World's First Full-fledged Communication Robot "wakamaru" Capable of Living with Family and Supporting Persons

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1. Introduction

Mitsubishi Heavy Industries, Ltd. (MHI) has developed the world's first communication robot "wakamaru"(1) that is capable of living with a family and sold to users living in the 23 wards of Tokyo.

This full-fledged robot has three features. (1) It can serve people as an individual personality because it has a design showing friendliness and presence. (2) It can communicate naturally and fully with people by making eye contact. (3) It can provide a service supporting family life by its autonomic movement (it has its own daily rhythm and adapts to its owner's everyday life).

For example, (1) it gives a morning call and informs the owner of the day's schedule (schedule management), (2) if it detects a moving object while alone in the house, it notifies this by e-mail (home security function), (3) it presents various items of information and services by using the Internet, and (4) if there is no response from the owner when it wakes him up in the morning, when he returns home in the evening, or at other specified times, it notifies to a specified security station (notification of abnormality).

The robot living with people needs to move autonomously while avoiding injury to people. The "wakamaru" has its own biorhythm defined by three elements: time, place, and behaves. For example, it carries out tasks requested by the owner at the appropriate time, moves freely around the house while communicating with people, and returns to its charging station when the battery level is low.

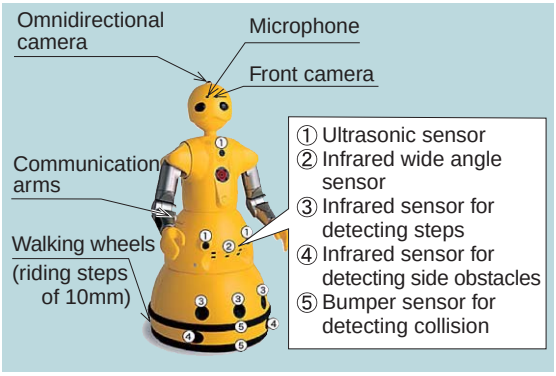

Fig. 1 Configuration of "wakamaru."

The computer vision technology (technology for detecting moving objects and recognizing faces) and the autonomic moving technology for realizing autonomic behaviors are described below.

2. Computer vision technology

As shown in **Fig. 1**, the "wakamaru" searches for moving people through 360 degrees by an omnidirectional camera in the head, and recognizes faces by the front camera embedded in its forehead. It can identify a total of ten people including the owner, family members and friends. Thus, it can face the person and mentions appropriate topics with gestures while talking. An outline of the human detection is shown in **Fig. 2**.

In conventional moving object detection methods, the robot often falsely recognizes a flapping curtain, a skin-colored lamp and small articles as human face. Accordingly, we improve the reliability of human recognition by a particle filter technique which estimates three-dimensional positions of the human head with probabilistic models(2).

3. Autonomic moving technology

The "wakamaru" moves in the house using a map as shown in **Fig. 3**. The robot stores the locomotion route and the positions of specified places (entrance, bed, sofa, etc.) in the house by teaching , moves independently along the route while remaining aware of its position, and carries out its tasks such as waking up the owner in the morning. Through self-localization using markers and avoidance of obstacles on the basis of information from sensors, reliable autonomic action is achieved.

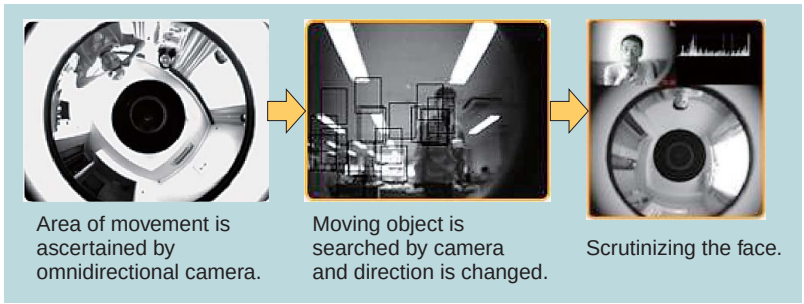

Fig. 2 Visual detection of human beings

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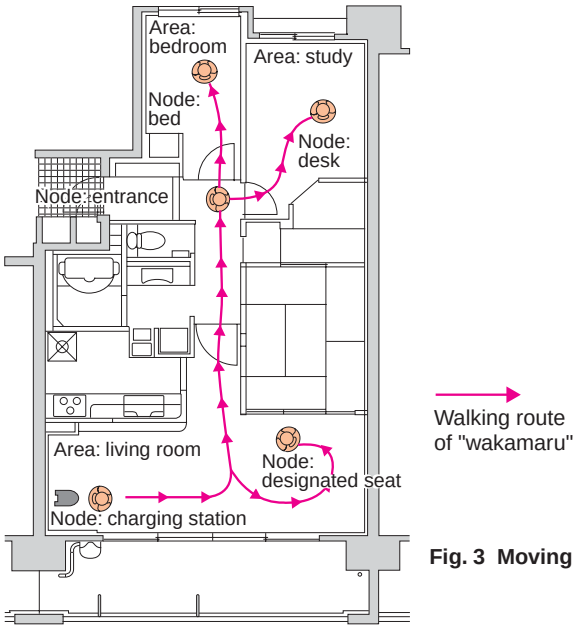

Fig. 3 Moving map

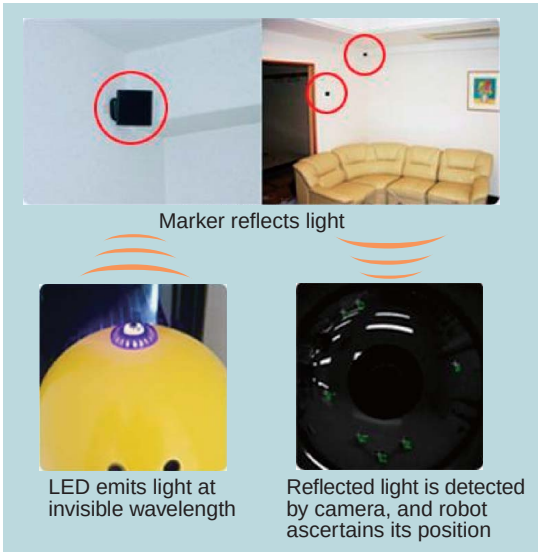

Fig. 4 Self-localization by markers

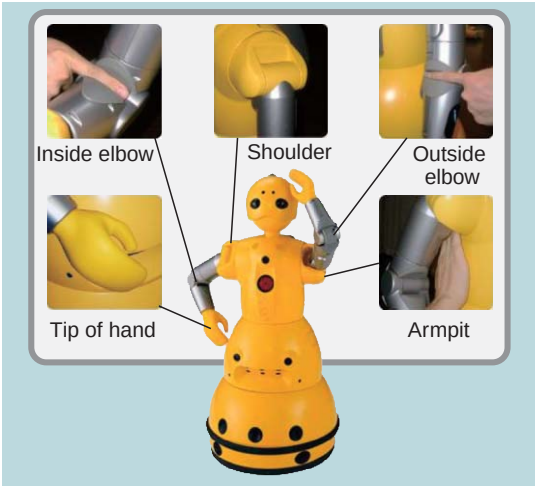

Fig. 5 Design of arms for safety of human beings

(1) High reliability of self-localization

In self-localization by odometry (to determine the traveling distance and the posture angle from the rotational angle of wheels), errors increase due to slipping of wheels. In self-localization by camera, errors occur under the influence of sunshine conditions, changes in lighting and location of people.

The "wakamaru," emits invisible light from LEDs embedded around the head-top camera, and detects markers installed throughout the house (Fig. 4). The robot calculates from the positions of detected markers by the least square method and revises errors of odometry.

(2) Avoidance of obstacles by sensors

Positions of walls, furniture and obstacles detected by ultrasonic sensors and infrared sensors are stored as local map. And the "wakamaru" selects the best route to avoid obstacles in the local map and adjusts its speed by using the evaluation score that changes with the distance to obstacles.

4. Prevention of collision with human beings

We performed risk analysis as shown in **Fig. 5**. As the result, we designed the "wakamaru", with reference to toy safety standard to preventing fingers from being pinched by the robot's elbow or armpit. Following safety checks and witness inspection by The Safety Engineering Laboratory, a nonprofit organization, the "wakamaru" is the first to have been authorized as a robot of lowest possible risk at the present technical level.

5. Conclusions

Household robots are required to be highly reliable and safe in a variety of different family environments. The "wakamaru" features numerous advantages, including highly reliable detection of human beings by estimating the position of the human head using the probability model, highly reliable autonomic locomotion by self-localization using markers, obstacle avoidance with various sensors and human safety designs such as prevention of pinching of fingers.

References

(1) Kawauchi et al., Home-use Robot "wakamaru", Mitsubishi Juko Giho Vol. 40 No. 5 (2003)
(2) Tomonaka et al., Computer Vision Technologies for Home-use Robot "wakamaru", Mitsubishi Heavy Industries Technical Review Vol. 42 No. 1 (2005)


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