ROBOESL PROJECT

ROBOTICS-BASED LEARNING INTERVENTIONS FOR PREVENTING SCHOOL FAILURE AND EARLY SCHOOL LEAVING

Erasmus+ 2015-1-IT02-KA201-015141

Output 1: Curricula for 10 exemplary interdisciplinary robotics projects

Curriculum 5: The sunflower

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[1] EDUMOTIVA stands for 'European Lab for Educational Technology

Declaration

This report has been prepared in the context of the ROBOESL project. Where other published and unpublished source materials have been used, these have been acknowledged.

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Abstract

This document contains the description of the Curriculum n. 5, entitled ‘The sunflower’ which is part of the Intellectual Output 1 (Curricula for 10 exemplary interdisciplinary robotics projects) developed and tested in teacher training courses within the context of the ERASMUS+ ROBOESL project. In this Curriculum one or two color sensors are used to maintain the robot at a predefined distance and orientation with respect to a light source, simulating heliotropism. In the curriculum the state diagram is also introduced.

Chapter 1: **Short description and scenario (O1.1)**

(author: Daniel Cummins)

Let’s make the robot to follow a light source using one or two color (or NXT light) sensors.

1.1 The scenario

There is no special scenario to be built for developing this experience but, according to the proposed theme, you should ask the students to prepare a natural scenario where the robot emulates, and is dresses as, a sunflower.

1.2 Connections with subjects

1. Natural science: heliotropism is a natural tendency shown by several plants (and in some sense also by animals and humans) to orientate and adapt their external apparatuses to the sunlight source. In those cases, when it is a diurnal phenomenon, like in the case of sunflowers, the flower head can actually follow the relative course of the sunlight; when seasonal, it is a much slower behavior but nonetheless the effects can be very evident (fig 1). Some plants exhibit only leaf heliotropism. For sunflowers, it is interesting to make the students observe that a real heliotropism is present only during the bud stage whereas, when the head is completely developed, it definitely faces east.

Figure 1. Heliotropism

2. Human development and technology: nowadays a great attention is devoted to sustainable development with a wider and wider use of renewable energies. When providing solar energy production plants, for maximizing the solar energy harvesting you have to orientate photovoltaic panels in order to be as much orthogonal to sun rays as possible. This means that you should provide panels of a sort of heliotropism for the sake of efficiency.

3. Philosophy and cybernetics: the Italian neuroscientist and cyberneticist Valentino von Breitenberg is famous for the 1984 publication “Vehicles: Experiments in Synthetic

Psychology” where he describes 14 types of simple vehicles directly controlled by ‘light sensors’ (fig. 2). Each of these experiments conceptualizes ‘natural’ behaviors, like fear and attraction, through fairly simple machines. Some of these behaviors are reproduced by the examples in this curriculum.

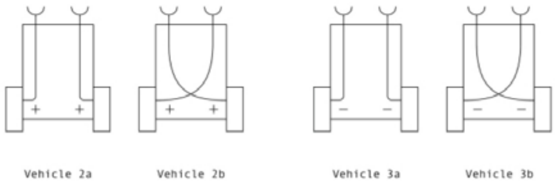


Figure 2. Some Breitenberg vehicles

Chapter 2: **Pedagogical objectives (O1.2)**

2.1 General objectives

- To provide students with a stepwise approach for a step by step acquisition of technical skills in using robotic technologies (hardware and software) building on existing knowledge and skills.
- To offer the robotics benefits for all children, especially those at risk of school failure or early school leaving.
- To engage students in STEM related subjects through interaction with the robotics technologies.
- To support self-directed action allowing learners to learn independently.
- To engage students in robotic constructions and problem solving through an interdisciplinary scenario that reflects aspects of real-life problems and situations.
- To align the robotics project to learners' needs and interests through tasks that derive from the initial activity but introduce new levels of complexity and difficulty.
- To translate the sunflower concept into robotic constructionist and algorithmic experiences.
- To engage students in role playing with the aim of understanding the limitation of the solution with one sensor and to playfully understand the need for using two sensors.

2.2 Specific objectives

More specifically, upon successful implementation of the activities described in this curriculum students will achieve the following objectives:

- Understand how to control the power of the motor through the light sensor
- Understand how the light sensor measures the ambient light
- Understand how the advanced math block operates
- Use the output of the advance math block to control the power of the motor
- Use variables and to understand their role in the context of the given problem
- Understand the use of nested switch blocks into the loop block and to apply these programming concepts into the solution of the problem
- Compare the use of the "switch" with the "if-then" conditional statement based on the statements used in the body of the switch programming construct
- Understand the difference between the wait block and the busy waiting block, and integrate the appropriate block into the algorithmic solution

- Record/keep the value of variables and activate the appropriate features in order to read this value
- Compare the current value of a variable with the previously recorded value for making the robot move towards the light source
- Challenge students thinking on how to make the robot move towards the light when two light sensors are available
- Understand what a range block does in order to get a logic value i.e. true or false
- Make comparisons using the appropriate block and to use the result of the comparison which is a logic value with the aim of making the robot mow when two light sensors are available

Chapter 3: **Suggestions for learning methodologies (O1.3)**

This curriculum follows the methodology introduced in the previous curricula. However, it is tailored to the scenario introduced in the current curriculum. A special worksheet has been designed as a reference and supporting tool for the students. The students are encouraged to work in groups. The teacher acts as a scaffolder and facilitator of the learning process. S/he provides feedback without revealing solutions and probing students through key questions to overcome emerging problems and difficulties. The activity starts with the delivery of the scenario to the students. The teacher in an easy to grasp way elaborates on the sunflower scenario. The students are encouraged to discuss the given scenario in groups and to form a general methodology for dealing with the problem. The students are then called to decorate the robot based on the given scenario. The activity progresses with the teacher engaging students in the sub-tasks of the "sunflower project".

In the context of this activity the students are encouraged to decorate the robot based on the scenario given. The students are then called to explore ways according to which the robot reacts (by approaching or moving away from the light source) to ambient light variations. Before of the exposure to the software experimentation the students are encouraged to address a solution in the paper using a flow diagram when the different "states" are briefly described. With the support of the teacher, the students translate the diagram in an algorithmic solution. The teachers raise key questions that challenge students' thinking on the role of the "if-then" conditional statement.

In the context of the next sub-task the students are encouraged to reflect upon ways to making the robot react when the light source is moving. The half-baked approach is proposed: the teacher provides a half-baked solution (that mainly integrates the use of the variable light (see figure 8)). The teacher may consider to add more parts of the final solution to the half-baked example. S/he then supports the students in understanding what the half-baked solution represents and identifying the missing parts that make the robot follow the moving light.

In the context of the next task the students are engaged in role playing. The teacher provides all the necessary instructions/rules for the execution of the role play. The aim here is through role playing to help students playfully realize the limitations of the current solution and the need for using an additional light sensor. The teacher exploits the lessons learnt through role playing and introduces the next task to the students according to which they are called to address an algorithmic solution with two light sensors. Once again the half-baked approach is suggested. The teacher can provide a half-baked solution that includes the use of the "range block" (see figure 12). More parts of the solution may be integrated in the half-baked solution that will be provided to the students.

In general, it is advisable to use the half-baked solution in order to help students regulate the behavior of the robot decreasing their cognitive load.

A. The role of the students

Students first discuss the problem through a free dialogue in their group and after that they devise an action plan to solve it. They work in groups following the worksheet and the discrete feedback they receive from the teacher. Students may extend their work to variants suggested by the teacher or devised by students themselves. First, they find solutions making trial and error experimentations. In the end they are supported to find a mathematical solution to the same problem. The final solutions of the groups are presented in the class, are discussed and evaluated with students reflecting with critical mind on their work, expressing their views and recording their experiences in a diary or questionnaire.

B. The role of the teacher

The teacher in this constructivist theoretical framework like that described above does not function as an intellectual “authority” that transfers ready knowledge to students but rather acts as an organizer, coordinator and facilitator of learning for students. S/he organizes the learning environment, raises the questions / problems to be solved through a worksheet, offers hardware and software necessary for students’ work, discreetly helps where and when necessary, encourages students to work with creativity, imagination and independence and finally organizes the evaluation of the activity in collaboration with students.

Chapter 4: **Technical guidelines (O1.4)**

4.1 Building instructions

For implementing this curriculum, the only shrewdness is to move the color sensor from the position kept so far in a higher one in order to better capture the ambient light and a possible source of light in front of the robot. Some variants require two color sensors put on opposite sides of the robot.

4.2 Illustrative solution

We start this curriculum with a representative example of using one color sensor capturing the ambient light to control the straight-line motion of the robot. The following variants improve the robot behavior by using one more color sensor to differentiate lateral sensitiveness.

We want that the robot maintains a certain proximity with respect to a source of light (fig. 3).

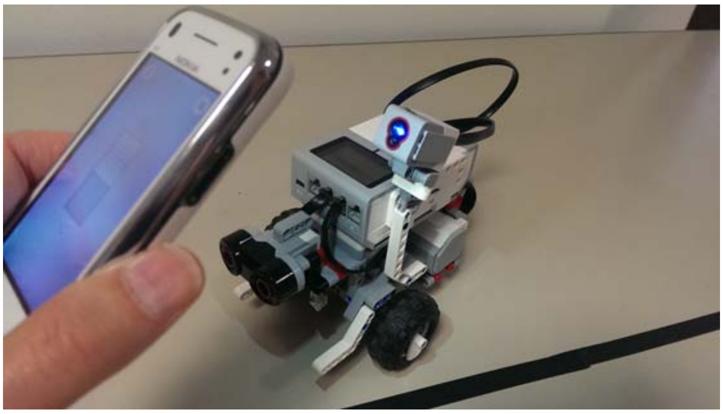


Figure 3. How to mount the color sensor for capturing ambient light

A first solution is similar to the proportional method for line following we used in the 'Let's play and dance' curriculum: to control the motor speed on the basis of the difference between the current light measure and the expected value, moving away if positive (too close) or approaching if negative (too far). The 'expected value' must be set experimentally, it must be a bit higher than the global ambient light so that, if the sensor does not 'see' the light source, the robot moves forward but it reverts the motion if a strong light strikes the sensor. Then the trick is to multiply this difference by a suitable value (positive or negative? Let's see) and use the result as the power parameter for a straight line motion (fig. 4).

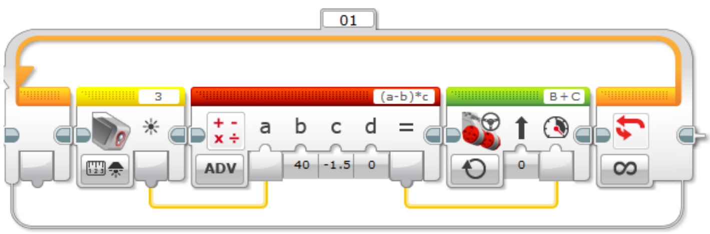


Figure 4. Proportional reaction to light variations

In the program the expected value has been fixed to 40 and the magic factor to -1.5, so a negative value. Other settings can slightly modify the behavior of the robot and should be experimented. By the way, this first solution is similar as the Breitenberg vehicle n.1.

Another approach to a solution of the task is to think the robot manifests different 'states'. They are summarized in the diagram of fig. 5.

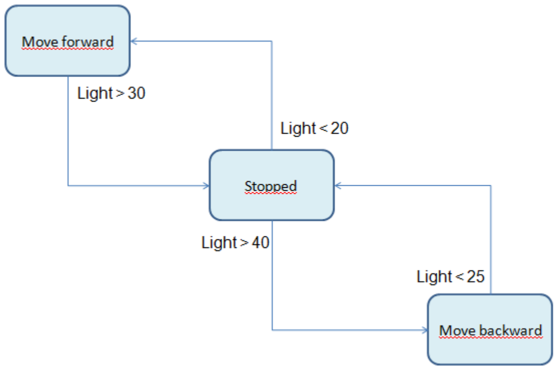
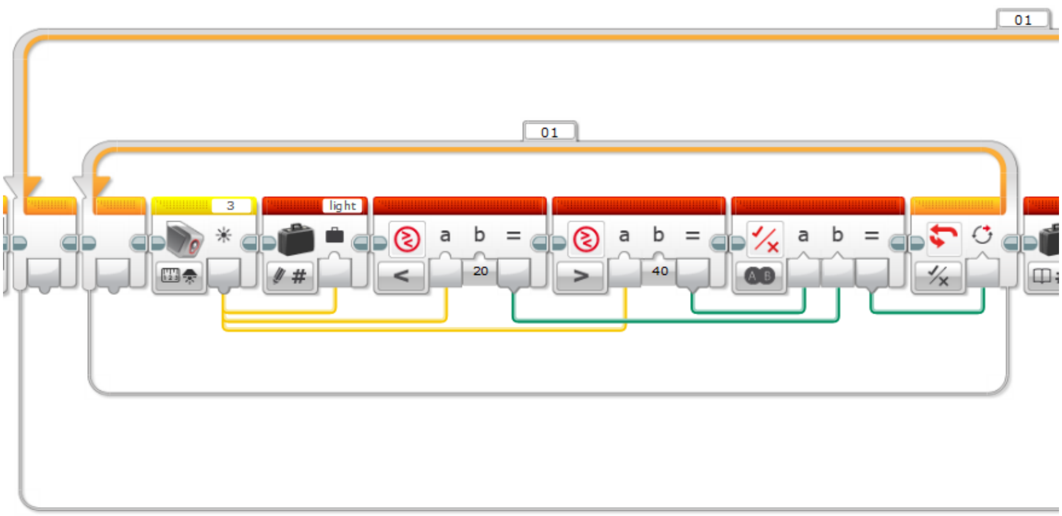


Figure 5. A state diagram for the follow light problem

You should ask the students to draw this diagram from the scratch, trying to describe the different situations in which the robot could be. Starting from a *Stopped* state, there are two possibilities: the robot starts moving forward (at constant speed) if the sensor detects less light, that is under a certain threshold, or it starts moving backward if the light is too strong, that is over another, higher threshold. From each one of these new states the robot comes back to the *Stopped* state respectively when light returns higher and lower than the intermediate thresholds. If you analyze the proposed diagram, you can argue that the robot is maintained in a position so that the light measure tends to stay in the range 20..40.

To implement this behavior, starting from the *Stopped* state, you can notice that the robot must be sensitive to both thresholds (less than 20 or greater than 40): this means that a single `Wait` command is not suitable because it stops the program waiting for just one condition. So it is necessary to use, instead of this block, a form of *busy waiting* consisting in repeating, in a waiting loop, the test whether the light measure is less than 20 or greater than 40 (fig. 6). The two comparisons are made separately and then combined with an `Or` command: the program exits from this loop when either of the two conditions is met. The following switch serves only to distinguish which one of the two conditions is now actually met and to move the robot consequently. The motion ends when the other threshold is reached and the robot comes back to the *stopped* state.



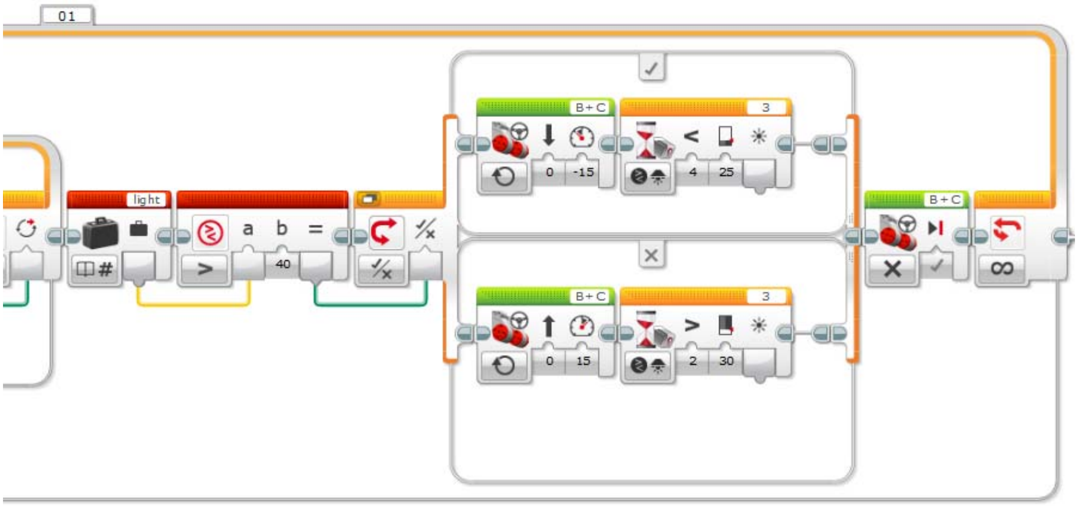


Figure 6. A program for maintaining a distance from the source light

While the presented solution is the 'direct' implementation of the scheme of fig. 5, fig. 7 shows an equivalent, and apparently simpler, solution where the *busy waiting* regards the whole external loop.

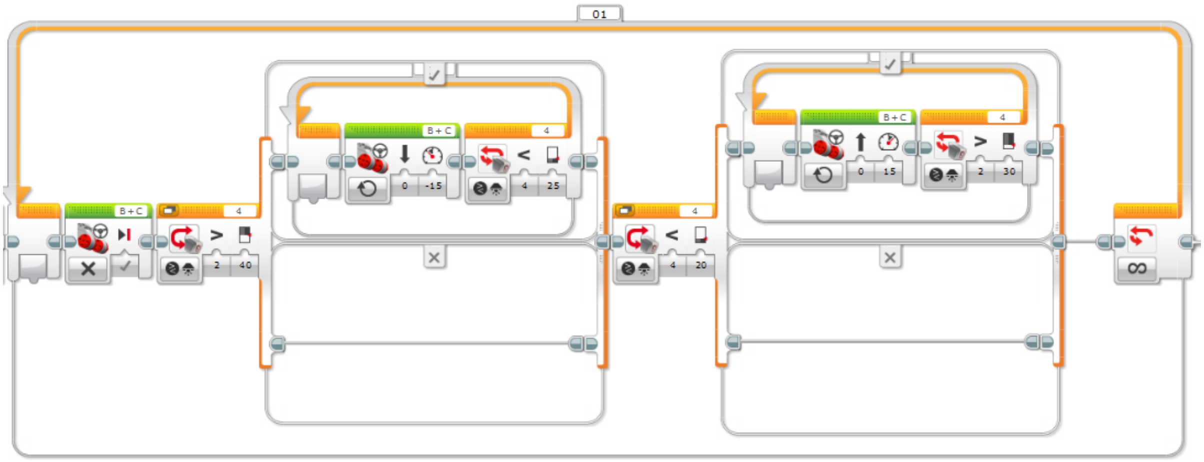


Figure 7. Another solution

These first programs were preparatory for introducing a first solution to emulate the heliotropism of a sunflower. We have still only one color sensor mounted and we assume to move around a torch to make the robot spin to follow the motion of the light. If you maintain the robot stopped when the light measure is over a certain threshold, when it gets lower due to the motion of the light source, you cannot discriminate if the source has moved on one side or the other. The simple solution is to spin a bit in one direction and check if the light moved in that direction: if true, the measure increases, if false it decreases, and in this case we make the robot spins in the other direction. Now it is sufficient to repeat the process until the measure returns over the threshold because the sensor is again in front of the source. The corresponding program is shown in fig. 8.

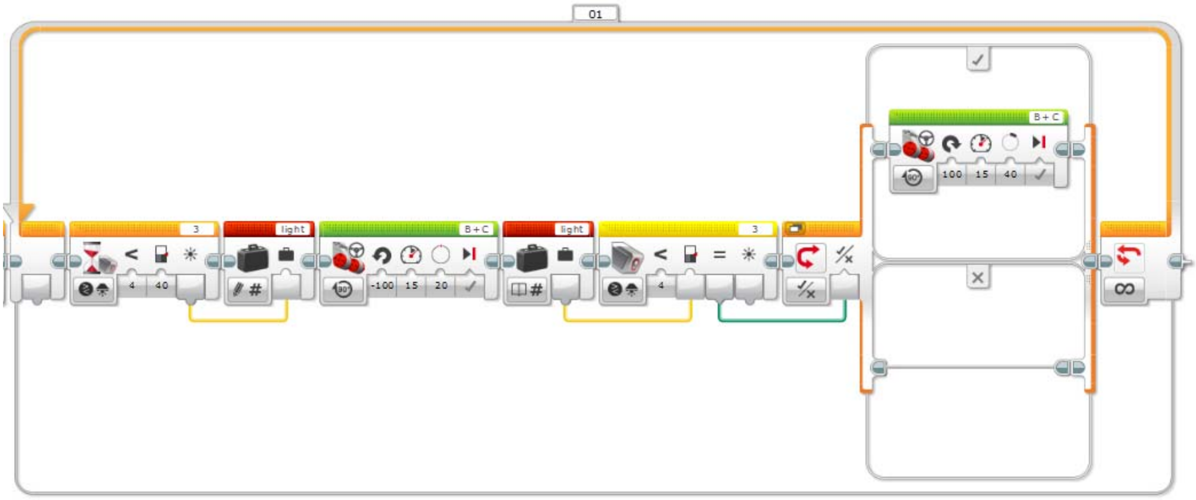


Figure 8. The sunflower, solution 1

Due to the limitation intrinsic in the use of just one light sensor, the solution works though not in a so precise and stable way.

4.3 Implementation suggestions

The problem to track a moving item with just one sensor is a very general one. To be aware of this, you could ask one student to run the program of fig. 9 on one robot, kept in his hands, with the ultrasonic sensor mounted on port 4 and directed to another student at a distance of less than 80 cm. The robot emits a continuous sound. Now ask the first student to close his/her eyes and to the second to move on one side. The robot stops to play the sound. How can the first student find again the other student using the robot? He would probably adopt the strategy to turn a bit on one side but, if he cannot capture the other student again, he would try to turn on the other side. This is more or less what the program in fig. 8 does. The not completely satisfactory solution stimulates the students to think about a more powerful solution using two sensors which can measure different levels of light according to their relative position with respect to the source.

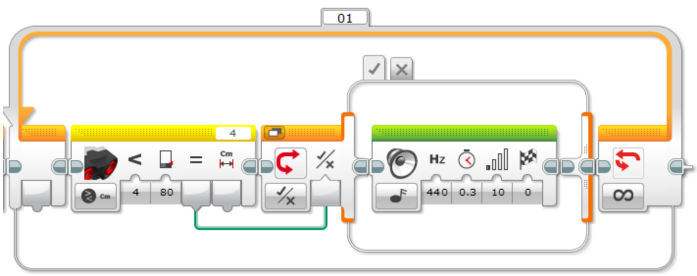


Figure 9. Detecting an object with a ultrasonic sensor

4.4 Extensions and variants

4.4.1 Variant a: The sunflower, solution 2 (with two sensors) [easy/medium]

Let's now imagine to mount 2 color sensors, one on each side of the robot (fig. 10).

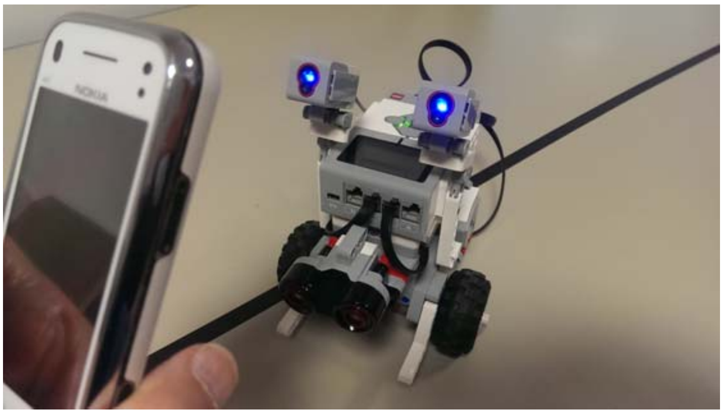


Figure 10. Two color sensors to discriminate the light direction

Due to the position of the two sensors, only if the source light is more or less in a centered position with respect to them, the two measured levels are almost equal, that is their numeric difference is around 0 (a very small positive or negative number). When the source moves on one side, the two measures differ and the greater measure reveals also that side. Say Right and Left respectively the measures of the right and left sensor, if the difference Right-Left is positive and above a certain threshold, the robot has to turn to right to have the source centered again, on the contrary to the left if that difference is under a certain other negative threshold. Turning must be stopped when the difference is between the two mentioned threshold. The representation of the system states is given in fig. 11 and it is implemented by the program of fig. 12.

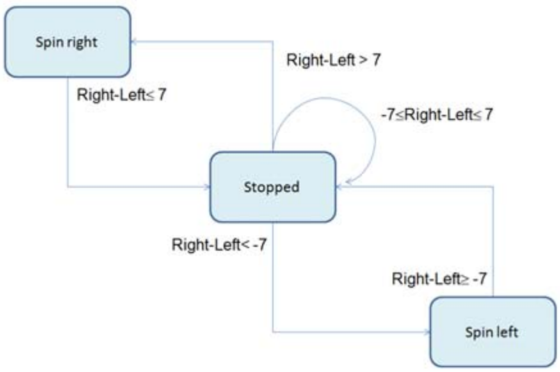
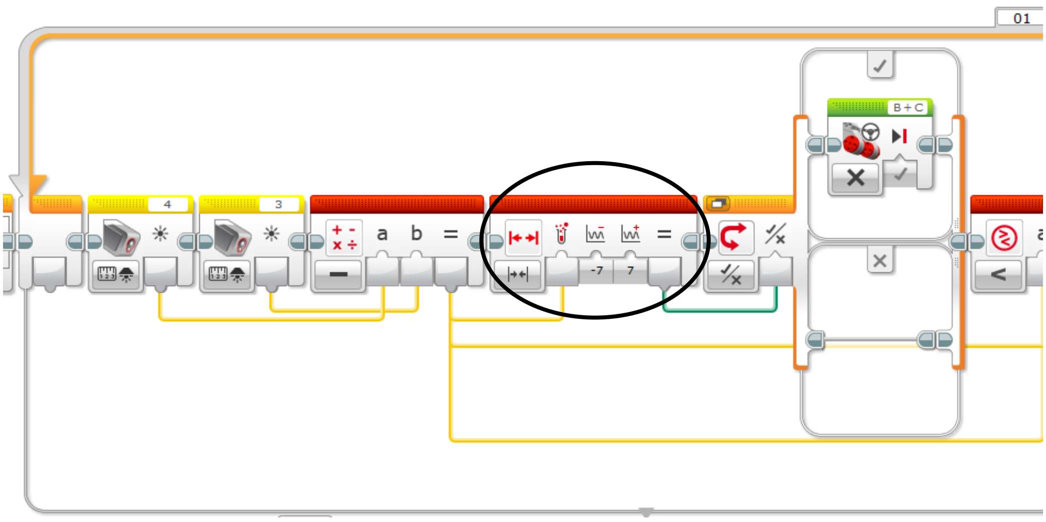


Figure 11. State diagram with two sensors



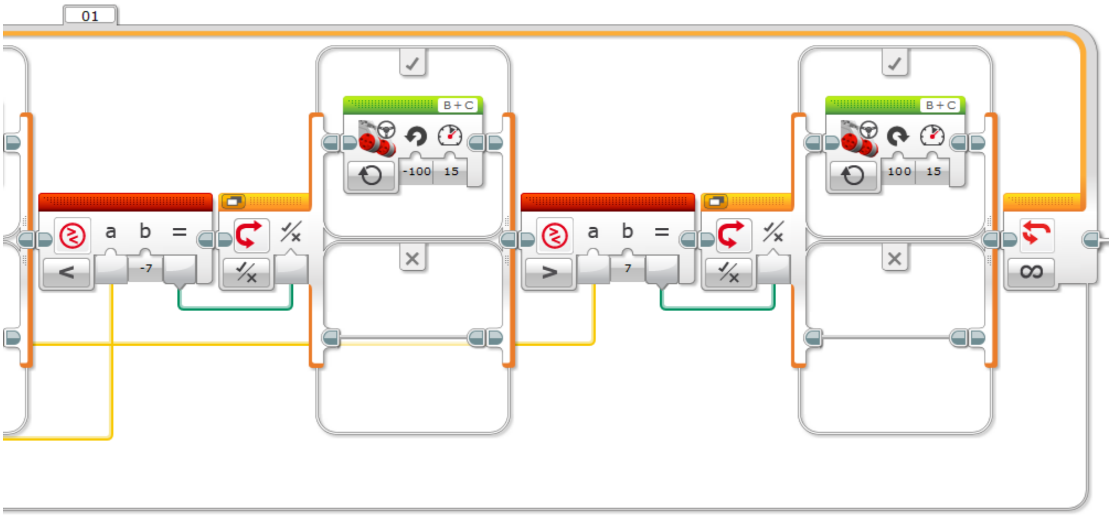


Figure 12. The sunflower solution 2, with two sensors

The `Range` command, highlighted in fig. 12, is a block returning a logical value true if the input value is within the two indicated bounds (‘inside’ option; when set to ‘outside’, it returns true if the value is less than the first bound or greater than the second bound).

4.4.2 Variant b: The sunflower, two sensors proportional [easy/medium]

Adopting an approach similar as the one used in fig. 4 but involving both sensors, we control the spinning of the robot on the basis of the difference between the two measures: we have to make the robot turn on one side if on that side the color sensor captures more light than the other sensor, so that we maintain the source of light in an intermediate position with respect to the couple of sensors (fig. 13). In case the robot turns on the wrong side, it is sufficient to exchange the two ports on the `Color Sensor` commands or the sign of the *c* factor of the `Math` command.

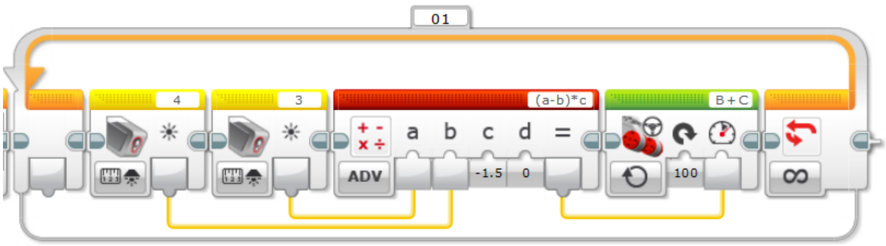


Figure 13. – The sunflower solution 3, with a proportional control

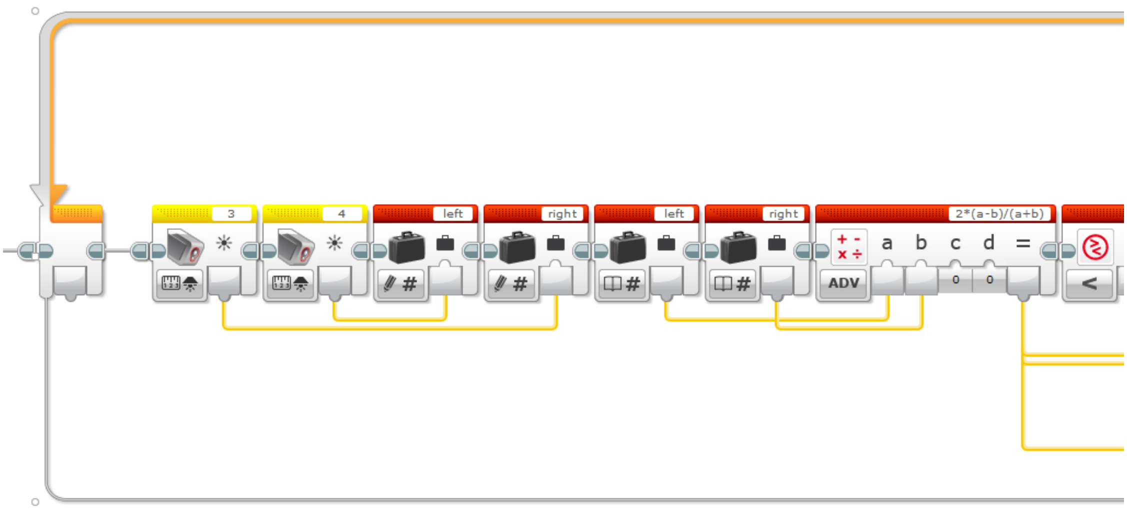
If you decide to use a mixed setup, with one EV3 Color sensor and one NXT light sensor, substitute the expression (a-b)*c of the `Math` command with (a-b+d)*c and tune the d parameter, positive or negative, in order to compensate the difference of sensitiveness of the two sensors.

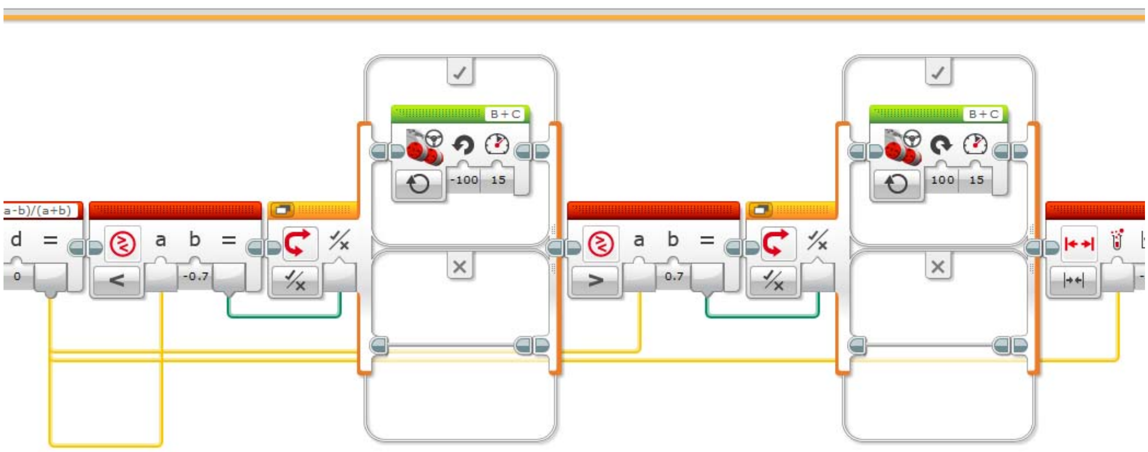
4.4.3 Variant c: A curious animal [medium/difficult]

Let’s now extend the solution making the robot both spinning and moving forward-backward, according to the measures of the couple of color sensors. When a significant difference arises between these measures, we have to make the robot turn and this realignment gets precedence; on the contrary, if the absolute value of the difference is less than a first threshold t1, the robot can be commanded to move according to the average value of the two measures, forward if this value is less than another threshold t2, backward if is greater than a third threshold t3 (t3 > t2). The behavior seems the one of a little curious animal, willing to remain close to the light source but not too much!

We have a slightly delicate technical problem: because now the light source can be very close to the sensor or quite far (always in relative terms), when the source is significantly unaligned with respect to the sensors, you can have a relatively high difference between the two measures when the source is close but a much limited difference when it is far. Because we want to give priority to the alignment in any case, it is advisable to condition turning on a relative difference, that is the ratio between such a difference and the average of the two measures m1 and m2, in formula 2*(m1-m2)/(m1+m2). Threshold t1 becomes also relative (a percentage) instead of absolute.

The complete solution is given in fig. 14.





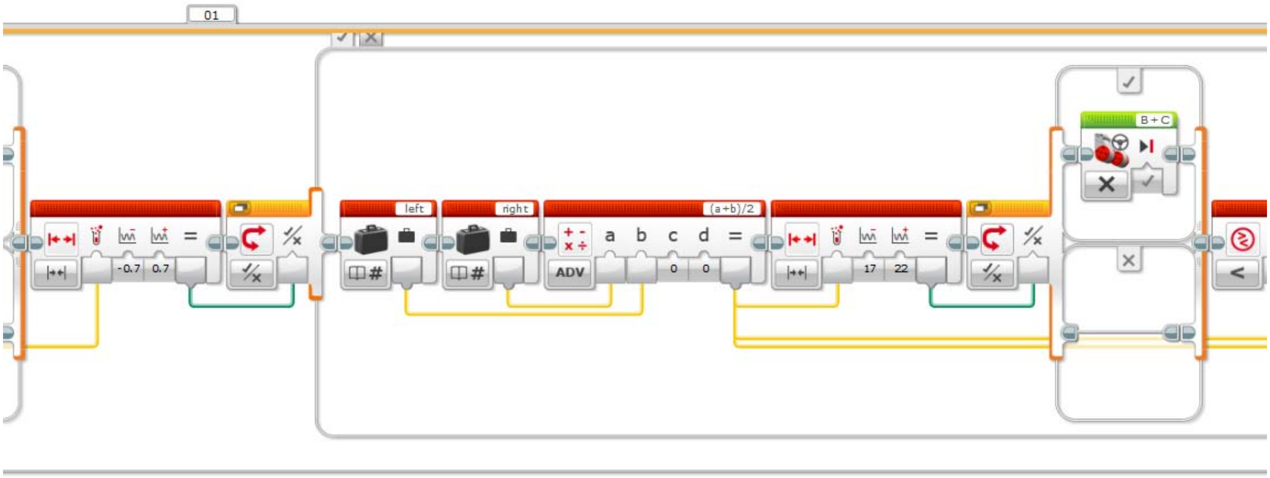


Figure 14. A curious animal

Chapter 5: **Evaluation tools (O1.5)**

Use the rubric below to evaluate your students' achievement in each specific objective of this curriculum.

Name of student (or group of students): …………………………………………………

upon completion of the activities described in this curriculum students achieved the following objectives	**Evaluation score** **0 = not attempted** **1 = attempted without success** **2 = partial success** **3 = completed with teacher's help** **4 = completed without teacher's help**
Mount correctly one or two color sensors and programmed them to capture ambient light	
Translated the scenario into a realistic representation on their desk	
Properly used the Math command with the advanced option to set a generic formula	
Instructed the tribot to go back and forth according to the measured light (one sensor)	
Significantly used a state diagram	
Discovered how to recognize the direction of the motion of the light source with one sensor	
Exploited the difference in discrimination power when using two sensors instead of one	
Properly used the Range command	
Instructed the tribot to turn and go back and forth according to the measured light (two sensors)	