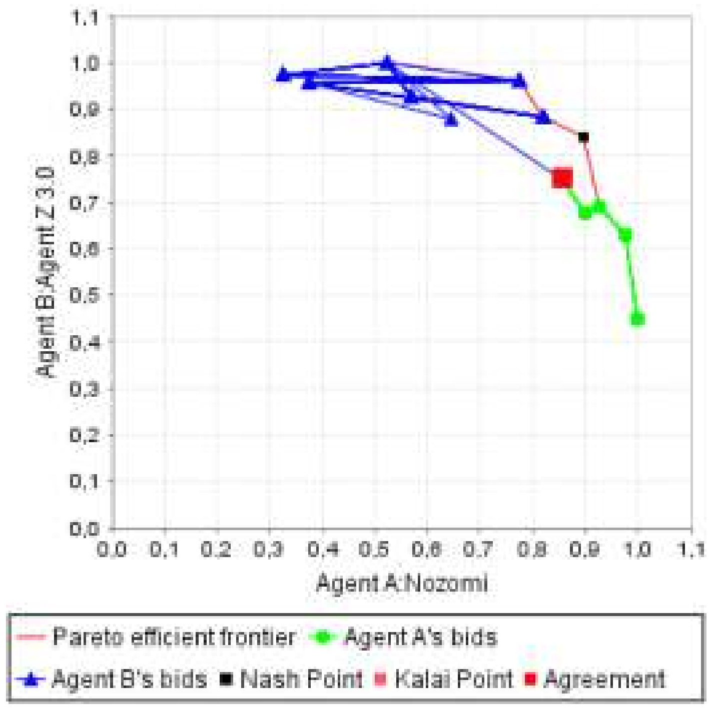

Figure 92 : Nozomi vs Agent Z3.0 – Grocery Domain

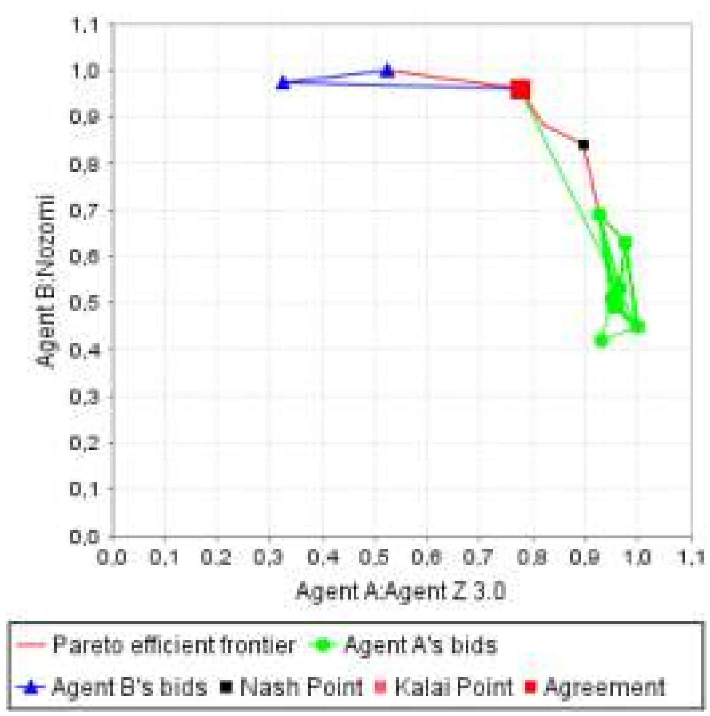

Figure 93 : Agent Z3.0 vs Nozomi – Grocery Domain

Table 51 : Agent Z3.0 vs Nozomi – Grocery Domain

Agent	Agent Z 3.0	Nozomi		Nozomi	Agent Z 3.0
Average time of agreement	0.992627	0.992627		0.943764	0.943764
Std time of agreement	0.00143	0.00143		0.041913	0.041913
Average time of end of negotiation	0.992627	0.992627		0.943764	0.943764
Std time of end of negotiation	0.00143	0.00143		0.041913	0.041913
Average rounds	367.2	367.2		346.9	346.9
Std rounds	2.20101	2.20101		16.03087	16.03087
Percentage of agreement	100	100		100	100
Average utility	0.775	0.96		0.883	0.813
Std utility	1.17E-16	2.34E-16		0.019322	0.043474
Average utility of agreements	0.775	0.96		0.883	0.813
Average discounted utility	0.625307	0.774573		0.720141	0.663186
Std discounted utility	0.000193	0.000239		0.021188	0.040148
Average discounted utility of agreements	0.625307	0.774573		0.720141	0.663186
Average nash distance	0.169706	0.169706		0.029547	0.029547
Average nash distance of agreements	0.169706	0.169706		0.029547	0.029547
Average pareto distance	0	0		0.027659	0.027659
Average pareto distance of agreements	0	0		0.027659	0.027659
Average kalai distance	0.169706	0.169706		0.029547	0.029547
Average kalai distance of agreements	0.169706	0.169706		0.029547	0.029547
Average social welfare	1.735	1.735		1.696	1.696
Average social welfare of agreements	1.735	1.735		1.696	1.696
Average exploration	0.01475	0.001875		0.00275	0.014
Average joint exploration	0.016375	0.016375		0.01475	0.01475
Perc pareto bids	0.714278	0.975504		0.96443	0.713702
Average unfortunate moves	0.148645	0.007689		0.00275	0.172321
Average fortunate moves	0.040325	0.002198		0.000549	0.010484
Average nice moves	0	0		0	0
Average selfish moves	0.119055	0.002732		0.083587	0.186674
Average concession moves	0.207538	0.008224		0.09739	0.195951
Average silent moves				0.815724	0.43457

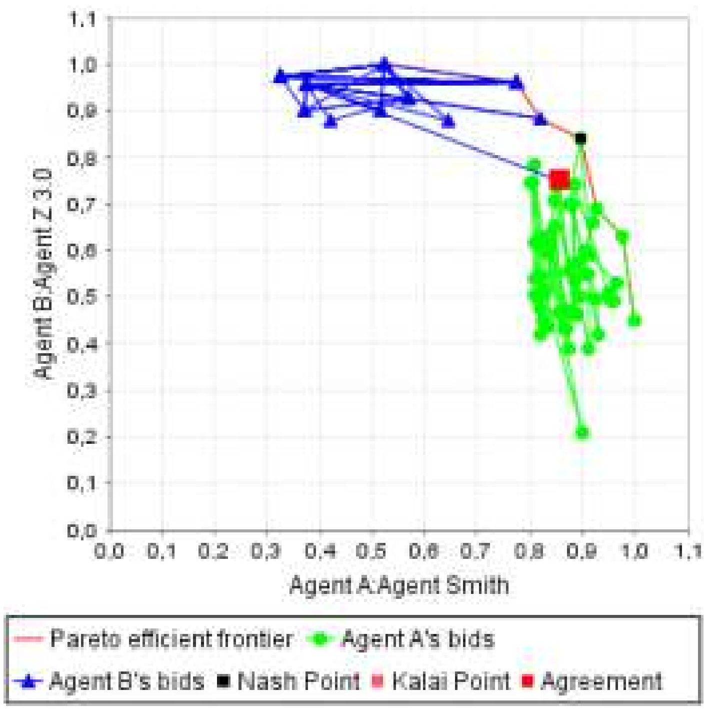

Figure 94 : Agent Smith vs Agent Z3.0 – Grocery Domain

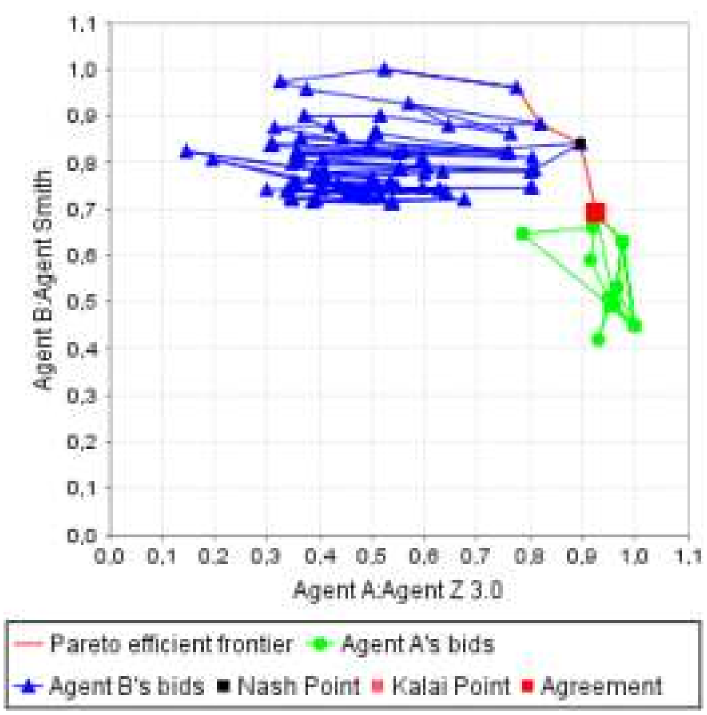

Figure 95 : Agent Z3.0 vs Agent Smith – Grocery Domain

Table 52 : Agent Z3.0 vs Agent Smith – Grocery Domain

Agent	Agent Z 3.0	Agent Smith		Agent Smith	Agent Z 3.0
Average time of agreement	0.584469	0.584469		0.570636	0.570636
Std time of agreement	0.039594	0.039594		0.062194	0.062194
Average time of end of negotiation	0.584469	0.584469		0.570636	0.570636
Std time of end of negotiation	0.039594	0.039594		0.062194	0.062194
Average rounds	165.9	165.9		138.6	138.6
Std rounds	9.53881	9.53881		12.54503	12.54503
Percentage of agreement	100	100		100	100
Average utility	0.826	0.6675		0.645	0.9265
Std utility	0.146814	0.108788		0.155403	0.105384
Average utility of agreements	0.826	0.6675		0.645	0.9265
Average discounted utility	0.727038	0.588812		0.571751	0.818097
Std discounted utility	0.124208	0.099537		0.145335	0.084885
Average discounted utility of agreements	0.727038	0.588812		0.571751	0.818097
Average nash distance	0.239605	0.239605		0.282296	0.282296
Average nash distance of agreements	0.239605	0.239605		0.282296	0.282296
Average pareto distance	0.101673	0.101673		0.022306	0.022306
Average pareto distance of agreements	0.101673	0.101673		0.022306	0.022306
Average kalai distance	0.239605	0.239605		0.282296	0.282296
Average kalai distance of agreements	0.239605	0.239605		0.282296	0.282296
Average social welfare	1.4935	1.4935		1.5715	1.5715
Average social welfare of agreements	1.4935	1.4935		1.5715	1.5715
Average exploration	0.014313	0.048875		0.038625	0.015563
Average joint exploration	0.063188	0.063188		0.052563	0.052563
Perc pareto bids	0.437983	0.066836		0.085728	0.477433
Average unfortunate moves	0.30653	0.289641		0.162274	0.327125
Average fortunate moves	0.085851	0.067764		0.040516	0.063576
Average nice moves	0	0.170917		0.069762	0
Average selfish moves	0.214997	0.165451		0.25318	0.215712
Average concession moves	0.347451	0.272347		0.368862	0.320756
Average silent moves	0.045171	0.033879		0.105406	0.072831

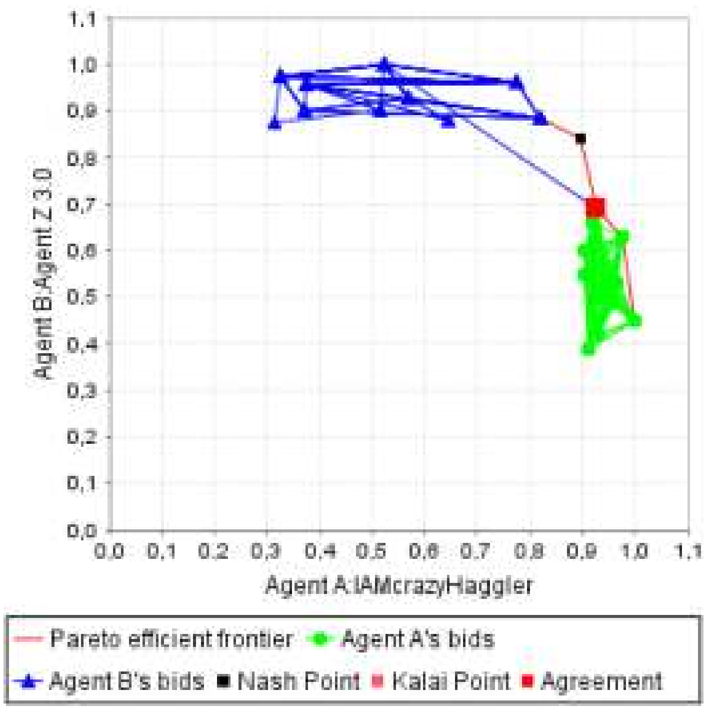

Figure 96 : IAMcrazyHaggler vs Agent Z3.0 – Grocery Domain

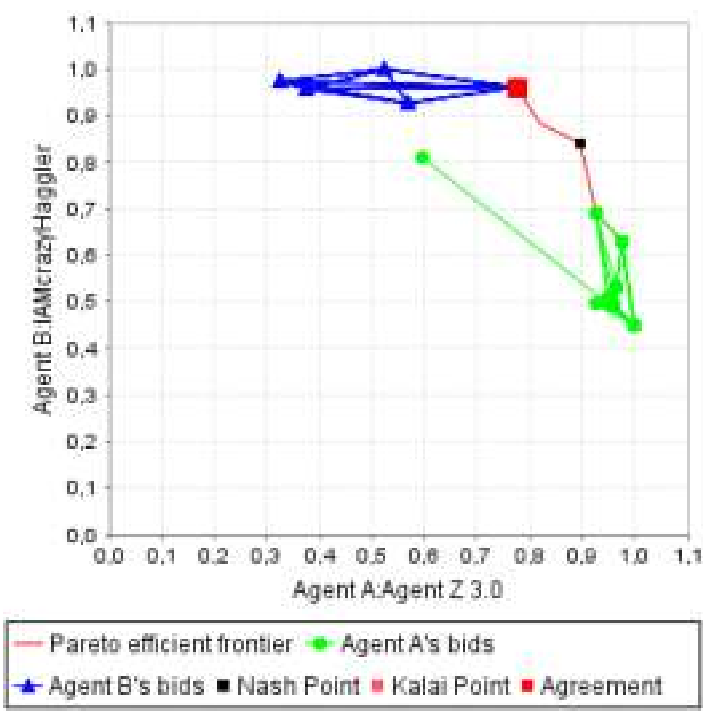

Figure 97 : Agent Z3.0 vs IAMcrazyHaggler – Grocery Domain

Table 53 : Agent Z3.0 vs IAMcrazyHaggler – Grocery Domain

Agent	Agent Z 3.0	IAMcrazyHag		IAMcrazyHag	Agent Z 3.0
Average time of agreement	0.682071	0.682071		0.865873	0.865873
Std time of agreement	0.218383	0.218383		0.20683	0.20683
Average time of end of negotiation	0.682071	0.682071		0.865873	0.865873
Std time of end of negotiation	0.218383	0.218383		0.20683	0.20683
Average rounds	250.2	250.2		318	318
Std rounds	80.2701	80.2701		76.97619	76.97619
Percentage of agreement	100	100		100	100
Average utility	0.8035	0.9285		0.9105	0.712
Std utility	0.050224	0.052178		0.025216	0.048717
Average utility of agreements	0.8035	0.9285		0.9105	0.712
Average discounted utility	0.694727	0.80118		0.754904	0.591935
Std discounted utility	0.063578	0.045873		0.014584	0.06132
Average discounted utility of agreements	0.694727	0.80118		0.754904	0.591935
Average nash distance	0.12754	0.12754		0.131008	0.131008
Average nash distance of agreements	0.12754	0.12754		0.131008	0.131008
Average pareto distance	0	0		0.013829	0.013829
Average pareto distance of agreements	0	0		0.013829	0.013829
Average kalai distance	0.12754	0.12754		0.131008	0.131008
Average kalai distance of agreements	0.12754	0.12754		0.131008	0.131008
Average social welfare	1.732	1.732		1.6225	1.6225
Average social welfare of agreements	1.732	1.732		1.6225	1.6225
Average exploration	0.01825	0.00625		0.047125	0.024125
Average joint exploration	0.0235	0.0235		0.06975	0.06975
Perc pareto bids	0.522013	0.429658		0.186676	0.559893
Average unfortunate moves	0.24873	0.165856		0.205782	0.22902
Average fortunate moves	0.074054	0.174152		0.18455	0.083654
Average nice moves	0	0		0.01308	0
Average selfish moves	0.223944	0.235034		0.272898	0.246573
Average concession moves	0.330316	0.232614		0.263008	0.284233
Average silent moves	0.122956	0.192344		0.060683	0.156521

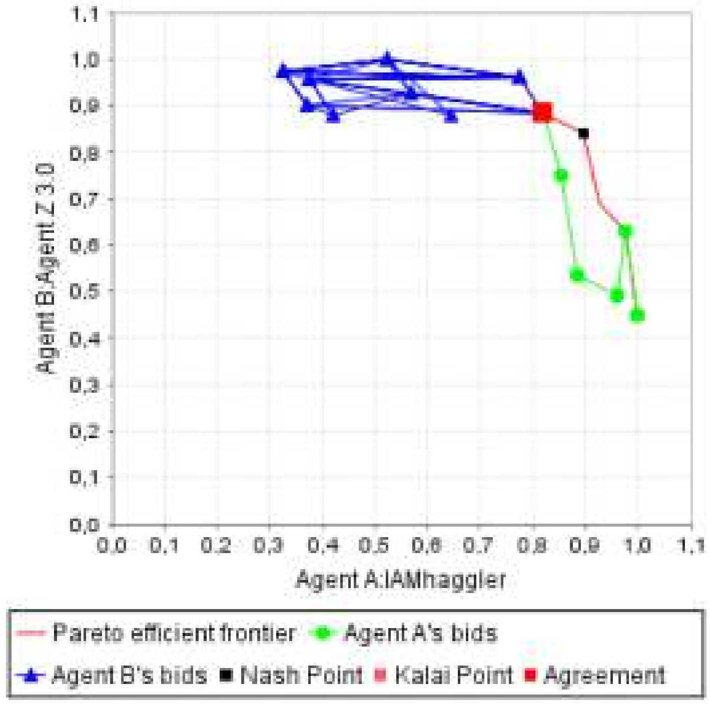

Figure 98 : IAMhaggler vs Agent Z3.0 – Grocery Domain

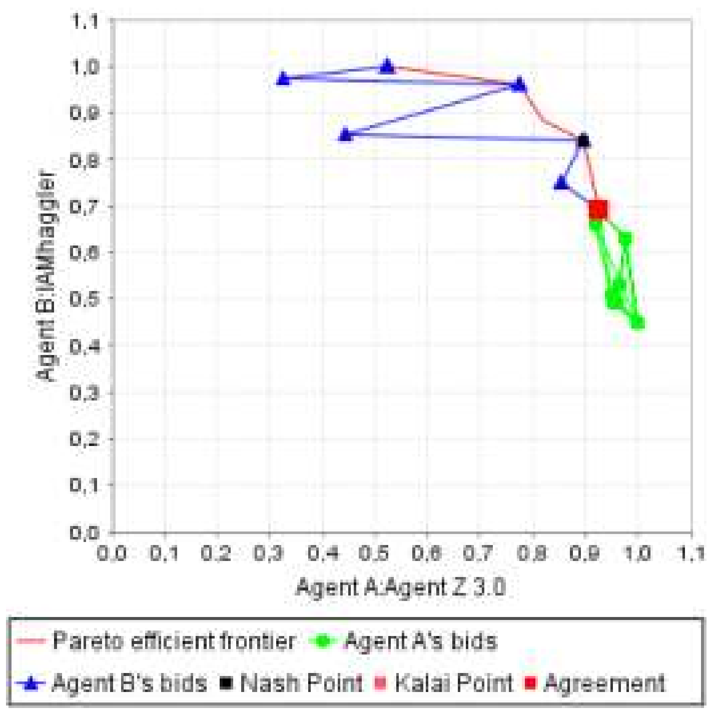

Figure 99 : Agent Z3.0 vs IAMhaggler – Grocery Domain

Table 54 : Agent Z3.0 vs IAMhaggler – Grocery Domain

Agent	Agent Z 3.0	IAMhaggler		IAMhaggler	Agent Z 3.0
Average time of agreement	0.375044	0.375044		0.315943	0.315943
Std time of agreement	0.035446	0.035446		0.006554	0.006554
Average time of end of negotiation	0.375044	0.375044		0.315943	0.315943
Std time of end of negotiation	0.035446	0.035446		0.006554	0.006554
Average rounds	124.6	124.6		105	105
Std rounds	11.96476	11.96476		2.494438	2.494438
Percentage of agreement	100	100		100	100
Average utility	0.919	0.72		0.82	0.885
Std utility	0.012649	0.063246		1.17E-16	0
Average utility of agreements	0.919	0.72		0.82	0.885
Average discounted utility	0.847362	0.664339		0.765856	0.826564
Std discounted utility	0.005373	0.064035		0.001084	0.00117
Average discounted utility of agreements	0.847362	0.664339		0.765856	0.826564
Average nash distance	0.122376	0.122376		0.087464	0.087464
Average nash distance of agreements	0.122376	0.122376		0.087464	0.087464
Average pareto distance	0	0		0	0
Average pareto distance of agreements	0	0		0	0
Average kalai distance	0.122376	0.122376		0.087464	0.087464
Average kalai distance of agreements	0.122376	0.122376		0.087464	0.087464
Average social welfare	1.639	1.639		1.705	1.705
Average social welfare of agreements	1.639	1.639		1.705	1.705
Average exploration	0.014875	0.003875		0.004063	0.013563
Average joint exploration	0.0185	0.0185		0.01475	0.01475
Perc pareto bids	0.450363	0.910674		0.728238	0.448097
Average unfortunate moves	0.316314	0.039179		0.028828	0.312009
Average fortunate moves	0.056392	0		0	0.050913
Average nice moves	0	0		0	0
Average selfish moves	0.249164	0		0	0.274513
Average concession moves	0.37813	0.04543		0.076962	0.362565
Average silent moves	0	0.91539		0.894211	0

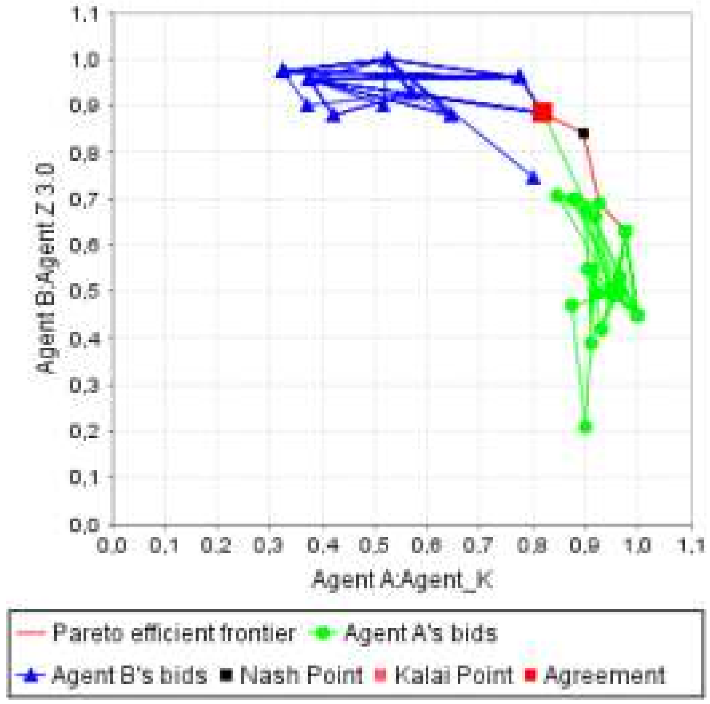

Figure 100 : Agent K vs Agent Z3.0 – Grocery Domain

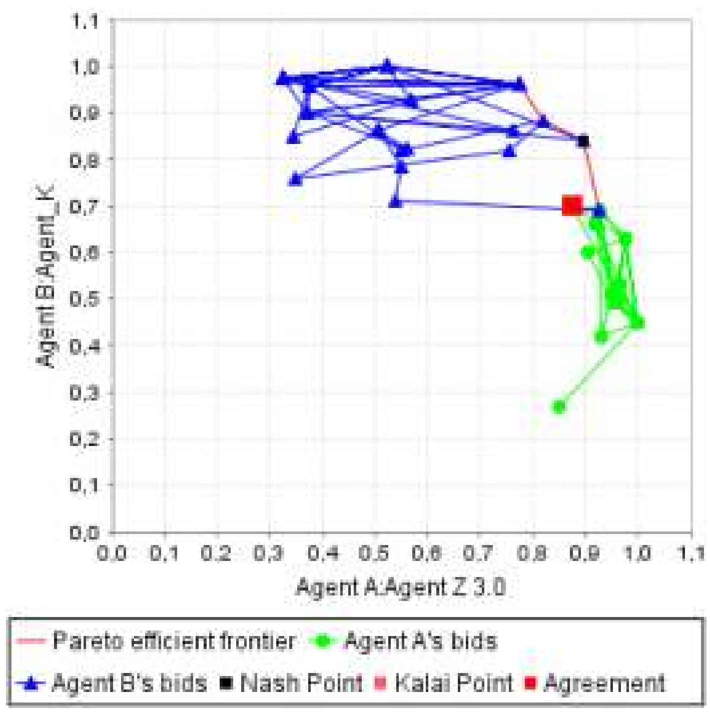

Figure 101 : Agent Z3.0 vs Agent K – Grocery Domain

Table 55 : Agent Z3.0 vs Agent K – Grocery Domain

Agent	Agent Z 3.0	Agent K		Agent K	Agent Z 3.0
Average time of agreement	0.701111	0.701111		0.822458	0.822458
Std time of agreement	0.111826	0.111826		0.016384	0.016384
Average time of end of negotiation	0.701111	0.701111		0.822458	0.822458
Std time of end of negotiation	0.111826	0.111826		0.016384	0.016384
Average rounds	254.9	254.9		299.2	299.2
Std rounds	40.70613	40.70613		5.6921	5.6921
Percentage of agreement	100	100		100	100
Average utility	0.803	0.886		0.8385	0.8625
Std utility	0.054681	0.110348		0.031715	0.043732
Average utility of agreements	0.803	0.886		0.8385	0.8625
Average discounted utility	0.689486	0.763384		0.701977	0.721947
Std discounted utility	0.035521	0.109777		0.02891	0.035706
Average discounted utility of agreements	0.689486	0.763384		0.701977	0.721947
Average nash distance	0.153592	0.153592		0.071074	0.071074
Average nash distance of agreements	0.153592	0.153592		0.071074	0.071074
Average pareto distance	0.013584	0.013584		0.00922	0.00922
Average pareto distance of agreements	0.013584	0.013584		0.00922	0.00922
Average kalai distance	0.153592	0.153592		0.071074	0.071074
Average kalai distance of agreements	0.153592	0.153592		0.071074	0.071074
Average social welfare	1.689	1.689		1.701	1.701
Average social welfare of agreements	1.689	1.689		1.701	1.701
Average exploration	0.021188	0.007875		0.016688	0.022938
Average joint exploration	0.028625	0.028625		0.036375	0.036375
Perc pareto bids	0.529208	0.673711		0.684121	0.576036
Average unfortunate moves	0.221919	0.196127		0.080959	0.20959
Average fortunate moves	0.084996	0.201161		0.088337	0.066147
Average nice moves	0.001087	0		0.001357	0
Average selfish moves	0.239974	0.071315		0.248342	0.232767
Average concession moves	0.31419	0.071196		0.266981	0.263197
Average silent moves	0.137834	0.460201		0.314023	0.228298

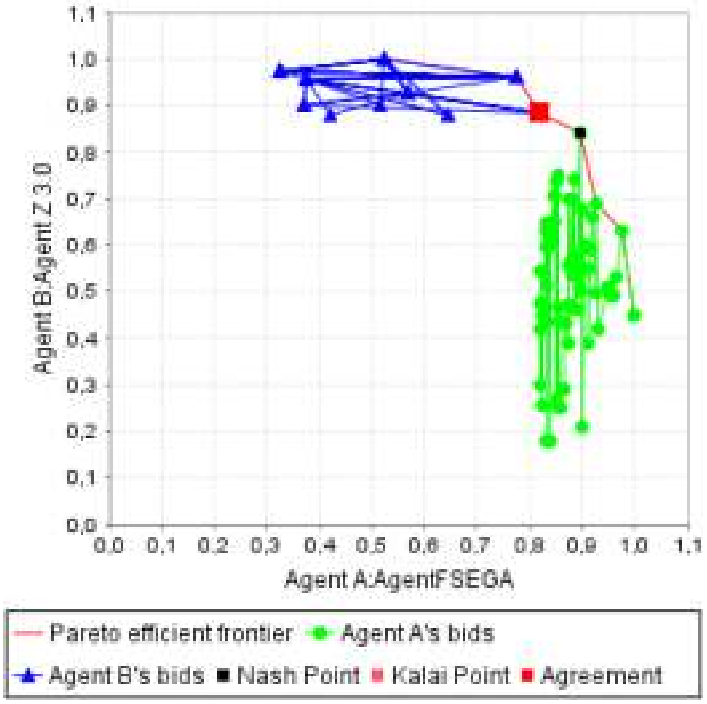

Figure 102 : FSEGA vs Agent Z3.0 – Grocery Domain

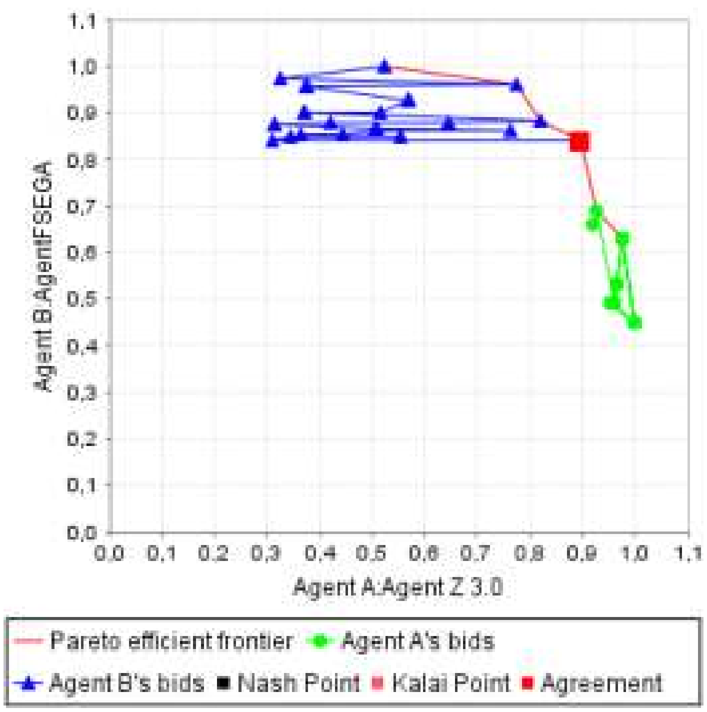

Figure 103 : Agent Z3.0 vs FSEGA – Grocery Domain

Table 56 : Agent Z3.0 vs FSEGA – Grocery Domain

Agent	Agent Z 3.0	FSEGA		FSEGA	Agent Z 3.0
Average time of agreement	0.528856	0.528856		0.40383	0.40383
Std time of agreement	0.116957	0.116957		0.120832	0.120832
Average time of end of negotiation	0.528856	0.528856		0.40383	0.40383
Std time of end of negotiation	0.116957	0.116957		0.120832	0.120832
Average rounds	184.2	184.2		136.2	136.2
Std rounds	42.26057	42.26057		44.77301	44.77301
Percentage of agreement	100	100		100	100
Average utility	0.6895	0.7395		0.8135	0.8785
Std utility	0.186465	0.042259		0.014916	0.052496
Average utility of agreements	0.6895	0.7395		0.8135	0.8785
Average discounted utility	0.615017	0.660365		0.746008	0.805148
Std discounted utility	0.167827	0.051996		0.031758	0.048768
Average discounted utility of agreements	0.615017	0.660365		0.746008	0.805148
Average nash distance	0.243641	0.243641		0.100377	0.100377
Average nash distance of agreements	0.243641	0.243641		0.100377	0.100377
Average pareto distance	0.169749	0.169749		0.013435	0.013435
Average pareto distance of agreements	0.169749	0.169749		0.013435	0.013435
Average kalai distance	0.243641	0.243641		0.100377	0.100377
Average kalai distance of agreements	0.243641	0.243641		0.100377	0.100377
Average social welfare	1.429	1.429		1.692	1.692
Average social welfare of agreements	1.429	1.429		1.692	1.692
Average exploration	0.016188	0.044938		0.0395	0.015313
Average joint exploration	0.061125	0.061125		0.052313	0.052313
Perc pareto bids	0.444448	0.061018		0.081417	0.447468
Average unfortunate moves	0.305855	0.384546		0.479778	0.331593
Average fortunate moves	0.061706	0		0	0.088129
Average nice moves	0	0.187252		0.257624	0
Average selfish moves	0.233462	0		0	0.213214
Average concession moves	0.364334	0.190433		0.182608	0.338376
Average silent moves	0.034643	0.23777		0.07999	0.028689

Appendix G : Amsterdam Party Domain – Agent Z1.0

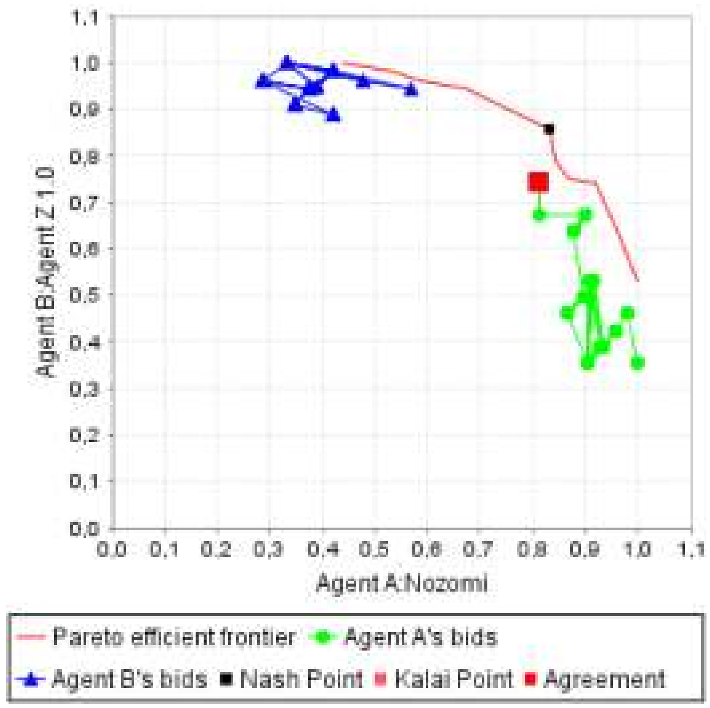

Figure 104 : Nozomi vs Agent Z1.0 - Amsterdam Party Domain

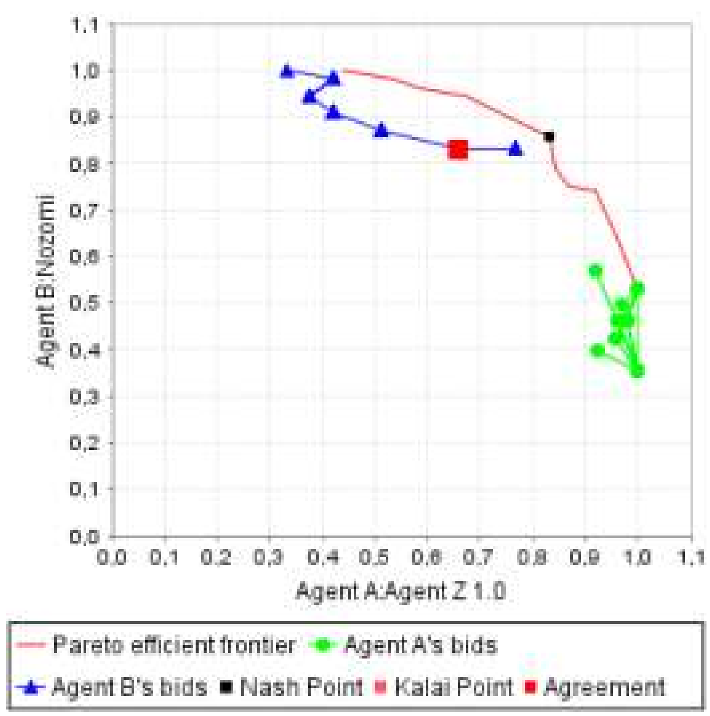

Figure 105 : Agent Z1.0 vs Nozomi - Amsterdam Party Domain

Table 57 : Agent Z1.0 vs Nozomi - Amsterdam Party Domain

Agent	Agent Z 1.0	Nozomi		Nozomi	Agent Z 1.0
Average time of agreement	0.992598	0.992598		0.986674	0.986674
Std time of agreement	0.000649	0.000649		0.015147	0.015147
Average time of end of negotiation	0.992598	0.992598		0.986674	0.986674
Std time of end of negotiation	0.000649	0.000649		0.015147	0.015147
Average rounds	393.8	393.8		391.1	391.1
Std rounds	0.632456	0.632456		6.806043	6.806043
Percentage of agreement	100	100		100	100
Average utility	0.665333	0.837667		0.813	0.763583
Std utility	0.088142	0.026013		0.059259	0.08086
Average utility of agreements	0.665333	0.837667		0.813	0.763583
Average discounted utility	0.665333	0.837667		0.813	0.763583
Std discounted utility	0.088142	0.026013		0.059259	0.08086
Average discounted utility of agreements	0.665333	0.837667		0.813	0.763583
Average nash distance	0.174644	0.174644		0.122528	0.122528
Average nash distance of agreements	0.174644	0.174644		0.122528	0.122528
Average pareto distance	0.093634	0.093634		0.043451	0.043451
Average pareto distance of agreements	0.093634	0.093634		0.043451	0.043451
Average kalai distance	0.174644	0.174644		0.122528	0.122528
Average kalai distance of agreements	0.174644	0.174644		0.122528	0.122528
Average social welfare	1.503	1.503		1.576583	1.576583
Average social welfare of agreements	1.503	1.503		1.576583	1.576583
Average exploration	0.005093	0.002679		0.005787	0.005787
Average joint exploration	0.007771	0.007771		0.011376	0.011376
Perc pareto bids	0.04013	0.003046		0.006566	0.086651
Average unfortunate moves	0.025531	0.016852		0.118839	0.026227
Average fortunate moves	0.021444	0.004087		0.127454	0.013381
Average nice moves	0.002043	0.010722		0.00102	0.003074
Average selfish moves	0.041855	0.002551		0.023821	0.063345
Average concession moves	0.046447	0.021949		0.035545	0.069067
Average silent moves	0.862679	0.943838		0.693321	0.824905

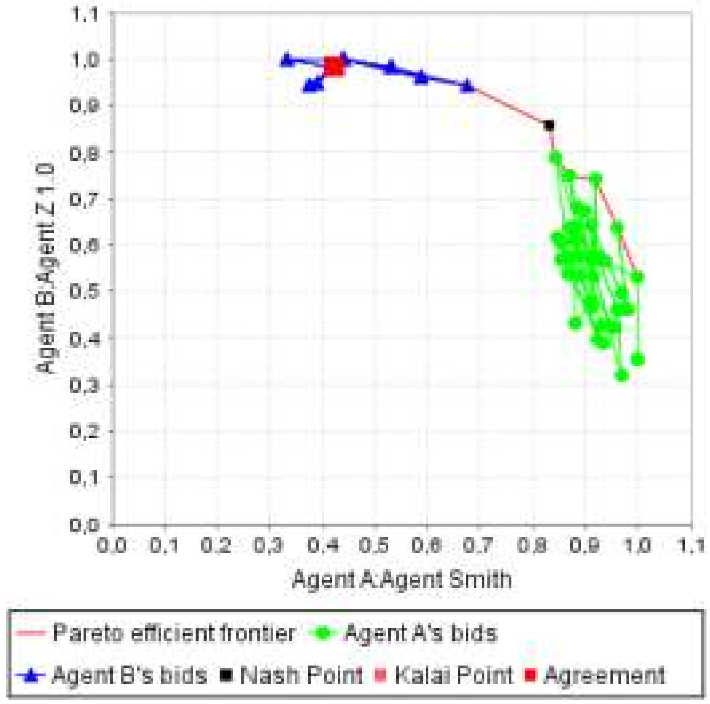

Figure 106 : Agent Smith vs Agent Z1.0 - Amsterdam Party Domain

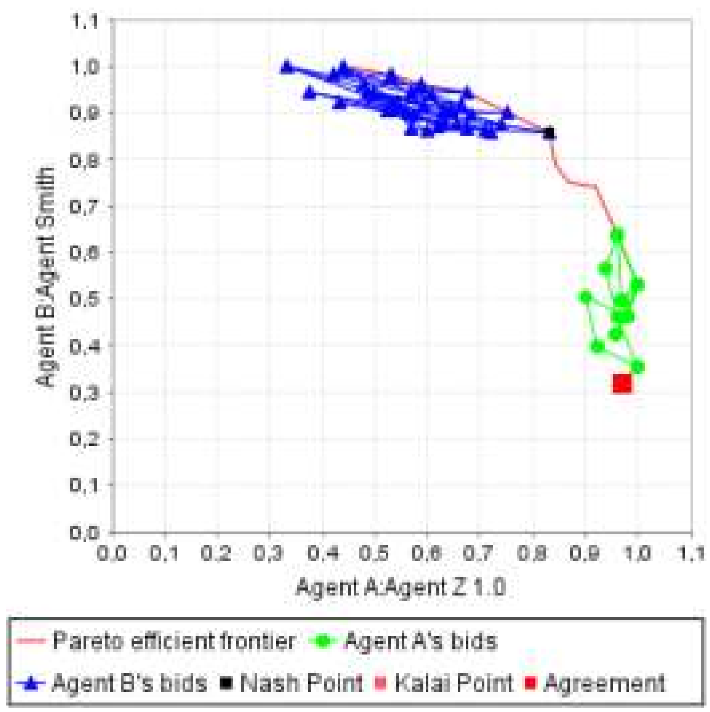

Figure 107 : Agent Z1.0 vs Agent Smith - Amsterdam Party Domain

Table 58 : Agent Z1.0 vs Agent Smith - Amsterdam Party Domain

Agent	Agent Z 1.0	Agent Smith		Agent Smith	Agent Z 1.0
Average time of agreement	0.625874	0.625874		0.621409	0.621409
Std time of agreement	0.003891	0.003891		0.006281	0.006281
Average time of end of negotiation	0.625874	0.625874		0.621409	0.621409
Std time of end of negotiation	0.003891	0.003891		0.006281	0.006281
Average rounds	82.6	82.6		84.4	84.4
Std rounds	0.843274	0.843274		1.577621	1.577621
Percentage of agreement	100	100		100	100
Average utility	0.98	0.502333		0.489167	0.98425
Std utility	0.017638	0.108398		0.047449	0.015323
Average utility of agreements	0.98	0.502333		0.489167	0.98425
Average discounted utility	0.98	0.502333		0.489167	0.98425
Std discounted utility	0.017638	0.108398		0.047449	0.015323
Average discounted utility of agreements	0.98	0.502333		0.489167	0.98425
Average nash distance	0.386143	0.386143		0.364563	0.364563
Average nash distance of agreements	0.386143	0.386143		0.364563	0.364563
Average pareto distance	0.051646	0.051646		0.007144	0.007144
Average pareto distance of agreements	0.051646	0.051646		0.007144	0.007144
Average kalai distance	0.386143	0.386143		0.364563	0.364563
Average kalai distance of agreements	0.386143	0.386143		0.364563	0.364563
Average social welfare	1.482333	1.482333		1.473417	1.473417
Average social welfare of agreements	1.482333	1.482333		1.473417	1.473417
Average exploration	0.003571	0.011276		0.012037	0.003373
Average joint exploration	0.01498	0.01498		0.015377	0.015377
Perc pareto bids	0.504239	0.115244		0.123071	0.629926
Average unfortunate moves	0.102927	0.116026		0.124253	0.048324
Average fortunate moves	0.080732	0.055128		0.06563	0.028983
Average nice moves	0.007439	0.062885		0.084874	0.012143
Average selfish moves	0.098232	0.31391		0.293452	0.138599
Average concession moves	0.105427	0.346667		0.315337	0.160149
Average silent moves	0.605244	0.105385		0.116454	0.611801

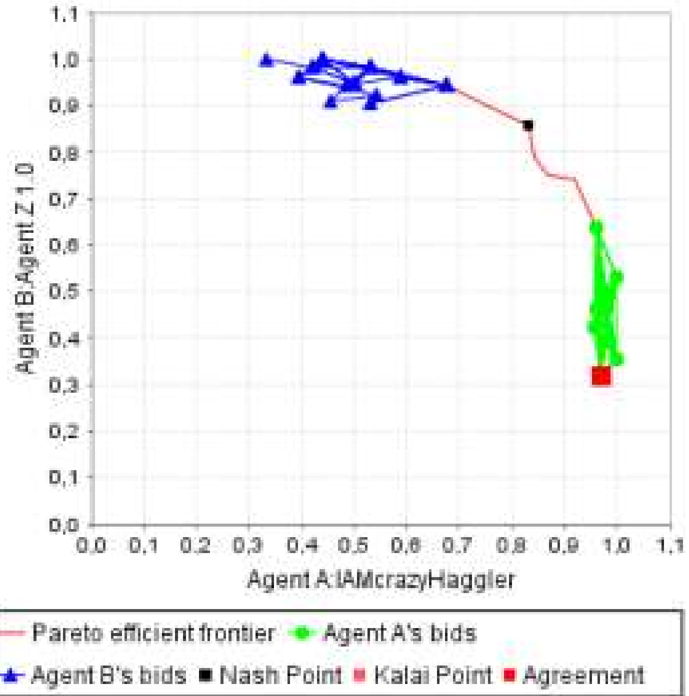

Figure 108 : IAMcrazyHaggler vs Agent Z1.0 - Amsterdam Party Domain

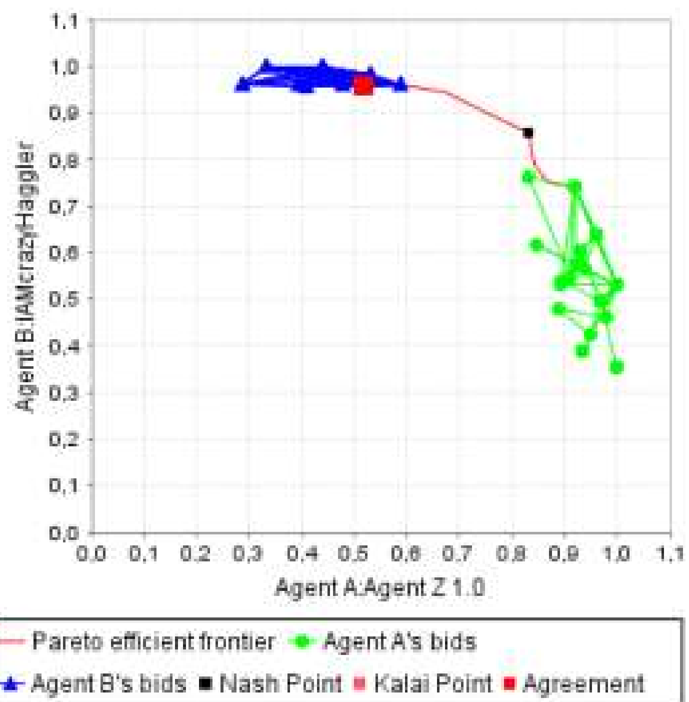

Figure 109 : Agent Z1.0 vs IAMcrazyHaggler - Amsterdam Party Domain

Table 59 : Agent Z1.0 vs IAMcrazyHaggler - Amsterdam Party Domain

Agent	Agent Z 1.0	IAMcrazyHag		IAMcrazyHag	Agent Z 1.0
Average time of agreement	0.992379	0.992379		0.993376	0.993376
Std time of agreement	0.002031	0.002031		0.001495	0.001495
Average time of end of negotiation	0.992379	0.992379		0.993376	0.993376
Std time of end of negotiation	0.002031	0.002031		0.001495	0.001495
Average rounds	389	389		389	389
Std rounds	1.054093	1.054093		0.942809	0.942809
Percentage of agreement	100	100		100	100
Average utility	0.437	0.97575		0.979	0.4465
Std utility	0.088254	0.019355		0.018529	0.076074
Average utility of agreements	0.437	0.97575		0.979	0.4465
Average discounted utility	0.437	0.97575		0.979	0.4465
Std discounted utility	0.088254	0.019355		0.018529	0.076074
Average discounted utility of agreements	0.437	0.97575		0.979	0.4465
Average nash distance	0.411568	0.411568		0.436588	0.436588
Average nash distance of agreements	0.411568	0.411568		0.436588	0.436588
Average pareto distance	0.042869	0.042869		0.089187	0.089187
Average pareto distance of agreements	0.042869	0.042869		0.089187	0.089187
Average kalai distance	0.411568	0.411568		0.436588	0.436588
Average kalai distance of agreements	0.411568	0.411568		0.436588	0.436588
Average social welfare	1.41275	1.41275		1.4255	1.4255
Average social welfare of agreements	1.41275	1.41275		1.4255	1.4255
Average exploration	0.008598	0.016733		0.009921	0.007242
Average joint exploration	0.022685	0.022685		0.016964	0.016964
Perc pareto bids	0.570724	0.298202		0.247691	0.72477
Average unfortunate moves	0.056835	0.220146		0.23606	0.040409
Average fortunate moves	0.050118	0.167435		0.180937	0.027456
Average nice moves	0.003611	0.050644		0.0505	0.007254
Average selfish moves	0.071326	0.230501		0.202074	0.079275
Average concession moves	0.084771	0.237728		0.203118	0.088612
Average silent moves	0.73334	0.093547		0.127312	0.756994

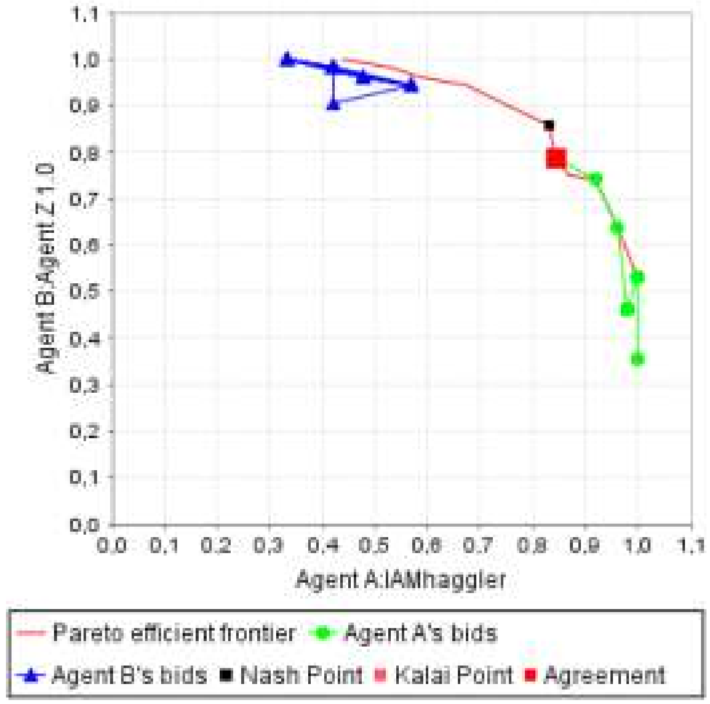

Figure 110 : IAMhaggler vs Agent Z1.0 - Amsterdam Party Domain

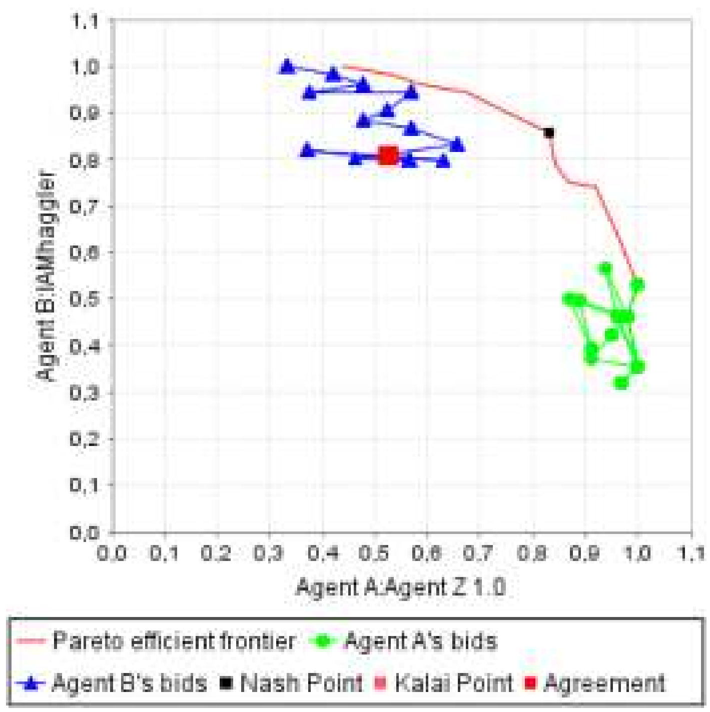

Figure 111 : Agent Z1.0 vs IAMhaggler - Amsterdam Party Domain

Table 60 : Agent Z1.0 vs IAMhaggler - Amsterdam Party Domain

Agent	Agent Z 1.0	IAMhaggler		IAMhaggler	Agent Z 1.0
Average time of agreement	0.993275	0.993275		0.992753	0.992753
Std time of agreement	0.001862	0.001862		0.001671	0.001671
Average time of end of negotiation	0.993275	0.993275		0.992753	0.992753
Std time of end of negotiation	0.001862	0.001862		0.001671	0.001671
Average rounds	304.2	304.2		303.6	303.6
Std rounds	3.938415	3.938415		3.533962	3.533962
Percentage of agreement	100	100		100	100
Average utility	0.617	0.78575		0.819667	0.58325
Std utility	0.187754	0.043161		0.038856	0.172425
Average utility of agreements	0.617	0.78575		0.819667	0.58325
Average discounted utility	0.617	0.78575		0.819667	0.58325
Std discounted utility	0.187754	0.043161		0.038856	0.172425
Average discounted utility of agreements	0.617	0.78575		0.819667	0.58325
Average nash distance	0.266831	0.266831		0.277315	0.277315
Average nash distance of agreements	0.266831	0.266831		0.277315	0.277315
Average pareto distance	0.138376	0.138376		0.137427	0.137427
Average pareto distance of agreements	0.138376	0.138376		0.137427	0.137427
Average kalai distance	0.266831	0.266831		0.277315	0.277315
Average kalai distance of agreements	0.266831	0.266831		0.277315	0.277315
Average social welfare	1.40275	1.40275		1.402917	1.402917
Average social welfare of agreements	1.40275	1.40275		1.402917	1.402917
Average exploration	0.005721	0.003241		0.001984	0.004497
Average joint exploration	0.008962	0.008962		0.006085	0.006085
Perc pareto bids	0.03813	0.001303		0.225193	0.054891
Average unfortunate moves	0.02986	0.015991		0.014514	0.02134
Average fortunate moves	0.025881	0.00137		0.003952	0.011997
Average nice moves	0.001339	0		0.00661	0.001351
Average selfish moves	0.042302	0.006628		0.001325	0.052505
Average concession moves	0.0535	0.04049		0.013878	0.061172
Average silent moves	0.847118	0.935521		0.959721	0.851634

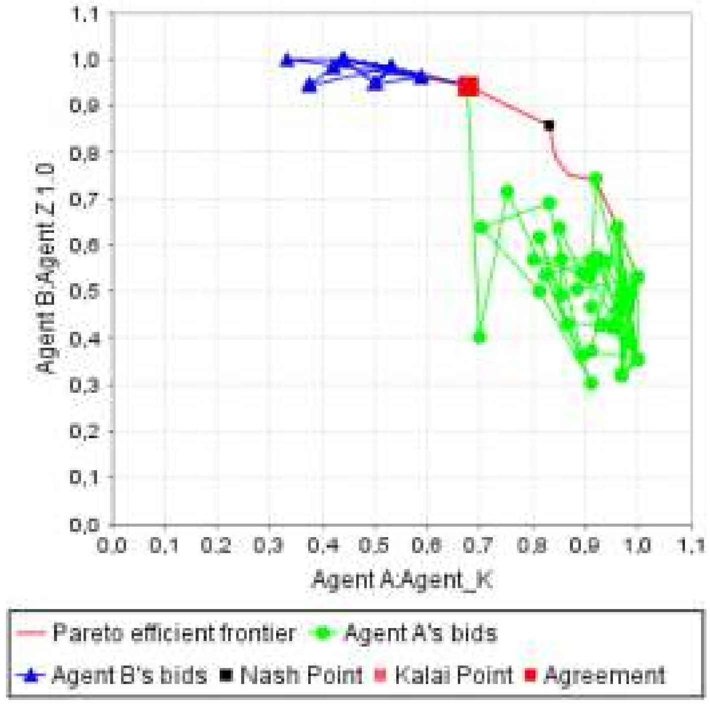

Figure 112 : Agent K vs Agent Z1.0 - Amsterdam Party Domain

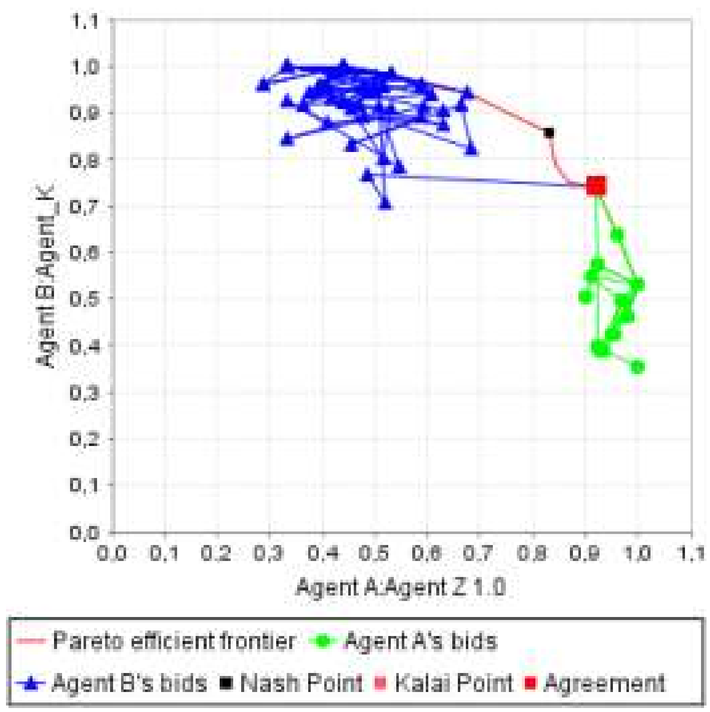

Figure 113 : Agent Z1.0 vs Agent K - Amsterdam Party Domain

Table 61 : Agent Z1.0 vs Agent K - Amsterdam Party Domain

Agent	Agent Z 1.0	Agent_K		Agent_K	Agent Z 1.0
Average time of agreement	0.89247	0.89247		0.892148	0.892148
Std time of agreement	0.058646	0.058646		0.070219	0.070219
Average time of end of negotiation	0.89247	0.89247		0.892148	0.892148
Std time of end of negotiation	0.058646	0.058646		0.070219	0.070219
Average rounds	347	347		347.4	347.4
Std rounds	23.17086	23.17086		27.75768	27.75768
Percentage of agreement	100	100		100	100
Average utility	0.892	0.707667		0.699833	0.91475
Std utility	0.132061	0.050284		0.034359	0.041689
Average utility of agreements	0.892	0.707667		0.699833	0.91475
Average discounted utility	0.892	0.707667		0.699833	0.91475
Std discounted utility	0.132061	0.050284		0.034359	0.041689
Average discounted utility of agreements	0.892	0.707667		0.699833	0.91475
Average nash distance	0.197291	0.197291		0.14673	0.14673
Average nash distance of agreements	0.197291	0.197291		0.14673	0.14673
Average pareto distance	0.026196	0.026196		0.012877	0.012877
Average pareto distance of agreements	0.026196	0.026196		0.012877	0.012877
Average kalai distance	0.197291	0.197291		0.14673	0.14673
Average kalai distance of agreements	0.197291	0.197291		0.14673	0.14673
Average social welfare	1.599667	1.599667		1.614583	1.614583
Average social welfare of agreements	1.599667	1.599667		1.614583	1.614583
Average exploration	0.00582	0.020899		0.019345	0.005952
Average joint exploration	0.026422	0.026422		0.025661	0.025661
Perc pareto bids	0.509818	0.374043		0.292942	0.717382
Average unfortunate moves	0.055038	0.208704		0.233296	0.033197
Average fortunate moves	0.052243	0.11518		0.145868	0.021425
Average nice moves	0.003999	0.084789		0.078411	0.008449
Average selfish moves	0.033842	0.193483		0.134078	0.081902
Average concession moves	0.039159	0.209595		0.182905	0.079412
Average silent moves	0.815719	0.18825		0.225442	0.775615

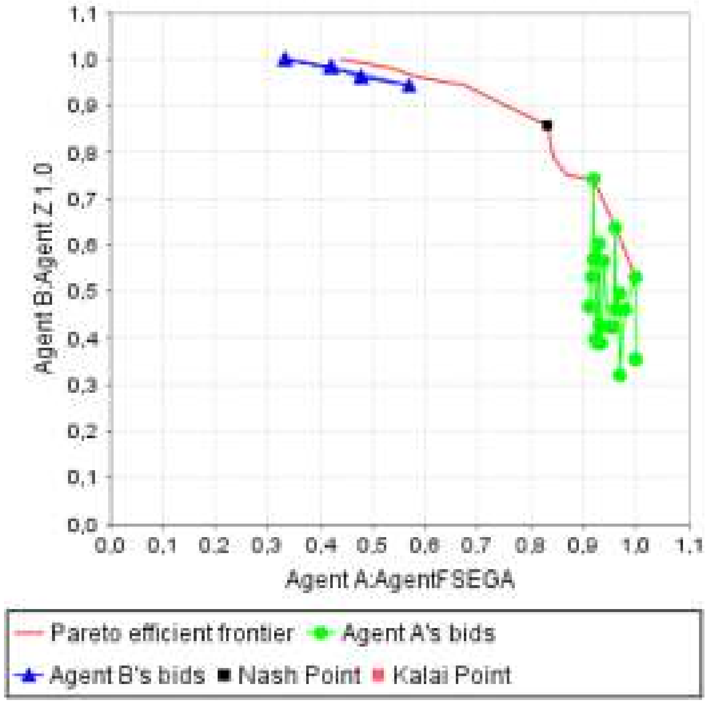

Figure 114 : FSEGA vs Agent Z1.0 - Amsterdam Party Domain

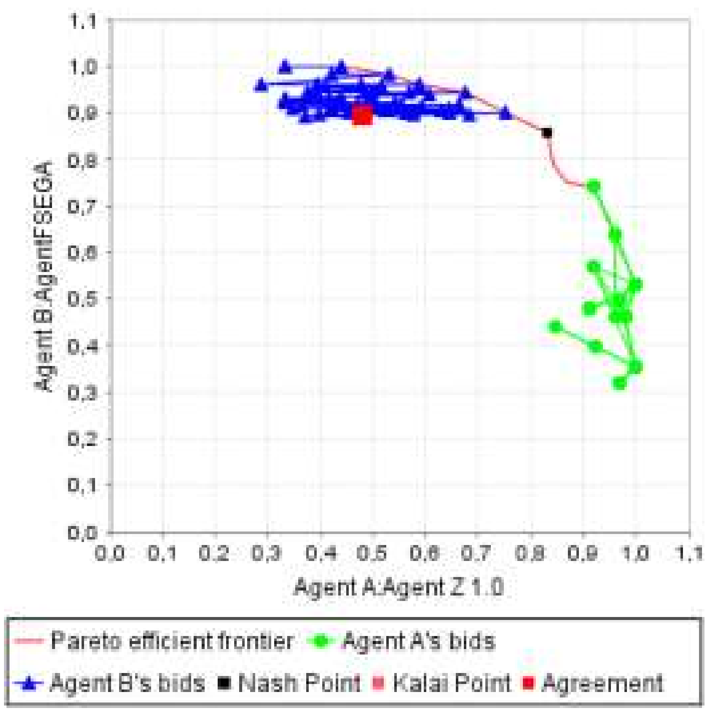

Figure 115 : Agent Z1.0 vs FSEGA - Amsterdam Party Domain

Table 62 : Agent Z1.0 vs FSEGA - Amsterdam Party Domain

Agent	Agent Z 1.0	AgentFSEGA		AgentFSEGA	Agent Z 1.0
Average time of agreement	0.993336	0.993336		0.994343	0.994343
Std time of agreement	0.001077	0.001077		NaN	NaN
Average time of end of negotiation	0.993336	0.993336		0.993775	0.993775
Std time of end of negotiation	0.001077	0.001077		0.002542	0.002542
Average rounds	115.8	115.8		50.7	50.7
Std rounds	6.425643	6.425643		11.95408	11.95408
Percentage of agreement	100	100		70	70
Average utility	0.492333	0.894		0.634833	0.30725
Std utility	0.164926	0.00254		0.438128	0.229775
Average utility of agreements	0.492333	0.894		0.906905	0.438929
Average discounted utility	0.492333	0.894		0.634833	0.30725
Std discounted utility	0.164926	0.00254		0.438128	0.229775
Average discounted utility of agreements	0.492333	0.894		0.906905	0.438929
Average nash distance	0.341022	0.341022		0.654915	0.654915
Average nash distance of agreements	0.341022	0.341022		0.424648	0.424648
Average pareto distance	0.100934	0.100934		0.429244	0.429244
Average pareto distance of agreements	0.100934	0.100934		0.144982	0.144982
Average kalai distance	0.341022	0.341022		0.654915	0.654915
Average kalai distance of agreements	0.341022	0.341022		0.424648	0.424648
Average social welfare	1.386333	1.386333		0.942083	0.942083
Average social welfare of agreements	1.386333	1.386333		1.345833	1.345833
Average exploration	0.006217	0.018816		0.008168	0.002381
Average joint exploration	0.025033	0.025033		0.010516	0.010516
Perc pareto bids	0.366067	0.086595		0.120976	0.374587
Average unfortunate moves	0.14185	0.421182		0.478367	0.031857
Average fortunate moves	0.107099	0		0	0.024974
Average nice moves	0.01735	0.471455		0.303983	0.020014
Average selfish moves	0.095187	0		0	0.094294
Average concession moves	0.119897	0.089738		0.175583	0.169906
Average silent moves	0.518617	0.017625		0.042067	0.658954

Appendix H : Amsterdam Party Domain – Agent Z2.0

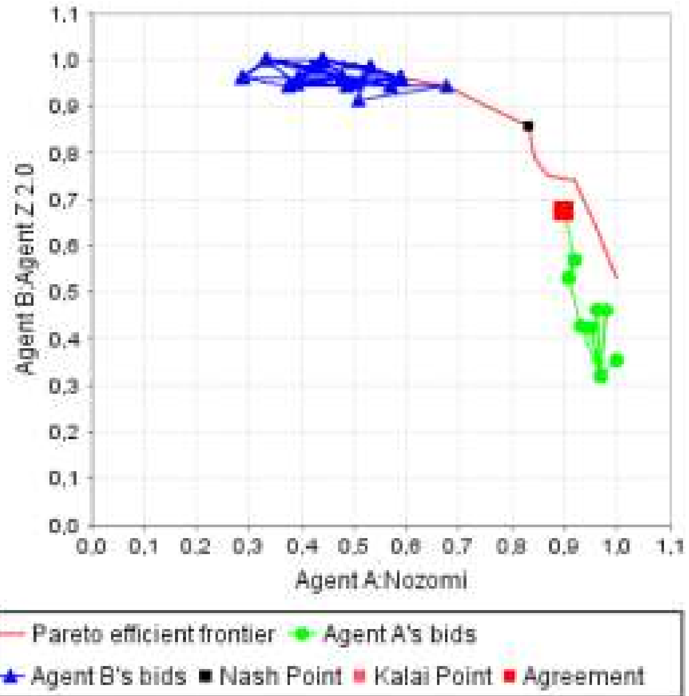

Figure 116 : Nozomi vs Agent Z2.0 - Amsterdam Party Domain

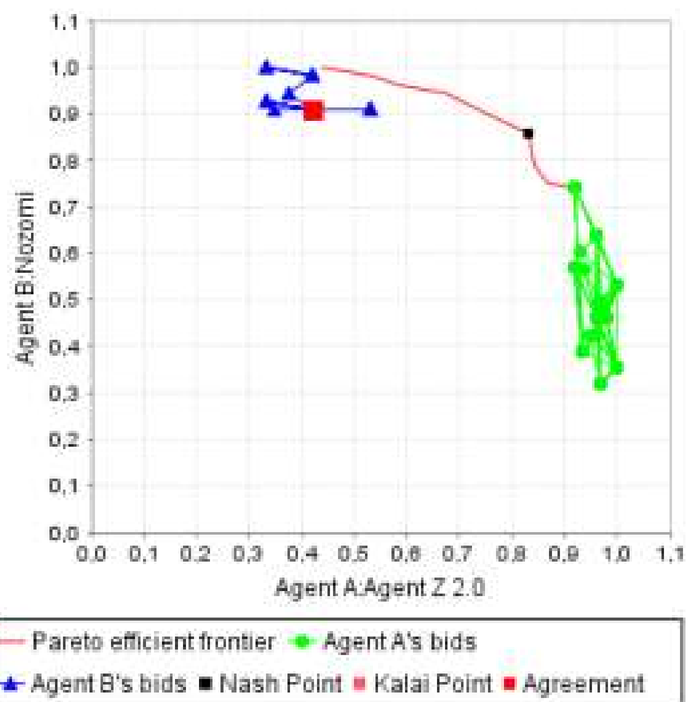

Figure 117 : Agent Z2.0 vs Nozomi - Amsterdam Party Domain

Table 63 : Agent Z2.0 vs Nozomi - Amsterdam Party Domain

Agent	Agent Z 2.0	Nozomi		Nozomi	Agent Z 2.0
Average time of agreement	0.993611	0.993611		0.993471	0.993471
Std time of agreement	0.001335	0.001335		0.001748	0.001748
Average time of end of negotiation	0.993611	0.993611		0.993471	0.993471
Std time of end of negotiation	0.001335	0.001335		0.001748	0.001748
Average rounds	342.7	342.7		345.4	345.4
Std rounds	2.311805	2.311805		3.533962	3.533962
Percentage of agreement	100	100		100	100
Average utility	0.477667	0.90925		0.902667	0.624333
Std utility	0.055434	0.005534		0.017091	0.050044
Average utility of agreements	0.477667	0.90925		0.902667	0.624333
Average discounted utility	0.477667	0.90925		0.902667	0.624333
Std discounted utility	0.055434	0.005534		0.017091	0.050044
Average discounted utility of agreements	0.477667	0.90925		0.902667	0.624333
Average nash distance	0.356452	0.356452		0.242943	0.242943
Average nash distance of agreements	0.356452	0.356452		0.242943	0.242943
Average pareto distance	0.08272	0.08272		0.07704	0.07704
Average pareto distance of agreements	0.08272	0.08272		0.07704	0.07704
Average kalai distance	0.356452	0.356452		0.242943	0.242943
Average kalai distance of agreements	0.356452	0.356452		0.242943	0.242943
Average social welfare	1.386917	1.386917		1.527	1.527
Average social welfare of agreements	1.386917	1.386917		1.527	1.527
Average exploration	0.020172	0.003571		0.003968	0.019643
Average joint exploration	0.02381	0.02381		0.021561	0.021561
Perc pareto bids	0.247897	0		0	0.385969
Average unfortunate moves	0.386746	0.066841		0.048116	0.289516
Average fortunate moves	0.121549	0.014053		0.039428	0.091042
Average nice moves	0.087984	0.058657		0	0.147092
Average selfish moves	0.193646	0.03585		0.052848	0.225353
Average concession moves	0.210075	0.041711		0.067969	0.246996
Average silent moves	0	0.782889		0.791639	0

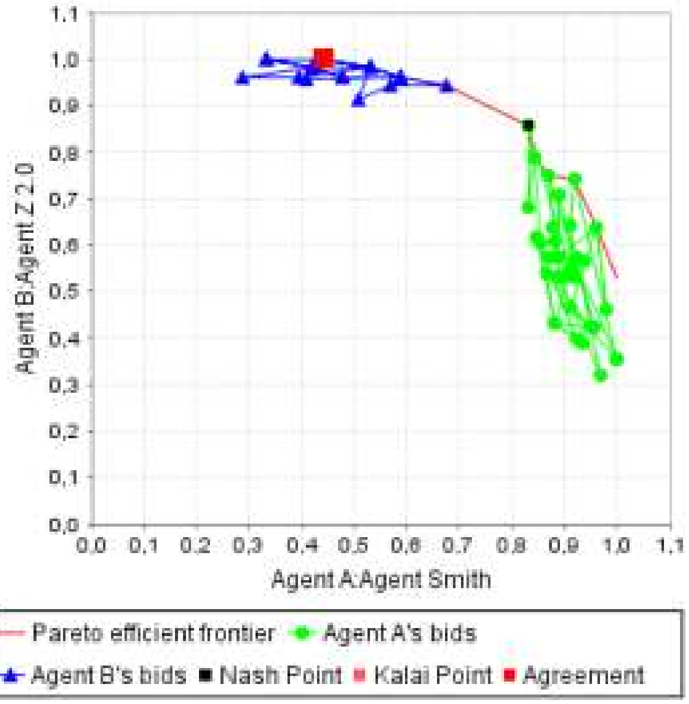

Figure 118 : Agent Smith vs Agent Z2.0 - Amsterdam Party Domain

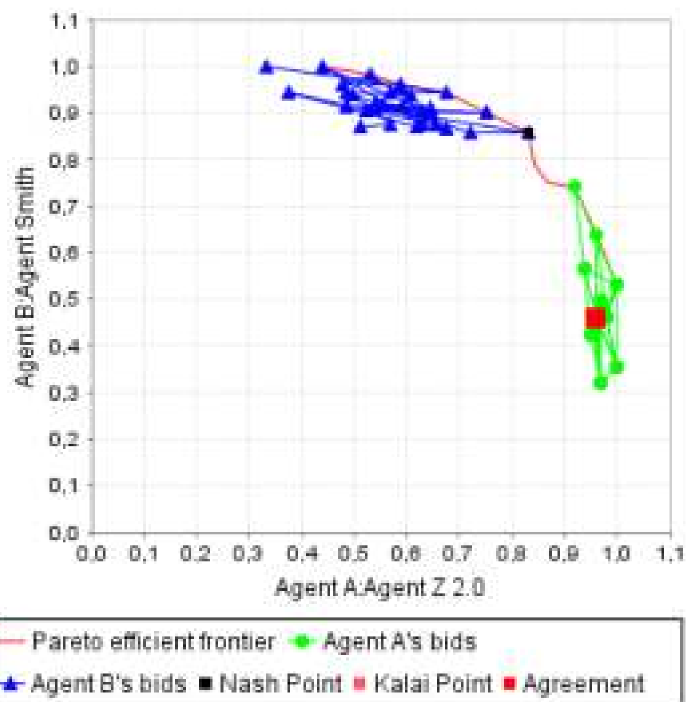

Figure 119 : Agent Z2.0 vs Agent Smith - Amsterdam Party Domain

Table 64 : Agent Z2.0 vs Agent Smith - Amsterdam Party Domain

Agent	Agent Z 2.0	Agent Smith		Agent Smith	Agent Z 2.0
Average time of agreement	0.62069	0.62069		0.620989	0.620989
Std time of agreement	0.008061	0.008061		0.005856	0.005856
Average time of end of negotiation	0.62069	0.62069		0.620989	0.620989
Std time of end of negotiation	0.008061	0.008061		0.005856	0.005856
Average rounds	71	71		81.4	81.4
Std rounds	1.632993	1.632993		1.074968	1.074968
Percentage of agreement	100	100		100	100
Average utility	0.963167	0.457333		0.489	0.972
Std utility	0.021132	0.065509		0.131996	0.023915
Average utility of agreements	0.963167	0.457333		0.489	0.972
Average discounted utility	0.963167	0.457333		0.489	0.972
Std discounted utility	0.021132	0.065509		0.131996	0.023915
Average discounted utility of agreements	0.963167	0.457333		0.489	0.972
Average nash distance	0.420903	0.420903		0.361668	0.361668
Average nash distance of agreements	0.420903	0.420903		0.361668	0.361668
Average pareto distance	0.090602	0.090602		0.033763	0.033763
Average pareto distance of agreements	0.090602	0.090602		0.033763	0.033763
Average kalai distance	0.420903	0.420903		0.361668	0.361668
Average kalai distance of agreements	0.420903	0.420903		0.361668	0.361668
Average social welfare	1.4205	1.4205		1.461	1.461
Average social welfare of agreements	1.4205	1.4205		1.461	1.461
Average exploration	0.007672	0.009458		0.011045	0.008664
Average joint exploration	0.017063	0.017063		0.018981	0.018981
Perc pareto bids	0.239076	0.159921		0.144472	0.430854
Average unfortunate moves	0.360098	0.140917		0.140471	0.282756
Average fortunate moves	0.120859	0.088197		0.067958	0.083205
Average nice moves	0.067969	0		0.017628	0.136538
Average selfish moves	0.145299	0.300158		0.316951	0.194487
Average concession moves	0.305775	0.346975		0.324336	0.303013
Average silent moves	0	0.123754		0.132656	0

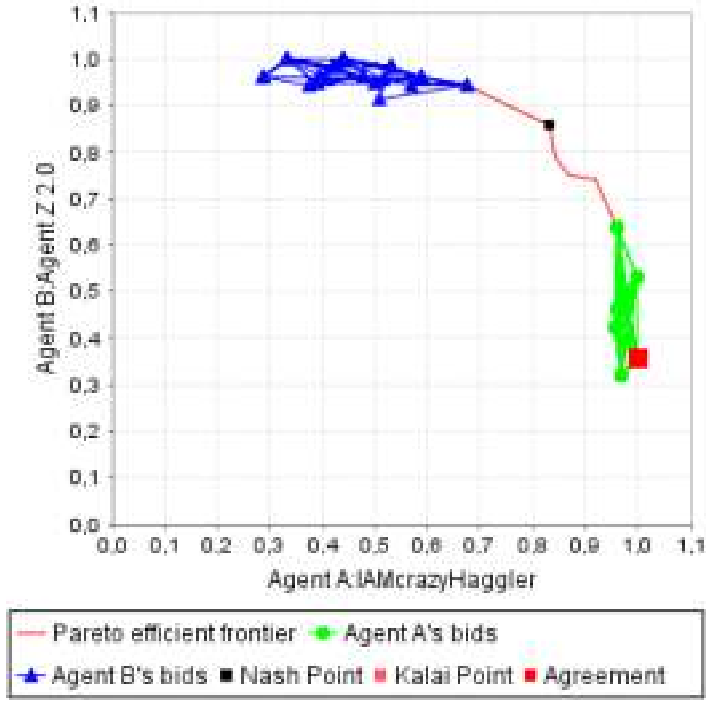

Figure 120 : IAMcrazyHaggler vs Agent Z2.0 - Amsterdam Party Domain

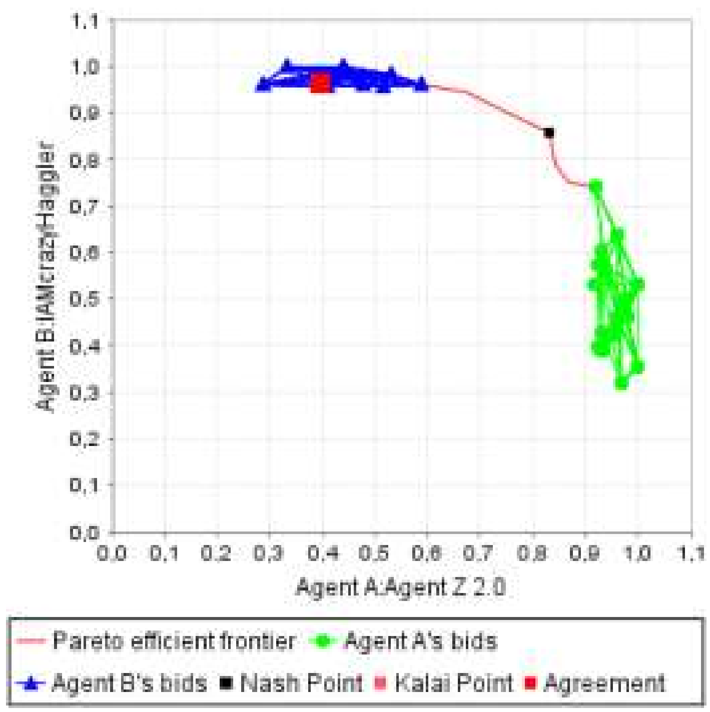

Figure 121 : Agent Z2.0 vs IAMcrazyHaggler - Amsterdam Party Domain

Table 65 : Agent Z2.0 vs IAMcrazyHaggler - Amsterdam Party Domain

Agent	Agent Z 2.0	IAMcrazyHag		IAMcrazyHag	Agent Z 2.0
Average time of agreement	0.992391	0.992391		0.993083	0.993083
Std time of agreement	0.001355	0.001355		0.001243	0.001243
Average time of end of negotiation	0.992391	0.992391		0.993083	0.993083
Std time of end of negotiation	0.001355	0.001355		0.001243	0.001243
Average rounds	338.2	338.2		339.6	339.6
Std rounds	3.457681	3.457681		2.319004	2.319004
Percentage of agreement	100	100		100	100
Average utility	0.461167	0.968667		0.9765	0.488333
Std utility	0.092169	0.014472		0.0174	0.07372
Average utility of agreements	0.461167	0.968667		0.9765	0.488333
Average discounted utility	0.461167	0.968667		0.9765	0.488333
Std discounted utility	0.092169	0.014472		0.0174	0.07372
Average discounted utility of agreements	0.461167	0.968667		0.9765	0.488333
Average nash distance	0.386704	0.386704		0.396671	0.396671
Average nash distance of agreements	0.386704	0.386704		0.396671	0.396671
Average pareto distance	0.040625	0.040625		0.057934	0.057934
Average pareto distance of agreements	0.040625	0.040625		0.057934	0.057934
Average kalai distance	0.386704	0.386704		0.396671	0.396671
Average kalai distance of agreements	0.386704	0.386704		0.396671	0.396671
Average social welfare	1.429833	1.429833		1.464833	1.464833
Average social welfare of agreements	1.429833	1.429833		1.464833	1.464833
Average exploration	0.023181	0.015642		0.009921	0.018816
Average joint exploration	0.038029	0.038029		0.026554	0.026554
Perc pareto bids	0.252004	0.310456		0.249067	0.430554
Average unfortunate moves	0.372432	0.204586		0.237401	0.276958
Average fortunate moves	0.16113	0.157603		0.18128	0.098704
Average nice moves	0.082679	0.046419		0.049041	0.124152
Average selfish moves	0.14573	0.248663		0.200871	0.218604
Average concession moves	0.238029	0.240276		0.203753	0.281581
Average silent moves	0	0.102452		0.127655	0

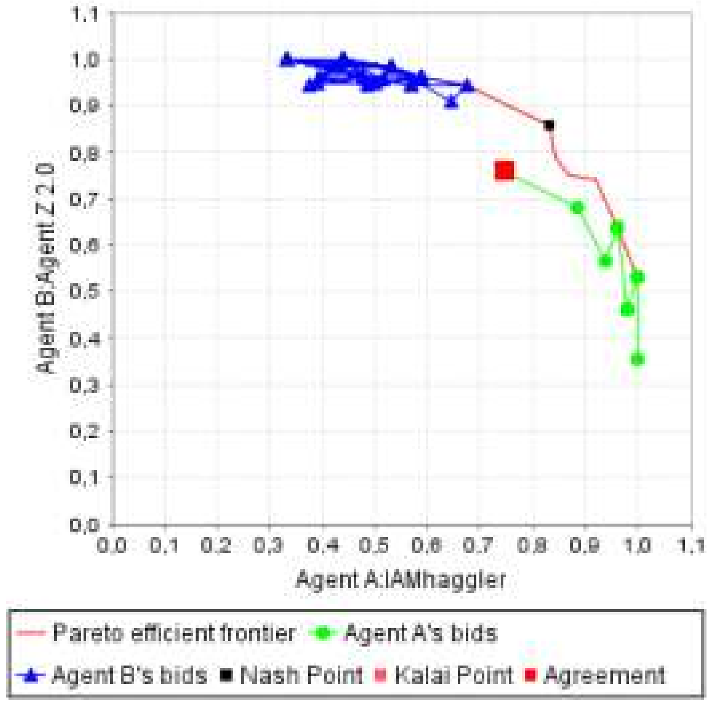

Figure 122 : IAMhaggler vs Agent Z2.0 - Amsterdam Party Domain

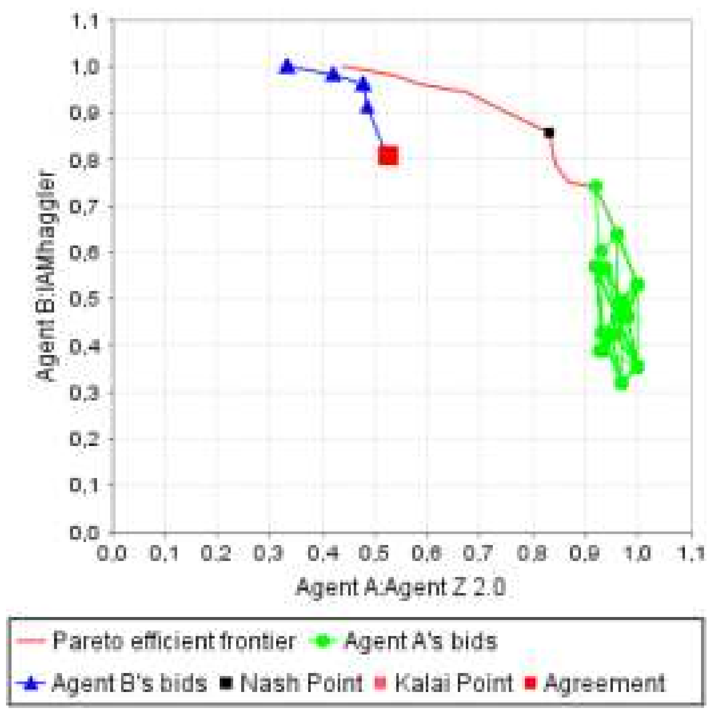

Figure 123 : Agent Z2.0 vs IAMhaggler - Amsterdam Party Domain

Table 66 : Agent Z2.0 vs IAMhaggler - Amsterdam Party Domain

Agent	Agent Z 2.0	IAMhaggler		IAMhaggler	Agent Z 2.0
Average time of agreement	0.856237	0.856237		0.994519	0.994519
Std time of agreement	0.186579	0.186579		0.002422	0.002422
Average time of end of negotiation	0.856237	0.856237		0.994519	0.994519
Std time of end of negotiation	0.186579	0.186579		0.002422	0.002422
Average rounds	233.2	233.2		273.6	273.6
Std rounds	54.36666	54.36666		3.405877	3.405877
Percentage of agreement	100	100		100	100
Average utility	0.798833	0.757167		0.778	0.70575
Std utility	0.163963	0.091958		0.043232	0.066105
Average utility of agreements	0.798833	0.757167		0.778	0.70575
Average discounted utility	0.798833	0.757167		0.778	0.70575
Std discounted utility	0.163963	0.091958		0.043232	0.066105
Average discounted utility of agreements	0.798833	0.757167		0.778	0.70575
Average nash distance	0.194347	0.194347		0.164642	0.164642
Average nash distance of agreements	0.194347	0.194347		0.164642	0.164642
Average pareto distance	0.049835	0.049835		0.104697	0.104697
Average pareto distance of agreements	0.049835	0.049835		0.104697	0.104697
Average kalai distance	0.194347	0.194347		0.164642	0.164642
Average kalai distance of agreements	0.194347	0.194347		0.164642	0.164642
Average social welfare	1.556	1.556		1.48375	1.48375
Average social welfare of agreements	1.556	1.556		1.48375	1.48375
Average exploration	0.017229	0.002679		0.002149	0.016997
Average joint exploration	0.019808	0.019808		0.016832	0.016832
Perc pareto bids	0.221799	0.005456		0.94974	0.451861
Average unfortunate moves	0.397544	0.013241		0.014676	0.257915
Average fortunate moves	0.146968	0		0	0.091591
Average nice moves	0.10914	0		0.007338	0.113224
Average selfish moves	0.175159	0.001099		0	0.227051
Average concession moves	0.17119	0.060035		0.018347	0.310219
Average silent moves	0	0.925625		0.959639	0

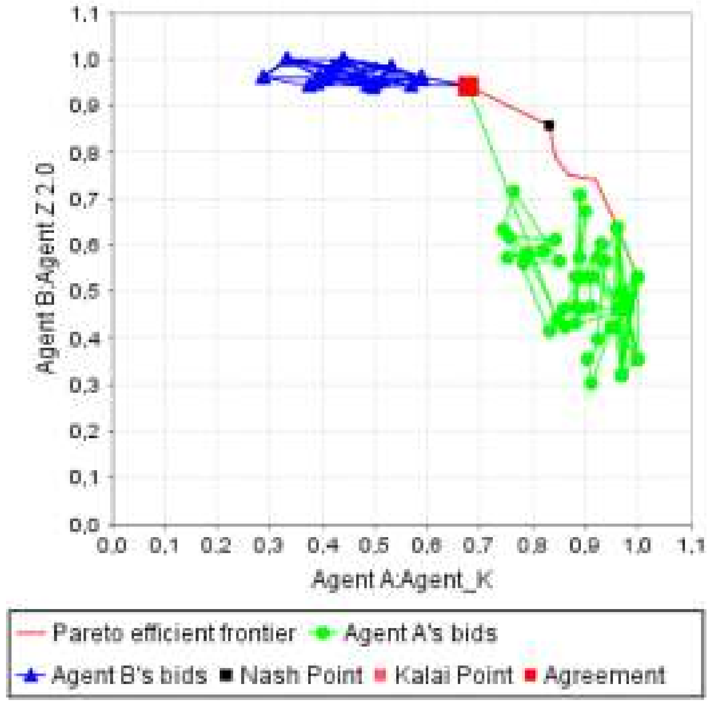

Figure 124 : Agent K vs Agent Z2.0 - Amsterdam Party Domain

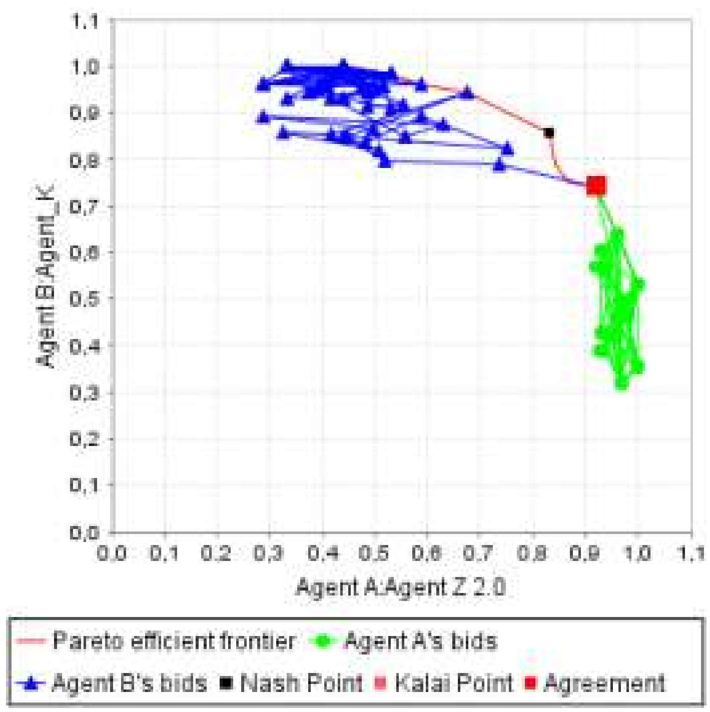

Figure 125 : Agent Z2.0 vs Agent K - Amsterdam Party Domain

Table 67 : Agent Z2.0 vs Agent K - Amsterdam Party Domain

Agent	Agent Z 2.0	Agent_K		Agent_K	Agent Z 2.0
Average time of agreement	0.843982	0.843982		0.856171	0.856171
Std time of agreement	0.012952	0.012952		0.047951	0.047951
Average time of end of negotiation	0.843982	0.843982		0.856171	0.856171
Std time of end of negotiation	0.012952	0.012952		0.047951	0.047951
Average rounds	287.2	287.2		291.8	291.8
Std rounds	4.91709	4.91709		15.97776	15.97776
Percentage of agreement	100	100		100	100
Average utility	0.928	0.722		0.679667	0.89925
Std utility	0.016865	0.044975		0.009487	0.136769
Average utility of agreements	0.928	0.722		0.679667	0.89925
Average discounted utility	0.928	0.722		0.679667	0.89925
Std discounted utility	0.016865	0.044975		0.009487	0.136769
Average discounted utility of agreements	0.928	0.722		0.679667	0.89925
Average nash distance	0.166221	0.166221		0.195235	0.195235
Average nash distance of agreements	0.166221	0.166221		0.195235	0.195235
Average pareto distance	0	0		0.028324	0.028324
Average pareto distance of agreements	0	0		0.028324	0.028324
Average kalai distance	0.166221	0.166221		0.195235	0.195235
Average kalai distance of agreements	0.166221	0.166221		0.195235	0.195235
Average social welfare	1.65	1.65		1.578917	1.578917
Average social welfare of agreements	1.65	1.65		1.578917	1.578917
Average exploration	0.020833	0.018221		0.018022	0.01918
Average joint exploration	0.038161	0.038161		0.036243	0.036243
Perc pareto bids	0.259042	0.370654		0.268439	0.402929
Average unfortunate moves	0.3764	0.218798		0.245425	0.284994
Average fortunate moves	0.154248	0.129183		0.146348	0.105081
Average nice moves	0.083178	0.081321		0.0869	0.115327
Average selfish moves	0.157008	0.180728		0.159986	0.210607
Average concession moves	0.229166	0.208105		0.176874	0.283991
Average silent moves	0	0.181865		0.184465	0

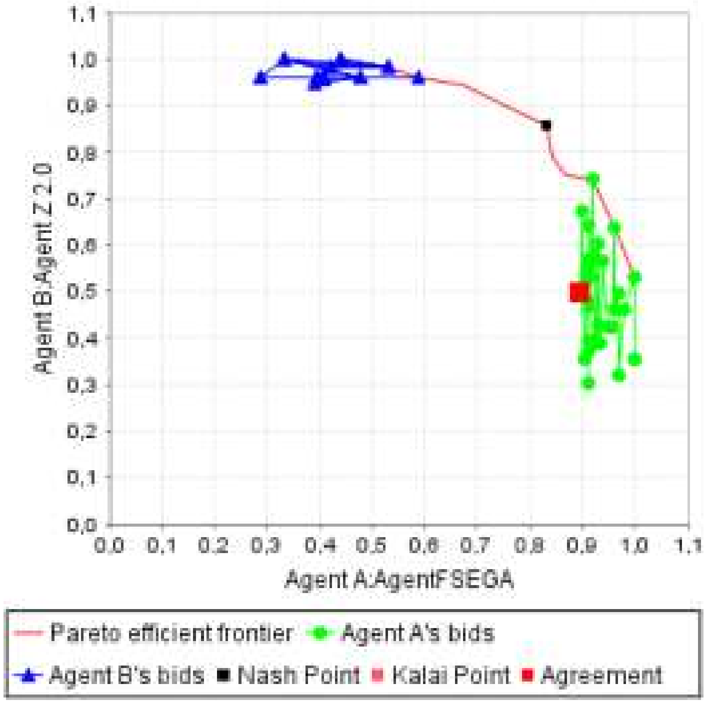

Figure 126 : FSEGA vs Agent Z2.0 - Amsterdam Party Domain

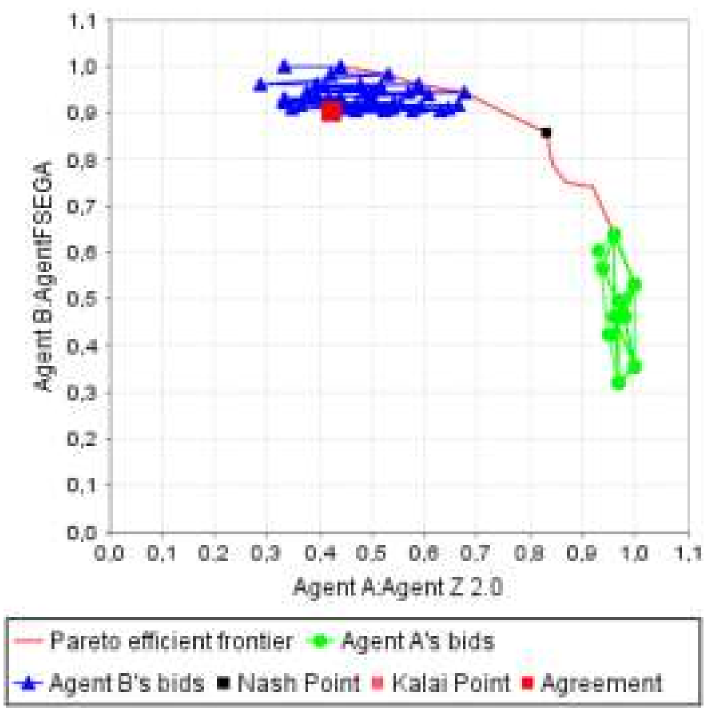

Figure 127 : Agent Z2.0 vs FSEGA - Amsterdam Party Domain

Table 68 : Agent Z2.0 vs FSEGA - Amsterdam Party Domain

Agent	Agent Z 2.0	AgentFSEGA		AgentFSEGA	Agent Z 2.0
Average time of agreement	0.992248	0.992248		0.994417	0.994417
Std time of agreement	0.001493	0.001493		NaN	NaN
Average time of end of negotiation	0.992248	0.992248		0.993057	0.993057
Std time of end of negotiation	0.001493	0.001493		0.003952	0.003952
Average rounds	79.2	79.2		48.8	48.8
Std rounds	25.4244	25.4244		7.480345	7.480345
Percentage of agreement	100	100		70	70
Average utility	0.482333	0.911083		0.644333	0.360833
Std utility	0.117812	0.012454		0.445576	0.258288
Average utility of agreements	0.482333	0.911083		0.920476	0.515476
Average discounted utility	0.482333	0.911083		0.644333	0.360833
Std discounted utility	0.117812	0.012454		0.445576	0.258288
Average discounted utility of agreements	0.482333	0.911083		0.920476	0.515476
Average nash distance	0.352737	0.352737		0.605609	0.605609
Average nash distance of agreements	0.352737	0.352737		0.354211	0.354211
Average pareto distance	0.078488	0.078488		0.390607	0.390607
Average pareto distance of agreements	0.078488	0.078488		0.089786	0.089786
Average kalai distance	0.352737	0.352737		0.605609	0.605609
Average kalai distance of agreements	0.352737	0.352737		0.354211	0.354211
Average social welfare	1.393417	1.393417		1.005167	1.005167
Average social welfare of agreements	1.393417	1.393417		1.435952	1.435952
Average exploration	0.008598	0.012765		0.007837	0.005919
Average joint exploration	0.021362	0.021362		0.013492	0.013492
Perc pareto bids	0.249691	0.116401		0.123842	0.41176
Average unfortunate moves	0.349292	0.403453		0.47418	0.300351
Average fortunate moves	0.144749	0		0	0.087031
Average nice moves	0.088365	0.47078		0.304114	0.137021
Average selfish moves	0.149072	0		0	0.199395
Average concession moves	0.268523	0.096155		0.178614	0.276202
Average silent moves	0	0.029612		0.043091	0

Appendix I : Amsterdam Party Domain – Agent Z3.0

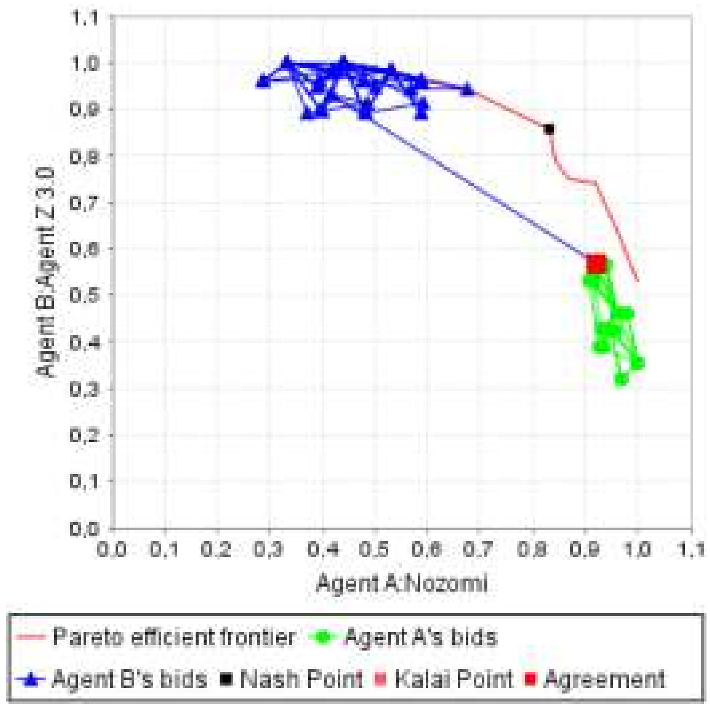

Figure 128 : Nozomi vs Agent Z3.0 - Amsterdam Party Domain

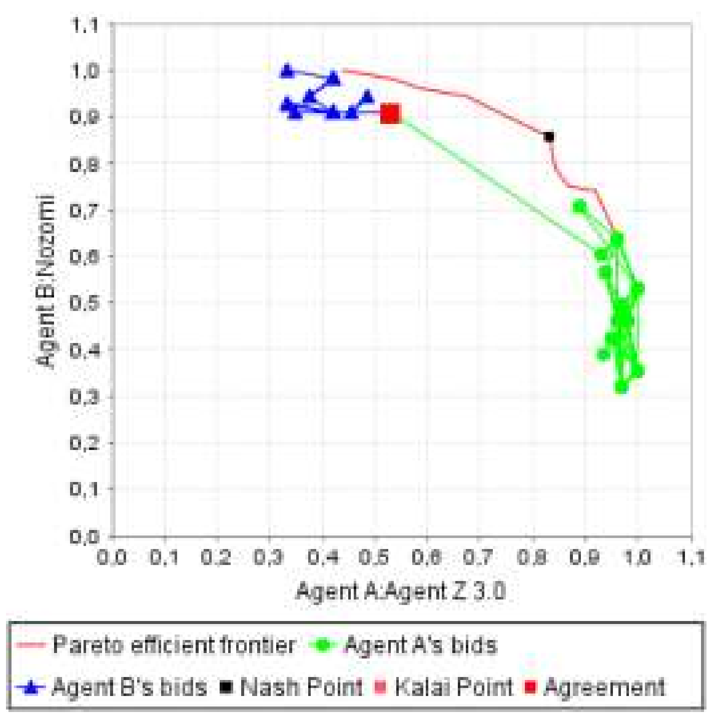

Figure 129 : Agent Z3.0 vs Nozomi - Amsterdam Party Domain

Table 69 : Agent Z3.0 vs Nozomi - Amsterdam Party Domain

Agent	Agent Z 3.0	Nozomi		Nozomi	Agent Z 3.0
Average time of agreement	0.960104	0.960104		0.990215	0.990215
Std time of agreement	0.043667	0.043667		0.007861	0.007861
Average time of end of negotiation	0.960104	0.960104		0.990215	0.990215
Std time of end of negotiation	0.043667	0.043667		0.007861	0.007861
Average rounds	331.4	331.4		342.6	342.6
Std rounds	16.24261	16.24261		4.812022	4.812022
Percentage of agreement	100	100		100	100
Average utility	0.627833	0.857		0.895833	0.670583
Std utility	0.135624	0.06572		0.024823	0.078373
Average utility of agreements	0.627833	0.857		0.895833	0.670583
Average discounted utility	0.627833	0.857		0.895833	0.670583
Std discounted utility	0.135624	0.06572		0.024823	0.078373
Average discounted utility of agreements	0.627833	0.857		0.895833	0.670583
Average nash distance	0.227096	0.227096		0.196663	0.196663
Average nash distance of agreements	0.227096	0.227096		0.196663	0.196663
Average pareto distance	0.068997	0.068997		0.066057	0.066057
Average pareto distance of agreements	0.068997	0.068997		0.066057	0.066057
Average kalai distance	0.227096	0.227096		0.196663	0.196663
Average kalai distance of agreements	0.227096	0.227096		0.196663	0.196663
Average social welfare	1.484833	1.484833		1.566417	1.566417
Average social welfare of agreements	1.484833	1.484833		1.566417	1.566417
Average exploration	0.013955	0.003638		0.004497	0.012765
Average joint exploration	0.01756	0.01756		0.015575	0.015575
Perc pareto bids	0.287476	0.004046		0	0.397924
Average unfortunate moves	0.269539	0.081575		0.073098	0.153334
Average fortunate moves	0.117862	0.049821		0.057219	0.044646
Average nice moves	0.060565	0.026713		0	0.094049
Average selfish moves	0.131773	0.032457		0.059987	0.115188
Average concession moves	0.12556	0.040619		0.068186	0.166288
Average silent moves	0.294702	0.768815		0.741509	0.426494

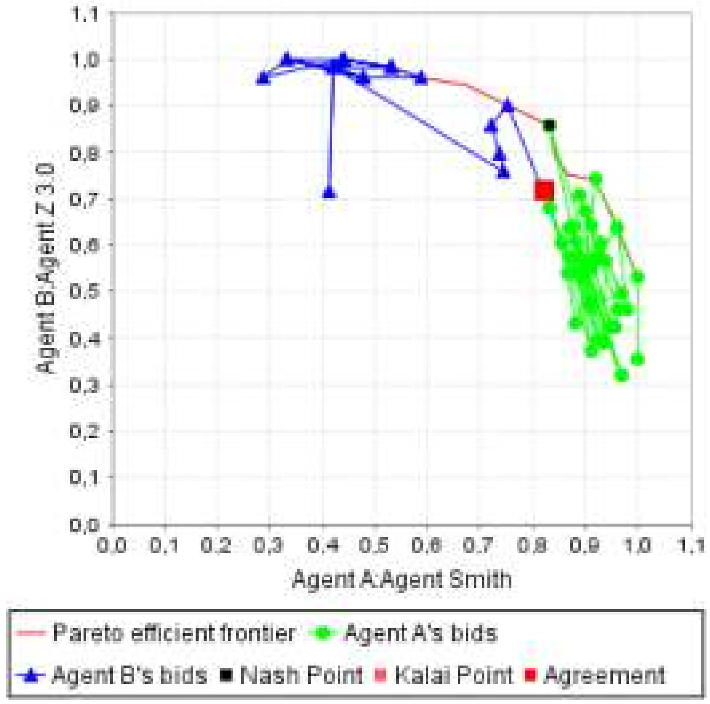

Figure 130 : Agent Smith vs Agent Z3.0 - Amsterdam Party Domain

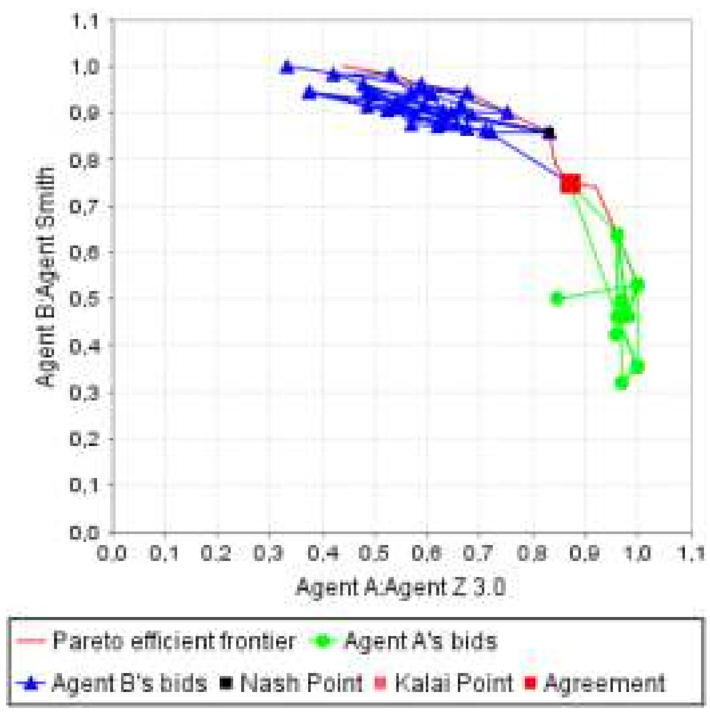

Figure 131 : Agent Z3.0 vs Agent Smith - Amsterdam Party Domain

Table 70 : Agent Z3.0 vs Agent Smith - Amsterdam Party Domain

Agent	Agent Z 3.0	Agent Smith		Agent Smith	Agent Z 3.0
Average time of agreement	0.61418	0.61418		0.606709	0.606709
Std time of agreement	0.028193	0.028193		0.036252	0.036252
Average time of end of negotiation	0.61418	0.61418		0.606709	0.606709
Std time of end of negotiation	0.028193	0.028193		0.036252	0.036252
Average rounds	69.4	69.4		78.6	78.6
Std rounds	3.596294	3.596294		4.141927	4.141927
Percentage of agreement	100	100		100	100
Average utility	0.938667	0.635833		0.558833	0.9035
Std utility	0.101886	0.139224		0.191431	0.145247
Average utility of agreements	0.938667	0.635833		0.558833	0.9035
Average discounted utility	0.938667	0.635833		0.558833	0.9035
Std discounted utility	0.101886	0.139224		0.191431	0.145247
Average discounted utility of agreements	0.938667	0.635833		0.558833	0.9035
Average nash distance	0.278134	0.278134		0.334439	0.334439
Average nash distance of agreements	0.278134	0.278134		0.334439	0.334439
Average pareto distance	0	0		0.025756	0.025756
Average pareto distance of agreements	0	0		0.025756	0.025756
Average kalai distance	0.278134	0.278134		0.334439	0.334439
Average kalai distance of agreements	0.278134	0.278134		0.334439	0.334439
Average social welfare	1.5745	1.5745		1.462333	1.462333
Average social welfare of agreements	1.5745	1.5745		1.462333	1.462333
Average exploration	0.006515	0.009226		0.01078	0.00625
Average joint exploration	0.015608	0.015608		0.016468	0.016468
Perc pareto bids	0.312216	0.159364		0.116433	0.486963
Average unfortunate moves	0.351345	0.111097		0.125574	0.214613
Average fortunate moves	0.163701	0.096855		0.067894	0.044188
Average nice moves	0.149947	0		0.018023	0.152327
Average selfish moves	0.099623	0.289598		0.335492	0.207127
Average concession moves	0.194866	0.353693		0.342749	0.31262
Average silent moves	0.040518	0.148758		0.110268	0.069124

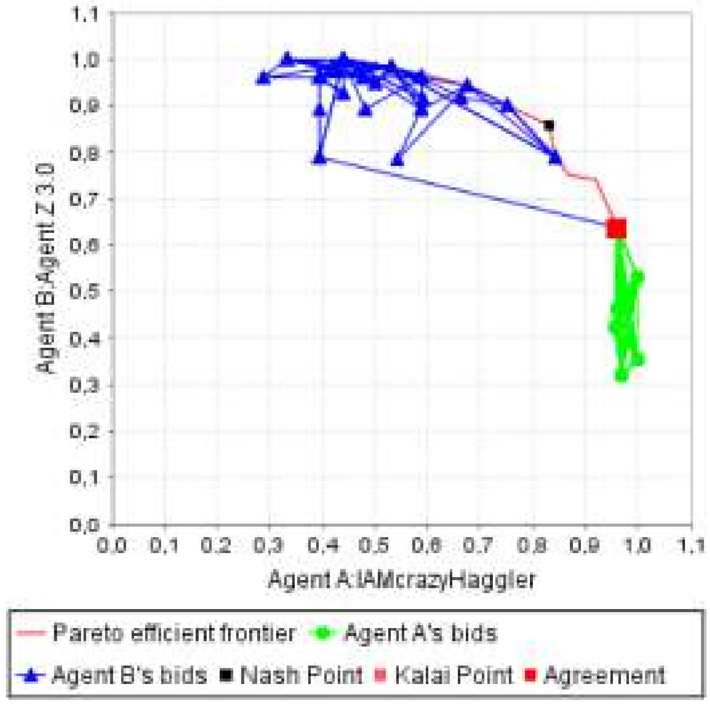

Figure 132 : IAMcrazyHaggler vs Agent Z3.0 - Amsterdam Party Domain

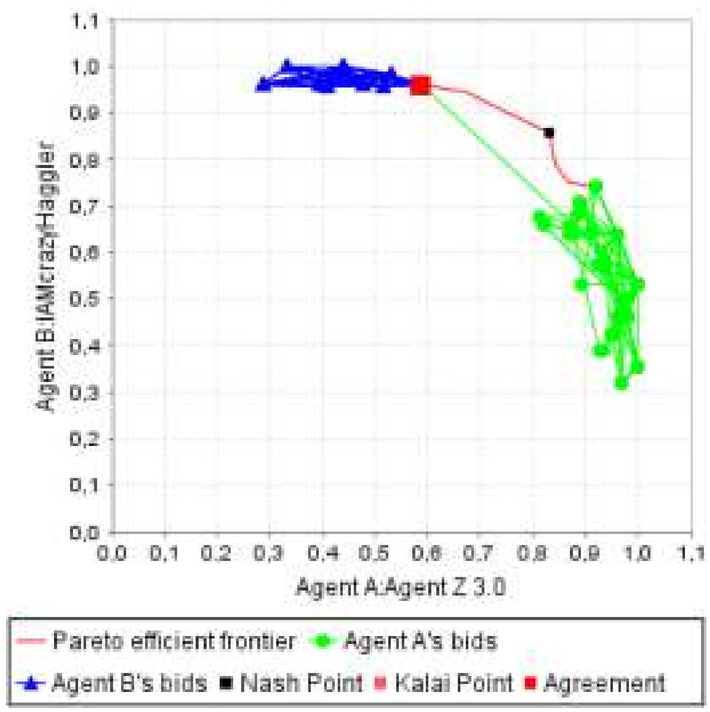

Figure 133 : Agent Z3.0 vs IAMcrazyHaggler - Amsterdam Party Domain

Table 71 : Agent Z3.0 vs IAMcrazyHaggler - Amsterdam Party Domain

Agent	Agent Z 3.0	IAMcrazyHag		IAMcrazyHag	Agent Z 3.0
Average time of agreement	0.993444	0.993444		0.953529	0.953529
Std time of agreement	0.001527	0.001527		0.123644	0.123644
Average time of end of negotiation	0.993444	0.993444		0.953529	0.953529
Std time of end of negotiation	0.001527	0.001527		0.123644	0.123644
Average rounds	339	339		326.4	326.4
Std rounds	3.265986	3.265986		43.74471	43.74471
Percentage of agreement	100	100		100	100
Average utility	0.586667	0.96		0.952333	0.641
Std utility	1.17E-16	2.34E-16		0.024244	0.013703
Average utility of agreements	0.586667	0.96		0.952333	0.641
Average discounted utility	0.586667	0.96		0.952333	0.641
Std discounted utility	1.17E-16	2.34E-16		0.024244	0.013703
Average discounted utility of agreements	0.586667	0.96		0.952333	0.641
Average nash distance	0.264692	0.264692		0.247714	0.247714
Average nash distance of agreements	0.264692	0.264692		0.247714	0.247714
Average pareto distance	0	0		0.007044	0.007044
Average pareto distance of agreements	0	0		0.007044	0.007044
Average kalai distance	0.264692	0.264692		0.247714	0.247714
Average kalai distance of agreements	0.264692	0.264692		0.247714	0.247714
Average social welfare	1.546667	1.546667		1.593333	1.593333
Average social welfare of agreements	1.546667	1.546667		1.593333	1.593333
Average exploration	0.022354	0.016369		0.009854	0.017394
Average joint exploration	0.03664	0.03664		0.024603	0.024603
Perc pareto bids	0.37678	0.294001		0.244549	0.552688
Average unfortunate moves	0.252213	0.214361		0.244188	0.174185
Average fortunate moves	0.146223	0.171393		0.199598	0.073876
Average nice moves	0.044957	0.049381		0.050328	0.088094
Average selfish moves	0.182923	0.238665		0.199747	0.216311
Average concession moves	0.223202	0.233974		0.195428	0.264794
Average silent moves	0.150484	0.092227		0.110711	0.182741

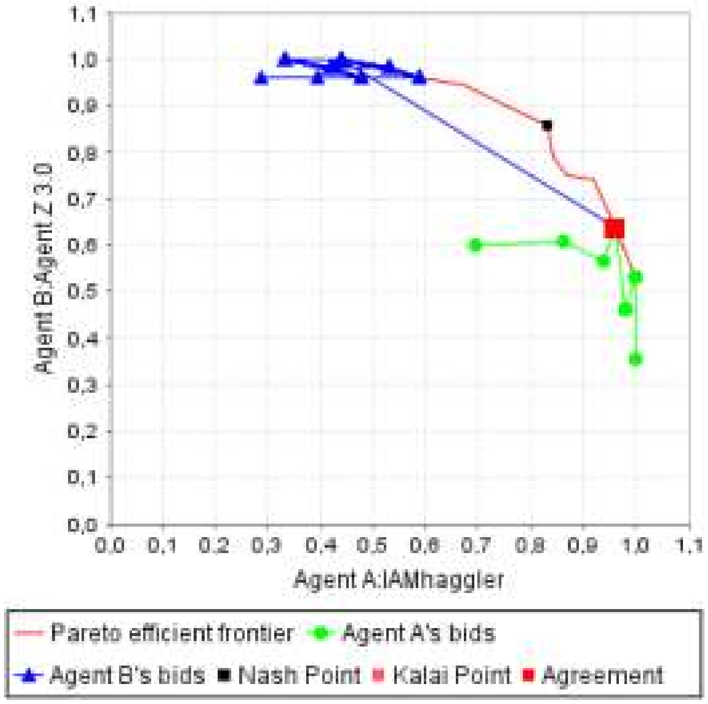

Figure 134 : IAMhaggler vs Agent Z3.0 - Amsterdam Party Domain

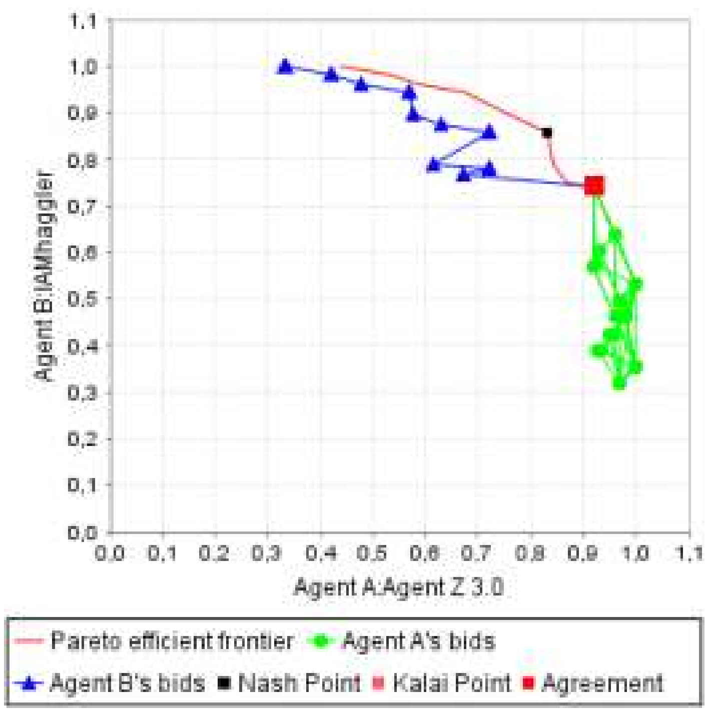

Figure 135 : Agent Z3.0 vs IAMhaggler - Amsterdam Party Domain

Table 72 : Agent Z3.0 vs IAMhaggler - Amsterdam Party Domain

Agent	Agent Z 3.0	IAMhaggler		IAMhaggler	Agent Z 3.0
Average time of agreement	0.82719	0.82719		0.992961	0.992961
Std time of agreement	0.186617	0.186617		0.002539	0.002539
Average time of end of negotiation	0.82719	0.82719		0.992961	0.992961
Std time of end of negotiation	0.186617	0.186617		0.002539	0.002539
Average rounds	223.8	223.8		274.2	274.2
Std rounds	53.59478	53.59478		3.705851	3.705851
Percentage of agreement	100	100		100	100
Average utility	0.848667	0.73325		0.862333	0.742667
Std utility	0.128233	0.09211		0.073077	0.069082
Average utility of agreements	0.848667	0.73325		0.862333	0.742667
Average discounted utility	0.848667	0.73325		0.862333	0.742667
Std discounted utility	0.128233	0.09211		0.073077	0.069082
Average discounted utility of agreements	0.848667	0.73325		0.862333	0.742667
Average nash distance	0.18485	0.18485		0.132684	0.132684
Average nash distance of agreements	0.18485	0.18485		0.132684	0.132684
Average pareto distance	0.036268	0.036268		0.024203	0.024203
Average pareto distance of agreements	0.036268	0.036268		0.024203	0.024203
Average kalai distance	0.18485	0.18485		0.132684	0.132684
Average kalai distance of agreements	0.18485	0.18485		0.132684	0.132684
Average social welfare	1.581917	1.581917		1.605	1.605
Average social welfare of agreements	1.581917	1.581917		1.605	1.605
Average exploration	0.010847	0.003307		0.001984	0.009458
Average joint exploration	0.014054	0.014054		0.009755	0.009755
Perc pareto bids	0.27466	0.003309		0.959235	0.727064
Average unfortunate moves	0.275716	0.021588		0.010972	0.119105
Average fortunate moves	0.10021	0		0	0.02501
Average nice moves	0.09062	0		0.007349	0.086687
Average selfish moves	0.120148	0.001087		0	0.09993
Average concession moves	0.096063	0.07348		0.018402	0.188035
Average silent moves	0.317243	0.903845		0.963278	0.481233

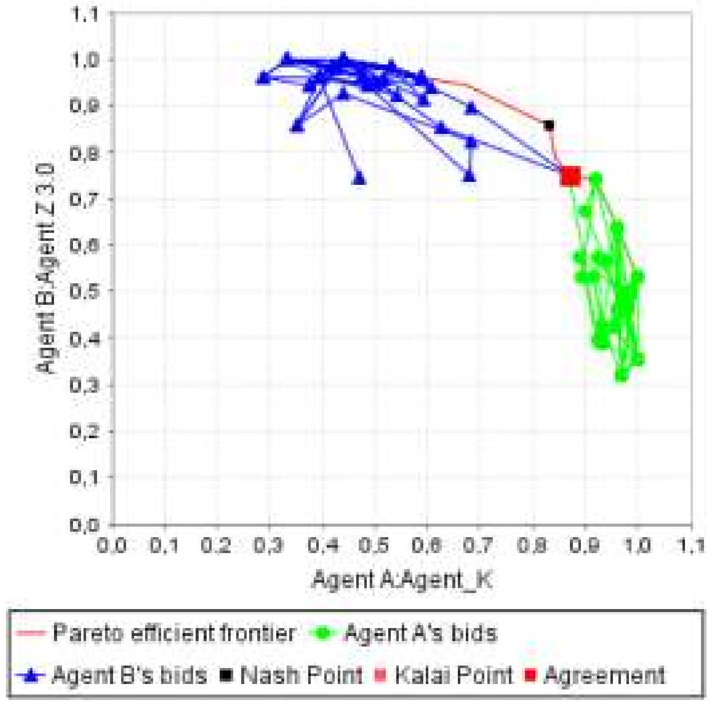

Figure 136 : Agent K vs Agent Z3.0 - Amsterdam Party Domain

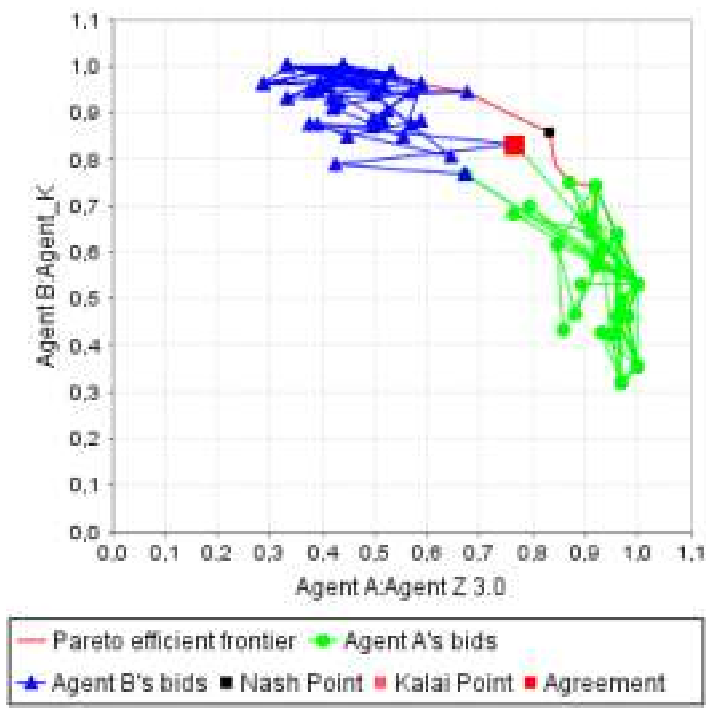

Figure 137 : Agent Z3.0 vs Agent K - Amsterdam Party Domain

Table 73 : Agent Z3.0 vs Agent K - Amsterdam Party Domain

Agent	Agent Z 3.0	Agent_K		Agent_K	Agent Z 3.0
Average time of agreement	0.829392	0.829392		0.772758	0.772758
Std time of agreement	0.022095	0.022095		0.034657	0.034657
Average time of end of negotiation	0.829392	0.829392		0.772758	0.772758
Std time of end of negotiation	0.022095	0.022095		0.034657	0.034657
Average rounds	281.6	281.6		262.8	262.8
Std rounds	7.426679	7.426679		11.83967	11.83967
Percentage of agreement	100	100		100	100
Average utility	0.739	0.82675		0.819667	0.7875
Std utility	0.130148	0.061031		0.053228	0.048658
Average utility of agreements	0.739	0.82675		0.819667	0.7875
Average discounted utility	0.739	0.82675		0.819667	0.7875
Std discounted utility	0.130148	0.061031		0.053228	0.048658
Average discounted utility of agreements	0.739	0.82675		0.819667	0.7875
Average nash distance	0.141457	0.141457		0.083281	0.083281
Average nash distance of agreements	0.141457	0.141457		0.083281	0.083281
Average pareto distance	0.051361	0.051361		0.036086	0.036086
Average pareto distance of agreements	0.051361	0.051361		0.036086	0.036086
Average kalai distance	0.141457	0.141457		0.083281	0.083281
Average kalai distance of agreements	0.141457	0.141457		0.083281	0.083281
Average social welfare	1.56575	1.56575		1.607167	1.607167
Average social welfare of agreements	1.56575	1.56575		1.607167	1.607167
Average exploration	0.019643	0.017725		0.014153	0.015807
Average joint exploration	0.036806	0.036806		0.028538	0.028538
Perc pareto bids	0.366176	0.378172		0.311454	0.517769
Average unfortunate moves	0.257704	0.22702		0.248089	0.199327
Average fortunate moves	0.155609	0.123187		0.14126	0.076579
Average nice moves	0.063421	0.085368		0.094108	0.105563
Average selfish moves	0.184029	0.183636		0.149806	0.212075
Average concession moves	0.210398	0.20129		0.166549	0.281064
Average silent moves	0.128839	0.179499		0.200189	0.125392

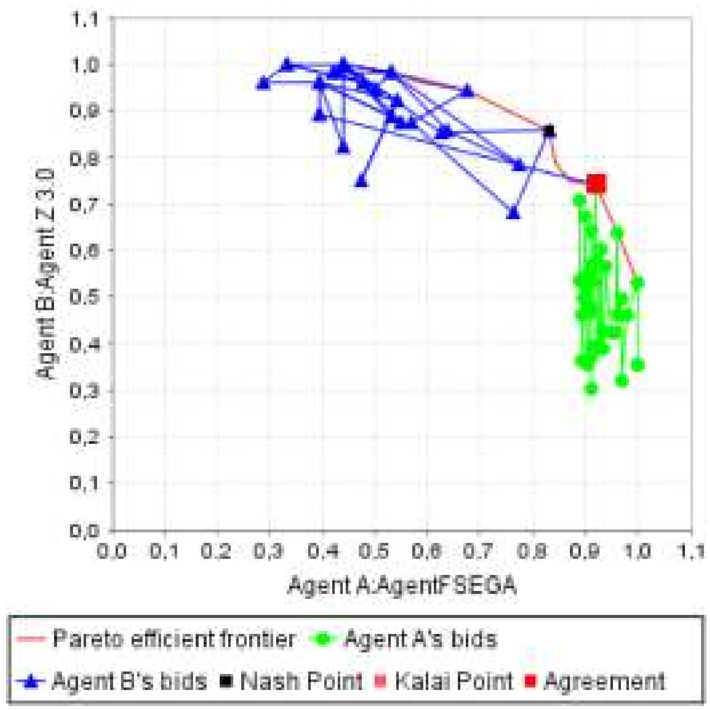

Figure 138 : FSEGA vs Agent Z3.0 - Amsterdam Party Domain

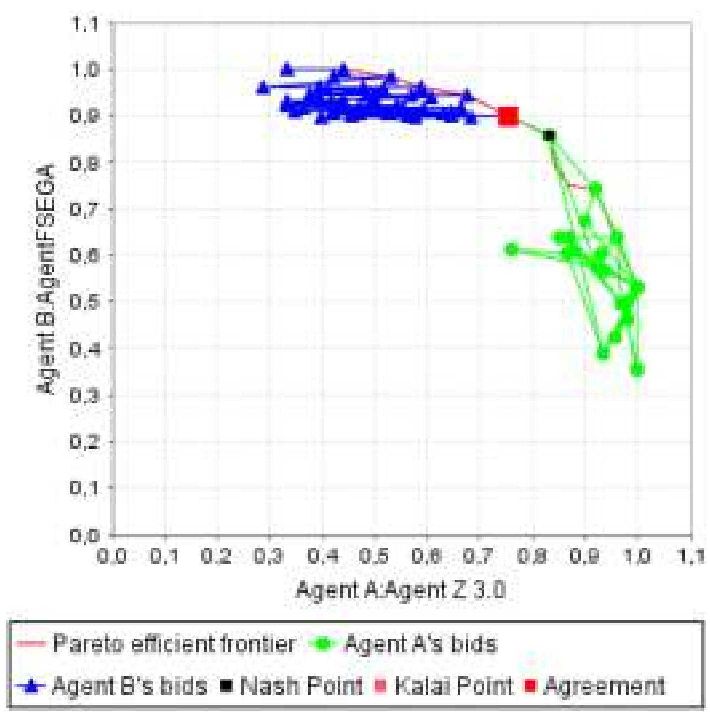

Figure 139 : Agent Z3.0 vs FSEGA - Amsterdam Party Domain

Table 74 : Agent Z3.0 vs FSEGA - Amsterdam Party Domain

Agent	Agent Z 3.0	AgentFSEGA		AgentFSEGA	Agent Z 3.0
Average time of agreement	0.985805	0.985805		0.993516	0.993516
Std time of agreement	0.014125	0.014125		NaN	NaN
Average time of end of negotiation	0.985805	0.985805		0.992669	0.992669
Std time of end of negotiation	0.014125	0.014125		0.003595	0.003595
Average rounds	76.8	76.8		49.2	49.2
Std rounds	29.14256	29.14256		10.92195	10.92195
Percentage of agreement	100	100		90	90
Average utility	0.616667	0.843917		0.644	0.520333
Std utility	0.21801	0.296835		0.444402	0.359064
Average utility of agreements	0.616667	0.843917		0.715556	0.578148
Average discounted utility	0.616667	0.843917		0.644	0.520333
Std discounted utility	0.21801	0.296835		0.444402	0.359064
Average discounted utility of agreements	0.616667	0.843917		0.715556	0.578148
Average nash distance	0.268932	0.268932		0.45851	0.45851
Average nash distance of agreements	0.268932	0.268932		0.376989	0.376989
Average pareto distance	0.109252	0.109252		0.327756	0.327756
Average pareto distance of agreements	0.109252	0.109252		0.242782	0.242782
Average kalai distance	0.268932	0.268932		0.45851	0.45851
Average kalai distance of agreements	0.268932	0.268932		0.376989	0.376989
Average social welfare	1.460583	1.460583		1.164333	1.164333
Average social welfare of agreements	1.460583	1.460583		1.293704	1.293704
Average exploration	0.008929	0.012202		0.007804	0.006448
Average joint exploration	0.021065	0.021065		0.014021	0.014021
Perc pareto bids	0.373337	0.128579		0.126027	0.44506
Average unfortunate moves	0.236596	0.397774		0.463585	0.156417
Average fortunate moves	0.11563	0		0	0.087115
Average nice moves	0.062332	0.472714		0.309018	0.092153
Average selfish moves	0.193959	0		0	0.265596
Average concession moves	0.279056	0.096526		0.183496	0.351271
Average silent moves	0.112428	0.032986		0.0439	0.047447

Appendix J : Camera Domain – Agent Z1.0

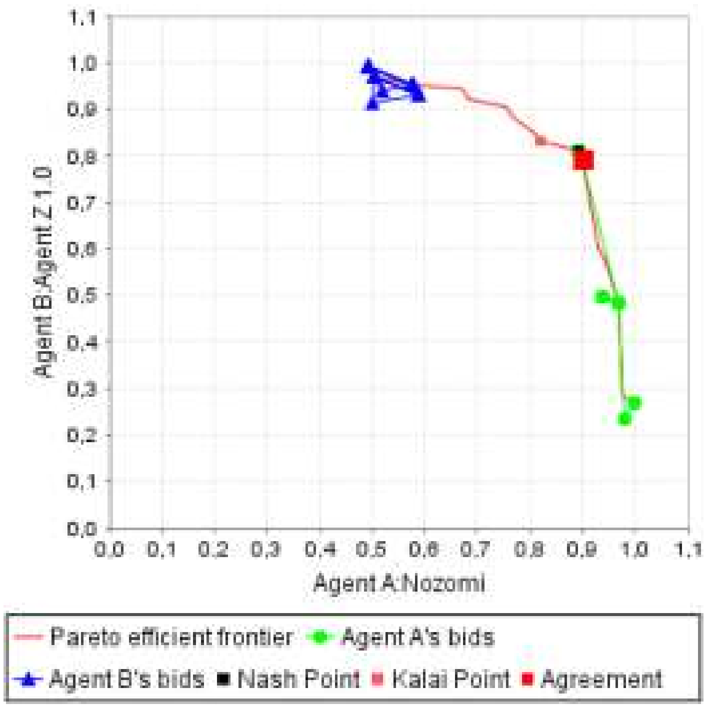

Figure 140 : Nozomi vs Agent Z1.0 – Camera Domain

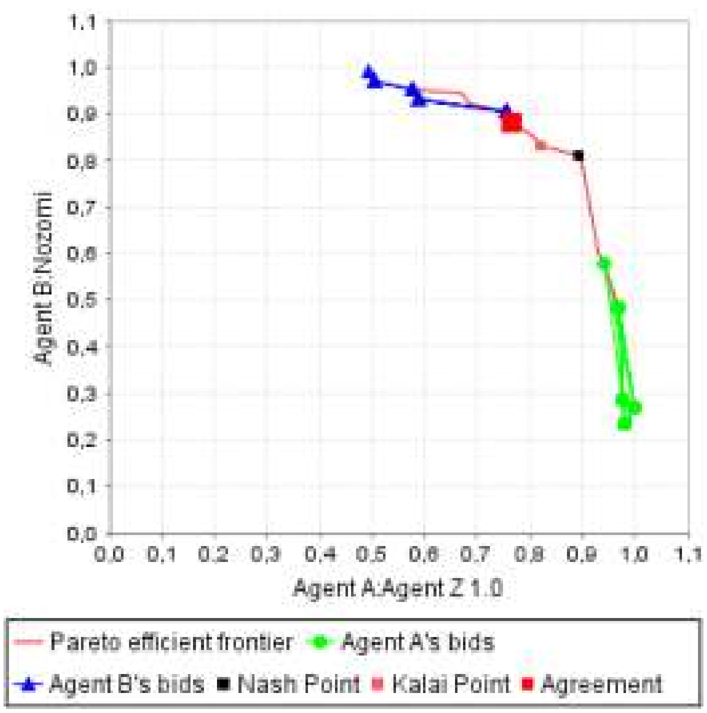

Figure 141 : Agent Z1.0 vs Nozomi – Camera Domain

Table 75 : Agent Z1.0 vs Nozomi – Camera Domain

Agent	Agent Z 1.0	Nozomi		Nozomi	Agent Z 1.0
Average time of agreement	0.983393	0.983393		0.992364	0.992364
Std time of agreement	0.033774	0.033774		0.001694	0.001694
Average time of end of negotiation	0.983393	0.983393		0.992364	0.992364
Std time of end of negotiation	0.033774	0.033774		0.001694	0.001694
Average rounds	390.5	390.5		394.4	394.4
Std rounds	13.54212	13.54212		0.843274	0.843274
Percentage of agreement	100	100		100	100
Average utility	0.766063	0.86896		0.873791	0.7872
Std utility	0.106705	0.04773		0.045523	0.060271
Average utility of agreements	0.766063	0.86896		0.873791	0.7872
Average discounted utility	0.683726	0.775262		0.778883	0.701699
Std discounted utility	0.096581	0.040345		0.040572	0.053742
Average discounted utility of agreements	0.683726	0.775262		0.778883	0.701699
Average nash distance	0.072304	0.072304		0.130164	0.130164
Average nash distance of agreements	0.072304	0.072304		0.130164	0.130164
Average pareto distance	0.019968	0.019968		0	0
Average pareto distance of agreements	0.019968	0.019968		0	0
Average kalai distance	0.117671	0.117671		0.089834	0.089834
Average kalai distance of agreements	0.117671	0.117671		0.089834	0.089834
Average social welfare	1.635023	1.635023		1.660991	1.660991
Average social welfare of agreements	1.635023	1.635023		1.660991	1.660991
Average exploration	0.003167	0.002167		0.001667	0.002222
Average joint exploration	0.005333	0.005333		0.003917	0.003917
Perc pareto bids	0.966636	0.240434		0.968051	0.663875
Average unfortunate moves	0.012941	0.017389		0	0.038731
Average fortunate moves	0.010962	0.010216		0	0.036698
Average nice moves	0	0		0	0
Average selfish moves	0.047151	0.035873		0.051992	0.045882
Average concession moves	0.060664	0.050285		0.07442	0.05302
Average silent moves	0.868282	0.886237		0.873589	0.825668

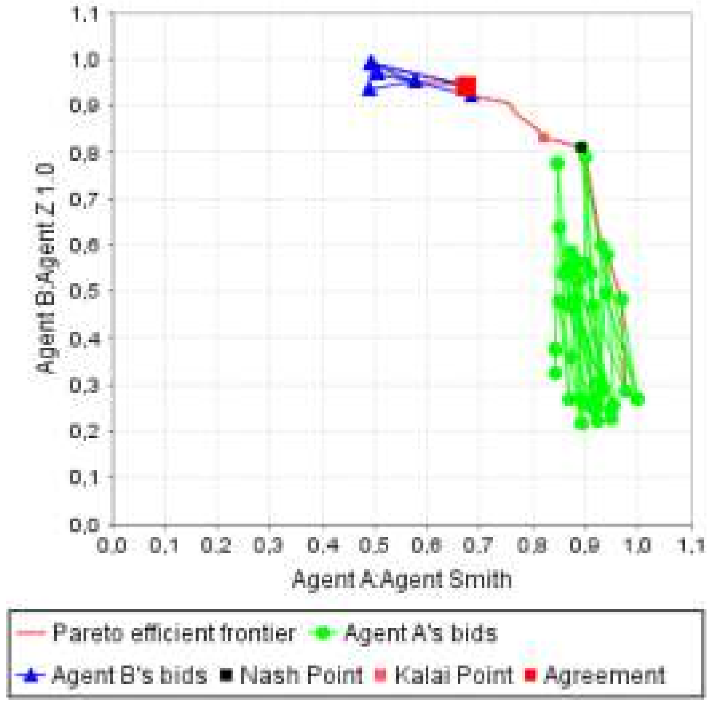

Figure 142 : Agent Smith vs Agent Z1.0 – Camera Domain

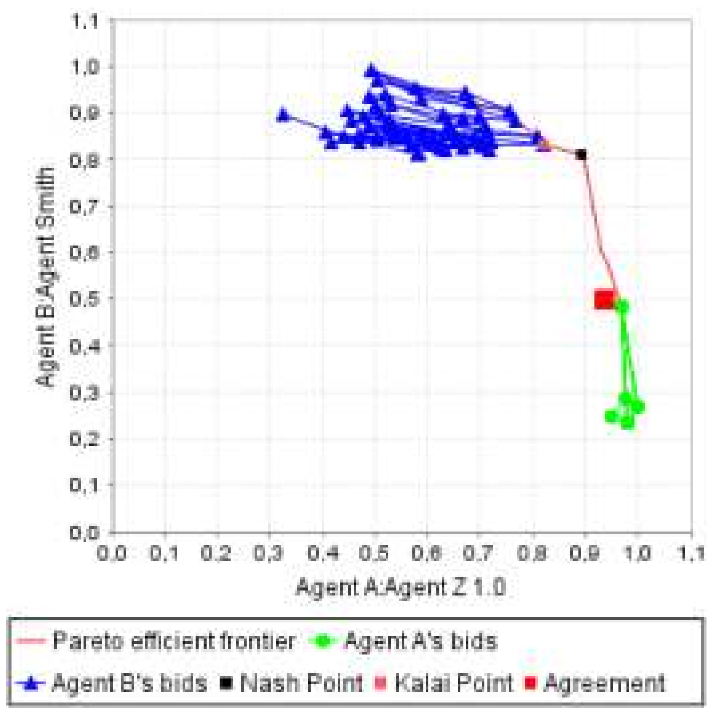

Figure 143 : Agent Z1.0 vs Agent Smith – Camera Domain

Table 76 : Agent Z1.0 vs Agent Smith – Camera Domain

Agent	Agent Z 1.0	Agent Smith		Agent Smith	Agent Z 1.0
Average time of agreement	0.615434	0.615434		0.617811	0.617811
Std time of agreement	0.004328	0.004328		0.002325	0.002325
Average time of end of negotiation	0.615434	0.615434		0.617811	0.617811
Std time of end of negotiation	0.004328	0.004328		0.002325	0.002325
Average rounds	103.8	103.8		118.6	118.6
Std rounds	1.988858	1.988858		2.065591	2.065591
Percentage of agreement	100	100		100	100
Average utility	0.966661	0.533982		0.415148	0.9654
Std utility	0.020905	0.059586		0.114292	0.019208
Average utility of agreements	0.966661	0.533982		0.415148	0.9654
Average discounted utility	0.900131	0.497239		0.386481	0.898711
Std discounted utility	0.019437	0.05557		0.10643	0.017958
Average discounted utility of agreements	0.900131	0.497239		0.386481	0.898711
Average nash distance	0.389747	0.389747		0.402968	0.402968
Average nash distance of agreements	0.389747	0.389747		0.402968	0.402968
Average pareto distance	0.002366	0.002366		0.015865	0.015865
Average pareto distance of agreements	0.002366	0.002366		0.015865	0.015865
Average kalai distance	0.317555	0.317555		0.440191	0.440191
Average kalai distance of agreements	0.317555	0.317555		0.440191	0.440191
Average social welfare	1.500643	1.500643		1.380548	1.380548
Average social welfare of agreements	1.500643	1.500643		1.380548	1.380548
Average exploration	0.001694	0.01325		0.015806	0.00275
Average joint exploration	0.014833	0.014833		0.018361	0.018361
Perc pareto bids	0.895777	0.158152		0.170056	0.699354
Average unfortunate moves	0.009884	0.149297		0.169758	0.071437
Average fortunate moves	0.005961	0.063264		0.001724	0.062874
Average nice moves	0	0		0	0
Average selfish moves	0.064881	0.266997		0.344159	0.141234
Average concession moves	0.088268	0.453408		0.454831	0.166724
Average silent moves	0.831007	0.067035		0.029528	0.557732

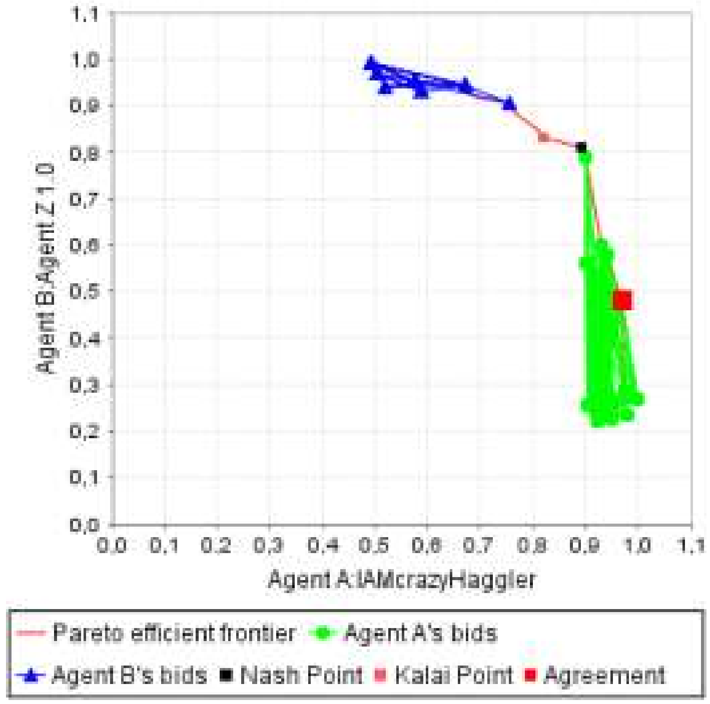

Figure 144 : IAMcrazyhaggler vs Agent Z1.0 – Camera Domain

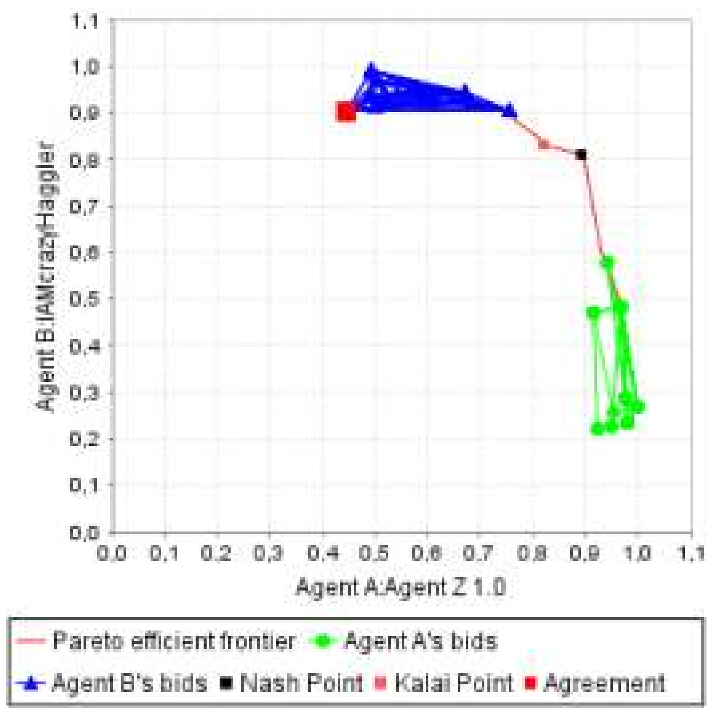

Figure 145 : Agent Z1.0 vs IAMcrazyHAggler – Camera Domain

Table 77 : Agent Z1.0 vs IAMcrazyHaggler – Camera Domain

Agent	Agent Z 1.0	IAMcrazyHag		IAMcrazyHa	Agent Z 1.0
Average time of agreement	0.992237	0.992237		0.993597	0.993597
Std time of agreement	0.001166	0.001166		0.001017	0.001017
Average time of end of negotiation	0.992237	0.992237		0.993597	0.993597
Std time of end of negotiation	0.001166	0.001166		0.001017	0.001017
Average rounds	391	391		389.6	389.6
Std rounds	0	0		1.264911	1.264911
Percentage of agreement	100	100		100	100
Average utility	0.345854	0.934251		0.939179	0.535416
Std utility	0.134143	0.017112		0.027014	0.082159
Average utility of agreements	0.345854	0.934251		0.939179	0.535416
Average discounted utility	0.308295	0.83279		0.837049	0.47719
Std discounted utility	0.119579	0.015284		0.024066	0.073201
Average discounted utility of agreements	0.308295	0.83279		0.837049	0.47719
Average nash distance	0.467481	0.467481		0.380181	0.380181
Average nash distance of agreements	0.467481	0.467481		0.380181	0.380181
Average pareto distance	0.045146	0.045146		0.030384	0.030384
Average pareto distance of agreements	0.045146	0.045146		0.030384	0.030384
Average kalai distance	0.498591	0.498591		0.307935	0.307935
Average kalai distance of agreements	0.498591	0.498591		0.307935	0.307935
Average social welfare	1.280106	1.280106		1.474594	1.474594
Average social welfare of agreements	1.280106	1.280106		1.474594	1.474594
Average exploration	0.004278	0.031778		0.019	0.00575
Average joint exploration	0.035583	0.035583		0.023083	0.023083
Perc pareto bids	0.899487	0.263265		0.516997	0.677117
Average unfortunate moves	0.018041	0.188205		0.206897	0.066028
Average fortunate moves	0.012371	0.191282		0.201182	0.070178
Average nice moves	0	0		0	0
Average selfish moves	0.089691	0.279487		0.252365	0.124382
Average concession moves	0.103608	0.295385		0.254416	0.145538
Average silent moves	0.776289	0.045641		0.08514	0.593874

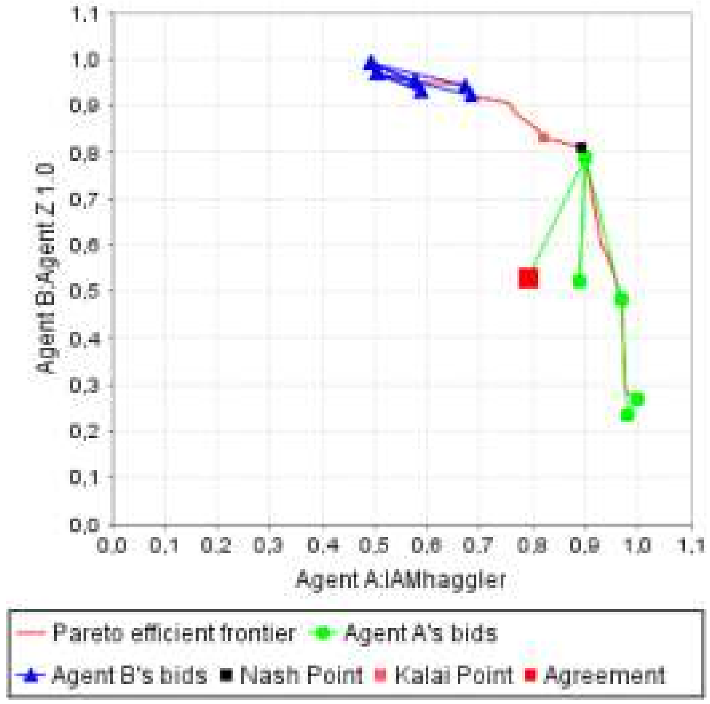

Figure 146 : IAMhaggler vs Agent Z1.0 – Camera Domain

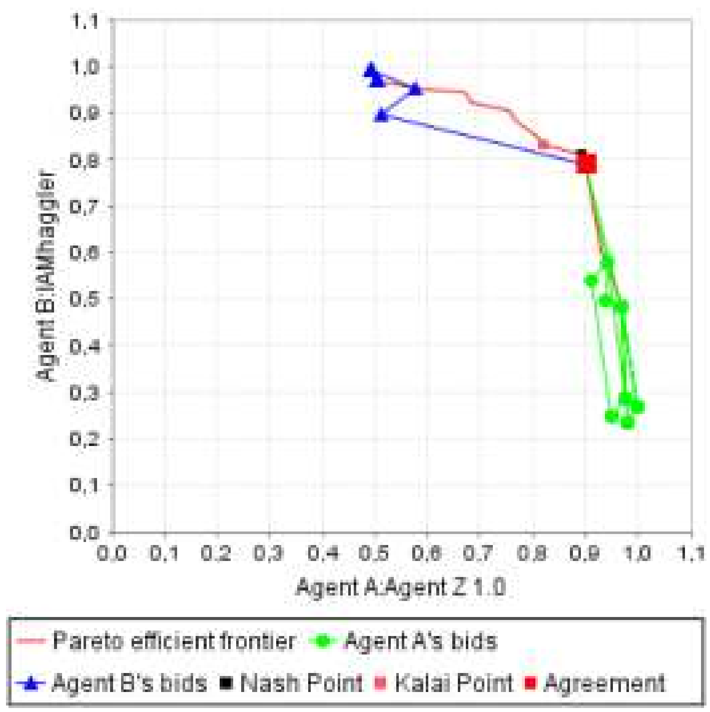

Figure 147 : Agent Z1.0 vs IAMhaggler – Camera Domain

Table 78 : Agent Z1.0 vs IAMhaggler – Camera Domain

Agent	Agent Z 1.0	IAMhaggler		IAMhaggler	Agent Z 1.0
Average time of agreement	0.993096	0.993096		0.992093	0.992093
Std time of agreement	0.001835	0.001835		0.001119	0.001119
Average time of end of negotiation	0.993096	0.993096		0.992093	0.992093
Std time of end of negotiation	0.001835	0.001835		0.001119	0.001119
Average rounds	294.2	294.2		293	293
Std rounds	2.149935	2.149935		1.699673	1.699673
Percentage of agreement	100	100		100	100
Average utility	0.578245	0.793659		0.826587	0.793721
Std utility	0.294123	0.047594		0.034465	0.114043
Average utility of agreements	0.578245	0.793659		0.826587	0.793721
Average discounted utility	0.515362	0.707402		0.736832	0.707528
Std discounted utility	0.262092	0.042543		0.030784	0.10162
Average discounted utility of agreements	0.515362	0.707402		0.736832	0.707528
Average nash distance	0.330825	0.330825		0.111684	0.111684
Average nash distance of agreements	0.330825	0.330825		0.111684	0.111684
Average pareto distance	0.094972	0.094972		0.0256	0.0256
Average pareto distance of agreements	0.094972	0.094972		0.0256	0.0256
Average kalai distance	0.310279	0.310279		0.0964	0.0964
Average kalai distance of agreements	0.310279	0.310279		0.0964	0.0964
Average social welfare	1.371904	1.371904		1.620307	1.620307
Average social welfare of agreements	1.371904	1.371904		1.620307	1.620307
Average exploration	0.003417	0.002361		0.0015	0.002778
Average joint exploration	0.005444	0.005444		0.00425	0.00425
Perc pareto bids	0.961852	0.480379		0.97811	0.881883
Average unfortunate moves	0.011659	0.021141		0.002749	0.024743
Average fortunate moves	0.007563	0.006123		0	0.023387
Average nice moves	0	0		0	0
Average selfish moves	0.055633	0.00616		0.002745	0.045358
Average concession moves	0.067315	0.021159		0.027487	0.052212
Average silent moves	0.857831	0.945418		0.967019	0.854301

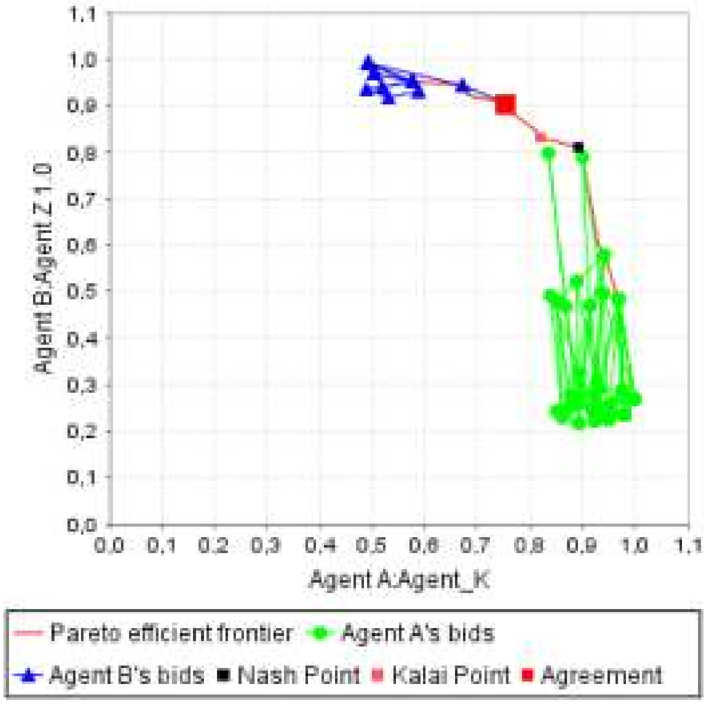

Figure 148 : Agent K vs Agent Z1.0 – Camera Domain

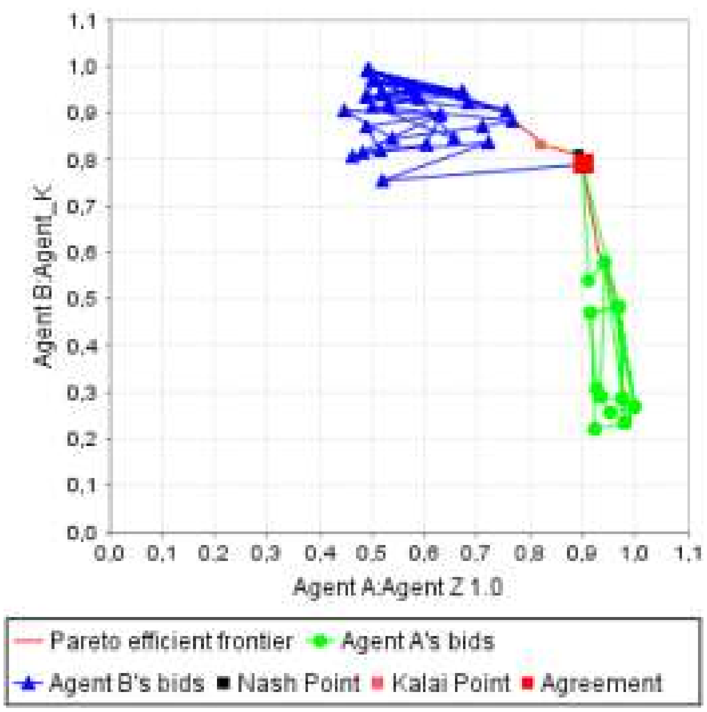

Figure 149 : Agent Z1.0 vs Agent K – Camera Domain

Table 79 : Agent Z1.0 vs Agent K – Camera Domain

Agent	Agent Z 1.0	Agent_K		Agent_K	Agent Z 1.0
Average time of agreement	0.937671	0.937671		0.922742	0.922742
Std time of agreement	0.057606	0.057606		0.094491	0.094491
Average time of end of negotiation	0.937671	0.937671		0.922742	0.922742
Std time of end of negotiation	0.057606	0.057606		0.094491	0.094491
Average rounds	363.3	363.3		354.4	354.4
Std rounds	22.93493	22.93493		37.80123	37.80123
Percentage of agreement	100	100		100	100
Average utility	0.851524	0.70173		0.7239	0.862177
Std utility	0.231323	0.036382		0.096964	0.107216
Average utility of agreements	0.851524	0.70173		0.7239	0.862177
Average discounted utility	0.76424	0.629612		0.650484	0.775186
Std discounted utility	0.207866	0.035328		0.087181	0.099604
Average discounted utility of agreements	0.76424	0.629612		0.650484	0.775186
Average nash distance	0.266303	0.266303		0.114933	0.114933
Average nash distance of agreements	0.266303	0.266303		0.114933	0.114933
Average pareto distance	0.024278	0.024278		0.041335	0.041335
Average pareto distance of agreements	0.024278	0.024278		0.041335	0.041335
Average kalai distance	0.204746	0.204746		0.156418	0.156418
Average kalai distance of agreements	0.204746	0.204746		0.156418	0.156418
Average social welfare	1.553254	1.553254		1.586077	1.586077
Average social welfare of agreements	1.553254	1.553254		1.586077	1.586077
Average exploration	0.003528	0.020222		0.016111	0.005194
Average joint exploration	0.0235	0.0235		0.020972	0.020972
Perc pareto bids	0.969024	0.511498		0.707328	0.66104
Average unfortunate moves	0.010915	0.164917		0.099006	0.062595
Average fortunate moves	0.007668	0.158108		0.094401	0.054973
Average nice moves	0	0		0	0
Average selfish moves	0.051726	0.25464		0.271588	0.097798
Average concession moves	0.060782	0.277116		0.278077	0.116679
Average silent moves	0.868908	0.14522		0.256929	0.667955

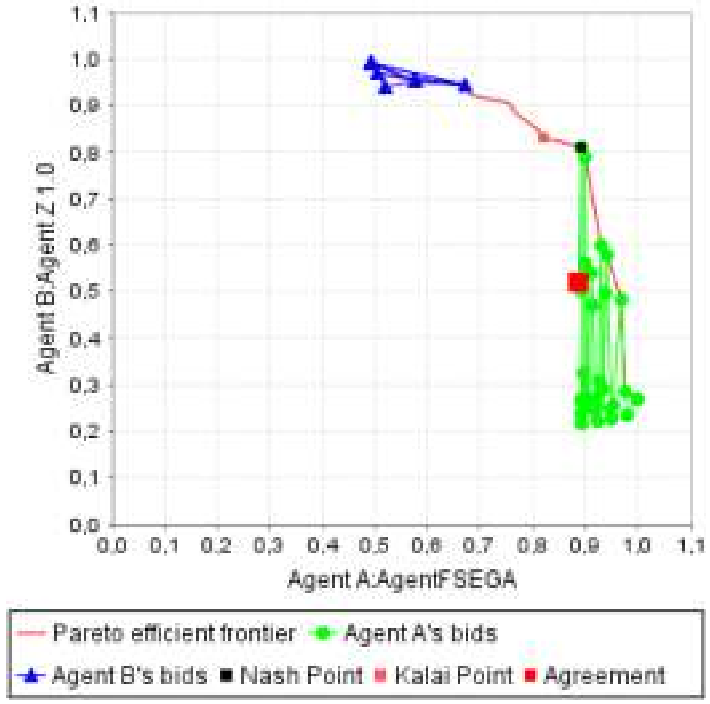

Figure 150 : FSEGA vs Agent Z1.0 – Camera Domain

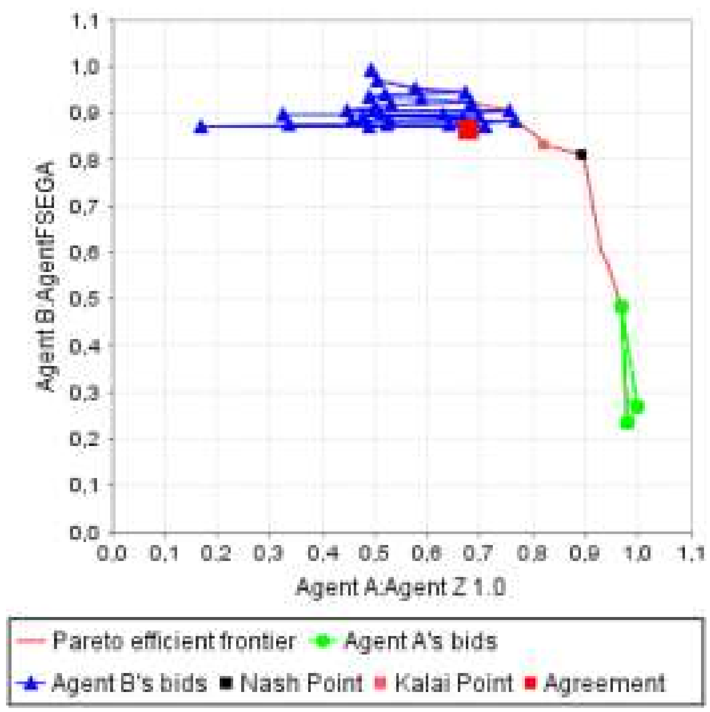

Figure 151 : Agent Z1.0 vs FSEGA – Camera Domain

Table 80 : Agent Z1.0 vs FSEGA – Camera Domain

Agent	Agent Z 1.0	AgentFSEGA		AgentFSEGA	Agent Z 1.0
Average time of agreement	0.995504	0.995504		0.993107	0.993107
Std time of agreement	NaN	NaN		0.00181	0.00181
Average time of end of negotiation	0.985427	0.985427		0.993107	0.993107
Std time of end of negotiation	0.012914	0.012914		0.00181	0.00181
Average rounds	45.2	45.2		70	70
Std rounds	7.130529	7.130529		17.46107	17.46107
Percentage of agreement	40	40		100	100
Average utility	0.212749	0.359377		0.85726	0.529996
Std utility	0.302457	0.46397		0.012794	0.114096
Average utility of agreements	0.531873	0.898443		0.85726	0.529996
Average discounted utility	0.189583	0.320226		0.764081	0.472392
Std discounted utility	0.269531	0.413424		0.011329	0.101713
Average discounted utility of agreements	0.473957	0.800566		0.764081	0.472392
Average nash distance	0.834452	0.834452		0.364139	0.364139
Average nash distance of agreements	0.279468	0.279468		0.364139	0.364139
Average pareto distance	0.63111	0.63111		0.105395	0.105395
Average pareto distance of agreements	0.04997	0.04997		0.105395	0.105395
Average kalai distance	0.826344	0.826344		0.291445	0.291445
Average kalai distance of agreements	0.316618	0.316618		0.291445	0.291445
Average social welfare	0.572126	0.572126		1.387255	1.387255
Average social welfare of agreements	1.430316	1.430316		1.387255	1.387255
Average exploration	0.000917	0.006056		0.009444	0.002417
Average joint exploration	0.006944	0.006944		0.011861	0.011861
Perc pareto bids	0.970373	0.291605		0.243682	0.674231
Average unfortunate moves	0.008226	0.492113		0.524731	0.074295
Average fortunate moves	0	0		0	0.068404
Average nice moves	0	0.003125		0	0
Average selfish moves	0.062499	0		0	0.161406
Average concession moves	0.086305	0.458022		0.444042	0.186726
Average silent moves	0.84297	0.04674		0.031227	0.50917

Appendix K : Camera Domain – Agent Z2.0

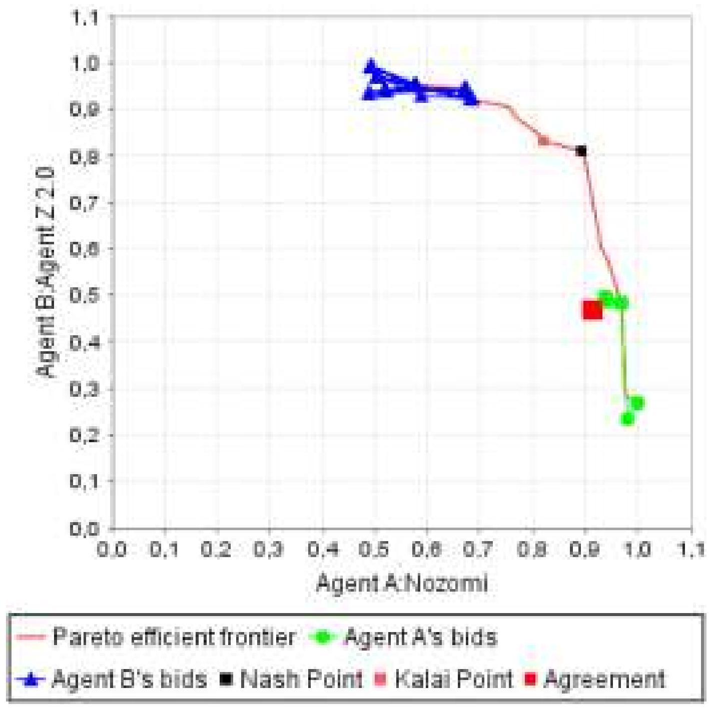

Figure 152 : Nozomi vs Agent Z2.0 – Camera Domain

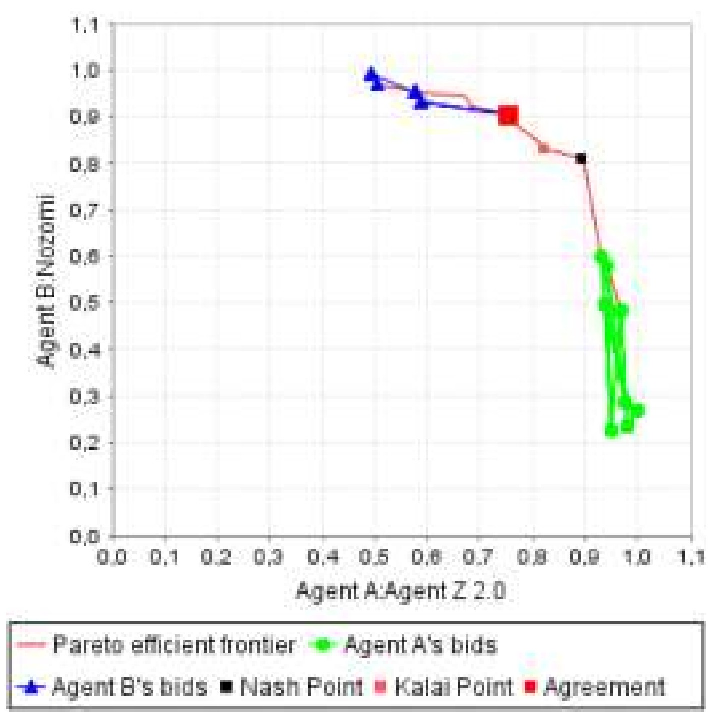

Figure 153 : Agent Z2.0 vs Nozomi – Camera Domain

Table 81 : Agent Z2.0 vs Nozomi – Camera Domain

Agent	Agent Z 2.0	Nozomi		Nozomi	Agent Z 2.0
Average time of agreement	0.992993	0.992993		0.992516	0.992516
Std time of agreement	0.001623	0.001623		0.00173	0.00173
Average time of end of negotiation	0.992993	0.992993		0.992516	0.992516
Std time of end of negotiation	0.001623	0.001623		0.00173	0.00173
Average rounds	338.4	338.4		339.9	339.9
Std rounds	2.1187	2.1187		0.737865	0.737865
Percentage of agreement	100	100		100	100
Average utility	0.489639	0.945229		0.896482	0.75792
Std utility	0.010375	0.018595		0.010265	0.005024
Average utility of agreements	0.489639	0.945229		0.896482	0.75792
Average discounted utility	0.436425	0.842502		0.799096	0.675586
Std discounted utility	0.009254	0.016627		0.009125	0.004503
Average discounted utility of agreements	0.436425	0.842502		0.799096	0.675586
Average nash distance	0.32603	0.32603		0.158294	0.158294
Average nash distance of agreements	0.32603	0.32603		0.158294	0.158294
Average pareto distance	0.027149	0.027149		0	0
Average pareto distance of agreements	0.027149	0.027149		0	0
Average kalai distance	0.362539	0.362539		0.091303	0.091303
Average kalai distance of agreements	0.362539	0.362539		0.091303	0.091303
Average social welfare	1.434867	1.434867		1.654402	1.654402
Average social welfare of agreements	1.434867	1.434867		1.654402	1.654402
Average exploration	0.008861	0.001667		0.001472	0.006528
Average joint exploration	0.009528	0.009528		0.007972	0.007972
Perc pareto bids	0.750294	0.189713		0.951173	0.516453
Average unfortunate moves	0.163547	0.053971		0	0.329571
Average fortunate moves	0.090678	0.047455		0	0.021936
Average nice moves	0	0		0	0
Average selfish moves	0.346928	0.091842		0.016568	0.323657
Average concession moves	0.398847	0.104307		0.039067	0.324837
Average silent moves	0	0.702425		0.944365	0

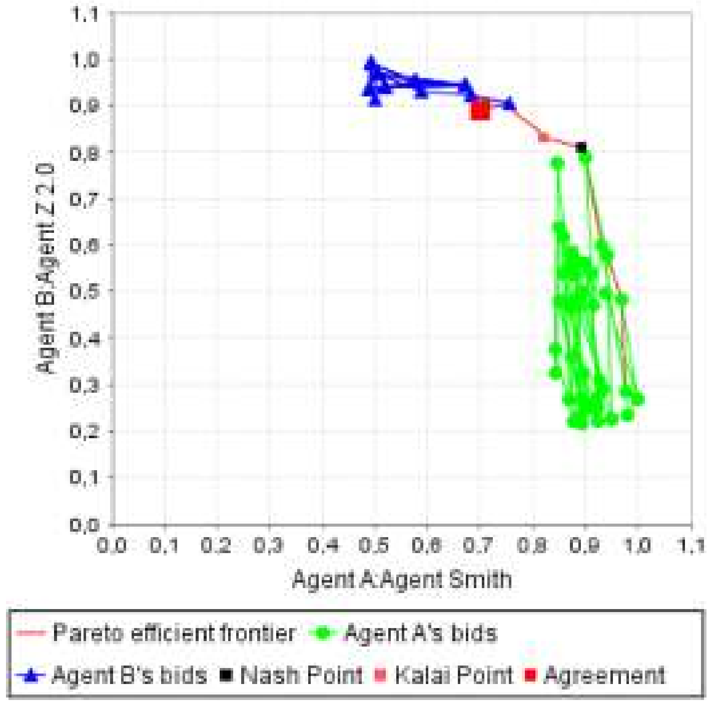

Figure 154 : Agent Smith vs Agent Z2.0 – Camera Domain

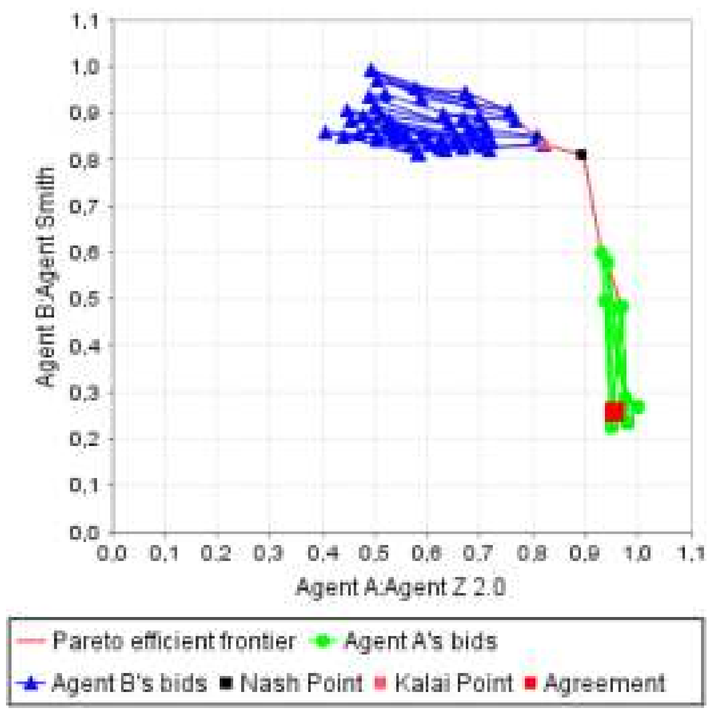

Figure 155 : Agent Z2.0 vs Agent Smith – Camera Domain

Table 82 : Agent Z2.0 vs Agent Smith – Camera Domain

Agent	Agent Z 2.0	Agent Smith		Agent Smith	Agent Z 2.0
Average time of agreement	0.618295	0.618295		0.616596	0.616596
Std time of agreement	0.003112	0.003112		0.004483	0.004483
Average time of end of negotiation	0.618295	0.618295		0.616596	0.616596
Std time of end of negotiation	0.003112	0.003112		0.004483	0.004483
Average rounds	98.2	98.2		111	111
Std rounds	1.75119	1.75119		1.885618	1.885618
Percentage of agreement	100	100		100	100
Average utility	0.9313	0.650906		0.245485	0.980429
Std utility	0.023794	0.074427		0.017704	0.01751
Average utility of agreements	0.9313	0.650906		0.245485	0.980429
Average discounted utility	0.866917	0.605909		0.228563	0.912829
Std discounted utility	0.022172	0.06929		0.016543	0.016317
Average discounted utility of agreements	0.866917	0.605909		0.228563	0.912829
Average nash distance	0.269107	0.269107		0.572519	0.572519
Average nash distance of agreements	0.269107	0.269107		0.572519	0.572519
Average pareto distance	0.003435	0.003435		0.030395	0.030395
Average pareto distance of agreements	0.003435	0.003435		0.030395	0.030395
Average kalai distance	0.198493	0.198493		0.605916	0.605916
Average kalai distance of agreements	0.198493	0.198493		0.605916	0.605916
Average social welfare	1.582206	1.582206		1.225914	1.225914
Average social welfare of agreements	1.582206	1.582206		1.225914	1.225914
Average exploration	0.006556	0.011722		0.014556	0.007278
Average joint exploration	0.018333	0.018333		0.021667	0.021667
Perc pareto bids	0.74577	0.177227		0.18732	0.587551
Average unfortunate moves	0.143036	0.101693		0.146406	0.347167
Average fortunate moves	0.074725	0.066605		0.027787	0.016404
Average nice moves	0	0		0	0
Average selfish moves	0.310057	0.322141		0.348005	0.312774
Average concession moves	0.472182	0.369986		0.429676	0.323654
Average silent moves	0	0.139575		0.048126	0

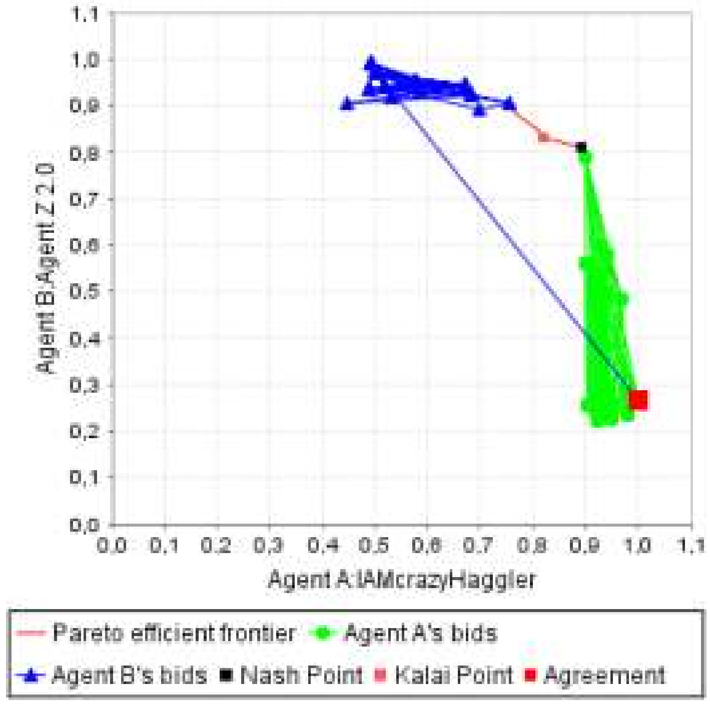

Figure 156 : IAMcrazyHaggler vs Agent Z2.0 – Camera Domain

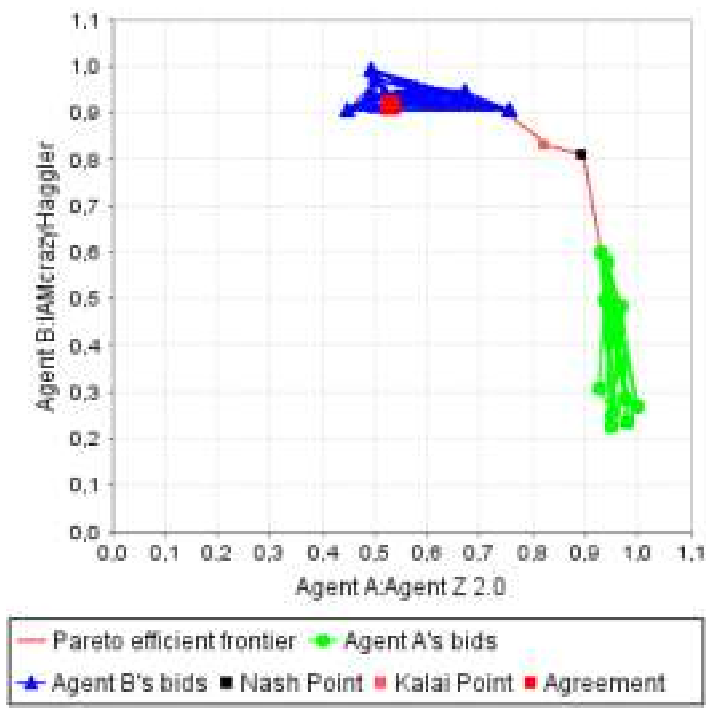

Figure 157 : Agent Z2.0 vs IAMcrazyHaggler – Camera Domain

Table 83 : Agent Z2.0 vs IAMcrazyHaggler – Camera Domain

Agent	Agent Z 2.0	IAMcrazyHa		IAMcrazyHa	Agent Z 2.0
Average time of agreement	0.992816	0.992816		0.992985	0.992985
Std time of agreement	0.002068	0.002068		0.001303	0.001303
Average time of end of negotiation	0.992816	0.992816		0.992985	0.992985
Std time of end of negotiation	0.002068	0.002068		0.001303	0.001303
Average rounds	336.4	336.4		337.7	337.7
Std rounds	2.065591	2.065591		3.335	3.335
Percentage of agreement	100	100		100	100
Average utility	0.344332	0.957589		0.940529	0.538067
Std utility	0.136074	0.034762		0.038978	0.101141
Average utility of agreements	0.344332	0.957589		0.940529	0.538067
Average discounted utility	0.30692	0.853534		0.838311	0.47959
Std discounted utility	0.121303	0.030948		0.034706	0.090149
Average discounted utility of agreements	0.30692	0.853534		0.838311	0.47959
Average nash distance	0.471838	0.471838		0.378086	0.378086
Average nash distance of agreements	0.471838	0.471838		0.378086	0.378086
Average pareto distance	0.027753	0.027753		0.028739	0.028739
Average pareto distance of agreements	0.027753	0.027753		0.028739	0.028739
Average kalai distance	0.505436	0.505436		0.306108	0.306108
Average kalai distance of agreements	0.505436	0.505436		0.306108	0.306108
Average social welfare	1.301921	1.301921		1.478596	1.478596
Average social welfare of agreements	1.301921	1.301921		1.478596	1.478596
Average exploration	0.011333	0.027472		0.0175	0.012861
Average joint exploration	0.038389	0.038389		0.02925	0.02925
Perc pareto bids	0.749042	0.272242		0.496325	0.557029
Average unfortunate moves	0.14981	0.197488		0.212147	0.327023
Average fortunate moves	0.092262	0.196305		0.207447	0.059614
Average nice moves	0	0		0	0
Average selfish moves	0.337558	0.273896		0.253819	0.288788
Average concession moves	0.420371	0.281613		0.247859	0.324575
Average silent moves	0	0.050697		0.078727	0

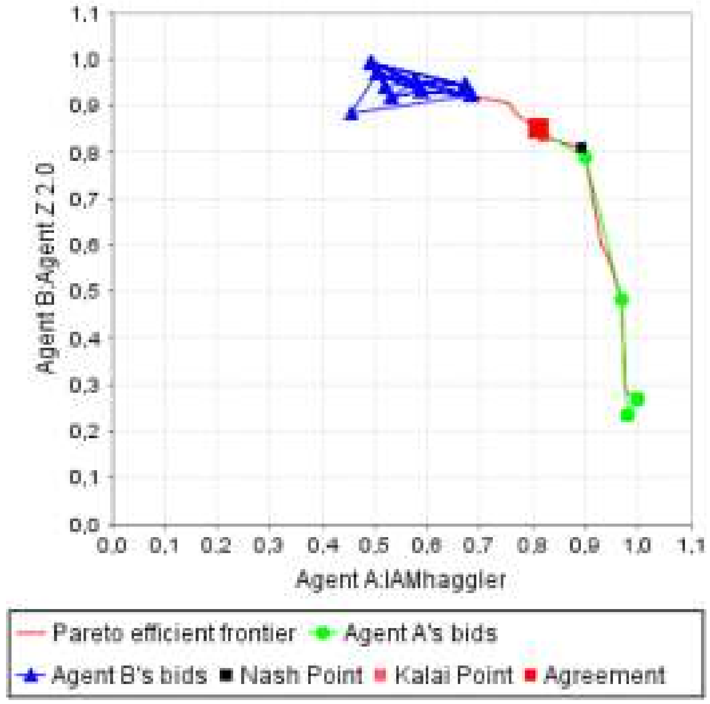

Figure 158 : IAMhaggler vs Agent Z2.0 – Camera Domain

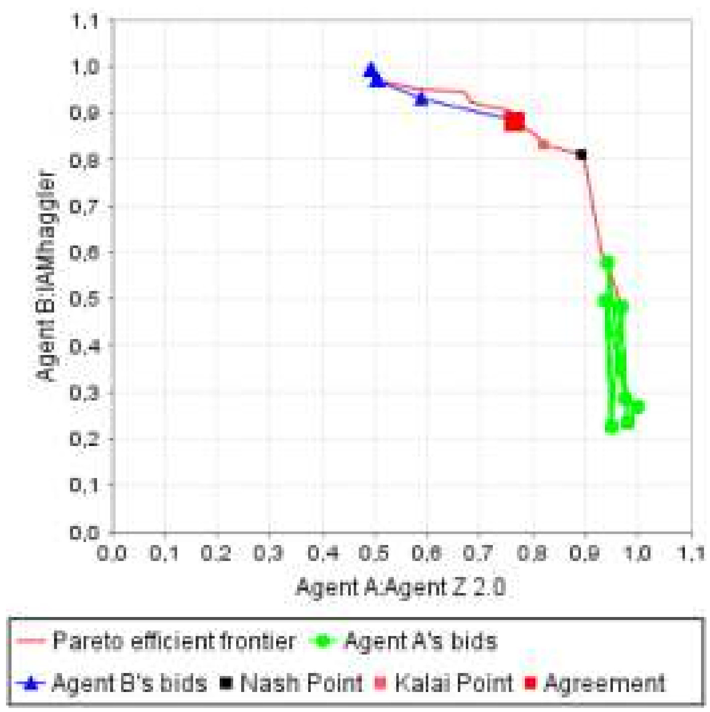

Figure 159 : Agent Z2.0 vs IAMhaggler – Camera Domain

Table 84 : Agent Z2.0 vs IAMhaggler – Camera Domain

Agent	Agent Z 2.0	IAMhaggler		IAMhaggler	Agent Z 2.0
Average time of agreement	0.993486	0.993486		0.993856	0.993856
Std time of agreement	0.001835	0.001835		0.002169	0.002169
Average time of end of negotiation	0.993486	0.993486		0.993856	0.993856
Std time of end of negotiation	0.001835	0.001835		0.002169	0.002169
Average rounds	265.1	265.1		263.6	263.6
Std rounds	3.900142	3.900142		3.627059	3.627059
Percentage of agreement	100	100		100	100
Average utility	0.8327	0.77961		0.81018	0.821782
Std utility	0.111656	0.054522		0.053672	0.12541
Average utility of agreements	0.8327	0.77961		0.81018	0.821782
Average discounted utility	0.742164	0.694844		0.722067	0.732396
Std discounted utility	0.099543	0.048632		0.048004	0.111739
Average discounted utility of agreements	0.742164	0.694844		0.722067	0.732396
Average nash distance	0.144252	0.144252		0.096115	0.096115
Average nash distance of agreements	0.144252	0.144252		0.096115	0.096115
Average pareto distance	0.025237	0.025237		0.023741	0.023741
Average pareto distance of agreements	0.025237	0.025237		0.023741	0.023741
Average kalai distance	0.097398	0.097398		0.10945	0.10945
Average kalai distance of agreements	0.097398	0.097398		0.10945	0.10945
Average social welfare	1.61231	1.61231		1.631962	1.631962
Average social welfare of agreements	1.61231	1.61231		1.631962	1.631962
Average exploration	0.007917	0.001278		0.00125	0.008028
Average joint exploration	0.009389	0.009389		0.009278	0.009278
Perc pareto bids	0.798574	0.225567		0.998496	0.586429
Average unfortunate moves	0.068514	0.008329		0.000758	0.315559
Average fortunate moves	0.041034	0		0	0.039084
Average nice moves	0	0		0	0
Average selfish moves	0.419651	0		0	0.314938
Average concession moves	0.470801	0.018903		0.026017	0.33042
Average silent moves	0	0.972768		0.973225	0

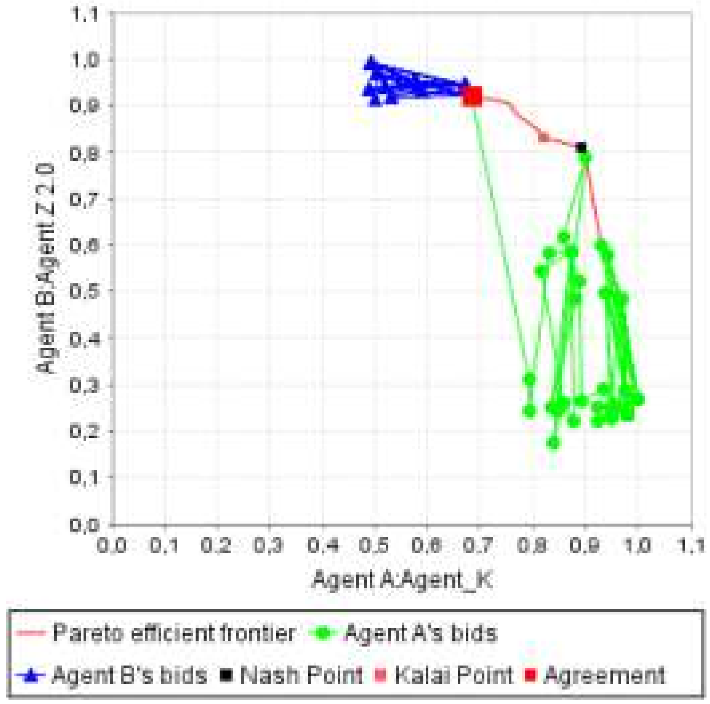

Figure 160 : Agent K vs Agent Z2.0 – Camera Domain

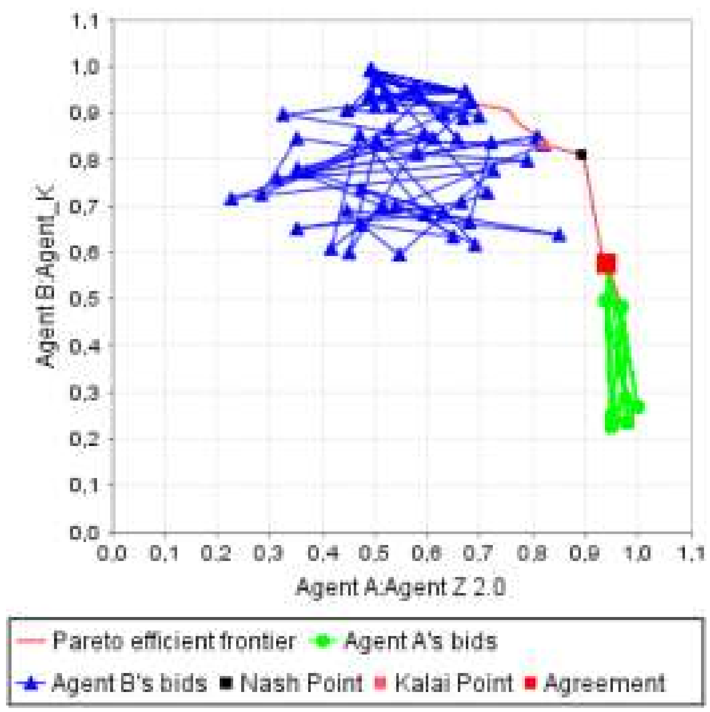

Figure 161 : Agent Z2.0 vs Agent K – Camera Domain

Table 85 : Agent Z2.0 vs Agent K – Camera Domain

Agent	Agent Z 2.0	Agent_K		Agent_K	Agent Z 2.0
Average time of agreement	0.892628	0.892628		0.9737	0.9737
Std time of agreement	0.065371	0.065371		0.049963	0.049963
Average time of end of negotiation	0.892628	0.892628		0.9737	0.9737
Std time of end of negotiation	0.065371	0.065371		0.049963	0.049963
Average rounds	301.4	301.4		329.1	329.1
Std rounds	22.0867	22.0867		16.9473	16.9473
Percentage of agreement	100	100		100	100
Average utility	0.868317	0.713886		0.700697	0.596415
Std utility	0.142472	0.035593		0.107311	0.254844
Average utility of agreements	0.868317	0.713886		0.700697	0.596415
Average discounted utility	0.78345	0.643876		0.625748	0.533412
Std discounted utility	0.130201	0.034988		0.094433	0.229768
Average discounted utility of agreements	0.78345	0.643876		0.625748	0.533412
Average nash distance	0.222724	0.222724		0.36446	0.36446
Average nash distance of agreements	0.222724	0.222724		0.36446	0.36446
Average pareto distance	0.026562	0.026562		0.189922	0.189922
Average pareto distance of agreements	0.026562	0.026562		0.189922	0.189922
Average kalai distance	0.159838	0.159838		0.32304	0.32304
Average kalai distance of agreements	0.159838	0.159838		0.32304	0.32304
Average social welfare	1.582202	1.582202		1.297112	1.297112
Average social welfare of agreements	1.582202	1.582202		1.297112	1.297112
Average exploration	0.009806	0.015222		0.02075	0.012472
Average joint exploration	0.024639	0.024639		0.032611	0.032611
Perc pareto bids	0.768165	0.554912		0.597987	0.540826
Average unfortunate moves	0.089744	0.162327		0.142222	0.303549
Average fortunate moves	0.062618	0.165369		0.130963	0.094975
Average nice moves	0	0		0	0
Average selfish moves	0.392348	0.232658		0.255232	0.282929
Average concession moves	0.45529	0.255869		0.272092	0.318547
Average silent moves	0	0.183777		0.199491	0

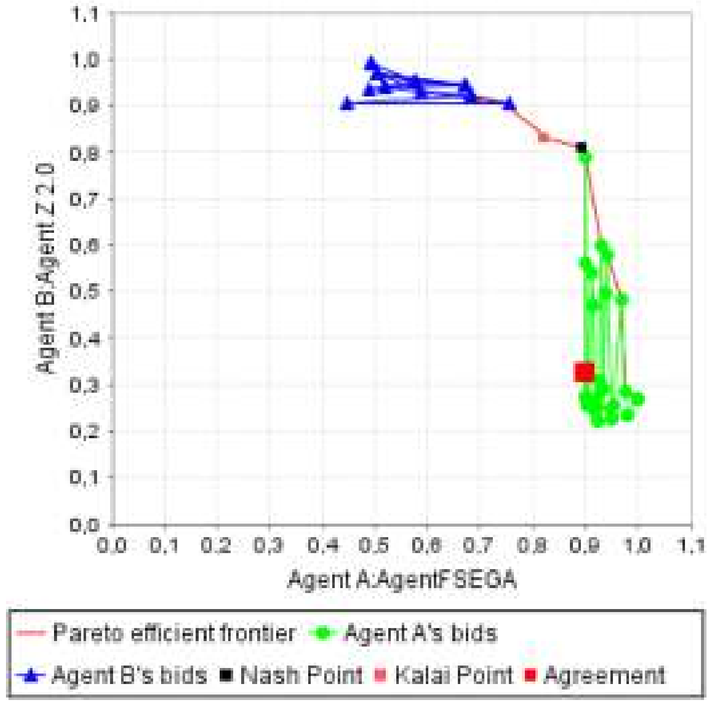

Figure 162 : FSEGA vs Agent Z2.0 – Camera Domain

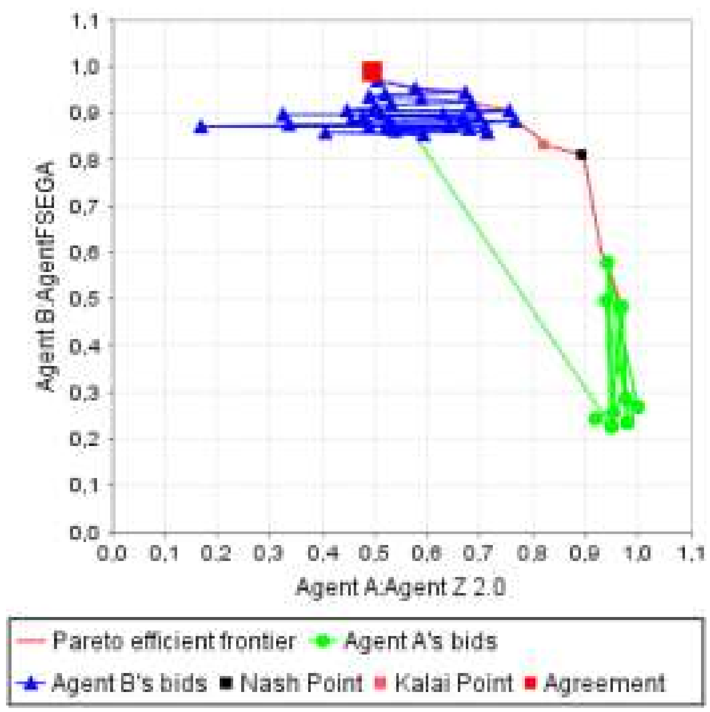

Figure 163 : Agent Z2.0 vs FSEGA – Camera Domain

Table 86 : Agent Z2.0 vs FSEGA – Camera Domain

Agent	Agent Z 2.0	AgentFSEGA		AgentFSEGA	Agent Z 2.0
Average time of agreement	0.994568	0.994568		0.99273	0.99273
Std time of agreement	0.002761	0.002761		0.00194	0.00194
Average time of end of negotiation	0.994568	0.994568		0.99273	0.99273
Std time of end of negotiation	0.002761	0.002761		0.00194	0.00194
Average rounds	52.6	52.6		70	70
Std rounds	4.788876	4.788876		8.178563	8.178563
Percentage of agreement	100	100		100	100
Average utility	0.323839	0.894514		0.878249	0.559751
Std utility	0.118538	0.003098		0.049665	0.177412
Average utility of agreements	0.323839	0.894514		0.878249	0.559751
Average discounted utility	0.288578	0.797152		0.782819	0.498936
Std discounted utility	0.105574	0.002687		0.044141	0.158144
Average discounted utility of agreements	0.288578	0.797152		0.782819	0.498936
Average nash distance	0.486845	0.486845		0.34134	0.34134
Average nash distance of agreements	0.486845	0.486845		0.34134	0.34134
Average pareto distance	0.088809	0.088809		0.088873	0.088873
Average pareto distance of agreements	0.088809	0.088809		0.088873	0.088873
Average kalai distance	0.511544	0.511544		0.269247	0.269247
Average kalai distance of agreements	0.511544	0.511544		0.269247	0.269247
Average social welfare	1.218354	1.218354		1.438	1.438
Average social welfare of agreements	1.218354	1.218354		1.438	1.438
Average exploration	0.004778	0.007167		0.009417	0.005722
Average joint exploration	0.011944	0.011944		0.015111	0.015111
Perc pareto bids	0.751489	0.263088		0.242401	0.56859
Average unfortunate moves	0.138022	0.500404		0.520277	0.336961
Average fortunate moves	0.041658	0		0	0.051257
Average nice moves	0	0		0	0
Average selfish moves	0.321495	0		0	0.274749
Average concession moves	0.498825	0.460533		0.449839	0.337032
Average silent moves	0	0.039063		0.029884	0

Appendix L : Camera Domain – Agent Z3.0

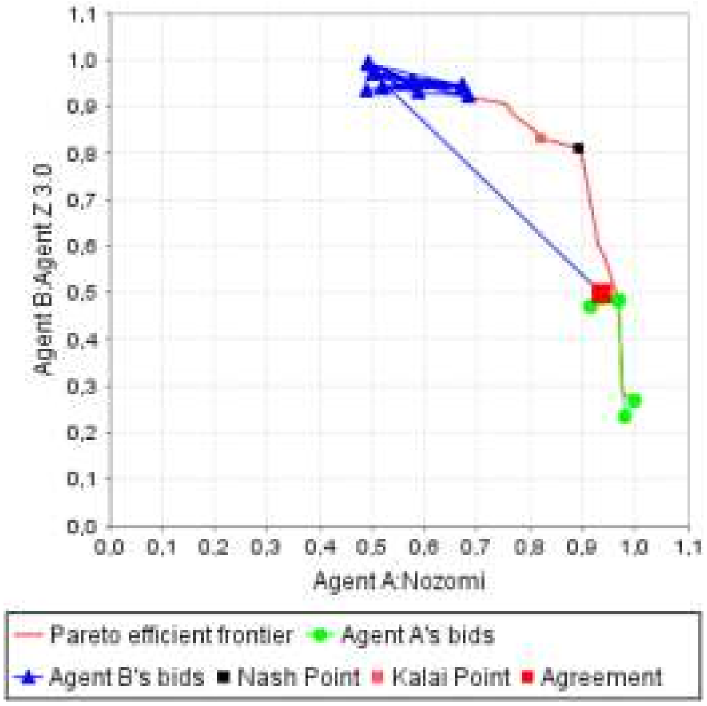

Figure 164 : Nozomi vs Agent Z3.0 – Camera Domain

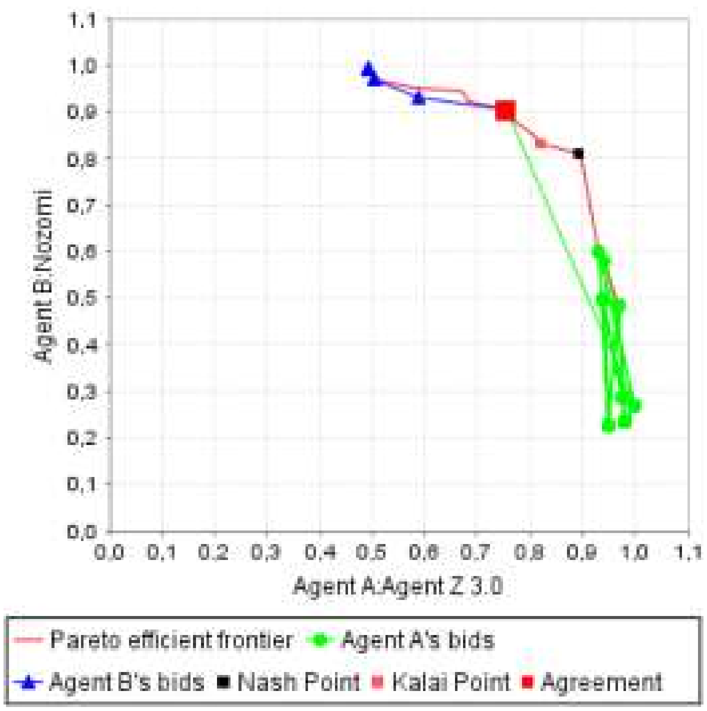

Figure 165 : Agent Z3.0 vs Nozomi – Camera Domain

Table 87 : Agent Z3.0 vs Nozomi – Camera Domain

Agent	Agent Z 3.0	Nozomi		Agent Z 3.0	Nozomi
Average time of agreement	0.993208	0.993208		0.992935	0.992935
Std time of agreement	0.001583	0.001583		0.001749	0.001749
Average time of end of negotiation	0.993208	0.993208		0.992935	0.992935
Std time of end of negotiation	0.001583	0.001583		0.001749	0.001749
Average rounds	338.4	338.4		340.2	340.2
Std rounds	0.843274	0.843274		1.932184	1.932184
Percentage of agreement	100	100		100	100
Average utility	0.497214	0.938		0.75584	0.900732
Std utility	5.85E-17	0		0.003289	0.00672
Average utility of agreements	0.497214	0.938		0.75584	0.900732
Average discounted utility	0.443165	0.836037		0.6737	0.802845
Std discounted utility	8.13E-05	0.000153		0.002997	0.005918
Average discounted utility of agreements	0.443165	0.836037		0.6737	0.802845
Average nash distance	0.316971	0.316971		0.162305	0.162305
Average nash distance of agreements	0.316971	0.316971		0.162305	0.162305
Average pareto distance	0.035749	0.035749		0	0
Average pareto distance of agreements	0.035749	0.035749		0	0
Average kalai distance	0.3526	0.3526		0.095812	0.095812
Average kalai distance of agreements	0.3526	0.3526		0.095812	0.095812
Average social welfare	1.435214	1.435214		1.656572	1.656572
Average social welfare of agreements	1.435214	1.435214		1.656572	1.656572
Average exploration	0.006639	0.001611		0.006556	0.001306
Average joint exploration	0.007222	0.007222		0.007944	0.007944
Perc pareto bids	0.897776	0.180271		0.752654	0.955689
Average unfortunate moves	0.0523	0.031509		0.179245	0
Average fortunate moves	0.054688	0.025564		0.005315	0
Average nice moves	0	0		0	0
Average selfish moves	0.15697	0.107016		0.153866	0.013652
Average concession moves	0.267544	0.114747		0.181013	0.033221
Average silent moves	0.468498	0.721164		0.48056	0.953126

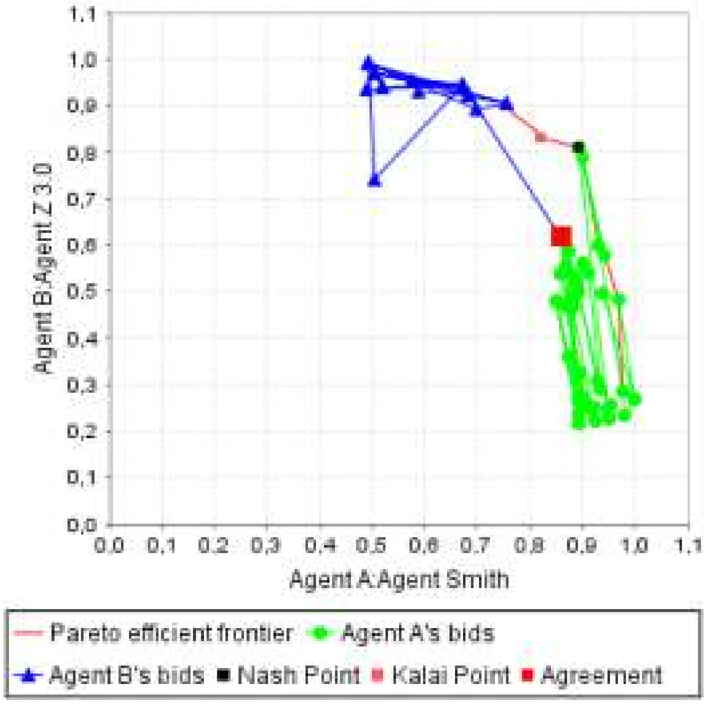

Figure 166 : Agent Smith vs Agent Z3.0 – Camera Domain

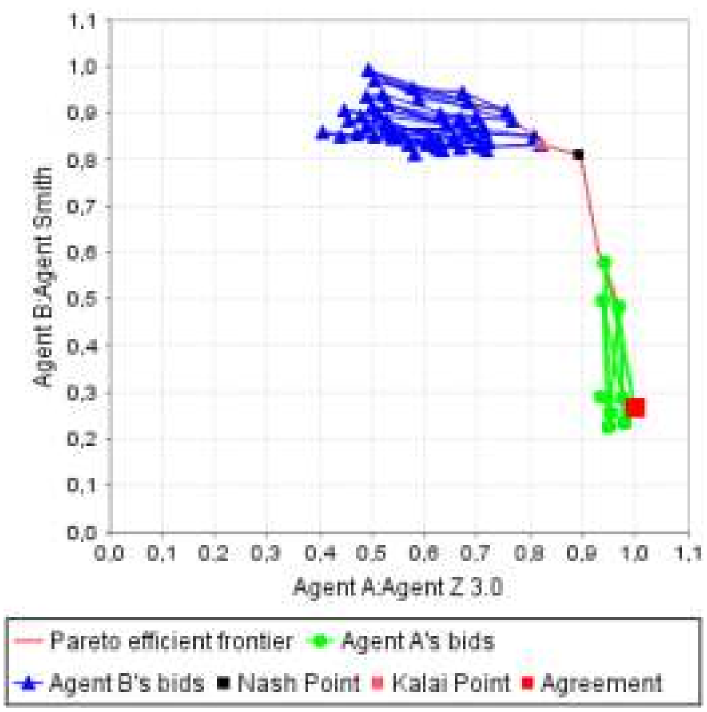

Figure 167 : Agent Z3.0 vs Agent Smith – Camera Domain

Table 88 : Agent Z3.0 vs Agent Smith – Camera Domain

Agent	Agent Z 3.0	Agent Smith		Agent Smith	Agent Z 3.0
Average time of agreement	0.56827	0.56827		0.607828	0.607828
Std time of agreement	0.037333	0.037333		0.0295	0.0295
Average time of end of negotiation	0.56827	0.56827		0.607828	0.607828
Std time of end of negotiation	0.037333	0.037333		0.0295	0.0295
Average rounds	91.1	91.1		111.8	111.8
Std rounds	5.321863	5.321863		4.315347	4.315347
Percentage of agreement	100	100		100	100
Average utility	0.806688	0.765969		0.374225	0.957326
Std utility	0.102583	0.142832		0.189668	0.089596
Average utility of agreements	0.806688	0.765969		0.374225	0.957326
Average discounted utility	0.755024	0.71762		0.349216	0.891993
Std discounted utility	0.093463	0.135919		0.178697	0.081327
Average discounted utility of agreements	0.755024	0.71762		0.349216	0.891993
Average nash distance	0.154516	0.154516		0.462559	0.462559
Average nash distance of agreements	0.154516	0.154516		0.462559	0.462559
Average pareto distance	0.050328	0.050328		0.013757	0.013757
Average pareto distance of agreements	0.050328	0.050328		0.013757	0.013757
Average kalai distance	0.135709	0.135709		0.487922	0.487922
Average kalai distance of agreements	0.135709	0.135709		0.487922	0.487922
Average social welfare	1.572657	1.572657		1.331551	1.331551
Average social welfare of agreements	1.572657	1.572657		1.331551	1.331551
Average exploration	0.005583	0.011083		0.014778	0.006833
Average joint exploration	0.016194	0.016194		0.021444	0.021444
Perc pareto bids	0.793534	0.198351		0.189562	0.591676
Average unfortunate moves	0.094303	0.115836		0.150529	0.315128
Average fortunate moves	0.058456	0.069175		0.023896	0.073967
Average nice moves	0	0		0	0
Average selfish moves	0.303767	0.302443		0.343001	0.207545
Average concession moves	0.497788	0.405902		0.447629	0.309486
Average silent moves	0.045685	0.106644		0.034945	0.093874

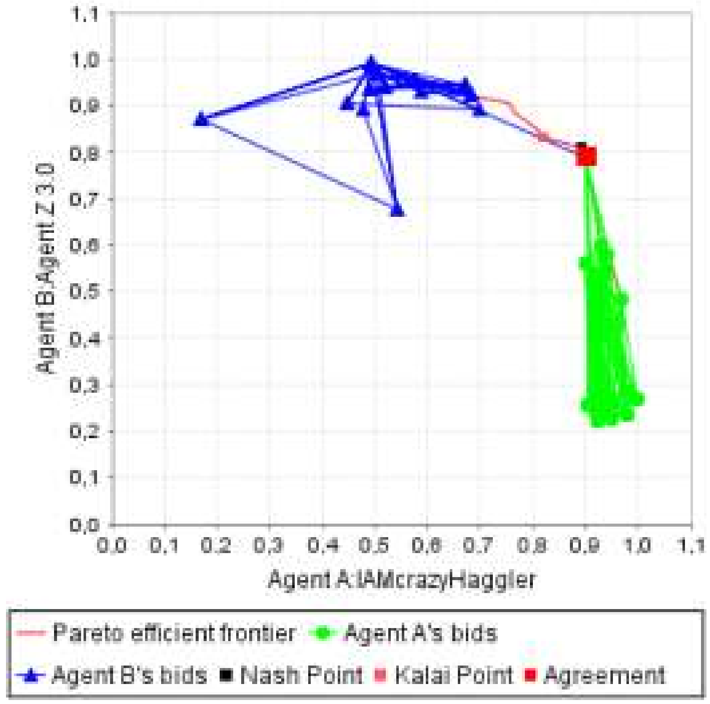

Figure 168 : IAMcrazyHaggler vs Agent Z3.0 – Camera Domain

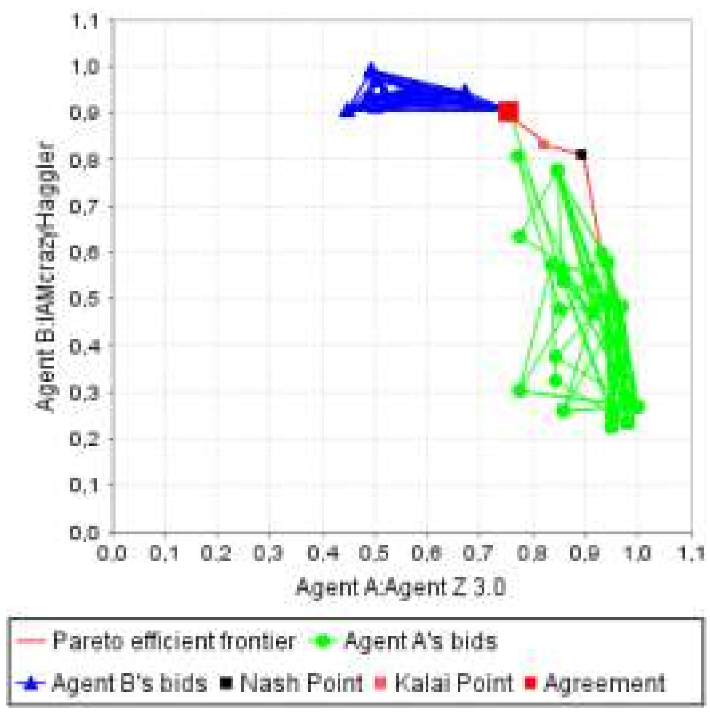

Figure 169 : Agent Z3.0 vs IAMcrazyHaggler – Camera Domain

Table 89 : Agent Z3.0 vs IAMcrazyHaggler – Camera Domain

Agent	Agent Z 3.0	IAMcrazyHa		IAMcrazyHa	Agent Z 3.0
Average time of agreement	0.778633	0.778633		0.858259	0.858259
Std time of agreement	0.227295	0.227295		0.217789	0.217789
Average time of end of negotiation	0.778633	0.778633		0.858259	0.858259
Std time of end of negotiation	0.227295	0.227295		0.217789	0.217789
Average rounds	263.8	263.8		290.6	290.6
Std rounds	76.83576	76.83576		74.93879	74.93879
Percentage of agreement	100	100		100	100
Average utility	0.75156	0.895977		0.895512	0.761297
Std utility	0.093103	0.013984		0.017119	0.017205
Average utility of agreements	0.75156	0.895977		0.895512	0.761297
Average discounted utility	0.686053	0.818807		0.81074	0.68965
Std discounted utility	0.080714	0.019812		0.015598	0.030081
Average discounted utility of agreements	0.686053	0.818807		0.81074	0.68965
Average nash distance	0.06086	0.06086		0.154946	0.154946
Average nash distance of agreements	0.06086	0.06086		0.154946	0.154946
Average pareto distance	0.011991	0.011991		0	0
Average pareto distance of agreements	0.011991	0.011991		0	0
Average kalai distance	0.121005	0.121005		0.088371	0.088371
Average kalai distance of agreements	0.121005	0.121005		0.088371	0.088371
Average social welfare	1.647537	1.647537		1.656809	1.656809
Average social welfare of agreements	1.647537	1.647537		1.656809	1.656809
Average exploration	0.009139	0.023472		0.0155	0.011528
Average joint exploration	0.031139	0.031139		0.025222	0.025222
Perc pareto bids	0.828422	0.293634		0.518224	0.594469
Average unfortunate moves	0.09054	0.209653		0.19093	0.264161
Average fortunate moves	0.063579	0.206268		0.207552	0.082217
Average nice moves	0	0		0	0
Average selfish moves	0.264339	0.258875		0.264707	0.21095
Average concession moves	0.393546	0.277198		0.253032	0.289097
Average silent moves	0.187996	0.048007		0.083779	0.153574

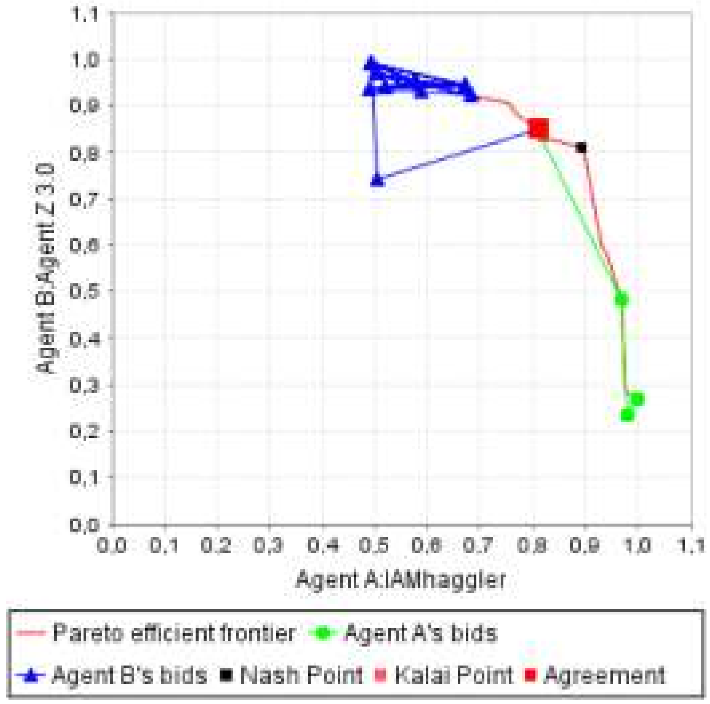

Figure 170 : IAMhaggler vs Agent Z3.0 – Camera Domain

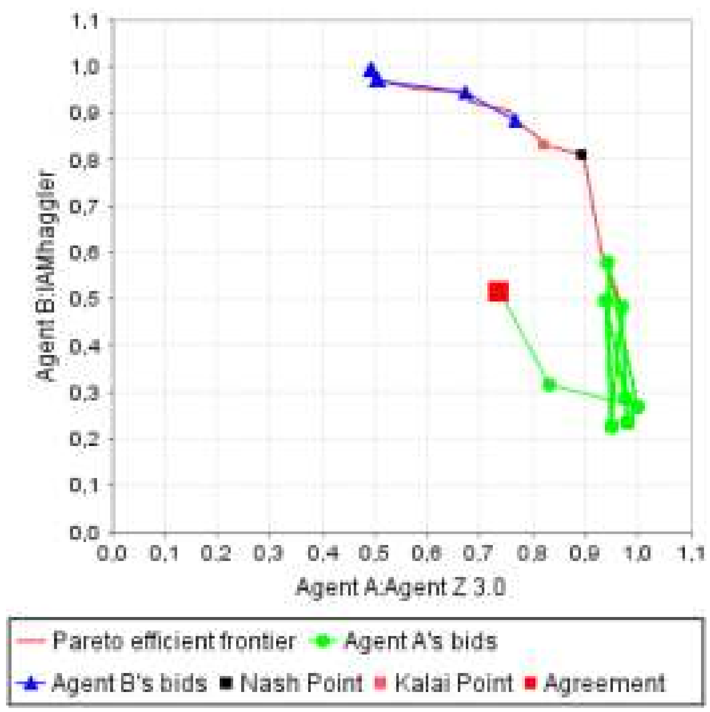

Figure 171 : Agent Z3.0 vs IAMhaggler – Camera Domain

Table 90 : Agent Z3.0 vs IAMhaggler – Camera Domain

Agent	Agent Z 3.0	IAMhaggler		IAMhaggler	Agent Z 3.0
Average time of agreement	0.988586	0.988586		0.99167	0.99167
Std time of agreement	0.002124	0.002124		0.002093	0.002093
Average time of end of negotiation	0.988586	0.988586		0.99167	0.99167
Std time of end of negotiation	0.002124	0.002124		0.002093	0.002093
Average rounds	263.2	263.2		260.8	260.8
Std rounds	3.552777	3.552777		2.898275	2.898275
Percentage of agreement	100	100		100	100
Average utility	0.812526	0.883697		0.651477	0.77224
Std utility	0.014968	0.026319		0.200392	0.041264
Average utility of agreements	0.812526	0.883697		0.651477	0.77224
Average discounted utility	0.724588	0.788063		0.580782	0.688425
Std discounted utility	0.013184	0.023624		0.178715	0.036942
Average discounted utility of agreements	0.724588	0.788063		0.580782	0.688425
Average nash distance	0.011438	0.011438		0.228977	0.228977
Average nash distance of agreements	0.011438	0.011438		0.228977	0.228977
Average pareto distance	0	0		0.1183	0.1183
Average pareto distance of agreements	0	0		0.1183	0.1183
Average kalai distance	0.070207	0.070207		0.189132	0.189132
Average kalai distance of agreements	0.070207	0.070207		0.189132	0.189132
Average social welfare	1.696223	1.696223		1.423717	1.423717
Average social welfare of agreements	1.696223	1.696223		1.423717	1.423717
Average exploration	0.005028	0.001111		0.001028	0.006417
Average joint exploration	0.006	0.006		0.007444	0.007444
Perc pareto bids	0.919835	0.222735		0.999219	0.76085
Average unfortunate moves	0.033057	0.007635		0	0.183186
Average fortunate moves	0.012963	0		0	0.006161
Average nice moves	0	0		0	0
Average selfish moves	0.202052	0		0	0.136335
Average concession moves	0.269595	0.01527		0.020945	0.199366
Average silent moves	0.482334	0.977095		0.979055	0.474952

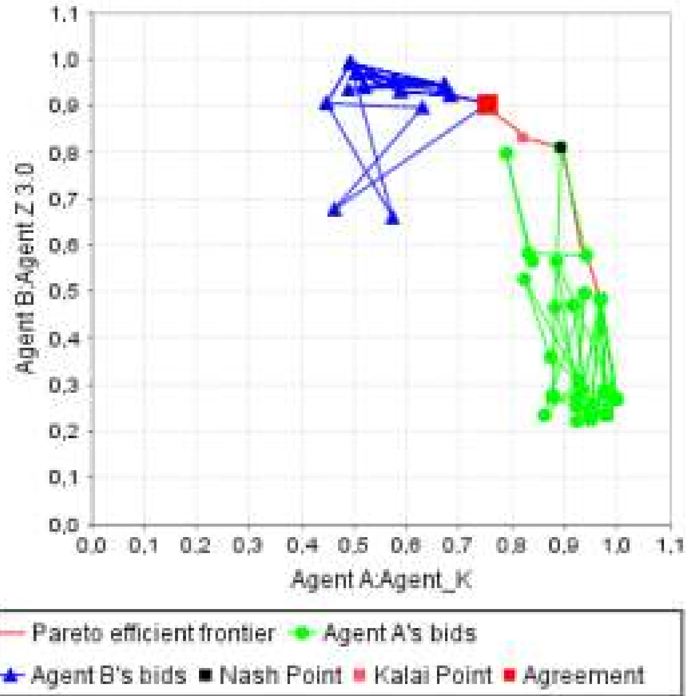

Figure 172 : Agent K vs Agent Z3.0 – Camera Domain

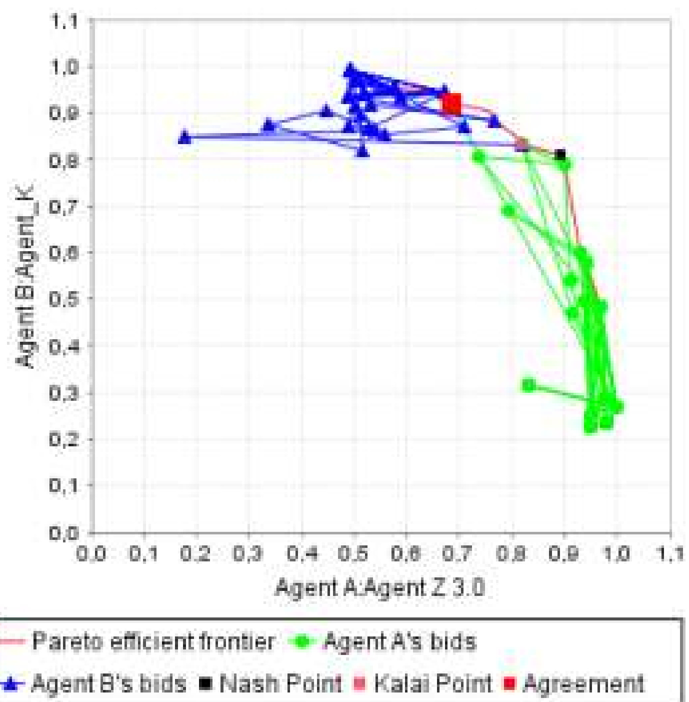

Figure 173 : Agent Z3.0 vs Agent K – Camera Domain

Table 91 : Agent Z3.0 vs Agent K – Camera Domain

Agent	Agent Z 3.0	Agent_K		Agent_K	Agent Z 3.0
Average time of agreement	0.813623	0.813623		0.752687	0.752687
Std time of agreement	0.019812	0.019812		0.046316	0.046316
Average time of end of negotiation	0.813623	0.813623		0.752687	0.752687
Std time of end of negotiation	0.019812	0.019812		0.046316	0.046316
Average rounds	273	273		251.5	251.5
Std rounds	6.616478	6.616478		16.15377	16.15377
Percentage of agreement	100	100		100	100
Average utility	0.770796	0.813294		0.847829	0.786791
Std utility	0.077641	0.040042		0.038625	0.089605
Average utility of agreements	0.770796	0.813294		0.847829	0.786791
Average discounted utility	0.701523	0.740199		0.777058	0.721109
Std discounted utility	0.071311	0.038058		0.036205	0.082241
Average discounted utility of agreements	0.701523	0.740199		0.777058	0.721109
Average nash distance	0.102336	0.102336		0.116367	0.116367
Average nash distance of agreements	0.102336	0.102336		0.116367	0.116367
Average pareto distance	0.063727	0.063727		0.011937	0.011937
Average pareto distance of agreements	0.063727	0.063727		0.011937	0.011937
Average kalai distance	0.085018	0.085018		0.074321	0.074321
Average kalai distance of agreements	0.085018	0.085018		0.074321	0.074321
Average social welfare	1.584091	1.584091		1.634619	1.634619
Average social welfare of agreements	1.584091	1.584091		1.634619	1.634619
Average exploration	0.010389	0.0105		0.009389	0.012278
Average joint exploration	0.019444	0.019444		0.021	0.021
Perc pareto bids	0.817528	0.603281		0.808243	0.565447
Average unfortunate moves	0.070084	0.169822		0.069621	0.270122
Average fortunate moves	0.053876	0.161062		0.065627	0.071869
Average nice moves	0	0		0	0
Average selfish moves	0.345975	0.231439		0.293348	0.254136
Average concession moves	0.397058	0.250595		0.322063	0.300491
Average silent moves	0.133007	0.187082		0.249343	0.103383

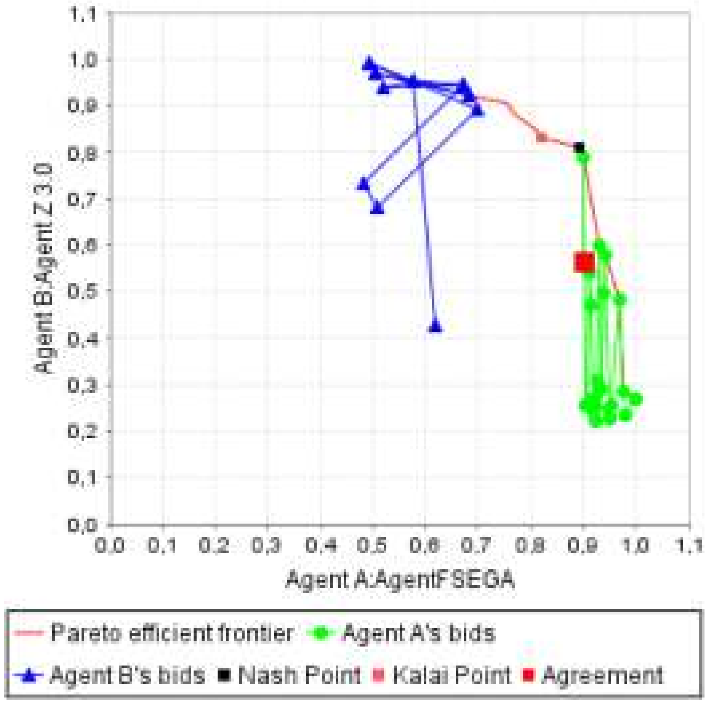

Figure 174 : FSEGA vs Agent Z3.0 – Camera Domain

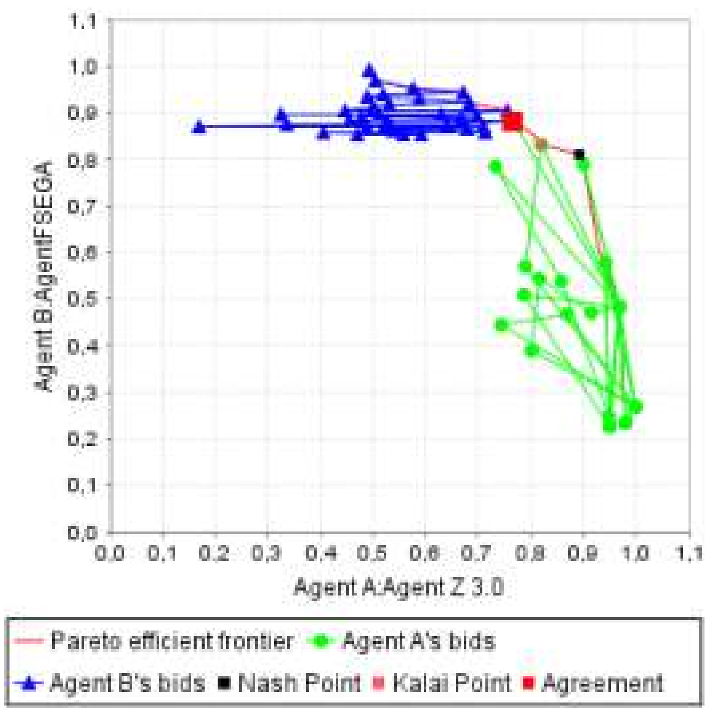

Figure 175 : Agent Z3.0 vs FSEGA – Camera Domain

Table 92 : Agent Z3.0 vs FSEGA – Camera Domain

Agent	Agent Z 3.0	AgentFSEGA		AgentFSEGA	Agent Z 3.0
Average time of agreement	0.96184	0.96184		0.992486	0.992486
Std time of agreement	NaN	NaN		NaN	NaN
Average time of end of negotiation	0.964587	0.964587		0.992324	0.992324
Std time of end of negotiation	0.057426	0.057426		0.001613	0.001613
Average rounds	44.5	44.5		61	61
Std rounds	1.433721	1.433721		10.66667	10.66667
Percentage of agreement	90	90		90	90
Average utility	0.439115	0.63064		0.793446	0.68868
Std utility	0.316219	0.435183		0.278789	0.241977
Average utility of agreements	0.487906	0.700711		0.881607	0.7652
Average discounted utility	0.393061	0.564801		0.707256	0.61387
Std discounted utility	0.28255	0.389782		0.248504	0.215692
Average discounted utility of agreements	0.436735	0.627557		0.78584	0.682078
Average nash distance	0.490256	0.490256		0.250276	0.250276
Average nash distance of agreements	0.410902	0.410902		0.144257	0.144257
Average pareto distance	0.326973	0.326973		0.101854	0.101854
Average pareto distance of agreements	0.250133	0.250133		0	0
Average kalai distance	0.507472	0.507472		0.184585	0.184585
Average kalai distance of agreements	0.434285	0.434285		0.075521	0.075521
Average social welfare	1.069755	1.069755		1.482126	1.482126
Average social welfare of agreements	1.188617	1.188617		1.646807	1.646807
Average exploration	0.004278	0.005972		0.008056	0.006333
Average joint exploration	0.009944	0.009944		0.014333	0.014333
Perc pareto bids	0.755204	0.302005		0.271206	0.535143
Average unfortunate moves	0.056494	0.497619		0.526067	0.17418
Average fortunate moves	0.094632	0		0	0.161031
Average nice moves	0	0		0	0
Average selfish moves	0.248074	0		0	0.292089
Average concession moves	0.453009	0.455801		0.438031	0.308253
Average silent moves	0.147792	0.04658		0.035902	0.064446

Appendix M : ADG Car Domain – Agent Z1.0

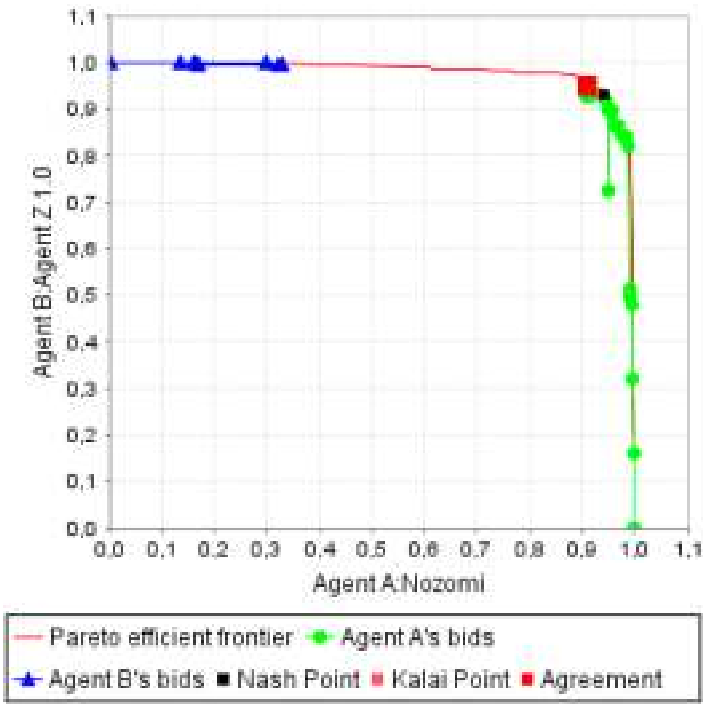

Figure 176 : Nozomi vs Agent Z1.0 – ADG Car Domain

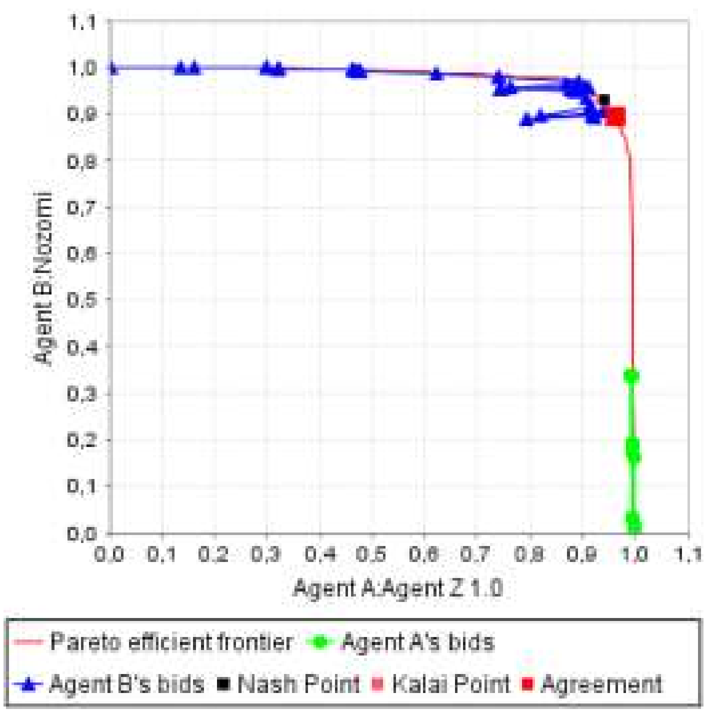

Figure 177 : Agent Z1.0 vs Nozomi – ADG Car Domain

Table 93 : Agent Z1.0 vs Nozomi – ADG Car Domain

Agent	Agent Z 1.0	Nozomi		Nozomi	Agent Z 1.0
Average time of agreement	0.378692	0.378692		0.702121	0.702121
Std time of agreement	0.205767	0.205767		0.250969	0.250969
Average time of end of negotiation	0.378692	0.378692		0.702121	0.702121
Std time of end of negotiation	0.205767	0.205767		0.250969	0.250969
Average rounds	146.8	146.8		275.2	275.2
Std rounds	81.56497	81.56497		98.84758	98.84758
Percentage of agreement	100	100		100	100
Average utility	0.95618	0.87898		0.85408	0.95246
Std utility	0.010527	0.035012		0.060543	0.015634
Average utility of agreements	0.95618	0.87898		0.85408	0.95246
Average discounted utility	0.95618	0.87898		0.85408	0.95246
Std discounted utility	0.010527	0.035012		0.060543	0.015634
Average discounted utility of agreements	0.95618	0.87898		0.85408	0.95246
Average nash distance	0.067204	0.067204		0.078628	0.078628
Average nash distance of agreements	0.067204	0.067204		0.078628	0.078628
Average pareto distance	0.011756	0.011756		0.023147	0.023147
Average pareto distance of agreements	0.011756	0.011756		0.023147	0.023147
Average kalai distance	0.060272	0.060272		0.081751	0.081751
Average kalai distance of agreements	0.060272	0.060272		0.081751	0.081751
Average social welfare	1.83516	1.83516		1.80654	1.80654
Average social welfare of agreements	1.83516	1.83516		1.80654	1.80654
Average exploration	0.000763	0.001424		0.002379	0.001571
Average joint exploration	0.002219	0.002219		0.003944	0.003944
Perc pareto bids	0.504265	0.376198		0.121644	0.302484
Average unfortunate moves	0.003141	0.033956		0.094286	0.00814
Average fortunate moves	0.001818	0.015274		0.084908	0.00061
Average nice moves	0	0		0.012329	0
Average selfish moves	0.128289	0.11378		0.098395	0.121974
Average concession moves	0.146381	0.371139		0.23931	0.134847
Average silent moves	0.720371	0.465852		0.470771	0.734428

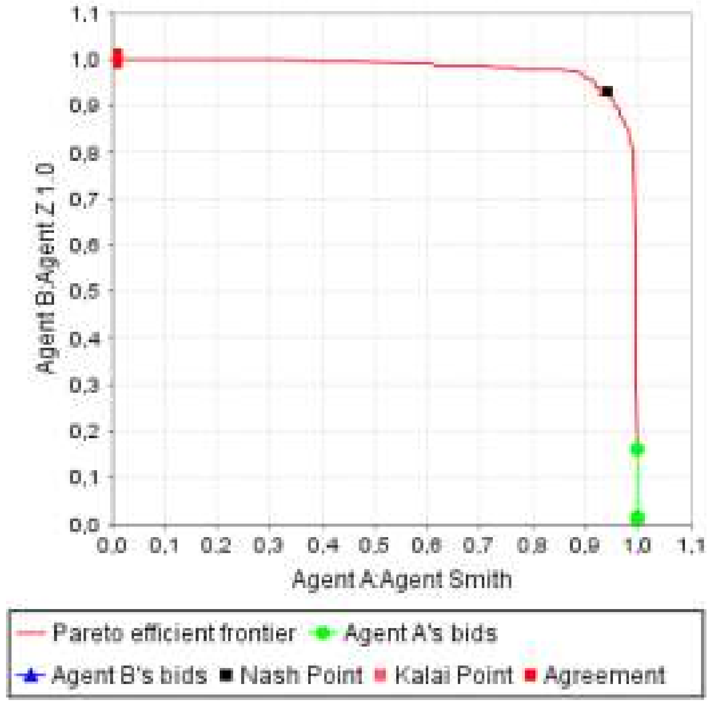

Figure 178 : Agent Smith vs Agent Z1.0 – ADG Car Domain

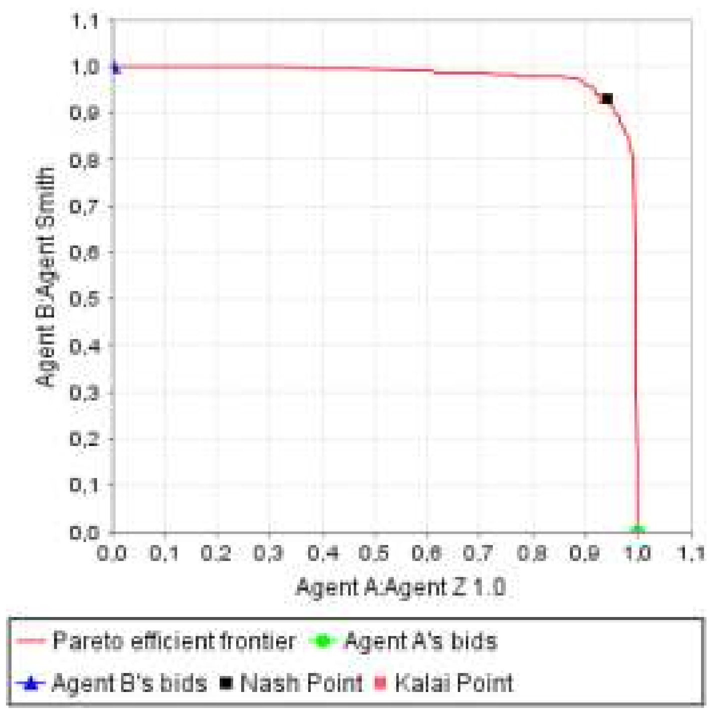

Figure 179 : Agent Z1.0 vs Agent Smith – ADG Car Domain

Table 94 : Agent Z1.0 vs Agent Smith – ADG Car Domain

Agent	Agent Z 1.0	Agent Smith		Agent Smith	Agent Z 1.0
Average time of agreement	0.772387	0.772387		NaN	NaN
Std time of agreement	0.021834	0.021834		NaN	NaN
Average time of end of negotiation	0.772387	0.772387		0.015754	0.015754
Std time of end of negotiation	0.021834	0.021834		0.001338	0.001338
Average rounds	10	10		3	3
Std rounds	0	0		0	0
Percentage of agreement	100	100		0	0
Average utility	0.9974	0.14365		0	1
Std utility	0.001578	0.052098		0	0
Average utility of agreements	0.9974	0.14365		NaN	Infinity
Average discounted utility	0.9974	0.14365		0	0
Std discounted utility	0.001578	0.052098		0	0
Average discounted utility of agreements	0.9974	0.14365		NaN	NaN
Average nash distance	0.799536	0.799536		0.931515	0.931515
Average nash distance of agreements	0.799536	0.799536		NaN	NaN
Average pareto distance	0.021323	0.021323		0	0
Average pareto distance of agreements	0.021323	0.021323		NaN	NaN
Average kalai distance	0.792592	0.792592		0.93397	0.93397
Average kalai distance of agreements	0.792592	0.792592		NaN	NaN
Average social welfare	1.14105	1.14105		1	1
Average social welfare of agreements	1.14105	1.14105		NaN	NaN
Average exploration	0.000122	0.000192		6.41E-05	6.41E-05
Average joint exploration	0.000314	0.000314		0.000128	0.000128
Perc pareto bids	0.86	0.6		1	1
Average unfortunate moves	0	0.25		NaN	NaN
Average fortunate moves	0	0		NaN	NaN
Average nice moves	0	0		NaN	NaN
Average selfish moves	0	0		NaN	NaN
Average concession moves	0.225	0.25		NaN	NaN
Average silent moves	0.775	0.5		NaN	NaN

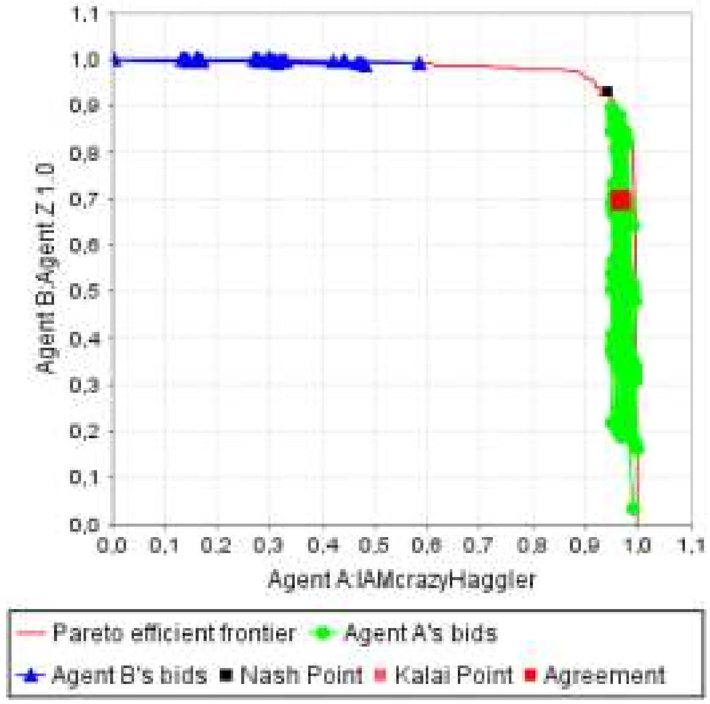

Figure 180 : IAMcrazyHaggler vs Agent Z1.0 – ADG Car Domain

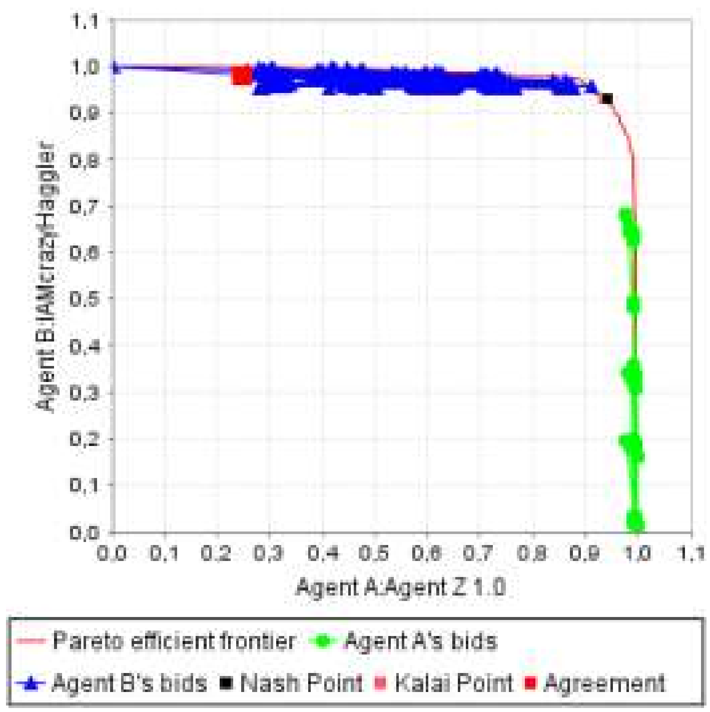

Figure 181 : Agent Z1.0 vs IAMcrazyHaggler – ADG Car Domain

Table 95 : Agent Z1.0 vs IAMcrazyHaggler – ADG Car Domain

Agent	Agent Z 1.0	IAMcrazyHa		IAMcrazyHa	Agent Z 1.0
Average time of agreement	0.992178	0.992178		0.9916	0.9916
Std time of agreement	0.001613	0.001613		0.00118	0.00118
Average time of end of negotiation	0.992178	0.992178		0.9916	0.9916
Std time of end of negotiation	0.001613	0.001613		0.00118	0.00118
Average rounds	389.2	389.2		390	390
Std rounds	0.632456	0.632456		0	0
Percentage of agreement	100	100		100	100
Average utility	0.52018	0.96192		0.9663	0.48112
Std utility	0.279423	0.007757		0.012234	0.158083
Average utility of agreements	0.52018	0.96192		0.9663	0.48112
Average discounted utility	0.52018	0.96192		0.9663	0.48112
Std discounted utility	0.279423	0.007757		0.012234	0.158083
Average discounted utility of agreements	0.52018	0.96192		0.9663	0.48112
Average nash distance	0.41026	0.41026		0.460721	0.460721
Average nash distance of agreements	0.41026	0.41026		0.460721	0.460721
Average pareto distance	0.056771	0.056771		0.031305	0.031305
Average pareto distance of agreements	0.056771	0.056771		0.031305	0.031305
Average kalai distance	0.412894	0.412894		0.453782	0.453782
Average kalai distance of agreements	0.412894	0.412894		0.453782	0.453782
Average social welfare	1.4821	1.4821		1.44742	1.44742
Average social welfare of agreements	1.4821	1.4821		1.44742	1.44742
Average exploration	0.003693	0.012357		0.012389	0.004508
Average joint exploration	0.016101	0.016101		0.016884	0.016884
Perc pareto bids	0.378678	0.027679		0.024103	0.210256
Average unfortunate moves	0.013466	0.198882		0.172165	0.013402
Average fortunate moves	0.008795	0.188549		0.190722	0.009278
Average nice moves	0.002591	0.003087		0.007216	0.001546
Average selfish moves	0.239774	0.305509		0.317526	0.232474
Average concession moves	0.243929	0.303458		0.311856	0.223196
Average silent moves	0.491445	0.000515		0.000515	0.520103

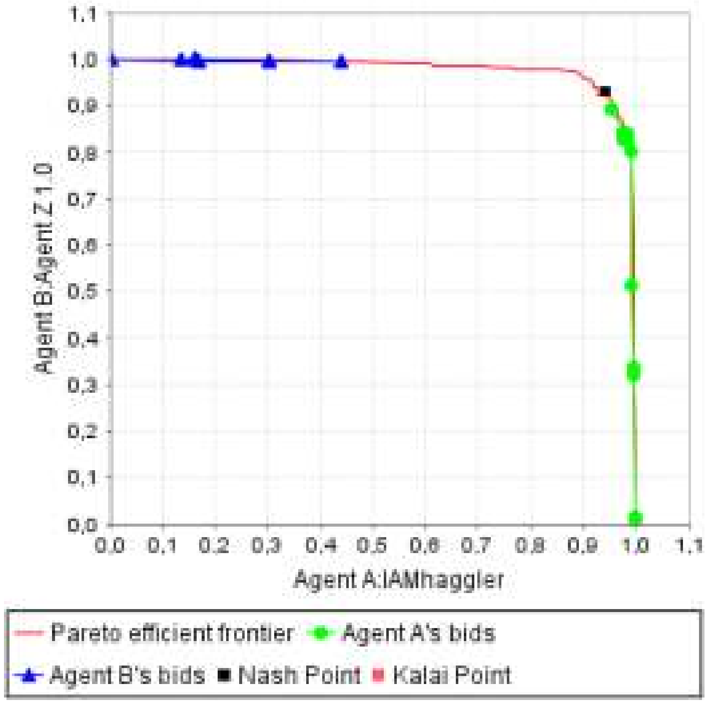

Figure 182 : IAMhaggler vs Agent Z1.0 – ADG Car Domain

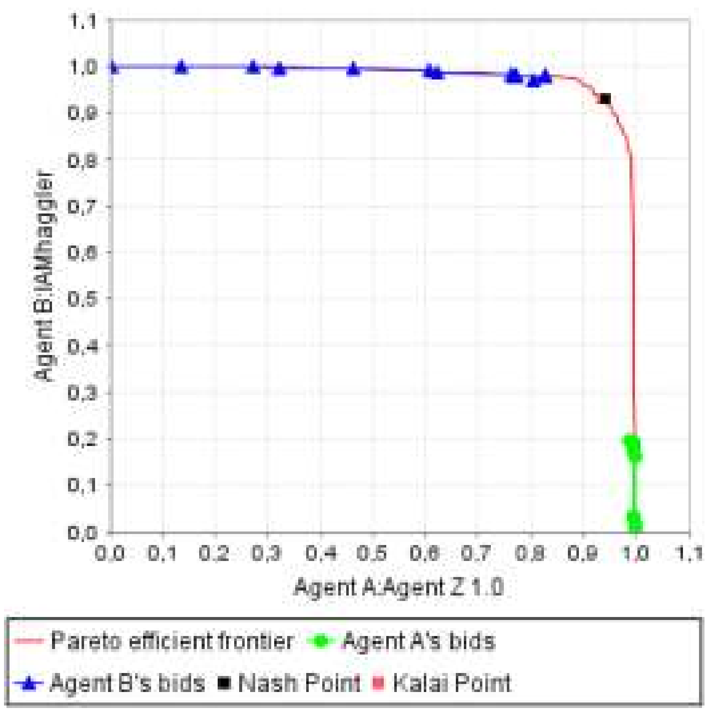

Figure 183 : Agent Z1.0 vs IAMhaggler – ADG Car Domain

Table 96 : Agent Z1.0 vs IAMhaggler – ADG Car Domain

Agent	Agent Z 1.0	IAMhaggler		IAMhaggler	Agent Z 1.0
Average time of agreement	0.993292	0.993292		0.996828	0.996828
Std time of agreement	NaN	NaN		NaN	NaN
Average time of end of negotiation	0.99225	0.99225		0.992173	0.992173
Std time of end of negotiation	0.002186	0.002186		0.004002	0.004002
Average rounds	90.2	90.2		88.9	88.9
Std rounds	3.966527	3.966527		10.47165	10.47165
Percentage of agreement	60	60		30	30
Average utility	0.33508	0.55839		0.262	0.27104
Std utility	0.436932	0.481245		0.422141	0.439463
Average utility of agreements	0.558467	0.93065		0.873333	0.903467
Average discounted utility	0.33508	0.55839		0.262	0.27104
Std discounted utility	0.436932	0.481245		0.422141	0.439463
Average discounted utility of agreements	0.558467	0.93065		0.873333	0.903467
Average nash distance	0.760296	0.760296		0.95741	0.95741
Average nash distance of agreements	0.385665	0.385665		0.10614	0.10614
Average pareto distance	0.423208	0.423208		0.708964	0.708964
Average pareto distance of agreements	0.038679	0.038679		0.02988	0.02988
Average kalai distance	0.757905	0.757905		0.955268	0.955268
Average kalai distance of agreements	0.383958	0.383958		0.106967	0.106967
Average social welfare	0.89347	0.89347		0.53304	0.53304
Average social welfare of agreements	1.489117	1.489117		1.7768	1.7768
Average exploration	0.000628	0.000725		0.000744	0.000628
Average joint exploration	0.001321	0.001321		0.001366	0.001366
Perc pareto bids	0.357405	0.14518		0.917226	0.199456
Average unfortunate moves	0	0.031372		0.016164	0.005013
Average fortunate moves	0.004495	0		0.002439	0
Average nice moves	0	0.002273		0	0
Average selfish moves	0.122769	0.015323		0.004193	0.101063
Average concession moves	0.13935	0.189824		0.230383	0.132017
Average silent moves	0.733386	0.761209		0.746821	0.761907

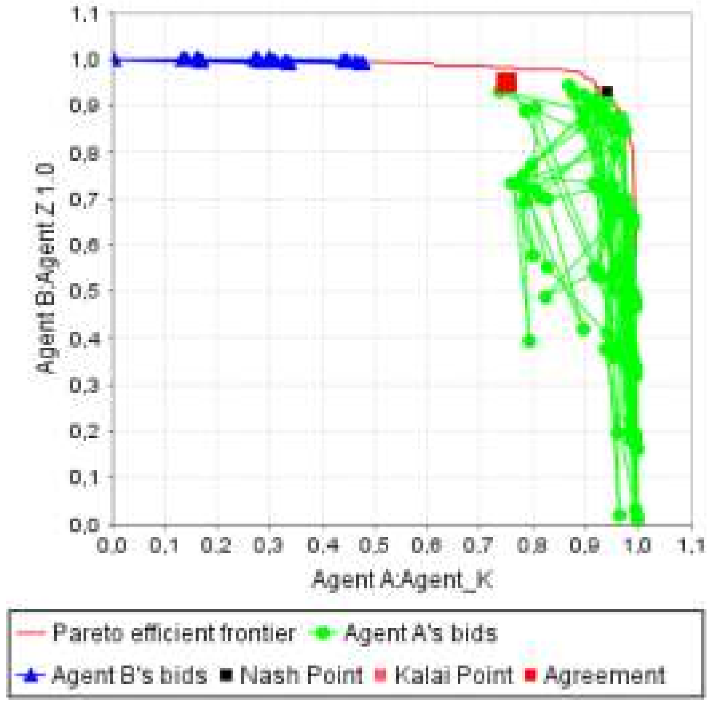

Figure 184 : Agent K vs Agent Z1.0 – ADG Car Domain

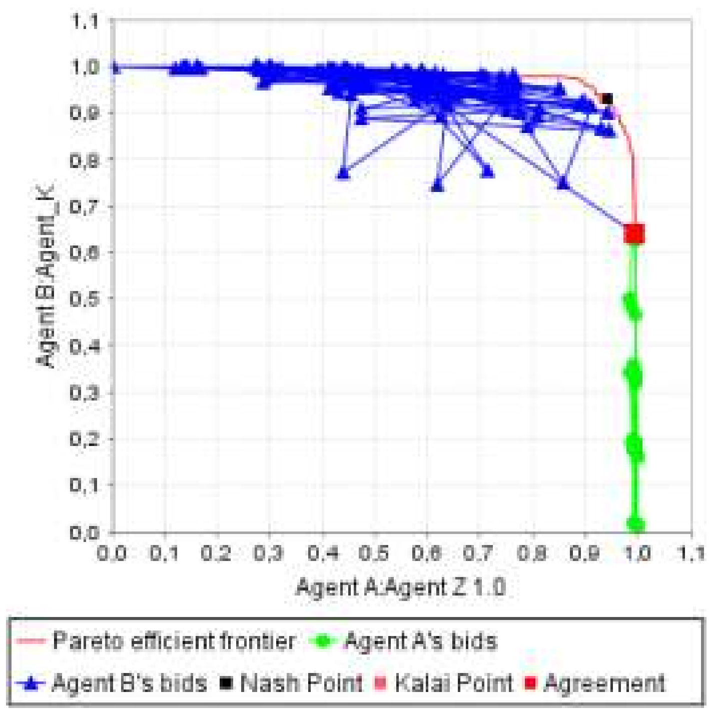

Figure 185 : Agent Z1.0 vs Agent K – ADG Car Domain

Table 97 : Agent Z1.0 vs Agent K – ADG Car Domain

Agent	Agent Z 1.0	Agent_K		Agent_K	Agent Z 1.0
Average time of agreement	0.795929	0.795929		0.73109	0.73109
Std time of agreement	0.072437	0.072437		0.102318	0.102318
Average time of end of negotiation	0.795929	0.795929		0.73109	0.73109
Std time of end of negotiation	0.072437	0.072437		0.102318	0.102318
Average rounds	311.8	311.8		287	287
Std rounds	28.6465	28.6465		40.46672	40.46672
Percentage of agreement	100	100		100	100
Average utility	0.9548	0.79236		0.75272	0.97455
Std utility	0.008588	0.092223		0.11201	0.018043
Average utility of agreements	0.9548	0.79236		0.75272	0.97455
Average discounted utility	0.9548	0.79236		0.75272	0.97455
Std discounted utility	0.008588	0.092223		0.11201	0.018043
Average discounted utility of agreements	0.9548	0.79236		0.75272	0.97455
Average nash distance	0.150906	0.150906		0.180766	0.180766
Average nash distance of agreements	0.150906	0.150906		0.180766	0.180766
Average pareto distance	0.023822	0.023822		0.014297	0.014297
Average pareto distance of agreements	0.023822	0.023822		0.014297	0.014297
Average kalai distance	0.143888	0.143888		0.184328	0.184328
Average kalai distance of agreements	0.143888	0.143888		0.184328	0.184328
Average social welfare	1.74716	1.74716		1.72727	1.72727
Average social welfare of agreements	1.74716	1.74716		1.72727	1.72727
Average exploration	0.00218	0.00924		0.00865	0.002167
Average joint exploration	0.011266	0.011266		0.010818	0.010818
Perc pareto bids	0.392371	0.076043		0.107328	0.243982
Average unfortunate moves	0.004073	0.152524		0.126245	0.008465
Average fortunate moves	0.004684	0.143301		0.129302	0.004446
Average nice moves	0.003224	0.008266		0.014021	0.003209
Average selfish moves	0.147929	0.329343		0.353007	0.139638
Average concession moves	0.156438	0.348069		0.3688	0.147793
Average silent moves	0.683652	0.018497		0.008625	0.696449

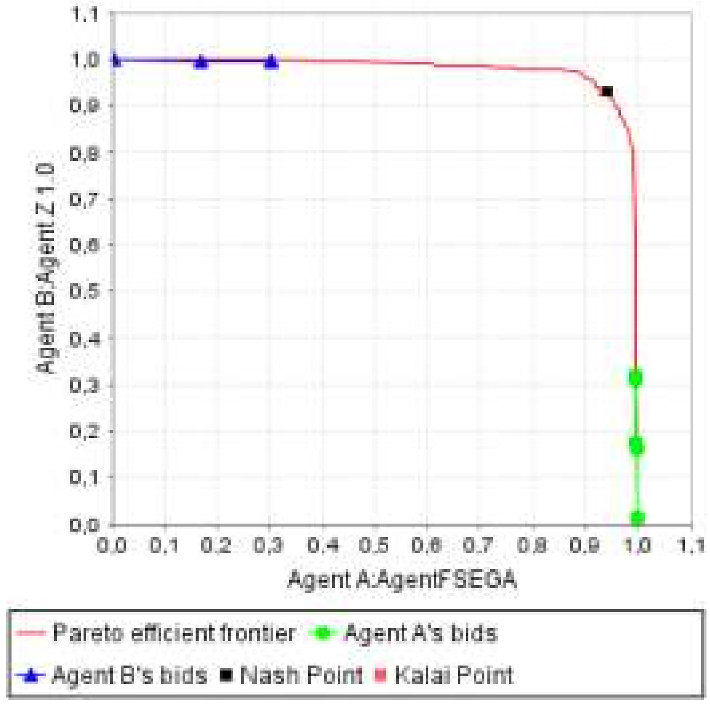

Figure 186 : FSEGA vs Agent Z1.0 – ADG Car Domain

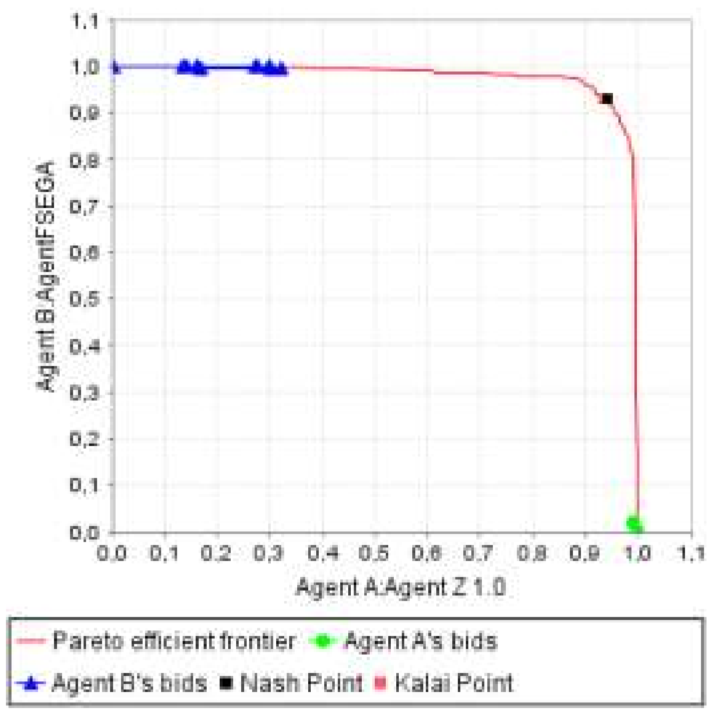

Figure 187 : Agent Z1.0 vs FSEGA – ADG Car Domain

Table 98 : Agent Z1.0 vs FSEGA – ADG Car Domain

Agent	Agent Z 1.0	AgentFSEGA		AgentFSEGA	Agent Z 1.0
Average time of agreement	NaN	NaN		0.993472	0.993472
Std time of agreement	NaN	NaN		NaN	NaN
Average time of end of negotiation	0.968251	0.968251		0.972293	0.972293
Std time of end of negotiation	0.018426	0.018426		0.023571	0.023571
Average rounds	34.2	34.2		32.3	32.3
Std rounds	1.47573	1.47573		1.418136	1.418136
Percentage of agreement	0	0		30	30
Average utility	0	0		0.2988	0.09945
Std utility	0	0		0.481114	0.173437
Average utility of agreements	NaN	NaN		0.996	0.3315
Average discounted utility	0	0		0.2988	0.09945
Std discounted utility	0	0		0.481114	0.173437
Average discounted utility of agreements	NaN	NaN		0.996	0.3315
Average nash distance	1.322241	1.322241		1.109326	1.109326
Average nash distance of agreements	NaN	NaN		0.612527	0.612527
Average pareto distance	1	1		0.703244	0.703244
Average pareto distance of agreements	NaN	NaN		0.010813	0.010813
Average kalai distance	1.318826	1.318826		1.104842	1.104842
Average kalai distance of agreements	NaN	NaN		0.605548	0.605548
Average social welfare	0	0		0.39825	0.39825
Average social welfare of agreements	NaN	NaN		1.3275	1.3275
Average exploration	0.000212	0.000596		0.00068	0.00018
Average joint exploration	0.000808	0.000808		0.000859	0.000859
Perc pareto bids	0.830515	0.351471		0.480784	0.879984
Average unfortunate moves	0.005882	0.204338		0.35119	0
Average fortunate moves	0	0		0	0
Average nice moves	0	0.124461		0.174643	0
Average selfish moves	0.030515	0		0	0.012917
Average concession moves	0.124044	0.186691		0.203214	0.108064
Average silent moves	0.839559	0.48451		0.270952	0.87902

Appendix N : ADG Car Domain – Agent Z2.0

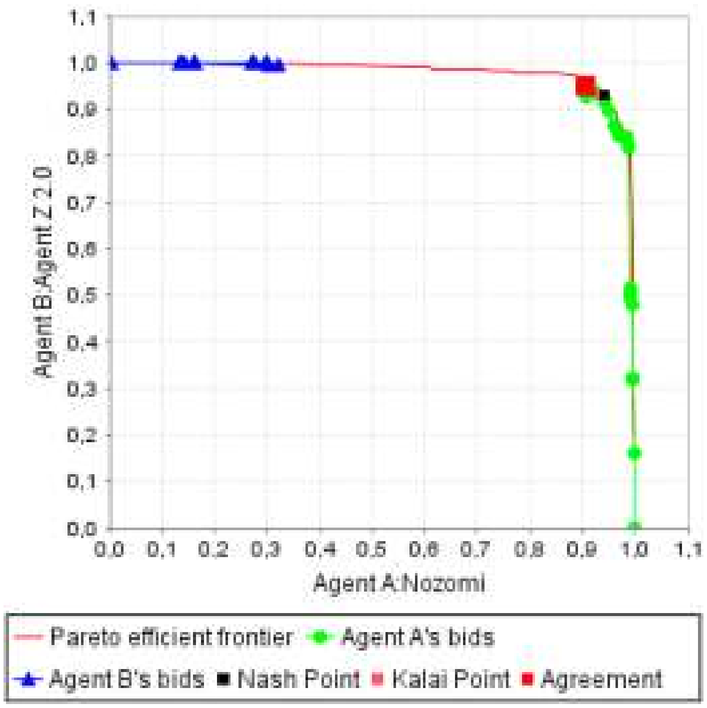

Figure 188 : Nozomi vs Agent Z2.0 – ADG Car Domain

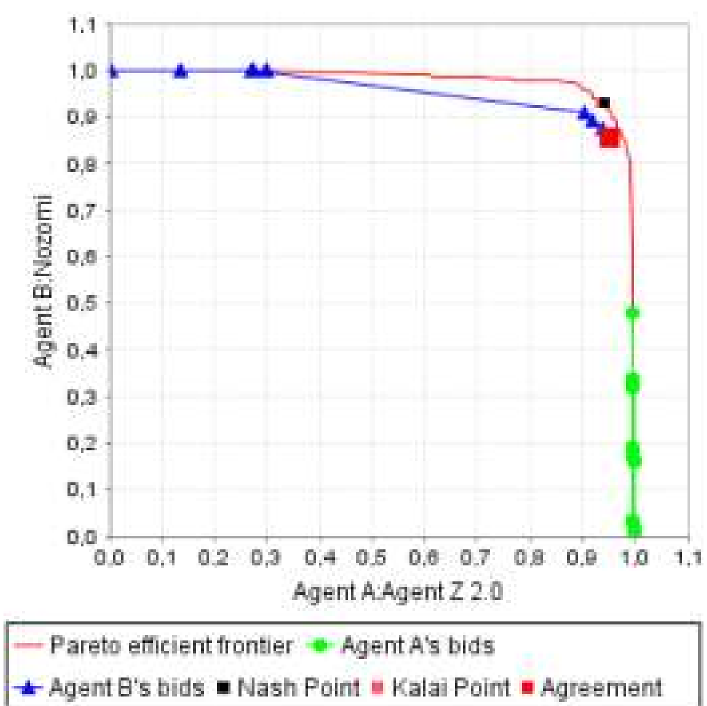

Figure 189 : Agent Z2.0 vs Nozomi – ADG Car Domain

Table 99 : Agent Z2.0 vs Nozomi – ADG Car Domain

Agent	Agent Z 2.0	Nozomi		Nozomi	Agent Z 2.0
Average time of agreement	0.874902	0.874902		0.871272	0.871272
Std time of agreement	0.068097	0.068097		0.069712	0.069712
Average time of end of negotiation	0.874902	0.874902		0.871272	0.871272
Std time of end of negotiation	0.068097	0.068097		0.069712	0.069712
Average rounds	211.2	211.2		212.1	212.1
Std rounds	15.33188	15.33188		15.93354	15.93354
Percentage of agreement	100	100		100	100
Average utility	0.95612	0.81604		0.86492	0.89465
Std utility	0.008942	0.102883		0.052669	0.159652
Average utility of agreements	0.95612	0.81604		0.86492	0.89465
Average discounted utility	0.95612	0.81604		0.86492	0.89465
Std discounted utility	0.008942	0.102883		0.052669	0.159652
Average discounted utility of agreements	0.95612	0.81604		0.86492	0.89465
Average nash distance	0.128096	0.128096		0.128569	0.128569
Average nash distance of agreements	0.128096	0.128096		0.128569	0.128569
Average pareto distance	0.01766	0.01766		0.029467	0.029467
Average pareto distance of agreements	0.01766	0.01766		0.029467	0.029467
Average kalai distance	0.121125	0.121125		0.130902	0.130902
Average kalai distance of agreements	0.121125	0.121125		0.130902	0.130902
Average social welfare	1.77216	1.77216		1.75957	1.75957
Average social welfare of agreements	1.77216	1.77216		1.75957	1.75957
Average exploration	0.001231	0.000911		0.000731	0.002347
Average joint exploration	0.002046	0.002046		0.003059	0.003059
Perc pareto bids	0.766961	0.817678		0.559635	0.436546
Average unfortunate moves	0.002625	0.0117		0.003443	0.004895
Average fortunate moves	0	0.005412		0.005644	0
Average nice moves	0.001724	0		0.001667	0.002895
Average selfish moves	0.45096	0.046095		0.045771	0.483288
Average concession moves	0.538177	0.134084		0.122085	0.499836
Average silent moves	0.006514	0.802708		0.82139	0.009087

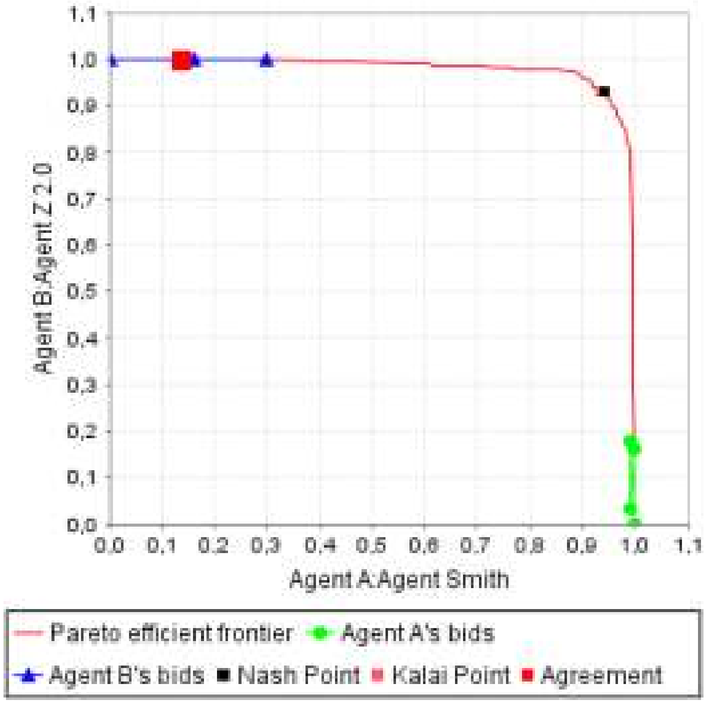

Figure 190 : Agent Smith vs Agent Z2.0 – ADG Car Domain

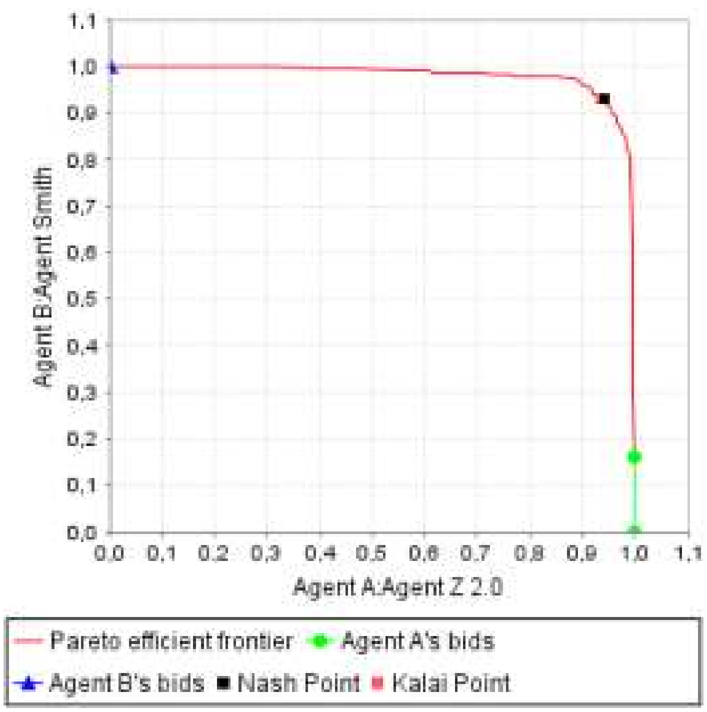

Figure 191 : Agent Z2.0 vs Agent Smith – ADG Car Domain

Table 100 : Agent Z2.0 vs Agent Smith – ADG Car Domain

Agent	Agent Z 2.0	Agent Smith		Agent Smith	Agent Z 2.0
Average time of agreement	0.758748	0.758748		NaN	NaN
Std time of agreement	0.008635	0.008635		NaN	NaN
Average time of end of negotiation	0.758748	0.758748		0.0191	0.0191
Std time of end of negotiation	0.008635	0.008635		0.000745	0.000745
Average rounds	10	10		3	3
Std rounds	0	0		0	0
Percentage of agreement	100	100		0	0
Average utility	0.9986	0.1462		0	0.9984
Std utility	0.000516	0.013168		0	0
Average utility of agreements	0.9986	0.1462		NaN	Infinity
Average discounted utility	0.9986	0.1462		0	0
Std discounted utility	0.000516	0.013168		0	0
Average discounted utility of agreements	0.9986	0.1462		NaN	NaN
Average nash distance	0.797092	0.797092		0.931414	0.931414
Average nash distance of agreements	0.797092	0.797092		NaN	NaN
Average pareto distance	0.010208	0.010208		0.0016	0.0016
Average pareto distance of agreements	0.010208	0.010208		NaN	NaN
Average kalai distance	0.790146	0.790146		0.933858	0.933858
Average kalai distance of agreements	0.790146	0.790146		NaN	NaN
Average social welfare	1.1448	1.1448		0.9984	0.9984
Average social welfare of agreements	1.1448	1.1448		NaN	NaN
Average exploration	0.000256	0.000256		6.41E-05	0.000128
Average joint exploration	0.000513	0.000513		0.000192	0.000192
Perc pareto bids	0.8	0.6		1	1
Average unfortunate moves	0	0.25		NaN	NaN
Average fortunate moves	0	0		NaN	NaN
Average nice moves	0	0.15		NaN	NaN
Average selfish moves	0.25	0.1		NaN	NaN
Average concession moves	0.75	0.25		NaN	NaN
Average silent moves	0	0.25		NaN	NaN

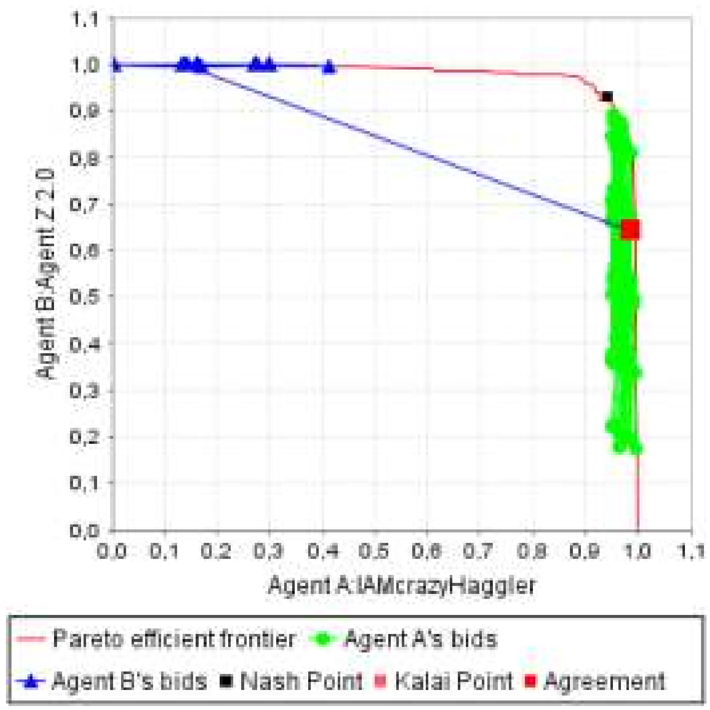

Figure 192 : IAMcrazyHaggler vs Agent Z2.0 – ADG Car Domain

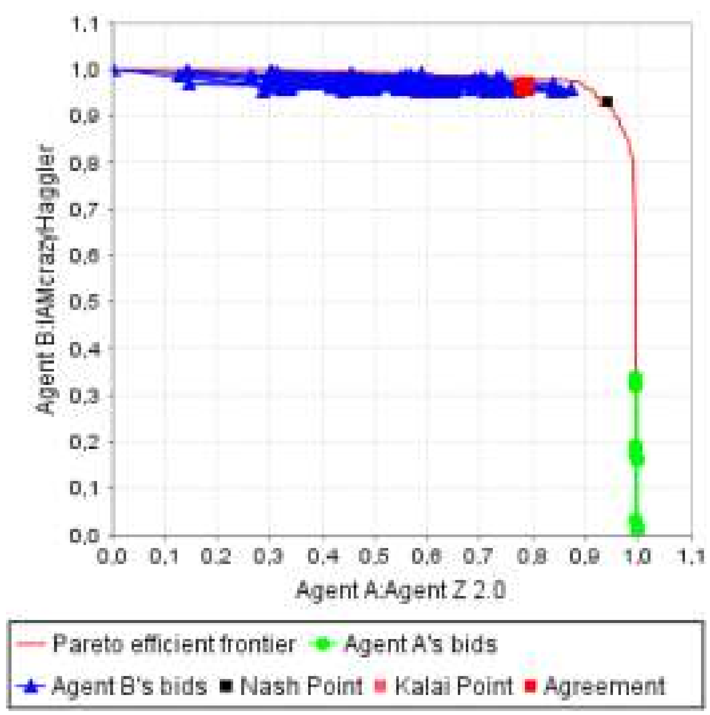

Figure 193 : Agent Z2.0 vs IAMcrazyHaggler – ADG Car Domain

Table 101 : Agent Z2.0 vs IAMcrazyHaggler – ADG Car Domain

Agent	Agent Z 2.0	IAMcrazyHa		IAMcrazyHa	Agent Z 2.0
Average time of agreement	0.993158	0.993158		0.994072	0.994072
Std time of agreement	0.002331	0.002331		0.002197	0.002197
Average time of end of negotiation	0.993158	0.993158		0.994072	0.994072
Std time of end of negotiation	0.002331	0.002331		0.002197	0.002197
Average rounds	249.2	249.2		251.1	251.1
Std rounds	5.473167	5.473167		5.486347	5.486347
Percentage of agreement	100	100		100	100
Average utility	0.49512	0.96782		0.97492	0.56811
Std utility	0.196781	0.01046		0.015415	0.181447
Average utility of agreements	0.49512	0.96782		0.97492	0.56811
Average discounted utility	0.49512	0.96782		0.97492	0.56811
Std discounted utility	0.196781	0.01046		0.015415	0.181447
Average discounted utility of agreements	0.49512	0.96782		0.97492	0.56811
Average nash distance	0.436015	0.436015		0.375239	0.375239
Average nash distance of agreements	0.436015	0.436015		0.375239	0.375239
Average pareto distance	0.04367	0.04367		0.019889	0.019889
Average pareto distance of agreements	0.04367	0.04367		0.019889	0.019889
Average kalai distance	0.438688	0.438688		0.368243	0.368243
Average kalai distance of agreements	0.438688	0.438688		0.368243	0.368243
Average social welfare	1.46294	1.46294		1.54303	1.54303
Average social welfare of agreements	1.46294	1.46294		1.54303	1.54303
Average exploration	0.001558	0.0079		0.007951	0.002334
Average joint exploration	0.009253	0.009253		0.010273	0.010273
Perc pareto bids	0.676624	0.019183		0.022194	0.435854
Average unfortunate moves	0.055122	0.218414		0.176745	0.092966
Average fortunate moves	0	0.197132		0.184366	0.006526
Average nice moves	0.03656	0.004784		0.008842	0.057605
Average selfish moves	0.373601	0.287473		0.314291	0.368263
Average concession moves	0.494975	0.290579		0.314193	0.39529
Average silent moves	0.039742	0.001619		0.001563	0.07935

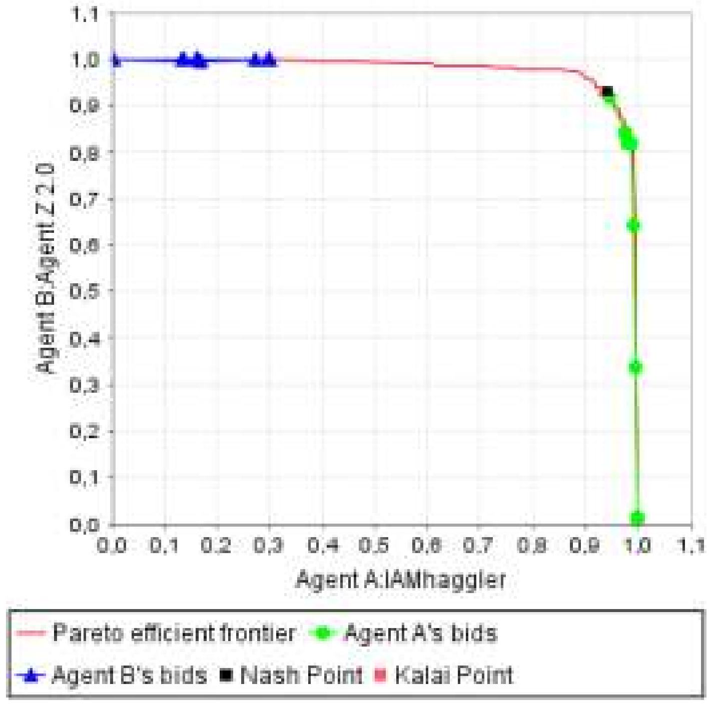

Figure 194 : IAMhaggler vs Agent Z2.0 – ADG Car Domain

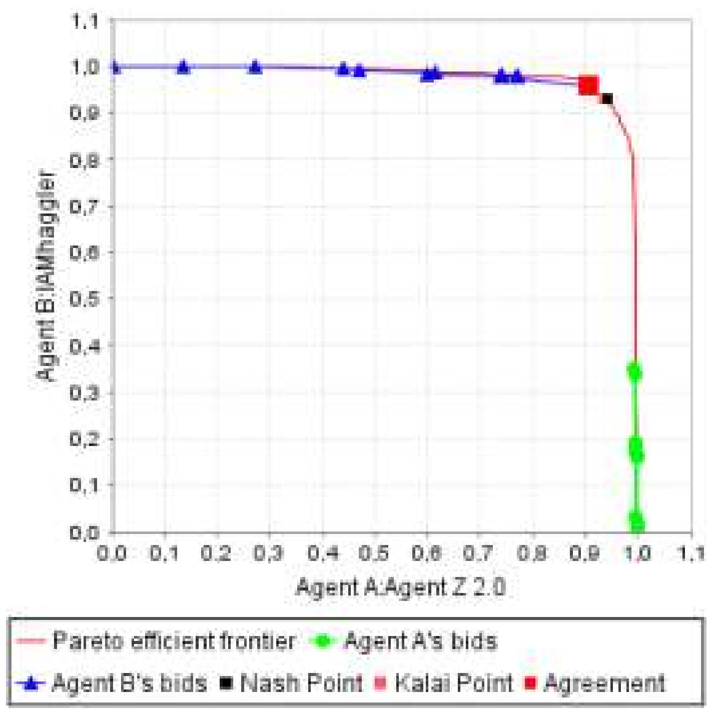

Figure 195 : Agent Z2.0 vs IAMhaggler – ADG Car Domain

Table 102 : Agent Z2.0 vs IAMhaggler – ADG Car Domain

Agent	Agent Z 2.0	IAMhaggler		IAMhaggler	Agent Z 2.0
Average time of agreement	0.995851	0.995851		0.994811	0.994811
Std time of agreement	NaN	NaN		NaN	NaN
Average time of end of negotiation	0.99335	0.99335		0.994131	0.994131
Std time of end of negotiation	0.002534	0.002534		0.00225	0.00225
Average rounds	76.8	76.8		70.8	70.8
Std rounds	2.65832	2.65832		1.135292	1.135292
Percentage of agreement	30	30		50	50
Average utility	0.26708	0.28062		0.46352	0.44756
Std utility	0.431254	0.452986		0.489352	0.475405
Average utility of agreements	0.890267	0.9354		0.92704	0.89512
Average discounted utility	0.26708	0.28062		0.46352	0.44756
Std discounted utility	0.431254	0.452986		0.489352	0.475405
Average discounted utility of agreements	0.890267	0.9354		0.92704	0.89512
Average nash distance	0.951984	0.951984		0.695831	0.695831
Average nash distance of agreements	0.08805	0.08805		0.069421	0.069421
Average pareto distance	0.702013	0.702013		0.504687	0.504687
Average pareto distance of agreements	0.006711	0.006711		0.009374	0.009374
Average kalai distance	0.949841	0.949841		0.693218	0.693218
Average kalai distance of agreements	0.088877	0.088877		0.067609	0.067609
Average social welfare	0.5477	0.5477		0.91108	0.91108
Average social welfare of agreements	1.825667	1.825667		1.82216	1.82216
Average exploration	0.000718	0.000596		0.000616	0.000968
Average joint exploration	0.001238	0.001238		0.001577	0.001577
Perc pareto bids	0.759542	0.153037		0.359015	0.321885
Average unfortunate moves	0.010763	0.018793		0.008739	0.054631
Average fortunate moves	0	0		0	0
Average nice moves	0.002632	0		0	0
Average selfish moves	0.383072	0		0.026392	0.342834
Average concession moves	0.603534	0.202393		0.23752	0.386279
Average silent moves	0	0.778814		0.727349	0.216256

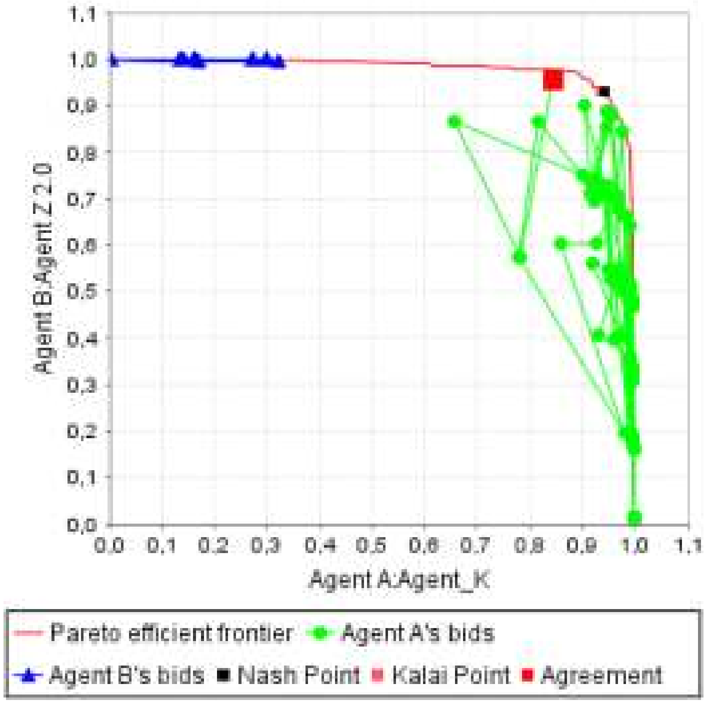

Figure 196 : Agent K vs Agent Z2.0 – ADG Car Domain

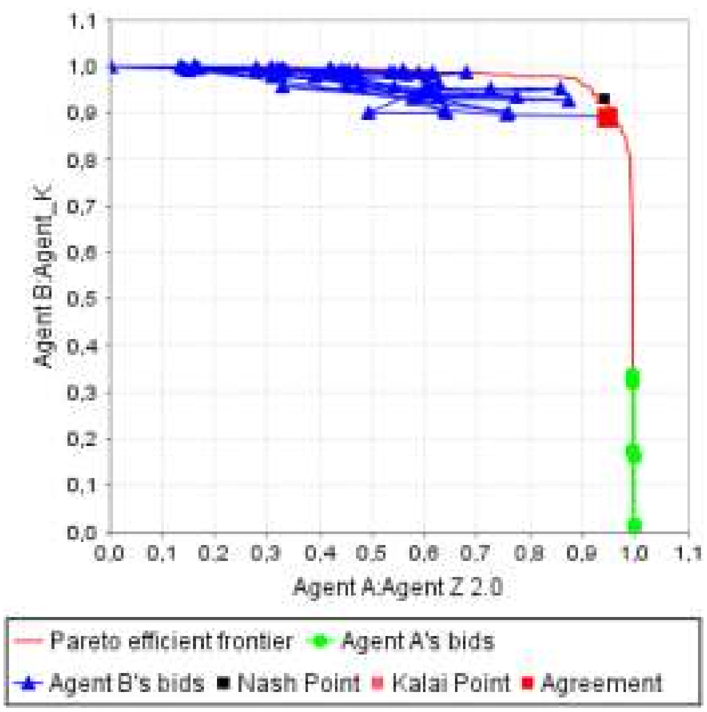

Figure 197 : Agent Z2.0 vs Agent K – ADG Car Domain

Table 103 : Agent Z2.0 vs Agent K – ADG Car Domain

Agent	Agent Z 2.0	Agent_K		Agent_K	Agent Z 2.0
Average time of agreement	0.788406	0.788406		0.753563	0.753563
Std time of agreement	0.151268	0.151268		0.120912	0.120912
Average time of end of negotiation	0.788406	0.788406		0.753563	0.753563
Std time of end of negotiation	0.151268	0.151268		0.120912	0.120912
Average rounds	173	173		184.2	184.2
Std rounds	39.1578	39.1578		29.65655	29.65655
Percentage of agreement	100	100		100	100
Average utility	0.87084	0.79983		0.74008	0.96558
Std utility	0.154499	0.099005		0.144859	0.013244
Average utility of agreements	0.87084	0.79983		0.74008	0.96558
Average discounted utility	0.87084	0.79983		0.74008	0.96558
Std discounted utility	0.154499	0.099005		0.144859	0.013244
Average discounted utility of agreements	0.87084	0.79983		0.74008	0.96558
Average nash distance	0.201848	0.201848		0.192036	0.192036
Average nash distance of agreements	0.201848	0.201848		0.192036	0.192036
Average pareto distance	0.067817	0.067817		0.03077	0.03077
Average pareto distance of agreements	0.067817	0.067817		0.03077	0.03077
Average kalai distance	0.196416	0.196416		0.195486	0.195486
Average kalai distance of agreements	0.196416	0.196416		0.195486	0.195486
Average social welfare	1.67067	1.67067		1.70566	1.70566
Average social welfare of agreements	1.67067	1.67067		1.70566	1.70566
Average exploration	0.001173	0.005245		0.005604	0.00218
Average joint exploration	0.006335	0.006335		0.007791	0.007791
Perc pareto bids	0.715661	0.068821		0.095892	0.434009
Average unfortunate moves	0.044703	0.151511		0.151768	0.095448
Average fortunate moves	0	0.135745		0.114994	0.008745
Average nice moves	0.017316	0.007393		0.019059	0.035301
Average selfish moves	0.38935	0.325407		0.338311	0.373252
Average concession moves	0.523413	0.36535		0.372307	0.414856
Average silent moves	0.025219	0.014594		0.00356	0.072399

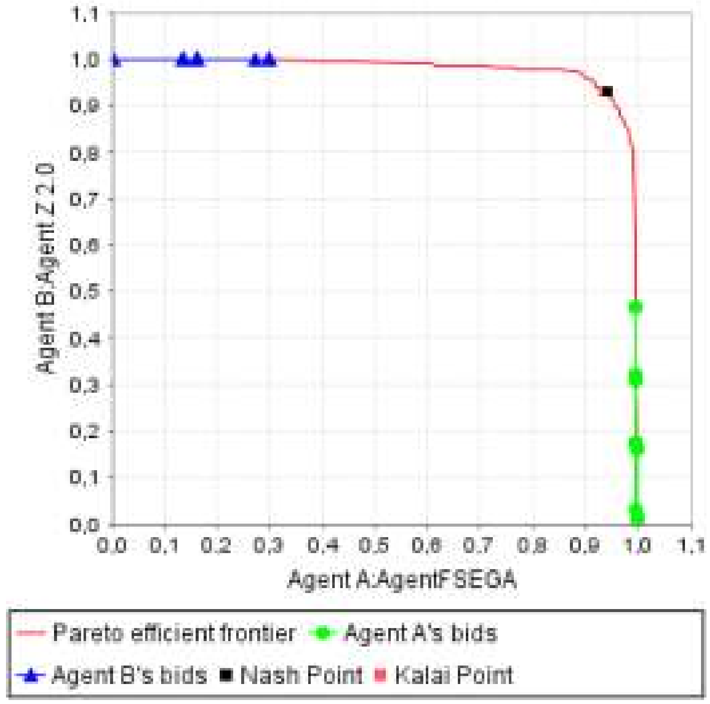

Figure 198 : FSEGA vs Agent Z2.0 – ADG Car Domain

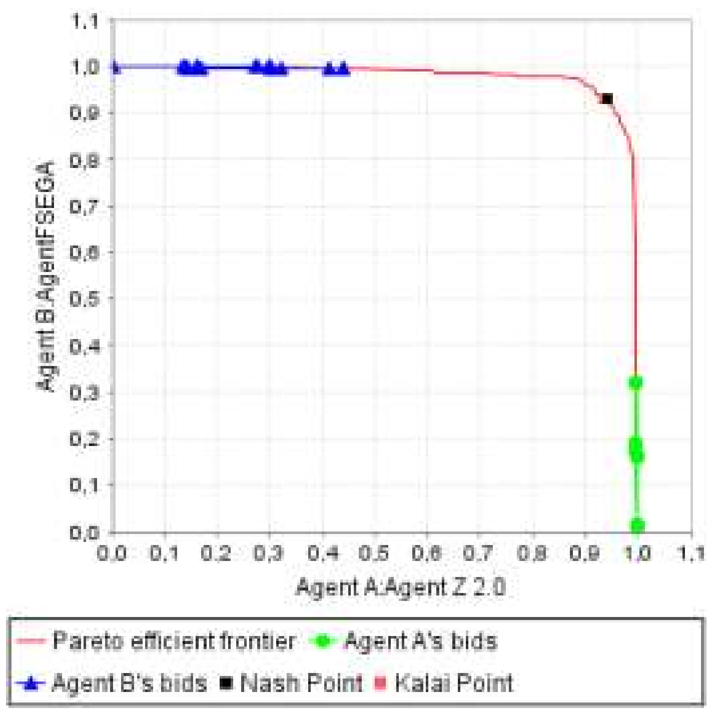

Figure 199 : Agent Z2.0 vs FSEGA – ADG Car Domain

Table 104 : Agent Z2.0 vs FSEGA – ADG Car Domain

Agent	Agent Z 2.0	AgentFSEGA		AgentFSEGA	Agent Z 2.0
Average time of agreement	0.992907	0.992907		0.995187	0.995187
Std time of agreement	NaN	NaN		NaN	NaN
Average time of end of negotiation	0.980522	0.980522		0.985534	0.985534
Std time of end of negotiation	0.018936	0.018936		0.011789	0.011789
Average rounds	43.4	43.4		48.4	48.4
Std rounds	2.221111	2.221111		4.427189	4.427189
Percentage of agreement	40	40		40	40
Average utility	0.1288	0.39804		0.3977	0.13872
Std utility	0.16628	0.513867		0.513429	0.182624
Average utility of agreements	0.322	0.9951		0.99425	0.3468
Average discounted utility	0.1288	0.39804		0.3977	0.13872
Std discounted utility	0.16628	0.513867		0.513429	0.182624
Average discounted utility of agreements	0.322	0.9951		0.99425	0.3468
Average nash distance	1.037371	1.037371		1.032163	1.032163
Average nash distance of agreements	0.610066	0.610066		0.597047	0.597047
Average pareto distance	0.601024	0.601024		0.605698	0.605698
Average pareto distance of agreements	0.002561	0.002561		0.014246	0.014246
Average kalai distance	1.036377	1.036377		1.027324	1.027324
Average kalai distance of agreements	0.612704	0.612704		0.590071	0.590071
Average social welfare	0.52684	0.52684		0.53642	0.53642
Average social welfare of agreements	1.3171	1.3171		1.34105	1.34105
Average exploration	0.000744	0.000814		0.000955	0.000981
Average joint exploration	0.001513	0.001513		0.002026	0.002026
Perc pareto bids	0.719641	0.320527		0.40386	0.44181
Average unfortunate moves	0.015263	0.224443		0.375432	0.069052
Average fortunate moves	0	0		0	0
Average nice moves	0	0.095988		0.249136	0
Average selfish moves	0.360672	0		0	0.416356
Average concession moves	0.624065	0.239969		0.187716	0.480164
Average silent moves	0	0.4396		0.187716	0.034427

Appendix O : ADG Car Domain – Agent Z3.0

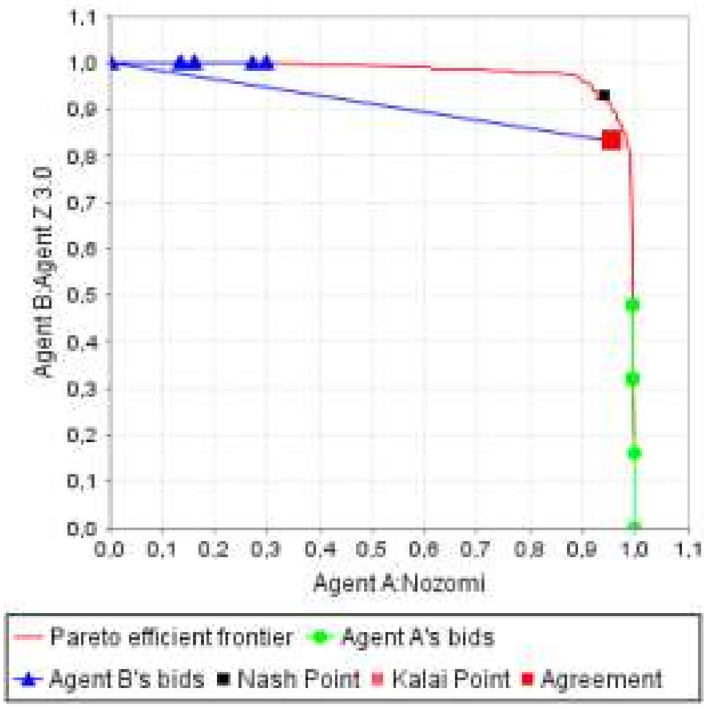

Figure 200 : Nozomi vs Agent Z3.0 – ADG Car Domain

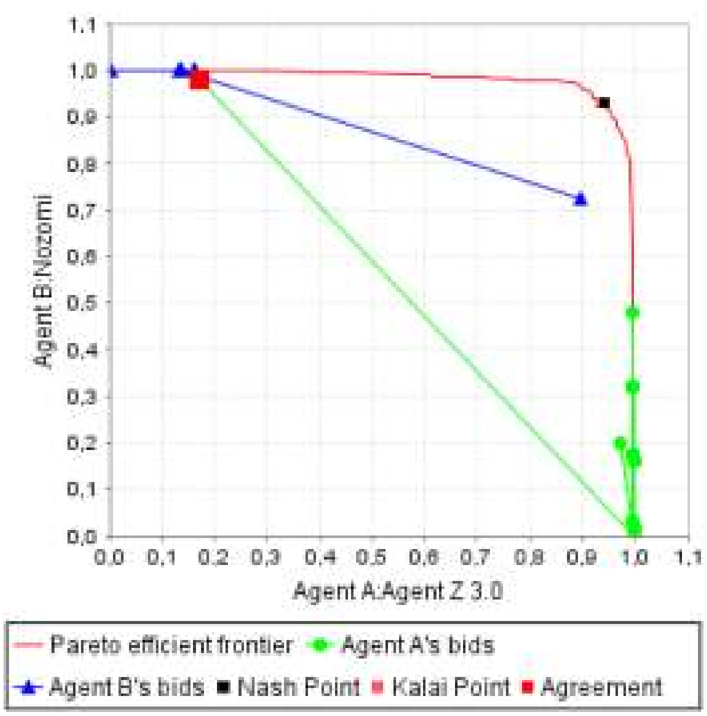

Figure 201 : Agent Z3.0 vs Nozomi – ADG Car Domain

Table 105 : Agent Z3.0 vs Nozomi – ADG Car Domain

Agent	Agent Z 3.0	Nozomi		Nozomi	Agent Z 3.0
Average time of agreement	0.773821	0.773821		0.819078	0.819078
Std time of agreement	0.090175	0.090175		0.016449	0.016449
Average time of end of negotiation	0.773821	0.773821		0.819078	0.819078
Std time of end of negotiation	0.090175	0.090175		0.016449	0.016449
Average rounds	180.3	180.3		189.3	189.3
Std rounds	21.11898	21.11898		5.271517	5.271517
Percentage of agreement	100	100		100	100
Average utility	0.7728	0.83125		0.85096	0.57042
Std utility	0.172057	0.10913		0.110503	0.245878
Average utility of agreements	0.7728	0.83125		0.85096	0.57042
Average discounted utility	0.7728	0.83125		0.85096	0.57042
Std discounted utility	0.172057	0.10913		0.110503	0.245878
Average discounted utility of agreements	0.7728	0.83125		0.85096	0.57042
Average nash distance	0.23748	0.23748		0.419025	0.419025
Average nash distance of agreements	0.23748	0.23748		0.419025	0.419025
Average pareto distance	0.09999	0.09999		0.113205	0.113205
Average pareto distance of agreements	0.09999	0.09999		0.113205	0.113205
Average kalai distance	0.235098	0.235098		0.414752	0.414752
Average kalai distance of agreements	0.235098	0.235098		0.414752	0.414752
Average social welfare	1.60405	1.60405		1.42138	1.42138
Average social welfare of agreements	1.60405	1.60405		1.42138	1.42138
Average exploration	0.000808	0.000487		0.000378	0.002078
Average joint exploration	0.001206	0.001206		0.00245	0.00245
Perc pareto bids	0.838326	0.552297		0.763211	0.636119
Average unfortunate moves	0.004097	0.012121		0.001087	0.003093
Average fortunate moves	0.002041	0.00864		0.002129	0.002085
Average nice moves	0.001538	0		0	0
Average selfish moves	0.282901	0.046396		0.045997	0.320192
Average concession moves	0.404782	0.102018		0.080359	0.330692
Average silent moves	0.30464	0.830825		0.870429	0.343938

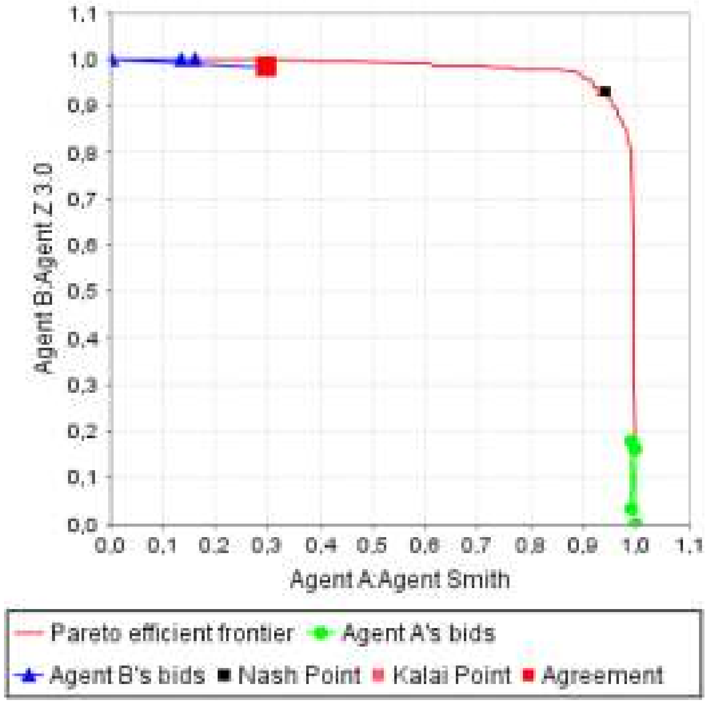

Figure 202 : Agent Smith vs Agent Z3.0 – ADG Car Domain

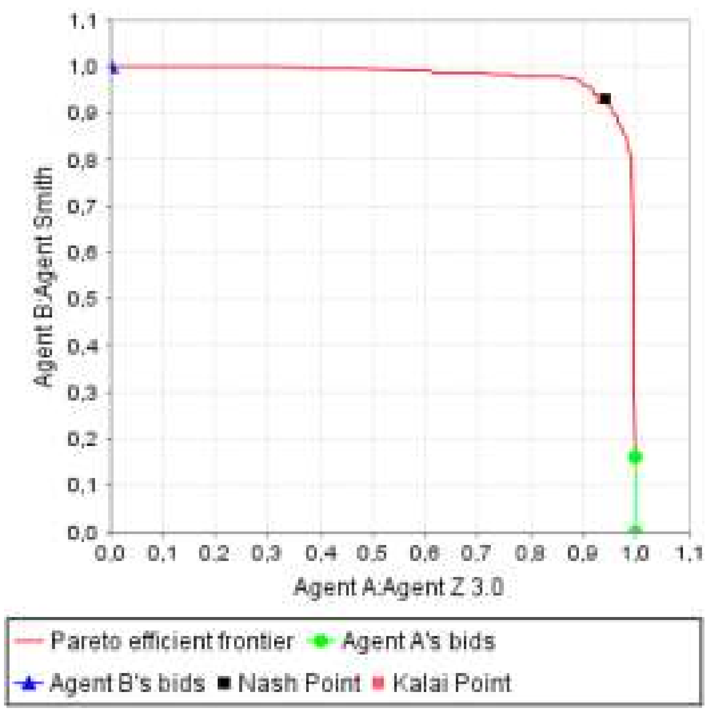

Figure 203 : Agent Z3.0 vs Agent Smith – ADG Car Domain

Table 106 : Agent Z3.0 vs Agent Smith – ADG Car Domain

Agent	Agent Z 3.0	Agent Smith		Agent Smith	Agent Z 3.0
Average time of agreement	0.765803	0.765803		NaN	NaN
Std time of agreement	0.021085	0.021085		NaN	NaN
Average time of end of negotiation	0.765803	0.765803		0.019266	0.019266
Std time of end of negotiation	0.021085	0.021085		0.001373	0.001373
Average rounds	10	10		3	3
Std rounds	0	0		0	0
Percentage of agreement	100	100		0	0
Average utility	0.9811	0.31468		0	0.9984
Std utility	0.000876	0.097079		0	0
Average utility of agreements	0.9811	0.31468		NaN	Infinity
Average discounted utility	0.9811	0.31468		0	0
Std discounted utility	0.000876	0.097079		0	0
Average discounted utility of agreements	0.9811	0.31468		NaN	NaN
Average nash distance	0.627785	0.627785		0.931414	0.931414
Average nash distance of agreements	0.627785	0.627785		NaN	NaN
Average pareto distance	0.021622	0.021622		0.0016	0.0016
Average pareto distance of agreements	0.021622	0.021622		NaN	NaN
Average kalai distance	0.620843	0.620843		0.933858	0.933858
Average kalai distance of agreements	0.620843	0.620843		NaN	NaN
Average social welfare	1.29578	1.29578		0.9984	0.9984
Average social welfare of agreements	1.29578	1.29578		NaN	NaN
Average exploration	0.000289	0.000256		6.41E-05	0.000128
Average joint exploration	0.000545	0.000545		0.000192	0.000192
Perc pareto bids	0.7	0.6		1	1
Average unfortunate moves	0	0.25		NaN	NaN
Average fortunate moves	0	0		NaN	NaN
Average nice moves	0	0.25		NaN	NaN
Average selfish moves	0.25	0		NaN	NaN
Average concession moves	0.75	0.25		NaN	NaN
Average silent moves	0	0.25		NaN	NaN

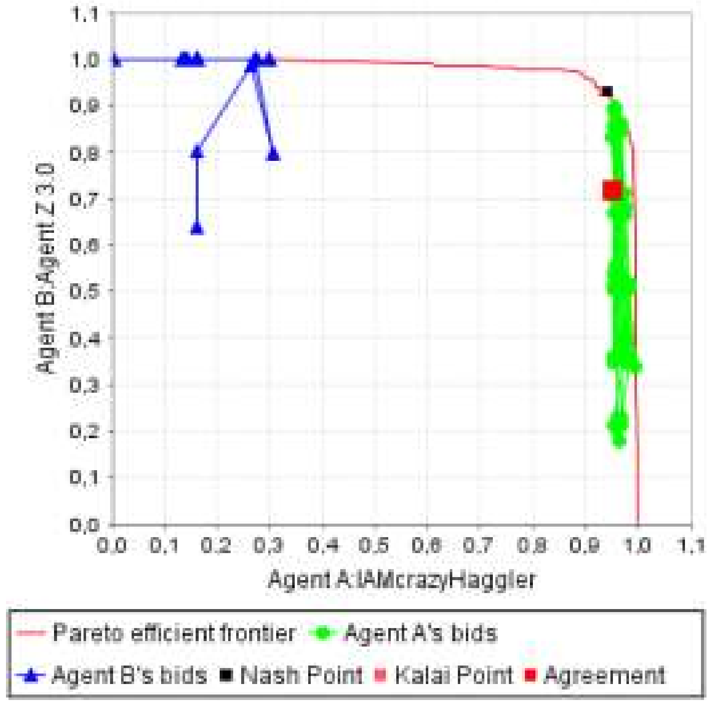

Figure 204 : IAMcrazyHaggler vs Agent Z3.0 – ADG Car Domain

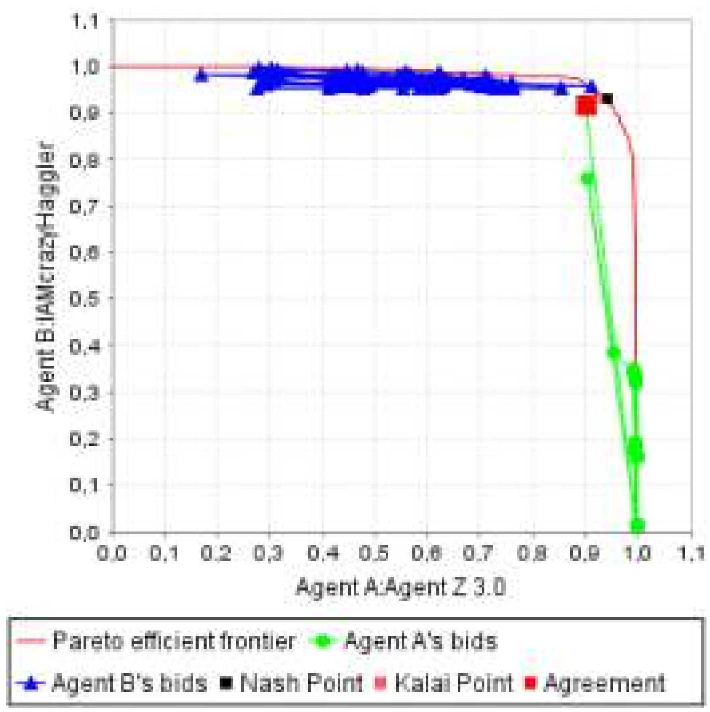

Figure 205 : Agent Z3.0 vs IAMcrazyHaggler – ADG Car Domain

Table 107 : Agent Z3.0 vs IAMcrazyHaggler – ADG Car Domain

Agent	Agent Z 3.0	IAMcrazyHa		IAMcrazyHa	Agent Z 3.0
Average time of agreement	0.763644	0.763644		0.631642	0.631642
Std time of agreement	0.225035	0.225035		0.148698	0.148698
Average time of end of negotiation	0.763644	0.763644		0.631642	0.631642
Std time of end of negotiation	0.225035	0.225035		0.148698	0.148698
Average rounds	183.8	183.8		149.9	149.9
Std rounds	57.13104	57.13104		38.18217	38.18217
Percentage of agreement	100	100		100	100
Average utility	0.82752	0.96027		0.9503	0.7981
Std utility	0.088287	0.013351		0.018924	0.088881
Average utility of agreements	0.82752	0.96027		0.9503	0.7981
Average discounted utility	0.82752	0.96027		0.9503	0.7981
Std discounted utility	0.088287	0.013351		0.018924	0.088881
Average discounted utility of agreements	0.82752	0.96027		0.9503	0.7981
Average nash distance	0.10461	0.10461		0.145056	0.145056
Average nash distance of agreements	0.10461	0.10461		0.145056	0.145056
Average pareto distance	0.018855	0.018855		0.02527	0.02527
Average pareto distance of agreements	0.018855	0.018855		0.02527	0.02527
Average kalai distance	0.108453	0.108453		0.138238	0.138238
Average kalai distance of agreements	0.108453	0.108453		0.138238	0.138238
Average social welfare	1.78779	1.78779		1.7484	1.7484
Average social welfare of agreements	1.78779	1.78779		1.7484	1.7484
Average exploration	0.001488	0.005854		0.004745	0.001969
Average joint exploration	0.007227	0.007227		0.006707	0.006707
Perc pareto bids	0.692655	0.014225		0.023614	0.470626
Average unfortunate moves	0.046176	0.20439		0.185447	0.064407
Average fortunate moves	0.00413	0.214919		0.177327	0.007933
Average nice moves	0.03657	0.004037		0.002299	0.037078
Average selfish moves	0.316881	0.273964		0.315288	0.378916
Average concession moves	0.397259	0.301051		0.317944	0.398791
Average silent moves	0.198985	0.001639		0.001695	0.112876

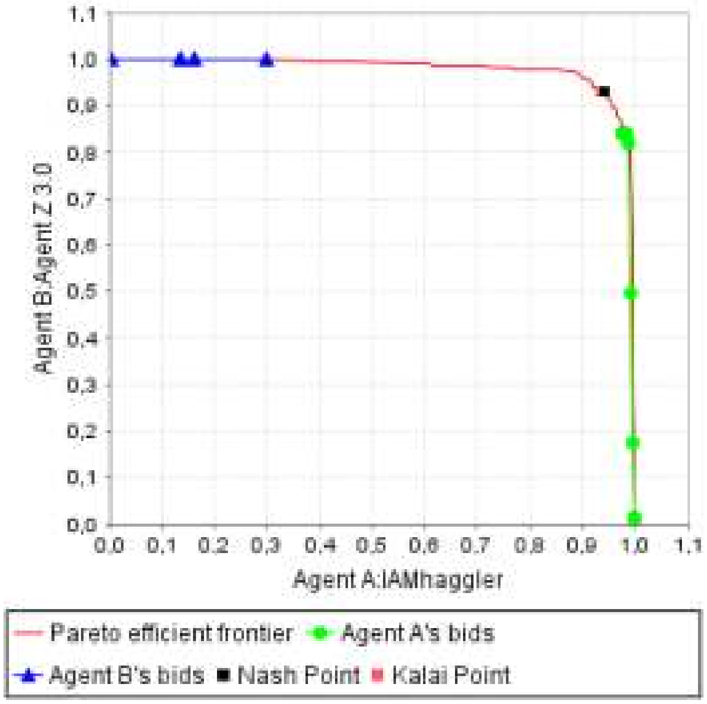

Figure 206 : IAMhaggler vs Agent Z3.0 – ADG Car Domain

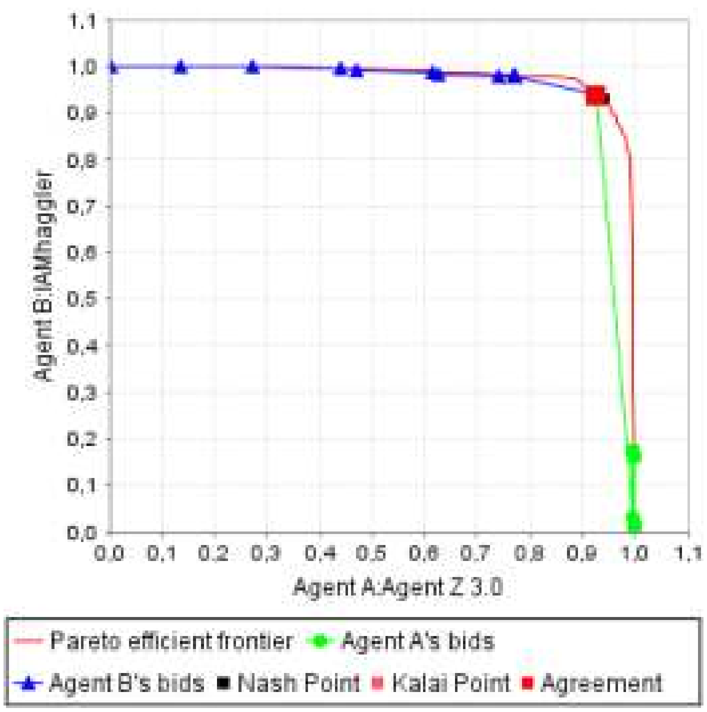

Figure 207 : Agent Z3.0 vs IAMhaggler – ADG Car Domain

Table 108 : Agent Z3.0 vs IAMhaggler – ADG Car Domain

Agent	Agent Z 3.0	IAMhaggler		IAMhaggler	Agent Z 3.0
Average time of agreement	0.996469	0.996469		0.993368	0.993368
Std time of agreement	NaN	NaN		NaN	NaN
Average time of end of negotiation	0.995349	0.995349		0.994275	0.994275
Std time of end of negotiation	0.002105	0.002105		0.002787	0.002787
Average rounds	74.2	74.2		68	68
Std rounds	2.20101	2.20101		1.054093	1.054093
Percentage of agreement	50	50		60	60
Average utility	0.46504	0.42036		0.5486	0.55807
Std utility	0.49025	0.444621		0.472816	0.480956
Average utility of agreements	0.93008	0.84072		0.914333	0.930117
Average discounted utility	0.46504	0.42036		0.5486	0.55807
Std discounted utility	0.49025	0.444621		0.472816	0.480956
Average discounted utility of agreements	0.93008	0.84072		0.914333	0.930117
Average nash distance	0.711467	0.711467		0.551743	0.551743
Average nash distance of agreements	0.100694	0.100694		0.038079	0.038079
Average pareto distance	0.520894	0.520894		0.40607	0.40607
Average pareto distance of agreements	0.041788	0.041788		0.010116	0.010116
Average kalai distance	0.706399	0.706399		0.549678	0.549678
Average kalai distance of agreements	0.093973	0.093973		0.036914	0.036914
Average social welfare	0.8854	0.8854		1.10667	1.10667
Average social welfare of agreements	1.7708	1.7708		1.84445	1.84445
Average exploration	0.000532	0.000603		0.000577	0.000654
Average joint exploration	0.001103	0.001103		0.001225	0.001225
Perc pareto bids	0.881574	0.159229		0.916756	0.678235
Average unfortunate moves	0	0.022165		0.00303	0.035829
Average fortunate moves	0	0		0	0
Average nice moves	0	0		0	0
Average selfish moves	0.207585	0		0	0.209002
Average concession moves	0.331993	0.210284		0.242992	0.232799
Average silent moves	0.460422	0.767552		0.753977	0.522371

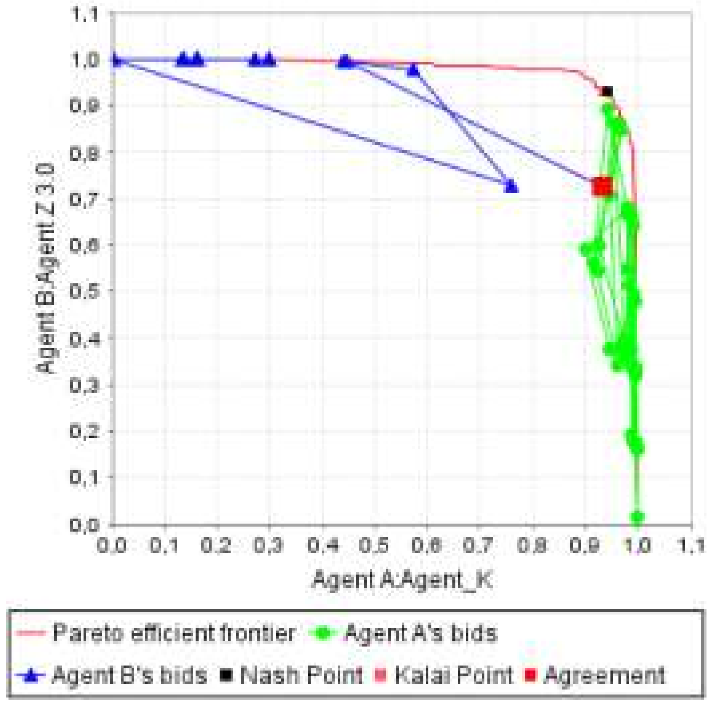

Figure 208 : Agent K vs Agent Z3.0 – ADG Car Domain

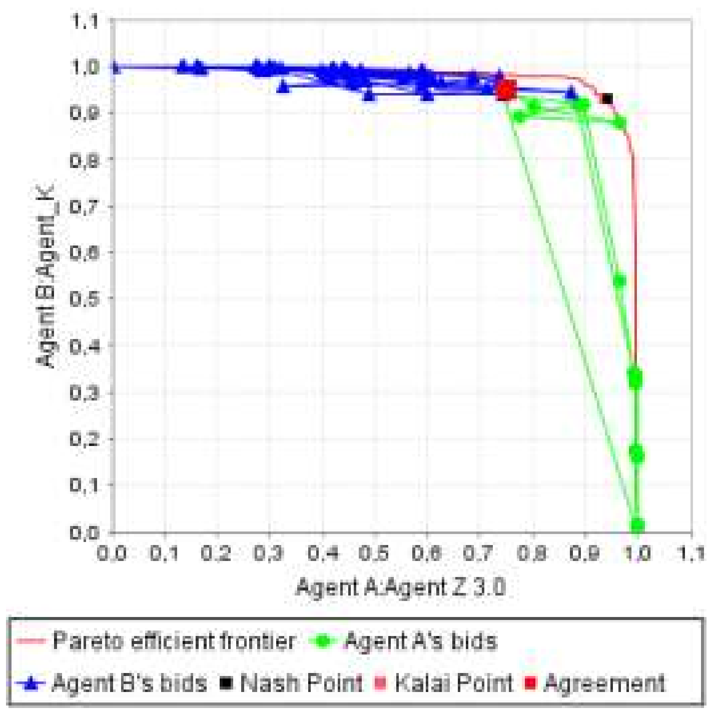

Figure 209 : Agent Z3.0 vs Agent K – ADG Car Domain

Table 109 : Agent Z3.0 vs Agent K – ADG Car Domain

Agent	Agent Z 3.0	Agent_K		Agent_K	Agent Z 3.0
Average time of agreement	0.631116	0.631116		0.551135	0.551135
Std time of agreement	0.129951	0.129951		0.045472	0.045472
Average time of end of negotiation	0.631116	0.631116		0.551135	0.551135
Std time of end of negotiation	0.129951	0.129951		0.045472	0.045472
Average rounds	126.3	126.3		127.8	127.8
Std rounds	43.65789	43.65789		11.5547	11.5547
Percentage of agreement	100	100		100	100
Average utility	0.86768	0.87937		0.9287	0.85253
Std utility	0.087798	0.112335		0.017041	0.066244
Average utility of agreements	0.86768	0.87937		0.9287	0.85253
Average discounted utility	0.86768	0.87937		0.9287	0.85253
Std discounted utility	0.087798	0.112335		0.017041	0.066244
Average discounted utility of agreements	0.86768	0.87937		0.9287	0.85253
Average nash distance	0.133629	0.133629		0.090675	0.090675
Average nash distance of agreements	0.133629	0.133629		0.090675	0.090675
Average pareto distance	0.036021	0.036021		0.035961	0.035961
Average pareto distance of agreements	0.036021	0.036021		0.035961	0.035961
Average kalai distance	0.133198	0.133198		0.084533	0.084533
Average kalai distance of agreements	0.133198	0.133198		0.084533	0.084533
Average social welfare	1.74705	1.74705		1.78123	1.78123
Average social welfare of agreements	1.74705	1.74705		1.78123	1.78123
Average exploration	0.000923	0.003867		0.003809	0.001892
Average joint exploration	0.004681	0.004681		0.005745	0.005745
Perc pareto bids	0.755855	0.076169		0.14631	0.448177
Average unfortunate moves	0.018757	0.152394		0.113693	0.06813
Average fortunate moves	0	0.128049		0.116401	0.003257
Average nice moves	0.00997	0.00762		0.022923	0.021082
Average selfish moves	0.355625	0.328652		0.346659	0.416305
Average concession moves	0.484785	0.370332		0.387794	0.436026
Average silent moves	0.130864	0.012953		0.01253	0.055199

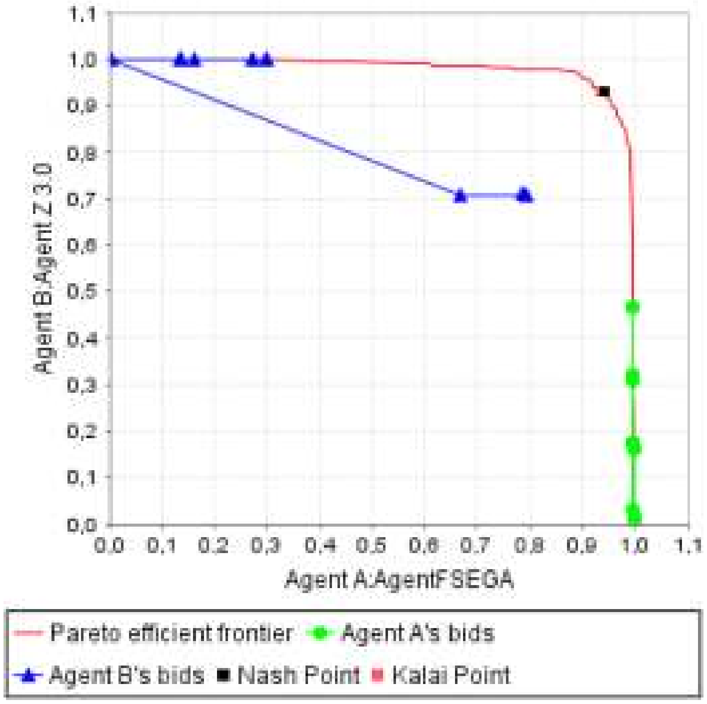

Figure 210 : FSEGA vs Agent Z3.0 – ADG Car Domain

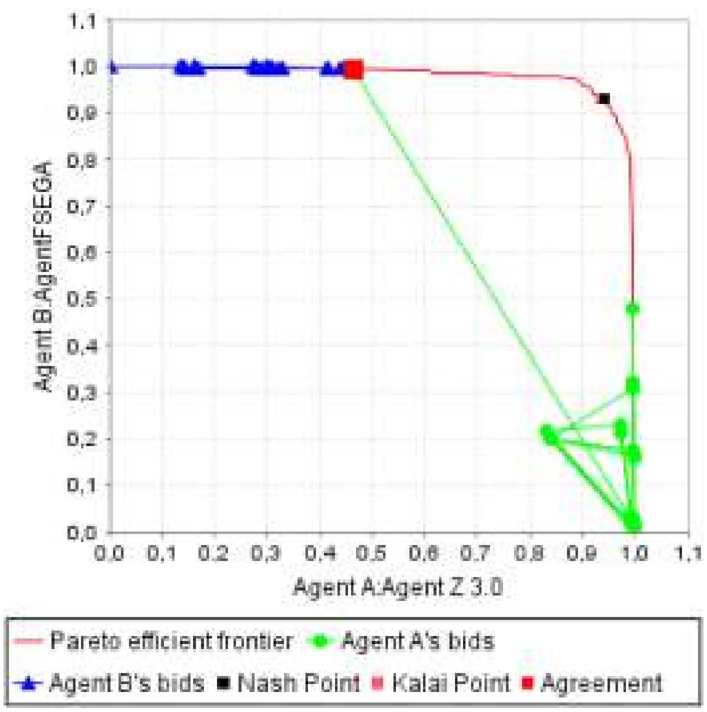

Figure 211 : Agent Z3.0 vs FSEGA – ADG Car Domain

Table 110 : Agent Z3.0 vs FSEGA – ADG Car Domain

Agent	Agent Z 3.0	AgentFSEGA		AgentFSEGA	Agent Z 3.0
Average time of agreement	0.999842	0.999842		0.996164125	0.996164
Std time of agreement	NaN	NaN		NaN	NaN
Average time of end of negotiation	0.894815	0.894815		0.978089452	0.978089
Std time of end of negotiation	0.078062	0.078062		0.034193458	0.034193
Average rounds	39.6	39.6		48.6	48.6
Std rounds	1.577621	1.577621		9.834180754	9.834181
Percentage of agreement	10	10		20	20
Average utility	0	0		0.0994	0.04641
Std utility	0	0		0.314330399	0.146761
Average utility of agreements	0	0		0.497	0.23205
Average discounted utility	0	0		0.0994	0.04641
Std discounted utility	0	0		0.314330399	0.146761
Average discounted utility of agreements	0	0		0.497	0.23205
Average nash distance	1.322241	1.322241		1.238070047	1.23807
Average nash distance of agreements	1.322241	1.322241		0.901387764	0.901388
Average pareto distance	1	1		0.9	0.9
Average pareto distance of agreements	1	1		0.5	0.5
Average kalai distance	1.318826	1.318826		1.234295931	1.234296
Average kalai distance of agreements	1.318826	1.318826		0.896177485	0.896177
Average social welfare	0	0		0.14581	0.14581
Average social welfare of agreements	0	0		0.72905	0.72905
Average exploration	0.000571	0.000744		0.000955434	0.000872
Average joint exploration	0.001289	0.001289		0.001878807	0.001879
Perc pareto bids	0.788459	0.354035		0.406416688	0.518418
Average unfortunate moves	0	0.213099		0.379291499	0.034972
Average fortunate moves	0.031053	0		0	0.002857
Average nice moves	0	0.10655		0.242456004	0
Average selfish moves	0.313538	0		0	0.40355
Average concession moves	0.515526	0.244152		0.176197327	0.438839
Average silent moves	0.139883	0.436199		0.20205517	0.119782

Appendix P : Energy Domain – Agent Z3.0

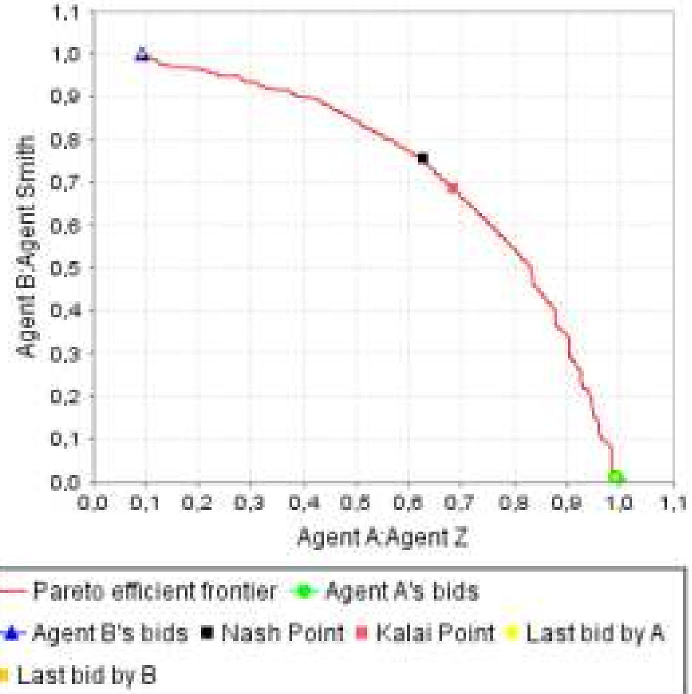

Figure 212 : Agent Z3.0 vs. Agent Smith - Energy Domain

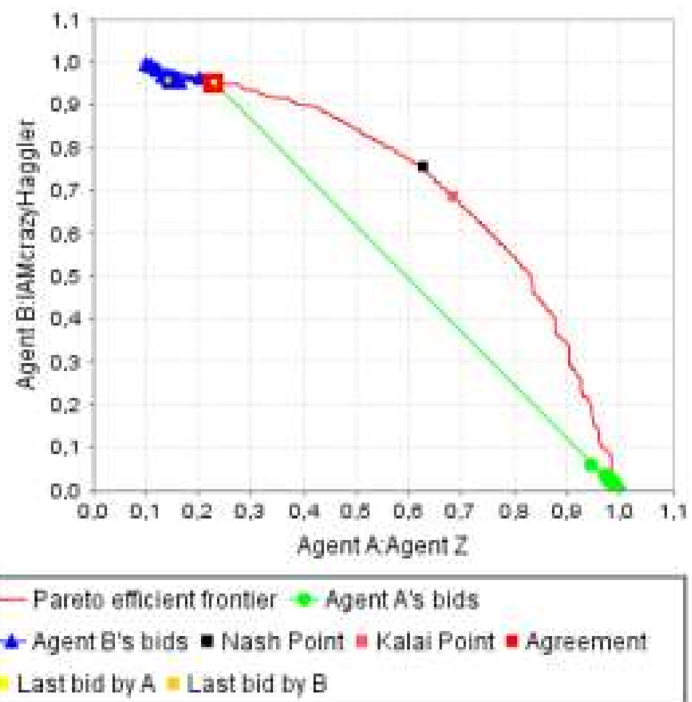

Figure 213 : Agent Z3.0 vs. IAMcrazyHaggler - Energy Domain

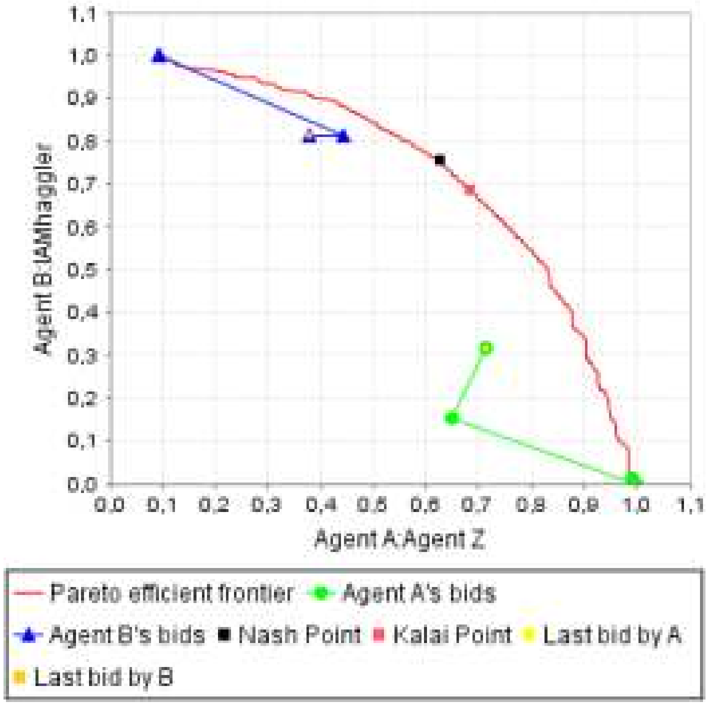

Figure 214 : Agent Z3.0 vs. IAMHaggler - Energy Domain

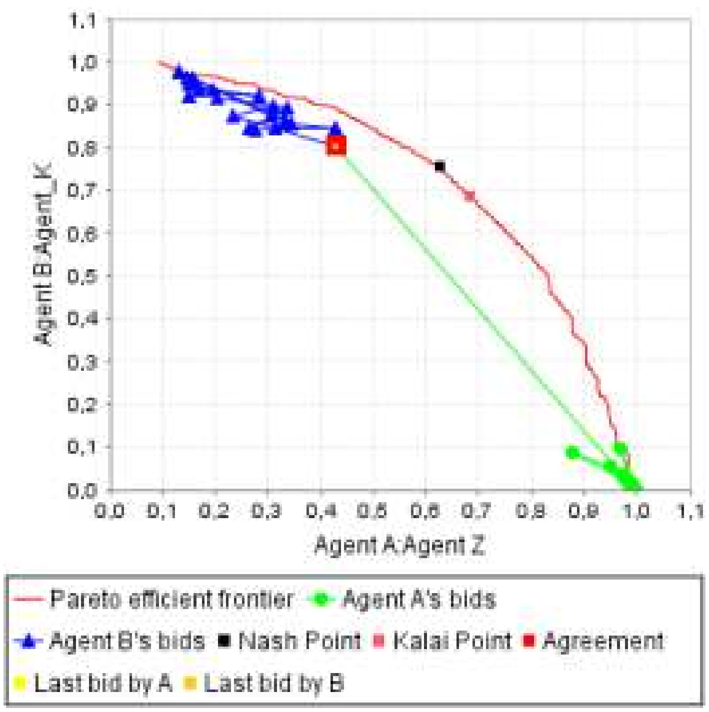

Figure 215 : Agent Z3.0 vs. Agent K - Energy Domain

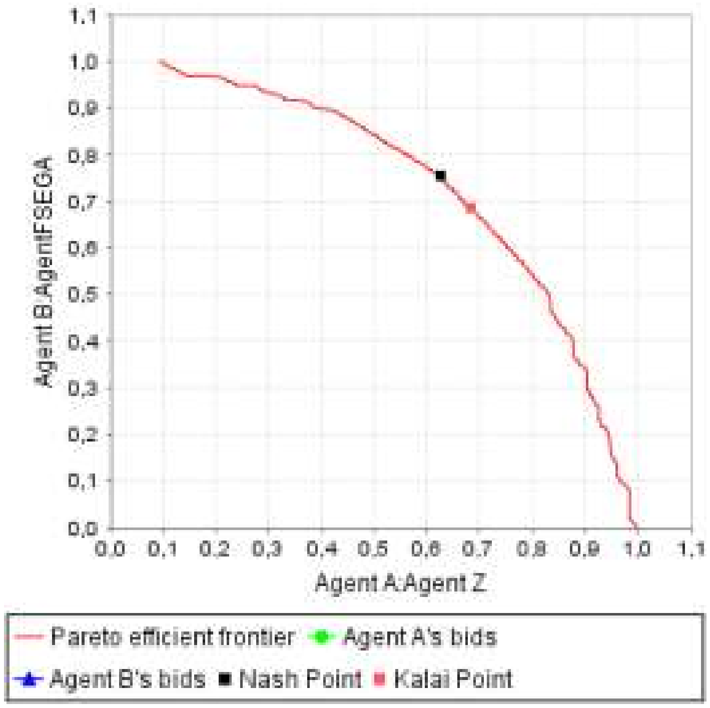

Figure 216: Agent Z3.0 vs. FSEGA - Energy Domain

Appendix Q : Agent Z – V1.0 Source Code

```
package agents.cultural;
import java.util.Date;
import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;
import java.util.Random;
import negotiator.Agent;
import negotiator.Bid;
import negotiator.actions.Accept;
import negotiator.actions.Action;
import negotiator.actions.Offer;
import negotiator.issue.Issue;
import negotiator.issue.IssueDiscrete;
import negotiator.issue.Value;

/**
 * Main class of the cultural agent.
 */
public class CulturalAgent extends Agent
{
   // Action of partner will be stored here.
   private Action actionOfPartner=null;

   // Population will be stored here.
   private List<Bid> population = new ArrayList<Bid>(Settings.POPULATION_SIZE);

   // Initialize the random number generator.
   Random random = new Random((new Date()).getTime());

   // Belief space will be stored here.
   private BeliefSpace beliefSpace;
```

```
/**
 * Called when new negotiation session starts.
 */
public void init()
    {
  // Create belief space.
  beliefSpace = new BeliefSpace(utilitySpace);
  // Load settings.
  Settings settings = Settings.getInstance();

  // Update the Belief Space with the BAI.
  try {
    beliefSpace.accept(utilitySpace.getMaxUtilityBid());}
  catch (Exception e) {
    System.out.println(e);
  }
    }

/**
 * Returns best accepted individual (BAI) from the population.
 * @return BAI (Bid).
 */
private Bid fitness() {
  Bid bai = null;
  try {
    // Loop over the population.
    for (Bid bid : population) {
      // Utility should not be equal to the previous max NTU.
      if (utilitySpace.getUtility(bid) == beliefSpace.getPreviousMaxNTU()) {
        continue;
      }
```

```
            if (bai == null || utilitySpace.getUtility(bid) > utilitySpace.getUtility(bai)) {
                // New candidate for best accepted individual is found.
                bai = bid;
            }
        }
    } catch (Exception e) {
        System.out.println(e);
    }

    if (bai == null) {
        bai = population.get(0);
    }

    return bai;
}

/**
 * Returns agent version.
 * @return agent version.
 */
public static String getVersion() { return "1.0"; }

/**
 * Returns agent name.
 * @return agent name.
 */
@Override
    public String getName()
    {
            return "Agent Z 1.0";
    }
```

```
/**
 * Called when message from the opponent is received.
 * @param opponentAction received message.
 */
public void ReceiveMessage(Action opponentAction)
	{
		// Store received action of partner.
   actionOfPartner = opponentAction;
	}

/**
 * Called when it's our turn to make action.
 * @return
 */
	public Action chooseAction()
	{
		Action action = null;
		try
		{
			if(actionOfPartner == null) {
      // We are starting the negotiation. Offer max NTU bid.
      return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
	}
			if(actionOfPartner instanceof Offer)
			{
				// Get partner's bid.
      Bid partnerBid = ((Offer)actionOfPartner).getBid();

      // Update situational knowledge utility component of the Belief Space.
      beliefSpace.setSKU(partnerBid);
```

```
// Accept offer if termination criteria is met.
if (isTermination()) {
   return new Accept(getAgentID());
}

// Keep sending the same offer till the last quoter of the time available for the
negotiation
// in case partner bid utility is less or equal to the min NTU or
// in case partner have sent the same offer
if (timeline.getTime() < Settings.OPPONENT_PRESSURE_TIME && (
      utilitySpace.getUtility(partnerBid) <= Settings.MIN_NTU ||
      beliefSpace.getPreviousSKUBid() != null &&
partnerBid.equals(beliefSpace.getPreviousSKUBid()))) {
   sleep(Settings.TIME_TO_SLEEP_BEFORE_SENDING_AN_OFFER);
   return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
}

// Produce next generation.
population.clear();
Bid parent1 = beliefSpace.getMaxNTUBid();
Bid parent2 = beliefSpace.getSKUBid();
for (int i = 0; i < Settings.POPULATION_SIZE /2; i++) {

   // Copy the first child from the parent 1.
   HashMap<Integer, Value> values = new HashMap<Integer, Value>();
   ArrayList<Issue> issues=utilitySpace.getDomain().getIssues();
   for (Issue issue: issues)
   {
      values.put(issue.getNumber(), parent1.getValue(issue.getNumber()));
   }
   Bid child1 = new Bid(utilitySpace.getDomain(), values);

   // Copy the second child from the parent 2.
```

```
values = new HashMap<Integer, Value>();
issues=utilitySpace.getDomain().getIssues();
for (Issue issue: issues)
{
   values.put(issue.getNumber(), parent2.getValue(issue.getNumber()));
}
Bid child2 = new Bid(utilitySpace.getDomain(), values);

// Crossover.
int issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
int issueNumber =
utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
Value tempOption = child1.getValue(issueNumber);
child1.setValue(issueNumber, child2.getValue(issueNumber));
child2.setValue(issueNumber, tempOption);

// Mutation of the first child.
if (random.nextDouble() < Settings.MUTATION_PROBABILITY) {
   issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
   issueNumber =
utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
   IssueDiscrete issueDiscrete =
(IssueDiscrete)utilitySpace.getDomain().getIssue(issueIndex);
   int issueValue = random.nextInt(issueDiscrete.getNumberOfValues());
   child1.setValue(issueNumber, issueDiscrete.getValue(issueValue));
}

// Mutation of the second child.
if (random.nextDouble() < Settings.MUTATION_PROBABILITY) {
   issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
   issueNumber =
utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
   IssueDiscrete issueDiscrete =
(IssueDiscrete)utilitySpace.getDomain().getIssue(issueIndex);
```

```
                int issueValue = random.nextInt(issueDiscrete.getNumberOfValues());
                child2.setValue(issueNumber, issueDiscrete.getValue(issueValue));
            }

            population.add(child1);
            population.add(child2);
            //population.add(getRandomBid());
        }

        // Calculate Best Accepted Individual using the fitness function.
        Bid bai = fitness();

        // Update the Belief Space with the BAI.
        beliefSpace.accept(bai);

        // Send offer.
        sleep(Settings.TIME_TO_SLEEP_BEFORE_SENDING_AN_OFFER);
        return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
        return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
                    }
                } catch (Exception e) {
                        System.out.println("Exception in
ChooseAction:"+e.getMessage());
    sleep(0.1);
    action=new Accept(getAgentID()); // best guess if things go wrong.
                }
                return action;
    }

  /**
   * Checks whether one of the following termination criteria is satisfied:
   * - current time is more or equal to the 99% of the time interval for the negotiaion
   * - SKU is more or equal to the 99% of max NTU.
```

```
     * @return boolean value indicating whether the negotiation process should be
terminated.
     */
    private boolean isTermination() {
        return timeline.getTime() >= Settings.TIME_TERMINATION_CRITERIA ||
                beliefSpace.getSKU() / beliefSpace.getMaxNTU() >=
Settings.SKU_TERMINATION_CRITERIA;
    }
}
```

Appendix R : Agent Z – V2.0 Source Code

```
package agents.cultural;
import java.io.BufferedWriter;
import java.io.FileWriter;
import java.util.Date;
import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;
import java.util.Random;
import negotiator.Agent;
import negotiator.Bid;
import negotiator.actions.Accept;
import negotiator.actions.Action;
import negotiator.actions.Offer;
import negotiator.issue.Issue;
import negotiator.issue.IssueDiscrete;
import negotiator.issue.Value;



/**
 * Main class of the cultural agent.
 */
public class AgentZ extends Agent
{
   // Action of partner will be stored here.
   private Action actionOfPartner=null;

   // Population will be stored here.
   private List<Bid> population = new ArrayList<Bid>();

   // Initialize the random number generator.
   Random random= new Random((new Date()).getTime());
```

```
    // Belief space will be stored here.
    private BeliefSpace beliefSpace;

    // Size of the population.
    private int populationSize;

    // Partner bids.
    private List<Bid> partnerBids = new ArrayList<Bid>();

    // Our bids.
    private List<Bid> ourBids = new ArrayList<Bid>();

    // Partner utility model.
    private HardHeadedFrequencyModel partnerUtilityModel;

    // Logger.
    private Logger logger;
    /**
     * Called when new negotiation session starts.
     */
    public void init()
        {
      try {
        // Initialize logger.
        logger = Logger.getInstance();

        // Create belief space.
        beliefSpace = new BeliefSpace(utilitySpace);
        // Load settings.
        Settings.getInstance().initialize();
        logger.write("TTC="                                          +
String.valueOf(Settings.TIME_TERMINATION_CRITERIA));
```

```
            // Calculate domain size.
            int domainSize = 1;
            ArrayList<Issue> issues=utilitySpace.getDomain().getIssues();
            for(Issue lIssue:issues)
            {
              switch(lIssue.getType()) {
                case DISCRETE:
                  IssueDiscrete lIssueDiscrete = (IssueDiscrete)lIssue;
                  domainSize *= lIssueDiscrete.getNumberOfValues();
                  break;
                default: System.out.println("Issue type " + lIssue.getType() + " is not
supported by the Agent Z");
              }
            }
            logger.write("Domain size = " + domainSize);
            populationSize = domainSize * Settings.POPULATION_SIZE_PERCENT / 100;
            if (populationSize % 2 == 1) populationSize++;
            logger.write("Population size = " + populationSize);

            // Update the Belief Space with the BAI (Max NTU Bid).
            beliefSpace.accept(utilitySpace.getMaxUtilityBid());

            // Initialize opponent utility model.
            partnerUtilityModel = new HardHeadedFrequencyModel(utilitySpace,
partnerBids);

          } catch (Exception e) {
            System.out.println(e);
          }
            }

    /**
     * Returns best accepted individual (BAI) from the population.
```

```
 * @return BAI (Bid).
 */
private Bid fitness() {
    Bid bai = null;
    try {
        // Loop over the population.
        for (Bid bid : population) {
            // Utility should not be equal to the previous max NTU.
            /*if (utilitySpace.getUtility(bid) == beliefSpace.getPreviousMaxNTU()) {
                continue;
            }*/
            boolean skipBid = false;
            for (int i = 0; i <= Math.min(5, ourBids.size()) - 1; i++) {
                if (ourBids.get(ourBids.size() - 1 - i).equals(bid)) {
                    skipBid = true;
                    break;
                }
            }
            if (skipBid) continue;

            if (bai == null || utilitySpace.getUtility(bid) > utilitySpace.getUtility(bai)) {
                // New candidate for best accepted individual is found.
                bai = bid;
            }
        }
    } catch (Exception e) {
        System.out.println(e);
    }

    if (bai == null) {
        bai = population.get(0);
    }
```

```
        return bai;
    }

/**
     * Returns best accepted individual (BAI) from part of the population that is acceptable for the opponent.
     * @return BAI (Bid).
     */
    private Bid fitness_new() {
        Bid bai = null;
        Bid maxPartnerUtilityBid = population.get(0);
        try {
            double maxParnterUtility = 0;

            // Find maximum partner utility.
            for (Bid bid : population) {
                if (partnerUtilityModel.getBidEvaluation(bid) > maxParnterUtility) {
                    maxParnterUtility = partnerUtilityModel.getBidEvaluation(bid);
                    maxPartnerUtilityBid = bid;
                }
            }

            // Calculate minimal accepted partner utility.
            double minAccepted = maxParnterUtility * timeline.getTime();

            // Loop over the population.
            for (Bid bid : population) {
                if (partnerUtilityModel.getBidEvaluation(bid) < minAccepted) continue;

                if (bai == null || utilitySpace.getUtility(bid) > utilitySpace.getUtility(bai)) {
                    // New candidate for best accepted individual is found.
                    bai = bid;
```

```
                }
            }
        } catch (Exception e) {
            System.out.println(e);
        }

        if (bai == null) {
            bai = maxPartnerUtilityBid;
        }

        return bai;
    }


    /**
     * Returns agent version.
     * @return agent version.
     */
    public static String getVersion() { return "2.0"; }

    /**
     * Returns agent name.
     * @return agent name.
     */
    @Override
        public String getName()
        {
                return "Agent Z 2.0";
        }

    /**
     * Called when message from the opponent is received.
```

```
 * @param opponentAction received message.
 */
public void ReceiveMessage(Action opponentAction)
    {
        // Store received action of partner.
  actionOfPartner = opponentAction;
    }

/**
 * Called when it's our turn to make action.
 * @return
 */
    public Action chooseAction()
    {
        Action action = null;
        try
        {
            if(actionOfPartner == null) {
      // We are starting the negotiation. Offer max NTU bid.
      logger.write("We are starting the negotiation. Offering the max NTU bid");
      logger.write(beliefSpace.getMaxNTUBid().toString());
      ourBids.add(beliefSpace.getMaxNTUBid());
      return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
    }
            if(actionOfPartner instanceof Offer)
            {
                // Get partner's bid.
      Bid partnerBid = ((Offer)actionOfPartner).getBid();
      logger.write("Partner bid: " + partnerBid);

      partnerBids.add(partnerBid);
      partnerUtilityModel.updateModel();
```

```
// Update situational knowledge utility component of the Belief Space.
beliefSpace.setSKU(partnerBid);

// Accept offer if termination criteria is met.
if (isTermination()) {
   logger.write("Termination criteria is met. Accepting the offer.");
   return new Accept(getAgentID());
}

// Produce next generation.
logger.write("Producing next generation.");
population.clear();
Bid parent1 = beliefSpace.getMaxNTUBid();
logger.write("First parent: " + parent1.toString());

int numberOfPartnerBidsToUseAsParents = Math.min(3, partnerBids.size());
int currentPartnerBidNumber = 0;
for (int i = 0; i < populationSize / 2; i++) {
   Bid parent2 = partnerBids.get(partnerBids.size() - 1 - currentPartnerBidNumber);
   logger.write("Second parent: " + parent2.toString());
   currentPartnerBidNumber++;
   if (currentPartnerBidNumber >= numberOfPartnerBidsToUseAsParents) currentPartnerBidNumber = 0;

   // Copy the first child from the parent 1.
   HashMap<Integer, Value> values = new HashMap<Integer, Value>();
   ArrayList<Issue> issues=utilitySpace.getDomain().getIssues();
   for (Issue issue: issues)
   {
      values.put(issue.getNumber(), parent1.getValue(issue.getNumber()));
   }
```

```
Bid child1 = new Bid(utilitySpace.getDomain(), values);

// Copy the second child from the parent 2.
values = new HashMap<Integer, Value>();
issues=utilitySpace.getDomain().getIssues();
for (Issue issue: issues)
{
   values.put(issue.getNumber(), parent2.getValue(issue.getNumber()));
}
Bid child2 = new Bid(utilitySpace.getDomain(), values);

// Crossover.
int issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
int issueNumber =
utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
Value tempOption = child1.getValue(issueNumber);
child1.setValue(issueNumber, child2.getValue(issueNumber));
child2.setValue(issueNumber, tempOption);

// Mutation of the first child.
if (random.nextDouble() < Settings.MUTATION_PROBABILITY) {
   issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
   issueNumber =
utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
   IssueDiscrete issueDiscrete =
(IssueDiscrete)utilitySpace.getDomain().getIssue(issueIndex);
   int issueValue = random.nextInt(issueDiscrete.getNumberOfValues());
   child1.setValue(issueNumber, issueDiscrete.getValue(issueValue));
}

// Mutation of the second child.
if (random.nextDouble() < Settings.MUTATION_PROBABILITY) {
   issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
```

```
            issueNumber = utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
            IssueDiscrete issueDiscrete = (IssueDiscrete)utilitySpace.getDomain().getIssue(issueIndex);
            int issueValue = random.nextInt(issueDiscrete.getNumberOfValues());
            child2.setValue(issueNumber, issueDiscrete.getValue(issueValue));
        }

        population.add(child1);
        population.add(child2);
        logger.write("Child: " + child1.toString());
        logger.write("Child: " + child2.toString());
    }

    // Calculate Best Accepted Individual using the appropriate fitness function.
    Bid bai;
    if (timeline.getTime() < Settings.TIME_TERMINATION_CRITERIA) {
        bai = fitness();
    } else {
        bai = fitness_new();
    }
    logger.write("Best accepted individual:" + bai.toString());
    logger.write("Utility: " + utilitySpace.getUtility(bai));

    // Update the Belief Space with the BAI.
    beliefSpace.accept(bai);
    ourBids.add(bai);

    // Send offer.
    sleep(Settings.TIME_TO_SLEEP_BEFORE_SENDING_AN_OFFER);
    logger.write("Sending the offer");
    return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
            }
```

```
                } catch (Exception e) {
                        System.out.println("Exception in ChooseAction:"+e.getMessage());
        sleep(0.1);
        action=new Accept(getAgentID()); // best guess if things go wrong.
                }
                return action;
        }


    /**
     * Checks whether one of the following termination criteria is satisfied:
     * - current time is more or equal to the 99% of the time interval for the negotiaion
     * - SKU is more or equal to the 99% of max NTU.
     * @return boolean value indicating whether the negotiation process should be terminated.
     */
    private boolean isTermination() {
        return timeline.getTime() >= Settings.TIME_TERMINATION_CRITERIA ||
            beliefSpace.getSKU() / beliefSpace.getMaxNTU() >= Settings.SKU_TERMINATION_CRITERIA;
    }
}
```

Appendix S : Agent Z – V3.0 Source Code

```
package agents.cultural;
import java.util.Date;
import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;
import java.util.Random;
import negotiator.Agent;
import negotiator.Bid;
import negotiator.actions.Accept;
import negotiator.actions.Action;
import negotiator.actions.Offer;
import negotiator.issue.Issue;
import negotiator.issue.IssueDiscrete;
import negotiator.issue.Value;


/**
* Main class of the cultural agent.
*/
public class AgentZ extends Agent
{
// Action of partner will be stored here.
private Action actionOfPartner=null;

// Population will be stored here.
private List<Bid> population = new ArrayList<Bid>();

// Initialize the random number generator.
Random random= new Random((new Date()).getTime());

// Belief space will be stored here.
```

```
private BeliefSpace beliefSpace;

// Size of the population.
private int populationSize;

// Partner bids.
private List<Bid> partnerBids = new ArrayList<Bid>();

// Our bids.
private List<Bid> ourBids = new ArrayList<Bid>();

// Partner utility model.
private HardHeadedFrequencyModel partnerUtilityModel;

// Logger.
private Logger logger;

private double ourCurrentUtilityLimit = 1;

/**
* Called when new negotiation session starts.
*/
public void init()
{
try {
// Initialize logger.
logger = Logger.getInstance();

// Initialize settings.
Settings.getInstance().initialize();

// Create belief space.
```

```
beliefSpace = new BeliefSpace(utilitySpace);
// Load settings.
Settings settings = Settings.getInstance();
logger.write("TTC=" + String.valueOf(Settings.TIME_TERMINATION_CRITERIA));
// Calculate domain size.
int domainSize = 1;
ArrayList<Issue> issues=utilitySpace.getDomain().getIssues();
for(Issue lIssue:issues)
{
switch(lIssue.getType()) {
case DISCRETE:
IssueDiscrete lIssueDiscrete = (IssueDiscrete)lIssue;
domainSize *= lIssueDiscrete.getNumberOfValues();
break;
default: System.out.println("Issue type " + lIssue.getType() + " is not supported by the
Agent Z");
}
}
logger.write("Domain size = " + domainSize);
populationSize = domainSize * Settings.POPULATION_SIZE_PERCENT / 100;
if (populationSize % 2 == 1) populationSize++;
logger.write("Population size = " + populationSize);

// Update the Belief Space with the BAI (Max NTU Bid).
beliefSpace.accept(utilitySpace.getMaxUtilityBid());

// Initialize opponent utility model.
partnerUtilityModel = new HardHeadedFrequencyModel(utilitySpace, partnerBids);

} catch (Exception e) {
System.out.println(e);
}
}
```

```
/**
* Returns best accepted individual (BAI) from the population.
* @return BAI (Bid).
*/
private Bid fitness() {
Bid bai = null;
Bid bestBid = null;
try {
// Loop over the population.
for (Bid bid : population) {
if (bestBid == null || utilitySpace.getUtility(bid) > utilitySpace.getUtility(bestBid)) {
// New candidate for best bid is found.
bestBid = bid;
}

// Utility should not be equal to the previous max NTU.
/*if (utilitySpace.getUtility(bid) == beliefSpace.getPreviousMaxNTU()) {
continue;
}*/
boolean skipBid = false;
for (int i = 0; i <= Math.min(4, ourBids.size()) - 1; i++) {
if (ourBids.get(ourBids.size() - 1 - i).equals(bid)) {
skipBid = true;
break;
}
}
if (skipBid) continue;

if ((bai == null || utilitySpace.getUtility(bid) > utilitySpace.getUtility(bai)) &&
utilitySpace.getUtility(bid) > 0.85) {
// New candidate for best accepted individual is found.
bai = bid;
```

```
}
}
} catch (Exception e) {
System.out.println(e);
}

if (bai == null) {
return bestBid;
}

return bai;
}

/**
* Returns best accepted individual (BAI) from part of the population that is acceptable
for the opponent.
* @return BAI (Bid).
*/
private Bid fitness_new() {
Bid bai = null;
Bid maxPartnerUtilityBid = population.get(0);
try {
double maxParnterUtility = 0;

// Find maximum partner utility.
for (Bid bid : population) {
if (partnerUtilityModel.getBidEvaluation(bid) > maxParnterUtility) {
maxParnterUtility = partnerUtilityModel.getBidEvaluation(bid);
maxPartnerUtilityBid = bid;
}
}

// Calculate minimal accepted partner utility.
```

```
double minAccepted = maxParnterUtility * timeline.getTime();

// Loop over the population.
for (Bid bid : population) {
if (partnerUtilityModel.getBidEvaluation(bid) < minAccepted) continue;

if (bai == null || utilitySpace.getUtility(bid) > utilitySpace.getUtility(bai)) {
// New candidate for best accepted individual is found.
bai = bid;
}
}
} catch (Exception e) {
System.out.println(e);
}

if (bai == null) {
bai = maxPartnerUtilityBid;
}

return bai;
}


private Bid fitnessCooperation() {
Bid bai = null;

try {
double maxUtility = 0;
for (Bid bid: population) {
if (utilitySpace.getUtility(bid) > ourCurrentUtilityLimit) continue;
if (utilitySpace.getUtility(bid) > maxUtility) maxUtility = utilitySpace.getUtility(bid);
}
```

```
if (maxUtility == 0) return population.get(0);

List<Bid> bidsWithMaxUtility = new ArrayList<Bid>();
for (Bid bid: population) {
if (utilitySpace.getUtility(bid) == maxUtility) bidsWithMaxUtility.add(bid);
}

double maxPartnerUtility = 0;
for (Bid bid: bidsWithMaxUtility) {
if (partnerUtilityModel.getBidEvaluation(bid) > maxPartnerUtility) {
bai = bid;
maxPartnerUtility = partnerUtilityModel.getBidEvaluation(bid);
}
}
} catch (Exception e) {
System.out.println(e);
}

return bai;
}

/**
* Returns agent version.
* @return agent version.
*/
public static String getVersion() { return "3.0"; }

/**
* Returns agent name.
* @return agent name.
*/
@Override
```

```
public String getName() {
return "Agent Z 3.0";
}

/**
* Called when message from the opponent is received.
* @param opponentAction received message.
*/
public void ReceiveMessage(Action opponentAction)
{
// Store received action of partner.
actionOfPartner = opponentAction;
}

/**
* Called when it's our turn to make action.
* @return
*/
public Action chooseAction()
{
Action action = null;
try
{
if(actionOfPartner == null) {
// We are starting the negotiation. Offer max NTU bid.
logger.write("We are starting the negotiation. Offering the max NTU bid");
logger.write(beliefSpace.getMaxNTUBid().toString());
ourBids.add(beliefSpace.getMaxNTUBid());
return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
}
if(actionOfPartner instanceof Offer)
{
```

```
// Get partner's bid.
Bid partnerBid = ((Offer)actionOfPartner).getBid();
logger.write("Partner bid: " + partnerBid);

partnerBids.add(partnerBid);
partnerUtilityModel.updateModel();

// Update situational knowledge utility component of the Belief Space.
beliefSpace.setSKU(partnerBid);

// Offer best opponent's offer if time is coming to the end.
if (timeline.getTime() >= Settings.TIME_TERMINATION_CRITERIA) {
Bid bestBid = null;
for (Bid bid : partnerBids) {
if (bestBid == null || utilitySpace.getUtility(bid) > utilitySpace.getUtility(bestBid)) {
bestBid = bid;
}
}

return new Offer(getAgentID(), bestBid);
}

// Accept offer if SKU termination criteria is met.
if (isTermination() && utilitySpace.getUtility(partnerBid) >= 0.5) {
logger.write("Termination criteria is met. Accepting the offer.");
return new Accept(getAgentID());
}

// Produce next generation.
logger.write("Producing next generation.");
population.clear();
Bid parent1 = beliefSpace.getMaxNTUBid();
```

```
logger.write("First parent: " + parent1.toString());

int numberOfPartnerBidsToUseAsParents = Math.min(3, partnerBids.size());
int currentPartnerBidNumber = 0;
for (int i = 0; i < populationSize / 2; i++) {
Bid parent2 = partnerBids.get(partnerBids.size() - 1 - currentPartnerBidNumber);
logger.write("Second parent: " + parent2.toString());
currentPartnerBidNumber++;
if (currentPartnerBidNumber >= numberOfPartnerBidsToUseAsParents)
currentPartnerBidNumber = 0;

// Copy the first child from the parent 1.
HashMap<Integer, Value> values = new HashMap<Integer, Value>();
ArrayList<Issue> issues=utilitySpace.getDomain().getIssues();
for (Issue issue: issues)
{
values.put(issue.getNumber(), parent1.getValue(issue.getNumber()));
}
Bid child1 = new Bid(utilitySpace.getDomain(), values);

// Copy the second child from the parent 2.
values = new HashMap<Integer, Value>();
issues=utilitySpace.getDomain().getIssues();
for (Issue issue: issues)
{
values.put(issue.getNumber(), parent2.getValue(issue.getNumber()));
}
Bid child2 = new Bid(utilitySpace.getDomain(), values);

// Crossover.
int issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
int issueNumber = utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
Value tempOption = child1.getValue(issueNumber);
```

```
child1.setValue(issueNumber, child2.getValue(issueNumber));
child2.setValue(issueNumber, tempOption);

// Mutation of the first child.
if (random.nextDouble() < Settings.MUTATION_PROBABILITY) {
issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
issueNumber = utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
IssueDiscrete issueDiscrete =
(IssueDiscrete)utilitySpace.getDomain().getIssue(issueIndex);
int issueValue = random.nextInt(issueDiscrete.getNumberOfValues());
child1.setValue(issueNumber, issueDiscrete.getValue(issueValue));
}

// Mutation of the second child.
if (random.nextDouble() < Settings.MUTATION_PROBABILITY) {
issueIndex = random.nextInt(utilitySpace.getDomain().getIssues().size());
issueNumber = utilitySpace.getDomain().getIssues().get(issueIndex).getNumber();
IssueDiscrete issueDiscrete =
(IssueDiscrete)utilitySpace.getDomain().getIssue(issueIndex);
int issueValue = random.nextInt(issueDiscrete.getNumberOfValues());
child2.setValue(issueNumber, issueDiscrete.getValue(issueValue));
}

population.add(child1);
population.add(child2);
logger.write("Child: " + child1.toString());
logger.write("Child: " + child2.toString());
}

// Calculate Best Accepted Individual using the appropriate fitness function.
Bid bai;
if (timeline.getTime() < Settings.LEARNING_TIME) {
bai = fitness();
```

```
} else {
double cFactor = utilitySpace.getUtility(partnerBids.get(partnerBids.size() - 1)) -
utilitySpace.getUtility(partnerBids.get(partnerBids.size() - 2));
ourCurrentUtilityLimit -= cFactor;
bai = fitnessCooperation();
}
logger.write("Best accepted individual:" + bai.toString());
logger.write("Utility: " + utilitySpace.getUtility(bai));

// Update the Belief Space with the BAI.
beliefSpace.accept(bai);
ourBids.add(bai);

// Send offer.
sleep(Settings.TIME_TO_SLEEP_BEFORE_SENDING_AN_OFFER);
logger.write("Sending the offer");
return new Offer(getAgentID(), beliefSpace.getMaxNTUBid());
}
} catch (Exception e) {
logger.write(e.getMessage());
System.out.println("Exception in ChooseAction:"+e.getMessage());
sleep(0.1);
action=new Accept(getAgentID()); // best guess if things go wrong.
}
return action;
}

/**
* Checks whether one of the following termination criteria is satisfied:
* - SKU is more or equal to the 99% of max NTU.
* @return boolean value indicating whether the negotiation process should be terminated.
*/
```

```
private boolean isTermination() {
return beliefSpace.getSKU() / beliefSpace.getMaxNTU() >=
Settings.SKU_TERMINATION_CRITERIA;
}
}
```

Vita

Mohammed Zaher Hammadih was born in 1988, in Hama, Syrian Arab Republic. He studied his elementary and secondary education in the National Charity School in Dubai, UAE. He graduated from high school in 2006 with 98.2% and ranked 13th in the UAE. He was awarded the Bachelor of Science degree in Civil Engineering and ranked the 1st in his batch, from the University of Sharjah, UAE in 2010. He immediately began his Master's program in Engineering Systems Management at the American University of Sharjah. During his graduate studies at the American University of Sharjah, he worked as a part time graduate teaching and research assistant and was involved in a variety of research activities.

In his work experience, he is the distinguished founder and principal of Sama Deira Real Estate, a property brokerage and facility management firm in Dubai, UAE. He is generally recognized as a successful real estate professional in the Dubai market. He has negotiated the sale of numerous large and complex real estate transactions in the recent past. Moreover, he was the founder for Apex Multiplex Technical Services LLC, an engineering technical service firm in Dubai, UAE. In 2012, Hammadih established Sama Deira Building Maintenance and Cleaning, a specialized firm in maintain freehold buildings in compliances with Dubai Land Department requirement for owners associations. Moreover, he jointly established HuskyMonkey Technology, which is an IT firm specialized in offering classified listing in the Middle East and CRM solutions provider for various organizations. It is important also to highlight that Hammadih is a board member in several owner associations for several projects in Dubai such as The Princess Tower, which is the highest residential tower in the world.

On social work, Hammadih is a permanent volunteer in Dar Al Ber Society since 2002, in which he participated in several charitable activities.