Laurea in Bioingegneria

Microelettrovalvola per Bioprinting:
prove e misure preliminari

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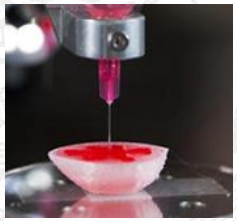
What is Bioprinting?

Bioprinting can be defined as the use of computer-aided transfer processes for patterning and assembling living and non-living materials with a prescribed 2D or 3D organization in order to produce bio-engineered structures serving in regenerative medicine, pharmacokinetic and basic cell biology studies.
(International Conference about Bioprinting and Bio Manufacturing - Bordeaux 2009)

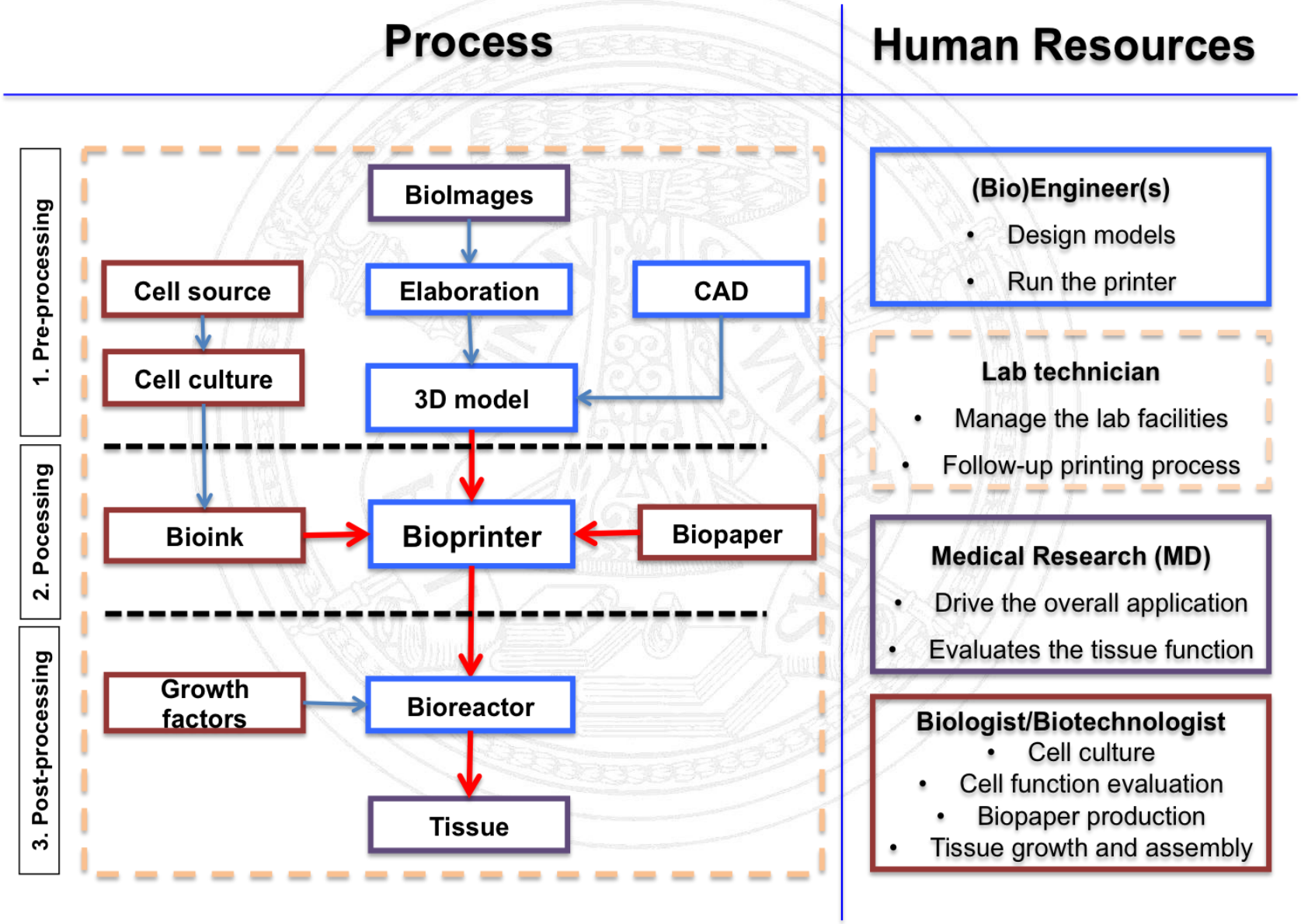
- Based on the **three "B"**:
  - **Bioink**:

  - **Biopaper**:

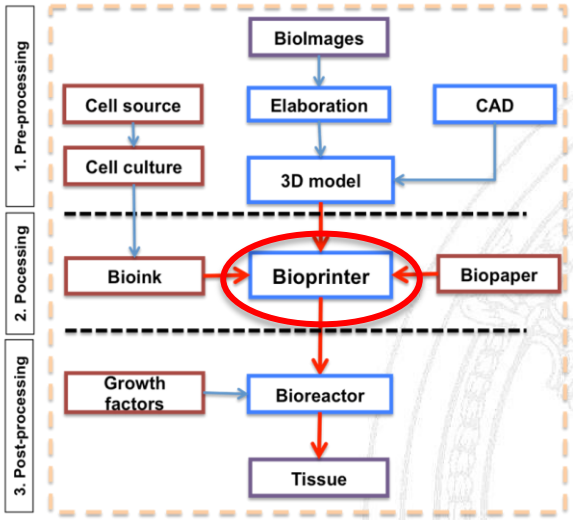


  - **Bioprinter**:

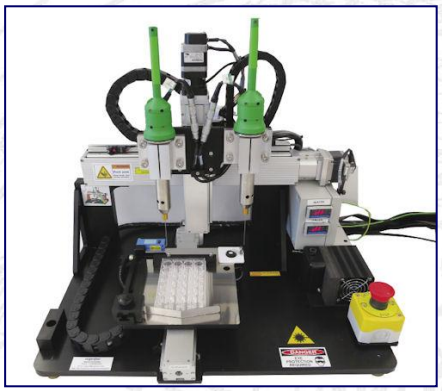
Bioprinting workflow



Bioprinters



NovoGen MMX



Not marketed

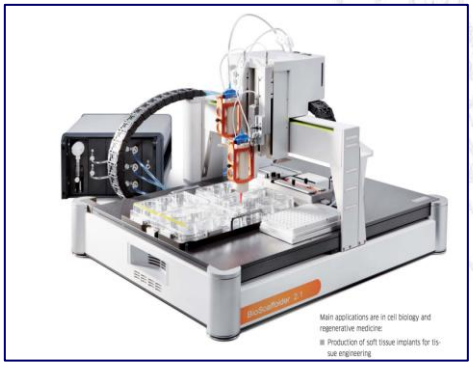
3D Bioplotter

$ 200000

3D Discovery

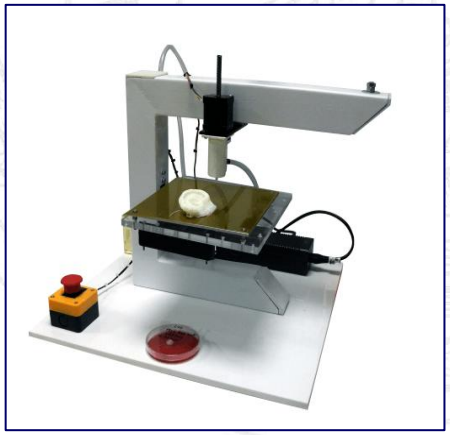
$200000

BioScaffolder 2.1



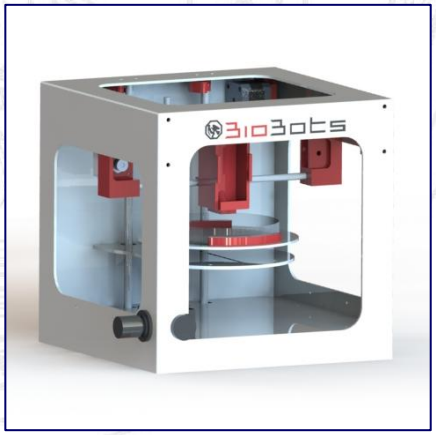
$ 180000

Alpha and Omega



£ 12000/18000

BioBots



$ 10000

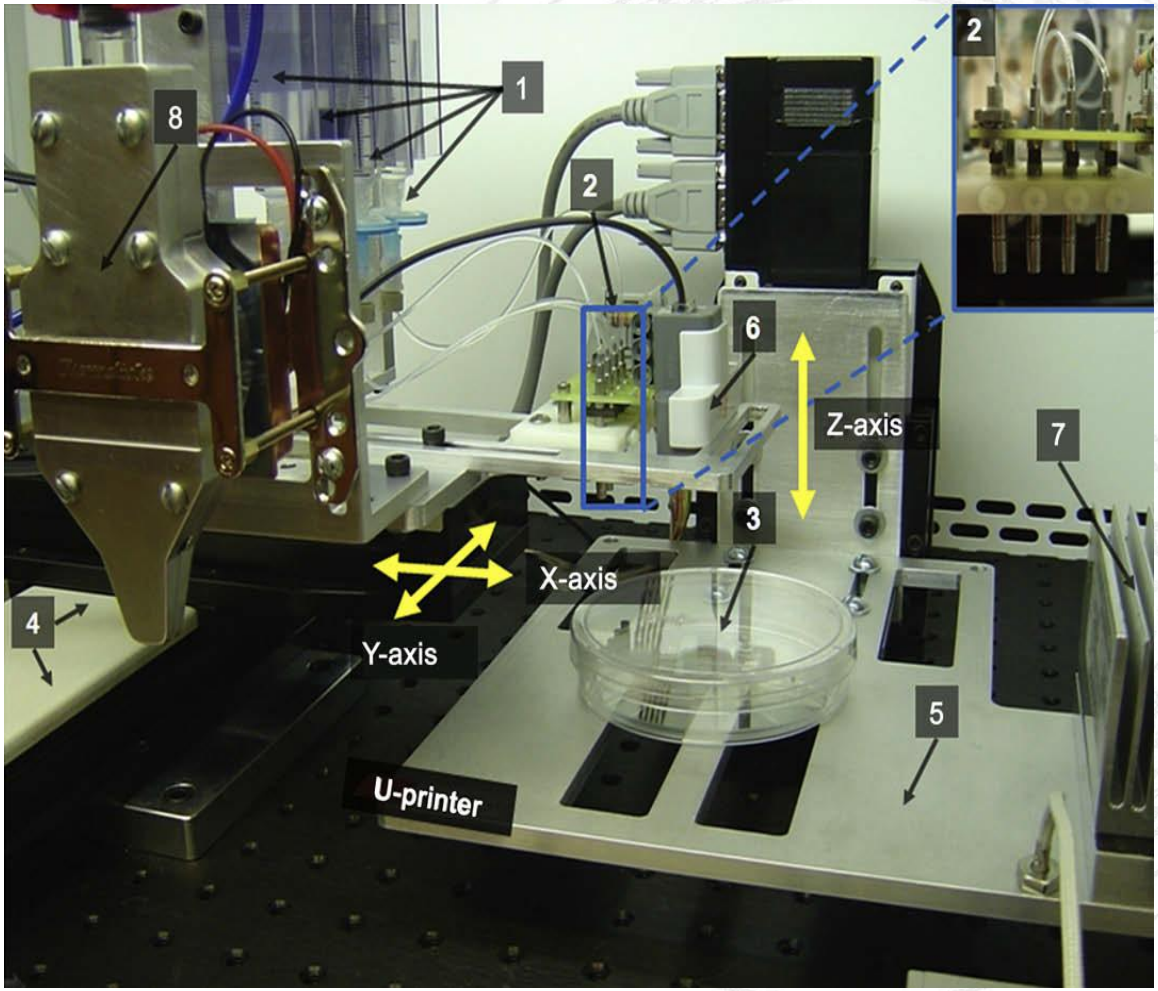
Inkredible

$ 5000/9000

Refs: https://replicatore.wordpress.com/2015/09/06/top-10-biostampanti-commerciali-2/

BioPrinting project – Lee's bioplotter

❑ BioPrinting project's Goal:



Lee's **Bioplotter**: modular tissue printing platform

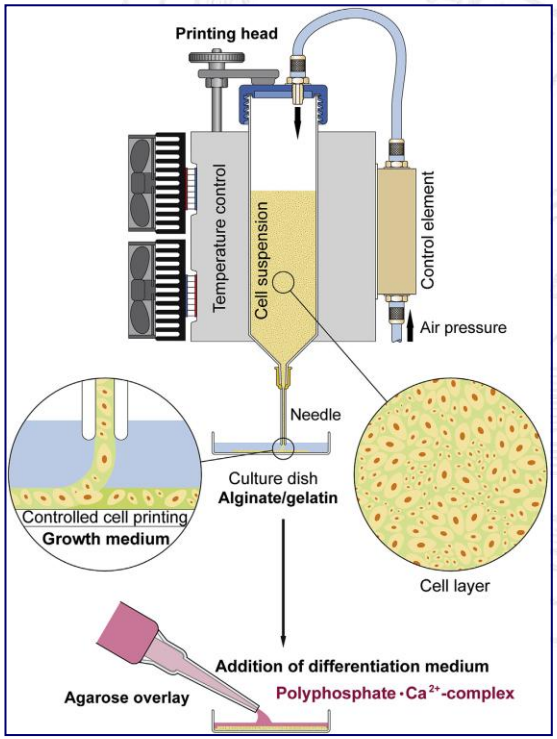
1. 4 syrynges as "cartridges" to load cell suspensions and hydrogel precursors
2. An array of 4-channel dispensers
3. Target substrate
4. Horizontal stage
5. Vertical stage
6. Range finder
7. Vertical stage heater/cooler
8. Optional indipendent heating/cooling for the dispenser

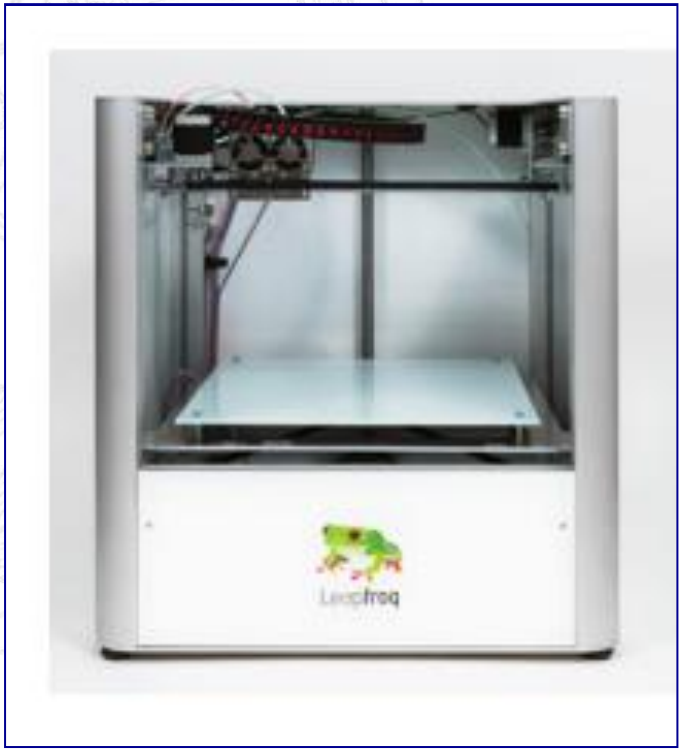
Fig. Lee 2008, Multi-layered culture of human skin fibroblasts and keratinocytes through three-dimensional freeform fabrication

BioPrinting project – Our approach

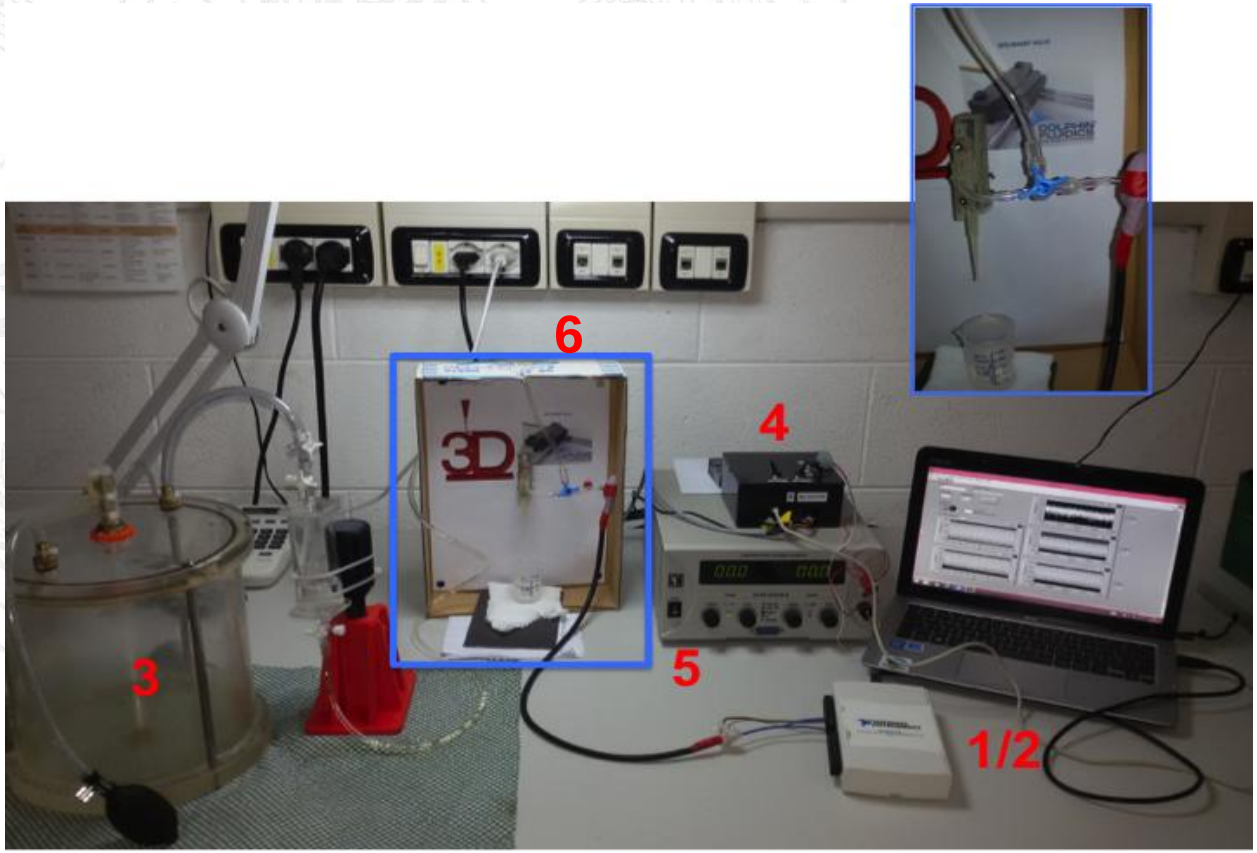
- Inspiring by Lee's bioplotter, this is our purpose:

Develop a simple work plan, not automated → Integrate the dispenser in a 3D printer → printing proofs (with cells)





- **Global setup**: the following material was necessary for the development of the project
  1. Acquisition of pressure signal whit 0Psi to 15Psi Gauge Honey-Well sensor, DAQ National Instrument, computer
  2. Acquisition of the piston position signal, to control the valve opening / closing
  3. Air pressurization system
  4. Control Box's valve
  5. Power supply
  6. Microelectrovalve

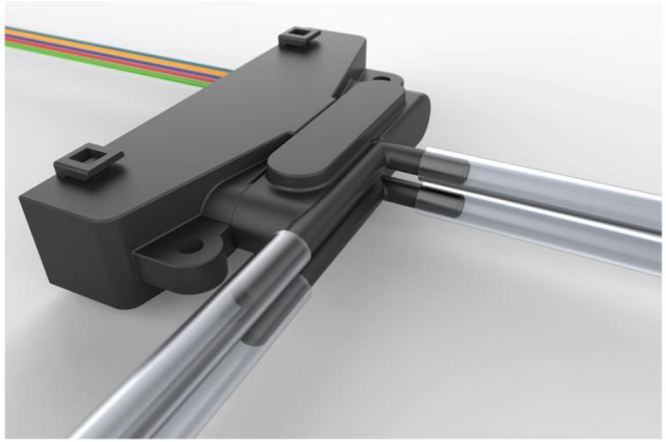


Microelectrovalve - Features

❑ Dolphin Fluidics' DFD-Smart

The DFD-Smart is a modular system with 2-way valves, total isolation, ideal for controlling fluid flows at high hygienic nature and not be contaminated. Each valve can be single, double or coupled in a fluidic block. Each channel can be controlled on-off or proportional independently.

DFD SMART VALVE

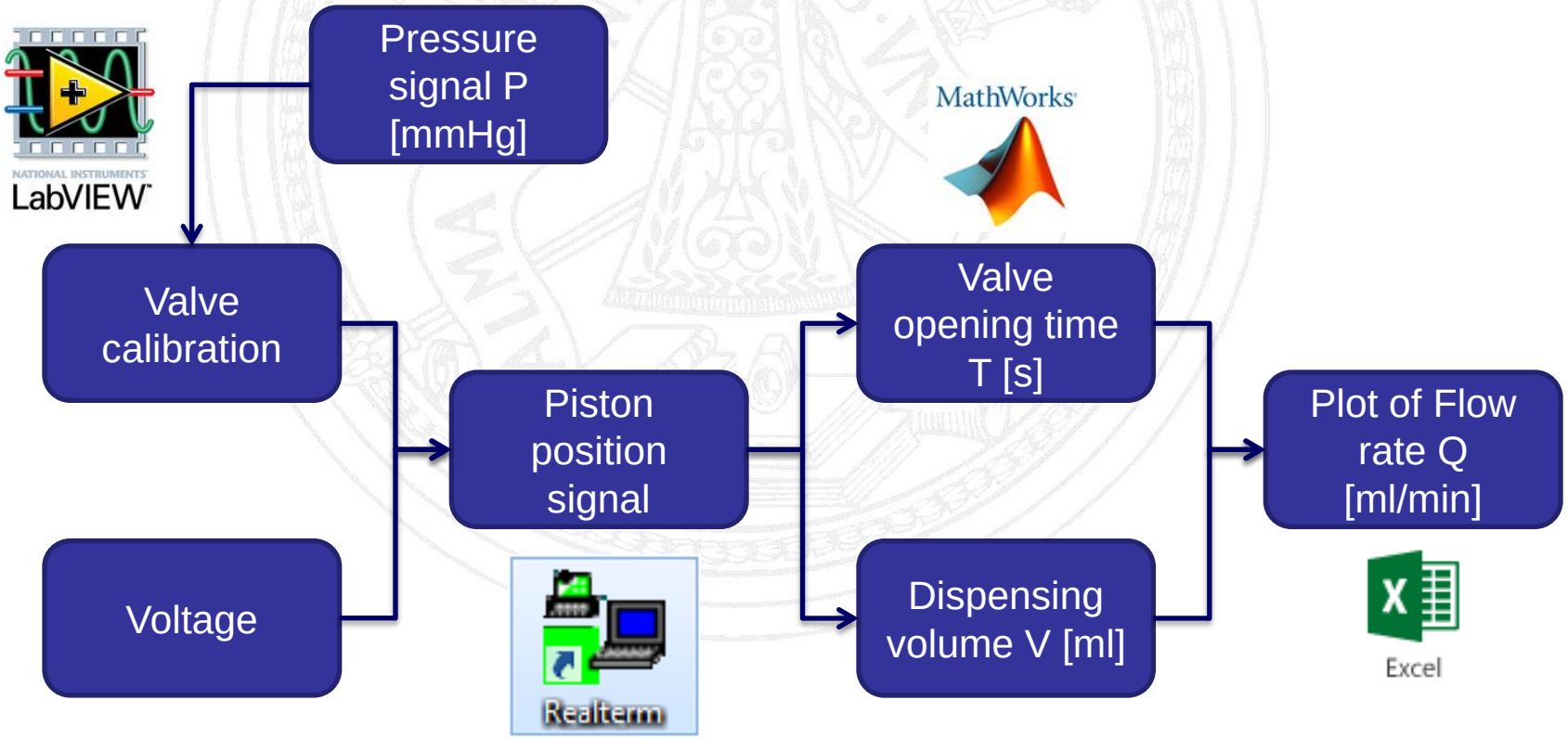


Technical Data	
Nozzle Diameter	Ø 0.8 mm
Pressure Range	0 – 4.0 bar
Operating Temperature	-10° C - +65° C
Current Range	150 mA – 240 mA
Response Time @ 0.6 W	180 ms
Holding Power	0.1 W
Implementation Power	0.4 – 0.6 W
Life-time	Million of cycles
Control	On/Off and Analogic

Microelectrovalve - Measurements

- The purpose of the setup is to measure the performance of the first prototype of the **microelectrovalve DFD-Smart** (Dolphin Fluidics) by drawing a graph of the flow rate Q [ml/min] as a function of working pressure P [mmHg].

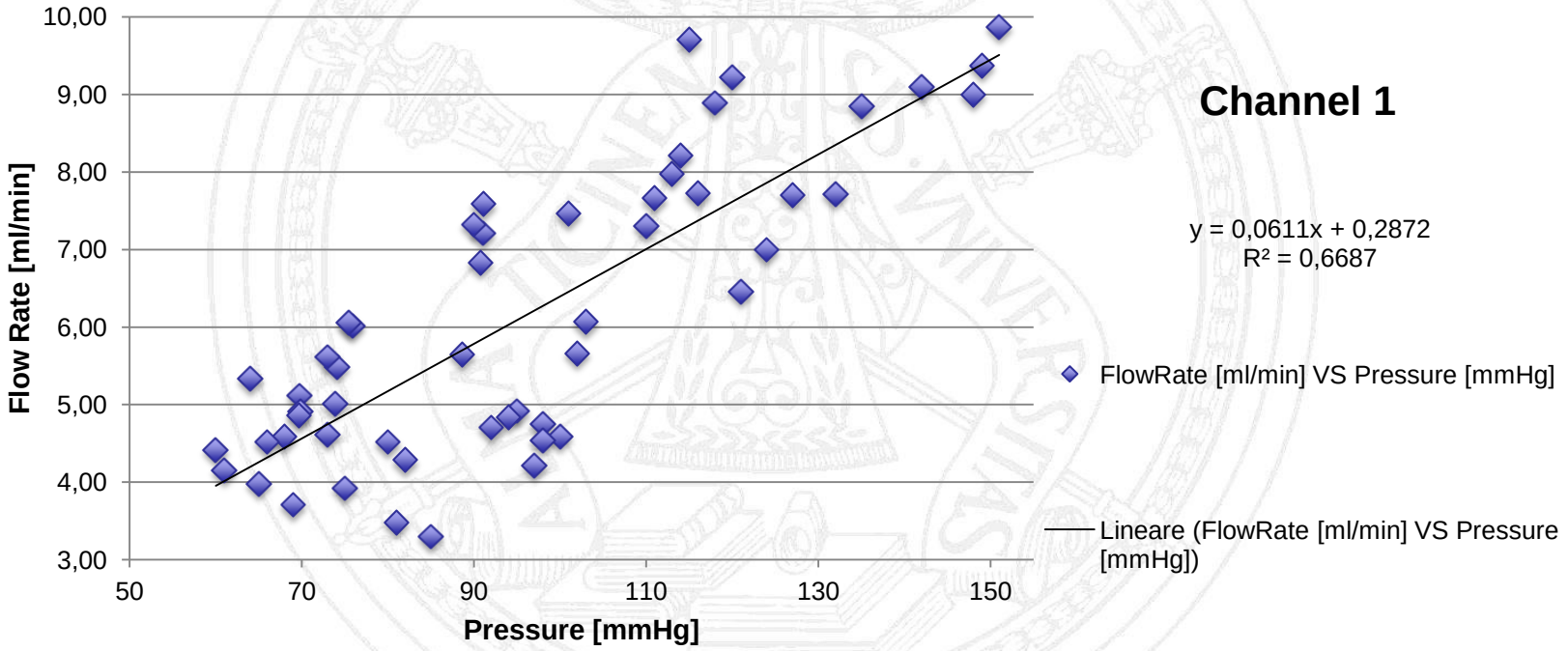
- **Steps** of measurement process:



First setup - Results

❑ Testing conditions:

- ➢ Range pressure from 60 to 150 mmHg
- ➢ Constant voltage of 3.3V (100% of the valve opening)



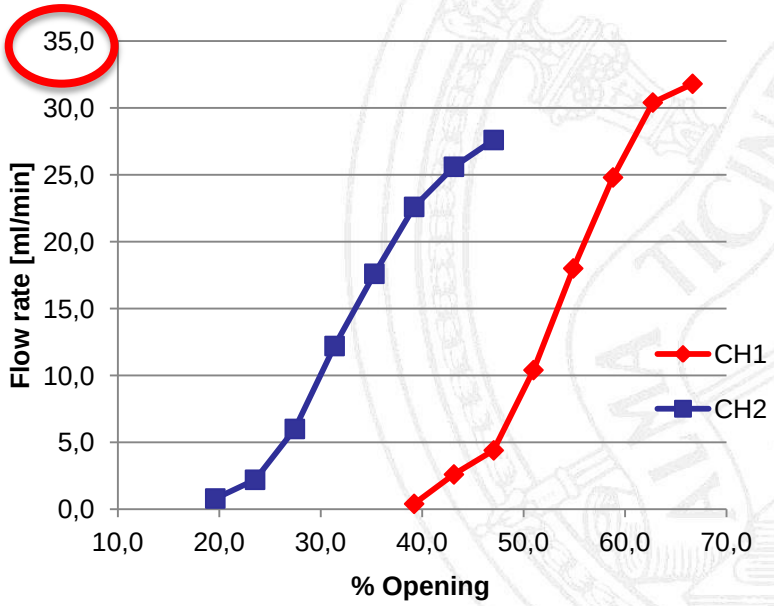
Conclusion:

1. **Low accuracy and precision** of the measurements
2. **Leakage** phenomenon for pressure under 150 mmHg
3. **Channel 2** was **clogged**

❑ **@ P = 120 mmHg**: plot of the Flow rate as a function of the valve opening percentage

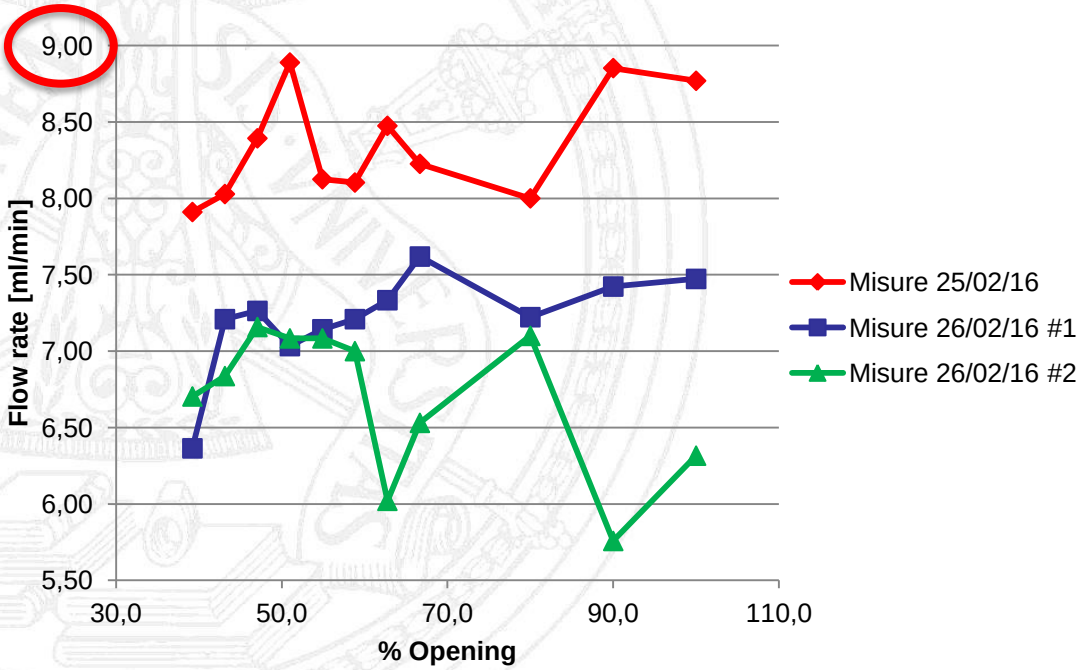
Dolphin Fluidics

Channels' characteristic



UniPV

CH1 flow rate [ml/min]

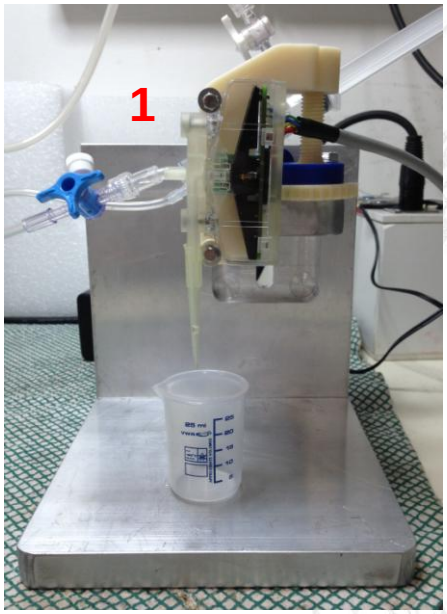


Conclusion:

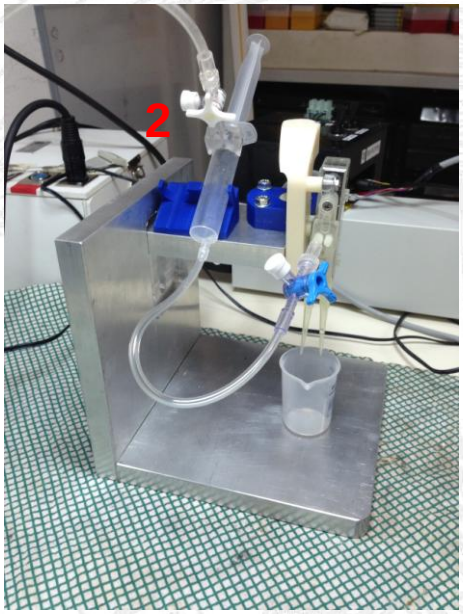
1. The measures do not reproduce the **sigmoid curve**
2. Low repeatability
3. Both channels dispensed less than what we expected, because they were **clogged**

Third setup – Results (I)

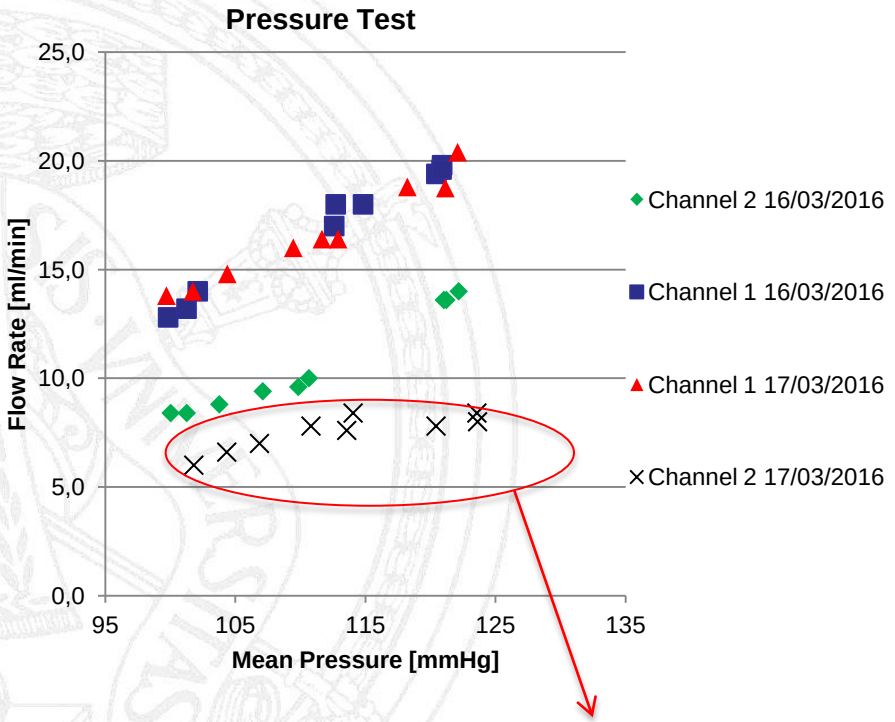
- The flow rate was measured by pressurizing a 10 ml syringe, containing H2O



1. Microelectrovalve



2. Syringe



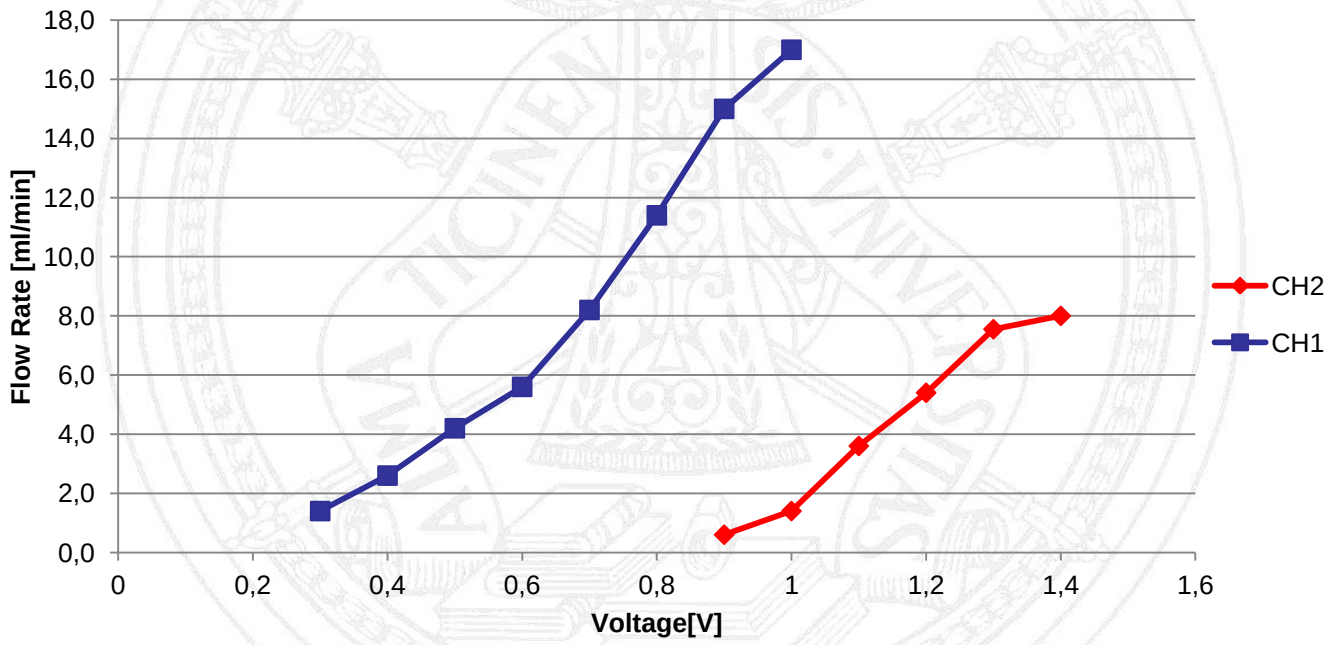
CH2 tends to **clog** easily

Conclusion:

1. Channel 1 presents **more accuracy** and **repeatability** than channel 2
2. Channel 2 **dispensed less** than channel 1
3. It's often necessary to **clean** the channels

Third setup – Results (II)

- **Testing conditions for the characteristic of the channels**:
  - Average working pressure: 120 mmHg
  - Valve opening time: 30 s
  - Variation of the voltage and of the valve opening percentage



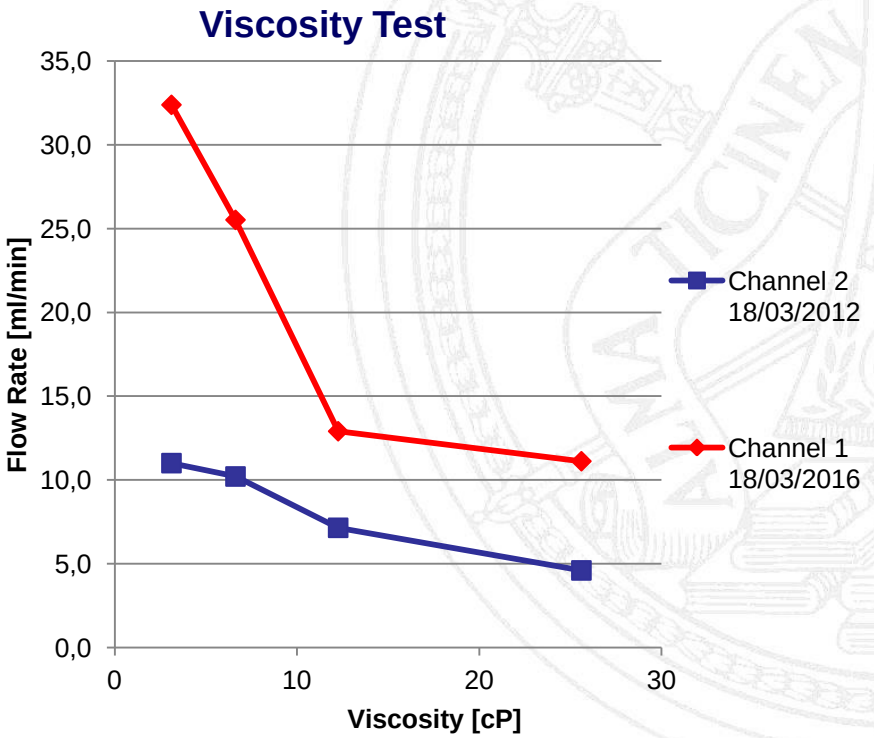
Conclusion:

1. Both channels present a **sigmoid curve**
2. CH1 dispensed from 0.3V, while CH2 from 0.9V
3. CH1 dispensed more than CH2

Third setup – Results (III)

- A step forward: the valve was tested with
  - **glycerol solution** to simulate silk hydrogel
  - Constant pressure of 120 mmHg
  - 100% of the valve opening

Water/glycerol Mix	Dynamic viscosity		Density
	cP or mPa.s	Pa.s or N·s·m−2	kg.m-3
Glycerol 35%	3,1076	0,0031076	1098.6
Glycerol 50%	6,622	0,006622	1143.7
Glycerol 60%	12,255	0,012255	1169.1
Glycerol 70%	25,604	0,025604	1193.3



Conclusion:

1. Flow rate decreases with increasing viscosity
2. Channel 2 dispenses less than channel 1
3. Both channels tend to become clogged, so a frequently clean was necessary
4. The valve is able to dispense up to **25 cP**

There is a real possibility of making printing tests with **silk-based solution**

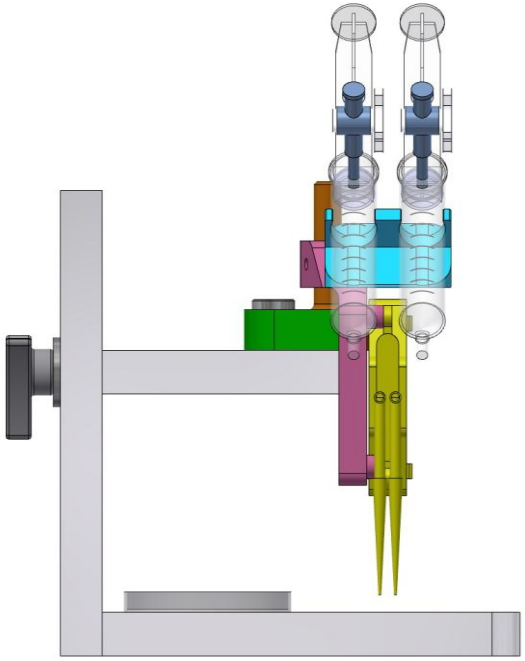
Limitations and future developments

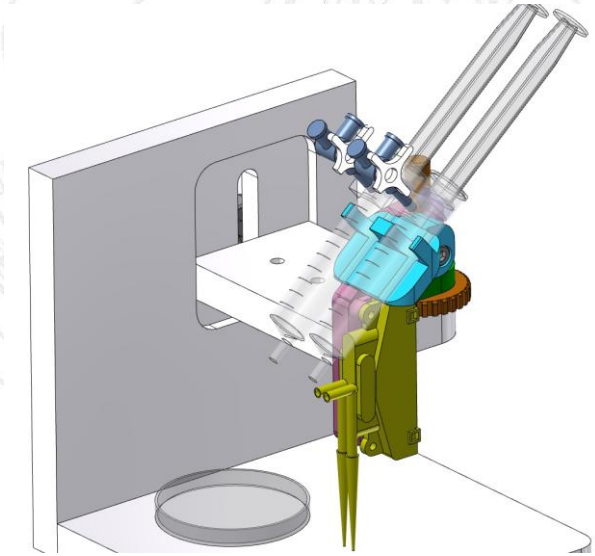
Limitations:

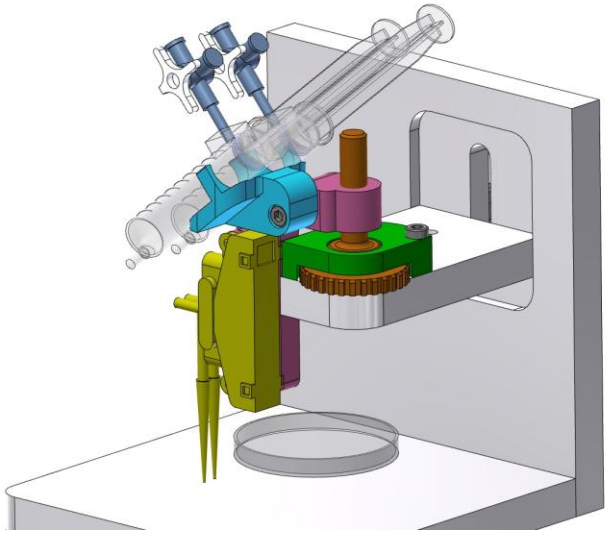
- The accuracy decreases under 100 mmHg of pressure
- Low precision beacuse of the manual control of the dispensing
- Channels tend to clog easily

Improvements:

- Digital control of the pressure signal (constant pressure of 1 - 3 Psi)
- Syringes washing system
- New support for the syringes, to minimize the distance between syringes and the valve
- Automated control of the dispensing



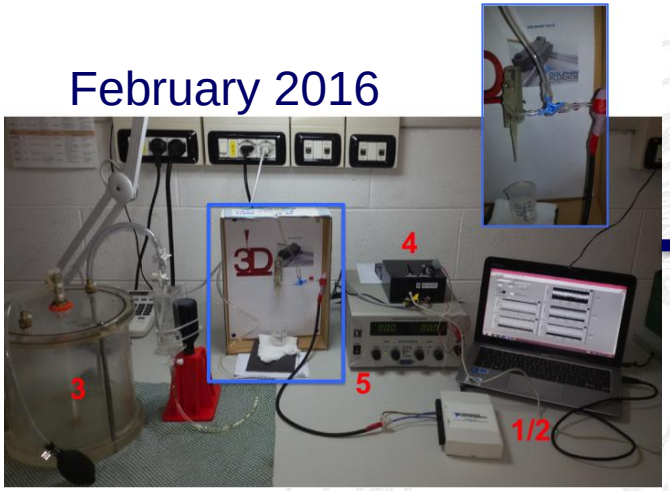


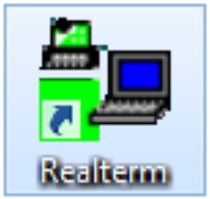


Ackn.: Mr. Pierangelo Bergamaschi

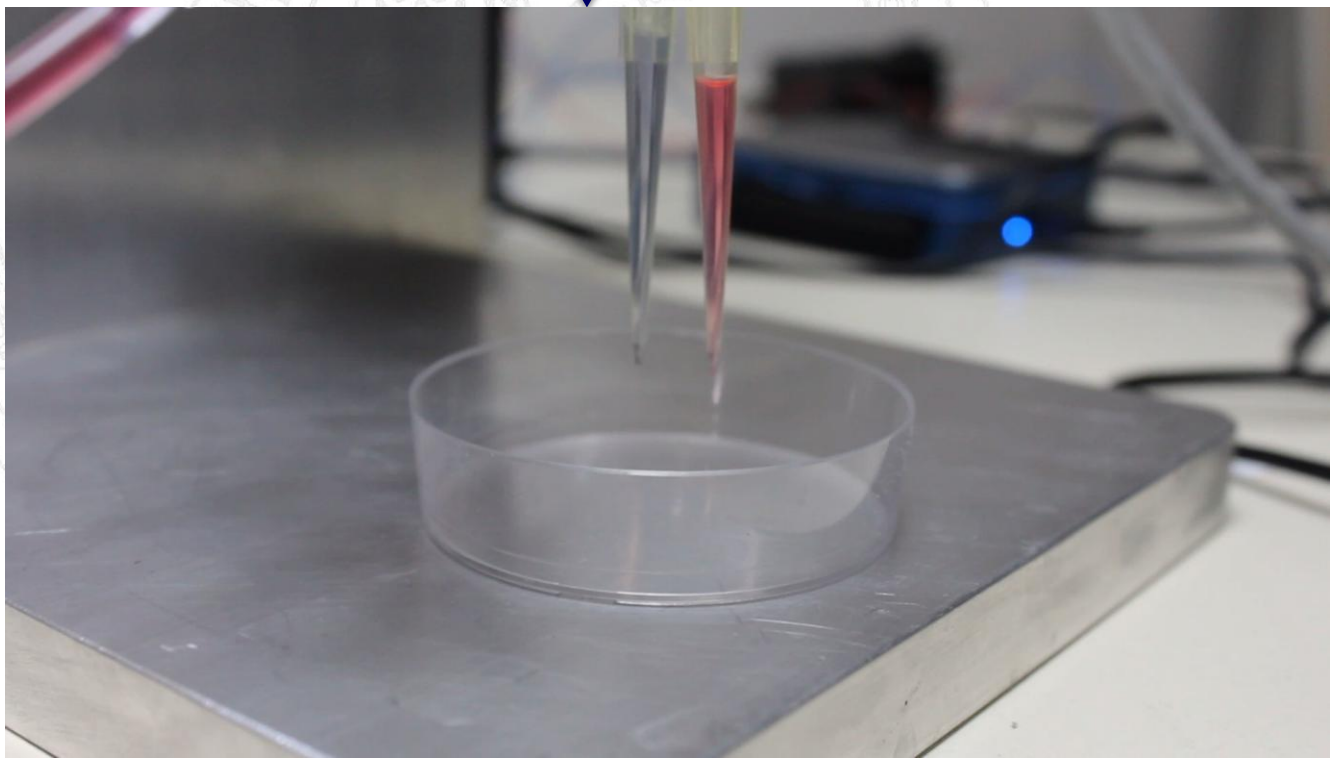
Conclusion

February 2016





April 2016 Video



GRAZIE PER L'ATTENZIONE