Teachers Teaching with Technology™

T³ EUROPE

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Rover, a Sm@rt Wheelchair

Electric wheelchair steering control through head movements

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Rover, a *Sm@rt* Wheelchair

Electric wheelchair steering control through head movements

1. Learning objectives and system aspects

a. Learning objective and curriculum

This project consists in developing a robotic prototype for controlling the movement of an electric wheelchair, only with head movements. This is especially relevant for people who can only move their head in a controlled way, due to a tetraplegia or similar condition.

Despite there are already some commercial systems designed for this situation, they have significant disadvantages, namely in terms of technological complexity (and consequently high prices), or because they require the use of any kind of accessory (e.g. helmet, glasses, objects inserted in the mouth, among others), much more intrusive and uncomfortable for the user. In addition, these devices generally involve specific eye movements, face expressions or voice commands, which are usually complex to learn and to use.

The device proposed in this project transforms smooth head movements into controlled motion direction situations. The wheelchair will be simulated by the use of a programmable robotic vehicle (TI-Innovator ROVER), so its extrapolation to the full-scale model is extremely simple, by simply using relays to connect the control unit to each of the electric motor of wheelchair wheels.

This project will involve several STEM dimensions as well as SDG's, with very simple configuration and use of programable systems, being for that a very interesting first project for everyone. Despite that simple approach, it is also possible to further develop of the proposed configuration, giving the possibility to the exploration by some more experienced users.

b. Learning outcomes

(1) Learners will be able to conceptualize simple computer algorithms;

(2) Learners will be able operationalize simple computer algorithms in coded programs, using TI-Basic Language;

(3) Learners will be able to identify and mathematically manipulate physic variables evaluated by sensors, in order to control project outputs;

(4) Learners will be able to design and create a functional simulator of an electric wheelchair, driven from head movements;

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(5) Learners will be able to judge and compare the advantages and disadvantages of technological development.

c. Science background

Regarding the STEM approach of the project, we can say that all four dimensions could be reached during its development. The ***T***echnology engagement will be assured by the use of a graphic programable calculator (TI-Nspire™ CX-II), a Robotic Vehicle (TI-Innovator™ Rover), an I/O Interface (TI-Innovator™ Hub), as well as a motion sensor (Ultrasonic Ranger), to read head position. In order to convert head's user position in steering responses of the wheelchair, ***E***ngineering competences must be involved. It will be necessary to conceptualize the major logic functioning of all the apparatus, physically connect all the parts (taking in consideration ergonomic and effectiveness issues), as well as the development of an algorithm and its implementation in code, to give the adequate response to smoothly control the wheelchair movement. Certainly, the conversion of head distance to the sensor in controlled movement of the wheelchair will need ***M***athematical modeling and function exploration. Last, but not least, ***S***cience will act as a link for the entire project, as it can be called upon to analyze the circumstances that lead to human paralysis or uncontrolled movements, or to explain the functioning of a position sensor, for instance.

d. Connection with Sustainability Development Goals

This project has a direct connection with Goal 3: ***- Ensure healthy lives and promote well-being for all at all ages*** and Goal 12 - ***Ensure sustainable consumption and production patterns***. In fact, students taking into consideration the special needs of a part of the population who doesn't have the freedom of mobility of other ones, and developing systems to help them having a more comfortable life, are two dimensions of personality development that will lead to more inclusive and tolerant citizens, at the same time contributing to more healthy and for sure happier lives for some less favored persons. On the other hand, this project may have the potential to improve students and teacher deeper reflections about SDG's. Regarding the multidisciplinary aim of the project (besides the STEM approach), it can lead to very interesting analysis and discussion among scholar communities, about how to overcome the unsustainable consumption of natural resources, which causes soil devastation, pollution, climate changes and, above all, meaning an inequal enjoy of life from every world inhabitant. One can take into consideration that most of technologic devices are only available for a minority of more developed countries, but the damage for the environment due to its production is worldwide. In Appendix, teachers and students can find more information/ proposals to develop further discussion about this aspect, namely the relationship between United Nations Sustainable Development Goals, Engineering, Ethics, Biology and Sociology.[1]

[1] Cf. 2020, Christine Bürki, Biologist, Expert for sustainable development.

All the referred dimensions can be developed in conjunction with the curriculum, inside the classroom. In addition to the theoretical knowledge and practical skills promoted, the theme of this project will certainly contribute to the formation of citizens who are more attentive to the world around them and civically intervening for a better and fairer world for all.

2. The actual activity

In this project, students are challenged to use science and technology to resolve a real-life problem, with the advantage of being sensitized for paying attention to other and for contributing to make life better for the less favored, taking into special consideration the concern of not leaving anyone behind.[2]

a. Previous investigation/ background

In this preliminary section, students must be encouraged to find information and develop some competences in order to facilitate the effective development of the purposed project. Some of the following questions should be worked, prior to the main activity:

1. What are the physiologic causes for human paralysis? Are there different types? How different is the life of someone who is paralytic? What could be done to promote the well-being for someone who is paralyzed?

2. Are there developed technical solutions to control an electric wheelchair without using the hands? What are the *pros* and *cons* of each solution?

3. What are the damages to the planet of the crescent technological advances? Do these technological advances also influence all the inhabitants of the planet, as do their harmful consequences[3]?

4. What´s an algorithm? How can one control a robot's movement?

5. How to code? How to use TI-Innovator Hub to interact with the world (refer students to the ***10 Minutes of Code lessons*** for review, or to get an introduction to coding: https://education.ti.com/en/activities/ti-codes/nspire/10-minutes).

b. Overview of the project

In this project, the electric wheelchair will be simulated by the robotic vehicle TI-Innovator™ Rover. Therefore, it will be installed in the back of "wheelchair user" a backpack, in which will be fixed a

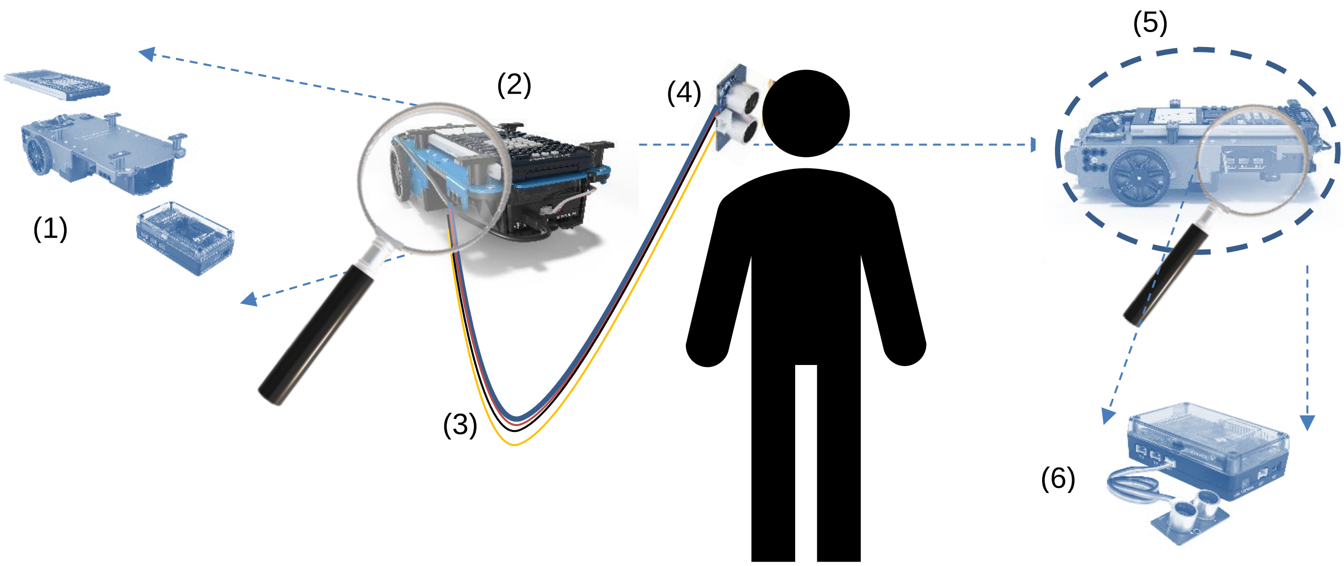
[2] Special dedication is given to this discussion in the appendix.
[3] See appendix

motion/ position sensor (Ultrasonic Ranger). This sensor should evaluate user's head position in order to send driving commands for the simulated wheelchair – Rover. It's something like if the head of the user would act as kind of a joystick, that would control the movement of the robotic car. Special care should be taken to correctly fix the sensor related to user's head, and to convert head distance from sensor in turning information. Teachers could explore the mathematical relations between these two variables, in order to define appropriate range, sensibility and accuracy of this "human remote control".

TI Technologies and Materials (per group of students)

- 1 TI-Nspire™ CX II;
- 1 TI-Innovator™ Hub;
- 1 TI-Innovator™ Rover;
- 1 Ultrasonic Ranger;
- 3-meter electronic wire x 4 (used to extend the length of Ultrasonic Ranger's connecting cable);
- 1 Backpack (or similar, used to fix the Ultrasonic Ranger near user's head);
- Duct Tape;
- Ice cream sticks (or similar, to build Ultrasonic Ranger's support on backpack);

System General Layout



Legend:

(1) – Rover setup, components view (TI-Nspire™ CX, TI-Innovator™ Rover, TI-Innovator™ Hub).

(2) – Rover setup, perspective view.

(3) – 3-meter electric wire,

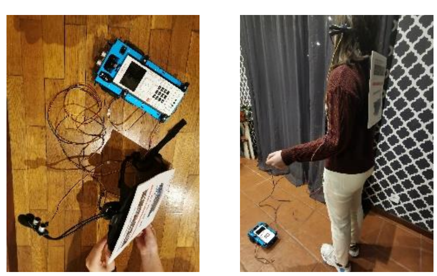
(4) – Ranger Sensor

(5) - Rover setup, lateral view

(6) - TI-Innovator™ Hub, detailed Ranger connection view

Application overview

The following pictures show a possible configuration of this project, in a real application.



(general view)

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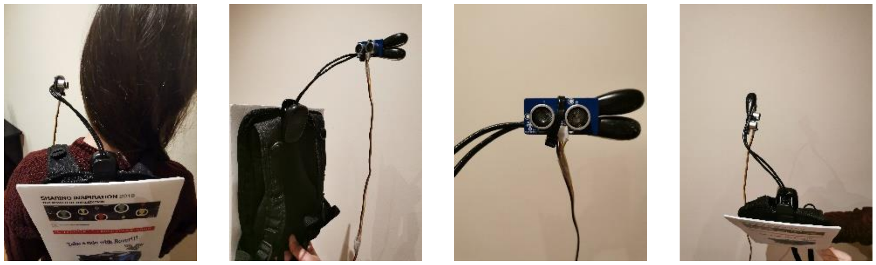


(detailed ranger sensor view)

It can be also seen in the following link a working application of the project, presented as a national Science contest, by Portuguese students, who won a trip to NASA for it!

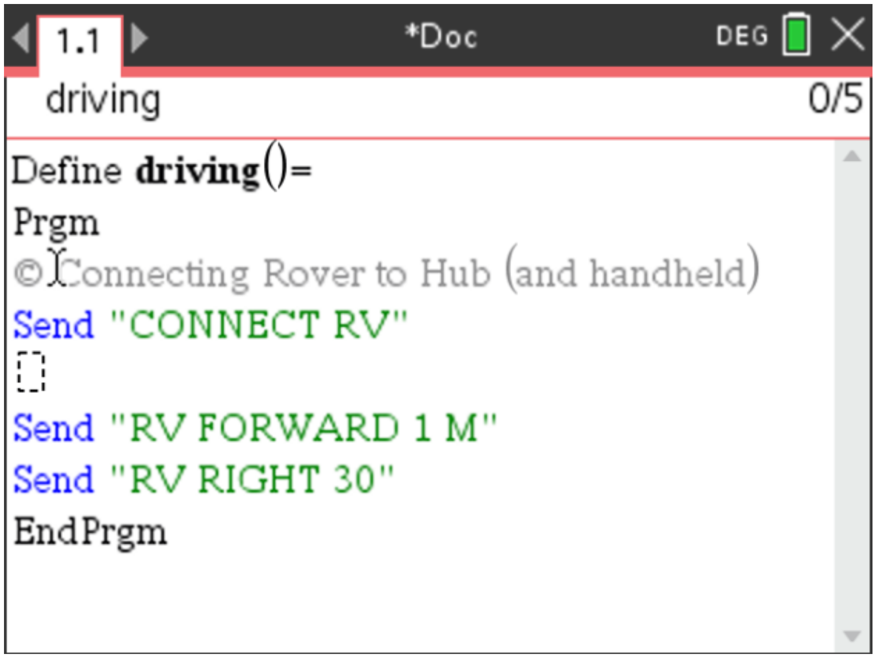
https://www.youtube.com/watch?v=Sbe5jqTemuo&feature=youtu.be

First steps

To see how to connect Rover (with Hub) to TI-Nspire please refer to https://education.ti.com/html/webhelp/EG_Innovator/EN/content/eg_splash/eg_innovroversug.HTML

1. Let’s command some simple driving instructions to Rover, for instance, “Go forward for 1 meter, then turn right 30 degrees”

   The program to execute the above instructions should be similar to this (implemented in file *driving_Rover.tns*):



To see other commands and configuration information, please refer to TI Innovator Technology Guidebook, https://education.ti.com/download/en/ed-tech/9682D7EC137E48798E3B250EFD65983D/2E21B21360CC46A094E86AF33192E471/TI-Innovator_Technology_Guidebook_EN.pdf.

2. With TI-Innovator Hub inserted in Rover, connect Ranger sensor to IN 1, as shown in next figure:

Now, let's try to read and display the distance information acquired by this sensor. The program could look something like this (implemented in file *ranger_distance.tns*):

```
Define ranger_distance()=
Prgm
© Connecting Rover to Hub (and handheld)
Send "CONNECT RV"

© Connecting Ranger Sensor to IN 1
Send "CONNECT RANGER 1 TO  IN 1"

© Reading sensor information
Send "READ RANGER 1"
Get dist

© Displaying sensor information
Disp "The distance is ",dist
EndPrgm
```

- From one test to another, please change hand distance from sensor and check that the readings are consistent.
- (how about using a cycle ***For… EndFor*** to do several tests at once?

3. In this challenge, the movement of Rover will be dependent on the reading of the sensor, i.e. the distance of the hand (in the final design, from the head of the system operator) to the sensor. For that, we'll use an ***If...Then…Else…EndIf*** control statement, and turn right or left according to distance information. Something like this (implemented in file *ranger_distance_driving.tns*):

```
Define ranger_distdrive()=
Prgm
© Connecting Rover to Hub (and handheld)
Send "CONNECT RV"
□
© Connecting Ranger Sensor to IN 1
Send "CONNECT RANGER 1 TO  IN 1"
□
© Reading sensor information
Send "READ RANGER 1"
Get dist
© Turning right or left according to sensor distance
If dist<0.5 Then
  Send "RV RIGHT 30"
Else
  Send "RV LEFT 30"
EndIf
```

4. We're almost there! In this simplified version of the wheelchair with remote control (simulated by Rover), we will just add the instruction for it to move generically forward, turning left or right according to the distance information read by the sensor. In this startup phase, it is easier to vary the distance read by the sensor by approaching or moving the hand, or any other object that we want to use as control. You can find an example of this program below (implemented in file *Rover_Wheelchair_STEM_Project_Simple.tns*) .

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```
Define rover_stem()=
Prgm

Send "CONNECT RV"
Send "CONNECT RANGER 1 TO  IN 1"

For i,1,100

    Send "RV FORWARD TIME 120"
    Send "READ RANGER 1"
    Get d

    If d<0.5 Then
      Send "RV STOP "
© turn right
      Send "RV RIGHT 30"
      Cycle
    EndIf
    If d>0.7 Then
      Send "RV STOP "
© Turn left
      Send "RV LEFT 30"
      Cycle
    EndIf
EndFor
Send "RV STOP "
Text "Thank's for driving me!"
Send "DISCONNECT RV"
EndPrgm
```

5. In order to make the wheelchair control a little more realistic, it will be interesting to fix the position sensor (Ranger) next to the "operator's" head (for example, fixing it to a backpack, with a flexible support), so that the head position is the direction indicator. To do this, it is

necessary to extend the cable connecting the sensor to the Hub, up to about 3 meters. This extension does not require special knowledge/skills and you can acquire wire similar to that used on the sensor cable in any electricity/electronics store. However, if you have access to an electronics workshop, a new cable with the appropriate resistance for many trips will be easily adapted. You can also find more complete program versions for this project in teacher files. It would be desirable that improvements to the program presented in the previous point be suggested in advance by the students involved in the project. It would also be interesting for students to explore the program now presented to understand the function of the commands added to the code. The file *Rover_Wheelchair_STEM_Project_Complete.tns* has a more complete version of the above program, including a routine to calibrate sensor distance according to the user's head movement. The file *RoverSI2019.tns* presents an even more complete version of this project, including a game mode, where the user can move with Rover (in this case playing the role of a robotic car, instead of a wheelchair simulator) on a surface with a black track over green ground, on which are placed blue strips, that activate a small quiz for the player.

3. Further project ideas

Although it is possible to run the Rover/ Electric chair with only a few lines of code, one quickly comes to the conclusion that a version for use in a real context would require several improvements (as is the case with most technological products, which follow year after year in increasingly improved versions). Here are some development suggestions for students most interested in the project, which easily transforms it in a project for an entire school year:

- Progressive rotation equation (instead of fixed at 30º);
- Controlled start/stop movement;
- Variable speed of movement;
- Use of virtual barriers (colored strips) to limit movement/avoid danger, for child users;
- Step detection;
- What about a real scale model?