Conflict Reduction Analysis of Bulk Agent Approach in Multi Agent Systems

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Abstract— **Our universe can be considered as the largest multi agent system with no visible conflicts. Particles in different dimensions interacts, based on different gravitational rules, which defines the universal extra dimensions called 'Bulk'. The same concept can be modeled, as the Bulk Agent Approach in multi agent systems to overcome potential conflicts, which also empowers the direction of the emergent success of the overall system. On the other hand, it is a design challenge in multi agent systems, how to avoid unnecessary conflicting chaos, which could consume large computational resources and valuable time. Lack of resources or social knowledge could lead to either resource conflicts or knowledge conflicts. As a solution, Argumentation Based Negotiation (ABN) with the support of conflict evading and re-planning has been presented in the literature as one of the best approach in conflict resolution techniques. However, conflict evading and re-planning would not be useful in an environment where resources are not abundant. Therefore, we present our novel approach as a solution for the burning limitations of conflict evading and re-planning. Philosophical explanations and Brane Cosmology, which explains on how gravity governs on brane particles, based on the concept of universal extra dimensions, are the main inspirations for our research. Any multi agent environment can be considered as a multi-dimensional universe, where the universal norms originate in a higher dimension. These universal norms provide the guidelines for emergent success of the whole system. However, universal norms can change dynamically based on the social and environmental changes in the lower dimensions. Therefore, in our architecture we define higher dimensions by an agent type called Bulk Agents whereas agents in the lower dimensions are called Brane Agents. The Bulk Agent monitors behaviors of the Brane Agents and provides the direction or the guideline for the success of the overall system. These directions were shared among brane agents as Volatile Ontology so that the overall agent society is well capable of avoiding potential conflicts which otherwise would increase the failure rate of the system. Our analysis are experimented based on an application called Multi Agent Marketplace. Our experiments were analyzed based on statistical figures which has shown that the conflicts can be avoided or resolved with minimal computational time and resources by introducing Bulk Agents, which represents the extra dimensions in multi agent systems. This paper presents the results of our analysis on identifying the level of effectiveness of the Bulk Agent approach in conflict resolution in Multi Agent Systems. Keywords-multi agent systems; bulk agent; conflict resolution; brane agent; cosmology**

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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 early 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.

There are eight sections in this paper including the introduction. Second section explains current trends and practices such as ABN approach in conflict resolution of Multi Agent Systems. 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 inspirations. Fifth section presents our approach as an extension to our previous research paper, which contains, in detail architectural model on Bulk Agent Approach. In this paper, we elaborate our experiment with statistical analysis with the calculated success rate of our approach in a Multi Agent Marketplace. As the sixth section we present the implementation details of our research with a conflict monitoring tool. Conflicts on our multi agent application are evaluated based on observational as well as statistical data collected in collection experiments. Results of our

evaluation were discussed in the Seventh section. As the eighth and the last section of this paper we conclude with a summary of our findings with future research plans.

2. REVIEW ON CURRENT TRENDS IN CONFLICT RESOLUTION

There are two types of conflicts in literature which are categorized based on the cause of each of them. Conflicts can be occurred due to limited resource which have to be shared among agents, i.e. agents has to compete with each other to win and get the control of resources, as they are crucial to achieve their goals. Therefore, conflicts due to resources are called Resource Conflicts [9]. Conflicts can also be observed in multi agent environments, when the agent's knowledge or the ontology has gaps in between, i.e. when agents are communicating based on different perceived knowledge, resulting Knowledge Conflicts [9].

To overcome such conflicting situations Argumentation, Negotiation and Coordination play a major role in multi agent systems. On the other hand, deciding on "How" and "When" to communicate, is a more important aspect in multi agent conflict resolution studies [7, 2, 4, 9, 8, 5]. Among various conflict resolution techniques explained in literature, Argumentation-based Negotiation (ABN) has shown promising results when the conflicts occurs as a result of resource limitations [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 in 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 abandon 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 only 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.

B 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 lack of knowledge, motivation and/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. False understanding on those influences could trigger conflicts, and that could increase the risk of system failures. Based on ABN approach such conflicts can be resolved, only if it has following four features available in the multi agent environment. (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 third and fourth requirements, it is clear that global shared ontology is 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 passing 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.

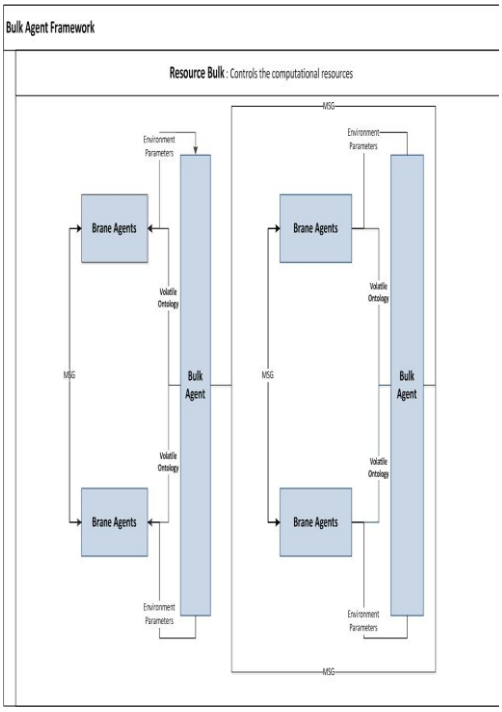

Figure 1: Bulk Agent Framework

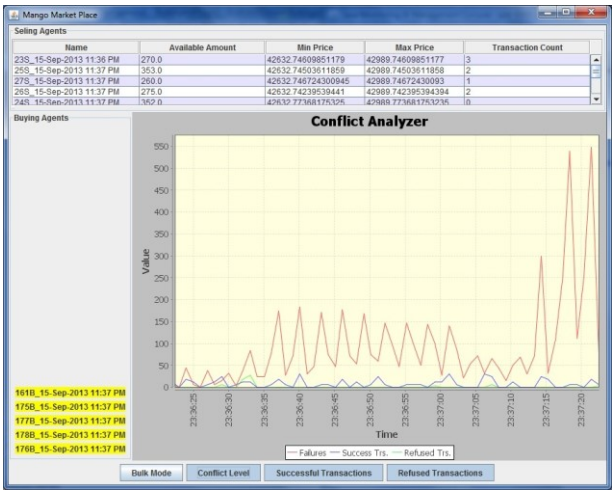

Figure.2: Multi Agent Marketplace Monitoring Tool.

Similarly, we conceptually model an agent structure with their responsibilities that could be defined based on the dimensions that agents operate.

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". In the same way, "We cannot see parts of a system until we see a failure" as explained by Heidegger's concept of Breakdown. Such a philosophical definition of a success of a system can be best experimented based on our approach on bulk agents which defines the direction of the success of overall system.

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

It means that, 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 solution, based on a higher dimensional agents (Bulk Agents) which perceive the environments and its resources from a higher perspective, so that it can define the direction of the success of the overall system.

5. BULK AGENT APPROACH

If we consider a multi agent system as a universe with multi dimensions, universal agents can have lower dimensions as well as higher or extra dimensions. Results of higher dimensional changes could influence on lower dimensions, whereas each lower dimensional changes have at least a minimal influence on the higher dimension. Such concept can be implemented by defining an agent called Bulk Agent to represent the universal extra dimensions.

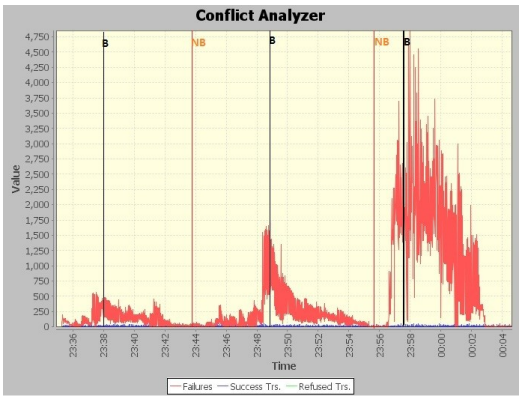

Figure 4: Conflict analyzer graph

In most multi agent systems, social influences can be modeled based on a bulk agent, which helps, shows or direct the success of overall system. It should be noted that, according to the multi agent problem in hand, it is necessary to model the higher dimension in the multi agent systems which controls or maintain the rules, universal to the lower agents. To represents the global knowledge, as well as the knowledge on how the social influence based on globally shared ontology can be generated, 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 the 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

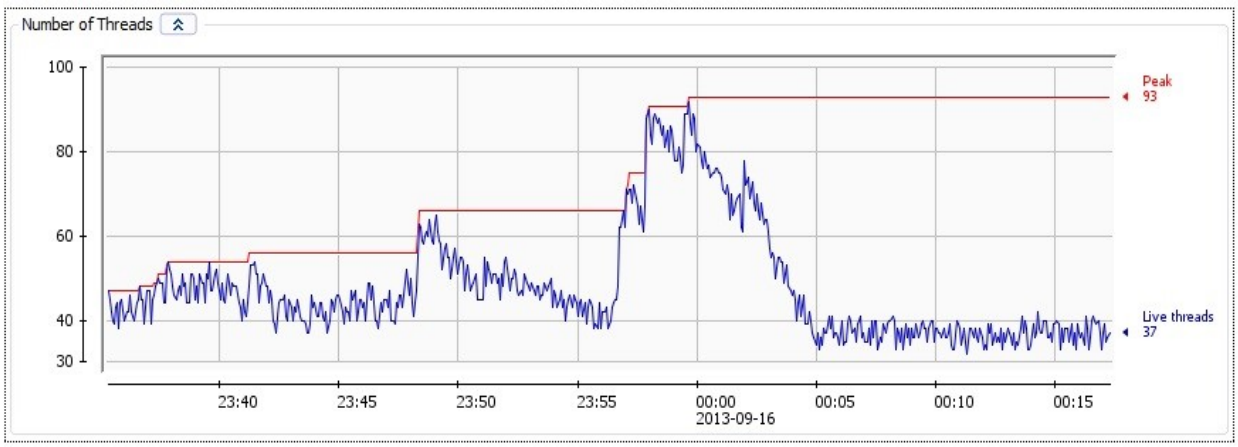

Figure 3. Thread usages in the multi agent marketplace

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 in non-conflicting situations, so that the conflicts can be resolved fast and easy.

In other words, agents can argue not only based on a localized knowledge of agent's operations, but also the global influences and direction of the success, which again is volatile to the emergent effect. So the main concept of this research is to define agents as brane and bulks and define their ontology in such a way that, the complexity of the overall system can be reduced drastically as the conflicts can be better avoided or resolved at the higher dimensions. As shown in the Bulk Agent Architecture [17] in Figure 1, multiple bulk agents can be formulated and allowed 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].

6. IMPLEMENTATION

Our multi agent marketplace is implemented in the *JADE* multi agent framework. As shown in the Figure 2, buyer agents in a given moment of time is listed in yellow color in the left side panel whereas the sellers with their selling price range is shown in the grid at the top. The conflict analyzer graph shows the rate of successful (or useful) and failed (or irrelevant) transactions (or communication) in blue and red colors respectively.

As shown in the Figure 2, 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.

We have evaluated the effectiveness of the bulk agent approach based on the number of successful transactions and the amount of communication. In order to analyze the level of conflicting situations, statistical figures were counted based on failed communication or the communication effort that has taken to avoid arguments, and the cost over benefit of agents. Moreover consumption of computational resources by the overall system with and without the Bulk Agent approach has been separately evaluated.

Our application monitoring tool can be used to enable or disable the Bulk Agent in the agent environment so that we can compare conflicting levels as well as the computational usages of the overall system. We have used the JConsole to monitor the computational resource consumption. There are three overlapping charts in the Conflict Analyzer graph to indicate the conflicting levels, successful transactions and refused transactions. Refused transactions were calculated, based on how many times a transaction has been abundant in-between due to the demand fluctuations and the uncertainty. In other words, by the time a buyer is ready to pay for a pre-defined price, seller could sell the same item to another buyer, so that the first buyer's transaction is refused. Analysis on refused transaction count is necessary to measure the amount of uncertainty in the market.

7. EXPERIMENT AND EVALUATION

In our experiment, initially we let the system to run for some time till it reaches o the equilibrium state. Then we introduce the bulk agent to the market and then observe the pattern of conflict reduction. When it reaches to the minimum conflicting level, we removed the effect of the bulk agent. In each such iteration rapid increase in the conflicting level has been observed. We did this experiment multiple times and collected statistic figures to identify the effectiveness of the Bulk Agent Approach in the Multi Agent Marketplace that we have implemented.

Experimental results in the conflict analyzer graph is shown in the Figure 4. Each black line indicate the time that we have enabled the Bulk Agent mode whereas the long vertical red line indicates the time that we have disabled the operations of the Bulk Agent. Accordingly, it indicates higher amount of conflicts when the effect of the bulk agent is not present. But the system goes down to the minimal level of conflicts, whenever the bulk agent is introduced 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.

In JADE, message passing is facilitated using asynchronous threads. Therefore, the 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 3, 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.

This paper is presented as a solution to avoid costly conflicting operations in multi agent systems and we don't clam this as another multi agent problem solving algorithm. However, there is a potential of improving this approach as a problem solving algorithm as the next phase of our research.

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