Case Study Resource

Dyson Day 2023 Noah Gordon

Abstract

Bioprinting is a rapidly advancing field that holds transformative potential for biomedical research. However, the technology's accessibility is limited by the substantial cost, cumbersome size, and immobility of commercial bioprinters. We addressed these barriers by developing bioArm, an open-source, affordable, compact, and portable bioprinter. This project adds key multimaterial functionality to bioArm, along with vital enhancements to the platform's software and robustness, resulting in a powerful, accessible, open-source bioprinting platform for the field of biomedical research.

Built upon the advantages of stage-moving 3D printers, we designed bioArm 2.0 to facilitate precise printing in one location by manipulating a lightweight tubing system. This allows for a multimaterial printing without recalibration and the possibility for more than 2 materials, features which can't be achieved through the movement of the stage between two nozzles. Following the bioArm ethos, we designed this novel multimaterial printing mechanism to be simple, robust, and predominantly composed of inexpensive 3D printed parts.

Our testing yielded successful results. We showcase a successful implementation of multimaterial printing and significant improvements in bioArm's capabilities, most notably including the calibrated extrusion of known volumes and enhanced robustness. We demonstrate this functionality through the printing of various structures including multiline and core-shell extrusions. Significantly, bioArm 2.0's design brings high-quality bioprinting within reach for many laboratories, serving as an open-source platform that costs less than 1000 pounds. This democratization of bioprinting technology facilitates its use in a wider range of applications, including stem cell research, cancer research, and the creation of artificial tissues.

bioArm 2.0 represents a milestone in the field of bioprinting. It stands as a powerful, accessible tool ready for deployment in diverse medical research settings. We anticipate that future studies, already planned in our lab, will leverage bioArm 2.0's capabilities to advance stem cell scaffolding, artificial muscle creation, and cancer research. bioArm 2.0 represents a promising milestone in the advancement of accessible bioprinting.

Design

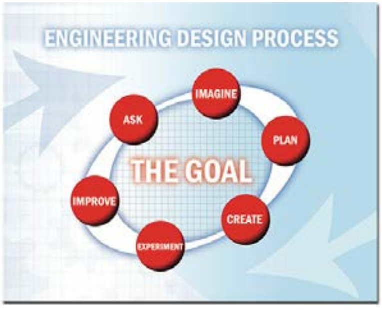

Figure 1: Engineering Design Process [2]

To solve the problem of inaccessibility in bioprinting, we used the same engineering design process as we would to solve any new problem.

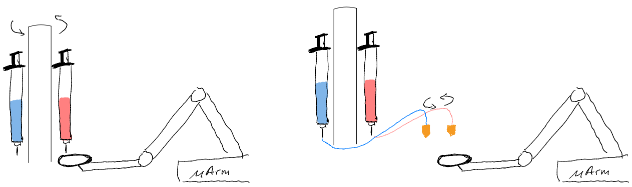

Figure 2: Mechanism concept designs

Our novel idea was to use a tubing system. Instead of manipulating the large and bulky syringe carriages (left), manipulating the light and flexible tubing (right) allowed us to have a lightweight, robust, and inexpensive multimaterial printing solution.

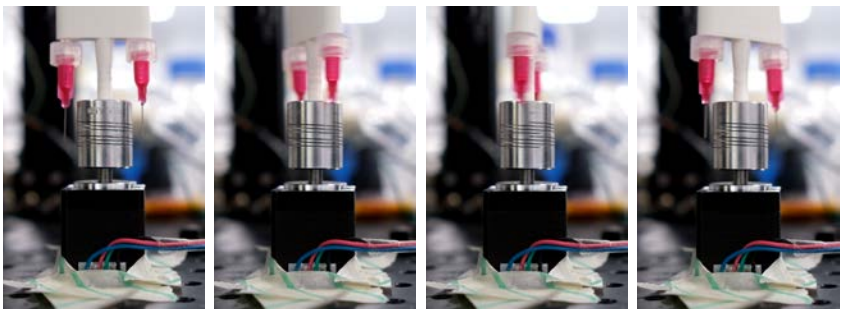

Figure 3: The mechanism viability prototype

After we came up with the initial design on paper, we created a prototype to test if our solution was viable (Figure 3).

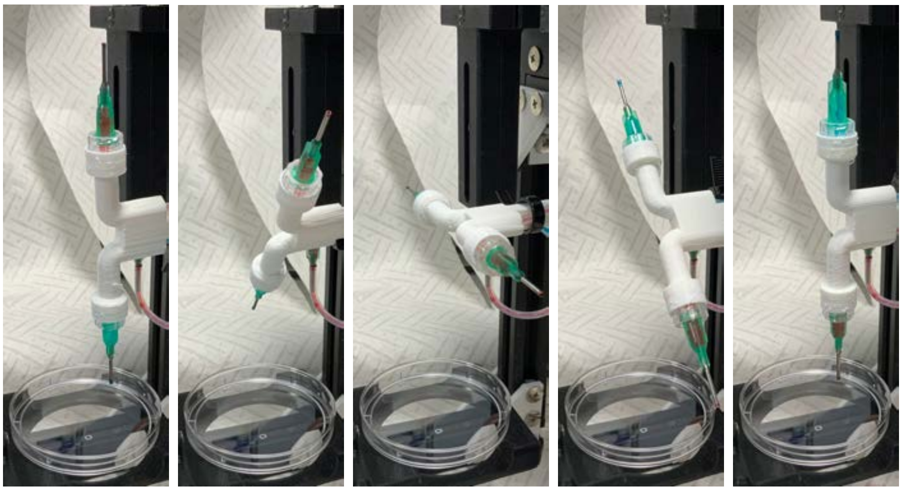

Figure 4: Automated Printhead Switching

Having determined the viability of our idea with a prototype for a mechanism, we built prototypes for the printhead design. After many iterations, our design changed in many ways. Figure 4 features a vertically rotating mechanism as well as an entirely new 3-D printed part, changes that arose after many iterations of testing and refinement.

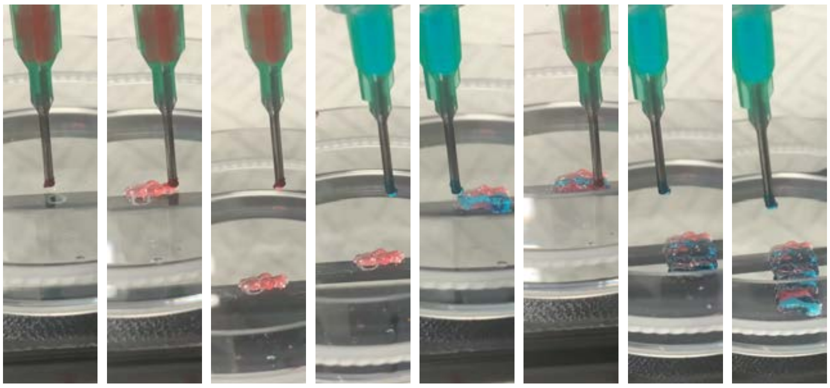

Figure 5: Multiline printing demonstration

Finally, after months of work implementing our engineering deisgn process, bioArm 2.0 was completed. Figure 5 shows bioArm 2.0 demonstrating its automatic multimaterial capability.

Conclusion

The bioArm 2.0 project has been a highly successful venture, demonstrating the feasibility and potential of a low-cost, compact, multimaterial bioprinter. This project addressed and improved upon the limitations of the bioArm 1.0 design, particularly in the areas of multimaterial functionality and printer robustness.

We introduced a novel rotating mechanism that enables automatic and smooth transition between different materials, thereby overcoming the limitations of single material bioprinting. Our innovation has not only expanded the capabilities of bioprinting but also set a benchmark for achieving multimaterial bioprinting with the same zero-point. The transformation from the bioArm 1.0 to the bioArm 2.0 is a testament to the importance of iterative design and thorough testing. From the mechanism viability prototype to the pre-final prototype, each stage of the design process was informed by rigorous testing and evaluation, leading to a series of improvements and advancements. bioArm 2.0 bioprinter's successful prints and competitive performance with the commercial bioprinter and the Feinberg lab's Replistruder IV indicate a promising future for accessible bioprinting. bioArm 2.0 proves that high performance does not have to be synonymous with high cost or large size.

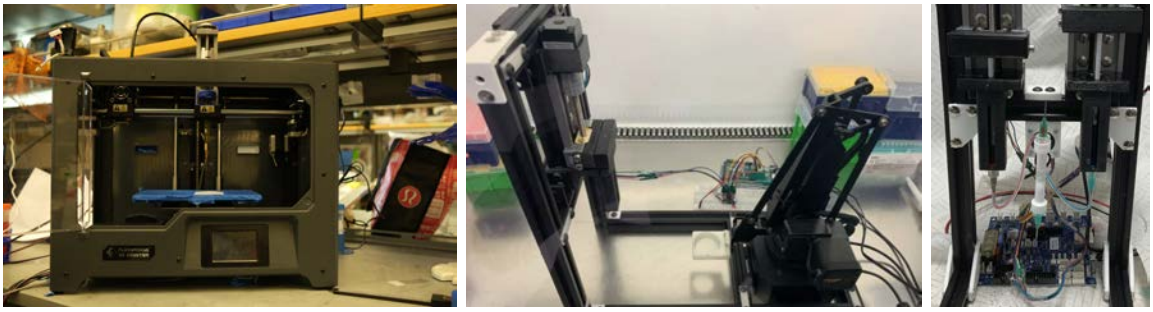

Figure 6: Replisturder IV (left) bioArm 1 [1] (middle) bioArm 2 (right)

Feature	Commercial Bioprinter	Replistruder IV	bioArm1	bioArm2
Space saving			✓	✓
Low cost		✓	✓	✓
Robust	✓	✓		✓
Multi-material	✓			✓
Open-source software		✓	✓	✓

This project succeeded in its aim to improve upon the bioArm 1.0 platform and offer an affordable, compact, and highly functional multimaterial bioprinter. As bioprinting continues to shape the landscape of tissue engineering and regenerative medicine, innovations like the bioArm 2.0 will play an important role in driving forward this important technology.

References

[1] Iek Man Lei et al. "A hackable, multi-functional, and modular extrusion 3D printer for soft materials". In: *Scientific Reports* 12.1 (2022), pp. 1–9.

[2] NASA. *Educational Resources for Teaching about Space and Planetary Science*. [Online; accessed 5-July-2023]. 2023. URL: `https://www.nasa.gov/audience/foreducators/best/edp.html`.