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Agent-based Simulation in a Normative Environment Using the EPMP Domain

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Abstract: Simulation is a way of doing thought experiments besides the deduction and induction methods. Agent-based Simulation (ABS) falls under the domain of artificial intelligence when agent is used to perform certain tasks such as behaviour prediction, optimization of functions or time-constrained work-flow management. This work discussed the use of ABS on a computational normative framework based on a set of empirical characteristics that influence agents' performance in time-constrained environment. The ABS simulates a domain called the Examination Preparation and Moderation Process (EPMP) which entails document submission processes with deadlines. The simulation is conducted in six different environments and the results of the agent performance in each environment are presented and discussed. The results indicate that the simulation conducted in the EPMP is suitable and effective for evaluating normative agent-based systems.

Key words: Agent-based simulation, EPMP, normative framework, software agent, time-constrained environment

INTRODUCTION

Simulation denotes animating a model of a system with suitable inputs and observing the corresponding outputs (Bratley *et al*., 1987; Macal and North, 2010). Simulation is a way of doing thought experiments besides the deduction and induction methods (Axelrod, 1997). It falls under the domain of artificial intelligence when it is used to perform certain tasks such as behaviour prediction in a chemical reaction, medical diagnosis or optimization of functions. The artificial intelligence method can be thought of as simulation of human perception, decision making or social interaction.

This study claims that validating the logical formalisms in designs (akin to "proof of concept") and designing a simulation study are effective validation methods for normative agent-based systems in general. To substantiate the claims, the simulation of agent's behaviour in an educational setting is based on a normative agent framework called the Obligation-Prohibition-Recommended-Neutrality- Disliked (OP-RND) Framework (Ahmad *et al*., 2009, 2011). The domain selected for the governance of the OP-RND framework is the Examination Preparation and Moderation Process (EPMP) at Universiti Tenaga Nasional, Malaysia. This domain requires modelling the actions of a Lecturer agent in executing the process of preparing and submitting examination paper to the authority agent.

In EPMP, the submission of the examination set represents the normative goal, G_N which is a mandatory obligation that must be fulfilled by all agents. Nonetheless, within the same duration, the lecturer is also responsible for other conflicting goals that need to be accomplished along with the normative goals. These other goals represent, the personal goals, G_P which are the needs of each individual lecturer, such as taking leave, attending workshops or courses, attending meetings or supervising students.

To validate the OP-RND framework using agent-based simulation, three hypotheses were formed. First, a normative goal is attainable by an agent adhering to the norms while coping with conflicting goals. Second, optimization functions improve the performance of agents in meeting the deadlines. Third, in order to improve or maintain compliance with the norms, agents should be endowed with human-like abilities to prioritize their goals and work diligently.

RELATED WORK ON AGENT-BASED SIMULATION

Agent-based computing and computer simulation can be divided into two strands:

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- Micro-attempts to model specific behaviour of specific individuals and the structure is viewed as emergent from the interactions between the individuals
- Macro-based on mathematical models where, by the set of individuals is viewed as a structure that can be characterized by a number or variables (Davidsson, 2002). In qualitative studies such as in social science, researchers often begin with a hypothesis or a research question which will be validated by means of induction or deduction methods. With induction, researchers make conclusions based on observations while with deduction, researchers start off with premises and rules then conclude the premises (Axelrod, 1997)

Axelrod (1997) proposed a third validation method which is simulation. With simulation, researchers begin with premises and rules but ultimately, they perform empirical analysis based on observations in the simulated environment. Axelrod (1997) also claims that simulation is most beneficial in agent-based modelling because simulation produces a model that captures the interaction among independent agents and its environment. In line with this view, Macal and North (2010) claim that by modelling the agents individually and simulating the environment, researchers are able to analyze the diversity of the agent's interaction and the system as a whole.

From the literature, a number of agent-based simulation models are identified. One example is the Agent-based Social Simulation (ABSS) that constitutes the intersection of three scientific fields, namely, agent-based computing, social sciences and computer simulation (Davidsson, 2002). ABSS investigates the use of agent technology for simulating social phenomena on a computer. The role of ABSS is to provide models and tools for agent-based simulation of social phenomena and to apply these in different areas.

Agent-based simulations also exist within the framework of multi-agent systems such as the Multi Agent-based Simulation (MABS) and normative agent systems such as Social Aspects of Agent Systems (SAAS) (Davidsson, 2002). Social simulation corresponds to the simulation of social phenomena on a computer using any simulation technique and it typically uses simple models of the simulated social entities, e.g., cellular automata and objects that are able to perform only very basic interaction. Figure 1 shows the intersection of these simulation models.

Normative environment: Norms are rules that are socially enforced and specify behavioural expectations by defining what are correct and incorrect in a given situation. Savarimuthu *et al.* (2007) defined norms as behaviours that are expected by the members of a particular society. Castelfranchi *et al.* (1999) argued that norms are represented by mental objects entering the mental process that interact with beliefs, goals and plans. Consequently, norms become a mechanism that drives the behaviour of agents especially in those cases when behaviour might affect other agents (Lopez and Marquez, 2004). Norms are typically specified as conditional sentences defined under which circumstances of deontic concepts such as obligations, prohibitions and permissions are established (Tinnemeier *et al.*, 2010).

In the artificial intelligence literature, a norm is treated as a behavioural constraint that is, a reduction of the action repertoire and therefore, of the actions physically available to the system (Castelfranchi *et al.*, 1999). Social norms form the basis of an approach to agent coordination, facilitating decision-making by autonomous agents and avoiding unnecessary conflicts (Bazzan *et al.*, 2002). Norms are usually used to specify the ideal behaviour of the agents within the system (Lacroix *et al.*, 2008).

Normative autonomous agent is an autonomous agent having behaviours that are shaped by obligations it has to comply with, prohibitions that limit the kind of goals it can pursue, social commitments that are created during its social interactions and social codes whose fulfilment represents social satisfaction for the agents (Lopez and Marquez, 2004). Castelfranchi *et al.* (1999) proposed that an autonomous normative agent is able to take into account the existence of social norms in its decision (either to follow or violate a norm) and to react to violations of the norms by other agents. They propose

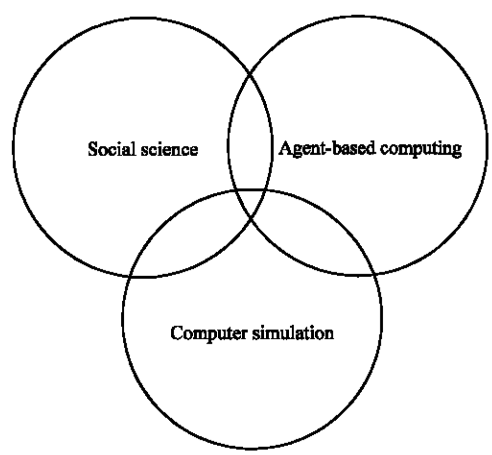

Fig. 1: Agent-based social simulation and their relationship (Davidsson, 2002)

deliberative normative agents that have explicit knowledge about the enacted norms in a multi-agent environment and can make a choice whether to obey or violate the norms. Hollander and Wu (2011) assert that normative agents must satisfy the regular notions associated with artificial agents and possess the capability to:

- Represent norms in a format that allows them to be reasoned over and modified during the lifetime of the agent (knowledge representation)
- Recognize and infer the norms of other agents based on the observations and interactions while not confusing the norms with individual rules and constraints (learning theory)
- Transmit norms, in both an active and passive fashion, to other agents (communication and network theory)
- Sanction other agents who do not comply with known norms if those norms require it (morality and law)

This work is based on the simulation of agent behaviour in a normative environment. The next section discusses the selected domain in such environment.

EPMP DOMAIN

The study attempted to determine the actions of a Lecturer in executing the process and to collect initial information for the conception of the framework. The EPMP has been chosen because of the following reasons:

- This domain has the obligation from the authority which is the submission of the examination set
- There are tasks in time-constrained environment which the stakeholders need to fulfil by submitting the examination set before the deadline
- There are unwritten norms that involve actions on how the stakeholders reason and decide within the duration
- By the deadline, the work performance relies on the stakeholder's action of submitting the documents

Work process: We have developed a model of a work process of our College, namely, the Examination Paper Preparation and Moderation Process (EPMP) using the agent-based approach. In the EPMP, a Lecturer is obligated to prepare and submit a completed examination paper set (questions, solutions and marking scheme) within two weeks to a moderator who reviews the paper. However, within the same duration, the lecturer is also responsible for other goals that need to be accomplished along with the preparation and submission tasks. In this instance, we call the paper submission to the moderator as the normative goal, G_N which needs to be fulfilled.

The other goals which we called the personal goals, G_P, are based on the need of each individual lecturer, such as taking leave, attending workshops or courses, attending meeting or supervising students. Our analysis reveals that there are two types of personal goals: Mandatory, G_{PM} and discretionary, G_{PD}. G_{PM} is a non-normative terminal state which an agent must achieve, i.e., it is immutable and an agent must mandatorily attempt to achieve the goal stipulated by all its requirements. G_{PD} is a non-normative terminal state which an agent could choose to achieve or ignore, i.e., it is subject to change and an agent can discretionarily decide to achieve the goal, put it on hold or disregard it completely. All goals, G_N, G_{PM} and G_{PD} need to be scheduled within the two weeks duration.

Normative framework: We simulate the above scenario in a normative framework which espouses five principles: Obligation, Prohibition, Recommended, Neutrality and Disliked (Ahmad *et al*., 2009). The Recommended principle guides an agent to perform an action and gets rewarded for doing it but not penalized for leaving it. In Neutrality, the agent is not rewarded or penalized if it complies with or violates the norms. In Disliked, the agent is rewarded if it leaves an action but is not penalized for doing it. Figure 2 shows the OP-RND framework.

Preliminary issues: The EPMP schedule is modelled as discrete time slots, t(n) where, n = 1, . . . 14, representing the days in the two weeks duration of the preparation and submission tasks. Figure 3 shows the timeline of the EPMP process from t (0)-t(14). t(0) represents the start time while t(1)-t(14) represent the normative periods as specified in Fig. 2.

In theory, our premise is that when norms are complied, lecturers submit the documents in the recommended period. To validate this premise, we simulate the lecturers as independent agents and observe their decisions and performance in submitting the documents. We have set the evaluation criteria as follows:

- Submission day
- Normative goal achievement
- Accuracy of the simulation results by comparing the theoretical insights with the results of the simulation

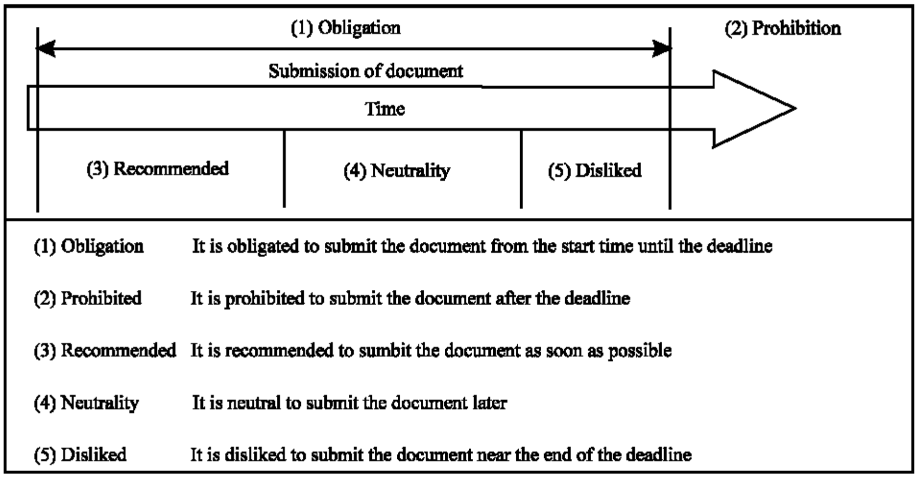

Fig. 2: OP-RND framework showing the normative periods of recommend, neutrality and disliked (Ahmad *et al*., 2009)

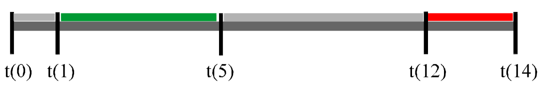

Fig. 3: Submission timeline and normative periods

The agent establishes its plan at t(0) based on the goals G_N, G_{PM} or G_{PD}, generated in each slot. The normative periods of the OP-RND framework ensure that the agent reasons on the reward and penalty and depending on its progress in achieving the normative goal, it selects a task from a set of pre-compiled tasks with which it decides to submit the document.

Among others, the set of pre-compiled tasks consists of its ability to sacrifice any slot of its discretionary personal goals which provides extra slots for the achievement of the normative goal. The ability to increase its diligence due to its mandatory personal goal supports its reasoning in making decisions.

AGENT-BASED SIMULATION OF EPMP

There are five components in the simulation:

- **The normative functions:** These constitute the main principles used to establish the normative framework. These functions implement the obligation, prohibition, recommended, neutrality and disliked operations stipulated by the rules' and norms' specifications. The norm is regulated using the OP-RND framework in the BDI architecture (Ahmad *et al*., 2011)
- **Static and dynamic environments:** These are the environments used in the simulation. The static environment is one in which no changes are made to the conflicting goals between normative and personal goals at their specific slots as the simulation progresses. In other words, when an agent establishes its plan at t(0), it proceeds with the plan knowing that it will succeed in achieving the normative goal. The dynamic environment is one in which the goals are randomly changed at their specific slots (by an Event Generator) as the simulation progresses. When an agent establishes its plan at t(0), it has to re-evaluate the plan depending on the changes to the goal type at some specific slots as the simulation progresses to ensure that it complies with the rules and norms
- **Event generator:** In a real organizational situation, goals change due to the dynamics of events affecting humans while performing their jobs. For example, a person is supposed to attend a group meeting the next day and is prepared for the meeting (i.e., the normative goal). However, he has been postponing his appointment with the dentist for a tooth problem (discretionary personal goal). Just before the meeting is due to start, the tooth ache becomes unbearably painful so much so that he has to cancel the meeting and see the dentist immediately (mandatory personal goal). Such scenario represents common occurrences of events which require changes to plans. In this simulation of multi-agent environment, similar changes do happen and are inevitable. To simulate a mechanism for mutable goals, we deploy the event generator to randomly generate the normative and personal goals which replace existing goal types with any of them at any random time slots

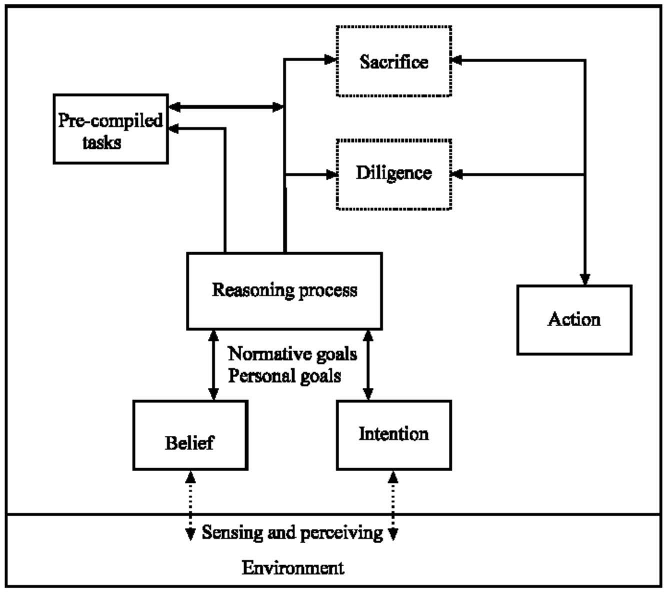

Fig. 4: Components of normative environment

- **Reward and penalty:** Our normative framework stipulates that an agent which submits the document in the recommended period is rewarded one point. If it submits in the Neutrality period, no reward or penalty is given. If it submits in the Disliked or in the Prohibited period, a penalty point is given. The reward/penalty structure is part of the framework's strategy to motivate agents in complying with the norms, thus improving its performance. A rational agent will attempt to get the reward and avoid the penalty. The reward/penalty structure thus acts as a motivating criterion for improved agent's performance
- **sacrifice and diligence:** There are also two optimization functions which are termed as sacrifice and diligence. The sacrifice function enables an agent to reason and disregard any tasks that have lower priorities to make way for the accomplishment of the normative goal while the diligence function enables an agent to boost its effort in accomplishing the normative goal in time-constrained situations (Ahmad *et al.*, 2011)

In Fig. 4, an agent builds its belief and intention by sensing and perceiving the environment. From its internal set of belief and intention, it performs reasoning based on its goal (normative goal) and constraints (personal goals). The reasoning process is also influenced by the sacrifice and diligence factors which serve as the driving force of decision-making.

In the next section, we discuss the result of agent-based simulation in EPMP under six different environments, five of which are static and the remaining one is dynamic.

RESULTS AND DISCUSSION

The submission of the documents is the empirical characteristic of the action and the behaviour of the agents, i.e. performance, complexity and quality of authority's obligation (Dumke *et al.*, 2000). Therefore, the performance measurement is the submission of the document within the stipulated time. As such, the focus of this simulation is to see whether agents could submit the document within the fifth day of the 14 day duration.

To model the process of preparing and submitting examination paper set in the EPMP, five simulation tests in static modes and one in dynamic mode were conducted. Simulation under static mode refers to the environment in which no changes are made to the conflicting goals. On the contrary, simulation under dynamic mode refers to the environment in which the goals are randomly changed at their specific slots as the simulation progresses. In each mode, 100 agents are deployed for each simulation run.

Static modes:

- **Mode A :**The normative framework with single goal
- **Mode B:** The normative framework with multiple goals

- **Mode C:** The normative framework with sacrifice function and multiple goals
- **Mode D:** The normative framework with diligence function and multiple goals
- **Mode E:** The normative framework with both sacrifice and diligence functions and multiple goals

Dynamic mode:

- **Mode F:** The normative framework with rational agent

Simulation results from both static and dynamic modes are then compiled and tabulated. Statistical analysis is performed to compare the agents' performance and analyze their meaning and significance. This is carried out by computing the statistical variables of the submissions for all modes (Cardinal *et al*., 2006; Green *et al*., 2000). The values of the computed statistical means in Table 1 and 2 indicate the submission day.

Table 1 shows the statistical results for static modes while Table 2 shows the statistical results for dynamic mode.

The result in Mode E (mean = 4.80) of the static modes, indicates that the optimizing functions play a very significant role in enabling the agents to comply with the norms, without which delays in submission are inevitable. However, the goals are pre-determined at specific slots during the simulation process in Mode E.

Conversely, in the dynamic environment, Mode F shows the best result of 5.70 (mean for submission day) compared to all modes in the static environment. The result shows that multiple tasks (conflicting goals) and constraints impede agents' performance. This phenomenon indicates that the agents in mode F are able to prioritize task and increase diligence due to execution of the two optimization functions.

The result indicates that the simulation conducted in the EPMP is suitable and effective for evaluating normative agent-based systems. The logical formalisms in the design of normative framework are therefore, validated. The general conclusions that could be drawn from the result in Table 2 can be summarized as follows:

- Without any constraints and competing goals, agents are able to comply with the norms indicating that the normative OP-RND framework performs as intended
- When imposed with competing goals, agents are generally not able to comply with the norms
- In dynamic environments, agents' performance somewhat degrades
- Agents can improve their performance significantly if they are able to prioritize their goals and increase their efforts appropriately

A radical approach to this problem would be to develop multi-agent systems that are inherently normative and benevolent. The results from the simulation indicate that in order to improve or maintain compliance with the norms, agents should also be endowed with human-like abilities to prioritize their goals by ignoring or postponing trivial tasks and at the same time capable of maximizing their effort and resources to complete their assigned tasks in the shortest possible time.

Table 1: Statistical results for static modes

	Mode A	Mode B	Mode C	Mode D	Mode E
N					
Valid	100.0	100.00	100.00	100.00	100.00
Missing	000.0	000.00	000.00	000.00	000.00
Mean	005.0	013.55	011.64	005.63	004.80
Sd. Deviation	000.0	002.354	003.183	003.410	002.655

Table 2: Statistical results for dynamic modes

	Mode F
N	
Valid	300.0
Missing	000.00
Mean	005.70
Sd. Deviation	002.989

CONCLUSION

Agent-based simulation offers a convenient means of verifying and validating processes in the real world. In this paper, we employ an agent-based simulation approach to observe and study the ability of agents to comply with the norms of the EPMP work process imposed upon a constraint of conflicting goals. The results indicate that the simulation conducted in the EPMP is suitable and effective for evaluating our normative agent-based system. Standardization will help promote agent-based simulation as the approach to model social sciences and other human-related disciplines. In our future work we shall develop a framework for the deployment of such standard in agent-based simulation.

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