Proposal of a Empathic Multi-agent Robot Design based on Theory of Mind

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ABSTRACT

We propose a reference design of a social robot controller with the capability to have an emotional communication with a human, e.g. a robot who can recognize and show emotions; the proposed design is based on a multi-channel input-output pattern and a reasoning system that takes into account the states and the values of those channels. The multi-agent system can meet the needs of the design requirements and bring it closer to the human behaviour through application of a recently formalized theory of mind in the implementation of agents.

CCS CONCEPTS

• **Theory of computation → Distributed computing models**; *Automated reasoning*; • **Computing methodologies → Theory of mind**; **Multi-agent systems**; **Cooperation and coordination**; *Cognitive robotics*; *Intelligent agents*; • **Computer systems organization** → Robotic autonomy.

KEYWORDS

cognitive robotics; human robot interaction; emotions; affective computing; computational logic; perception; communication; empathy; theory of mind

1 INTRODUCTION

As in our previous work [6] :

> It can result counter-intuitive and ethically challenging to use the term "empathy" writing about computers and robots considering the definition of empathy as *"the capacity to understand what another person is experiencing from within the other person's frame of reference, ie, the capacity to put oneself in another's shoes"* [3]. Since *"the essence of emphatic interaction is accurate understanding of another person's feelings"* [2], we want to concentrate our effort in trying to design an empathetic human-robot interaction on the feelings utterances recognition and analysis; even if they can't be "felt" by a machine to the extent that we can attribute to a human, we can give a machine the ability to recognize those evidences, act accordingly and also implement the tools to show emotions as a feedback to the human to enrich the interaction.

In the context of BDI Agents, theory of mind that has been formalized by [11] in way that can be implemented with current multi-agent technologies by means of internal states of the agents, their beliefs, desires and intentions. Our approach is based software only based on the most up-to-date available digital perception technologies; even if emotions can't be "felt" by a machine to the extent that we can attribute to a human, we can design a robot in order to recognize those evidences, act accordingly on the base of theory of mind, using tools to show emotions as a feedback to the human to enrich the human-robot interaction. Trying to receive and transmit as much relevant information as possible, including interaction sequences with apparently void communication intervals, with the highest possible perceptive quality and considering as much communication channels as possible, while being aware of the context, it could be possible to improve the human-robot interaction to the point that it can be considered empathic, or rationally compassionate over time [13] . In human communication and interaction, people constantly display emotions, even subconsciously. This communication happens through verbal and non verbal channels; during a verbal communication, we are supposed to use shared words and grammar rules used to explicit the meaning of one's thoughts while a non-verbal communication involves a complex and not explicitly shared set and combination of audition, vision, olfaction/taste, tactility, etc; these multiple channels in human-human interaction can be recognized in theory of communication and applied to empathic robot engineering [6]. In our reference design proposal a significant pillar is the model of communication in which each verbal and non-verbal channel requires an agent role to be assigned to it, and to be orchestrated with all the others.

2 INTERACTION PLANNING TECHNOLOGIES

We requires to adopt a **white box approach** where the system shall be accountable for all decisions made during the human-robot interaction. So even if we allow black boxes for the perception layer, i.e. object detection, speech recognition, etc., their supervision and the overall planning controller of the robot shall be implemented by the result of logic reasoning multi-agent system and explicit knowledge representation.

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The conventional *Sense-Plan-Act* paradigm in robotics does not necessarily implies to be considered a sequential system, but rather a parallel and concurrent asynchronous events handling system [5]. In our proposal, continuous updates are received from the perception layer as event predicates; intelligent agents keep reasoning and pro-actively deliberate actions derived by a static and dynamic knowledge base; actions then have to be executed by the actuation layer, according with the physical limit of the robot hardware, eventually sending back direct feedback states about the outcome of the deliberated action or indirectly through the environment by general state change.

2.1 Logic multi-agent system frameworks

We are analysing, adopting and comparing three different logic multi-agent system development tools and frameworks that allow definition of the agent behaviour by means of a declarative logic programming languages, so to comply with the "white box" requirement.

- **DALI**: enriched with the PyDALI extension, allows to exchange events logic states by a shared Linda tuple space server. Agent behaviours in response to asynchronous events are described in a super set of Prolog. Agents can be proactive and reason upon internal states with preconditions, while deliberating about their executable actions. [7, 8]. DALI can also be extended with answer set programming (ASP) modules to tackle NP-Hard logic programs [9].
- **QuLog/Teleor** : The agent behaviours can be described by universal planners that take perceptions as asynchronous events coming from a shared tuple space server, called Pedro, and they can reason upon their internal states and production rules, producing always executable actions. Teleor and QuLog [5] are extensions of the open source multi-threaded high performance Qu-Prolog interpreter/compiler [12].
- **JaCaMo** : Inherently a BDI multi agent model implemented in Java, with a complete development environment based on Eclipse [4]

2.2 Robot Emotional Engine

Several emotional engines can be found in literature such as the one by Adam and Lorini [1], which describes a BDI (Belief Desire Intention) reasoning model that can be appropriately implemented within our design proposal. Others aim to control a complex animatronics robot head to express emotional states [10]. Our proposal is to adopt the formalized theory of mind as in [11], extending our empathic robot design methodology [6] .

3 ARCHITECTURAL DESIGN

The proposed model implies that sub-systems controllers should go beyond a basic reactive behaviour, quite be implemented as agents that communicate to each other according to the multi-modal hierarchy by means of asynchronous events and pro-active behaviours. Emotional expression action shall be deliberated by a voting mechanism where each agent responsible for a communication sub-channel proposes its solution and a general agent receiving all proposal, which according to the chromemics agent deliberates the action that has the majority in a timely manner.

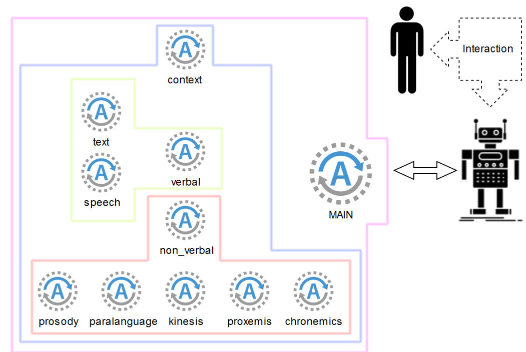

Figure 1: Multi-agent system organization to implement an empathic human-robot interaction. The agents communicate according to the hierarchy of the 8-dimensions communication model: verbal(test, speech), non_verbal(prosody, paralanguage, kinesis, proxemis, chronemics), and context.

The logic multi-agent system appears to be the most effective approach in this context, as shown in Fig 1 .

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