



Title	Dexterous Manipulation Planning with a Simple Two-fingered Gripper
Author(s)	Raessa, Mohamed Salaheldin Moustafa Abdelfatah
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Abstract of Thesis

Name	(MOHAMED SALAHELDIN MOUSTAFA ABDEL FATAH RAESSA)
Title	Dexterous Manipulation Planning with a Simple Two-fingered Gripper (単純な2指グリップによる器用な操りの動作計画)
Abstract of Thesis Manipulating long and heavy objects using a single robot arm is challenging. The difficulty originates from the objects' shapes and masses. They dictate how external forces, such as gravity and inertia affect the object's stability during the manipulation process. Robot arms usually use simple two-finger grippers to interact with the environment. Such grippers do not possess enough dexterity for manipulation tasks. Recent studies showed that robot hand dexterity could be enhanced using intrinsic resources as well extrinsic ones. I extend the extrinsic dexterity approach by studying the effect of gravitational forces on manipulated objects. I developed methods to eliminate the effect of undesirable disturbances and utilize them in a controlled way to plan beneficial manipulation motions. This thesis focuses on the phenomena of in-hand slip motion that objects encounter while being manipulated. Such a motion introduces unexpected changes in the grasped object pose and hinders the progress of the planned sequence. In the first step of this research, I explore the paradigm of extrinsic manipulation to find ways to enhance simple grippers dexterity to complete flipping tasks of small objects. The robot uses pivoting with visual feedback to flip objects by changing their in-hand pose through pushing against an extrinsic fixture. The improved flipping ability is utilized to perform precision assembly. Inspired by the results from the first step, I aim at enabling manipulators to flip large objects. However, flipping large objects is more challenging due to the in-hand slip (drooping) problem. In the second step, I solve this problem by implementing a constrained motion planner that enables robot manipulators to flip heavy and large objects without slip. Based on the soft-finger maximum friction torque, I develop a constraint relaxation method to estimate a critical rotation angle that a robot end effector can rotate while avoiding in-hand slip. The critical rotation angle is used in a motion planner to generate slip-free motion. The third step of my research builds on the understanding of the in-hand slip phenomena. I implement a hierarchical motion planner that utilizes constrained in-hand slip and regrasping for reposing long and heavy objects. The planner includes a task level layer and a motion level layer. At the task level, I build a graph using regrasping and constrained in-hand slip and find mixed regrasping and drooping sequences by searching the graph. Cartesian planning is used at the robot motion level to generate motions between adjacent critical grasp poses of the task level layer's sequence. The results show the improved capability of robot arms to manipulate long and heavy objects. In the fourth step, I develop a robotic manipulation planner for human-robot collaborative assembly. Unlike previous methods, which study an independent and fully AI-equipped autonomous system, the proposed method explores the subtask distribution between a robot and a human. The robot in the system works on pick-and-place tasks and provides workpieces to humans. The human collaborator works on fine operations like aligning, and screwing. I extended the constrained planner developed in the previous step to generate comfortable handovers from the robot to the human collaborator. The results show that the system can help humans finish the assembly task comfortably.	

論文審査の結果の要旨及び担当者

氏 名 (MOHAMED SALAHELDIN MOUSTAFA ABDEL FATAH RAESSA)			
	(職)	氏 名	
論文審査担当者	主 査	教 授	原 田 研 介
	副 査	教 授	佐 藤 宏 介
	副 査	教 授	長 井 隆 行
論文審査の結果の要旨 本論文は、単純な 2 指グリップを用いてロボットが対象物を操作する動作計画に関するものである。研究の目的は、広く産業応用がされている 2 指グリップの用途を広げ、今までの産業用ロボットでできなかった様々な作業ができるようにすることにある。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、多指ハンドを使う場合との比較、操作に失敗した場合のリカバリ、センサを付加した場合にどうか、指先に自由回転可能な関節を搭載するとどうなるか、人の心地よさの評価指標の詳細、などであった。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MOHAMED SALAHELDIN MOUSTAFA ABDEL FATAH RAESSA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。			