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An E-Commerce Communicative Multi-Agent Agent Model

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ABSTRACT

This paper discusses research in process of the development of a cooperative communicative intelligent agent model referred to as ALMA (Agent Language Mediated Activity). The ALMA model has been derived to facilitate and support electronic commerce initiatives for a wide range of applications. This model is used as a basis for on-going research into cooperative communicative intelligent agents while supporting multi-agent agent architectures over a range of ubiquitous commerce initiatives.

INTRODUCTION

Our research flows along the lines of the cooperative agent branch of the software agent categories as proposed by Franklin and Gaesser [1] and extended by Klusch [3]. Our perspective, directed at Internet based business, defines a model for agents where the emphasis is on user efficiencies. Lateral research includes such areas (not limited to) as: information dissemination, decision making, and business intelligence is equally applicable.

We are defining business in the broadest sense that includes government, profit, and non-profit organizations. We envision that our model will be able to be applied to not just electronic commerce but also such areas electronic business and mobile commerce that goes beyond B2C and B2B encompassing ubiquitous commerce.

RESEARCH FOCUS

This research is focused on the dynamic complex world of doing business electronically in particular in finding ways that businesses and individuals can more efficiently utilize the resources available through the Internet while achieving user efficiencies. User efficiencies, relating to doing business electronically, is a more complex business and a social issue. User efficiencies is only beginning to be addressed in current research from the perspective of intelligent agents.

There continues to be a need to research and develop models and architectures to support businesses and individuals in achieving their goals and objectives in the e-commerce, m-commerce, and e-business environments. These models and architectures can lead to the development of applications to address the labor-intensive operations that the vast resources of the Internet are imposing on businesses and individuals. An initial step in the development of these applications is the design of appropriate models and architectures that can work with and for businesses and individuals. To this end, software agents are considered a viable and essential player in aiding business and individuals in labor efficiencies.

AGENT CONCEPTS

Agents operating, on the Internet, are being used for a range of business and individual applications. These applications are being used for information dissemination, simple decision making, and business intelligence which relate to labor efficiency. These applications complement and enhance the activities conducted by businesses as well as those conducted by individuals.

The pace of recent technological advancements in the field of Internet data transactions, labor costs and information retrieval has generated a lot of interest in the use of *agent* and *intelligent agent* technology for business and individuals. The terms, *software agent* and *software intelligent agent*, are often used interchangeably. The term agent is also used to refer to concepts that have been applied to either or both types of agents as well as non-software agents.

In general an *agent* represents or acts on the behalf of another agent. An agent may be some type of software agent, an entity, or a human agent. The term *software agent* (i.e. *agent*) means that the software application has more "capabilities" than the conventional information technology software application. The term *software intelligent agent* (i.e. *intelligent agent or i-agent*) not only acts on behalf of another agent, but it has the capability to make one or more decisions on behalf of another agent. These decisions can be simple or complex. Overall *intelligent agents* can be thought of as being "more clever" in comparison to traditional software applications [3].

Agents that are currently in production and those being researched are designed for a specific task or specific purpose. For example software agents are being used for maintenance and reporting of problems and status in telecommunications, servers, and in the management of networks. In the business arena, agents are being used to a lesser extent to improve the efficiency of business practices, especially labor intensive practices such as constantly checking for available resources before engaging the entity to that resource.

INTELLIGENT AGENTS

Intelligence is not a physical quality but rather an abstract property that is usually associated with an entity. Although a clear and satisfactory definition for intelligence is still being debated, instances of intelligent activities have been characterized in various fields of study. Thereby intelligent activities are not necessarily difficult to characterize [13]. The general view is that whatever the term intelligent agent refers to, these i-agents (intelligent agents) will have a basic set of attributes and facilities. For example, an intelligent agent's state must be formalized by its knowledge and its ability to *act* within the limits of that knowledge. Furthermore, if an agent is intelligent it must be able to *interact* and *cooperate* with other agents (human or electronic) using some type of agreed upon communications. Intelligent agent researchers are using an understanding of how humans think as a model for designing software intelligent agents [2]. An i-agent must also be aware of its own existence and its status at any point in time.

In addition to attributes and facilities, i-agents maintain many processes. These processes involve creative reasoning that integrates a range of old and new information, on the basis of an inferential process that is deemed to be *intelligent*. If a process is just a data driven automatic reaction to a specific environmental input and is not *inferential*, then it is consider to be a program or a software tool rather than an i-agent [1].

COOPERATIVE COMMUNICATIVE AGENTS

Cooperation is defined as a multiple agent activity, whereby the agents work together to achieve their ends or goals. A communicative capability is needed in order for the agents to exchange information about their goals, nature, and status. The agents share and evaluate each others information so that they can achieve their goals.

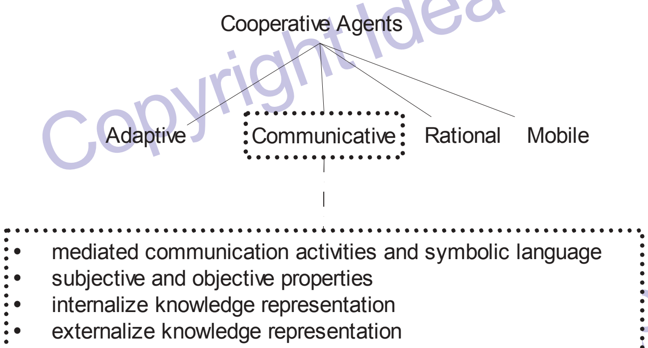
To accomplish cooperative communicative activities between agents there are four high level properties that these agents need to incorporate. These four properties are:

- one or more symbolic languages
- subjective and objective qualities,
- internalization and externalization abilities, and
- mediate activities using communicative tools.

Mediated activities require communicative tools that utilize one or more symbolic languages. Mediated communication activities and symbolic language provides a means for agents to establish an agreed upon common medium of exchange. Agent research and developed prototypes, have used a number of symbolic languages. As of 2001, no agreed upon standard exists. DARPA, FIPA, and OMG are trying to lead the way by proposing standardized symbolic languages. FIPA-ACL and KQML [4, 5, 6] are two proposed symbolic language standards. Even though this standardization is a step in the right direction, the design of agent models does not currently sufficiently integrate the dynamics of the tools for mediate communicative activities. These agents need the ability to use communicative tools and symbolic patterns in order to facilitate mediated agent cooperative communicative activities. Thereby a higher degree of standardization is still needed.

Subjective and objective qualities are required by multiple agents to perform bi-directional and multiple communicative activities. Agents need to have the ability to internalize knowledge representations for communicative patterns and to externalize internal patterns for knowledge representation to other agents. This provides a basis to facilitate inter- and intra-agent communicative activities. To Klusch's taxonomy, we have added the cooperative communicative agent's classification including the four properties as described above.

Figure 1: Research addition



Internalization is about how the agent refers to itself, its self awareness, and its accessible knowledge base. Externalization is how, the agent knowing about itself and status, references itself to its external environment. The incorporation of these properties and those shown in figure 1, provide a theoretical basis for investigating a range of intelligent agent models and architectures in cooperative communicative intelligent agents.

For an agent to be cooperative and communicative it needs to be self aware. Activity theories, as proposed by Vygotsky [9, 10], provide a basis for the explanation of cognitive development. Activity theories provide a theoretical framework for investigating cooperative communicative agents activities. By linking communicative activities to a developmental learning process, Vygotsky proposed new directions in the area of cognitive sciences involving learning, thinking, and language development. These areas are being extended into the development of agent models and architectures. A number of variations of Vygotsky's theories have been used in research of human computer interaction to model the flow of communication tools for human-computer mediated activities.

AGENT LANGUAGE MEDIATED ACTIVITY (ALMA)

ALMA (Agent Language Mediated Activity) is a cooperative communicative intelligent multi-agent agent model and architecture. The model is based on a theoretical mediated activity framework. The model is used to describe a range of intelligent agent cooperative communicative activities for electronic business and individual activities.

The Agent Language Mediated Activity (ALMA) differentiates between processes at various categories and levels taking into consideration the goals and objects that these processes are oriented. Objects include such areas as activities and actions. *Activities* are oriented towards *motives*. Each motive is a conceptual knowledge based system's object that satisfies one or more of an agent's need. *Actions* are the processes functionally and hierarchically subordinated to activities that are driven by the specific agent's own goals and objectives. Actions are realized through step-by-step operations that are determined by the actual condition of the activity in its environment. The range of agent activities (agent evoking agent) involves agents' *motives* that are mainly of environmental origin, while agent subject *actions* are mainly goal driven. Agent operations involve formal interaction of the agents' subjectivity and objectivity with the mediation of the communicative tools. [7, 8]

ALMA follows Vygotsky's works, in its classic form, and takes into account the subjectivity and objectivity dialectics of agent mediated communicative activities. The ALMA model will be used as an initial step into the research-in-progress into the development of a cooperative communicative multi-agent agent prototype. The development is intended to display subjective and objective traits and to perform internalization and externalization of conceptual representations.

In describing the research that has produced the initial design of the ALMA model and its architecture, an activity model is be presented. This model is derived from activity theory and is presented as if the agent was autonomous. Next agent concepts are be expanded to incorporate communicative properties into the model. Finally the model incorporates intelligent agent characteristics thereby showing the current state of the research and development of the ALMA model and its architecture.

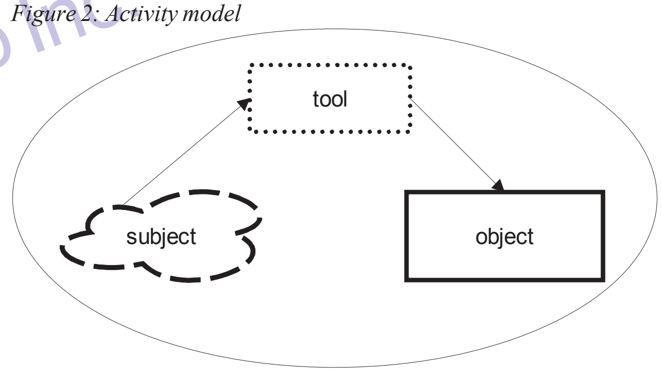
Activity Model

Figure 2 is an activity model. This model considers an agent as if it was autonomous. Within the oval is the environment of the activity. Within this environment all mediated activities for an agent occurs.

The *mediated activities* model takes into account agents' *subjective* (subject) as well as *objective* (object) characteristics. This model can be used to describe rational, inferential and potential intentional agent activities. The agent's *mediated activities* are mediated using a communicative tools such as FIPA's agent communication language (ACL).

Subject or subjective properties of the agent has a fuzzy boundary. The subject illustrates the agent's capability to act or perform an action. It can be an originator of an act or can act on behalf of another agent. Some electronic agent or human agent evokes this initial action or act as if the agent was autonomous.

Figure 2: Activity model



The communicative tool, or just tool, mediates the subject's act or action. This mediation can be static or dynamic and adapts to the particular environment that the agent is in. The tool performs its mediation activity in influencing how the goals and objectives gets accomplished. The resulting object represents the final objective of the originating subject's act or action.

By using a tool in the activity model we can analyze agent subjectivity, its internal and external processes, and its objectivity in an asymmetric fashion. The current object oriented approach to model agent activities is directed towards the design of the agents' internal modules. However, we note that object oriented (OO) modeling provides an environment where an agent and its communicative tools and goals are symmetric. This creates a situation where the dialectics of an intelligent agent's *subjective* and *objective* communicative activities, in an environmental context, are not adequately taken into account.

When a subjective entity is dialectically related by tool mediation to a goal, as in an objective cognitive concept, then their subjectivity and objectivity can be dialectically identified as a single agent entity. We can derive from figure 2 that whenever agents are internalizing communicative concepts, a modification of their knowledge base using some type ontology is needed.

As an agent is a substitute for a range of human activities in a particular instance, commercial, or industrial context, mediated activity tools are ideal for modeling agent activities where agents' individual actions can be analyzed in a contextual environment. Agents' activities are also *dynamic* and under continuous development in an historical time related environment. [14] The more important aspect of mediated activity is the use of tools as *mediators* in performing an activity hence the term *mediated*. [12, 15,16] Autonomous agents are in fact using symbolic linguistic tools such as ACL (Agent Communication Language) as mediators in communicative activities.

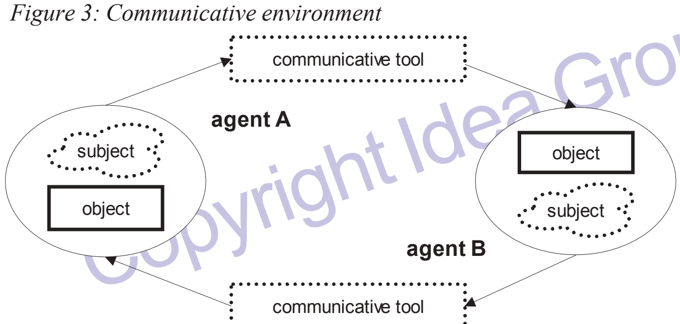
A number of cognitive models can be used to describe agent's activities in a contextual environment for example. The situation action model explains the contingent nature of agent activities out of a given situation. It follows that this model focuses on the situated activity without taking into account the organizational structure of multiple agent's relations, the accumulated knowledge, or the agent historical values in the knowledge base.

Communicative Activity

One of the most important changes in current agent research is the development of multi-agent coordination and cooperation requiring a range of communicative activities that are *necessarily mediated*. This mediation involves the use of symbolic language tools that requires a common or "translated" ontology. The theoretical approach is centered on mediated linguistic tools and ontology standards that allow different agents to be able to communicate and interact over a range of environments. In electronic business environments this becomes an essential feature, as there is no guarantee that the communicative requests of agents encountering other agents can be translated.

Our communicative environment, figure 3, shows two agents, in the ovals, with their particular activity model. Some type of agent control language is required to facilitate the communicative activities. Thereby enabling the two or possibly more agents to communicate.

Figure 3: Communicative environment



Therefore, as a result of communicative activities with a number of agents, a cognitive learning activity process can be said to happen in the agent knowledge base. Cognitive scientist and philosophers quite often imply, in a metaphorical way, that speech and language are in fact mediating tools. For example, Wittengstein [17] on his "Philosophical Investigations" relates tools in a toolbox with word generation functionality. Kempson [17] contrasts Austin's [18] concept of speech-act with Grice's [11] co-operative principle of communication. In both cases the underlying concepts are considered in agent communicative activities.

The concept of mediating agent communicative activities is important in modeling multi-agent agent communications. Although agents are software programs, they are conceived in the ALMA model as entities with subjective and objective qualities, as shown in our activity model (figure 3). Communicative tools necessarily mediate environmental communicative perceptions need to be performed by agents otherwise an agent will not have a cooperative ontology in place to perform efficient communicative activities.

Agent modeling requires therefore an analysis of the context in which the agent performs its activities. Communicating agents must be able to integrate easily within the context of their environment, such as the Internet or wireless networks, where a range of multiple agents interact and cooperate with people, organizations, and federated multi-ontology systems. This communication must allow for interactive symbolic *mediated activities* using some form of standardized symbolic language as the communicative tool.

Intelligent Activities

Intelligence, in this case, says that agent B is given decision making permission by another agent (agent A) to make one or more negotiated decisions on behalf of agent A. From the computer science perspective of intelligence, software agents are considered autonomous, asynchronous, distributed processes with distinct object related traits, thus do not act for another agent. From the artificial intelligence (AI) perspective agents are communicative, intelligent and rational with the possibility of intentional communication, thus exhibiting *subjective* traits but not *objective* traits. These two perspectives require differing architecture design and modeling approaches. The first incorporates the *object oriented* characteristics while the second implies intelligent communication and therefore requires a *subject oriented* paradigm.

THE ALMA MODEL

As previously described, the unit of analysis in a tool mediated activity model is a mediated activity in a given contextual environment. The work of an encoding / decoding device is not inferential or creative. It is not inferential because the symmetrical relation between a message and a signal is quite different from the asymmetric relation of premises to conclusion i.e. the meaning of a sentence doesn't logically follow from its sound. Also an encoding/decoding device is rarely creative. It could be dangerous if it was so. A creative encoding/decoding will change the process symmetry quite often generating communication errors. Therefore encoding/decoding can only be just an ancillary process of the creative and inferential language mediated activity of a symbolic linguistic communication in specific contexts. [13] A creative and inferential language mediated activity in fact requires the *asymmetric* kind of model that the ALMA model proposes. ALMA proposes to be able to frame a number of agent internal activities as well as external ones.

Inferential activities are encapsulated *inside* the agent architecture involving the process of internalized conceptual representations stored into the agent internal knowledge bases. Using the MA model described above, communicative *subjective* self-expressions are *externalized* using mediating linguistic tools and subsequently the same agent can *internalise* communicative expressions in an *objective* fashion. [9, 10]

These activities are extremely important for modeling agents' learning and development processes and will be thoroughly investigated in our next stage of research. While agents can *externalize* their ontology and knowledge bases data ontogenetically implanted by the programmer at agent creation time, the capability of *externalize* inferential knowledge *internalized* by agents during the process of communicative mediated activities implies an agent possessing a number of internal inferential activities mediated by a range of tools encapsulated inside the agent architecture.

Subjective and objective inferences engines are to be built inside the agent model. ALMA uses a number of specialized knowledge bases tailored for the each of the specific subject and object modules. A knowledge base for high level meta-representations integrated with the other knowledge bases will provide a federated KBS environment. [20, 21, 22, 23] A multiple ontology environment capable to store communicative representations for both internalization and externalization activities will be available together with an ontology for conceptual meta-representation. The ALMA model can be easily associated with recent cognitive sciences theories such as Sperber's [12, 23] language meta-representations and relevance theories.

A diagram of the ALMA architecture that is currently being researched is illustrated in figure 4. The diagram clearly identifies the subject and object modules and associated connections. The ALMA internal modules take into account the current standardization efforts, although certain critical areas need to be built specifically with the theoretical communicative framework in mind.

The architecture shown in figure 4 represents the research in progress into the application of mediated activity theories on communicative agents in a cooperative multiple agent environment. The dotted line indicates the proposed ontology for the model. However, the ontology itself is being looked at as an internal intelligent agent, thus an agent within an agent. The dotted line also represents the communicative tool that is incorporated into an intelligent agent.

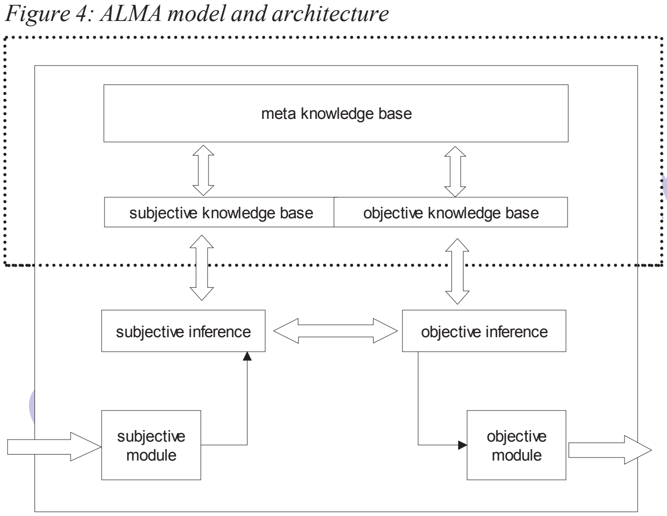
Research continues to be done in looking at meta- representations externalization and in the area of conceptual representation and reflection in information systems. [19] A representation relevance inference engine is being looked at in the ALMA architecture to see the need and applicability that may be added in future together with the possibility of an agent introspection module.

Given the work by FIPA and OMG, as previously noted, we endeavor to adhere to current ACL standards while prototyping ALMA. We expect to research and create new ontology's reflecting mediated activity theory whenever necessary.

SUMMARY

This paper describes research in process of a new cooperative communicative intelligent agent model. These concepts have been used in describing a model and an architecture for cooperative communicative intelligent agents. This cooperative communicative intelligent agents are intending to use an agent communication language (ACL) as a mediating tool for agent communicating activities. Within this paradigm a novel approach has been presented, adapting and expanding Vygotsky's tools of mediated activity theory to multi-agent communicative activities. The resulting model is referred to as ALMA (Agent Language Mediated Activity).

Figure 4: ALMA model and architecture



REFERENCES

1. Franklin, S. and Gaesser, A.: "It is an Agent or just a program?: A taxonomy for autonomous agents." Proc. 3rd International Workshop on Agent Theories, Architectures and Languages (ATAL-96), Springer, LNAI, 1996.
2. Odell, J. Ed.: Agent Technology, OMG Document 00-09-01, OMG Agents interest Group, September 2000.
3. Klush, M.: *Intelligent information agents: Agent based information discovery and management on the Internet*, Springer Verlag 2000.
4. Cohen, P.R. and H.J. Levesque: Communicative Actions for Artificial Agents. *Proceedings of* the *First International Conference on* Llulti-Agent Systems, AAAI Press, San Francisco, June 1995.
5. K. Fuchi and T. Yokoi (Ed.), *Knowledge Building and Knowledge Sharing*, Ohmsha and IOS Press, 1994.
6. FIPA: Agent Communication Language. http://www.fipa.org/spee/fipa97/FIP.k97.html
7. Kaptelinin, V.: Computer Mediated Activity. In *Context and Consciousness*.Nardi, B., MIT Press, Cambridge. 1996.
8. Kuutti, K.: Activity Theory as a potential framework for HCI research.. In *Context and Consciousness*. Nardi, B., ed. MIT Press, Cambridge. 1996.
9. Vygotsky, L.S.: *Minds in Society*. Harvard University Press, Cambridge. 1978.
10. Vygotsky, L.S.: *Thought and Language*. MIT Press, Cambridge. 1986.
11. Grice, Paul: *Studies in the Way of Words*, Cambridge, Mass.: Harvard University Press. 1989.
12. Sperber, Dan & Deirdre Wilson: *Relevance: Communication and Cognition*. Oxford: Blackwell. 1986/1995.
13. Sperber, Dan: Understanding Verbal Understanding in J. Khalfa ed. *What is Intelligence?* Cambridge University Press. 1994.
14. Kuutti, K.: Activity Theory as a potential framework for HCI research.. In *Context and Consciousness*. Nardi, B., ed. MIT Press, Cambridge. 1996.
15. Nardi, B.A.: Studying Context. In *Context and Consciousness*. Nardi, B., ed., MIT Press, Cambridge. 1996.
16. Parker, S.T.: Higher intelligence, propositional language and culture as adaptation for planning.In *Tools, Language and Cognition in Human Evolution.* Eds Gibson,K. & Ingold, T. Cambridge University Press UK. 1993.
17. Wittgenstein, L.: *The Blue and Brown Book*. Harper & Row. NY. 1958.
18. Austin, J.L.: *How To Do Things With Words*. Oxford University Press, NY. 1965.
19. Edmond, D.,and M.P. Papazoglou: Reflection is the essence of cooperation. In M.P. Papazoglou and G. Schlaegeter (Eds.), *Cooperative Information systems: Trends and Directions*, Academic Press, pp.233-262, 1998.
20. Wiederhold, G.: Interoperation, mediation and ontologies. Proceedings of *International Workshop on Heterogeneous cooperative Knowledge Bases*, Tokyo, 1994.
21. Gruber, T.R.: A translation approach to portable ontology specifications. *Knowledge Acquisition*, 5:199-220, 1993.
22. Guarino, N. and Welty, C.: Ontological Analysis of Taxonomic Relationships. Laender,A and Storey, V., eds., *Proocedings of ER-2000: The International Conference on Conceptual Modeling*. October 2000. Springer-Verlag LNCS.
23. Sperber, D.: Metarepresentations in an evolutionary perspective. In Dan Sperber ed. *Metarepresentations: A Multidisciplinary perspective*. Oxford University Press, 2000.