GERMANY/HONG KONG JOINT RESEARCH SCHEME
THE PROJECT REPORT
(for Project Completion)

Project Number: G_HK002/11

Title

Micro-vision Based 3D Tracking for Biological Cell Injection

Particulars

	Hong Kong team	German team
Name of Project Co-ordinator (with title)	Dr Youfu Li	Prof Sergej Fatikow
Name of Co-Investigator (if any)		Miss. Christian DAHMEN , Mr. Robert TUNNELL , Mr. Michael WEIGEL-JECH , Mr. Tim WORTMANN
Institution or Institutional affiliation	√ CityU; ☐ CUHK; ☐ HKBU; ☐ HKIEd; ☐ HKU; ☐ HKUST; ☐ LU; ☐ PolyU	√ University of Oldenburg; ☐ Others: _____
Other project team members (if any)		

Funding Period

	1st year	2nd year (if applicable)
Start Date	1/1/2012	1/1/2013
Completion Date	31/12/2012	31/12/2013

Objective(s) as per original application

The objectives of the project include the following:

1. To provide a novel means for the important and difficult tasks in introducing 3D visual information in micro manipulation by introducing a Localization Reference Object;
2. To implement tracking of the pipette's depth motion;
3. To explore 3D tracking of the pipette tip with micro-vision;

Details of Report [Please attach relevant document(s)]

i) Outline of proposed research and results obtained

In this project, we propose to explore 3D tracking of the pipette tip with micro-vision. Among others, the objectives of the project include investigation into a novel means for the important and difficult tasks in introducing 3D visual information in micro manipulation and the implementation of tracking of the pipette's depth motion.

Tracking the depth of the end-effecter has been a long-standing problem in micro manipulations. As an optical microscope is widely used in cell injection systems, it is highly desirable to use this microscopy visual information for tracking the injection pipette. To the visual sensing, there are two major problems with pipette tracking: (1) As the pipette is a transparent glass tube, its image features are dependent on both reflective and refractive optics and presents complex variations when the Z-axis distance varies. (2) The sensitivity of image appearance variation with depth motion is non-linear and decreases as the pipette gets farther from the microscope focal plane. Thus the focus cues can reveal the pipette's depth reliably only within a region near the focal plane, which results in a limited work space. Solving the above problems would enhance much the automation level in micro-manipulation. During the whole process of operation, as the proposed use of a reference object could present a 'clean' image neighborhood, a low computational cost computer vision algorithm would be able to yield robust and precise 3D estimation in real time.

In this project, the formulation of the methodologies relevant to the above proposed work has been studied. In particular, some challenging issues in 3D visual sensing and tracking have been tackled. In studying general target tracking problems [1], a vision system was set up which is robust to illumination. According to the characteristic of the proposed system, a rotating adaptive Haar wavelet transform was developed for tracking tests. The proposed feature can effectively handle the nonisotropic distortion of catadioptric vision system. For robust tracking, we develop a rotational kinematic model based adaptive particle filter, which can handle various movements including rapid movement. The proposed tracking algorithm can well deal with some short term occlusion as well [1].

As a well known problem in stereo vision systems, the short baseline problem which highly limits the measurement accuracy in a short baseline arrangement stereovision system. In tackling such a problem, we present a new and different projecting-imaging model for 3-D measurement error analysis [2]. We explored the exact mathematical model that exists between the height of an object's surface, the phase distribution map and the parameters of the setup. Then, some practical considerations are taken into account to improve the measurement accuracy. By studying the problem of how uncertainty of the parameters in the proposed model would affect the final measurement accuracy, we gave a rigorous analysis on the baseline length between the projector and the camera. In City University of Hong Kong, a prototype the 3D vision system needed for studying the short baseline issues have been set up [2]. In the Div. Microrobotics & Control Eng, Dept Comp Sci, University of Oldenburg, a micro-vision system has been set up that can give 3D information based on stereovision and attempts have been made in using the 3D information in guiding micro-handling and even nano-handling. This complements the methodological studies using normal scale vision systems built in City University of Hong Kong.

ii) Significance of research results

Incorporating 3D visual measurement is very important in many applications including micro- or nano-handling. In this work, we made some useful attempt in studying the issues relevant to this. The investigation of suitable and effective visual sensing and tracking technologies is of paramount importance to automated micro- and nano-handling strategies. In studying the tracking problem, we developed a tracking method that integrates a kinematic model based adaptive particle filter with a wavelet transform. The proposed method can not only handle the nonisotropic distortion in the vision system but also effectively deal with various motions. Short baseline problem is common to 3D vision systems and it needs to be explored for micro-scale visual sensing in particular. In this project, some error analysis is performed based on a 3-D shape measurement with a short baseline. With a model based on conventional stereovision, the measurement accuracy will be limited from the biased parameters of the system and biased pixel point localization. Through analysis, it is found that the factors will become more uncertain when the baseline decreases. Hence, we proposed a geometric projecting-imaging model based on fringe projection profilometry technique. By exploring the new phase to height mapping relationship, measurement errors in particular the depth/height error is analyzed with respect to the length of the baseline. The above research is very important to the field of industrial robotics and automation for applications at micro-scale. The 3D visual sensing with proper sensory feedback in the tracking will significantly enhance the level of automation in micro-handling robot work cell.

iii) Research output

1. Y. Tang, Y. F. Li, T. Bai and X. Zhou, Rotating Adaptive Haar Wavelet Transform for Human Tracking in Thermal Omnidirectional Vision, *2012 **IEEE** International Conference on Multisensor Fusion and Information Integration (MFI 2012)*, Hamburg, Germany, pp. 324-329, Sept. 2012. (Finalist for best conference paper)
2. J. Liu and Y. F. Li, Performance analysis of 3-D shape measurement projector-camera system with short baseline arrangement, ***IEEE** International Conference on Robotics and Biomimetics (ROBIO 2013)*, Shenzhen, China, pp. 1444-1449. Dec. 2013.

iv) Potential for or impact on further research collaboration

In this project, we investigated the feasibility of incorporating 3D visual measurement in the tracking for micro-handling applications. In this work, we proposed a geometric imaging model in 3D visual sensing based on fringe projection profilometry. By exploring the new phase to height mapping relationship, measurement errors in particular the depth/height error is analyzed with respect to the length of the baseline. The above research is very important to the field of industrial robotics and automation for applications at micro-scale. The above investigations are further on-going in implementing the short baseline in a micro-vision system for cell handling, in City University of Hong Kong with collaboration between the PI's research group and another one in the dept of Mechanical and Biomedical Engineering.

In the German partner's institute (AMiR) at the University of Oldenburg, the importance of 3D vision for micro and nano handling is well noted and they are actively looking into the relevant issues. In fact, an important focus of their research is on microsensing including vision. In particular, a group of researchers in AMiR have studied vision feedbacks for micro and nano manipulation. Being able to incorporate 3D measurement in their micro vision system have been an aim for their work. Through the joint project, effective communications between researchers on the two sides have been established. This will certainly enhance future research collaborations in this area. In fact, efforts are being made in extending the research for further collaborative work towards implementation of 3D visual tracking in micro-manipulation.