Microvascular Channel Bioprinting Shutoff Valve

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BME Design

Motivation and Background

- **Over 100,000** people in the U.S. are waiting for a life-saving organ transplant [1]
- Tissue engineering, by way of 3D Bioprinting, allows for the fabrication of functional tissues and organs, but there remain gaps regarding **vascularization** [2], [3]
- Every cell must be within 50-70 μm for necessary perfusion [4]
- The smallest capillaries are 10 μm in diameter, and fabricating micron size resolutions remains a challenge [5]

- Dr. Dean's lab utilizes **Kenics Static Mixers (KSMs)** and a **CEVIC Device** to print alternating channels of GelMA/SA/LAP hydrogel and HEC fugitive ink (Figure 1) [3]
- The CEVIC must **print resolutions sequentially** (largest to smallest) to **mimic the transformation of arteries to capillaries** in the body
- A mechanism to instantaneously switch between KSM outputs while shutting off the previous KSM is needed

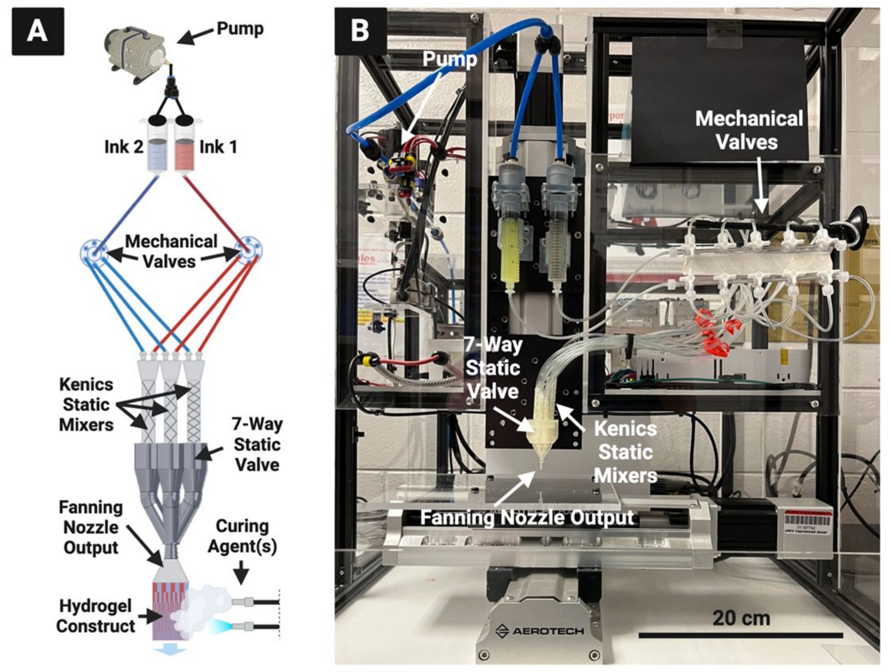

Figure 1: Dean lab bioprinting setup [3]

Problem Statement

To create an **automated, programmable valve** to seamlessly **shut off** or **switch** between **KSM outputs** and **multiple hydrogel resolutions.**

Design Specifications

1. **Automated** and **seamless** switching between KSM resolutions
2. **Low shear** stress on cells and minimize dead space in the tubing
3. Biocompatible materials
4. Preserve alternating pattern
5. **Maintain vascular network resolution**: 10 μm – 1 mm [5]
6. Must produce a **continuous hydrogel sheet** with **channels that can branch** within <1 cm

Final Design

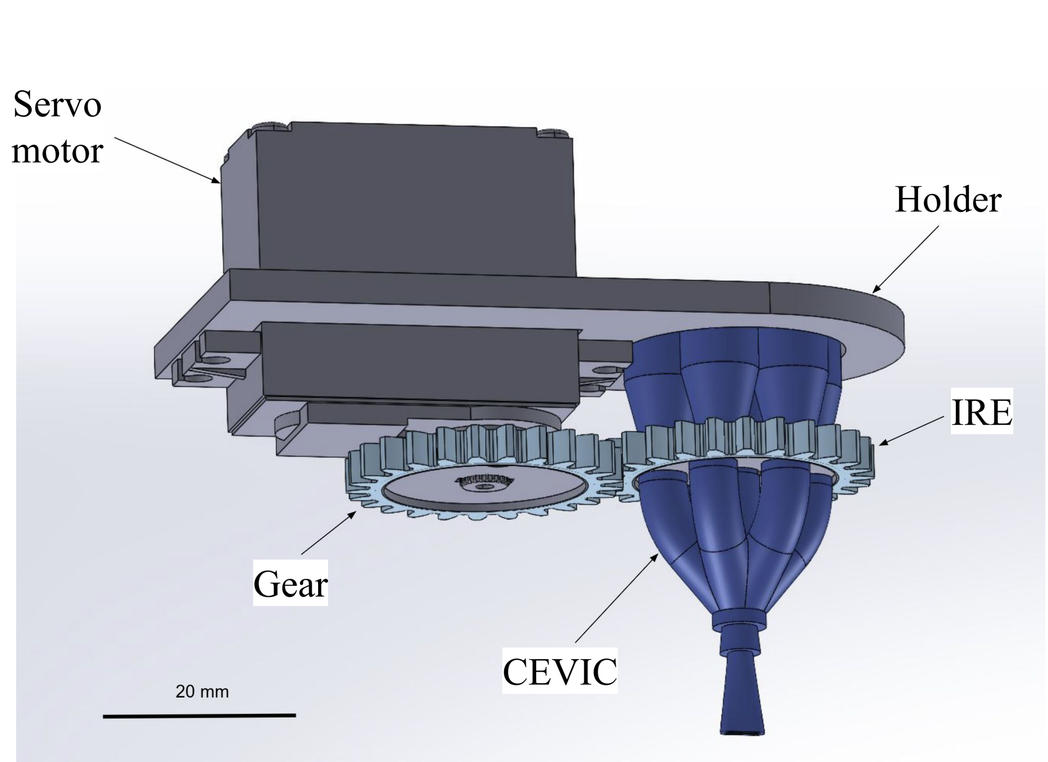

Figure 2: 3D model of assembled CEVIC, IRE, and Servo in holder

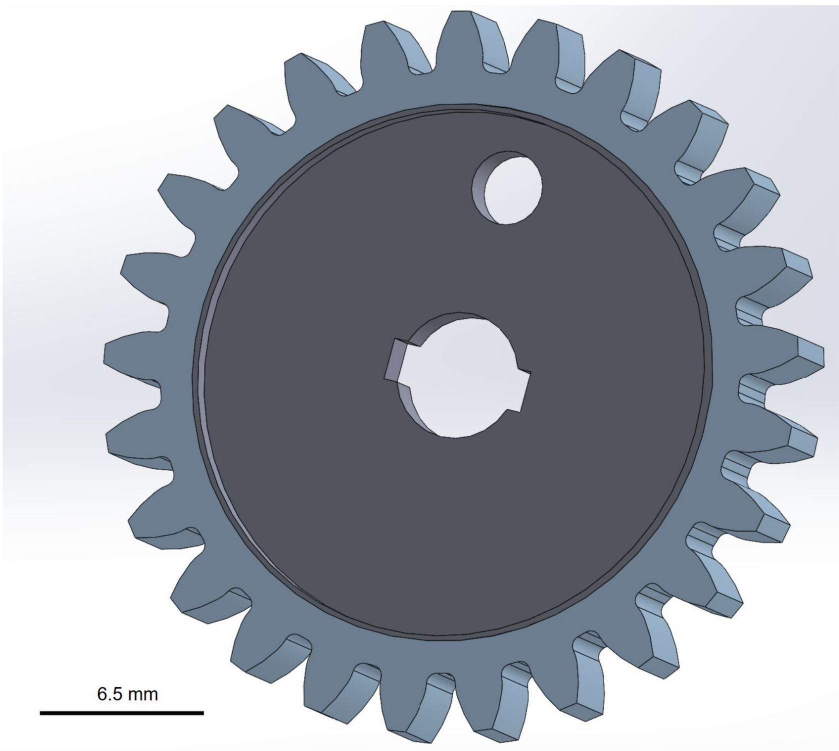

Figure 3: Isolated 3D model of IRE. 3D printed with Biomed Clear Resin

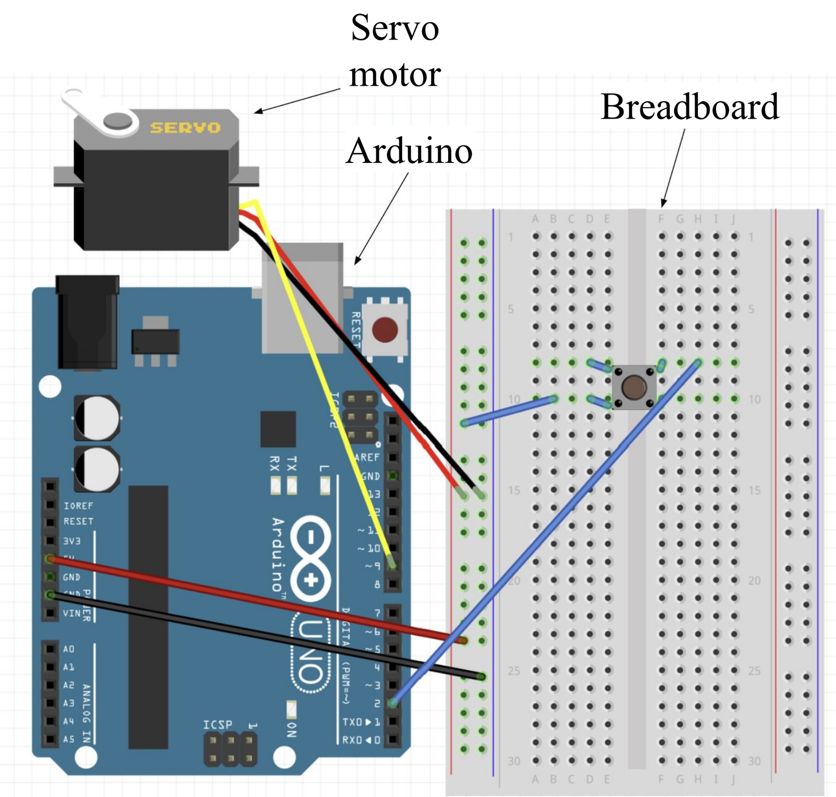

Figure 4: Circuit diagram of final circuit used to test

Testing

Table 1: Testing purpose and procedure for Durability of Integrated Rotary Element (IRE), Functionality of Shutoff Valve, and Electronics Testing

Testing Category	Durability of IRE	Functionality of the Shutoff Valve	Electronics Testing
Purpose	Verify the IRE's **strength** and **functionality** withstands repeated use	Evaluate the **operational performance** of the complete assembled Shutoff Valve	Ensure the servo motor **reliably** rotates the IRE by the required 60 degrees for each cycle and measure time it takes to switch to each KSM
Procedure	Test **five** samples for **100 cycles** and check for wear and cracks	**Simulate printing** using manual syringe methods and the contrasting colored dyed gelatin	**Measure time** it takes to move the **IRE 60, 90, and 180 degrees** using Arduino and **confirm starting point consistency** using protractor

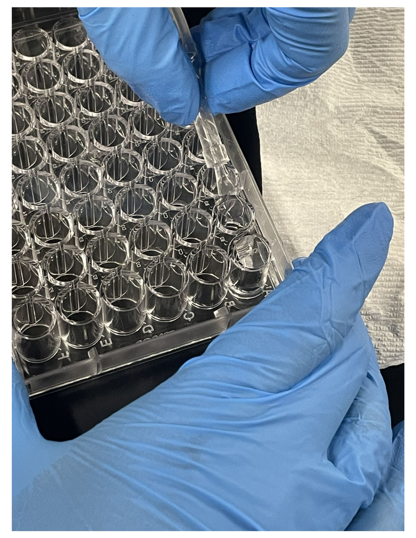

Figure 5: Demonstration of hydrogel printing

Figure 6: Dyed gelatin for printing simulation for valve functionality testing

Figure 7: Photo of the integrated rotary element after the durability testing

Testing Results

- The IRE experienced slight scratches over multiple durability rotations/cycles **but still remained functional**
- The IRE **turned with the appropriate degrees** consistent with the Arduino code
- The IRE and CEVIC worked in unison to print a hydrogels that **maintained its resolution pattern**
- The CEVIC experienced leakage issues when printing a hydrogel (Figures 5 & 6)

Future Work

Mechanical

- Develop and test further shutoff mechanisms to control bioink output without clogging the IRE
- Include an elastic material within the IRE to facilitate smooth rotation

Electrical:

- Include relay in circuit, with the goal of fully automating shutoff mechanisms
- Incorporate pressure sensors to better estimate servo torque

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References

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