別紙４－１（課程博士（英文））

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Abstract（Doctor）

Title of Thesis	Motion Trajectory Generation Considering Safe Operational Support for Rotary Cranes

Approx. 800 words

This thesis presents a comprehensive study on motion trajectory generation considering safe operational support for rotary cranes. Rotary crane systems are commonly utilized to transport heavy loads and hazardous materials in the construction industry. Most rotary crane operations are performed manually, which can be challenging for new or unskilled operators. Although cranes are necessary tools for mobility, unfortunately, they are one of the major causes of accidents in the construction industry. Therefore, the development of a method that is supports new and unskilled operators in operating the crane manually is highly expected.

The main objective is to develop a system for motion trajectory generation that ensures safe, smooth, and precise load transportation while minimizing load-sway and supporting operators through intuitive interfaces. The proposed framework integrates path planning, optimization, trajectory generation, and user-friendly interface design to enhance safety and efficiency in crane operation. Motion trajectory guidance for unskilled operators is necessary to prevent collisions and ensure both safety and efficient load transfer.

An algorithm for trajectory generation is developed by combining the A* algorithm with simple motions. Collision detection and information about the distance between the load and the nearest obstacle are also included in the algorithm to increase the operator's awareness. Additionally, point cloud data and octree structures are implemented to represent the obstacles in the actual crane site. Precise final load positioning in construction sites is a challenging task in manual crane operation, as the small abrupt motion can cause load-sway. A trajectory generation system that integrates obstacle avoidance and load-sway suppression is proposed.

A Load Monitor Camera (LMC) captures the load environment, and the result is displayed on a user-friendly interface designed with error prevention, simplicity, and ergonomic considerations. A usability evaluation confirms that the interface reduces task completion time and is well accepted by novice users. The operator selects the final load position from the LMC image, after which a slow-motion trajectory is automatically generated using a cycloidal velocity profile to suppress

load-sway. The A* algorithm is used for obstacle avoidance, and its efficiency is validated through comparison with the Dijkstra algorithm. A benchmark comparison with an S-curve trajectory demonstrates the proposed method's superiority in minimizing sway. Additionally, a disturbance sensitivity analysis under wind conditions evaluates system robustness and highlights potential improvements. Simulation and experimental validations using a lab-scale rotary crane demonstrate the effectiveness of each proposed method in achieving safe and precise load transportation.

To enhance rotary crane performance in terms of motion trajectory generation considering safe operational support, the proposed approaches are described as follows in this thesis: Chapter 2 introduces the fundamentals of rotary crane kinematics, dynamics, and trajectory generation, followed by a review of path-planning algorithms, trajectory generation methods, and user interface concepts applied to operator-assistive systems.

Chapter 3 proposes a trajectory generation method composed of simple motion sequences for manual operation support. This approach is particularly suitable for supporting manual or semi-automatic operation, where operators can easily interpret and execute the generated motion sequence. By decomposing crane motion into 1 DOF and simple combined motions, the approach enables safe and intuitive control while ensuring collision avoidance through the A* algorithm. Simulation results verify that the method supports operators in achieving smooth and safe load transportation. Chapter 4 extends this concept to real environments by integrating three-dimensional point cloud data for automatic trajectory generation. Using octree-based environmental modeling, the method detects obstacles and automatically generates collision-free trajectories composed of simple motions. Simulations and experiments confirm the feasibility of this method in realistic conditions, showing its potential for practical site applications.

Chapter 5 focuses on small-distance motion during final load positioning, where precision and safety are critical. The method employs nonlinear optimization to determine maximum allowable boom velocities and accelerations while maintaining sway constraints. A cycloidal velocity profile achieves smooth motion transitions with zero initial and final velocities, effectively suppressing load-sway. Simulation and experimental results confirm that the proposed approach enhances positioning accuracy while maintaining negligible sway. Chapter 6 further integrates obstacle avoidance, slow-motion planning, and load-sway suppression into a unified control framework. The method combines the A* algorithm with a slow-motion cycloidal velocity profile and a user-friendly LMC interface for visual target selection. Experimental verification demonstrates smooth and collision-free load motion under mild wind disturbance, outperforming conventional S-curve trajectories in terms of smoothness and stability. Finally, Chapter 7 presents the concluding remarks of this thesis and prospective future works.