



Awareness in Robotics: An Early Perspective from the Viewpoint of the EIC Pathfinder Challenge “Awareness Inside”

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Abstract. While consciousness has been historically a heavily debated topic, awareness had less success in raising the interest of scholars. However, more and more researchers are getting interested in answering questions concerning what awareness is and how it can be artificially generated. The landscape is rapidly evolving, with multiple voices and interpretations of the concept being conceived and techniques being developed. The goal of this paper is to summarize and discuss the ones among these voices connected with projects funded by the EIC Pathfinder Challenge “Awareness Inside” call within Horizon Europe, designed specifically for fostering research on natural and synthetic awareness. In this perspective, we dedicate special attention to challenges and promises of applying synthetic awareness in robotics, as the development of mature techniques in this new field is expected to have a special impact on generating more capable and trustworthy embodied systems.

Keywords: Awareness · Robotics · Autonomous Systems · Living Machines · Artificial Consciousness

1 Introduction

According to the Cambridge English Dictionary [1], awareness is the “*knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience*”. It may seem that, according to this broad definition, awareness is already widespread in robotics. Think, for example, of a drone creating an internal representation of its environment using a SLAM algorithm [10], a manipulator detecting an interaction with its environment through an observer [15], or a social robot acquiring knowledge on the logical structure of its environment [3] or its body [9]. If we accept this broad definition, it is evident that a common framework that enables the discussion

This is a shortened version of the full-length manuscript [12].

of levels of awareness across domains is missing. Even more, the concept may be loaded with more complex significance than this interpretation suggests. For example, *awareness* is sometimes semantically associated with the term *consciousness*, which is a much more debated concept. Researchers have proposed several definitions of the latter, including philosophical [14], psychological [8], architectural [5], neural correlates [4], and computer science theory [2].

As Artificial Intelligence (AI) progresses in reproducing a growing number of human capabilities [7, 11, 13], it is thus natural to ask if and how synthetic awareness can be produced and embodied into physical agents. Ultimately, questions that need answering include: What is awareness exactly? Can this concept be formalized philosophically or technically? What distinguishes an aware agent from a non-aware one? Does awareness improve the performance of robots? Is it even ethical to endow artificial agents with awareness?

In this vein, in June 2021, the European Innovation Council (EIC) opened a Pathfinder Challenge call for proposals with the explicit aim of pushing the boundaries of AI [6]. The call challenged the scientific community to define and achieve true awareness and understand awareness beyond the perception of surroundings or self-awareness. The call also pointed towards the role that awareness could play in both clinical settings and technology, also given the importance that trustworthy AI has in this field for the EU roadmap. The call suggested that robots or decision support systems that appear ‘aware’ could play a role in gaining human trust.

Eight projects were selected among the applicants, covering a large portion of the European research landscape. This paper aims to introduce this multi-faceted view to awareness research and provide some preliminary discussion on how these activities will impact the robotics field in the future. In the rest of the manuscript, we will review how each project looks at the challenge. In doing that, we observe that the views on awareness vary from project to project. At the same time, we show that—although not all of them are intended to generate direct applications for robotics—they all have the potential to generate disruptive innovation in this field.

2 A Bird View on the Projects’ Goals¹

SYMBIOTIK introduces a user-centric approach to information visualization, leveraging awareness and emotion-sensing to enhance human-machine cooperation for improved decision-making. The project aims to augment cognitive functions and create more natural, user-friendly interfaces.

ASTOUND is developing an AI architecture for artificial consciousness based on the Attention Schema Theory. The goal is to enhance natural language understanding in virtual agents by creating a model miming human awareness of attention states - with an expected impact in collaborative robots (cobots).

SymAware develops a conceptual framework for situational awareness in multi-agent systems, focusing on formal modeling and logical specifications, social

¹ More thorough descriptions are available in the full-length manuscript [12].

learning, risk quantification, and task negotiation. SymAware aims to improve coordination and functionality in dynamic environments, targeting autonomous vehicles and traffic management for unmanned aircraft systems.

CAVAA explores the concept that awareness enhances survival by enabling entities to interact with the unseen aspects of their environment, proposing a model where awareness is defined as a detailed experience of a consciously perceived virtual world. CAVAA aims to replicate this model of awareness in robots and artificial agents.

EMERGE seeks to establish collaborative awareness among minimal artificial agents, focusing on how simple agents can collectively develop an awareness of their existence, environment, and cooperation for shared goals. The project will enable collaboration and self-regulation in cyber-physical systems - especially focusing on modular soft robots, robotic swarms, and cobots.

METATOOL combines archaeology, neuroscience, and robotics to explore how robots can mimic ancient human cognitive advancements in tool invention. The project seeks to equip robots with an advanced understanding and creation of tools through self-awareness and operationalizable abstraction.

SUST(AI)N aims to enhance smart buildings with distributed, precision-sensing AI for energy autonomy and intelligent system integration. This approach will leverage probabilistic reasoning, optimizing the interaction between sensors, data, and node configurations - with potential applications in swarm robotics, multi-agent systems, and energy-efficient autonomous robots.

VALAWAI focuses on developing AI tools that adhere to human values, aiming to create value-aware AI applications capable of making or recommending explainable decisions based on ethical guidelines. This effort is crucial for ensuring the ethical deployment of AI, with applications ranging from medical protocols to social robots.

3 Discussion and Conclusions

This paper summarized ongoing and diverse activities around synthetic awareness, driven by the EIC Pathfinder Challenge “Awareness Inside” call funded by the European Union through the Horizon Europe program. This diversity enriches our understanding and poses significant challenges in defining and achieving a unifying concept of awareness applicable across different robotic applications. For example, the very definition of awareness varies strongly from project to project, with its position towards consciousness ranging from direct opposition (EMERGE) to almost a synonym of hard consciousness (ASTOUND). While in the context of SymAware, awareness is emphasized as the ability of agents in a multi-agent setting to recognize and comprehend external stimuli, especially in scenarios involving the presence of human beings, METATOOL awareness focuses on the neuroscience-derived idea of uncertainty monitoring. In both projects, awareness involves perceiving, adapting, coordinating, communicating, and making informed decisions while ensuring safety and resilience in a dynamic environment.

Of the eight projects, five are specifically focused on robotics-related experiments. Namely, METATOOL investigates robots capable of self-evaluation and tool invention; SymAware holds relevance for various applications, encompassing both industrial and domestic robotic systems, with a specific emphasis on autonomous vehicles and air-traffic control systems; CAVAA utilizes social robots like MiRo-e for its tests; EMERGE explores various robotic applications; and VALAWAI showcases its ideas through domestic social robots. Interestingly, the authors of this paper who are involved in the remaining three projects also believe in applying their innovation to robotics. More specifically, the SYMBIOTIK and ASTOUND innovation could transform social robotics. The SYMBIOTIK project could enhance human-robot interactions by integrating awareness and emotion-sensing capabilities into robotics, making these interactions more natural and user-friendly. Developing artificial consciousness based on the Attention Schema Theory, the ASTOUND project will enhance the performance of natural language understanding and provide collaborative robots with the capability to effectively and safely interact with human partners by predicting their intentions and objectives. Finally, in line with the goals of EMERGE, the SUST(AI)N project could advance collaborative and swarm robotics, as well as multi-agent systems, by developing a distributed form of self-aware intelligence, enhancing system performance, reliability, and adaptation through a hierarchical learning model and energy-efficient, self-sufficient technologies.

Ultimately, all the authors of this paper believe that incorporating awareness components in technology could make systems more resilient, adaptable, and human-centric. We believe that understanding awareness will allow AI systems to better grasp and respond to various situations. Synthetic awareness will advance AI towards more coherent, adaptive, and self-evolving behavior.

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