HRI를 위한 핸드오버 동작의 최적화 방안 연구

이상준*, 장병옥**

요약

본 논문은 유비쿼터스 시대의 유비쿼터스 홈 서비스 로봇의 인간과 상호 작용하는 로봇 팔과 손의 움직임에 대한 연구이다. 로봇이 물체를 건네주기 위해서 물체를 잡는 단계에서의 에티켓 요소는 물체의 다양한 모양, 물체의 기능성, 안전성의 세 가지 측면으로 분류 할 수 있다. 제안된 3D 파지 플래너에서는 실험 대상으로 각각의 다른 특징을 가진 우리 주변 환경의 물체들을 모델링 하였으며 이러한 다양한 물체들의 특성들에 위에서 언급한 에티켓 요소들을 고려하여 최적의 파지 점을 계산하며 또한 물체 건네주기 동작을 위한 전문화된 방법: 두 손과 두 팔을 이용한 두 단계 물체 옮겨 건네주기 (H2G2) 을 제시하였다.

Study on the Optimal Method of Handover Operation for HRI

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ABSTRACT

In the era of ubiquitous, ubiquitous home-service robot exist on one of the most important roles for human-helper. We propose the advanced methods of determination of grasp sites for handover operations. And also, we address useful operations for handover: two-step handover with midair re-grasp. We show the effectiveness of our algorithm for interaction between human and robots with 3D graphical simulations, and then it is tested with our humanoid real home service robot. The designed 3D grasp planner is modeled using each different objects and finally, proved the proposed grasp method which is considering etiquette factor for efficient human grasp.

Key Words : HRI, Humanoid Robot, Motion, Handover

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Ⅰ. Introduction

The handover motion involves holding of an object by both a human and a robot, and implicates functional and social relationship between the giver and the receiver. It needs to consider many grasp constraints including object shapes, collision between the robot hand and all other objects, object functionalities, safety with manners mainly. Etiquette for the human-robot interaction is especially important for robots engaged in household service and in public places to interact with humans in a friendly manner. If service robots could perform with respectable manner while interacting with people, people shown those acts would feel respected and well served with convenience, regardless whether the performer is human or not. Although there is no unique way to define the etiquette sensitive behaviors of robots, the etiquettes deal with polite ways of handing over objects as defined by customs of cultures, usually to facilitate the receiver's convenience after the object handover. When handing a book over, for example, it is considerate of the giver to grasp it so the book is right side up in the receiver's viewpoint. The receiver then can open the book without re-orientation.

그림 1. 휴머노이드 홈 서비스 로봇: 핸드오버 동작
Fig 1. A humanoid home-service robot: handover operation

In addition to the arms motion planning aspect with considering determining grasp sites include the above grasp constraints (call them GC5), for the grasp based arms motion planning we address handover operation: two-step handover with a midair re-grasp to transfer the object from one hand to the other (H2G2). For H2G2 operations there are performed for more complicate tasks by using dual-arm manipulator. Dual-arm motion planning is very complicate to perform more intelligent motions. These three methods of planners need as input the geometry of the environment, the initial and goal configurations of various objects and arms, a set of potential grasps of the objects, and the inverse kinematics of the arms. The factors determining the mode of handover include object size, weight, the initial pose, and its spatial relationship with nearby objects. Three separate arms motion planning but related grasp planners are developed to support the corresponding modes of handover operations, which are tested with a home-service robot called IDRO shown in Fig. 1. Simply constraints related to etiquettes is well illustrated in Fig. 1, which shows a robot handing over a Coke with a grasp that does not consider a place for human to grasp and a remote control with that considers the human grasp.

II. Related Works

2.1 Grasp Planning

Cutkosky and Wright have classified the types of grips needed in a manufacturing environment and examined how the task and object geometry affect the choice of grasp [1]. Three tree like classification for grasp can be seen in figure 2. Stansfield has chosen a simple classification and built a rule-based system that provides a set of possible hand pre-shapes and reach directions for pre-contact stage of grasping [2]. This algorithm doesn't evaluate all possible grasps. She does not try to choose the best grasp for optimization and stability. Borst et al. apply grasp planning to task wrench space [3]. For object manipulation several papers present grasp algorithms [4, 5], which are mostly concerned with finding a fixed number of contact locations. Other systems developed for particular hands usually restrict the problem, e.g., allowing one contact per finger [6]. Pollard has developed a method of adapting a given prototype grasp of one object to another object [7]. Hirata et al. have developed coordinated control algorithms to handle a single object with multiple manipulators [8].

2.2 Motion Planning

Motion planning with intentions for robot and human arm manipulation is related to several different areas of research. We roughly classify this related work into manipulation planning of humanoid robot which has dual arms and hands. WABOT1 is the first humanoid robot that has dual arms and legs developed in 1973 in Japan [9].

Hwang et al. and Kaneko et al. present grasping and motion planning algorithms for humanoid robots [10, 11]. Hasegawa et al. [12] propose a one-handed re-grasping strategy for positioning and orienting an object, but it just manipulates an object by one hand. They don't mention even an arm operation. Our re-grasp planner considers avoid contact between the object and the environment, between the object and the human hand; they necessarily involve multiple arms (e.g. dual arms and hands)

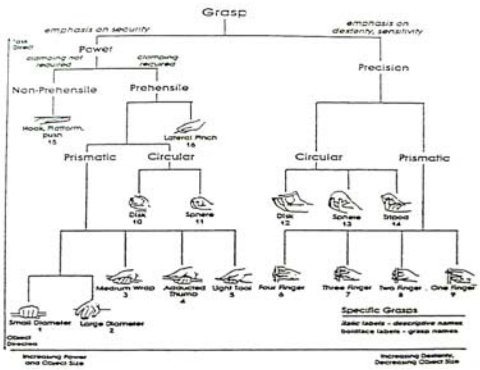


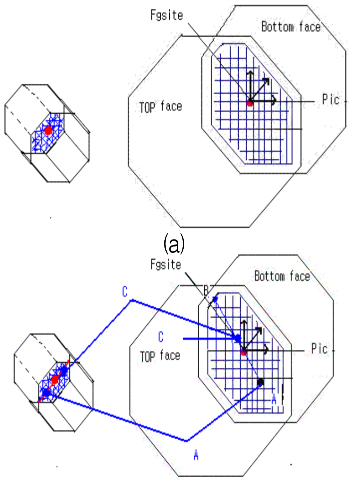
그림 2. Cutkosky와 Wright의 파지법 분류
Fig 2.Cutkosky and Wright's taxonomy of human grasps

III. Grasp Planner for Handover Operations

3.1 Grasp Planning for Handover

For every pair of faces of a polyhedron, check whether they are nearly parallel. If they are not, go to the next pair. If they are, check whether the distance between the faces is less than the gripper's maximum width. If not, go to the next pair of faces. If it is, project the vertices of the two faces along the common normal to generate two polygons, and see if the polygons' intersection has an enough area. If it does, the approximate centre of the intersection, Pic, is the origin of a possible grasp site (Fig. 3(a)). The orientation of the grasp site is determined by matching x, y, z and n, o, a of the grasp site with those of Fgrasp, and then rotating the robot hand about o axis at a finite interval, storing the angles with collisions detection between the hand and other objects.

Repeat this for all pairs of faces to get all possible grasp sites of the object.



(a)

(b)

그림 3. 파지면 계산 (a) 평면의 투시 교착점 (b) 인간 파지점을 고려한 로봇의 파지점 결정
Fig 3. Grasp sites computation (a) intersection of the projections of parallel faces (b) determination of grasp sites with considering human grasp sites

For purpose of handover an object to people robot should consider receiver's grasp site, C, before determination of his grasp site. We assume human grasp the same surface of an object with robot grasping sites. To be considering receiver's safety and conveniences for etiquettes we address new grasp method for handover operation. Fig. 3(b) shows us that determination of grasp sites for handover operation with considering human's grasp sites: From the origin of a grasp site, Pic, robot get new grasp site, A, which is determined by (Pic + MAX)/2, MAX is maximum value of distance of the object at closed direction from robot to Pic on the object, and B can be measured as minimum value (MIN) at closed sites from human. Finally, human get new grasp site, C, which is computed by (A+B)/2.

3.2 H2G2 - Grasp Planning for Re-grasp Handover using Dual Hands

If there is no Fgsite that satisfies GC5, a two-step handover with a re-grasp is considered. Let's assume we pick up the object with the first hand, transfer it to the second, and handover to the human with the second. We first place a copy of the object to be grasped in midair. We then find all grasp sites, first, that can be used to move the object in midair back to the initial object position enforcing satisfaction of GC5 except the functionality and etiquette constraints. Next, we find all grasp sites, second, that can be used to handover the object from the midair position to a human enforcing satisfaction of all of GC5 plus the collision avoidance between the first and the second hand. The grasp sites that belong to both first and second are the ones that can be used for a two-step handover with midair re-grasp (Fig. 4).

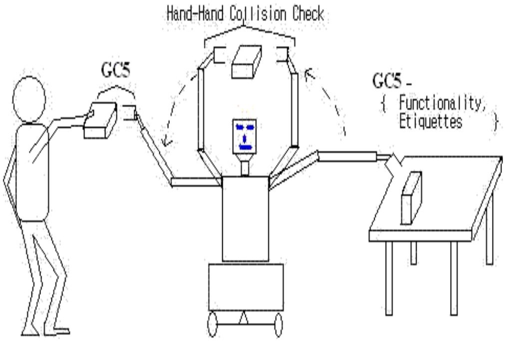


그림 4. 재 파지를 고려한 핸드오버
Fig 4. Handover with a midair re-grasping

IV. Motion Planner for Handover Operations

We simply provide with our arm motion planning for handover operations. For the motion planning of handover objects to human the algorithm divides the trajectory up to six segments (1. move, 2. approach, 3. decide_of_grasp_site, 4. grip, 5. lift, 6. handover), each of which can be independently generated using interpolation for position and orientation. The robot moves to the space above the object to be grasped by a given distance. The orientation changes linearly from the initial to the object grasping orientation with the gripper open. The robot arms then moves down to the object. The gripper then moves to the chosen grasp site that avoids dangerous features and respects manners, functionality, safety. And then, the gripper continuously closes to grab the object. The robot then lifts up the object, goes to the human\transfer the object to second arm and hand and finally, handover the object to receiver. Figure 5 shows the flow for handover operation planner step by step. In order to prevent unreachable grasps sites of the object from being planned, the user may import a world model containing obstacles as well as the robot arm model so that reachable constraints may be considered.

Traditionally, for the arm motion planner inverse kinematics solvers can be divided into two categories: analytic and numerical solvers. Most industrial manipulators are designed to have analytic solutions for efficient and robust control. Paden [13] independently discussed methods to solve an inverse kinematics problem by reducing it into a series of simpler sub-problems whose closed-form solutions are known. We are using numerical method using Jacobian matrix and its pseudo inverse which relies on an interactive process to obtain solution. Rose et al. [14] extended this formulation to handle variety constraints that hold over an interval of motion frames.

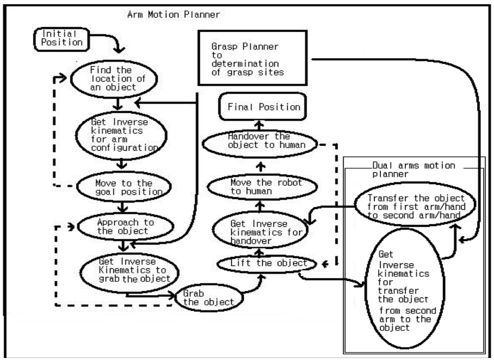


그림 5. 핸드오버 동작 플래너의 흐름

Fig 5. A flow of handover operation planner

V. Implementation and Experimental Results

In order to handover an object which lies scattered with disorder on the table we can apply H2G2 operation using dual arms and hands. For this case there is focused on dual-arm motion planning for handover operation between robot and human. For the first arm and hand end-effector position robot is manipulated from base coordinate to grab an object by inverse kinematics operation. And it is moved to reachable area for transferring to the other hand in midair. In order to transfer an object to the other hand, final reached position of first hand with grabbed an object can be set as end-effector position of the other hand. And then, we apply re-inverse kinematics to manipulate second arm. (Fig. 6). Our planner computes new configuration from current position and orientation of second hand to human location by inverse kinematics to handover the object after transfer the object to second hand. Finally, robot hand over an object to human.

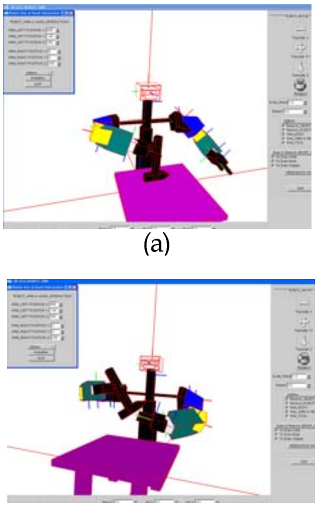


그림 6. H2G2 동작 시뮬레이션 (a) 한손과 한팔을 이용한 해머 파지 (b) 다른 손으로 해머 건네주기
Fig 6. H2G2 operation simulation: (a) grasp a hammer by one-armed and handed (b) transfer a hammer to second hand

VI. Conclusions

This paper has addressed advanced grasp determination algorithms with grasp based motion planning for three different handover operations in esteem etiquette factors: two-handed handover with a midair re-grasp. Our grasping algorithms respect the constraints associated with etiquettes which include object functions, object shapes and safety. Our simulator is designed by editing parameters in a compact configuration files. Variety objects can be modeled easily in our grasp planner. Also, humanoid robot which has dual arms can simply be designed as only giving DH parameters in our configuration file of arm motion planner. Finally, after done simulation work, the etiquette sensitive grasp planner has been tested with our robot IDRO in household environment, and has shown a satisfactory performance.

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