



Low-cost open software and hardware to acquire data on airway smooth muscle contractility.

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Rationale

Airway smooth muscle (**ASM**)
changes its length in response to specific stimuli.

This ASM property is called **contractility**.

ASM **contractility** is a fundamental determinant of **airway caliber**
both in normal and pathological conditions.

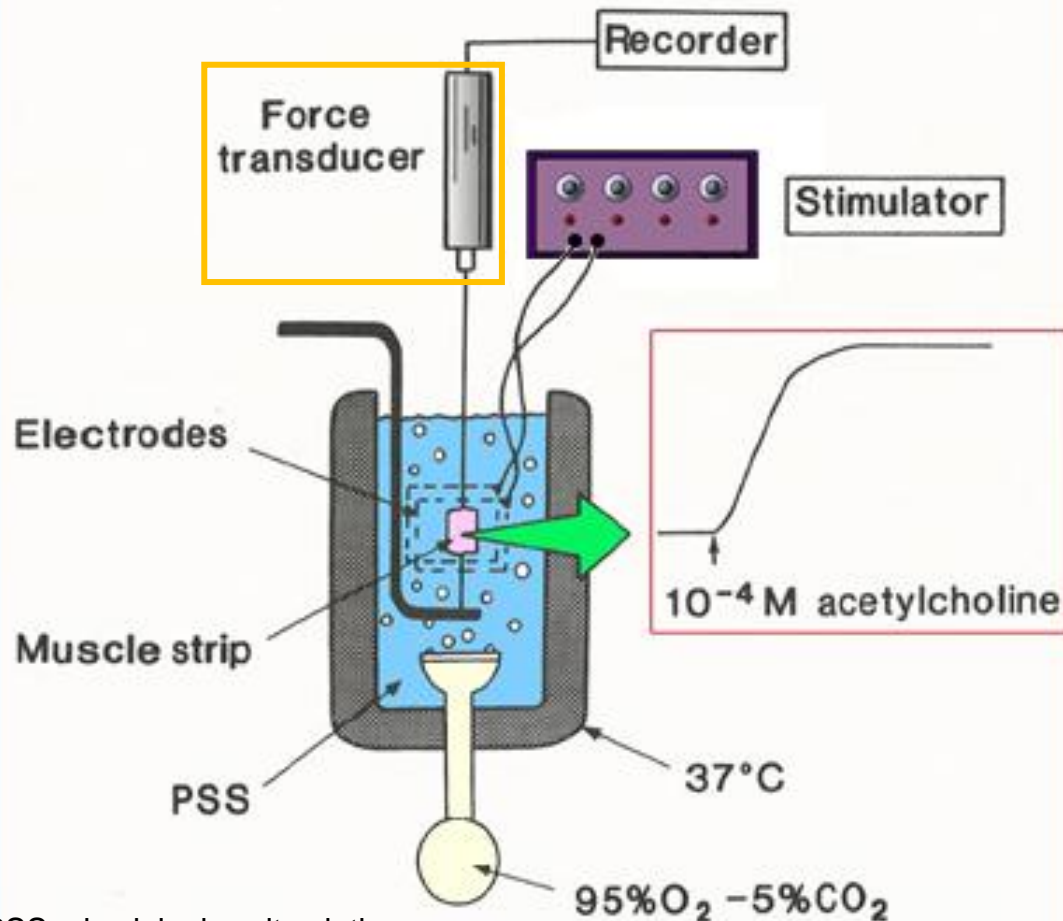
Why study ASM contractility?

A more detailed understanding of the mechanisms providing the
ASM contraction and relaxation **could improve actual health
strategies and the development of new therapy approaches.**

Hardware for in vitro studies on human or bovine ASM contractility

Data acquisition core: force transducer (MODEL FT03, Grass Medical Instruments, Fullerton, CA)

ORGAN CHAMBER



Experimental applications

- ✓ Dose-response curves to specific drugs (contractile or relaxing agents)
- ✓ Frequency-response curves to electrical field stimulation
- ✓ Assessment of contractility alteration upon electrical field stimulation induced by specific drugs

Advantages

- ✓ Parallel studies
- ✓ Assessment of different drug doses in every experimental procedure
- ✓ Absence of humoral material
- ✓ evaluate simplified models of pathophysiological alterations

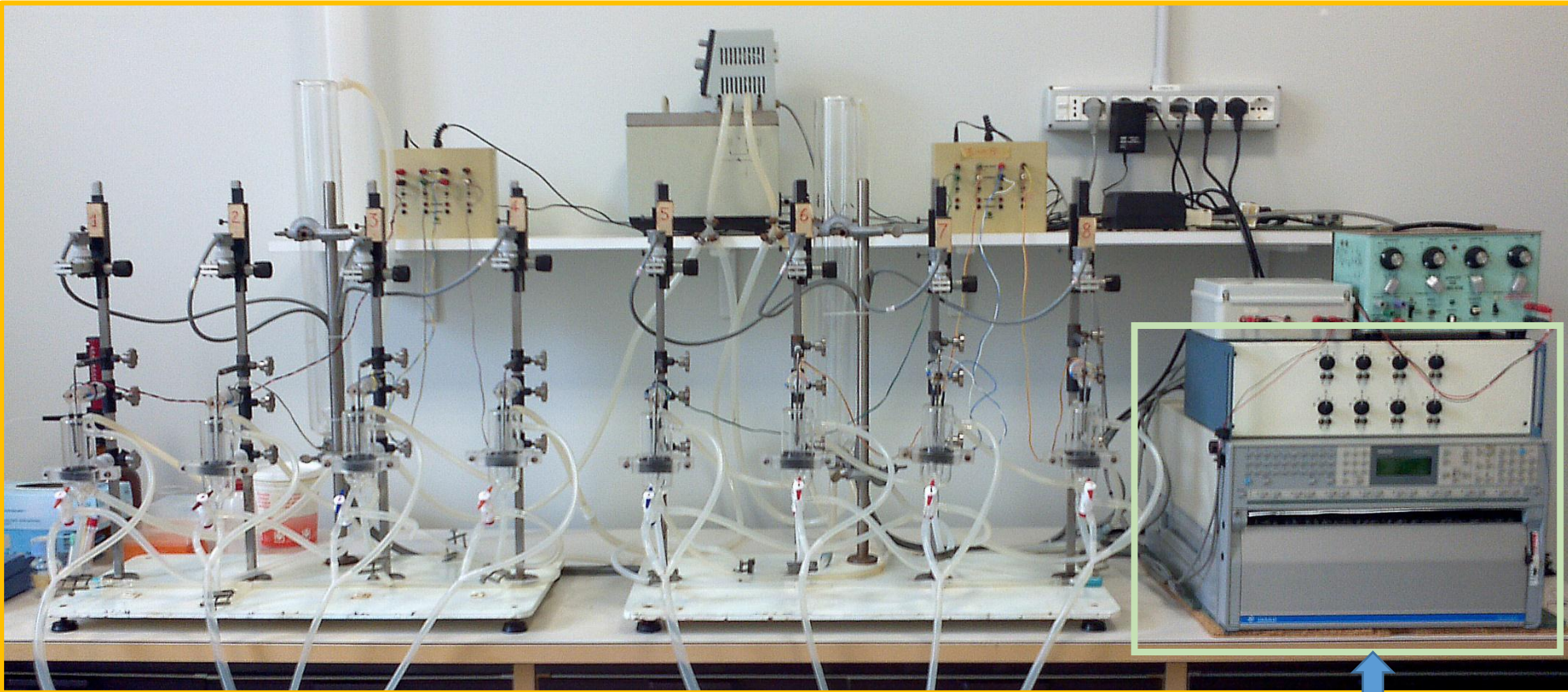
Disadvantages

- ✓ duration of experimental procedures
- ✓ length of data analysis

PSS: physiologic salt solution

Example of one organ chamber hardware

System setup



Data acquisition hardware initial setup:

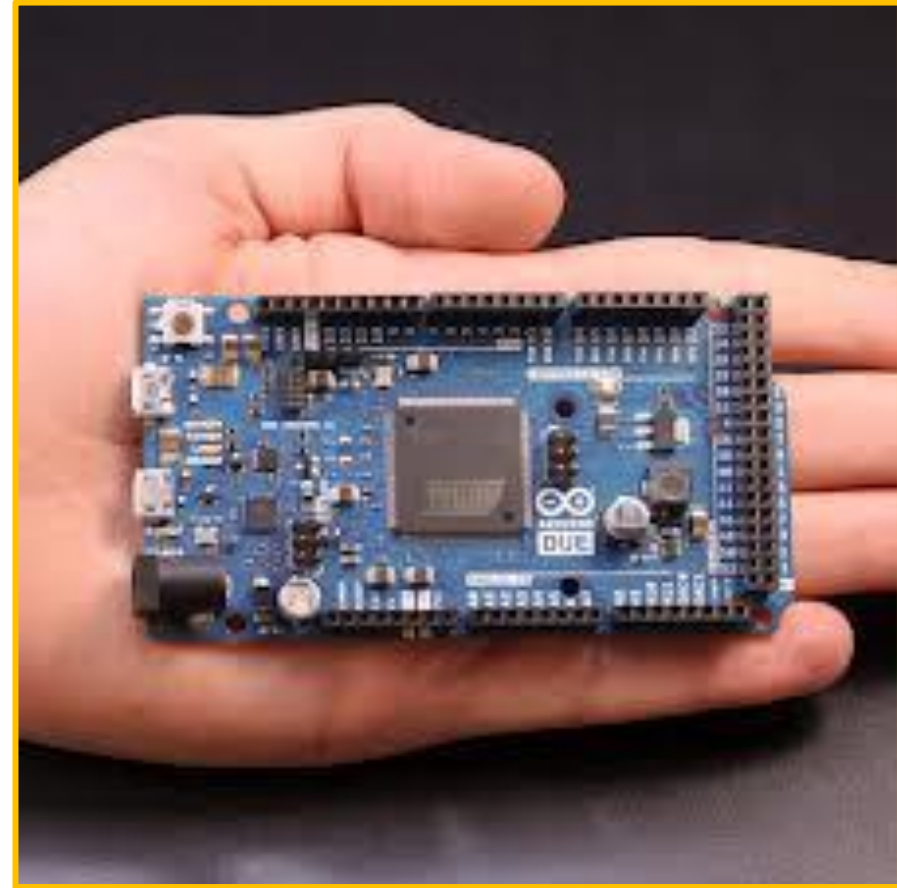
- ✓ 8 force transducers (MODEL FT03, Grass Medical Instruments, Fullerton, CA)
- ✓ 8-channel signal pre-amplifier
- ✓ Chart recorder (Gould model TA-4000, Valley View, OH)



Low-cost open software and hardware implementation:
Arduino due + processing instead of Gould TA-4000

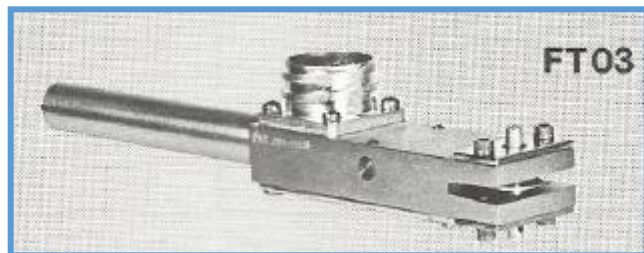
Why do we change from GOULD TA-4000 to arduino due + processing?

- ✓ Low cost open hardware and open software
- ✓ Optimization of signal to noise ratio on the basis of experimental setup
- ✓ Improve the data acquisition and their analysis
- ✓ Avoid interpolation errors (systematic and visual)
- ✓ Possibility to digitally store and analyze data in real time, during the experimental procedures



Experimental set up and hardware details (1)

Force transducers



STATIC SPECIFICATIONS

	FT03
Maximum displacement, mm	1.1
Maximum force, kg	10
Maximum applied voltage	8V DC
Nominal bridge resistance, ohms	350

- Developed to measure muscle contractions isometrically
- Four bonded strain gauges form a bridge which measures the strain produced on a cantilever beam by an applied force
- Gravity effect reduces to one dimension

DYNAMIC SPECIFICATIONS

	MODEL FT03			
	No Spring Used	Red & Black	Yellow & Black	Black
Color of Spring:				
Maximum Working Range kg	0.05	0.2	1	2
Minimum Reliable Force mg	2	10	50	100
Self-Resonant Frequency Hz	85	170	330	500
Output mV/kgm/Volt Applied	30	7.5	1.5	0.7

Experimental set up and hardware details (2)

Gould TA4000



- ✓ Chart paper width: 384 mm
- ✓ Chart speed: 1 mm/h to 200 mm/s (accuracy $\pm 5\%$)
- ✓ Thermal head resolution: 8 dots/mm
- ✓ Distance from waveform printing to actual visibility: 4mm
- ✓ Input sensitivity: 50mv/cm to 10v/cm
- ✓ 8 channel mode: 40 mm each channel
- ✓ Bandwidth: 10kHz at -3dB
- ✓ Peak capture: 70 μ s
- ✓ Noise: Max 3 dots at 50mV/cm

Arduino due

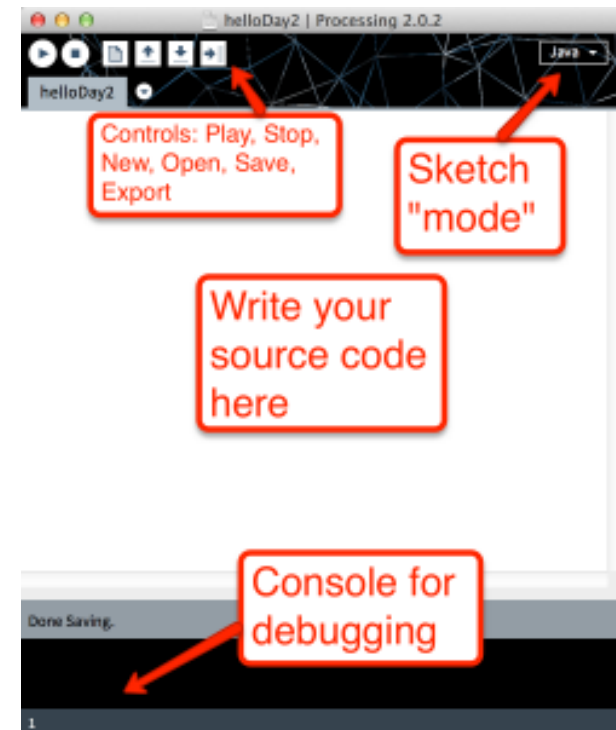


Microcontroller	AT91SAM3X8E
Operating Voltage	3.3V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-16V
Digital I/O Pins	54 (of which 12 provide PWM output)
Analog Input Pins	12
Analog Outputs Pins	2 (DAC)
Total DC Output Current on all I/O lines	130 mA
DC Current for 3.3V Pin	800 mA
DC Current for 5V Pin	800 mA
Flash Memory	512 KB all available for the user applications
SRAM	96 KB (two banks: 64KB and 32KB)
Clock Speed	84 MHz

Processing

Processing is an open source programming language and environment for people who want to create images, animations, and interactions.

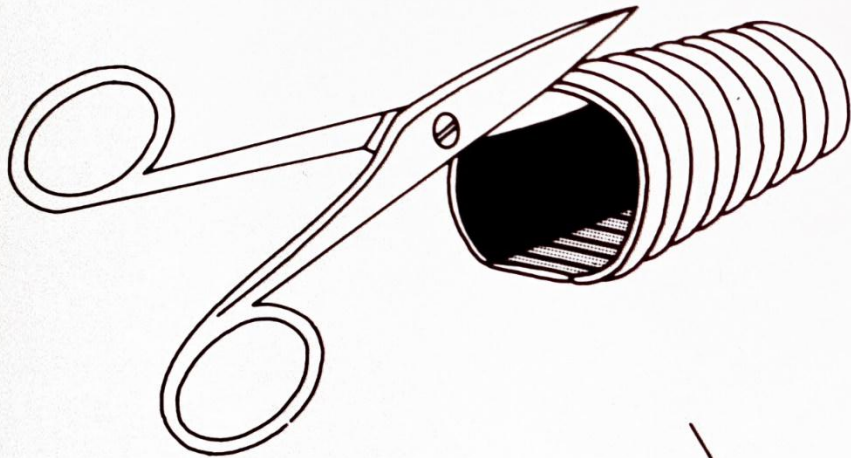
- free to download and open source
- Interactive programs using 2D, 3D or PDF output
- OpenGL integration for accelerated 3D
- For GNU/Linux, Mac OS X, and Windows
- Projects run online or as double-clickable applications
- Over 100 libraries extend the software
sound, video, computer vision, and more...
- Well documented
(processing.org)



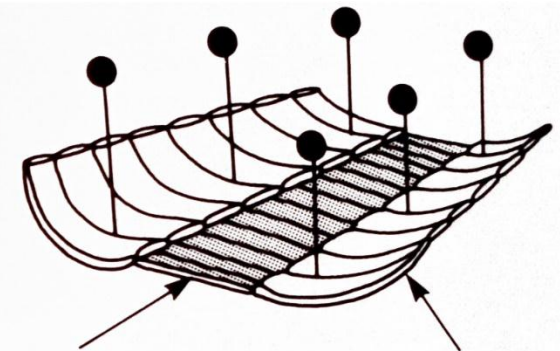
Experimental set up, samples preparation

PREPARATION OF TRACHEAL SMOOTH MUSCLE STRIPS (Performed in physiological salt solution)

Isolated tracheal segment

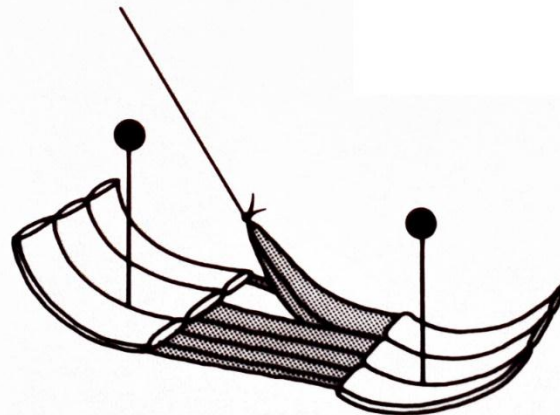


Adventitia and epithelium removal



Smooth muscle

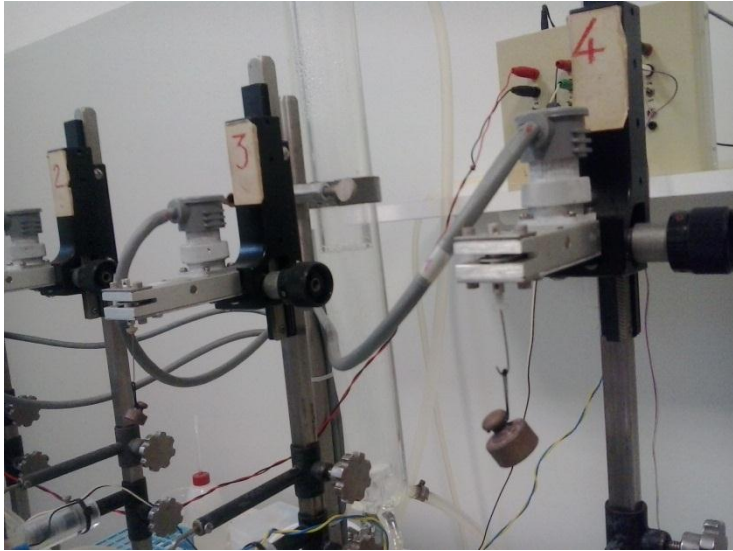
Cartilage



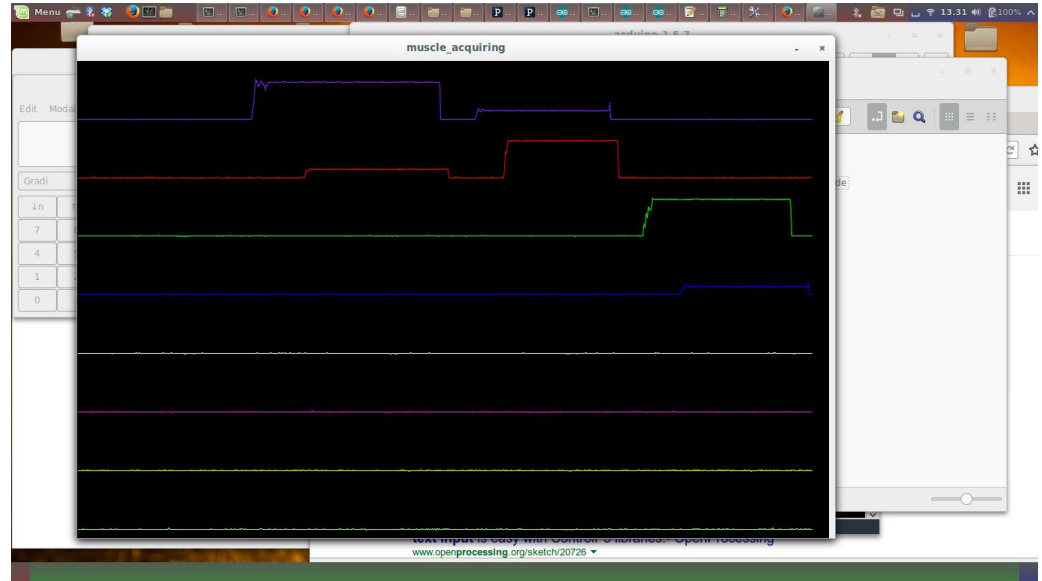
Cutting of smooth muscle strip



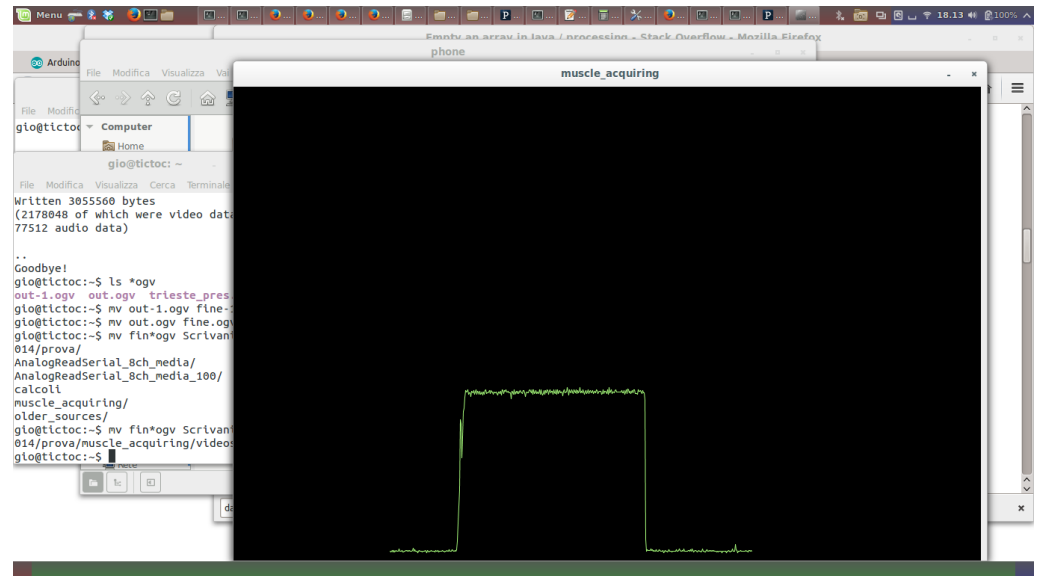
Experimental set up, calibration



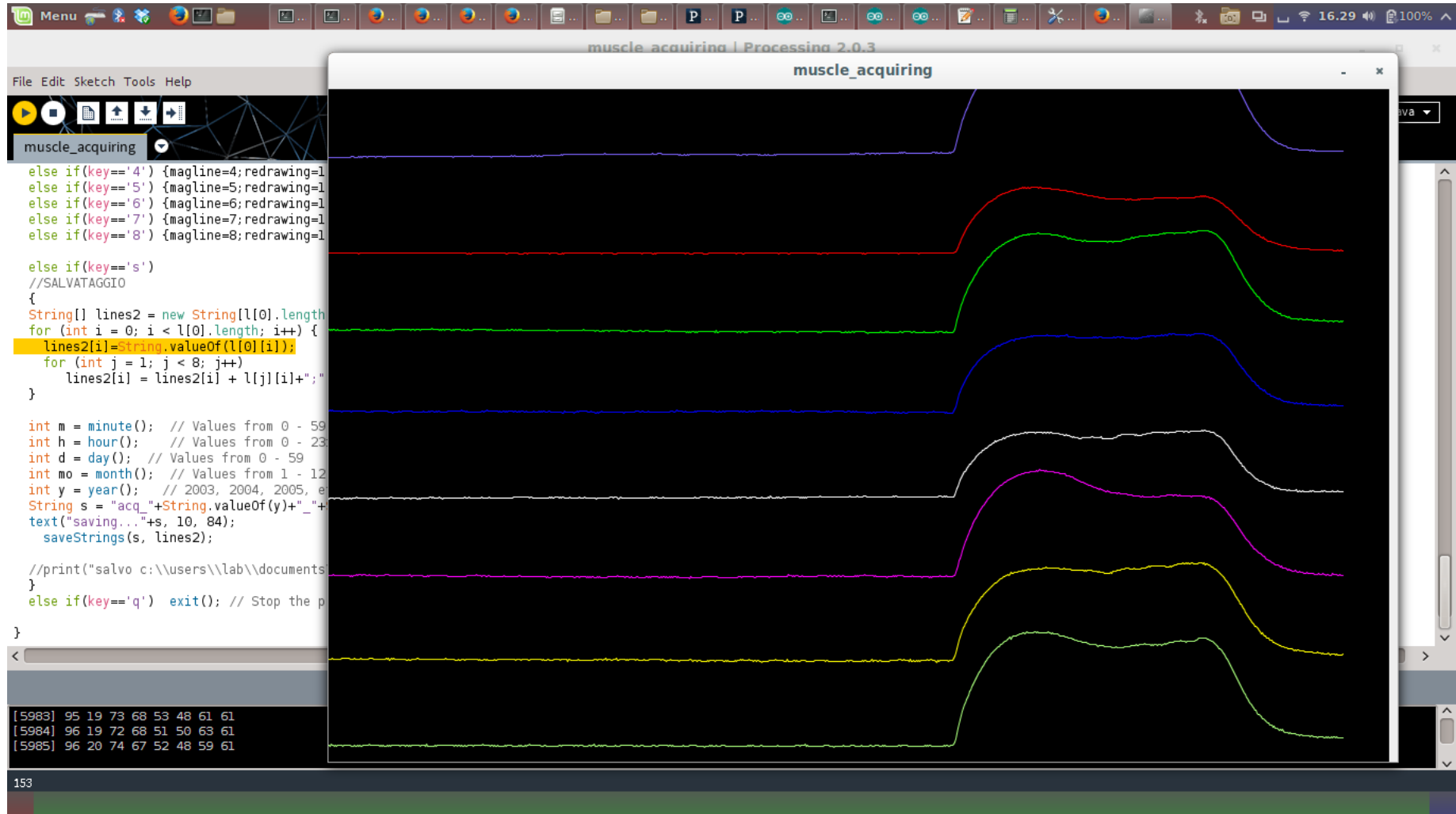
Calibration with 5 g and 20 g



Tracking calibration



Electrical stimulation



- ✓ Muscles were contracted simultaneously every 5 min for 30 s by electric field stimulation (25 Hz, 25 V, and 0.5 ms stimuli duration; SD9, Grass Medical Instruments, Quincy, MA).
- ✓ The electric stimulations waves were monitored using an oscilloscope (GOS-622G, Melchioni Elettronica, Milan, Italy).

Electrical stimulation

The screenshot shows a desktop environment with a Java application window titled "muscle_acquiring" and a terminal window. The terminal window displays the following text:

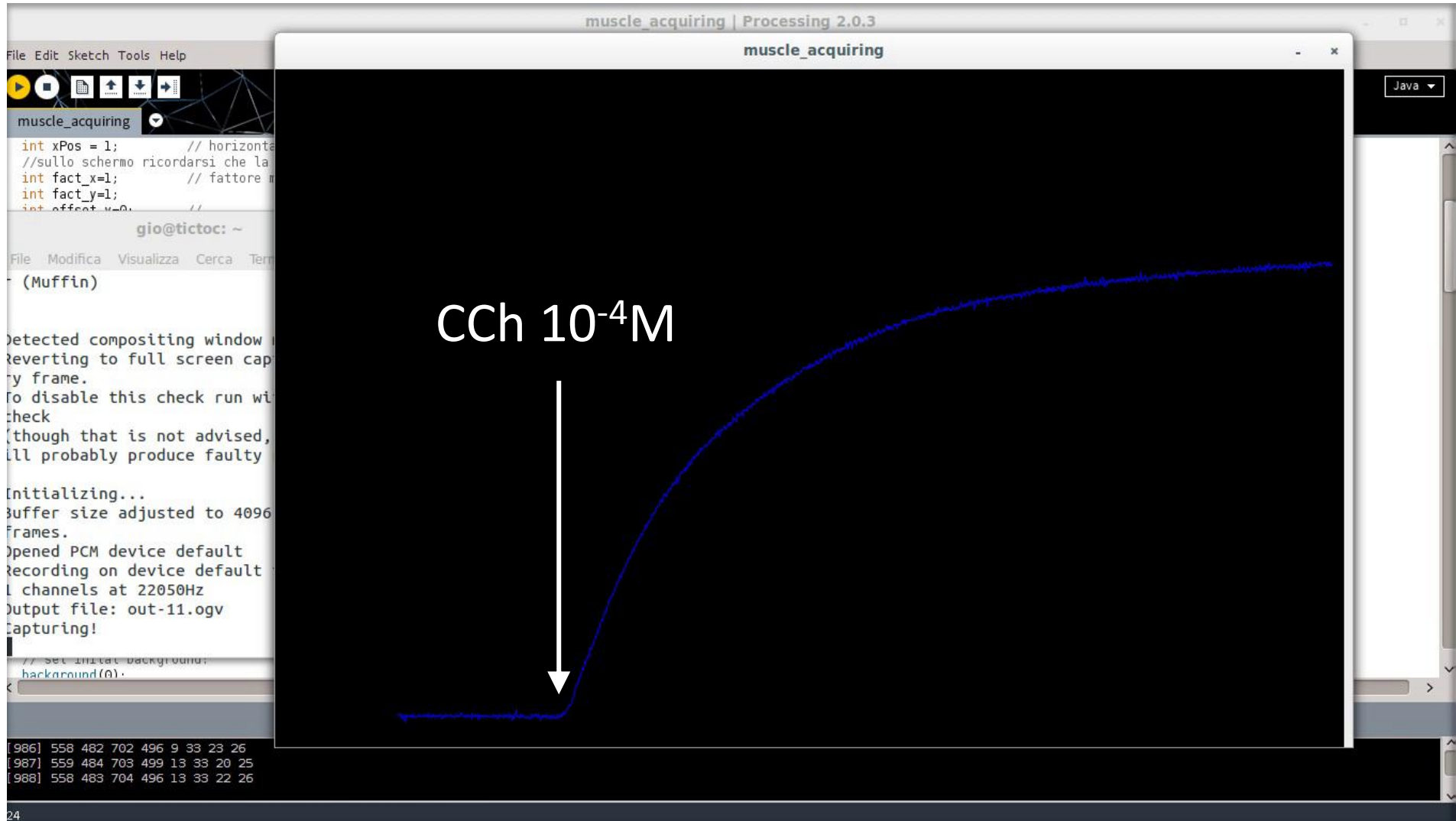
```
gio@tictoc: ~  
File Modifica Visualizza Cerca Terminale Aiuto  
[initial recording window is set to:  
<:0 Y:0 Width:1366 Height:768  
&adjusted recording window is set to:  
<:6 Y:0 Width:1354 Height:768  
&your window manager appears to be Mutter  
&- (Muffin)  
  
&Detected compositing window manager.  
&Reverting to full screen capture at every  
&frame.  
&To disable this check run with --no-wm-  
&check  
&(though that is not advised, since it will  
&probably produce faulty results).  
  
&Initializing...  
&Buffer size adjusted to 4096 from 4096  
&frames.
```

The Java application window shows a red waveform on a black background. The terminal window also displays a table of data:

[6168]	107	6	106	90	23	44	38	41
[6169]	107	6	108	91	23	38	35	40
[6170]	109	7	108	87	19	38	36	42

Example of a single trace magnification

Chemical stimulation



Example of muscle response to carbachol (CCh) 10⁻⁴M

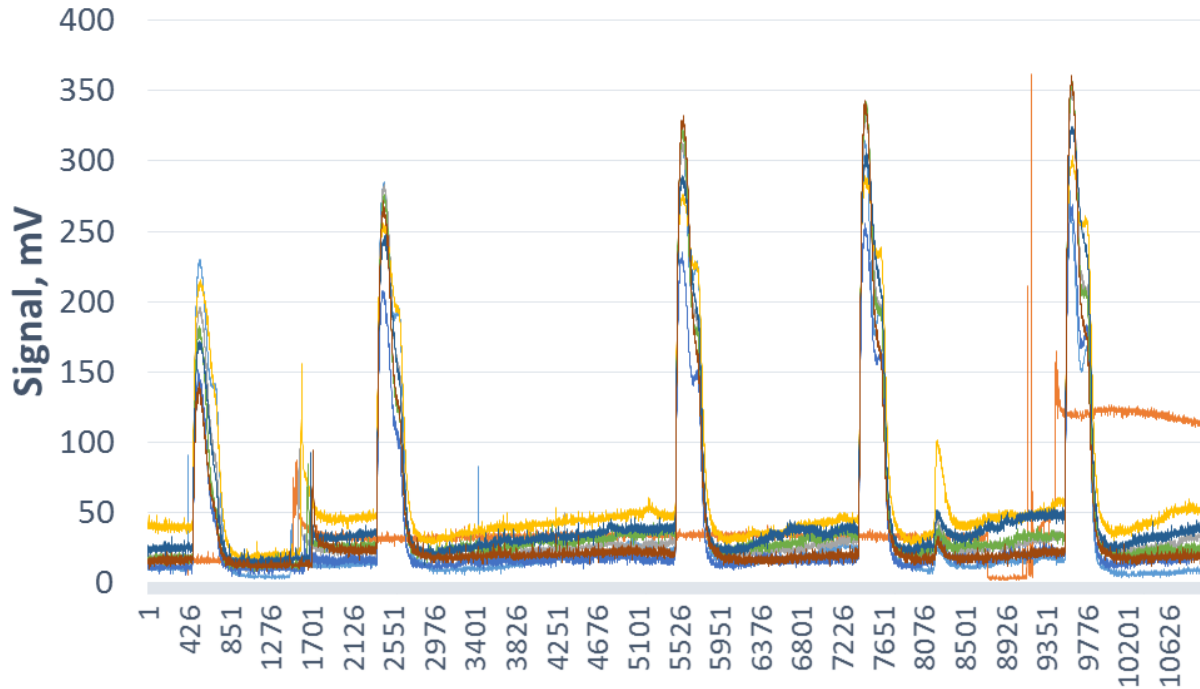
Comparison of collected data

Gould TA4000 →

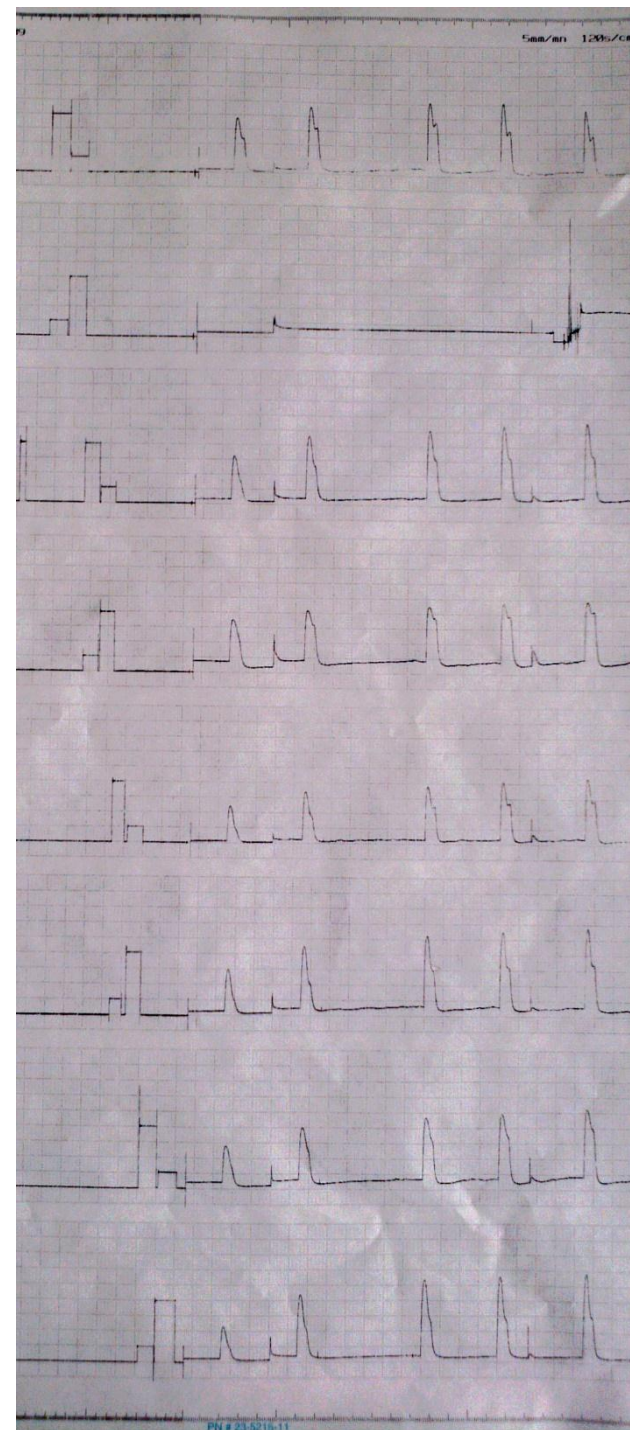
Arduino due



Example of 8 channel acquisition



— channel 1 — channel 2 — channel 3 — channel 4
— channel 5 — channel 6 — channel 7 — channel 8



Results and future direction

- ✓ Sensitivity improvement 3 times in examples,
- ✓ easily one order of magnitude.
- ✓ Avoid systematic uncertainty due to manual intervention.
- ✓ Realtime data visualization
- ✓ Full data acquisition available in digital format (csv) for further investigation.

- ✓ Trigger stimulation controlled by Arduino
- ✓ Offline data analysis (Matlab/Octave)
- ✓ Chemical excitation controlled by Arduino driven actuators.



Thank you for your attention

