In this chapter, we present the concept of using image processing for tactile sensors as appropriate tools in localizing/recognizing objects in robotic in-hand manipulation tasks, a concept originally derived from our localized displacement phenomenon (LDP) idea. Our approach operates on a moderately high-resolution intensive array of data obtained from a tactile sensor when a robotic gripper grasps an object that is small relative to the size of the fingers. Instead of using tactile data as an array of discrete numbers, we treat the data as grayscale images. By working with successive images from the tactile sensor by exploiting image-processing tools, we are able to extract rich information about the contact situation between an object and the gripper. Experimental results show that from the processed data, one can realize the grasped object’s position/orientation, contact shape, especially the stick-slip condition on the contact surface, which is derived for the first time by this sensor. We also modeled an object-grasping gripper with tactile feedback for various postures of the object, utilizing Beam Bundle Model, and a corresponding experiment setup to validate computed results. The success of this research once again shows the potential of LDP in soft tactile systems, even for the commercialized sensor used in this chapter.

7.1 Introduction

In the field of robotics, imitating human touch is still a challenging task for anthropomorphic robotic hands. Humans can perform dexterous tasks based on not only vision, but also on rich information obtained from the touch mechanism. Even in cases of visual occlusion, a person can easily assess the characteristics of a grasped object, such as friction, roughness, and its position/orientation within the fingers. This is due to cutaneous mechanoreceptors, that include four functionally distinct types of tactile afferent [1]. These afferents have particularly high densities in the fingertips, bringing dynamical events, such as skin deformation, direction and spatial distribution of
contact forces. Recent research on robotics continues to focus on the creation of robotic hand with humanlike sensory systems to perform dexterous tasks, especially a tactile sensing system. However, to imitate all the human tactile afferents would require a complex fusion of several sets of sensors embedded under robotic skin, and there would still remain tremendous difficulties in terms of compactness and effectiveness. Therefore, recent research tends to create multi-modal robotic skin sensors that obtain information ranging from pressure to temperature sensations [20], [56]. There is another trend that attempts to perceive as much information as possible from a sole-modal tactile sensor of pressure distribution, such as texture [72], object formation and recognition [57], [84]. By using advanced technology such as piezoresistive or capacitive array devices, today’s tactile sensors have improved sensitivity and higher spatial resolution, but they are still far from human afferents. Nonetheless, tactile information has been used widely in robotic hands in many potential applications, such as object recognition and the assessing of contact states.

Conventional applications using tactile sensors attempt to extract information on force distribution on a contact surface to ascertain when contact occurs or is broken, and the location of contact. There are also numerous studies working on object recognition using machine-learning techniques, incorporating uncertainties in measurements. [57] have modeled tactile sensors using a point-spread function, and made use of tactile images to obtain local surface information during object exploring. [84] also utilized tactile images of objects, taking advantage of ”bag-of-features” in vision to propose a recognition method. A tactile sensing system is also utilized in assisting stable grasping in robotics. [68] showed that a tactile sensor could collect contact location information, enhancing the stability of a system in a peg-in-hole task. Contact point location between object and robotic finger was also mentioned in [85] and [86], as an efficient tool to localize a grasped object when vision was occluded, by using image moments. More recently, the authors in [87] and [88] have been employing tactile sensors attached to robotic hands, in companion with machine-learning techniques (Support Vector Machine, Hidden Markov Model), to estimate the stability of a given grasping task. Results promise tactile feedback could carry meaningful information for stable grasping in a blind grasp. Most of these approaches used small, coarse-resolution tactile sensors, therefore the obtained data merely brought discrete and insufficient information about the contact status. With increasingly developing technology, it is promising to create a sensor of high resolution. At that time, a different look at tactile sensors will be required, with more advanced and convenient processing methods, to bring rich and reliable information for recognition and control. Moreover, conventional research on tactile sensors only focuses on normal pressure distribution, and pays little consideration to tangential factors, such as the detection of slip action of a grasped object.

Nowadays, most of well-known robotics hand are equipped with tactile array sensors, such as PR2 [90], Barrett hand [88], Gifu-2 hand [91].