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RESEARCH ARTICLE

Evolving synthetic pain into an adaptive self-awareness framework for robots

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Abstract
In human–robot interaction, physical contact is the most common medium to be used, and the more physical interaction occurs, at certain times, the higher possibilities of causing humans to experience pain. Humans, at times, send this message out through social cues, such as verbal and facial expressions in which requires robots to have the skill to capture and translate these cues into useful information. The task of understanding human pain concept and its implementation on robots plays a dominant factor in allowing robots to acquire this social skill. However, it is reported that the concept of human pain is strongly related to the concept of human self-awareness concept and cognitive aspects with complex nerve mechanisms, hence, it is crucial to evolving appropriate self-awareness and pain concepts for robots. This paper focuses on imitating the concept of pain into a synthetic pain model, utilised in justifying the integration and implementation an adaptive self-awareness into a real robot design framework, named ASAF. The framework develops an appropriate robot cognitive system-"self-consciousness" that includes two primary levels of self-concept, namely subjective and objective. Novel experiments designated to measure whether a robot is capable of generating appropriate synthetic pain; whether the framework's reasoning skills support an accurate synthetic pain acknowledgement, and at the same time, develop appropriate counter responses. We find that the proposed framework enhances the awareness of robot's body parts and prevent further catastrophic impact on robot hardware and possible harm to human peers.

Introduction

As the number of robots application in various areas of human life grows, it is inevitable to see more collaboration

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tasks take place. During the interaction, humans and robots commonly utilise physical medium to engage, and at a certain situation, this may cause humans to experience pain. At times, humans deliver this pain message through social cues in which requires robots to have the ability to capture and translate these cues into useful information. It is primarily important to have an adequate understanding of human pain concept before addressing the issue on how this concept can be integrated into robot framework.

Studies suggest that human pain is strongly related to the concept of self and it is reported that the degree of one's self-awareness is related to the ability to feel the pain Hsu, Schubiner, Stracks, and Clauw (2010), and the kinds of counter responses humans might generate Steen and Haugli (2001). Investigating pain as a means to develop robot self-awareness raises important questions of how robots can conceptualise, detect and respond to the severity of the pain levels. This pain investigation requires an appropriate model of the pain to be developed so as robots can have an understanding of pain concept. An important question raises about how this concept of pain can be generated as compared to humans; pain is strongly related to human self-awareness concept and cognitive aspects of complex nerve mechanisms. Hence, having an appropriate concept of self-awareness are important as Gorbenko, Popov, and Sheka (2012) mentions that robots with self-awareness have the ability to behave more effectively in novel situations compared to those without it. On top of that, evolving pain concept dedicated for robots becomes priority by which can be used by robots to understand and further to interpret human pain captured through social cues.

This paper addresses the challenge of developing self-aware robots by conceptualising pain and implementing it in a synthetic pain model within a new robot self-awareness framework that provides a novel approach towards the detection of and response to synthetic pain for a robot. Our approach implements the concept of the self divided into subjective and objective self-awareness Lewis (1991). It is important to point out that the terminology of "consciousness" for our robot is to signify the robot's focus of attention, and it should not be understood as to mean human consciousness. By changing the nature of robot consciousness, from objective to subjective or vice versa, a robot has the ability to categorise and recognise internal events. Such a robot would be able to develop an appropriate behaviour in response to the synthetic pain that it is experiencing, e.g., alerting a person for help or changing its behaviour as a preventive action.

Integrating the pain concept into the robot's self-awareness framework enables the robot to perform assigned tasks whilst at the same time, being conscious/aware of its internal state of well-being. This is particularly important in human–robot interaction tasks because if a robot is damaged then that may put people at risk of injury. The remainder of the paper proceeds as follows: related works and highlights of the state-of-the-art in self-awareness and pain studies are presented followed by the overview of proposed robot self-awareness framework. Experiment stages including environmental set up are briefly described followed by the results, evaluation and discussions. Finally, the overall achievement and possible future developments conclude the paper.

Related studies

Self-aware robots and self concept

Studies on the notion of robots being self-aware which are first reported in Michel, Gold, and Scassellati (2004) and Scassellati (2002) do not include how to develop the concept of self. The study reported in Michel et al. (2004) presents the NICO robot that possesses the capability of recognising itself in the mirror. Since then, studies of self-aware robots have continued to grow as reported in Birlo and Tapus (2011) and Bongard, Zykov, and Lipson (2006). In other areas, health services, for instance, the implementation of self-awareness has been highlighted in Agha-Mohammad, Ure, How, and Vian (2014) where systems need to diagnose their state health. The key element of the study captures the uncertainties needed to develop the appropriate control and planning scheme as described in the earlier paper by Marier, Rabbath, and Lechevin (2013).

Much of the literature also identifies the lack of the concept of "self". This paper uses the definition of self-awareness in Lewis (1991) which divided the concept of self into two levels, subjective awareness and objective awareness. Subjective self-awareness concerns the machinery of body and objective self-awareness concerns focusing the attention capability towards one's self, thought, actions and feelings. The author shows that human adults have the ability to function at both levels. Under certain conditions, human adults utilise one level of self-awareness at a time. However, it can be inferred that these two primary levels of self-awareness coexist and that human adults utilise them by switching between them. We utilises this insight, particularly the ability to switch between subjective and objective awareness, and through this action, a new framework can be used to change the robot awareness from subjective to objective, and vice versa. In this framework, we refer to the subjective element as the physical parts of a robot, such as robot motors and joints; and the objective elements as the metaphysical aspects of the robot, such as robot's representation of its position towards an external object.

Human pain concept and self-awareness

Few studies have correlated pain with the self-awareness concept in humans. The earliest reported study conducted by Steen and Haugli (2001) investigates the correlation between musculoskeletal pain and the increase of self-awareness in humans. The study suggests that having an awareness of the internal relationship between body, mind and emotions enable a person to address and understand messages communicated by the pain. Another study carried out by Hsu et al. (2010) proposes that the development of affective self-awareness is associated with the pain's severity level based on reports of people who suffer from fibromyalgia.[1] The study by Steen and Haugli (2001) is based on the assumption that humans attention is directed from

[1] A widespread pain and tenderness in the human body and sometimes accompanied by fatigue, cognitive disturbance and emotional distress Channel (2014).

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