3D Tissue Scaffold Printer

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Goal and Challenges

The goal of this project is to develop a machine which is able to produce a meniscus scaffold. By weaving polymer string on a pin board, this machine can manufacture a meniscus scaffold which can have collagen injected into it. Finally, the meniscus scaffold with collagen will be capable of being used as knee tissue regeneration. In order to produce a meniscus scaffold, the machine is designed in three parts, a weaving system, meniscus pin board and collagen system. In addition, a path-planning algorithm is design to analyze native meniscus contour to generate vital weaving paths.

In this project, the main challenges are:

1. The design of the prototype weaving machine.
2. How to set up the communication between machine and computer.
3. How to analyze the contour of native meniscus and to apply current weaving method to it.

Motivations and Objectives

Meniscus is a soft tissue in human beings knee. It is a part that can be torn when people do sports or work. There are around 600,000 knee arthroscopies need to be done according to some research. Meniscus is not capable of healing itself. If patients do not have their meniscus repaired or preplaced, they will suffer pain from their knee after just removing the broken part of meniscus out. Thus, a great number of artificial meniscus need to be produced in order to help patient heal their knee. Right now, manufacturing a meniscus scaffold by hand takes 8 to 10 hours. It is not efficient and cost money. Therefore, we design a 3D tissue printer to produce meniscus automatically. It saves the cost of labor force and time.

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Advising professor W. Jiang
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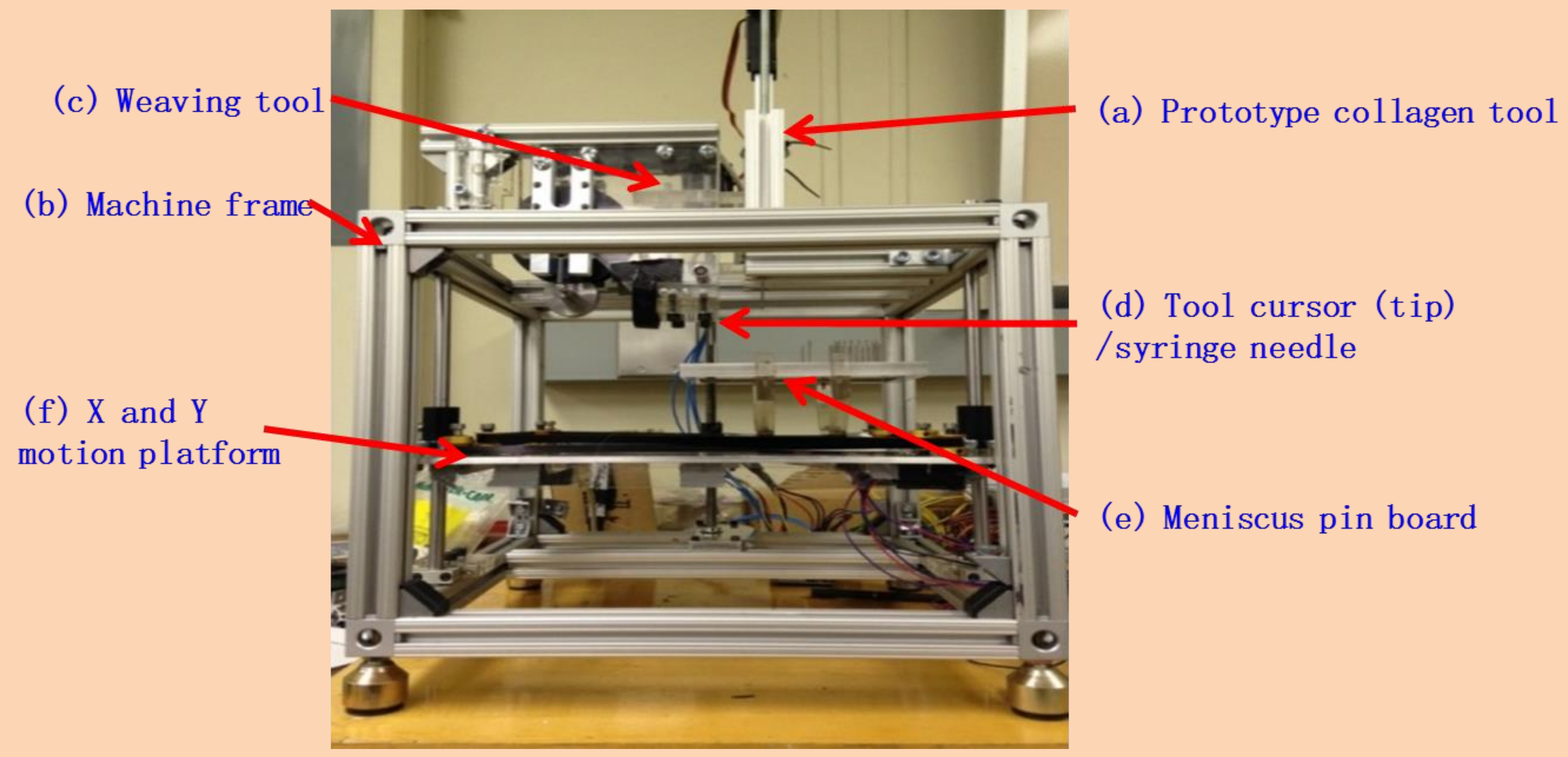
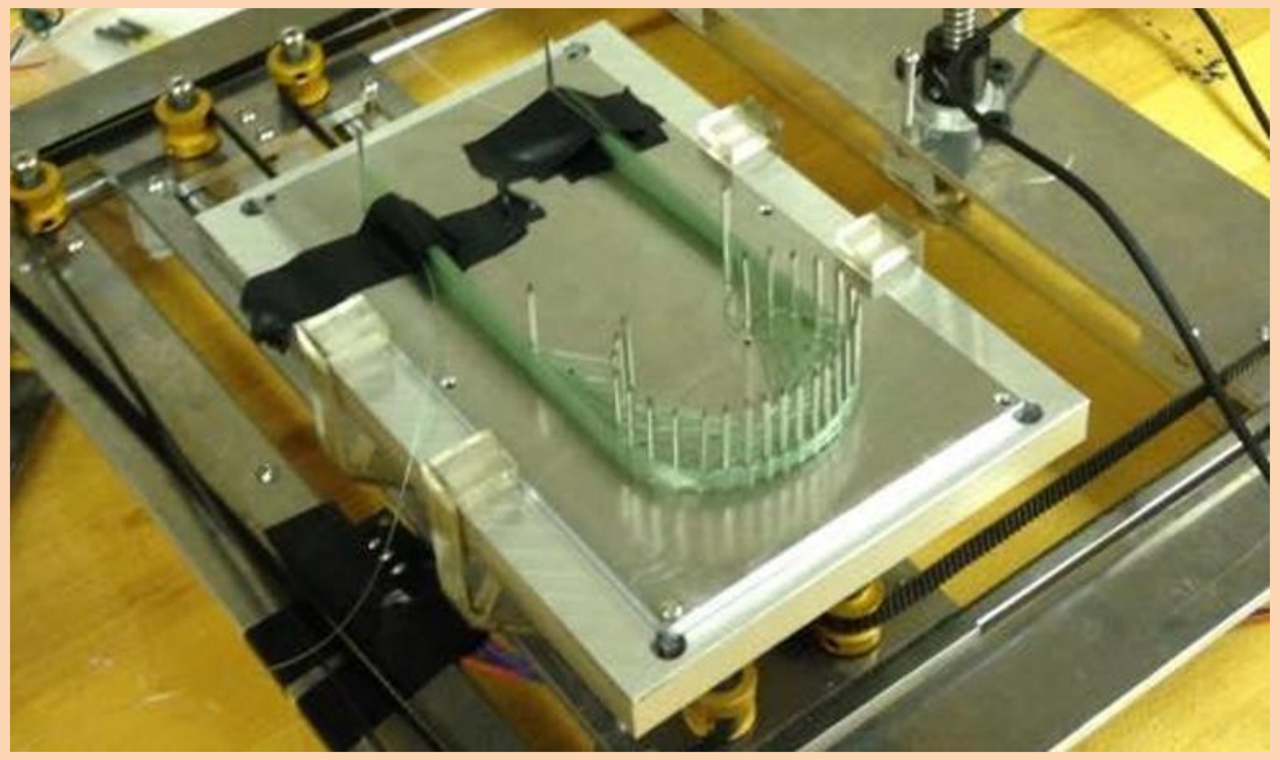
RWJ meniscus regeneration team

Methodology

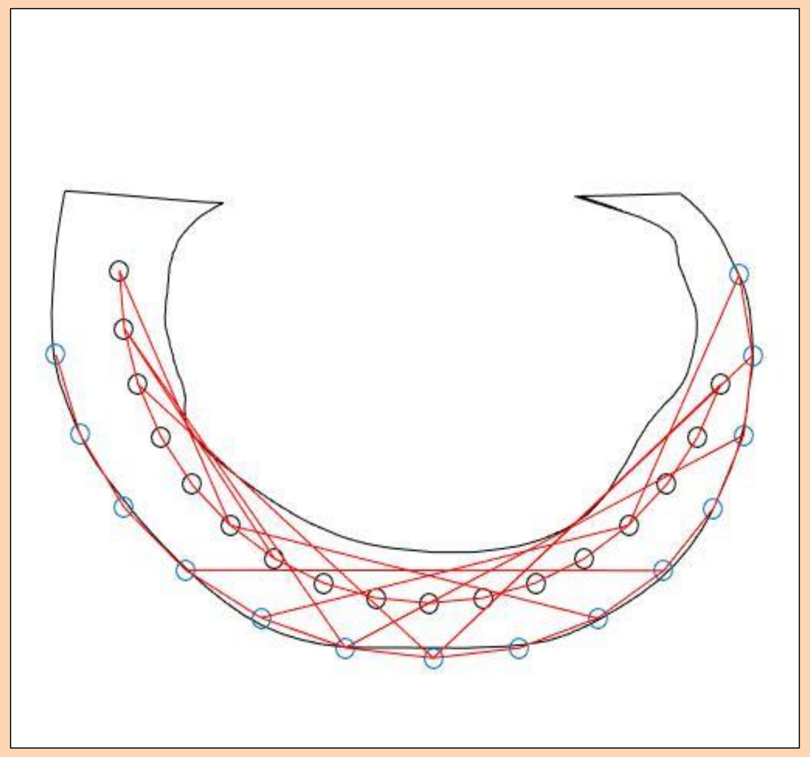
The material we used for menisci scaffold is polymer, P(DTD DD), which is suggested by RWJ. This material can work as fiber in artificial meniscus. The maximum tension that P(DTD DD) can handle is 1N. So, when we design the weaving system, we have to make sure that the polymer string will not be broken. In order to keep the string in tension and prevent it from being broken, we have a weaving tool, which is shown left. There is a string in the weaving tool which can gently roll back the spool and make the string in tension. On the pin board, 25 small needles and 4 large needle are put on the metal board. The cursor needle in the weaving tool will go through the needles to form some patterns in order to generate scaffold. The figure below indicates what does pattern look like and the whole path that the weaving tool will go through. For the path planning algorithm, we employ least square algorithm to find the most fitting circle and ellipse for the meniscus curvature. Then we put pins along the circle and ellipse. Finally, the algorithm will determine the paths between these pins so that a similar scaffold curvature will be formed.





Results

The 3D tissue printer we design is capable of producing a complete meniscus scaffold without collagen. As the figure showing above, there is mesh in the scaffold which allows to be injected collagen into it. In addition, there is a UI (user interface) which is able to help user control and monitor the process of printing. Our path planning algorithm allows to read a meniscus MRI data and generate a 3D model. Then, it is able to generate a set of unique weaving path based on the cross-section of the model. In the end, a series of g-code will be send to our machine and the machine will start to work.



References

[1] Joshua S. Levy, Dylan R. Vas, and Kyle P. MacKinnon. “3D Scaffold Weaver”
[2] Balint, E., Gatt Jr., C., & Dunn, M. (2012). Design and mechanical evaluation of a novel fiber-reinforced scaffold for meniscus replacement.