別紙４（課程博士）

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Abstract
論文内容の要旨　(博士)

Title of Thesis 博士学位論文名	Collision Avoidance and Object Following Control for a Mobile Robot in Human Living Environment （人間生活環境における移動ロボットの衝突回避と物体追従制御）

(Approx. 800 words)

(要旨　1,200 字程度)

With recent technological developments, mobile robots are expected to occupy the same environments as humans and provide fully autonomous or semi-autonomous assistance. Robot navigation is the safe movement of a robot toward its goal and is accomplished by knowledge of the environment. Obstacle avoidance is one of the main requirements of robot navigation. During the past few years, the potential field method for obstacle avoidance and target setting has gained popularity among roboticists. In this approach, the obstacles and targets exert repulsive and attractive forces on the robot, respectively.

As our most powerful sense, vision provides us with an enormous amount of information and enables intelligent interaction with our dynamic environment. Vision-based robotics systems have recently increased in popularity, and several new approaches have been proposed. Despite the huge efforts invested in creating effective low-cost service mobile robots, vision-based motion control and path planning remain theoretically challenging. The basic principle involves iterating two structures from motions captured by a stereo camera. As the distance to a detected object and motion can be predicted and measured by depth mapping, the stereo camera can be substituted by a single red–green–blue depth (RGB-D) camera. A popular RGB-D camera is the Kinect sensor, a motion sensing device developed by Microsoft Corporation.

Vision-based robot navigation might enable the production of service robots that can track and follow moving targets. Tracking mobile robots generally require expensive sensors such as range finders, tend to disregard obstacle avoidance, and are developed as single robots. Moreover, their algorithms are complex.

In this study, we combined the potential field method with visual sensing to create a moving-object-following robot; that is, a robot that tracks and follows an object attached to a human, wheelchair, or another robot (leader robot). The attached object considered was a blue circular mark. The robot was mounted with a Kinect sensor, and the position of the blue circle and depth mapping for the distance calculation were detected by an RGB image detection system. The designed mobile robot system can track and follow a moving object in environments wherein humans coexist; using only the information acquired by vision sensors and IR proximity sensors. The designed reference controller generates a reference trajectory for obstacle avoidance and the robot is moved along its reference trajectory by a simple proportional integral (PI) controller. This proposed method enables collision avoidance, is robust to brief occlusion, and to some extent, is also applicable to swarm robots. The simple algorithm makes the proposed method easily modifiable to robotic applications other than mobile robots.

First, we derive reference models from the dynamic modeling of the two-wheeled differential drive mobile robot

with non-holonomic constraints. The collision avoidance scheme is achieved by the model reference control based on the potential field path planner. A system integration method, by which the robot moves in a dynamic environment, is also presented. The effectiveness of the proposed controller is demonstrated by discussing the results of simulations and experiments. The next step is to present a new collision avoidance approach for four-wheeled human-operated mobile robots. Because the proposed method considers the non-holonomic constraint of a mobile robot, it provides practical collision avoidance control. In a verification experiment, entirely unskilled operators maneuvered the robot to its destination without collisions, demonstrating the effectiveness of the proposed approach.

The proposed method also presents the collision avoidance control technique applicable for swarm robots moving in a rehabilitation environment containing static and moving obstacles. A leader–follower formation is adopted, in which the leader of the swarm robot team follows the rehabilitee, while the other robots follow the leader. The effectiveness of the proposed system is demonstrated by presenting the results of a simulation study in which several static and dynamic obstacles were placed in a human living environment.

The final step is combining the potential field method with visual sensing to create a moving-object-following robot; that is, a robot that tracks and follows an object attached to a human, wheelchair, or another robot (leader robot). In this study, the attached object was a blue circular mark. The robot was mounted with a Kinect sensor, and the position of the blue circle and the depth mapping for the distance calculation were detected by RGB imaging. The effectiveness of the proposed method is discussed in the context of human-following, wheelchair-following, and leader robot-following systems and by presenting an experiment that extended into the hallway outside the laboratory testbed. Experiments were conducted in several environmental settings.

In order to prove that proposed method easily modifiable to robotic applications other than mobile robots, we discuss the possibility of achieving human and object following without specific shape detection. We compare the proposed system design with the work undertaken by several references. The effectiveness of the proposed method was experimentally evaluated in several course settings.

This thesis proposes a moving-object-following mobile robot functioning as a mobile service robot in a human living environment. The algorithms and hardware are simplified as much as possible in this design, enabling the proposed robot to assist in a wide variety of dull, repetitive tasks in human environments, such as transporting the disabled. Despite the application of inexpensive Kinect and proximity sensors, the system performed as expected in this investigation, in which the effectiveness of the proposed method was confirmed in different experimental scenarios. The possibility of creating swarms of service robots by the proposed method is also discussed in this thesis.