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Ontology enhancing process for a situated and curiosity-driven robot

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HIGHLIGHTS

- A new framework for human–robot interaction is proposed.
- A meaningful representation of the world model by using ontologies is implemented.
- We propose a framework that solves the grounding problem in the area of human–robot collaboration.

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ABSTRACT

Nowadays, robots need to be able to interact with humans and objects in a flexible way and should be able to share the same knowledge (physical and social) of the human counterpart. Therefore, there is a need for a framework for expressing and sharing knowledge in a meaningful way by building the world model. In this paper, we propose a new framework for human–robot interaction using ontologies as powerful way of representing information which promote the sharing of meaningful knowledge between different objects. Furthermore, ontologies are powerful notions able to conceptualise the world in which the object such as Robot is situated. In this research, ontology is considered as improved solution to the grounding problem and enables interoperability between human and robot. The proposed system has been evaluated on a large number of test cases; results were very promising and support the implementation of the solution.

1. Introduction

The problem of managing meaningfully the relation between representation of the concept and the concept itself is defined as *grounding problem* [1,2]. According to Ziemke, the problem of embedding a robot in the environment in such a way that its behaviours/representations are intrinsic/meaningful to itself, rather than dependent on the external designer is also known as grounding problem [3]. Anchoring has been defined as a form of grounding problem where only active agents (such as humans, robots) are considered. Harnad et al. in [4] proposed that the solution to the grounding problem can be achieved through "iconisation and classification". Grounding problem has been studied from years and researchers around the world have proposed different solutions for the same. However, each existing solution has its weakness especially when the interoperability of the knowledge/information is required between different objects (such as human, robot, or agent) and still a lot of work needs to be done in this area.

In Computer Science, Ontology is a description or formal representation of a particular domain, containing concepts and their relationships [5–7]. The collection of concepts within the ontology is structured to facilitate the interoperability of the knowledge between different objects (such as human and robot). The ontology structure can be thought of as a graph where nodes are concepts and links among nodes are relationships [8,9]. Furthermore, the ontology structure is based on properties about particular objects which result in improving the interoperability in human–robot collaboration scenario [10–12]. This also allows the concept to be clearly organised and expressed in a meaningful format. In our opinion, ontologies are powerful notions able to conceptualise the world in which the agents, such as robots, are situated. We also claim that ontologies are powerful way of representing information which eases the sharing of meaningful knowledge between different objects and enable interoperability between them [13,14].

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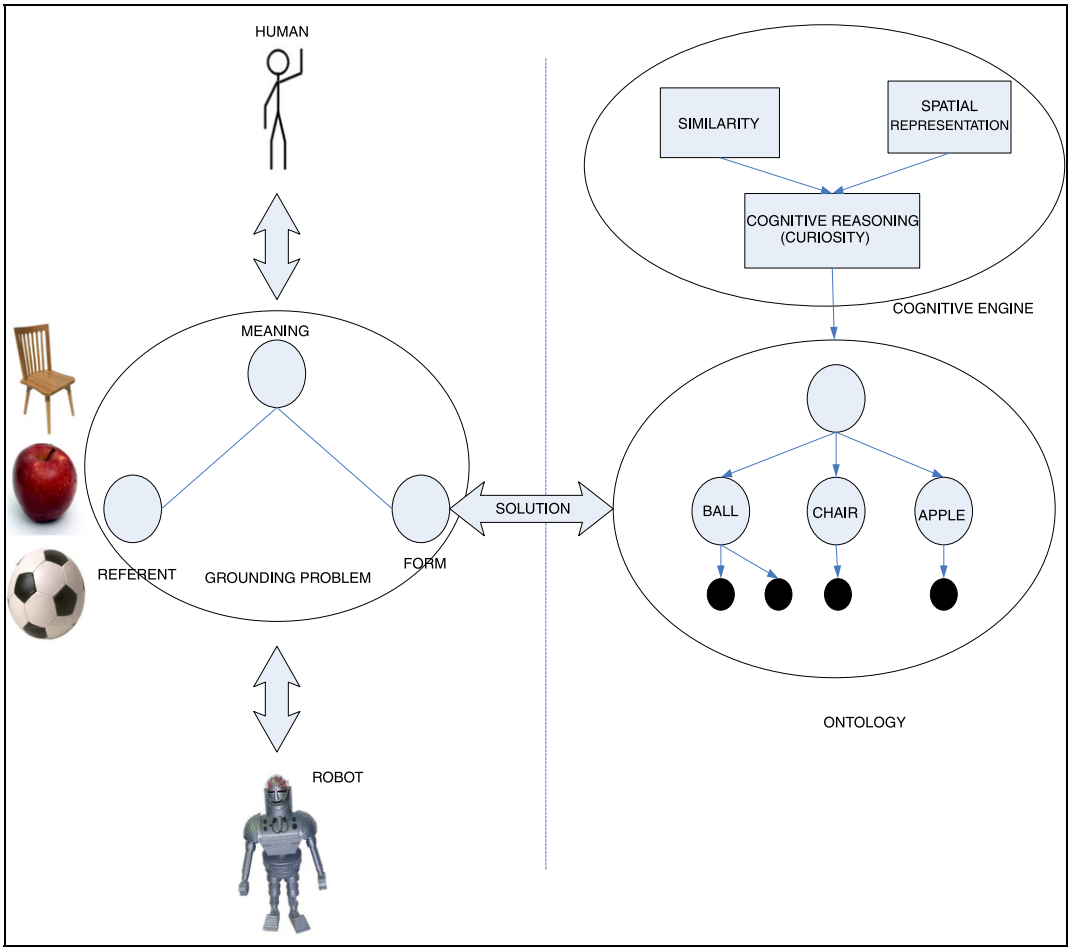

Fig. 1. The framework is the conceptual solution for grounding problem.

The aim of this research is to propose a meaningful representation of the world model by using ontologies and implementing reasoning system that can explore the information inherent within an ontology-based representation. In this paper, we have explored (1) the use of ontology concepts for the object recognition and (2) how it can be enriched using different typology of inputs. We propose a framework that solves grounding problem in the area of human–robot collaboration where robot has to collaborate with a human partner in the same environment and share knowledge/information about the objects/elements present in the environment.

Self-learning and Social learning can play an important role in enhancing/updating the ontology. Self-learning is the ability of the robot to enrich the ontology with new objects and also extract its properties directly from the world whereas social learning is the ability to enhance the ontology with social information shared by human. Sharing of social knowledge is the medium for proficuous human–robot interaction. We have created wide series of cognitive skills in robot which together built a framework for ontology enhancing process.

One of the important skills required for human–robot collaboration is spatial and perspective reasoning that humans only acquire late in the childhood development. These skill models, ported on the robot, enable the robot to reason about perspective and space. According to Trafton et al. in [15] during a collaboration talking between humans, people frequently change frame of reference or take another person's perspective. One of the solutions to deal with this typical aspect of human talking is the use of spatial representation. Having a spatial representation, as discussed by Kennedy et al. in [16], helps to reason about partners' position, their goals and the meaning of their commands.

Similar to human being, the robot should have the ability to extract information from the environment using its camera and detects objects in the environment using the input feed. This requires image processing capability to be incorporated in the acquisition unit of the robot. Finally, another important cognitive skill required is concerning the extraction of the level of similarity between two objects. This refers directly to the human ability of comparing two objects and extracts the physical similarities between them. The robot has to learn about the physical element present in the environment using *self-learning*. This has been called *curiosity* and it has been computationally translated into a numeric value based on the classification in [17]. In addition, the robot has to learn from the human using the social learning.

All of the skills discussed above become the fundamental components of the necessary framework used to implement the ontology enhancing process. The skills discussed are embedded in our proposed framework and are discussed in detail in Section 2. The ontology enhancing process with all its components and the communication system developed for the human to teach the robot is discussed in Section 3 whereas the tests and the relative results are listed in Section 4. In conclusion, the evaluation of the results, the final discussion and further work have been written in Section 5.

2. Proposed framework

We propose a framework that solves grounding problem in the area of human–robot collaboration (Fig. 1). The robotic application is composed of the cognitive engine and the ontology. The