Faculty of Engineering and Information Technology

A Methodology for Operationalising the Robot Centric HRI Paradigm:

Enabling Robots to Leverage Sociocontextual Cues During Human-Robot Interaction

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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 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.

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List of Acronyms

Acronym	
ANOVA	Analysis of Variance
C	Compliant
CAS	Centre for Autonomous Systems
D	Dimension
DOF	Degree-of-freedom
FEIT	Faculty of Engineering and Information Technology
FPYE	Face Plane Yaw Estimation
GP	Gaussian process
GUI	Graphical User Interface
H	Hypothesis
HHI	Human-Human Interaction
HL	Human-Likeness
HRI	Human-Robot Interaction
HSS	Head-to-Shoulder Signature
HYE	Head Yaw Estimation
JA	Joint Attention
L	Looking
!L	Not Looking
NC	Non-Compliant
PCA	Principal Component Analysis
RGB	Red Green Blue
RGB-D	Red Green Blue Depth
ROS	Robot Operating System
RMS	Root Mean Squared
RQ	Research Question
UTS	University of Technology, Sydney

Abstract

A Methodology for Operationalising the Robot Centric HRI Paradigm:

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The presence of social robots in society is increasing rapidly as their reach expands into more roles which are useful in our everyday lives. Many of these new roles require them to embody capabilities which were typically not accounted for in traditional Human-Robot Interaction (HRI) paradigms, for example increased agency and the ability to lead interactions and resolve ambiguity in situations of naïvety. The ability of such robots to leverage sociocontextual cues (i.e. non-verbal cues dependent on the social-interaction space and contextual-task space in order to be interpreted) is an important aspect of achieving these goals effectively and in a socially sensitive manner.

This thesis presents a methodology which can be drawn on to successfully operationalise a contemporary paradigm of HRI – Kirchner & Alempijevic's Robot Centric HRI paradigm – which frames the interaction between humans and robots as a loop, incorporating additional feedback mechanisms to enable robots to leverage sociocontextual cues. Given the complexities of human behaviour and the dynamics of interaction, this is a non-trivial task. The Robot Centric HRI paradigm and methodology were therefore developed, explored and verified through a series of real-world HRI studies ($n_{total} = 435 = 16 + 24 + 26 + 96 + 189 + 84$).

Firstly, by drawing on the methodology, it is demonstrated that sociocontextual cues can be successfully leveraged to increase the effectiveness of HRI in both directions of communication between humans and robots via the paradigm. Specifically, cues issued by social robots are shown to be recognisable to people, who generally respond to them in line with human-issued cues. Further, enabling robots to read interaction partners' cues *in situ* is shown to be highly valuable to HRI, for example by enabling robots to intentionally and effectively issue cues. In light of the finding that people will display HHI-predicted sociocontextual cues such as gaze around robots, a novel head yaw estimation framework which showed promise for the HRI space was developed and evaluated. This enables robots to read human-issued gaze cues and mutual attention *in situ*.

Next, it is illustrated that a robot's effectiveness at achieving its goal(s) can be increased by adding to its ability to moderate the cues it issues based on information read from humans (i.e. increased interactivity).

Finally, the above findings are shown to generalise to other sociocontextual cues, social robots and application spaces, demonstrating that the developed methodology can be drawn on to successfully operationalise the Robot Centric HRI paradigm, enabling robots to leverage sociocontextual cues to more effectively achieve their goal(s) and meet the requirements of their expanding roles.