Development of a Bead Manipulator Module for a Biofabricator

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Statement of Purpose: A significant challenge is to extend current biofabrication techniques, e.g., bioprinting, to build three-dimensional structures[1]. Anchorage dependent cells need a solid surface to facilitate growth. One possible approach is to precisely place an array of polymeric structures in layer-by-layer deposition[2] as shown in Figure 1.

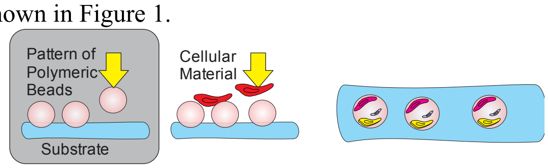

Figure 1: Bead component in a 3D tissue structure.

A pick-and-place robot with vacuum-based bead manipulation is proposed. It is difficult to create a geometry for the port that contacts the bead in order to reliably pick up only one bead from a bulk container. This work demonstrates the use of image analysis and vacuum to identify and pick up a single bead as the key component of an automated system.

Methods: A diagram of a prototype of the system is shown in Figure 2. MATLAB (The MathWorks, Inc) software controls a robotic arm (Lynxmotion), performs image processing, and controls the vacuum system. A USB 16-Servo Controller (USC01A, Pololu) interfaces the robot to the computer. An end effector was formed by squaring off the end of a 20 gauge needle. An opaque box was built around the system with a light inside to control the lighting for the camera. Using image processing (MATLAB Image Processing and Image Acquisition Toolboxes) beads are identified and their location stored.

In this demonstration, 0.75mm polylactide beads were scattered on an acrylic plate. An image was taken with the camera and the beads identified. Registration points on the acrylic plate were calibrated to the equivalent robot position, where the space between two points was used as a scale to convert pixel distances to robot units (1/2 inch per every robot unit). The needle moved to a bead and then paused. A relay, controlled by the Pololu board, was used to activate the vacuum. The designated bead was vacuumed onto the needle, and the robot moved the bead to a designated location, where the vacuum was released. In future use, this process would be repeated to form an array of beads.

Results: By calibrating the camera location to the robotic arm location in space, the robotic arm moved to a determined bead location. Figure 3 shows the original image captured by the camera; the two black dots in the bottom left of the left image are the registration points. The processed image used to determine the bead locations is shown in the right side of Figure 3. The vacuum end-effector with a bead that was picked up from the plate is shown in Figure 4.

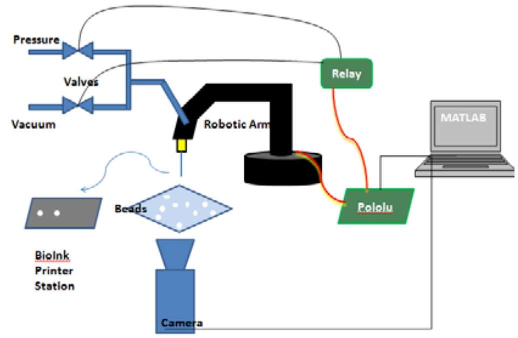

Figure 2: Diagram of prototype system.

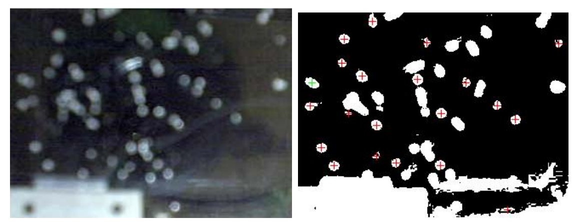

Figure 3: Image captured from camera (left). Image thresholded to identify beads (right).

Figure 4: End-effector with bead

The basic concept to identify and pick up single beads was validated. The testing was greatly hampered by the precision of the prototype robot, but as an estimate of success, approximately 8/10 beads were picked up when the robot was properly positioned. Release of the beads shows that air pressure will be needed to reliably release the bead from the chuck.

Conclusions/Future Work: This design shows great potential for manipulating absorbable beads. By picking up the beads one at a time, a flexible system can be made to place any desired array of beads. The robotic arm will now be improved to create more accurate positioning in order to allow implementation of the module in a bioprinting system.

References: 1. T Burg et al., *Phil Trans R Soc A*. 2010; 368:1839. 2. KJL Burg et al., *IEEE EMB* 2003; 22:84.

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