A Preliminary Work on Visualization-based Education Tool for High School Machine Learning Education

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Abstract – **Artificial Intelligence (AI) has become one of the most recurrent topics nowadays, due to its many industrial applications and its wide range of research topics in academia. Within AI, Machine Learning (ML) is one of the most prominent sub-fields, the popularity of which is complemented with its high demand as a professional skill for different industries. In the last few years, teaching ML is thus increasingly common in different levels of education. However, the curricula implemented for several courses or programs to learn ML are not always appropriate for the backgrounds of students, particularly high school students, as programming and complex math experience are usually required to implement ML models and understand the potential of this field. For this reason, it is possible for students to have difficulties with the lack of experience required or expected and to have prior to learning ML topics. In addition, motivation can be affected, as the curriculum does not sufficiently engage the student in the learning process. In this work, we propose a visualization tool to introduce high school students to the ML field, which will be implemented using concepts of gamification and adapting the content of the curriculum without requiring exhaustive experience in programming or math.**

Index Terms – Artificial Intelligence, Education, Gamification, Machine Learning, Visualization.

INTRODUCTION

Artificial Intelligence (AI) is currently one of the most prominent topics within the field of computer science, and due to the massification of its applications in the real world, having knowledge of this has become a vital skill in a variety of industries. As technology continually evolves and new implementations of AI are proposed, learning AI at some point of pre-college education will become part of the standard education in the near future, as it is being recognized as "the next big thing" [1][2]. Several subjects related to AI, such as Machine Learning (ML), have already been offered in the curricula of undergraduate programs from several universities, and even in some high schools, as part of an extracurricular pensum. However, the process of learning ML can be considered a significant challenge for students due to several variables, such as lack of mathematical background, new technologies, and/or computer science knowledge. According to Rattadilok [3], teaching ML is not trivial, and there have been some key challenges commonly encountered in the teaching process such as the level of engagement and the willingness of the students to learn new technologies, which are critical for success. The appropriate set of topics selected to be taught for a specific group of students according to its standard level of education is a crucial factor for the motivation of students in any field and for teaching ML, due to the popularity of the subject and the number of people of varying ages interested in obtaining knowledge related to it.

Lately, AI, and in particular ML, have been one of the most requested skills in industry [4], and teenagers are looking at this field as a potential career for their future. However, adapting the ML curriculum from higher to secondary education is limited to the tools available that allow students to learn without having a specific background in computer sciences. For instance, typically required skills are at least a medium level of experience in programming and a solid background in mathematics and statistics. Aside from the fact that learning programming can be a fun experience, sometimes a young student does not have an affinity into the Information Technology (IT) world and does not need full exposure to programming but may want to learn ML as a starting point to get into the IT field.

This work discusses the implementation of a game-based tool to teach ML to high school students, taking advantage of the engagement strategies used by video games and adapting the curricula of ML courses traditionally used in higher education to a more reasonable level of complexity for secondary education. The tool will be implemented as a 2D platform video game, inspired as a combination of several video game concepts in which the main goal relies on getting the user to be engaged in the game and to learn the theory behind ML without losing that level of engagement.

The remainder of this paper is composed as follows: background and motivations, which is summarized a set of related works and provides the motivations behind this project; the methodology, which explains the development of the application, the tools used in the development process, and the model framework used as guidance for this project; brief coverage of the ML topics along with the reasons for the selection of the specific topics to be included

in the application; and finally, conclusions are provided while ideas for future works are proposed.

Background and Motivations

Several works were reviewed prior to the initial development of this project, and a brief description of those works is presented in this section. In [5], Derrac et al. proposed the use of KEEL [6] as a software package to teach data mining (DM). This tool was proposed when considering the problem that most of the teaching techniques for an AI topic require programming experience, which therefore implies a certain amount of time and effort consumed by writing a program rather than learning the actual theory behind DM. KEEL is a Java-based open-source tool that allows users to asses AI algorithms, provides visualization for the evolution and feedback of the progress of the algorithms along with accessibility to the final results from the same graphical user interface, all without ending extensive time learning and implementing programming concepts. Chiang et al. proposed to adapt a traditional video game with ML technology and use it as a learning motivation for students in AI topics, attracting students' attention by a popular character and using a simple interface to demonstrate a real application of AI [7].

Rattadilok also proposed the idea to adapt a popular game to engage students into the ML field, integrating the learning process into a game situation, creating context while learning, offering rewards, and using good criteria at the time to define the goals of his proposal, exposing different concepts such as machine teaching and gamification [3]. On the other hand, Castro et al. proposed a visualization tool for cybersecurity education, focusing on the development of a framework standardized to fit different kinds of topics for education in the information technology field [8].

In addition, in summer 2019, the very first edition of an AI/ML summer camp was offered by the Electrical and Computer Engineering (ECE) department at Purdue University Northwest (PNW) [9]. For two weeks, high school students were instructed in the AI/ML field, learning through hands-on experience, attending guest speaker presentations, and attending theoretical lectures. At the end of the summer camp, a brief survey was taken by the participants, providing crucial feedback. For instance, most of the students expressed that they liked the game-based experience from the use of Scratch [10] through machine learning for kids [11]. In addition, some students agreed that the content presented along the summer camp was easy to understand without digging into complex concepts, that could have caused frustration in the learning process. Students also expressed agreement regarding the way in which the information was provided to them and the fact that they could check such information at any time.

One important characteristic of the students was that, according to Figure 1, most of the attendees did not have any prior experience in AI/ML before the summer camp. This information supports the growing trend in young students' interest in this field.

#	Answer	Bar	Response	%
1	No Experience		16	72.73%
2	Beginner		6	27.27%
3	Intermediate		0	0.00%
4	Advanced		0	0.00%
	Total		22	100.00%

FIGURE I
STUDENTS' PRIOR EXPERIENCE ON AI/ML BEFORE THE 2019 SUMMER CAMP

All of this feedback has provided us an idea of some features needed in the ML learning process.

Based on the review of related works, the data collected, and the personal experiences from the AI/ML summer camp at PNW, the motivation to develop a tool for ML education proposed at the beginning of this paper was met. In the following section, a description of the development process of the tool will be provided, which includes methodology, software design, and other aspects related to the learning process as well as the goals expected from the tool.

Methodology

After an extensive review of several related works, an initial idea was proposed as a tool for ML education, focusing on one particular target: high school students. Among the most important facts retrieved from the research performed, we will include in the design of our work particular attention to what is actually involved in the traditional teaching of ML: to ensure the understanding of ML techniques as well as the usage thereof [12] and how engagement techniques and strategies [13] from game technology can be implemented in order to retain attention and avoid frustration from the users within the learning process.

A 2D game-based educational tool was proposed, and its development contemplated the points previously mentioned. A selected set of topics to be learned will be included in the game as part of the challenges to be accomplished by the user to complete the game/ML course. The development of the tool will be performed using Unity3D [14] as the main software engine, while some other graphic editors will be used in the posterior stages of the project. Unity3D has incorporated an integrated code editor (IDE) that allows the developer to have an improved experience in working with the programming and graphic design portions of the project. The use of Unity3D as an engine allows the project to be implemented for several platforms. We have decided, however, to develop this tool as a web application in order to allow the user easy access without the constraints of requiring a specific operating system or expensive hardware. In addition, this accessibility

allows us to collect information from the final user related to the learning process and goals achieved, conducted remotely as a metric to measure the learning level of the user.

The application initially contemplates the implementation of four main modules, as seen in Figure II, which provides the main menu of the application. The **introduction to machine learning** module is the access to the game-based ML course, where the selected topics will be covered within the context of the game.

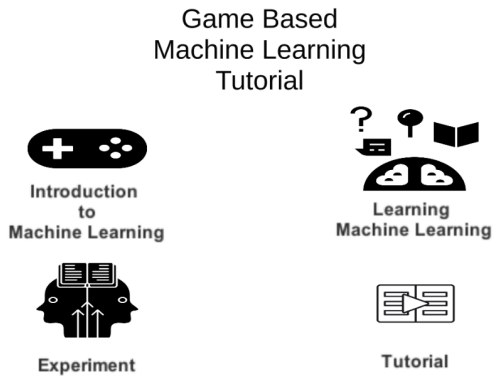

FIGURE II
THE MAIN MENU OF THE ML GAME-BASED EDUCATIONAL TOOL

Each of the ML topics will be delivered to the user following the structure shown in Figure III in order to ensure the retention and understanding of the ML topics. The structure showed in Figure III is based on four stages. The **explanation** stage has the goal to explain or describe the ML topic as an introduction to the user. These explanations are expected to be performed according to the context of the game and the constraints of the target users. The **animation** stage has the duty to show the previously explained topic in an animated way to reinforce the understanding of the user. The **real-world implementation** stage has the purpose of showing the user how the topics previously used are actually implemented in the real world as well as how important they are currently. The **assessment** stage is utilized to evaluate and measure the understanding of the user for each of the topics reviewed.

The remainder modules, shown in Figure II, have the following functions. **Learning machine learning** will allow the student to review the information previously learned through the game in a more traditional way, by the use of images, graphs and printed information. The **experiment** module will allow users to access different open-source recourses, such as machine learning for kids [11], that allow them to apply their knowledge in an experimental way. The **tutorial** module will allow the user to get familiar with the application through the use of audio and video that explain the functionality and purpose of each module.

The game being developed is inspired by platform games. Figure IV gives an example of a popular 2D platform video game. The context of the game will be determined following engagement strategies for games [13], in which the user is expected to be challenged to take actions, have a variety of scenarios, and ensure a focus on goals.

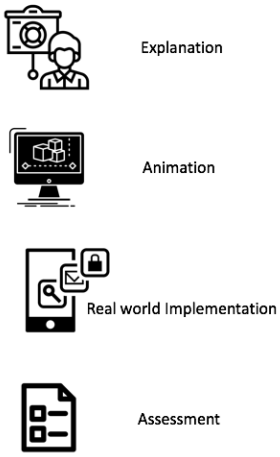

FIGURE III
STAGES STRUCTURE OF THE LEARNING PROCESS FOR THE ML TOPICS

Figure V presents screen captures from a prototype of the application, specifically from the introduction to machine learning modules, in which the influence of platform games is strongly presented.

FIGURE IV
EXAMPLE OF A 2D PLATFORM VIDEO GAME, SUPER MARIO BROS, 1985

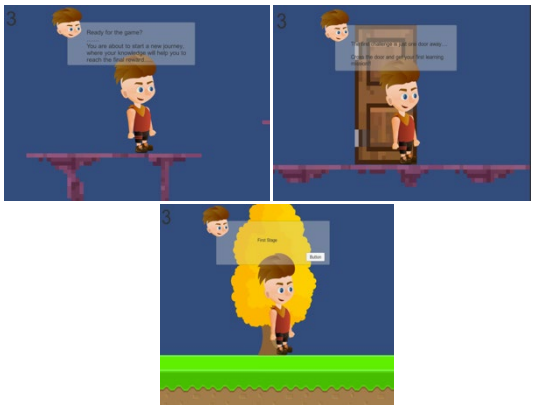

FIGURE V
THE INITIAL PROTOTYPE OF THE INTRODUCTION TO MACHINE LEARNING MODULE BASED ON SUPER MARIO BROS GAME

GAME-BASED EDUCATION TOPIC IN MACHINE LEARNING

AI/ML has a vast set of subjects to cover. In particular, this subject area has an important number of topics to be presented within the educational process, and the selection of an appropriate set of topics is crucial for the success of a proposed course. Based on the feedback received from the students of the AI/ML summer camp 2019 at PNW [9], the conclusions from different research works [15][16], and the characteristics of our target users, a set of ML topics was determined and considered to be included in the ML educational tool in its first stage. The topics selected are:

- Basic concepts: definition and comparison of AI, ML, and DL; types of ML problems in supervised and unsupervised learning.
- Basic ML algorithms: KNN classifiers, linear regression, Naïve Bayes, simple clustering algorithms.
- Machine learning workflow: loading of data, preprocessing of data, feature selection, parameter optimization, ML modeling, validation, and accurate measurement.
- Explainable AI.

This set of topics is tentative and subject to the addition or reduction of topics based on the feedback of the test users.

CONCLUSIONS AND FUTURE WORK

Due to a remarkable increment of people interested in learning ML, the massive use of ML technology in different industries and the increasing requirement of this skill for a professional career, the implementation of different tools for educational purposes in ML is a priority concern nowadays. A game-based educational tool is expected to create engagement in new users interested in entering the ML field, and the experience from the AI/ML summer camp 2019 at PNW gave us a solid understanding of how this tool could be implemented. The current status of the tool is the prototyping thereof, and a complete first version is expected to be tested in the upcoming edition of the AI/ML summer camp as well as through an open-source web platform.

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