SORBONNE UNIVERSITÉ

Ecole doctorale SMAER
Sciences **M**écaniques, **A**coustique, **E**lectronique, **R**obotique

Thesis subject 2018

Laboratory: ISIR (Institute for Intelligent Systems and Robotics) UMR 7222

University: Sorbonne university

Title of the thesis: Simultaneous tactile localization and mapping of an object in a robotic hand

Thesis supervisor: Prof. Véronique Perdereau

Email contact: vperdereau@isir.upmc.fr

Collaborations within the thesis: Institut Pascal, IFMA, Clermont-Ferrand - Nazarbayev University, Kazhakstan

This subject can be published on the doctoral school's web site: Yes

Thesis's summary (abstract):

With the increase of living standards of society and the aging of the population, in-door robots are expected to replace humans in many areas [Bill Gates, Scientific America, 2008]. Obviously, robots' end-effectors play an important role in different robotic tasks. Various robotic hands have therefore been developed with different levels of anthropomorphism to reproduce the human hand functionality and dexterity. The capability of executing object manipulation tasks, in which fine movements are required, strongly depends however on the knowledge on the target object.

Among several properties, this knowledge includes the object shape. One of the ways to represent this shape is to construct a point cloud on the surface. Infrared depth cameras similar to the KINECT are commonly used for creating the cloud. However, they can work in specific distance ranges (more than 15 cm) only and can be occluded by the hand itself. Tactile sensors do not have these limitations, they can measure the local geometrical coordinates of physical contacts [Cutkosky, 2014]. Thus, the tactile sensors can be used to create the point cloud of the object surface.

There are already some works on object or shape recognition with tactile sensors, and manipulation algorithms that use tactile information have also been proposed as well as 3D shape reconstruction methods. Nevertheless, an advanced autonomous robotic manipulation system that combines information coming from multiple sensor arrays installed over a robotic hand for object recognition has still not been developed to the best of our knowledge.

At ISIR, we have succeeded to integrate a prototype of a tactile skin with a multi-fingered dexterous robot hand, the Shadow hand. This tactile skin was developed at CEA, Paris. It uses capacitive technology and consists of

pressure sensing arrays attached onto the links of the hand. With this tactile skin, the robot hand will be able to control contacts that occur at multiple locations. In order to control these contacts, a new framework should be developed and validated with the robot platform to localize a known object within a robot hand or even to reconstruct the shape of an unknown object by manipulating it.

Subject

Among the efforts that have been made in order to achieve object recognition through information obtained from tactile sensors, several results show it is feasible. Some of the work done used tactile arrays information and converted it into images in order to treat it with image processing techniques. Pezzementi et al [1] used tactile images to implement a bag-of-features technique using novel image descriptors algorithms based on Fourier transform with excellent performance, being able to recognize an object with an average accuracy of 80 percent on several trials. Khasnobish et al. [2] also used tactile image for object-shape recognition and 3D reconstruction with an implementation of a hybrid recognition scheme that uses not only the considered features obtained through images, but also gradient-related information of these images. Some more object or shape recognition work has been done, like that of Khasnobish A. et al [3] using feed-forward Neural Networks for object clustering and classification. Other sorts of tactile data have also been used in object shape recognition, such as the geometrics of the object [4]-[6].

Tactile data would definitely provide with the information needed to recognize an object when this is not in the vision range of the robot. But one more challenge arise from this: how to acquire this data? The exploration of the object has then an importance that needs to be taken into account. Furthermore, most of the works previously mentioned focuses on the treatment of the data, but very little focuses on the reconstruction of an object model by the use of tactile data, not to mention that treating data coming from multiple sensors simultaneously remains an unexplored subject. And little work has been done on active object manipulation.

If the shape of the manipulated object is not given in advance, the points of contacts should be simultaneously localized and mapped (i.e., on-line reconstruction of the surface of the object) during the manipulation of the object. The hand should perform finger gaiting in order to find contacts with the object: at each finger gaiting (action), the robot gather a new point of contact that is used to reconstruct the shape of the object. This would take a similar approach as the Simultaneous Localization and Mapping (SLAM) algorithm, normally used in the context of localizing mobile robots in unknown environments.

After identifying the limitations in previous research, the following PhD thesis work plan is proposed:

- *Recognition and reconstruction of a 3D model of an object through data coming simultaneously from different sensors installed in a morphologic hand.*
  By using data coming from different sensors simultaneously, image-processing techniques like bag-of-features or eigen-faces, can be used to recognize the object. Since the patches of sensors will be

separated onto the hand, the result is not a complete image, but several separated ones. In order to treat them, algorithms to treat incomplete images, like the ones presented in [8] to [10] can be implemented. In addition, the kinematic model of the robotic hand will be used to know relative position of each sensor in space, which would help to infer a 3D model of the object.

- *Study the way humans explore unknown objects in order to create an exploration algorithm to be implemented in the morphologic hand to collect the data needed.*
  By using the data that the ISIR got from the HANDLE project [11], several different experiences can be designed to study how human do haptic exploration. With the data obtained from these experiences, feasible techniques of exploration in a robotic hand will be designed to be implemented and get the data correctly.
- *Using dynamic data coming from the sensors and use it not only in recognition but also for other parameters estimation, as softness, that can be used for dexterous manipulation algorithms.*
  Once the recognition is achieved, the next step will be recognizing pattern in images that would tell whether the object is deformable or not [7]. Slippery patterns will also be detected [12] by treating the dynamic data through signal processsing techniques. These parameters and the kinematic model of the hand will be used to implement an active exploration strategy of the object (such as shown in [11]) in order to recover its shape. This technique will combine spatially and temporally the results of the static reconstruction obtained in the first step of this work.
- *Using visual information to develop the 3D model and increase the list of recognizable objects as well as to transform the visual data into tactile information.*
  As humans usually use both tactile and vision information to recognize, characterize and explore the objects, integration of a vision input with tactile data will also be used as it happens in humans [13]. This vision and tactile combination will not only be used to reconstruct and recognize unknown objects, but also to recognize objects which are already known from vision. The geometrical features of these objects are to be taken into account in this case.

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