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USING COGNITIVE AGENT IN MANUFACTURING SYSTEMS

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ABSTRACT

Cognitive agents for business and industrial environments are one of the most dominant ideas in multi-agent scheme today. We propose a general, flexible, and powerful architecture to build software agents that embed artificial cognitive factors. The propose agent possesses sensible knowledge and reactive abilities, and interacts with the external complex business environment, including other agents. We examine if artificial cognitive states can improve the performance of agents in some business and industrial conditions. Our agent model generates responsive actions in reaction to certain stimuli. **C**ognitive **A**gent **M**odel (CAM) is proposed for this purpose. Sales and Production Planning (SPP) (as business and manufacturing application) is chosen to demonstrate the use of our agent. Netlogo is used as an agent programming language. It is the agent-oriented language used to simulate and implement our proposed models.

Keywords: *Agent, Agent Modeling, Cognitive Factors, Believable, Behavior, Decision Making, Intelligent, Multi-Agent System.*

1. INTRODUCTION

There were many debates about creating machines with human level intelligence in the first eras of artificial intelligence (AI) field. As the years conceded and the difficulties became clear, such debates disappeared as most of the AI scientists wisely concentrated on producing some small aspect of human intelligence. It has been more than 50 years since Alan Turing described the prototypical test for intelligent machines. In Turing's view, a computer is call intelligent if it could pass as a human while conversing via a computer terminal [1].

The artificial intelligence technology had swung from symbol-processing techniques, to reactionary forays into neural networks and other sub-symbolic approaches, and on to biologically inspired genetic algorithms and fuzzy reasoning. Today, most scientists acknowledge that a combination of technical approaches used to achieve human-level performance. Minsky described a set of mechanisms that he called mental agents that operate in parallel and that compete and cooperate to yield human intelligence [2].

In Cognitive Artificial Intelligence [3][4], they explore for a better understanding of human cognition and behavior, and ways to implement their findings in artificial devices like computer programs, agents, virtual characters or robots. These two forms of research are view as two separate pillars, and many subjects in the research of Cognitive Artificial Intelligence are based on either one of those: investigation of phenomena concerning human intelligence, or finding a way to implement or improve aspects of intelligence in programs, agents or robots.

Manufacturing is an essential factor in economic welfare. Information technology is as an energetic tool in manufacturing performance. Manufacturing is one area where a vision of intensive coordination through automation has been articulated. Computer integrated manufacturing is advanced as a next phase for improving manufacturing efficiencies and performance by reducing intra-organizational coordination costs. The typical arguments advanced for computer integrated manufacturing focus on improving organizational efficiencies through sharing, reusing and sometimes standardizing information [5]. Cognitive agents are used recently in manufacturing information system to energize several information systems such as production,

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decision support, business intelligence, education, tutoring, entertainment or expert.
This paper will combine the theories and insights from almost all the disciplines related to Cognitive Artificial Intelligence: philosophy, psychology, and computer science are used extensively. From the research in human intelligence, we will use the relevant studies on the phenomenon of cognitive state, its role in human behavior, and the cognitive theories, which resulted from these investigations. We will try to build a model for a cognitive agent, which contrivance human intelligence. In this field, we will try to implement the proposed cognitive agent blueprint, and evaluate it in a manufacturing simulation environment.

Cognitive factors (states) are facts in humans and other animals. However, why would we need to endow artificial agents with cognition abilities? Two main answers are possible, depending on what our principal concern is when modeling cognition. If we have a more scientific interest, we will use artificial agents as a test bed for theories about natural cognitive factors in animals and humans, providing a synthetic approach that is complementary to the analytic study of natural systems. If we have a more engineering motivation, we might want to exploit some of the roles that cognitive factors play in biological systems in order to develop mechanisms and tools to ground and enhance autonomy, adaptation, and social interaction in artificial agent societies.

As we will show in this paper, cognitive states form an essential part of human intelligence, and it is possible to recreate the role that these states play in humans in cognitive artificial intelligence. While cognitive agent can improve its performance in order to compete with regular one. We think that this research on both cognitive human aspect and the implementation of these features in an agent sheds light on the subject of cognitive factors from these two different perspectives. Therefore, it enables us to see these factors as an essential research topic in Cognitive Artificial Intelligence.

2. RELATED WORKS

In this subsection, some related works are introduced. As shown in the previous sections, the subject of cognitive factors is concern as a very inspiring topic. It is still unclear how some cognitive states transit from the subconscious to the conscious brain. Searching for a better explanation, researchers on agent's technology demonstrate some models in this field.

L. Monostori, J. Vancza and S. R. T. Kumara [6], multi software agent system was introduced. A comprehensive survey was performed to study the potential of agent in manufacturing applications. They concluded that the evolution of agent technologies and manufacturing would probably proceed hand in hand. They proof that applying agent technologies in manufacturing system is beneficial.

Rodríguez, L.-F., Gutierrez-Garcia, J.O., Ramos, F. [7], addressed how to model the interaction of emotion and cognition in agent architectures to generate consistent emotional states and display believable emotional behaviors. A Computational Models of Emotions (CMEs) was developed. An integrative framework was proposed. There was a focused on two main aspects: (1) emotions underlying mechanisms model is proposed, and (2) input and output interfaces incorporate and facilitate the interaction between affective methods implemented in CMEs and cognitive methods implemented in agent architectures.

Sakellariou, I., Kefalas, P., Savvidou, S., Stamatopoulou, I., Ntika, M. [8], described a formal model of artificial emotions based on the dimensionality theory. Simulation results of an initial experimental were evaluated. The model includes interesting aspects of emotions, such as emotion changes due to perception, long term affects due to mood, and emotion contagion due to social interactions.

Harris, T., Gittens, C. [9], suggested a model for the development of believable agents. He proposes the use of a descriptive approach to agent design. The approach is used in-game agents. Agents are designed to learn human emotional responses from real world data. Training data was collected and fed to the descriptive learning believable agent model. A comparative study was conducted to determine whether agents designed using this approach were more believable than agents designed using more traditional approaches.

Zhang, Y.Li, L. [10], proposed a novel personality model based on the Revised NEO Personality Inventory (NEO PI-R). Associated to the widespread Big-Five-Personality Factors (Big5) model. The proposed model is capable in describing a diversity of personalities. Merging with emotion models, it aids to produce more reasonable emotional reactions to external stimuli. A novel resistant construction is also suggested to effectively simulate the complex negative emotions. Emotional reactions towards multiple stimuli are also effectively simulated with the proposed personality model.

Tavakoli, M., Palhang, M., Kazemifard, M. [11], modeled the human cognitive process for intelligent agents using Five Factor Model of personality. Another function of personality is introduced, and its interactions with other functions. Effective sociality is constructed among agents with different personalities to improve sharing of knowledge and subsequently supportive cooperation. This is significant since the fundamental advantage of multi-agent world is decentralized investigation. This architecture is implemented in a predator-prey environment, and its selective applications are discussed.

3. COGNITIVE AGENT-BASED MODELING

As we live in a progressively complex business world. The systems that we need to study, analyze, and model are becoming more complex in terms of their interactions and dependencies. We are beginning to be able to take a more realistic view of these systems through Agent-Based Modeling and Simulation. Manufacturing system is one of these systems that are deeply studies, models, improves, and simulates. Micro-level of manufacturing processes can be model in Agent Based Model (ABM). We can now compute large-scale Agent-Based Simulations (ABS) models.

Cognitive science is the scientific study of the mind and its main thinking and cognitive processes. It examines the functions, nature, and the activities of cognitive system. Cognitive researchers study intelligence and behavior, with a focus on how nervous systems model, represent, process, and transform information. The analysis of cognitive science spans many levels of information systems, organization, from learning and decision to logic and planning. The main concept of cognitive science is that thinking process can be understood in terms of representation the components of the mind and the computational procedures that operate on those components. Cognitive science has had its own representation, symbols and notion of agency. Cognitive scientists are developing agent-based models of personality, emotion, cognition, and behavior [12].

Cognitive states (factors) play a significant role at agent's mental control-level [13]. Some cognitive factors such as emotions may lead to reflexive behavior; it may strengthen the motivation and desires of an agent [14]. It can create new promoters and it can set new goals or objectives. In fields such as artificial intelligence, a major objective has been the advance of believable, intelligent agents whose behavior is influenced by affective states [15]. This subsection purposes to build software cognitive agents with the mission to energize several information systems such as production, decision support, business intelligence, education, tutoring, entertainment or expert. Therefore, we want to develop artificial cognitive mechanisms that can perform the role cognitive factors plays in human decision-making process. We try to investigate if cognitive factors can improve the performance of the agent in some circumstances.

3.1 Model Requirments

To be reliable with the aim of adding artificial cognitive factors to software believable agents with different believes, desires, and attitudes for several application areas [16] [17], we will introduce a set of requirements for the proposed agent model CAM:

1. **Decision Making Module:** It is an event drive action oriented appraisal module. Moreover, the model should have a flexible, generic, domain-independent way of appraising events to be useful in a variety of applications.
2. **Detectable and Appraisal Module:** This module should be able to generate artificial cognitive states with different concentrations. Some of the state's intensities should also decline over time and re-generated according to the present conditions based on previous experience (flash backs).
3. **Cognitive States Module:** This module is clustering a variety of states, which are easily submitted under a general definition. These states may contain action planning, situation appraisal, personality, sensitivity, sensation, temper and perception ((or affection states). Personality and other affection state play an

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important role in determining the passionate or expressive behavior of the agent.

4. **Satisfactory Module:** Objective (desired goals) represents a list of actions agent desires to achieve ultimately in the future. In this case, this list of actions is set/initialize in agent profile and it represents the agent's goals satisfaction.
5. **Adaptability Module:** The module enables the agent to learn and adapt in its uncertain and dynamic environment. According to the current situation agent adjusts its goals or desires to satisfy the current mission.

3.2 Cognitive Agent Model (Cam)

Cognitive Agent Model is demonstrated in Figure 3.1. Receiver detects stimuli from the environment to abstract the perception events features. Reflex has to direct mapping functions from Receiver to the Executor (reactive). Executor has the final

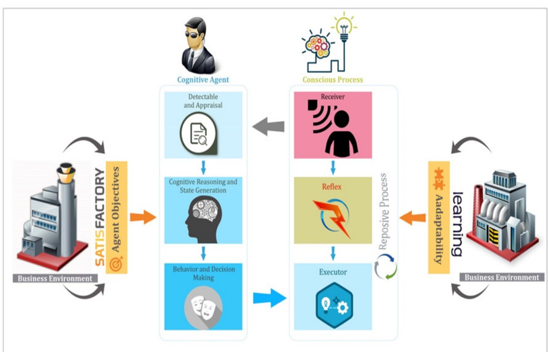

Figure 3.1: Cognitive Agent Model

Receptor and Executor is domain dependent, so the agent-based designer is the responsible for determining, designing, and implementing them. CAM model consists of responsive and premeditated mechanisms. There is certain path for cognitive state information. The responsive mechanism covers direct mapping from Receiver to Executor, while premeditated mechanism has two processes: the cognitive reasoning/making decision and behavior/action process. The cognitive reasoning process executes recognition, evaluation, decision-making and planning [18]. The cognitive state generation process generates cognitive signals according to the cognitive appraisals results [19] [20]. Agent's appraisal on cognitive-inducing situation variables apply to event-based state, attribution state (agent-based) and attraction state (object-based). Cognitive states, which are generated according to the cognitive appraisals, influence cognitive processes such as first-hand goals constructing and conflict dissolving in problem solving. While not of our behaviors are generated under premeditated mechanisms in the case of real life, so responsive mechanisms are required to avoid, for instance, a sudden difficulty and supporting agent existence [21].

As shown in Figure 3.1, premeditated mechanisms simulate the high information-processing pathways of the mind that lead from cognitive stimulus to cognitive response; while the reactive mechanisms simulate the low road that provides the quick pathway for our quick reactions. The premeditated mechanisms leads through the cognitive appraisal process and provides a more accurate representation of the stimulus, but takes a little longer to reach the mind decision-making center then the proper action to be taken by CAM agent.

3.3 Model Assumptions

The hypothesis is based on the assumption that cognition in animals are mechanisms that enhances adaptation in dynamic, uncertain, and social environments, with narrow resources and over which the individual has a very limited control. When an artificial agent is confronted with an environment presenting similar features, it will need similar mechanisms in order to survive and enhance its behavior, survival, learning, and adaptation.

4. MANUFACTURING APPLICATION

The manufacturing information system on which our proposed agent CAM will be implemented and tested is one of the manufacturing/industrial application named Sales and Production Planning (SPP). SPP is an incorporated business management processes through which the high executive management constantly focuses on its out stream. It supports orientation and harmonization all business functions of the organization. The SPP consists of up to date forecasting that leads to a sales plan, production plan, inventory plan, customer lead-time plan, new product development plan, strategic initiative plan and resulting financial plan. SPP is one of the management information system that ensures that material is not requested for production until there exists an end item for it to produce: It starts with the complete product and works backward to plan the requirements of all necessary raw materials (based on bell of material). The main objective of SPP is to keep stock level to minimum. It is applicable to discrete and dependent demand systems, allocating items in inventory when they are required. The system must be time phased so that predetermined materials arrive at the point in time when they are need. Time phasing results in reduced inventory levels, since holding costs are a factor in determining ordered raw material or Work In Progress (WIP) [22].

Agents are not a magic potion for industrial applications. Like any other technology, they have certain capabilities, and are best used for problems whose characteristics require those capabilities. Five such characteristics are particularly salient: agents are best suited for applications that are modular, decentralized, changeable, ill-structured, and complex. SPP application is selected as a demonstration application for CAM-agent, because the interface between SPP manufacturing environment and CAM agent is more challenging. Even though the SPP application may be functionally defined, as a legacy program it is a well-defined "thing" in the applications domain and so deserves agent-hood. Its presence in the system will not preclude the development of techniques for emergent scheduling as long as its agent behaviors restrict it to serving as a link with the rest of the system rather than drawing on its centralized scheduling behavior.

5. OUTPUTS ANALYSIS

Now, we will start our experiments on the constructed agents and answer the following questions: do artificial cognitive factors work for agent's benefit? Can they have artificial genitive states? How does cognitive factors motivate agents to act? Simulation will be run two times, with the di□erent world settings.
Based on the functional roles of cognitive factors proposed by cognition researchers for natural systems, it is worth asking whether cognitive factors could serve similar functional roles in artificial systems. Specifically, we can specify 12 potential roles for cognition factors in artificial agents:

- Action selection
- Adaptation
- Social regulation
- Sensory integration
- Alarm mechanisms
- Motivation
- Goal management
- Learning
- Attention focus
- Memory control
- Strategic processing
- Self-model

We start our investigation on the building of artificial cognitive agent and trying to answer the following assumptions: Do cognitive factors work for agent's advantage? Can they have sensation, personality, temper or other cognitive factors? How does personality stimulate agents to action?

5.1 Environment Situations

In order to implement and test CAM-agent's architecture, we used some specific benchmarks for simulations. We selected a business planning application "SPP application", in which agents had to manage system (factory) inventory object, while maintaining other goals as well. In the constructed simulation, agents are tested head to head in a real-time situation, thus making it easy to compare performance of agents under similar circumstances in real-time. CAM-Agent (Cognitive Agent) runs into this simulated world, together with SPP-Agent (Conventional Agent) in order to benchmark both performances against each other. Several experiments are conducted with different business variables settings. Both agents' Thinking Mechanisms (Behavioral) are tested and investigated. Randomness plays a big role in our agent-based modeling and simulation.

Agent Goal

The goal is to find how artificial cognition in agent improve the performance of agent's behavior.

The performance measures for the simulations are:

- Main Mission: minimum inventory level.
- Agent's Performance Measures:
  - Sales Orders Level.
  - Suppliers Information Level.
  - Purchasing Orders Level.

Main mission (goal) for both agents is to manage inventory and keep material level as good as they can.

Cognitive Agent Evaluation Criteria

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1. Cognitive agent "loves" nothing more in life than taking care of main factory inventory status.
2. Cognitive agent is motivated by the idea of reaching its mission and sensing that the mission is adopted is somehow beneficial ("supportive feeling").
3. Agent has main goal should set and sub goals that support the main goal.
4. Agent interaction with its environment (social interaction with other entities).

Agents live in the simulation-manufacturing environment with their own set of objects, which behave (interact) similar, and in which the agents have to make sure that:

- Their inventory status does not decay completely.
- They do not run out of cash (all business process will be stopped).

We run the simulation under certain manufacturing conditions. Simulation state variables that are used are Sales-Order, Purchasing-Orders, Sales Capacity and Procurements Ability (see Table 5.1). Tables and plots enable us to study the difference in behavior between both agents.

Table 5.1: Manufacturing Environment Setting

Manufacturing Situations	Random Number Generators
Cognitive Factor Influence	Medium Importance
Maximum Suppliers Searching Data	20
Maximum Searching Cost	10
Maximum Sales Job Orders	20
Maximum Inventory Decline	10
Maximum Procurement Orders	20
Maximum Procurement Decline	10

Notice that these are not all the options available for us to set. We ran the simulation various times with these settings. As clear suppliers' available data, incoming job orders from customers or distributors, and suppliers, alternative and materials purchasing orders are *high*. While Searching and decline variables if *Low*.

Table 5.2: Conventional-Agent Outputs

Exp. No.	Inventory Level (Main Goal)	Cash Level	Sales-Orders Capacity	Purchasing Orders Capacity
1	**49.9**	92.0	80.3	49.8
2	**54.8**	95.2	84.2	44.5
3	**89.6**	80.3	80.6	67.8
4	**75.9**	95.0	85.1	50.5
5	**45.3**	92.5	82.6	37.8
6	**50.4**	91.0	83.4	53.8
7	**90.5**	100	86.3	55.4
8	**83.0**	89.4	80.4	62.9
9	**82.5**	60.0	80.4	75.6
10	**66.4**	96.7	85.1	33.7

Table 5.3: Cognitive-Agent Outputs

Exp. No.	Inventory Level (Main Goal)	Cash Level	Sales-Orders Capacity	Purchasing Orders Capacity
1	**87.2**	87.2	100	94.2
2	**98.1**	94.1	99.5	88.9
3	**97.5**	87.5	99.3	95.1
4	**98.6**	92.6	99.3	96.7
5	**91.5**	80.7	96.8	98.2
6	**100**	92.5	98.9	95.2
7	**98.4**	83.6	100	93.1
8	**87.2**	89.1	100	90.8
9	**96.1**	94.2	100	93.3
10	**91.8**	95.1	98.9	89.6

Performance of the Conventional-Agent is tolerable, as shown in previous (see tables 5.2 & 5.3), although it has great complications keeping its main goal and mission status within desired values. It also fails to maximize its purchasing capacity level while cash level is satisfactory. Cognitive-Agent performs better than the Conventional-Agent under identical manufacturing environment. Results are clear in Figures (5.1, 5.2, 5.3, 5.4, and 5.5).

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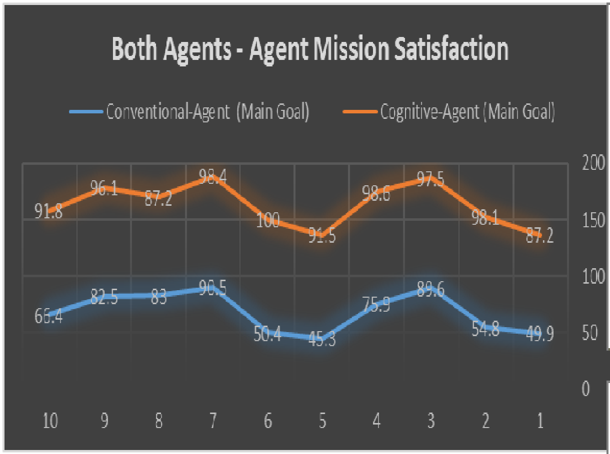

Figure 5.1: Both Agent Mission Satisfaction (Maintain Inventory Level) Output Comparison

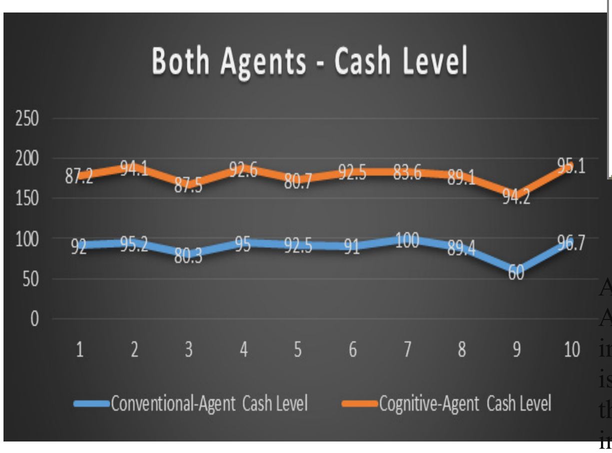

Figure 5.2: Both Agent Cash Level Output Comparison

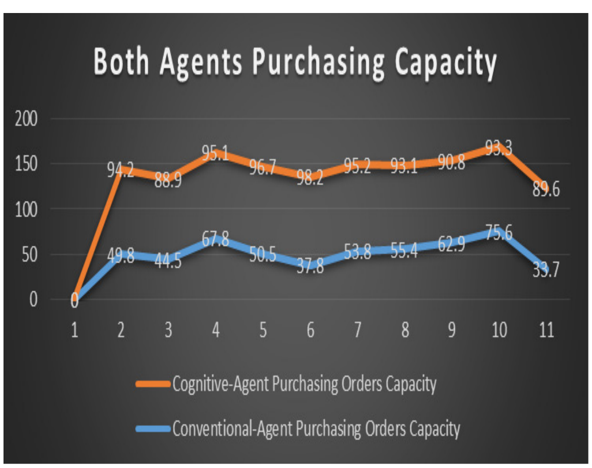

Figure 5.3: Both Agent Purchasing Capacity Output Comparison

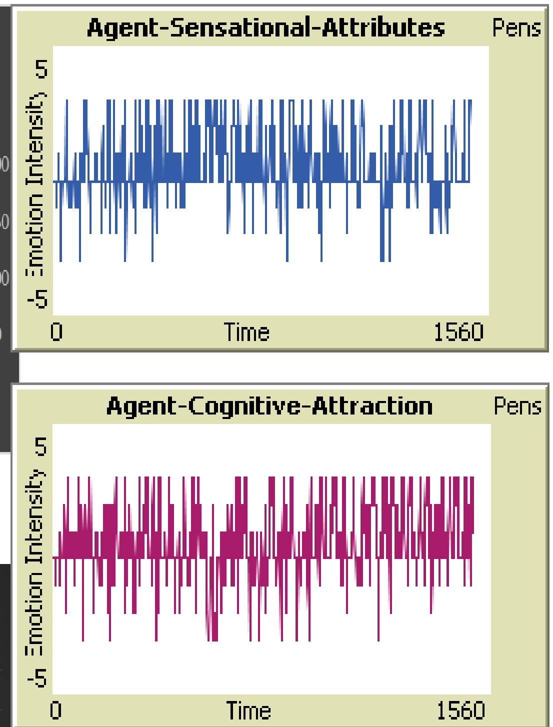

Figure 5.4: Agents Cognitive States

As shown from previous diagrams. Conventional-Agent fails to satisfy its main goal to maintain the inventory level. Inventory level of the CAM-Agent is better because it executes according to a fixed threshold values (no cognitive reasoning and interpretation). In addition, for Conventional-Agent many objectives can be satisfied in the same level of low priority, where this situation can indeed have effect on the agent, resulting in failure to keep up inventory status. This clarifies the large variations in inventory status, compared to the relative no fluctuations in it CAM-Agent.

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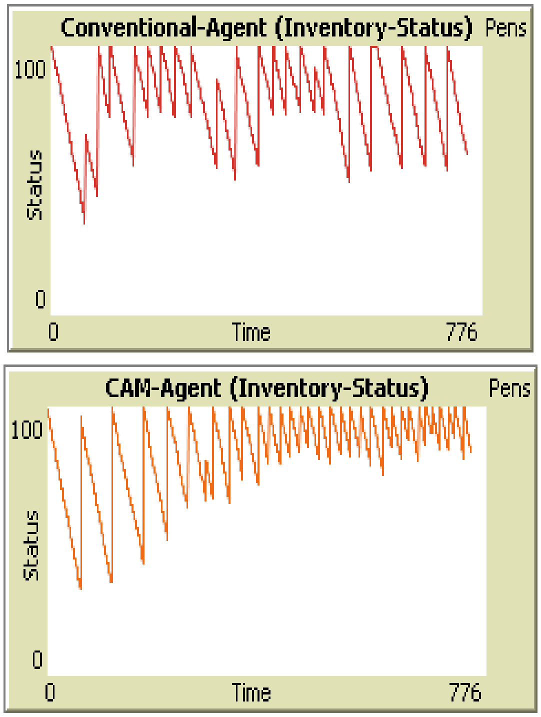

Figure 5.5: Agents Stock Conditions

The CAM-Agent's main goal is steady; whereas the Conventional-Agent's main goal is more fluctuating, this general fashion is a positive one. CAM-Agent acts and directed by its artificial cognitive factors, which aids agent to reach its main m1ission in stable trend.

6. CONCLUSION

The premise behind this research was that cognitive states are the phenomena that emerged from the interaction of certain module within the intelligent cognitive agent. Before one can properly understand what cognitive factors are and reconstruct them, one must first model these modules and their interactions to increase our understanding of why they occur and how they are beneficial.

To recall, the main objective of this research was to try to model artificial cognitive factors, to investigate the role of them in agent's behavior (action plan). The enthusiasm of this paper is to inspect the concept of software cognitive agents, and find out why we are able to consider these artificial constructed reasoning machines as intelligent. The concept of instrumentalism was explained, and put into practice, which enabled us to grasp the concept of artificial intelligent agents, and led us to the conclusion that we can honestly say these agents are intelligent. What this work has achieved is to increase our understanding of how some artificial cognitive factors could possibly operate using cognitive mechanism.

At the foundation of this research, we had incomplete knowledge as to what was required from an agent and how it would work. Our overall complex idea on what we have achieved was resulting from what was understood from the literature and what was gradually built during our agent-based simulations. Progress was only made when our ideas were significantly simplified and an open-mind was adopted to determine how the system ’wanted’ to work.

We tried to go deeply through cognitive and affective state and their relation. We introduced some previous works, and cognitive projects; to step toward our starting point in modeling them.

A new conceptual model for cognitive agent is presented in solving dynamic applications. We propose and implement our main cognitive agent model (CAM). The design is supposed to mimic some of the human’s behaviors. During implementation, we could notice that artificial cognitive states are used in different ways to influence decision-making process and agent mental or thinking process.

In order to test CAM-agent’s architecture, we used some specific benchmarks for simulations. We selected Sales and Production Planning (SPP), in which agents had to manage system inventory entity, while maintaining other missions as well.

The conclusions from simulation experiments are that artificial cognitive states can be successfully modeled in software cognitive agents. We found that cognitive agent could outperform its conventional counterpart in the SPP application business conditions.

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