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Smart edutainment game for algorithmic thinking

Bourouaieh Douadi [a] *, Bensebaa Tahar [b], Seridi Hamid [c]

[a]LABSTIC University 8 Mai 45, BP 401, Guelma 24000, Algeria
[b]LRI University Badji Mokhtar, BP 2300, Annaba 23000, Algeria
[c]LABSTIC University 8 Mai 45, BP 401, Guelma 24000, Algeria

Abstract

Algorithmic thinking is a key ability in computer science education. This paper presents a novel approach in conceiving a hybrid learning environment that combines digital games characteristics, Micro World, and algorithm animation principles. AlgoGames supports learner's first steps in algorithmic thinking by offering funny and challenging learning situations. Two main options are available to learners. The first one is a micro world, inspired by LOGO, where the student can write and visualize algorithms that create and act upon objects. The second option involves teacher's reference algorithms; the student is faced with world objects' behavior and has to mime it. A primary evaluation was conducted showing real game-like motivation in using the system.

Keywords: E-Learning; Serious Games; Algorithmic Thinking; Algorithm Animation;

1. Introduction

This paper presents AlgoGames, an ongoing work on algorithmic learning. Algorithmic thinking is a key ability in computer science education. In almost every computer science course students have to deal with this very important topic. E-learning technologies had offered algorithm animation and visualization tools to assist students. Despite intuitive technological/visual appeal and multitude attempts over the last two decades, algorithm animation researches failed and showed disappointing results. The main stream of this paper is about how we can conceive a useful learning support that combines game motivational aspect, algorithm visualization, and algorithmic thinking learning specificities. This novel approach is reinforced with a Micro World part to promote the constructivist side of the tool. Also, an Artificial Intelligence based technique has been used to evaluate learner's algorithms, producing a simple learner model for teachers. Thus, AlgoGames supports learner's first steps in algorithmic by offering funny and challenging situations. We suggest a game based conception founded on objects animation. Two main options are available to the student. The first one is a Micro World, inspired by LOGO, where the student can write and visualize algorithms that create and act upon objects. The second option involves teacher's reference algorithms (exercises); the student is faced with world objects' behavior and has to mime it. A primary evaluation of AlgoGames was conducted showing real game-like motivation in using the system. This paper is organized as follows. Section 2 presents a theoretical foundation review. Section 3 describes AlgoGames foundations. Section 4 describes an evaluation of AlgoGames. Finally, Section 5 presents our conclusions.

* Bourouaieh Douadi. Tel.: +213-791216628
E-mail address: bourouaieh@yahoo.fr

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2. background

What makes algorithmic thinking so difficult to teach? And what has been done technologically to overcome this fact? This section discusses some answer elements.

2.1. Hidden mind of algorithms

Algorithmic thinking can be developed independently from any technologies, implementation, or specific programming languages. Futschek (2006) defines it as a set of connected abilities with a strong creative part. It's about acquiring specific methodology for solving problems. Even if teachers stress all the time the crucial character of integrating algorithmic thinking, most computer science students found it hard and boring. Moreover, almost researchers report the difficult aspect of the algorithms study (Kehoe & Stasko & Taylor, 2001) (Shaffer & al, 2010). Käasboll (1998) reported high failure rates in many introductory programming courses. Futschek (2006) reported *'... a very high drop out rate during the first study year and a low success rate in the topics Programming and Algorithms & Data Structures"* So, algorithmic thinking is most about creativity, skill that is hard to teach (Futschek, 2006). Even if there is a long teaching experience, there is no predominant teaching method. Trying to solve many carefully chosen problems is one of the widely used methods (Futschek, 2006). Undeniably, creating algorithms is difficult and has a secret that can't be directly and classically taught.

2.2. What E in E-learning brings to algorithmic learning?

Beyond the classical course repository in learning management systems, researches and technologies in E-learning have mainly focused on Algorithm visualization and animation (hereafter referred to as "AVs") tools and technologies. AVs have been also intended for professional programmers as alternative debugging tools. First AV system appears about 1981 with the "Sorting out Sorting" by Ronald Baecker. After that, hundreds of analogous systems have been implemented followed by scores of written papers (Shaffer & al, 2010). AVs have been intuitively seen by teachers as a pedagogically valuable pedagogical. Students have been also interested and "liked" to see how algorithms work. In fact, some positive facets of AVs have been denoted but empirical researches about the benefits of AVs showed disappointing results (Futschek, 2006) (Kehoe & Stasko & Taylor, 2001). Recently, wider survey on the state of the AVs field can be found in (Shaffer & al, 2010) with a discussion section about the pedagogical effectiveness of algorithm visualizations. Despite their continual technological evolutions, AVs have failed to significantly proof their pedagogical benefits.

2.3. Video games and learning

The term serious game is older than one can imagine, it was first used in 1970 by Clark Abt in his book "SERIOUS GAME". Recently, a more formal definition of the term was given by Zyda (2005): *"Serious Game: a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives"*

According to (Young, 2010), digital games based learning evolution can be divided in three phases: Phase I was the edutainment games. Serious Games were the second phase. They succeeded in re-catching community attention (Van Eck, 2006) (Annetta, 2008). Finally, Third phase has been suggested by J.R. Young (2010) who called it Smart Games. For J.R. Young many of the serious games aren't much of fun. So, Digital Game-Based Learning Revolution (Prensky, 2001) acceptance is constantly growing over education and learning academic communities. The research agenda is full of promises about the effective emergence of the appropriate pedagogical aids and teaching methods for the *Net Generation*.

2.4. Fun in learning

"Games are engaging, they can be effective, and have a place in learning" was stated by Van Eck (2006). Furthermore, digital game benefits on learning are now well established, although a lacking of proof on deep learning effects (Hays, 2005) (Annetta, 2008). Some reported benefits are learner motivation (to complete learning activities), increasing interest in the subject matter, and generation of positive emotional engagement. Moreover, most cited learning theories sustaining digital game based learning include (Charsky, 2010) (Annetta, 2008) (Van Eck, 2006): constructivism, constructionism and active learning. A growing body of literature embodies theories from other domains, as cognitive psychology and educational theories, to explain why, how and when digital games are effective for teach (Van Eck, 2006). Digital based learning games use video game characteristics to provide challenging and motivating learning environments. Games characteristics include challenging activities, curiosity, rules, choices, fun and social recognition (Charsky, 2010).

3. AlgoGames conception and features

We wanted our system to have a good compromise between teaching algorithmic thinking and fun. We start by exposing fun possibilities in the algorithmic thinking case and then present the basic conceptions underlying AlgoGames. The goal is to conciliate fun, teaching, and constructivist learning.

3.1. Fun in the Algorithmic thinking case, AlgoGames basics

What about algorithmic thinking? Is there any fun? Is it possible? At first, even if algorithm visualization tools have their valuable sides, they aren't too much fun. A kind of entrainment in the hard algorithmic world has been brought by LOGO programming language (Papert, 1991). Although a complete programming language, LOGO remains best known for its *Turtle* figures and children's learning orientation. LOGO inspired a plethora of systems, especially robot programming games. Robot programming games are funny enough to keep their users engaged, but most of them are intended to Artificial Intelligence researches and use a definite programming language (Java, C++, etc.). In fact, robot programming games are not intended specifically for algorithmic thinking pedagogical purposes, thought some of them can (are) be used in computer science curriculums.

Accordingly, our work aims to overcome some of the former shortcoming by answering the question of how can the algorithmic thinking skill be supported with fun and sound pedagogical outcomes. So, AlgoGames have been conceived to offer, above robot-programming game principles, some specific characteristics:

- Micro World conception to let learners in their free explorations and constructions
- Opportunity for teachers to propose their own algorithms as exercises for students, giving a more instructive character and promotes challenging activities.
- Algorithm evaluation, providing a simple learner model to both teachers and learners
- Independent algorithmic language (in use all over our universities), to avoid hassles of programming languages and focus on the essential cognitive activities. AlgoGames uses its own compiler to execute algorithms.

AlgoGames, like programming games, can be considered as a sort of AVs, although users can't in the actual version view data structure internal state. In fact, AlgoGames has been conceived to concretize our view of a pedagogically helpful algorithmic thinking funny tool.

3.2. Funny pedagogical AlgoGames conception and implementation

AlgoGames is based on the well established idea of Worlds and Objects animation and interactions. Each world has its own objects, and every type (or class) of objects can be controlled via a set of possible commands (methods). Worlds' objects have their visual representation. Actually, *Phantom Trotting World* is in use at AlgoGames (see Fig 1 and Fig 2) but it is possible to develop other worlds to meet specific learning objectives (teaching trees, sorting, etc.). AlgoGames conception and implementation consists of two main views: the Micro World view, and the challenges view. In the Micro World view the learner is free to explore and construct any idea or self settled challenges, see Fig 1. In the challenges view, the learner is faced with a set of challenging exercises. Exercises are visual, no text is shown, and the learner can only observe the animation resulting from teachers' exercises execution, see Fig 2. The challenge consists of miming the observed animation. Teachers can write exercises as much are they want and change them at any time. Teachers' exercises are called "reference exercises".

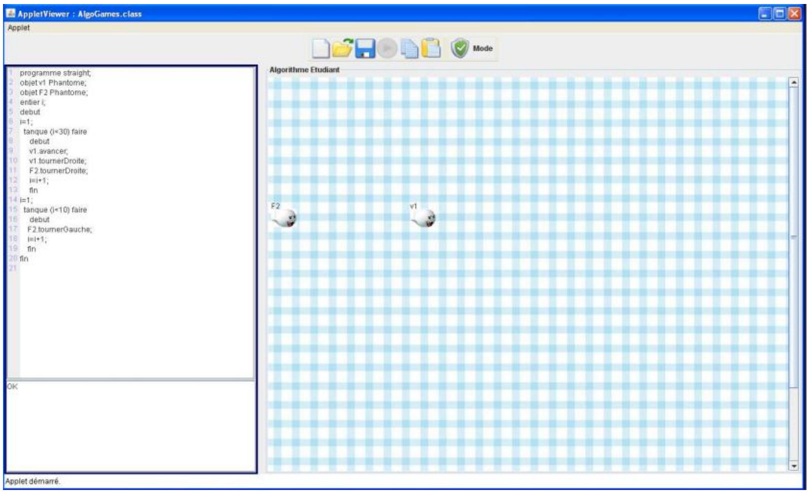

Fig. 1. Micro World view

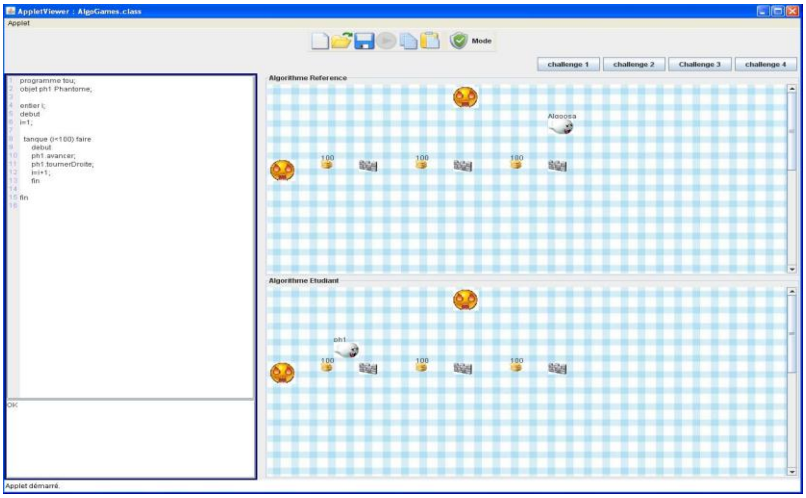

Fig. 2. Challenge view

Java 2D technologies have been chosen because most 3D game technologies (as game engines) are demanding in specific configurations and capabilities. For now, AlgoGames has been deployed as an applet accessible via *Moodle* learning management system. Worlds and objects are conceived as plug-ins. As an example, the actual *Phantom Trotting World* contains *phantoms*, *Walls*, *Monsters* and *coins*.

3.3. Learner assessment and feedback in AlgoGames

As all is about animation, feedback is immediate resulting from what the learner is seeing. In the Micro World view, the learner compares the resulting animation to what he intended to do with his algorithm. In the *challenges* view the learner can visually compare his animation with the reference one. With this immediate and visual feedback, the learner can instantly evaluate what he has written.

Besides, a basic overlay learner-modeling component provides teachers with estimated information about learners' level. The used heuristic has been derived from experimented teachers' interviews. They were asked about their method in marking students' algorithms. So, a simple reactive multi-agent system provides an overall evaluation of each student's algorithm. Each agent provides a score, and a whole 'mark' is calculated by a weighting function. This automatic evaluation reflects the distance between the learner algorithm and the reference algorithm. As examples, *loopAgent* computes the ratio between the number of loops used in the learner's algorithm and those used in the teacher's algorithm; *NestedLoopAgent* computes the same ratio but of one-level nested loops.

4. Evaluation

A primary evaluation of AlgoGames was conducted in a two sessions (one and a half hour each) experiment with thirty four students and one teacher to write reference algorithms. The goal of the study was to seize the students' impressions about AlgoGames comparatively to what they had in their classic lectures. Neither learning effects nor the relevance of the automatic assessment component were in the scope of the study. Students were issued from the second-year course in a computer science information system curriculum; they already had an introductory course in Algorithms and data structures (namely *Info 1* and *Info 2*) in their first-year study. Students were provided with brief instructions of using AlgoGames. Discussions had taken place with students, and comments included that the system "would be effective if we got it last year" or "really amusing and useful". Most important point was to note the students' enthusiasm on continuously using AlgoGames especially in the challenge view. The initial results of this limited primary of AlgoGames, gives us confidence that our system has potential value as a pedagogical aid for teaching algorithmic topics with the funny side of games.

5. Conclusion and future work

Mastering the algorithmic thinking skills will always require a lot of work from students. We also think that teachers will stay for a long time as a necessary mediator for learning processes in this field. However, by gathering algorithm visualization principles and digital video games characteristics in AlgoGames system we aim to offer a helpful tool for students and teachers. This tool tends to be a funny learning companion, accordingly to the smart game movement. Furthermore, AlgoGames will be evaluated through the whole academic year for the first-year students in order to establish (or invalidate) its learning effects. In addition, the question of how to conceive a game world to meet specific algorithmic topic needs has to be investigated.

References

Annetta, L. (2008), Video games in education: why they should be used and how they are being used. Theory Into Practice, 47, 229-239.

Charsky, D. (2010), From Edutainment to Serious Games: A Change in the Use of Game Characteristics,. *In Games and Culture*, 5(2), Sage Pub., pp177-198.

Futschek, G. (2006), Algorithmic Thinking: The Key for Understanding Computer Science, *LNCS 4226*, Springer, pp. 159 - 168.

Hays, R. T. (2005), The effectiveness of instructional games: a literature review and discussion, Naval Air Warfare Center Report.

Kaasboll J. Exploring didactic models for programming. Norsk Informatikk-konferanse, Høgskolen i Agder 1998.

Kehoe, C., Stasko, j., and Taylor, A. Rethinking the evaluation of algoritm animations as learning aids: an observational study. *International Journal of Human-Computer Studies* 54,2 (Feb 2001), 265-284.

Michael Zyda, From Visual Simulation to Virtual Reality to Games. *Computer*, vol. 38, no. 9, pp. 25-32, Sept. 2005.

Papert, S., Situating Constructionism, Chap. 1 in HAREL, I. & PAPERT, S. (eds.) Constructionism, Ablex Publishing Corporation, 1991

Prensky, M. (2001), The Digital Game-Based Learning Revolution, McGraw-Hill.

Shaffer, C., Cooper, M.L., Alon, A.J.D., Akbar, M., Stewart, M., Ponce, S., et al. Algorithm Visualization: The State of the Field. In Proceedings of TOCE. 2010.

Van Eck, R. (2006), Digital Game-Based Learning: It's Not Just the Digital Natives Who Are Restless. *EDUCAUSE Rev.*, 41(2), 16–30.

Young, J. (2010). 5 teaching tips for professors – from video games. (http://chronicle.com/article/5-Lessons-Professors-Can-Learn/63708/) The Chronicle of Higher Education.