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Adaptive Probabilistic Behavioural Learning System for the effective behavioural decision in cloud trading negotiation market

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HIGHLIGHTS

- Bilateral negotiation process is modelled as the multi-stage Markov decision problem.
- Adaptive Probabilistic Behavioural Learning analyse offer using inference engine.
- Operational view of proposed learning tactics is modelled as layered data flow graph.
- Flow graph predicts behavioural tactics and suggest counter tactics from rule base.
- Behavioural decision making heuristic is based on the probability distribution.

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ABSTRACT

In cloud e-commerce application, building an automated negotiation strategy by understanding the uncertain information of the opponent preferences, utilities, and tactics is highly challenging. The key issue is to analyse and predict the uncertain behaviour of the opponent tactics to suggest the appropriate counter tactics that can reach maximum consensus. To handle such uncertain information, negotiation strategies follow several tactics with and without learning ability. Strategies without learning ability are restricted to negotiate with the opponent having only deterministic behaviour. To overcome this problem most researchers exploited the negotiation strategies with fixed learning ability using Bayesian learning, neural network learning, and genetic tactics. These tactics can learn the opponent's behaviour and cannot guarantee to generate suitable counter-offer for all offers submitted by the opponent cloud service provider. This limitation motivates to propose a novel Adaptive Probabilistic Behavioural Learning System for managing the opponent having unpredictable random behaviours. The proposed Adaptive Probabilistic Behavioural Learning System contains a Behavioural Inference Engine to analyse the sequence of negotiation offer received by the broker for effectively learning the opponent's behaviour over several stages of negotiation process. It also formulates the multi-stage Markov decision problem to suggest the broker with appropriate counter-offer behavioural tactics generation based on the adaptive probabilistic decision taken over the corresponding negotiation stage. Therefore, this research work can outperform the existing fixed behavioural learning tactics and hence maximize the utility value and success rate of negotiating parties without any break-off.

1. Introduction

Cloud computing is being used in different application domains such as science, industry and government [1]. The vision of this new cloud computing paradigm is to provide huge computing power and Information Technology services as a utility like electricity, gas and water [2]. Cloud computing offer high performance, availability, and throughput for their services after confirming the Service Level Agreement (SLA) between the customer and the service provider [3]. An SLA is a contract made to promise the vision of cloud computing Quality of Service (QoS) goals [4]. SLA types are broadly classified as provider predefined (static) SLA and negotiated (customized) SLA [5]. In general, cloud provider like Microsoft Azure defines a common SLA for all consumers that promised to guarantee 99.9% availability in their SLA document. This kind of SLA is called provider predefined SLA which is

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automatically established and commenced as soon as the consumer confirms the service request with online payment. The provisioning of services to such SLA is a semi customized provisioning in cloud and it is in compliance to a set of predefined non-functional properties specified by the providers QoS goals. In this case, the consumer with special QoS requirement cannot be satisfied by the current cloud provisioning mechanism due to its predefined SLA template. This limitation brings up the following challenges: (1) Guarantee the pre-established contracts despite of its dynamic workload changes in the cloud infrastructure management [6]; (2) Maximize revenue and differentiate the SLA with respect to type of clients in the providers cloud management system [7]; (3) Agree on customized provisioning scenario in cloud management system [8]; (4) Customer driven service management that can provide personalized service provisioning in cloud [9]; (5) Dynamic estimation of behaviour-based resource provisioning management across the cloud layers [10].

To overcome the above challenges, most researchers focused on the negotiation framework and strategies for enforcing the negotiable SLA concept in the cloud management system. An SLA-oriented cloud management system (SLAOCMS) was proposed in the previous research work emphasizing the need for a negotiation framework in the service layer of the cloud (present on top of the application layer) [11]. The negotiation framework is addressed as one of important architectural element in the vision of future SLA-oriented resource management in cloud [12]. In addition to that, the need for negotiation framework is addressed as a major research issue to agree on fully defined provisioning scenario that can define the negotiated SLA between the consumer and cloud service provider [13]. This scenario motivates the study of a many-to-many cloud service negotiation framework, for supporting the negotiable SLA concept, which can satisfy the customized service provisioning mechanism.

In the previous research work [14], a novel automated dynamic SLA negotiation framework is proposed for supporting the customized service provisioning mechanism in the SLAOCMS. This framework minimizes the total negotiation time and communication overhead among the negotiating parties by optimizing the negotiation process in both framework and strategy level. In the framework level, a multi-point negotiation characteristic approach is incorporated by using the agent controller and additional agent controller components in the broker part of negotiation framework. In the strategy level, a Classified Similarity Matching approach and Truncated Negotiation Group Gale Shapely Stable Matching approach were introduced to optimize the negotiation process through the redundancy identification and appropriate negotiation pair grouping among the negotiating parties. These approaches can optimize the negotiation conflict in the pre-request negotiation context. To further optimize the negotiation conflict among the negotiation parties, a novel probabilistic decision making model is introduced in the broker part of negotiation framework [15]. This model enables to optimize the negotiation conflict in the long-term negotiation context by choosing the appropriate probabilistic behavioural decision at each stage of negotiation process. In addition to that, a Bulk Negotiation Behavioural Learning approach was introduced into the previous research work of negotiation framework for optimizing the negotiation conflict in the long-term negotiation context [16]. This approach can learns the opponent's behaviour using reinforcement learning technique in the broker part of negotiation framework by concurrently generating multiple offers to the opponent's based on different negotiation behavioural tactics. To further optimize the negotiation conflict, there is a need to embed a behavioural learning system in the negotiation framework for assisting the negotiating participants to generate favourable offer or counter-offer during the negotiation process.

Therefore, the objective of this research work is to develop an Adaptive Probabilistic Behavioural Learning System for effectively learning the opponent's negotiation behaviour by analysing the sequence of offers received during the negotiation process. The novel contributions of the proposed research work includes: (1) the modelling of multi-stage Markov decision problem for providing optimal behavioural decision that can generates the suitable counter offers in the broker agent, (2) the behavioural inference engine that can analyse the offer received by the broker agent based on the effective interaction with the probabilistic rule base and adaptive logical controller, and (3) an operational view of proposed Adaptive Probabilistic Behavioural Learning tactics is modelled as the layered data flow graph that can predicts the behavioural tactics of the opponent's offers over the specified time interval and suggest the suitable counter tactics available over the probabilistic rule base. These contributions can significantly optimize the negotiation conflict occurring in the cloud trading negotiation framework which can maximize the success rate and minimizes the communication overhead among the negotiation parties.

The remainder of this paper is organized as follows. Next section presents the related works. Section 3 represents the proposed architecture of behaviour-based cloud trading negotiation framework and also gives the conceptual design of adaptive probabilistic behavioural learning system component information. In Section 4, modelling of negotiation strategy between the broker and provider agent is formulated based on the adaptive probabilistic behavioural learning system. It also includes the formulation of multi-stage Markov decision problem, modelling the operational view of agent's behavioural learning patterns with respect to state space, action space, and state transition function. Experimental evaluation is discussed in Section 5. The final section deals with conclusion and future scope of this research work.

2. Related works

In the cloud based e-commerce negotiation framework, optimal management of broker negotiation strategy poses a series of challenges due to lack of behavioural prediction regarding the opponent's information [17]. The automated negotiation strategy can be classified into two types such as negotiation strategy without learning ability and with learning ability [18]. Lots of research works are available in case of negotiation strategy without learning ability where the negotiation attributes like price, speed, and time-slot constantly changes over the time [19–21]. This strategy exploits tradeoff and concession tactics to maximize the utility value and success rate respectively. The tradeoff tactics can outperform the concession in terms of utility, but may incur negotiation break-off if the opponent's information is incomplete. To overcome this limitation, a mixed strategy using trade-off and concession tactics were introduce for balancing the utility and success rate [22]. However, this approach could only provide certain degree of intelligence to handle the opponent with uncertain information. Designing the negotiation agent with learning and predicting the information of opponent's strategy was identified as a challenging issue [23].

In order to handle the opponent's uncertainty, very few research works are available in case of negotiation strategy with learning ability. This strategy has more intelligence to learn the opponents tactics using Evolutionary behaviour learning [24], Co-evolutionary learning [25,26], Reinforcement learning [27,28], Bayesian learning [29], and Neural network learning [30–32] for improving both utility value and success rate. Moreover, intelligent learning in automated negotiation is still identified to be an emerging area of research in this decade [33]. In cloud context, there is