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Theatrical approach: Designing human-like behaviour in humanoid robots

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HIGHLIGHTS

- Proposing a theatrical approach to find rules for designing natural behaviour of a robot.
- Analysing instructions of a stage director and interactions between a robot and humans on the stage.
- Showing that the rules are directly applicable to a humanoid robot to improve naturalness.
- Developing an instructive interface to design the behaviour of a robot.

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ABSTRACT

A key challenge in designing humanoid robots is producing natural and human-like behaviour. This study addressed this challenge by developing an instructive interface to design natural and human-like behaviour in a humanoid robot that will be helpful not only for professional robot motion designers but also for nonprofessionals. A staging method called contemporary colloquial theatre theory has been developed in the field of theatre to reproduce the natural behaviour of humans. Based on the theory, to design robot behaviour, we extracted implicit knowledge from a director's instructions given to a robot actor in a robot theatre project, where the robot functions as an actor and interacts with human actors. This paper shows the validity of applying this knowledge extraction method by means of a public stage play entitled Night On The Milky Way Train and two short plays created for the purpose of carrying out an analysis. Our analysis produced important rules for designing the behaviour of humanoid robots. The rules were extracted in forms suited to the instructive function of the interface. In this paper, we report the results of a subjective experiment conducted to verify the effectiveness of this function. Our experimental results suggest that the rules derived are effective in improving robot behaviour.

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1. Introduction

Many humanoid robots have been developed and used successfully in human–robot interactions (HRI) in the daily lives of humans [1–3]. Several studies have stressed the importance of natural human-like behaviour in humanoid robots [4,5]. However, how to guide humanoid robots to move naturally has been a formidable issue for robot motion designers because of the lack of knowledge of how human motions should be represented [6]. Hirata, a world-famous professional stage director, has succeeded in achieving natural human-like behaviour in humanoid robots as part of a robot theatre project. Hirata is an advocate of contemporary colloquial theatre theory (CCTT), which is a method for staging and instructing human actors. Instructions based on CCTT are characteristically and highly focused on reproducing examples of daily human interaction. To create special performances based on CCTT, he seldom allows actors to perform exaggerated and unnatural actions, such as looking at the audience or read aloud from their scripts, as in some stage plays by other directors. The instructions to actors advocated by CCTT are precise, for example, "step 30 cm forward" and "wait 0.3 more seconds before reading your lines". Such precise instructions are expected to be compatible and directly applicable to humanoid robots, and instructing robots in this way has actually been attempted in the robot theatre project. As a result, the ability of robots to behave in a natural human-like manner in stage plays has been extensively appreciated, and

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Fig. 1. Robot theatre: Night on the milky way train.

authoritative theatres in many countries have repeatedly extended invitations for robot theatre performances [7]. Acting instructions for robots based on CCTT are expected to involve hints for robot designers to make humanoid robots behave in more natural ways, but have not yet been sufficiently analysed for that purpose. This study was conducted to help determine how to derive rules for designing the natural behaviour of humanoid robots in the theatrical approach.

In recent years, relatively inexpensive humanoid robots have become more widely used in society [8–10]. The price of robots is falling as the technology advances and more people are expected to interact with robots and design their behaviour. However, it is very difficult for nonprofessionals to endow the robots with natural human-like mannerisms; only certain professionals, such as some stage directors, who are familiar with how humans move, and researchers in robotics are capable of achieving it. Hence, a platform is necessary to enable a novice to design natural and human-like robot behaviour without the help of a professional. A central issue in the HRI field is how to develop platforms that can easily bring out the potential of humanoid robots.

Fig. 1 shows the highlight of a stage play involving human and humanoid robot actors. It was presented as a public performance in May 2013, and followed with two short plays that had been created for facilitating a more detailed analysis for this research.

The results of the analysis of the stage performance of *Night On The Milky Way Train* are presented in Section 2. An analysis of more controlled and slightly different plays was conducted to confirm the results presented in Section 2, and the results of this subsequent analysis are presented in Section 3. An interface developed with an instructive function for use by novices as well as professionals in making robot behaviour more natural and human-like based on the rules derived from the analysis results and the results of an evaluation of the effectiveness of the instructive function are described in Section 4. The results are discussed and conclusions drawn from the study are presented in Section 5.

2. Public performance: Night on the milky way train

Hirata's plays have been performed in many countries. The results of questionnaires on the impression that robots make in the plays show that most audience members feel that robots exhibit natural human-like behaviour [7]. Some members of the audience forget that robots are performing on the stage, as they act very human-like. Although the robots do not have emotion and are not even intelligent, people feel that the robots possess emotion and intelligence and in fact, a number of people are moved by the robots' performance and cry. Therefore, a robot's performance was analysed to obtain essential rules that would endow robots with natural human-like behaviour.

To derive the rules for designing natural humanoid robot behaviour, we focused on a well-established play that includes many motions in various situations. The play entitled Night On The Milky Way Train developed by Hirata and performed for ten days in public in Osaka, Japan in May 2013 was analysed. The duration of the play is an hour and a half. A humanoid robot and at most four human actors interact with one another on the stage. The play pays homage to a famous Japanese fairy tale written by Kenji Miyazawa, who was one of the most famous Japanese poets and author of children's literature. The play is a sad story that asks us "What is true happiness?", and dwells on "Self sacrifice", "Penitence", "Death" etc., making a deep impression on the audience. Therefore, both the human actors and the robot are required to possess high levels of acting ability.

In this play, a humanoid robot, Robovie-R3, played the role of Campanella, who is one of the friends of the main character, Giovanni performed by a human actor. Three other human actors were also on the stage playing the roles of their friends and a teacher.

2.1. Apparatus of the stage play

The humanoid robot Robovie-R3 was developed by the Advanced Telecommunications Research Institute International (ATR) in Japan and Vstone Co., Ltd. (Fig. 2).

Robovie-R3 is a life-sized humanoid robot platform that has a height of 108 cm and weighs 35 kg. It has two degrees of freedom (DoF) on each eye (pan and tilt), three DoFs on the neck (pitch, roll, and yaw), two DoFs on each shoulder, two DoFs on each

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