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A Low-Cost Example, Combining MIT App Inventor, Arduino Specific Components and Recycled Materials to Foster Engineering Education

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Introduction

- Learners in all over the world are trying to acquire multi-disciplinary skills and knowledge, in order to tackle the challenges of the 21st century.
- The fast evolving mobile market industry resulted in a plethora of low-cost computer systems and pairing electronic components, at very affordable prices.
- Seizing the opportunity, many relevant educational activities are developed, commonly under the STEM “umbrella”.
- Following the example of primary and secondary education, the curriculum of the engineering institutions has to be updated accordingly, as well.

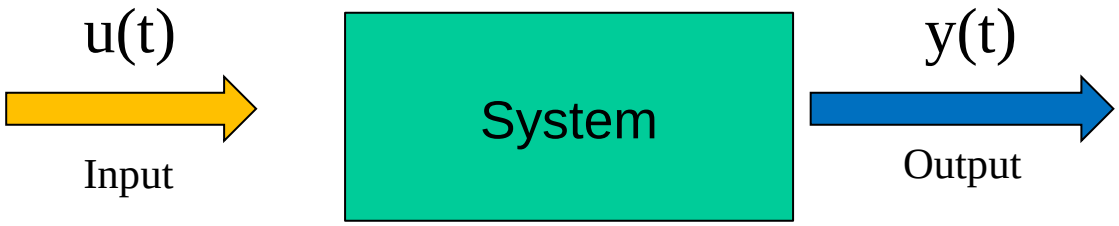
Objectives

- Through a PBL approach and wanting to make things more appealing, a characteristic automatic control case is highlighted: An adjustable air flow control system.
- Hardware: arduino-like boards, some additional low-cost components (sensors / motor drivers / radios) and recycled materials.
- Programming: Arduino IDE and visual tools (ardublock / MIT app inventor) for fast development and remote interaction functionality, via smart phones, in pace with the IoT trends.
- The proposed case although tailored for university-level students is also suitable for secondary and vocational education, due to its simplicity and its modular and scalable architecture

System

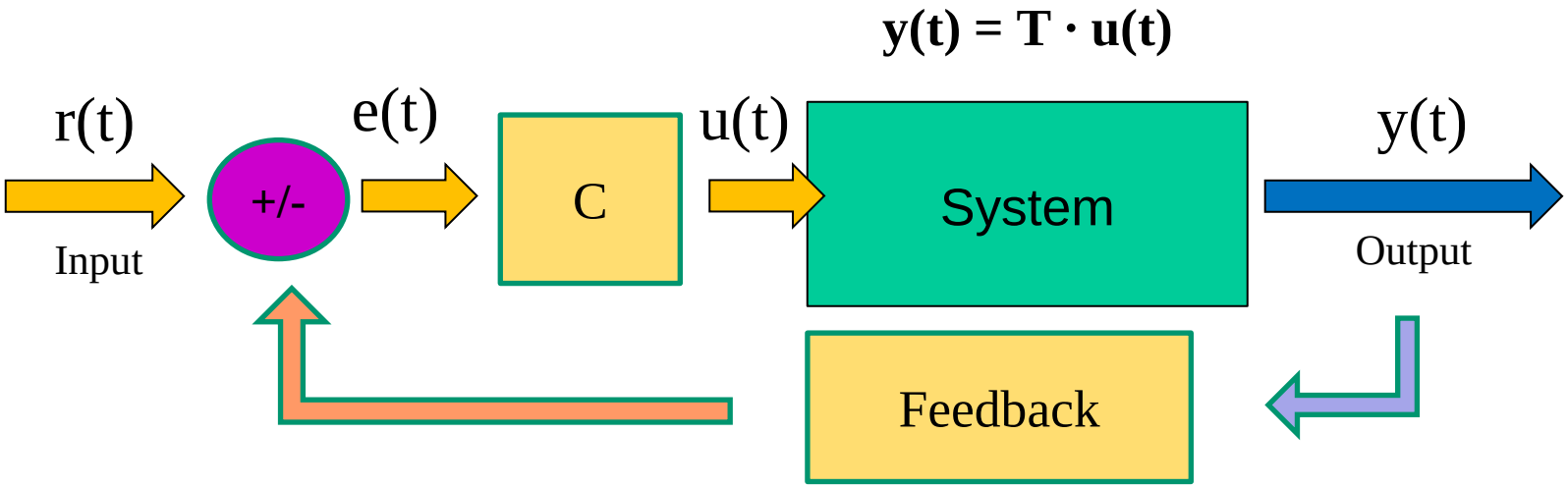
- System: a group of interacting or interrelated entities that form a unified whole.
- Surrounded and influenced by its environment, is described by its boundaries, structure and purpose and has input(s) and output(s)

$$\mathbf{y(t) = T \cdot u(t)}$$



Automatic Control System

- No need for human presence – "decent" behavior for long periods
- Continuously monitors output in order to adjust inputs (u(t)) and achieve the minimal error (e(t)) between desired/reference (r(t)) values and actual values (y(t)).
- C: A typical controller block (i.e., PID)

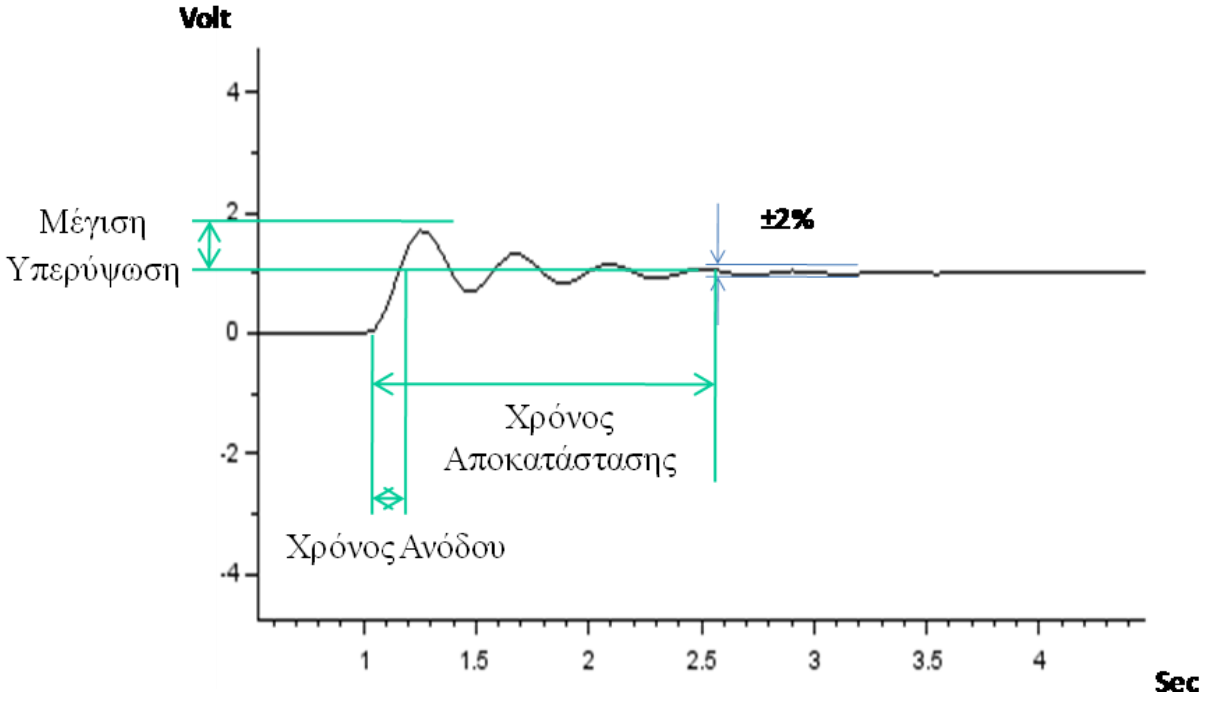


Sensors and Actuators

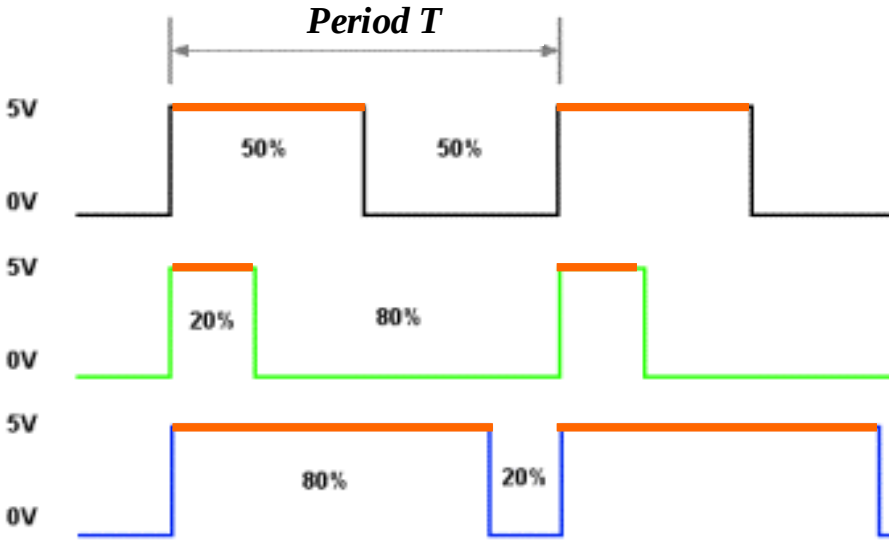
- Sensors and actuators provide physical interaction of the computerized system with the real world (physical computing concept)
- Sensors: Convert signals and provide input for the microcontroller.
- Actuators: Transform microcontroller decisions into actions

Desired Behavior

- A good automatic control system should have short rise time short settling time and small peak overshoot.



PWM to Adjust DC Output

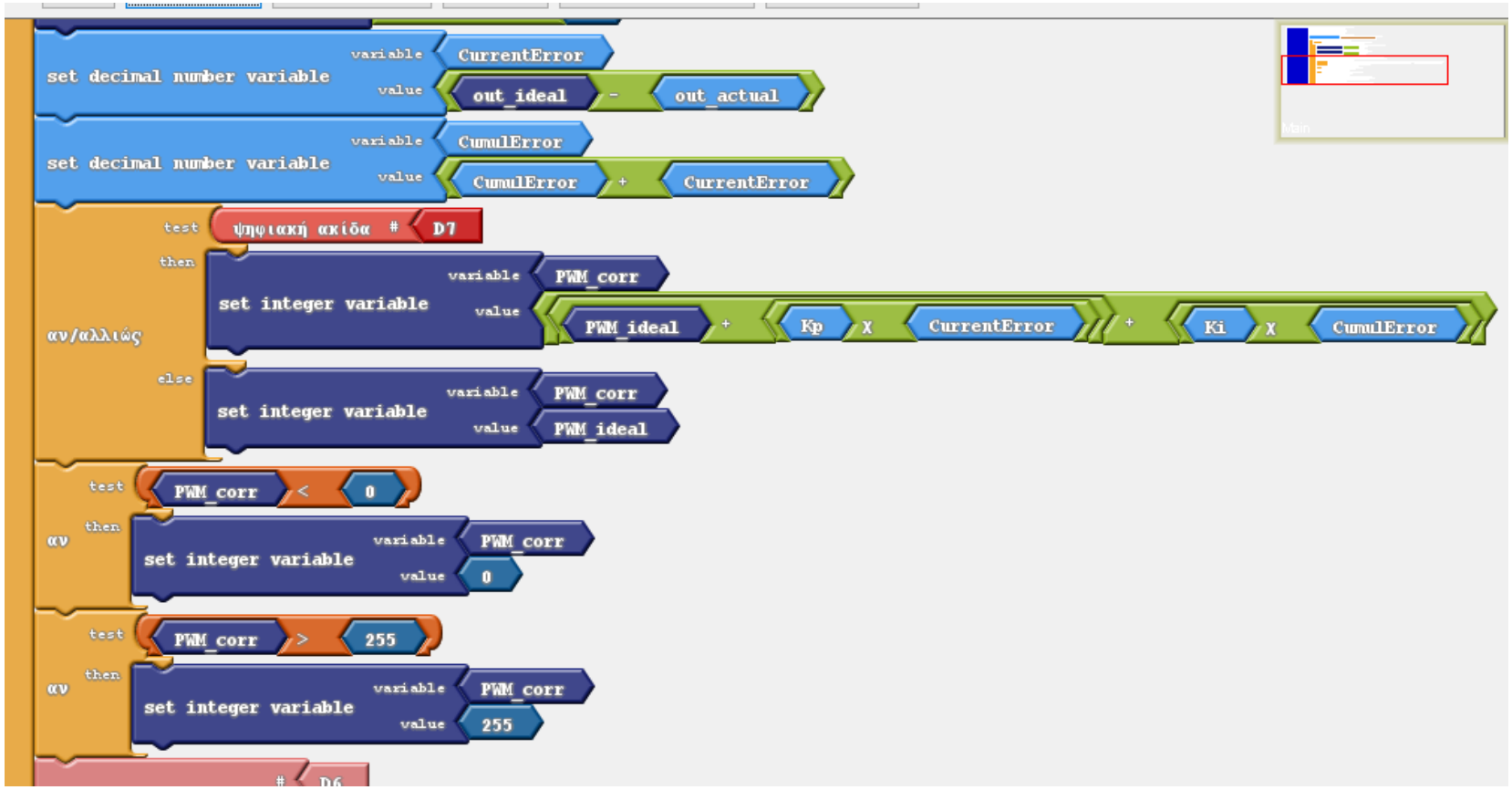


- A cheap technique for variable (speed) operation of DC motors is based on the Pulde Width Modulation method (PWM). In this way “pure” digital outputs can imitate analog behavior.
- **Duty Cycle**: D = [duration_On / (duration_On + duration_Off)] · 100 %

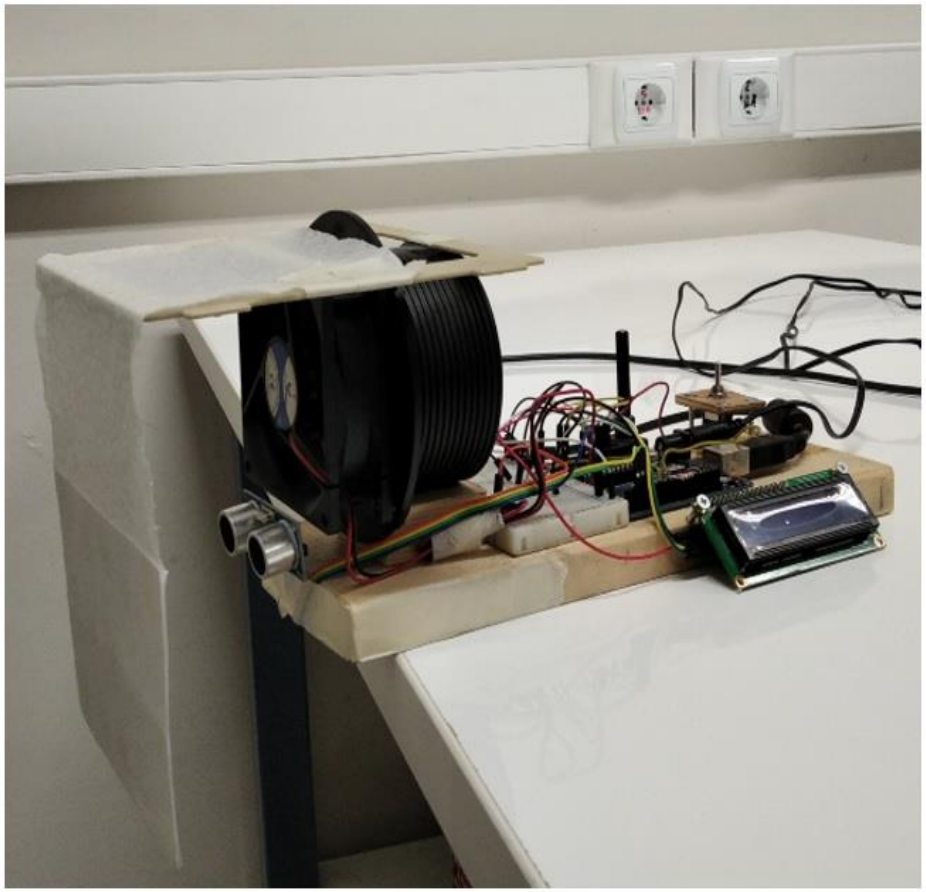
PID Control via Arduino

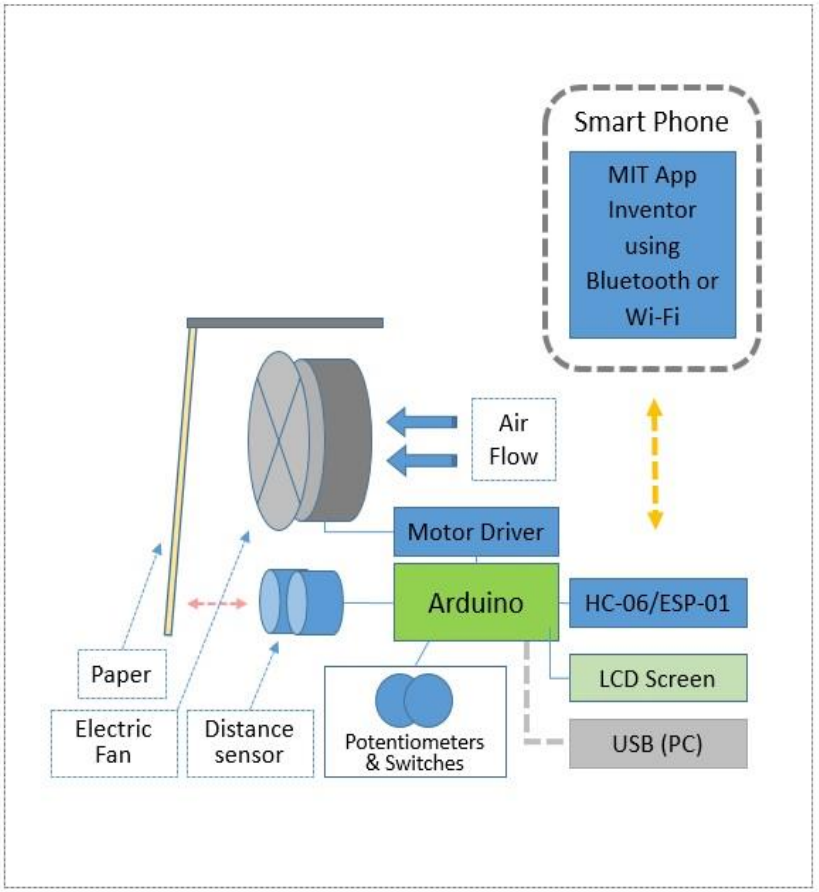
- The PID controller takes into account the current error (Present - Proportional), the cumulative error (Past - Integral), the expected error (Future - Derivative).
- solutions using the PID library.
- https://playground.arduino.cc/Code/PIDLibaryBasicExample/
- … or by Implementing the algorithm on its own
- … by using visual block programming environments (e.g. ardublock)

The PID Control Functionality



Design and Implementation Overview





Functionality

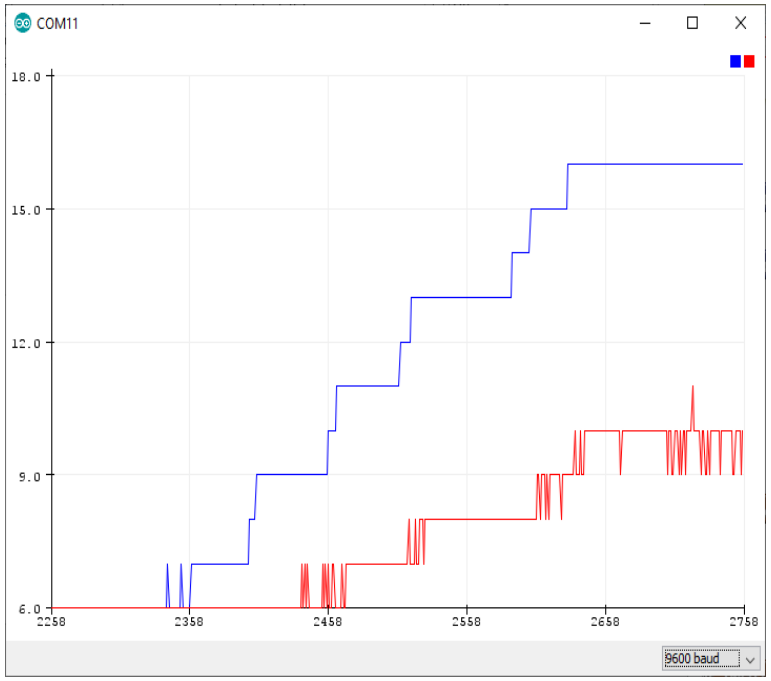
- The ultrasonic distance readings are used to adjust/correct the fan's output and thus the air flow value in order the latter to become close to the desired value (set point).
- The desired air flow level is set via potentiometer
- The PID functionality and its parameters can also be set via potentiometer
- A minimal motor driving circuit (transistor) is used to handle the motor of the fan.
- Monitoring via serial monitor, serial plotter or a 16x2 LCD screen.
- Alternatively, the above functionality can be provided via a smart phone using MIT app inventor and a cheap bridging radio module.

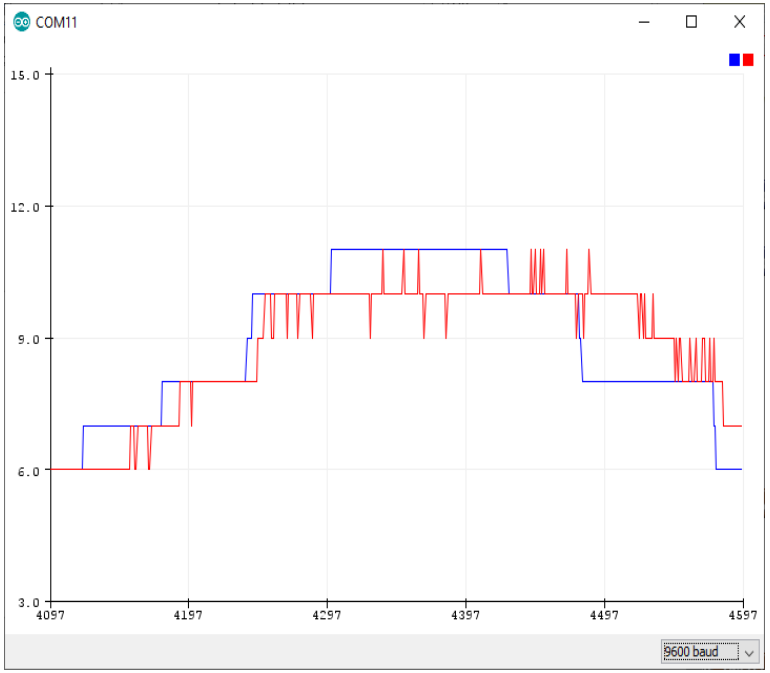
Results (technical)

- Set a desired flow level.
- Use your hand as an obstacle inside the tube to reduce the air flow (external cause).
- Monitor system's behavior via the serial plotter application of the Arduino IDE environment.
- Two cases:
  - With PID control OFF
  - With PID control ON
- Easy to observe the differences

Results (technical)

- Behavior without (left) and with (right) automatic control functionality
- The blue curve represents the target and the red the real one.



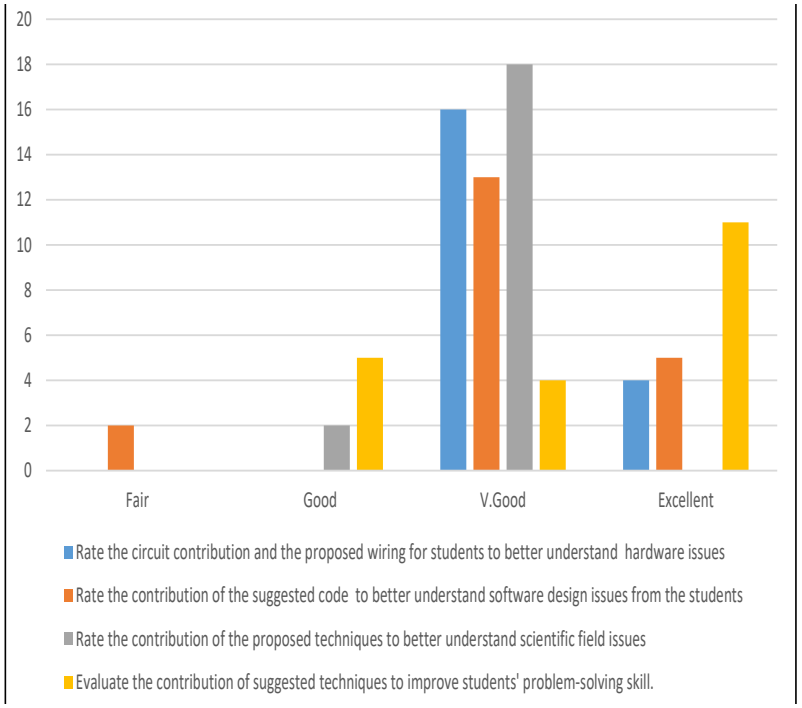


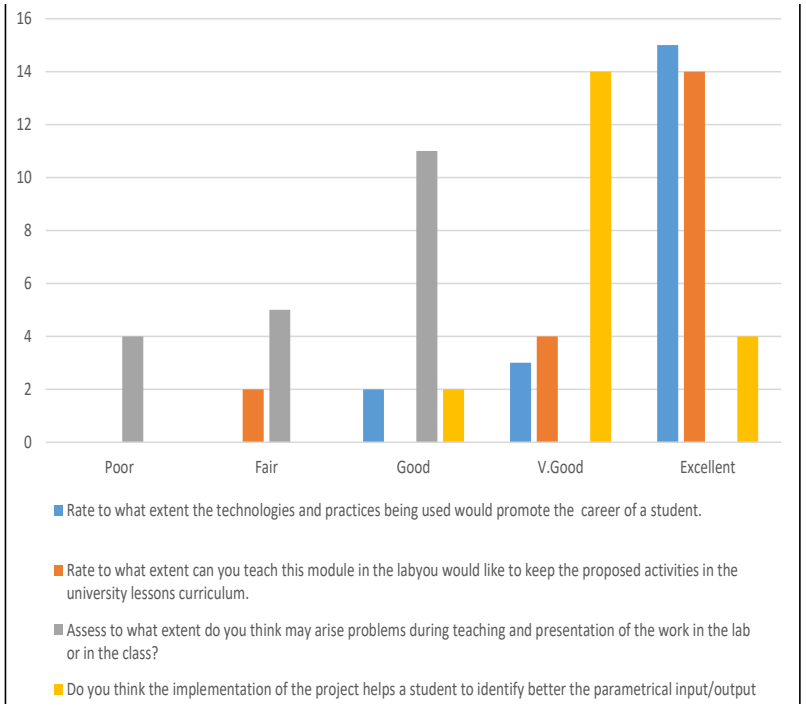
Results (pedagogical)

- Interesting as activity.
- Like to keep in students' weekly curriculum.
- Useful for better understanding of both technical and theoretical issues.
- Beneficial for future careers.
- More preparatory work should be done with teachers/professors in order to fluently circulate the discussed automatic control concepts, especially in secondary education.
- Nice to have more similar projects.

Results (pedagogical)

- Students' and Teachers' opinions about the automatic control project paradigm.





Conclusions

- A low-cost example for better communicating the automatic and remote control fundamentals
- The setup maximizes the reusability of electronic components being involved and to exhibit high modularity, thus allowing for several educationally meaningful check points.
- Persons getting involved assessed the whole interaction with the control platform as beneficial for their studies and as a practice that they would like to keep in the university curriculum.
- Future plans include refinements of educational methods and implementation of more similar projects, to highlight a variety of cases that students will have to tackle in their professional careers.

References

- Markham, T. (2011) Project Based Learning. Teach. Libr. 2011, 39, 38–42.
- Doran, M. V, and Clark, G. W. (2018) 'Enhancing Robotic Experiences throughout the Computing Curriculum', SIGCSE'18, February 21-24, Baltimore, MD, USA (pp. 368–371).
- Arduino Uno (2020). Arduino Uno board description on the official Arduino site. Retrieved in September 2020 from the site: https://store.arduino.cc/arduino-uno-re
- Ardublock (2020). Official site of the ArduBlock programming tool. Retrieved in August 2020 from the site: http://blog.ardublock.com/
- App Inventor (2020), The MIT App Inventor programming environment. Retrieved in September 2020 from the site: http://appinventor.mit.edu/explore/
- Anwar, S., Bascou, N., Menekse, M. and Kardgar, A. (2019). A Systematic Review of Studies on Educational Robotics. Journal of Pre-College Engineering Education Research (J-PEER), doi: 9. 10.7771/2157-9288.1223.
- Zaharakis, I., Sklavos, N. and Kameas, A., (2016). Exploiting Ubiquitous Computing, Mobile Computing and the Internet of Things to Promote Science Education, doi:10.1109/NTMS.2016.7792451.
- Alimisi R., Loukatos D., Zoulias E., Alimisis D. (2020) Introducing the Making Culture in Teacher Education: The eCraft2Learn Project. In: Educational Robotics in the Context of the Maker Movement. Edurobotics 2018. Advances in Intelligent Systems and Computing, vol 946. Springer, Cham. doi: 10.1007/978-3-030-18141-3_3
- Tan, J. T. C., Iocchi, L., Eguchi, A. and Okada, H. (2019) "Bridging Robotics Education be-tween High School and University: RoboCup@Home Education", 2019 IEEE AFRICON, Accra, Ghana, 2019, pp. 1-4, doi:10.1109/AFRICON46755.2019.9133791.
- Loukatos, D., Kahn K. and Alimisis D. (2018) 'Flexible Techniques for Fast Developing and Remotely Controlling DIY Robots, with AI flavor', Proceedings of 'EDUROBOTICS 2018', Rome, Italy, published by Springer, ISBN 978-3-030-18141-3
- Loukatos D., Arvanitis K.G., (2019) "Extending Smart Phone Based Techniques to Provide AI Flavored Interaction with DIY Robots, over Wi-Fi and LoRa interfaces", MDPI – Education Sciences, August 2019, vol. 9, issue 3, pp.224-241, doi: 10.3390/educsci9030224.
- ESP8266 (2020). The ESP8266 is a low-cost Wi-Fi microchip (Wikipedia). Retrieved in September 2020 from the site: https://en.wikipedia.org/wiki/ESP8266

Thank you very much for your attention !