About including a virtual teacher in a competitive or collaborative context in AlgoPath

Estelle Perrin*, Sébastien Linck*and Dimitry Zekrouf*
*CReSTIC
IFTS - University of Reims Champagne-Ardenne
Charleville-Mézières, France
Email: estelle.perrin@univ-reims.fr, sebastien.linck@univ-reims.fr, dimitry.zekrouf@etudiant.univ-reims.fr

***Abstract*—AlgoPath is an entertainment program to help students with no classical computer science background understand the main concepts of algorithmics. It looks like a serious game in which the player builds a world of concrete, paths and grass. We show in this paper that the inner model of AlgoPath is based on the Model-View-Controller architecture (MVC). We intend to add a virtual teacher in this architecture, who oversees the players' interactions and intervenes when the interactions do not correspond to what is expected by a real teacher. We explain how the model of the virtual teacher interacts with the Controller component of the architecture. We describe the model that lets a real teacher add his particular comments for the various mistakes that can be made by a player. We explore the solutions to implement two multiplayer gameplay types: a competitive one, in which two or several players fight against one another to be the first to find the best algorithm, and a collaborative one, in which they have to find the best algorithm as a team. Finally, we explain our choice to develop the distributed version of AlgoPath with Unity.**

I. Introduction

Today's students are not the people they used to be. They live in a world surrounded by electronics: smart phones, tablets and computers (preferably connected to the Internet), ... provide them with video games, chats, e-books, information at any time. Such students, born after the eighties, are called digital natives as opposed to digital immigrants [1]. They live in a world full of multimedia but sometimes multimedia seem to remain away from their teaching space. It is particularly the case with algorithmics courses where the teacher asks them to think with a pen and a sheet of paper. This technique may seem odd for a course dedicated to computer science.

Students may want to graduate in computer science without having a full computer science background. For example, we offer in our university under-graduate courses dedicated to web-sites design. The courses include design, project management, communication, HTML and CSS languages but also PHP language. The latter is much related to algorithmics and object-oriented programming concepts. This leaves us with students having difficulties to catch a good mental representation of an algorithm and not being motivated to do so. Variables, conditional instructions, loops, parameters, functions, objects, polymorphism, etc will remain meaningless words however hard teachers can try to explain. Nick Ellis pointed out in [2] that in the matter of word meaning, "the eyes see vividly, but ears only faintly hear, fingers barely feel and the nose doesn't know". Virtual environments like computer games can motivate students to engage in learning activities [3]. So to help students conceptualize and learn, we created the virtual world of AlgoPath. In this world, variables are 3D figures born in huts and carrying backpacks. Statements are made of grass and stones. Functions and procedures are forests - for more details see [4] and [5] and for a blink of it see Fig.1.

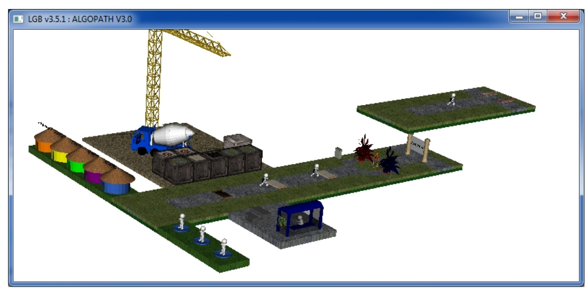

Fig. 1. This is the world of AlgoPath.

If AlgoPath can currently help students avoid common mistakes (such as using a variable in an expression before it has been set or forgetting to assign a parameter passed by reference), it cannot - in its previous versions at least - help them find the flow of statements for a given problem. In this paper, we discuss the inner model of AlgoPath that is based on the Model-View-Controller architecture (MVC) in order to include a virtual teacher. The role of this virtual teacher is to reproduce the advice, hints and tips a real teacher would give in a 'I-don't-know-what-kind-of-statement-I-should-add' situation. We also want this virtual teacher to be there helping students whether they are playing against one another to find the best algorithm or they are looking for the best algorithm as a team.

This paper is sectioned as follows: section II reviews the different models of a virtual teacher and the impact of gameplays on learning activities. Section III shows the inner model of AlgoPath. Section IV discusses the introduction of a virtual teacher in the architecture of AlgoPath. Section V describes the technology that will be used in AlgoPath to implement the virtual teacher and section VI concludes this paper and proposes future work.

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II. State of the Art

We review the impact of gameplays on the learning process in section II-A and the ways a virtual teacher is included in a virtual environment in section II-B.

A. Multi-player interactions

Numerous studies dealing with human relations have been conducted. We focused on papers analyzing competitive or cooperative aspects of relations between individuals or groups. The first studies were conducted in 1949 (see for example Deutsch [6] [7]). Competitive or cooperative relations initiated in classrooms obey the same principles that exist among humans in the context of everyday life. Relations between students involved in the learning of problem-solving are studied in [8]. It shows that cooperative learning is a better way to solve non linguistic problems such as mathematics. Thanks to the exchange of information and recommendations between students, more ideas are shared and students solve problems more rapidly than alone. The usefulness of cooperative learning in the context of scientific courses is shown in [9]. It states that cooperative students significantly outperform conventional students.

Today these relations are studied within a computer-made environment often named virtual learning environment or serious game. Tom Weneck, a games designer and critic, pointed out in [10] that games are emblematic of the time they come from. Social media are embedded in our lives. So, games, learning environments and serious games naturally appeared, taking into account relations between players. For example, players can only succeed if they cooperate with one another.

Not all serious games engage students in committed learning. [11] shows that learning activities have to be integrated inside the game story but also outside of the game story when the computer is off. The game story is important to keep learners in the process but the gameplay is essential too. Players engaged in a collaborative gameplay spend more time in the game and, by doing so, get a higher quality result [12] because the efforts made to achieve the objectives are more important. Similarly, playing with friends leads to greater efforts and to a better commitment [13]. So we can assume that playing with other classmates can have an interesting influence on learning.

Collaborative gameplay seems to benefit to non-linguistic learning [11]. Collaborative and competitive gameplays can be mixed in games as described in [14]. The game ”Escape from Wilson Island” described in [15] involves teams. The gameplay focuses on collaborative tasks so that players need to coordinate their actions in order to succeed.

B. Role of a virtual teacher

A serious game or a virtual learning environment remains a tool for learning activities. Learning activities may involve a teacher. That is the reason why it may be interesting to include a teacher in the game. In a virtual environment, the teacher acts as a gamemaster: the system determines the learning style of an individual and proposes the most appropriate content based on her/his errors or on her/his progress during the process of learning. Studies focus on the structure of the courses and the way the student learns [16] to adapt the chronology of the ongoing needs of the student. The e-teacher of [17] assists students in the choice of his/her courses. The presentation of the content is adapted to her/his way of learning [18] [19]. The intelligent tutoring system described in [20] helps students during their learning progress. The content changes according to the students’ skills and knowledge.

In [21], the virtual teacher of the virtual learning environment is an expert system. The latter can be decomposed into two parts. The first detects and identifies the errors made by students. The second is a pedagogical model that offers an assistance to students.

III. Model

In this section, we want to show how the inner model of AlgoPath is structured in order to understand how it is possible (1) to develop AlgoPath in a distributed context and (2) to include a virtual teacher in it.

AlgoPath is based on the Model-View-Controller architecture [22] (see Fig. 2). MVC was conceived as a general solution to the problem of users controlling a large and complex data set, which is usually the case with games. MVC consists of three kinds of objects. The Model is the application object, the View is its screen presentation, and the Controller defines the way the user interface reacts to user input.

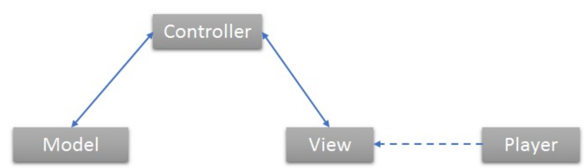


Fig. 2. The MVC architecture.

MVC is known to increase flexibility and reuse. A View must ensure that its appearance reflects the state of the Model. Whenever the Models data change (generally in response to a user interaction), the Model - through the Controller - notifies Views that depend on it. In response, each View can update itself. MVC is also known to handle pretty well multiple Views to a Model to provide different presentations.

Each non-abstract class in Fig. 3 has a visual representation in the world of AlgoPath. For example, the class ”Integer” is represented by a blue hut in AlgoPath. As a consequence, we have a class diagram of the same kind for the visualization of AlgoPath (the class at the top of the hierarchy in the visualization class diagram is called ”Visualization”). An ”assignment” is represented by a 3D figure with a backpack running on a straight forward stone path when it is viewed in an imperative programming context (see Fig. 4(b)), but it is represented by a 3D figure sitting on a couch on a flooring carpeted with baize in an object-oriented programming context (see Fig. 4(a)). Obviously, assignments are not the only statements that can

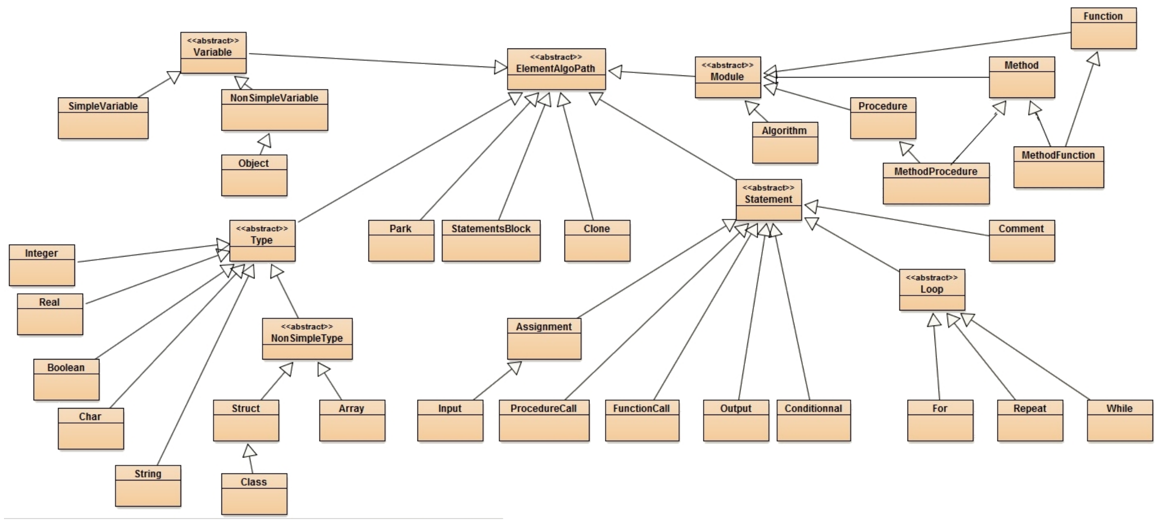
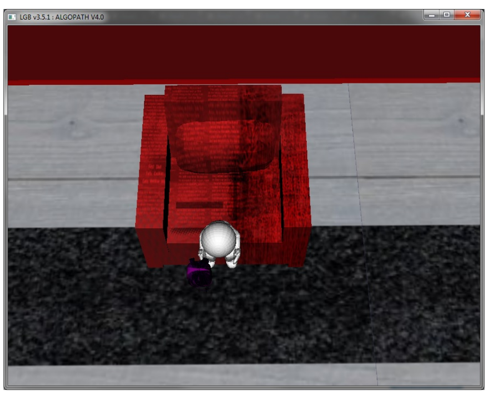


Fig. 3. Class diagram of the model of AlgoPath.

be viewed differently depending on the context. The choice of a MVC architecture was also driven by these situations because we knew that an ”ElementAlgoPath” might need to be represented differently according to the context in use.



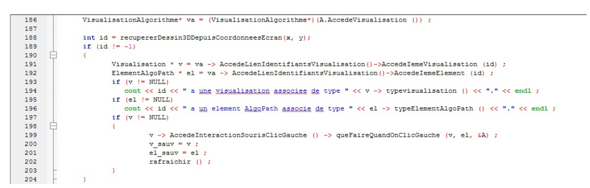
(a) View of an assignment in object-oriented language context.

(b) View of an assignment in imperative language context.

Fig. 4. Different views of an assignment in AlgoPath.

As the visualization is totally independent from the model, this architecture is also suitable if we may decide to change the world theme.

Thanks to object-oriented programming, the Controller part is very synthetic (see Fig. 5). It only has to determine which visualization part the user clicked onto, find the corresponding ElementAlgoPath data and launch the appropriate interaction. Within each ”visualization” class, several interactions are stored (when the user clicks on the left button, when the user clicks on the right button and so on if necessary). Consequently, we have a third class diagram dedicated to interactions.



```
VisualisationAlgorithme* va = (VisualisationAlgorithme*)(A.AccedeVisualisation ()) ;

int id = recupererDessin3DDepuisCoordonneesEcran(x, y);
if (id != -1)
{
        Visualisation * v = va -> AccedeLienIdentifiantsVisualisation()->AccedeIemeVisualisation (id) ;
        ElementAlgoPath * el = va -> AccedeLienIdentifiantsVisualisation()->AccedeIemeElement (id) ;
        if (v != NULL)
           cout << id << " a une visualisation associee de type " << v -> typevisualisation () << "." << endl ;
        if (el != NULL)
           cout << id << " a un element AlgoPath associe de type " << el -> typeElementAlgoPath () << "." << endl ;
        if (v != NULL)
        {
                v -> AccedeInteractionSourisClicGauche () -> queFaireQuandOnClicGauche (v, el, &A) ;
                v_sauv = v ;
                el_sauv = el ;
                rafraichir () ;
        }
}
```

Fig. 5. A portion of the code of the Controller dedicated to left clicks in AlgoPath.

IV. Virtual Teacher

The previous versions of AlgoPath ([4] and [5]) were developed for a single player. When used in classrooms, a teacher needs to explain to her/his students the algorithm to be achieved before the session starts. The dialog between students and teacher is necessary because even if AlgoPath was able to help students go through conceptual errors, it couldn’t help them find the algorithm the teacher thought of. Because of that, AlgoPath couldn’t be seen as a real serious game in which the goal to be achieved by the player is encoded (and not specified by a human). In this section, we present the new features we are currently implementing into AlgoPath in order to create a virtual teacher (see section IV-A). Then we explain how we modified the inner model of AlgoPath to add the virtual teacher (see section IV-B) and how AlgoPath is suitable in a single player mode (see section IV-C) and in a multi-player mode (see section IV-D).

A. New features of AlgoPath

In this section, we explain the new features we want to implement within AlgoPath:

- The teacher can design her/his own algorithms. A database of algorithms stores each algorithm the teacher wants to store. In that way at the beginning of a session, the teacher can pick a precise algorithm or AlgoPath can pick one randomly.
- A virtual teacher is designed within AlgoPath. This virtual teacher is only available if the player chooses to be challenged. The virtual teacher must oversee the interactions of the player. So it is in direct connection with the Controller part of the MVC architecture of AlgoPath presented in section III. The virtual teacher can be seen as a super controller. It can change the course of events within AlgoPath and can propose advice and hints in order to help the player find the best interaction.

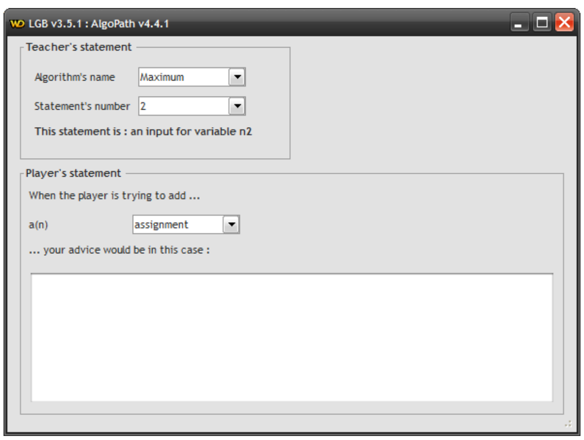


Fig. 6. The interface to set the virtual teacher for an algorithm.

- Each teacher has her/his own way of teaching. We do not want AlgoPath to be the reflection of only one way of teaching. So AlgoPath proposes a tool in which the teacher can express her/his own words (see Fig. 6). Before the player can be challenged to find an algorithm, the teacher has to fill a database of rules for the algorithm if the player is wrong. The system reviews each interaction made by the teacher during the designing of the algorithm leading to an ElementAlgoPath. It recalls each one of them to the teacher. It asks her/him what should be said if the player made the wrong interaction. There are only six possible wrong interactions. As the answer is probably linked to the wrong interaction, the teacher has to find a sentence she/he would say for every wrong interaction (pretty much all interactions but the right one). This sentence is either a tip leading to the right interaction or a specific comment regarding the wrong interaction. When these steps are fulfilled, the virtual teacher can give the comments a real teacher would give whatever the couple (wrong interaction, right interaction) is. The process of finding the algorithm must be seen in a linear way by the virtual teacher even if designing an algorithm is not necessarily sequential and continuous. For this first version, we do not want to take into account every possible order leading to the right algorithm. But this assumption is moderated for the interactions leading to the creation of variables. The variables of an algorithm belong to three sets: the input, the output and the others. Before expressing the statements of an algorithm, the player has to answer two questions: (1) what are the variables needed for input? (2) what are the variables needed for output? Once she/he has answered these questions, the player can create the variables in any order she/he wants. During the design of the statements of the algorithm, the player can also create a variable at any time. In the end, the virtual teacher only checks that the player created the right number of every type of variables for the output, the input and the algorithm.
  The real teacher has some preparatory work to do but once the game is on, the Virtual Teacher acts on its own and the interactions between the real teacher and the Virtual Teacher are no longer necessary. Let's take an example: the two first statements leading to the full algorithm of the computation of the maximum of two values are inputs. Players may interact with the wrong statements boxes. The real teacher has two choices: either she/he can write the same advice for all the wrong interactions (for example, something like ”Think of asking the user the values first”) or she/he can write a specific comment (for example, she/he can write ”It is good to think of setting variables but ask the user instead” if the player interacts with the assignment box instead of the input box). The way teachers teach is very personal and we thought that letting them express their own words was the best option.
- The evaluation of a player is performed at the end of a game. The score is calculated according to the number of errors the player made - obviously, the fewer she/he made, the better the score is. This score is added to her/his previous scores in order to get a global evaluation. Only the teacher and the player can see the scores.

B. Model

To fully implement the features described in the previous section (see section IV-A), we modified the MVC architecture presented in section III.

The real teacher creates algorithms and states sentences the system stores into the Model. The player tries to find the algorithm the teacher or AlgoPath selected. The Controller catches interactions. If necessary, it passes them to the Virtual Teacher. The Virtual Teacher accesses the real teacher's sentences. It is also an engine following simple rules to oversee the Controller. The Virtual Teacher computes if the interaction is correct or not. If it is, the whole system acts as if the Virtual Teacher was not there. If it is not, the Virtual Teacher stops the interaction, disrupts the system and takes over the actions of the View. The View displays the specific guidance in correlation with the stopped interaction. Another interaction may occur again and the system iterates. See Fig. 7 for an overview of this process.

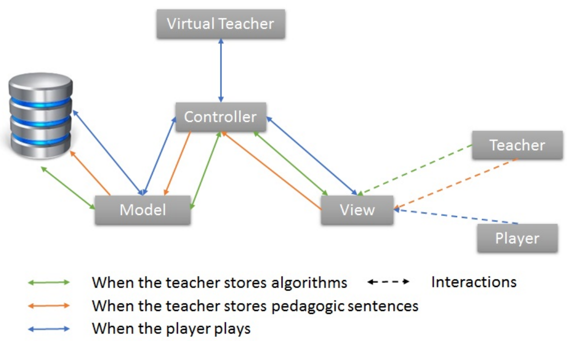


Fig. 7. A possible integration of a virtual teacher inside the MVC architecture.

The database shown in Fig. 7 can be split into two independent parts: one for data of algorithms (the ones the teacher designs and the ones the player designs) and one for data of the virtual teacher (rules and sentences it must access).

Fig. 7 also summarizes the three modes:

- When the teacher stores algorithms to be further used in the classroom or at home. In that case, the Virtual Teacher is off.
- When the player plays. In that case, the Virtual Teacher is on.
- When the teacher stores pedagogic sentences she/he would say in the classroom if errors were to be made by the player. In that case, the Virtual Player is off.

C. Single Player

When this tool is fully developed, we will be able to use Algopath in either single or multi-player modes. This section explains how it can be used by a single player. There are two cases:

1) The player is self-thinking in a classroom. Before the course, the teacher has prepared her/his exercice within AlgoPath. She/he can explain the subject of the exercice and afterwards gives them the name of the algorithm. Instead of taking a pen and a paper, each student begins to play with AlgoPath. They choose the algorithm thanks to the name the teacher gave them and try to find the algorithm by themselves. The Virtual Teacher helps them go through the process at any time if necessary.
2) The player is self-thinking at home. After school, a student can try again the exercice the teacher gave during class or she/he can let AlgoPath pick a new one for her/him. Here again, the Virtual Teacher helps her/him by expressing words the real teacher would way if she/he were there.

In both cases, the whole model of AlgoPah presented in section IV-B is installed on the computer of the player.

D. Multiplayer

As explained in [23], a virtual environment is a two-dimensional or a three-dimensional virtual world (real or not). The virtual environment incorporates realistic graphics to create an immersive experience. According to this definition, AlgoPath is a virtual environment.

A networked virtual environment is a computer system that creates virtual worlds, where the users can interact in real time both with the game and with the other users connected. The users are connected to the Internet and work on different computers, accessing the same virtual scene. The architectures that support these types of environments usually fall into one of the following categories:

1) client-server architectures, where the client communicates its changes to the server and the server, in turn, communicates the changes to all the other clients;
2) or, peer-to-peer architecture where the clients communicate directly with one another [24].

Papers such as [25][26] address the problems of network bandwidth, CPU cycles, damage of the interactivity and consistency of the game, ..., for such environments.

Having such an architecture, AlgoPath can be used by several players. These players can be with a real teacher or not. If they are not, the group of players can play:

1) in a collaborative gameplay. An algorithm is chosen. The players design the same algorithm altogether. Consequently, Views are the same on every computer. In this gameplay, the Virtual Teacher is on. The Controller passes on the interactions of every player to the Virtual Teacher. The first correct interaction that the Virtual Teacher receives updates the Views of every player. The player who gives the correct answer scores. Anyhow, the players receive personal advice from the Virtual Teacher if their interactions are not correct. The game ends when the algorithm is complete.
2) in a competitive gameplay. As in the collaborative gameplay, an algorithm is chosen and the Virtual Teacher is on, but the winner is the one who finds the whole correct algorithm first. In that case, Views are independent and advice personal. The game is finished when there is a winner. Every player scores according to the rate of correct interactions she/he did during the play.

We are concerned about such gameplays being disturbing for students who have difficulties to find correct answers. So we thought that the teacher, if she/he is part of the game, can rebalance the game by questioning certain individuals. For example, she/he can choose among those who score lowest. For that purpose, we thought of initiating a gameplay with tokens. If a player has the token, she/he has the priority over the other players. It means she/he has more time to think and to answer. The system informs the other players that she/he has the priority and that they have to wait. If the player who has the token takes too much time to answer, the token is removed either by the teacher or by the system. The game goes on until another token is given.

V. IMPLEMENTATION

The first versions of AlgoPath were standalone applications. The 3D content was featured thanks to the VTK library [27]. VTK consists of a C++ class library for 3D computer graphics, image processing and visualization. We need to turn it into a distributed application to implement the features we detailed in section IV-A. When implemented, players will want to access it at home or during courses in classrooms. They will want to access it through different kinds of hardware: computers, tablets or even smartphones. Presenting AlgoPath on the web seems relevant to meet these requirements.

In recent years, 3D graphics have become an increasingly important part of the multimedia web experience. A large number of technologies for the development of 3D content can be found on the web [28]:

- VRML, X3D and ISO standards: VRML was developed in 1994 and replaced by X3D in 2004. Several applications and browser plugins were developed to enable the display of VRML scenes in the browser (CosMo Player, WorldView, VRMLView, ...). X3D was designed to be compatible with VRML.
- X3Dom was introduced in 2009. It is designed to work with web standards such as Ajax.
- XML3D is very similar to X3Dom. It proposes to extend the existing properties of HTML wherever possible, embedding 3D content into a web page, with the maximum reuse of existing features.
- Xflow is a solution to process intensive data on the web. It is integrated into XML3D. It provides character animation, simulations of various types (fire, smoke, air movements, ...).
- CSS 3D enables to format elements using 3D transforms (rotations, scales, translations). But CSS 3D cannot perform true light and shadow.
- Google O3D is an open-source JavaScript API for creating interactive 3D applications in the browser. It is viewed as bridging the gap between desktop based 3D accelerated graphics applications and HTML based web browsers.
- WebGL (Web Graphics Library) is a JavaScript API for rendering interactive 3D graphics within any compatible web browser without the use of plug-ins. It is intended to be used by experienced graphics programmers. Several libraries originated from WebGL such as SpideGL or LightGL or Three.js.
- Java3D features a full scene graph and is able to render using Direct3D or OpenGL. JOGL (Java OpenGL) and LWJGL (LightWeight Java Game Library - it featured Minecraft, the popular multiplatform game) are libraries that provide 3D graphics, 3D sound and controllers (joysticks, ...) to applications.

The selection of the appropriate technology depends on the needs and requirements of the application developed. Unity [29] is a proprietary videogame engine which, compared to the technologies listed above, is highly superior, aiming to be an application to create video games. It is powerful and fully integrated with a complete set of tools and rapid workflows to create interactive 3D and 2D contents. So we chose Unity to develop AlgoPath in a distributed way. The implementation is at its beginning (see Fig. 8). For us, one of the main interests of Unity is that a Unity scene can be created entirely in code. Unity accepts C# or JavaScript code but it is also possible to import our own library. The latter lets us import the M-part and the C-part of the MVC model of AlgoPath, the V-part being totally handled by Unity.

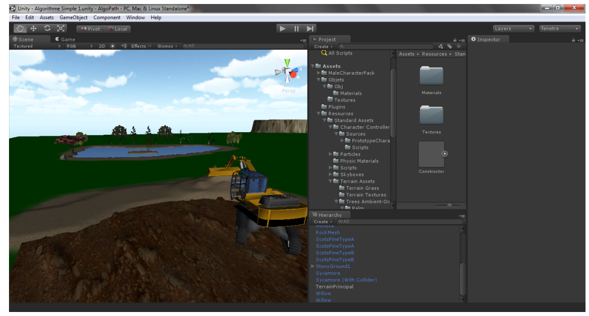


Fig. 8. Distributed version of AlgoPath in progress using Unity.

VI. CONCLUSION AND FUTURE WORK

In this paper, we explained how we made the model of AlgoPath evolved in order to add new features, turning it into a distributed virtual environment in which students can play in a collaborative or competitive way. The main feature is a Virtual Teacher. The Virtual Teacher intervenes whenever necessary to give the player hints and tips. This advice comes from a real teacher who has to specify her/his own words thanks to a tool embedded in AlgoPath. Consequently, her/his pedagogy goes beyond the classroom. This new version of AlgoPath will be implemented using Unity, a videogame engine.

Future work will focus on realizing focus groups so that AlgoPath can be properly evaluated. Some have already begun with the University of Lorraine in France. Results will show if the new features are appreciated by teachers and students or not. Moreover, we want to improve the quality of the virtual teacher. We stated that the virtual teacher has to follow the flow of statements and therefore, so have the players. When in practice programmers do not think straight but go back and forth. More thoughts will also have to be given to implement a collaboration during oriented-object programming.

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