A Conceptual Modeling Method to Use Agents in Systems Analysis

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1 Introduction

Information systems research uses conceptual modelling to represent many aspects of a domain. The Entity-Relationship Diagram [4] was developed to deal with data modelling and the Data Flow Diagram [5] to handle how information was transferred and transformed in an organization. However, most of these diagrams do not explicitly represent all of the why, what, and how aspects of an information system functioning in a business. For example, the assumptions behind the processes that occur in a business, and the business context that an information system is operating under. It has been proposed by [20] that system analysts are in need of a new construct to fully represent the domains that information systems are situated in. He has proposed that the "agent" is that concept. He states that the autonomous nature of the agent makes it the perfect conceptualization of actors within an organization, which is essential in understanding the business context and assumptions.

Unfortunately, no standard method for creating these agent models exist, and the definition of agent components (even the nature of an agent) is not clear [6]. It has not been disputed that an agent interacts with and changes its environment, but there is little consensus on how the agent achieves these changes. This confusion has led to various conflicting methodologies [1].

We propose that by conceptualizing the agent as a feedback system, we can begin to develop a standard method of describing agents in a business domain, which can then reconcile the disparate agent methodologies. A feedback system takes input from the environment, uses them to decide how to affect the environment, and takes the outcome of affecting the environment as input to the next round of actions [2]. Although many researchers have referred to agents as a system [18], no agent methodologies or definitions have defined their agent concepts in terms of a feedback system. We propose that by analyzing agents as a feedback system, we can better understand and represent business context and assumptions in conceptual modelling. We call such an agent representation a "conceptual agent". Our research question is: *what are the constructs of a conceptual agent, how can they be used in systems analysis, and how useful are these constructs in gathering requirements and developing and maintaining information systems?* We call the resulting framework the "Conceptual Agent Model" or CAM.

For the remaining of this paper, we will give background into using agents in conceptual modeling in Section 2. In Section 3, we will understand agents in terms of a feedback system. In Section 4, we will discuss the CAM framework, a methodology to use it, and some empirical studies to validate its usability, usefulness, and quality. We will conclude the work, discuss current progress, and future research plans in Section 5.

2 Literature Review

There is much confusion, even in the agent literature, about what constitutes an agent [1]. However, most researchers agree that intelligent agents should be able to "perceive their environment and respond in a timely fashion", "exhibit goal-oriented behaviour by taking the initiative", and "interact with other agents" ([18], p.32).
Agents began as a software tool, but have been proposed as a conceptual modeling paradigm ([20], [10]). Generally, conceptual models are composed of constructs which are used to represent aspects of the real world. [16] state that conceptual

models can aid systems analysts as a communication tool, an analysis of the business domain, input for design, and documentation for the requirements of the system. Agents in conceptual modelling have been used in two ways, either as part of a design methodology or as a pure conceptual construct for analysing a domain. Design methodologies are used to create agent systems and were not created for conceptual agent modelling ([1], [12]). However, they do include an analysis stage where the agents need to be conceptualised. Agent conceptual models, on the other hand, are used to represent a domain for systems development, even non-agent oriented systems. There are many methodologies and frameworks for using agents for conceptual modelling ([19], [17], [21]). However, these modelling languages relate to partial aspects of agents mentioned by [18] and do not state how to use the language to model an agent, or even how these concepts are related to agent behaviour.

3 The Conceptual Agent

To reconcile the confusion in existing conceptual agent languages, we use system theory [9], a model of feedback systems [2], and Bunge's ontology as adapted by Wand and Weber ([14], [15]) as the foundation for the proposed Conceptual Agent Model (CAM). More specifically, CAM describes the agent as a system with a simulator (its "brain") and an effector (its "body"). An agent is an entity that is aware of the world through its *perceptions* of it and can affect its world by taking *actions* using *resources*. However, the agent has to have the *capability* to use these resources properly. The agent performs actions to achieve a specific *goal* and must decide, using *reasoning*, which actions it wants to take to achieve its goal. The agent observes its world and may form *beliefs,* or assumptions, about the world based on its perceptions. By *learning* about the world in this way, the agent can then reason as to what it is going to do. When thinking about its goal, the agent develops options of what it wants to do. These wants can be grouped together as a *procedure* and tell us what the agent wants to do to achieve its goals. When a procedure is decided upon, it directs the actions of the agent. In the end, nine concepts were developed to describe agent behaviour. Fig. 1 shows, graphically, the different concepts and how they relate to the world, the simulator, and the effector [10]. An italicized concept in the figure is dynamic and is directly related to the static concept above it. That is, learning is triggered by perceptions, reasoning selects procedures, and actions use resources.

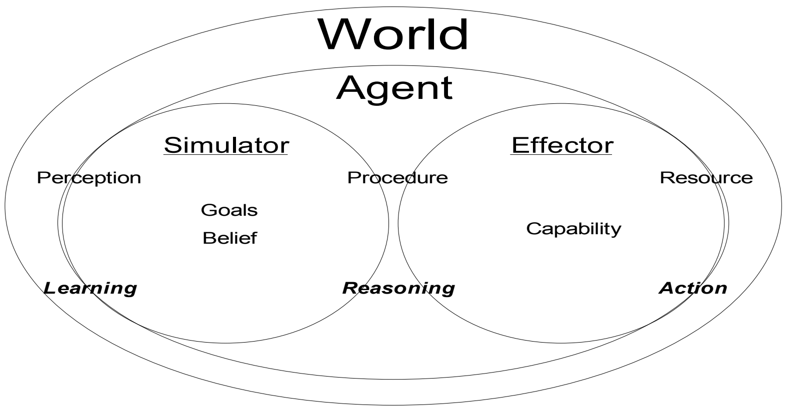

Fig. 1. Agent Terms linked to the Conceptual Agent

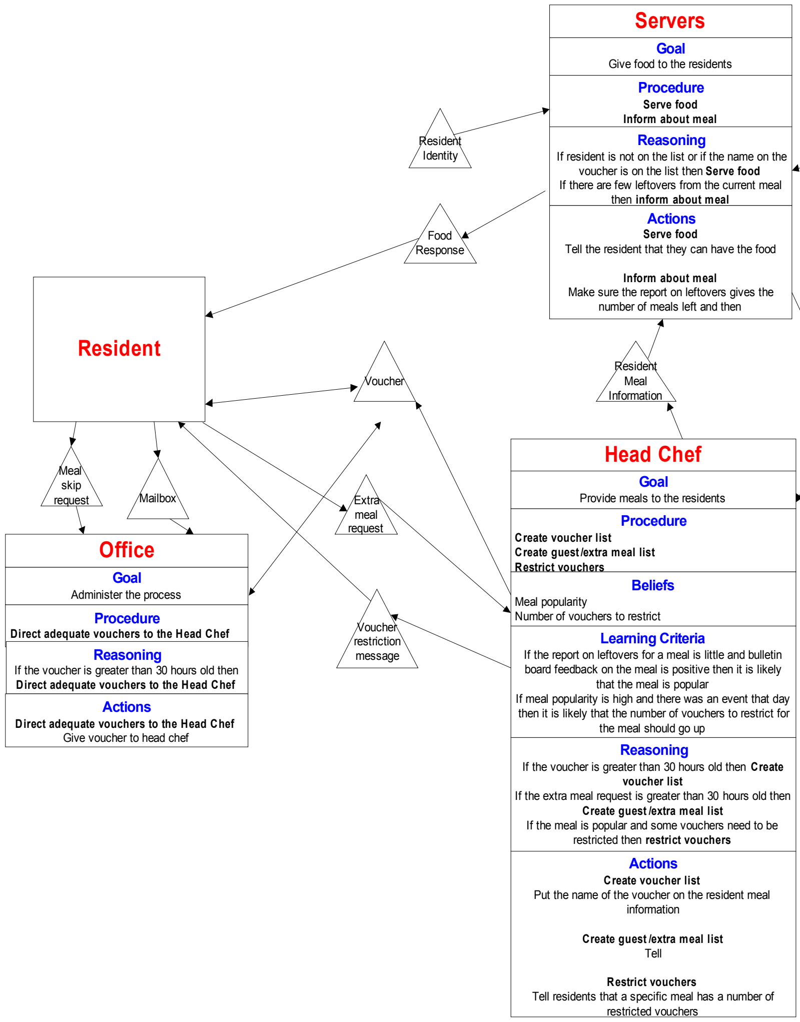

Fig. 2. CAM model of the voucher system

An example of representing a simple meal voucher system using the conceptual agent concepts is given in Fig. 2. In the figure, learning is abbreviated using learning criteria and resources and perceptions are outside the agent and shown as components of the environment. Perceptions and resources in the model are displayed as triangles. If an interaction arrow goes from the triangle to the agent, then it is a perception of the agent. Otherwise, it is a resource. The “resident” agent is not explicated because it is a stakeholder rather than part of the system.

4 CAM – The Proposed Research

Although Section 3 presented the various conceptual agent concepts, they are still not clearly defined and we do not know the effectiveness and efficiency for using them in systems analysis. We will resolve these problems in three essays which will: 1) develop a more thorough theoretical foundation for CAM, 2) develop a CAM methodology, and 3) test if the insights gathered from CAM are useful for modelling agents in a domain. The main contribution of this proposed research will be the CAM methodology, which will enable modellers to use conceptual agents in the design of systems.

4.1 Essay 1: Models of Conceptual Agents

Before we can understand how to systematically use agents to model a domain, the constructs must be clearly defined and cover the static, dynamic, and interactive elements of the conceptual agent. To do so, we plan to develop three conceptual models of agents. The static model will describe the structural components of a conceptual agent and their relationships. The dynamic model will describe how these constructs can be used to represent agent behaviour. The interaction model will describe how agents interact with each other in a domain. These three models should answer the first part of the research question, which is *what are the constructs of a conceptual agent?*

To answer this question we must first understand the environment in which the agent is situated in. We can start by introducing the concept of entities, which are things in the world. The attributes of these things can be defined as the state of the entity. If we were to describe entities, we would describe them through their state. There are two kinds of entities, dynamic entities have the ability to change the world, called capabilities, and can perform actions which change the states of entities, while static entities do not have capabilities and can not perform actions. Dynamic entities also have rules which govern actions. These rules can show why these actions occur. However, they are a thing that the dynamic entity has and can not be considered states since they are not attributes of entities.

The agent itself is a dynamic entity and so also has a state. However, the agent also has specializations of states (beliefs and perceptions). There are also desired states which describe states that the agent wants to be in. These states are further specialized into wants and goals. Agents also have specializations of actions; perceiving, learning, and reasoning.

Recall in Section 3, we describe how agent constructs are being used. We will further explain these constructs in Table 1 so that the more detail explanations can be used as a foundation to clearly define the agent constructs. Table 2 then verifies these explanations against existing literature and determines how the constructs are related to each other. The result of this is given as a graphical representation in Figure 3.

Table 1. Explanation of Agent Concepts

Term	Explanation
Capability	The ability of the entity to change the environment. The entity may try to change the environment but without the capability they can not. Capabilities must exist with agents for actions to occur.
Goal	The preferred states that the agent wishes to be in. The goal is the destination that the agent wants to be in. Once the agent has achieved its goal the agent no longer takes actions.
Beliefs	The facts about the world that the agent knows about the environment without observing the environment. This can be thought of as the assumptions the agent has about the environment, specifically, the agent's beliefs about the effect of actions on the environment.
Perception	The state of the agent that reflects the state of other entities. The agent is only aware of the environment through its perceptions. We assume that the agent's perceptions accurately reflect the environment.
Wants	a specific type of belief about how the agent can reach its goal. Assuming that the goal is the destination of the agent, the wants are beliefs about how the agent will reach that destination. Wants are specific states of the environment that the agent thinks will eventually lead to the goal.
Procedures	Composed of wants. When several wants are composed together they can act as a guide for the agent in achieving its goal.
Actions	Events that change the state of an entity. Actions on the environment are how the agent achieves its goals. However dynamic entities can perform actions on their own state. This means that the dynamic entities can perform external (other entities' state) and internal (own entity's state) actions.
Learning	Change in the agent's belief. Learning occurs when the agent observes the environment. When an agent learns, their beliefs about the outcome of their actions change.
Reasoning	Change in the agent's procedures. Sometimes the agent must change its procedures (wants) when the environment, or its beliefs, change. In other words, reasoning can change what the agent wants to do to achieve its goal.

Term	Explanation
Perceiving	Changes in the agent's perception. Since we assume that the perception accurately reflects the environment, we assume that the agent's perceiving is accurate.

Table 2. Relationship between Constructs

Statement	Reference
Entity has State.	[15] (p.210)
Dynamic Entity has Capability.	[18] (p. 32)
Dynamic Entity and Capability can perform Action.	[18] (p. 32)
Action can change State.	[15] (p. 210)
Agent has Perception.	[3] (p. 16)
Agent has Goal.	[11] (p. 103)
Agent has Belief.	[9] (p. 495)
Perceiving can change Perception.	[9] (p. 407)
Learning can change Beliefs.	[9] (p. 407)
Reasoning can change Procedures	[9] (p. 433)
Wants can lead to Goals	[3] (p. 28)
Dynamic Entity has Rules	[9] (p. 67)
Procedures can direct Actions	[3] (pp. 16 and 29)
Rules can guide Actions	[9] (pp. 17 and 67)

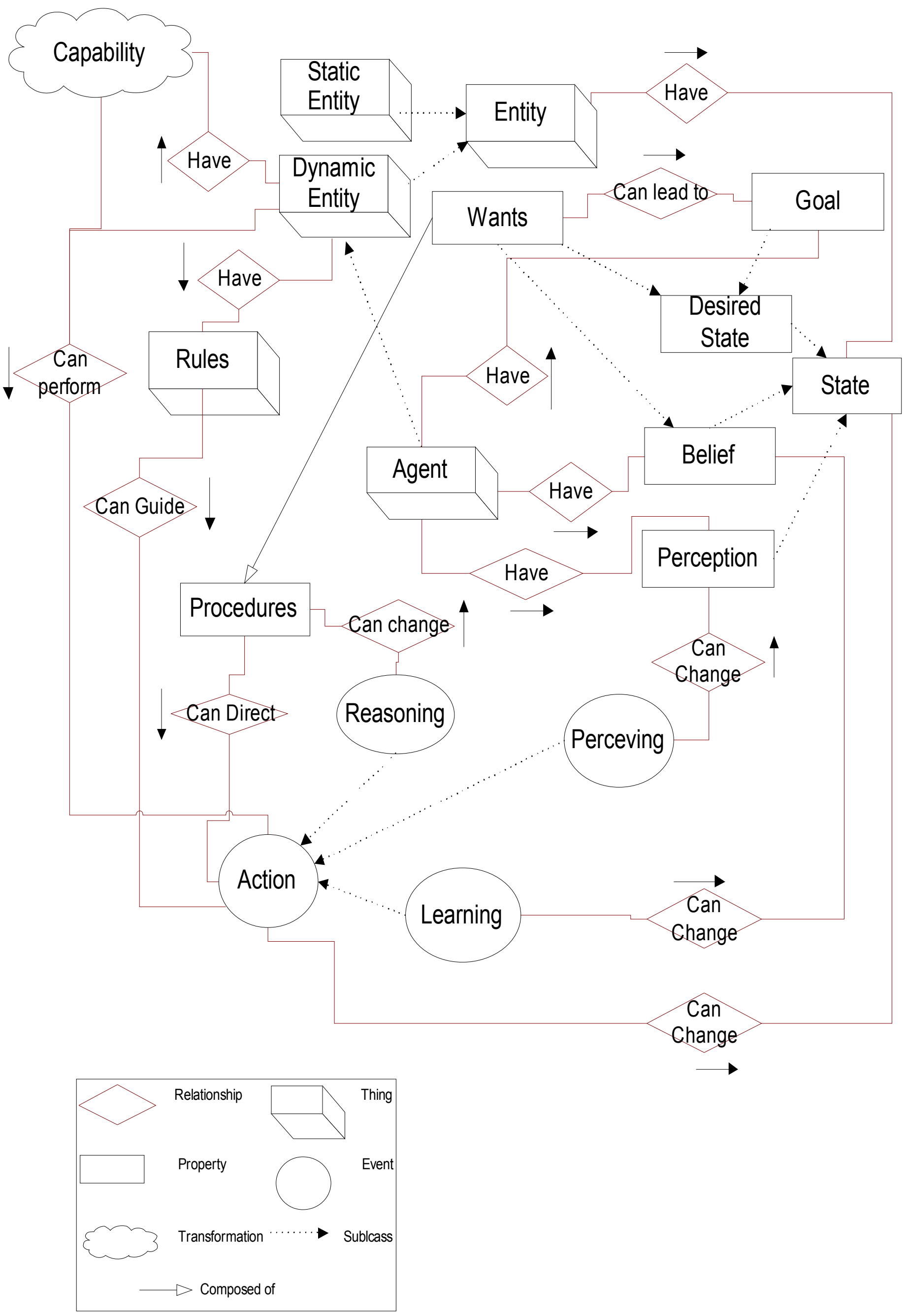

Fig. 3. Proposed Structural Model of Agents

Some of these constructs and relationship in Figure 3 can then be used to describe agent behaviour. By investigating the inputs and outputs of events in the structural model and the agent literature, we can determine how the agent behaves. The flow of this behaviour is then summarized in Table 4 together with where they can be found or derived from the literature. In doing so, we discovered that specialized rules for the actions of learning and reasoning needed to be explicitly shown. We called these rules learning criteria and reasoning rules for learning and reasoning, respectively. All these are then documented as a conceptual dynamic model in Figure 4.

Table 3. CAM concepts in relation to Agent Behaviour

Statement	References	Notes
Perceptions used by Learning criteria.	[9] (p. 407)	Perceptions are processed by the agent into beliefs.
Learning criteria change Beliefs.	[9] (p. 407)	Perceptions change beliefs via the learning criteria.
Goals determine Wants.	[13] (p. 613)	Agents with different goals will have different wants but may share the same beliefs.
Goals determine Reasoning Rules.	[3] (pp. 24 and 47)	Only by incorporating the goal of the agent into the reasoning rules can the rules be used to help the agent select the "correct" procedure.
Beliefs used by Learning criteria.	[3] (pp.31 and 33)	Changes in beliefs can change other beliefs of the agent.
Reasoning rules use Beliefs.	[13] (p. 614)	Reasoning rules use assumptions about the outcome of actions to choose procedures.
Perceptions used by Reasoning rules.	[18] (p. 39)	Along with understanding the outcome of actions agents must also be aware of the environment to choose the correct procedure.
Reasoning rules select Procedure.	[9] (p. 433)	These rules are conditional statements of what the agent wants to do based on beliefs and perceptions.
Procedure directs Action.	[3] (pp. 16 and 29)	The agent's procedures are "conduct controlling pro attitudes". So can be used to determine what actions the agent will take
Resources and Capabilities are used in Actions.	[13] (p. 613)	Agents use abilities and privileges to perform actions.

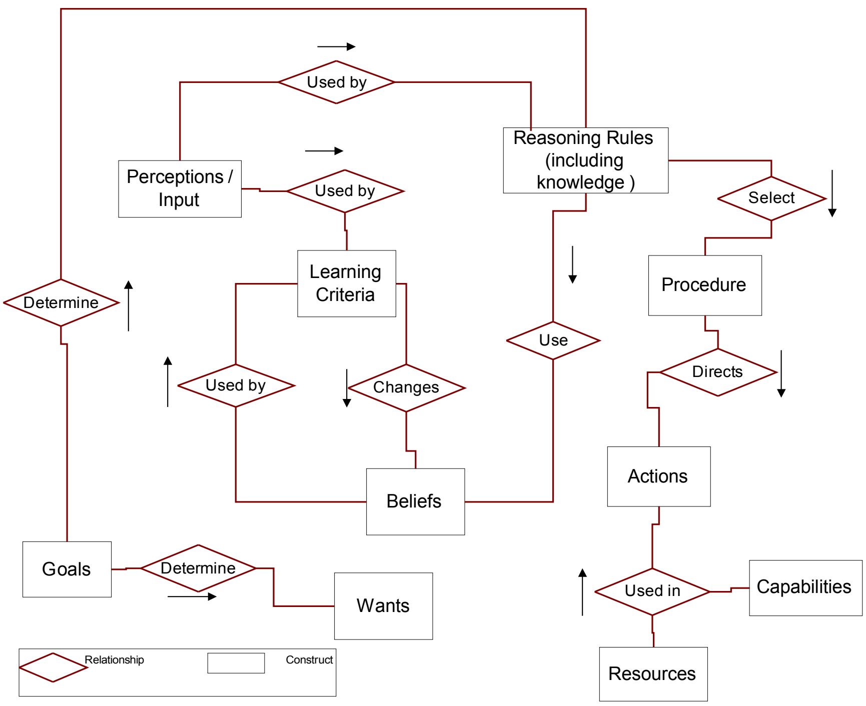

Fig. 4. Proposed Dynamic Conceptual Model of Agents

Lastly, we use the insights about agent behaviour found in the dynamic model (Figure 4) and agent literature to determine how agent concepts can be used to describe interaction in the environment. All these are presented in Table 4. Table 4 also introduces the concept of an external entity to show that the dynamic entity is interacting with an entity other than itself. Figure 5 shows the graphical representation of how agent constructs can represent interaction.

Table 4. Agent Interaction

Statement	References	Notes
Dynamic Entities perform External actions.	[11] (p. 100)	Refers to dynamic entities causing events in the world.
External actions change States.	[18] (p. 37)	External actions according to Wooldridge are mapped to states of the environment.
Agents have Perceptions.	[18] (p. 39)	Perceptions are how the agent knows about the environment.
Communication changes Perceptions.	[7] (p.83)	Content of communication can be discerned by analysing the perceptions that are changed.
External Entities have State.	Derived from previous models.	By changing the entities' states the dynamic entity can interact with the environment.

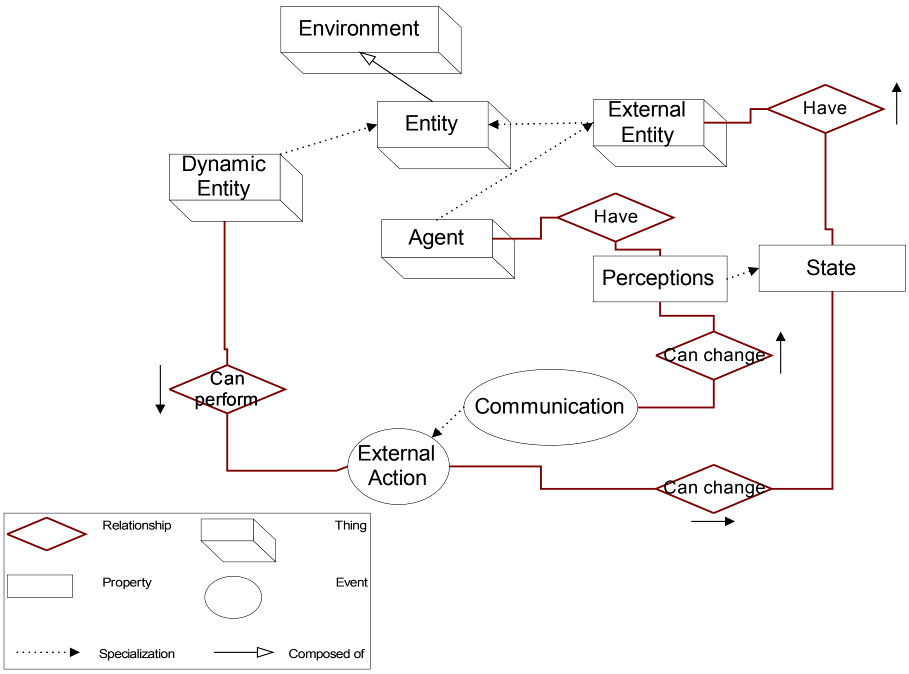

Fig. 5. Proposed Interactive Conceptual Model of Agents

To ensure that these constructs and their relationships can represent the real world, we will test them using the area of disaster management [8]. Also, to ensure we are on the right track, we will conduct a small test study to determine how people model agents without the CAM constructs. We hypothesize that individuals will implicitly use the constructs while trying to describe the agents.

The contributions of the essay will be a set of clearly defined conceptual agent concepts and the relationships between them to describe agent behaviour and interaction. Also we will gather some insight into how laypeople think about describing actors in a business process.

4.2 Essay 2: Conceptual Agent Modelling Methodology

This paper will focus on the development of a method for representing agents in a domain using the CAM constructs. First we will use the conceptual models in Essay 1 to create integrity rules. For example, using Fig. 3 (the static model), we can derive a rule that “only reasoning can change procedures”. We can then develop the modelling rules for CAM, which describe under what circumstances one should include a representation of a domain using a particular construct. For example, when modeling agent actions, modelers should focus only on the states (e.g., resources) relevant to the agent. Unlike integrity rules, which are used to correct a complete model, modeling rules are used to guide the creation of the CAM model. Once both sets of rules are determined, we will create a method for the CAM constructs. This will provide the sequence and steps, which will fulfill the integrity and modeling rules, in representing a domain using the CAM constructs.

To determine if these are useful, we shall conduct cases studies. The first case study is a post-hoc analysis, which will determine if the CAM integrity rules lead to a better representation of a domain. To test this hypothesis, we will use a CAM model developed without using the integrity rules, and analyse its previous iterations to determine if the diagrams violate the integrity rules. In [10], the researchers used CAM to create a model of a marketing problem, without using the integrity rules, and consulted with a marketing domain expert. The constructs were used to communicate our conceptualization of the problem to the expert. If there are more violations in the first iteration of the model than the last one, which was verified as accurate by the expert, we can say that the rules help to create a better representation of the domain. In our second case study, we take the lessons learned from the [10] and test if the use of CAM can aid in understanding a domain, specifically, we will test *if the CAM modelling and integrity rules can aid in knowledge acquisition in experts?* Our expert will be a senior disaster management planner, with extensive knowledge about his field. We will use the CAM modelling and integrity rules to guide our questions and document the knowledge we find. The model and method are valid if the expert's supervisor can use the information, since, it is to be used as a representation of the expert's knowledge when the expert is gone.

The methodology and its use as proposed in this essay should answer the second part of the research question, which is *how can conceptual agent constructs be used in systems analysis?* The main contribution of this essay will be a methodology to use CAM constructs to model a domain. Other potential contributions include the development of a systematic method for knowledge acquisition, and a proof of concept for using agent modelling for knowledge management purposes.

4.3 Essay 3: Empirical Study on Conceptual Agent Model (CAM) Method

The purpose of this study is to answer the third part of the research question, which is *how useful are the conceptual agent constructs in gathering requirements and developing and maintaining information systems?*

In order to answer this question, we need to show the usability, usefulness, and quality of the method. To show usability, we plan to ask a few novice modelers to use the method to represent a domain. To show usefulness, we plan to select a a business problem from an object-oriented systems analysis and design text book with the solution, use CAM to derive the conceptual agent diagram, and then ask experts to comment on both the CAM and object-oriented solutions. We hypothesize that the CAM derived diagram will be more useful to the expert. To show quality, we plan to show that the method is better at creating representative diagrams than not using it.

Among the three, quality is the most challenging one to study. We plan to test the method's quality by having participants model a domain. The study will begin by taking twenty participants and splitting them into two groups. Both groups will be taught the definition of an agent and examples of how they can be modelled. However, one group will also learn about the method through examples. Since we found, from a pilot study, that modeling all nine concepts of agents takes more than 2 hours, this creates a validity problem (e.g., cognitive load). To overcome this research concern, we will limit the proposed study to only two constructs. We selected the reasoning and actions constructs because they were the most and least salient agent concepts found in the pilot study.

During the study, we plan to record the subjects' modelling process and determine, through independent review of the transcripts, if modellers who were exposed to the method were more certain about identifying agent, reasoning, and action constructs than those who did not.

The main contributions of this essay are the tests of the usability, usefulness, and quality of the CAM method, important data on how the method is used, and any breakdowns that may occur. These data can hopefully lead to refinements of the method.

5 Conclusion, Research Progress, and Future Research

There has been a call to use agent concepts in systems analysis to fully model the business context and assumptions in a domain. Given the existing problems of using agents (e.g., confusing terminology), we propose conceptualizing the agent as feedback system to develop and test a conceptual agent model (CAM) framework. This is done by providing a precise definition of agents in terms of its static structure, dynamic behaviour, and interactions (essay 1), a methodology of using the conceptual agent concepts defined in the static, dynamic, and interaction model (essay 2), and test the method's usability, usefulness, and quality (essay 3). In the end, we will have method which can be used by modellers to bring in the business assumptions and context into design of information systems.

So far in essay 1, we have compared the constructs in the static, dynamic, and interaction models to other methodologies, and conducted a test study to determine how they compare to a layperson's concept of agents. We have found that the CAM constructs can incorporate all aspects of a layperson's understanding of an actor in a domain and that the constructs explicitly cover all aspects of agent modelling proposed by [20]. In essay 2, we have developed the integrity and modelling rules for CAM, and have conducted the post-hoc analysis mentioned in Section 3.2. We found that the final diagram adhered more to the integrity rules than the first iteration. Therefore, we can say that if the integrity rules were used in [10], then the model would have been accepted by the marketing domain expert sooner. So far we have not conducted any tests for essay 3.

For future research, we can conduct a larger empirical test of the usefulness of the CAM method by analysing it and comparing it to other modelling methods. We are also interested in using this work to analyse work systems in non-business areas such as government. Lastly, I would like to thank my supervisor Dr. Carson Woo for his support throughout the research.

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