Principles of Bioinstrument Design: Syringe Pump/Microscope

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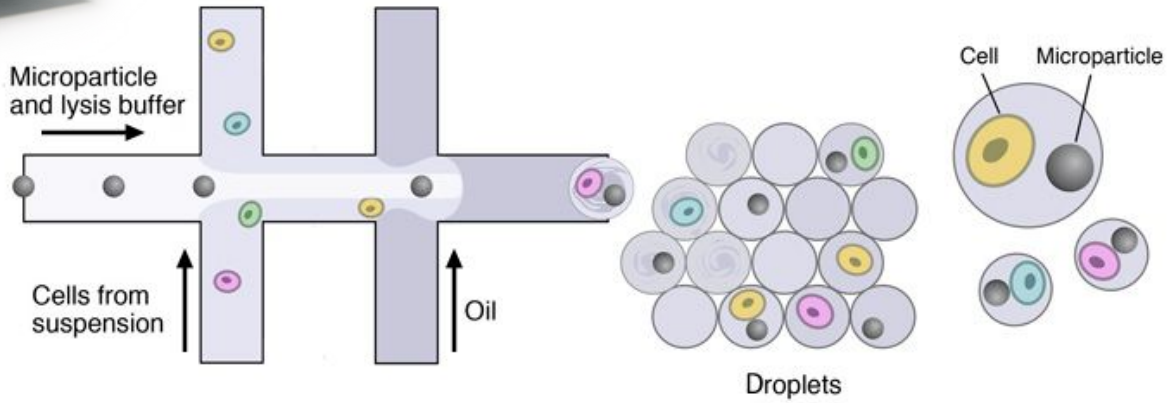
(We work under Professor Lior Pachter in BBE/CMS)

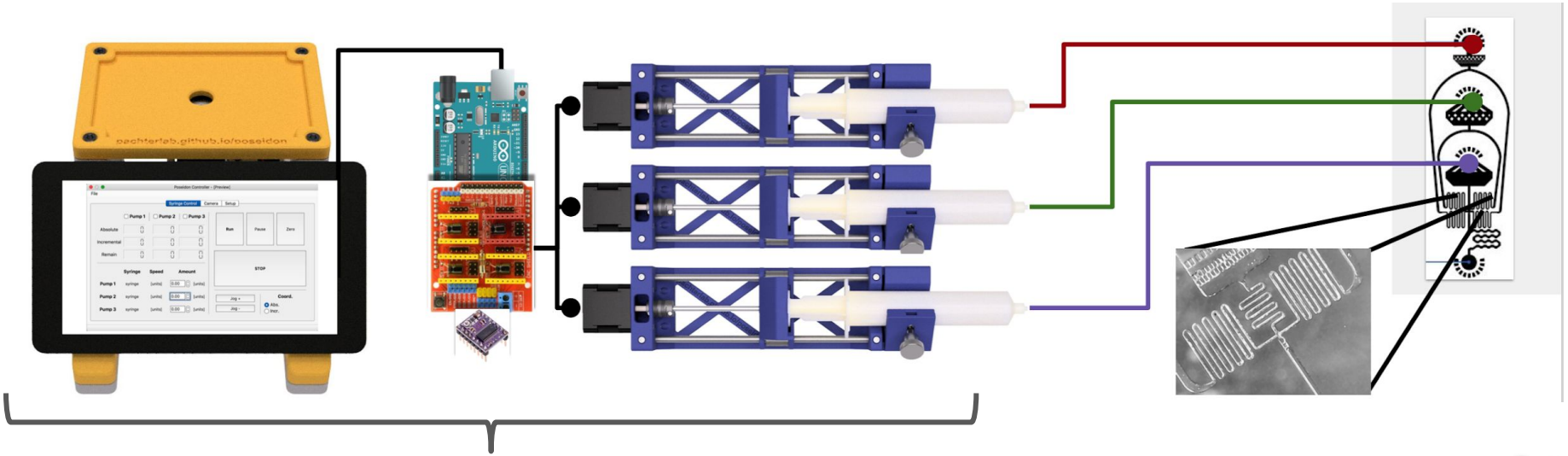
Single-cell RNA Seq profiles thousands of cells

← Cost for a single 10x Genomics Machine $75k
Cost per run: $1500

Cost for a DropSeq rig → and Pumps $10K
Cost per run: $600



The problem: syringe pump/microscopes expensive, not hackable



Poseidon Cost: ~$310

Harvard Pumps Cost: ~$5-10K

We followed 6 Principles of Bioinstrumentation to tackle the problem

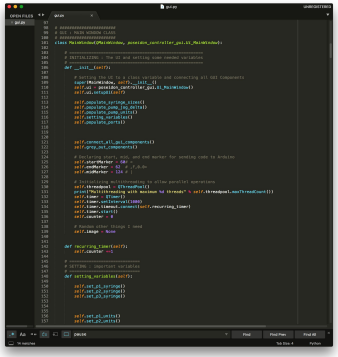
1. Functionality **(Follow functional requirements)**
2. Simplicity **(Avoid complicated solutions)**
3. Modularity **(Use standard components)**
4. Robustness **(The “idiot user” approach)**
5. Benchmarking **(Test and retest and retest)**
6. Documentation **(Videos, pictures, text)**

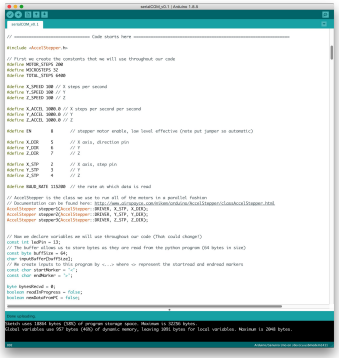
Recommendation: print out a list like this and post it to your wall. It can help serve as a template for making design decisions.

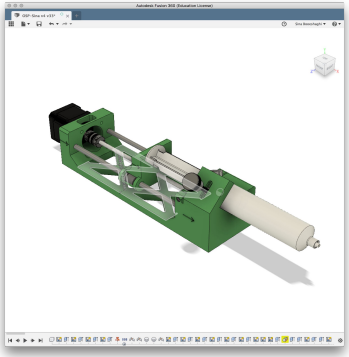
Functionality: Always start with a set of functional requirements

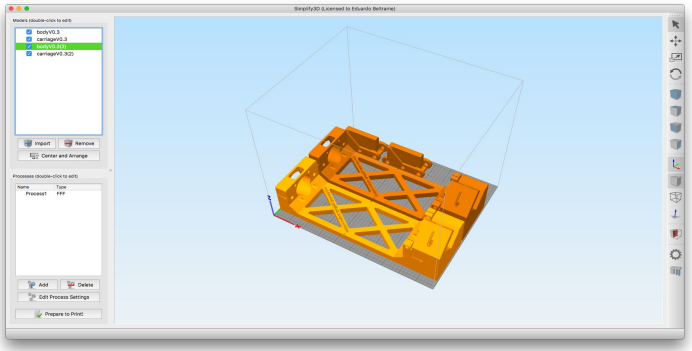
Specification	Description	Associated Value
Pump Size	Can be printed in one shot	Build Volume 8 x 8 x 10 in
Syringe Sizes	Adaptable to BD syringe	[1, 3, 5, 10, 20, 30, 60] mL
Desired Flow Rate	from DropSeq Protocol*	1,000-15,000 µL/hr
Stepper Motor Driven	Run off of Arduino 12VDC	200 steps/rev w/ 32 µstep
Microscope	Magnification	Image microfluidic device
Cost	Total cost of the system + parts	<$500

With these requirements in mind, we selected the appropriate design tools

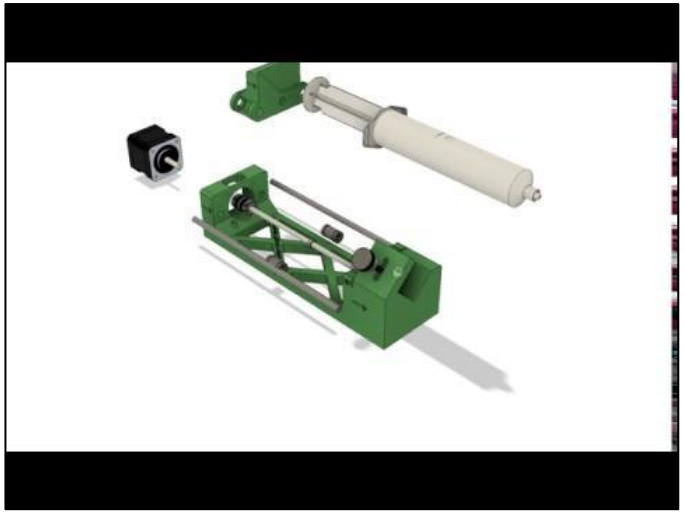


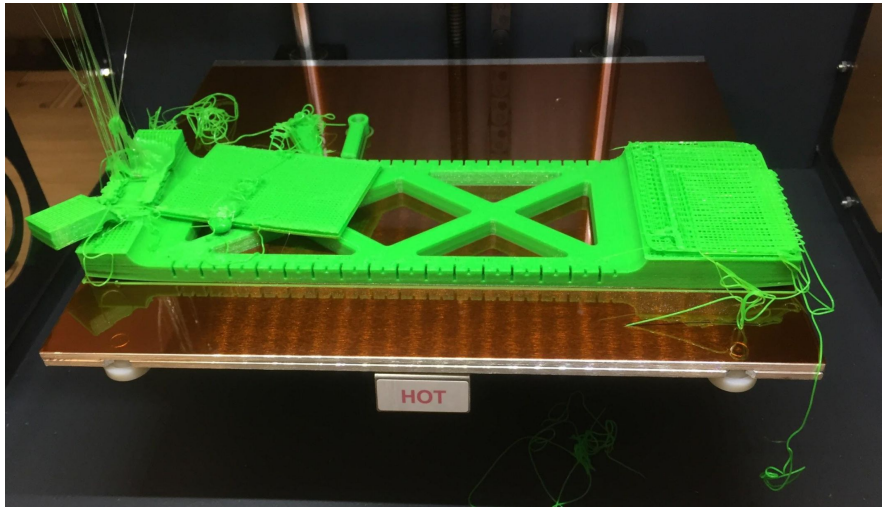






Then we began designing and iterating..

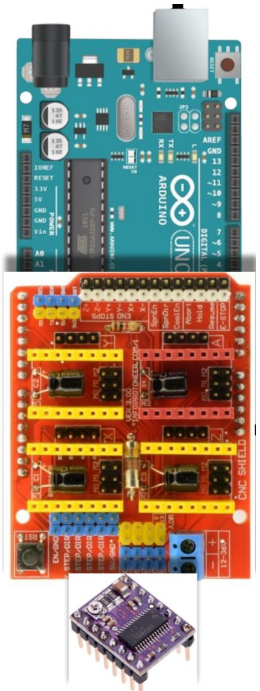


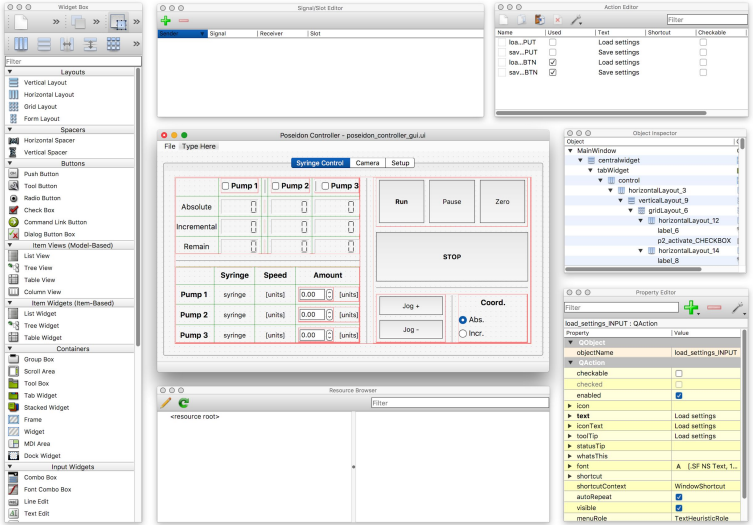


Simplicity: We wanted the system to be simple enough to use but flexible enough to hack

Hardware:

Plug and play parts, no soldering required

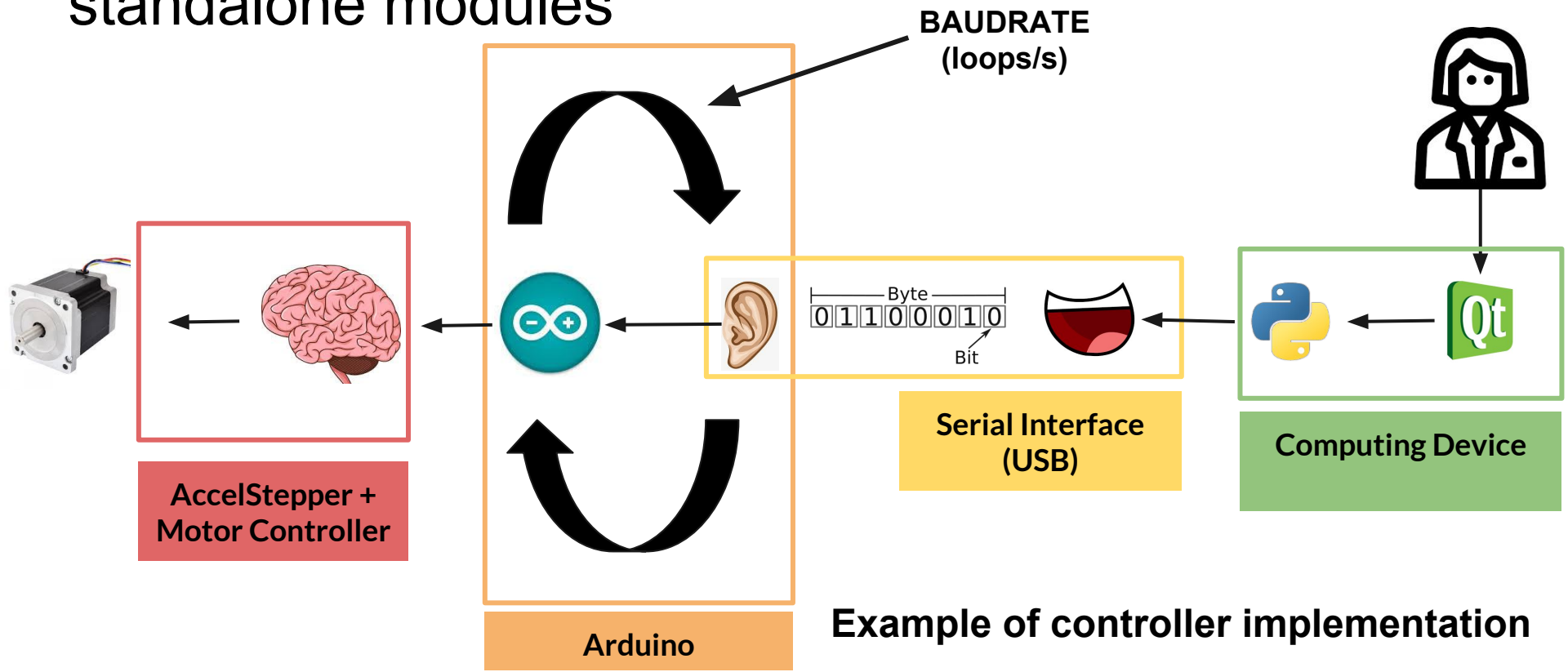




Software:

Drag and drop GUI development, controls written in python

Modularity: System can be broken down into standalone modules



Example of controller implementation

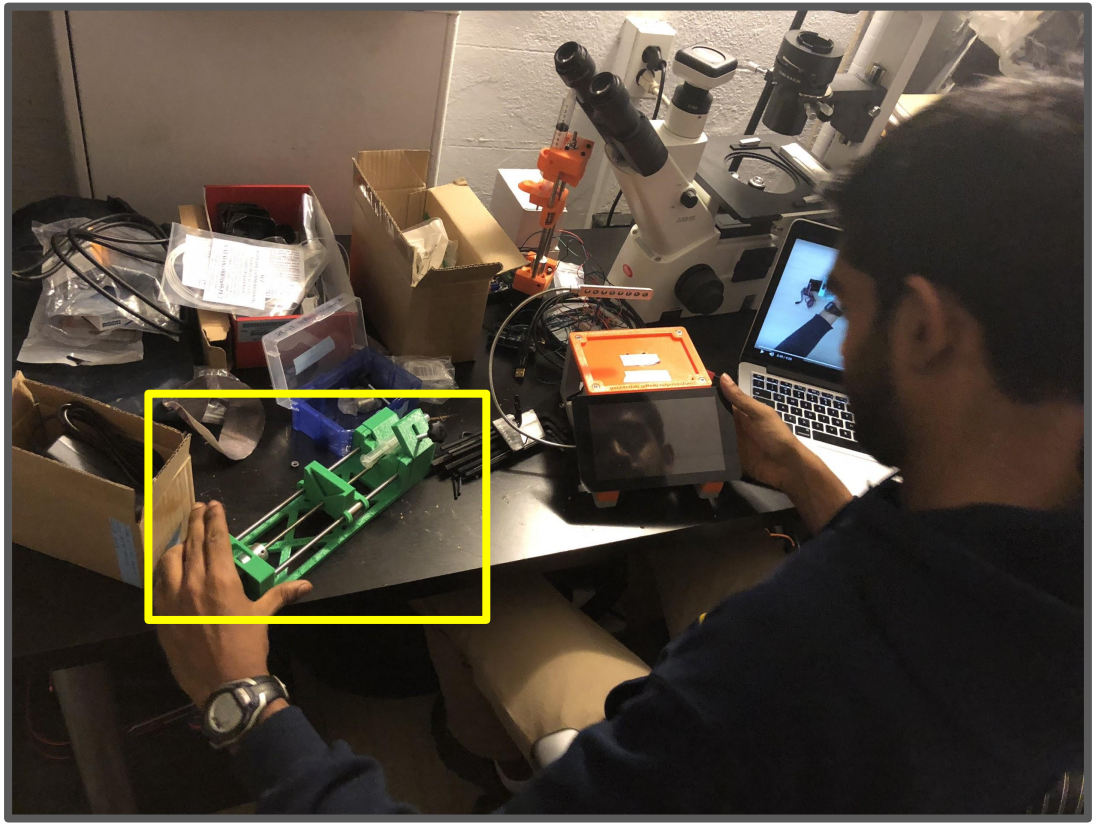
Modularity: We used standard components

Syringe Pump Array		Cost per pump	31.445							
Total for 3 pumps	$141.92									
Item Number	Item Description	Items per package	Items per Pump	Items per 3 pumps	Packages per 3 pumps	Cost per Package	Price per item	Cost per 3 pumps	Cost per pump	Supplier
1	Nema 17 Stepper Motor (Bipolar, 40mm, 59Ncm)	3	1	3	1	31.99	10.66333333	31.99	10.66333333	Amazon
2	5mm to 5mm Motor Shaft Coupling	10	1	3	1	22	2.2	22	2.2	Amazon
3	6mm Steel Rod (length 200mm, pack of 2)	2	2	6	3	6.24	3.12	18.72	6.24	Amazon
4	6mm Linear Bearing (pack of 12)	12	2	6	1	10.66	0.8883333333	10.66	1.776666667	Amazon
5	M5x0.8 Threaded Rod (length 170mm)	5	1	3	1	7.98	1.596	7.98	1.596	Amazon
6	M5x0.8 nut	50	2	6	1	6.23	0.1246	6.23	0.2492	Amazon
7	M3x0.5 socket head screws to mount motor (length 20	100	4	12	1	8.47	0.0847	8.47	0.3388	Amazon
8	M5 knob (hold syringe in place)	10	1	3	1	11.9	1.19	11.9	1.19	Amazon
9	12V power unit (end stripped to fit CNC shield power ir	1	0.3	1	1	9.89	9.89	9.89	2.967	Amazon
10	Arduino + CNC Shield Pack + DRV8825 (4)	1	0.3	1	1	14.08	14.08	14.08	4.224	Amazon
Microscope		Per Microscope	160.2768							
Microscope Total	$169.01									
Item Number	Item Description	Items per package	Items per microscope	Packages per microscope	Cost per package	Price per item	Miscroscope cost			Supplier
1	Raspberry Pi Motherboard	1	1	1	34.99	34.99	34.99			Amazon
2	Raspberry Pi 7" touchscreen display	1	1	1	68.7	68.7	68.7			Amazon
3	Raspberry Pi Power Suppy (5v 1.5A DC)	1	1	1	9.99	9.99	9.99			Amazon
4	16gb MicroSD card (comes with adapter)	1	1	1	7.17	7.17	7.17			Amazon
5	Keyboard + Mouse Bundle (wired)	1	1	1	14.44	14.44	14.44			Amazon
6	M5x0.8 Socket Head Screw (length 14mm)	15	8	1	7.5	0.5	4			Amazon
7	M5x0.8 nuts	50	8	1	6.23	0.1246	0.9968			Amazon
8	USB Camera	1	1	1	19.99	19.99	19.99			Amazon
Project Total	$310.93									

Robustness: Employing the idiot user approach

Notice something wrong with the device?

Robustness: Employing the idiot user approach



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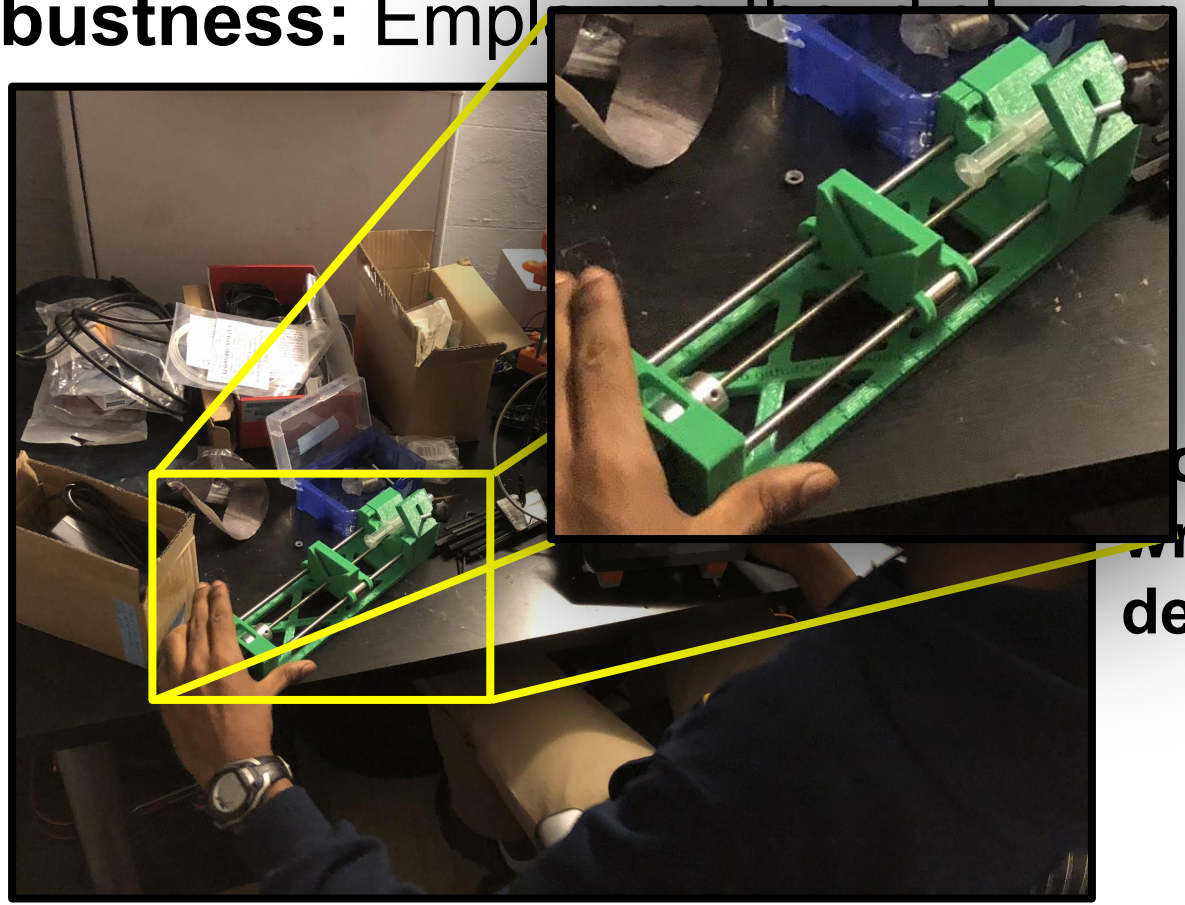
Robustness: Empl approach



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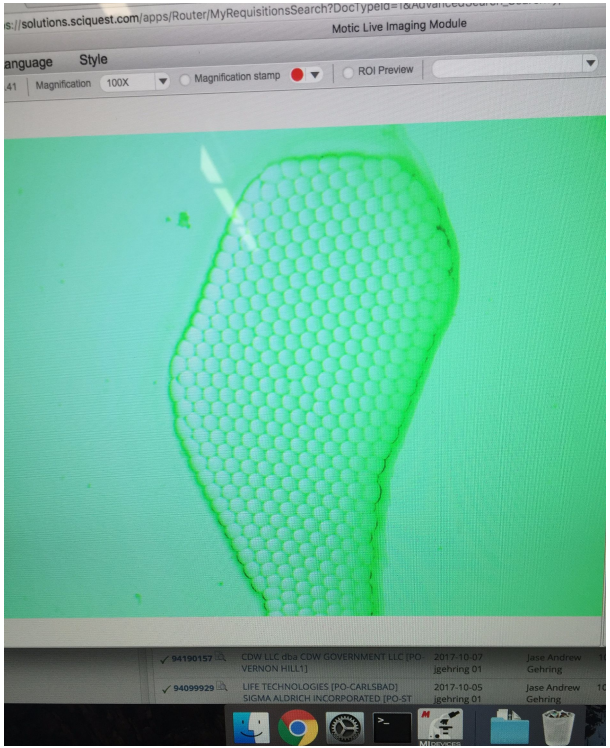
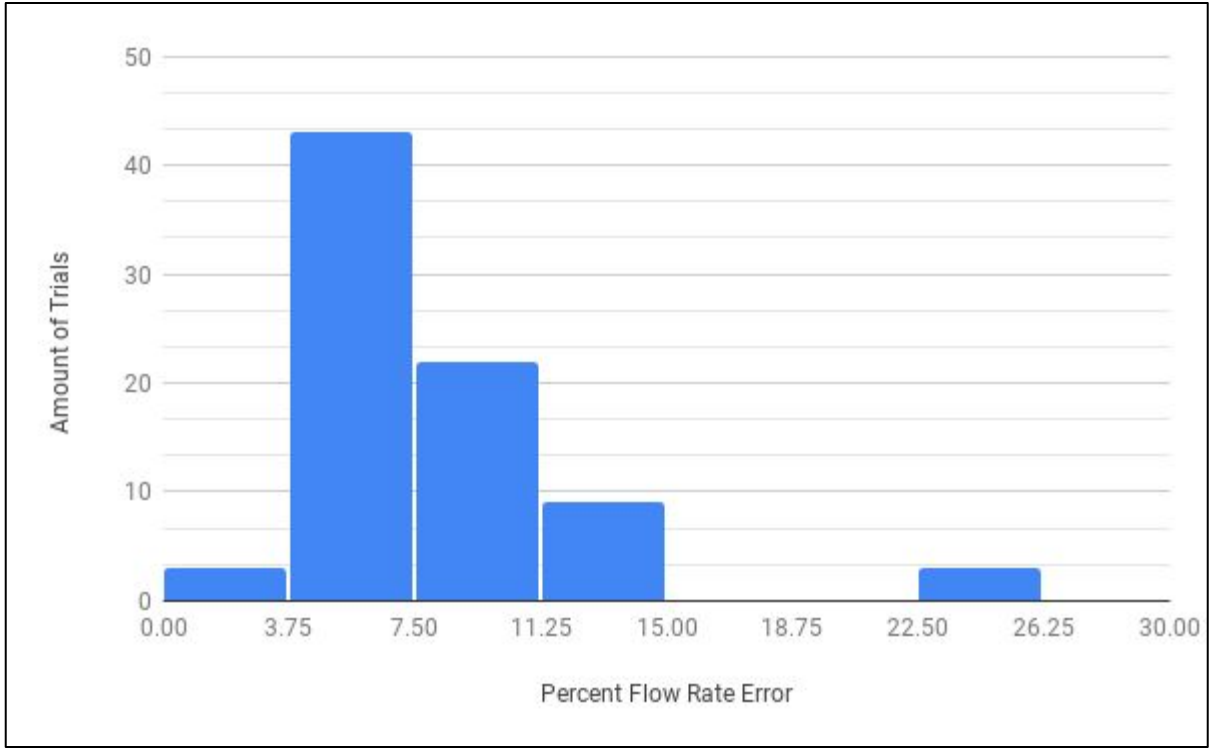
Benchmarking: Test and retest and retest





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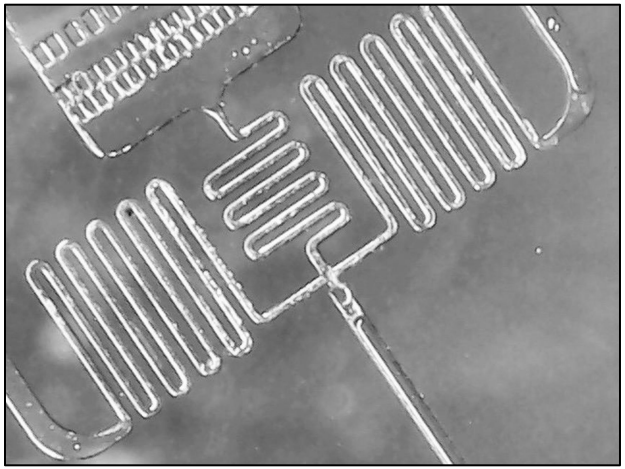
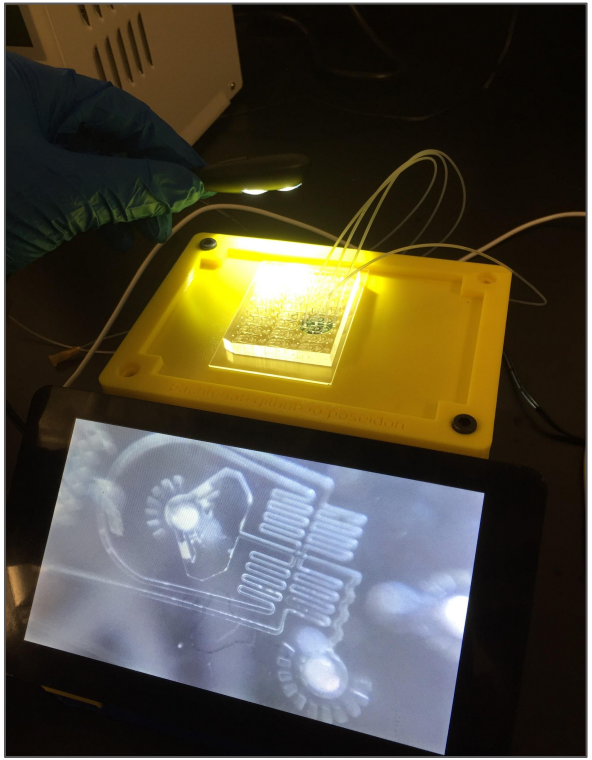
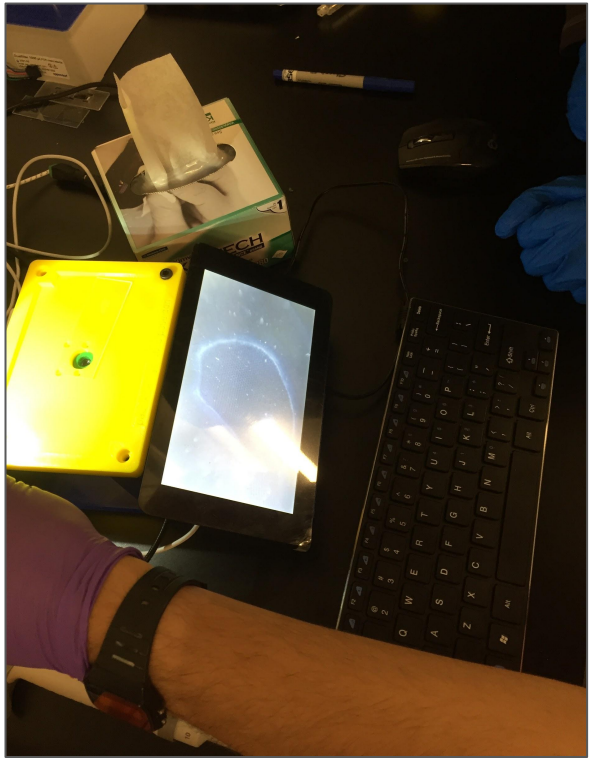
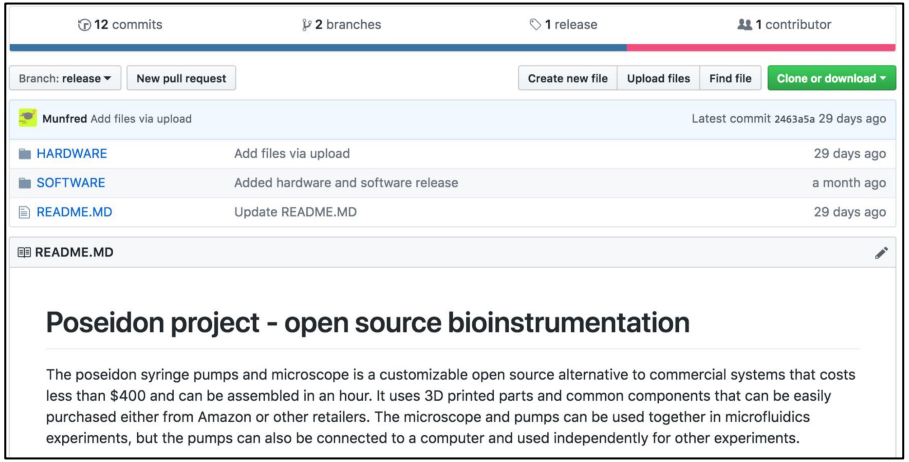
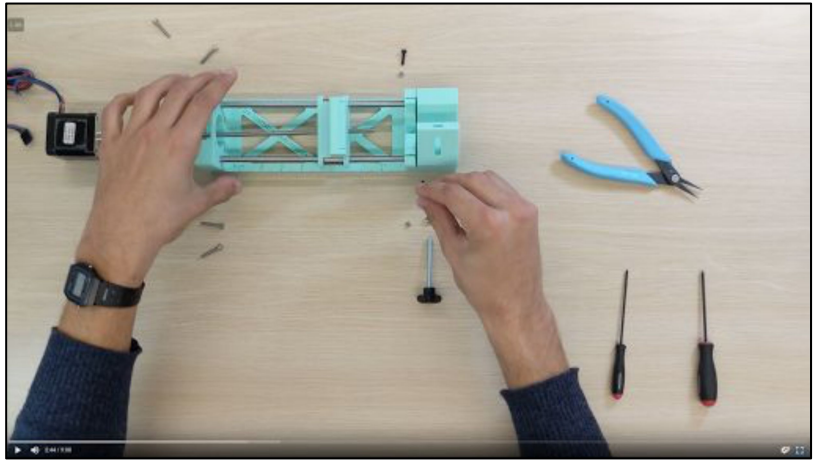






Documentation: The most important (and hardest) part of designing





“Any code written by oneself six or more months ago should be considered someone else’s code”

Recap: Principles are good, only if you follow them

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A many thanks to those who helped on the project

Professor Lior Pachter

Jase Gehring

Eduardo Da Veiga Beltrame

Dylan Bannon

Project website: https://pachterlab.github.io/poseidon/hardware

If you like these kinds projects then reach out to us!

With the skills you will learn in Justin's class, we can work together to develop all sorts of novel bioinstruments. Our goal is to produce open, reliable, and modifiable bioinstruments for academic, medical, and research applications.

Examples of possible projects:

1. Fast Pressure Liquid Chromatography (Protein purification, liquid handler)
2. Automated fraction collector
3. Centrifuge microfluidics

Or just stop by our offices in the basement of Kerckhoff to check out our lab.

Contact: Sina Booeshaghi (abooesha@caltech.edu)