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Pre-robot: an open-source educational robotics platform for preschoolers

Francisca Coiro[0], **Miguel A. Solis**[1,2], **Cristóbal J. Nettle**[2], **Anibal Chila**[0]

[1]Facultad de Ingeniería, Universidad Andres Bello; [2]Centro de Innovación y Robótica

***For correspondence:**
francoirodiaz@gmail.com; miguel.solis@unab.cl; cristobal.nettle@innovacionyrobotica.com; chilanibal@gmail.com

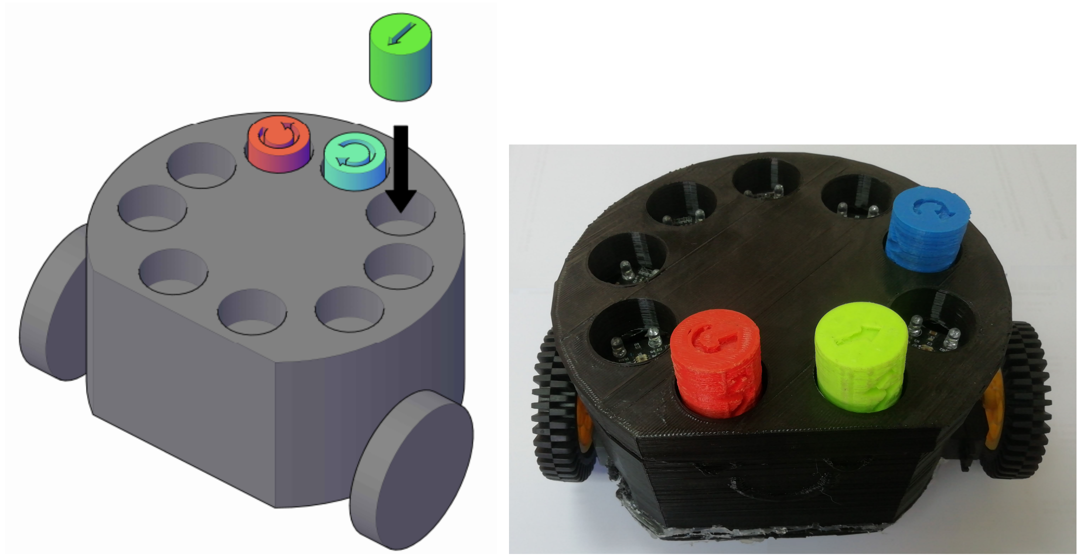
Abstract Educational robotics represent a novel and attractive scenario for stimulating different abilities frequently related to science, technology, engineering, and math. To this extent, there exist multiple approaches depending on the specific ability being tackled, and resources needed such as physical equipment or computational tools.
Commercial platforms, as well as open-source educational kits, have made extensive contributions in diminishing coding abilities required for specifying desired behavior on the physical agent, such as programming through block sequences or embedding a smartphone or tablet for more intuitive uses. This work describes prototyping specifications for a novel open-source robot aimed to foster computational thinking abilities on preschool children, including a first approach involved on the built platform, with an embedded processing unit for not requiring any further equipment, and work on development for minimizing costs.

Introduction

In search of stimulating computational thinking and logical reasoning, robotics has proved to be effective when teaching computer science (***Fagin and Merkle, 2003***) and also enhancing skills for modularizing solutions in school problems (***Benitti, 2012***). Moreover, literature has reported several approaches for integrating science and technology curriculum in K-12 schools by encouraging teamwork with the construction of open-ended autonomous platforms (***Kolberg and Orlev, 2001***), or by fostering craft-based hands-on activities (***Mataric et al., 2007***), or including commercial platforms (***Souza et al., 2018***) or open low-cost platforms (***Vega and Cañas, 2018***) to name a few.

Although there has been found a growing interest on the use of robotics for enhancing learning activities as much in schools as students with extra-curricular interests looking into formal and informal K-12 curricula (***Cho, 2011***), including authors local scenario (***Navarrete et al., 2016***), a recent study (***Garcia et al., 2017***) about science and technology perception in youth was made, surveying 1010 people between 15 and 29 years old in authors country (Chile, South America). Although 73% of people identify themselves familiar with browsing the Internet for scientific information, only half of them agree with thinking that science and technology development will help to minimize social gaps, and only 1% of the total participating people perceive that science and technology benefits education area.

Educational robotics have been identified as a transformational tool for learning, computational thinking development, thinking on engineering problems and coding (***Eguchi, 2014***), and also have reported benefits on preschool children such as helping with executive functions development (***Di Lieto et al., 2017***), which is the final user of the prototype described throughout this document. It is worth to note that it should be clearly differentiated whether the desired approach corresponds to use robotics in school education, or education in robotics in the way of training teachers to use



(a) 3D model

(b) Physical prototype

Figure 1. Pre-robot with a basic routine.

robotics for teaching purposes (***Alimisis, 2012***).

Symbolic capacity on children enables them to identify signs in a way that they can start coding and decoding on different representation systems such as written language. Educational robotics activities in this context should consider methodological principles for defining expected outcomes from such activities, as well as defining appropriate content sequence and activities organization. To this end, those methodologies should seek significant learning with observation, experimentation and globalized learning in a game-based environment so workspace becomes comfortable without detriment of representing a challenging scenario for knowledge and learning stimulation.

Although the literature has shown that commercial platforms intended for greater ages could be also applied to preschool children (***Mousa et al., 2017***), there are also multiple preschool robotics kits (***Elkin et al., 2016***; ***Anzoátegui et al., 2017***). Nevertheless, to the best of the authors' knowledge, this prototype entitled *pre-robot* is the first open-source platform that could be easily reproduced with appropriate equipment access and minimal prototyping skills.

The remainder of this document describes the more relevant aspects for developing the first version of this open-source prototype developed for preschool children, and also possible activities which teachers could perform in order to achieve some of the declared expected results. Finally, some conclusions related to other possible activities are given, as well as ongoing work for lowering implementation costs and fostering worldwide reproducibility.

Prototype description

This prototype is intended for programming its movement actually onboard, by placing tubular-shaped colored tokens on the top of its chassis with signs representing its behavior as shown in Figure 1. The platform follows the instructions according to the tokens repeatedly within a loop. In case of empty slots, the robot stops and waits for a 1-second delay, a pre-settled amount. Taking Figure 1 (b) as an example, the robot starts performing a counter-clockwise turn (red token of the back left), reading the following tokens in a counter-clock fashion. After turning, the robot performs a straight movement (green token) for 1 second. As follows an empty slot, the robot stops and waits for another second, continuing with a clockwise rotation (blue token). Finally, as there are five empty slots, the robot stops and waits for five seconds, completing a loop iteration and starting again. During the performance, white light is powered on showing which token slot is being executed at

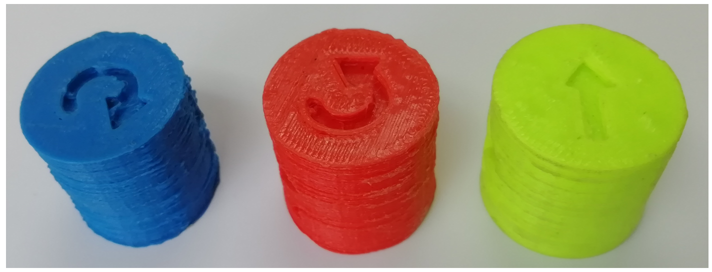


Figure 2. Tokens for programming Pre-robot.

every moment, as activity feedback.

Without detriment to encouraging contributions for prototype enhancement, the following subsections describe the main components used in this first version. All ongoing material will be available and open under GNU General Public License v3.0 at a Github repository: https://github.com/miguel-a-solis/prerobot

Structural design

Given that this platform is intended for being used with preschool children whose manual dexterity and fine motor skills are still on development, tokens or coding blocks were shaped big enough with a basic form for allowing an easy fit on the programming surface. This surface was designed in a round shape for taking advantage of its form through its potential for introducing the *loop* concept, and type of behaviors are distinguished by colors with a sign that represents the corresponding behavior as shown in Figure 2 with structural characteristics detailed in Table 1.

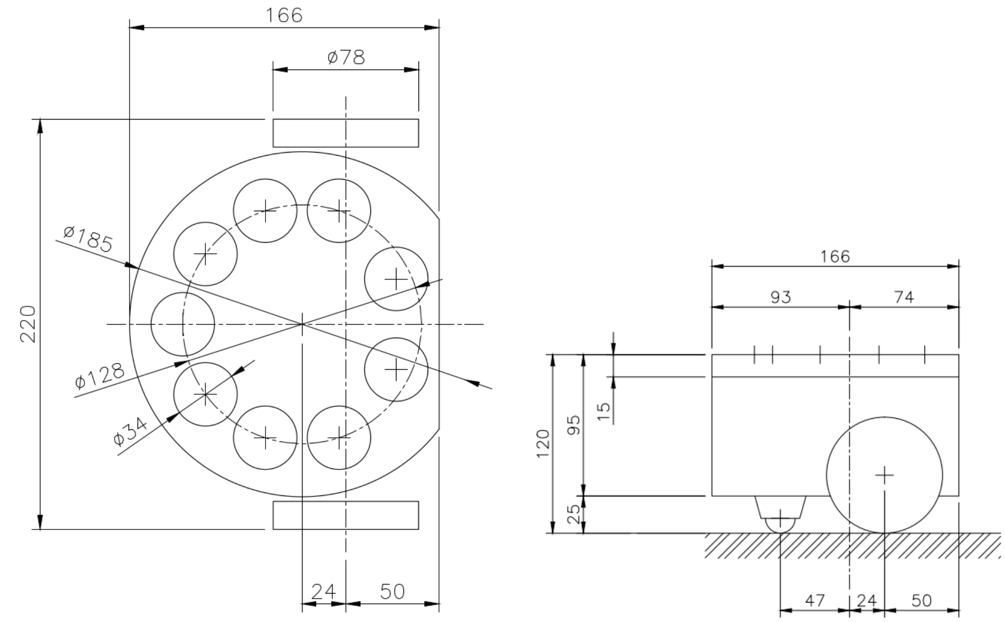
Diameter	30 [mm]
Height	30 [mm]
Material	PLA
3D layer thickness	0.2 [mm]
3D printing infill	12.5 %

Table 1. Programming tokens characteristics.

Figure 3 shows side and top view for the chassis and structural components, whose parameters are summarized in Table 2.

Top view	
Complete cover diameter	185 [mm]
Shorter-side cover diameter	166 [mm]
Token slot diameter	34 [mm]
Equally spaced token slots	9 slots
Side view	
Cover thickness	15 [mm]
Chassis height (from base to top side of cover)	95 [mm]
Basis height (from floor surface to bottom side of chassis)	25 [mm]
Straight side length	166 [mm]
Wheels diameter	78 [mm]

Table 2. Pre-robot structural parameters.



(a) top-view (b) side-view

Figure 3. Main parameters for prototype (measures in [mm]).

Hardware components

Although authors are currently developing subsequent version which replaces color sensors in order to diminish prototyping costs (without detriment to continue using colored tokens), this first version use TCS3200 color sensor, which features 4 white light-emitting diodes that allow developers to improve acquired data. This module also features 64 photodiodes where 16 are filtered for red, 16 are filtered for green, 16 are filtered for blue and the remaining 16 photodiodes have no filter.

Finally, sensor outputs a measure of color components in light intensity perceived and after processing this data, the robot performs corresponding behavior and then the development board identifies whether there is a token in the following slot or not, along with its color. Hardware used in this prototype consists of 9 TCS3200 color sensors (one for each token slot), 2 general-purpose servo motors model GS-3360BB, and Arduino Uno (***Banzi and Shiloh, 2014***) development board for processing data and interpreting desired behavior. Wiring diagram for one color sensor (for one token slot) is shown in Figure 4, noting that for reading each token slot at a time, each VCC pin will have to be connected to a different digital output from Arduino which will be triggered for reading a given token slot.

The costs of the platform as described here go around $75 USD, considering 3D plastic and hardware components. A new developing version diminishes materials cost to $30 USD. Similar commercial platforms are: Fisher-Price Code ’n Learn Kinderbot (around $50 USD), Bee-Bot Educational Robot (around $95 USD), and Blue-Bot robot (around $127 USD).

Sample activities

In order to make learning fun in early childhood, creative and hands-on activities that appeal to children’s interests should be designed. Some simple activities that can be easily done with this mobile platform include learning carpets, as shown in Figure 5, where pre-robot should be programmed for solving the corresponding challenge.

Specifically, learning carpet in Figure 5 (left) consists of coding a behavior such that pre-robot goes first to a fixed location whose accomplishment represents obtaining a key. Then, the child

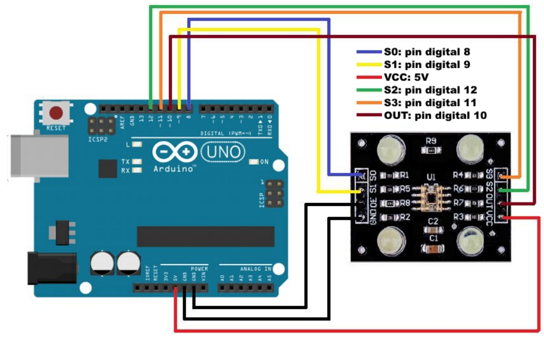


Figure 4. Wiring diagram for color sensor (one token slot).

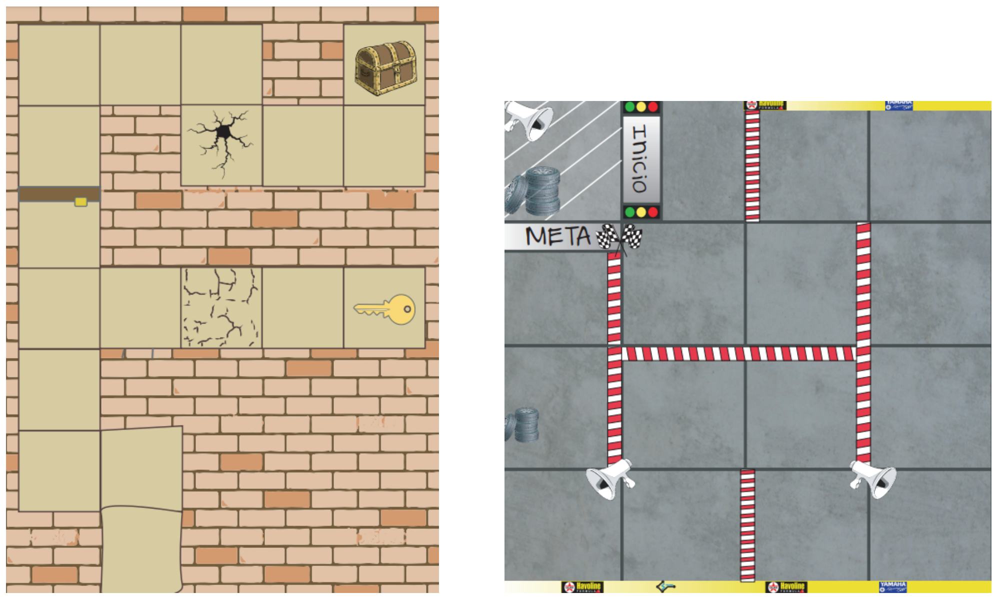


Figure 5. Learning carpets. (Left) Treasure hunt. (Right) Race track

would have to put new tokens for getting into the final cell where the treasure is located.

On the other hand, learning carpet in Figure 5 (right) represents a race track where pre-robot should move while avoiding some obstacles, that could be improved by placing physical obstacles in corresponding places.

Conclusions

This work documents a reproducible prototype for introducing first notions of coding on preschool children, as task scheduling and simple computational thinking, introducing iterations and ordering instructions. This, by using their symbolic capacity to identify signs in a way that they can start coding a given behavior on this mobile platform, without requiring any further equipment such as a computer, tablet or phone.

It is important to note that while the platform does not require extra equipment (phone or tablet), it could be extended following that purpose, which might improve interest and motivation for producing meaningful learning (***Ausubel et al., 1980***).

Although final users of this platform correspond to children, the first version of this prototype is intended for giving some preliminary insights on teachers about using robotics for teaching purposes on preschoolers.

Although literature has shown that commercial platforms intended for greater ages could be also applied on preschool children and there are also multiple preschool robotics kits, to the best of the authors knowledge, this prototype entitled *pre-robot* is a first approach for an open-source platform that could be easily reproduced with appropriate equipment access and minimal prototyping skills. The following modifications include changing color sensors for a simpler token identification by measuring the impedance of an internal resistor integrated within the token.

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