# Outreach Activities for Introducing Fundamental Control Notions using an Educational Robot

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***Abstract*— This paper reports insights from outreach activities implementing fundamental control engineering notions on educational robots. These interactive workshops allow children to program and control mobile robots, converting abstract concepts into engaging challenges adapted to their age. The proposed workshops are designed based on gamification and basic sequencing approaches, therefore introducing first control notions in a playful atmosphere. The particularity of this paper consists in involving undergraduate engineering students in designing control and robotics workshops adapted to younger learners. The objectives are firstly to inspire children (and especially girls) in pursuing engineering curricula by demonstrating how control theory empowers robots and other devices they already use, and secondly to motivate engineering students to pursue their studies within the control specialization.**

***Index Terms*— Control Education; K-12 Education**

## I. Introduction

For several years now, numerous studies have highlighted a persistent decline in young people's interest to pursue science and engineering disciplines, e.g., [1]–[4]. Therefore, in the last years, numerous efforts have been dedicated to educate the general public, and in particular the young generation [5]. To this aim, numerous events are organized, e.g., Open Days in universities / research laboratories, science festivals such as "Fête de la Science" [6], "European Researchers' Night" [7], summer camp/schools, mentoring activities such as seminar series [8], etc. In addition, the European "Researchers at Schools" initiative [7] allow researchers to teach children in schools, thus opening a scientific perspective.

Automatic control is usually introduced very late in university curricula, which could be perceived as an abstract and difficult engineering field, despite the intuitive understanding of the fundamental concepts such as feedback, control, stability, and robustness, which are nevertheless at the heart of autonomous systems. To make control more accessible, researchers have focused on designing fun and interactive activities aimed at making learning about control more accessible and motivating from an early age. Therefore, several activities have been proposed: the "Girls in Control" international online workshop [9], [10], the Control Advent Calendar [11], board games [12], escape games [13], etc. Hands-on experimentation on ground robots and drones allows children to have first interactions with robotics [14]–[16]. In this context, researchers have explored the use of educational robots as a concrete tool for teaching science and engineering, demonstrating their potential to boost youth' motivation and curiosity, e.g., [17]–[19].

The current paper proposes an application of control fundamentals on open-source programmable quadruped robots for outreach purposes, contributing to the societal impact of control by proposing a series of workshops allowing children of different ages to acquire basic notions of control, robotics and informatics by programming Petoi[1] dog robots. One particularity of this paper is that the workshops have been developed and implemented by undergraduate students of CentraleSupélec[2] during their projects within the "Pedagogical Innovation and EdTech" Students' Project Hub. In addition, on one hand, this paper allows undergraduate students to acquire advanced skills on writing scientific papers, and on the other hand, it allows them to have a first contact with the Automatic Control research community, as part of inspiring mentoring activities. In this context, this paper focuses on teaching the fundamental structures of informatics (in particular the *for loop*) and control (i.e. the *feedback loop*). Therefore, this paper shows that it is possible to introduce the principles of control as early as elementary school, combining a playful approach, scientific rigor, and experimental practice through the use of an educational quadrupedal robot.

The paper is organized as follows. Section II II-A offers some prerequisites for using the Petoi Bittle dog robots. An overview of the proposed workshops is presented in Section III, while the proposed pedagogical approach together with the developed workshop materials are detailed in Section IV. Feedback from the workshops' participants, together with lessons learned and feedback from the authors are presented in Section V, followed by concluding remarks.

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[1]The authors have no relations or conflicts of interest with Petoi [20].

[2]CentraleSupélec is one of the most prestigious French graduate engineering school, called "Grande Ecole". CentraleSupélec has a three-year curriculum, preceded by two intensive years of higher education in "Classes préparatoires".

## II. PRELIMINARIES ON PETOI DOG ROBOTS

This section details the main hardware and software capabilities of the Petoi robot dog used for the proposed hand-on experimentation workshops.

### A. Hardware

The developments presented in this paper use a *Petoi Bittle* robot with a customized Arduino board NyBoard V1.1, including 9 servomotors (2 for each leg and one for the neck) and a microcontroller ATMega328PA. Once assembled, we use the Petoi's custom app to calibrate the robot and define custom skills by adjusting the servomotors' angles.

The Petoi Bitlle robot dog comes with numerous extensible modules (that can be easily attached on the robot), such as a light sensor or an ultrasonic sensor. The proposed workshops are using a vision sensor module, which is a MU Camera running the onboard vision algorithm that recognizes a wide set of objects (e.g., balls, colors, human faces, provided cards). The Vision Sensor module includes the camera and the necessary wiring, as well as a set of cards that the camera can recognize (illustrating numbers, arrows indicating directions, parking place, one-color cards, etc.).

### B. Software

The Petoi Bitlle robot support Mind+ [21] (block-based programming similar to Scratch [22]), Python and C/C++. For outreach workshops mainly Mind+ is used for coding. The robot's motors can be individually controlled through Mind+. Already programmed skills (such as walking, running, or jumping) can be defined as single block inputs to streamline instructions. An example code is provided in Fig. 2, illustrating a sequence composed of "stand-up", "walk forward" and "pick front" actions.

Fig. 1. Illustration of one Petoi Bittle robot dog

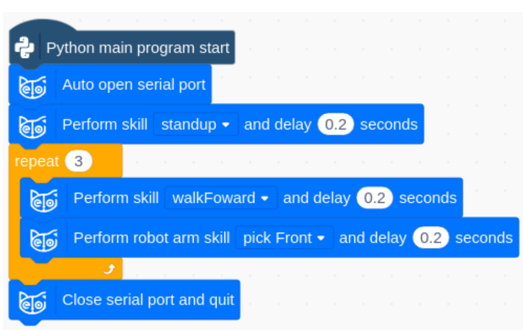


Fig. 2. Petoi Bittle robot dog code example

However, the camera module is not compatible with Mind+. Therefore, it is better to directly modify the source code when adding it, using the MuVisionSensor3 Arduino Library. The camera can thus be programmed into different operating modes to detect several types of objects. The outputs from the camera are the image position, label and size, allowing the user to define the exact behavior of the robot. For example, specific code can be written so that the robot responds to the MU Vision Sensor traffic cards (e.g., indicating the walking direction). The camera will then output a different label according to the type of card (e.g., forward/right/left arrow, stop sign), which can be used to send a "walk forward" instruction when detecting a forward arrow or "turn left" and "turn right" when detecting left and right arrows, respectively. The detection functionality of the MU Vision Sensor can be used extensively, creating a leader-follower setup with two or more robots (where one is controlled individually via Bluetooth and the other ones follow it, autonomously).

An individual robot can be controlled by the Petoi App, connecting the Bluetooth module to the mainboard and then itself to the user's phone. The mobile app allows the user to give simple instructions and the possibility to overwrite them (which is different from the coding blocks, where instructions follow a strict order, and define custom skills).

## III. ROBODOG WORKSHOPS OVERVIEW

This section describes the target audience, the educational goal of the the proposed workshops activities, together with the developed material and pedagogical approach.

### A. Education purpose and target audience

The purpose of the proposed educational "RoboDog Workshop" is to foster the interest of pupils (from 8 year old children to high-school youths) in science. More specifically, the aim is to familiarize them with complex concepts from control engineering, robotics and programming through playful activities using Petoi Bitter robots. In order to address different audiences with different levels in programming and different expectations, the timeline and the content of the workshops are adapted.

Four occuracies of the "RoboDog Workshop" workshops have been proposed both for children visiting CentraleSupélec and children from the elementary school Gambetta in Massy, in the Paris region:

- 2 occurrences of the "RoboDog Workshop 1", each one with half of the 8 to 9 years old kids of one class of Gambetta School. This workshop was developed and implemented by a first team of students of CentraleSupélec.
- 1-day event "Journée de clôture OSER", organised by the CentraleSupélec students of OSER [3] [23]. The "RoboDog Workshop" was one the multiple parallel events organized during this event for high-school learners.

[3]This students' organization of CentraleSupélec is committed to equal opportunity, inclusion and diversity.

- 2 occurrences of the “RoboDog Workshop 2”, each one with half of the kids of the same class of Gambetta School. This workshop was developed and implemented by the second team of students of CentraleSupélec, which are the first four authors of the current paper.
- 1-day event “Bouge la Science”, organised by the CentraleSupélec students of “Espérance en Béton” [24] for 150 secondary school learners. The “RoboDog Workshop 2” was one of the parallel scientific activities proposed to several groups of children during an entire afternoon.

### B. Brief description of the workshops

The “RoboDog Workshop” was designed in two steps.

A first team of students from CentraleSupélec assembled the robots, understood the robot operation and start coding the robots. Then, they proposed a first version “*RoboDog Workshop 1*” for kids aged from 8 to 9 years old, allowing them to: 1. test some Scratch programs developed for this particular activity; 2. discover how the robots can be controlled via Mind+, which is very similar to Scratch; 3. familiarize with the robots in a game situation by manually controlling the robots. Therefore, the kids participated in teams to a race with the robots.

A second team of students from CentraleSupélec continued the project of their colleagues the next semester, proposing the “*RoboDog Workshop 2*”, which integrated basic control concepts. As the workshop was intended to a very young audience, the students proposed a progressive approach focused on simplicity, intuition, and hands-on manipulation. To overcome the difficulties associated with text-based environments (such as Arduino), Mind+ was used for programming. This version is described and analyzed in the remaining part of this paper.

## IV. “RoboDog Workshop 2” material

This section starts with a short focus on the preparation before the workshop and continues with the presentation of the activities during the “RoboDog Workshop 2”.

### A. Workshop preparation

The children are regouped in small groups and there is one CentraleSupélec student per group of pupils.

The following hardware materials are necessary to carry out the workshop and it is recommended to test it before each workshop occurrence:

- several Petoi Bittle robot dogs (one robot per group or three or four children);
- a set of additional charged batteries for the robots;
- a computer with Mind+ and Arduino installed;
- a USB-A to USB-B (micro-USB) cable;
- a Bluetooth chip compatible with Arduino.

Before the workshop, it is necessary to print worksheets and surveys for each participant.

- *Worksheets*. At the beginning at the workshop, lab worksheets are provided to the children to follow the activities and, in some cases, to take some notes by filling in the blanks.
- *Survey sheets*. In the end of the workshop, to collect the feedback of the children, survey paper sheets are provided. The questions and answers are adapted according to the age of the pupils. For younger children, the possible answers are two smileys (one happy face and one sad face, see Fig. 3). Older pupils can rate their impressions on a scale from 1 to 5, either on printed surveys or on online surveys using their phones.

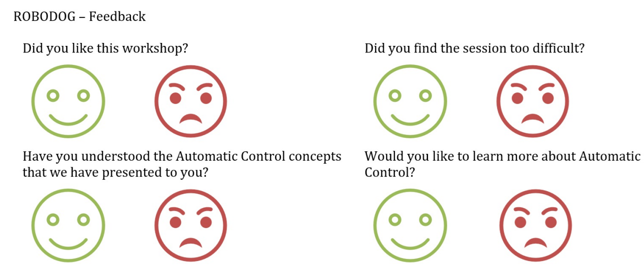


Fig. 3. Feedback sheet for younger children

During the workshop, the groups of children are challenged to solve a maze by leading the robots in an autonomous way, using the Mind+ codes they designed. Therefore, before the session, a maze is made with tape on the floor (see Fig. 9). For this challenge, we also used arrow cards recognized by the camera module, to lead the robot in the direction of the arrow drawn on the card.

### B. Teaching block code during the “RoboDog Workshop 2”

The workshop starts with a short presentation of the CentraleSupélec students and an ice-breaker question. As this was the second session with the same participants, the children were asked what they remember from the “RoboDog Workshop 2”.

The first part of the workshop aims at teaching children the base of coding with blocks using Mind+, similar to Scratch. Indeed, Scratch is now part of curriculum in French secondary schools. The pedagogical objective of the workshop is twofold: 1. to offer pupils a first approach of block coding in a playful way, with hands-on experiments on the Petoi robot dog ; 2. to introduce first notions of automatic control for K-12 pupils.

Controlling the Petoi Bittle robot dog with Mind+ can be done by installing a Bluetooth chip to the device, connecting it to the computer, and then uploading the Mind+ block code to the device. Then, it is possible to charge some initial code to explain the basic block programming concepts.

The first activity of the workshop consists of the running predetermined actions by the robot. The pupils do not have access to the code, they must identify each action, determine the order in which the actions are run and write it on their paper sheet (see Fig. 4).

After completing this exercise, the children can see the code. The CentraleSupélec students explain them the link between programming with blocks and controlling the robot

**Part 1**

- Run the provided code (for this click on Run at the top right of the screen).
- Notice the RoboDog reaction.
- Recognize and number the sequence of actions
  - Move forward ......
  - Lift the paw ......
  - Stretch ......
  - Shake the head ......
  - Play dead ......

Fig. 4. Wording of the first activity of the workshop

with these blocks: each block commands an action and the order of the actions depends on the order of the blocks.

The second activity asks the pupils to modify the code to change a precise action by another one, specified by the wording. The objective is now to ensure that the children understand the link between the block and the action.

**Part 2**

Modify the previous code so that, instead of lifting its paw, the RoboDog starts boxing.

Click on Run.

Fig. 5. Wording of the second activity of the workshop

The kids send instructions to the robot using the Petoi robot dog Mind+ extension.

*C. Teaching the "for loop" during the "RoboDog Workshop 2"*

The next step is to teach the "for loop" to secondary school children. In the first place, the pupils need to change the code to obtain a specific sequence suggested by the wording. They are guided in their choice of blocks to remove and blocks to add.

**Part 3**

Delete the actions from 3 to 5 and add the block "For" to get the code on the right hand side. Click on Run. What happens?

The bloc repeat is used to repeat the sequence of instructions inside the block as many times as indicated.


**To go further**: Using the block repeat, try to go around the obstacle!

Fig. 6. Wording of the third activity of the workshop

The pupils who finish quickly the previous activity are challenged with an optional activity, i.e., trying to rotate the robot around an obstacle using a "for loop". This non mandatory activity is placed here to foster their curiosity and to ensure that all groups of children can move on to the next activity together.

*D. Teaching the "feedback loop" during the "RoboDog Workshop 2"*

In this part, the CentraleSupélec students explained the "feedback" notion and provided several examples of autonomous systems using feedback.

Then, they continued the "feedback loop" activity with a fill-in-the-blank text to complete the definition of feedback. Children can choose from a list of missing verbs. The goal is to help them proactively understand this fundamental concept of automatic control. To ensure that the children have understood, the text presents several situations and asks them to determine whether a feedback loop is present.

**Part 4**

Complete the following definition using the following words: encounter, decide, stop, detect.

*A feedback loop is when a robot ............. something in its environment and .............. what it should do next based on what it has seen or heard. For example, if a robot moves forward and ........... a wall, it will .............. to avoid bumping into it.*

Encircle only the sentences describing a feedback loop:

1. A robot moves forward and stops when it encounters a wall.
2. A ball rolls when someone pushes it.
3. Garden lights turn on automatically when night falls.
4. A flashlight turns on when the power button is pressed by someone.

Fig. 7. Wording of the fourth activity of the workshop

*E. Guiding the robot through a maze during the "RoboDog Workshop 2"*

During the last activity of this workshop, each group of children has to guide the RoboDog through a maze drawn on the ground (see Fig. 9). The goal is to make the pupils try out the two methods of controlling the robots: first, using the traditional block-based instructions in a certain order (i.e., in open-loop), and, second, using the principle of feedback (i.e., closed-loop) based on the information from the robot camera.

The second control method is implemented using Arduino rather than Mind+. In addition, cards indicated directions supplied with the camera module are used (Fig. 8). The Arduino code recognizes the cards with arrows to make the robot go forward or to turn on the sides. The CentraleSupélec students explain that the camera is attached to the RoboDog and continuously scans the environment to detect a card. Therefore, the camera is the element (i.e., sensor) of the feedback loop implemented in the control method.

## V. Feedback

This section briefly describes the feedback on the "RoboDog Workshop 2" from the learners and from the CentraleSupélec team.

**Part 5**

In this game, your robot must navigate through a maze. To help it find its way, you will use the direction cards. Each card gives the robot a special instruction:

- Left turning arrow: The robot turns left when it sees this card.
- Straight arrow: The robot moves forward when it sees this card.
- Right turning arrow: The robot turns right when it sees this card.

Fig. 8. Wording of the last activity of the workshop

Fig. 9. Maze during the workshop conducted in the Gambetta School

## A. *Analysis of the learners' opinions*

The learners' opinions[4] on the "RoboDog Workshop 2" was collected from the "Journée de clôture OSER" event (from teenagers visiting CentraleSupélec) and from one class of the Elementary School Gambetta in Massy in the Paris Region (where CentraleSupélec students taught this workshop).

*Feedback from "Journée de clôture OSER" event*. One session was taught to a group of fifteen year old children, and one session to a group of eighteen years old learners.

*Feedback from one class of the Elementary School Gambetta*. Two sessions were taught (one session par half class) for the 25 children Gambetta elementary school: twelve children in the first subgroup, thirteen children in the second one.

During all the workshops similar behavior was observed: children regardless of their age were engaging playfully with the robots.

To assess the quality of the workshops, the learners answered the following survey questions:
(1) Did you like the workshop?
(2) Was the workshop difficult to follow?
(3) Did you understand the control principles that were presented?
(4) Would you like to learn more about control engineering?
There was an additional open question for older pupils:
(5) Do you have any comments?

The feedback from the "Journée de clôture OSER" event is provided in Fig. 10-13. The figures show that 84% of the teenagers understood the control principles and at least 61% want to learn more about control engineering.

The feedback from the Gambetta elementary school pupils is provided in Fig. 14-15. It is important to notice that 100% of the kids understood the presented control principles (and this information was verified by their answers on the provided written exercise) and that 100% want to know more about control engineering, which is very encouraging.

These results show that the workshops were perceived as playful and engaging and that they sparked the interest for control engineering. However, a rather high portion of learners found the workshops hard, meaning that there is still

[4]Collecting the learners' opinions is one of the main difficulties in these activities due to time constraints, because the children fill in the survey just before their break time.

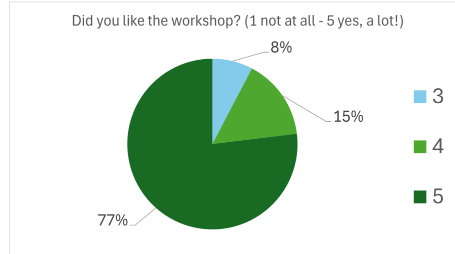


Fig. 10. Answers from the "Journée de clôture OSER" event for the first question

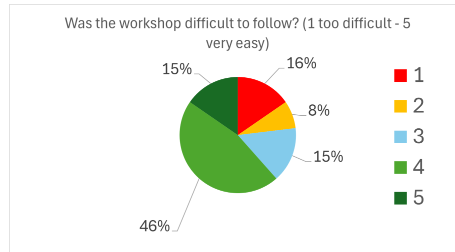


Fig. 11. Answers from the "Journée de clôture OSER" event for the second question

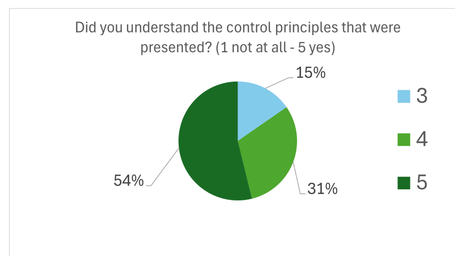


Fig. 12. Answers from the "Journée de clôture OSER" event for the third question

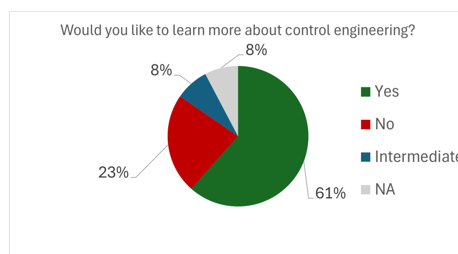


Fig. 13. Answers from the "Journée de clôture OSER" event for the fourth question

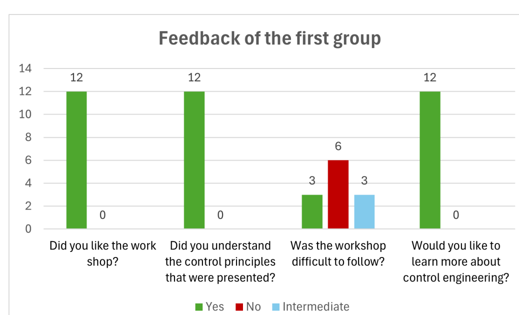


Fig. 14. Feedback of the first subgroup of elementary students

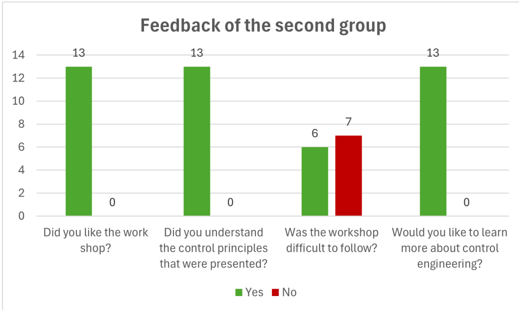


Fig. 15. Feedback of the second subgroup of elementary students

room for improvement, especially to adapt the workshops to the respective target audiences.

### *B. Feedback from CentraleSupélec students and their project advisors*

Overall, the CentraleSupélec team felt they were contributing to something meaningful both for them and for the learners, while acquiring both technical and pedagogical skills. This project was an interesting challenge to bring complex concepts within anyone's reach. The children' capacity to understand the presented concepts at such a young age was very impressive.

The supervising team from CentraleSupélec was impressed both by their students' engagement in this project and by their success in making children succeed in handling the mobile robots, while understanding difficult notions for their ages such as the "feedback loop".

## VI. Conclusion

This paper presented a hands-on and playful approach to teach fundamental control theory concepts, often considered abstract and challenging, to children of various ages using the Petoi Bittle robot dog educational robots. The workshops successfully engaged children and helped them understand basic notions such as the "for loop", the "feedback loop", through block programming in an interactive way. Future work will focus on expanding these workshops to different age groups and learning levels, developing additional modules, and making the materials openly available online to facilitate wider replication in diverse educational contexts.

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