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# Intelligent Agents: A Comprehensive Survey

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***Abstract* – One agent in computer science is software or other computational type entity with some intelligence characteristics. Therefore, an intelligent agent is a composition of hardware, software with some intelligent features. Each intelligent agent perceives its environment with collecting some information about that environment through its sensors attempt to achieve its goals by acting through its actuators. Intelligent agents are having some internal characteristics (such as: autonomy, Learning/ reasoning, reactivity and goal oriented) and some external characteristics (such as: communication, cooperation, mobility). In this paper, we attempt to provide a comprehensive survey about history of intelligent agents' evolution, various types of intelligent agents which are proposed, different applications of intelligent agents and some discussion about creating favorite intelligent agent.**

***Keywords* – Intelligent Agents, Artificial Intelligence, Perceive Environment, Sensors, Actuator.**

## I. Introduction

Artificial Intelligence provides facilities for creating intelligent agents which are having some intelligent behaviors and they are able to act instead of human or robots. Each intelligent agent is capable to perceive its environment by sensors and act upon that environment through actuators. Commonly three major types of intelligent agents including Human agents (different organs of human body such as eyes, ears are used as sensors and other parts of the body such as hands or legs are used as actuators) and Robot agents (using some devices such as Camera as a sensor and other devices such as motors as actuators) and Software agents (using file contents or other received packages through network as a sensor and some files are using as actuators) are available and various applications of these agents in education, business, industry, different government or private organizations are using these agents for specific goals such as Transportation systems management, Traffic and Incident management, Geographic Information Systems management and etc.

There are six types of environments and each intelligent agent based on its goal or structure should perceive minimum one of these environments. These environments are: Fully observable vs. partially observable, Deterministic vs. stochastic, Episodic vs. sequential, Static vs. Dynamic, Discrete vs. Continuous, and Single agent vs. Multi-agent. Therefore, each agent has specific goal and attempts to achieve that goal with the help of perceiving its environment by sensors and then try to select right action which helps the agent to be successful on obtaining its main goal with highest performance.

This investigation is organized in five sections. Second section includes some basic concepts which are used in this paper. Section three, presents some of important applications of intelligent agents. Section four, discusses about autonomous agents and some of their applications. Finally section five summarizes the paper.

## II. Basic Concepts

In this section, the main concepts of intelligent agents, their components and structures are discussed.

### A. *Intelligent Agent*

There are several definitions for intelligent agents.

- Based on Russell and Norvig [1] definition, an agent is anything that can be get information about its environment or perceive its environment by sensors and then try to select appropriate action within various actions which are available and attempt to achieve the expected goals by acting through actuators (Figure 1).

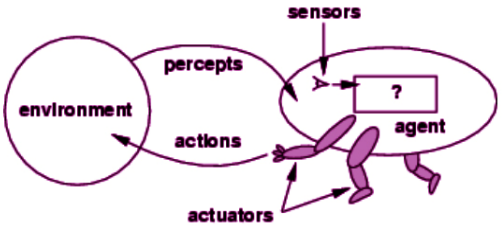


Fig.1. An Intelligent Agent [1]

- Based on Maes [2] definition, an autonomous agent is a computational system that has some complex dynamic environment and some sensors and can act autonomously in this dynamic environment and do some act for achieving goals for which they are designed.
- Hermans [3] defined intelligent agent as a pieces of software that act based on information which is gathered from dynamic environment and achieve the goals successfully. Further, the type of action for achieving goals might be change due to changes in dynamic environment.
- Gilbert [4] defined an intelligent agent as software that can act instead of human user and do some repetitive task automatically or remember the things which are forgotten by people or making recommendation for people and doing some complex tasks instead of people intelligently.

Intelligent agents are having some internal and external characteristics. We discuss about this characteristic in this part.

*A.1. Internal Characteristics*

An intelligent agent has some internal characteristic including autonomy, Learning/reasoning, reactivity and goal oriented. We discuss about each characteristic in below.

- *Autonomy*

Intelligent agents especially software agents can be sense their environment and act based on their perceive and knowledge obtained from their environment and the rules given by the designer. In the other words, each agent has control over the tasks which are done by its own.

- *Learning/Reasoning*

An intelligent agent has capability to learn experiences and then use these experiences for adopting its behavior in environment.

- *Reactivity*

Each intelligent agent should be able to react based on information which is getting from its environment.

- *Goal-Based*

Each intelligent agent has a goal and based on information which is having from its environment, it attempts to achieve that goals.

*A.2. External Characteristics*

Moreover, each intelligent agent has some external characteristics such as: communication, cooperation, mobility which is more discussed in below.

- *Communication*

Each agent need to interact with its environment (such as a human, other agents and etc.) to achieve its goals.

- *Cooperative*

For doing some complex tasks one agent needs to cooperate with other agents and increase its own capabilities for achieving its goals or doing tasks easily.

- *Mobility*

One intelligent agent may navigate within electronic communication networks.

*B. Different Types of Environments for Intelligent Agents*

The first step for one agent is perceiving its environment. Since there are different types of environments and each of these environments has a specific characteristic, in this part we try to discuss about these environments. Further, there are several types of intelligent agents based on their structure and duties, therefore in the following part the types of intelligent agents are discussed.

There are several types of environments which are available such as:

- *Fully Observable vs. Partially Observable*

If one agent's sensors can be give full information about its environment from different points or dimensions, it means that environment is fully observable. However, sometimes for different reason (such as noise or problems on sensors or etc. ) it is not possible for sensors to get full information or help for perceiving total environment, in this case the partially observable environment will be assign to that agent.

- *Deterministic vs. Stochastic*

The environment is deterministic if one agent can decide exactly about its next state and select the appropriate action for moving to that state with the help of current state's information. Therefore, whenever one environment is fully observable, it would also be mostly deterministic. Further, in case of stochastic environments, the current state of one agent is not capable to determine completely next state or the exact action which is required for achieving that state.

- *Episodic vs. Sequential*

In case of episodic environment, one agents' perceiving from its environment is divided into several atomic "episodes". Each one of these episodes can act independently and perceive its own environment and act separately for achieving a specific goal which is dedicated for that episode.

- *Static vs. Dynamic*

Static environment is unchanged during time passing and there is no need one agent look world continually and check what is happening for applying changes on itself. In the other words, static environment does not change due to time passing; agent's actions or world's various statuses. Whereas, dynamic environment can be affected by any of these situations such as passing time, perceiving environment by sensors or agent's action. In case of semi-dynamic, environment will not change by time passing but the selected action by agent may change by passing time.

- *Discrete vs. Continuous*

In case of discrete environment, there is limited number of percepts, states or actions are available for an agent. However, in case of continuous environment there is not this type limitations for agents' perceives, actions or current and next states.

- *Single Agent vs. Multi-Agent*

If one agent works itself without dependency to other agents, it would be single agent. But sometimes agent needs to collaborate with other agents for doing some actions; in this case it would be call as multi-agent.

*B.1. Types of Intelligent Agents Based on Their Actions*

There are four types of intelligent agents which are using generally for various purposes. These types are:

- *Simple Reflex Agents*

These agents are working basically based on the current states or current percept or information which is gathering by their sensors. Therefore, the before information or percepts are not considering for selecting the appropriate actions for achieving the goals. Since the selected actions are based on only the current percepts therefore, achieving goals would be difficult in case of partially observable environments that we have not full percept of the environment. In the other words, simple reflex agents are applicable in case of having fully observable environment. Further, these agents are having limited intelligence level. Structure of this agent is shown in Figure 2.

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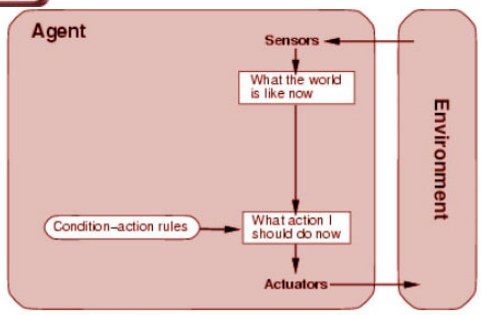


Fig.2. Simple Reflex Agent [1]

- *Model-Based Reflex Agents*

These agents have history of before states or percepts and actions which are made for achieving goals by agent that are stored. Therefore, in case of partially observable environment or whenever, some percepts are incomplete, agent can search for finding the matching state or percept, actions and their goals in the history and use that case for current state and try to act such as before successful action to achieve the requested similar results. Structure of this agent is shown in Figure 3.

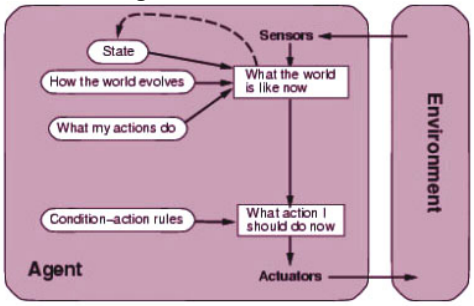


Fig.3. Model-Based Reflex Agents [1]

- *Goal-Based Agents*

In some cases, knowing the current state or percept of environment, is not sufficient for selecting appropriate actions within available actions. Therefore, selection of exact and correct action is depending on desirable goal which is expected to obtain by the agent. In the other words, an agent obtain state or current situation or percepts of its environment through its sensors, then look the desirable goal which should be achieve and then look for sort of goal information and situations which are required for achieving that goals and then try to use appropriate program for getting the favorite results by running an action and finally choosing an action for achieving the desirable goal. The Structure of this agent is shown in Figure 4.

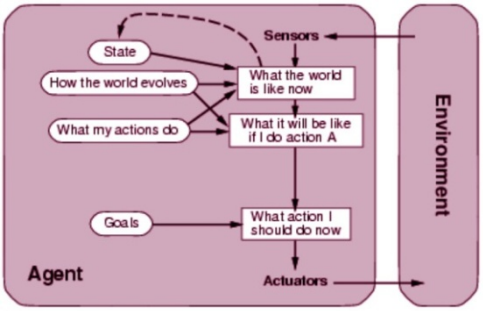


Fig.4. Goal-Based Agents [1]

- *Utility-Based Agents*

In this agent, each utility is a function that maps a state onto a real number. In the other words, it makes an internal map of functions. This map is useful for handling unexpected situations for achieving their goals. The Structure of this agent is shown in Figure 5.

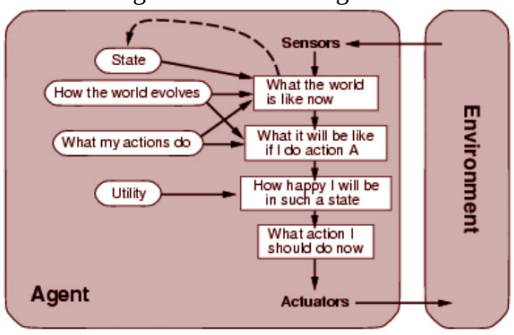


Fig.5. Utility-Based Agents [1]

- *Learning Agents*

One of ways for creating easy and fast programs is building learning machines. Therefore, in this case, there is no need to write programs or rules by hand. Further, we can teach these learning machines and make them ready for acting in unknown environments. Learning agents have various elements with different functionalities including:

- *Learning Elements:* making improvement is the main responsibility of these elements. This element uses feedbacks of expert people or critic for making decision to achieve best performance.
- *Performance Elements:* selecting external actions is the main responsibility of these elements.
- *Problem Generator:* suggesting actions for getting better experience or performance is the main responsibility of this element.

The Structure of this agent is shown in Figure 6.

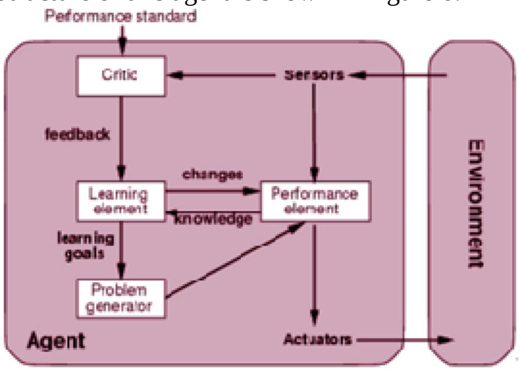


Fig.6. Learning Agents [1]

### C. *Intelligence Levels of Intelligent Agents*

Lee and his colleagues [5] defined four levels for agents' intelligence. These levels are:

✓ *Level 0:* these agents are able to retrieve the requested document or file or contents for users. One example of agents with intelligence level 0 is web browsers which they can retrieve webpages and their contents based on the URL that users mentioning in address bar that browsers.

✓ *Level 1:* These agents are able to provide search facility for users. Agents in this level are called as a search

engines. One example for agents with intelligence level 1 is google that allow users to type their keyword or favorite words and then google search relevant indexes and find some pages and related documents and allow users to select their favorite webpages within the presented results by google.

✓ *Level 2:* This agent gather profile information of users and search for relevant data related to their data or browsing history. Agents with intelligence level 2 are called as software agents or semi-intelligent agents [6].

✓ *Level 3:* Agents in this level have learning capability and can be help users for taking decision. Agents with intelligence level 3 are referred as learning or truly intelligent agents.

## III. Various Applications of Intelligent Agents

There are several applications of intelligent agents are available in various area including medical and healthcare [7~20], transportation and travel agents [21~24], eLearning [25~ 40], Internet searching, Web Applications, Computer Network Management & Evolution of Web [41 ~ 45 ], grid computing & software distribution[46 ~ 48], telecommunication [49], federal investigation[50 and 51], law Enforcement[52], military[53~55], e-business, e-commerce and market analysis [56~60], e-libraries [61and 62], game [63 ~ 65], personal assistance[66 ~67] and etc. Some of research works which have been published related to these applications are mentioned in the remaining of this section.

- *Medical and Healthcare Applications*

Several applications of intelligent agents are available. Several research efforts [7 ~ 19] have proposed an intelligent agents for collecting information about problem or disease of patients data from different sources , analyzing these data, selecting important information and presenting the extracted knowledge for doctors. [11] proposed a multi-agent system that provides information about healthcare centers or hospitals and the availability of doctors in these centers, in special area or one city and allows the mobile users to contact with doctors and send medical records for them or book a physical visit time with them. Several multi-agents are proposed for monitoring the status of patients and help doctors to diagnose the status of patients and taking decision for treatment [12, 13, and 14]. [15] developed an intelligent agent that can help to develop or improve medical distance education or training. [16] Proposed a multi-agent system for monitoring the application of medical protocols. [17] discussed about TeleCARE project which is developed an agent-based framework for supporting assistant to elderly community of people employing tele-supervision or tele-assistance. [18] proposed an agent-based health care system for creating secure medical information of users for enhancing the speed of administrative activities. This system prevents patients information from various attacks. Iantovics [19] proposed Large-Scale Medical Diagnosis System (LMDS), which is a complex system. In this system, artificial agents and physicians are cooperating for discovering solutions of complicated medical diagnosis problems. Vicaria [20] made a multi-agent intelligent learning environment (it is named as AMPLIA) for medical knowledge support and diagnostic reasoning. The main goal of AMPLIA is generating realistic models with the help of knowledge that is available in each case and uses these models for diagnostic training.

- *Transportation and Travel Agents*

Intelligent agents are useful for solving problems in the area of traveling [21] also. Srivihok et al. [21] proposed a personalized support system for managing traveling information for travelers based on their interests that can be use this system in e-commerce or in tourist industry. This system extracts customers or travelers behaviors and then tries to recommend information to meet their interests. Authors in this study, used two learning approaches for proposing personalized support system. First they made various clusters of users based on their ages or genders. In second step, they attempted to make personalization based on travelers' profile, trip features and other unique interests of users. Schleiffer [22] proposed an intelligent agent for traffic management. Chen & Cheng [23] mentioned important and critical issues that are existing in developing agent-based control and management systems. Some of these issues were: extendibility, flexibility and interoperability. Sadek & Basha [24] used self-learning intelligent agents for solving Dynamic Traffic Routing (DTR) to create for users and safely transportation. They developed an agent for simulating a model for a highway. This proposed agent has capability to learn itself by interacting with the simulation mode. Authors claimed that, this proposed approach was highly scalable and applicable to a variety of networks and roadways.

- *E-learning Application*

Various applications of intelligent agents in e-learning area are available [25~40]. Wilges et al. [25] built an Animated Pedagogical Agent as a Learning Management System that is manipulated Intelligent Learning Objects with the goal of implementing a set of resources for developing intelligent objects. Akram [26] proposed an agent based eLearning management system architecture for providing self-paced, personalized and collaborative opportunities for learners. Their experimental results have shown that, their proposed LMS architecture improving performance in compare with other LMSs in Heterogeneous Learning Environment. Oprea [27] proposed the architecture of a multi-agent system as an agent-based knowledge management system for monitoring research activities which are running in university environment. Caleb [28] used hybrid rule and case based reasoning scheme for proposing a multi-agent mediating system model. Soliman at el. [29] have implemented an IPA (Intelligent Pedagogical Agent) which is providing support for multi-modal communication. Mwinyi at el. [30] proposed a model for synchronization in HLMS (heterogeneous LMS) for sharing learning contents in learning Institutions with using Sharable Content Object Reference Model (SCORM) and integration of rsync with Multi-Agent

System (MAS). Mendez and his colleague [31] for handling the applications in tutoring side proposed an agent based architecture which has been integrated with Virtual Environment for supporting realistic training. Scutelnicu [32] for integrating the JADE-based MAS (multi-agent system) with Moodel (Modular Object-Oriented Dynamic Learning Environment) is proposed an approach. Cecilia [33] proposed an Intelligent Tutoring System model integrated with the Moodel LMS which had capabilities for delivering the resources for the learners based on the pattern of their performance on tasks or their usages of the proposed resources by instructors. Lucila at el.,[34] proposed an ILMS (Intelligent Learning Management System) architecture that was applied to Moodel. In the other hand, they designed and implemented an intelligent agent which had capabilities for selecting teaching strategy based on learners' learning style. Soliman [35] made an evaluation for intelligent agent development frameworks. Yaghmaie [36] proposed a framework based on multi-agent systems and used both Semantic Web ontology and SCORM. Parchment and his colleagues [37] have made a software agent for Android enabled handset for solving scheduling and cancellation of appointments on behalf of teacher.

Further, there are several research works that have attempted to use intelligent agents for creating adaptive learning approaches [38 ~40]. Sun [38] proposed a multi-agent architecture which has a learning style schemes and it is used to adapt learners' individual requirements and expectations. TSAI at el. [39] proposed an adaptive learning system based on intelligent agents (IAELS) for improving learner's learning capabilities. Lai at el, [40] designed an adaptive learning model for improving learners' learning outcomes by enhancing their intrinsic motivations to learn.

- *Internet Searching and Web Applications, Computer Network Management & Evolution of Web*

Authors in [41] present the latest researches in the area of combination of intelligent agents with web technology and applications. Authors developed and multi-agent system for the usability analysis of Websites. This system have capabilities such as: resource discovery, browsing assistant for browsing page, resource management in virtual environment and etc. Murugesan [42] has been introduced intelligent software agents as a way for searching web, retrieve data and information, making online shopping, creating recommendation for users and etc. These agents had capabilities for transferring information along various computers, searching users' favorite information on Web, personalization of webpages, making online shopping, filtering or managing users' emails and other web-based applications.

Maes [43] proposed an learning agent named as Maxims which had capabilities for delete, sort, forward, archive email messages or learn priorities. Based on its predictions' results, it had capabilities to advise and understand the future behaviors of users. Beranek& Newman Inc. has developed a software agent that has capabilities for filtering data on the Internet and delivers special managed data to users. Knowles [44] proposed Personal Internet Newspaper that had an intelligent agent and was accessible by any WWW browser. Whenever, users send request for getting information through keywords, agent has been dispatched to make searches and get the results. Roesler& Hawkins [45] developed an intelligent agent named as Telescript that has many personalized functions such as filtering users' emails, shopping materials and etc. Telescript was able to communicate with other agent for doing its functionalities.

- *Grid Computing*

Talia [46] implemented high performance complex intelligent agent by using cloud systems and software agents which had both systems capabilities such as: reliability, flexibility, autonomy and e dynamic behaviors and etc. Srivastava at. el,[47] used cloud computing through a service-oriented interface to offer on demand services and made an agent which had facilities for providing better services to cloud computing. Authors made an implementation of an application in cloud computing using intelligent agents.

Rodriguez [48] proposed an agent with the help of cloud computing service which could be present clients in virtual environment. They discussed challenges that are exist for implementing this agent also.

- *Telecommunication*

Albayrak [49] has mentioned application of agents on telecommunication, such as: providing or supporting real time performance, security management, mobility providing, reliability. However, this author describes two factors, including fully dependability and integration of these agents, as requirements for high performance of this agent.

- *Federal Investigation*

Bansal at el. [50] for securing fingerprint images, proposed multi-agent system architecture for watermarking. For securing each individual users' fingerprint image, they used fuzzy based hybrid approach. For handling huge amount of data or fingerprint images, multi-agent configured to act as a distributed system. Yaxuan [51] also proposed a model for creating secure fingerprint.

- *Law Enforcement*

Wang [52] proposed an agent-based model for crime simulation with integration of geographic information systems (GIS) and artificial intelligence (AI) technologies. This proposed model allows users to make artificial societies which consist of offender agents, target agents, and crime places for crime pattern simulation purposes.

- *Military*

Lockheed Martin Advanced Technology Laboratories has been designing and implementing intelligent mobile agent proto-types for various military applications since 1995. McGrath at el. [53] studied and made an agent for supporting and developing several capabilities of agents in the military domain such as: information push and pull, monitoring of sentinel information. Bhattacharyya [54] attempted to discover the impact of some of the inherent ethical issues, threats and some remedial issues on human civilization and existence. Author studied about human

ethics in contrast to machine ethics and the problems occurred by non-sentient agents. Artificial Intelligent offers a lot of facilities in military decision making for creating natural sketch-based interfaces. Moisescu [55] designed a single integrated framework that is capable to provide a unified map-based interface for helping military for taking decisions in various situations with learning methods and pattern recognition.

- *Market Analysis & E-Business & E-Commerece*

Intelligent agents providing facilities for managing buying and selling activities and cope with overloading and expedite the process of buying activity. MOGOŞ and SOCOLL [56] applied intelligent agents to knowledge management in e-business. They used data mining techniques for quick Knowledge discovery and mobility of intelligent agents. Keeney &Raiffa [57] proposed a theory for price comparison, creating recommendation based on user profiling. Protocols for auction is proposed by Wolfstetter [58]. Wellman &Wurman [59] proposed an agent that provides C2C and B2C e-commerce and exchange data and information between vendors and customers. Wang [60] proposed an agent-based marketplace. Goods are exchanging between buyer and seller in marketplace based on requests. Each intelligent agent has knowledge about materials or goods that are exchanging between buyers and sellers. Trott [61] offered an intelligent agent to anticipate customers' online questions and deliver them service based on their interest or selections.

- *E-Library*

Guoying [62] made a comprehensive survey about the design, methodologies and applications of intelligent agents in the library environment. In this article, different intelligent agents technologies are divided in two main application area: digital library (DL) [including architecture of multi-agent for DLs, agent-based DL projects, agents that are supporting search process in DLs, intelligent agents for distributed heterogeneous information retrieval and etc.] of and services in traditional libraries [including automatic reference service, user interface for library systems, multi-agent architecture for library services and etc.]. This survey covers information about different architecture, framework and technology models of intelligent agents in library systems.

L. Zick [63] examined the characteristics of intelligent agents, software agents and possible tasks for software agents in libraries. He used medical library-based information in his research for testing his proposed method.

## IV. AUTONOMOUS AGENTS

Artificial intelligence (AI) researchers for a first times defined agents using notions in type of mentality signs such as intention, belief, obligation and knowledge [68]. Some other AI researchers considered on study of emotional agents [69 and 70]. Computer science researchers defined intelligent agents as entities with some sort of persistent control [71].

Autonomous agents are proposed first by Carl Hewitt and his colleagues [72, 73] in 1973 as a novel approach of intelligent intelligence.

There are different types of autonomies that are proposed by researchers. In this article we attempt to mentions various types of autonomy.

Authors in [74] have suggested four types of autonomy as follow:

- *Agent Autonomy*

Agent's ability for taking decision for its action is characterized by agent's relationship with its motivational states.

- *Autonomy As Personal Efficacy*

One person can be make himself /herself autonomous by learning special skills, therefore s/he can be obtain ability to solve all her/his problems in the world without requiring the help of others.

- *Autonomy as Psychological Independence*
- *Normative Autonomy*

Basically it can be moral autonomy or autonomy based on special knowledge or confuse that one person may be obtain from his/her environment.

Other types of autonomy are defined as:

- *Authenticity*

Arpaly [75] defined that authenticity is distinct from autonomy (self-control). In the other words, authentic and autonomous are not "one and the same". Therefore, authenticity is define one person's value or it is one personal identity.

- *Self-Identified Autonomy*
- *Heroic Autonomy*
- *Reason-Responsive Autonomy*

Autonomic computing is defined in 2001 by IBM for a first time [76~78] as an approach with a minimum of human interference to self-managed computing systems. Generally, autonomic computing is one of the fundamental technologies of software agents, which is simulation of the natural intelligence possessed by the brain using general computers. Various research efforts are made in the area of autonomic computing and autonomous agents, we discuss about some of these research works in this part.

Wang [79] proposed a cognitive informatics perspective on autonomous agent systems (AAS's). He developed a hierarchical reference model of AAS's for possessing intelligent behaviors by using three layers known as autonomous, autonomic and imperative from up bottom. Author used facets of mathematics and cognitive informatics for developing theoretical framework for Autonomous Agent Systems (AAS's) known as intelware.

Tentori at el. [80] applied autonomous agents' capabilities in healthcare environments for providing privacy of medical information and demands of patients. These researchers made an agent-based privacy-aware system and extended the simple Agent Library for smart Ambients (SALSA) agent framework. Further, they used customized privacy-aware mechanisms for adapting the applications according to the patients and other users' context, for satisfying their privacy requirements into SALSA. The privacy-aware facilities into SALSA is working by mentioning the implementation of an agent-based pervasive hospital application and this application

provided relevant information for workers in hospital on the basis of contextual information and let them communicate with each other through the contextual messages.

Boccardo at el. [81], developed a framework with C++, with capabilities for interpreting script files, and named as Massive Battle. The full description of initial setting of the parameters for each platoon is included in script file. A presented system works by extending basic behaviors, simulating complex movements of platoons of soldiers marching along a path. This system has capabilities for reconstructing historical battles and stores this information in its library. Therefore, this system is works for online interactive simulations. The proposed systems provided a Battle Editor along with editing tools and a set of tools for enhancing the simulation results or increasing the speed of simulation.

Drewes at el. [82], made a neural network-based evolutionary autonomous agent with considerably more biological realism. The biological realism in this research work was extended to spiking network itself, the Gabor filter-modeled first stage of virtual processing and the columnar organization of the virtual cortex. Authors claimed that, they used biological features in this research, because these features can be lead to greater computational power on dynamic cognitive tasks.

Sierhuis at el, [83] used Brahms and KAoSmodels for implementing a model for human-robot teamwork, with special focus on the differences between autonomous agents and human. These authors used integration of an agent simulation and development environment with a framework for distributed agent systems and team work policies.

Schetter at el. [84] presented architecture for multiple satellite autonomy using a message passing simulation environment (TeamAgent) for agent based software (MAS) which can provide capabilities for agent-based multi-satellite systems to fulfill their complex mission objectives. Authors claimed that TeamAgent was well suited for the simulation of multi-agent based systems that is applied to the space domain.

Skov [85] created a framework which is included an overall architecture of the involved agents and sketches for the interaction between the agents and the users. This framework is a multi-agent supported community chat room and provides for users facilities for identifying, retrieving and filtering their favorite, interesting or relevant conversations or information by exploring or monitoring activities in one or more chat rooms. Therefore, users on internet can be communicate with their agents and delegate their specific operations or tasks to those agents. These agents are able to observe the behavior of users in internet and make recommendation, based on their behavior in internet and profiles which are updated dynamically, for specific conversations in chat rooms or joining a specific chat room and etc.

The other application of autonomous agents is video-game industry [86]. Increasing the difficulty of the games is one of them main goals of Game AI to make challenges for human players. In the other words, a game take place in dynamic complex world, and it is requires complex decisions taking based on partial knowledge.

Talukdar [87] developed rules for off-line problems and claimed that, these rules are applicable for online problems through autonomous agents.

## CONCLUSION

This article is a comprehensive study about intelligent agents, different types of intelligent agents based on their functionalities, their various applications. Various definitions which are existing for intelligent agents along with several applications of intelligent agents are covered. Further, autonomous agents are discussed and various applications of these agents are presented separately.

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