Automated Assembly of Hybrid Microsystems

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Abstract

The paper describes the design of a system for the automated assembly of hybrid microsystems and the accuracies of the components. The influences on the accuracy will be analyzed on the basis of an example for an automated assembly process. While the object sizes reach centimeter range, they have to be assembled with an assembly accuracy of only a few micrometers. A relative positioning accuracy of 0.8 µm is reached in this process.

1 Introduction

Nowadays, an ongoing trend of miniaturization of products and components can be observed in nearly all application areas in the world. In this context, a distinction is drawn between monolithic and hybrid microsystems. The latter group requires some kind of assembly process. For the assembly of hybrid microsystems, a high assembly accuracy in the range of a few micrometers is required. In order to reach this accuracy, an assembly system for sensor guided microassembly has been developed at the Collaborative Research Centre 516 "Design and Manufacturing of Active Micro Systems".

2 Assembly system

The size-adapted assembly system (fig. 1) consists of a parallel robot "micabo^{F2}" with high accuracy and an integrated 3D vision sensor with only one camera. Additional components are an assembly fixture and part trays for the adjustment of parts inside the robots workspace.

The robot "micabo^{F2}" [1] has 4 degrees of freedom (DOF) for part handling and 1 DOF for focusing the vision sensor. The workspace enfolds 160 x 400 x 15 mm³. The control of the parallel linear drives can hold the desired position with an encoder resolution of 0.1 µm. In accuracy measurements according to EN ISO 9283 [2] the robot "micabo^{F2}" achieved a repeatability of 0.6 µm. This high repeatability is a good precondition for a microassembly process.

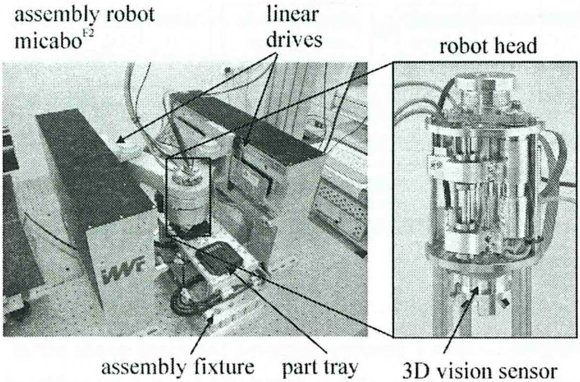

Figure 1: Size-adapted assembly system

The 3D vision sensor [3] needs only one camera and a single image for a 3D imaging process by applying the principle of stereo photogrammetry. It is based on a 3-dimensional reconstruction of the objects from a pair of images. The field of vision has a dimension of 11 mm in length and 5.5 mm in width with a resolution of 19 µm/pixel. Repeatability measurements showed standard deviations of $\sigma_x = 0.092$ µm and $\sigma_y = 0.114$ µm.

A real-time system is used to control the assembly system. It features a PowerPC750 digital signal processor (DSP) running at 480 MHz. Two different control loops (fig. 2) are used for the integration of the sensor information in the control system.

The process control gives commands to the robot control and demands information from the vision sensor system. The internal control loop works at a system execution time of 0.2 ms. The outer control loop works with 1 ms and contains the 3D vision sensor, which sends information about relative positions of the assembly group to the process control. A resulting vector of the current position from the robot control and the relative position vector from the vision system is calculated inside the process control and transmitted to the robot control.

At present, the sensor guidance works according to a so called "look-and-move" procedure. This means that the robot's movement stops before a new imaging process starts and a new position correction is executed.

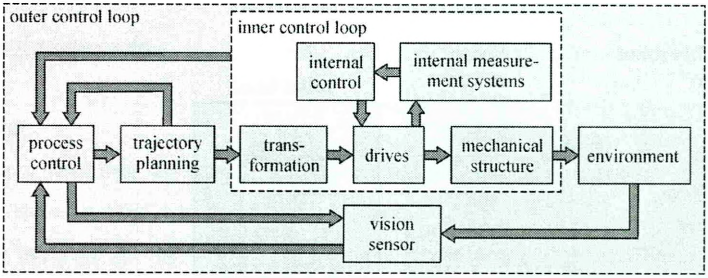

Figure 2: Control of the assembly system

3 Microassembly Process

A major task of the assembly system is to validate principles for the assembly of hybrid microsystems. As an example, the assembly of a linear stepping motor, according to the reluctance principle, is described. The motor parts were mainly manufactured with micro technologies developed at the Collaborative Research Center 516. One assembly task is the joining of guides on the surface of the motor's stator element. In Figure 3 (left) the assembly group of two guides on a stator is shown. The right image shows the view of the 3D vision sensor on the assembly scene.

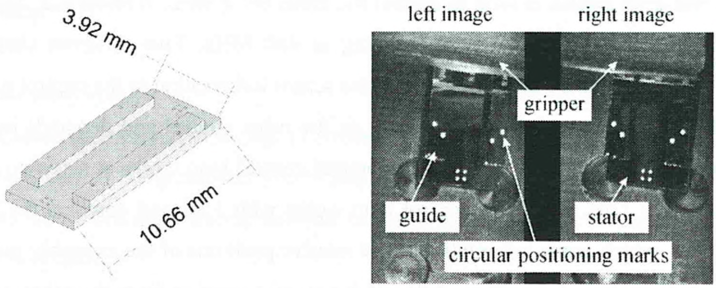

Figure 3: Assembly group guides on stator (left); view of 3D vision sensor (right)

Circular positioning marks on the group of components, which are manufactured in a photolithographic manufacturing process, are used by the 3D vision sensor for the imaging process. The positioning marks (4 on stator and 2 on each guide) in both images are measured and a resulting relative position vector is calculated. If a positioning precision of <0.8 µm is reached in the xy-plane, a last relative position correction is executed by a movement in z-direction (height) of the robot, which completes the assembly process.

Positive influences on the accuracy of the automated assembly process are a high repeatability of the assembly robot and the 3D vision sensor and narrow tolerances of the geometry of the assembled parts and of the assembly fixture. Negative influences include varying light conditions and tilted planes of the group of components. Therefore, an integrated lighting module ensures stable light conditions. The proper adjustment of the gripper and part trays is necessary for a high assembly precision.

4 Conclusion

In the above described assembly process, a relative positioning precision of 0.8 µm is reached with the presented size-adapted assembly system. Due to the relatively large part sizes (10 mm x 8 mm) and displacements of the parts during the z-movement in the assembly process lead to an assembly precision in the range of (1...30) µm.

5 Acknowledgement

The authors gratefully acknowledge the funding of the reported work by the German Research Center (Collaborative Research Center 516).

References:

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