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Sujet de thèses 2014

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Titre de la thèse : **Saisie et manipulation dextre d'un objet déformable**

Résumé du sujet

La manipulation dextre est un sujet de recherche intense dans le domaine de la robotique. Mais il y a encore peu de recherche développée sur la manipulation d'objets déformables de nos jours puisque la plupart des travaux ont été effectués sur des corps rigides seulement. De nouvelles applications concernant la chirurgie, l'industrie alimentaire et les services à la personne avec l'augmentation des besoins en automatisation industrielle nécessitent l'étude du problème de la saisie et manipulation d'un objet déformable pour apporter des capacités nouvelles au robot. En effet, la modélisation et la simulation d'objets déformables peuvent contribuer, par exemple, au développement futur de simulateurs de chirurgie pour former de nouveaux médecins à palper les organes avec des sensations haptiques, de robots manipulateurs pour manipuler ou couper la viande ou d'autres produits mous, ou saisir et manipuler objets de la vie quotidienne pour aider les gens. Des recherches sur les objets déformables ont été menées avec des modèles géométriques et topologiques pour des objets déformables à une et deux dimensions. Une approche pour manipuler des objets déformables sans modélisation de la déformation a été développée sur la base du concept de diminution de la rigidité ; ce modèle n'est cependant pas adapté pour les objets déformables hétérogènes. Une approche de fusion de capteurs a été considérée en utilisant les informations tactiles et visuelles pour la manipulation d'objets mono dimensionnels seulement. Le sujet de thèse porte sur la modélisation, la simulation et la mise en œuvre d'un planificateur de haut niveau pour effectuer des tâches de manipulation d'objets déformables tridimensionnels homogènes et hétérogènes et de la même manière, un nouveau planificateur d'objets non modélisés qui combine des informations de fusion de capteurs pour la planification automatique en temps réel du mouvement. La mise en œuvre finale sera effectuée sur la plate-forme expérimentale du projet européen HANDLE en utilisant le matériel et le logiciel déjà existant. Une analyse des capteurs tactiles et visuels existants disponibles pour la saisie et la manipulation d'objets déformables sera faite afin de choisir la solution la plus appropriée et de nouveaux algorithmes seront développés et implémentés.

Sujet développé

1 Introduction

In robotics research and applications, autonomy has presented long-standing challenge on many fronts, mainly for motion control, human interaction, environment/object sensing and modelling, and robot manipulation. New applications concerning surgery, food industry and daily life services together with the increase of industrial automation require investigating the problem of deformable object grasping and manipulation. Medical robots have to deal with biological tissues and organs. In the robot-assisted surgery, since most human organs are deformable, the integration of physics-based deformable modelling has the potential to improve dexterity, precision, and speed during the surgery as well as to enable some new medical methods. Virtual/augmented reality based simulation and medical training systems help enhancing medical capability in which deformable modelling plays a very important role. Food industry also has to deal with deformable objects, for example, the meat sector is concerned with automation with robot machines capable of manipulating different kinds of meat and soft tissues since it is a real challenge to enhance the competitiveness [1] in that area. Hardness of working conditions has produced a shortage of skilled workers and a high rate of musculoskeletal diseases. In real life scenarios, robots may encounter deformable objects such as curtains, cables, plastic bottles, ropes, plants, etc. and need a new planning algorithm, rather than one based on solid bodies, to interact with them. Textile industry deals with the processing of highly deformable objects. The price for cloths mainly depends on the cost of handling and processing textiles. Therefore robotic manipulation of deformable bodies can potentially contribute to the deployment of manipulators in this industry to automate processes. However, manipulation of flexible objects in a dynamic and unconstrained situation poses a number of challenges in robotics. The configuration of the object shape needs to be sensed fast enough to plan the motion with accuracy and good performance and the properties of the material relevant to its deformation must be sensed visually or haptically. Another issue is that the deformation of an object under external forces is difficult to model and depends on the actual properties of the material.

2 State-of-the-art

Manipulation planning differs from standard motion planning techniques in that the focus is in the robot and its displacements rather than in the object to be manipulated. Robotic manipulation can be divided in two consecutive main tasks, the first one associated with grasping the object and keeping a stable force closure to ensure that the object will not fall or slip [2], and the second one associated with in hand-robot manipulation and dexterous manipulation for purpose exploration and object recognition [3]. Typically those approaches use tactile information in the servoing control scheme to extract relevant features from the object in contact and plan an adequate motion [4] [5]. There also exist multisensory approaches in which vision and force feedback are integrated in the control scheme together with tactile information to plan the best motion for robot physical interaction [6]. However the planning strategies used for rigid bodies will not be accurate in grasping and manipulating objects that will deform with time and may lose contact force closure since the object has changed its initial topological and geometrical properties. Modelling and manipulation plans of deformable objects are therefore needed. Algorithms for planning paths are either based on topological or geometrical information. Geometric planning strategies modelling the elastic behaviour of the object, for example manipulation plans for flexible plates, are presented in [7]. These algorithms have problems when obstacles are presented since the manipulator information is not taken into account for planning. The problem of path planning for linear deformable objects such as ropes and cables in presence of obstacles is addressed in [8] by a variational approach but this formulation does not consider the manipulator either. Other approaches use the manipulator for planning tasks, such as tie knots, where topology is more important than geometry [9]. This model is developed for linear deformable objects and not for two- and three-dimensional deformable objects. A novel approach for manipulating deformable objects without modelling and simulating deformation is presented in [10]; this method is based on the concept of decreasing rigidity to quickly compute an approximation of the Jacobian matrix of the deformable object and also incorporate techniques to avoid collision and excessive object stretching of one- and two-dimensional objects. The main drawback of this approach is that heterogeneous deformable objects will not be properly manipulated since the decrease of rigidity may widely vary depending on where the object is grasped. In general these models consider the grasping task and the manipulation task as two separate tasks. A novel and more robust approach is presented in [11] where grasping and manipulation is performed using a real time vision system. However this model is only applied for one-dimensional object manipulation. In general, there is no robust approach which can be used for modelling and manipulating a variety of deformable objects.

3 Proposal

The thesis subject will be focused on modelling, simulating and implementing a robust planner for performing manipulation tasks with homogeneous and heterogeneous deformable objects and a new planner for un-modelled objects that combines tactile force and vision information for planning the motion in real time. The real implementation will be carried out using existing robotic hardware and software in the laboratory such as the robot manipulator and the Shadow hand together with the software developed in the HANDLE project [12]. New software will also be implemented and an analysis of existing tactile and vision sensors available for grasping and manipulating deformable objects will be done in order to select the most suitable solution. The thesis will be organized in the following way:

- Review in deep state of the art and identify scenarios of deformable object grasping and manipulation in order to define a protocol to carry out different tests and research in the laboratory using already existing hardware and software.
- Select and model three-dimensional deformable objects through the use of different elasticity models like Navier-Cauchy equations, mass-spring models, finite element methods and other ones and apply them in simulation. Realize simulations in Gazebo using its new multi-engine support capabilities and particularly focusing in Bullet and Simbody engines that apply elastic models for simulation of collisions.
- Develop tactile and visual servoing control techniques for deformable objects to extract relevant features from them and incorporate them into high level planners. Develop two main planners, one planner using the deformable object modelling to guarantee closure with no loose contact while manipulating the object and also to avoid collisions. Develop predictor models based on deformation modelling and include them in the planner to estimate how objects will behave under simple manipulation tasks.
- Implement another planner for unknown objects that combines multi-sensorial fusion of information coming from tactile and visual feedback but without requiring any previous model. Planner may be based on learning techniques which do not require a previous model or on novel techniques applied to deformable objects such as the rigidity decreasing

approach. Tactile sensors will provide tactile information through tactile servoing of deformable objects and vision information will be obtained from Kinect camera sensor, both available in the laboratory. OpenCV and Matlab will be used to apply computer vision techniques, analyze and visualize the data.

- Use advanced robotic techniques for motion planning with ROS and novel MoveIt software and integrate them with Gazebo and OpenCV in simulation. Validate the results of the simulations and perform real implementations with the available robot manipulator and Shadow hand taking into account the testing protocols defined at the beginning.
- Benchmark the efficiency of modelling, simulation and application to deformable object grasping and manipulation in terms of time response and accurateness and the efficiency of developed planning strategies.

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