Using Empirical Modelling to Simulate Robotics in Kids' Club

P. J. Eronen
Department of Computer Science, University of Joensuu, P.O Box 111, FIN-80101 Joensuu, Finland
peronen@cs.joensuu.fi

J. Järvelä
Research and Development Centre for Information Technology in Education, University of Joensuu, P.O Box 111, FIN-80101 Joensuu, Finland
jjarvela@cc.joensuu.fi

C. Roe
Department of Computer Science, University of Warwick, United Kingdom, CV4 7AL
croe@dcs.warwick.ac.uk

M. Virnes
Department of Computer Science, University of Joensuu, P.O Box 111, FIN-80101 Joensuu, Finland
mvirnes@cs.joensuu.fi

1 Introduction

The Kids' Club, run by the Department of Computer Science at the University of Joensuu in Eastern Finland, gives children the chance to construct robots using the LEGO Mindstorms kits (The LEGO group, 2002) and program them using computers. The children in the club are all between 10 and 14 years old and have been participating in the group for up to one year. They have developed a competent understanding of programming and basic robotics, which was demonstrated by the success they achieved in winning their league in the RoboCup Junior robot football world cup (Executive Committee for RoboCup-2002, 2002).

The task of creating robots and programming them has proved to be both mentally and technologically challenging. Often the children encountered problems that were not related to their actions. The technical environment, comprising computer hardware, software and robotics kits has been sometimes unreliable, which can disrupt the children's learning process. The staff of Kids' Club have recognised the need for a computer-based environment, which allows rapid and flexible generation of simulated robots, their behaviour and problem-oriented tasks for them to solve. A simulation environment would help the children to construct the mental models of robots and their tasks without being distracted by real-world problems such as non-working connections between the robot and the computer being used to program it. In this paper we describe the outline for a system that simulates the robotics environment.

This paper is in three main sections. The first describes the activities of the Kids' Club and the goals set for it. The second section outlines Empirical Modelling (EM) and how it is suited to the creation of environments for investigative exploration. The third section explains the pedagogical issues surrounding the creation of a computer-based environment to investigate robot behaviours and how EM is an appropriate way to address these issues. A preliminary outline for the proposed system is also described in the third section.

2 The Kids' Club

Kids' Club is an active research laboratory, where children work together with research workers and university students. For children, Kids' Club is a technology club where they can work in an open-minded environment with interesting tools and have lots of room to follow their individual desires. Children not only learn skills in the field of information and communication technology (ICT), but also have an essential role in contributing to the research community. (Eronen et al., 2002a)

The children learn various skills by using different tools of educational technology. The technical environments include visualisation and concretising tools (e.g a visual programming environment (IPPE) (Jormanainen et al., 2002), control technologies (Empirica Control) (Lavonen et al., 2001) and programmable bricks (LEGO Mindstorms) (The LEGO group, 2002). Children solve small scientific problems working collaboratively in a playful, explorative way. For example, through working with IPPE and robots children learn to understand basic control structures in procedural programming when creating the behaviour for a robot, or mathematical formulas and laws of physics when measuring the speed of a robot.

From a research perspective the aim of Kids' Club is to develop novel ways to learn and teach ICT. We would also like to stimulate children's interest in ICT and encourage them to become both active and confident users of information technology, and doers in information technology society.

The pedagogical background (Eronen et al., 2002b) for Kids' Club is based on problem-based learning, creative problem solving and group processes. In the Kids' Club children are designers, who work in pairs in projects without a tight schedule, but in a goal-oriented way within a certain subject. We have not defined a strict curriculum nor do we have any tests. Problem-based learning creates an iterative process from the definition of the problem to presenting the project, through ideas of possible solutions, building, programming and testing the LEGO robot. In this process concretising tools make constructions of mind concrete giving a wider perspective on learning (Papert, 1980). In problem situations children ask help from mentors whose role is not to teach, but to instruct and help children. The mentors are under-graduate and graduate students of computer science and their backgrounds are in computer science and education. To strengthen the learning process children reflect on their learning with the help of a Virtual Reflecting tool, VirRe, at the end of each Kids' Club meeting. Web-form that was used earlier for reflecting was not pleasant to children. Neither it was productive way to collect data for researchers and tutors. Thus, we developed VirRe that records children's answers and web-camera picture into one video file.

According to mentors and children's experiences after the first year, it seems that Kids' Club is a promising environment for developing educational technologies. We can get immediate and constructive feedback from children, which is one of the aims of Kids' Club. Secondly, children's excitement to act in the environment and learn by solving problems shows that visual and concretising tools offer an attractive environment for learning abstract skills like programming.

3 Empirical Modelling

Empirical Modelling (EM) is an approach to computer-based modelling that has been developed at the University of Warwick over many years (The Empirical Modelling Research Group, 2002a). The construction of models using these techniques aims to support learning in situations where the process is difficult to prescribe and approaches to learning need to be flexible to support different styles. The Empiricist Perspective on Learning described in (Roe and Beynon, 2002) underpins the learning process that is typical of building models using EM. Most traditional approaches to program construction emphasise the importance of behaviours. The presumption is that the most fundamental aspect of a system is its overall state-transition model. We believe the concept of 'state-as-experienced' to be the most important consideration when constructing computer-based models. The state is a snapshot of external observed values at a particular moment in time. There is no restriction made on possible future states that the system may go into.

This situation is typical of a spreadsheet. Users are free to make any changes that they desire by redefining the value of an observed quantity or by changing a dependency within the system. This experiential interaction is a key characteristic of the EM approach and gives a flexible environment within which exploratory model construction can take place concurrently with improving domain understanding.

This allows us to engage with the primitive modelling that is required to gain initial understanding of a domain before we can articulate about possible sensible behaviours. This perspective on learning and model construction is more fully explained in (Roe and Beynon, 2002).

We use definitive scripts to represent state-as-experienced. A script contains observables and dependencies. An observable is an element of the state that refers to something we can directly apprehend or indirectly determine in the real-world context we are trying to model. A dependency reflects the way in which these observables are indivisibly linked together. By making redefinitions in a definitive script we can explore transitions between states that may be important.

Our modelling environment called TkEden can be used as a 'black-box' to explore software created by another modeller, as a 'partial model' through the construction of small auxiliary scripts to carry out new tasks or refine the current situation, or as an environment for a modeller to construct models of his own (Roe, 1999). Models created by another modeller can be presented in a layered format. Each layer introduces new concepts to increases the complexity and range of options available to learners. We call this technique 'cognitive layering'.

4 Simulating Robotics

In a simulation the learner is in an authentic environment in which she interacts with elements incorporated in it. Simulations are computerized models, which are designed to teach how an imaginary or real system works. (Roblyer and Edwards, 2000) In the Robotics Simulation Environment (RSE) learners can program and operate virtual robots that resemble real-world Lego robots. The simulation is situational, which means that learner is put in a hypothetical problem situation and she is asked to react (Roblyer and Edwards, 2000). There are two main goals in using the RSE.

The first goal is to help learners build mental models about robotics that can be used when creating real-world robots. When interacting with real-world robots technical problems can hinder understanding of the fundamental principles. In a simulation the learner can concentrate on the essential features. She does not need to think about the physical design of the robot or resolve technical issues. The learning is made easier in the simulation by presenting a predefined learning path, starting with making predictions about ready-made robots behaviour working through to building their own robots and programming them.

A second goal of the RSE is to exceed real world limitations. Lego robots have only a few different sensors (e.g light sensors, touch sensors), but in a simulation environment we can include new sensors, for example to detect robot interactions. Different scenarios can be generated, for example there can be a traffic scenario, where a robot must be programmed to survive in heavy traffic with other cars, pedestrians and crossroads.

In the RSE, learners are in control of their own learning. The learner uses the simulation, and a mentor provides scaffolding when it is required. Learning is a result of the learners' own actions, when she interacts with the environment. The motivation for using the environment stems from the children's tendency to research their own surroundings and make experiments to get feedback. (von Wright, 1993). The process of learning is best described as mental model building.

Mental models are cognitive artefacts, constructions of the mind, which represent, organise and restructure domain knowledge in a way that observable or imaginary world becomes conceivable (Seel, 2001). They are naturally evolving, and develop when people interact with their environment, other people and artefacts. Mental models produce predictive and explanatory power in understanding different interactions (Norman, 1983). According to constructivism, they are adaptable when faced with a conflict situation and grow stronger through interaction in the environment. In the RSE the learner is in a situation where she has to make predictions about the functions of the robots. In the beginning learners' mental models are inaccurate and incomplete. Learners can refine their mental models with feedback from the simulation. The mental model, which is not viable, must be improved in order to succeed in reaching the wanted goals (Norman, 1983) (Seel, 2001). Learners mental models of robotics evolve when interacting with the RSE.

The process of mental model building in RSE is summarised in Figure 1. The process begins with a problem. The learner can have a vague hypothesis for solving the problem, or she can observe the environment in order to form a hypothesis. The learner begins the testing cycle, where she can test her hypothesis and refine it with feedback from the environment. Eventually the testing cycle produces a solution to the problem. The learners' mental model will be refined. The new mental model raises new questions and produces new problems. The refined mental model also increases the learner's ability to predict the behaviour of operations in the environment. The mental model acquired through interaction with RSE can be transferred to the process of concrete robot building.

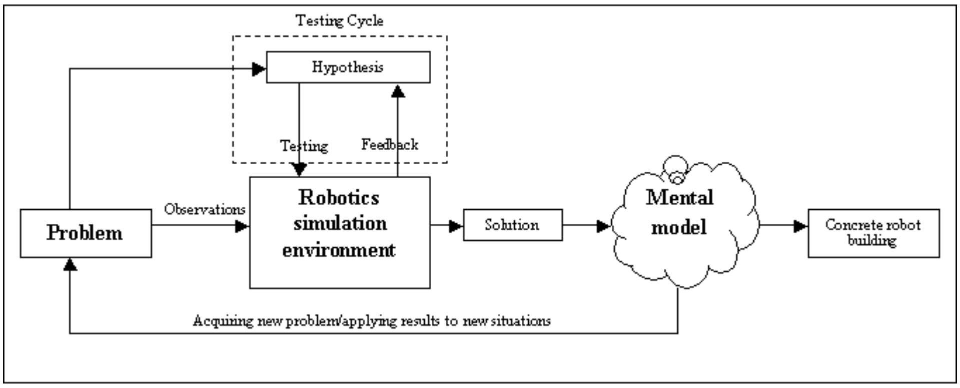

Figure 1: The process of constructing mental models in RSE.

The RSE's design is based on cognitive layering (The Empirical Modelling Research Group, 2002b). By separating concepts into layers the learner can control the pace that she is acquiring new skills and the way those skills are being developed. Our design has five levels to support different kinds of learning.

On the first level the learner is provided with ready-made robots with pre-programmed behaviours. The learner may activate the robot and observe its behaviour. The environment visualises the activities of the sensors, when they are activated, for example when running into wall. This is the "black-box" approach, where the internal functionality of the robot can be conjectured according to the observed behaviour of the robot. This helps the learner to realise the possibilities of the system and see the dependencies between situations and reactions.

The second level gives the learner control over the movement of the robot. The situation is analogous to radio-controlled toys, except the fact that the robots may have internal reaction made ready for example for running into wall. This way the learner may reproduce the situations where the robot's behaviour was especially interesting and observe them more carefully.

On the third level, the learner has to build the behavioural scheme for the robot. This includes creating the dependencies between the observables. For example the dependency between the motor rotation and tyres has to be made or the connection between the activation of touch sensor with the change of direction of rotation in motors. By linking the elements of the robot with dependencies, the behaviour of the robot is created. The third level allows also the learner to introduce new environments for the robot to act in.

The learner is allowed to construct the robot from scratch on the fourth level. She can add sensors of interest into the system and change the qualities of them. For example the rotation speed of the motor or the sensitivity of the light sensor can be changed.

The fifth level is the most open, where the learner can control everything. In addition to controls allowed by earlier levels, the learner can design sensors of her own or change the operation of the system. It is also possible to alter the source code of the RSE itself, whilst it is running. This kind of system ”hacking” brings up interesting scenarios, where advanced learners can change the appearance and functionality of the system according to their specific needs.

5 Future Work

The current prototype simulation is a first attempt at creating an environment that is both useful to the children in the Kids' Club and matches their conceptual model of the programming environment for the robots. Our plan is to follow an iterative design methodology such that each cycle increases the number of children it is tested on. There should be a simultaneous reduction in the amount of changes needed to improve the environment (Pratt, 1998).

The initial work on the collaboration of using Empirical Modelling to help simulate Kids' Club activities shows that this approach gives a flexible environment within which exploratory experiments can be carried out, which can be conceptually applied to the task of creating behaviours for real-world Lego robots.

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