

Micro and Meso Scale Robotic Assembly

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The focus of this paper is on a set of meso and micro scale robotic tools for the assembly of systems in which the size of the parts being manipulated and/or the assembly tolerances are of the order of microns or less. Here, a robotic system is defined as one that includes sensors, processors and/or actuators capable of emulating some of the perceptual, cognitive and/or motor skills of humans.

The major driver for microrobotic assembly of microsystems is the combined need for high precision and high throughput at low cost. In order to accomplish this objective, we use a three-pronged approach.

- Multiscale manipulation. The goal is to combine the large motion range of low precision devices with the high positioning precision of successively smaller devices that have limited motion range.
- Parallel manipulation. The goal is to achieve orders of magnitude speed-up by using arrays of micromanipulators performing the same task, e.g. [1]. Gripper-free manipulation is an alternative method that uses force fields rather than mechanical contact, e.g. [2].
- Modularity. The goal is to reduce set-up time through modular designs that enable the rapid reconfiguration of assembly cells. This is a particularly powerful approach at the microscale, given the possibility to design an extensive library of microparts from which highly customized assembly cells can be rapidly configured to match the requirements of a broad diversity of assembly tasks.

A few illustrative examples of this approach are presented in this paper, based on work done at the Center for Advanced Technology.

1. Coarse - Fine Positioning

Figure 1 shows a reconfigurable robotic system for the precision assembly of components with microparts [3]. The system consists of five subsystems, tied together via a PC running a supervisory control program.

- A coarse positioning system.
- A fine positioning system.
- A gripper and fixturing system.
- A high-resolution vision system.
- An adhesive dispensing and curing system.

The main premise of this design includes the ability to quickly reconfigure assembly tasks, and replace system hardware, such as adding sensors and fixtures. The high level control application interfaces with different subsystems independently, using multithread routines coordinated via a separate assembly planning and execution thread.

A general purpose, large space positioning robot, RobotWorld by Yaskawa, is used as a coarse motion manipulator. It has four degrees of freedom (x, y, z, θ). Several “pucks” are used to hold various end-effectors. One of them is a microgripper for handling optical fiber. Another end-effector includes a syringe tip and UV curing lamp used by the adhesive dispensing and curing system. Motion parameters are transferred to the main control program via TCP/IP Ethernet communication. For achieving micron level accuracy, the system is equipped with a fine motion manipulator that has four degrees of freedom (x, y, z, θ). The same PC-based DSP motion control card is used to control the fine motion manipulator, the microgripper, the UV adhesive dispensing and curing system, as well as the part fixturing system. The relative position between the fixture and the assembled parts is determined by a vision system using a $\frac{1}{2}$ ” CCD camera, optics, and the Intel Open Source Image processing libraries.

The system was used to pick and place microlenses, to assemble optical fiber arrays, to terminate fibers with pins and sockets, and to assemble RF diode arrays (fig.2).

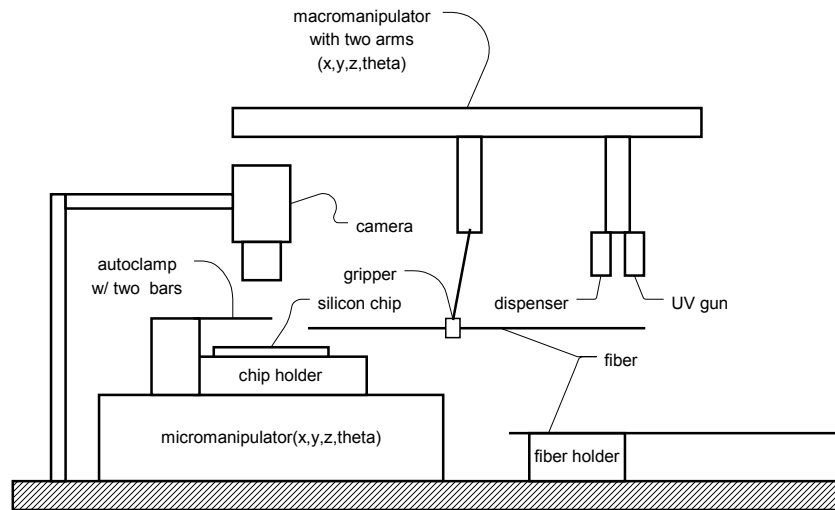
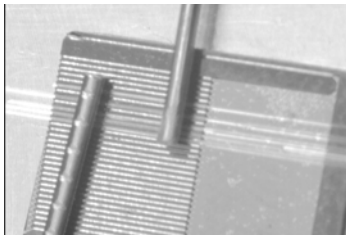
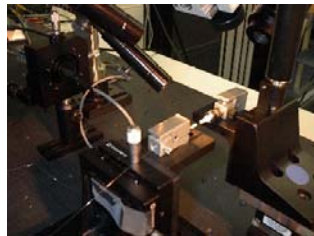


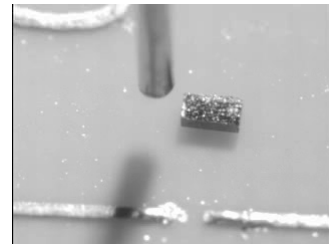
Figure 1. Reconfigurable assembly system



2a Fiber arrays



2b Fiber terminations



2c Diode arrays

Figure 2. Applications

Figure 3 shows a device with a two degree of freedom remote center of rotation, developed by Dr. Yves Bellouard at RPI. The joints are made with flexures, which eliminates backlash, stick-slip effects, and wear. Furthermore, the joints are linear since they use the elasticity of the material. A stainless steel prototype was built, measuring 85mm x 85mm x 60mm, with a range of motion of ± 2.5 deg. The device was equipped with a submicron adjuster, and has a resolution of 0.9 mdeg, accuracy of 0.02 mdeg and repeatability of <0.02 mdeg. It was designed for the precise positioning of fibers by defining the center of rotation at the tip of the fiber. Because of its modular design, the mechanism can be rapidly reconfigured.

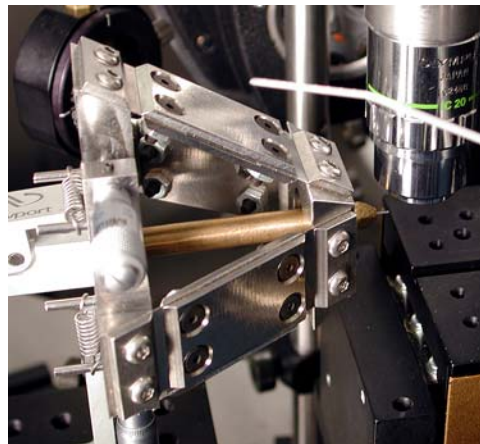


Figure 3 Remote Center of Rotation Device.

2. Parallel Microassembly

Figure 4 illustrates a parallel assembly architecture that is being explored as part of a collaborative effort with the Zyvex Corporation under funding from the NIST ATP. It uses a 2D array of microrobots sharing a Cartesian platform. Typical link dimensions are of the order of hundreds of microns, while typical operations may include pick and place, alignment, and compliant insertion.

Key research issues include:

- Kinematic design optimization to accommodate task dependent requirements for maximum
 - range of motion
 - stiffness or compliance along selected axes
 - positional accuracy along selected axes
- Dynamic modeling and optimum motion control
- Motion planning algorithms for compliant insertion and fault tolerance

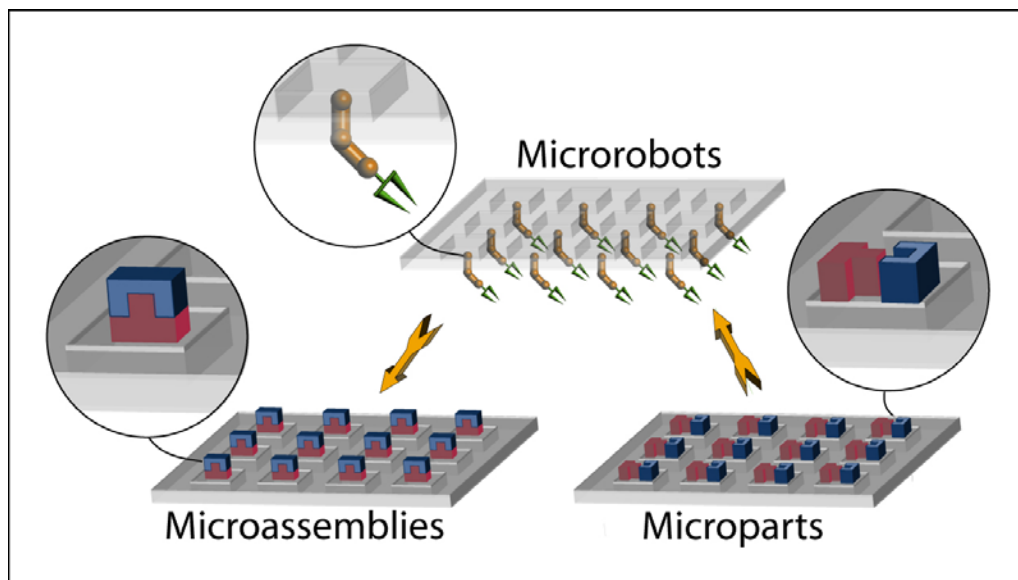


Figure 4. Parallel manipulation

3. Summary

The cost effective assembly of heterogeneous microsystems requires modularity, parallelism and a multiscale approach. Several examples were used to illustrate on-going work in these areas.

4. Acknowledgement

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5. References

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