EXTRACTING LEARNING ANALYTICS FROM GAME BASED LEARNING SESSIONS GENERATED BY MULTIMODAL DATA SOURCES.

by

APOSTOLOS MARIOS TRAMPAS

BSc, Informatics Engineering, Technological Institute of Crete, 2017

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

SCHOOL OF ENGINEERING

HELLENIC MEDITERRANEAN UNIVERSITY

2021

Approved by:

Associate Professor
Vidakis Nikolas

Copyright

Abstract

Our lives are affected by the continuous and robust growth of technology. Technology is part of our everyday lives, from work and communications to health and education and we live in a technological revolution with changes every day. The Information and Communication Technologies (ICT) have become an essential and necessary tool for our lives. This technological invasion has affected the field of education and the way that students process and acquire knowledge and information. Thus, and since the development of the internet, many educational systems are base their learning process in computers and educational software. eLearning environments, online courses, teleconferences, online quizzes, videos, audio, educational and serious games etc. have developed to provide an alternative educational process based on the technological standards that today's students have. But all those teaching alternatives can provide useful information, regarding students' behavior during the learning process. All information systems collect user data to analyze them and provide a personalized user experience. In the field of the education, the analysis, and the extraction of valuable information about students' behavior during the learning process, leads to the extraction of learning analytics.

Learning analytics though have more than one form. In this master thesis we will focus on the emotional learning analytics. Emotions play a significant role during the educational process on how students acquire knowledge. Emotions can be extracted by analyzing facial expressions, speech, or gestures. By analyzing and recording the different emotional states that a student had during the learning process, it is able to draw conclusions about the student's behavior during the teaching process, as well as about the process itself.

By those terms, in this master thesis we will develop an API, able to process raw data produced by the IOLAOS collaborative educational platform, and extract learning analytics based on emotions that a student had during the learning process.

Table of Contents

List of Figures

List of Tables

Acknowledgements

Firstly, I would like to express my gratitude to my supervisor Dr. Nikolas Vidakis, Associate Professor at the Department of Electrical and Computer Engineering of the Hellenic Mediterranean University, for his continuous support, and guidance in all those years of our collaboration. His valuable knowledge and suggestions contributed to the fulfillment of this master thesis. Moreover, I would like to thank my family for their support and their patience during my studies. I am also thankful to Nile – Gamelab team for their help and advice during the development of this work. Finally, I would like to express my warmest thanks to Anthie, Vasilis, George, Ilias and Alexis for their support during my studies.

Chapter 2 - Introduction

The 21st century is characterized by the accelerated and rapid technological advance. The consistently increasing evolution of the technology, affects peoples' lives around the globe. From the second half of the 20th century, when the third technological evolution started, people faced the rise of electronics, telecommunications and of course computers. The third technological revolution is also known as the digital revolution, due to the shift from analog / mechanical electronics, into digital, where computers, microprocessors, mobile phones developed, changing radically the traditional industrial and business approaches. Although, many consider that by the half and late 1990s we live the fifth technological revolution or the Industry 4.0. This consideration is brought out by the one thing that has come up into everyone's life, the Internet. The development of the Internet and the World Wide Web (or www), as well as their evolution through the years, have transform the way that people live, communicate, work, educate, interact with each other, and entertain. For instance, even and the simple phone call has change. Many people, nowadays, prefer to communicate through mobile applications via camera sound and text through the internet, rather than just typing a phone number and waiting for someone to response. We also live in an era that we can say with confidence that the internet has made life easier and faster. Imagine that we are just a few clicks away from everything we want, rather than searching for days for just a simple information. And of course, that rise of technology and internet, has an impact on education and therefore on educational systems, procedures, and methods.

Through the years of the technological revolution, we have observed a remarkable change on education. Traditional educational systems have transformed in a way to go with the flow with the technological achievements and especially in terms like the computers and therefore with the internet. Many educational systems use the computers as part of their curriculum and syllabus and others are based exclusively on them. Digital educational systems have come to the surface, changing radically the way that educational process is held. Today's students are characterized as digital natives, born in a century that everyone use technology, and as a result education needed to be transformed in the way to keep up with them. As a result, there is a large development and use of digital educational systems as complimentary tools to the traditional learning, but also as the main source of learning. Many countries around the globe use computers and the internet, and

therefore the convenience that provide to educate students of all ages more efficient and easier. Teachers and educators, have managed to transform the traditional educational methods they use, associating them with computers and create educational environments that students / learners play an important factor as they participate actively and directly with the educational process itself.

Based upon those motives, through the years and especially during the rise of the internet, digital educational procedures and developments have been accomplished. First, the eLearning systems, able to transfer knowledge and course syllabus through a web page, where learners can interact with the educational procedure either synchronously or asynchronously. The main use of an eLearning environment can be done by a simple web browser through a computer, a tablet or ever a smartphone. Those systems support the use of videos, texts, quizzes, audio, assessments etc. and the use teleconferencing, in order to transform knowledge. During the COVID-19 pandemic, many educational systems transform completely their courses and educational proceeding, to be done through eLearning systems. Moreover, a trend in education nowadays tends to be the serious games or educational games. Serious games can transfer knowledge or train existing knowledge on a subject with the use of an amusing game environment, where learning comes first and then the entertainment. Learners can reach the provided knowledge through interactions with the game world during the gameplay. Furthermore, social media can work as a complimentary tool in educational procedures, Through the social media, students can build groups and communities based on related hashtags and online conversations and as a result organize large- or small-scale group projects.

However, technology is not always something that we see and interact with. Computers were made to execute complex calculations, to solve a problem. Most of the times when users just click a button in a web site or an application, the system performs a flow of computational events that users have never thought or imagine. Those events when they executed properly, they bring back to the user the outcome of his / her interaction with the system. For instance, when someone types a search term in a search engine and just clicks the search button, the engine itself knows his / her interests and adjust the results according to them. The only thing that user sees is the search term and the result, but in this interval of milliseconds the system has done through algorithms that user cannot see the proper calculation of the available results. Those “behind what we see” algorithms, computer and software engineers have managed to use the during digital learning processes.

Firstly, the rise of artificial intelligence, which now is a trend in computer science worldwide, has managed to automate basic as well as more complex activities of our lives. In education the artificial intelligence has developed automated systems for assessments, grading, feedback and even more for tutoring. Via artificial intelligence, educational procedures can be adjusted in each student separate based on his / her needs and therefore fetch a powerful teaching assistant.

Also, the manipulation and use of the big data can enhance the learning experience. Information like students' enrollment, performance, feedback during the learning process can be consider as vital information to draw conclusions about the learner and the educational process itself. With the COVID-19 pandemic and therefore with the use of online educational services and resources, we have bigger data than ever.

Finally, big data can be manipulated in a way to provided learning analytics. Through learning analytics, educators can measure student's performance during an educational process and read insights about their behavior and as a result to optimize the learning experience and the procedure itself. Moreover, through learning analytics, educators can find hidden insights about students' that may have academic or behavioral challenges.

In those terms, learning analytics are characterized as a powerful tool for creating student centered educational systems and learning processes, to transform the traditional teacher centered education to a learning environment that meets students' needs. In this master thesis we will deal with the manipulation and process of raw multimodal learning data, to draw conclusions about learners' behavior based on the alternating between sentiments during a learning process.

Scope

The scope of this master thesis was the instigation on scientific areas regarding eLearning systems, serious games and learning analytics. More specific a detailed overview of how digital education takes places inside eLearning environments, as well the fundamental pedagogical theories and elements according to the Hexa-C Metamodel (HCMm). Also, how games can be part of an effective learning process and explain and understand the fields of "Game – based learning" and "Serious Games". Finally, the main topic of this master thesis is the understanding how the learning analytics and the emotional learning analytics work, as well as the different techniques that can be used to extract learning analytics.

Furthermore, in this master thesis, we will focus on the development and augmentation of algorithms able to manipulate educational data, extract, and store learning analytics. In this context, we will try to figure out how computer science fields of Artificial Intelligence, Machine Learning, Data Visualization, Gamification and Learning Analytics Specifications.

Finally, the main scope of this master thesis is to develop a fully functional software RESTful API able to manipulate and extract learning analytics. The development phases will be based on the theoretical background of this work.

Objectives

As mentioned before, in this work we will manage to manipulate educational raw data in order to draw conclusions about students' behavior during an educational process. The provided data will be available from resources that the IOLAOS Educational Platform provides. The software development concerns the implementation of an API able to retrieve raw data, manipulate the data, analyze those data, extract user emotions on specific data like videos and sounds and finally combine the extracted information and save it in data sources. This API is consisted of four basic elements:

Element A: Develop algorithms that (a) retrieve data and (b) manipulate to a certain common data structure.

Element B: Use Artificial Intelligence and Machine learning principles to augment existing algorithms that extract user's emotions from videos, speech, and text.

Element C: Retrieve users' data that occur during the gameplay of serious games.

Element D: Combine the extracted information in proper data structures, easy understandable by programmers that want to visualize or re-analyze the extracted knowledge.

Moreover, in terms of development, in this work we will manage to combine different Object - Oriented Programming Languages, like Java, Python and JavaScript using Representational state transfer (RESTFul) APIs, backend development principles and software design patterns.

Outline

Chapter 1: Introduction. A brief description of the topic as well as the scope and the objectives of the present master thesis.

Chapter 2: Background. An extended description of the theoretical and technological background of this work.

Chapter 3: The IOLAOS Framework. A description of the framework that this master thesis is part of as wall as a description of the collaborative IOLAOS Platform.

Chapter 4: Observation & Learning Analytics Module – System Analysis. The analysis of the software developed for this master thesis, regarding textual and requirements analysis, as long as use case scenarios descriptions.

Chapter 5: Observation & Learning Analytics Module – System Design. The design of the software developed for this master thesis, regarding software architecture, system structure, data repository architecture, system behavior and technologies, frameworks, libraries, good practices and design patterns used in the development phase.

Chapter 6: Implementation. The description of the implemented modules as well as the documentation of the developed services are presented.

Chapter 7: Case Study - Learning sessions. A presentation regarding the functionality of the developed system.

Chapter 8: Conclusion & Future Work. The results of this master thesis are presented as well as future developments on the system.

Chapter 3 - Background

In this chapter, we will deal with the background of this work. As described before this master thesis concerns the extraction of learning analytics based on learner's emotions during an educational session, by manipulating multimodal raw data. Since the discussion revolves around the field of education and learning, there are some major topics that we must address. First of all, in this chapter we will talk about the field of the eLearning, its concepts and uses. Also, we will highlight the terms of game – based learning, serious games and how serious games are involved with a digital learning process. Moreover, since the main topic of this master thesis is the learning analytics, we will do a brief designation on what, how and why to use learning analytics, how they can be used in educational processes and inside serious games. Finally, we will deal with emotional learning analytics and therefore with the field in Computer Science, called "Affective Computing".

eLearning

Our world is characterized by a continuous and rapid technological revolution, an increasing usage of the internet and resources from the cloud. In 2018, according to Zenith Optimedia, the internet consumption per capital worldwide amounted to 39 minutes using a desktop and 122 minutes using a mobile per day. That means that people are spending approximately 2 ½ hours each day using only the internet, without including the time that people spend each day in front of a screen. In America it was estimated that people spent each day about 11 hours staring a screen, including desktops, laptops, smartphones, tablets, and television. Also, it is estimated that since October 2020, 4.66 billion were active internet users, encompassing the 59 percent of the global population. Combining all those numbers, it is easy to understand that more than half the planet uses technology in an everyday basis. However, it is also very easy to conclude that this global usage of technology can have negative impact when it is not used properly. In our work we will deal only with the proper usage of technology and specifically software and programing.

The technological revolution had a great impact in the field of education, teaching and learning. The traditional educational methods and practices need to catch up with technology transform as students have changed scientifically compared to those of the past. Students' changes do not only concern their behavior, manner of speaking, and clothing, but, as Mark Prensky stated, they depend on the propagation of the technology [1][2] ((see Appendix C). Prensky characterized

the technology as “an event able to change things so fundamentally that there is absolutely no going back”. Today’s students, have spent most of their lives interacting with computers, video games, smartphones etc. As a result, they think and process information and knowledge different than their elders. Prensky characterized today’s students as “Digital Natives” and students of the past as “Digital Immigrants” [2]. The “Digital Natives” are all those students who were all born into the digital world and all of them speak the same “digital language”. On the other hand, students of the past that were not born into the digital world, but they learnt how to use and adapt technology are characterized as “Digital Immigrants”. Nowadays kids, and therefore students, we can characterize as “Digital natives”. However, education consists of “Digital Immigrant” teachers, assuming that learners are the same as the learners of the past. As mentioned before learners today think different and they face fundamental problems with the traditional educating methods. For example, learners prefer to interact via a screen with the knowledge, rather than watching a teacher reading from the textbook or writing on the blackboard. As Prensky mentioned, natives will not go backwards changing their way of thinking and throw away the new technology and use the old to keep up with the immigrants [2]. As a result, on the on-hand education should be reconsidered in terms of methods, content, and resources, and on the other hand should be changed in a way that will consider students’ different way of thinking, their needs, and their behavior.

Under those circumstances eLearning systems emerged. eLearning is the educational process that uses multimedia content and takes place using technology. As a term, describes the use of information and communication technologies to present educational content. The available educational material is presented using multimedia like pictures, sounds, videos, graphics etc., or through computer-based software like educational games, applications, and web sites. An eLearning procedure can be held inside the environment of a typical class, or outside the class, either online or offline.

eLearning is divided into two main categories namely synchronous and asynchronous eLearning. The asynchronous eLearning is based on techniques able to deliver knowledge and educational material in a way there is no need for students or teachers to be online at the same time. Asynchronous eLearning systems are accessed through internet and students can access and use the educational material whenever they prefer by logging in into an online platform, browse through the available material, watch, read or interact with it or download it to their devices. Educators by logging in to the same system can create lessons and manage educational material in

general. Asynchronous eLearning supports teacher – student, teacher – teacher and student – to student communication via messages. Very popular asynchronous eLearning environment are the online courses. Users prefer online courses because they can combine them with their everyday life and tasks.

The synchronous eLearning is based on student – teacher interaction using a real time computer software, but each one of the participants is on a different location. Through synchronous eLearning environments participants can interact with each other, in a way similar as a traditional class. Users interact with the educational material via video conferences, chatrooms, virtual classrooms and share different ideas, perspectives, and opinions to discuss or solve a problem. As a sequence, the real time communication between participants helps them enhance the feeling of socialization, encourages teamwork in small or large groups and as a result overcomes the isolation feeling.

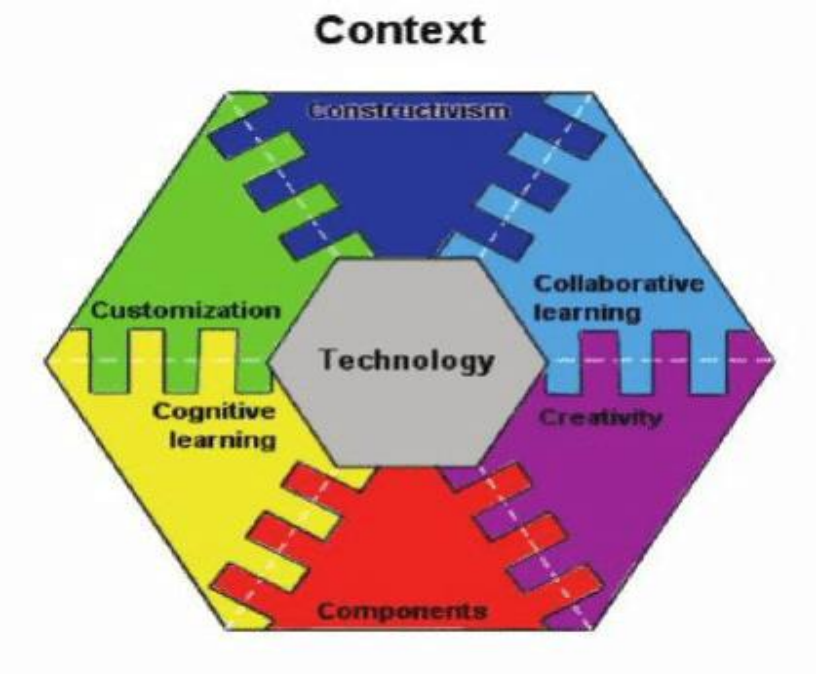


Figure 1 The Hexa-C Metamodel [3]**.**

However, an eLearning process must be effective and well structured, in order to be considered successful. All those technological resources and equipment are the different mediums to present and transfer knowledge, and not the learning process itself. Learners, behaviors, learning approaches, learning methods, strategies may vary considerably. De Villier concluded in a synthesis of educational theories and methods, the Hexa-C Metamodel (HCMm) [4]. The HCMm, which is also known as the "Six C's", is consisted of six learning fundamentals: cognitive learning,

constructivism, components, creativity, customization, and collaborative learning (see Figure 1). Each one of "Six C's" should be considered in the design and implementation of eLearning activities, as well as they can be used to evaluate from a theoretical perspective an educational software or a web – based learning application.

Figure 1 presents the Hexa-C Metamodel as a conceptual entity, consisted of the "Six C's" which are merged to each other. At the heart of the scheme, the technology is mounted as the implementation to transfer knowledge and educate, and not as a mean for the learning process. Context describes all these methods, content, educational resources, and material that may vary according to each situation, that makes an eLearning process or an eLearning environment different each time. As mentioned before the Hexa-C Metamodel is a synthesis of six learning fundamentals:

Cognitive Learning: From an early age in our life, as humans we develop abilities to recognize and obtain knowledge. Cognitive learning theories define that learners should build new knowledge based on the existing one, as well as that learning should support the understanding of information, for each student to construct highly organized and complex knowledge structures [5]. The built knowledge though, can be retained and used in other domains. Cognitivism focuses on how knowledge is received, organized, saved, and retrieve by the mind. As an outcome, it is based on aspects like mental models, information processing, critical thinking, self-regulation, and knowledge integration. This approach focuses on a learning process that educators encourage learners to develop critical thinking and puzzle over and focuses on the learning process as a medium for knowledge cultivation [6].

Constructivism: "Learning is an energetic process" and constructivists base their thoughts on that phrase. As humans we develop knowledge through our interactions and our experiences with the world. Humans are characterized by experimentation and exploration of the knowledge, rather than being passive listeners and memorize it [7]. Constructivists believe that education is a process that students construct their knowledge, and not a process that teacher transfers knowledge to them. Students are involved in different and complex situations, for assessment and problem-solving skills evaluation [8]. Moreover, constructivists believe that, as humans learn from their mistakes, so should the students. Piaget and Papert, mentioned that knowledge is a personal view of the world, that is built, maintained, and reapplied based on each learner's personal experiences [7].

Customization: Each learning process should meet each learner's personal needs. Students differ in the way that obtain and receive knowledge [9]. This happens due to the different ways that students think or due to special needs. Thus, learning should be available for everyone and customizable for each learner. With customization we built student - centered learning environments or learning processes, adaptable to each student, eliminate obstacles like time and place and students can take the initiative regarding the learning methods and the sequence of learning.

Collaborative learning: Learners many times face the same problems and same tasks. However, each learner thinks and act different. In collaborative learning, learners tend to work as groups and share different responsibilities within a team with roles and tasks. The key elements of cooperation within a learning process are the communication, the shared goals and opinions, the interpersonal skills, the collaborative assessment and finally the individual and collective responsibility [10]. Collaboration within a learning process, often occurs in constructivism describing how students can work in groups and face tasks that require complex knowledge and skills [8]. The rise of the internet transformed the collaborative learning from a process that occurs online within the boundaries of a classroom, to a process independent that occurs in many forms, synchronous or asynchronous.

Components: Learning outcomes occur according to an instructional plan, appropriate knowledge, and performance. The Hexa-C Metamodel as a framework shares the belief that an instructional process, sometimes is better for learning specific skills or knowledge. As components, are defined the student's basic skills and knowledge in a topic as well as methods for educator to teach it [3]. Components can be used during the design of an adequate, powerful, and engaging learning process.

Creativity: Designers should consider that a learning process needs to transfer affective, motivating, and creative learning experience, through instructional methods. The "ARCS Model of Keller and Suzuki", argues that a learning process should gain learners' attention, establish relevance, ensure confidence and attain learners' satisfaction [11]. A learning process is considered successful when participants are engaged and absorbed with it. In computer - based learning processes, human computer interaction, software design and software usability should be applied, for better learners' engagement with the learning functionality.

During the Industry 4.0 technological era, and during the COVID-19 pandemic, eLearning became a trend for education. From preschools to universities transformed their educational process, into an eLearning activity with many available tools, like teleconferences, learning management systems (LMSs) and Massive Open Online Courses (MOOCS). Although, there is a promising and rising eLearning activity, that many educators do not consider or pay attention to it such as the serious / educational games. In this master thesis, we will focus on the game – based learning as a learning activity and the serious games as a learning tool.

Game – based Learning

Games are a medium to transfer knowledge for decades. For instance, chess during the Middle ages was used to educate people how to analyze the different factors that will influence the process of an action, develop problem – solving skills and determination. This process is called "Strategic thinking" and is an international fundamental in thought process. Except chess, in 1812 Prussian officer were taught strategy through a game invented by Kreigsspiel. In the field of education, during the development of Kindergarten, mid of 1800s, Friedrich Wilhelm August Fröbel used as a pedogeological method the education through playing [12]. They used games, songs, and fairytales as educational tool, due to their nature that enhances students' fantasy and improved students' creativity, emotional awareness, and physical activities. Fröbel, believed that students are the focal point of the learning process and educators are just the instructors who help students discover their interests [12]. Against those who believed that playing hibernates kids, Fröbel was convinced that kids enhance their creativity and fantasy through playing, and as an outcome teacher can use games as a tool during the learning process.

Teaching is based on different techniques, used by teachers and students as well. Teaching or educating is the physical process that teachers transfer knowledge and information to students, and students absorb it and is divided into two categories. The "School teaching" and the "Physical teaching". On the one hand, "School teaching" happens inside the environment of a classroom, such as a school or a university and the learning subject, the learning material, and the learning process, are predefined in the curriculum. Learners are part of classes and section according to their age, learning all together without taking into account different needs, unique characteristics, talents or even more special needs. On the other hand, "Physical teaching" is the learning process

where people learn through their interactions with their surroundings and the world. Through socialization and exchange of opinions people learn and teach simultaneously. We can say that "Physical training" is complementary for the school teaching. In both phases of teaching types, games can play an important factor for learning.

Albert Einstein stated that "Play is the highest form of research". Through play, especially kids develop and practice in writing, reading, speaking, and singing, skills that work as fundamentals for their school readiness. Moreover, playing is the critical activity to discover the world and interact with, and gain mental, physical, and social skills, necessary for their adult life [13]. Plato also stated that the play of a small kid probably is the art or occupation that will follow in his/her adult life. Based upon the motives described so far, we can clearly say that playing and therefore games can contribute actively to the learning process and of course can develop students' skills, talents, and creativity [14].

Creativity is one of the most important characteristics of the human beings. Creative people ask, explore, experiment, find solutions and have emotional sensitivity. Creativity is innate and according to suitable tools and techniques people can develop and train this talent [15]. However, traditional teaching methods and systems many times destroy students' creativity and do not take into account their creative thinking, fantasy and thoughts. Rules, regulations, and restrictions destroy learners' creativity, and the traditional learning environments are made up entirely of them. Furthermore, teachers' attention is in subjects like mathematics, physics, and grammar, forgetting subjects like music, drawing or theater. But creativity leads on an amusing learning, not only for kids, but for adults too. When the learning process happens through an entertaining way, learners do not come up against something boring and compulsory [16].

Game based learning absorbs those concepts described before and applies them into the educational process. Learners can work in order to reach a specific target or goal, through decision and problem solving. Exactly as a game procedure works. The main concept of game – based learning is teaching through repetition, failure, and reaching goals [17]. Student/Player gradually builds up skills and knowledge, navigating through different levels of playing. Also, a challenging learning procedure could help to enhance player's awareness about new knowledge. These principles are also met into games and video games, but in game – based learning they also applied into a teaching curriculum. Flight simulators are a perfect example for game – based learning in contemporary learning processes. Pilots use them to acquire specific skills during their training,

while they are given specific goals to accomplish, facing different situations each time, designing, and executing the appropriate methods and procedures. During the 21st century game – based learning occurs from video games, and so we can characterize it as "Digital game – based learning" [18].

Digital Game – based Learning

In the previous paragraph we have presented the terms "Digital natives" and "Digital immigrants". Today's students are characterized as Digital natives, due to their immediate contact with the technological achievements and game – based learning transformed from board games like chess, to games that work in a computer environment. Due to this transformation, Mark Prensky defined the term "Digital – Game based Learning" [18]. Today it is easier to use digital mediums, like computer games, to provided knowledge and present educational material.

A typical video game, is an electronic software, including a graphical user interface, data, controls and an output on a screen. Players are interacting with the game material, and the game provides feedback for their interactions. The first video games were introduced in 1950s and 1960s, in room sized computers, while the next years video games were available only in specific places. Now, players can play games in their homes, using their personal computers, game machines, or their phones or tablets. The digital game – based learning makes use of video games to present educational material and teach [14].

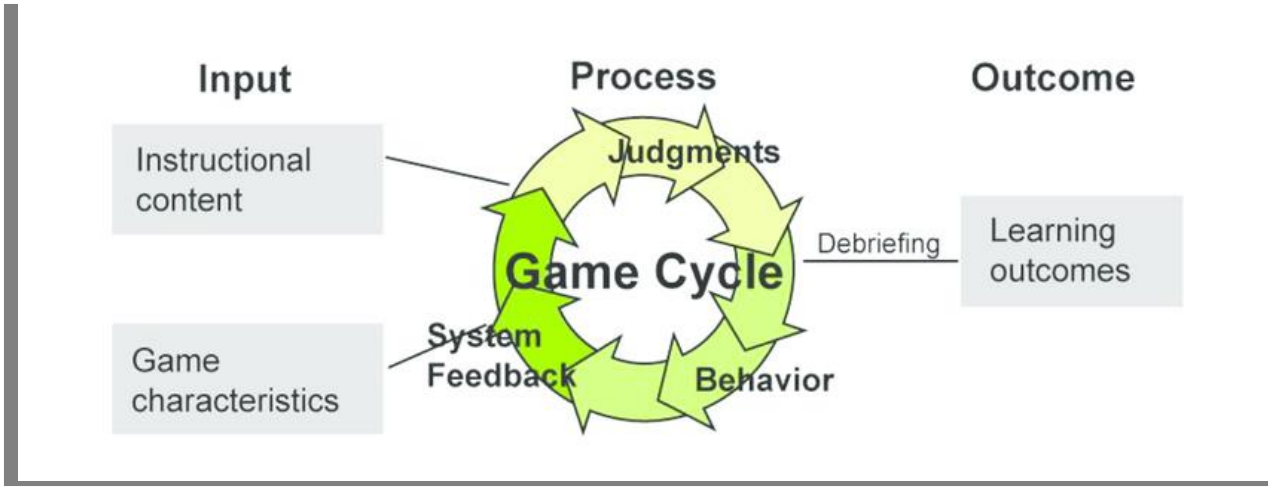


Figure 2 Digital - game based learning process [19]**.**

Gariss et al., introduced a model that presents the correlation of education and video games, as well as the integration of teaching inside the video games and describes how teaching takes place in educate – relating games [19]. The main characteristic of digital game – based learning is that educational material and therefore the lesson is part of the features of a game. Knowledge is absorbed during the repletion of the game. Learners during repletion face cognitive behavioral changes and exhibit different emotional states. The Figure 2, shows the connection between the learning results with the game cycle. According to Gariss et al., the model is divided into three main parts, the input, the process and the outcome [19]. The input module contains the:

- Instructional content: the educational material that will be displayed during the gameplay and the educational methods and tool that the video game supports.
- Game characteristics: factors that all video games share, like score, animations, sounds, graphics etc.

The process stands for the gameplay and all the events that occur during the game cycle. A digital game – based learning in order to be affective must base on a game that provides:

- Judgements: Learners during the gameplay face different situations. Many of them are more complex as others. Players need to follow a sequence of decisions to solve problems. The problem – solving decisions should be based on specific knowledge that learners already have or need to acquire during the gameplay.
- Behavior: Learners' behavior is affected during the game. Behavior can change according to different game states. For instance, when a learner enjoys the gameplay face a specific emotional state, the happiness.
- System feedback: Each game provides a feedback according to player's decision and interactions with the game environment. Also, feedback is also called output. Output describes a set of signals that presented on the player and affect the present state of the game.

The three modules described before are part of the game cycle. A game cycle can have more than one iteration during the learning process. Finally, the learning process and therefore the game finishes and the learning outcomes are extracted. These learning outcomes describe the learning impact that the process had on each student. Digital game – based learning often shares characteristics of gamification. Gamification and game – based learning are two different terms, although are tightly connected with each other.

Gamification stands for the integration of game design and game principles to non – game applications and software [20]. It can be applied to develop fun, engaging and effective experiences to any filed of industry, in order to motivate and challenge users. Table 1 below presents the gamification principals that occur in a non – educational application.

Table 1 Gamification principles.

Points	Levels	Challenges	Quests
Rewards	Leaderboard	Achievement Badges	Feedback
Progress	Conditions	Context	Complexity

Also, we can characterize gamification principles as gaming elements inside an activity. For instance, the gamification approach can be applied in the marketing field. The LinkedIn platform equates the development of a user profile as the development of a character in a role – playing game. In addition, the platform Foursquare implemented gaming elements like the point collection each time when the user visits a specific place. The user with the most points, was promoted to the "Mayor of the area", among the other users. In the context of a classroom and a learning process, gamification is the assessment points that a student earns, a badge like a sticker as a grading mark, or a teamwork project that learners should work as a team to solve tasks and reach specific goals. However, these examples cannot be described as games. They only use game elements to motivate users and therefore gamification is the effect of gaming philosophy in non-game environments.

On the other hand, digital game - based learning, describes the use of games as a learning process with defined learning outcomes. The philosophy between digital game - based learning refers to the ability of students to apply knowledge that learnt during the gameplay, in real world problems and situations [21]. As described before the learning process occurs inside a video game. The video games that have defined learning outcomes, called "Serious Games".

Serious Games

The term "Serious Games" or "Educational Games", describes the type of games, board or video games, that are designed and developed with the philosophy of learning comes in first place and then the amusement. Serious games first appeared and became popular in the 1960s and 1970s,

in the form of paper – based games. During the 2000s, the serious games started to gain ground with the rise of the computers, the internet, consoles, and hand – held devices and by the 2010s had become a trend in fields like the economy. In this master thesis, we will limit our work on the field of serious games that belong on the category of video games and they are known as digital serious games or digital educational games.

Serious games are responsible to educate people into a specific material, or to enhance existing knowledge [22]. Their design and development are based on the combination of learning and entertainment, as well as on the nature of the games to attract people. The elements and the different tools – techniques that we can combine to develop an effective educational – serious game, are presented on the Figure 3.

Figure 3 Serious games elements [23]**.**

The four interconnected elements that synthesize a serious game are, the educational content, the game techniques, the serious purpose, and the storytelling. Each one of these elements is detailed described below:

Educational content: As stated previously**,** serious games focus on the fact that education and learning come first and then the amusement. Each educational game must have defined learning

outcomes on a specific learning topic or learning area and students will use this serious game as the main learning process [24]. The teaching purpose should be clear to the student and each one should know what he/she is going to learn and what are the steps that has to follow in order to reach the available knowledge of the serious game. Also, in a typical teaching process that happens inside the environment of a traditional class, teachers have organized in a proper way the educational material for a specific subject. The better structured the learning material, the more understandable is from the learners. Moreover, the term content refers in educational theories and educational methods. Serious games should be consisted of appropriate educational theories and methods, according to their scope. The suitable theory and method will develop a robust and educational effective serious game, where students will assume and assimilate the provided knowledge in the best possible way [25].

Serious Purpose: Playing video games fulfills different purposes in humans' lives. People play video games as they need to entertain themselves, improve socializing skills, challenge, achieve goals, prevent boredom and monotony or simply to relax. But in case of serious games, the main purpose differs. Serious games have as main goal the education and learning. People play serious games in first place for learning a topic or a skill and in second place for the purposes that mentioned before[22], [26]. In simple worlds serious or educational games are willing to promote learning and behavior change, combining teaching and entertainment.

Game techniques: A serious game belongs in the category of video games. During the gameplay, players come in touch and interact with many and different game elements, to reach a goal or achieve a skill. Video game development, and as far as serious games development, in the context of a digital approach, concerns in first place a robust implementation of the fundamental elements of "Human – Computer Interaction (HCI)" field [27]. The field of HCI, studies the methods that software developers should follow during the development phase of a product, in order to ensure software functionality, usability and an enhanced user interaction experience. In serious games, studying and implementing HCI principles, helps to develop an effective educational game, with enhanced learning experience and efficiently learning outcomes. Also, video games and therefore serious games, should contain gamification elements. The Table 1 in the "Digital Game – based learning" paragraph, presents the different gamification principles which can be used in the context of an educational game. But video games, need to entertain learners during the educational process too. As mentioned before, students use serious games to educate themselves, but with an amusing

learning experience. So, graphics, animations, sounds, videos, colors, and pictures, are being used during the development of a serious game [32] (see Appendix A). Moreover, during the years many different implementation ways have introduced to develop games. Game developers use game engines during the development phase and develop either 3D or 2D games. Famous game engines are the "Unreal Game Engine", developed by the "Epic Games" company, or the "Unity 3D", developed by the "Unity Software Inc.". However, serious games can be implemented as web applications, using mostly JavaScript frameworks and libraries, as well as using cross browser application programming interfaces (APIs), like "Three.js" or "Babylon.js", able to develop and display 3D graphics in the context of a web page and therefore inside a web browser. Lastly, as the game development and the rise different game development programming tools continues, the different platforms that support game play vary. At the start of digital serious games development, learners were able to play only in computers sized as a room. Nowadays, players/learners play games in personal computers, smart devices like smartphones and tablets and even more in game consoles like "PlayStation", "Xbox" or "Nintendo Switch".

Fun and storytelling: Developing a serious game, we point three elements, the objectives of the goals of the game, the content, or the transferred information and finally the design of the game. These three elements are tightened together and combined to develop an effective educational game. However, these three elements need to be transferred to each student into a motivating context. During the learning process, learners should be excited to play the serious game and not facing it as a boring and a conventional teaching method [29]. For instance, the development of a motivating and entertaining character helps to keep the student interested during the gameplay. Also, the educational content should be presented through a motivating way. Serious games' designers need to consider the flow and the content of the story [25]. However, a successful serious game storytelling, needs a well pre - organized educational material, as well as already defined learning methods, objectives, and outcomes.

Through the years and the continuous development of technology and software, the use of serious games in different application areas and fields, is constantly increasing. The three main entities, "Learning", "Simulation", "Games" of the Figure 4below, are intersected with each other. Combining "Simulation" with "Learning", develops applications that can be used for training purposes. For instance, a motivation tool for health or nutrition. "Simulation" and "Games" provide applications that simulate real different world problems and activities. As mentioned

before, the most known simulation game is a flight simulator. Lastly, the combination of "Games" with "Learning", products the edutainment applications. Edutainment or educational entertainment uses application able to teach using entertainment. For example, an interactive 3D game about mythology.

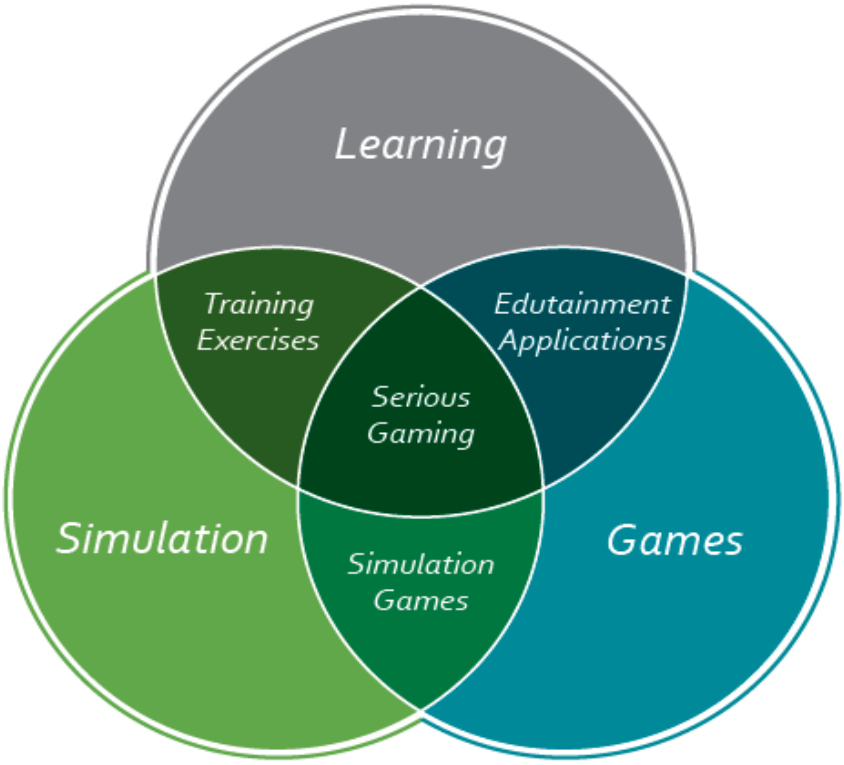


Figure 4 Serious games entities [30]**.**

Simulation games, training exercises and edutainment applications, are emerged from this combination. The focal point of all those products, is the field of serious games. As a result, serious games can be used for simulation, training and learning purposes, introducing serious games in different and separate application areas. The different application areas vary, and as a result we meet serious games as educational tool in areas like health or military, to education and culture. The below table presents the different areas that use serious games as tools or as mediums for an educational process, as well as the different purposes that serious games have in each application area [14].

Table 2 Serious games application areas.

Area	Purpose	Examples
Health	Training, motivation, treatment, prevention.	Operation simulation games. Motivation tools. Rehabilitation applications.
Politics	Advertising, policy making, social communication.	Environmental games. Urban planning games. Tourism.
Security	Defense, disaster control, crisis control.	Natural disasters simulation and crisis control games. Fire simulation games.
Military	Training, recruitment.	Flight simulators. Warfare battle scenarios.
Education	Training, teach, educate.	History – based games. Mathematics learn games. Lifelong learning games (electricians, coocking etc.).
Culture	Create and present interactive multimedia.	Archeological sites games. Museum tours.

As we can conclude from the Table 2 , serious games have many different application areas and many different purposes of use. The establishment of serious games as learning tools during an educational process, led to the development of many educational video games during the years, especially the last two decades when the use of personal computers and game consoles became popular and of course due to the rise on the Internet. Based on research, some of the significant serious games of all times are:

Flight Simulator (1982): Many, consider the flight simulator as the godfather of serious games. Since the 1982 when it was first launched, till 2020 when was its last release, it is considered as the best aviation simulator and the best one of the commercial flight simulators as it does not contain combat flight simulations.

IBM City One (2010): Players are facing complexities of city planning and city organizing situations. Players handle real – world simulations, like water and energy consumption or financial

problems and design solutions to solve complex situations. “City One” is addressed in occupations like civil engineers, city officers or economy officers.

Minecraft (2012): One of the most popular serious games like the “Flight Simulator”, “Minecraft” focuses on the creativity and building. Players build construction using cubes inside a 3D game environment. Players need to survive by gathering resources, explore, create and defend their world. Studies concluded that Minecraft, helped the development of players’ brain cells and also introduced kids into computer programming.

Sea Hero Quest (2016): The “Alzheimer’s Research UK”, the “University College of London”, the “University of East Anglia”**,** the company “Glitchers” and the “Deutsche Telekom”, designed and implemented a mobile game able to help researchers prevent and study dementia. Players through a sea journey taken by a son in order to recover his father’s memories that were lost on dementia, need to navigate, shoot flares and chase creatures. During the gameplay, the game extracts players’ data. The provided data were much more than those that can be obtained in a laboratory. Researchers studied the player’s data to prevent dementia.

To conclude, serious games are the medium for modern digital game - based learning processes. As software, they belong to the category of video games, but as main purpose educates, and amusement comes next. The find application in a vary of fields and as a result the context differs according to the objectives of each serious game. In this master thesis, we will focus on the digital serious games that used in the field of education.

Digital Serious Games in Education

In 1971 at the state of Minneapollis, the serious game called “The Oregon Trail” introduced in the field of education and became the first digital serious game in education. In approximately 40 years of its existence, the “Oregon Trail” sold nearly 65 million copies. As a sequence, it became the most popular education game of all times. During the late 1980s and early 1990s., the computer support instruction was rising, and educators were able to develop instructive games and tools using software like “Adobe Authorware” and “Adobe Flash”. The result was the development of games able to present and teach specific knowledge and skills, as long as the development of tools that simulate basic or complex concepts and procedures.

The effectiveness and the success of serious games led to the formulation of companies, expertizing in the design and implementation of educational games, and as a sequence to the establishment of an educational games market. The development of educational games led to the creation of a new entertaining and motivating learning process [31]. Learners were able to come in touch with fancy graphics, animations colors etc. and interact with the game objects [28] (see Appendix A). For instance, playing and learn math equations through a game is more entertaining, than doing math equations in a piece of paper. During that point, the term "Edutainment" was born. The "Edutainment", combines the entertainment and the education, using fundamental techniques to create entertaining learning environments and processes [32] (see Appendix A).

In the field of education, we should take in advance five main fundamental elements:

1. **Teaching priority:** A serious game is a game but its main propose is to teach or educate.
2. **Entertainment:** Serious game is typically a game, so it should entertain learners too.
3. **Information and Communication Technology:** The integration of ICT technologies in the field of education means and the use of video games during a towards a learning process.
4. **Multiple objectives:** During a learning process, serious games can be used for teaching, assessment, educating, training, or relaxing purposes.
5. **Addressed in different ages:** Serious games do not only exist inside the environment of a school. In the field of life - long learning serious games can be a powerful tool for learning purposes.

In addition, research have concluded to the pedagogical virtues of serious games. Evidence concluded that serious games pedagogical benefits are [33][34]:

Intrinsic motivation: As intrinsic motivation, is described the self – determined level of motivation a human can reach. In simple words, it is the personal interest that a human has for an activity. In the context of education, the challenge, the curiosity about an activity, the different options for manipulating an activity based on decisions and a fictional environment enhance learners' motivation. Furthermore, the competence is a characteristic of video games. In educational games, learners compete to each other, developing and improving their skills. And finally, the engagement of many players/learners in the same activity and their cooperation and communication motivates learners. When students are motivated and engaged in a play, it is easy to forget that they are part of learning process and by reaching the highest level of pleasure improves learner's creativity and significant learning outcomes and efficient cognitive efforts arise.

Situated Learning: Based on Jonassen et al., situated learning depends on facing real – world problems and situations [35]. Thus, the gained knowledge is based on real – world context. According to Piaget, learners construct and gain knowledge by interacting with the environment [7]. During the learning process, students are considered active, and they enhance knowledge individually, in their own way, based on their interaction with the environment that learning process occurs. Students are developing problem solving skills by completing tasks inside a competitive game environment. Finally, players/students collaborate within a group or a team. Wenger defined that team, as the group of individuals that face the same problems and work together to invent solutions [36].

Learning from mistakes: Astolfi mentioned that "error, then, becomes constructive instead of destructive". Serious games are based on the philosophy of test-error behavior [33]. Learners during the game play take risks and learn from their mistakes. As a result, learners improve logical thinking and problem - solving skills and, they can experiment in order to reach a goal. During the game play, student develops possible scenarios that can lead to a positive or negative feedback [33]. In case of negative feedback, students should reconsider the implemented scenario, redesign it, and repeat until they find appropriate solution.

The development of serious games especially for educational properties as well as the elements included on a serious game ecosystem are the same that described in the previous paragraph about serious games. In reference to, those elements are the serious purpose, the educational content, the fun and storytelling and finally the game techniques.

To sum up, learning process can be based on alternatives able to deliver knowledge and information. Available eLearning environments, game – based learning and serious games are the mediums of a motivating, amusing and effective learning experience, but always with emphasis on the education. Defined learning outcomes and objectives should be included and considered during the design of an alternative learning procedure. However, serious games, game – based learning, eLearning environments are not only a useful and robust tool for an alternative educational process. These mediums provide useful data and useful information that when is analyzed, useful conclusions about learners' behavior and the learning process itself can be drawn. These conclusions called "Learning Analytics".

Learning Analytics

The contemporary computer systems and application, and the use of internet, lead to the production of large collections of data. The field that systematically analyzes and extracts information based on these collections, called "Big Data" [37]. Data are being processed using application software and algorithms, and fundamental statistical methods. Big data analysis concerns the data capturing, storage, analysis, transferring, visualization and sharing. The usage of big data refers on the use of analytics, predictive or user behavior. The analysis of a large or a small sized dataset leads to the extraction of valuable information. In the context of education, the valuable information that occurs by the analysis of educational data leads to the extraction of learning analytics [38].

> *"Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs."*
>
> *Wikipedia*

Figure 5 Learning analytics definition [39]**.**

According to the learning analytics definition on the Figure 5 above, as learning analytics we define the ways that we can develop algorithms able to collect data, analyze data and draw conclusions about them. The processed results concern the behavior that a student has during an educational process. Moreover, analytics can provide significant insights not only for a specific student. Using learning analytics, we can provide results about future insights of a student inside a learning process and about the effectiveness of the learning process [40]. Learning analytics extraction is based on four fundamental methodologies [41].

1. **Descriptive Analytics:** Raw data are collected and parsed in such way to draw conclusions about something, making these outcomes understandable to the stakeholders. The use of a variety of historical data to make parallels, is referred to as descriptive analytics. The provided outcome answers the question "What happened?" or "What is happening?". To better understand patterns towards the data and evaluate metrics over time, data aggregation and data mining techniques are being used. In the field of education, learning analytics concern feedback gathered from students regarding satisfaction and graduation surveys, and

the available data are used to review and evaluate all levels of student lifecycle. Students' lifecycle starts from admission process to student orientation, to student enrolment, to assessment, to study, and graduation. Using descriptive analytics, we can better identify student's weaknesses or strength inside a learning process ort inside a teaching environment. Moreover, using descriptive analytics we can model possible outcomes in the near term. Providing future information, it is possible to maximize the positive results and minimize the negative ones. Descriptive analytics is the initial step in most organizations' data analysis, and in our case in the field of education, and it is a simplified method able to track the details about facts and what has already occurred.

2. **Diagnostic Analytics:** The data analysis is a deep – dive into the available data in search of useful knowledge and information, using advanced techniques and algorithms. Diagnostic analytics answer the question "Why did this happen?". Diagnostic analytics take descriptive analytics into account and move them a step further, by elucidating the causes for the available outcomes. Common techniques used in diagnostic analytics are that data discovery, drill – down, data mining and correlations. Data analysts identify the available data sources, that will assist them in interpreting the finding during the discovery process. The data investigation focuses on the concertation on a particular dataset. Using data mining techniques, analysts can get automated information from a large raw data set and find clear patterns in the data that will assess the nature of the investigation. Data analysts decide which data sources will be used, and in many cases, this necessitates searching for patterns outside organization's available datasets, meaning that possible associations on data can based on external sources. Inside a learning environment, diagnostic analytics are being used to identify learner's performance during the learning process, analyze patterns in order to produce metrics able to calculate students' engagement, to produce information and analyze the effectiveness of the learning process and design student support strategies.
3. **Predictive Analytics:** Using advanced statistical methods, data mining, machine learning and predictive modelling, it is possible to draw outcomes regarding future or unknown events. Predictive analytics answer the question "What will happen?", and based on historical data, analysts provide assessment of future incidents [42]. Advanced and complex algorithms provide patterns by analyzing historical data and presenting insights of what is to come. Predictive analytics are able to transform organizations. Organizations with a future picture

can predict possible outcomes or challenges. A form of intelligence is introduced through predictive analytics, making users able guide and design organization with the best possible way. Data scientists have developed multiple predictive models based on different objectives. The available models are presented on the Table 3.

Table 3 Predictive models.

Model	Usage
Forecast models	The most used model and it deals with the metric value estimation, predicting numeric values for new data based on historical datasets and input parameters.
Classification models	The most basic predictive model and categorizes data based on what has learned from historical data. Answers "yes or no" questions and aids in making decisions.
Outlier models	It focuses on those data that are un-ordinary inside a dataset. It detects odd statistics on their own or in combination with other metrics.
Time series models	It is consisted of a series of data entries, using time as input parameter. It uses past data to predict future outcomes using metrics.
Clustering models	It divides data into independent nested classes. It groups data based on same characteristics.

Inside an education environment, predictive analytics can be used to maximize semester enrolment numbers, to increase the rate of successful student graduations, to forecast student's failure or success, and to develop adaptive learning environments.

4. **Prescriptive Analytics:** Using advanced algorithms and machine learning techniques, prescriptive analytics can assist organizations in making informed decisions by analyzing raw data. Prescriptive analytics considers knowledge about future circumstances or scenarios, available resources, previous results, and current performance to propose a course of action or strategy. It can be used to make choices at any point in time, and answers the question "What should we do?" For its models, prescriptive analytics retrieves data from several descriptive and predictive resources and applies it to the decision-making process. This involves integrating present situations and weighing the implications of each action to see if the future will be affected. Furthermore, it may determine the implications of a decision

based on various potential scenarios. In education, prescriptive analytics can be used to enhance relationships between learners and teachers, improve learning environments and learning processes, increase student's enrollment and optimize student course roadmaps.

Analyzing educational data and drawing conclusions and results about them, led to the development of an engineering principle, called "Educational Data Mining". Educational Data Mining is an area that focuses on developing methods for exploring the specific and increasingly large-scale data produced by educational settings, and then using those methods to better understand students and the environments in which they learn [43]. If educational data are generated from students' use of interactive learning environments, computer-supported collaborative learning, or administrative data from schools and universities, often have several levels of substantive hierarchy, which must often be defined by the data's properties rather than being predetermined. In the analysis of educational data, time, series, and meaning are also essential considerations [44].

But why we should use educational data mining and learning analytics during a learning process? The answer is simple. Using learning analytics, it is possible to improve eLearning.

a. It is possible to predict learners' performance. The most important advantage of analytics is that they can show not only how a learner is doing now, but also how he or she can perform in the future inside the eLearning course. For instance, online facilitators can predict whether a particular learner is likely to fail the eLearning course, or whether the learner is likely to pass the eLearning course if additional information is given.
b. Learning analytics provide eLearning experiences based on students' personal needs. Learning analytics helps eLearning practitioners and online teachers to personalize eLearning experiences for each individual learner. For example, if data suggests that a learner is taking an unusually long time to complete an eLearning module, appropriate steps can be taken to provide the learner with more tailored instructional tools and eLearning course resources.
c. It is possible to increase learners' retention rates. Less learners will drop out or fail the eLearning course because more learners have the ability to boost their performance thanks to learning analytics data and intervention. If a learner is not doing well in an eLearning course, he or she is less likely to stay enrolled.
d. Learning analytics aid in the development of future learning process and future courses, as

not only current student is being supported but also the future ones. For example, if data suggests that the overwhelming majority of learners find one element of the eLearning course to be too challenging, the developers may modify the difficulty level of that particular eLearning module. Thanks to the data gathered today, this will result in more powerful and impactful eLearning environments in the future.

e. Finally, it is willing to achieve better quality of eLearning tools at a lower cost if it is obtained a comprehensive understanding of how eLearning courses and their related tools are used, as well as how learners acquire knowledge and which aspects of the deliverable are effective or not.

However, a huge obstacle of learning analytics occurs. There is a debate regarding ethics of "Big Data" and the use of "Artificial Intelligence"[45], [46]. Privacy, the issue of opaque "black box" algorithms, the possibility of training machine learning classifiers on biased datasets, and the risks of incorrectly predicting someone's actions are all topics of public and professional discussion. Moreover, questions about data access, user permission to record their data, the level of data protection in data storages, the data manipulating and the data ownership, are questions that concern between data analysts.

But as mentioned before, the field of learning analytics whether is used in a proper way, can change the completely the learning experience and the learning process itself. Moreover, we can draw conclusions about students' behavior and find hidden insights based on user data. Learning analytics occur in all different types of eLearning tools. Data can be collected and analyzed from educational resources like Learning Management Systems (LMS), Massive Open Online Courses (MOOCS), virtual classrooms, social networks, and online tests, but also in serious or educational games.

Learning Analytics in Serious Games

Games and therefore serious games are computer applications, and they can easily include modules able to collect data transparently in the gameplay. Crookall suggested two categories of data. The in-game data collection used for measuring a learner's performance and the in-game data collection used for evaluating the educational process, as well as monitoring learner's behavior, habits and activities during the gameplay and therefore the educational process [47]. The results of the data analysis and the reports must be available to the students for self – enhancement and self – evaluation. Moreover, serious games learning analytics can be used by the developers and the companies as feedback for improvement and new implementations.

However, the field of serious games learning analytics in not too "hot" for the serious games market. Costumers refuse to pay for modules and tools able to collect and analyze in-gamed data, characterizing them as useless code. This happens due to the essence of these algorithms that classifies them in the back-end part of an application, without fancy graphics, fancy graphical user interface elements, animations and interactions. In simple words funders pay only for what they see and do not pay attention that serious games learning analytics algorithms, modules and tool are able to extract valuable information on how learners reach the knowledge, how to improve the educational process and a serious game and to highlight each different learner's profile and skills.

Each game through the gameplay creates a lot of information about each different player's behavior inside the game. The field of game analytics is responsible for collecting and analyzing user's data from a game. In an educational or serious game though the field that is responsible for this procedure is the learning games analytics. Traces of player's interactions in a serious game are being recorder real time, without affecting the game's flow. Raw data can be stored in different formats, like databases or json files, but they must be in a readable form in order to be analyzed. The data can be recorded with three different fundamental ways [48]:

1. **Event based**: In this category are being included the data that occur when an event is triggered. In simple words, game produces event triggered data when something happens. For instance, when user's logs in the game can be recorded. Moreover, a user's interaction with a game's artifact can be considered as an event-based information.

2. **State based:** Game's information on this category can be recorder at a specific frequency, rather than at a specific event. For example, we can record repeatedly player's position on the virtual world, or player's life, or player's movement, or player's condition once per second. State

based events are usually used in MMORPG game, since player's avatar has always a different state while playing.

3. **Initiated events:** The last way to record data through gameplay, has to do with those data that can be switchable and can be enabled or disabled. For instance, it is not necessary to tracing player's position once per second when he is not moving, but only when his state is updated.

Many serious games are recording different data, like questions, interactions, completion in order to calculate the learning process outcomes. We can classify those data as static or dynamic. Static data are not changing overtime, while dynamic do.

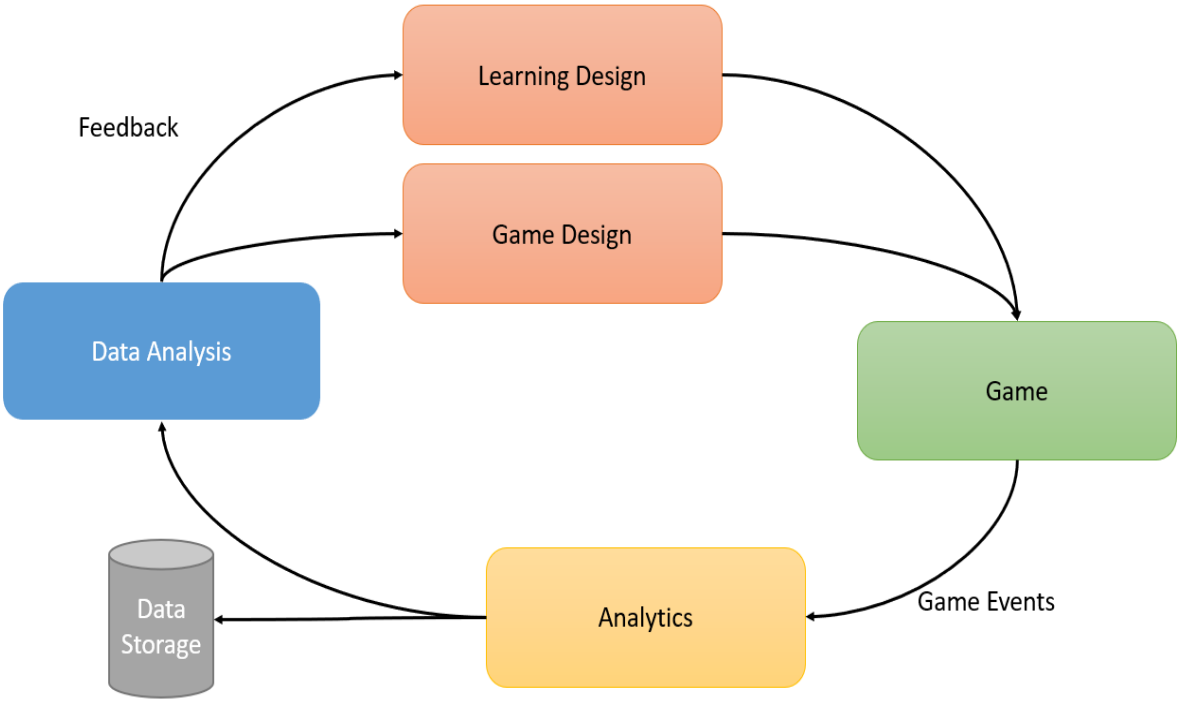


Figure 6 Use of Learning Analytics inside a serious game lifecycle.

Based on the Figure 6, we can see that game events produce raw data and data analysis produces information about learner's game experience and behavior during the game play. The validity and efficacy of these games in terms of their specified educational objectives must be observable and evaluated as educators and game developers. Analytics provide the opportunity to redesign the learning process in the context of a serious game, to be motivated, effected and have the best possible learning results.

The international e-Learning research, Ambient Insight presented in 2013, that the serious games development future is in the mobile devices sector. Mobile devices data collection is based on telemetry and user-generated data. Thus, the future is on location-based games, mobile augmented reality games and mobile learning services. Harmelen mentioned that with the new information, there will be a reestablished need to accumulate, consolidate, comprehend and anticipate what is to come – moving slowly from information driven evaluation to prescient appraisal [40]. Loh et all concluded that since the serious games are rapidly changing day by day and devices can collect different valuable data there is a demand of inventive approaches that can deliver noteworthy bits of knowledge for human execution estimation, appraisal, and enhancement [49]. However, there are some hidden insights that we can predict regarding a student's behavior inside an eLearning environment and of course during a learning process based on a serious game. These hidden insights are called emotions or affects. The field of learning analytics studies that develops systems and algorithms able to predict, recognize and simulate emotions or affects, is called Emotional Learning Analytics

Emotional Learning Analytics

Emotions or affects are an important marker, helping us to understand learners' different behaviors, how they study and how the acquire the knowledge. A very common strategy on collecting learning analytics is to code a dataset and extract information, like happiness, sadness, angry, etc. The extracted data can provide valuable information to the educators, as well as in research where they can use them to update existing datasets.

The affects recognition uses principals of the affective computing field and is based on machine learning algorithms. D'Mello mentioned three ways to detect learners' emotional states during an educational process in an eLearning environment. The affect detection based on event-based data, the affect detection from interactions and the affect detection based on differences on the body [50]. An experiment was developed, where learners were asked to study fundamental concepts of Python programming language through an eLearning environment. The experiment was based on recognizing several emotions but only engagement, confusion, sadness, surprise, boredom, concentration, and others. First, authors analyzed interaction events based on clickstream data along with each student's affect report and managed to identify differences between emotional

states on particular events during the learning process. On the other hand, in order to detect affects based on interactions, a supervised learning environment must be set up and automated affect detectors will collect data. As students interact with the affect detector, online human observers will provide real time annotations based on facial expressions, movement, gestures, and interactions. Finally, analyzing body signals can lead to extraction of valuable knowledge on an individual's emotional state. A very common to detect emotions is to analyze faces and upper body gestures. Emotions can be detecting by signals based on head pose, levels of brow's rise.

A vital component of education [51]and human development is the "Social and Emotional Learning (SEL)". SEL is the mechanism by which all kids and adults learn and apply the information, skills, and behaviors required to establish healthy identities, manage emotions, achieve personal and community goals, feel and display empathy for others, form and sustain positive relationships, and make responsible decisions. Via authentic school-family-community partnerships, SEL facilitates educational equity and excellence by building learning environments and interactions that include trusting and reciprocal relationships, comprehensive and substantive curriculum and instruction, and ongoing assessment. As a sequence, SEL will help to solve different sources of inequity and inspire young people and adults to work together to develop thriving schools and contribute to safe, secure, and just communities. Tracking the social and emotional learning with advanced analytics will help the development of learning programs, courses, processes, and environments that meet student's needs fast and effective.

Inside a learning environment, teachers believe that social and emotional learning, help learners to achieve goals regarding school, and afterwards in work and their lives. Students' cognitive growth and academic success are affected by the psychological aspects of learning [50]. Detecting learners' different emotional states, it is possible for educators to intervene, assist learner and create more personalized educational processes, according to each student's emotional profile. Moreover, developers by analyzing emotions and the use of machine learning and data mining techniques, can provide feedback about learners' behavior.

In Computer Science though, there is a need of developing intelligent systems, trained to detect and analyze a human's emotions and behavior according to detected emotions. Systems that are able and skilled to adapt, consider and respond on user's different emotional states are more effective and more reliable. As mentioned before, Rosalind Picard's book "Affective Computing" in 1997, is the landmark in this research area [52]. The Affective Computing Lab, in MIT that was

founded by Picard, developed machines able to detect, manage, explain and express affect. Emotions can be detected from many different channels that individuals use to perform impression and emotions. Emotional states can change by activating a series of responses on the neural system and thus making different expressions like facial, movement, gesture, and speech [53].

In the field of affective computing, emotions are captured by analyzing user's facial expressions, voice, gesture, or biometrics, such as blood pressure or heart rate. The collected data are analyzed from computer software and the computer estimates the emotion and provides a response. In order for the computer to estimate the emotion and provide a response there is a need of high-level machine learning knowledge. Thus, the last years many companies and departments have developed large databases relating to human facial interactions, patterns that are able to detect emotions, libraries and RESTful APIs, like Affectiva, IBM Watson APIs, CrowdEmoition, Google Cloud and others, available to measure emotions.

The Figure 7 presents a multimodal emotion analysis framework. Emotions can be categorized in subjective information, behavioral and psychological. The term multimodality contains those three categories that describe the different types of neural responses that can lead to different expressions.

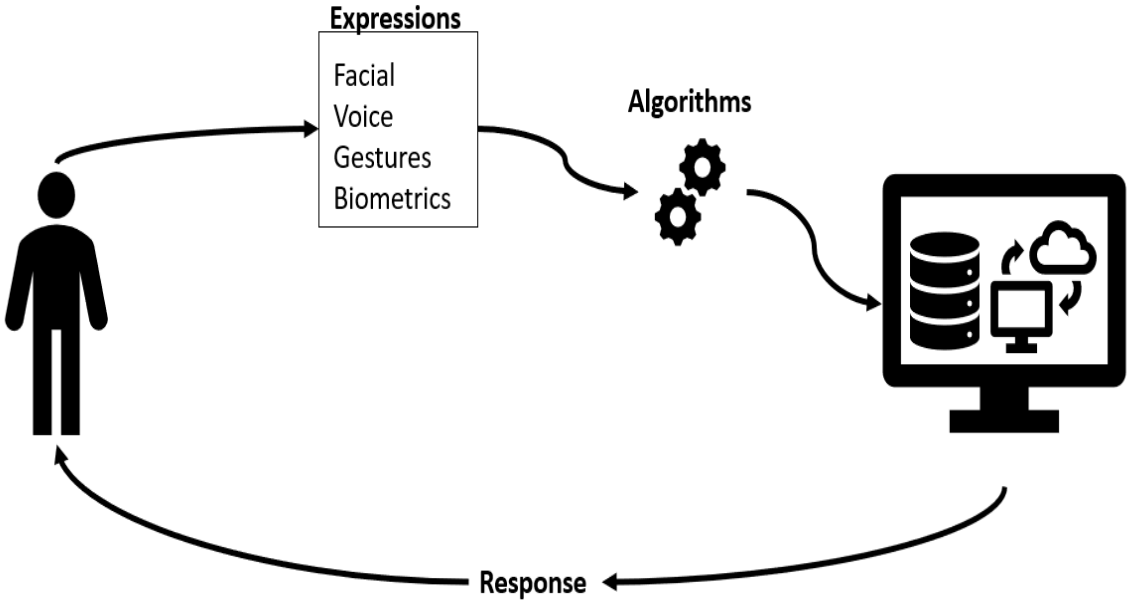


Figure 7 A basic multimodal emotion analysis framework.

According to Figure 7, a user can have an expression, an intelligent system can capture and analyze it, detect an emotion, and give a response to the user. An intelligent system like the described one before is based on big data analysis and cognitive computing. Within the large use of computers, smartphones, wearable devices etc., and the everyday use of the internet, the ways that data and information can be captured are becoming richer and richer. We live in the era where we have passed from the side of text-based information to the information can be gathered from images, videos, sounds and metadata like GPS position or timestamps. Combining the different ways of data, the high speeds of internet connections and the rise of cloud computing we can build huge datasets and develop data mining technologies. Cognitive computing is a way to handle and analyze the big data and a way to develop systems that imitate human logic. As Chen et all mentioned, cognitive computing can be described by four processes, the observation, interpretation, evaluation, and decision [54].

First, observation of information is the basis of cognitive computing. Individuals are gathering information and knowledge through their observation of phenomena and as well as from pre-existing knowledge gathered from education, observation and different experiences. The gathered information remains in memory and becomes knowledge. In cognitive computing, observation requires data collection from different data storages and different sources. Huge amount of data is collected and formatted in a way that can be able to be analyzed.

Next step is the interpretation. Interpretation is the ability to figure the data gathered from observation. As human, we have learned when we read to recognize words and explain them. In a cognitive system, interpretation is key for the identification, management and matching of individual information, to find relevant and valuable information.

The interpretation process is followed by the evaluation. Chen stated that “humans have the ability to evaluate evidence and apply it to solve different types of problems” [54]. A cognitive system can transform raw data information, to visualizations and pictures understandable from the user. Cognitive systems create visualizations at run time by event-based requests from the users. The visualizations are updated when new data and information are collected.

Last process is the decision. In cognitive computing decision making is based on taking actions, based on gathered data, heavily on evidence. Cognitive computing contains technologies and platforms based on machine learning, reasoning, human-computer interaction, computer vision, signal processing and artificial intelligence.

Based upon the motives of emotional learning analytics, affective computing, big data, and cognitive computing, it is possible to build intelligent systems relating on data gathered from human-computer interaction. For instance, an eLearning environment can be an intelligent system. Following the process on Figure 7, we can capture different user's facial expression from camera, voice expressions from microphone, gesture from sensors and camera and heart rate from biometric sensors. A cognitive system is able by following the processes of observation, interpretation, evaluation, and decision to detect user's emotions. By detecting user's emotions, an intelligent eLearning environment can response to the user by changing its interface. For instance, when a user is trying to answer a question and has given many times the wrong answer and the captured emotion of the user is anger or sadness, the system can respond to the user by changing the context of the specific question and making easier, or by giving some clues and help for the right answer.

Another remarkable example in affective computing can be in a biomedical system. Assuming doctors in a clinic are conscious for a specific patient with depression. Doctors have decided to capture videos of patient's behavior during the day. A system by analyzing the videos in the context of facial expressions, gestures, and movement it can predict patient's different emotional states. The system by visualizing properly the results and with the use of heavy machine learning technics, it is able to provide valuable information about the patient, based of course on evidence. Thus, doctors can have a clear detailed and structured view of patient's different emotional states and help him to deal with the depression.

According to what have mentioned until this point, we can conclude that we can detect and manipulate user's emotions from different sources, is a relatively new research field as well as is based on multimodality. According to Tao et al., the state-of-the-art technologies on affective computing, contain the speech processing, facial expression, gesture and movement, multimodality, and cognition [55][56].

Speech recognition

In affective computing the emotion detection from speech processing is based on prosodic features and quality features [55]. Prosodic features are the level, range, contour, rate and the nervousness of a human's voice. On the other hand, the quality features the quality of the human's voice that is going to be analyzed. Speech is affected indirectly from challenges in the nervous

system. These challenges can be transformed into valuable information in order to detect changes in different emotional stated based on speech. For example, talking in a state of fear, anger, or joy is faster and louder, with the tone of speech being stronger [57]. Other feelings, such as tiredness, boredom, or sadness, can lead to slower and lower speech tone [57]. Emotions can be detected by applying speech recognition patterns. Emotion speech recognition is used in dialogue systems in order to improve the way that the system responds. The improvement is based on the naturalness of the system's speech when is giving an answer. But the field of emotion detection from speech needs more improvement. It is true that humans are responding with different words, phrases, and syntactic structures. Therefore, an improvement on the language cognition is in need.

Facial expressions

Facial expressions are one the most common ways for individuals to communicate and express emotions. A common way to detect emotions from facial expressions is by analyzing video or pictures. Through the years there was a huge improvement in this field. Ekman and Friesen by developing the Facial Action Coding System (FACS), managed to categorize emotions in the context of six basic emotions, the joy, the anger, the surprise, the fear, and the sadness [56]. Also, the standard MPEG-4 provides nowadays methods that can be used for the creation of 3D facial models. Moreover, there have developed many analysis models that used in affective computing for expressions detection. Some they are the Fisher linear discriminant analysis (FDA) applied by Lyons, the principal component analysis (PCA), the Hidden Markov Models (HMM) and more [55]. However, there is an important issue on detecting facial expressions. The face expressions should be synchronized with speech when a human express an emotion. So first the speech must be analyzed and then mapping the face parameters with speech in order to extract emotion. The facial expression is still under re-search, but important and valuable improvements have been done.

Gestures and Movement

Body gestures and movement could be used effectively as a means of detecting the emotional state of a human [58]. Gestures are defined by the changes and the different positions of body arthroses. The gesture detection is based currently on hand gestures when the different hand arthroses positions can provide various information and various signs. Mainly there are two ways for gesture detection. The apparent-ness and the 3D modeling method. The apparent-ness method is based on analyzing hand features from 2D images. The 3D method on the other hand, detects

hand's gestures in a 3D environment [55]. Comparing the two methods, the apparentness method is easier and can be applied in real time environments like an application.

The body gesture and movement are based on the detection of arthroses different positions in the context of an image. But in order to detect different position of body arthroses there are some limitations, such as the simple background, the simple body movement, the use of manual initial points and the different colors according to each arthrosis. The detection is based on the use of anthroponomy knowledge. Gestures and movement detection are difficult in real time environments and also there is a need in the ex-traction of more robust results according to body language.

Multimodality

It is obvious that human to human interaction is multimodal, since humans can interact to each other via speech, facial expressions and gestures and express emotions by using those different channels. In human – computer interaction multimodal system is responsible for the improvement of the emotion recognition and to develop more powerful expressions [59]. Voice, facial expressions, or gestures are combined to identify a single affect. Multimodality in human computer interaction is widely used in smart rooms, virtual reality, biomedical applications, and eLearning environments. Different channels can be used to capture information and data. Applications have used facial data, speech data, motion and sensors' data and their combinations to analyze and detect emotions. The multimodal technology has been widely famous the last years, but the most systems cannot combine different channels and synchronize their data in order to process the information.

Affect Understanding and Cognition

Significant role plays the emotion understanding in an intelligent system. The affect understanding is consisted of processes for detecting data, memorizing information, capturing a human's mood and affects, building a complete model of human's behavior, updating this model and maintaining in. The most successful model for affect understanding is the OCC model which categorizes humans' affect as results of events, objects, and other agents.

Through the years, a huge progress in the development has succeeded in the affective computing field. Intelligent systems that detect facial expressions and changes on human's

different emotional states have benefited ongoing efforts to help individuals to struggle mental illnesses, like depression or autism. A research at the Imperial College of London's Intelligent Behavior Understanding Group by analyzing different emotional states using information from facial expressions together with audio and video, concluded that computer was able to detect affects that a human could not [60].

Another remarkable example is the Emotion & Pain Project. Using sensors, researchers managed to create algorithms that detecting affects from gestures and movement and measuring the level of pain that a patient feels. Knowing the level of pain algorithms will be able to recommend a different therapy for each different patient [61].

But affective computing has not only positive out-comes in the field of medical health. The North Carolina State University reported that in an eLearning session it is able to detect student's affects accurate by using the Computer Expression Recognition Toolbox (CERT). Thus, it was easy to estimate the validity of the educational process. This program was part of promoting the JavaTutor, which was able, according to students affects, to provide responses while they were learning Java [60].

Furthermore, another study was made by Eirini Christinaki, Nikolaos Vidakis and Georgios Triantafyllidis regarding the development of a serious game. In the context of the game, preschoolers with autism were taught different facial emotions in order to enhance their interactions with others [62]. The story telling of the game was based on showing images from different emotions and choosing the correct answer. The given images were based on the CAlifornia Facial Ex-pressions (CAFE) dataset. Using the Kinect, the student was able to choose the answer. Kinect is a gesture and movement sensor developed by Microsoft for Xbox 360 and was used in games. This example was not based on the detection and analysis of affects but is a different system that uses pre-existing knowledge and datasets in emotion detection, as well as gesture and movement detection as part of its development.

However, data privacy is one the major concerns in the field of emotional learning analytics. As mentioned before, data gathered are referring to different emotions and changes in the emotional states of an individual. This information is based on essential human behaviors and sometimes in subconscious emotions. Thus, it is obvious that humans are conceded if sensitive personal data like affects are detected, saved and pulled from different technologies relating to affective computing [63]. According to this concern, the MIT developed policies in order to protect

participants in affective computing research. There is a need, however, for an international standard that contains specific rules and guideline to manipulate intelligent systems in the affective computing field.

Another concern refers on the culturally based emotions. Individuals learn how and when to use the appropriate emotion interacting with their other individuals. The emotions differ according to nations and cultures, as long as in individuals with special conditions such as autism [64]. Affects based in cultural characteristics may weak the effectiveness that affective computing has.

Finally, always is the troubleshoot of financial issues. The cost of developing algorithms, datasets, systems that changes according to users' emotion requires expensive equipment that many cannot afford. Equipment such as sensors that calculate accurate result and computer specific software and specific hardware that can be used in affective computing, can be costed in high values. The continuing development of wearable devices such as smartwatches, can be a solution but there is still the need for further improvement.

To conclude, the prediction of different affects during an educational process varies according to the previous paragraph about affective computing, and emotions can be extracted from gestures, facial expressions etc. Moreover, emotional learning analytics, share the same fundamentals with learning analytics and the target field contains all the available mediums that construct an eLearning ecosystem. The next paragraphs of this master thesis, focus on the techniques that are being used to extract learning analytics, specifying and giving a detailed report to specific techniques that will be used in the software analysis, design and implementation chapters, as well as the ways to understand the extracted information will be presented.

Artificial Intelligence

Humans use consciousness and emotions, are thinking to solve real world problems and face real world situations. This is called intelligence. During the Word War II, the mathematician Alan Turing broke the encryption machine "Enigma" and helped Allied Forces to win the war. After some years Turing stated a simple but also a historical question: "Can machines think?". His work, entitled "Computing Machinery and Intelligence" and the "Turing Test or Imitation Game", in 1950s, are considered as the fundamentals of "Artificial intelligence or AI" [65]. At its core, "Artificial intelligence" is the field of computer science that aims to answer yes to Alan Turing's question. Artificial intelligence researchers try to emulate or mimic human intelligence in

machines and more specific in computers. Russel and Norvig in their work "Artificial Intelligence: A Modern Approach", characterized the artificial intelligence as [66]:

> *"Artificial intelligence is the study of agents that receive percepts from the environment and perform actions".*
>
> *Russel and Norvig (1995)*

Moreover, Russel and Norvig, stated four different approaches of artificial intelligence, the: "Thinking humanly, Thinking rationally, Acting Humanly and Acting rationally" [67]. The first two approaches are about logic and thinking patterns, while the others about actions. Norvig and Russel focused on logical agents who act to produce the best outcomes.

Nowadays, many people have become familiar with artificial intelligence and terms like machine learning or natural language processing are known in circles outside research areas. "Normal" people have come in touch with "Narrow Artificial Intelligence" and its products. Narrow AI is everywhere around us, and it is by far the most popular and simple application of AI today. During the last decade, Narrow AI has undergone several breakthroughs including social and economic benefits. The most famous Narrow AI application is the Google Search. It is known that Google uses AI, as it has developed its own Artificial Intelligence API. But almost all internet users, search terms in Google Search. The search engine of Google uses AI to manipulate data, based for instance on users' searches or users' GPS locations. Moreover, more examples of Narrow AI are image recognition software able to recognize objects on images or sentiments on faces, personal assistants like Siri and Alexa and self – driving cars.

But researchers, have defined four types of artificial intelligence [68]:

1. **Reactive machines:** About 25 years ago and especially in 1996, "Deep Blue" the IBM's chess playing supercomputer, beat Garry Kasparov and it became the first and perfect case of reactive machines. Deep Blue was able to recognize and remember all the pieces on a chess board and grasp how the move. It was capable to foresee its and its opponents' moves. Also, it was also capable to choose the right course of action from a range of choices. However, Deep Blue's actions and decisions were not based on the analysis of historical data to predict future, except

a rule that the same move could not be repeated three times and Deep Blue's actions were only based on present situation. Its functionality was to "see" the chess board the specific moment and design and choose the best possible move. Equivalently, Google developed AlphaGo, beating experts on Go game, using a neural network to evaluate game developments. Both machines' philosophy agrees on what Rodney Brooks argued that computers should use AI to recognize the universe explicitly and operate on what machines see and we should develop machines that behave like this. However, these machines do not understand the real world, which means that they cannot work outside of the specific tasks they were given and can easily get tricked. It is not possible for those AI systems to act different each type, and they respond in the same way each time they come across a similar scenario. By developing reactive machines, we are able to create trustworthy systems that behave with the best possible actions on the scenarios that were taught to behave in. However, this form of artificial intelligence is not what most of the people have imagined. If we want to develop robots to actually interact with and react with their environment and surroundings and also feel emotions like happiness or sadness it is not the best practice.

2. **Limited memory:** Intelligent systems derive knowledge and information from previous information or historical stored data and events. Compared with reactive machines, limited memory systems and computers, learn from past data and develop experiential awareness by observing historical events and information. These systems have preprogrammed representations of the world and by the observed information, they create temporary information and knowledge. For instance, autonomous cars have already installed information for lane markings or traffic lights and only used when a car wants to change lane or stop to a traffic light.
3. **Theory of mind:** The next frontier of Artificial intelligence in to develop machines capable to behave and adjust their behavior based on the ability to remember and understand emotions. As a sequence machines will acquire decision – making and problem – solving abilities just like humans. In simple words, the field theory of mind, will be reached when machines will behave just like humans. However, theory of mind, has not yet successfully developed. The main obstacle of

developing machines able to achieve theory of mind concerns the rapid alterations between sentiments. Machines cannot yet mimic these shifts and process them for communication. But, at the point that researchers will achieve to develop machines that have achieved the theory of mind, they will be a useful supporter for humans' everyday life tasks.

4. **Self – awareness:** If we imagine that the four types of artificial intelligence, are represented in a pyramid, self – awareness is positioned on the top of this pyramid. It is the final type of AI, it is the sequel of theory of mind, not yet achieved, but at the point when researchers will develop machines that have achieved the theory of mind, we will talk about machines that will have emotions and also will create their own mental states. At this point there are not available algorithms and hardware to develop for self – awareness AI, but when those systems will be developed, we will talk about machines that will behave the same way as humans.

Now, the only fields of artificial intelligence that researchers and scientists have developed, are the reactive machines and the limited memory systems. Researchers enhance the limited memory system and work on the theory of min, which is under research and under development. When scientists reach the theory of mind and self – aware AI, we will talk about Artificial Superintelligence (ASI).

However, artificial intelligence from its start faces some huge argues, from researchers and public. The most common question is what the result will be if the machines develop high levels of intelligence and become unmanageable from humans [69]. For many this is a scenario from a sci – fi movie, but it's a common discussion on Artificial intelligence ethics. Other debates on AI ethics are if robots should have the same rights as people or what about if robots hack humans' privacy. And finally, there is a huge debate regarding how the AI systems and machines will affect human employment. Today, many industries use automated systems to do certain jobs. If the AI reach a level that robots will be autonomous entities, may replace human resources and push people outside workforce. But, as the AI is still initial and research phase, it is a good point to reconsider these thoughts.

Beside the ethics, artificial intelligence has been introduced in different organizations and aspects of our lives and developed AI systems are being used more and more every day. The Table 4 presents the organizations that AI is being used nowadays [70].

Table 4 Artificial intelligence applications.

Field	Usage
Transportation	Autonomous cars will one day transport us from place to place, despite the fact that are on an early development phase yet.
Manufacturing	AI robots will help humans and work alongside with them, to perform a variety of tasks, like assembly and stacking.
Healthcare	Diseases are more easily and correctly diagnosed, drug development is sped up and streamlined, virtual nursing assistants track patients, and personalized patient experiences are developed.
Costumer Service	AI assistants will help organizations in completing organization tasks, such as appointments scheduling and making phone calls.
Media	AI assists in the interpretation of complex financial reports, and Natural Language Processing algorithms, automate the process of producing earning reports.
Communication	Speech recognition, dictation and communication technologies improve employees' efficiency and productivity. Also using AI, humans are able to interact even more effectively.
Education	Educational material is digitalized using AI technologies. Also, AI tutors can support the educational process, AI algorithms recognize students' emotions using facial or speech recognition and AI systems can provide a better and personalized learning experience based on students' needs.

According to the Table 4, artificial intelligence has application in everyday fields of human life. As this master thesis concerns the education and learning field, we will limit our work on how AI is used in education and especially in eLearning environments, and in addition how AI is interconnected with learning analytics which is the main of this work.

An effective eLearning environment should motivate students and help then reach knowledge [6]. AI algorithms can generate new learning content and update the eLearning environment. Using web crawlers, it is easy for an algorithm to identify outdated or difficult for the students learning material and search in the web for new. Moreover, AI systems can work as tutors during an eLearning process [71]. There are cases, where students are not answering questions about the subject, either because teacher is unavailable, either because they do not want

to interrupt the learning process or because there is a fear of looking unintelligent. As a result, learners could not clear their doubts and the learning content remains incomprehensible for them. Using AI, researchers and developers have managed to implement tutoring systems able to answer questions and find solutions on the fly. If an AI system is trained properly with huge amount of data and information, students can just ask the AI and receive the appropriate answer, avoiding wasted time searching on the Internet. Also, AI tutors or AI assistants, can use "Natural Language Processing (NLP)", for immediate communication with the student. Using NLP techniques and algorithms, developers can implement systems able to recognize and process human languages. Imagine the same eLearning environment able to communicate with all different users in their native languages.

A main advantage and vital concern regarding the effectiveness of an eLearning environment is the personalized learning. Using artificial intelligence, eLearning environments can deliver the same information, educational content and knowledge in each student based on his/her need. For example, AI can analyze historical data about learner's behavior during the learning process and based on the results can alter the learning material. In addition, AI is able to track learners during the process and identify the areas of lack and alter the learning process. Thus, learning becomes student – centered and it is not a one-size-fits-all approach while there are learners with different ways and pace that gain knowledge. But AI, is not only able to alter the learning process. Using artificial intelligence, we can improve accessibility in eLearning environments to students with special needs. AI can be used to transform spoken language into text using Natural Language Processing algorithms for people with hearing problems or transform the eLearning environment's GUI for partially - sighted learners or use voice commands with communication with the eLearning environment for students with mobility issues.

Artificial intelligence is vital for data analytics, and therefore for learning analytics. Data analysis is the process of transforming a raw dataset into useful information. The automation of data analysis process is based on AI. In the field of learning analytics, AI can be used to draw conclusions about students' behavior during the learning process easily and fast, and also to predict future outcomes. All the learning analytics techniques that are presented in Table 4 in paragraph 3.2 can be implemented with AI algorithms to automate their processes and their functionality. For instance, affective computing is based in AI. Computers are recognizing emotions in an image, using a pretrained model (historical data) and analyzing based on this model the input image.

Moreover, inside a serious game, we can use AI to track and record players' behavior and interactions during the gameplay.

However, artificial intelligence in eLearning and learning analytics faces the same ethics' issues that describe before. Implementing intelligent tutoring systems, it is possible to abrogate the role of the teacher and therefore a human expertise will be disappeared. Also, the student's personal data and information are exposed if ai hack student's privacy. And a huge issue about AI and learning analytics, regards the collection of data and if students are willing to let automated algorithms to track their behavior inside an eLearning environment, or a teaching process or a serious game.

But, if we imagine that we use artificial intelligence without exaggeration and we consider only the benefits of it, in is possible to take eLearning environments to a whole new level of experience. In this master thesis we will focus on artificial intelligence methods and techniques for:

- Analyze face videos and extract emotions.
- Analyze audio clips and extract emotions.
- Analyze text messages and extract emotions.
- Track learner's behavior during the gameplay of a serious game.

The four bullets above are using artificial intelligence research fields and techniques of machine learning, text mining, process mining. We concluded to focus on these methods due to the available data that we had at our disposal for analysis. The next paragraphs are giving an overview of the different techniques which, based on the bibliography, are being used to extract valuable information about a student's behavior and also we describe the research fields that we used for the development of this master thesis and the techniques that we can use to visualize the extracted data into a proper and understandable way.

Existing Techniques for Extracting Learning Analytics

Leitner et al., classified the available techniques that are used to extract valuable knowledge and information about students' behavior inside a learning process. Adapting their conclusions, the Table 5, presents the twelve different techniques that developers can use to implement intelligent systems algorithms and automated processes able to track learner's behavior inside an eLearning activity [72]. As mentioned before, from all those techniques above, we will focus our

work in three of them according to the provided data. More specific, machine learning will be used to develop emotion detection on videos and audio files, text mining will be used to develop emotion detection on chat messages and process mining will be used to track learner's behavior inside a serious game.

Table 5 Learning analytics extraction techniques (Leitner, [72]**).**

Techniques	Applications
Prediction	Predicting learner's performance behavior.
Clustering	Grouping learners according to similar characteristics.
Outlier Detection	Detecting learners with special educational needs.
Relationship Mining	Detecting learners' difficulties based on their behavior analysis.
Social Network Analysis	Analyzing learners' behavior on using communication tools.
Process Mining	Extracting data according to learners' traces inside the educational process.
Text Mining	Extracting data by analyzing text from forums, chats, emails etc.
Distillation of Data for Human Judgment	Visualizing and analyzing learners' tasks.
Discovery with Models	Extracting data by using machine learning models and learners' psychometric variables.
Gamification	Analyzing data depending on score, achievements and techniques that used to develop a more motivating end playful learning process.
Machine Learning	Extracting hidden students' insights by using complex algorithms.
Statistic	Analyzing data for decision-making.

Machine Learning

Machine learning is defined as the field of Artificial Intelligence that concerns the development of algorithms able to learn from training data and make predictions based on their knowledge. Those algorithms are making predictions without being specifically programmed to do so. Machine learning algorithms are classified in supervised, unsupervised, semi – supervised and reinforcement algorithms [65][73].

- **Supervised machine learning algorithms** base their future predictions in past learnt data. They start their analysis from a known dataset with labeled data and train data to produce an inferred function that can be used for mapping new examples. In simple words, supervised learning is where there are input values (x) and an output value (y) and we use an algorithm to learn the mapping function $y = f(x)$ from the input to the output. It is called supervised since the functionality of the algorithm learning from a trained dataset like a teacher

supervises a learning process and the learning stops when the algorithms reach an acceptable level of performance.

- **Unsupervised machine learning algorithms** is when there are no corresponding output values but only input data. These algorithms investigate how systems can infer a function from unlabeled data to present a hidden insight. Using datasets, the system can examine secrete patterns inside data and describe a hidden structure.
- **Semi – supervised machine learning algorithms** are something between supervised and unsupervised algorithms. They use both labeled and unlabeled data for training and are able to improve learning accuracy.
- **Reinforcement machine learning algorithms** are interacting with their environment by producing actions and searching for errors. Delayed reward, trial and error search are the common characteristic of reinforcement algorithms. They allow machines to detect the ideal functionality and behavior in order to maximize its performance.

Using machine learning, it is possible to manage and analyze massive data quantities and deliver accurate results in different research areas. The Table 6 presents the top applications of machine learning that are sweeping the real – world [74].

Table 6 Machine learning application types.

Application Types	Usage	Type
Traffic prediction	Predicts the traffic conditions based on past data or real time events.	Supervised / Reinforcement Learning
Product recommendations	E – commerce applications use machine learning to recommend and advertise products based on costumers' interest.	Unsupervised Learning
Self-driving cars	Using machine learning to detect people and objects.	Reinforcement Learning
Email Spam	Filters are using ML to categorize an email as a spam, important or normal.	Supervised Learning
Personal Assistants	Google assistant, Alexa, Cortana, Siri are using ML algorithms to use interact with humans by using voice instructions.	Reinforcement / Unsupervised Learning
Fraud Detection	Feed Forward Neural network helps customers to perform safe online transactions, by detecting fake accounts and ids that can steal money.	Supervised Learning
Stock Market Trading	Long short - term memory neural network for stock market trends prediction, due to ups and downs in shares.	Supervised / Unsupervised Learning
Automatic Language Translation	The most common translate platform is the Google Translate, where Google's GNMT (Google Neural Machine Translation) automatically translates a text into a familiar language.	Supervised / Unsupervised Learning
Weather Forecasting	Machine learning algorithms can predict future weather reports based on already predictions.	Supervised Learning
Medical Diagnostcis	Intelligent systems, using ML, can predict diseases and help doctors in diagnoses, for instance cancer of brain tumors.	Supervised Learning
Games	Introducing human, adaptive, and intelligent behaviors to non – player characters (NPCs) and enhances the gameplay, experience and decision making.	Reinforcement Learning
Speech Recognition	Algorithms able to convert speech to text and extract emotions from speech.	Supervised / Unsupervised Learning
Image Recognition	In image recognition, machine learning is used to identify objects, places, persons, faces, emotions etc. It is one the most common uses of ML.	Supervised Learning

State of the Art Machine Learning Applications used in this Thesis

For this work, the data analysis concerns videos, audio, and text, due to the available data. As mentioned already, we will focus in extracting learners' sentiments from the available data sources. As a sequence, machine learning will be used for image, audio and text analysis and based upon the motives of Table 5 and Table 6 we will use image emotion recognition, speech and text sentiment analysis and the developed algorithms will be based on existing implementations or systems that will be modified to fit our needs.

Image emotion recognition

First, image recognition is also known as computer vision, is a technique that aims to develop algorithms that behave like the human visual system. It refers to a group of algorithms and technologies that aim to analyze images and recognize the hidden representations of features behind them, then use these trained representations to perform tasks such as automatically classifying images into various categories, determining which objects are present and where in an image, and so on [75]. Image recognition is based on image processing stages like image import, image analysis, image manipulation and image output.

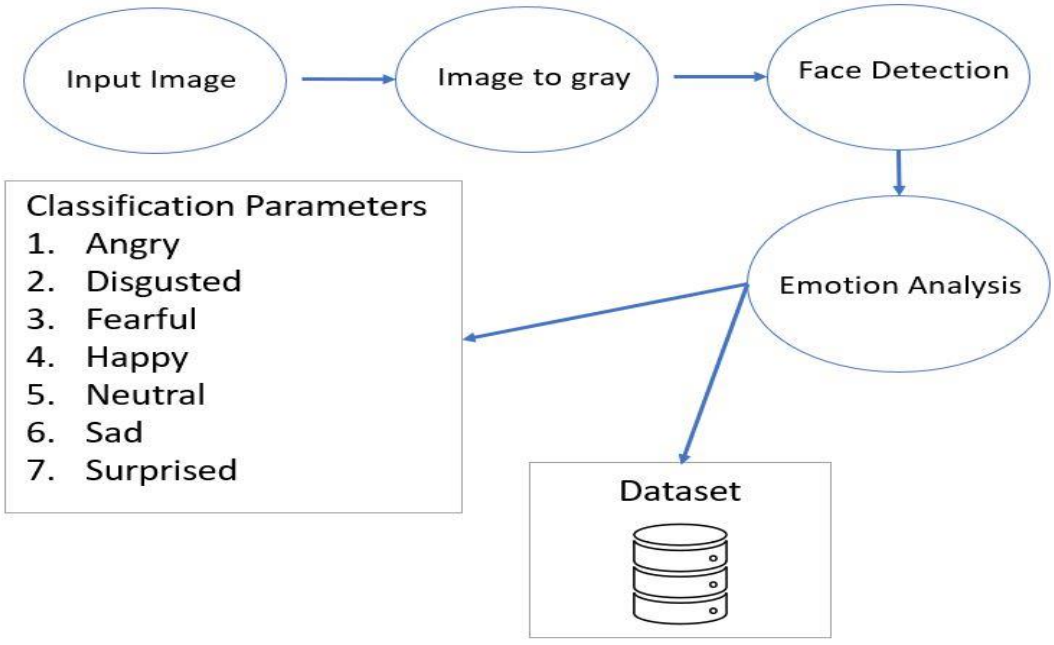


Figure 8 Emotion recognition from image[76]**.**

Using image recognition, it is possible for software to detect and identify objects, places, actions, people, or text in images. In addition, image recognition can be used to provide meta – tags be labeling the image content, perform image search or guiding robots and autonomous cars. In this work we will focus on using image recognition and image processing to detect person's emotions in images.

A human's face is the most exposed part of his / her body. As a result, computer vision systems to analyze images and recognize emotions. In this work, we will devote every effort to use and augment already developed algorithms that use image processing to detect faces in images and extract the face's sentiment, using OpenCV. According to Puri et all. and adapting their philosophy, we will develop an image emotion recognition module based on the flow diagram presented on the Figure 8. Based on the literature, as well as on existing developed algorithms and projects, found especially on GitHub and Medium code repositories we concluded that the face detection will be based on the Haar Feature - based Cascade Classifiers, using the "haarcascade frontalface default.xml" and the "haarcascade eye.xml" [77]. As Ahmad mentions, the cascades are XML files that contain OpenCV information to detect objects in images. OpenCV supports several built – in cascades, that detect eyes, mouth, hands, or legs [77]. The input images are converted into grayscale mode. For each image we use the above cascades and OpenCV functions to detect the face. When the face is extracted, we will use the FER-2013 dataset to train the model that extracts sentiments [78]. We will base our development on the open - source image emotion recognition algorithms developed by Arriaga et al. [79]. The implemented algorithm will be able to detect seven emotions – angry, disgusted, fearful, happy, neutral, sad, and surprised, as described on the flow presented on the Figure 8. Moreover, the image emotion recognition, will be based on video files data sources. According to Singh's. conclusions, the module will divide the video into frames and for each frame will execute the emotion recognition procedure described on Figure 8 [80].

Speech sentiment analysis

The second application of machine learning that we will highlight on this work, is the speech recognition and more specific the speech sentiment analysis, the field of computer science that works on the development of computers or any other type of machine, with functionalities and

processes able to identify and analyze humans' spoken words. Speech recognition is often used for medical dictation, voice commands, speech to text systems and personal assistants [81].

According to Naziya et all., Before any computer can understand voices, a microphone converts humans; sounds into electrical signals [82]. The electrical signal conversion into digital signals is done by computer's hardware devices, for instance the sound card. Once the digital signal is converted an implemented computer algorithm analyzes it and identifies individual parameters, which are the fundamental building blocks of speech and the occurred parameters are finally converted into words. However, algorithms sound relies inside the context of the speech because many words are sound alike. More specific, many algorithms perform automated context analysis using trigram analysis that combines two words with the probably appropriate third one. For instance, if a human says, "who am", algorithms identify that the next world will be "I". But in speech recognition the human observation and intervention sometimes is crucial. Algorithms that perform speech recognition, are based on trained dataset that include a huge amount of reading aloud sound samples.

A significant field of speech recognition is the identification and detection of emotions in humans' speech. According to Hartman et al., It is considered as one of the most promising and challenging topics in computer science and as one of the significant topics in Human Computer Interaction (HCI) field [83]. In humans detect the emotional states in voice is natural. But for computers it demands high accurate algorithms and models. As described before, in order a computer to recognize speech should follow several phases. So, and for the emotion recognition in speech. According to Selvaraj et al., the initial phase pre – processes the sound and identifies the speech and applies noise reduction filteringand afterwards, using Mel – frequency cepstral coefficient (MFCC) algorithms, the system extracts features [84]. The resulted features lead to the development of emotion – filled testing and training datasets. Emotions are concern the humans' emotional stages of Happiness, Neutral, Sadness, Fear, Surprise, Disgust and Anger. Based on Issa et al., The features are used as inputs for one-dimensional Convolutional Neural Networks, which use samples from the Ryerson Audio-Visual Database of Emotional Speech and Song (RAVDESS), Berlin (EMO-DB), and Interactive Emotional Dyadic Motion Capture (IEMOCAP) datasets [85]. Finally, utilizing Support Vector Machine (SVM) classifiers algorithms detects the emotion.

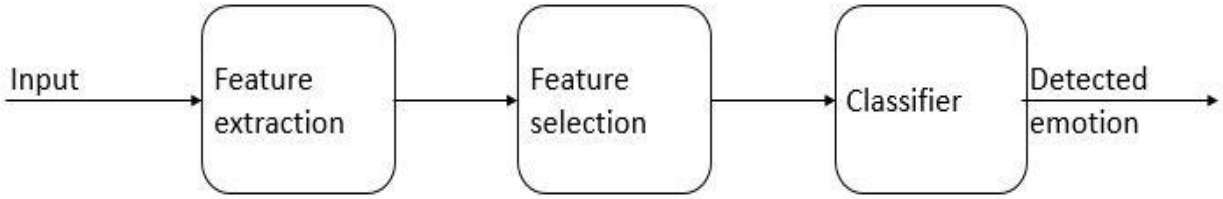


Figure 9 Speech sentiment analysis process [84]**.**

The described process of speech sentiment analysis, as well the proposed implementation described by Selvaraj et al. in Figure 9, are adapted and implemented in this work. Already developments found in GitHub, Medium, as well as on Data-Flair code repositories were followed towards the development of the SER module of this work. Also, based on Livingstone and Russo the dataset that was used was the Ryerson Audio-Visual Database of Emotional Speech and Song (RAVDESS) and the available speech audio files, were extracted from face students' video [86].

Text sentiment analysis

The final use of machine learning application in this work, concerns the analysis of the text and the emotion extraction from sentences. In addition to image and speech, computers are able to analyze text inputs and draw insights about the input and provide useful information, many times high – quality, for the input text. Text – based sentiment analysis, focuses on the feelings that cause people to write down specific words at specific moments [87]

Machine Learning Algorithms are based on the classification texts into various emotional states. We can detect emotions in text either with supervised or unsupervised learning techniques. According to Canales et al., supervised ML algorithms have been commonly used in text-based ED problems and have provided significantly higher detection rates than unsupervised ML techniques [88]. However, there is an argue on where we can apply machine learning for emotion recognition. It refers to whether the behavior is predictable or not.

More specific, languages' syntactic and meaning value are unaffected through the years. Words meaning do not change an as a result humans' ability to map emotional states is not affected. According to Seyeditabari et al., if a word is associated with an emotion inside the context of a

sentence, that word is generally associated with the same emotion in other sentences [89]. For instance, “Mark is happy” or “Happy holidays”. In both sentences the word “happy” is associated with the same emotional state. On the other hand, many times there is not a unique correspondence between words and emotion do not associate with the same state. For example, the sentence “I am so sad” and the sentence “Yes you are so sad”. Between those two sentences we understand that the word sad is not describing the same thing and the meaning of the two sentences differs. As a sequence, in many cases text emotion detection and recognition requires humans’ observation.
According to existing implementations found on GitHub code repository and based on Kumar et al. developments, we broke complex sentences into simple sentences, removed and ignored single characters and used the VADER lexicon to detect the sentence of each sub - sentence.

Techniques for Analyzing Learning Analytics

The data collection and analysis phases are followed by the explanation of them and the learning outcomes mining. Once the data are collected and analyzed, there are two techniques to draw outcomes, the data visualization, and the data mining [32][1] (see Appendix A & C).

Data Visualization

It is commonly accepted that colors and shapes catch our interests. Humans’ eyes are teased by colors and as a result observing colors and shapes, we can recognize and patterns. In the field of computer science, data visualization uses colors and shapes for visual representation of data and information, and it is considered as another kind of graphic art. Our eyes are kept gazed fixed on the message and we can easily spot patterns and outliners. Data visualization is a constantly growing field that applies graphs and charts for data representation. In simple terms using graphs, we can make data and information more understandable.

The field of data visualization increases and gets stronger every day. Contemporary computer systems and software and the internet as well are responsible of a huge amount production every day (Big Data), and as a sequence we live in data driven world. Professionals’ ability to use those data, to develop stories that answer who, what, when, where and how, becomes a fundamental in industries like economics, politics, education etc. When humans think about data visualization, the first imagine bar charts or pie charts, but there are more many data visualization types / methods that are presented on the Table 7.

Table 7 Data visualization methods.

Area Charts	Circle View	Matrix	Radial Tree	Streamgraph
Bar Charts	Bullet Graphs	Network	Highlight Table	Histogram
Box plots	Gantt Chart	Polar Are	Scatter Plot	Text Tables
Bubble Cloud	Heat Map	Treemap	Cartogram	Timeline

All the data visualization methods presented on the Table 7, aim to deliver information inside a clear and effective context. Information should be clear and understandable, and therefore people should be able to draw conclusion easily for what they see in the graph. As a result, data visualization scientists, should emphasize on the aesthetic representation of information and on the graphs' functionality. The data visualization process is based on a model with four stages, where the first stage is the data collection, the second is the data observation, the third is the data indicator and the fourth and last stage is the one that is presented to the final user and is the behavior stage.

The two main categories in the visualization concept are the data visualization and the information visualization. The data visualization presents the data in the context of tables, charts, histograms, plots etc [49]. On the other hand, information visualization makes it easier to understand the data by using entity relationship diagrams, trees, data flow charts etc [49].

Data visualization fields is on the rise and extends from simple visual representations to representations applied to complex mathematical models. In the field of digital education, data visualization could be a useful tool for presenting data gathered and analyzed for eLearning environments, activities, questionaries, teleconferences, or serious games and transform them into valuable and understandable information available for both teachers and learners to draw conclusions.

Data Mining

Data mining is a method that draws automated conclusion without the use of the human mind. It is based on categorization algorithms, techniques of machine learning, neural networks, artificial intelligence, statistics, and databases. In the context of learning analytics there is a category called "Educational Data Mining", that follows the data mining principals and techniques [50]. In an eLearning environment it is possible by analyzing data to make conclusions about students' educational level, help on students, improve the educational process and identify problems on educators' performance. The point of data mining is the extracted knowledge to be structured and

reasonable to human and enable him to settle on the correct choices. Data mining performs six main steps in order to extract information:

- Classification – Assigns a class to an object based on its attributes.
- Regression – Real life prediction for an object based on its attributes.
- Clustering – Categorize the objects by finding similar groups.
- Summarization – More descriptive, it an outline of the information.
- Association – Reveals conditions between the objects.
- Anomaly detection – Find changes that dependent on recently gathered information.

Making a two-layer structure, the described before concept of information visualization comes first and then the data mining.

Learning Analytics Specifications

In this section we will try to identify different standards and specifications which have been developed able to present the extracted data in a formal way. Learning analytics specifications can manage two categories of data: static data those that do not change over time and dynamic data that are been updated in the context of time.

First, SCORM specification is a worldwide standard, developed by ADL back in 1999 and used to develop learning analytics [32]. The SOCRM specification used to track learners' behavior in a serious game, and it was able to record learners' progress, answers in questions, interactions, completion, and success status. Also, SCORM was able to record learners' interactions and their different objectives in the gameplay of a serious game. However, SCORM was able to capture interactions but was unable to analyze them. Thus, Activity Streams specification was developed.

Activity Streams managed to create data in the form of triples actions, actors and verbs. Each triple has the philosophy of "who did what". This specification was applied to capture different interactions and behaviors in the context of social networks. The later specifications of IMS Caliper and the Experience API (xAPI) were based on the structure and the philosophy of the Activity Streams specification.

The IMS Caliper specification was developed to present learners' interactions in an educational environment. Developers are structuring the recorded data in the form of actor, action and object. Data are defined as metric profiles in the IMS Caliper specification. Profiles are containing vocabulary that developers can use to present learning analytics. Although, the IMS

Caliper provides simple vocabulary and making developers able to present only simple data and not more complex and extended information.

The drawback of the IMS Caliper, was solved by the development of the Experience API (xAPI). The Experience API was developed by Rustici Software, a company experienced with SCORM and hired by ADL in 2011. It is based on the philosophy of "who did wat" by using statements with actors, verbs and activities and more detailed information like results, timestamp, date etc . The recorded statements are saved in a Learning Record Store, a database responsible for receiving, storing and retrieving learning data. The huge advantage of the Experience API is the no limitation concerning the vocabulary that developers can use. Beside the vocabulary of verbs and activities provided by ADL, developers can build their own, recording almost every learners' activities. The Experience API defines each learning activity as a statement. The statement's format is based on Activity Streams philosophy of "who did what". Statements are consisted of actors (users), verbs (actions) and activities (objects) [90]. Each statement can be consisted of additional information like result, which is the outcome of an activity, timestamp, api's version and many more. (xapi.com, n.d.-a) Experience API saves statements in a Learning Record Store (LRS), that will be presented later.

The main advantage, as ADL says, is the freedom that Experience API provides in the aspect of statements, history, device, and workflow. Developers can create extended statements, using a reach store of verbs and activity and record almost every activity. History provides an easy communication of different LRSs and easy data sharing between them. Furthermore, all different devices are compatible to send Experience API statements, like mobile phones, games, applications and more. Last, Experience API is not only working in a LMS environment. Recording learners can start and end in wherever learner is and on whatever device learner uses. Figure presents the basic idea and philosophy on how Experience API works.

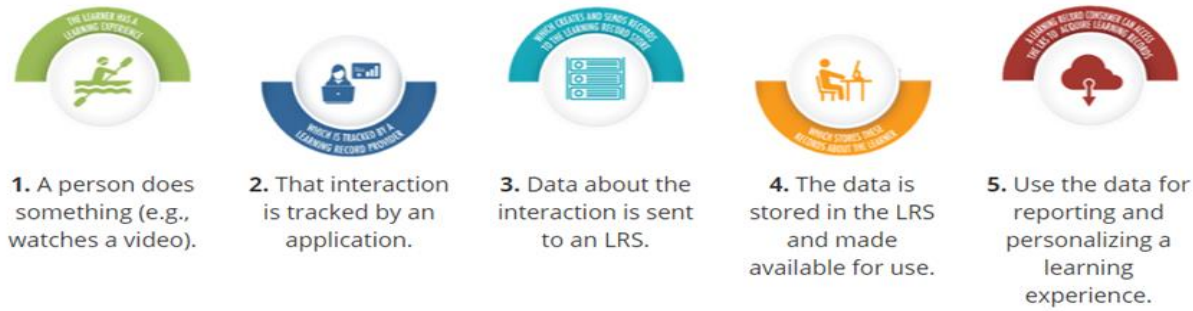


Figure 10 Experience API workflow [91]**.**

Experience API statements are being saved in a Learning Record Store. The LRS is a data record store, where recorded statements are being saved in sequential order. “The LRS is the heart of any Experience API ecosystem.”. It is responsible for receiving, storing, and retrieving learning data about learner’s activities, interactions, and experiences.

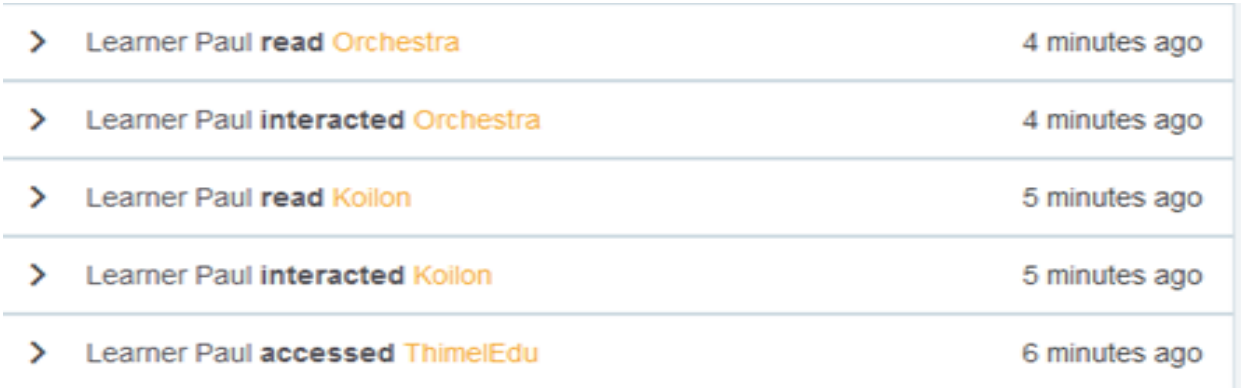


Figure 11 LRS recorded data [92]**.**

The Learning Record Store uses the MongoDB noSQL database for data storage and the stored statements are saved in the form of a list (Figure 11) and each record is a JSON object (Figure 12). Different LRSs can communicate and thus can exchange data with each other. In addition, an LRS has dedicated module responsible for visualizing the stored data using graphs (Figure 13).

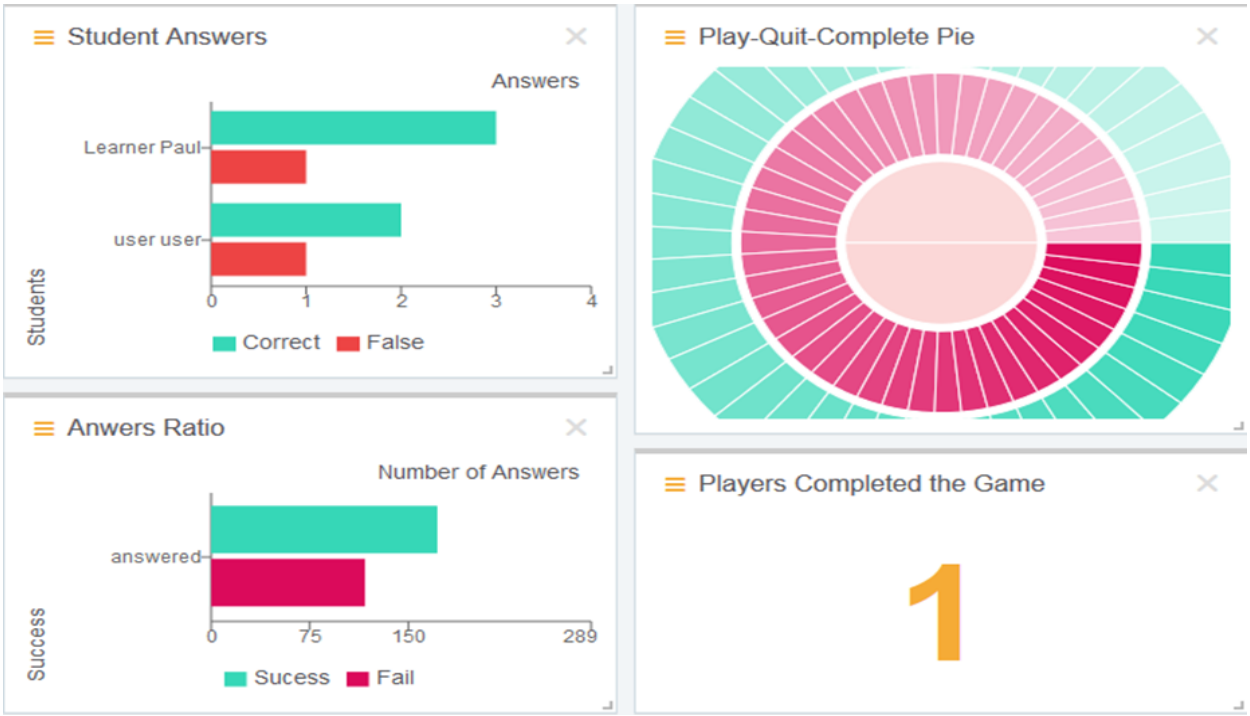


Figure 12 LRS data visualization module.

Counter to IMS Caliper, Experience API does not contain any limitations concerning the vocabulary that can be used in statements. A huge vocabulary of verbs and activities is provided by ADL, but developers can create their own verbs and activities for further information.

```
{
  "actor": {
    "name": "Sally Glider",
    "mbox": "mailto:sally@example.com"
  },
  "verb": {
    "id": "http://adlnet.gov/expapi/verbs/experienced",
    "display": { "en-US": "experienced" }
  },
  "object": {
    "id": "http://example.com/activities/solo-hang-gliding",
    "definition": {
      "name": { "en-US": "Solo Hang Gliding" }
    }
  }
}
```

Figure 13 Experience API statement [92]**.**

Moreover, Experience API provides extensions to expand recorded information. Statements are following the philosophy of "who did what". In particular, the Experience API statements are JavaScript objects. The figure below presents a simple statement. In this work we will develop algorithms that retrieve saved xAPI statements from a learning record store. The recorded statements concern player's / student's interactions inside a serious game. The behavior / interaction tracking algorithms and the serious game – LRS communication were implemented in previous developments.

Chapter 4 - The IOLAOS Framework

As described before, due to technological improvements and the robust growth of Information and Communication Technologies (ICT), learning environments and today's students are directly affected. New concerns and needs to redesign and reform the educational environments to adapt and support the new technologies, have been introduced. As Prensky stated, today's students are characterized as "Digital Natives", born and grown up in an era with robust technological achievements and as a sequence, native students from small ages know how to use a computer or a smartphone better than their teachers [2]. For that reason, conventional education methods and tools, like reading and writing, are no longer appropriate to transfer knowledge and train students for life success. Everyday exposure to technology, has transformed students and has developed skills like problem – solving and decision – making from early ages. As a result, it is crucial for education, to adopt emerging technologies and adapt learners' needs to the demands of the digital era. Also, there is a demand on developing eLearning personalized procedures based on learners' needs and virtual classrooms able to simulate a real – world traditional classroom inside a school environment. Moreover, there is a demand on how serious games can be used as pedagogical processes and how pedogeological approaches and methods can be emerged inside a serious game, in order to take advantage of their beneficial educational results. To that end, the "IOLAOS Educational Framework" was designed.

Architecture

Based on the Figure 14 above, the IOLAOS Framework architecture is consisted of 6 fundamental parts. The heart of this ecosystem is the "Common Data Space", which includes all the different data structures used to save data, information, and educational knowledge. The Common Data Space includes developments of relational databases like SQL, JSON and XML data structures, NoSQL databases like Firebase or MongoDB, multimedia data like videos, photos, sounds etc. and all the algorithms that manipulate those data structures and are being used for data interchange between the Common Data Space and the rest five elements around.

The up and left module of the IOLAOS Framework architecture, called "Template Codification", deals with the already defined philosophical educational and pedagogical methods and theories, learning styles, learning models, curriculums, and thematic areas, that being used in

traditional learning. These fundamentals are also crucial to be taken into advance during the design and the development phases of a successful and effective eLearning environment or process, with defined learning outcomes and results. IOLAOS as a service, encodes all these fundamentals for future use by game designers and game developers during the design and development of serious games, with educational added value. The "Template Codification" module stores the extracted information in data structures inside the "Common data space".

Next to the "Template Codification", is the "Game Compilation" module of the framework. IOLAOS' cooperates directly with serious games and uses them as the main process of the educational procedure. The "Game Compilation" module, concerns the development of serious games able to transform their educational content and their gameplay, based on specific educational theories, pedagogical methods etc. that have encoded in the "Template Codification" module. Those games will be able to adopt those theories and change their content and functionality based on them, but the learning outcomes and the provided knowledge will remain the same. Furthermore, the collaborative serious games with the IOLAOS Framework, will be personalized for each student according to his/her needs.

The third component of IOLAOS' architecture, the "Multimodality amalgamator", concerns all the available input and output modalities used for computer – users' interaction. IOLAOS' functionality is designed the support of different devices. For instance, a collaborative IOLAOS' serious game could be developed as computer software, as smartphone application or as a game console game. Each one of these devices - machines, has its one input devices. For example, computer has mouse and keyboard, smartphone has touch screen or gyroscope, and game consoles have controllers. The module "Multimodality amalgamator" is responsible to manage these devices and create the appropriate algorithms for user interactions based on different inputs.

The final component of the architecture is the "Inclusive Education – Training". The present master thesis and the developments that will be presented in the next chapters, are sub – components of this module. As described at the "Background" chapter, an eLearning activity should consider learners' needs, skills and personal to build effective and personalized learning environments and learning process with defined learning outcomes. The "Inclusive Education – Training" module, focuses on the technics and algorithms that manipulates and analyzes IOLAOS' data to draw conclusions about the learning process and suggest automatically possible solutions or improvements. To that end, as this work presents the analysis of learning data and the extraction

of information regarding learner's emotions during an learning session, we can say that is directly connected with this module's philosophy and is a sub – system of the "Inclusive Education – Training" component.

Although, the development of IOLAOS framework is still under research. Till this moment, successful developments include the IOLAOS eLearning Platform, collaborative games about different educational fields like the ancient theater or electrical power grids as well as an initial infrastructure of the common data space, the server infrastructure, and algorithms in the collaborative serious games able track students' behavior, collect and store learning analytics.

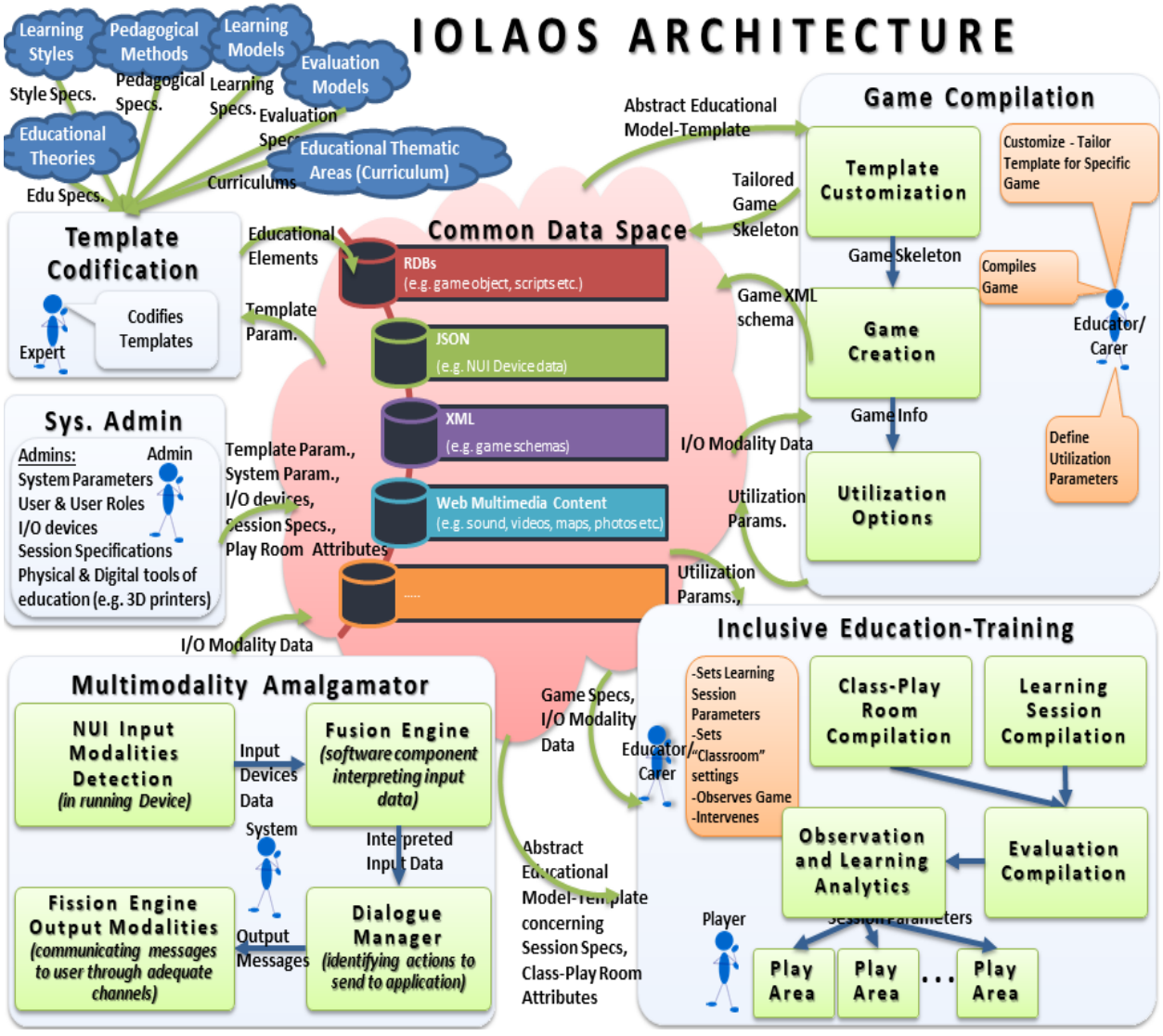


Figure 14 IOLAOS Framework architecture.

IOLAOS Platform

As mentioned before, IOLAOS platform is an eLearning infrastructure in the IOLAOS Framework ecosystem. Till now, it is the only full developed and functional component of the whole framework's architecture. Platform's design and development philosophy, was an open authorable and adaptive platform which allows third-party serious games developers to personalize and customize their games based on learning methods, learning styles, learning abilities & competencies and learner preferences, i.e., based on a learning process profiling. Also, as it is an eLearning environment, IOLAOS platforms supports the creation of synchronous virtual classes that use as educational material and educational method the serious games. The virtual classes are organized based on the philosophy of traditional school classes, where a teacher divides his/her class in subjects based on the curriculum and each subject is divided in learning sessions based on each content.

Furthermore, IOLAOS Platform is not an authoring tool. It is an open and adaptable platform which supports the [93]:

- collaboration of different groups of expertise people, each one adhered to its own user role,
- creation of user and learning profile,
- application of encoded learning theories, learning methods, pedagogical methodologies,
- definition of learners with special educational needs,
- creation and virtual simulation of traditional school classes,
- educators' observation of the learning process, by distance monitoring learners' face cameras and screens,
- capturing learners' cameras and screens for post – analysis of learners' behavior.

As a sequence, IOLAOS platforms needs the support of different roles. All the roles are presented on the Table 8, as well as the base functionallities based on each roles are presented on the Table 9.

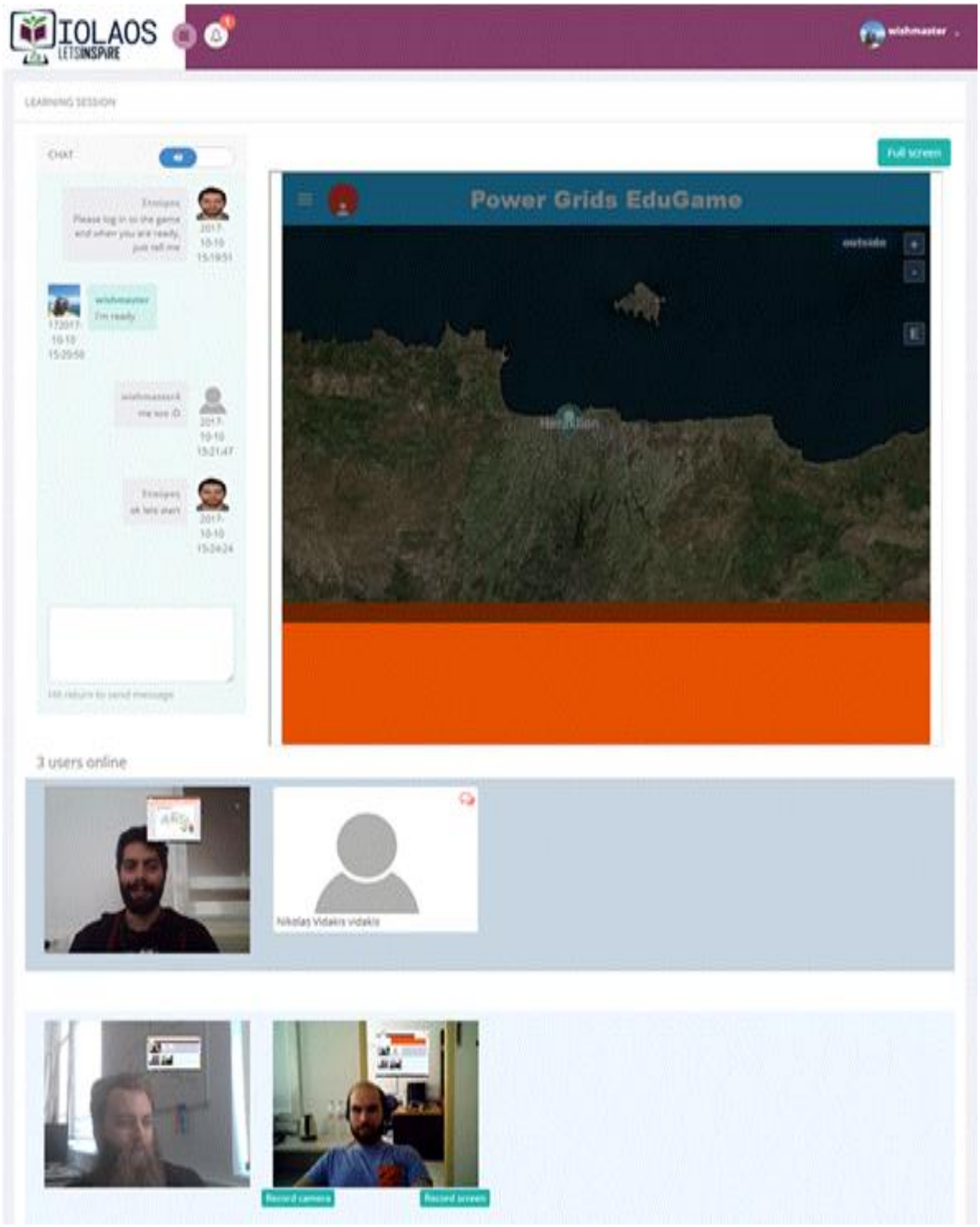
In conclusion, IOLAOS framework, and the platform as well, are yet in research level and under development. However, its philosophy can be a valuable outcome for a student – centered approach of eLearning environments. But to develop student – centered learning process, we need to analyze learners'' behavior inside them first. In the next chapters, the analysis, design, and

implementation phases of an API able to manipulate and analyze IOLAOS provided data, is presented.

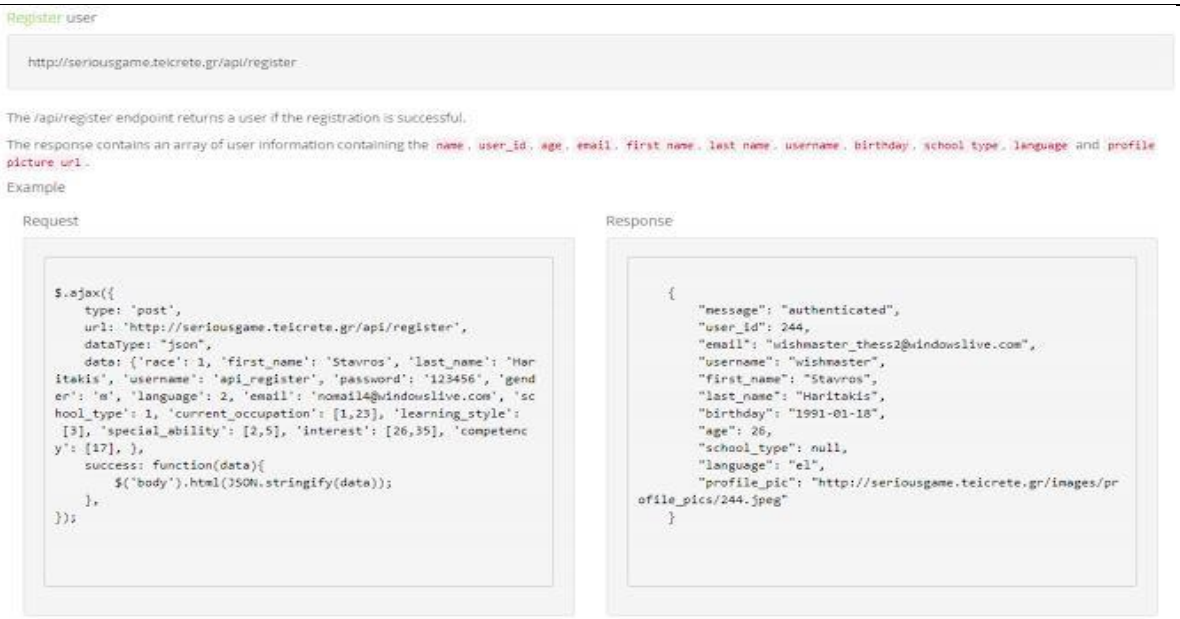
Table 8 IOLAOS Platform user roles

Role	Actions
Learner	• Participates in eLearning courses and learning sessions. • Plays the collaborative with IOLAOS, serious games.
Educator	• Creates Classrooms. • Creates Learning Sessions. • Monitors Learners. • Assigns game Preferences.
Game Developer	• Develops personalized serious games, based on IOLAOS criteria. • Uses the available REST API, to communicate with the platform and with "Common Data Space" component.
Educational Expert	• Applies learning theories, methods, and pedagogical methodologies in the collaborative serious games. • Defines students special need and create for each student his/her specific game preference based on his/her needs
Game Tester	• Monitors and tests games • Assigns IOLAOS maturity levels to games. • Rates Games and writes game reviews
Administrator	• Is responsible for platform's functionality and motoring.

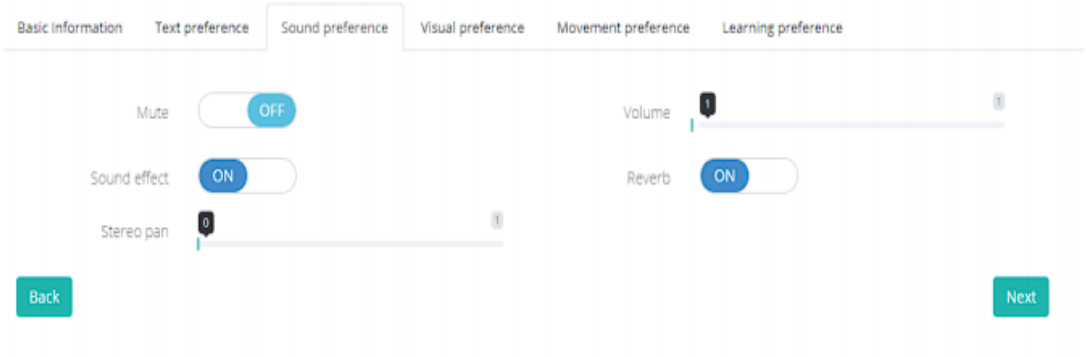
Table 9 IOLAOS Platform main functionalities based on each role.



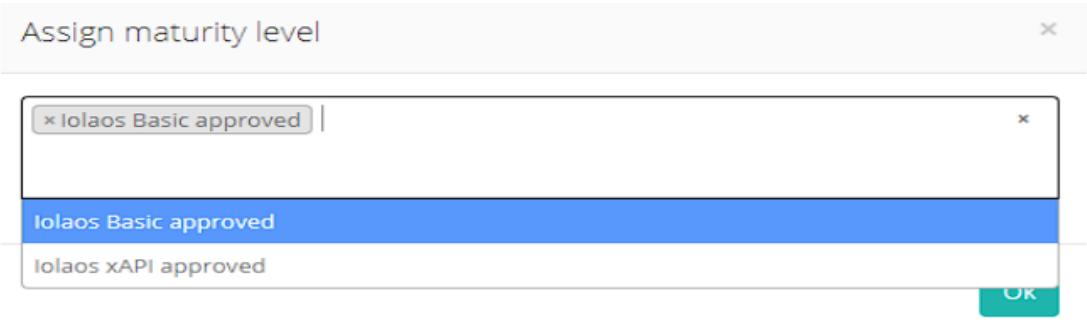
Action: Learning Session based on a serious game, with student monitoring via face cameras.
Roles: Educators, Learners



Action: Available REST API services.
Roles: Game Developers



Action: Game preferences creation.
Roles: Educational Experts



Action: Assigning IOLAOS maturity level on tested game.
Roles: Game Testers

Chapter 5 - Observation & Learning Analytics Module (OLAM) System Analysis

Textual Analysis

Based upon the motives described so far in the theoretical and technological background chapters, as well as the on the philosophy behind the IOLAOS architecture there is a need in the development of a system – tool for educators, able to manipulate and analyze the generated raw data from the IOLAOS Platform learning sessions. The generated raw data, concern learner's information captured during the learning session. During a learning session the systems records learner's face, screen, stores his / her chat messages and each serious game monitors student's behavior via xAPI triples.

First, the system should retrieve educators' school and classes. For each class, educator should be able to see classes' students. The system should consist of the appropriate services – algorithms that: connect with the IOLAOS Platform database, retrieve learner's personal information, retrieve learner's captured face videos, retrieve learner's captured screen videos, connect with the Learning Record Store, and retrieve learner's xAPI statements. The provided services should structure the information data in a proper way, easy understandable and manageable from the front – end part of the final system.

Second, the described system will use Artificial Intelligence and therefore Machine Learning techniques for data analysis. More specific, the AI part of the system – API will be divided in four modules. The first module is the analysis of student's face videos and the emotion recognition in faces. The face emotion recognition module will analyze the video, divide it into frames according to the frame rate, save the frames, detect the emotion of the face, extract a new image of the frame with the face and the emotion labelled and group together the processed images in seconds according to video's frame rate.

The second module is the speech sentiment analysis. Following the same phases described before, the speech sentiment analysis module retrieves learner's face video and extracts the audio and saves it as a file. The audio file will be analyzed and divided into audio clips. Machine learning algorithms and models will detect learner's emotion on each audio clip.

The final operation of the AI module will be the emotion extraction from chat messages. The system will use the retrieved chat messages, analyze them in sentences and detect emotions on each statement.

According to the Background chapter, the emotion detection modules of the system will be based on existing algorithms found from code repositories like GitHub, Medium and Data Flair and based on the literature. More specific, the image emotion recognition from videos will follow the video analysis process described by Singh and the emotion recognition procedure will be based on Puri et al proposed flow and Ahmad's et al. developments[76], [80] [77]. Moreover, the speech sentiment analysis algorithms will follow the process described by Selvaraj et al., will be based on implementations from code repositories and based on use the Livingstone and Russo we will use the RAVDESS dataset. Finally the text sentiment analysis module will follow the proposed process described by Kumar et al., and will use the VADER lexicon for sentiment analysis.

Moreover, for evaluation issues regarding the results of the AI modules and in order to confirm that the extracted emotion accrue from learner's interaction with the learning process, the system should analyze learner's recorded scree video. Using image processing techniques and more accurately the template matching technique, the system will divide the learner's screen video into frames and search for the IOLAOS logo in them. This module will be used as a complementary evaluation tool of the emotional state analysis.

Furthermore, the system will store the extracted data and information into a database. As a sequence, the system needs the development of an independent module that communicates with the database and retrieve the stored information.

Finally, the system will be implemented as an API, using the microservices architecture and programming languages that support microservices. The microservices will exchange JSON or XML to receive and send data. Also, the programming languages should be Object Oriented, like Java, Python, C++, C#, or JavaScript.

Requirements Analysis

According to the textual analysis the Table 10 presents the requirements of the system. The first column contains the abbreviation number of the requirement, the second column the name of the requirement and the third one type of the requirement. The requirements analysis phase

determines the needs, the operations, and the conditions of a system. It is determination process of:

- The services that the customer requires from a system,
- The constraints under which a system operates.
- The constraints under which the system is developed.

The requirements themselves are the descriptions of the system services and there are two types of requirements:

- The functional requirements, that determine the basic behavior of the system, describe the functions to be performed (features), In simple words they determine what a system should and should not do and they usually define if / then behaviors, calculations, data entry and processing, business processes and user-system interaction.
- The non-functional requirements determine how a system should behave and they do not affect the basic functionality of the system. Even if not met the system will still perform its main purpose. They define system behavior, capabilities and general features that affect the user experience (properties), and they determine how easy it is for the end user to use the system.

Table 10 System Requirements List.

A/A	Requirement Name	Type
FReq 1	Microservices architecture.	Functional
FReq 1.2	The back- end development will be installed in IOLAOS server.	Functional
FReq 1.3	The developed APIs will be independent and autonomous entities of the whole server.	Functional
FReq 1.4	Objected oriented principles.	Functional
NFReq 1.5	Data API will be developed with Java and the Spring Boot framework and JavaScript and express.js.	Non-Functional
NFReq 1.6	AI and Machine learning modules will de developed with Python and Python libraries and frameworks.	Non-Functional
Req 2	IOLAOS Platform data manipulation software.	
FReq 2.1	Communication with IOLAOS Platform database.	Functional
FReq 2.2	Development of services that retrieve data from IOLAOS Platform database.	Functional

NFReq 2.3	The microservices that retrieve data from the IOLAOS Platform database will be developed using the Spring Boot framework	Non-Functional
FReq 2.4	Communication with the LRS.	Functional
FReq 2.5	Development of services that retrieve data from the LRS.	Functional
NFReq 2.6	The microservices that retrieve data from the LRS will be developed using the express.js.	Non-Functional
FReq 2.7	The communication with the LRS will be developed with the tincan API.	Functional
Req 3	Emotion Detection from face videos.	
FReq 3.1	Extraction of video frames.	Functional
FReq 3.2	Detection of emotion in video frames.	Functional
NFReq 3.3	The emotion detection will be developed with Python, machine learning libraries and techniques based on Python.	Non-Functional
FReq 3.4	Categorize results in seconds.	Functional
FReq 3.5	Save the emotion images.	Functional
FReq 3.6	Store the results in the database.	Functional
FReq 3.7	Follow the described processes proposed Singh, Puri et al., and Ahmad et al [76], [77], [80].	Functional
Req 4	Emotion Detection from speech.	
FReq 4.1	Extract audio from the captured face video.	Functional
FReq 4.2	Split the extract audio into clips.	Functional
FReq 4.3	Detection of emotion in audio clips.	Functional
NFReq 4.4	The emotion detection will be developed with Python, machine learning libraries and image processing techniques based on Python.	Non-Functional
FReq 4.5	Store the results in the database.	Functional
FReq 4.6	Use the RAVDESS datasets, according to Livingstone and Russo [86]	Functional
FReq 4.7	Follow the described processes proposed Selvaraj et al. [84]	Functional
Req 5	Emotion Detection from text.	
FReq 5.1	Split text into sentences.	Functional

NFReq 5.2	The emotion detection will be developed with Python, machine learning libraries and techniques based on Python.	Non-Functional
FReq 5.3	Store the results in the database.	Functional
FReq 5.4	Follow the proposed process described by Kumar et al [94].	Functional
Req 6	Data retriever API	
FReq 6.1	Services development that retrieves stored information from the data analysis phase.	Functional
NFReq 6.2	The data retriever API will be developed using the Spring Boot framework	Non-Functional
Req 7	Data repository	
NFReq 7.1	Development of a relational data base.	Non-Functional
NFReq 7.2	Use MySQL for database development.	Non-Functional
FReq 7.3	The database will be part of the IOLAOS Common Data Space.	Functional
FReq 7.3	The database will be installed if the IOLAOS server.	Functional
Req 8	Application distribution.	
NFReq 8.1	Open – source.	Non-Functional
NFReq 8.2	Available services for independent applications	Non-Functional
Req 9	Communication between modules.	
FReq 9.1	Communication through HTTP requests.	Functional
NFReq 9.2	The modules exchange data responses in JSON format	Non-Functional

System Modelling

Use Cases

Table 11 Retrieve learner's data from IOLAOS platform database microservice use case scenario.

Use Case Name: Retrieve learner's data.	**Importance Level: High**
Primary Actor: API	**Use Case Type:** Functional
Stakeholders and Interests: IOLAOS Platform.	
Brief Description: *The system presents a specific learner's available raw data from a learning session in IOLAOS Platform. Educator receives all his/her the learning sessions and chooses for one learning session to retrieve learner's raw information and data.*	
Trigger: Educator's request for retrieving learner's raw data.	
Normal Flow of Events: 1. Request to IOLAOS common data space for the available learning sessions. 2. Receive response JSON with educator's learning sessions. 3. Request to IOLAOS common data space for learner's data inside a specific learning session 4. Collect and manipulate the available learner's data. **5.** Send a JSON response with learner's data.	

The first and initial use case of the API, is the data collection from the IOLAOS' common data space. The final output should be all the available raw data collected for a specific learner during a specific learning session. The API requests and receives for a specific educator his/her available learning session. Then, according to educator's preference, requests the available data for a specific learner. The data concern:

- recorded face video during the learning process,
- recorded screen video during the learning process,
- raw game data, based on Experience API statements,
- chat messages.

Algorithms collect the available data in JSON format from the IOLAOS' common data space and manipulate the response, if it is necessary, and develop structured JSON arrays that will finally be returned as a response to the business level of the system.

Table 12 Emotion detection from face video microservice use case scenario.

Use Case Name: Analyze learner's emotions from video.	**Importance Level: High**
Primary Actor: API	**Use Case Type:** Functional
Stakeholders and Interests: IOLAOS Platform.	
Brief Description: *The system contains operations that manipulates a video source form learner's face and analyzes the emotions of each frame.*	
Trigger: Business level request for emotion extraction on video sources.	
Normal Flow of Events: 1. Read the input video file. 2. Convert the video source into frames and saves the extracted images. 3. For each frame using machine learning models detect the face and extract learner's emotion. 4. Extract a new image labelled with a square around the face and a text with the detected emotion. 5. Save the new images, 6. Categorize the results in seconds based on videos frame rate. 7. Check if all the frames are processed. 8. Delete the extra frames data are not corresponding in videos durations in seconds. 9. Save the data in a database inside the IOLAOS common data space. 10. Create and send a JSON response with learner's face emotions.	

As described before the API, extracts face emotions from video. As presented on the normal flow of events describe on Table 12, the video emotion detection requests a video source file as an input. The video input is analyzed and based on the frame rate an algorithm extracts all its frames in image files. Each one of the image files is named properly according to the name of the video source file and the frame's serial number. The extracted frames are stored in a local folder. Each frame using machine learning models and algorithms, as well as using image processing, is analyzed to detect learner's face and extract the emotion of the detected face. The results of the face and emotion detection are new images labelled with a square around the face and a text with

the emotion. The system creates a new folder to save the processed images. Based on the video source frame rate, the system categorizes the results in seconds and deletes the extra frames. Finally saves the data in a database and returns a JSON response with the extracted data.

Table 13 Emotion detection from speech microservice use case scenario.

Use Case Name: Analyze learner's emotions from speech.	**Importance Level: High**
Primary Actor: API	**Use Case Type:** Functional
Stakeholders and Interests: IOLAOS Platform.	
Brief Description: *The system contains operations that manipulates a video source form learner's face, extract the audio from video and analyzes the emotions in learner's speech.*	
Trigger: Business level request for emotion extraction on video sources.	
Normal Flow of Events: 1. Read the input video file. 2. Extract the audio from the video source and saves the audio clip. 3. Split the audio file in clips based on offsets according to moments of silence inside the speech. 4. Using machine learning models and algorithms detect the emotion of each audio speech clip. 5. Save the data in a database inside the IOLAOS common data space. 6. Create and send a JSON response with learner's speech emotions.	

Likewise, the video emotion detection use case, the system supports the emotion extraction form speech. The above use case is functional for the API and based on the normal flow of events the initial step is the request of a video file as an input. The video source input file should be the same with the source mentioned on the face emotion detection from the use case described before. The system should extract the audio from the video source. Based on offsets regarding the time of silence in milliseconds, the system splits the audio into separate clips. The silence offset occurs approximately based on end user preferences. Through machine learning algorithms and models, each one of the extracted clips is analyzed and algorithms detects the emotion on learner's voice. Functions store the extracted data into the database and construct a JSON response with the emotion of each audio clip.

Table 14 Emotion detection from messages microservice use case scenario.

Use Case Name: Analyze learner's emotions from text.	**Importance Level: High**
Primary Actor: API	**Use Case Type:** Functional
Stakeholders and Interests: IOLAOS Platform.	
Brief Description: *The system contains operations that manipulates a video source form learner's face, extract the audio from video and analyzes the emotions in learner's speech.*	
Trigger: Business level request for emotion extraction on video sources.	
Normal Flow of Events: 1. Retrieve learner's chat messages during a learning session inside the IOLAOS learning platform. 2. Check if the message contains a single sentence, or it is a set of sentences. 3. Splits the message in parts / sub - sentences. 4. Using machine learning models and algorithms detect the emotion of each sub - sentence. 5. Save the data in a database inside the IOLAOS common data space. 6. Create and send a JSON response with learner's text messages emotions.	

The third and final module of the emotion detection use cases, is the emotion detection from text messages. The system receives learner's chat messages from a learning session inside the IOLAOS platform. The text messages are analyzed to detect if it is consisted of one sentence or is a set of sentences. In the second case, the message is divided into parts / sub – sentences. From each sentence using machine learning algorithms and models, we detect the possible overall sentence emotion. The same flow of events occurs in the case that each message is just a single sentence of a single word. The results are combined to implement a JSON structure, are saved in the database, and the JSON structure is returned as a response of the microservice.

Table 15 Learner's screen captured video analysis microservice use case scenario.

Use Case Name: Analyze learner's screen captured video during the learning process.	**Importance Level: High**
Primary Actor: API	**Use Case Type:** Functional
Stakeholders and Interests: IOLAOS Platform.	
Brief Description: For monitor*ing reason, the system contains operations that manipulates a video source form learner's screen, and checks based on specific points if learner is in the learning session or not.*	
Trigger: Business level request for screen captured video analysis.	
Normal Flow of Events: 1. Read the input video file. 2. Convert the video source into frames and saves the extracted images. 3. For each frame using image processing algorithms, template matching algorithms check if the frame contains is some point a specific logo or image. 4. Categorize the results in seconds based on videos frame rate. 5. Check if all the frames are processed. 6. Delete the extra frames data are not corresponding in videos durations in seconds. 7. Save the data in a database inside the IOLAOS common data space. 8. Create and send a JSON response.	

For controlling issues, and to evaluate the emotion extraction results during the learning prosses, the system should analyze learner's recorded screen video to check if learner is inside the learning process or not. The recorded screen video as an input of the system is transformed into frames and the extracted frames are saved on a local folder. Algorithms parse the frames folder and algorithms apply the template matching image processing technique find parts of the extracted frames that match to a template image. In our case the template image is the logo of the IOLAOS Platform. For instance, if an extracted frame is a screenshot of the IOLAOS learning process we apply the template matching technique to find if the IOLAOS Platform logo is contained in the captured frame. Likewise, the face emotion detection use case, the system creates a new folder to save the processed images. Again. based on the video source frame rate, the system categorizes the results in seconds and deletes the extra frames. Finally saves the data in a database and returns a JSON response with the extracted data.

The described use cases, draw a picture of the API's different functionalities. However, in terms of education and learning, the described system needs to have defined learning goals, to be characterized effective and robust.

First, the physis of the emotional learning analytics, as part of the learning analytics field and based on the background section of this master thesis, are able to help educators to detect and recognize students' hidden insights during a learning process. Also, the combination of this API with an already developed eLearning platform (IOLAOS Platform) and the educational data that are being produced during a learning session, leads to the extraction of quality pedagogical information that characterize students' behavior during a learning session.

In addition, the implementation of a system able to identify the changes between emotional states during the educational process, helps educators to develop personalized educational processes, as well to assist and intervene. In particular, as mentioned before, emotions affect student's cognitive learning, and their academic success of failure and also emotional learning helps students to gain knowledge and achieve goals. By detecting students' emotions from different data sources and providing a system able to draw such conclusions, educators can handle with more effective and efficient ways the flow of an educational process, have a feedback about learner's behavior, as well as they can manage to struct each students' emotional profile and build personalized educational material and sessions based on his/her emotional profile.

Moreover, despite the outcomes of learner's behavior, emotional learning analytics are able to identify weaknesses and characterize the learning process itself. Emotions can used as a key factor to identify weak points of the educational material, methodologies and tools that are used during the learning session. The learning experience though can be described by analyzing students' emotions and using data mining techniques it is possible to identify and provide alternatives of rules to modify the weak points and as a result to increase the effectiveness of the learning process.

However, despite the educational outcomes of the presented API, and the fact that it is a part of a whole system with graphical user interface and human – computer interactions, as final product will be a tool that automates the observation. Educators will not analyze by themselves the available extracted educational data but will import the data into a system to analyze them and draw conclusions. But due to the early yet phases of the emotional recognition regarding speech and text, in some points educators may need to evaluate the extracted information.

Finally, this system describes the initial step to analyze an educational process and its produced data, and to provide information able to help us in the development of inclusive and adaptive learning systems.

Chapter 6 - Observation & Learning Analytics Module – System Design

Software Architecture

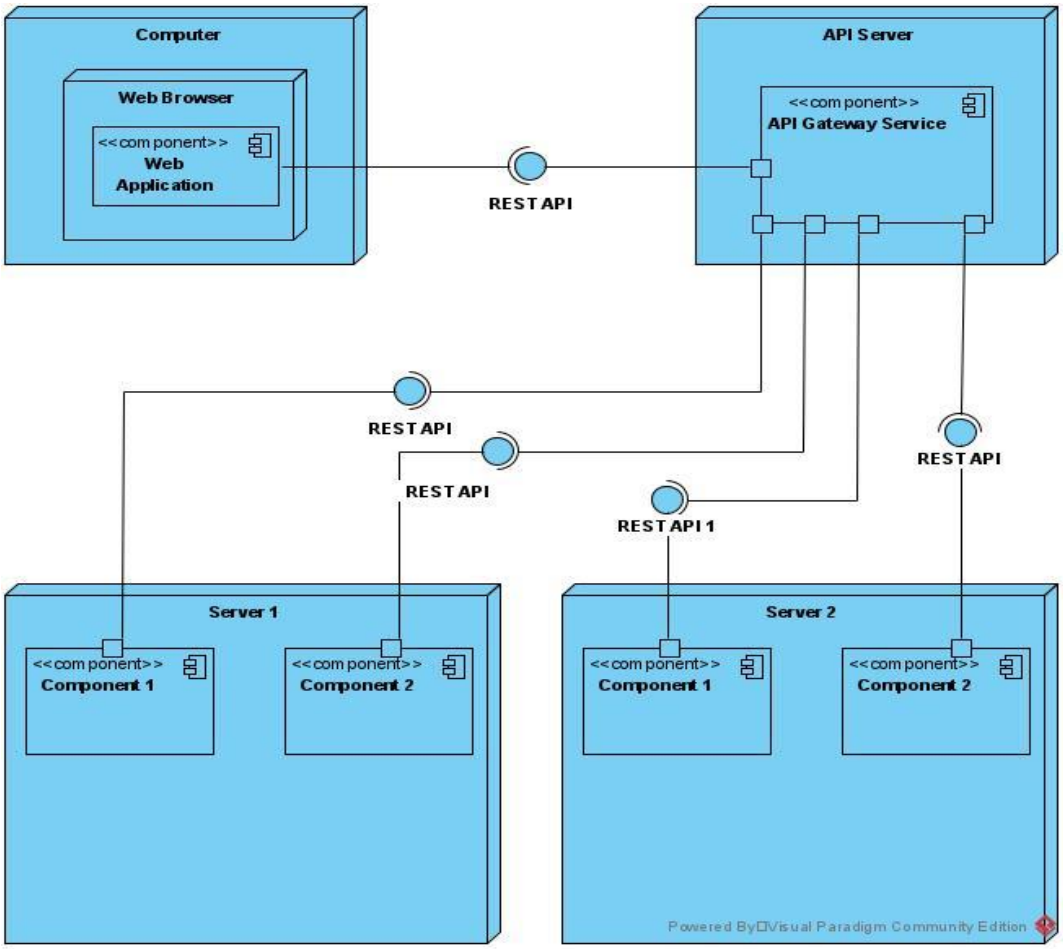


Figure 15 Microservices architecture logic.

The API development was based on the microservices architecture, or microservices. Microservices focus on the rapid, robust, and reliable development of large software systems, by building single function modules with well – defined interfaces. The microservice architecture structures the software as a collection of different services. Each one of the developed services, executes a unique function to serve a business goal. The entire application is decentralized and compared with the monolithic architecture, when a code error occurs it only affects one service. As a development principle microservices are easily and highly maintainable, testable, loosely coupled, independently deployable and improves scalability. Based upon those motives and, due

to different and independent data manipulation and data analysis operations, microservices architecture was used for the development of this work.

System Structure

Components Diagram

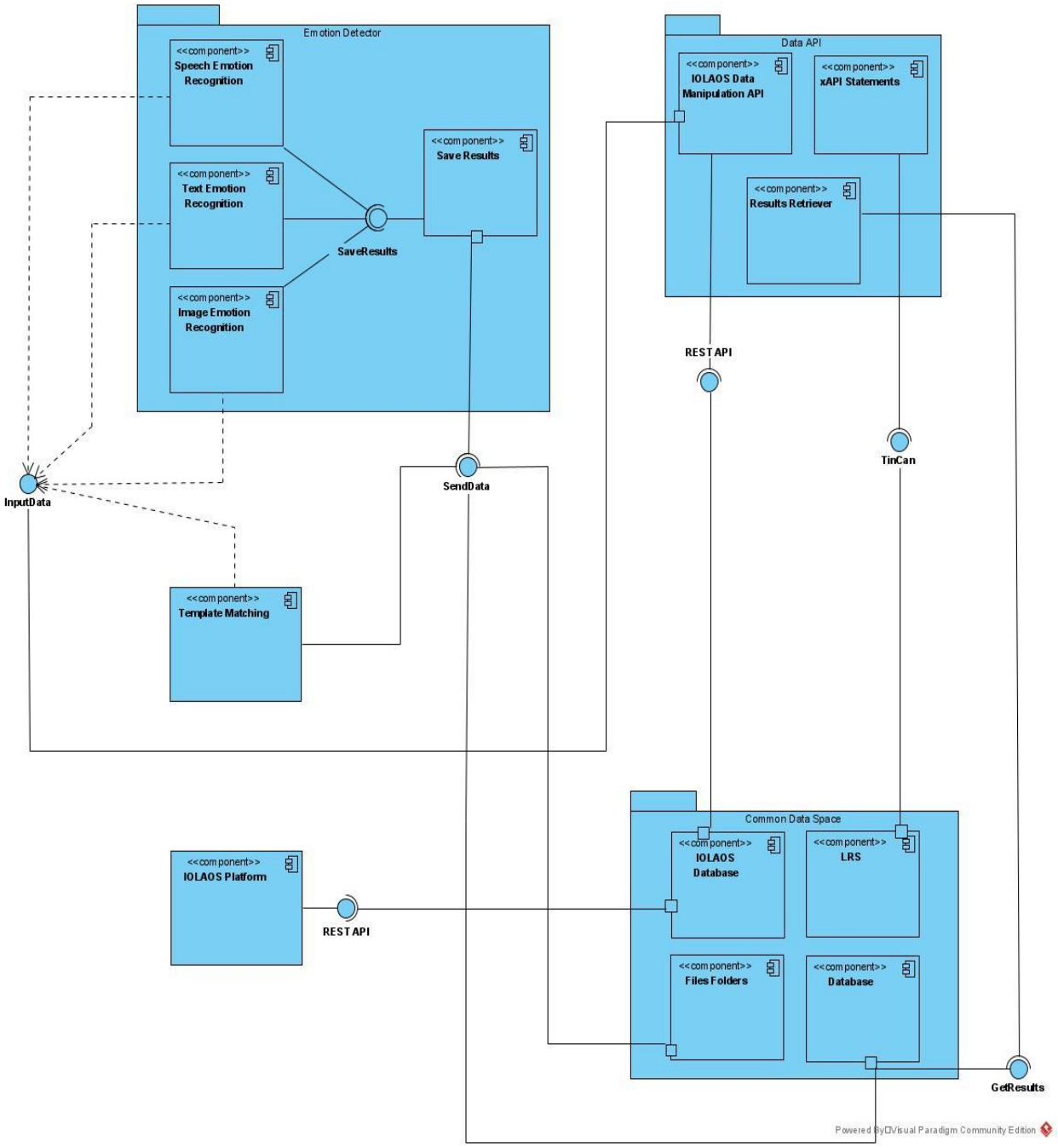


Figure 16 Software components diagram.

The presented components diagram on the Figure 16, shows the API's different modules, as well as the communication between modules. Based on the requirements analysis the system is consisted of three main entities, the Common Data Space, the Data API, and the Emotion Detector. Each one of the entities contains its own components / modules. Inside the Common Data Space there are all the data sources that the system will communicate. The available data sources are the IOLAOS Platform database, the Learning Record Store, the API's database, and the folders in the servers that are stored data like videos, images, audio.

The Data API is responsible for communication with the Common Data Space and its different data sources and the interchange of data and information. It consists of the IOLAOS Data Manipulation API which contains microservices to retrieve data from the IOLAOS platform database. The retrieved data contain information about educator's classes, learning sessions, students, and learning session's saved raw data like the learner's captured face videos. The xAPI statements component is responsible to retrieve raw educational data based on Experience API statements regarding student's behavior during the gameplay of a serious game. The xAPI statements contain gamification information like interactions inside the game world, scoring etc. The results retriever component is responsible to retrieve and send data to the front – end part of the application. The data concern the results of the Emotion Detector entity.

The Emotion Detector contains components able to extract emotion from 3 data sources, video, audio, and text. All the three components contain algorithms that manipulate and analyze the data source and using the appropriate machine learning algorithms and models they extract the emotion from each data source. Moreover, each one of each component is responsible to manipulate properly the data source for better results. The results through the Save Results component are structured in JSON objects and JSON arrays and stored in the database. Furthermore, the Template Matching component is responsible to search inside a video's extracted frames for a specific template and save the results into the database.

All the described entities and components communicate with each other via REST services. The components diagram on the Figure 16 contains the basic modules of the system. For more details, modules, and operations the uses cases describe through a detailed format the basic functionality of the API, the Class Diagram presents the above modules transformed into Object oriented classes and the sequence diagram describes the fully functionality of the system.

Data repository

Entity Relationship Diagram

The implemented database is a relational MySQL database that contains tables to store the extracted information from the emotion detection modules. As shown in the **Error! Reference s ource not found.** data manipulation and data analysis results are stored in different tables according to the type of the data source. As a sequence, there are tables that store the extracted information from video face emotion analysis, tables that store the results from speech emotion analysis and finally tables that store the result of text emotion analysis.

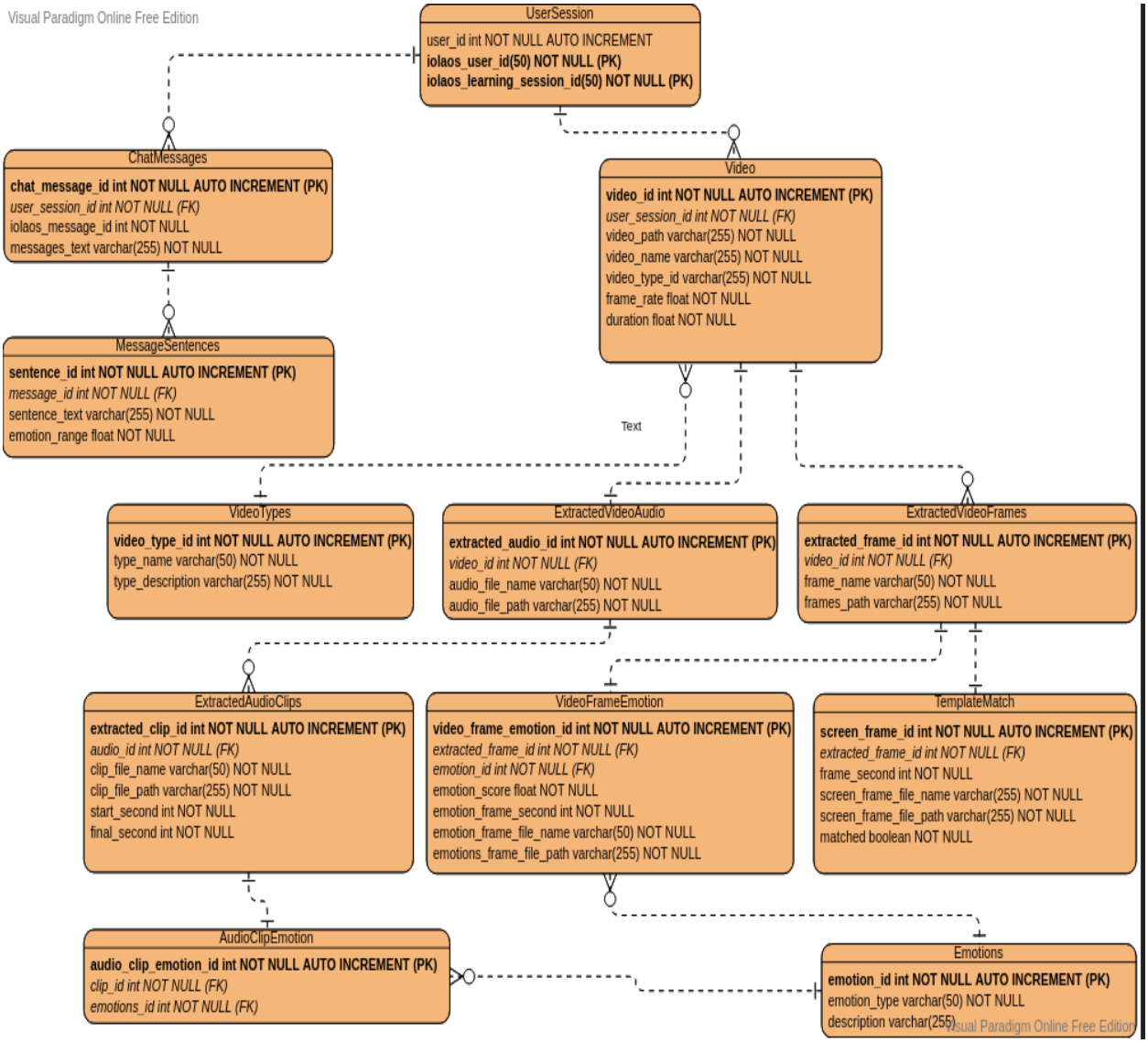


Figure 17 Data Entity Relationship Diagram (ERD).

System behavior

Sequence Diagram

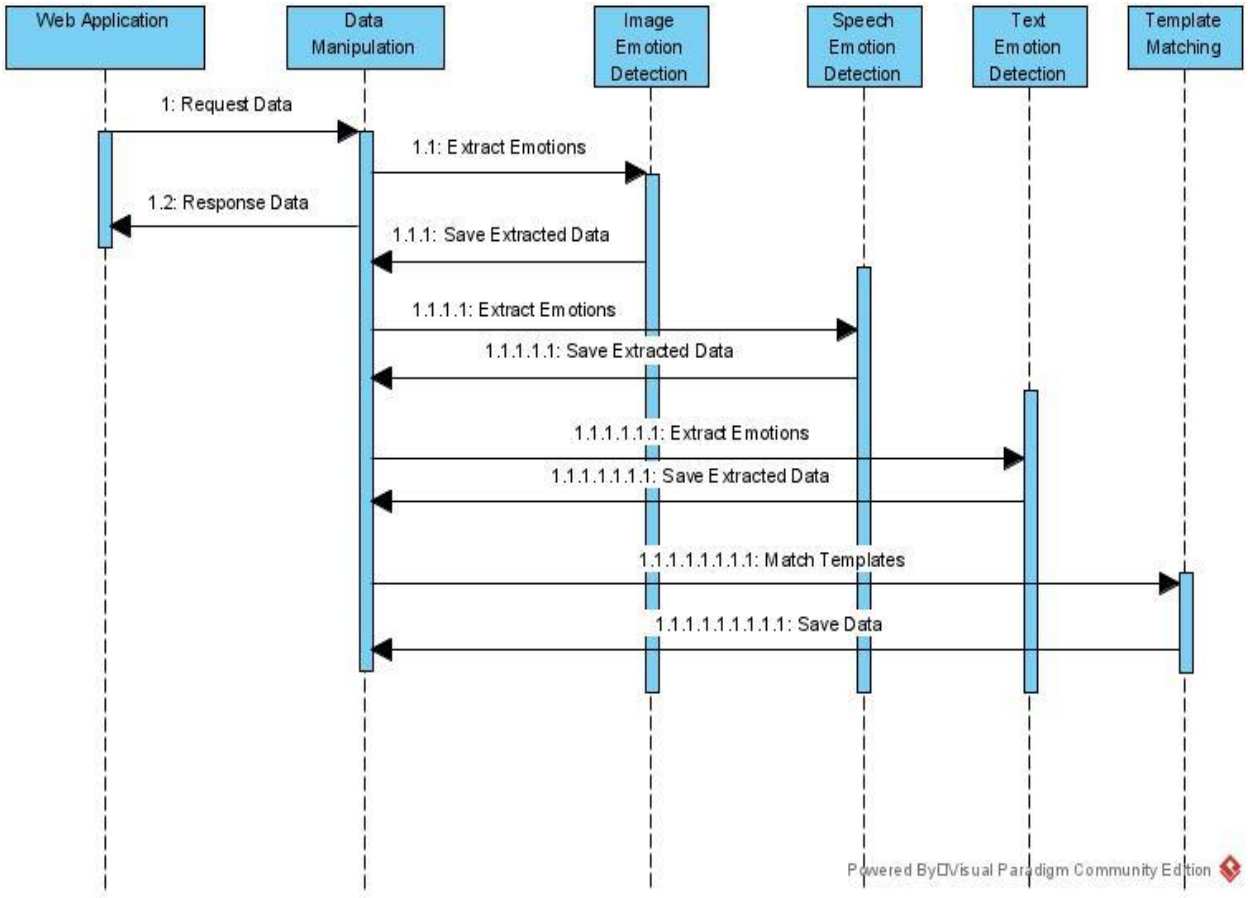


Figure 18 System sequence diagram.

The flow of events described on the Use Cases paragraph is also presented through a sequence diagram in the Figure 18. A web application requests the Data API, and the API responses with the available data. Also, the Data Manipulation API sends the requested data to the emotion detection algorithms and to the template matching algorithms. The data analysis phase of each module contains stages that described in the Use Cases section before. All the modules store the extracted information into a relational database. An interactive future – development system, will be able to present all the available data regarding emotions and learner's information, through an interactive environment where user will be able to interact process the available learner's information.

Technologies, Frameworks and Libraries

The development of this master thesis was based on Object Oriented programming languages, libraries, and frameworks that support the development of microservice architectures. Programming languages that were used are Java, Python and JavaScript.

First, Java programming language was used for the communication with the IOLAOS' platform database inside the IOLAOS' common data space, data manipulation and data transfer within the server and the business level. More specific, we developed using Java and Spring Boot framework REST services that request data from an SQL database. The Spring Boot framework is an open – source Java – based framework, used to develop microservices, providing easy to understand and easy to develop software, reducing development times, and implementing production ready applications. Its functionality is based on Maven dependencies configures in a set of dependencies .xml file. The main dependencies that used for these microservices were the: mysql-connector-java, spring-boot-starter-data-jpa, spring-boot-starter-jdbc, spring-boot-starter-web-services and json.

Second, the Python programming language was used for the development of the emotion extraction API. In the philosophy of the microservices architecture, we used the Flask API. Likewise, Spring Boot, Flask aims to the fast and reliable development of microservices. However, in this work, Python was used for machine learning purposes. More specific, emotion detection algorithms used Keras and TensorFlow for machine learning models training, OpenCV for image processing, librosa for analyzing audio, Scikit-learn for audio machine learning models and numpy. Also, the MySQL Connector for Python was used to save the extracted emotion results in the data storage.

Third, JavaScript was used for API development with operation the connection with the LRS and the collection of Experience API (xAPI) statements. In particular Node,js as a server for the development of the API. ExpressJS framework, was used as a back – end server -side logic to implement microservices that retrieve data from the LRS. Moreover, the tincan js library for Experience API implementation. Using tincan js, microservices were able to communicate with the LRS and request learner's recorded raw game data.

Finally, all the results of the emotion algorithms are saved into a relational database. The databased was developed using MySQL. Also, the data transfer between microservices or between the API and the business level, was based on JSON responses.

Good practices & design patterns

The code development of this work was based on five principles of object – oriented programming, called SOLID principles. The five solid principles are:

- Single – responsibility principle, which means that a class is one responsible for one and only one thing,
- Open – closed principle, means that classes can only be extended, and not modified,
- Liskov substitution, where class instances can be replaced with instances of their subtypes and the program should remain unaffected,
- Interfaces' segregation, where functionality of the program should be based on many different interfaces and not in one interface that contains all the operations,
- Dependency inversion, where high – level modules of a program and low level – modules of the program should not depend on each other, the system is based on abstractions and concrete implementations are based on abstractions.

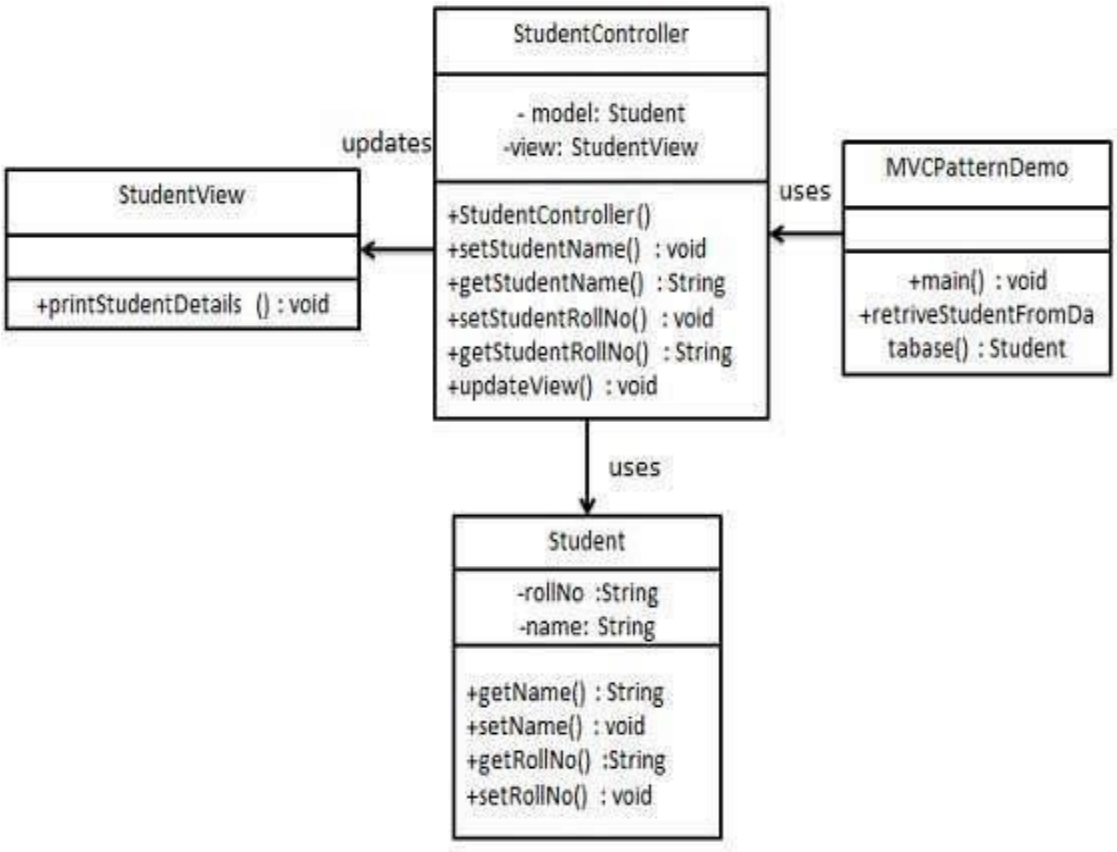


Figure 19 MVC design pattern UML class diagram.

Moreover, for the software development of this thesis we used design patterns. More specific the Model – View – Controller (MVC) design pattern was used. The Java's Spring Boot framework is based on the MVC design pattern. The software is divided into three interconnected modules, the Model, the View, and the Controller to separate the data presentation with the data manipulation levels (Figure 19). The Model is responsible for retrieving / storing data, the view is responsible to present the data and the controller manipulates the Model and the View.

Also, we used Data Access Object (DAO) design pattern in the Python microservices to store the extracted results in the database. The DAO pattern is used to separate the data accessing API with the business model. Using DAO, we add an intermediate layer between the database, its implementation and functionality and the algorithms that communicate with the database and retrieve data, update data, save data etc. In the DAO pattern they participate a Model Object which is a POJO class with getters and setters to store and save data, a Data Access Object interface where the operations performed on the model are defined and the Data Access Object concrete class that implements the described before interface to get data from a data source.

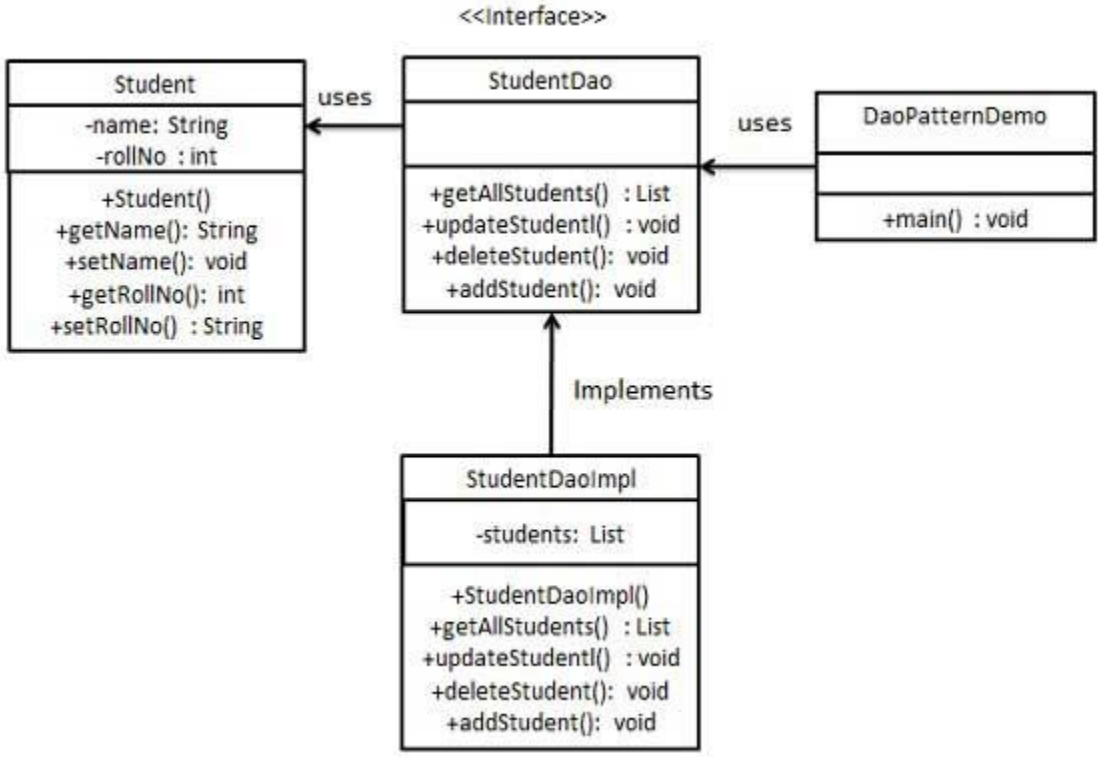


Figure 20 DAO design pattern UML class diagram.

Finally, we used singleton design pattern where it was needed. The singleton design pattern is one of the simplest design patterns. It provides one the best way to create a single object from a

class, using static methods to get class instances to the outside world. It contains a SingleObject class with a private constructor, a static instance of itself and a static method to return it static instance (Figure 20).

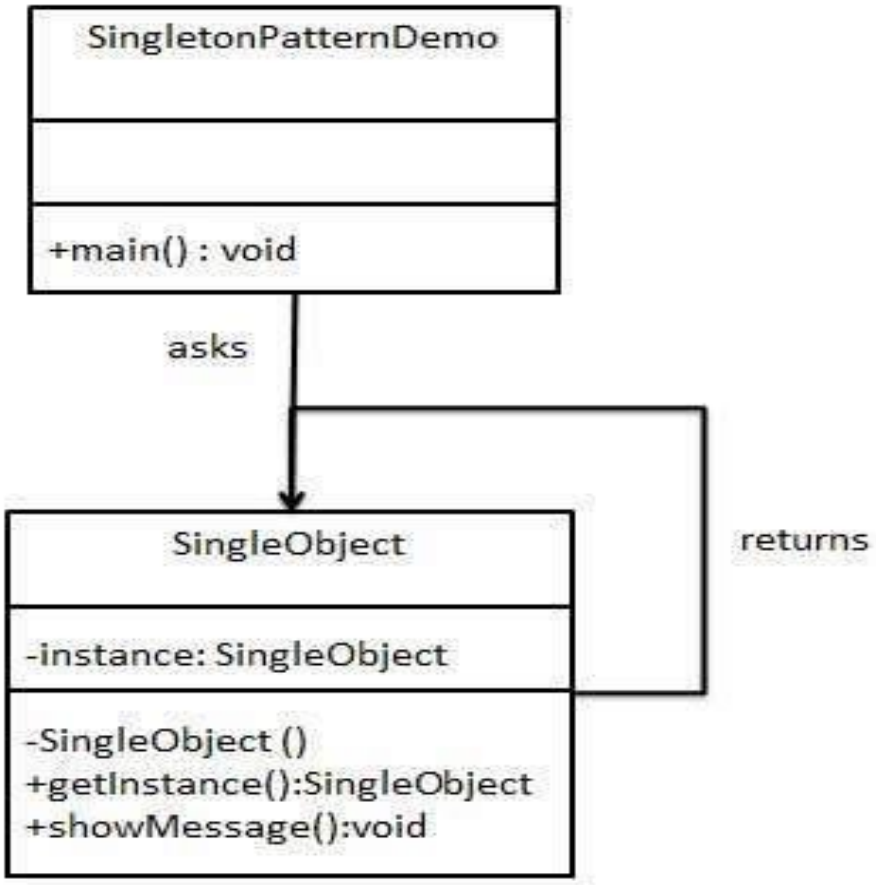


Figure 21 Singleton design pattern UML class diagram.

Chapter 7 - Implementation

During the implementation phase of the API, the outcomes from the requirements analysis phase and the system analysis and design were followed, in order to develop a well – implemented and robust API. Based on the components diagram and the microservices architecture we developed four independent RESTful APIs.

In particular, the first RESTful API, concerns the data manipulation from the IOLAOS Platform database. It was developed using Java Programming language and the Spring Boot framework. As a server – side / backend module, an Apache Tomcat server was used for API's deployment. The implementation was based on the Model View Controller and Data Access Object design patterns. Spring Boot is tightly connected with the MVC design pattern, since Models are defined the data which transferred from application's one layer to another, and Controllers contain all the services that manipulate those data and communicate with the View. The DAO pattern was used, in cases were an extra data manipulation and combination of data from different database tables occurred. More specific the Figure 22 presents through a UML class diagram system's classes, their attributes, functions, and relationships.

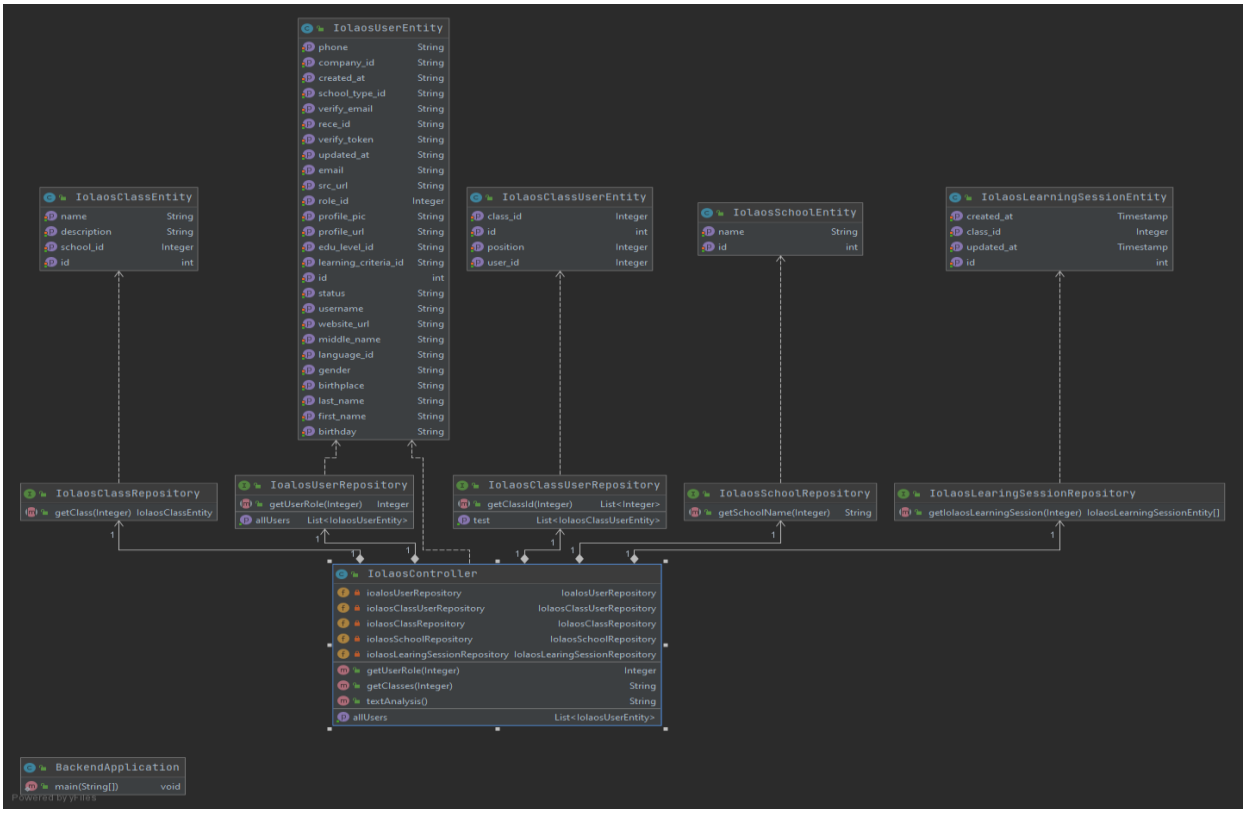


Figure 22 Data API implemented class diagram.

Although, Java and Spring Boot were used for the development of the data retriever module, to communicate with the database and request data. The philosophy was the same with the API described before, as well as the design patterns that were used. The implemented classes are presented in Figure 23.

The second module of the system is the Emotion and Image Processing API. For easier development and fast development, we divided it into the Emotion Detection API, with three individual modules, and the Image Processing API algorithms. As mentioned before the development of the emotion recognition algorithms were based on already implementations described on the Background chapter and in the system's textual analysis paragraph as well. Although, all modules run in the same server. More specific, we developed the Image Emotion Detector, the Speech Emotion Detector, and the Text Emotion Detector. The emotion detection modules followed the description in the use cases section and their functionality developed based on the normal flow of events in each use case scenario. The Image Processing API contains the template matching functionality as described in the use cases paragraph. The Python Programming language and libraries described in the Technologies section were used. In terms of design patterns, we used Singleton for machine learning models initialization classes and Data Access Object for data sources data manipulation.

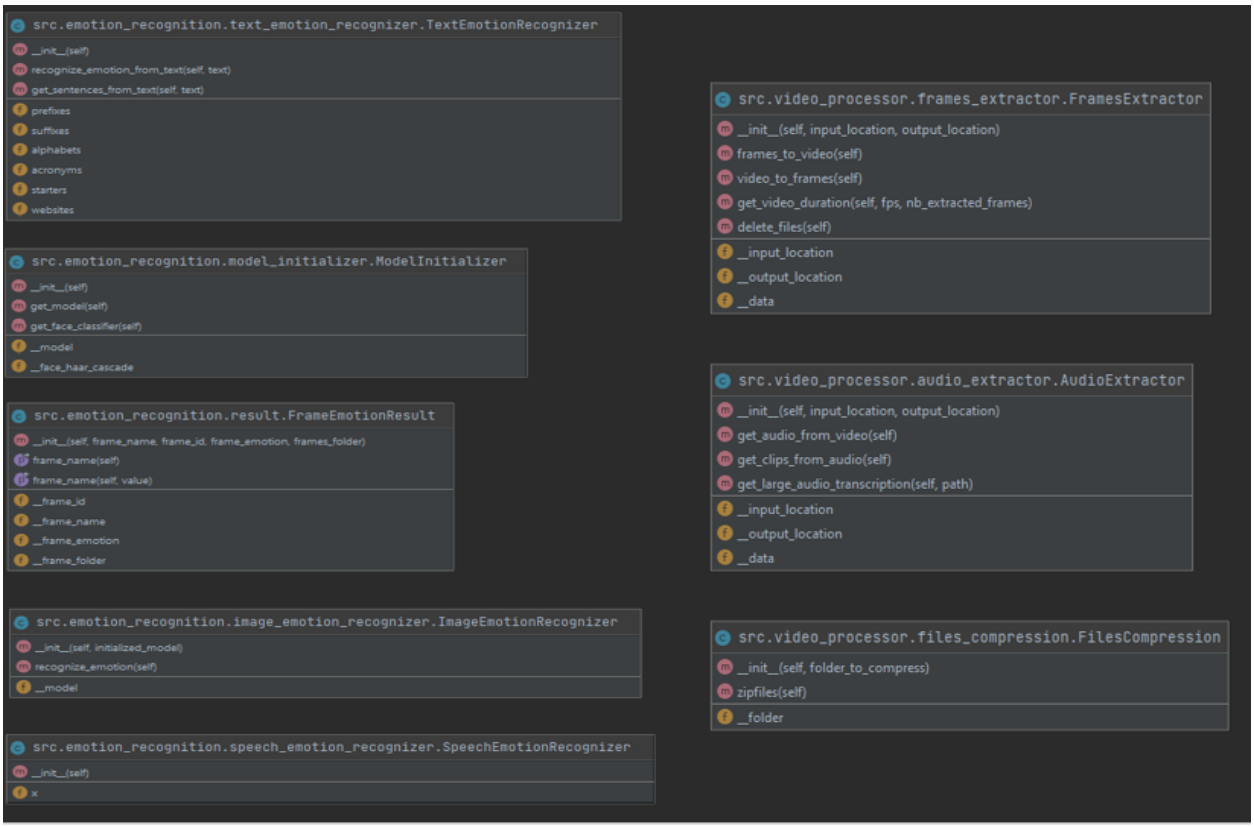


Figure 23 Emotion Detection and Image Processing implemented class diagram.

Finally, the fourth entity of the system is the communication with the Learning Record Store to retrieve learner's serious gameplay data. The API was developed with JavaScript programming language, express.js library foo microservices implementation and tincan.js, a library for connection and communication with the Learning Record Store.

REST API Services Documentation

In this section, the services documentation will be presented. In the next table, we present the all the available API services, in the form of name, endpoint, parameters and short description. For security reasons in each end point's URL the domain is not presented.

Table 16 API's provided services.

A/A	Endpoint	Parameters	Short Description
1	/getAllUsers	-	Returns all the IOLAOS Platform users
2	/getUserRole	userID	Returns the role type of a specific user.
3	/getClasses	userID	Returns educator's classes and learning sessions of each class in the IOLAOS Platform
4	/initiUser	-	Initializes IOLAOS Platform user in the database.
5	/extract_video_frames	file_path, file_name user_session_id video_type	Extracts all the frames of a video source.
6	/match_templates	video_id	Detects a specific image into a video frame.
7	/recognize_image_emotions	video_id	Recognizes face emotions from a set of video frames.
8	/recognize_speech_emotions	video_id	Recognizes speech emotions from a set of audio clips.
9	/extract_audio_from_video	user_session_id	Extracts audio from a video file.
10	/extract_clips_from_audio	video_id	Breaks an audio file into clips based on silence offsets.
11	/recognize_text_emotions	user_session_id	Breaks a message into sentences if it is necessary and recognizes the emotion a text message.
12	/save_chat_message	message	Saves a message in the database for later text sentiment analysis

Chapter 8 - Case Study - Learning Sessions

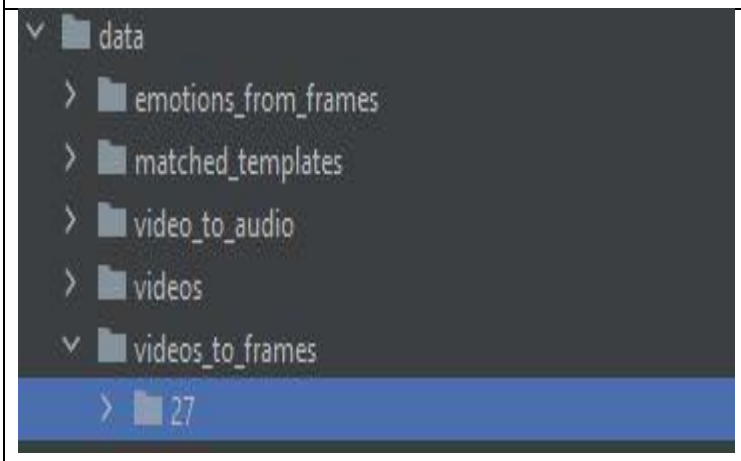
As described before the Data API retrieves all the available student's raw data from a learning session in the IOLAOS Platform. Those data concern student's face video, screen captured video, chat messages and xAPI statements. Due to development issues in the IOLAOS Platform, for the testing purposes we used dummy data.

The initial step is to add a new record in the database with initial information about the student. The information are the student id and the learning session id from the IOLAOS Platform. The next step is to recognize the emotions from the available data sources.

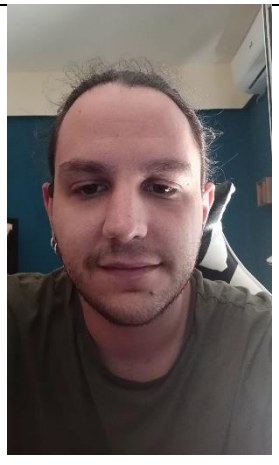
Table 17 Video frames extraction process.

extracted_frame_id	video_id	frame_name	frame_path
9782	27	1.jpg	files/data/videos_to_frames/27
9783	27	10.jpg	files/data/videos_to_frames/27
9784	27	100.jpg	files/data/videos_to_frames/27
9785	27	101.jpg	files/data/videos_to_frames/27
9786	27	102.jpg	files/data/videos_to_frames/27
9787	27	103.jpg	files/data/videos_to_frames/27
9788	27	104.jpg	files/data/videos_to_frames/27
9789	27	105.jpg	files/data/videos_to_frames/27
9790	27	106.jpg	files/data/videos_to_frames/27
9791	27	107.jpg	files/data/videos_to_frames/27
9792	27	108.jpg	files/data/videos_to_frames/27
9793	27	109.jpg	files/data/videos_to_frames/27
9794	27	11.jpg	files/data/videos_to_frames/27
9795	27	110.jpg	files/data/videos_to_frames/27
9796	27	111.jpg	files/data/videos_to_frames/27
9797	27	112.jpg	files/data/videos_to_frames/27
9798	27	113.jpg	files/data/videos_to_frames/27
9799	27	114.jpg	files/data/videos_to_frames/27
9800	27	115.jpg	files/data/videos_to_frames/27

a)



b)



c)

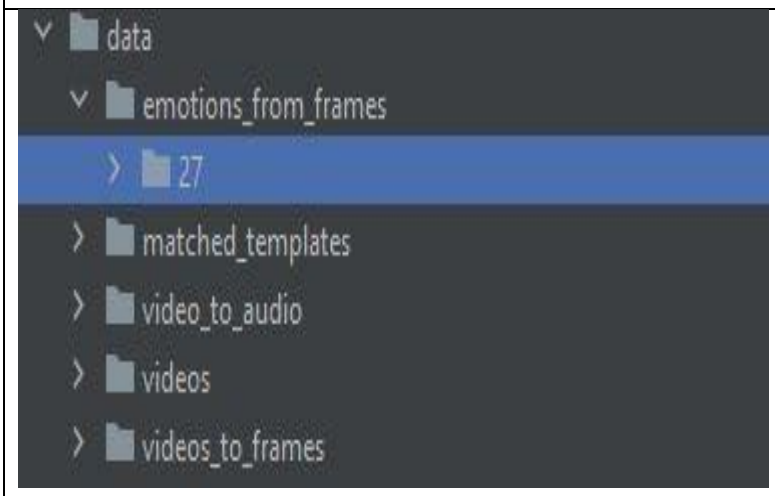
As described before, the image emotion recognition module retrieves the face video as input, extracts all the frames and records each frame in the database (Table 17.a) and saves them in a folder (Table 17.b) as well. Example of a face video frame is presented in the Table 17.c image. Using the extracted frames, the image emotion recognition service analyzes each frame and extract the emotion. The extracted information contains the emotion of the frame, the video sec that this emotion occurs and the emotion score. Again, the new information is saved in the database and the extracted emotion images are saved in a local folder.

Table 18 Image emotion recognition process.

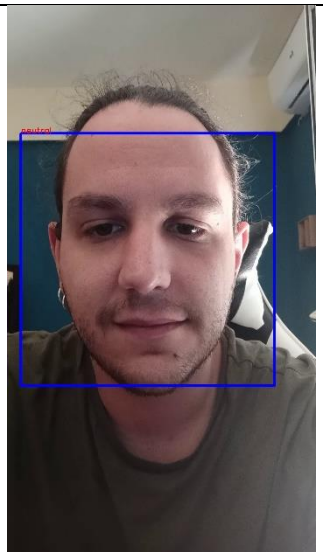
video_frame_emotion_id	extracted_frame_id	emotion_id	emotion_score	emotion_frame_second	emotion_frame_file_name	emotion_frame_file_path	emotion_text
801	9782	1	0.488054	1	1.jpg	files/data/emotions_from_frames/27	neutral
802	9893	1	0.429322	1	2.jpg	files/data/emotions_from_frames/27	neutral
803	10004	2	0.365871	1	3.jpg	files/data/emotions_from_frames/27	fear
804	10115	1	0.418539	1	4.jpg	files/data/emotions_from_frames/27	neutral
805	10226	1	0.437092	1	5.jpg	files/data/emotions_from_frames/27	neutral
806	10337	1	0.398084	1	6.jpg	files/data/emotions_from_frames/27	neutral
807	10448	1	0.396143	1	7.jpg	files/data/emotions_from_frames/27	neutral
808	10559	1	0.479679	1	8.jpg	files/data/emotions_from_frames/27	neutral
809	10641	1	0.432073	1	9.jpg	files/data/emotions_from_frames/27	neutral
810	9783	1	0.382752	1	10.jpg	files/data/emotions_from_frames/27	neutral
811	9794	1	0.480468	1	11.jpg	files/data/emotions_from_frames/27	neutral
812	9805	1	0.478332	0.480468	12.jpg	files/data/emotions_from_frames/27	neutral
813	9816	1	0.486134	1	13.jpg	files/data/emotions_from_frames/27	neutral
814	9827	1	0.460233	1	14.jpg	files/data/emotions_from_frames/27	neutral
815	9838	1	0.404694	1	15.jpg	files/data/emotions_from_frames/27	neutral
816	9849	1	0.412677	1	16.jpg	files/data/emotions_from_frames/27	neutral
817	9860	1	0.510507	1	17.jpg	files/data/emotions_from_frames/27	neutral
818	9871	1	0.387545	1	18.jpg	files/data/emotions_from_frames/27	neutral
819	9882	1	0.383823	1	19.jpg	files/data/emotions_from_frames/27	neutral
820	9894	1	0.449118	1	20.jpg	files/data/emotions_from_frames/27	neutral
821	9905	1	0.46448	1	21.jpg	files/data/emotions_from_frames/27	neutral
822	9916	1	0.417635	1	22.jpg	files/data/emotions_from_frames/27	neutral
823	9927	1	0.350767	1	23.jpg	files/data/emotions_from_frames/27	neutral
824	9938	1	0.369219	1	24.jpg	files/data/emotions_from_frames/27	neutral
825	9949	1	0.459546	1	25.jpg	files/data/emotions_from_frames/27	neutral
826	9960	1	0.407998	1	26.jpg	files/data/emotions_from_frames/27	neutral
827	9971	1	0.385838	1	27.jpg	files/data/emotions_from_frames/27	neutral

rameemotion 1 ×

a)



b)



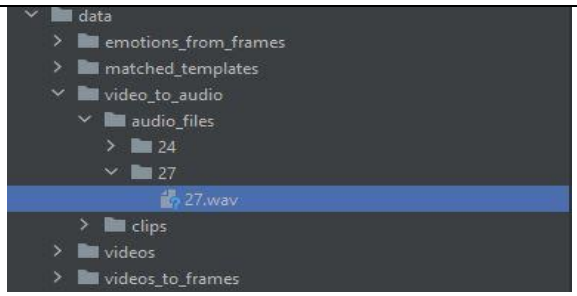
c)

The speech sentiment analysismodule retrieves the face video and extracts the audio Table 19 a), b). Based on silence offsets breaks the audio file into clips Table 19 c), d) and extracts the emotion from each clip Table 19 e). The extracted audio is saved in a local folder, the extracted clips too and the emotion information is recorded in the database.

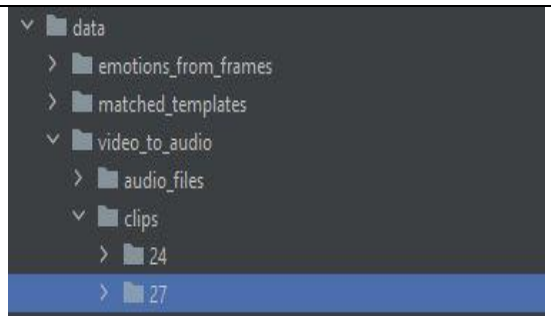
Table 19 Speech sentiment analysis process.

extracted_audio_id	video_id	audio_file_name	audio_file_path
3	27	27.wav	files/data/video_to_audio/audio_files/27/27.wav
NULL	NULL	NULL	NULL

a)



b)



c)

extracted_clip_id	audio_id	clip_file_name	clip_file_path	start_second	final_second
26	4	27_clip0.wav	files/data/video_to_audio/clips/27/27_clip0.wav	1	2
27	4	27_clip1.wav	files/data/video_to_audio/clips/27/27_clip1.wav	3	10
28	4	27_clip2.wav	files/data/video_to_audio/clips/27/27_clip2.wav	10	23
29	4	27_clip3.wav	files/data/video_to_audio/clips/27/27_clip3.wav	24	30
NULL	NULL	NULL	NULL	NULL	NULL

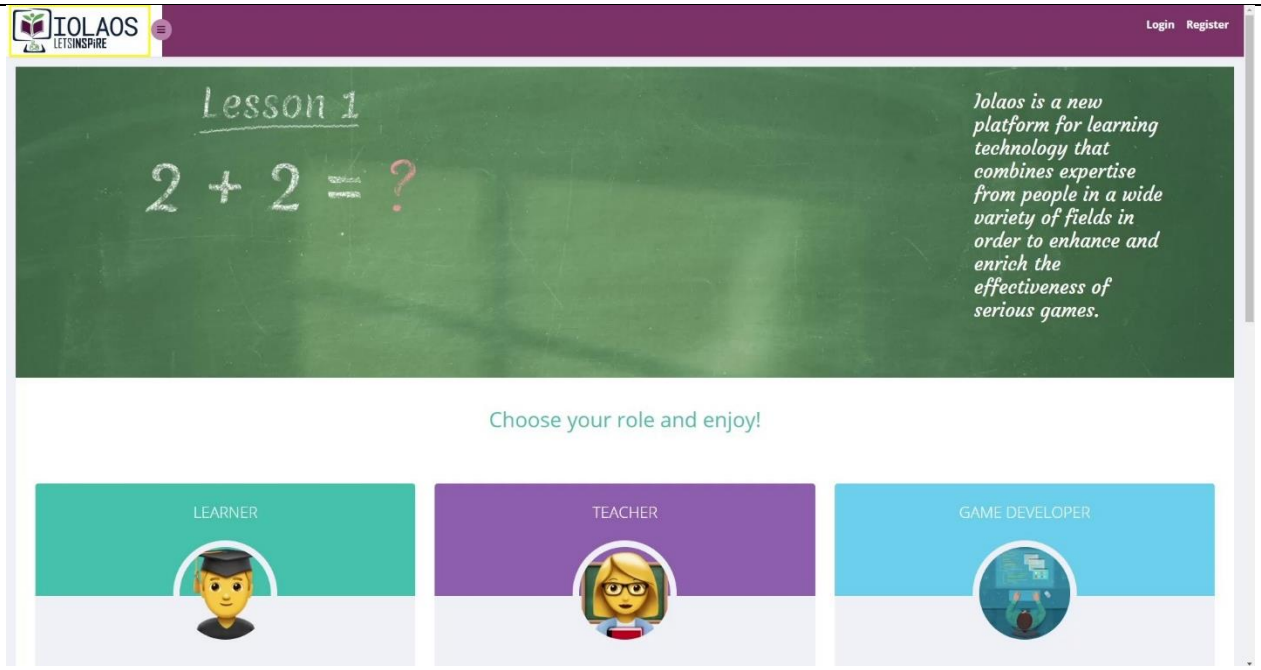
d)

audio_clip_emotion_id	clip_id	emotions_id	emotion_text
19	26	3	neutral
20	27	3	neutral
21	28	3	neutral
22	29	3	neutral
NULL	NULL	NULL	NULL

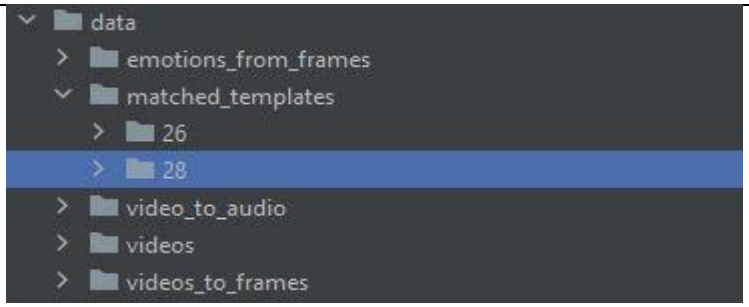
e)

The match template algorithm, breaks the screen video into frames and saves the extracted frames in a local folder and in the database (see Table 17). From each frame finds the logo of the IOLAOS Platform and creates a new image with the area the logo highlighted in a yellow square (Table 20 a)). The new images are saved in a local folder and into the database too (Table 20 b), c)).

Table 20 Template matching process.



a)



b)

	screen_frame_id	extracted_frame_id	frame_second	screen_frame_file_name	screen_frame_file_path	matched
▶	16	10652	1	1.jpg	files/data/matched_templates/28/	1
	17	11084	1	2.jpg	files/data/matched_templates/28/	1
	18	11195	1	3.jpg	files/data/matched_templates/28/	1
	19	11306	1	4.jpg	files/data/matched_templates/28/	1
	20	11417	1	5.jpg	files/data/matched_templates/28/	1
*	NULL	NULL	NULL	NULL	NULL	NULL

c)

Finally, the text sentiment analysismodule retrieves students' chat messages and saves them in the database (Table 21 a)). Following the procedure described in the use cases section, for each message checks if it consists of an only one sentence or it is a combination of sentences. In the second case breaks the message into sub – sentences (Table 21 b)). Finally extracts the emotion of the message (Table 21 b)).

Table 21 Text sentiment analysis process.

chat_message_id	user_session_id	iolaos_message_id	messages_text
13	3	19239	Hello! My name is Apostolis. I am very glad to be part of this learning session today.
NULL	NULL	NULL	NULL

a)

id	message_id	text	emotion_range	emotion_text
18	13	Hello!	0	neutral
19	13	My name is Apostolis.	0	neutral
20	13	I am very glad to be part of this learning session today.	0.5095	positive
NULL	NULL	NULL	NULL	NULL

b)

Chapter 9 - Conclusion & Future Work

The robust and continuous growth and evolution of technology and computers has an impact in the field of education. Modern eLearning systems, asynchronous or synchronous are developed and used as a complementary tool or even more as a main tool for the educational process. Research have concluded that traditional learning environments should adapt in the new technologies and the learning process should focus on each student's needs and learning paces. Thus, there is a crucial need in development of student – centered learning environments and learning process. Learning analytics are one of the mediums, that can be used to monitor and analyze student's behavior during the learning process and draw conclusion about learner and the learning process itself as well.

In this work we focused on the analysis of raw data retrieved from an eLearning platform, called IOLAOS. The main module of the IOLAOS platform is the virtual classrooms and therefore the online learning sessions. Each learning session is based on a serious game and during the session student raw data are being collected. The data concern face camera videos, screen captured videos, gameplay raw data and chat messages.

The presented system is an API with microservices able to collect and analyze those data. In particular, the API supports the collection of the raw data from IOLAOS database and the Learning Record Store. We focus the data analysis on the extraction of emotional learning analytics from student's face, speech, and text messages. The described module is based on existing state of the art image emotion recognition, sound and text sentiment analysis algorithms found in the literature and in code repositories, during our desktop research. Also, the extracted data are stored in data sources and manipulated by algorithms for future usage.

However, as described in the Technological Background chapter, there are some obstacles regarding the results from speech and text emotion analysis and detection, due to the early phase of this type of machine learning algorithms and models. Many times, the extraction of emotions from speech and text need additional observation to evaluate the results. Also, a huge concern in learning analytics collection, manipulation and analysis, regard ethics and personal data protection. Collecting and analyze users' data, and especially students' data, could cause major problem regarding the data accessibility, the data transparency, and the data ownership. Although, if the collected data are analyzed and manipulated with the appropriate operation, they could lead to the

development of improved learning systems, environments, and processes with defined learning outcomes.

The future work, focuses on the integration of the presented API with an application able to use the provided services, visualize the data and let end – user to interact with them. Moreover, there is a need to develop the presented services in real time algorithms and transform them in order to analyze students' emotions during the gameplay and transform the visual representation of the learning material according to student's emotions.

References

[1] N. Vidakis, A. K. Barianos, A. M. Trampas, S. Papadakis, M. Kalogiannakis, and K. Vassilakis, *in-Game Raw Data Collection and Visualization in the Context of the "ThimelEdu" Educational Game*, vol. 1220, no. November. Springer International Publishing, 2020.

[2] B. M. Prensky, "Digital Natives , Digital Immigrants," pp. 1–6, 2001.

[3] A. Vrdoljak, M. Banjanin, and K. Rakić, *Evaluating the effectiveness of the implemented models of ICT tools in teaching mathematics*. 2009.

[4] M. De Villiers, "Evaluation of an interactive learning environment: Theory and practice," *South African J. High. Educ.*, vol. 14, no. 3, pp. 120–131, 2010, doi: 10.4314/sajhe.v14i3.50175.

[5] P. Gaur, "Research Trends in E-Learning Poonam Gaur," *Shanlax Int. J. Commer.*, vol. 6, no. 1, pp. 36–39, 2018, doi: https://doi.org/10.5281/zenodo.1438182.

[6] M. S. A. El-seoud, N. Seddiek, M. M. El-khouly, and A. Nosseir, "E-Learning and Students ' Motivation : A Research Study on the Effect of E-Learning on Higher Education," pp. 20–26, 2014, doi: 10.3991/ijet.v9i4.3465.

[7] E. Ackermann, "Piaget's Constructivism , Papert's Constructionism : What's the difference ?," *Constr. Uses Perspect. Educ.*, pp. 1–11, 2001, doi: 10.1.1.132.4253.

[8] S. Sjøberg, "Constructivism and learning," *Int. Encycl. Educ.*, pp. 485–490, Jan. 2010, doi: 10.1016/B978-0-08-044894-7.00467-X.

[9] S. Charitakis, "Design and Development of Effective and Customizable Serious Game Platform Based on Learning Profile," 2017.

[10] S. Rutherford, *Collaborative learning: Theory, strategies and educational benefits*. 2014.

[11] J. Keller and K. Suzuki, "Learner motivation and E-learning design: A multinationally validated process," *Learn. Media Technol.*, vol. 29, pp. 229–239, Oct. 2004, doi: 10.1080/1358165042000283084.

[12] M. Gejdoš and I. Prachárová, "Fröbel'S Book „the Education of Man" and Its Pedagogical Legacy," *Int. J. New Econ. Soc. Sci.*, vol. 11, no. 1, pp. 339–346, 2020, doi: 10.5604/01.3001.0014.3552.

[13] "What is GBL (Game-Based Learning)?," 2013. http://edtechreview.in/dictionary/298-what-is-game-based-learning.

[14] M. Ulicsak, “Games in Education: Serious Games,” *A Futur. Lit. Rev.*, p. 139, 2010, [Online]. Available: http://www.futurelab.org.uk/projects/games-in-education.

[15] N. Behnamnia, A. Kamsin, M. A. B. Ismail, and A. Hayati, “The effective components of creativity in digital game-based learning among young children: A case study,” *Child. Youth Serv. Rev.*, vol. 116, p. 105227, Sep. 2020, doi: 10.1016/j.childyouth.2020.105227.

[16] O. Noroozi, H. Dehghanzadeh, and E. Talaee, “A systematic review on the impacts of game-based learning on argumentation skills,” *Entertainment Computing*, vol. 35. Elsevier B.V., p. 100369, Aug. 01, 2020, doi: 10.1016/j.entcom.2020.100369.

[17] M. Prensky, “The Games Generations: How Learners Have Changed,” *Digit. Game-Based Learn.*, vol. 1, no. 1, pp. 1–26, 2001, doi: 10.1145/950566.950596.

[18] M. Prensky, “The Games Generations: How Learners Have Changed,” *Digit. Game-Based Learn.*, vol. 1, no. 1, pp. 1–26, 2001, doi: 10.1145/950566.950596.

[19] R. Garris, R. Ahlers, and J. E. Driskell, “Games, Motivation, and Learning: A Research and Practice Model,” *Simul. Gaming*, vol. 33, no. 4, pp. 441–467, 2002, doi: 10.1177/1046878102238607.

[20] S. Papadakis and M. Kalogiannakis, *Using Gamification for Supporting an Introductory Programming Course. The Case of ClassCraft in a Secondary Education Classroom*. 2017.

[21] C. W. Kao, “The effect of a digital game-based learning task on the acquisition of the English Article System,” *System*, vol. 95, p. 102373, Dec. 2020, doi: 10.1016/j.system.2020.102373.

[22] N. Vidakis, E. Syntychakis, K. Kalafatis, E. Christinaki, and G. Triantafyllidis, *Ludic Educational Game Creation Tool: Teaching Schoolers Road Safety*, vol. 9177. 2015.

[23] “e-Learning, Gamification & Serious Games.” http://www.onseriousgames.com/differences-between-e-learning-gamification-and-serious-games/ (accessed Apr. 07, 2021).

[24] N. Vidakis, K. Barianos, G. Xanthopoulos, and A. Stamatakis, “Cultural Inheritance Education Environment: The Ancient Theater Game ThimelEdu,” 2018.

[25] M. Zeeman, “Factors that Influence Computer Science Students’ Attitude towards Serious Games in the Classroom,” *Mediterr. J. Soc. Sci.*, vol. 5, no. 21, pp. 413–418, 2014, doi: 10.5901/mjss.2014.v5n21p413.

[26] C. Girard, J. Ecalle, and A. Magnan, “Serious games as new educational tools: How effective are they? A meta-analysis of recent studies,” *J. Comput. Assist. Learn.*, vol. 29, no. 3, pp. 207–219, 2013, doi: 10.1111/j.1365-2729.2012.00489.x.

[27] R. Bernhaupt, K. Isbister, and S. de Freitas, “Introduction to this Special Issue on HCI and Games,” *Human–Computer Interact.*, vol. 30, no. 3–4, pp. 195–201, May 2015, doi: 10.1080/07370024.2015.1016573.

[28] N. Vidakis, A. K. Barianos, A. M. Trampas, S. Papadakis, M. Kalogiannakis, and K. Vassilakis, “Generating education in-game data: The case of an ancient theatre serious game,” in *CSEDU 2019 - Proceedings of the 11th International Conference on Computer Supported Education*, 2019, vol. 1, pp. 36–43, doi: 10.5220/0007810800360043.

[29] J. L. Ferreira de Almeida and L. dos Santos Machado, “Design requirements for educational serious games with focus on player enjoyment,” *Entertain. Comput.*, vol. 38, p. 100413, May 2021, doi: 10.1016/j.entcom.2021.100413.

[30] “flowleadership.org.” https://flowleadership.org/serious-games/ (accessed Apr. 07, 2021).

[31] T. Hess and G. Gunter, “Serious game-based and nongame-based online courses: Learning experiences and outcomes,” *Br. J. Educ. Technol.*, vol. 44, no. 3, pp. 372–385, 2013, doi: 10.1111/bjet.12024.

[32] S. Egenfeldt-Nielsen, “Overview of research on the educational use of video games,” *Digit. Kompet.*, vol. 1, no. 3, pp. 184–213, 2006, doi: 10.1353/dia.2006.0003.

[33] H. Rebah, “The educational effectiveness of serious games,” Nov. 2019.

[34] H. Mouaheb, A. Fahli, M. Moussetad, and S. Eljamali, “The Serious Game: What Educational Benefits?,” *Procedia - Soc. Behav. Sci.*, vol. 46, pp. 5502–5508, 2012, doi: 10.1016/j.sbspro.2012.06.465.

[35] D. Jonassen, T. Mayes, and R. McAleese, “A Manifesto for a Constructivist Approach to Uses of Technology in Higher Education,” in *Designing Environments for Constructive Learning*, T. M. Duffy, J. Lowyck, D. H. Jonassen, and T. M. Welsh, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 1993, pp. 231–247.

[36] S. Volejnikova-Wenger, P. Andersen, and K. A. Clarke, “Student nurses’ experience using a serious game to learn environmental hazard and safety assessment,” *Nurse Educ. Today*, vol. 98, p. 104739, Mar. 2021, doi: 10.1016/j.nedt.2020.104739.

[37] K. Michael and K. W. Miller, “Big Data: New Opportunities and New Challenges [Guest

editors' introduction]," *Computer (Long. Beach. Calif).*, vol. 46, no. 6, pp. 22–24, 2013, doi: 10.1109/MC.2013.196.

[38] T. Elias, "Learning Analytics: Definitions, Processes and Potential," 2011.

[39] "Learning Analytics." https://en.wikipedia.org/wiki/Learning_analytics (accessed Apr. 07, 2021).

[40] M. van Harmelen and D. Workman, "Analytics for Learning and Teaching," *Jisc*, vol. 1, no. 3, pp. 1–40, 2012, [Online]. Available: http://publications.cetis.ac.uk/wp-content/uploads/2012/11/Analytics-for-Learning-and-Teaching-Vol1-No3.pdf.

[41] K. Lepenioti, A. Bousdekis, D. Apostolou, and G. Mentzas, "Prescriptive analytics: Literature review and research challenges," *International Journal of Information Management*, vol. 50. Elsevier Ltd, pp. 57–70, Feb. 01, 2020, doi: 10.1016/j.ijinfomgt.2019.04.003.

[42] V. L. Uskov, J. P. Bakken, A. Byerly, and A. Shah, "Machine Learning-based Predictive Analytics of Student Academic Performance in STEM Education," in *2019 IEEE Global Engineering Education Conference (EDUCON)*, 2019, pp. 1370–1376, doi: 10.1109/EDUCON.2019.8725237.

[43] C. Romero and S. Ventura, "Educational data mining: A survey from 1995 to 2005," *Expert Syst. Appl.*, vol. 33, pp. 135–146, 2007, doi: 10.1016/j.eswa.2006.04.005.

[44] G. Siemens and R. S. J. d. Baker, "Learning analytics and educational data mining," *Proc. 2nd Int. Conf. Learn. Anal. Knowl. - LAK '12*, no. April 2012, p. 252, 2012, doi: 10.1145/2330601.2330661.

[45] J. T. Avella, M. Kebritchi, S. G. Nunn, and T. Kanai, "Learning analytics methods, benefits, and challenges in higher education: A systematic literature review," *J. Asynchronous Learn. Netw.*, vol. 20, no. 2, 2016, doi: 10.24059/olj.v20i2.790.

[46] D. Griffiths, "The Ethical Issues of Learning Analytics in Their Historical Context," in *Radical Solutions and Open Science*, D. Burgos, Ed. Singapore: Springer Singapore, 2020, pp. 39–55.

[47] D. Crookall, "Serious games, debriefing, and simulation/gaming as a discipline," *Simul. Gaming*, vol. 41, no. 6, pp. 898–920, 2010, doi: 10.1177/1046878110390784.

[48] A. C. Anders Drachen, Magy Seif El-Nasr, "Game Analytics – The Basics," *Game Anal.*, pp. 13–40, 2013.

[49] C. S. Loh, Y. Sheng, and D. Ifenthaler, “Serious games analytics: Methodologies for performance measurement, assessment, and improvement,” *Serious Games Anal. Methodol. Perform. Meas. Assessment, Improv.*, no. June, pp. 1–477, 2015, doi: 10.1007/978-3-319-05834-4.

[50] S. K. D’Mello, “Emotional Learning Analytics,” *Handb. Learn. Anal.*, pp. 115–127, 2017, doi: 10.18608/hla17.010.

[51] S. E. Zohora, A. M. Khan, A. K. Srivastava, N. G. Nguyen, and N. Dey, “A Study of the State of the Art in Synthetic Emotional Intelligence in Affective Computing,” *Int. J. Synth. Emot.*, vol. 7, no. 1, pp. 1–12, 2016, doi: 10.4018/IJSE.2016010101.

[52] S. Greene, H. Thapliyal, and A. Caban-Holt, “A Survey of Affective Computing for Stress Detection: Evaluating technologies in stress detection for better health.,” *IEEE Consum. Electron. Mag.*, vol. 5, no. 4, pp. 44–56, 2016, doi: 10.1109/MCE.2016.2590178.

[53] R. W. Picard, “Affective computing: Challenges,” *Int. J. Hum. Comput. Stud.*, vol. 59, no. 1–2, pp. 55–64, Jul. 2003, doi: 10.1016/S1071-5819(03)00052-1.

[54] Y. Chen, E. Argentinis, and G. Weber, “IBM Watson: How Cognitive Computing Can Be Applied to Big Data Challenges in Life Sciences Research,” *Clin. Ther.*, vol. 38, no. 4, pp. 688–701, 2016, doi: 10.1016/j.clinthera.2015.12.001.

[55] J. Tao and T. Tan, “Affective Computing and Interaction,” no. October 2005, 2011, doi: 10.4018/978-1-61692-892-6.

[56] N. Sebe, I. Cohen, and T. S. Huang, “Chapter 1 multimodal emotion recognition,” *Rev. Lit. Arts Am.*, pp. 981–256, 2004, [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.110.1129&rep=rep1&type=pdf.

[57] C. Breazeal and L. Aryananda, “Recognition of affective communicative intent in robot-directed speech,” *Auton. Robots*, vol. 12, no. 1, pp. 83–104, 2002, doi: 10.1023/A:1013215010749.

[58] G. Caridakis *et al.*, “Multimodal emotion recognition from expressive faces, body gestures and speech,” in *Artificial Intelligence and Innovations 2007: from Theory to Applications*, vol. 247, C. Boukis, A. Pnevmatikakis, and L. Polymenakos, Eds. Boston, MA: Springer US, 2007, pp. 375–388.

[59] S. Poria, E. Cambria, R. Bajpai, and A. Hussain, “A review of affective computing: From

unimodal analysis to multimodal fusion," *Inf. Fusion*, vol. 37, pp. 98–125, 2017, doi: 10.1016/j.inffus.2017.02.003.

[60] T. J. Brigham, "Merging Technology and Emotions: Introduction to Affective Computing," *Med. Ref. Serv. Q.*, vol. 36, no. 4, pp. 399–407, 2017, doi: 10.1080/02763869.2017.1369289.

[61] H. Meng, A. Kleinsmith, and N. Bianchi-Berthouze, "Multi-score Learning for Affect Recognition: The Case of Body Postures," in *Affective Computing and Intelligent Interaction*, vol. 6974, S. D'Mello, A. Graesser, B. Schuller, and J.-C. Martin, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 225–234.

[62] N. Vidakis, E. Christinaki, I. Serafimidis, and G. Triantafyllidis, "Combining Ludology and Narratology in an Open Authorable Framework for Educational Games for Children: the Scenario of Teaching Preschoolers with Autism Diagnosis," 2014, doi: 10.1007/978-3-319-07440-5_57.

[63] R. W. Picard, "Affective Computing," *Affect. Comput.*, pp. 1–9, 2019, doi: 10.7551/mitpress/1140.001.0001.

[64] R. El Kaliouby, R. Picard, and S. Baron-Cohen, "Affective computing and autism," *Ann. N. Y. Acad. Sci.*, vol. 1093, pp. 228–248, 2006, doi: 10.1196/annals.1382.016.

[65] C. Bartneck, C. Lütge, A. Wagner, and S. Welsh, "What Is AI?," 2021, pp. 5–16.

[66] S. J. Russell and P. Norvig, *Artificial intelligence: a modern approach*. Englewood Cliffs, N.J: Prentice Hall, 1995.

[67] R. M. Gagne, W. W. Wager, K. C. Golas, J. M. Keller, and J. D. Russell, "Book review: Principles of Instructional Design, 5th Edition," *Perfromance Improv.*, vol. 44, no. 2, pp. 44–46, 2005, doi: 10.1002/pfi.4140440211.

[68] H. Hassani, E. Silva, S. Unger, M. Tajmazinani, and S. MacFeely, "Artificial Intelligence (AI) or Intelligence Augmentation (IA): What Is the Future?," *AI*, vol. 1, p. 1211, Apr. 2020, doi: 10.3390/ai1020008.

[69] K. Thomsen, "Ethics for Artificial Intelligence, Ethics for All," *Paladyn, J. Behav. Robot.*, vol. 10, pp. 359–363, Nov. 2019, doi: 10.1515/pjbr-2019-0029.

[70] H. Chan, H. Shan, T. Dahoun, H. Vogel, and S. Yuan, "Advancing Drug Discovery via Artificial Intelligence," *Trends Pharmacol. Sci.*, vol. 40, Jul. 2019, doi: 10.1016/j.tips.2019.06.004.

[71] G. Cumming, *Artificial intelligence in education: An exploration*, vol. 14, no. 4. 1998.

[72] P. Leitner, M. Khalil, and M. Ebner, "Learning Analytics: Fundaments, Applications, and Trends," vol. 94, no. February, 2017, doi: 10.1007/978-3-319-52977-6.

[73] R. Michalski, J. Carbonell, and T. Mitchell, *Machine learning. an Artificial Intelligence approach. Volume 2*, vol. Vol. II. 1983.

[74] I. H. Sarker, "Machine Learning: Algorithms, Real-World Applications and Research Directions," *SN Comput. Sci.*, vol. 2, no. 3, p. 160, 2021, doi: 10.1007/s42979-021-00592-x.

[75] V. Tümen, Ö. F. Söylemez, and B. Ergen, "Facial emotion recognition on a dataset using Convolutional Neural Network," *IDAP 2017 - Int. Artif. Intell. Data Process. Symp.*, no. April, 2017, doi: 10.1109/IDAP.2017.8090281.

[76] R. Puri, M. Tiwari, A. Gupta, N. Pathak, M. Sikri, and S. Goel, "Emotion detection using image processing in python," *arXiv*, pp. 1389–1394, 2020.

[77] H. Ahmad, *Face Detection and Face Recognition In the Wild Using Off-the-Shelf Freely Available Components*. 2019.

[78] L. Zahara, P. Musa, E. P. Wibowo, I. Karim, and S. B. Musa, "The Facial Emotion Recognition (FER-2013) Dataset for Prediction System of Micro-Expressions Face Using the Convolutional Neural Network (CNN) Algorithm based Raspberry Pi," in *2020 Fifth International Conference on Informatics and Computing (ICIC)*, 2020, pp. 1–9, doi: 10.1109/ICIC50835.2020.9288560.

[79] O. Arriaga, P. G. Ploger, and M. Valdenegro, "Real-Time Convolutional Neural Networks for Emotion and Gender Classification," *arXiv*, 2017.

[80] D. Singh, "Human Emotion Recognition System," *Int. J. Image, Graph. Signal Process.*, vol. 4, no. 8, pp. 50–56, 2012, doi: 10.5815/ijigsp.2012.08.07.

[81] M. El Ayadi, M. S. Kamel, and F. Karray, "Survey on speech emotion recognition: Features, classification schemes, and databases," *Pattern Recognit.*, vol. 44, no. 3, pp. 572–587, Mar. 2011, doi: 10.1016/j.patcog.2010.09.020.

[82] S. Naziya S. and R. R. Deshmukh, "Speech Recognition System – A Review," *IOSR J. Comput. Eng.*, vol. 18, no. 04, pp. 01–09, 2016, doi: 10.9790/0661-1804020109.

[83] K. Hartmann, I. Siegert, D. Philippou-Hübner, and A. Wendemuth, "Emotion detection in HCI: From speech features to emotion space?," in *IFAC Proceedings Volumes (IFAC-*

PapersOnline), Jan. 2013, vol. 12, no. PART 1, pp. 288–295, doi: 10.3182/20130811-5-US-2037.00049.

[84] M. Selvaraj, R. Bhuvana, and S. Padmaja, "Human speech emotion recognition," *Int. J. Eng. Technol.*, vol. 8, no. 1, pp. 311–323, 2016.

[85] D. Issa, M. Fatih Demirci, and A. Yazici, "Speech emotion recognition with deep convolutional neural networks," *Biomed. Signal Process. Control*, vol. 59, p. 101894, May 2020, doi: 10.1016/j.bspc.2020.101894.

[86] S. Livingstone and F. Russo, *The Ryerson Audio-Visual Database of Emotional Speech and Song (RAVDESS)*, vol. 13. 2018.

[87] S. Shaheen, W. El-Hajj, H. Hajj, and S. Elbassuoni, "Emotion recognition from text based on automatically generated rules," *IEEE Int. Conf. Data Min. Work. ICDMW*, vol. 2015-Janua, no. January, pp. 383–392, 2015, doi: 10.1109/ICDMW.2014.80.

[88] P. M.-B. Lea Canales, "Emotion detection from text and speech: a survey," *Soc. Netw. Anal. Min.*, vol. 8, no. 1, pp. 1–8, 2018, doi: 10.1007/s13278-018-0505-2.

[89] A. Seyeditabari, N. Tabari, and W. Zadrozny, "Emotion Detection in Text: A Review," *arXiv*, 2018.

[90] Á. Serrano-Laguna, I. Martínez-Ortiz, J. Haag, D. Regan, A. Johnson, and B. Fernández-Manjón, "Applying standards to systematize learning analytics in serious games," *Comput. Stand. Interfaces*, vol. 50, pp. 116–123, 2017, doi: 10.1016/j.csi.2016.09.014.

[91] xapi.com, "overview." https://xapi.com/overview/.

[92] N. Vidakis, K. Barianos, A. Trampas, S. Papadakis, M. Kalogiannakis, and V. Kostas, "Generating Education in-Game Data: The Case of an Ancient Theatre Serious Game," 2019, doi: 10.5220/0007810800360043.

[93] N. Vidakis and S. Charitakis, *Designing the Learning Process: The IOLAOS Platform*. 2018.

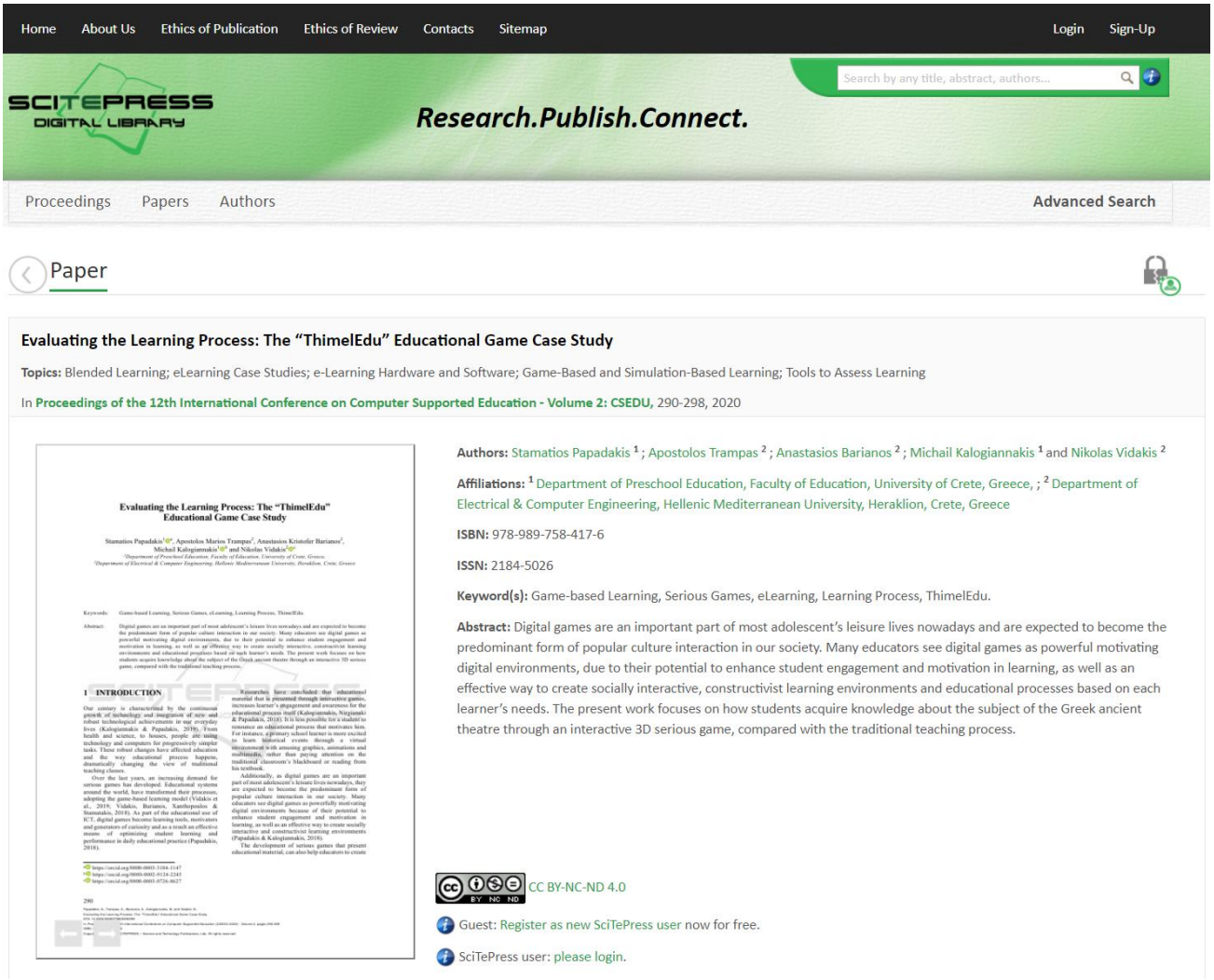
[94] K. M. Anil Kumar, B. R. Kiran, B. R. Shreyas, and S. J. Victor, "A Multimodal Approach to Detect User's Emotion," *Procedia Comput. Sci.*, vol. 70, pp. 296–303, 2015, doi: 10.1016/j.procs.2015.10.096.

Appendix A - Generating Education in-Game Data: The Case of an Ancient Theatre Serious Game

DOI: 10.5220/0007810800360043

Citation: N. Vidakis, A. K. Barianos, A. M. Trampas, S. Papadakis, M. Kalogiannakis, and K. Vassilakis, “Generating education in-game data: The case of an ancient theatre serious game,” in *CSEDU 2019 - Proceedings of the 11th International Conference on Computer Supported Education*, 2019, vol. 1, pp. 36–43, doi: 10.5220/0007810800360043.

Appendix B - Evaluating the Learning Process: The “ThimelEdu” Educational Game Case Study

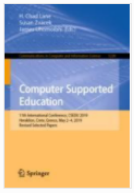


DOI: 10.5220/0009379902900298

Citation: S. Papadakis; A. Trampas; A. Barianos; M. Kalogiannakis, and N. Vidakis, (2020). Evaluating the Learning Process: The “ThimelEdu” Educational Game Case Study. In *Proceedings of the 12th International Conference on Computer Supported Education - Volume 2: CSEDU*, ISBN 978-989-758-417-6 ISSN 2184-5026, pages 290-298. DOI: 10.5220/0009379902900298

Appendix C - in-Game Raw Data Collection and Visualization in the Context of the "ThimelEdu" Educational Game

Springer Link



International Conference on Computer Supported Education
CSEDU 2019: Computer Supported Education pp 629-646 | Cite as

in-Game Raw Data Collection and Visualization in the Context of the “ThimelEdu” Educational Game

Authors Authors and affiliations

Nikolas Vidakis, Anastasios Kristofer Barianos, Apostolos Marios Trampas, Stamatios Papadakis, Michail Kalogiannakis, Kostas Vassilakis

Conference paper
First Online: 10 November 2020

1 Citations 187 Downloads

Part of the Communications in Computer and Information Science book series (CCIS, volume 1220)

Abstract

The widespread use of computer-based learning environments and the rise of big data have positioned learning analytics as a fundamental component of educational technology. Learning analytics provides methods for capturing and assessing student behaviors. In game-based learning environments, however, the development and integration of learning analytics has not yet reached their full potential. Research thus far has focused on the specification of learning analytics frameworks, implementation of different techniques and methods for the collection of data, and the development of automated assessment tools. Unfortunately, much work overlooks the importance of strategic data collection and therefore risks basing decisions on flawed or incomplete data. In this paper, we present our library that seeks to capture data in the context of a serious game, designed to be compatible with the Experience API (xAPI) and implemented in the Unity 3D game engine. Through this work, we aim to emphasize and extend the use of learning analytics in serious games, simplify the production of data, and record events with educational value.

DOI:10.1007/978-3-030-58459-7_30

Citation: N. Vidakis, A. K. Barianos, A. M. Trampas, S. Papadakis, M. Kalogiannakis, and K. Vassilakis, in-Game Raw Data Collection and Visualization in the Context of the “ThimelEdu” Educational Game, vol. 1220, no. November. Springer International Publishing, 2020.