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The Role of Semantic Tools for the Construction of Subjective Meaning in Multi-agents Communication Systems.

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Abstract

This paper explores, using a multidisciplinary approach, the links between the meaning making aspects of natural language and the externalization of subjective meaning performed during intelligent software agent communication. The role of applied ontology in the negotiation of externalized meaning process is also discussed. A multi-agent architecture incorporating the externalization of subjective meaning will be also presented.

1. Introduction

We live in the information age. In the last few years the quantity and scope of available online information have grown exponentially. Search and retrieval of relevant knowledge and information from corporate and worldwide web is increasingly required and this task is usually assigned to Software Agents performing intelligent communication and analytical activities. One of the more complex communication tasks among intelligent agents *is not* the tentative by one software agent to transfer to another agent data relevant to objective world related ontology. This task has already been performed quite well by a number of intelligent software agents currently available from the research community. [1, 2]

It is the communication of the linguistic symbolic meaning of internal knowledge information that a software agent externalize and the use of relevant shared information and knowledge requiring dynamic domain ontology that is an interesting new field in researching multi-agent and human-to- software agents communication.

The use of language as tool, as suggested in cognitive development theories proposed by Vygotsky, can provide a proper theoretical framework for investigating multiple cooperative agent communication activities. [3, 4, 5, 6, 7]

While performing cooperative activities with other agents, an agent can send and receive agent communication Language (ACL) Speech-Act messages. Although deprived of the richness of human verbal communication, a substantial form of meaningful communication is achieved providing an exchange of ontology driven information between software agents.

2. Software agent communication tools and subjective meaning construction.

Vygotsky's theories on thought and language are centered on the communication activities of internalization first and then externalization of knowledge mediated by communicative tools. Vygotsky's learning developmental schema's first social, then egocentric, then inner speech shows that the true direction of thought development is from the social to the individual, where the subject-object roles are exchanged in a dialectical fashion. [3, 4, 5, 6, 7]

When we talk in this paper about language as a communication tool applied in software agent technology we use its *semiotic* perspective. Semiotics is basically the study of sign systems and language is basically a *semiotic* meaning-making system for the reason that language itself is one of the semiotic tools

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used by intelligent entities for communication exchange. [8, 9, 10, 11]

While world objects can be described separately from their subjective meaning, the two are in fact interdependent. The internalization of perceptual objective data can be mediated and categorized by a subjective ontology based on meaning thus providing the building blocks for inference and communication of subjective meaning that characterize intelligent communication. [12]

Agent Communication Languages such as ACL are derived from speech-act human language communication models. The linguistics discipline is currently producing a rich research fieldwork in the development of linguistic meaning, from ontogeny to phylogeny and in particular the process of *learning how to mean,* that is vital for research investigations on software agent communication architectures. [13]

Current software agent communication actions or activities are still related to internalized objective environment. Intelligent software agent actions should model the organization and integration of both subjective and objective meanings related to objects existing in the environment where the subjective software agent operates.

If, as an example, a software agent enters in communication mode exchanging contracts on-line with a human agent then we tend to expect a conventional behavior in this situated environment and also attribute to the SA some kind of subjective mental states. This attribution seems to clash with the notion that mental states only apply to humans. Many e-commerce systems currently operating on the internet are involving at the same time intelligent software agents and their legal owners (Online Companies) thus requiring a clear identification of who are the legal subjects in the transaction and the examination of relevant intentional motivations behind online activities. [14] An issue emerges at this point: If we have to take into account human mental states and artificial artifacts mental states differently, then we will need to legislate and apply a different or duplicate commercial law for intelligent software agents. An alternative to this course of action is the use of Dennett's intentional stance that interpreting mental concepts in a flexible way can be applied in the analysis of interaction activities of both humans and intelligent software agents. [14]

In choosing Dennett's intentional stance we assume that behavior and related belief, desire and intention (BDI) forms of cognitive mental states embedded in the software program are directing and motivating an intelligent software agent activity including its epistemic states (Information on objects in the world) and its cognitive states. (Information on what objective goals to achieve) [15]

By applying an intentional stance to the analysis of software agent communication activities we could:

- Treat the software agent as a rational agent.
- Examine what BDI the agent should have. (given his objective place in the environment)
- Forecast rational normative activities the agent should perform in light of its BDI.
- Confirm that the agent is performing his communicative activities in a consistent and rational way.

Whenever in the light of the considerations above, an intelligent software agent appears to possess the capacity to process and communicate knowledge as intentional subjective state then we are justified in attributing to such an agent a number of BDI and associated mental states. [14]

Accordingly, we should give legal relevance and recognize, if present, a subjective intentionality in Software Agents acting in the online marketplace for their legal owners. Recognition of intelligent software agents systems and mixed systems including humans and agents subjective intentionality would imply:

- Interacting software agents would be authorized to attribute subjective intentional states to hybrid systems they interact with. In this case software agents will appear to have subjective intentional states and/or to exhibit them by speech-act communication.
- Interacting software agents will not be able to avoid objective interpretation of the other system behavior which corresponds to intentional states on the basis of ontological conventions applicable to the communicative interaction at hand.

In a hybrid online e-business environment, characterized by human and software agents interactions, the alternative between objectifying Human Computer Interaction (HCI) communicative activities in behavioral terms and subjectifying the same activities by using a BDI intentional stance needs to be considered. Adopting the intentional stance is not an arbitrary choice. Such perspective represents most

of the times the only possibility to explain and foresee objective behavioral activity of complex software agents. [14]
Also subjective intentional stance can be useful in putting humans and agents in an equal position in legal relationships and disputes. When collective organisational transactions involving customers, software agents and companies interact together in online communicative fashion then all the collective internal and external interactive members need to be considered as possessing subjective intentional states and BDI. The intentional stance can provide more information for legal enforcement and judgment in case of disputes than the behavioral examination of activities. [14]

3. Applied Ontology and Negotiation of Meaning.

Intelligent software agent communications activity require a common way to describe the same objects of the world they operate in i.e. they require the use of a common ontology. Ontology is a hierarchical description of the relation between concepts in a certain domain plus an unambiguous description of the concepts themselves. Since Aristotle the task of ontology was of provide a system of categories of reality in a universal fashion describing what exists. However the characteristics of universality proposed by Aristotle and transferred to ontology are problematic. As explained in Varzi (2001) we have two possibilities for ontology: one related to classic ontology as a catalogue that shows the structure of our physical world and perhaps other possible worlds independently from our cognitive capacity. [16] The other possibility is an ontology where this universal catalogue is aligned with our conceptual framework or a certain culture making sense of what is perceived and internalized. In the first case classic formal ontology will describe the nature of world entities, (Realism) in the second case of applied ontology the entities will be "filtered" by internalized perceptive and cognitive structures and can only be expressed by externalization of internal cognitive states. (Relativism) [17]
In the area of meaning construction and learning, linguistics tools such as semantics and semiotics presents a primary role. The ontology of language is an applied ontology that has a fundamental role for Human to Agent communication and Agent to Agent communication as language either natural or speech-act as language is modeling reality and present a high level of ontological choices related to learning, cognition and socio-cultural aspects of meaning. [3, 4]
Given that software agents as other information systems are representational, semiotics which is the study and use of symbols for conveying knowledge should be together with applied ontology important factors in the construction and conveyance of subjective meaning. [17]
Meaning in fact is derived from symbols analysis and interpretation. Meaning involves an agent understanding semantic rules and semiotic symbols and relating that understanding to its knowledge and objective experience. This is a philosophically subjective stance where the understanding of the ontological world depends on prior knowledge and experience. Information carried by semantic or semiotic communication is subjectively related to who externalized the symbols, why and how the symbols were produced and the relationships between the symbols and the environmental world where the communication activity was performed. [17]
The latest research work in systemic computational linguistics and semantics is viewing language as a semiotic system that can explain how experience and meaning can be learned and constructed by using language and symbols as mediating tools. [18]

4. Agent Language Mediated Activity Model

The Agent Language Mediated Activity Model (ALMA) agent architecture currently under research is based on the mediated activity framework described above and is able to describe a range of internal and external communication activities performed by multi-agents.
The ALMA model is designed to perform activities in an environment described in Figure 1 where the communicative process between agents uses an Agent Communication Language and is based on subjective and objective communication interfaces.
These two interfaces are specifically designed to provide the communicative activity capabilities necessary for an agent to perform the externalization of internally produced ACL messages and the internalization of ACL messages received from the agent's external environment. Subjective and Objective inference engines are inbuilt inside the agent model because the subjective and objective properties are created internally by the inferential and conceptualization process. ALMA will use also a specialized knowledge bases tailored for the each of the specific subject and object modules. The integrated Meta Knowledge Base System (MKBS) will use semantic and semiotics symbols to store and provide

relevant data for the externalization subjective agent module.

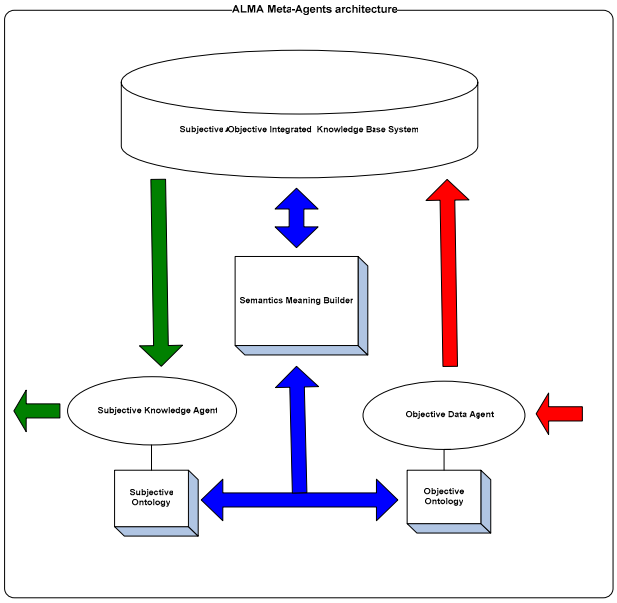

Fig 1 ALMA Software Agent Architecture Model

The use of a multi-agent architectural model and specialized internal subject and object ontologies is dictated by the research investigation on the learning aspects of the ALMA architecture and by the need to obtain and research snapshot data on the internalization and externalization of the ALMA architecture *internal* communicative activities. This research data will be important for the definition and tuning of dynamic integrated ontologies that will cover both internalization and externalization communication activities together with conceptual meta-representation.
The experimental ALMA intelligent software agent architecture described in Fig. 1 comprises an ontology driven central Semantic Meaning Builder inference engine providing inputs to a hierarchical Knowledge Base and internalization and externalization ontologies.
The two input/output specialized software agents with relevant ontologies are forming the internalization input and the externalization output of the meta-agent architecture. The subjective and objective ontologies are dynamically modified by the meaning builder inference engine new meanings discovery.
The ALMA model can also be used to model cognitive sciences internalization and learning theories such as activity theory, systemic linguistics, meta-representations and relevance together with theories of social cooperation. ALMA internal modules and applied ontologies will be developed taking into account the current efforts by a number of research organizations. [18, 19]
The ALMA architecture is constructed using FIPA (Federation of Intelligent Physical Agents) type of agents such as JADE agents and a knowledge base and subjective and objective ontologies built using the knowledge tool Protégé from Stamford University. [20]
The meaning builder in the middle of figure 1 is a specialized agent that will implement Halliday's linguistics theories. [12, 13]

5. Conclusions

In recent years, in particular with the increasing demands of internet applications in e-commerce and search engines, intelligent software agents are re-proposing multidisciplinary issues in Artificial Intelligence and Knowledge Engineering related to Philosophy, Natural Language and Cognitive Sciences. Each discipline is actively researching and continuously refining their applied theories providing research material for their integration into novel intelligent software agent and intelligent systems architectures. While each discipline carry on in their research endeavor, a coordinated multidisciplinary research approach is becoming important in order to resolve a number of Intelligent Systems most challenging questions such as software agents and human communication, and the construction and externalization of subjective Knowledge Base information meaning that forms the base of intelligent entities communication exchange.

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