Evolving Robot Empathy through the Generation of Artificial Pain in an Adaptive Self-Awareness Framework for Human-Robot Collaborative Tasks

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Bismillahirrahmanirrahim

All Praise and Gratitude to the Almighty God, **Allah SWT**, for His Mercy and Guidance which have given me strength and tremendous support to maintain my motivation from the very beginning of my life journey and into the far future.

I would like to dedicate this thesis to my love ones, my wife and my son,

Nor Faizah & Abdurrahman Khalid Hafidz

for always being beside me which has been a great and undeniable support throughout my study…

CERTIFICATE OF ORIGINAL AUTHORSHIP

This thesis is the result of a research candidature conducted jointly with another University as part of a collaborative Doctoral degree. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student:

Date: 13 March 2017

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Abstract

The application and use of robots in various areas of human life have been growing since the advent of robotics, and as a result, an increasing number of collaboration tasks are taking place. During a collaboration, humans and robots typically interact through a physical medium and it is likely that as more interactions occur, the possibility for humans to experience pain will increase. It is therefore of primary importance that robots should be capable of understanding the human concept of pain and to react to that understanding. However, studies reveal that the concept of human pain is strongly related to the complex structure of the human nervous system and the concept of *Mind* which includes concepts of *Self-Awareness* and *Consciousness*. Thus, developing an appropriate concept of pain for robots must incorporate the concepts of *Self-Awareness* and *Consciousness*.

Our approach is firstly to acquire an appropriate concept of self-awareness as the basis for a robot framework. Secondly, it is to develop an internal capability for a framework for the the internal state of the mechanism by inferring information captured through internal and external perceptions. Thirdly, to conceptualise an artificially created pain classification in the form of synthetic pain which mimics the human concept of pain. Fourthly, to demonstrate the implementation of synthetic pain activation on top of the robot framework, using a reasoning approach in relation to past, current and future predicted conditions. Lastly, our aim is to develop and demonstrate an empathy function as a counter action to the kinds of synthetic pain being generated.

The framework allows robots to develop "self-consciousness" by focusing attention on two primary levels of self, namely subjective and objective. Once implemented, we report the results and provide insights from novel experiments designed to measure whether a robot is capable of shifting its "self-consciousness" using information obtained from exteroceptive and proprioceptive sensory perceptions. We consider whether the framework can support reasoning skills that allow the robot to predict and generate an accurate "pain" acknowledgement, and at the same time, develop appropriate counter responses.

Our experiments are designed to evaluate synthetic pain classification, and the results show that the robot is aware of its internal state through the ability to predict its joint motion and produce appropriate artificial pain generation. The robot is also capable of

alerting humans when a task will generate artificial pain, and if this fails, the robot can take considerable preventive actions through joint stiffness adjustment. In addition, an experiment scenario also includes the projection of another robot as an object of observation into an observer robot. The main condition to be met for this scenario is that the two robots must share a similar shoulder structure. The results suggest that the observer robot is capable of reacting to any detected synthetic pain occurring in the other robot, which is captured through visual perception. We find that integrating this awareness conceptualisation into a robot architecture will enhance the robot's performance, and at the same time, develop a self-awareness capability which is highly advantageous in human-robot interaction.

Building on this implementation and proof-of-concept work, future research will extend the pain acknowledgement and responses by integrating sensor data across more than one sensor using more sophisticated sensory mechanisms. In addition, the reasoning will be developed further by utilising and comparing the performance with different learning approaches and different collaboration tasks. The evaluation concept also needs to be extended to incorporate human-centred experiments. A major possible application of the proposal to be put forward in this thesis is in the area of assistive care robots, particularly robots which are used for the purpose of shoulder therapy.

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