The Role of Context Information in Human-Robot Interaction

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Abstract— **In this paper we discuss the role of context information in the interaction process between social robots and people with special characteristics, which we claim to be a key factor to improve interactive features in robots and systems.**

We address the difference between situation and context, present its current use in nowadays applications and the benefits of incorporating it in the development of interactive robots. Moreover, we propose a conceptual adaptation to common existing architectures in order to take into account with contextual information in human-robot interaction. The proposed adaptations will constitute the foundations for a generic context-based human-robot interaction framework.

I. Introduction

This paper addresses the challenge of automatic adaptation of interaction strategies that aim to improve user acceptance.

There is an emerging trend focused on auto-adaptable and self-reconfiguring ambient intelligence systems to support smarter habitats. This concept envisages environments where the needs, moods and lifestyles of its inhabitants are taken into consideration to provide better services and life conditions. This pursuits the creation of more symbiotic and user-centric environments focused on people's well-being. Smart assistants and social robots are key elements to implement these environments.

As with humans, they will need to be capable of systematically interpret and understand the semantics of data patterns acquired by the overall setups. However, two entities cannot cooperate and understand each other if they do not share the same language and the same semantics, the same "understanding of the world". Therefore, smart assistants and social robots that operate in a smart environment need to share and learn contextual information so they can consequently adapt their services to the user's needs and desires, and improve their interaction patterns.

A. Context and contextualized information

There are many definitions of context in the literature, especially in fields related with linguistics, but since a few decades the subject has attracted the interest of robotics and computer science communities. For a revision on this subject refer to [1], [2]. To give a simple introduction lets consider the following dialogs between two people:

Dialog 1: A- Yesterday I had a car accident. B- Where? A- At the supermarket parking. B- Did you damaged the car?
Dialog 2: A- Yesterday I had a car accident. B- Where? A- In the highway while coming from Lisbon to Coimbra. B- Did you or somebody else get hurt?

It is clear that when A states different contexts for the accident, B reasons about the most probable consequences for each of the contexts. From here it becomes clear that the same information (car accident) can have different interpretations or predicted results depending on the associated context.

From another point of view we can say that knowing the context has reduced the uncertainty about the accident. Therefore instead of starting an interminable questionnaire, a reduced set of pertinent questions can be used to get all needed information.

Another example: During the participation of a researcher in an abroad conference, if the researcher's neighbourhood baker shows up, there may be some difficulty in trying to recognise the baker for a few seconds, although they know each other for many years. The reason for this trouble in a person recognition is the "out of context" appearance of the baker. In fact the human brain uses context to perform associations more rapidly by reducing the search space or matching set.

B. Current context-aware applications

Nowadays although there is a increasing number of context-related applications. Search engines try to contextualize the queries to provide or sort information based on the location, time of the day, and noted preferences of the individual that did the query, and those of most people in the region. The results are very appealing as a query on sport results in Brazil will show football results of local teams, while in the USA probably will show baseball or basketball results.

There is a growing number of location aware applications, especially in GPS devices and smartphones. These applications can warn the user of the proximity of some point of interest, select advertisements, or even select applications related with the location or region the user is located in [1].

In most cases, these applications use the "user's context" (location), to just perform queries to databases, but do not modify the way they behave or process the data based on that. Also, in most of these cases the used context does not evolve by incorporating more data.

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[1] An example of location based selection of applications is the Apple App Store for mobile devices.

C. What is ”the context”?

There is a frequent confusion between context and situation. Lets try to make a difference between these two concepts by looking at two examples.

Example 1: Its 11pm and it is raining in Tokyo. I am in my house in Coimbra drinking a cup of tea and reading the newspaper.

Example 2: Its 11pm and it is raining in Tokyo. I am in my house in Coimbra tele-operating a quadcopter flying on the skies of Tokyo, that is to be landed at the top of some tall building.

The first example states about the time and weather conditions in a remote place, at the time that I am drinking a cup of tea. Although being true, both the time and weather do not affect in any way my action. On the second example the same information must be taken into account as they affect both the visibility that I can get of the remote site, and the manoeuvrability of the device due to weather conditions.

Another example: You are going to pick a box laying on the floor to the nearest table. While going to grasp the box, you are told that there are eggs inside. As a consequence of knowing that you adapt your movements in order to keep the eggs intact, but still you grab, carry and put the box on the table. In fact you adapted your actions based on the acquired context (relevant) information.

We can now state that:

> *Context is the set of information that is relevant, affects or constrains how some action is taken, without being the at center of interest of the search or action.*

D. How to represent context

The common approach to represent context information is using explicit descriptions about the environment conditions and behaviours to be executed in the presence of those conditions. Complex domains of knowledge require more general and flexible representation besides explicit representations (e.g. first-order logic). For example, abstract and general concepts - such as Event, Time, Physical Objects, and Beliefs - that occur in many different domains are not well suited for first-order logic representation [3].

This problem is being partially addressed with ontological approaches to represent context. In spite of these efforts, context models are still lacking a formalism that promotes an objective representation of information and that allow the application of generalized algorithms.

Taking into consideration current approaches, there is still an open challenge to establish a well founded formalism that can represent context information, which can adjust to its dynamic nature.

II. Relevant Interaction Contexts

One important scenario of application of social robots is the mission of promoting autonomy at home, satisfying the basic needs of the elderly and meeting their expectations. The associated strategic goals in this type of service provision are to support the elderly in daily life activities and to promote psychosocial and spiritual wellbeing by avoiding the feeling of loneliness.

Activities such as preparing meals, plating up and distributing lunch and snacks, collecting clothes for washing, drying, ironing and repair, cleaning housing floor space, are identified as key issues to be addressed in domiciliary support. These activities require physical interaction with the environment and therefore may be addressed by the services expected from social robots.

Domiciliary service care provision focuses also on the social aspects of elderly daily life. Caregivers often follow-up potentially emergent situations identified by the institution itself or by third parties, by assessing the elderly cognitive and mental states through screening and referral activities. The services provided by smart assistant in terms of non-invasive monitoring of global wellbeing conditions assume an important role in the identification and follow-up of such cases.

In these scenarios it is commonly relevant to integrate context information about a person within his/her home environment in the broadest sense possible. In the particular case of interacting with elderly people, it is important to identify activities of daily life (ADLs) in order to provide correct services that can assist the user to attain his/her intended goals. Therefore, models must be developed that are capable 1) of using a priori knowledge, either hard-coded or from experience, and 2) of evolving in time.

However, in the human-machine interaction domain there is not available yet a satisfactory framework to reason and learn based in context information in a distributed system, which involves sharing contextual information between different components of the system [4], [5].

III. Context-aware Robots and their Acceptance by Users

Existing robotic systems that have been developed recently in order to provide assistance in domestic, professional and public environments are based on closed architectures, thus being operational only in specific contexts of usage, equipment and data. Furthermore, most of current perceptual models neglect the context and the spatial relation during the perception process.

Associated to these, current systems use static and implicit representations for context preventing dynamic system adaptation through information sharing and learning.

These claims are supported in the literature, according to Oliver Brdiczka et. al in [6], [7] ”... computerized spaces and their devices require situational information, to respond correctly to human activity. In order to become context aware, computer systems must thus maintain a model describing the environment, its occupants, and their activities. ... ”.

The typical approach to provide contextual information to the application is by manually defining the context models according to their end goal and taking into account particular user needs. This approach does not traduce the ”real world” in the sense that it fails if the user needs evolution over time is taken into account. Brdiczka [6], [7] continued and considered that "... New activities and scenarios emerge in a smart environment, and others disappear. New services must be integrated into the environment, whereas obsolete services should be deleted. Thus, a fixed context model is not sufficient. ...".

Moreover, long-term maintenance, required by common approaches, have a negative economical impact to the user, i.e. having an expert periodically adjusting the system according user needs would be expensive. Thus, the research for more intelligent, self-learning and self-adaptable systems is justified facing the inefficiency of the common approaches.

Taking into consideration with the above, we identified the development of a context-based human-interaction framework as an open challenge. Furthermore, this challenge cannot be left unanswered as it address a key aspect to improve user acceptance regarding social robots and smart assistants.

IV. Context-based Human-Robot Interaction Framework

The main objective of this work is the creation of a framework that addresses the problem of incorporating contextual information in the interaction process.

A. *Existing architectures*

The existing architectures for robots usually identify four layers as illustrated in figure 1 [8].

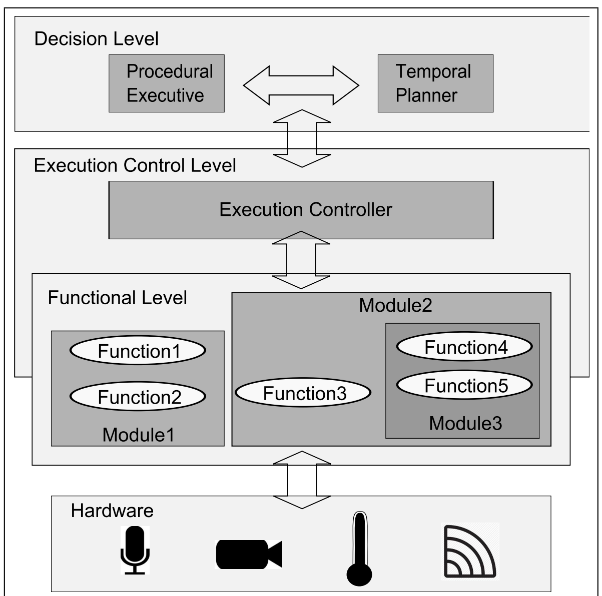

Fig. 1: Generic architecture for robots

The levels in this architecture are :

1) a *decisional level*, which includes the capacities of producing the task plan and supervising its execution, while being at the same time reactive to events from the functional level.
2) an *execution control level* that controls the proper execution of the services according to safety constraints and rules, and prevents functional modules from unforeseen interactions leading to catastrophic outcomes.
3) a *functional level* that includes all the basic built-in robot action and perception capacities. These processing functions and control loops (e.g., image processing, obstacle avoidance, motion control, etc.) are encapsulated into controllable communicating modules. Each module provides services which can be activated by the decisional level according to the current tasks.
4) a *hardware level*, which includes all the robot's sensors and actuators.

B. *Extending existing architectures*

The Context-based Human-Robot Interaction Framework (CB-HRI) is conceptually an extension of an existing architecture like presented previously. The concept is illustrated in figure 2

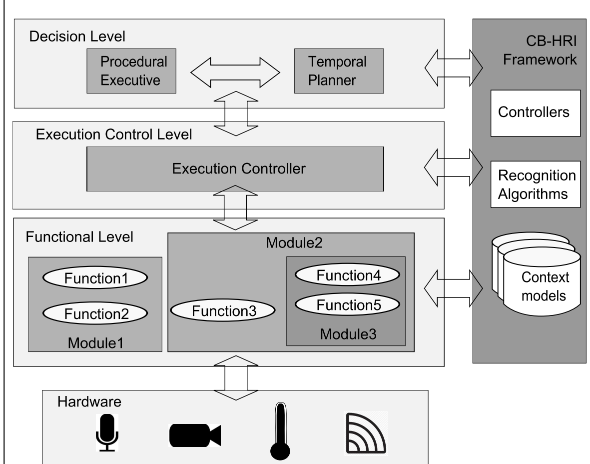

Fig. 2: Context-based Human-Robot Interaction Framework extending existing architectures

This framework acts as a middleware to integrate contextual information in the overall system and control the workflow related with human-robot interaction.

The main components of the framework are:

1) the *Controllers* module that includes the interfaces with other components in the architecture. It is responsible for the orchestration of the functionalities within the framework.
2) the *Recognition algorithms* module includes the algorithms to match perceived information with contextual information.
3) the *Context models* is a repository with a-priori context data models.

In our approach we propose contextual information as an integration mechanism between a variety of available algorithms and other resources that are known to perform well under a certain conditions.

Therefore, the CB-HRI framework must be integrated with the components dealing with perception, reasoning, data storage and actuation.

C. Context influence in the operation workflow

The proposed definition for Context considers it as the result of the transformation of raw sensor data into meaningful information, which is related to the situation, and constrain the resulting behaviour of the robot.

This process is attained through classification of sensor data taking into consideration with restrictions or rules that may apply for that situation.

In our approach we consider context recognition to be a periodic process that operates in the background of the system, while interacting with a user. This process is illustrated in figure 3. It plays the role of detecting changes in the context and triggers adaptation behaviours in the robot main execution loop (e.g. perception-action) while performing its main task.

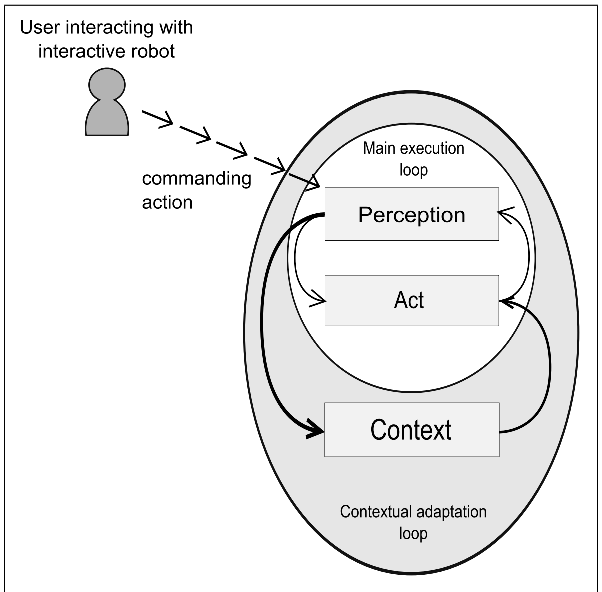

Fig. 3: Context verification process

V. Conclusion and Future Work

The paper considered the importance of addressing contextual information in the human-robot interaction process.

Moreover, we proposed a context-based human-robot interaction framework, which aims to provide a solution to the problem of integrating contextual information in the interaction processes.

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