Progressive Development of an Autonomous Robot for Children through Parallel Comparison of Two Robots

Shizuko Matsuzoe
University of Tsukuba
1-1-1 Tennodai, Tsukuba-shi,
Ibaraki 305-8573, Japan
shi25tty@gmail.com

Hideaki Kuzuoka
University of Tsukuba
1-1-1 Tennodai, Tsukuba-shi,
Ibaraki 305-8573, Japan
kuzuoka@iit.tsukuba.ac.jp

Fumihide Tanaka
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku,
Tokyo 113-8656, Japan
fumihide.tanaka@gmail.com

ABSTRACT

This study proposes and demonstrates a progressive development method for an autonomous robot that is used for childhood education. The main concept in this method is to iteratively explore new behavioral factors and use them to progressively develop the robot by concurrently using and comparing two robots in a classroom. Usually, in classrooms for young children, it is practically difficult to recruit a sufficient number of participants and conduct many experiments. The parallel comparison employed in the proposed method enables rapid development to deal with these difficulties.

Categories and Subject Descriptors

I.2.9 [**Artificial Intelligence**]: Robotics; K.3.1 [**Computers and Education**]: Computer Uses in Education

General Terms

Design

Keywords

Care-receiving robot, children-robot interaction, child education, learning support, progressive development, parallel comparison of two robots

1. INTRODUCTION

To support childhood education, we have introduced and tested a care-receiving robot (CRR). This robot purposely shows weak or incomplete behavior while interacting with children, such as answering questions incorrectly. Our previous studies showed that a CRR encouraged children's spontaneous learning by teaching and helping them to learn English words [6, 4]. The next research goal was to explore the weakness or incompleteness factors that were important for realizing a more effective and practical autonomous CRR. However, two problems must be overcome to realize the autonomous CRR. The first concerns the development of new weak or incomplete behaviors for the robots, because these robots have many such behavioral factors that need to be verified. As a result, exhaustive verification to determine the educational effectiveness of these factors is difficult. The second concerns the specific difficulties surrounding trials in the educational field, such as recruiting a sufficient number of participants and arranging a schedule with cooperating kindergartens or elementary schools.

To deal with these two problems, we propose a progressive development method involving the concurrent use of two robots. By iteratively exploring new behavioral factors for the CRR and testing them in a classroom environment, we aim to simultaneously accumulate hitherto lacking knowledge concerning possible weakness/incompleteness factors for the autonomous CRR and develop the autonomous CRR. From the viewpoint of progressiveness, a Wizard-of-Oz (WOZ) method is used for exploration. To deal with the difficulties of recruiting a sufficient number of participants and conducting many experiments, the idea of using two robots concurrently was adopted so that the process of development became more efficient.

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2. PROGRESSIVE DEVELOPMENT OF AN AUTONOMOUS ROBOT

To explore and implement important new behaviors for the autonomous robot, a *progressive development* method involving (1) the use of the WOZ method, (2) concurrent use of two robots, and (3) iterative exploration and verification in a real classroom was used.

The WOZ method was used to efficiently explore effective robot behaviors by using the operator's ability to evaluate the situation of the children and the robot. The explored behaviors (e.g., falling backward, bowing the head) represent *progress* in this development method. The WOZ method had been used as a simulation method to improve the system or interface in human-computer interaction [3]. A human "wizard" operates the system, leading participants to believe that they are interacting with an autonomous system. Based on the simulation results, the corresponding system or interface could be iteratively improved. Recently, the WOZ method has also been used to improve and evaluate interaction designs related to an agent or robot [5].

The concurrent use of two robots is advantageous in that the operator can control the WOZ robot competitively while observing the interactions between the children and the other robot. Our trial experiences indicate that by using the WOZ robot alone, it is difficult to differentiate whether children are engaged by the robot's novelty or new behaviors. Thus, we expect that the observation and comparison will together elicit better performance from the WOZ robot than when it is used alone. Another advantage is that the children can choose the robot that they want to play with based on a comparison between the robots. This is a simple and natural choice behavior, which is suitable for verifying the robots' imple-

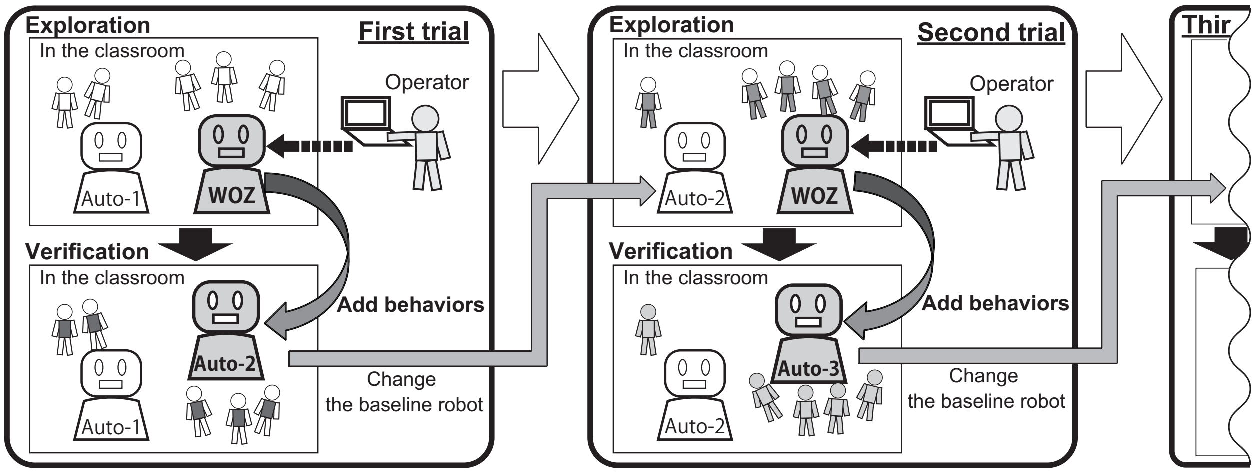

Figure 1: Progressive development of an autonomous CRR.

mentation for use in an actual educational environment. Alac et al. concurrently used two robots to investigate how children behaved around robots [1]. However, almost no studies have concurrently used two robots to develop and improve an autonomous robot.

The development method was explicitly divided into the exploration and the verification periods. In a real classroom, the iteration of both periods while upgrading the behaviors may reveal unique and unexpected findings related to certain situations. It was difficult to explore all the important behaviors during a single exploration period in the pilot trial, and the findings depend on various classroom conditions (e.g., children, toys, hours). Therefore, we iteratively accumulate knowledge concerning the important behaviors of the robot. In the field of learning science, the design experiment approach involving interventions and iterative implementation in a natural classroom has also been used to generate new theories and frameworks for educational methods [2].

Figure 1 shows the progressive development of an autonomous CRR. Each trial consists of exploration and verification periods. Each period lasts several days (e.g., 4 days). There are two robots in the classroom; therefore, the children can compare them and choose the one with which they want to play a certain learning game. In the exploration period, the WOZ robot is controlled remotely by an operator to explore new robot behaviors for further encouraging children's interest in the learning game relative to the autonomous robot that serves as the baseline in this trial. Additional behaviors for verification are decided based on video observations of the exploration period and interviews with the experimenters who play the role of guardians in the classroom. The verifications with the baseline and the improved robots are conducted with children who had not participated in the exploration. The Auto-1 robot played the role of the baseline to be improved in the first trial. The Auto-2 robot was implemented based on the exploration in the first trial. If the learning support in the Auto-2 robot was found to be effective, Auto-2 will be set as the baseline, and we will progress toward Auto-3 in the next trial.

3. CONCLUSIONS

In this study, we proposed the concept of a progressive development method involving the parallel comparison of two robots. We have conducted so far field experiments using this development method in a kindergarten classroom, in which children participated in a gesture game for learning English. Aldebaran Robotics' NAO was used for the experiments. Our ongoing analysis showed that the explored new behaviors of the improved CRR successfully helped children maintain their interest in the learning game with the robot. In addition, it is becoming clear that the improved CRR impacts children's learning. These early findings suggest that the proposed progressive development method can be used to gradually improve the autonomous robot to enhance its usefulness in promoting children's learning.

4. ACKNOWLEDGMENTS

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