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An Open Source Bioinstrumentation Applied to the Poseidon Syringe Pump System

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ABSTRACT: An environmentally friendly substitute for proprietary equipment is the Poseidon syringe pumps and microscopy system. Assembly guidelines and the source files are available at <https://pachterlab.github.io/poseidon> for under four hundred dollars and require only one hour of work. We described the Poseidon mechanism. Demonstrate design principles for free-to-use bioinstruments to promote their adoption and enhancement. Functioning, strength, safeguarding, ease of use, flexibility comparisons, and specification are the guiding concepts as well.

KEYWORDS: Open source, Bioinstruments, Arduino, 3D Printer, Poseidon system, Syringe pump, Microscope system

I.INTRODUCTION

Open-sourced hardware designs have grown in popularity in the past few years, owing to advancements in desktop 3D printers as well as free source circuit boards such as the Arduino system and Raspberry Pi computing systems (1-3). The advancements in this area have led to an increase in interest in open-source initiatives related to laboratory instruments, such as syringe pumps, microscopes, fluorescence imaging devices, micro-dispensers, single-cell transcriptomics technologies, and microscopes. Free or open-source electronics have a distinct advantage over commercial systems due to their ability to be customized for specific purposes, in addition to cost savings (13). Libraries of designs, software, and common elements can be used and altered between projects, reducing the need for developers to start from scratch. A new instrument. The named RepRap platform uses 3D printers that mainly rely on standard CNC software and hardware for milling. Open-source software and hardware developed for 3D printing technologies have been repurposed for various bio instruments, including liquid handlers, vial handlers, food dispensers, autosamplers, and bioprinters. Our laboratory is generally interested in creating new technologies high-throughput single-cell methods drop-seq²⁰ and also indrops²¹ use a small amount of flow control to run microfluid devices in the unexpected nature of single-cell genomics necessitates flexible software and hardware that can be modified and repurposed as the studies progress. We developed our own open-source multi-syringe pump array and microscope method for low-cost microfluidic experimental method inspired by Our team is interested in creating novel technologies for high-throughput single-cell applications such as drop-seq²⁰ and indrops²¹. These methodologies require perfect flow.

II. SYSTEM CONSTRUCTION

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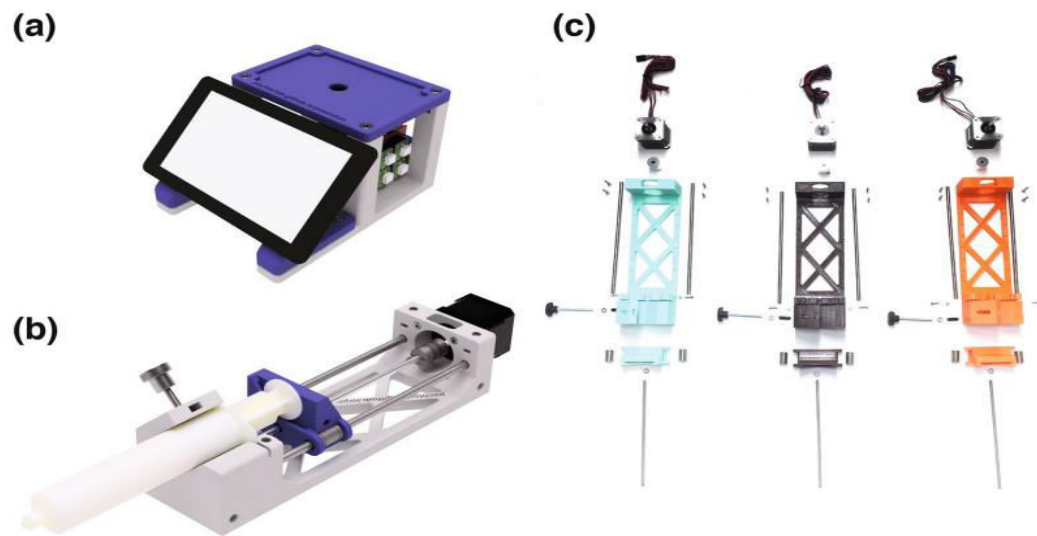


Figure 1. Model of the Poseidon system. (a) CAD rendering of the microscope station and (b) a single syringe pump loaded with a 60mL syringe. (c) Exploded view of all the components needed for assembling three pumps

We developed our own open-source multi-syringe pump array and microscope method for a low-cost microfluidic experimental method inspired by Our team is interested in creating novel technologies for high-throughput single-cell applications such as drop-seq²⁰ and indrops²¹. These methodologies require perfect flow control to run the microfluidic gadget The unpredictable nature of single-cell genomics necessitates flexible gear and software that can be repurposed as trials change. We developed our own open-source multi-syringe pump array and microscope system for low-cost microfluidics experiments, inspired by the versatile software interface and its commercial systems, and diy electronic and instrumentation project powered by open source hardware. The Poseidon system, which uses open-source syringe pumps and microscope microfluidics stations, combines advances and adaptations. The pumping mechanism and the microscope can be utilized along pumps can be used separately or in microfluidic investigations if they can be linked to a computer. For scientists on a small the allocated funds, the stand-alone microscope equipment is a viable alternative for simple light microscopy. The Poseidon system combines a Raspberry Pi and screen for the microscope, along with an Arduino board with a CNC interface to manage up to four pumps at once. A single pump uses a stepper motor to drive a lead screw before, which rotates a sled on a linear bearing to infuse or draw out the syringe plunger. Fig. 2 shows how the microscope camera and Arduino connect to the Raspberry Pi or desktop PC via USB. The system was built with easily available resources, including Autodesk Fusion 360 for CAD, Python 3, and PyQT for software, 3D printers for custom hardware fabrication, and off-the-shelf electronics and hardware parts (Fig. 3). We put direct links to the specific parts used for Poseidon in the GitHub source to improve reproducibility and adoption.

The following components are available:

1. 3D models and computer-aided design (CAD) files for the 3D printed components.
2. Pump controller and Graphical User Interface (GUI) software for controlling the Arduino.
3. Arduino firmware to relay commands via USB to drive the motors.

Poseidon's impact on open-source bio-instruments is restricted by restrictive design decisions and weak documentation, discouraging adoption. This is not surprising given that many projects are created by non-expert developers who are also end users. We discuss design concepts adapted to open-source bioinstruments, keeping the community in mind. The guiding principles are a culmination of our extensive experience creating the Poseidon system from the ground up, with the primary objective being ease of use. Our goal is for

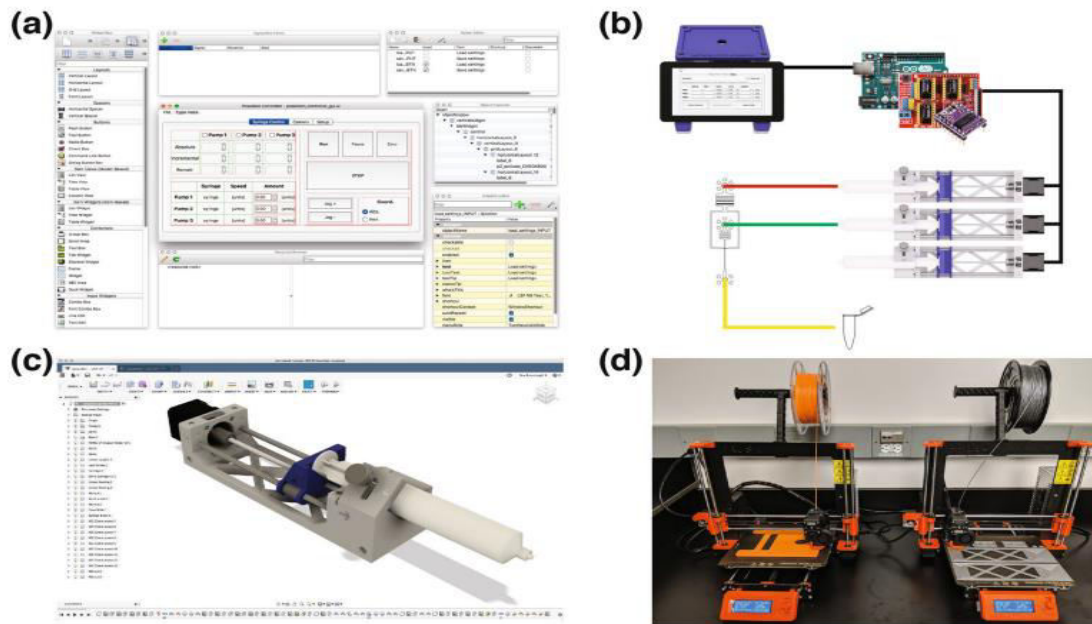


Figure 3. Overview of the tools used for developing the Poseidon system.

(a) The GUI was created using Qt Designer³¹, an open source drag and drop application for organizing buttons that allows users to easily change the GUI interface when adding new functionalities. (b) The GUI interfaces with a Python script that controls both the microscope and Arduino via USB. The Arduino controls the stepper motors on each pump using the CNC shield and stepper motor drivers. (c) The system's 3D printed components were designed using Fusion 360³², a cloud-enabled CAD software that streamlines collaboration and offers free licenses for academics, hobbyists, and small businesses. To modify the 3D model users can either work with Fusion 360 or any other CAD software. (d) The 3D printed components can be fabricated on any fused filament fabrication (FFF) 3D printer. Future developers to use these principles from conception to testing, resulting in more robust and flexible systems that can be easily adopted and modified.

III. METHODS

We planned towards developing a big instrument that is simple to use and adapted by others: The customers and Manufacturers can make changes and broaden the system. We identified two kinds of bio instrument users: those who look to endorse the design and browse it effortlessly and those who want to edit, become better, and customize models to their particular wants and needs, and they also want to use the program for innovative uses. Whilst the affordable price is an inducement for constructing and using open-source project instruments, it is not significant to drive project adoption for these two a variety of categories. A functioning freely available instrument addresses the needs posed by basic and highly educated users by applying to predefined designing principles such as operation, reliability confidence, and the simplicity.

Functionality:

Content is the procedure of creating a smartphone app. A requirement for function defines a specific measure that either a software or hardware system is required to meet in the field of manufacturing. The phrase of "good enough" comprises lots of creative choices made by builders while following the research-build-test cycle. Utility, preciseness, precision, quickness, expenditure, and difficulty are appropriate trades given the application's purpose. The positioning system needs to exceed the functional requirements that follow for use in microscopic applications such as

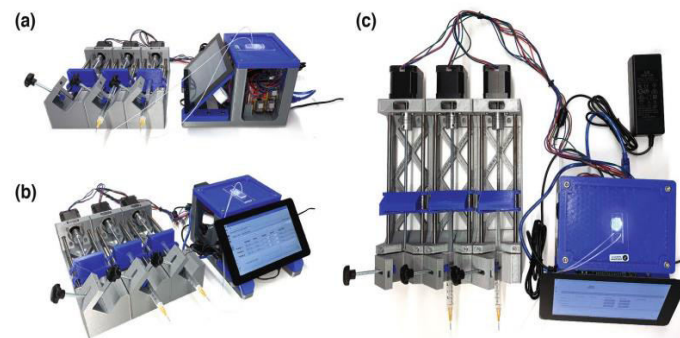
1. Precision screw pumping has been needed for creating monodisperse oil emulsion on particle creation

microfluidics chips at flow rates of 1 mL/hr.

2. The instrument provided sufficient intensity for viewing the emulsions and monitoring the microfluidic system.
3. The hardware and control programs must be adept of powering at least three different pumps autonomously.
4. The software interface should be simple allowing users to merely modify the flow rate, choose syringe type or diameter, and issue gradient pumping.
5. Applications essential to operate the magnifying device.

Robustness:

These were the fundamental necessities specified before we started putting up Poseidon. Creating a list of specific requirements is a prerequisite for any bio instrumentation project. After designing, to fulfill our aims, we selected reliable pumps with flow rates ranging from a handful of 100 tiny amounts per hour up to several hundred ml per minute. Our microfluidic device was photographed reliably using a cheap USB microscope. The 0.3 MP microscope features a CMOS sensor and eight dimmable LEDs. It may be easily swapped with any USB-compatible microscope. Representative photos are in S2. One software version incorrectly configured stepper motors to use a different micro stepping than the hardware, resulting in erroneous flow rates during user experimentation. During an experiment, small usability concerns were discovered menu to select the forward direction instead of a "+" or "-" sign in The displacement amount box. These tiny adjustments can have a significant influence on potential adopters who are testing a new system for the first time. Fig 4.



Safety:

Safety is the exchange of knowledge of hazards to users. In testing facilities, safety is of the utmost significance in guaranteeing reliable gadget operation. When building an open-source bio instrument, it's important to consider potential health, chemical, and biological risks in the laboratory, as well as those that may arise throughout instrument construction, use, and malfunction. Figure 2 shows how to use the Poseidon system. Configuration of the Poseidon framework for colloid creation in the rapid development of micro experiment with only two pumps angled view.

Simplicity:

The Leviathan syringes pump system utilizes a three-dimensional printed plastic from PLA and conventional parts that are suitable to use when handled carefully. However, incorrect application of polymers can present substantial hazards to the safety of people. Designers should examine how the devices they create perform at extreme temperatures. Facilitating the process of sourcing, building, and operating. Simplicity and ease of use are crucial for implementing bioinstruments. When sourcing components for a design, prioritize off-the-shelf options and only include difficult-to-find pieces if essential. The application is currently being processed. A current bill of materials (BOM) with many vendors for each part simplifies purchasing and adoption. We made sure that all components for the poseidon system could be purchased from Amazon. Using specialist equipment during assembly, such as soldering circuit board, a barrier to adoption. Specialized assembly methods may be necessary, although simplicity should be prioritized.

Modularity:

It refers to the construction of self-contained units. Because some users may desire to adapt. When adapting a design for new use cases, it's crucial to examine its adaptability to changes and reuse. A modular design with independent components that can interact with one another is easy. More easily repurposed and improved than a tightly embedded gadget. If a design is not modular, adding new features may necessitate a whole redesign. Poseidon was created to address the issue of our commercial, integrated system being too stiff to adapt to new needs. The software could not be upgraded or modified, and the small integrated touchscreen interface, promoted as an advantage³⁰, was as shown in Figure 4. The Poseidon system vs. the Harvard Apparatus system. We used a droplet-generating chip to compare the sizes of droplets from two systems. (a) Given flow rates, droplets with a diameter of 58 μm are expected. The diameters of droplets generated by the two technologies are comparable. (b) The Poseidon microscope imaged a microfluidic droplet-generating chip.

(c) A Poseidon-produced monodisperse emulsion photographed using a Motic AE31 trinocular microscope.



Figure 3. Summary of the design principles for open source bioinstrumentation.

Benchmarking:

It validates against established protocols. Users must know the extent to which an instrument design is relevant to the task at hand. However, it's crucial to clarify protocols used with instruments and offer benchmarking data. Although open-source instruments may not perform as well as commercial devices, they may still be suitable for some applications. It's crucial to compare devices to commercial ones and identify any flaws or undeveloped functionality. The Poseidon system has successfully produced monodisperse emulsions with the in Drops droplet creation device We attained the desired droplet size with minimal variation in droplet diameter.

Documentation:

These documents imply laying out the design. Clear instructions and documents are needed for fast and simple assembly. Videos, photos, and descriptions in words are necessary for exhibiting a design and promising adoption. Videos are an efficient but-saving time way to supply instructions for assembly. Pictures also accurately reflect what kind of time and effort expended by users Prepare to invest in assembling. Datasheet allows for faster and simpler learning about design. Understanding design decisions, perhaps inspired by technical problems or user feedback, can help users make changes to a design. Designers must consider and improve on how to go about implementing each feature, yet this expertise may not be readily readily availableIn this failure during operation, but also assuring a

construction process that can withstand variability in components. This is especially significant in biology applications where instruments must operate in various settings and with changeable input. Ensuring robustness required careful attention to minute details and extensive testing. Open-source hardware often includes 3D-printed components, which might vary depending on the printer used. Mechanical tolerance was integrated into 3D printed parts by many design-build-test cycles, such as altering print parameters to allow for a syringe to be pressed into the pump.

During testing, we found an unexpected hardware issue: When the printer encountered an excess slipping reluctance on the carriage, the long rods dislocated and damaged the molded plastic. To stop bending, we developed a consolidated body and tied the linear rods without fixed nuts. This level of customization is commonplace for bio-instruments and prospective makers.

IV. CONCLUSION

Conclusion Success and adoption of open-source software demonstrate that reliable and powerful technologies can be realized through community development and improvement. We have developed a modular, highly customizable syringe pump array and USB microscope system, Poseidon, with the potential for broad application across the bio-logical and chemical sciences. Syringe pumps can be used to operate microfluidic chips, control the chemical environment of a bioreactor, purify proteins, precisely add reagents to chemical reactions over time, or dispense specific amounts of fluid for any number of applications that require precise control of fluid flow. We have Figure 5. Summary of the design principles for open source bio instrumentation. Scientific microfluidic emulsion generation. In developing the Poseidon system as an open-source hardware device we have illustrated seven design principles that we hope can facilitate the successful development of open-source hardware devices (Fig. 5). Adhering to these principles from the outset of a project will maximize the chance of community adoption and spur further improvements.

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