From POPSICLE to CARoL in a Semester

Goran Trajkovski, Darush Davani, Gary Williams,
Daniel Stamate, Gleb Gudzenko, Daniel Bittner

Cognitive Agency and Robotics Laboratory
Towson University – COSC Department
8000 York Road, Towson, MD 21252-0001
{gtrajkovski, ddavani, awilli12, dstama1, ggudze1, dbittn2}@towson.edu

Abstract

POPSICLE (Patterns in Orientation: Pattern-Aided Simulated Interaction Context Learning Experiment) was introduced as a semester-long research group project of a course in Artificial Intelligence. The project concentrates on investigating aspects of human learning of simple environments. In this paper the project is overviewed, and comment on the pedagogical and management issues used to motivate and support students. The positive experiments from this undergraduate research experienced infused in teaching and AI related course was the inspiration for establishing the Cognitive Agency and Robotics Lab (CARoL) at Towson University, and within a semester prepare the infrastructure to teach a Robotics course on a shoestring.

Introduction

The problem of learning has been a central notion in the AI theories of Agency for a long time. In the past several years a large amount of work has been done in the domain of the Interactivist-Expectative Theory on Agency and Learning (IETAL), as a part of the growing trend in re-approaching two very different disciplines, Robotics, on one side and Developmental Psychology, on the other. IETAL concentrates on exploring the concepts of learning in an autonomous agent, through interaction with the environment it inhabits. In the process the agent develops intrinsic models of their environment with a relevant emotional context for a given set of active drives.

POPSICLE (Patterns in Orientation: Pattern-Aided Simulated Interaction Context Learning Experiment) represents an IETAL empirical investigation, designed to explore the use of the inborn schemas in humans, as well as their use of contextual information.

The experiment uses a simple 5x5 maze with obstacles, colored in different colors. The goal (food, water) is placed in a single place in this environment. Normally, following a one-color path takes the subject to a place where a particular drive (hunger, thirst) can be satisfied. In different stages of the experiment, different amount of information is presented to the subject (specific instructions, selected portions of the environment). Throughout the various stages of the experiment, the human agent sees either only the color of the square they are currently on (context 0), or that color and the color of the adjacent squares (context 1) in the four directions (North-East-South-West).

The paper is organized as follows. The section on the preliminaries gives the theoretical and previous research background for the POPSICLE experiment. In the next section the POPSICLE experiment is explained in details, and especially from the perspective of its incorporation in an upper-level undergraduate course. Inspired by the positive experiences from this course, we put together a lab to facilitate the interest of our students to explore. We discuss the robotiucs infrastructure and the ongoing (and future) project of the said lab.

Preliminaries

IETAL Agent: Algebraic Formalization

Accurate and reliable spatial representation is essential for the performance of the agents in a given environment. The agent should gain this knowledge during its interaction with environment. In recent approaches, this process was formalized as navigational map learning.

Traditional approaches consider these maps to be represented as planar connected graphs with nodes called Local Distinctive Places (LPD), and the edges are actions from the agent's repertoire, [3]. Problems arise when different places in the environment appear as same to the agent. It then may be confused as where actually is situated. This problem is called perceptual aliasing. The only way a node can be recognized as different then is to examine its context, [3].

Let set the set of LDP's $V=\{v_1, v_2, \dots, v_n\}$, and E is a subset of V×V. Let $L=\{l_1, l_2, \dots, l_n\}$ be a set of labels, or agent's LDP's perceptions, and $A=\{s_1,s_2, \dots, s_m\}$ the agent's actions repertoire. Let V:V→L and E:E→A, be fuzzy sets valued by the corresponding sets, which, in general, can be any algebraic or relational structure, [7,8]. The pair G=G(V,E) is the designer's ontology, or Designer Visible Environment (DVE), [6]. Let construct the set E', subset of LxL, in the following way: (l_i, l_j) belongs to E' if (v_i,v_j) belongs to V, for all i,j, such that $l_i=V(v_i)$ and $l_j=V(v_j)$, and let E':E'→A be defined via the following equivalence: $E'(V(v_i), V(v_j))=a_k$ if E(vi,vj)=a_k, for all i,j,k.

The projection graph G'=(L, *E'*) of G, where the vertices are reduced to their labels, the Agent Visible Environment (AVE).

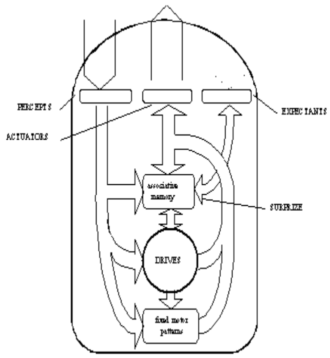

Fig. 1. Architecture of an IETAL agent, [3]. Note that the central part of the agent is given to its drives. Apart from the sensors and actuators, the agent has associative memory, and is equipped with an inborn pattern of actions from its repertoire, with which he starts exploring the environment. Based on its (in)ability to perform all or some of the actions in the schema, the agent builds its contingency tables. Each row of the table is attributed an emotional context for all the present drives, that is being updated as the agent explores the environment.

Emulating Abstract Agents on Humans

In the sense of IETAL, humans are the only linguistically competent agents, [3]. Humans are able to filter out all other stimuli and it is in this sense that we say that we are emulating an abstract bio-agent.

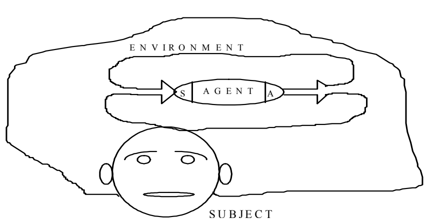

Fig 2 Emulating abstract agents on humans (S-stimuli, A-Action Repertoire)

We define the S and A sets of agent by telling the subject what inputs she should pay attention to and what possible motor actions she is allowed to do. In different stages of the experiment, different information is given to the object(s) of the experiments to define S: "On the screen you will be seeing patterns like this (demonstration of the patterns)". To define A the subject is told: "You are allowed to press or not to press these buttons (experimenter shows the buttons to the subject)". Schemas are defined similarly. An example may be the following (let's call it contingency schema): "Follow the tiles colored yellow". An example of external goal creation is the following: to define "react as fast as you can" goal the subject is told: "find the food". This concludes the definition of the abstract agent.

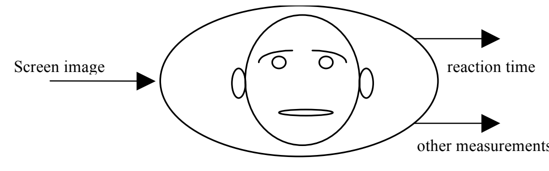

Fig 3 A Subject in the POPSICLE experimental setup

Having defined all the initial elements, the experimenter can now observe various aspects of the agent's sojourn in that particular environment. Of course, of particular interest are the structures that emerge during the agent-environment interaction. These are the networks of concept/behaviors. Because they are not directly observable the experimenter has to reconstruct them out of the agent's observable parameters.

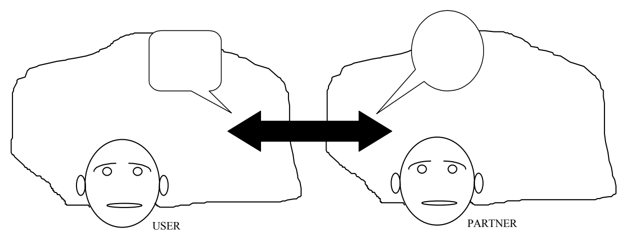

Fig 4 The human agents are linguistically competent. Four times during the experiment (Fig 8), they work together as a pair, and get to exchange linguistically the acquired concepts, [1,8].

Experimental Setup

A software product developed in JAVA (the "tester") guides the POPSICLE experiment. The tester is a series of environments.
These environments are essentially simple mazes made of tiles with obstacles and colors on each tile. Using separate keys, the agents move up, down, left and right in the given DVE. However, the AVE is different from the DVE, as shown in Figures 5, and Figures 6, and 7 respectively.
The tester present to the subjects of the experiments instances of the environment on two different context levels.

Carrying Out the Experiment: The Environment

Testing was administered via computer terminals in a computer lab. The batches were anywhere between ten and twenty-four subjects in size. There were 75 human subjects participating as subjects in this experiment.
Each subject was given a set of instructions that told them that they would be place in an environment with obstacles and a goal. They were given the procedures for navigation and told to find the goal as many times as possible in three

minutes. When the test began they were presented with context 0. No other information was given about meanings of the color tiles. They were not told whether the environment changed or whether the starting point changed.

X	1	1	1	1
2	3	9	2	1
2	3	3	9	1
4	2	2	4	1
4	4	9	4	0

Fig 5 One of the environments used in POPSICLE: 1-red, 2-yellow, 3-green, 4-blue, 9-black (obstacle), 0-Goal, X-Start.

4

Fig 6 An instance of context 0 – a blue tile (see legend in Fig 5).

	9	
1	1	Goal
	4	

Fig 7 Instance of the environment of context 1. The center tile is the tile of current position. The upper tile is the current position square is black (9) and represents an obstacle.

After the three minute time period each "partner" would join the "user". At this point they were to perform the same task only as a team. Here, once they realized it was the same environment, they were expected to exchange information and performance would be enhanced. When the time limit had expired the team was presented with a questionnaire that asked whether they had used any search pattern. If they had they were to explain what it was. Next, they were asked if the had noticed any patterns within the environment. Again, if they had they were to explain.

Upon finishing the questionnaire, the team would split up. Now each person would be told it was a new environment. They were also told they would receive more information. This information came in the form of context 1. They were again given three minutes to find the goal of this new environment as many times as they could. Once the time limit had expired they got back into their teams to do this environment at context 1.

Table 1. Timeline of the experiment POPSICLE within the overall course dynamics

Weeks	Activity
1-2	Choice of Project, Teaming
3-6	Review of Related Literature
7-10	Experimental Setup Design (Programming and Questionnaires)
11-12	Data Collection
13-15	Data Analysis

There were four sets like this. Each set included a new environment, a single person trial, and a team trial. In set one no information was given about the environment or the colors. In set two the subjects were told there was a pattern that could be found in the environment. In set three the pattern was explained. One of the colors led to the goal. Finally, in step four the subjects were told which color led to the goal.

The parameters that were measured were the interaction times, the parameters in the success of finding food, as well as the amount of pain (hitting an obstacle) encountered in the quest for food. From the data collected, we are able to extract data on the sequences used while in the environment, to attempt a study in the inborn schemas area, [2].

POPSICLE in an Undergraduate Course

The POPSICLE experiment was done by a group of six students taking an elective course in AI. The mere fact that they are involved in trendy research was an important component to students' motivation to meet and surpass the expectations of the project.

After the first two weeks of the course, when the general idea of the area of Artificial Intelligence has been adopted, and a session in what the work on each of the project would engage, the students started working intensively on the project. The initial goal was to have the experiment finished three weeks before the end of the semester, and to use the last part of the semester for data analysis and report writing. The complete timeline of the project is given in Table 1.

Designing Effective Interfaces

As a major part of the programming component of POPSICLE, the students needed to solve a myriad of issues with respect to the interface. These lead to fruitful in-class and on-line discussions while covering the topic of Human-Computer Interaction. They used their colleagues from the other teams to observe and poll when deciding which approaches to implement.

Observations

This particular project involved data generated by emulating agents on human subjects. The team members found an astonishing body of about 75 individuals that volunteered to participate in the data gathering and fill out the questionnaires. Colleagues of the instructor were eager to administer the data collection to entire classes.

There was no time for thorough statistical analysis of the data. Some basic statistical parameters that were derived lead to several conclusions.

As seen on student's written material (homework, exams), this project did give them a better understanding on multiple areas covered in the other part of the course. There was a strong tendency in their work to use examples of experiences from the projects in order to illustrate theoretical concepts.

Although it is not a stated goal of the AI course, the programs the student wrote gave them much more confidence in utilization of programming techniques (according to the exit interviews), and in Interface Design.

From POPSICLE to CARoL

CARoL

The promising results from POPSICLE and similar experiments in human cognition, modeling and simulation, done in an undergraduate setting and integrated with instruction, inspired us to create the CARoL laboratory at Towson University, as a center that houses hands-on experimenting for undergraduate students in the areas related to AI. A major part of the lab that we have been investing into has been the Robotics lab, as we want to encourage students to study learning in humans and apply the learned to program autonomous robots in a uniagent or multiagent setting. As we are working on funding activities, in order to start a new Robotics course, efforts were made to establish an infrastructure in the lab for teaching Robotics and doing research in Developmental Robotics on a shoestring.

The core piece of equipment used in this round will be the Brainstem-based robot from Acroname Inc [8]. The Brainstem was chosen for this course because of its versatility in hardware and software. The basic Brainstem can be easily modified to include other add-ons such as a compass, multifunctional analog and digital sensors and most importantly its ability to transmit the collected data. The Brainstem Kit is also simple enough that students could put it together from scratch within the class itself. Detailed technical information about the Brainstem is available at CARoL's website [9]. The Brainstem is programmed using C function calls, which are easily learned, even by non-major students. The team is working on setting up basic modules with predefined functions, which the student could cut and paste. However, the students will be motivated to write their own code, which would be more efficient, considering the Brainstem's limited memory.

CARoL was established in May 2003, and in that short period of time, we have been establishing the laboratory infrastructure, stressing on the experiments with physical agents. In the upcoming stage we will be building the web infrastructure for the course, geared for delivering Robotics courses electronically, without requiring the students to buy expensive books or software.

CARoL as a Research Lab

POPSICLE Revisited

In POPSICLE, Round II, we are expanding the opriginal approach. Students will interact in using a custom web application, powered by Macromedia's ColdFusion, which will allow results of the experiment to go straight into a database. Instead of having to come into a predetermined lab, subjects would be able to participate from any computer with Internet access at anytime. Instead of working directly with another user during the shared knowledge phases, students will be given pieces of the results of other users and will have determine on their own how to interpret them. The POPSICLE team hopes this approach will lead to better understand exactly what information a user will find helpful. The program itself would control what the user knows so it will be better equipped to measure what a user has learned or not learned. We are cutrrently working on the reward system for the experiment. In Phase I the team concluded several users were not trying hard enough to find the goal, therefore this new approach is designed to provide better results. The final benefit of the POPSCILE Phase II will be the increased amount of data available to the team at the end of the experiment. This data will allow us to strengthen the conclusions by allowing us to use probability functions, as well as make new conclusions of the patterns of learning.

SWORD

SWORD (Simulation with Online Robotic Development) is a an online application that will be available to students in the lab as well as out of lab, as a GUI application that students can use to perform the experiments while logged in from their home computers. SWORD will use the Macromedia web development tools ColdFusion and Flash, and it will store the data in an Oracle database. ColdFusion is used to connect to the database as well as to provide dynamic web development. The software will be used to pass parameters to Flash [10], which allows for web animation of the requested commands. Once a student is satisfied with the result obtained from the commands passed through the interface, SWORD will be able to download the customized program to the Brainstem. Once the program is stored, the agent will perform the defined operations. An institution teaching this class would need to have a copy of SWORD, a ColdFusion language interpreter, and an Oracle database.

The communication interface between the control unit and the agent will be performed using RF transceivers, which can be altered to be compatible with the Brainstem [9]. There can be multiple RF channels opened to allow concurrent operations.

CARoL as a Teching Lab

In addition to the Brainstem, the central robotics control unit in our new lab, students have access to various LEGO Mindstorm™ Robotics kits. These kits are cheaper then a Brainstem and much less complicated. They allow the student to follow simple instructions on color-coded materials. The kits also come with a software package that allows the student to create simple programs as well as load pre-made programs to the LEGO robot. Many students have experience using LEGOs from their childhood, which could help them feel less overwhelmed about the experience. Students might be inclined to use the best of both kits, since the LEGO Kits are easy to work with and the Brainstem is much more functional. Students can build the body of the agent using the LEGO kits, while controlling it using the Brainstem. Furthermore, the Brainstem would be much more affordable if bought individually rather then as a bulky and hard to assemble kit.

The Robotics Course

Instruction in the class will be delivered in three primary forms. The first form are in-class lectures teaching the basics of Artificial Intelligence and Robotics. These lectures are being reinforced with outside reading assignments from a variety of AI and Robotics textbooks. Readings include sections from a variety of available textbooks. This part of the class gives students a general understanding of the field as well as introduce topics the may be covered in future upper-level classes. Students are tested on the general concepts of AI and Robotics but are not expected to memorize a large number of facts or definitions. This allows them to concentrate on the "big picture" instead of being bogged down with memorization. The second form of instruction is with in-class lab activities. These lab activities consist primary of building various robots or robotic components. Labs towards the beginning of the semester rely on the LEGO robotics kits. As the semester continues, students will get into groups to start building a Brainstem. The number of groups will be dependent on the number of Brainstems the institution has available. The third and final form of instruction is via four out of class projects. The first project require the student to pick a company and write a short paper on how robotics could be used to enhance their business. Students will have to support their reasoning with material from the readings. The second project is a group activity that requirea the group to build their own LEGO robot. The robot can do anything the group chooses as long as its functionality is different from the in-class examples. The third project creates an original program using the SWORD application. A fun and challenging application is the competition between the groups, where the winning team receives extra credit for ingenuity and performance. Such a competition could be the implementation of a laser-tag game between two or more agents confined to an area, an efficient object mapping application or an effective avoidance application. The final project is a research paper on a topic in AI or Robotics that the student finds interesting. The student will be required to write a four to six page paper as well as prepare a five-minute presentation for the class. This will allow the student and the class to learn more about topics not covered in the class, while publishing their own paper.

Infrastructure Expansion Directions

The future expansion of these projects will be geared towards adding more robots and hands-on teaching aids. As new robots are added, SWORD will be updated to allow for the simulation of the new robots. Applications are also being developed to link Palm Pilots and Brainstems in order to eliminate the memory insufficiency. The Palm Pilots could be connected using BlueTooth technology or RF modules in order to allow interaction between multiple Brainstems without the need of a centralized database. Thus, with a strong, but relatively cheap infrastructure base, we can provide our students in class and those interested in research with opportunities to investigate.

Acknowledgment

The Towson University Center for Applied Cognition and Learning, and the College of Sciences and Mathematics of Towson University have supported this work.

References

[1] Ferber, J: Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence, Addison-Wesley, 1999.

Piaget, J Play, Dreams, and Imitation in Childhood. New York: Norton, .1945.

[2] Stojanov, G., Bozinovski S., Trajkovski, G "Interactionist-Expectative View on Agency and Learning", IMACS Journal for Mathematics and Computers in Simulation, North-Holland Publishers, Amsterdam, Vol. 44 (1997).

[3] Stojanov, G, Trajkovski, G, Bozinovski, S, "Representation vs. Context: A False Dichotomy: Introducing Intrinsic Representations", Proc. 3rd European Conference on Cognitive Science (ECCS) – Workshop on Context, Manchester, UK. (1997) 227-230.

[4] Stojanov, G, Trajkovski, G, "Spatial Representations for Mobile Robots: Detection of Learnable and Unlearnable Environments", Proc. First Congress of Mathematicians and Computer Scientists of Macedonia, Ohrid, Macedonia (1998) 151-156.

[5] Trajkovski, G., Stojanov, G., "Algebraic Formalization of Environment Representation", in (Tatai, G., Gulyas, L. (eds)) Agents Everywhere, Springer, Budapest, HU (1998) 59-65.

[6] Tepavcevic, A, Trajkovski, G.: "L-fuzzy Lattices: An Introduction", Fuzzy Sets and Systems, Elsevier, Amsterdam, NL, 123 (2001) 209-216.

[7] Trajkovski, G, "Representation of Environments in Multiagent Systems", PhD Thesis, "Ss Cyril and Methodius" University, 2002 (in Macedonian).

[8] --, Acroname, retreived online on Jan 12, 2004 on www.acroname.com.

[9] --, CARoL, retreived online on Jan 15, 2004 at www.towson.edu /cosc/robotics.

[10] --, Macromedia, retrieved online on Jan 18, 2004, at www.macromedia.com.