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Teaching Basic Concepts: Geometric Forms and Colors on a NAO Robot Platform

Diana Olvera, Uriel Escalona, Humberto Sossa

Instituto Politécnico Nacional, Centro de Investigación en Computación,
Ciudad de México, Mexico
a150815@sagitario.cic.ipn.mx

Abstract. Basic geometry figures and colors are some of the first approach on children mathematics learning, this process tend to be long-time and often is needed several sessions to learn these concepts correctly. Classical teaching models require a teacher and students, where teacher show the concept (name, form) and student repeat. Cases where the concept is not learned in a group, it is required personal sessions one-to-one, taking more time that teacher can give to each student. In this paper we propose the use of NAO robot as an educative platform to teach colors and geometry forms to children, using voice and image processing, with a game-like structure ensuring the learning process result in correct learning.

Keywords: NAO robot, teaching robots, geometric forms.

1 Introduction

The use of Information and Comunications Tecnologies (ICT) on daily life is a reality of our times, in education is a complement that allow a better transmission and demonstration of knowledge, however, this most be implemented with the correct planning over academic activities [3].

Education robotic offer a safe environment where kids can test a hypothesis and problem solutions according to age always supported by learning process well defined and tested to not engrave or threatened the development of kids [14]. Initial experiments as [2, 11, 8] show the benefits obtained when a computational systems helps in the education, emphasizing that the robot is not a replace of humans, only is used as a reinforcement.

This paper focuses on the idea of providing a robotic tool that can interact with children as many times as necessary, this being the main advantage of the use of robotic systems, since these do not show fatigue or boredom, so they can continue working the time that is necessary until the concepts to work are learned correctly.

1.1 Educational Robotic

The Educational Robotic (ER), implemented through a pedagogical approach, fosters a learning environment in which the use of robots in the classroom is justified to promote the learning of different areas [19, 2, 12].

It is defined in 1989 by Vivet as: "Activity of conception, creation and implementation operation, for didactic purposes, of technological objects, which are reduced reproductions very faithful and meaningful processes and robotic tools that are used daily, and that they are becoming more common in our social, productive and cultural environment ", or, as the discipline that allows to conceive, design and develop educational robots,to promote that the students begin in science and technology from an early age, in order to explore from another perspective the interaction with a robot to favor cognitive processes [13].

The six main reported areas that have been proposed in educational robotics are:

1. Support in primary and secondary education.
2. Adults in professional training.
3. Robotics applied to people with disabilities.
4. Pedagogical robotics to facilitate the development of cognitive processes and representation.
5. Robotics as a tool in laboratories.

The application of this discipline aims to explore how attractive it is for learners, as well as for educators the idea of learning by playing. With the use of educational robotics, technological approaches can be made from an early age, and breaking with the myths that this is only a science fiction thing.

In order to verify the objectives of educational robotics as an integrating discipline of different areas of knowledge, the development of two individual processes is necessary but highly dependent. On the one hand, functions must be established from the point of view of engineering for the study and process of conceiving, designing and constructing robotic mechanisms; and a second function, from the didactic point of view, to verify that these mechanisms effectively meet the educational purposes for which they were developed, which involves research in the disciplines of knowledge of education, teaching and learning. Therefore, this paper work focuses on providing educational skills to a robotic system that meets the basic requirements for execution in an educational environment.

2 Methodology and NAO Robot

2.1 NAO Robot

NAO robot (Fig. 1) is part of humanoid robots, referring to an artificial entity which has a similar shape to humans. Been one of the first humanoid robot released in 2006 by Aldebaran Company in France. In table 1 the main physical characteristics are shown.

Fig. 1. Humanoid Nao robot.

Table 1. NAO robot main characteristics.

Feature	Value
Size	573x311x275 mm
Weight	5.4 Kg
Processor	ATOM z530 1.6 GHz
RAM	1 Gb
Hard disk	8 Gb

With 25 grades of freedom, 2 HD cameras, touch sensors, 4 omnidirectional microphones and 2 speakers positioned around the body this robot can interact with the environment similar as a human can do.

The cameras are positioned in the head were proportionate a wide angle as shown in Fig 2.

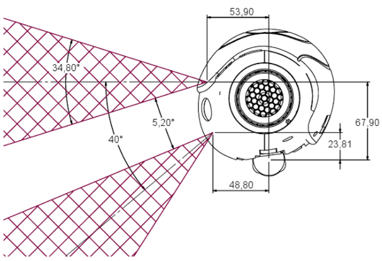

Fig. 2. Position and angle view of NAO cameras.

It can be programmed in several software as NAOQI-OS, Webots and Choregraphe, using C++, Java, Java Script and Python as programming languages.

NAO Programming Choregraphe (Fig. 3) is an intuitive graphic environment where algorithms are build by series of blocks, predefined sets allow the robot to complete from easy to complex tasks as face recognition. These blocks follow a sequence on time to execute the algorithm created in Python.

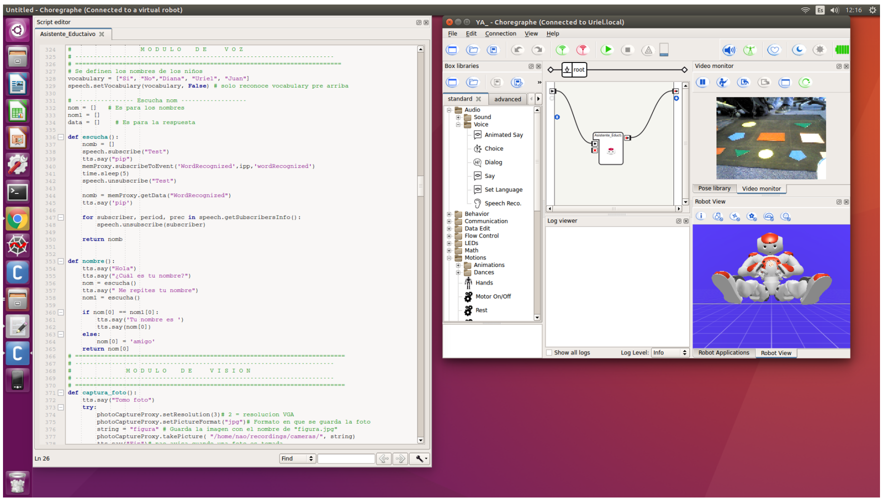

Fig. 3. Choregraphe, software to program NAO behaviour in block by Phyton.

2.2 Educational Environment with NAO Robot Setup

Among the first knowledge acquired in childhood are colors and figures, these are considered the first steps to the mathematical world and are essential to recognize the environment in which we find ourselves.

Color Selection The teaching of colors is a main area for the exploration of the environment, which is taught in the first years of the child's life. The teaching of colors for children has no age limits nor is there a metric of how many colors they should learn at an early age. However, it is suggested that children start with primary colors and then secondary colors, or, make a mixture of them, preferably 5 to 6 vibrant colors such as red, pink, green, blue, can help strengthen their learning.

According to [15] children can learn color in three steps:

1. Color association: Fist step is to hear name color, this can be made by the teacher or in case of ER by a robot.
2. Point out a color: Second step help children to know the differences between colors, in this activity children touch different colors and teacher or robot correct the name or reward a correct choice.

3. Name color: As a final step the children must be able to name the colors without the need to point out, this step make clear that children have learn correctly the colors.

When it comes to learning colors at an early age, patience is essential and although in some children the process may be short in other cases it can be a long process. So if the child already knows the fundamentals and differences, this does not mean that they should stop, but it is time to start teaching tertiary colors, as, a blue color has color variants for example color navy blue, sky blue, among others.

Geometry Figures Selection The initial understanding of geometry emerges in the early years as a physical knowledge of space [17]; it is possible to create activities to increase the learning of the geometry, the common geometric figures (Fig. 4) at an early age to use are flat (2D) include the circle, the triangle, the square, the rectangle, the pentagon, the rhombus and the ellipse, and the spatial figures (3D) include the sphere, the cylinder, the cone, the cube and the rectangular prism (Fig. 5).

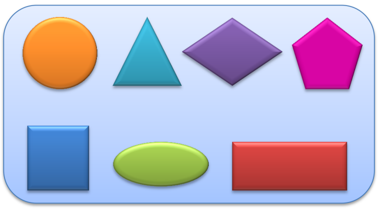

Fig. 4. 2D geometry figures.

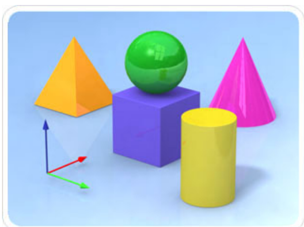

Fig. 5. 3D spatial figures.

It is known that children do not have the appropriate language to define the geometric figures with the appropriate word, however, children are able to find the similarities and differences in the forms present in the environment that surrounds them. The goal for these ages is precisely to develop this ability to discriminate one way and another, since they invent their own reference points using their everyday experiences.

Pattern Recognition To carry out the recognition of patterns there are many techniques of vision by computer [16], it is necessary to provide the robot with this type of characteristics to allow a mobility and interpretation to develop in the world around it. The accuracy of these algorithms depends on two major aspects. The first is the limitation of the hardware itself and the other is the robustness of the program, where the ideal is that there is a minimum number of failures [20] to be carried in real time [5, 4].

In this paper we propose the used of Ramer Dougles Peucker (RDP) algorithm, created in 1970 [6], it is an algorithm used to simplify and reduce the number of points on a line or curve, is commonly used in geographic map processing, or in the recognition system of certain objects [9].

The RDP algorithm (Fig. 6) is explained in [10, 7, 18, 1]. As follow, the points within a sector of points are located and renamed assuming an imaginary line between the first and last points in the system of the points of the curve, determining the furthest point for this sector as the first and the last point of the endpoints. In spite of this, if this point or all other points between the start and end points are closer than a fixed distance, eliminate all those points between the two points. However, in case the imaginary line is greater than the value "Standard of Tolerance or Disparity (e)", it means that these points have already been included within the points of the curve [1].

3 Learning Process and Results

A board with size 60 cm by 80 cm containing geometric figures of different colors is developed, besides a replica of these is added that will help the NAO robot with the interaction as shown in Fig 7.

This board include a blue pentagon, green triangle, pink square, yellow circle and red rectangle. All figures can be changed of position as well as rotated in 5 different spaces, the purpose is to change the position of the figures in each session to secure that children learn the object and not the space.

The main idea is that the child can interact with the geometry figures and color with different senses as sight and touch and NAO robot helps with sounds.

Teaching color with NAO robot follows this steps:

1. The NAO robot introduces itself and asks the name of the children,
   (a) The name is recorded for future interaction by microphone and natural language process algorithms,
2. NAO robot points out the different colors that exist on the board in order from left to right, indicating by sound the name of each one:
   (a) a photograph of the board is taken by the front camera of the NAO robot to know the position of each color using the RDP algorithm.

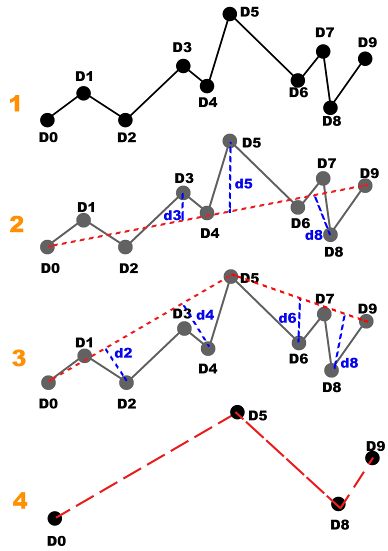

Fig. 6. RDP algorithm finds the relevant points of a series of points using a tolerance distance (e) as a limit value.

3. NAO robot asks the children to point and touch one of the 5 color:
   (a) a photograph of the board is taken with the hand of the children to identify which color has been hindered,
   (b) If the selection is correct, the NAO robot congratulates the children with his name and is instructed to take a prize,
   (c) If the selection is incorrect, the NAO robot corrects the children indicating the correct answer.
4. The process in (3) is repeated up to a maximum of 5 times per session.

In the case of geometrical figures the process is very similar done through the following steps:

1. The NAO robot introduces itself and asks the name of the children,
   (a) The name is recorded for future interaction by microphones and natural language process algorithms.
2. NAO robot points out the different geometrical figures that exist on the board in order from left to right, indicating by sound the name of each one:
   (a) a photograph of the board is taken by the front camera of the NAO robot to know the position of each geometric figure using the RDP algorithm.
3. NAO robot asks the children to point and touch one of the 5 figures randomly:
   (a) a photograph of the board is taken with the hand of the children to identify which figure has been hindered.

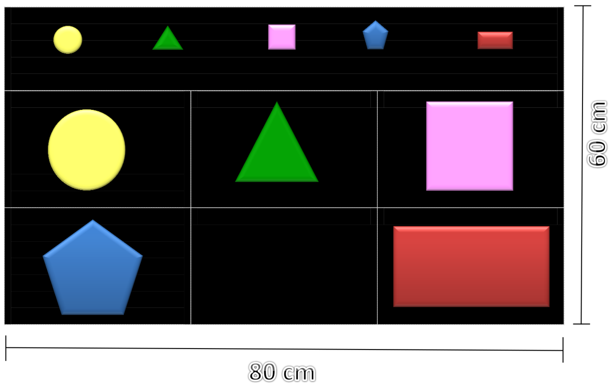

Fig. 7. Board with geometric figures and replicas for NAO robot.

   (b) If the selection is correct, the NAO robot congratulates the children with his name and is instructed to take a prize.
   (c) If the selection is incorrect, the NAO robot corrects the children indicating the correct answer.
4. The process in (3) is repeated up to a maximum of 5 times per session.

In both cases, color learning and geometric figure learning NAO robot uses the front camera to take a photograph of the interactive board to know the position of each figure (Fig. 8).

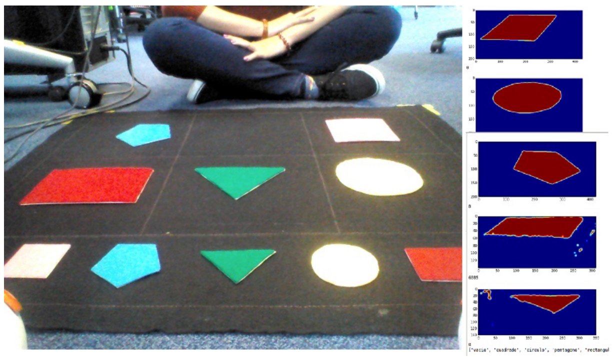

Fig. 8. Photograph from NAO robot point of view and RPD algorithm process.

As light conditions usually can not be controlled in a classroom the RGB information from the images is not enough to determine the figure in each section, so RDP algorithm provides a better solution as follows:

– Image taken from the frontal camera is divided in 5 sections which contain the figures.

– Images are binarized with a threshold near to 0 to separate black color of background from images.
– Blur method eliminates small noises as salt and pepper.
– RDP algorithm detects the number of edges in each image as follow:
  - square and rectangle result in 4 edges,
  - Triangle result in 3 edges,
  - Pentagon result in 5 edges,
  - Circle result in more than 7 edges.
– In the case of square and rectangle as both have 4 edges, internal value is taken, since pink is lighter than red this helps to correctly classified each figure.

Four children were selected with ages between 3 and 4 years to interact with NAO robot, at the beginning these children did not know correctly the colors and figures of the board. A series of 30 sessions were carried out interspersing the teaching of colors and geometrical figures. Their learning of these geometrical figures and color are shown in Fig 9.

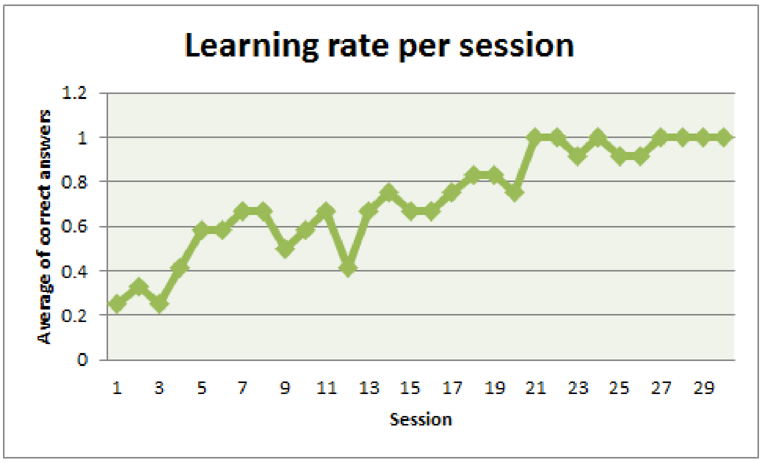

Fig. 9. Learning rate of geometrical figures and color by children.

It is observed that at the beginning of the sessions, the children could not correctly identify the geometrical shapes or colors, being their random choice, so that their percentage of success is close to 25%, as they progressed in their learning the children began to select correctly, and at the end in the last 4 sessions a 100% percent of success is reached.

Likewise, the response time (Fig. 10) between the NAO robot indicating the object and the child selecting it was measured. At the beginning, the child took a time of up to 7.5 seconds as he hesitated between several figures before selecting his answer, according to his understanding of geometrical figures and colors increased this time was reduced to a minimum average of 1.8 seconds.

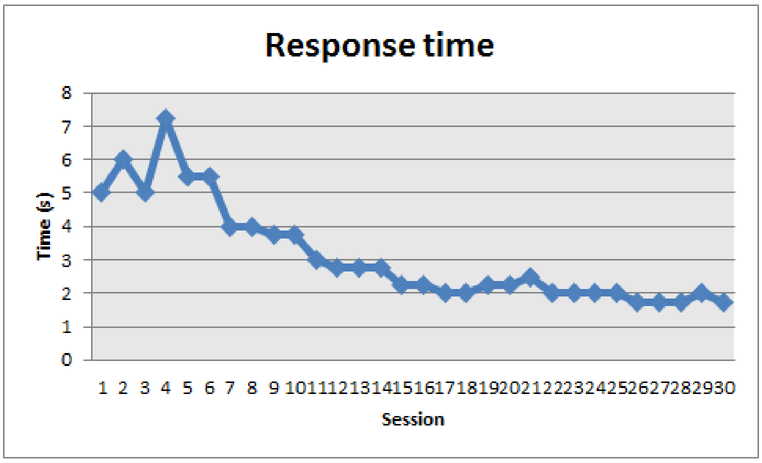

Fig. 10. Response time over sessions.

4 Conclusions

The teaching of concepts to children can be a late process and requires repetitiveness that sometimes can not be provided by a single educator. This paper proposes the use of an NAO robot as a platform for teaching and reinforcing geometric figures and colors to children, being one of the main advantages that the robot can repeat the teaching process as many times as necessary without becoming tired or bored.

In a period of 30 sessions the children demonstrate to have correctly learned the geometrical figures pentagon, square, rectangle triangle and circle, as well the colors red, blue, green, pink and yellow correctly. Being that the game-like teaching seemed interesting to them and they did not show boredom or difficulty to interact with the NAO robot.

Future improvements will focus on expanding the range of colors and geometrical shapes, in addition to introducing the children to concepts such as numbers and letters.

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