Image fusion and tracking for micromanipulation

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Abstract—In this paper, we present a method to conduct micro-image fusion and tracking. First, micro-images are matched with grouped features. Then the kinematics parameters, such as translational direction, rotational angle and axis, are deduced from inter-image relations of multiple frames based on a combination of homography decomposition and particle filter paradigm. With the kinematics parameters recovered, a mosaic of micro-images can be built up, which helps to represent the underlying micro-scene by extending the field-of-view and locate each of the micro-images in the sequence with respect to the global view. With the proposed method, localization and enlargement of the narrow field-of-view from a single micro-image can be achieved to facilitate either navigation or manipulation for micro-operation tasks.

Keywords: Micro-image fusion; micro-image tracking; particle filter.

1. INTRODUCTION

The recent investigation and discovery of the micro-world has led to rapid growth in micro-assembly operation, microsurgery, cell manipulations, integrated circuit repair, DNA handling, etc. [1–4]. In the micro-world, manipulation tasks are very difficult to handle, because the work space is not directly accessible and due to the small work space, manual manipulation always leads to low success rate and fatigue. On the other hand, many uncertain effects are introduced when the undesirable adhesion forces become dominant instead of gravitational forces in the micro-world. Since many factors, such as friction, dust, humidity, vibration and temperature, which are negligible in the macro-world, become important adverse effects for micromanipulation, conventional manipulation is usually unsuitable for micromanipulation tasks. Furthermore, the manipulation

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accuracy and tolerance of the micro-objects lie in a much smaller range compared to conventional manipulation applications. All these factors make visual sensing indispensable in improving the accuracy and efficiency for micromanipulation operations.

In the literature, visual sensing has been applied in many micromanipulation tasks to encounter the difficulties in handling micro-objects. To recognize the micro-environment and compensate the alignment error in micromanipulation, many visual recognition techniques have been developed. Pappas and Codourey proposed an approach in Ref. [5], which continuously estimates and updates the parameters describing the relationship between reference frame and the frame attached to the micro-robot by extended Kalman filter; these parameters are then fed into the micro-robot controller. However, the range of motion is very small due to the limited field-of-view. Yamamoto et al. report an estimation method based on shape matching to determine the tip position of the needle head, even within the target [6–8]. Similar methods are used in Ref. [9] to detect the pose of the grasping loop for cell manipulation and to recognize micro-objects in Ref. [10]. However, using this template matching method to detect objects typically located to 1 pixel resolution, no orientation change is allowed for an acceptable match and the computation time could be very long if no prior information is provided. Since 3D information and control are very important to some micromanipulation tasks, there are also calibration techniques developed for repeatable errors in micromanipulation [11–13]. To recover 3D information from the micro imaging system, depth estimation method [14], 3D virtual modeling [15, 16] and laser measuring technique [17], have been gradually developed. Visual feedback and servoing are also gaining increasing interest in the micromanipulation field. In Refs [18, 19] visual feedback is enhanced to help compensate the uncertainties in micro domain. A visually servoed MEMS manipulator is introduced in Ref. [20]. A CAD model based tracing and servoing system is introduced in Ref. [21].

In this paper, we propose a novel architecture to recognize and reconstruct the micro-environment with micro-images. Micro-images are the images captured from the microscope. Micro-images are widely used for various micromanipulation tasks. However, due to the high magnification of the microscope, these images are sensitive to noises caused by temperature changes, vibration, humidity difference, etc., and the field-of-view of micro-images is usually very limited. Furthermore, repetitive patterns often occur in micro-images. To overcome the problems mentioned above, such as micro-images recognizing and limited field-of-view, in this paper we propose a method that integrates both visual modeling and tracking. Micro-image fusion is proposed to enlarge the field view, particle-filter-based kinematics parameter recovery is utilized to track the micro-object and relocate the operator field-of-view through the microscope. The proposed method contributes in interpreting the micro-environment from micro-image data and reducing the operator’s burden to locate the interested region under the microscope.