Construction of a Cost-Effective Organ Printer

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***Abstract*- Bio-printing is a process that involves patterning of cells to create 3-dimensional tissue constructs. When many bio-printed layers are combined, they can be used produce complex architectures and, potentially, organs. Applications for organ printers are numerous and include both fundamental research as well as an alternative source for organ transplants. The purpose of this design project is to create an organ printer that is more cost effective than current organ printers as well as to minimize the size of the printers.**

I. Introduction

Bio-printers are currently used in laboratory settings to create tissues that can be used in research studies. The current problem with bio-printers that are on the market today is they are often not able to print more than one type of cell at a time, and organ printers are typically extremely expensive because of the research and development costs that come with developing new technology. Having the ability to print organs for patients whenever they are needed would be beneficial to hospitals since some patients currently wait for a period of time on the order of months-to-years to receive a transplant [1].

The long wait for an organ transplant is primarily due to the low supply and high demand for specific tissues [1]. Many of those same patients on transplant wait lists die of organ-related illnesses because they are not able to wait a long period of time for an essential organ, such as a heart. Organ printers would provide a way for doctors and surgeons to print the specific organ that the patient needs, including the ability to tailor the structure with the anatomically correct dimensions for the target patient.

For this design project, an organ printer will be constructed for use in clinical, academic, and/or research settings. Thus, the goals are to obtain optimal bio-printing results while maximizing cost-efficiency. Another aspect of this design project is to be able to print different types of cells, such as cardiac cells and stem cells, so that there is a wider range of tissues that can be created with the organ printer. This paper describes the design concept for the newly developed organ printer along with preliminary results.

II. Customer Needs

The printer must meet a set of criteria in order for the project to be considered successful. The main customers of this organ printer would be hospital staff and laboratory staff. It would be essential for the staff to know how to use the printer to prevent injury to themselves and to prevent damage being caused to the components of the printer and the printer itself. Several of the highest priority needs that were considered when creating this system were the easy removal of the manufactured organ from the printer, printing resolution in three dimensions, the short- and long-term viability of the printed structure, and a printing environment that is biocompatible. These needs are essential in ensuring that the printer produces organs and tissues that are sterile and can be used in an emergency patient surgery.

Several of the other needs that were considered in the development of this printer were the ease of loading gel and cells into the syringe pump, programming requirements for the specific organ or tissue to be manufactured, amount of time to print the specific structure, and the survival rate of the cells prior to the printing of the organ. These needs were prioritized lower than the previously described needs because they are necessary for the project to be a success, but they are not as critical in the early stages of development.

III. Materials and Methods

The basic concept of the printer involves a print head that scans in the X-, Y-, and Z- directions as it deposits cells, thus building a three-dimensional tissue construct. The printer contains two vertical walls that connect to a bottom plate that also joins the X- and Y-axes. Two motors are utilized to move the print head carriage in the X- and Y-direction, whereas a linear actuator is used for movement in the Z-direction. A bracket will be connected to the bottom of the linear actuator; the bracket will be attached to the syringe tube that will dispense the cells that are suspended in the bio-ink solution. An Arduino Mega was chosen to control the motors of the printer. The casing for the printer, as well as the threading which moves the X-axis, were designed and fabricated previously. The Arduino Mega is programmed by code that is created using the Arduino IDE software. The code controls the EasyDriver that is housed on an electronic breadboard, which will direct the motors regarding direction and step length. The code will include a set of base instructions that will be customizable depending on the organ that is requested by the hospital or laboratory staff. Figure 1 displays a flow chart that describes how the information will be transmitted to the printer.

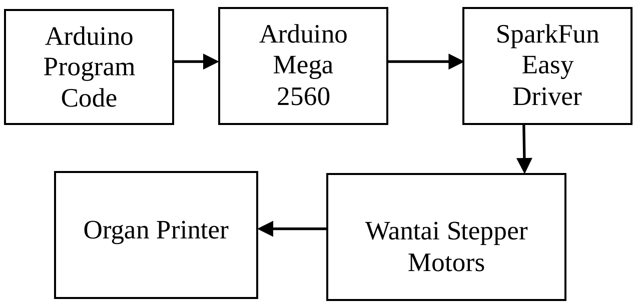

Fig. 1 – Block Diagram of the Motor Control of the Stepper Motors

The code that controls the movement of the printer is created in Arduino and uploaded directly to the Arduino Mega 2560. The Arduino Mega is powered via USB connection to a laptop computer from which the code has been uploaded. The Arduino powers one of the positive rails of the breadboard, and it also directs the SparkFun EasyDriver, which controls the step length and direction of the motors. A power supply is used to provide power for the EasyDriver and Wantai stepper motors. The movement in the Z-axis is controlled by the Firgelli linear actuator. Figure 2 shows the current state of the printer foundation. The linear actuator is shown in the center of the image.

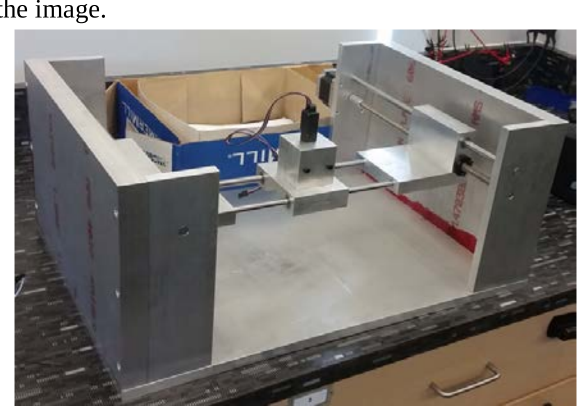

Fig. 2 — Organ Printer Foundation

The objective of this design concept is to make the development of the organ printer as simple as possible, while simultaneously keeping the cost as low as possible. The components of this design are relatively inexpensive and easy to access, so they can be replaced easily if the part appears to be malfunctioning. The code that controls the movement of the printer is also created to be as user friendly as possible; the code is designed so that it can be debugged with little to no technical expertise for the user. The ideal program would have the capability of selecting a pre-programmed organ with the desired measurements included as user inputs in the program.

IV. Verification and Validation

A variety of verification and validation tests are envisioned to evaluate the system. Verification testing will commence in the spring of 2017 when the Y-axis has been installed along with the bracket for the syringe tube and needle. Preliminary testing has been performed to confirm that the components that are already created are functioning properly for the task that they are designed to perform. As construction of the printer continues, the testing for each component of the printer will continue. Several of the tests to verify the design of the organ printer include determining whether or not each of the 3 axes operate in the direction that is specified, ensuring that the printer is small enough to fit inside of a fume hood (which would provide the most sterile results), and monitoring the printing time to ensure that the cells have the best chance to survive the printing process.

V. Discussion

The creation of a low-cost organ printer that can be made available to hospitals and laboratories would enable access to bio-printing for a wider range of facilities. Additionally, it could eventually help boost the supply of organs available for transplants in case of an emergency surgery in a hospital. Ultimately, the ability to lower the total cost of an organ printer will allow more research and clinical facilities to invest in an organ printer that could be beneficial for their work in the long-term.

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