Mathematics tools in GeoGebra for enabling interaction between students, concepts and the real world

Joanna Upchurch and Tymoteusz Typrowicz

Team code: 17-0368

Middle School no. 1 in Leżajsk

Poland

E-mail: AsiaUp@wp.pl

ABSTRACT

Developments in the field of robotics and programming are discussed in the light of the need for interactivity and socialization of the process of learning mathematics. Robots are shown to provide an 'object to think with' that can encourage learning and exploration of mathematical concepts. GeoGebra is an easily-accessible program that draws together several branches of mathematics to create a tool that can be used for, among others, controlling a Lego robot. The program's range of usability allows for the selection of an appropriately simple function for controlling the movement of a robot and its reaction to the appearance of obstacles in its path, making it a useful tool for even inexperienced robotics teams.

KEYWORDS

robotics, sensors, GeoGebra, Raspberry Pi

INTRODUCTION

Almost two decades have passed since Prensky (2001) coined the term 'Digital Natives' to describe how technology had become an integral part of the lives of learners born since about 1980 and the fact that their interaction with technology was progressing ever further and deeper. Even before the age of the digital natives, however, education was based on the idea that learning a subject like mathematics was an interactive activity, reliant on feedback, rather than a process of absorption of information (Piaget 1985). Also, learning was already seen as a social activity, due to the important role of social language in the development of thinking (Vygotsky 1986) which caused learners to benefit more from collaborative, rather than individual, activity.

In this environment, technology may enable students at a range of levels and abilities to understand and take part in mathematical tasks and activities (Hollebrands, 2007). As Johnson (2003) argues, robotics in particular offers educational opportunities due to its inherent multi-disciplinary nature, involving a synthesis of several technical topics. Robots provide what Papert (1993), referring to the computers of his time, called "an object-to-think-with" that will, like the computer before it, further contribute to the socialisation of the process of education in the future.

Through educational robotics, children may become familiar with difficult topics, such as programming, gearing, and mathematical representations, while attempting to make their robot work, and in so doing experience concrete learning, associated with what they create, observe and interact with (Petre and Price 2004).

CONCEPT AND DESIGN

Today, there are many small educational robot environments available based on a range of programs, of which the authors have previous experience of using Python. Many others have reported interesting results using simple Lego robots running GeoGebra.

GeoGebra (International GeoGebra Institute) was developed by Markus Hohenwarter in 2001 as an open source dynamic program designed to make mathematics accessible to everyone, including pupils as young as six (Hohenwarter & Jones 2007). By combining Geometry with Algebra, it enables visualization of abstract concepts, representations to see connections, and experiments to discover mathematics (Lavicza 2007).

GeoGebra enables users to manage an interaction between the physical environment of robotics and the virtual environment of the program. This encourages confidence and interest in using mathematical language and leads to social interaction in collaborative work. Even relatively simple problems can provide rich challenges in geometric and algebraic problem solving (Haapasalo and Samuels 2011).

Cognitive psychology tells us that our world is one of meanings, rather than stimuli. This requires a developmental approach: students should have opportunities to use spontaneous procedural knowledge. At the same time, one of the most important goals of modern education is to provide ways for pupils to identify and create links within complicated multi-causal knowledge networks. This requires conceptual knowledge alongside the abovementioned procedural skills.

The working hypothesis was that GeoGebra would prove to be a useful tool for visualising data from the robot's sensors, allowing the authors' relatively inexperienced team to extract a degree of functionality out of the robot and improve the comprehensibility of the task.

IMPLEMENTATION

Given the fact that even simple problems can develop into complex learning outcomes, and also the presence of significant time constraints caused by a shortened schedule, it was decided to employ GeoGebra in a relatively basic function together with navigation programming of a Raspberry Pi that calculated a formula for a trapezoidal area. GeoGebra was used online while the robot was running via a wireless connection.

Flores et al. (2016) developed a course for preservice secondary mathematics teachers at the University of Delaware aimed at promoting thinking, learning and problem-solving activities using a range of technologies featuring five themes that make use of GeoGebra and a Lego robot. The first, and most basic, of these was to generate data by taking measurements from a motion detector and represent it using a graphing calculator.

The authors decided to attempt to replicate this stage with their middle school student team in order to set up realistic goals to provide a positive learning experience, which would, nonetheless, satisfy the five stages of the innovation adoption process laid out by Rogers (1995). These are: *knowledge, persuasion, decision, implementation* and *confirmation*. As a result of the project, the team members were to become *aware* of the existence of this technology, be *persuaded* of its value and potential, *decide* to use it in greater depth in future, *implement* it in other problem areas and thereby receive *confirmation* of its value.

NAVIGATION AND PATH PLANNING

The GeoGebra software was used to enable accurate autonomous driving and navigation of the robot, which is equipped with a sensor that scans the environment in a certain range and sends the indications generated to the GeoGebra program, which, in turn stores the data and feeds them into a graph or table. Detection of unknown stationary or moving obstacles is an important requirement for navigation of a mobile autonomous robot through a course; therefore, it is necessary to scan the area in front of the robot and enable it to react appropriately to an obstacle. An algorithm in the GeoGebra program was used to extract the data for objects that were inside the collision area and determine whether the measured radius of each point was within a minimum value of 15cm. Due to noise encountered in the measurements, one point was not regarded as sufficient to constitute evidence of a real-world object. Instead, at least ten points had to be within the critical area in the GeoGebra graph to be indicative of an obstacle. Figure 1 shows how data from the sensor were used to modify the path planning.

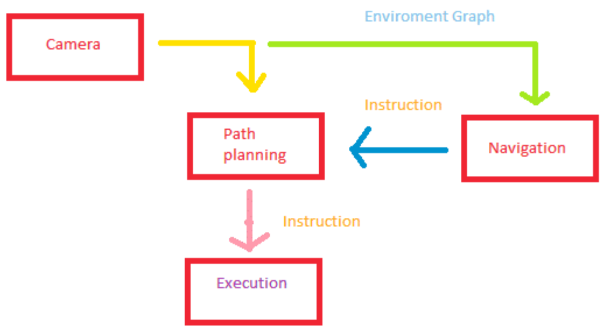

Figure 1: Illustration of path planning procedure.

Figure 2 shows the program for setting up the robot parallel to a flat surface opposite.

```
import piconzero as pz, time, hcsr04 as sonar
pz.init()
pz.cleanup()
sonar.init()
sonar.cleanup()

#configuration of sensor ports
setInputConfig(1,0) #left sensor
setInputConfig(1,1) #right sensor
# end of block

S1=readInput(0)
S2=readInput(1)
 while S1 =/= S2 :

    if S1>S2 :
        pz.spinRight(10)
        pz.timesleep(1)

    if S1<S2 :
        pz.spinLeft(10)
        pz.timesleep(1)


    else :
        break



pz.cleanup()
sonar.cleanup()
```

Figure 2. Robot set-up program.

Figure 3 shows the program for gathering data on the basis of indications from an ultrasonic sensor, set up in parallel with the opposite surface, during straight-line movement of the robot.

```
import piconzero as pz, time, hcsr04 as sonar
pz.init()
pz.cleanup()
sonar.init()
sonar.cleanup()

 A1=[]
t # Time, number of measurements,
accuracy and frequency in seconds
setInputConfig(1,0) #sensor
k=input()
pz.forward(10)
w=0
while k < (t+1) :
    readinput(0)
    k=readinput(0)
    A1.append(k)
    pz.timesleep(1)
    w=w+1
print A1
```

Figure 3. Program for gathering data from sensor.

RESULTS/CONCLUSIONS

The project has shown that even within a limited time frame an inexperienced team of middle school students can achieve a certain degree of functionality with a robot that they have created. The hypothesis, that GeoGebra is useful for the purpose of visualising data from a robot's sensors, has received some support from the experiment.

It has proven to be a satisfying introduction to the area, which is certain to lead the members of the authors' team toward further exploration. It is recommended that other teams who are at the early stage of this steep learning curve should also keep a realistic limit on their plans in order to complete a modest project rather than fail to succeed with a more ambitious one, which may likely lead members to lose interest in the field.

It is clear that GeoGebra is an effective guide not only for robots' movement around a course but also for many other projects in the course of collaborative education.

ACKNOWLEDGEMENTS

The team would like to thank their mentor, Mr. Polański, whose dedication and hard work made it possible for them to participate in the project. Gratitude is also expressed to the three reviewers whose insightful comments led to substantial improvements to the paper.

REFERENCES

Flores, A., Park, J. & Bernhardt, S.A. (2016) *Learning Mathematics and Technology through Enquiry, Cooperation and Communication: A Learning trajectory for Future Mathematics Teachers* in Niess, M. (ed.) Handbook of Research on Transforming Mathematics Teacher Education in the Digital Age. IGI Global pp. 324-352.

Haapasalo, L. & Samuels, P. (2011) *Responding to the Challenges of Instrumental Orchestration through Physical and Virtual Robotics.* Computers & Education 57 (2), pp. 1484-1492.

Hohenwarter, M., & Jones, K. (2007) *Ways of linking geometry and algebra: the case of GeoGebra.* In D. Küchemann (Ed.), Proceedings of the British Society for Research into Learning Mathematics.27(3), University of Northampton, UK: BSRLM.

Hollebrands, K. F. (2007) *The role of a dynamic software program for geometry in the strategies high school mathematics students employ.* Journal for Research in Mathematics Education, 38(2), 164-192.

Johnson, J. (2003) *Children, robotics, and education.* Artificial Life and Robotics (7), pp. 16-21.

Lavicza, Z (2007) *GeoGebra Dynamic Mathematics for Everyone.* Presentation. International GeoGebra Institute.

Papert, S. (1993) *Mindstorms: Children, Computers, and Powerful Ideas.* London: Basic books.

Petre, M. & Price, B. (2004) *Using robotics to motivate 'back door' learning.* Education and Information Technologies, 9(2), pp. 147–158.

Piaget, J. (1985) *The equilibration of cognitive structures: The central problem of intellectual development.* Chicago: University of Chicago Press. (Original work published 1975).

Prensky, M. (2001*) Digital Natives, Digital Immigrants*. On the Horizon, 9(5), pp. 1-6.

Rogers, E. (1995) *Diffusion of Innovations.* London: Simon and Schuster.

Vygotsky, L. (1986) *Thought and Language.* MIT Press. (Original work published 1962).

Geogebra url: http://www.geogebra.org