

# An Educational Robotic Game for Transit Education Based on the Lego MindStorms NXT Platform

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## Abstract

This paper describes the development of an educational game using Lego MindStorms NXT 1.0 platform of educational robotics and Java technology, seeking the construction of knowledge about the Transit Education for children, in a fun and interesting way. With this game children can experience situations of urban traffic, leading to reflections on what attitude to take in view of typical situations. The game seeks to simulate urban traffic close to real-world situation.

**Keywords:** Educational robotics, Educational games, Lego MindStorms NXT.

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## 1. Introduction

The game developed is based upon the ideas of Jean Piaget and Lev Vygotsky. From the viewpoint of Constructivism, new concepts and knowledge are developed when the user interacts with game objects. Also according to Vygotsky and Piaget, enjoyable activities stimulate curiosity and self confidence, improving language development, concentration and attention. Through games children can learn to act in a cognitive sphere, enabling them to choose their own actions.

Educational games are enjoyable activities with specialized educational aim to develop thinking and learning for children [Pinto 2008]. We already know that robotics hold children's attention, becoming a powerful resource for building knowledge.

The game's proposal is multidisciplinary. One of its goals is to provide integration between disciplines such as Portuguese when dealing with interpretation of questions and alternatives to respond the quiz, Mathematics when carry on analysis of indicators of energy (fuel) and time, and Science, when working with of motorist interactions in transit. The transversal theme Transit Education is present in all interactions.

This paper is organized as follows: Section 2 presents our motivation; Section 3 presents related work; Section 4 describes the game development; Section 5 talks about the challenges in game

development; Section 6 discusses evaluation, verification and validation. Section 7 presents our conclusions and future works.

## 2. Motivation

According to the latest DENATRAN<sup>1</sup>'s yearbook, there were 653,827 transit accidents with 33,996 fatalities, 105,337 of these were motorists. The punishment for transit violations have become tougher, but still were not enough to reduce accidents.

Much of the motorists have an aggressive and violent behavior in transit. These attitudes are associated with lack of Transit Education. For this reason new laws were added to the Brazilian Traffic Code in order to promote Transit Education and the development of new supportive tools.

Robotics have increasingly been used as effective educational tool [Lund *et al.* 1999, D'Abreu and Chella 2001, Matarić 2004], and it would suit our goal of creating a game scenario as realistic as possible.

The game proposed differs from other educational tools by making a combination of Mobile Robotics and traditional educational game, increasing children's interest in the game, as exemplified by the work of [Lund 1999].

## 3. Related Work

At Escola Politécnica de São Paulo (USP) a game with goal of learning in Transit Education has been developed. That tool gives learners opportunities to navigate in a virtual scenery that reproduces actual rules of the urban traffic [Assis *et al.* 2006].

Lund [Lund 1999] reports a series of experiments carried out at the Lego Lab, investigating the use of robots in games for children. Lego Pacman was one of the games developed and it was aimed to answer whether some aspects of the virtual game can be applied in the real game.

The conclusion of that experiment was that some features may not be passed to the physical game because they are really difficult to implement in the real world. Children associate the features

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<sup>1</sup> National (Brazilian) Department of Transit

implemented with the virtual game and they start playing with them, but they ask what is possible to do and what is not possible to do in a physical game with the use of robots.

The platform Saberlândia [Pinto 2008] allows, from context and content provided, the automatic generation of action games. The main focus of that project was to develop an authoring system for building knowledge by playing and use of multimedia resources such as Virtual Reality and Robotics to improve motivation. The robotic device used was the mobile platform FURGBOL. The movements of virtual characters in the game are shown by the robots in a real environment.

Our bibliographic research so far has shown no articles no articles relating Lego Mindstorms NXT and educational game focused on Transit Education. However, the work of Lima [Lima *et al.* 2006] describes the development of an application that uses computer resources, Robotics and curriculum subjects to allow a new and interesting learning about traffic.

## 4. Game Development

Our game was developed by adapting the methodology Design Bible, described by [Assis *et al.* 2006] and [Taylor 2010].

### 4.1 Design Bible

The following is the game specification as recommended by [Bittencourt 2005].

**Overview of the game:** The game is an urban environment with houses, buildings, traffic signs and streets. The player (user) is the motorist, and has the goal of reaching a certain point in the city with the highest score possible.

**Goal:** From the viewpoint of the player, the goal is to reach a destination point with the highest score. From the educational viewpoint, the goal is the player build knowledge of transit laws through the interaction with the urban environment.

**Educational Goal:** Following Bloom's taxonomy of educational objectives [Roberts 1994], the game's cognitive goal is to know traffic laws and their signs, as well as understanding of related questions and answers. The psychomotor goal is to control a radio-controlled vehicle in order to meet the goal established by the game. Finally, an effective goal is to stimulate self-confidence of the player after each correct answer and objective level reached.

**Interactivity:** The level of interactivity in the game is high, allowing unexpected discovery and free exploitation through a remote control.

**Target audience:** Students in the final stages of elementary school.

**Scenario:** The game takes place in an urban environment built on a scale-model where the vehicle travels according to player's instructions received through software. In the model there are buildings, schools, clubs, banks, houses and traffic signs, as seen in Figure 1.



Figure 1: A physical urban scenario

**Characters:** The game offers only a “single-player” option, where the character motorist interacts with the urban environment.

**Game start:** The game starts with the player in a predetermined position according to the game level. The player has an energy bar (representing vehicle fuel) and a time bar (representing the timeout to arrive at the target location). The player is informed that he/she must reach a certain point in the city with maximum energy spending minimal time, abiding signs and traffic laws.

**User interaction:** The player controls the vehicle in the scale model through a graphical user interface (GUI), as shown in Figure 6. To be given control, the player must choose a game level. If a player arrives at the place determined by the level chosen, he/she is entitled to play a bonus by answering questions (Quiz) on certain game situations. When answering the questions correctly, the player earns points and increases their score.

**Time and energy:** The energy and the time spent are always visible. At the beginning, time bar and energy bar are both full. They get empty by the passage of time according the level chosen. If energy or time run out before the player gets to the point determined by the chosen level, the game is restarted and the player does not get any points.

**End of the game:** The end of the game occurs when the user reaches a point determined by the chosen

level, or when the robotic vehicle walks outside the street, or when time or fuel end. The user knows their score when finishes a level with success.

## 4.2 Game architecture

The proposed game has an architecture shown in Figure 2. We have four subsystems: Agents, Game, Scenario and Base Maps. Inside the Game subsystem we have the following modules: Player Interface, Interface Editor and Game Engine. Communication between Player Interface and Scenario happens via Bluetooth, according to commands received by the Player who is motorist's character.

A map determines positions of traffic signs and buildings placed on the scenario. The Player can create new maps using Editor Interface. The Transit Guard Agent monitors the behavior of Player and applies penalties when he/she causes a transit violation. The Animated Help Agent follows the Player providing guidelines for game playing. Communication between Agents and Editor Interface, Player and Game Engine, Base Maps and Game engine are pre-programmed.

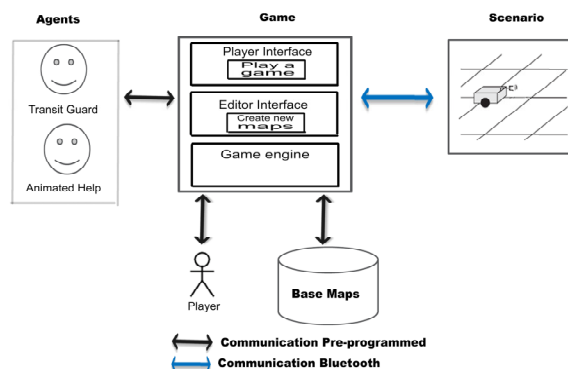


Figure 2: System Architecture

## 4.3 Development of the animated agent

According to [Wilges *et al.* 2004] agents, in general, are called “pedagogical agents” when applied to teaching and learning systems. The animated agent is not pedagogical, as it. Only monitors and guides the player's interaction with the educational system, improving generic educational aspects of the system.

Several systems were developed using pedagogical agent: a proposal of an pedagogical agent for the TelEduc of [Wilges *et al.* 2004], the SEMEAI of [Gomes *et al.* 2005] and the Kurrupako 3A [Reategui *et al.* 2006]. The educational game developed by [Portela 2009] uses animated agent following the player from the welcome to the end of the game, in order to motivate him and help him through every task. The tool used to produce animated agents in that game was the Microsoft Agent Scripting Helper (MASH) of BellCraft [MASH 2010], the same we used in this work.

The MASH character chosen was Robby. It was renamed to “*Robô de Lata*” (*Tin Robot*), as seen in Figure 3. The goal of the animated agent is to help and guide the player in the use of the game. The behavior of the agent is shown in Table 1.

Table 1: Behavior of the animated agent

Speech animated agent	Behavior
	The agent presents itself to the user, and tries to help the user to enter the game.
	The agent asks the user to select a level by pressing the “ <i>Começar jogo</i> ” (game start) button
	The agent draws user's attention to the chosen goal and then asks the user to press the “ <i>Controlar carro NXT</i> ” (control NXT car) button.
	The agent helps the user to turn on, accelerate and control the car. The agent also reminds the user that he can see the GPS map.
	If the user reaches its goal, the agent shows that he has bonus.
	If the user chooses to play a bonus, the animated agent helps him to answer the questions, and warns users that they can get help and leave the bonus anytime they want.
	If the user reaches its goal, the agent congratulates him for the feat and it makes a customized animation according to the chosen level.

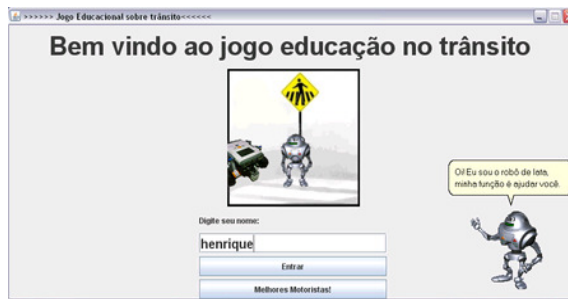


Figure 3: Animated agent “Robô de Lata”

#### 4.4 Building the physical environment

The Physical Environment is aimed to represent an urban setting with streets, houses, buildings and signs. A model was assembled as shown in Figure 1. The position of the plates and location of points goals are shown in Figure 4.

The floor is lined with cardboard and it was marked on a square grid with dimensions 35 cm by 35 cm. The positions red, blue and black represent locations of the school, club and bank respectively. The positions of dark blue color represent constructions that are homes or buildings.



Figure 4: Map that represents the real environment

The traffic signs are positioned to avoid direct collision with mobile robotic device. The choice of traffic signs and their locations were defined to allow the player to reflect what action to take on the situation. The player is penalized if he/she takes a wrong attitude causing a traffic violation.

#### 4.5 Assembly of mobile robotic device

The mobile robot is has a wheel-based, terrestrial autonomy and is non-holonomic, its control is teleoperated and it is autonomous when it ceases to be teleoperated. The robot has two wheels mounted with a differential drive model, for easier construction and implementation. The main drawback for this model is its difficulty to follow straight lines. The motion of the robot is like in a tricycle, with the difference that traction and direction occur on the two wheels on the same axis as can be seen in Figure 5. The robotic device uses the Lego Mindstorms NXT 1.0 platform.

A Nokia N95 cell phone was attached to the mobile robot to upload images and videos to the application via Bluetooth, as can be seen in Figure 5.



Figure 5: “Car” mounted with Lego NXT

#### 4.6 Coding Tools

Eclipse integrated development environment (IDE) was the choice of development tool for the following reasons:

- It's a free software;
- It's environment friendly;



- It's widely used by the programming community;
- Being a very extensible IDE, it allows to integrate various tools into a single development environment;
- It's easily integrated to NXJ Lejos.

Lejos plugin for Eclipse was also used. It allows to compiling, submitting and implementing programs for the Lego Mindstorms NXT. Lejos is one of the most popular firmware that may be embedded into Lego NXT.

Implementation of remote control was done using the package ICommand 0.7. This package was chosen because it is compatible with Bluetooth technology and it has easily integrated with Java 2 Platform, Standard Edition (J2SE).

BlueCove is a Java library for Bluetooth that currently allows interfaces with Mac OS X, WIDCOMM, BlueSoleil and Microsoft Bluetooth stack found in Windows XP SP2 or Windows Vista and WIDCOMM and Microsoft Bluetooth stack on Windows Mobile. The BlueCove allows registering Bluetooth devices with Lego NXT.

To deal with the images sent by mobile, the Java Media Framework (JMF) was used, allowing an extension of library media for J2SE.

The software used to send images from the cell-phone camera to the computer via Bluetooth was Mobiola Web Camera 3.0 version of Warelex. We also used a virtual drive camera e2eSoft to virtualization of a drive compatible with JMF.

## 5. Challenges

One of the challenges we faced was mapping the mobile device in the environment of the GPS tool. When the player press the GPS button, a map with the location of mobile device is open, as shown in Figure 6. Odometry was used, but location based odometry is vulnerable to cumulative errors.

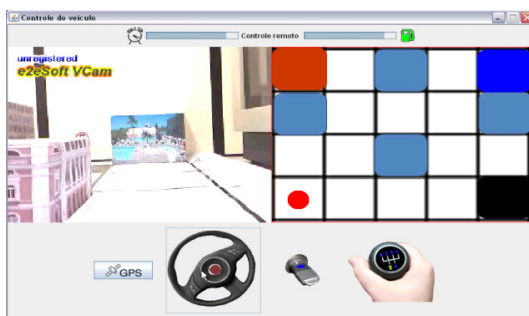


Figure 6: Virtual remote controller

Odometry errors can be systematic errors and non-systematic errors [Borenstein and Feng 1996]. An example of systematic error is the incorrect measurement of the wheels, and an example of non-systematic error is the skipping of the wheels when the robot moves. Errors can be controlled because the environment where the devices works is controlled, as free as possible of uneven ground and slippery with use of a carpet made of cardboard, as shown in Figure 1.

The game was designed to be semi-automatic. After finishing a "circuit", the player can choose to play again, then the robot has to autonomously return to the starting point of the game. For this a matrix is used to represent the "driving" environment. In the matrix all the movements of the robot are recorded and when the game ends, a stack/queue algorithm is used to find the best path back to the robot's initial position o. The path found is executed resulting in robot motion using odometry-based navigation. To make the odometry-navigation, the API ICommand 0.7 package was used.

The algorithm to find the best path was based on the algorithm described in [Pereira 2010], and has two steps: notation and extraction. The first step (notation) records in the array the minimum number of steps needed to reach each position. The second step (extraction) extracts the smaller path from the matrix. Figure 7 shows the algorithm to find the best path.

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### Algorithm notation(L)

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L[2, 2] ← 1
insert the position (2, 2) in an empty queue F
while the queue F is not empty do
    remove an position (i, j) of the queue F
    for each position (x, y) adjacent to (i, j) such that L[x, y]=0 do
        L[x, y] ← L[i, j] + 1
        insert the position (x, y) in queue F

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### Algorithm extraction (L)

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if L[n-1, n-1] = 0 then there is no output, stop execution of the function
Insert the position (n-1, n-1) in an empty queue P
while the position (2, 2) is not in the top stack P do
    (i, j) is the position on the top of the stack P
    find a position (x, y) adjacent to (i, j) such that L[x, y]=L[i, j]-1
    insert the position (x, y) in stack P
show the path stored in the stack P

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Figure 7: Best Path Algorithm [Pereira 2010]

Where  $L[n, n]$  is a square matrix, assuming the position of the labyrinth entrance is at position (2,2) and its output at position (n-1, n-1).  $L[i, j] = k$ , indicates that  $k$  steps are necessary to reach the position (i, j). Only free movement between locations and adjacent (vertically or horizontally, not diagonally) are allowed.

There are other algorithms to find the best path, but the one we have chosen had a good balance of simplicity and efficiency.

## 6. Preliminary evaluation of the game

We performed a preliminary evaluation to validate the game. Some people of different ages were given the opportunity to play the game. These tests were shown to be unique, much more productive, motivating, enjoyable and fun.

We tested the consistency of the game, the animated agent behavior interacting with the player and the player's interest in learning through game playing.

An evaluation of a game should exam both software quality and educational aspects, with special attention to pre-game and post-game situations that the game designer wanted to achieve [Passerino 1998]. Thus, the aim of the experiment is to evaluate aspects of quality of play, enthusiasm, concentration and motivation of the player, and also to assess the technical and pedagogical aspects of the game.

Figure 8 shows a user playing the game on LaboREAM - Laboratório de Robótica Educativa do Amazonas (Educational Robotics Laboratory of Amazonas). In order to evaluate the technical and pedagogical assumptions described throughout this article, a set of key questions were asked to the players before and after the play.



Figure 8: A person using the game

Preliminary data analysis indicated that users enjoyed the whole experience and suggested some improvements for the next versions of the game.

## 7. Conclusions and Future Work

This work presented an educational game that combines Educational Robotics and virtual gaming aimed at knowledge construction about the Transit Education theme, specially for children.

The constructivist theories of Piaget and Vygotsky are the main references for the game, and from the combination of several technical and pedagogical elements, the product has a distinct potential for supporting its educational goal.

Some observational and inquiring experiments were carried out in order to validate the first version of the game, and initial analysis suggested that the objectives are to be met. During these experiments, some improvements were devised for its next versions

As future works, we intend to allow users to access to the game through the Web, using JSP technology and Applets, allowing global access. This will involves to build a JSP server, to create a user registration system for dealing with profiles of people accessing the game.

Information about players can allow animated agents adapt to each user, making personalized recommendations, directing learning for each player.

Because of the high level of interactions with the scenario collisions with the physical obstacles can happen, causing odometry errors. New robots models are tested for better performance in the game.

Finally, we have the challenge of improving the location of the mobile device in the environment using the combination of two types of location: the relative location based on odometry and an absolute location based on natural and artificial landmarks.

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