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A semantic approach for enhancing assistive services in ubiquitous robotics

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HIGHLIGHTS

- Overview of the ubiquitous robotics and ambient intelligence.
- Hybrid model that bridges together the NKRL and the HARMS model.
- Context Aware modeling based on the upper ontologies of NKRL.
- Semantic Reasoning based Collective Intelligence in ubiquitous robotics.

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ABSTRACT

The Ambient Intelligence (AmI) technologies have the potential to create intelligent environments with new generation of assistive services, enhanced with ubiquitous robots. These environments have the ability to be anticipatory, responsive and intelligent providers of assistive services anytime and anywhere. These services can assist frail persons effectively in their daily tasks. One of the main challenging research problems in assistive robotics is to endow ubiquitous robots with ability to pro-actively taking on some tasks to help humans in performing complex activities, by participating with them just as other humans do, in normal societies or organizations.

In this paper, we propose a collective intelligence framework based on narrative reasoning and natural language processing. In the proposed approach, we propose a hybrid model that bridges together the Narrative Knowledge Representation Language (NKRL), from natural language processing field, and the HARMS (Humans, software Agents, Robots, Machines and Sensors) model, from multi-agent systems engineering field. This model is able to (i) drive the dialogues between humans, robots and smart devices, (ii) understand a complex situation, and (iii) trigger reactive actions, in the ubiquitous environment, according to given contexts.

Two scenarios dedicated to the assistance of a frail person in a smart home equipped with a companion robot and smart objects are implemented and discussed for validation purposes of the proposed framework.

1. Introduction

The Ambient Intelligence (AmI) technologies have the potential to create intelligent environments with new generation of assistive services. In the near future, the daily living environments will be populated with service robots that have powerful sensing, interaction and reasoning capabilities, thanks to the latest advances in wireless sensing, pervasive and cloud computing technologies. Service robots are called, in this context, ubiquitous robots due to their ability to be anticipatory, responsive and intelligent providers of assistive services anytime and anywhere. These services can assist frail persons effectively in their daily tasks [1–3].

The intelligence of "ubiquitous robots" is strongly related to their ability to collect data everywhere, transforming these data into useful knowledge and make sound reasoning with situations and contexts, in order to be continuously aware of humans activities. One of the main challenging research problems in assistive

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robotics is to endow ubiquitous robots with ability to proactively taking on some tasks to help human in performing complex activities, by participating with them just as other humans do, in normal societies or organizations [4]. For instance, we can envision ubiquitous robots that help frail people in keeping normal social connectedness with the external world [5,6] or monitoring their well-being and healthcare [7]. The main concern of the "ubiquitous robot" will be the supply of non-intrusive advices and reminders to encourage these people for respecting dietary instructions, reminding them to take medicines in time, in order to enhance their therapeutic observance and avoid adverse drug events.

The level of intelligence of ubiquitous robots can be measured somewhat by the quality of their cooperation with the other smart objects, on the one hand, and their ability to foresee collective approaches in order to be more participatory in the execution of human complex activities, on the other hand.

To allow for that, we need suitable engineering framework to enable robots – and smart objects – with number of cognitive and physical capabilities closer to humans, but also complementary in scope of the capabilities commonly lacking in humans. Complementary capabilities concern the provision of an extension to humans, with functions that human cannot provide for themselves, similar to that of common tools. In this case, the robotic tools are autonomous and human-like, in form.

In this paper, we deal with the design of assistive services by cooperating together humans, robots and smart objects. Our proposal is an extension of seminal work presented in [8], which concerns collective intelligence framework based on cognitive reasoning and natural language processing.

In this work, we demonstrate how the proposed reasoning components will enhance the cognitive capabilities of ubiquitous robots in order to recognize situations and better cooperate with humans to solve daily living. The proposed approach consists of bridging together the Narrative Knowledge Representation Language (NKRL) [9], from natural language processing field, and the HARMS model [10], from multi-agent systems engineering field. The benefits of integrating NKRL within HARMS' layers are twofold: (i) better support for understanding the semantics of users' situations/activities and their context in HARMS and (ii) better management of the interactions between robots, humans and smart objects. In fact, NKRL provides interesting knowledge management tools based on *n*-ary ontologies and spatio-temporal reasoning, which were applied for driving human–robots situated dialogues in natural language [11,7]. In addition, NKRL allows on the one hand the inference of implicit relationships between events and their corresponding contexts. On the other hand, it offers a mean for defining inference rules to trigger reactive actions in given contexts.

This paper is structured as follows: Section 2 presents a scenario that motivates our research while Section 3 presents a review of related works concerning context-aware modeling in the robotics field. Section 4 details the different modules of the architecture of the semantic human–robot interaction system that consist of a new reasoning component for collective intelligence and context awareness according to the reference model HARMS. Section 5 details the implementation and the evaluation of experimentations that have been conducted with regard to the proposed scenario. This paper concludes with a short conclusion and an overview of the ongoing works.

2. Intelligent assistive services for frail people

Designing intelligent assistive services becomes particularly urgent for frail people living alone and suffering from minor disabilities that impact their ability of doing correctly daily living tasks such as taking care of their home, buying food from grocery, walking in street, etc. In the worst cases, minor disabilities correspond to mild cognitive decline that implies severe issues such as complete or partial loss of all sense of time, disorientation in familiar places such as home or when visiting regular places outdoor.

In fact, sometimes, when frail people leave their home to go to a regular place (their children home, neighbors, coffee shop, etc.), it becomes difficult or impossible for them to find the way to return home. Hence, they arrive at the home disappointed, sad and anxious. Sometimes they do not even find their way to home. They get lost in the streets, wondering "Where am I?, What am I doing here?, Where do I live?" and should ask for help. Moreover, they do not know what day it is, what date and what season it is, etc. They may request repeatedly the time from people in their surroundings ten times a day, but they do not know why and what to do.

According to clinicians, the loss of spatio-temporal orientation leads to a loss of autonomy is a high risky disorder, which usually implies worry and psychological fatigue among family members. In this case, the logical clinical decision consists of: (i) preventing these people to stay alone as they usually do and (ii) suggest them some rehabilitation tasks allowing a partial recovery of their memory capabilities by using landmark for space and time points. The main issue in this case is how guaranteeing that the patient detects and understands all these landmarks.

In this paper, we deal with Steve, a frail person, living alone in a smart home equipped with a companion robot, called Kompai, and smart objects that cooperate together to assist Steve in different scenarios.

We consider two main scenarios. The first one concerns an assistive service that supplies to Steve contextual information in order to increase his awareness of time and space when he is feeling lost. In the second scenario, a smart refrigerator and the companion robot cooperate together to help in keeping the refrigerator and food cupboards full with necessary food. When a food is missing, these objects will appear in the list of Steve, who is able of buying that.

These scenarios present different complexities in how the proposed system can recognize a situation and make reasoning, based on standard approach, in order to enable a form of collective intelligence and natural interaction among actors to solve different issues.

3. Context awareness

Context awareness is an important feature not only in the ambient intelligence (AmI) field, but also in robotics [12]. Context is a centric concept that characterizes the context of an individual or a group of individuals. Making applications aware of the human's context means that these applications are capable of detecting events and changes in human environment, his/her situations, activities and interactions with other entities, which are commonly captured by means of sensors. We denote two categories of sensors: wearable sensors and environmental sensors. Wearable sensors can be embedded in wearable single device such as wristband or can be deployed on the body to form body area sensor network. These sensors are useful, for instance, for the monitoring of vital signals through physiological sensors or for the detection of an individual's motion through inertial sensors. Environmental sensors are – called also wireless environmental sensor networks – usually composed of basic motes, that can measure for instance the ambient temperature, light and air quality or to detect events such as motions or sounds. Video sensors such as cameras are considered as complex environmental sensing systems that can be used for capturing and tracking objects locations, recognizing motion patterns.