論文の内容の要旨

論文題目　Minimal Time and Compact Designs for a Redundant Manipulator System with Multiple-Goal Tasks

(多点巡回作業を行う冗長マニピュレータシステムの作業時間並びに作業領域の最小化設計)

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(本文)

Multiple-goal tasks are very significant applications in manufacturing. These tasks are defined by goals that are distinctly separated and the path between any two goals is not given in advance such as in spot welding and inspection tasks. Manipulator systems are utilized in these tasks due to their re-programmability and speed. Several design methods are proposed ranging from purely programming-based methods to methods involving a design of specialized system. These design methods have to be appropriately selected depending on specific design criteria. For instance, some design methods may not be applicable to several tasks. Applicability to several tasks is crucial since it is related to the cost-effectiveness of a design method. Furthermore, some design methods may require a substantial amount of calculation time, which is impractical in manufacturing.

In this study, the selection of design methods is based on their applicability to several tasks, fast design time and the effectiveness in optimizing a performance index. Two performances indices are considered such as the task completion time and the work cell size. Minimizing the task completion time is important to reduce wasted time and increase productivity. A compact design is desired for the efficient use of space in manufacturing. A manipulator system consisting of a 6-DOF manipulator and a 1-DOF positioning rotary table is utilized in this study. The criterion on applicability to several tasks is addressed by utilizing a standard manipulator while that on fast design time, a design time is set as a constraint.

In minimizing task completion time, two scenarios are considered: a scenario in which the placements of manipulator and positioning table are fixed (fixed manipulator system setup) and a scenario in which their placement can be varied and designed (variable manipulator system setup). A fixed manipulator system setup can be very practical in actual manufacturing setting due to massive structures of manipulator and other equipment. For that reason, programming-based methods are employed involving goal rearrangement and motion coordination between manipulator and positioning table. The simulation results show that in fixed manipulator system setup, a combination of nearest neighbor algorithm (*NNA)* and Dijkstra algorithm (*DA*) can achieve a better solution in solving the motion coordination compared to *NNA* by about 10.9% and comparable to that of *DA* (13.8%), in a much faster calculation time than DA by a factor of 4 to 11. On the other hand, a variable manipulator system setup is applicable if modifications in the manipulator placement are possible. Therefore, a holistic approach is proposed combining programming-based methods and a hardware-based method; the combination of methods includes the base placement design, the tool attachment design, goal rearrangement and motion coordination. The tool attachment design is a novel method of adding a linkage at the manipulator end-effector. The improvement achieved in using the proposed method is about 14.36% compared to employing only goal rearrangement and motion coordination.

In designing a compact work cell, the *compactness* is evaluated on the basis of the size and the swept volume of manipulator and positioning table. This evaluation is crucial since a manipulator motion can sweep a substantially large volume depending on a given task. Since it is observed that designing a compact work cell can lead to an impractical length of time for executing a task, the problem is formulated by imposing a task completion time constraint. The proposed method combines the base placement design, the tool attachment design, the goal rearrangement and motion coordination. Two schemes of motion coordination are proposed based on minimal task completion time and based on the swept volume. It is observed that designing a compact work cell using the proposed method can reduce the work cell size by at most 28%.