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Appendix A:
Bulk Agent Projects and Libraries

A.1 IntelliJ IDEA project modules

Bulk Agent Marketplace developed Java based projects in the IntelliJ IDEA IDE. There are two main modules. Firstly the BulkAgentPlugin which contains the basic class structure which can be incorporated in building the bulk agent concept in any multi agent application in the JADE framework. Secondly the jadepra, which contains the customised source code of the JADE. In our customizations we have altered some security measures and minor changes on basic structures of agents.

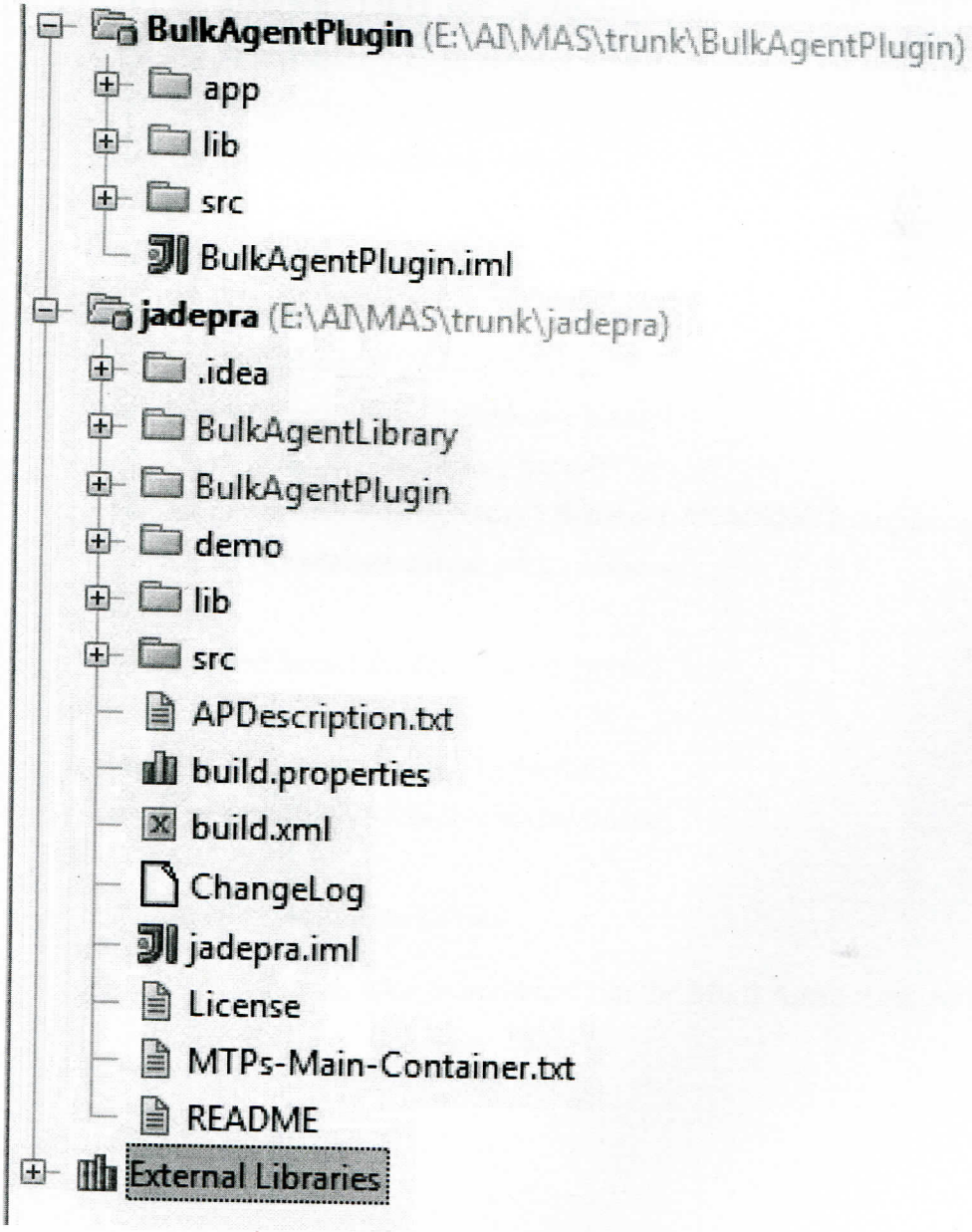

Figure A.1: Modules of the development

A.2 IntelliJ IDEA project details

The third party libraries use in the implementation and deployment of the application is given below.

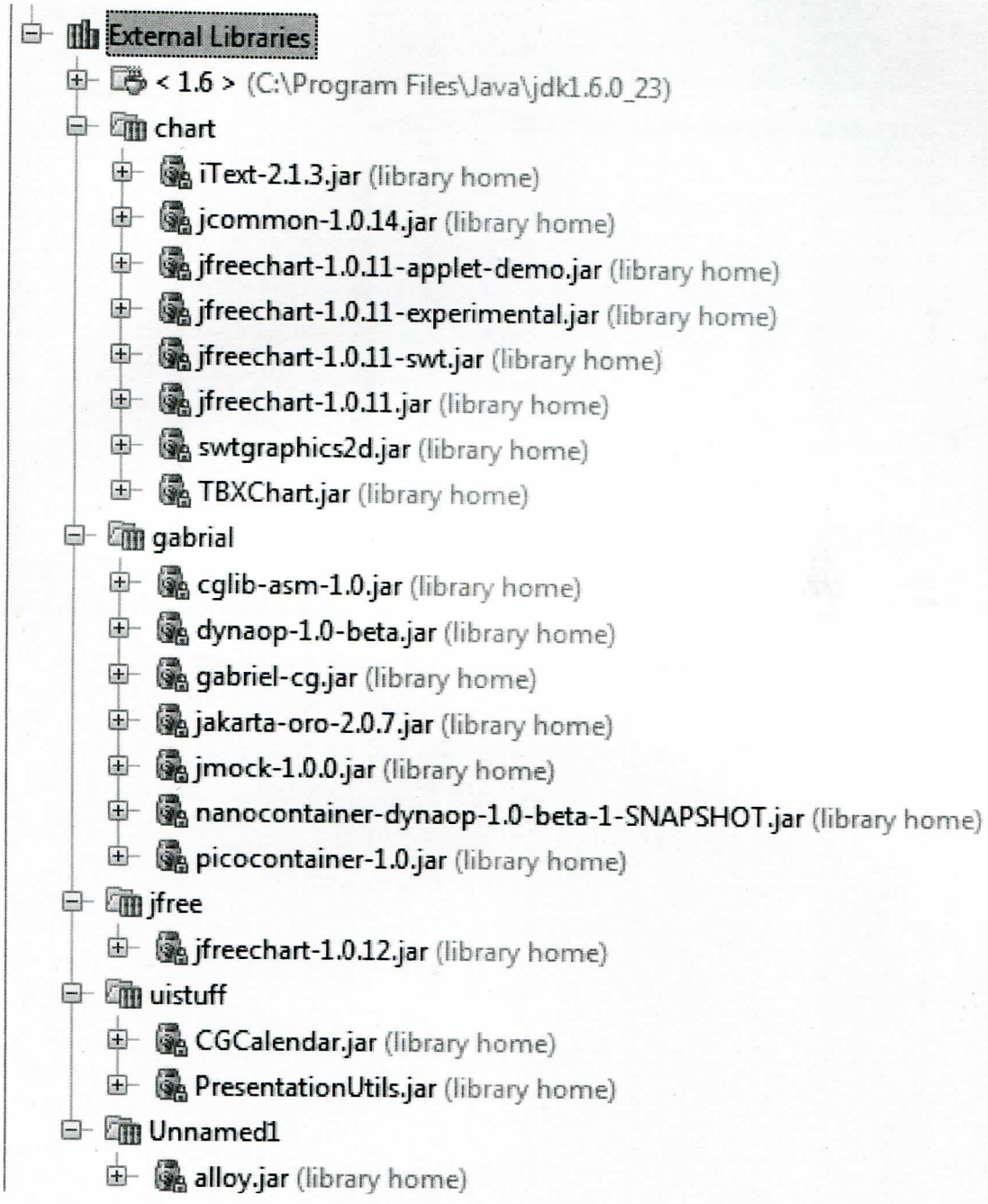

Figure A.2: Libraries used to build and run the Multi Agent Application

A.3 Module/Library Dependency of BulkAgentPlugin

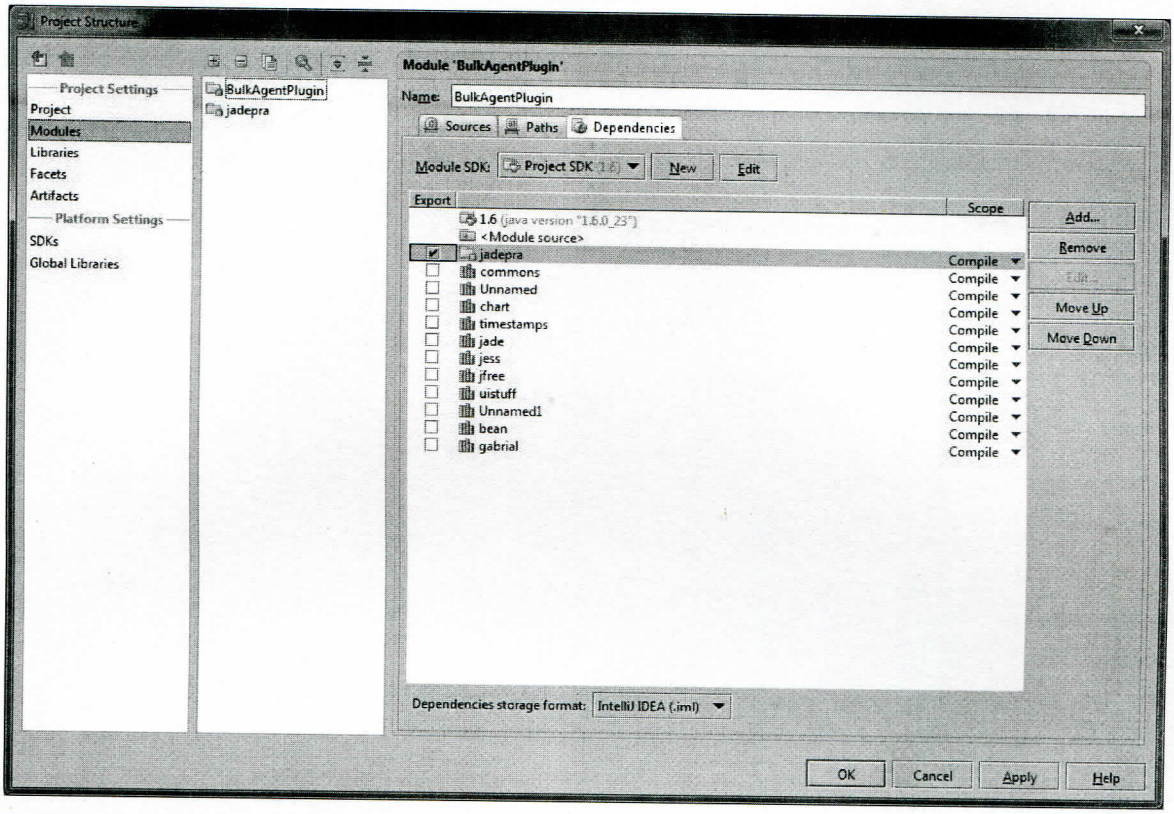

Figure A.3: Module Dependency of BulkAgentPlugin

A.4 Module/Library Dependency of jadepra

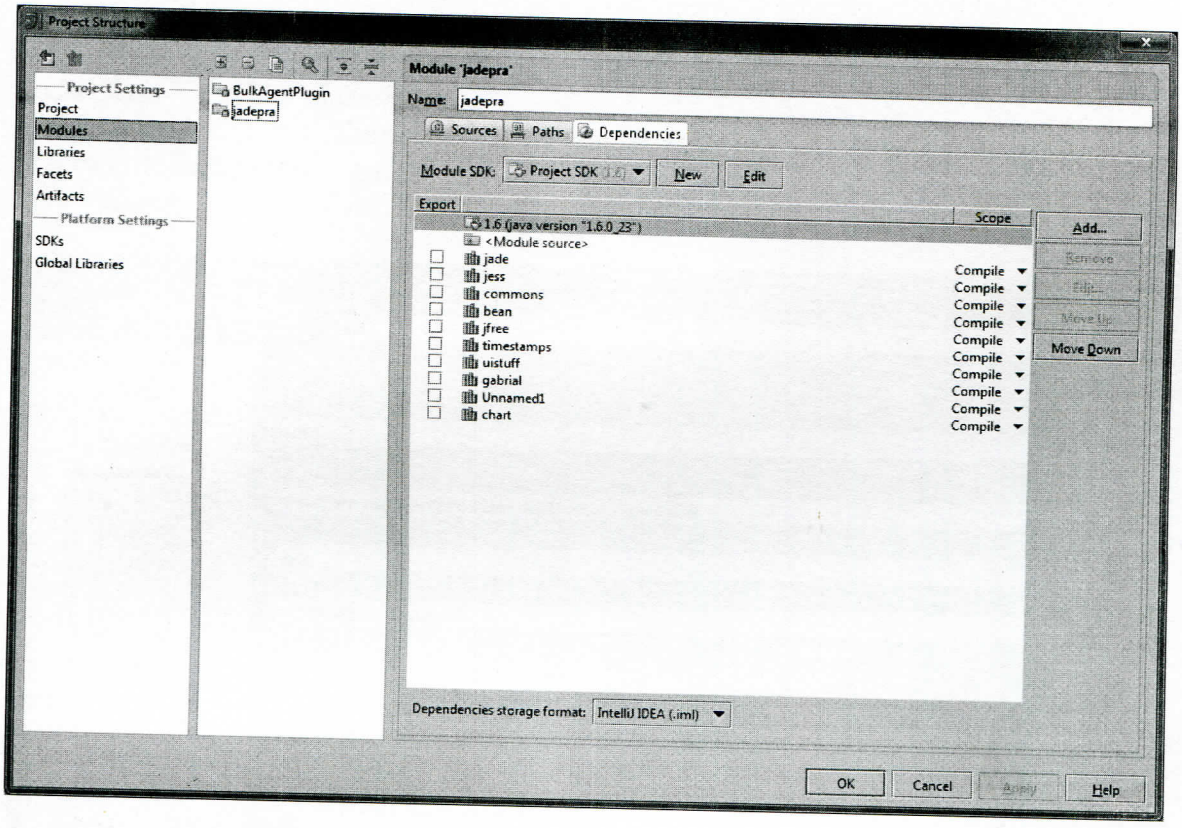

Figure A.4: Module Dependency of jadepra

A.5 Application Execution instructions

Run the Boot.java class with the following parameters.

Main Class : jade.Boot
VM Parameters : -Xmx256m -XX:PermSize=256m -XX:MaxPermSize=256m
Programme Parameters : -gui
Java Version : JDK 1.6

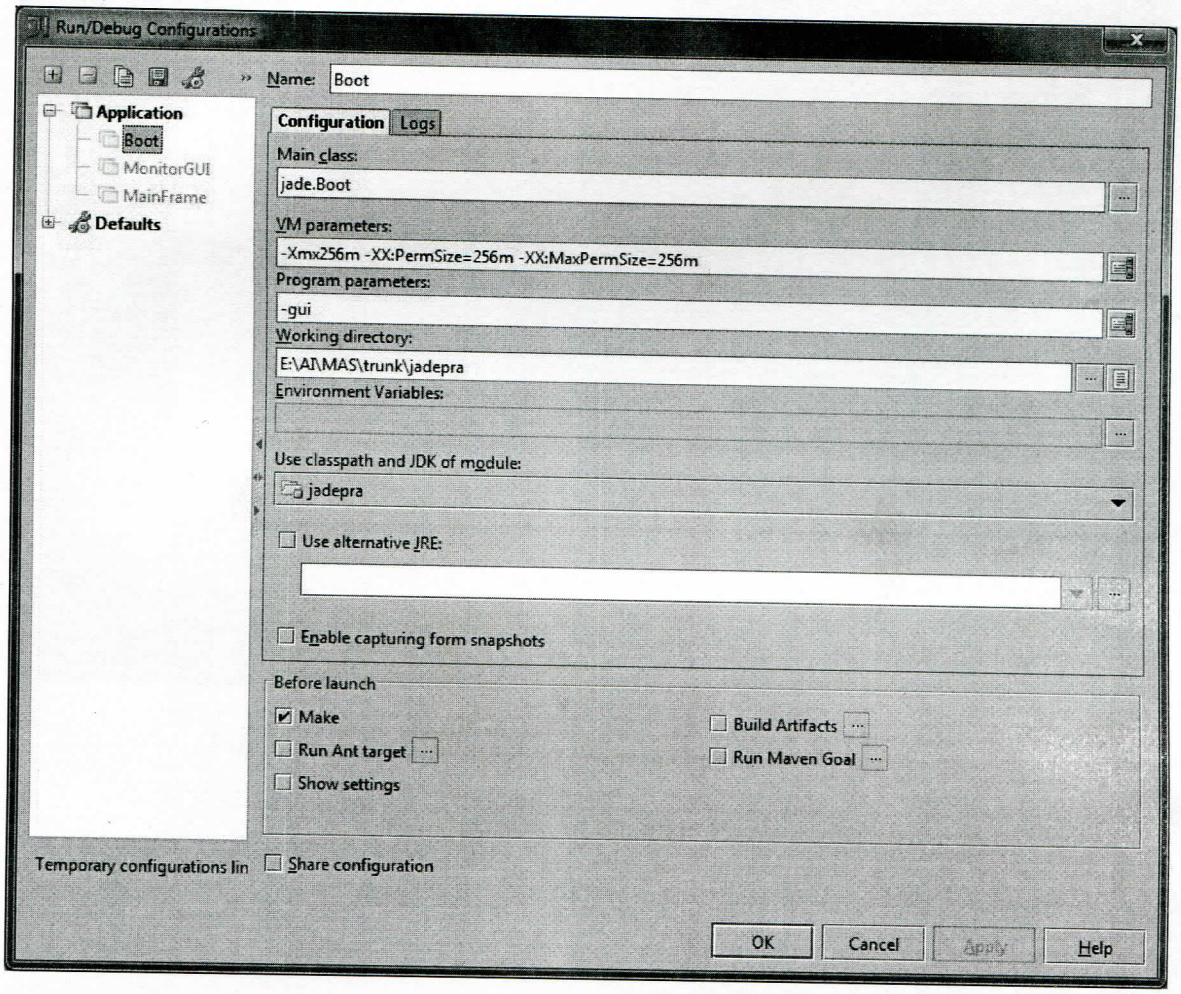

Figure A.5: Executing Parameters

Appendix B: Experiments and Evaluation Results

B.1 Conflicts with Bulk-Normal

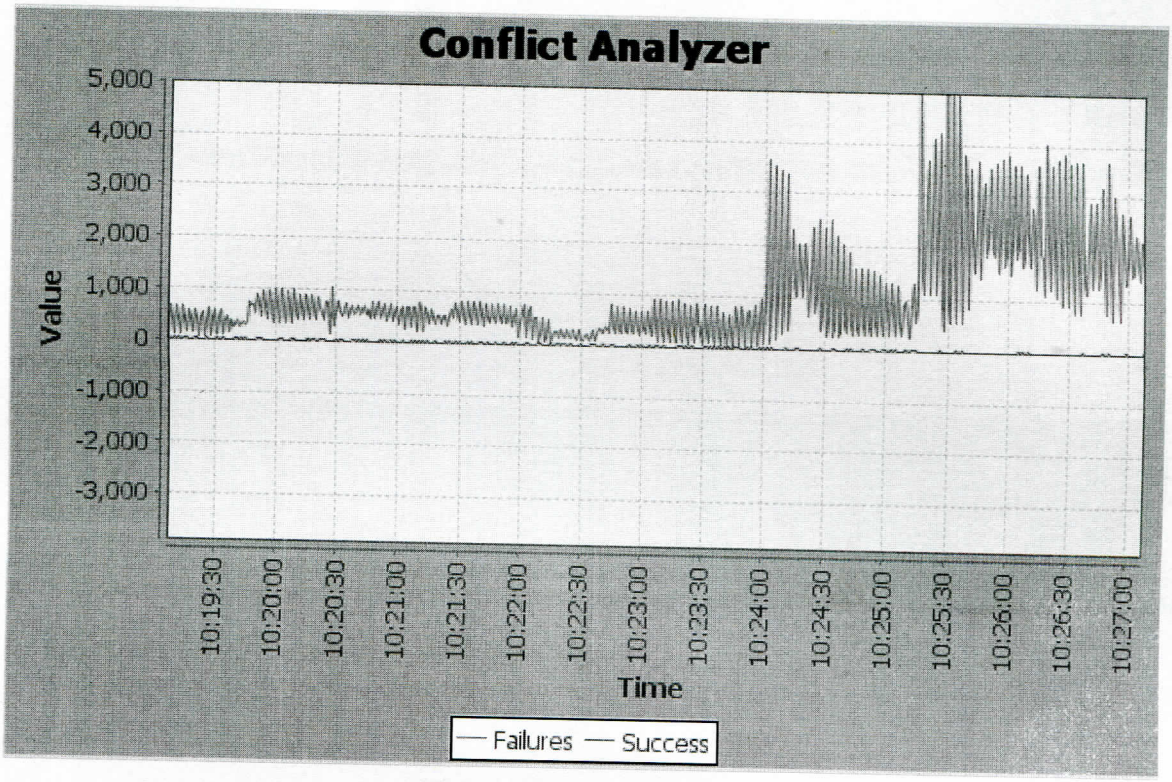

Figure B.1: Conflicts with Bulk Agent - Normal Mode

B.2 Transaction with Bulk-Normal-Bulk

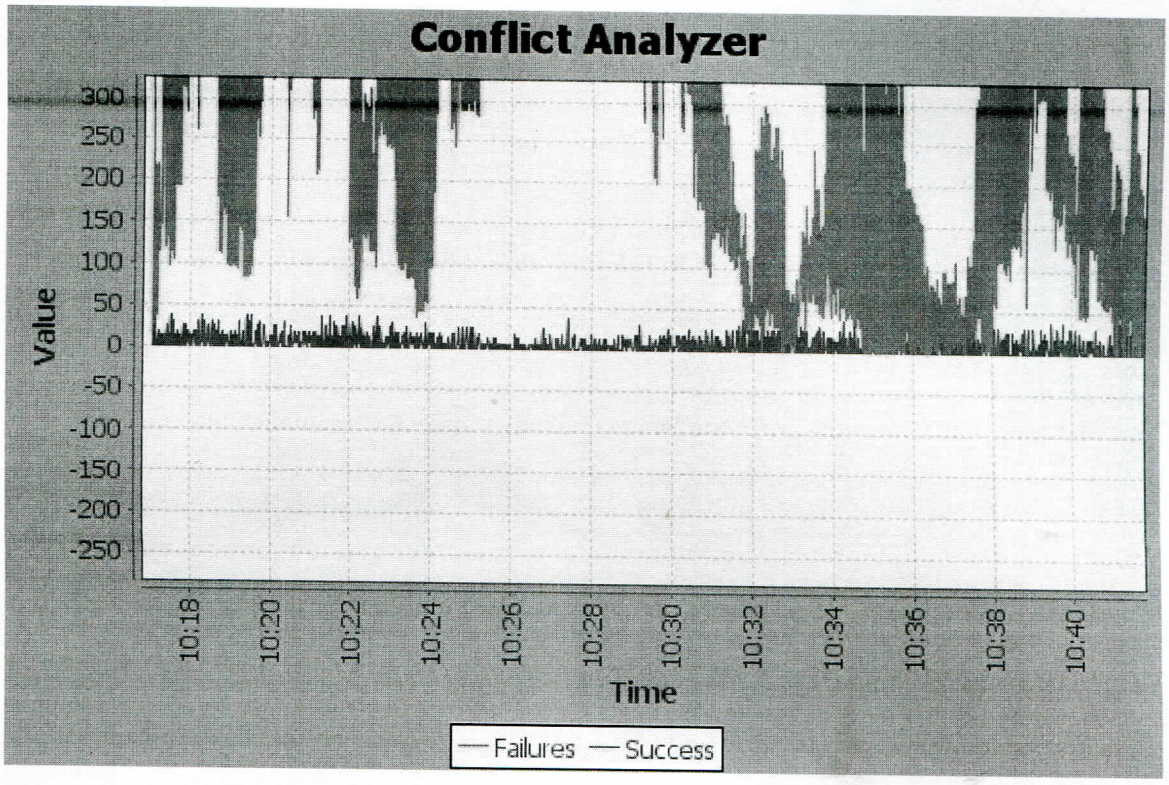

Figure B.2: Transaction with Bulk Agent - Normal Mode - Bulk Agent

B.3 Conflicts with Bulk-Normal-Bulk-Normal

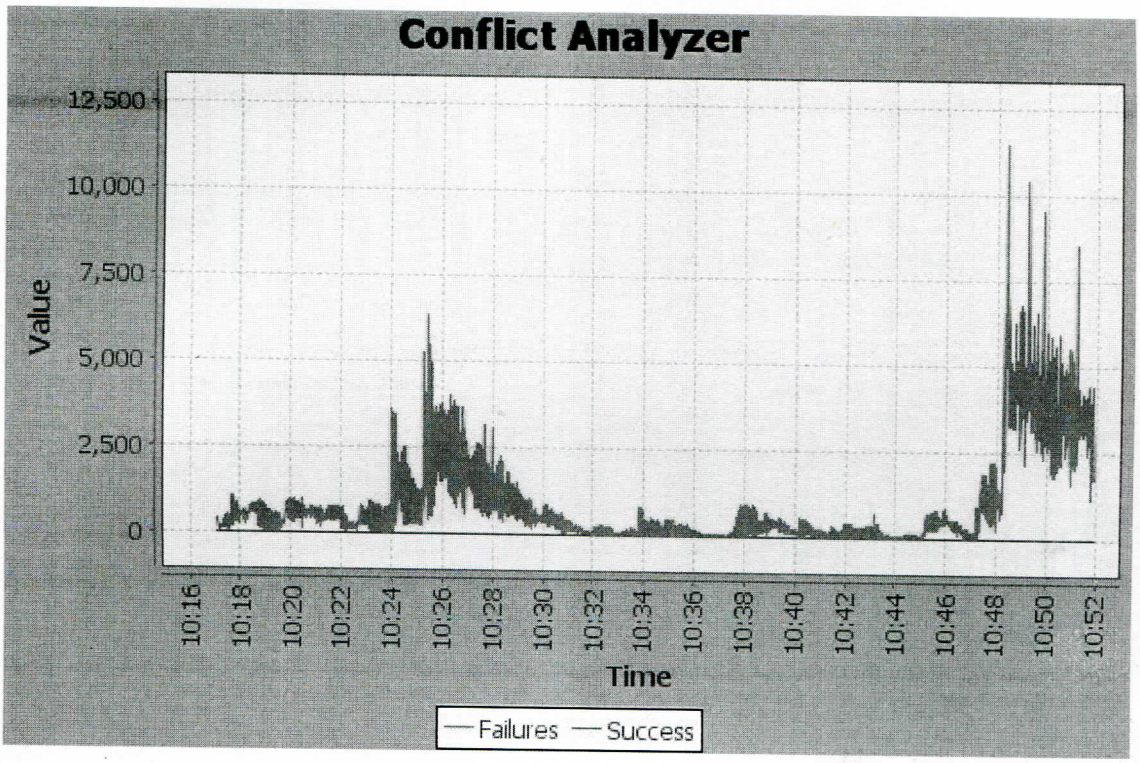

Figure B.3: Transaction with Bulk Agent - Normal Mode - Bulk Agent-Normal Mode

B.4 Computational Usages with Bulk-Normal-Bulk-Normal

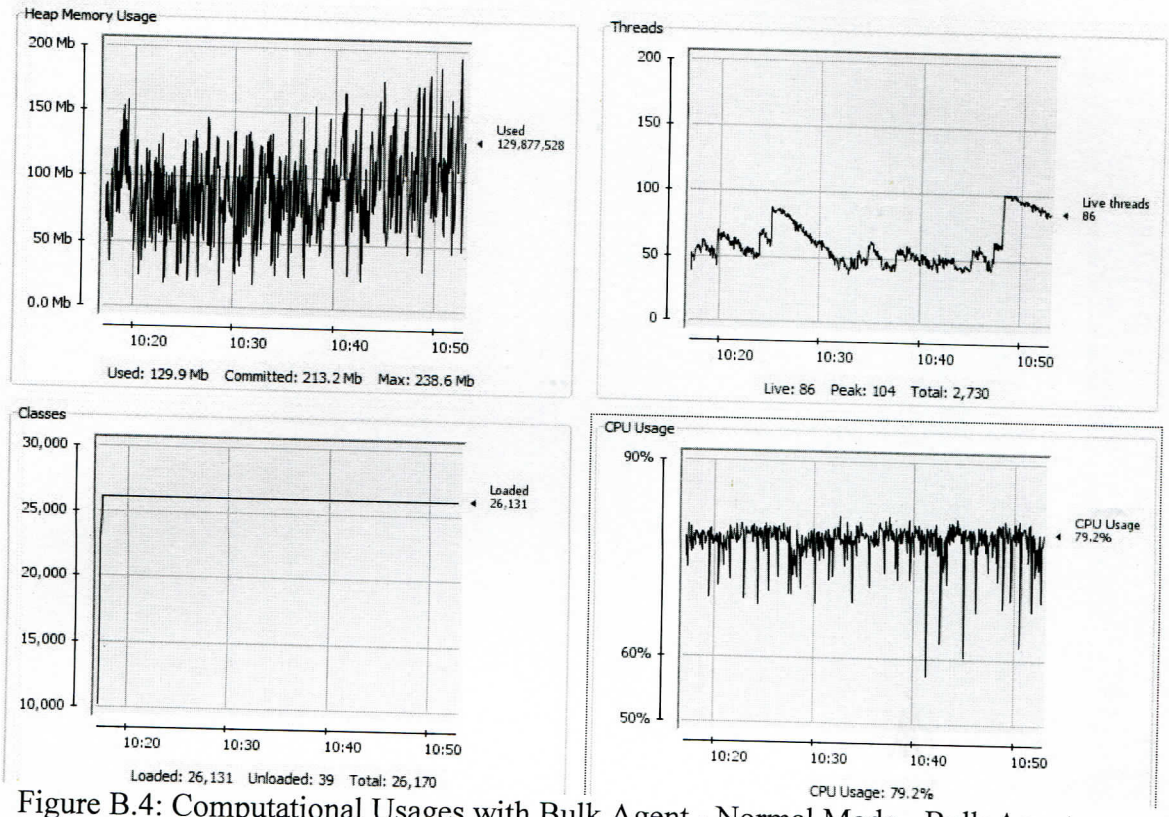

Figure B.4: Computational Usages with Bulk Agent - Normal Mode - Bulk Agent-Normal Mode

Appendix C:

Statistical Data of the Experiment in Success Rate Evaluation

Ex. No	Starting Conflict level	With Bulk Agent			Without Bulk Agent		
		Maximum Conflict Level	Reduction	Duration in Min.	Maximum Conflict level	Increase	Duration in Min
1	450	50	400	3	1600	1550	2
1	1600	50	1550	7	3750	3700	4
1	3750	50	3700	8	4000	3950	3
2	525	70	455	2	1000	930	3
2	1000	50	950	6	4250	4200	2
2	4250	50	4200	9	4250	4200	2
3	400	40	360	3	1400	1360	3
3	1350	50	1300	8	3700	3650	3
3	3250	70	3180	6	4250	4180	3
4	500	40	460	4	1000	960	2
4	1200	50	1150	9	4250	4200	4
4	3900	50	3850	9	3900	3850	5
5	550	50	500	2	1000	950	3
5	1250	50	1200	6	4250	4200	2
5	4200	70	4130	9	4300	4230	2
6	500	70	430	5	1000	930	3
6	1500	50	1450	6	4250	4200	2
6	5000	70	4930	10	5000	4930	5
7	800	50	750	2	1000	950	3
7	800	60	740	8	4250	4190	2
7	4300	60	4240	6	4300	4240	2

8	200	50	150	5	1000	950	5
8	1450	60	1390	9	4250	4190	4
8	4000	70	3930	9	4200	4130	2
9	550	50	500	3	1750	1700	3
AVG	1891	55.2	1835.8	6.16	3116	3060.8	2.96

Conflict reductoin speed	298.02	per second	
Conflict reductoin percentage	97.08	%	in 6.16 min
Conflict increase speed	1034.05	per second	
Conflict increase percentage	98.23	%	in 2.96 min

Table C.1: Statistical Data Collected in the Experimented

Appendix D:

First Conference Publication - AMS2013

D.1 The AMS2013-Asia Modelling Symposium 2013(Seventh Asia International Conference on Mathematical Modeling and Computer Simulation) - In Press.

Exploiting Bulk Agent Approach for Conflict Resolution in Multi Agent Systems

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Abstract— **Conflicts are inevitable when autonomous agents operating in Single Multi Agent System to achieve their own goals. Therefore various conflict resolution techniques were presented in the literature. Argumentation Based Negotiation (ABN) has been considered as one of the best approach so far. Evading and re- planning are also two different cost effective options which should be considered as the first option in resolving conflicts. On the other hand, nature can be considered as a one big natural multi agent environment, where all elementary agents interact with no visible conflicts. Cosmological studies and theories have been used to explain most of the natural phenomena that we scientifically experienced. How brane particles interacts each other in a universal extra dimension (bulk) and share the same governing rules such as gravity is the main inspiration for our research. We postulate that the conflicts can be avoided or resolved with minimal computational time and resources by introducing bulk agents which represent extra dimensions of a multi agent system.**

Keywords-multi agent systems; bulk agent; conflict resolution; brane agent; cosmology

I. INTRODUCTION

Communication is the key feature that drives emergent roperty in Multi Agent Systems (MAS). Changes in an gent's Environment where one or more autonomous gents competing for their own goals, lead to conflicts n knowledge or Resources. Moreover, any Multi Agent ystem can be considered as a system, where Agents are ommunicating to resolve conflicts on each other. lowever in some circumstances, certain conflicts could ot be resolved or remain unresolved for long time onsuming large amount of time and resources. In eveloping a novel strategy for conflict resolution in MAS, e have been inspired by cosmological studies on how atural systems manifest their existence. In fact the same henomena can be observed in philosophy as well. Based n cosmological and philosophical studies, we postulate at conflicts in MAS can be resolved with minimal amount of time and effort, by an upper level agent called bulk agent which is supported by the knowledge and control of the dimension higher than the other operating agents, which are called brane agents. Our first motive is to find a model which improves the potential of conflict evading, whereas the second motive is to resolve conflict consuming less amount of time and resources. We would like to present a Multi Agent Environment Structure which satisfies our motivations.

There are five sections in this paper. First section explains current trends and practices such as argumentation based negotiation in conflict resolution of Multi Agent Systems. We also explain the various pitfalls that Multi Agent System designers could fall-in. The Bulk Agent approach is backed by philosophical and cosmological finding. Therefore we present the third section to elaborate cosmological background and the fourth section contains various philosophical concepts which support the background of our approach. Fifth section contains high-level architectural diagram of the proposed Multi Agent Framework along with an example application. As the sixth and the last section of this paper we discuss our concept and current developments and future research plans.

II. REVIEW ON CURRENT TRENDS IN CONFLICT RESOLUTOIN

Communication strategies such as Argumentation Based Negotiation and Coordination play a major role in multi Agent systems. "How" and "When" to communicate, is a part that has been well studied in literature on agent's conflicts [7, 2, 4, 9, 8, 5].

Conflicts are inevitable in Multi Agent systems when the autonomous agents compete for their own goals. There are two types of conflicts. Conflicts on resources can be occurred among resource agents, whereas Conflicts on the knowledge can be seen when the ontology or the desires of an agents are different [9]. Among various conflict resolution techniques explained in literature, Argumentation-based Negotiation (ABN) provides

/hat promising results when the conflicts occurs as a of resource limitations [9].

rgumentation Based Negotiation

th the increase of information and resource demand ulti agent system, negotiation is an essential feature ercome conflicting situations. Heuristic-based and based approaches are two alternatives in the studies flict resolution strategies, at the early stages in the ıre [13]. However Argumentation-based approach own more potential in handling the demand of ation and flexibility in a ring structured multi agent [13]. Arguments in different condition can be d as three types of arguments [13]. (I). Reward (A, Q) denotes that if negotiator B realizes P, negotiator give it rewards Q. (ii). Threat (A, B, P, Q) denotes negotiator B does not Realize P, negotiator A will threat Q. (iii). Appeal (A, B, P, Q, R) denotes that ator A desires Negotiator B realizes P, but not Q for R.

the ABN approach agents can exchange proposals the target of resolving conflicts. To support and the proposal in an argument, meta-information is eed to be attached [9]. In such proposals arguments s critics, appeals etc. can be defined to influence the ent to accept the proposal. Finally, Conflicting , agreeing into one proposal would resolve the ct.

owever arguments are needed to select, communicate valuate with the cost of computational time and ces. To minimize such costs, it is necessary to e and avoid by possible ways, such as evading g an alternative means) or re-planning (modifying tended cause of actions)[9]. It is identified that the ve argumentation is effective than the indiscriminate entation [9]. Moreover evading and re-planning ques are more effective when the resources are ant; whereas ABN approach presents more effective of resolving conflicts when resources are ained [9]. So before any argumentation starts it is ary to identify conflicts which the arguing is able. So to minimize the cost of resolving conflicts, st approach can be, "argue only if the evading is not le".

en though the Argumentation-based negotiation) is fast immerging technology for conflict tion[2,4], high consumption of time and utational resources to generate, select and evaluate ents[9], has motivated us to find an better alternative ighly conflicting environments. On the other hand, me conflicts, due to the limitation of knowledge and sources of agents, these two options could fail. In worlds, to evade it is necessary to have more than ption, and to re-plan it is necessary to have a second le plan for agents. However these approaches have experimentally proven only in agent environments no social structure, so that all agents communicate o-peer [9]. So, Analysis on Social relationships and ures among agents is yet to be studied further in the xt of conflicts.

B. Is it worth to argue?

Kraus, Sycara and Evenchik [5], has analyzed the notion of how and when to argue. Their experiment is based on two agents that need to perform a task which cannot be complete. They propose that if the argument is going on more than certain amount of time stop the argument and re-plan. However we argue, "Is it worth to argue and disregard the arguments, when the conflict cannot be resolved?" This tells us that Arguments as well as re-planning could sometimes consumes time and resources without a promise of results, which can be observed in the human societies as an analogy for multi agent societies. On the other hand, Argumentation-based negotiation has to be implemented with fast and complex operations in time critical systems. One option could be adding some tactics such as Last Minute Tactic into agents to make the other party agreed. However any tactic can be defined with some level of assumption, as the tactic can be used only if the environment supports for that. For example to have the Last Minute Tactic effectively, the assumption of availability of information and deadline for agents needs to be satisfied [8]. In other words, tactics are useful only when the supporting assumptions are met.

C. Knowledge Conflicts

Knowledge conflicts in a agent society can be occurred due to lack of knowledge, the motivation and/or the less or no capacity to work with the social influences [11]. The main reason behind this is the incomplete, diverse or conflicting information and influences. On the other hand, in a Multi Agent Society, influences on an agent's action can occur internally or externally to an agent. In a highly complex society, there can me one or more influences, and it is unlikely that an agent could know all the influences at the same time. So it is obvious that, such complex social influences could make incomplete information of agent's about the society, which results large amounts of knowledge conflicts at the same time. ABN provides promising solutions even for such knowledge conflicts [11]. However to resolve the conflicts with the knowledge in hand, it is required to have (i) a schema to reason in social settings; (ii) a mechanism to identify a suitable set of arguments; (iii) a language and a protocol to exchange these arguments; and (iv) a decision making functionality to generate such dialogues[11]. According to the first requirement it is required to have global understanding of set of rules to reason on social settings. By analyzing the second, third and fourth requirements, we would like to argue that, if agents are allowed to share a global shared or upper ontology, (which best describes the social schema and the state of the immerged society) then the exchange of arguments can be reduced. Because the shared global ontology generates a resistance for agents to go against society and we postulate that, it helps the agents to recover fast from conflicting state.

D. Resistance and consensus

Even though there is a resistance to avoid the social consensus, it is an immerged property but not a governing rule as such within our approach. So, challenging the existing influences helps the society to come into a

consensus of social influences, manage influences and make it more effective as a society [12]. With all this, According to our strategy it is necessary to have an upper level agent with overall knowledge and control to recover from conflicts. Here the upper level knowledge means the upper ontology and the upper control means the controlling power of changing upper ontology as well as low level behavior and the shared ontology.

E. *Is your system anarchic?*

There are various pitfalls and misconceptions that any Multi Agent System Designers could fall in. Michael Wooldridge and Nicholas R. Jennings have pointed out eight types of such pitfalls [7]. They can be listed out as Pitfalls in Political, Management, Conceptual, Analysis and Design, Micro Level, Micro Society Level, and implementation. Under the Micro Society Level some designers could fall into the misconception of "Your system is anarchic [7]". I.e. The pit fall of believing that, all agents have to be peers in the agent society and require no real structure. It is true, that some Multi Agent System require less or no structures in their society. However many systems require considerable amount of system-level engineering and structuring. Correct structures according to the problem in hand could deliver efficient, accurate solutions with less complexity in the design. With this misconception, most System designs could be very complex and highly difficult to model and develop. After developing the overall system, it would consume large amount of resources. Structured society could be one design option when the requirement is to "*achieve a common goal by a close-knit team of agents; abstraction hierarchies modeling the problem from different perspectives; or intermediaries acting as a single point of contact for a number of agents*"[7]. Sometimes reason for agents ending up with continues arguments, without immerging to the common agreement, is in most cases due to the inappropriate architectural design, falling into the pitfall of "Multi Agent System is always anarchic". In summary, Multi Agent systems are not necessarily anarchic.

III. Bulk Agents In Brane Cosmology

No irresolvable conflicts can be observed in the nature even though it is far complex than the most complex multi agent systems. Some of the high level and complex natural phenomena have been best described in some theories of cosmology then the standard model. Study on how the complexity is hidden from one dimension to its lower dimension in the nature can be a way to reduce the complexity of Multi Agent Systems. Explanations on cosmology on natural phenomena such as gravity are worth to study in the scope of this analysis. In Brane Cosmology, natural phenomena were examined, explained as Extra Dimensional Sequence of states.

Nordstrom has proposed the concept of extra dimensions in the early twentieth century and later extended by Kaluza and Klein. Early phenomenological observations and analysis on extra dimensions in the universe, has been revealed today by the Developments of string theory and its extension, M-theory. According to these explanations particles are confined on a hyper-surface (called Brane) embedded in a higher dimension (called Bulk). [10]

According to the Brane Cosmology our Time and space defines a 4 dimensions and the Brane is compacted to this 4 dimensions and restricted to the higher dimensions [2, 6, 10]. Higher dimensions are called "Bulk". Observable universe of the brane is on this 4 dimensions and no reference to the bulk (5th dimension or higher as in Fig.1) is appropriate in the context of the Brane.

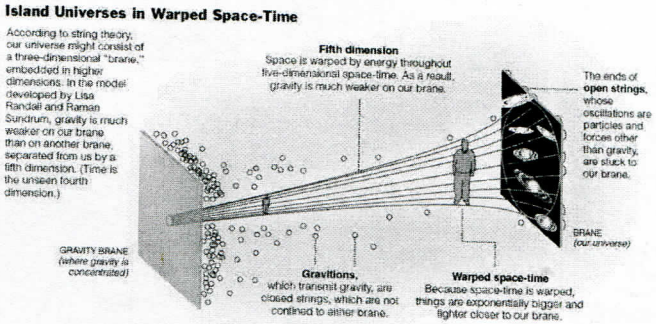


Figure 1: Brane world in the bulk and wrapped space time [14]

A Brane with all the other branes stay or interact with its Builk. So the bulk and other branes have the influence effect on our brain which cannot be seen in standard models [2, 6, 10].

Any Brane has its corresponding dimension. A particle is a 0 Brane in the zero dimensions whereas string like objet is a 1 Brane in single dimension. In String theory, state of vibrations in 1 Brane represents the elementary particles. A Two dimensional object is a 2-brane or membrane. Likewise when there are three space dimensions and one time dimensions, it become 4 dimensional spaces where the 4-branes like us can be found. For us 5th or higher dimensional phenomena such as gravity belongs to the bulk of our Brane. How we map this concept of brane cosmology for our conflict resolution strategy is explained in the fifth section of this paper.

IV. Philosophical Inspiration

Scientifically as well as philosophically our hypothesis can be supported and elaborated further. According to the Michael Polanyi, Laws governing particulars could never account for the organization principles of a higher entity [3]. He further pointed out that success of an immerged system cannot be explained from some of its parts. According to the Heidegger's concept of Breakdown, we cannot see parts of a system until we see a failure. In other words, failures of a system reveal some of its parts of where the failure occurred.

So, we can derive that to direct a set of agents to a resolved state or to success, it is necessary to have an immerged high level perception over the overall organization, which is a different work than having ontological knowledge for individual agents.

Albert Einstein once said that "*The significant problems we face cannot be solved at the same level of thinking we were at when we created them*". I.e. In resolving some problems such as complex agent conflicts, it is necessary to come out of the same level of thinking, where at when we created, which supports the concept and

e necessity of having higher level knowledge and ntrol.

Even in the very core of Buddhist Philosophy, ffering cannot be end just by living with it, but by derstanding the four noble truths which are called *ukkha, Samudaya Nirodha, Marga.* I.e. we can stop the ffering by understanding what it really is (*Dukka*), and nding what is the cause (*Samudaya*), and removes it *lirodha*) to reveal the method of how the suffering can be pped (*Marga*). Suffering is an ongoing conflict we all ce in the sansar, whether we like it or not. According to ddhist philosophy it is necessary to build an ability in e mind to understand 4 noble truths. This ability can be ilt only by observing the self and the suffering from a rd person's view [15, 16] which is called "*Vipassana*" or *lidarshana*" (The Meditation Strategy). In other words is meditation helps, one to understand the truth and the th, from a higher level knowledge which disconnects the wer level perceptions.

V. BULK AGENT APPROACH

The influence of higher or extra dimensions on Branes the Brane Cosmology is the main inspirational undation of the Agent Architectural Concept that we are esenting in this paper. Agents running in a predefined ent framework are analogous to the Branes in lower mensions. In Most Multi Agent Systems all the agents e interacting in a same level of dimension. When the nflict arises it is necessary to follow some method of nflict resolution to come out of the conflicting state the agent society.

According to the Multi Agent problem in hand, if we del a higher dimension in the multi agent system which ntrols or maintain the rules universal to the lower agents, st of the conflicts of agents can be avoided as well resolved consuming minimal amount of time and ources. Some resources limited to the Overall System n be well controlled and managed by introducing one or gher dimensional bulk agent, so that the Bulk agent uld make sure that the limited resources will not go out, any case. Such a bulk agent is essential in any Multi ent Framework as the computational resources are stly depending on the underling hardware available. It obvious that a Multi Agent Solution to a problem has a ect impact on the underling resource available for nts. So In our proposed framework, we would like to roduce the global bulk agent called the resource bulk. introducing the resource bulk, we are able to reduce the sign and development complexity of the overall system. the other bulks and branes will run in a lower mension than the resource bulk.

In this approach any change in the states of agents has emergent effect into the bulk agents, whereas any state the bulk agents have a ruling or controlling effect o the individual brane agents which would build a istance or discouragement for brane agents to go against rules of bulk agents. In this way brane agents are dependent and at the same time directional. So in an al System of this concept, Bulk agent represents the erall emergent rules and effects of all the branes. Apart m this the Global rules and direction for a success, can

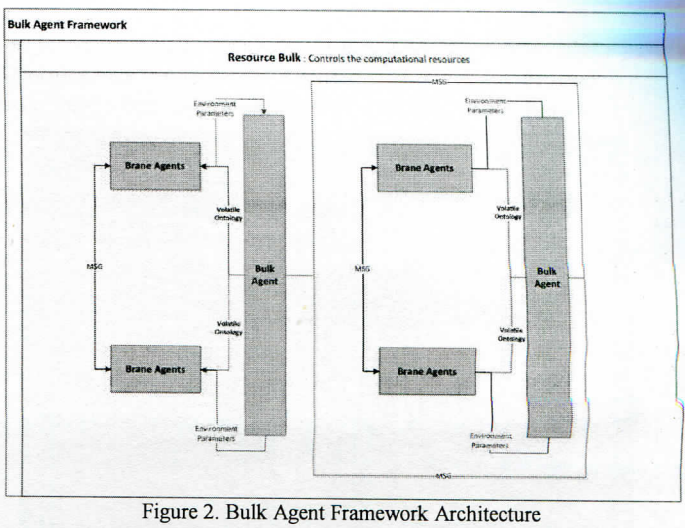


Figure 2. Bulk Agent Framework Architecture

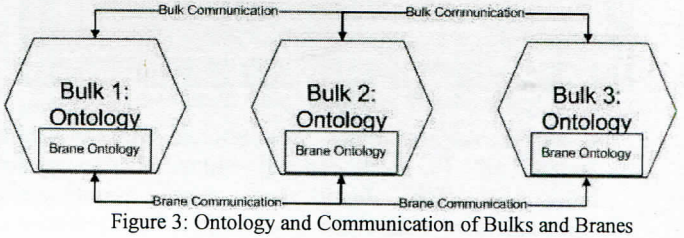


Figure 3: Ontology and Communication of Bulks and Branes

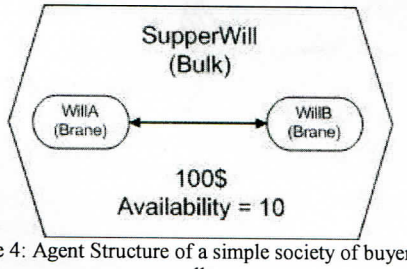


Figure 4: Agent Structure of a simple society of buyer and seller

also be modelled to the bulk. We can see that there are two types of ontology behind a bulk agent.

(i). Volatile Ontology (Ontology of the Bulk Agent immerged from the overall brane agents).

(ii). Concrete Ontology (Ontology of the Bulk Agent which has no impact from the brane agents).

Volatile Ontology makes bulk agents not dictators or an agent rules at the top in a hierarchical agent framework model. Both of this ontology will be allowed to share with lower level brane agents appropriately, maintaining the rules defined in the upper ontology. So in a conflicting situation, rules of the builk will show more power of resistance in a conflicting situation than a non-conflicting situation which makes the conflict to be resolved fast and easy. Because in an argumentation state agents would argue not only based on their state but also the global rules that governs which intern is volatile to the emergent effect.

So the main Idea of this research is that if we can model each agent as one brane in one builk, and each builk too is a brain in another builk, (Framework is the final bulk) we can reduce the complexity of the overall system drastically as the conflicts are resolved at the higher dimensions . So, as a solution to the above problem,

lti Agent Framework which facilitates Higher nensional Bulk Agents will be implemented. The posed framework will be able to generate agents and r dimensional ontology and the bulks that each agent ongs to. There will be one global bulk agent that ialized by the framework itself to resolve computing urce utilization conflicts. Default behaviour of the urce bulk agent is to give uniform resources to all nts. However its ontology has to be defined by the user ave a control over the resource utilization.

There can be N number of extra dimensions in the ti Agent Application. Each agent need to be assigned bulk agent in the next higher dimension and a bulk t cannot be a brane of lower dimension agents. The level architecture of the proposed agent framework el is given in the Fig. 2 and Fig. 3 which explains how communication and the ontology are maintained. It ys how multiple bulk agents can be formulated allows them to communicate while keeping their own logy unique for its brane environments. By putting all rane agents within the bulk ontology, we display the parent, high-level and no-secrete ability of bulk agents serving its brane environment.

To experiment this concept we have implemented an cation of Multi Agent Virtual Marketplace where r agents buy items from seller agents based on the act net protocol. We can simply explain our concept aking a unit of operation in this Bulk Agent etplace. For example, say we define two brane agents d WillA and WillB. Both have the access to the agent d SupperWill which is the bulk agent. WillA is ng to sell some items to WillB. In the overall agent ty only 10 items are available. This information is d among all the agents by the bulk. When an agent an item, bulk agent is notified and that makes the bulk luce the global availability count.

When a new item is brought into the market by a brane , SupperWill increases the global availability count. ng such knowledge on the society most of the rce and knowledge conflicts can be avoided and any nents will not take too long as each agent understands ate of the society and resources at the time they start rguments. As a result of these arguments global ge market price will immerged. As shown in the 4, the global market price is 100$. So agents will resistance to sell or buy the items too law or too high his market price, however it is not a restriction. So market price and availability of items in the market art of the volatile ontology of the Bulk, which is d with the Brane Agents. In this case, formulas to ate the available items and market price are the ete ontology of the Bulk Agent which is not shared with the brane agents. Please note that this is just a simple explanation to understand the basic behaviour of our agents and the concept. More complex real world

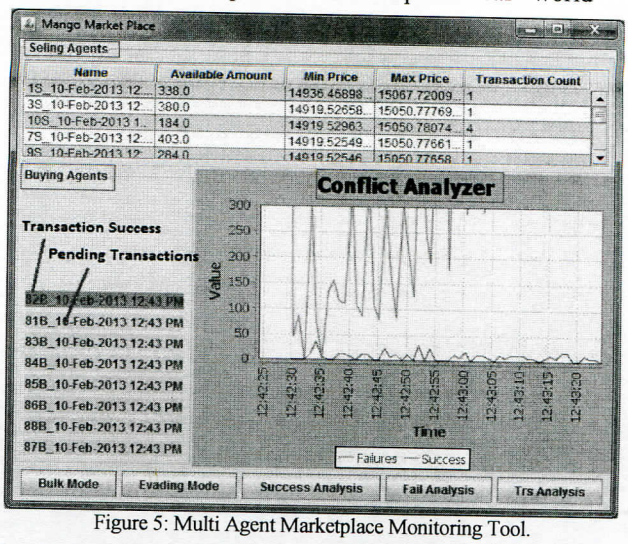


Figure 5: Multi Agent Marketplace Monitoring Tool.

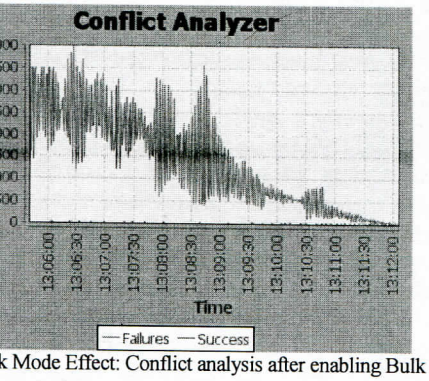
application could include more complex concrete/volatile ontology which would resolve most of the design, implementation and operational difficulties and complexities including issues associated with resource consumption.

VI. Implementation

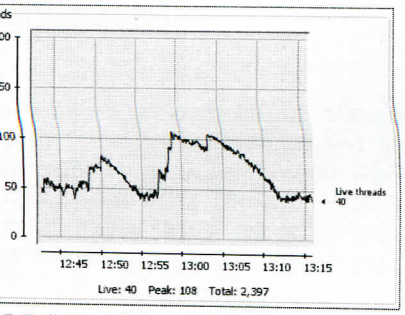
With all the benefits there is a computational as well as timesharing cost associate with bulk agents. In other words bulk agents are costly. Therefore bulk agent's global volatile ontology should be utilized only by agents who need it most. We postulate that this approach provides promising results in a multi agent system, where agents compete each other.

This approach has been experimented to analyze the effectiveness using multi agent system where supplier agents and buyer agents compete each other for a better price in an agent market place. In such competitions, to overcome some conflicts and to gain the benefit of higher knowledge on the agent's environment or the society, some agents can utilize the volatile shared ontology of the bulk agents when needed. To avoid all the agents accessing costly shared ontology of the bulk, there will be a price to be paid by brane agents. (I.e. The price needs to be paid to gain the competitive advantage).

In such agent environment, effectiveness of the bulk agent approach can be evaluated, by comparing the number of transactions, number of arguments, cost and benefit of agents who has used the volatile ontology against the agents who ignored the bulk agent ontology.



k Mode Effect: Conflict analysis after enabling Bulk Mode



7: Bulk Mode Effect: Thread Usage for Asynchronous Message Passing

utation and communication cost consumed by the stem can also be evaluated with or without bulk e have implemented a monitoring tool for Multi larket Place as shown above. We have ed the Multi Agent Marketplace in the Java lti Agent Freamwork called JADE.The conflict raph shows the rate of successful (or useful) and irrelevant) transactions(or communication) in red colors respectively. Various conflict modes can be enabled or disabled using the set buttons provided at the bottom so that we can nd compare the effectiveness of each mode

VII. Experiment and Evaluation

lained above, the application is implemented to different conflict resolution modes such as ode, Bulk Agent Mode, Conflict Evading Mode, from the monitoring the conflicts we also he computational usages in of our system.

the Bulk Agent market place for a considerable time under Normal Mode and then Switch back ode to observe the changes in the environment ss and fail rate. We have seen a considerable reduction in the fail rate, when the bulk mode is shown in the Figure 6.

here are high amount of communication we can level of threads in JADE as it involves ous message passing. As shown in the Fig. 7, ing the bulk mode the message passing threads s down to 40 from 100. Unnecessary ations due to conflicts were well utilized in the t approach. Therefore Bulk Agents mode makes nvironment better.

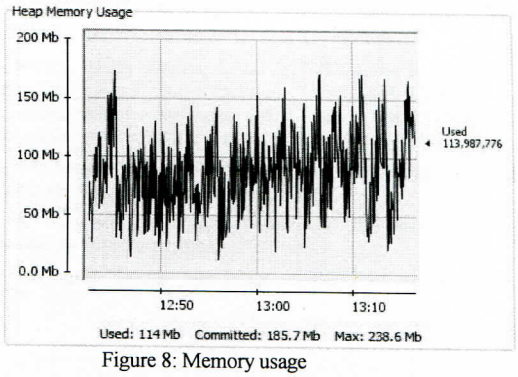


Figure 8: Memory usage

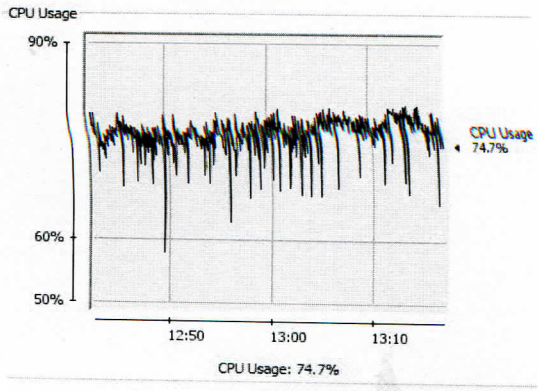


Figure 9: CPU Usage

As shown in the Figure 8 and Figure 9 there is no visible change in usage of Memory or CPU both in Bulk and Normal mode. When our agent society is full with conflicts, computational resources needs to be allocated for conflict resolutions, whereas when we have less conflicting society more agents can come in to the marketplace, make necessary usefull transactions and complete their objectives and goals comsuming the same ammount of computatonal resouces. This experimental result has been well observed repeatedly in varioiuse Agent Mode combinations. In other words Bulk Mode can make the environment better without consuming high amount of computation resources.

VIII. Conclusion

In this paper we presented the concept of bulk agents which represents extra dimensions in a multi agent system in the scope of conflict resolution. This concept is inspired not only from the cosmological findings but also from the philosophical explanations.

We have presented the model architecture of the Bulk Agent Framework which has been implemented. We have implemented an application of our concept in a Multi Agent Marketplace. With this fundamental experiment we have observed promising results that can be gain in resolving conflicts in a bulk agent environment. We postulate that building this concept into a generic framework, most of the real world multi agent solutions can be implemented with minimal amount of design and developments.

We also present two new ontological concepts, which are called "Volatile Ontology" and "Concrete Ontology" under bulk agents. Moreover such systems can be easily

eled to have agents communicating only when they led at the right time instead of communicating all the with no end. Benefits that we could gain are not only very less level of complexity in design, and lopment but also in monitoring, maintaining and the ng the system adding multiple levels of bulk agents. Most conflicts can be avoided by agents instead of ving by augments which results in less amount of nunication overhead. Especially this concept would e sure that the agent's knowledge on society will be and that leads to very less level of communication in flict.

inally by considering all our implementation and ation results we postulate that Multi Agent onments get better when the Volatile Ontology of the Agent is well utilized.

ACKNOWLEDGEMENT

uthors would like to gratefully acknowledge the orship by CodeGen International and its CEO, Dr. a Subasinghe for participation at the AMS2013-Asia eling Symposium 2013 (Seventh Asia International erence on Mathematical Modeling and Computer ation) conference for presenting this paper.

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ond Conference Publication - SLAAI2013

1 The SLAAI2013-SLAAI Annual Session 2013- In Press.

Conflict Reduction Analysis of Bulk Agent Approach in Multi Agent Systems

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Abstract

iverse can be considered as the largest multi ystem with no visible conflicts. Particles in dimensions interacts, based on different ional rules, which defines in the universal extra ons called Bulk. The same concept can be d, as the Bulk Agent Approach in multi agent to overcome potential conflicts, which also rs the direction of the emergent success of the system. On the other hand, it is a design e in multi agent systems, on how to avoid ary conflicting chaos which could consume omputational resources and valuable time. tation Based Negotiation (ABN) with the of conflict evading and re-planning can be ed as one of the best approach in conflict n techniques. Philosophical explanations, and e Cosmology and how gravity governs on brane in the concept of universal extra dimensions is inspiration for our research. Our analysis are on a Multi Agent Marketplace and its ary results, which has shown that the conflicts oided or resolved with minimal computational resources by introducing bulk agents, which extra dimensions in multi agent systems. this paper presents statistical analysis to the level of effectiveness of Bulk Agent in conflict resolution in Multi Agent Systems.

Keywords-multi agent systems; bulk agent; conflict resolution; brane agent; cosmology

1. Introduction

Autonomous agents must communicate to overcome hurdles of conflicts on knowledge and resources in achieving goals. Conflicts should be avoided whenever possible, so that the limited computational resources can be better utilize for the intended role of the agent, which converges the whole society to the emergent success as quickly as possible. Our novel and alternative approach has been conceptualized based on the inspiration on cosmological and philosophical studies on how natural systems manifest their existence. Our hypothesis is that conflicts in MAS can be resolved with minimal amount of time and effort, by an upper level agent called bulk agent which is supported by the knowledge and control of the dimensions higher than other operating agents, called brane agents.

Bulk Agent approach is a model with a novel multi agent environment structure, which improves the potential of conflict evading, and it also supports agents to resolve conflicts, consuming minimal amount of time and resources.

re are eight sections in this paper including the oduction. Second section explains current ds and practices such as ABN approach in lict resolution of Multi Agent Systems. The Agent approach is backed by philosophical cosmological finding. Therefore we present the section to elaborate cosmological background the fourth section contains various osophical inspirations. Fifth section presents approach as an extension to our previous rch paper, which contains, in detail tectural model on Bulk Agent Approach. In paper, we elaborate our experiment with tical analysis with the calculated success rate r approach in a Multi Agent Marketplace. As ixth section we presents the implementation ls of our research with a conflict monitoring Conflicts on our multi agent application is ated based on observational as well as tical data collected in collection experiments. lts of our evaluation were discussed in the nth section. As the eighth and the last section is paper we conclude with a summary of our ngs with future research plans.

Review on Current Trends In Conflict Resolutoin

e are two types of conflicts in literature, which ategorized based on the cause of each of them. licts can be occurred due to limited resource n has to share among agents. I.e. agents has to ete each other to win and get the control of rces, as they are crucial in achieve their goals. efore, conflicts due to resources are called urce Conflicts[9]. Conflicts can also be ved in multi agent environments, when the 's knowledge or the ontology has gaps in een. I.e. when agents are communicating on different perceived knowledge, resulting vledge Conflicts [9].

overcome such conflicting situations mentation, Negotiation and Coordination play or role in multi agent systems. On the other deciding on "How" and "When" to nunicate, is much important aspect in multi conflict resolution studies[7, 2, 4, 9, 8, 5]. ng various conflict resolution techniques ined in literature, Argumentation-based tiation (ABN) has shown promising results the conflicts occurs as a result of resource tions [9].

A. Argumentation Based Negotiation

At the early stages of literature on multi agent conflict resolution techniques, Heuristic-based and Game-based approaches were introduced [13]. However with the increase of complexity, information and resource demand in a multi agent systems, negotiation becomes an essential feature to overcome conflicting situations. Hence, ABN became a fast immerging technology for conflict resolution[2,4]. Based on a ring structured multi agent system, it has been shown that the ABN approach has more potential in handling the flexibility and the demand on negotiation[13]. Moreover, there are three types arguments in ABN approach. (i). Reward (A, B, P, Q) denotes that if negotiator B realizes P, negotiator A will give it rewards Q. (ii). Threat (A, B, P, Q) denotes that if negotiator B does not Realize P, negotiator A will give it threat Q. (iii). Appeal (A, B, P, Q, R) denotes that negotiator A desires Negotiator B realizes P, but not Q for reason R. Based on these argument types, agents can exchange proposals with the intension of resolving conflicts. Moreover, meta-information should also be attached with each proposal to justify and convince the proposal[9]. Each agent would bring proposals for the favor of itself. However the conflicts can be resolved when agents agree on one proposal with the help of inbuilt self compromising ability.

Each argument in resolving a conflict has to consume some level of computational time and resources. Taking necessary means to minimize such cost, is much more important than the arguments them-self. Therefore, it is necessary to analyze and avoid (finding an alternative means) conflicts by possible ways. For the same purpose, Conflict Evading (finding an alternative means) and Re-planning (modifying the intended cause of actions) has been introduced in the literature as an alternative to ABN approach[9]. Moreover, It has been identified that the selective argumentation is effective than the indiscriminate argumentation[9]. However, when there is a resource conflict, it is necessary to have abundant resources to utilize the evading or re-planning approaches, whereas, ABN approach shows more effective means in resolving conflicts when the resources are constrained [9]. So the best approach suggested is "argue only if the evading is not possible". But, these approaches have been experimentally proven only in agent environments with no social structure, so that all agents communicate peer-to-peer [9]. So, Analysis on Social relationships and structures among

agents is yet to be studied further, in the context of conflict resolution.

Arguments as well as re-planning could sometimes continue indefinitely without a promise of a resolution. As Kraus, Sycara and Evenchik have proposed[5], when the arguments and negotiations consumes long durations, it should be stopped and start re-planning. But, after consuming large computational resources, it could be a huge loss for the multi agent system to abundant or disregard all the arguments and negotiations. Hence, the question is "Is it worth to argue?". In a situation where solution is time critical arguments could makes the system fail. As a solution some level of tactics needs to be defined such as Last Minute tactic in the system. But these tactics are based on some level of assumptions, as the tactic can be used fully if the environments supports in various ways such as availability of information and deadline for agents[8]. Hence, in a situation where assumptions are invalid tactics may not be useful enough.

Shared Global Ontology Vs Knowledge Conflicts

How the multi agent knowledge should be modeled in a system is mainly a design problem. But knowledge on the agent society has to be a dynamic ontology, which should continuously changing based on the social changes. On the other hand, due to the lack of knowledge, motivation or less or no capacity to work with social influences create conflicts in multi agents societies[11]. When the environment and system complexity increases, social influences from various factors could also be increased on agents. The understanding on those influences could cover conflicts, and that could increase the risk of system failures. Based on ABN approach such conflicts can be resolved, only if it has following features available in the multi agent environment. (i) a schema to reason in social things; (ii) a mechanism to identify a suitable set arguments; (iii) a language and a protocol to change these arguments; and (iv) a decision making functionality to generate such dialogues[11]. According to the third and fourth requirements, it is clear that global shared ontology required to define the social schema and the state of the immerged society. Modeling social influences and a resistance to failures, based on a global shared ontology would reduce argument failing and it also helps the fast recovery from conflicts. However, shared global ontology would not solve all the problems. It's still required to further design and implement a strong agent structure which supports and smoothen the flow of social and environmental knowledge, without falling into the misconception of anarchic system[7].

3. Cosmological Inspiration

We can consider the whole universe as a great multi agent system, which contains no visible conflicts. Each planet, star or galaxy including the planet earth and its humans, share the same universal phenomena with no observable conflicts. It is worth to study how the complexity of such a vast system manages in the context of complexity science and its technologies, such as Multi Agent Technology.

According to the Brane Cosmology, gravity defines the direction to the success in the universal evolution, starting from the origin of time. As explained in String theory and its extension M-theory, particles are confined on a hyper-surface (called Brane) embedded in a higher dimension (called Bulk) [10]. We are living in a world of 4 dimensions, where first 3 dimensions define the space which floats on the 4th dimension called time. To analyze the universe, mathematical concept called Brane defined in the theoretical physics. A particle in a world of P dimension is called a P-brane which are compacted to its dimension, while restricting to its higher dimensions[2, 6, 10]. For us, 5th or higher dimensional phenomena such as gravity belongs to the bulk of our Brane. In the same way gravity in our dimension is much weaker than the gravity on lower dimensions. Due to this difference, we perceive the space and time continuum in our universe, much differently than the lower dimension. That makes our sun to keep its nuclear reactions continue for millions of years, providing enough time for us to evolve from a single cell to humans, before it explodes. In other words gravity in the universal extra dimension defines the success of the overall universe. How we map this concept of brane cosmology for our conflict resolution strategy is explained in the fifth section of this paper.

4. Philosophical Inspiration

Laws governing particulars could never account for the organization principles of a higher entity, as explained by Michael Polanyi [3]. He further pointed out that "success of an immerged system cannot be explained from some of its parts".

e same way, "*We cannot see parts of a system we see a failure*" as explained by Heidegger's ept of Breakdown. Such a philosophical ition of a success of a system can be best imented based on our approach on bulk s which defines the direction of the success of ll system.

significant problems we face cannot be solved same level of thinking we were at when we ed them", as explained by Albert Einstein.

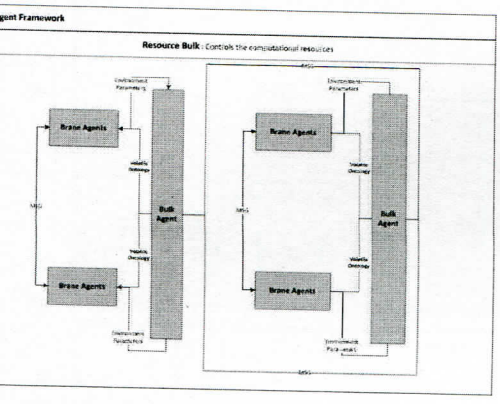

Figure 2. Bulk Agent Framework Architecture[17]

on, based on a higher dimensional agents Agents) which perceive the environments s resources from a higher perspective, so that define the direction of the success of the l system.

5. Bulk Agent Approach

consider a multi agent system as a universe nulti dimensions, universal agents can have dimensions as well as higher or extra sions. Results of higher dimensional changes nfluence on lower dimensions, whereas each dimensional changes have at least a minimal ce on the higher dimension. Such concept implemented by defining an agents called Agent to represent the universal extra sions.

f multi agent systems, social influences can deled in a bulk agent, which helps, shows or he success of overall system. It should be hat, based on the multi agent problem in t is necessary to model the higher dimension multi agent systems which controls or in the rules, universal to the lower agents. resents the global knowledge, as well as the dge on how the social influence based on y shared knowledge can be generated,

I.e. It is necessary to observe from a higher context so that the bigger picture of the problem can be perceived which resembles the solution. On the other hand, Buddhist philosophy defines the concept of *Vipassana* meditation, which can be used to train our mind to perceive the suffering as a observation from the perspective of a third party[15, 16], just to come out from the context of suffering and to understand the big picture or the truth as defined in four noble truths. All these philosophical concepts motivates us to find a

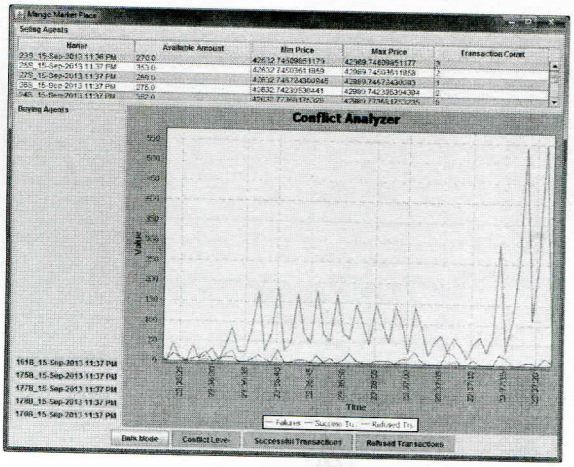

Figure.1. Multi Agent Marketplace Monitoring Tool.

motivate us to define two ontological concepts as explains below.

(i). Volatile Ontology (Ontology of the Bulk Agent immerged from the overall brane agents).

(ii). Concrete Ontology (Ontology of the Bulk Agent which has no impact from the brane agents).[17]

Volatile Ontology will be generated by the bulk agent and it will be shared among brane agents. Volatile Ontology may contain the social knowledge based on the so called big picture of the society. To generate such ontology and show the direction of success to other agents, it is necessary to have an ontology inbuilt in to the Bulk Agent. That ontology may not be changed based on the brane agent's actions or influences. Therefore, such ontology is called Concrete ontology. It is important to note that the Volatile Ontology should not make bulk agents a ruler of the society, or the dictators, as it would abuse the very meaning and the ability of multi agent concept to handle complex requirements and uncertainty. This model helps us to define an ontology which shows more power of resistance in conflicting situations than a non-conflicting situations, so that the conflicts can be resolved

sy. In other words, agents can argue not on a localized knowledge of agent's but also the global influences and the success, which again is volatile to nt effect. So the main concept of this to define agents as brane and bulks and r ontology in such a way that, the of the overall system can be reduced as the conflicts can be better avoided or resolved at the higher dimensions. As shown in the Bulk Agent Architecture[17] in Figure 2, multiple bulk agents can be formulated and allows them to communicate while keeping their own ontology unique for its brane environments. This approach has been successfully implemented in a Multi Agent Marketplace where

supplier agents and buyer agents compete each other for a better price[17].

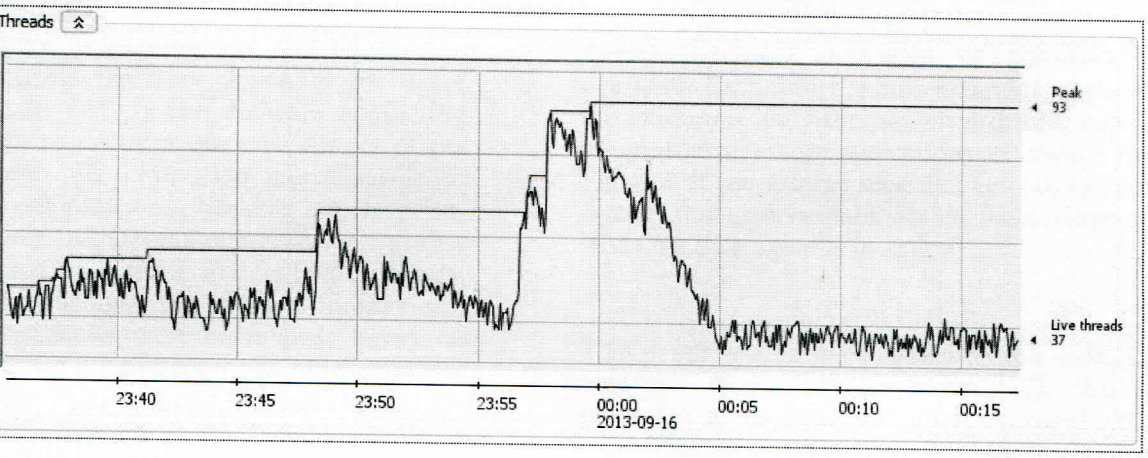

Figure 2. Thread usages in the multi agent marketplace

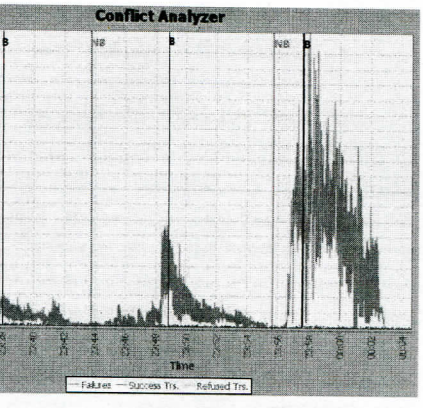

Figure 3. Conflict analyzer graph

6. Implementation

gent marketplace is implemented in the agent framework. As shown in the yer agents in a given moment of time is ow color in the left side panel whereas ith their selling price range is shown in the top. The conflict analyzer graph ate of successful (or useful) and failed nt) transactions(or communication) in colors respectively.

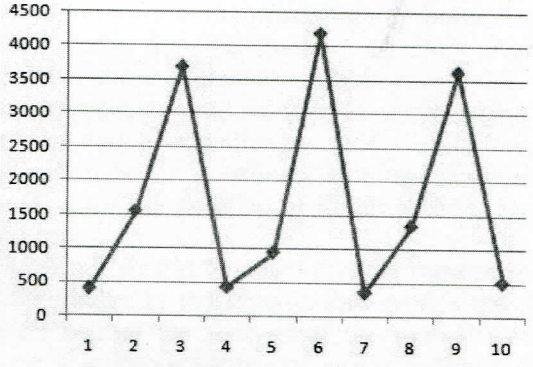

Figure 4. Conflict reduction level analysis of 10 iterations

As shown in the Figure 1, we have implemented the conflict monitoring tool to monitor successful transactions (blue colored graph) and amount and level of conflicting situations (red colored graph). The conflict analyzer graph is used to obtain the statistic figures to calculate the overall success of the system. In our multi agent marketplace, to maintain the competitive advantage, while avoiding conflicts, knowledge on the overall system is essential. Such knowledge gap can be better bridged by the volatile shared ontology of the bulk agent when needed.

evaluated the effectiveness of the bulk oach based on the number of successful s and the amount of communication. In alyze the level of conflicting situations, figures were counted based on failed ation or the communication effort that to avoid arguments, and the cost over agents. Moreover consumption of nal resources by the overall system with it the Bulk Agent approach has been valuated.

ation monitoring tool can be used to disable the Bulk Agent in the agent t so that we can compare conflicting ell as the computational usages of the tem. We have used the JConsole to computational resource consumption. hree overlapping charts in the Conflict aph to indicate the conflicting levels, ransactions and refused transactions. nsactions were calculated, based on imes a transaction has been abundant due to the demand fluctuations and the In other words, by the time a buyer is for a pre define price, seller could sell m to another buyer, so that the first action has to be refused. Analysis on saction count is necessary to measure f uncertainty in the market.

xperiment and Evaluation

ment, initially we let the system to run ne till it reached to the equilibrium we introduce the bulk agent to the then observe the pattern of conflict Vhen it reaches to the minimum vel, we removed the effect of the bulk h such iteration rapid increase in the vel has been observed. We did this nultiple times and collected statistic entify the effectiveness of the Bulk ach in the Multi Agent Marketplace mplemented.

results in the conflict analyzer graph ne Figure.3. Each black line indicate we have enabled the Bulk Agent the long vertical red line indicates ve have disabled the operations of the Accordingly, it indicates higher nflicts when the effect of the bulk resent. But the system goes down to vel of conflicts, whenever the bulk luced to the market. It can be seen that the average conflicting level decreases down to 50, regardless of how large the initial conflicting level. In other words more than 90% of conflicts can be avoided based on the Bulk Agent Approach in our Multi Agent Marketplace. For the ease of understanding, Figure 4 shows amount of conflict reduction with the support of Bulk Agents in 10 iterations.

In JADE, message passing is facilitated using asynchronous threads. Therefore, amount of live threads indicates the level of communication overhead. Each time the bulk agent is introduced to the market, it has been observed drastic reduction of unnecessary communications as shown in the Figure 2 It can also be seen that amount of parallel threads that always stabilizes at the average of 40 when the bulk agent is in action.

8. Conclusion

This is our second paper based on the Bulk Agent approach in conflict resolution [17]. We have presented some statistical analysis based on our experimental result which has shown a drastic conflict reduction by 90% within the average of 5 to 6 seconds. Moreover the reduction of communication overhead makes the system lightweight while maintaining a better agent society with the introduction of Bulk Agents. Moreover these statistical analysis shows that, our novel approach would solve most of the design and implementation challenges of multi agent application as it consumes minimal amount of threads with the promise of lower communication overhead.

However, it should be noted that the right selection of knowledge in the volatile ontology is the main secrete behind the success of the overall system. Hence it is important to encourage further studies on structures and best practices in defining Volatile and Concrete ontology.

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