Sequential Re-planning for Dextrous Grasping Under Object-pose Uncertainty

Claudio Zito*, Marek S. Kopicki*, Rustam Stolkin*, Christoph Borst**, Florian Schmidt**, Maximo A. Roa** and Jeremy L. Wyatt*

***Abstract*— This work shows how successive grasp attempts can be re-planned to make use of tactile information acquired during previous grasp attempts. Our main contributions are to enable planning of dexterous grasping for high degree of freedom manipulators, and belief updating from tactile sensors in 6 dimensional space. The method is demonstrated in trials with simulated robots. Sequential re-planning is shown to achieve a greater success rate than single grasp attempts, and trajectories that maximise information gain require less re-planning iterations than conventional trajectories before a grasp is achieved.**

I. Introduction

In robot grasping, there is typically uncertainty associated with the location of the object to be grasped. However, if the object is not in its expected location, then a robot equipped with tactile sensors, or torque sensors at finger joints, may gain information to help refine localisation knowledge from tactile contacts (or lack of such contacts) during the execution of a reach to grasp trajectory. This work, firstly, describes how to iteratively update localisation knowledge using tactile observations from a previous grasp attempt; secondly, shows how successive grasp trajectories can be planned with respect to these iteratively refined object poses; and, thirdly, shows how each reach-to-grasp trajectory can be deliberately planned to maximise new tactile information gain, while also reaching towards the expected grasp location derived from previous information. This work is an extension of our early work which was published as a two page workshop abstract [4]. Further details are available in [3].

We make several assumptions. First we assume that the object is of known shape, in the sense that a high density point cloud model or mesh model is available. Second we assume that a pre-computed grasp (i.e. a set of finger contacts) is known a priori for this object. Third we assume the availability of an unreliable estimate of the object's pose. In our scenario we employ a depth image obtained from an Asus Xtion Pro depth camera. This gives an incomplete point cloud of the object surface. Using a model fitting procedure similar to the sampling from surflet pairs method presented in [1], a probability density over the object pose is estimated, represented as a particle set. Given this distribution, a reach-to-grasp trajectory is planned. This trajectory has as its goal configuration the pre-computed grasp under the assumption that the object is at a pose corresponding to the mean position of the particle set. The path to this goal configuration is found using a stochastic motion planner. This planner works with a cost function that allows deviations from the shortest path that maximise the chance of gathering tactile observations that will reduce pose uncertainty in the object location. When a contact is made, then the observations (both tactile contact and no-contact signals) collected at poses along the reach-to-grasp trajectory are used to perform a particle filter update. Replanning then occurs with the new pose distribution, and a new reach-to-grasp trajectory can be constructed. This process is then iterated until a successful grasp is achieved.

The benefit of planning with beliefs is the ability to reason about the informational effects of sequences of actions. In typical belief space planning this means performing a kind of pre-posterior analysis, in which planned actions (here trajectories) cause imagined observations that are in turn used to perform a Bayes' update of the belief state. Because the belief space grows exponentially in the length of the planned action-observation sequence these methods are exact but inefficient. Our work instead builds on the approach of Platt et al. [2]. That work plans a sequence of actions that will generate observations that distinguish a hypothesised state from competing hypotheses while also reaching a goal position. The informational value of a trajectory is the difference in the expected observations between the hypothesised position and each alternative. Platt et al. applied this to planning for a two degree of freedom manipulator using a laser range finder for observations, and employed an optimisation framework for planning. Here we show how this approach can be extended to planning the motion of a manipulator performing multi-finger grasping. Our innovations are i) embedding an informational measure in the trajectory segments considered by a randomised path planner, here a PRM planner, and ii) creating an observation model for contact sensing by a multi-finger hand that palpates the object to be grasped.

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*IRLab, School of Computer Science, University of Birmingham, United Kingdom, {cxz004,stolkinr,msk,jlw}@cs.bham.ac.uk

**German Aerospace Center, DLR, Wessling, Germany, {christoph.borst,florian.schmidt,maximo.roa}@dlr.de

References

[1] U. Hillenbrand and A. Fuchs. An experimental study of four variants of pose clustering from dense range data. In *Computer Vision and Image Understanding*, 2011.

[2] R. Platt, L. Kaelbling, T. Lozano-Perez, and R. Tadrake. Simultanious localization and grasping as a belief space control problem. Technical report, CSAIL, MIT, 2001.

[3] C. Zito, M. Kopicki, R. Stolkin, and J. Wyatt. Dextrous grasp planning and execution under object pose uncertainty. Technical report, http://www.cs.bham.ac.uk/c̃xz004/download/Zito_tech_report_2012.pdf, 2012.

[4] C. Zito, R. Stolkin, M. S. Kopicki, M. Di Luca, and J. L. Wyatt. Exploratory reach-to-grasp trajectories for uncertainobject poses. In *Proceedings of the Workshop on Beyond Robot Grasping: Modern Approaches for Dynamic Manipulation. Intelligent Robots and Systems (IROS)*, 2012.