Sustainable Care Support System with Environmentally Adaptive Swarm Intelligence Robots

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Abstract: This research aims to develop a caregiver-assisted robot system that provides cooperative support to caregivers. This will address the problem of the shorthanded caregivers at the care facilities. The robot will be used in various situations on behalf of the caregiver, such as talking to the care-receiver, carrying objects, guiding the care-receiver's steps, and fall detections. However, it is difficult to design all appropriate action scenarios for the robot in advance, assuming various care support facilities. In this study, we approach a sustainable care support system by gradually adapting and evolving the basic behavior patterns of robots to the environment. This paper shows a prototype system of a centralized care support system infrastructure that utilizes swarm intelligence robots currently under study.

Keywords: swarm intelligence, evolutionary robotics, Multi-access Edge Computing, nursing care

1. Introduction

In 2022, the population over 65 years old in Japan will exceed 28%, and the aging population in Japan is higher than in European countries [1]. Since 2000, the shortage of caregivers has continued [2] and robots and ICT (Information and Communication Technology) are required to compensate for this problem. This research aims to develop a system where humans and robots can cooperate to provide care support. This paper introduces the concept of a Care Support System in which robots autonomously talk to the care-receiver, carry objects, guide the care-receiver, and detect falls to assist the caregiver.

2. Difficulties in System Design

When designing a robot for a long-term care facility or disaster relief, it is not always possible to disclose all required specifications, such as support details and persons requiring support information, in advance. For example, the following situations are not the same in each care facility (nursing home).

- Number of caregivers
- Number and status of care facility residents
- Layout and structure of rooms in care facilities

Therefore, even if a caregiver support robot system can be optimally designed according to the requirements and specifications interviewed at one care facility, it faces the problem that it cannot be used sustainably under different conditions. As the situation of caregivers and residents changes, the specifications required for robotic behavior should also evolve. For example, a case may arise in which the user wants to use more robots for carrying things rather than a talking robot. A system that continues to adapt to changing conditions should address the following technical issues.

(1) Creating all behavior for all robots would lead to code bloat, complexity, and management complication.

(2) It is too much trouble for humans to keep adjusting all of the robot's parameters and behavior optimally.

In this study, each of the swarm robots learns the optimal action scenario while working. Behavior models and evaluations learned for each robot situation are centrally managed. This will enable a sustainable care support system that autonomously adapts to its environment.

3. Multidisciplinary Technology for Sustainable Care Support System

An overview of the system under planning is shown in Figure 1. Swarm robot systems, in which multiple robots perform cooperative behavior, are expected to increase efficiency through parallel work [3, 4]. The following multidisciplinary technologies are needed to realize environmentally adaptive swarm-intelligent robots based on evolutionary computation.

- Robot Operating System (ROS 2) [5]
- Multi-access Edge Computing (MEC)
- Evolutionary Computation / Particle Swarm Optimization (PSO) [6]
- Image Processing on Heterogeneous FPGAs

The MEC will be used to centrally manage the training data of each robot and provide a bird's eye view of the behavior and status of all robots. The behavior of the entire care support robot will be optimized using an evolutionary computation algorithm based on PSO [6].

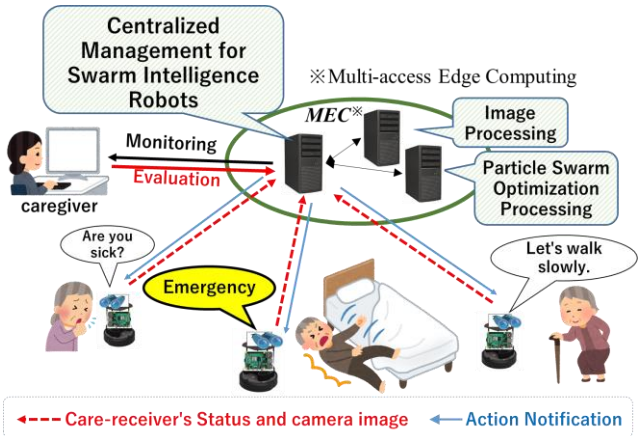

Fig. 1 Conceptual Diagram of Sustainable Care Support System.

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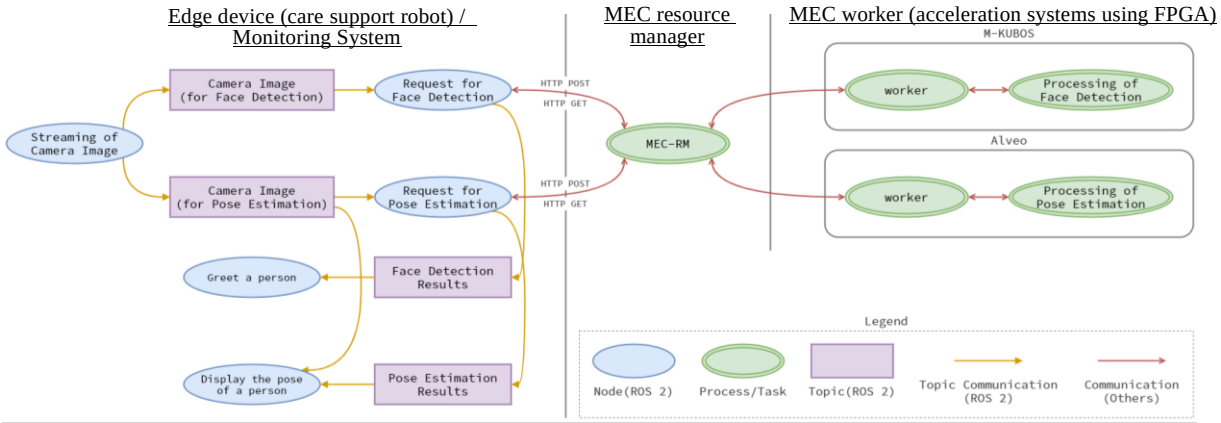

Fig. 3 ROS 2 nodes and topics of the prototype system.

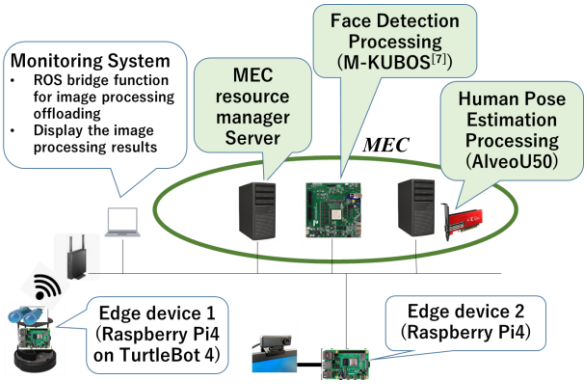

Fig. 2 Prototype of nursing care support system.

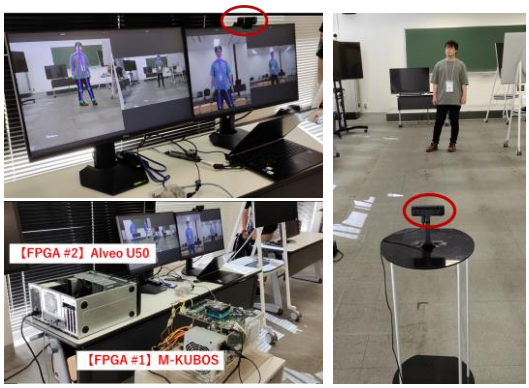

Fig. 4 Photo of the prototype system.

TABLE 1 ROS 2 system environment.

Item name	Specifications
Operating System	Ubuntu 22.04 LTS
ROS2 distributions	Humble Hawksbill
Programming Language	Python 3.10

4. Challenge: Overview of Prototype System

Figure 2 shows a prototype of a caregiver support system. Image processing is useful for providing appropriate assistance according to the care-receiver's behavior. Real-time image analysis is performed by MEC instead of edge devices. The MEC system resources were configured with two types of FPGA devices to accelerate and save power during image analysis. In this prototype system, the MEC performs face detection and pose estimation simultaneously using images from cameras on two edge devices (Raspberry Pi 4), which correspond to the robots. Depending on the face position and the height of the pose obtained from the image analysis, the robot will take actions such as saying appropriate words, detecting a fall, and so on. Figure 3 shows the task structure of the prototype system. Nursing-care robot applications are built in ROS 2 [5] (left side of Figure 3). Table 1 shows the system environment of ROS 2. Figure 3 shows only the image processing tasks, but the real robot also activated the ROS node for autonomous driving. It should be noted that learning the optimal behavior for each situation and centralized management schemes are future issues.

5. Conclusion

This paper presented a care support system that is currently under study. In the future, we will clarify a centralized management scheme for the optimized behavior of swarm robots, which will be realized using MEC.

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