A Multiscale Calibration of a Photon Video Microscope for Visual Servo Control: Application to Micromanipulation

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Abstract *– Since many years the need of automated microassembly systems i.e. systems to assembly micrometric parts, MEMS (Micro-Electro-Mechanical Systems) , MOEMS (Micro-Opto-Electro-Mechanical Systems) etc., becomes more and more necessary because of the development of micro components based products. The corresponding tasks (supervision, control, quality inspection, ...) involve accurate metric measurements from images. The main image source is the photon videomicroscope whose features are the weakness of the depth-of-field and that of the field-of-view. The paper deals with the modelling and calibration of that kind of imaging system. A multiscale calibration paradigm is proposed and validated by means of a commercial video microscope. The model is derived from the usual perspective model. The latter is simplified by considering a single scale factor and then the link between the zoom and that scale factor is established. The calibration is performed through a virtual pattern made by tracking a silicon micro part in the images of the scene. The final error between the projection of a pixel and its model is about 1.45 pixel indicating the accuracy of the approach. At the end, the model is used to perform a visual servoing whose purpose is the aligning and centering of a micropart with a gripper.*

Keywords *– Calibration, multiscale, photon video microscope, virtual pattern, visual servoing, microassembly, micromanipulation*

I. INTRODUCTION

Contrary to macroscopic and mesoscopic scales where assembly can be achieved without images of the scene, manipulation at microscopic scale always requires images. The manipulation of biological objects like pollens or ovocytes are typical examples of micromanipulation. But since many years the manipulation of artificial objects like monolithic microcomponents, MEMS and MOEMS, has emerged. In that case the images represent the views of the work scene from which a lot of metric informations can be derived : the pose of a component or a gripper, the distance between a component and a gripper, the speed of a gripper, ... Those data are required for the 2D or 3D reconstruction of the scene, the quality inspection or the control of manipulators.
Microassembly corresponds to assembly at the microscale, and implies the manipulation of components where the size ranges between 1 μm and 1 mm and the accuracy about 1 μm ([8]), ([6]), ([11]). As a consequence the photon videomicroscope is required as the image source in the set-up devoted to that task. The latter exhibits high resolution, but has two drawbacks which are the weakness of the field-of-view and that of the depth-of-field. For the system used in the experiments exposed below (LEICA MZ16A) the field-of-view is 700 μm x 900 μm at the maximum of the zoom, the depth-of-field varies between 2.9 mm and 0.035 mm according to the numerical aperture of the objective. Those elements complicate the calibration and use of the video microscope.
The paper deals with that problem of calibration. Some solutions have been proposed in the literature. The main is that of Zhou and Nelson ([2]). These authors point out the differences between a standard image source (with a standard video lens) and a video microscope. They model the latter by the usual perspective non linear model in which the optical tube length T_{op} is introduced in the equations. In fact, many microscopes include a tube between the sensor and the lens (whose focal length is noticed f) in order to increase the magnification. As a consequence the field-of-view as well as the depth-of-field become weak. The parameters of their model are T_{op}, f, d and k_1 where d is the distance between the object plane and the front focal plane and k_1 is the lens radial distortion. Tsai algorithm ([10]) is used to compute the above parameters and the extrinsic ones (the three Euler angles α, β and γ), and the translation vector $(T_x, T_y, 0)^T$ of a fixed zoom and focus video microscope. The calibration sample is made of squares of 10 μm side etched in a glass plate. Ammi et al. ([1]), Daflon et al. ([2]) consider the linear perspective model but use a virtual 3D pattern: a target point is tracked in the images of the scene. In the case of Ammi et al., the calibration approach of Zhang ([12]) is modified considering simplification due to microscope imaging. Figl et al. ([4]) consider the linear perspective model and the algorithm of Tsai in their experiment of calibrating a variable zoom and focus microscope. A non linear model including non paraxial distortion is introduced by Danuser ([3]) in the modelling of a stereo microscope.

In the first section of the paper the linear model of the video