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Form 3

Abstract of Thesis

Name	(Wang Zhenting)
Title	Human-Robot Collaborative Assembly Tasks Based on Graphic Instruction Manuals (説明図に基づく人とロボットの協調組立作業)

Abstract of Thesis

Human-robot collaboration provides a transformative method for enhancing the efficiency, precision, and flexibility of an assembly task by integrating the strengths of humans and robots. It is preferable to combine the advantage of robots in repetitive, high-precision, and physically demanding tasks with the creativity and adaptability of humans in complex and dynamic environments.

It is preferred to generate the assembly task sequence that can be executed by a robot to execute a human-robot collaborative assembly task. The graphic instruction manual is a widely used method for providing humans with guidance on constructing a product. However, it is still a challenge for robots to automatically understand the details of the assembly task based on the ambiguous knowledge obtained from the implicit instruction images. To enhance the accuracy of robotic assembly planning by understanding the graphic instruction manual, a two-step error correction method using the component, symbol, speech bubble, and model number information included in the instruction manual was proposed. This kind of information was first used to generate the Assembly Task Sequence Graph (ATSG). After constructing the ATSG, an error correction by verifying the total number of components used in the assembly task was performed.

To achieve a successful HRC assembly task, a task allocation method that considers assembly complexity while ensuring the stability of each sub-assembly task was proposed. The stability of each sub-assembly task and the appropriate timing to provide support for maintaining stability, as well as the agent responsible for executing the support motion, were evaluated by the relationship of the Center of Gravity (CoG) and the contact area. The dynamic liaison complexity of each sub-assembly was calculated separately for the human operator and the robot, enabling the assignment of sub-assembly tasks to the most suitable operator.

Considering human safety and comfort during the HRC assembly, the human-related complexity based on an ergonomic risk evaluation method called Rapid Upper Limb Assessment (RULA) was defined. The Forward and Backward Reaching Inverse Kinematics (FABRIK) method was employed to predict human reaching motion, using only the target location of the manipulated part and the initial human pose before starting a sub-assembly task. By integrating the proposed human-related complexity with product- and task-related complexities, sub-assembly tasks can be assigned to the appropriate agents before the execution of each subtask. The allocation result is transmitted to a human-centered HRC interface, facilitating communication between human operators and robots during the assembly task.

様式７

論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

人間-ロボット協調(HRC)は、人間とロボットの相補的な強みを活用し、組立作業の効率性、精度、適応性を向上させるアプローチを提供する。本論文では、まずグラフィカルな組立説明書からロボットの動作を計画するために、二段階のエラー補正手法を提案した。次に、HRCによる効率的な組立作業を実現するために、組立の複雑性と各サブアセンブリの安定性を考慮した新たなタスク割り当て手法を導入した。さらに、HRC組立作業における人間の安全性と作業快適性を考慮し、上体の姿勢評価に基づく人間による作業の複雑性指標を定義した。本研究は、組立計画、エラー補正、作業負荷の最適化などの課題に対処し、産業組立環境における人間-ロボット協調の効率性、精度、作業者の負担軽減を向上させることに貢献するものである。

主査、副査で論文の審査をおこなった結果、いくつかの疑問点が挙げられた。それらは主に、①組立で用いるツールの決定と評価、②グラフィカル組立説明書から組立の困難さを決める手法や妥当性、③エラーの評価方法、④提案手法に一般性、ならびに⑤研究で用いられている仮定やより一般的な問題への拡張性といったものであった。審査の際に出た疑問点に関する議論を中心に。最終審査をおこなった。最終審査ではWang君は全ての疑問に明確に回答した。これにより、主査、副査全員一致で本論文は博士（工学）として価値があるものと認められた。