Publishable Summary

Popularity of micro systems has been increasing steadily over the recent years due to advances in manufacturing of such small scale systems. Micro (and nano) scale components are usually designed after a long, complicated and expensive process. The tasks are performed by highly trained personnel and the devices are manufactured in extremely specialized facilities with strict external requirements (temperature, humidity, vibration, etc.). Potential application of modular design and development techniques at micro scale introduces many benefits. It will increase the focus of researchers on building one (or fewer different types of) dependable micro module(s) rather than tackling each design problem separately. The development and research effort can then be concentrated on solving common problems. As a result, a mighty and dependable micro module can be mass-produced at an affordable price, which can be used in many different applications. Using one type (or few types) of micro mechatronic components will increase the number of skilled developers who are familiar with the component's mechanical and software structure. Conceptually, the proposed micromechatronic device will have an outer shell with multiple contact interfaces that handle mechanical and electrical interaction among devices in a pack (Figure 1). It would include a micropower plant (and storage) unit, microsensors and actuators as well as a microcomputer, all of which are connected to a cell bus handling both power and communication among the cell components. A group of these Mechacells (Mechacell Pack) can perform tasks under different conditions, sharing mechanical, electrical and computing resources. Some of the technologies that will make the mass produced micromechatronic cells feasible are currently under development or available at a very large cost. A good example of this is the availability of micropower plants.

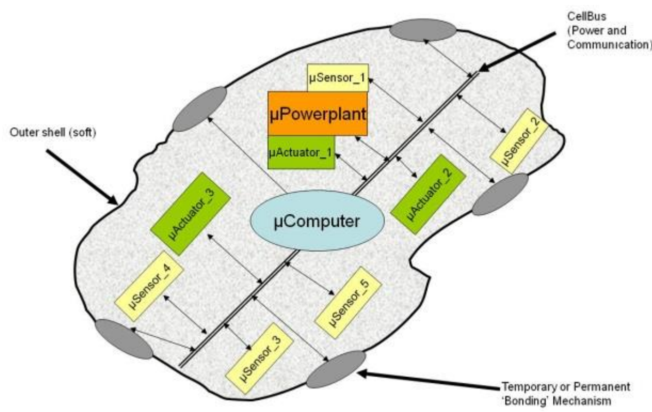

Figure 1 micro Mechatronic Cell (MechaCell) and its components

Specifically, the project achieved three important objectives:

1. Develop design requirements for a representative application.
2. Develop mathematical and empirical models for the MechaCell Prototype and a pack of MechaCells.
3. Develop a macro scale positioning testbed.

Three alternative prototype solutions for the MechaCell device were developed initially (Years 1-2). A simulation model including the mathematical models for the proposed device and a baseline controller which is used for different scenarios for the positioning study are developed. In the second phase of the project (Years 3-4) the actual experimental testbed and prototypes for the positioning studies is built (Figure 2).

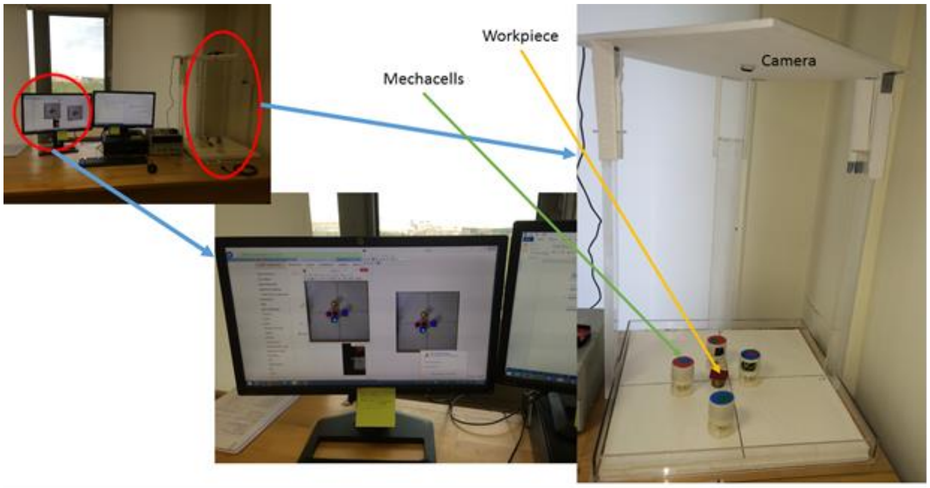

Figure 2 MechaCells and the Test Bed

The implemented version of the MechaCell device has three actuators for motion in two directions and rotation about itself about itself by use of a novel steering mechanism.. It carries a micro accelerometer and a pressure sensor to measure the load on contact and communicates with other MechaCells and the supervisory controller via wireless Bluetooth connection.

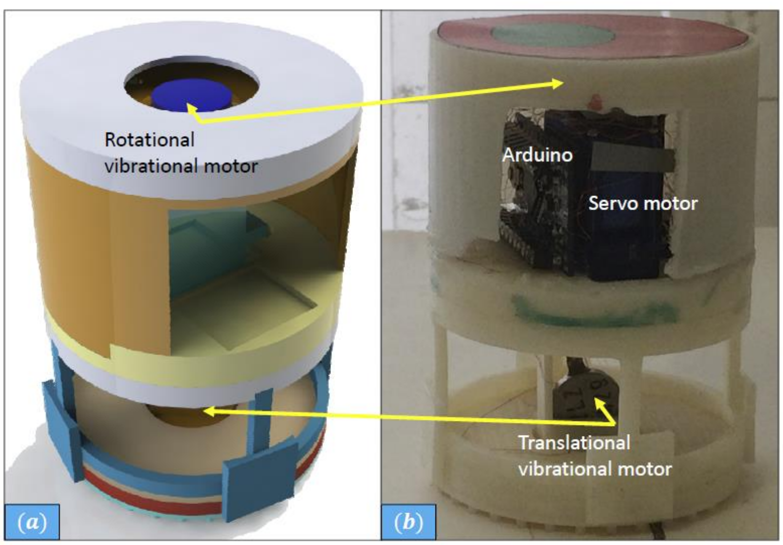

Figure 3 Actual and CAD drawing of the developed Mechacell

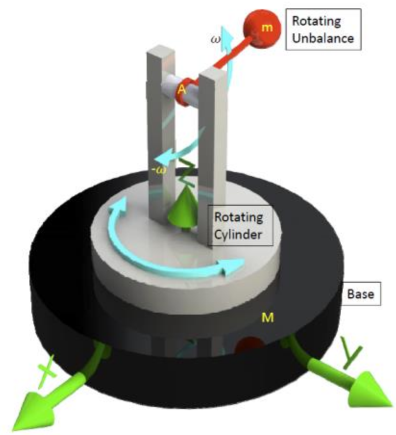

Figure 4 Steering of the MechaCell with 3D rotating unbalance system

MechaCell devices are actuated with two separate and mutually independent mechanisms: translational section and rotational section. Translational section translates the MechaCell in the xy – plane, and rotational section rotates the device about its own axis. A novel approach has been taken in the design of the locomotion mechanism for this module. Vibrational force produced by a rotating unbalance moving in 3D spherical space is used for both steering and locomotion as shown in Figure 4.

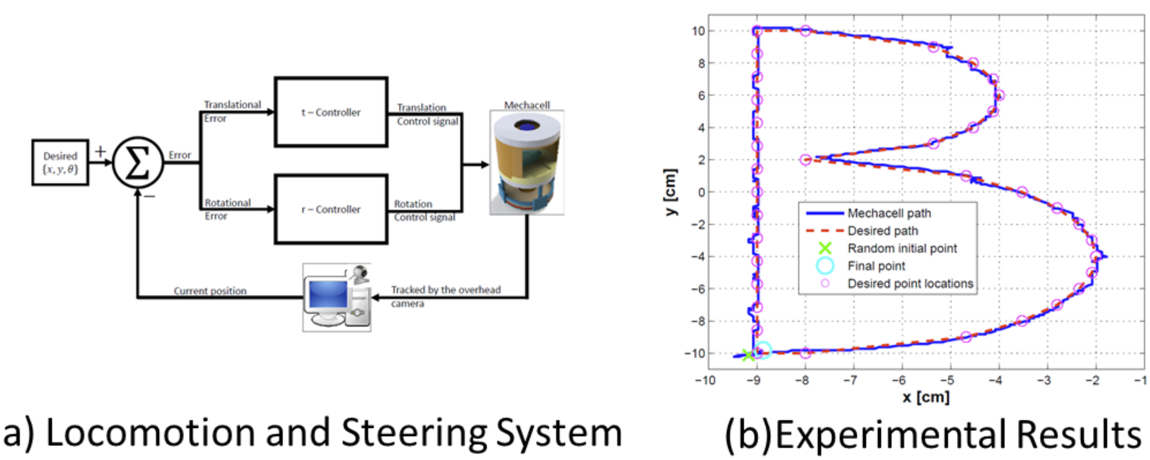

Figure 5 Testbed Results

The test bed houses a high definition camera system where the position of each MechaCell and the work piece is monitored and send to all peers in real-time. MechaCells can also use the on-board accelerometer measurements for emulating different distributed autonomous operation scenarios such as gracefull degradation and profile tracking (Figure 5).

The developed mechaCell prototype and the testbed system combination promise high value, high impact research opportunities such as distributed dexterous manipulation of hard to reach delicate workpieces. The initial results of the project produced one conference and two journal publications currently under review.