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Awareness in Robots

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Abstract. This study explores the concept of awareness in robots. Human awareness, rooted in psychological and cognitive sciences, encompasses conscious perception of self and the environment. In contrast, robotic awareness is engineered, focusing on programmed perception, autonomy, and interaction with humans and the environment. This research highlights the converging functionalities of cognitive capabilities in robots.

Keywords: awareness · human cognition · metacognition · robotics

1 Introduction

The concept of awareness transcends the simple act of knowing, encompassing a spectrum that ranges from basic sensory perception to complex cognitive functions. This broad notion of awareness serves as a point of convergence for disciplines such as psychology, neurobiology, cognitive neuroscience, and robotics. Each field contributes unique perspectives and understandings, yet they are united in their exploration of awareness as a fundamental aspect of both living beings and artificial systems. It is important to recognize that awareness extends beyond the individual level. It also entails awareness of the environment.

In the literature, the term 'awareness' is broadly employed, encapsulating aspects such as consciousness, intelligence, cognition, and metacognition across both human and nonhuman agents. This general application allows its usage in diverse research contexts, though it sometimes leads to ambiguity. Clinically, the concept of awareness, relates to responsiveness. It might denote the state of consciousness where a person is able or unable to recall an episode [1]. In metacognitive studies, awareness is often linked to the capacity for monitoring and control. Some researchers do not call it metacognition but executive function [2,12] as it is largely modulated by working memory [13]. In the fields of neurobiology and cognitive neuroscience, awareness signifies the embodied and brain-based human consciousness [11]. In robotics, awareness is defined as the capability of a non-biological system to perceive its environment or itself and

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respond based on this input, akin to human or animal awareness. This gives rise to the notion of 'synthetic awareness', a term used to describe robots' ability to predict the outcomes of their actions, mirroring the human brain's capacity to anticipate behavioral consequences. 'Synthetic awareness' in robotics aligns with the notion of human metacognition but remains distinctly non-anthropomorphic.

Given these perspectives, any extensive examination of awareness should start with an understanding that, in biological systems, neuronal activity underpins states of awareness. This introductory exploration aims to identify the layers of awareness, dissecting its various forms and functions. By doing so, it seeks to provide a understanding of how awareness operates within robotics.

2 Literature Review

2.1 Awareness in Robots

Embodied robots, unlike human or animal agents, are non-biological cognitive systems with artificial origins. As such, traditional paradigms from human and animal cognitive research may not be entirely applicable when investigating a technical system engineered to cognize [3]. The term 'cognize' from the Oxford dictionary encompasses 'to perceive, know, or become aware of' [4]. Notably, the entry integrates the three dimensions of cognition: perception, knowledge acquisition, and awareness. The definitions of cognition differ slightly between broad reference sources, but none distinguish between 'natural' and 'synthetic' versions. In humans, cognition is inherent; in robots, it is designed and regulated, including the possibility for (synthetic) awareness.

In the fields of cognition, artificial intelligence, and related areas, there are two primary perspectives. One maintains that awareness and consciousness are distinct, while the other views them as the same phenomenon [5,6]. The debate is complicated as some researchers define one concept through the other, leading to circularity. Roboticists frequently do not explicitly include either construct in their models [9]. Nonetheless, several cognitive processes targeted and successfully recreated in robots bear functional similarities to the fundamental qualities of conscious cognition or awareness exhibited in organic cognitive systems. Robots now exhibit cognitive capacities that allow them to navigate uncertainties, which can be recognized as enablers of synthetic awareness. Such capabilities encompass the environment and self-awareness.

Environment Awareness in Robots. Environment awareness in robots is an expanding field that draws from the study of human perceptual awareness, particularly vision and attention. This area of research has progressed from static saliency maps to dynamic, context-aware models that mimic the evolutionary processes of cognitive abilities. Notable advancements in robotic simulations have been influenced by human brain mechanisms, as evidenced by the evolution from basic attention models to sophisticated Bayesian models that guide the exploratory behaviors of modern unmanned aerial vehicles (UAVs) [14]. Essentially, environment awareness refers to the ability of robots to react to their environments. Robots have the cognitive ability to perceive data and recognize its importance and causal relationships. It allows them to not only perceive the presence of objects and entities in their visual area, but also perceive the relationships that exist among these elements. This form of awareness serves as a substitute for the robot's grasp on the world.

Social Awareness in Robots. The exploration of social awareness in robots, a branch of human-robot interaction and human-autonomy teams, delves into cognitive architectures that enable robots to interact socially. These architectures draw from human and animal social behaviors, facilitating a robot's ability to navigate social contexts, collaborate, and ensure personal assistance and safety [19,22]. Central to these frameworks is the robot's capacity for social cue recognition and response adaptation, underpinned by sensor technology and contextual behavior modification [18]. Robot social engagement relies on situational and feedback awareness, guided by shared mental models and forward models [20,21].

Self-awareness in Robots. The main reason for adding self-awareness in robots is that self-aware systems can handle novel situations with significantly higher flexibility and efficiency than non-self-aware counterparts [7,8]. Self-awareness in robots refers to a robot's ability to identify its own condition while also situating itself within an environment and delimiting itself from it. In cognitive robotics and autonomous systems research, self-awareness states are often postulated and implemented as internal models. These models' lower-level organization may vary; for example, they could be knowledge-based [15]. However, they all have a conceptual congruence. This congruence is manifested through robot skills such as self-assessment, self-monitoring, self-regulation, self-localization, self-adaptation, self-preservation, and others that fall under the category of self-derivation. Some publications contend that the literature contains a "lack of the concept of self" [10, p. 9]. However, self-concept is one of the most intensively explored subjects in psychology and philosophy, with a broadly accepted understanding of its meaning [16]. In some ways, self-concept and self-awareness are synonymous: both refer to identifying oneself as a distinct agent independent from (1) the environment and (2) others. The latter is intimately tied to the ability of humans and animals to recognize their own physical selves, as demonstrated by the mirror test paradigm [16], but it is also applicable to robotic agents that pass the mirror test [17].

3 Conclusions

Our pursuit to understand awareness in robots shows that cognitive capabilities, though fundamentally different in origin, indicates converging functionalities.

This research has underscored that robotic awareness is engineered, aiming to replicate the functional aspects of human conscious cognition and adaptability. In humans, awareness is deeply rooted in conscious processing of self and the environment. Awareness in robots is an engineered construct, rooted in modulated perception, autonomy, and interaction with humans and the environment. Robots, equipped with 'synthetic awareness' are able to predict outcomes of actions and improve their performance, somewhat akin to human metacognition. This synthetic awareness relies on computational, not biological, processes.

Moreover, both humans and robots possess the ability to process sensory information from their surroundings, though the underlying mechanisms differ significantly. Humans rely on a biologically evolved cognition, enabling them to perceive, interpret, and adapt to environmental changes intuitively. This involves complex processes like visual recognition, spatial awareness, and cognitive flexibility, essential for survival and decision-making. Robots' awareness is based on data perception, recognition of objects and entities, and understanding relationships within their environment. However, unlike humans, robots still lack the innate, adaptive responses and cognitive flexibility that come from biological evolution.

Additionally, self-awareness in robots is primarily a programmed state, focusing on self-assessment, monitoring, and adaptation within an environment. Unlike humans, robot self-concept does not necessarily include agency. As a result, the awareness in robots is limited by the level of complexity of their sensory and processing systems.

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