別紙４－１（課程博士（英文））

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Abstract (Doctor)

Title of Thesis	Person Identification and Person's Awareness Estimation for an Attendant Robot

Approx. 800 words

Developed countries including Japan are becoming aged societies, and they suffer from a chronic shortage of caregivers. In this decade, robotic caregiving has been attracting people's attention as a solution for the problem and they are expected to be deployed in the next decade.

In this thesis, we investigate a robotic attendant system for caregiving. In this system, a robot follows a person and keeps him/her away from dangerous situations. In case the person is going to be involved in an accident (e.g., bumping into an obstacle and falling from a step), the robot prevents the accident by interacting with him/her (e.g., informing the person of the obstacle). However, if the robot interacts with the person every time it finds an accident risk, it could be annoying for the person. To be socially accepted, the robotic attendant system has to avoid disturbing the person as long as he/she is in a safe situation so that it becomes comfortable for the person. To minimize the risk of accidents while maximizing the comfortableness of attendance, we focus on a person's awareness. By estimating the person's awareness of obstacles, the robot can assess the collision risk and interact with the person only when an accident is likely to happen.

First, we present robust person tracking and identification methods. Attendant robots have to be able to follow a specific target person reliably. In case there are several persons, the robot may lose track of the target person due to occlusion. In such cases, it is required to identify the target person among surrounding persons (i.e., re-identification) to resume the tracking and continue to follow the target. We propose online learning-based person identification methods based on deep convolutional neural network-based appearance features and illumination invariant height and gait features. They can identify the target person robustly in severe illumination environments. We also propose a wearable device-based identification method. In this method, we let the target person hold a smartphone and identify him/her by matching the foot strike timings detected by the smartphone and the ones of surrounding persons detected by a laser range finder mounted on the robot. By combining the online learning-based and wearable device-based identification methods, we realize a robust and reliable person following system.

Second, we propose a system to measure and analyze real persons' attending behavior. In this system, an observer carrying a 3D LIDAR follows persons to be measured while keeping them in the sensor view. It allows us to measure the behavior of the persons without area and time limitations. The system first constructs a 3D environmental map beforehand and then estimates the sensor pose and tracks surrounding people online. As a field test, we measured the behavior of professional caregivers attending an elderly with dementia in a hospital. A preliminary analysis of the attendant behavior reveals how they decide the positioning with respect to the elderly while paying attention to the surrounding environment to prevent accidents.

Third, we propose methods to estimate a person's awareness of the surrounding environment. In the case of person-following robots, they cannot observe features which directly reflect the person's awareness (e.g., head orientation and gaze). We, thus, propose methods to estimate a person's awareness solely from the person's trajectory. As a proof-of-concept, we propose a model to estimate a person's awareness of an obstacle in a corridor. Then, we extend the model so that it can handle arbitrary obstacles and environmental structures with a deep convolutional network.

Finally, we present a proposal for the system design of an attendant robot. The robot reliably follows a specific target person with the proposed person identification methods, and its behavior is designed based on the assessment of accident risks with awareness estimation for safe and comfortable attendance. It would be a step towards a socially acceptable robotic caregiving system.