Employment of Artificial Intelligence Mechanisms with Motion Controllers to Support Accessibility and Usability

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Information and Enterprise Systems

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“You will face many defeats in life, but never let yourself be defeated."

Hindi Proverb

Acknowledgments

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To my brother, my niece and my nephew, I would like to wish them all the success in their lives, so they can find true happiness in whichever path they wish to follow.

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Resumo

Atualmente, algumas aplicações apresentam problemas de acessibilidade não sendo fáceis de serem utilizadas por pessoas com determinadas deficiências e para determinados graus e também para determinadas idades.

Com o objetivo de melhorar a usabilidade dos softwares para pacientes com incapacidades visuais, auditivas, físicas, de fala, cognitivas, de linguagem, de aprendizagem e neurológicas, este estudo foca no movimento de várias partes do corpo.

A dissertação demonstra protótipos utilizando práticas de engenharia de software com novas funcionalidades quando comparadas com as tradicionais, defendendo um conceito de interação virtual que permite responder a diversas necessidades como a acessibilidade a pessoas com determinadas limitações e adicionar novas funcionalidades.

Por meio de uma câmara, o software processa as informações fornecidas pelo ambiente e utiliza algoritmos de inteligência artificial para visão computacional para interagir com o utilizador de forma dinâmica, respondendo aos movimentos realizados.

Foi desenvolvido um controlador de *drone* via *web*, oferecendo a possibilidade de ser utilizado por pessoas com diferentes tipos de deficiência.

Para garantir a validade dos métodos, foi realizado um questionário, que permitiu analisar o comportamento dos utilizadores e também se gravou o que acontece ao utilizar os protótipos para fins demonstrativos, permitindo obter conclusões sobre possíveis processos para melhorar as funcionalidades deste tipo de sistemas.

Palavras-chave: Inteligência Artificial, Engenharia de Software, Controladores de Movimento, Drones e Visão de Computador.

Abstract

Currently, some applications have accessibility issues not being easy to be used by people with certain disabilities and for certain degrees and also taking in consideration different ages.

With the objective to improve the usability of the software for patients with incapacities like visual, auditory, physical, speech, cognitive, language, learning and neurological, this study focuses on the movement of several body parts.

The dissertation demonstrates prototypes using software engineering practices with new features when compared to traditional ones, defending a concept of virtual interaction allowing to respond to various needs such as accessibility to people with certain incapacities and adding new features.

By using a camera, the software will process the information provided by the environment and use artificial intelligence algorithms for computer vision to interact with the user dynamically, responding to the movements performed.

A drone controller via web was developed, offering the possibility to be used by people with different type of disabilities.

In order to assure the validity of the methods, a questionnaire was performed, which allowed to analyze the behavior of the users and also was recorded what happens when using with the prototypes for demonstrative purposes, allowing to obtain conclusions about possible processes to improve the functionalities of these type of systems.

Keywords: Artificial Intelligence, Software Engineering, Motion Controllers, Drones and Computer Vision.

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Abbreviations

AI	**A**rtificial **I**ntelligence
AIML	**A**rtificial **I**ntelligence **M**ark Up **L**anguage
API	**A**pplication **P**rogramming **I**nterface
AR	**A**ugmented **R**eality
CGI	**C**omputer **G**enerated **I**mages
FR	**F**unctional **R**equirements
GUI	**G**raphical **U**ser **I**nterface
IR	**I**nfra**r**ed
HTML	**H**yper**t**ext **M**arkup **L**anguage
HTTP	**H**yper **T**ext **T**ransfer **P**rotocol
HTTPS	**H**yper **T**ext **T**ransfer **P**rotocol **S**ecure
HUD	**H**eads **U**p **D**isplay
IDE	**I**nterface **D**evelopment **E**nvironment
JSON	**J**ava**S**cript **O**bject **N**otation
MAS	**M**ulti **A**gent **S**ystems
MR	**M**ixed **R**eality
ML	**M**achine **L**earning
ROI	**R**egion **o**f **I**nterest
SLAM	**S**imultaneous **L**ocalization **a**nd **M**apping
UAV	**U**nmanned **A**erial **V**ehicle
UI	User **I**nterface
VR	**V**irtual **R**eality
XML	E**x**tensible **M**arkup **L**anguage

Chapter 1

1

1. Introduction

This chapter introduces the research performed being divided in six main sections. First, will mention the context and motivation of the dissertation; second will show a detailed definition of the problem. The objectives appear as third and the research questions at fourth. The final part will show the research methodologies used and an outline section where an explanation of the document structure is showed mentioning an overview of the upcoming chapters.

1.1 Context and Motivation

New technologies have been emerging and appearing in society like motion controllers, augmented reality (AR), virtual reality (VR), mixed reality (MR), internet of things (IoT) changing the behavior of the user (Hoyer et al., 2020); these new technologies work in real time and may use specific artificial intelligence (AI) mechanisms, which improves the usability that might vary depending on the context (Kim, 2019).

There is a need to improve the behavior of artificial intelligent agents for the applications to make the software more efficient and to provide more functionalities, retrieving important information from the surrounding environment like positioning, distances allowing to implement several mechanisms, like motion controllers. With the objective to improve the usability and accessibility of the software for patients with disabilities like visual, auditory, physical, speech, cognitive, language, learning and neurological, this study focuses on the movement of 3 body parts: hand motion (Guo et al., 2021), eye gaze (Antunes, 2017) and general body (including arms, legs, hands, feet and head).

The usage of motion controllers can facilitate the interaction for different type of persons, which can help people with different type of disabilities, making the applications in some cases easier to use.

Drones are used nowadays for several purposes like getting geographical images, disaster response, operations of rescue, healthcare and agriculture.

The applications can have more tasks to achieve objectives in several areas like, physiotherapy, medical (Le et al., 2010), unmanned aerial vehicles (UAVs), formation among others and should also provide the possibility to be used by people with different type of disabilities.

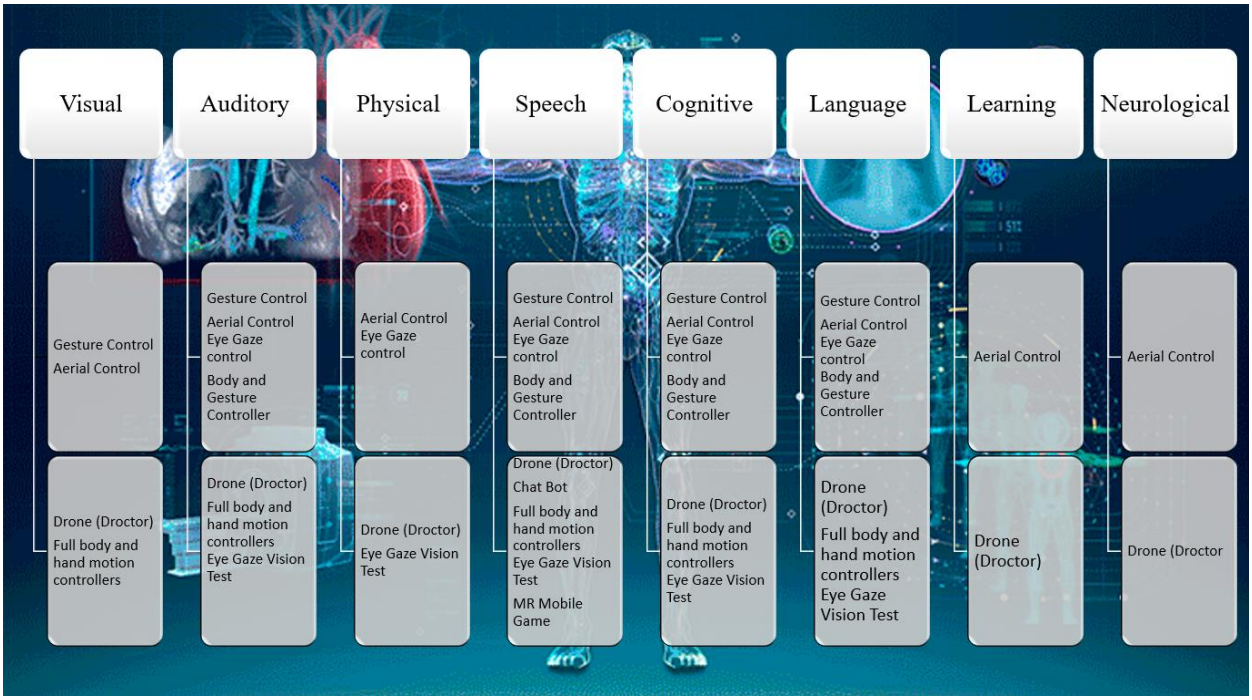


Figure 1. Common disabilities and technologies used to reduce the usability gap, plus the applications developed that can be used for the mentioned disorders depending on the degree of incapacity.

1.2 Problem Definition

Nowadays the applications have some problems, like not being easy to be used by people with visual, auditory, physical (Jia et al. 2007), speech, cognitive, motor (Chin et al., 2018) language, learning and neurological disabilities (Trewin, 2018), correctly augmenting during motion (Babu et al., 2018) and limited responsive AI (Acemoglu, & Restrepo, 2020; Ghafghazi et al., 2021; Kim & Song, 2022).

The employment of artificial intelligence can be enhanced and provide more useful functionalities than the current ones; the interaction with the user in software engineering terms can be improved. Many gaps can be found in MR systems like missing of responsive AI in some cases, or a correct and more functional treatment of the information provided by the environment.

Concerning the problem of accessibility and usability for users of different ages and disabilities, several applications were developed taking in consideration the degrees of handicap.

The developed “Droctor” system, a web drone controller (Sarkar et al, 2016) is able to be used by people with auditory, speech and learning incapacities.

Concerning visual, auditory, speech, language and some motor and cognitive incapacities, a motion controller of the movement (Yashoda et al., 2018) of several body parts like hands, fingers, arms, legs, head, body and feet was implemented.

Users with movement and earing problems can use the aerial control and the eye gaze control.

The iris movement controller allows to resolve the problem of usability for people with certain levels of auditory, physical, speech, cognitive, language, learning and neurological incapacity.

This work aims to a scientific approach based on the combination of technologies to solve issues that occur every day, looking for an automation of the reply from the information system by improving the AI response mechanisms to the inputs from the user.

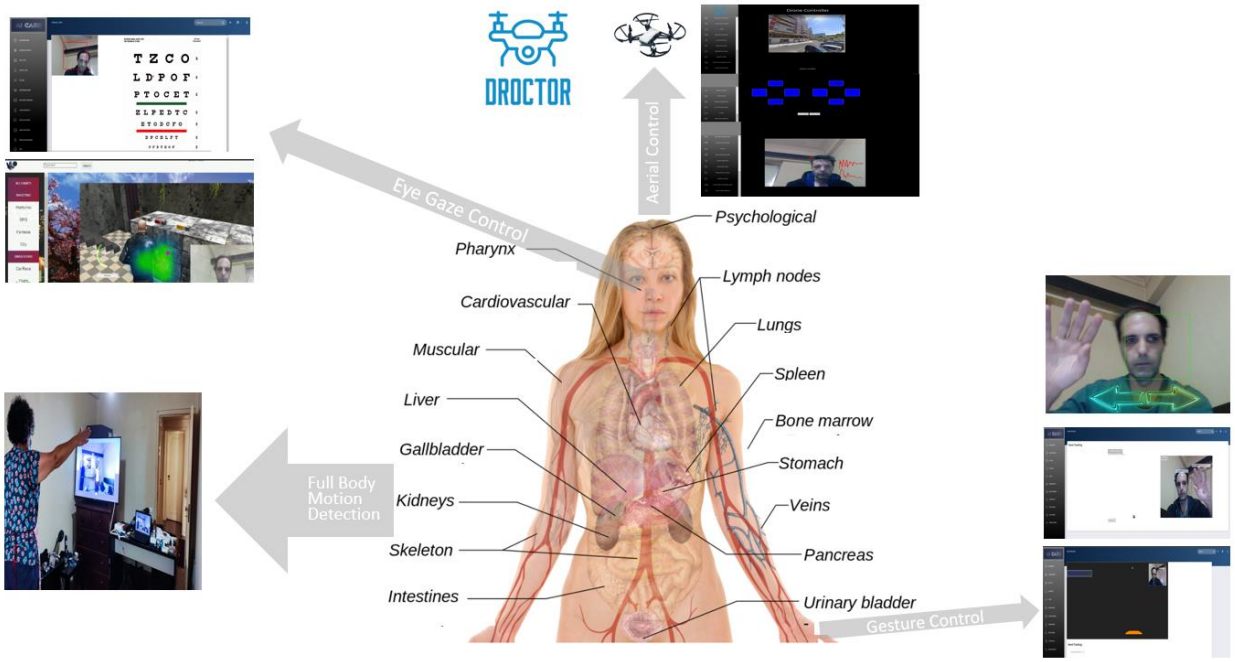


Figure 2. Developed Systems for different types of disabilities, some with motion control for interaction with some of the human body parts.

The objective is to find an innovative concept as a solution for this situation considering the engineering aspects such as using inputs, AR elements and AI mechanisms in order to produce an output.

Zhao et al. (2018) looked for a solution of controlling drones movement using motion detectors, increasing the interactivity of the system and allowing the use for people with visual and certain motor problems.

A literature analysis of existing research was conducted in order to identify the technical limitations of this problem (Wang, 2021).

Motion controllers are needed for people with certain types of disabilities in order to perform different type of tasks, like eye gaze for people with motor disabilities (Sunny et al., 2021) or hand controllers for users that have visual problems.

1.3 Objectives

The research in cause aims to find solutions to the problems related with traditional applications, developing responsive AI mechanisms and also use of motion controllers (Wozniak et al., 2016) to improve the accessibility for people with different disabilities.

Virtual systems have been developing over the last years, but still faces many issues. The development of theoretical artefacts will help to provide more functionalities to achieve pre-determined objectives and also to allow the use for different types of people.

Concerning the employment of artificial intelligence mechanisms, the research tries to implement new functionalities to the traditional processes. The architectures of multi-agent systems reveal high importance in order for the system to provide accurate detection.

Unmanned aerial vehicles (UAVs) can be controlled by hand motion, making the process easier for people with visual disabilities.

The research objectives to add a new methodology to the process of interaction with the systems using motion controllers. The study focuses on the application of AI mechanisms, where the virtual elements can be controllers of an AI agent or have mechanisms that respond to the inputs performed by the user. The main objectives of the dissertation are:

- Improve the usability and accessibility of the software systems by using motion controllers allowing people with different type of disabilities to perform tasks. (Objective 1).
- Increase the efficiency and functionality of the applications by adding AI mechanisms making easier to provide functionalities, control and interactivity with the users. (Objective 2).

1.4 Research Questions

These questions allow to determine the problem and fundament this study, facilitating the achievement of the proposed objectives.

- RQ1 - How motion controllers using artificial intelligence mechanics can facilitate the usability and accessibility of the applications for people with disabilities like visual, auditory, physical, speech, cognitive, language, learning and neurological? (Research Question 1).
- RQ2 - How can the implementation of AI mechanisms in softwares provide more efficiency, control and functionality? (Research Question 2).

The first research question is more related with the first objective aiming to provide a solution for the problem of accessibility for people with visual, auditory, physical, speech, cognitive, language, learning and neurological. The answers to the questions, allow to satisfy the proposed objectives, due to being focused

on the possible solutions for the research problem. The study focuses on the methodologies to develop systems increasing the efficiency and usability when compared with traditional processes.

The second question is related to the development of a methodology using algorithms to perform certain tasks increasing the functionality of the softwares, being more focused on the second objective.

1.5 Research Methodologies

This section mentions the different types of research performed for the dissertation, facilitating the conduct and organization of the work performed.

1.5.1 Exploratory Research

The Exploratory Research can be very useful when answering questions like how and why, helping to understand the nature of the problem aiming to generate hypothesis and getting insights and ideas. The methodology in cause tries to answer the knowledge gaps and analyses the scope. Some of the advantages are determining the reliability of methodological characteristics and obtaining primary knowledge on the object of research (Zukauskas et al., 2018). The questionnaires to the final users and observation will follow a qualitative research process and the performance analysis, the results of the algorithms, the softwares/prototypes and the analysis of code, papers and sites will follow a quantitative methodology.

1.5.2 Research Paradigm and Methodology

The research aims to provide answers to the investigation questions in order to achieve the proposed objectives, using a continuum epistemological perspective, analyzing the nature, origin and scope of knowledge to reach a possible response to the problem. A double approach (positivist, interpretative) requires the combination of the quantitative and qualitative overviews. The research will provide a possible solution by implementing artefacts to reach the proposed objectives and answer the research questions.

The developed solutions were tested and the performance and distances to execute the tasks were measured taking in consideration the existing processes.

The data collection follows a quantitative perspective and the surveys an open-ended format. By using exploratory research, it is important to understand the nature of the problem, so a study of the challenges was done, taking in consideration the existing methodologies used for different types of disabilities as well as an investigation of other researches, using motion controllers and the approaches used to resolve problems like accessibility for certain handicaps.

The study focuses initially on the limitations and possible technologies, like implementing motion controllers and AI mechanisms; on a second phase, prototypes were developed some with motion controllers offering the possibility to be used by people with different type of disabilities. The third stage is concerning implementation of the developed systems and in the fourth stage, a questionnaire to the users was performed, as well as tests to improve usability based on performance and measurement metrics to qualify the developed artifacts. After the results, will be possible to obtain conclusions mentioning if the presented solution is reliable.

For the first objective and the first research question several prototypes were developed and tested like an eye gaze controller allowing the usage for different type of users and for the first objective and the first research question a prototype was developed to defend the concept of improving AI mechanics in order to provide more functionalities and control to achieve objectives

The survey to the testers followed a qualitative approach and the artefacts to defend the concept used a quantitative approach.

The qualitative research might be more flexible or adjustable and may use categorization and patterns, to perform this research methods like interviews, focus groups and observation can be used. Basis in exploration and understanding of the nature of the problem and hypothesis can be determined. Intends to create knowledge and fill research gaps, providing an interpretation of the problem. This type of approach can be adjusted to what is learned following an iteration process aiming to explore the problem.

Quantitative research may have a more mathematical overview and manipulation of observations to describe and explain the phenomena that the observations reflect employing empirical methods. May analyze data in a more numerical perspective in order to achieve conclusions or to justify certain assumptions (Sukamolson, 2007).

Table 1. Quantitative and qualitative approaches. Adapted from (Mack et al., 2005).

	Quantitative	*Qualitative*
General framework	• Seek to confirm hypotheses about phenomena • Instruments use more rigid style of eliciting and categorizing responses to questions • Use highly structured methods such as questionnaires, surveys, and structured observation	• Seek to explore phenomena • Instruments use more flexible, iterative style of eliciting and categorizing responses to questions • Use semi-structured methods such as in-depth interviews, focus groups, and participant observation
Analytical objectives	• To quantify variation • To predict causal relationships • To describe characteristics of a population	• To describe variation • To describe and explain relationships • To describe individual experiences • To describe group norms
Question format	Closed-ended	Open-ended
Data format	• Numerical (obtained by assigning numerical values to responses)	• Textual (obtained from audiotapes, videotapes, and field notes)
Flexibility in study design	• Study design is stable from beginning to end • Participant responses do not influence or determine how and which questions researchers ask next • Study design is subject to statistical assumptions and conditions	• Some aspects of the study are flexible (for example, the addition, exclusion, or wording of particular interview questions) • Participant responses affect how and which questions researchers ask next • Study design is iterative, that is, data collection and research questions are adjusted according to what is learned

1.6 Document Structure

This work is organized as follows. The present Chapter 1 is where the context, motivation and definition of the problem is done mentioning also the objectives, challenges and research questions which this dissertation intends to answer followed by the research methodologies used, that in this case was the exploratory research due to focusing on the problem showing important insights.

The second chapter mentions the theoretical background which provides concepts and principles and also to prove the nature of the problem, as well as related work and investigations showing how other authors approached the problem.

Chapter three show the development done with motion controllers for applications focusing on the AI mechanisms demonstrating a process and prototypes to add functionalities.

The fourth chapter will be more focused on a prototype that allows to control a drone.

On the fifth chapter shows the tests and results obtained taking in consideration qualitative and

quantitative aspects, by using a questionnaire and measuring distances and performance in order to justify and defend the proof of concept in cause.

The final chapter will show the conclusions obtained from all the developed process, looking for an efficient solution for the previously described issues taking in consideration the work performed and the results obtained.

Figure 3. Dissertation structure.

Chapter 2

2. Theoretical Background and Related Work

Taking in consideration the objectives, the proposed questions, the necessary technologies and the research performed by other authors, this section will provide more insights concerning the topics related with the investigation in cause, demonstrating the nature of the problems, how other researchers approached for a solution and which limitations and challenges exist.

2.1 Multi-Agent Systems

An AI system is composed by an agent and an environment. The agents act in this environment, and there may be other agents.

Concerning simple reflex agents, generally the function is based on a set of rules, actions and conditions. Historical data is ignored and act only based on current perception. The action/condition allows to define a state, for example if the condition is true, perform a certain action.

Model-based reflex agents use models to assess the environment, in these models it is important to find a rule, whose condition satisfies the current situation. There are models that use the history of perception and internal memory to make decisions about an internal "model" of the environment. Internal memory allows these agents to store part of their navigation history and then use this semi-subjective history to help them understand things about their current environment, even when everything they need to know cannot be directly observed.

Goal-Based Agents make decisions depending sometimes on the distance to the target having to choose between multiple possibilities, usually selecting the one that reaches a desired target state. All of their actions have the objective of reducing the distance from the goal to the value of 0. Decisions can be represented explicitly and can be modified, making the process more flexible. This implementation generally requires research and planning and the behavior can be easily altered.

Utility-based agents do not act only on a non-objective basis, but in a better way to achieve it. The utility of the agent differs from its counterparts, helping to choose the best alternatives, when there are several available. Aims to maximize the utility function, this function maps a state with utility measurements. The process is flexible and adapts to changing environments, the agent is able to make rational decisions, even when the objectives are inadequate.

Learning Agent is related to Machine Learning (ML), this type of agent manages to learn from past experiences and performs actions without these being explicitly defined in the Code.

The learning agent consists of two elements: the learning element and the performance element. The performance element offers the possibility for the agent to select the actions based on the perceptions

received. The learning element assesses the behavior of the performance element and proposes improvements. Sometimes, it also suggests actions and mechanisms that allows to improve the behavior of this agent.

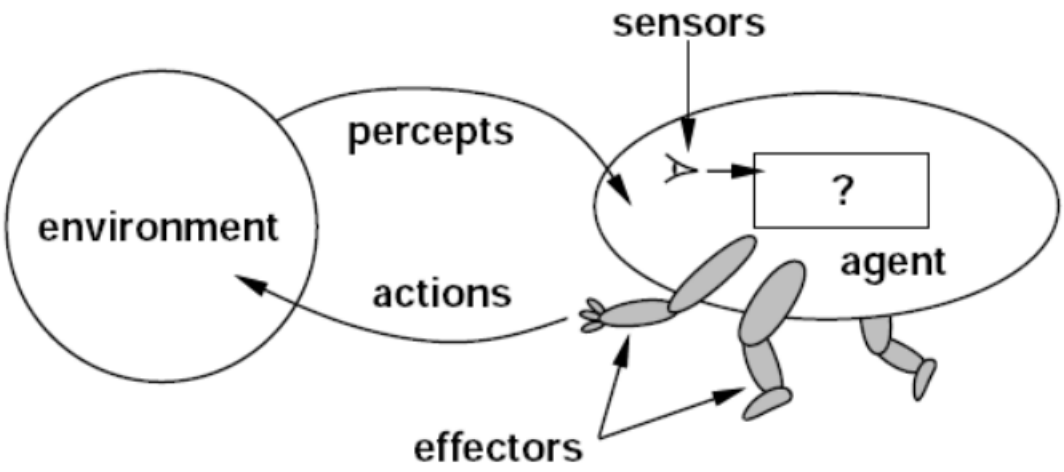


Figure 4. An Intelligent Agent (Russell & Norvig 2003).

Multi-Agent System (MAS) corresponds to an area of research and study of artificial Intelligence (AI) in modern times. A Multi-Agent System consists of various decision-making agents that interact in a shared environment to achieve common or conflicting goals. It can be said that it is focused on behavior analysis, definition of algorithms and placement of objectives.

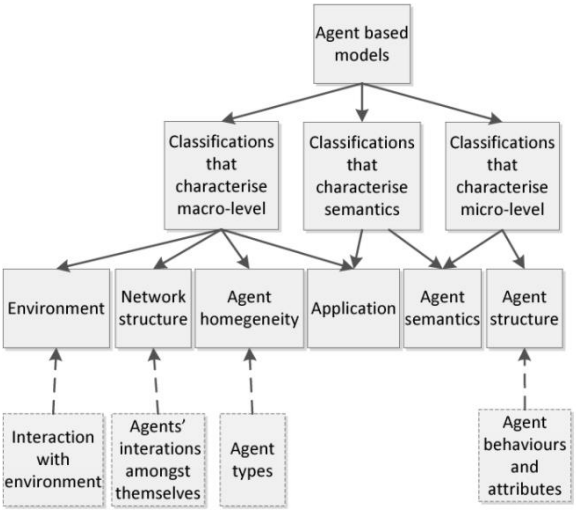
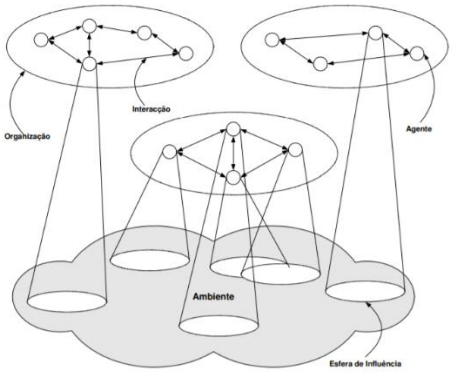


Figure 5. Classification of Agent Based Models. Adjusted Pudane (2017).

In Multi-Agent System, various agents can interact with each other; these agents can be homogeneous or heterogeneous, and should be analyzed their organization, interaction, relationship with the environment, spheres of influence and the communication process between agents.



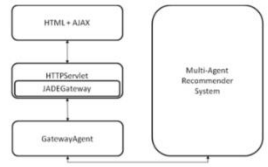


Fig. 1 Interaction with the recommender system.

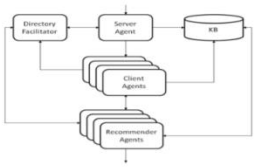


Fig. 2 Multi-agent recommender system architecture.

```
// created for each client
while not end of session {
  receives request from server
  sends request to recommenders
  waits for responses
  determines winner
  sends results to providers
}
updates knowledge base
destroys itself
```

Fig. 3 Client agents behaviour

```
receives request from client
sends bid to client
builds recommendation set
if wins bid
  sends recommendations
  //directly to GatewayAgent
updates knowledge base
sends results to provider
determines winner
sends results to provider
```

Fig. 4 Recommender agents behaviour

Figure 6. Theorization of architectures and behaviors in recommenders (Morais et al., 2012).

Over time, distributed artificial intelligence has been evolving and has been applied to abstraction and divide and conqueror concepts for problem solving. Distributed Artificial Intelligence focuses on: Granularity of two agents; heterogeneity of two agents; methods for the distribution of control (among the agents) and possibilities of communication between the agents.

In general terms, communications are governed by protocols, which allow to define standards in the process of sending data. The Knowledge Sharing Effort (KSE) is developed in the KQML (Knowledge and Query Manipulation Language) based on the exchange of messages for knowledge and the KIF (Knowledge Interchange Format).

Learning can be interactive or individual and must have various aspects such as the property of the objective, or the method used. In the coordination of agents, different types of dependencies can be verified, such as independence, unilateral, mutual and reciprocal dependency.

There are several types of architectures, this study will describe some of the more commonly used.

Deliberative Architectures: the decisions of the agents are based on logical reasoning.

Reactive Architectures: are usually performed in real time and the agent acts from interactions with the environment, the behaviors are sometimes defined having in mind the functionalities and it is possible to have various behaviors at the same time.

Hybrid Architectures: combines reactive architecture with deliberative architecture. As actions have in account the environment and the functionalities of the agent.

Architecture by layers: based on the existence of subsystems. It can be considered that on the horizontal layers the software is linked to the input sensors and the output actions and in the vertical the input sensors and the actions have at least one layer between them, from the input to the output this will go through several filters.

Architecture BDI (Belief-Desire-Intention): The belief can be seen as the current state of the agent based on what he considers to be true at a given moment (like the knowledge of the environment).

The wishes are the objectives, which can arise later; the wish can be obtained from the use of a reasoning on the existing sub-desires.

The intentions can be seen as actions and tasks that the agent chooses to perform in order to accomplish his objective.

Generic Architecture of a Social Agent: agents usually have models of other agents. In this type of architecture, the agents can learn, in order to improve their decisions in the future. According with Foo (2007), the behavior of the agents can follow the mathematical model of game theory and search for the Nash equilibrium.

The agents can be evaluated over several perspectives like the Performance Measure, Environment, Actuators and Sensors (PEAS).

2.2 Ubiquitous Augmented Reality and Virtual Reality

Ubiquitous AR has been the most common approach for dynamic objects. The outliers are identified by cues; in example, by re-projecting and removing the matches that are not accordant to the expected motion.

These approaches lead to erroneous estimation of motion in scenes with very few inliers.

PARSAC (Tan et al., 2013) has adapted Random Sample Consensus RANSAC (Fischler & Bolles,1981) to handle dynamic scenes. RANSAC allows to efficiently remove outliers even when the inlier ratio is rather low, so that the camera pose can be reliably estimated on challenging situations (Wang et al., 2022).

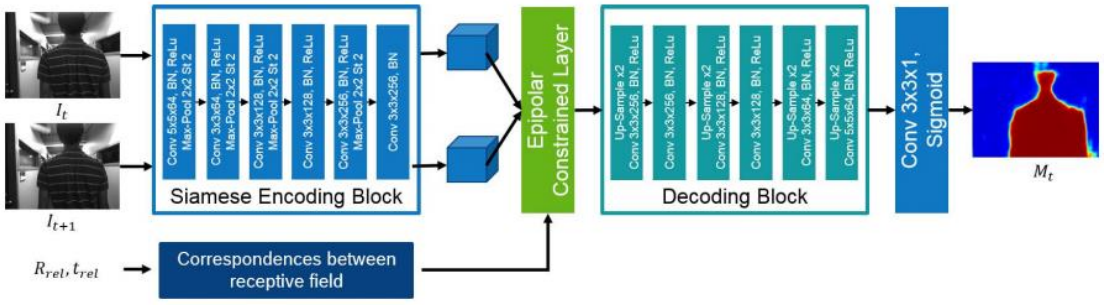


Figure 7. Example of a Deep Neural Network (Babu et al., 2018).

Babu et al., (2018) have developed a Multi-motion MC-VIO algorithm that is able to track landmarks related to primary and secondary motions. Ubiquitous Augmented Reality (AR) should provide exact values anytime, anywhere and should be able to localize and provide virtual elements on static and also moving coordinates of the real world.

Babu et al., (2018) considered that:

1. The camera pose is vital for the approach in a dynamic environment, considering a moving vehicle the objects outside the vehicle are based on the inertial coordinate frame and the objects inside the vehicle in a local coordinate frame. In a dynamic environment, the application of AR is more complex.

2. The camera tracking of the moving objects is required to generate AR anywhere, anytime. On a moving vehicle, for example it will be necessary to view virtual objects inside the vehicle and outside.

The (Babu et al., 2018) approach performs multi-motion tracking in larger dynamic environments.

Random sample consensus (RANSAC) is an iterative algorithm to calculate the in liners removing the outliners consequently. Process: 1. Randomly selecting a subset of the data set 2. Fitting a model to the selected subset. 3. Determining the number of outliers. 4. Repeating steps 1-3 for a prescribed number of iterations.

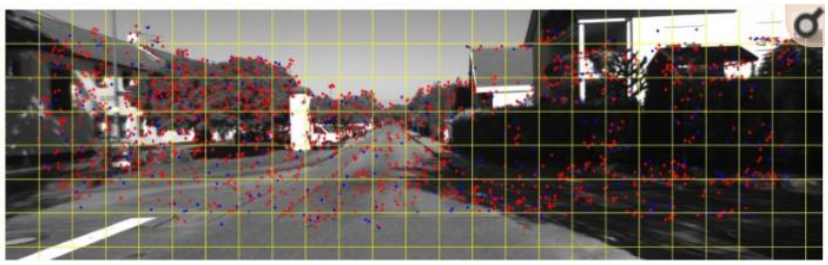


Figure 8. Features detection process before and after bucketing: the red points stand for features before bucketing, the blue points stand for features after bucketing, and the yellow lines depict individual buckets. Source: (Liu et al., 2017).

For some cases, to create AR in an efficient manner, it is necessary to calibrate the camera in order to correct the lens distortion.

One of the commonly used processes to detect collisions for augmented elements is the use of point clouds, for example, Kinect retrieves 4d depth information of the images and programs that use Point Cloud Library (PCL) are able to create cloud points according with overhangs of the real images.

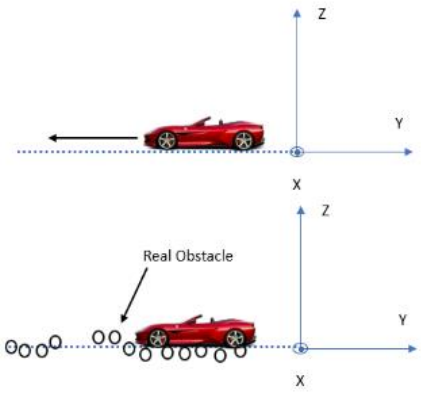


Figure 9. Demonstration of collisions with point clouds.

The moment the augmented element detects a specific point cloud, it will be triggered via code to do another function like stopping. In the image below, a project developed in OSG and PCL that creates virtual elements in real world images using two 3D coordinate systems that interact with each other providing information in order to facilitate the process of placing AR elements.

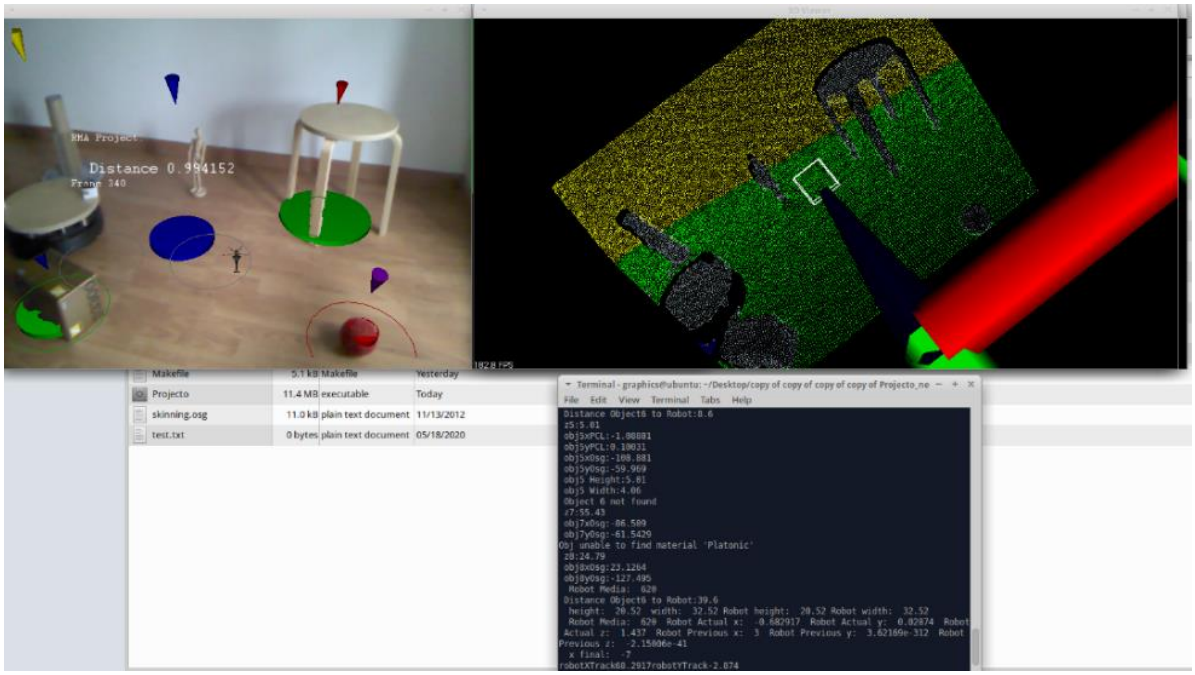


Figure 10. Previous project developed in Point Cloud Library (PCL) and Open Scene Graph (OSG).

Virtual Reality (VR) allows to provide a visual experiment, using specialized hardware like the VR glasses, HUDs (Head mounted displays), data gloves or special installations like Cave Automatic Virtual Environment. VR development requires the use of specialized libraries and add-ons in order to treat the images accordingly so it can be seen on the display. Factors like the player position and orientation should be taken in consideration. A 3D map can be created using engines like Unity or Unreal Engine among other possibilities.

According with Zheng et al. (1998), there are three factors that any VR application should have, that is response to the user actions, the 3D graphics should be in real time, and there should be a sense of immersion. The virtual reality over a high-speed network can be a research tool because big datasets, advanced graphics and real time processing can be used.

The process of data visualization can be described as a sequence of fundamental processing steps (Haber, 1990). Simulation: the data sensing and measurement are used as an input. Data selection and filtering: The data obtained has to be analyzed and selected. Visualization mapping: The data has to be transformed to primitives as well as their properties like color and size. Rendering: The primitives are rendered as images that will appear on the screen.

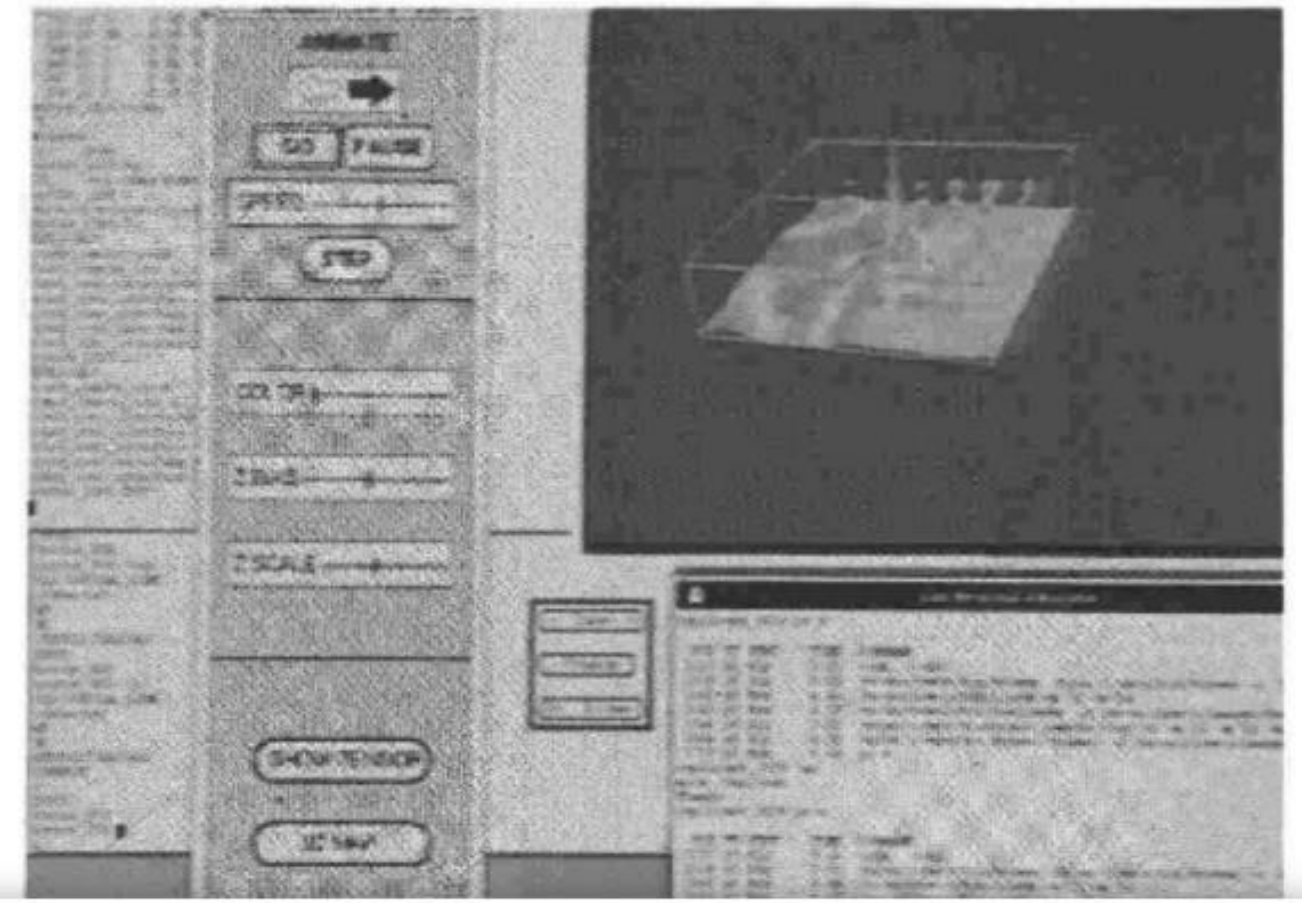


Figure 11. Supercomputer Visualization (Haber, 1990).

Virtual Reality facilitates the interface between man and machine; computer generated images (CGI) and 3D dimension images can be generated and several hardwares may be required in order to create a sense of immersion like the VR glasses.

Krevelen (2010) work is based on automatic calibration, human tracking, use of displays and a global positioning system. Mixed Reality (MR) is based on the insertion of virtual elements into the real world captured via a sensor like a webcam. The real environment can give much information like the positioning, depth and Red, Green, Blue (RGB) values of each pixel which can help the process of inserting computer-generated images into the images captured by a sensor.

Engines like Unity and Unreal Engine allow to add these virtual elements to a real-world environment.

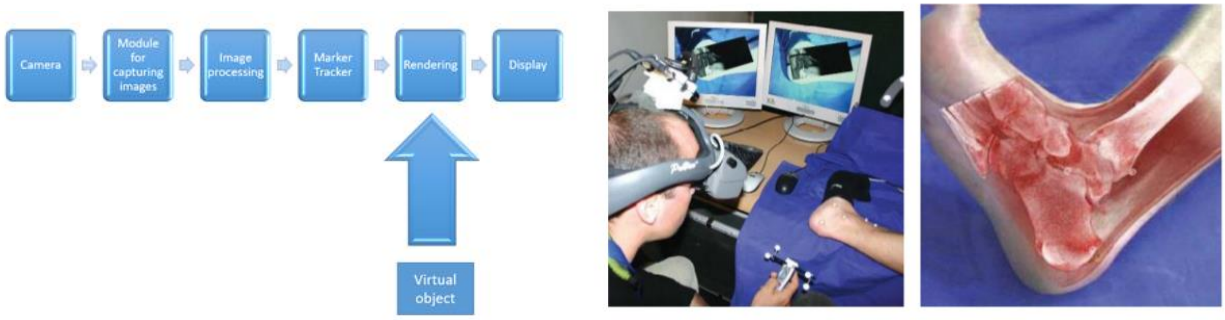


Figure 12. Virtual Object Rendering and Medical Scanner (Krevelen, 2010).

Considering the study of Krevelen (2010) based on automatic calibration and human tracking, various monitors can be used and also a global positioning system, taking into account various UIs and positioning of two pixels. There is a possibility of obtaining different types of mixed reality.

To facilitate the process of explaining the pinhole camera model in the figure below. The point Oc is in the world coordinate system (Xw, Yw, Zw). OcXcYcZc is the camera coordinate system, o′uv is the pixel coordinate system (PCS), and oxy is the retinal coordinate system (RCS) (Wang & Lynch, 2014).

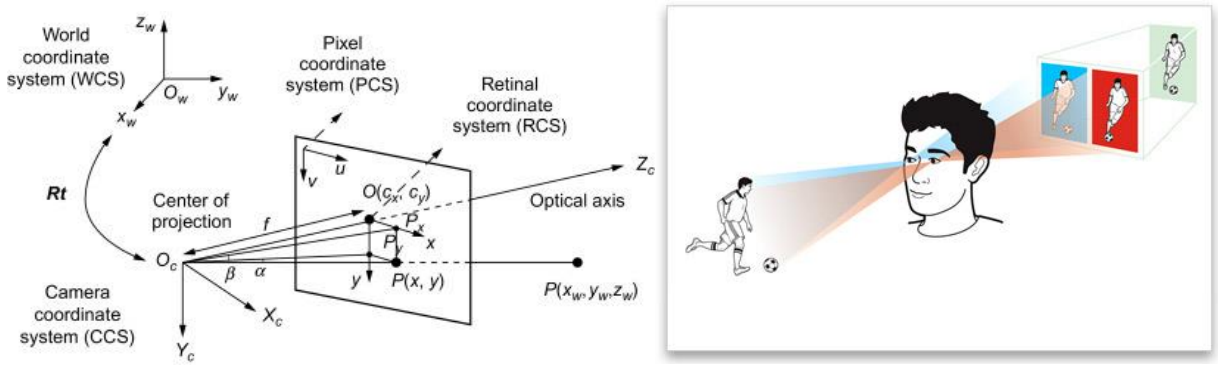


Figure 13. Pinhole model, adjusted from (Huang et al., 2014).

In order to prospectively project a 3D homogenous point Q = (X, Y, Z, 1) to the plane of the camera, with n as the z coordinate of the image plane; the equation provided by resolving the matrix system below will give the homogeneous coordinates of the pixel, q= (x', y', w') (Huang et al., 2014).

$$\begin{bmatrix} x' \\ y' \\ w' \end{bmatrix} = \begin{bmatrix} n & 0 & 0 & 0 \\ 0 & n & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \qquad \lambda \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = \begin{pmatrix} f & 0 & o_x & 0 \\ 0 & f & o_y & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix}.$$

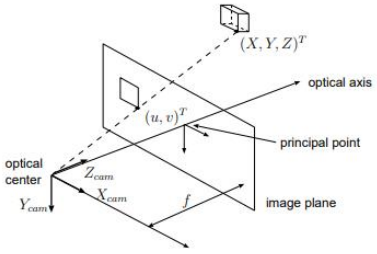


Figure 14. Adapted from the work of (Morvan, 2009).

In the figure above the left matrix corresponds to the coordinates of the homogeneous 2d point q and the matrix on the right to the homogeneous 3d point D. The matrix in the middle is the transformation matrix that allows to get the coordinates of one point knowing the other. The use of a Multi-motion MC-VIO algorithm may allow to track landmarks related to primary and secondary motions. It has been the most common approach for dynamic objects.

2.3 Usability and Content Accessibility

The Web Content Accessibility Guidelines (WCAG) 2.0 aims to make web content generally accessible with a focus on people with disabilities. There are several types of disabilities that must be taken into account, such as, visual auditory, physical, speech, cognitive, language, learning and neurological. These measures take into account various aspects such as security, compatibility, navigation, video presentation, text presentation, adaptability, assistance with Input (such as correctors), possible accessibility and usability improvements can be done with the keyboard or the Liquid Crystal Display (LCD) by improving visibility like adjusting color combinations that facilitate the process of focusing and making easier to read the showed image. Information Systems (IS) should be predictable and must follow patterns and time constraints such as defining frames that allow the user to perform his task via the application in a more efficient and effective manner.

The WCAG is able to address a number of questions, but can not respond to all possible types of deficiencies, because disabilities vary according with different aspects like grade, for certain levels the system may not be used with efficiency or in cases where patients have combinations of different disabilities. The age of the users has also to be taken in consideration, some Hz (Hertz) frequencies might not be heard after certain ages; guidelines can be used in order to make the web content easier to use for older people, because normally the abilities change or decrease due to aging. The usability has to be managed and developed to improve the obtention of results for users in general.

In information systems usability, systems must be easy to use, effective and pleasant to use, minimize errors, increase satisfaction, decrease frustration, make tasks more productive and hide unnecessary technical details from the user.

The design of interfaces requires identifying needs and establishing requirements (where users are defined under correspondent metrics, needs are ascertained and profiles are drawn). Whenever possible there should be alternative designs taking into account conceptual and physical models. In this process, there must be the development of demo versions and tests, such as prototypes and Mockups to be able to present a solution closer to the need of the customer. What was developed, should be evaluated in several aspects like the number of errors, or the number of requirements fulfilled. The system should focus on the user and identify the more accurate usability criteria.

Usability objectives are:

Effectiveness or effective use: how good is the application at producing the expected results? Efficiency or efficient use: should be fast, have automatic error and exception handling. Safety or safe to use: avoid unwanted situations (prevent errors). Usefulness or good use: number of functions correctly offered. Should be easy to learn and memorize.

The World Wide Web Consortium (W3C) in accessibility aims to be developed for patients with disabilities and to allow these systems to be operated by users with difficulties to: understand, comprehend, navigate, interact and contribute via web.

Online accessibility tries to cover all disabilities that affect access to the web, such as: auditory, cognitive, neurological, physical, speech and visual.

The International Organization for Standardization (ISO) 9241-11:2018 is more focused on the Ergonomics, improving the human-machine interaction; showing usability definitions and concepts distinct from those of accessibility, such as the possibility for a specific user to manipulate specific tools in order to meet specific goals in terms of effectiveness, efficiency, and satisfaction, for a specific context of use, while the ISO/TR 16982:2002 is more focused on the User-Centered Design and can be defined as the design of products (and services) that users can use both for a specific purpose or to perform other requested operations and tasks with very little effort and great efficiency.

Table 2. WCAG compliance levels. Adapted from (Noh et al., 2015).

Compliance Level	**A**	**AA**	**AAA**
Importance	Importance 1	Importance 2	Importance 3
Concept	Must	Should	May
Definition	Must comply	Should comply	May comply
Significance	Fulfillment of basic requirements	Removal of grave defects	Removal of slight defects
	Guarantee of web accessibility	Increase in web accessibility	Improvement of web accessibility
	Access to web contents is impossible in case of noncompliance	Causes difficulty in accessing web contents in case of noncompliance	Causes inconvenience in accessing web contents in case of noncompliance

WCAG A (minimum) represents the simplest considerations, based in a criterion that has to be met and possess the most basic notions and the main standards according to a set of rules. WCAG AA deals

with higher and most common barriers for certain deficiencies within certain grades; must be complied with and holds more rigid rules, which greatly facilitate accessibility to the website. WCAG AAA (maximum) represents the highest level of accessibility, and is possible to perform, but may have high requirements and might be difficult to apply to the entire site, as an example the definition of the front end code easing the processes of reuse, where all pages use the same master page or just maintaining certain elements such as the head or the left and right menus and the footer.

What happens should be evaluated as the number of errors, or the number of requirements met. Must focus on the ease of use and identify processes to improve accessibility. The objectives of usability are: Effectiveness or effective use (in example: How much is the system capable of producing considering the expected result?) Efficiency: High speed of processing, with automatic handling of errors and exceptions. Safe to use: Avoid undesirable situations (prevent errors). Provide utility: the number of functionalities must be correctly offered and aiming to resolve the problem in an optimal way. Should be easy to learn how to use and to memorize. Other aspects of W3C are considered in accessibility to ensure that the systems are developed for people with disabilities and allowing users with difficulties to: perceive, understand, navigate, interact and contribute using the web. Online accessibility also aims to be implemented in mobile phones, smart watches, Smart TVs and other devices with different screen sizes (the use of bootstrap may help in this process) and also for different input modes.

Other cases to be considered are the improvement of the access to people with mutated abilities due to aging, people with temporary impairments such as temporary weakness, or people with situational limitations, like being in environments with strong sunlight, or situations without certain types of hardware like sound columns making the hearing of audio not possible, and people who use slow Internet connections or that have very limited bandwidth.

Dix et al. (2004) shows various forms of assessment, such as assessment through eye tracking which can be done by a web camera or other sensors allowing eye gaze control to interact with the application. On the work of (Dix et al., 2004) there are also references to handwriting and virtual reality among others as a form of Human-Machine interaction.

Figure 15. Eye tracking equipment. Retrieved from (Dix et al., 2004).

People with disabilities can use tools and sites if these are well defined. Currently, there are many accessibility barriers that make it difficult or impossible for some people to use them. The images must have alternative text, for people who cannot see, a reader can be used, which reads the information on a page aloud, including the alternative text of the visual image.

Other objectives are to facilitate the use of search engines and help access for situations with low bandwidth.

Some people cannot use the applications well, such as older users with limited motor control. The accessibility of a system should not depend on the mouse. All functionalities must be possible to carry out. For persons with certain disabilities there is the possibility to use assistive technologies like mimic, voice input, voice recognition, transcriptions for audio or transcriptions of examples. The combination of colors must have the usability standards, as well as the placement of elements must respect pre-defined and standard rules in order to facilitate use. In the study of (Vanderheiden & Henry, 2003) an analysis of various aspects, such as, the difficulties as factors that influence the design of interfaces is performed.

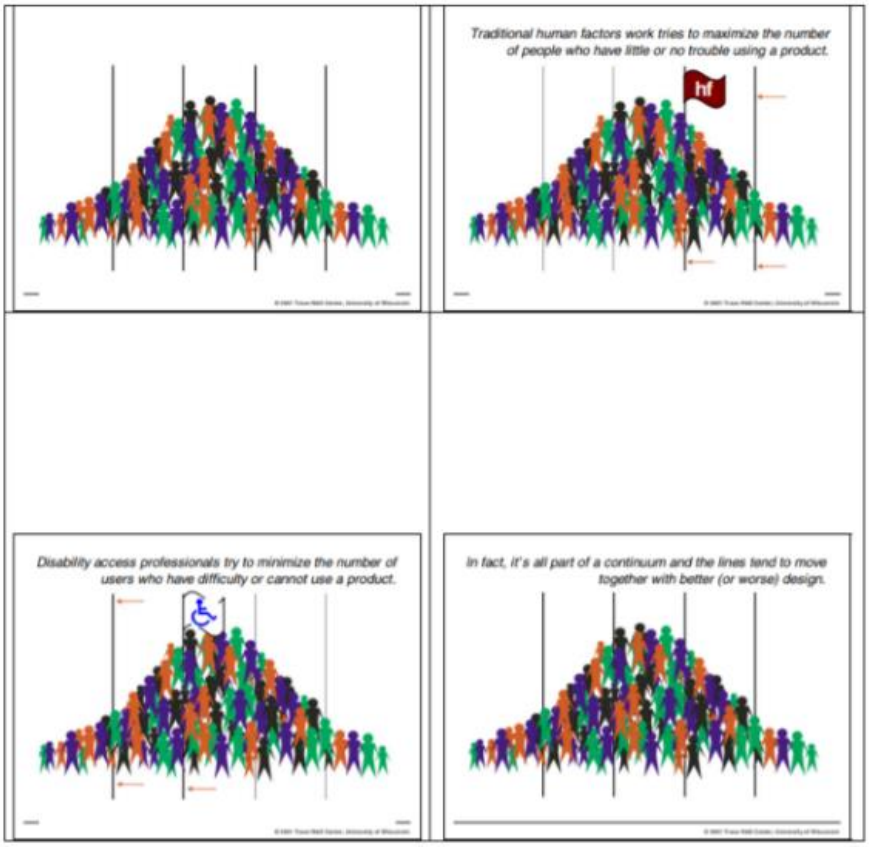


Figure 16. Analysis of accessibility and usability. Retrieved from (Vanderheiden & Henry, 2003).

In the work of (Nielsen, 1994) we can find heuristics and evaluation methods that allow to define strong points and weaknesses regarding the usability of the applications.

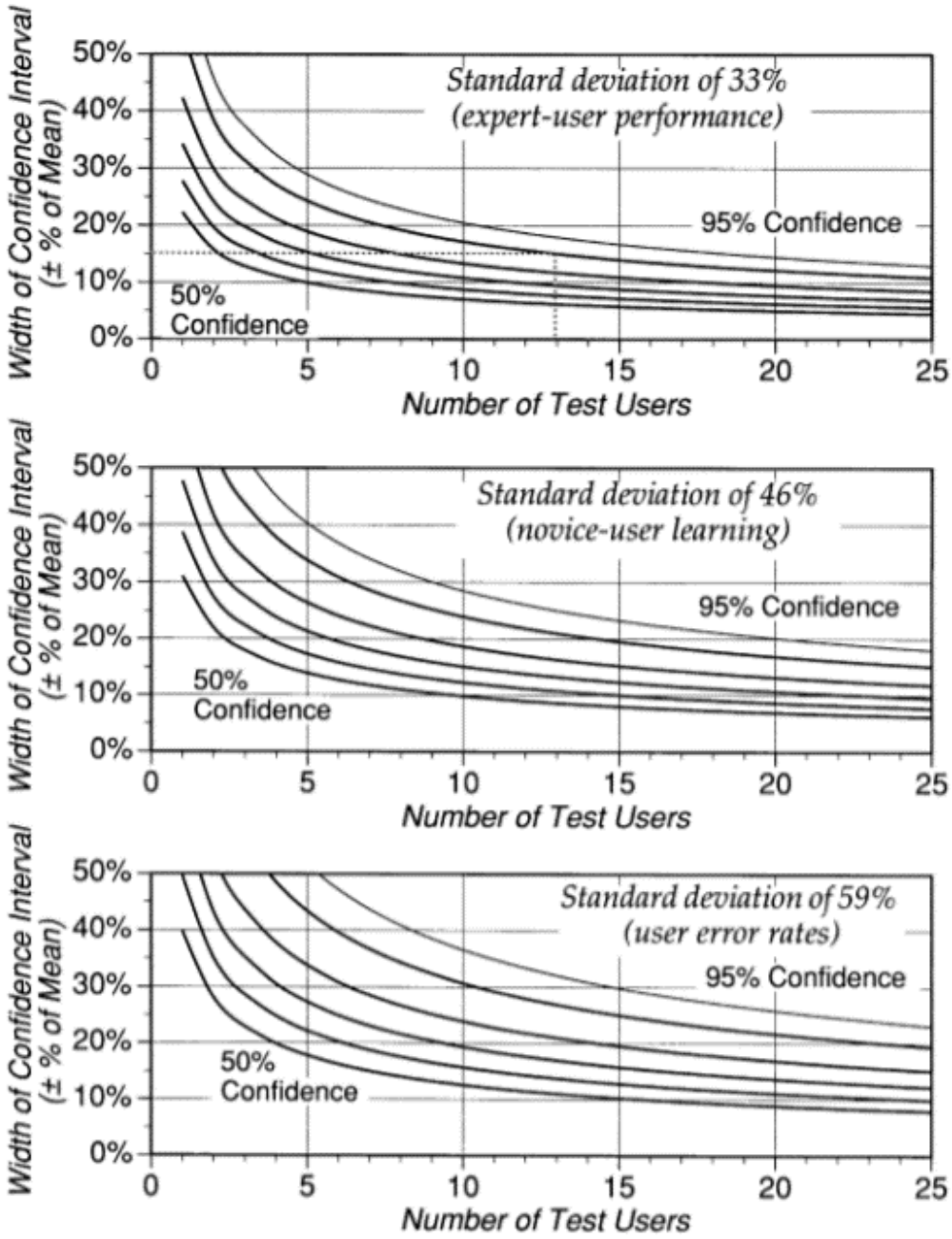


Figure 17. Test with Users. Retrieved from (Nielsen, 1994).

New technologies have appeared in this area that facilitate accessibility or use for people with special needs. Tests with users can give important information in the definition of strengths and weaknesses, such as discovering errors and finding points to improve. In the usability of information systems, the Nielsen heuristics are commonly used as a standard practice, allowing to validate and improve the interfaces, being commonly used in User Experience (UX) and can be associated with the WCAG. Garrett (2020) shows references to various aspects of UX such as colors, the placement of elements must follow a set of rules in order to facilitate accessibility.

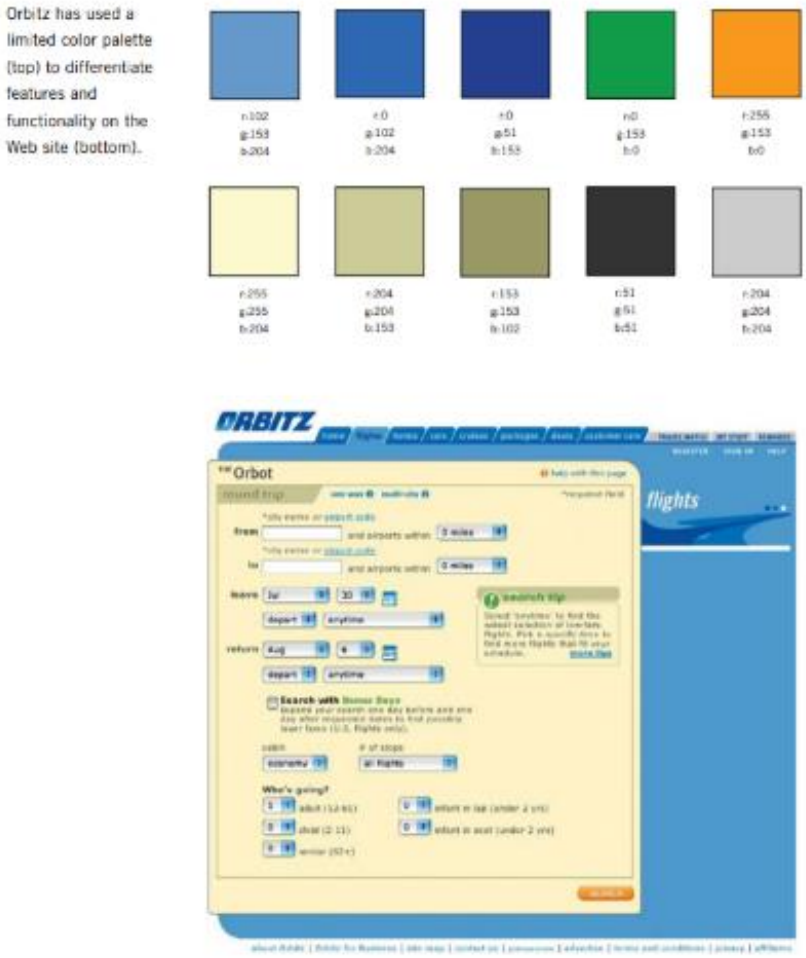


Figure 18. Reference to the choice and combination of colors. Retrieved from (Garrett, 2020).

2.4 Motion Controllers and the Equations of Distance and Movement

Nowadays motion can control applications, there are several known mechanisms which allow the interaction of the user with a system based on his movements. Eye gaze can improve the dialogues between humans and computers and the process of selection can be faster than using a mouse or a keyboard (Sibert & Jacob, 2000).

Hand gestures can be captured by the webcam using JavaScript specific libraries allowing also to interact with the system. There are many ways of interacting with a computer being the most common the keyboard and the mouse, but now there are advanced controllers that use camera and image treatment mechanisms to determine positioning and movement of parts of the body allowing to execute preprogrammed commands (Sziládi et al., 2016).

Figure 19. Leap Motion Controller (LMC) showing a virtual representation of the hand and distinguishing the fingers.

The equation of the distance between two points in a 3D space is given by the formula:

$$AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \tag{3}$$

The Euclidian distance formula is:

$$\sqrt{\sum_{i=1}^{n} (q_i - p_i)^2}. \tag{4}$$

The equation of movement of a UAV can be defined by the formula:

$$\tau = H(\mathbf{q})\ddot{\mathbf{q}} + C(\mathbf{q}, \dot{\mathbf{q}}) + G(\mathbf{q}) \tag{5}$$

Where H is the inertia matrix, C the centripetal matrix and G the gravitational matrix (Barrientos et al., 2002).

These formulas allow to perform measurements and can be used for evaluation of performance; a shorter calculated distance to perform a certain task may indicate less effort.

2.5 Web Development

In web development, it is common to use databases and APIs, the browser has to be able to open the page and process the information. HTML can combine with CSS to make the page layout and improve esthetical aspects; JavaScript or Angular can be used for functionalities.

Nowadays web applications commonly use Web services and APIs to communicate with parts of the application or other applications. On the HTML code, there are several inputs or tags that allow to display forms. The application can be divided in tiers, and the data layer makes the interface with the database. According with the study of (Haris, 2019) it is pointed out that PHP is the programming language more used; the research also mentions the several advantages of the MVC architecture like security. The process of comparing frameworks is not easy and several criterias should be taken in account like debugging, how it connects with the database among many other factors. Many technologies can be used in web development like .NET, Java Spring MVC, on the frontend it can be used Angular or JavaScript. The choice of technology is an important factor. Concerning web development, the servers can be configured according with the type of application that is going to be implemented. PHP appeared in 1995 by Rasmus Lerdorf, a technology that has been used in large scale, especially on the backend side.

Occurances of patterns:	Sub-system 1	Sub-system 2	Sub-system 3	Sub-system 4	Sub-system 5	Sub-system 6	Sub-system 7
Files with code duplication (over 30 lines)	3	1	-	7	2	3	8
Data injection	86	4	1	-	-	-	-
Thread and synchronization issues	-	-	6	-	-	-	-
Cross site scripting	-	-	3	-	-	-	-
Usage of resource after it was closed	-	2	1	-	-	-	-
Code that is likely to cause NullPointerException	5	2	2	3	2	-	20
Calling methods of immutable objects without using the result	10	-	-	2	1	-	-
Not closing resources	-	7	2	2	2	4	190

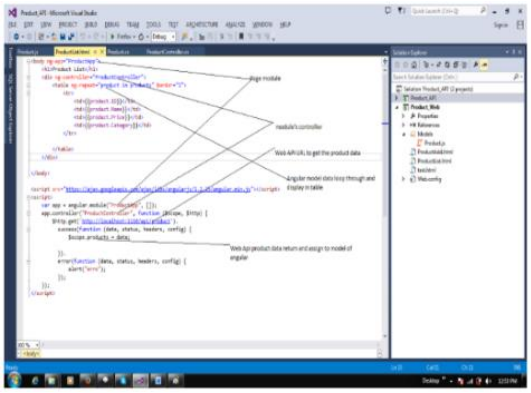


Figure 20. Application of MVC with frontend, backend and data layer with C# and code metrics (Haralambiev, 2011).

According with (Haralambiev, 2011) some metrics that can be used for code performance are: Files with code duplication (over 30 lines), data injection, thread and synchronization, cross site scripting, usage of a resource after it was closed, code that is likely to cause NullPointerException, calling methods of immutable objects without using the result and not closing resources.

On the controller can be defined several operations like, associating the http command to a certain function, such as, the Create Read Update and Delete (CRUD) of the created entities. Microsoft has the Entity Framework and the ADO.NET, which helps the development process.

Node.JS can be used in several platforms being a runtime environment that allows to use JavaScript.

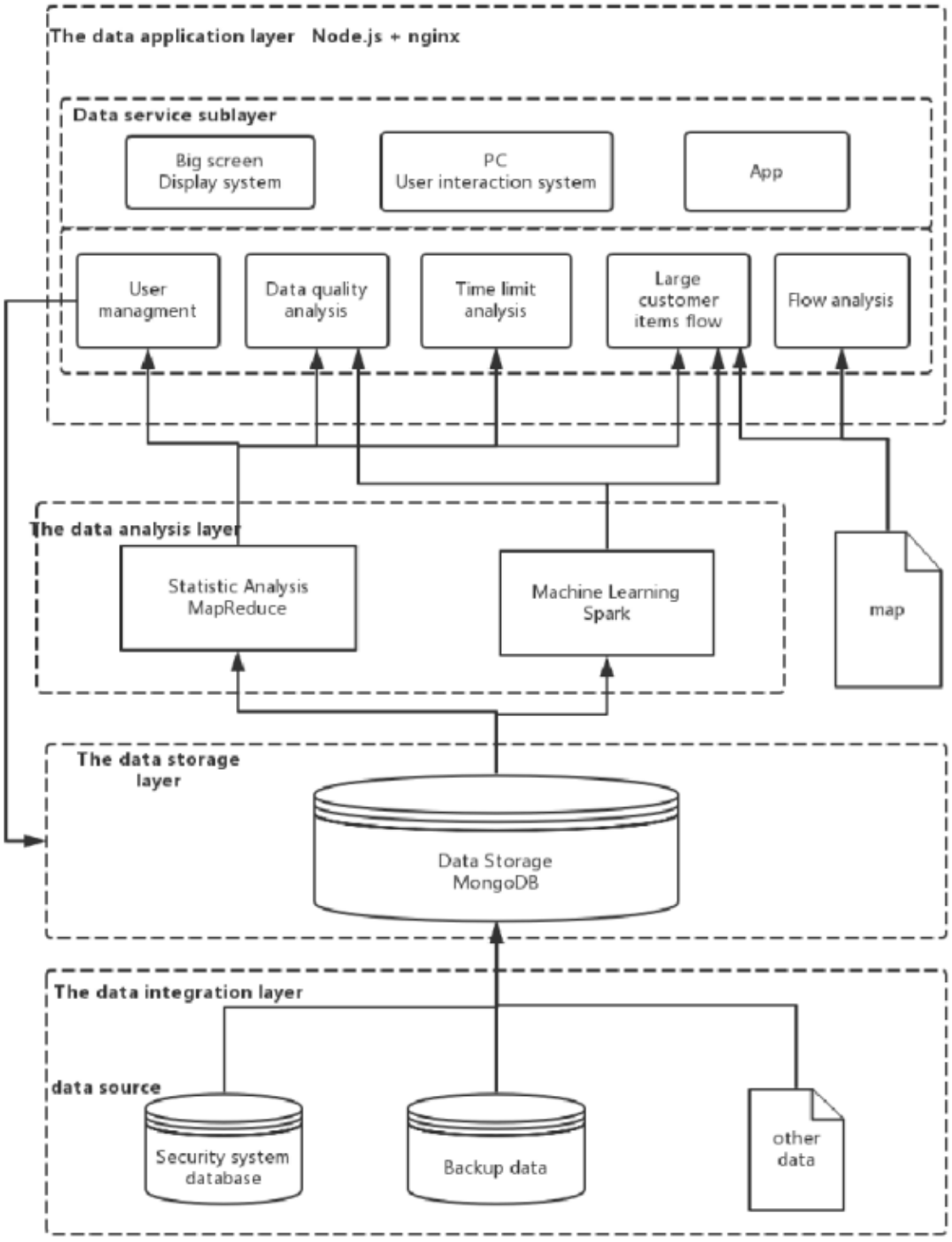


Figure 21. Example of an architecture in Node.JS. Adapted from (Liang et al., 2017).

Node.JS has an API for Input and Output (IO) operations. Chitra and Satapathy (2017) compared the IIS with the Node.js in terms of performance and concluded that Node.js might be more appropriate for IO systems and not so adequate to applications that require high CPU usage.

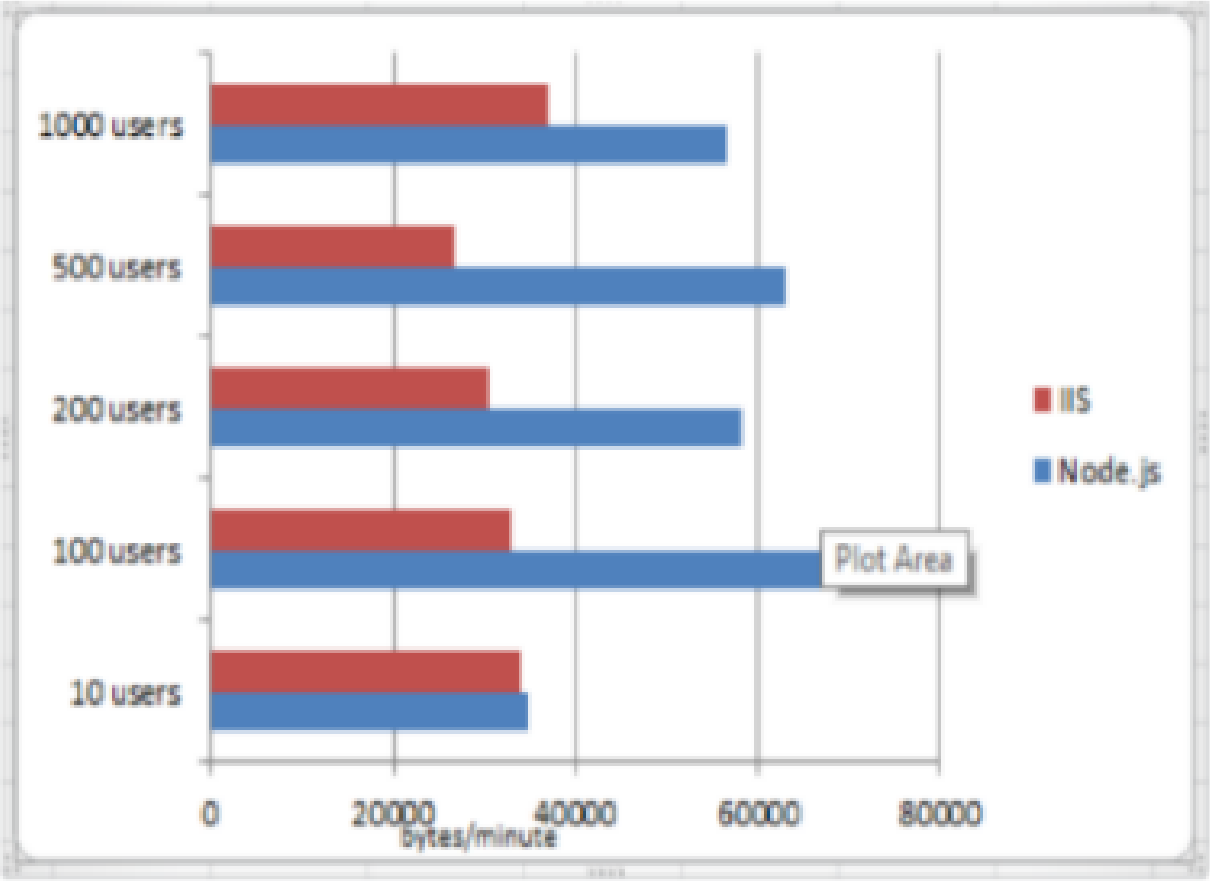


Figure 22. Speed comparison between Node.js and IIS (Chitra & Satapathy, 2017).

2.6 Motion Controllers for Unmanned Aerial Vehicles

Nowadays aerial drones can be controlled by gestures and motion. Sensors like leap motion are able to recognize gestures allowing the development of a drone controller (Sarkar et al, 2016).

Figure 23. Drone controller with leap motion (Sarkar et al, 2016).

Drones can also be controlled by body motion responding to certain positions (Gio et al 2021).

Chapter 3

3. Overview of Systems with Motion Controllers

This chapter will describe the steps performed to implement motion controller systems to improve usability, it has three main sub sections being the first focused on hand motion tracking and controlling, the second focuses on the use of eye gaze presenting a prototype of performing a visual test, the third a full body motion controller that can be used for physiotherapeutic activities and the fourth a web drone controller system.

Motion Controllers can help the accessibility to Information Systems for people with several disabilities like visual auditory, physical, speech, cognitive, language, learning and neurological. The use of these type of technologies has been increasing over the last years but have some limitations with many research challenges.

People with certain disabilities like visual, auditory, physical, speech, cognitive, motor, language, learning and neurological disabilities have difficulties in using applications, providing research challenges in order to make the applications possible to use.

More useful functionalities can be added to the systems in order to be accessible for different incapacities.

Taking in consideration the accessibility and usability for users of different ages and disabilities, several softwares were developed the majority web based taking in consideration the degrees of handicap.

For people with auditory, speech and learning incapacities, the “Droctor” system, a web drone controller was developed in order to answer to handicaps such as auditory, speech and learning disabilities and also allowing to carry objects for people with specific motor disabilities like not being able to use the legs making easier to reach to objects.

Relatively to visual, auditory, speech, language and some motor and cognitive incapacities, was developed a full body motion controller prototype that responds to the movement of several body parts like hands, fingers, arms, legs, head, body and feet.

Concerning cases with movement and earing problems the aerial control and the eye gaze control can be used.

The eye gaze controller can be accessed by people with certain levels of auditory, physical, speech, cognitive, language, learning and neurological incapacity.

The work aims to improve the AI response mechanisms to the inputs from the user. This section presents prototypes and processes used for certain activities and how to achieve the objectives.

3.1 Employment of Artificial Intelligence Mechanisms for Gesture Control

With the objective to increase the accessibility for users of different ages and disabilities and to make the usability process easier, an online motion controller was implemented via web using several programming languages like JavaScript.

Open CV is able to detect the players movement. Via python code it is possible to detect the position of the hands during web camera video streaming. This technology detects the hands movement while the user is interacting with the online platform, allowing to control virtual objects that interact with the system.

Another possibility of getting hand movement instead of a camera is by the use of specific sensors like leap motion that has a library that allows to use the Unity game engine to develop applications which can be used for different areas like training and healthcare.

With JavaScript it is possible to develop applications that interact with the movement of the hands in real time, facilitating the use for people that have visual limitations or that do not have a keyboard or a mouse.

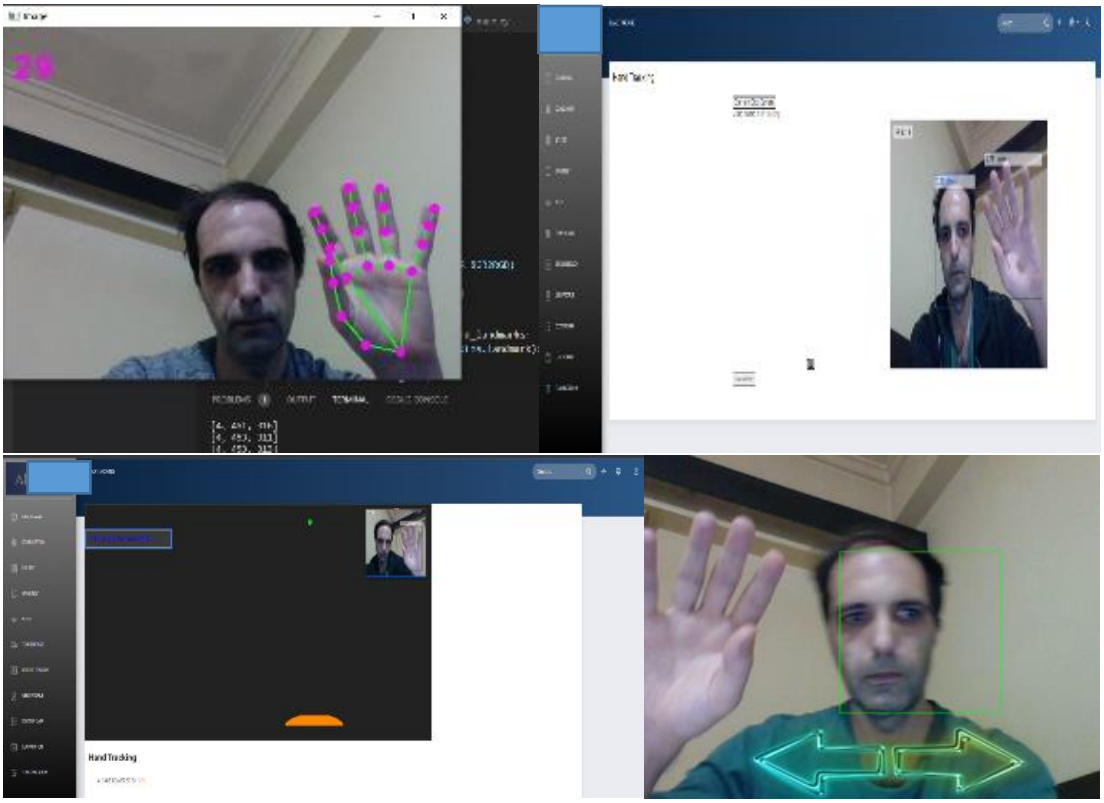


Figure 24. Hand detection and comparison. Using gesture control. Adapted from the code of (Dibia, 2022).

The developed system used the handtrack.js to detect hands from the video captured by a web camera and to control virtual elements, in order to be able to interact, the system first has to detect a hand, after detection the hand movements will control the virtual objects allowing to perform tasks like playing games.

This type of application can be very useful for physiotherapeutic activities concerning the hands and also makes the process of interaction easier as it does not require to use other hardwares like keyboard or mouse.

The use of hand controllers has been increasing but still faces many challenges, the process of hand recognition may fail and the quality of the camera and the level of lightning may also affect the normal functioning of these type of systems.

3.2 Employment of Artificial Intelligence Mechanisms for Eye Gaze

The eye movement can interact with a web application, after detection of the iris via the web cam. On the developed application was used JavaScript libraries in order to make possible the realization of tests and to facilitate the interaction.

Eye gaze controllers can be very helpful for people with motor disabilities, controlling the application with the movement of the eyes and has many research challenges. Via Open CV using python it is possible to detect the movement of the iris.

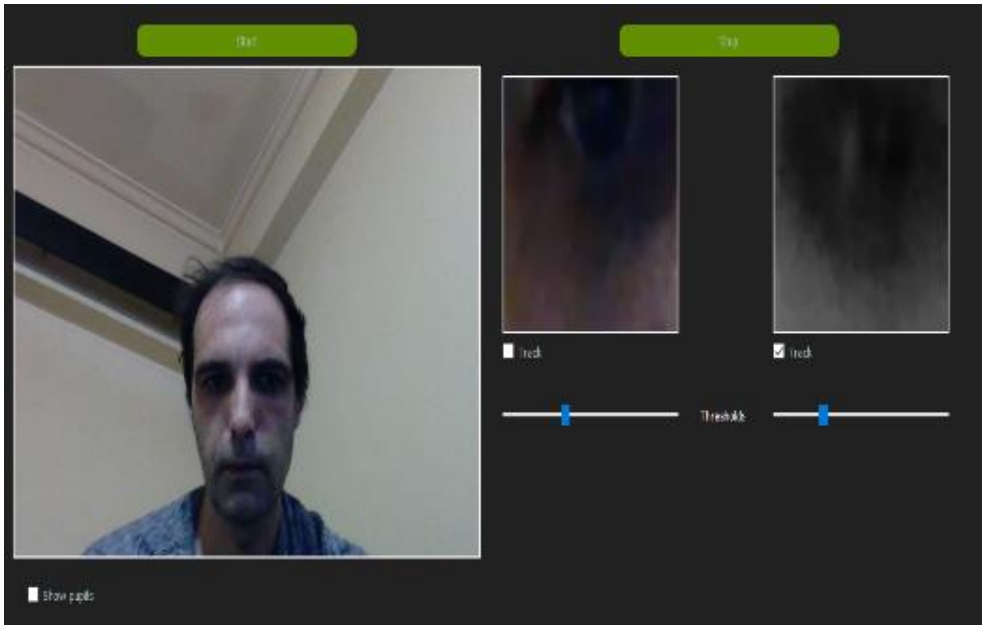


Figure 25. Use of Python to detect the eyes.

The detection process faces many AI challenges, it can be improved and for some cases may require a calibration process where the user looks to certain points of the screen in order to configure the use.

The presented prototype shows a possible solution for performing the visual test online where an orange dot works as a cursor mentioning where the patient is looking which facilitates the evaluation of a visual test providing more insights.

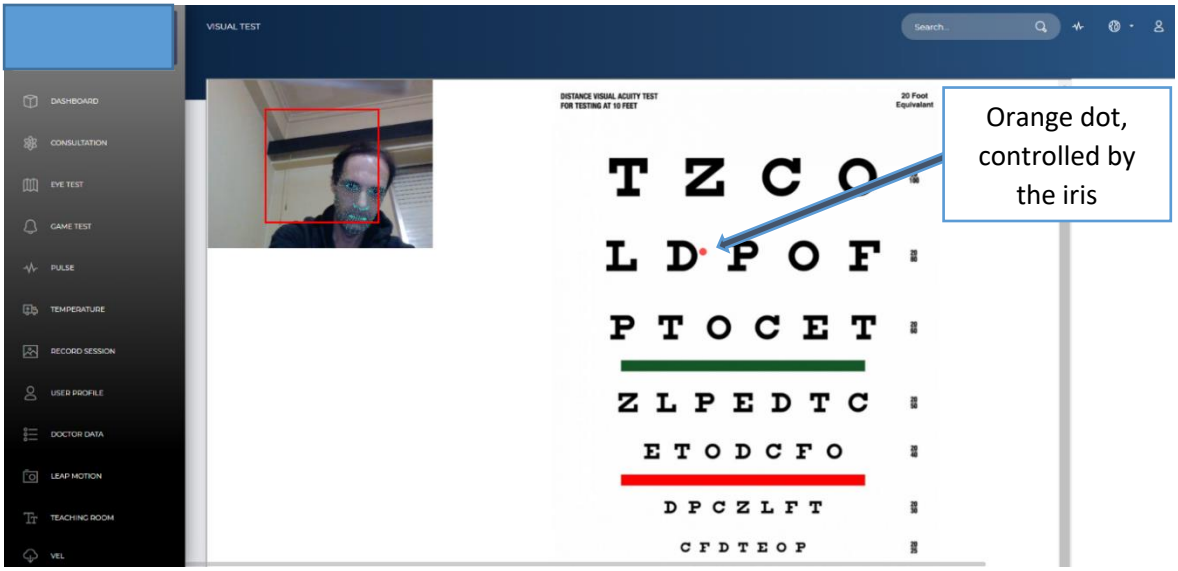


Figure 26. Eyes detection and interaction with the web application.

Via JavaScript and using the webgazer.js it is possible to detect the eyes automatically without the need of calibration on real time and will show on the screen a point that corresponds to where the user is looking, the process requires a web camera.

During usage, the systems records where the user was looking and via AI presents a prediction of the user emotional states like happy, surprise and neutral, which can be used for evaluation purposes as well as the logs obtained for the eye movement.

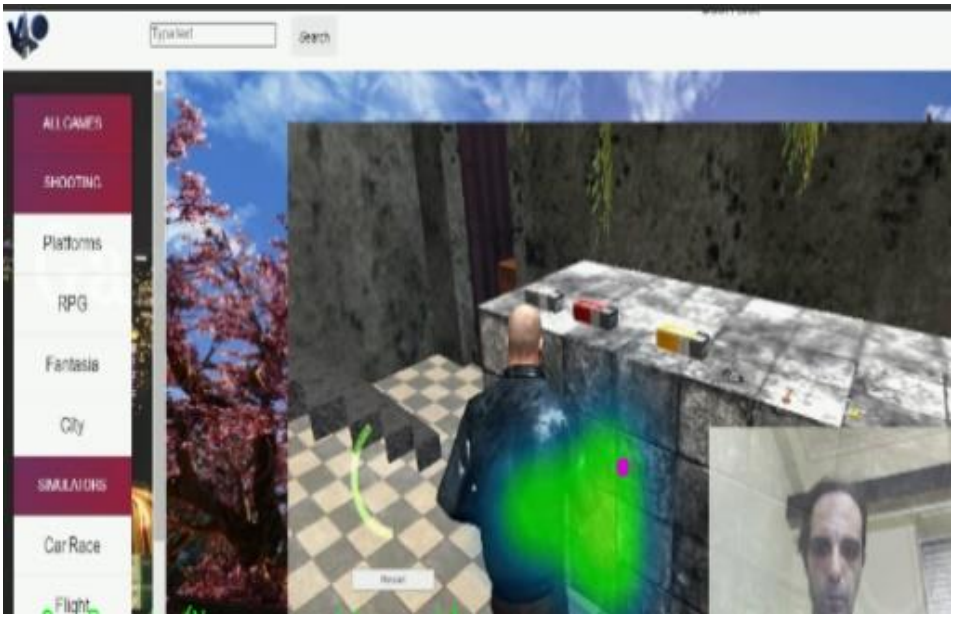


Figure 27. Displaying the area where the user is looking in a recording.

During tests were recorded sessions, these recordings allow access to several types of informations like the predicted state of emotion of the user, the time taken, the coordinates in the screen of where the user was looking among other information in order to test if the proposed prototype is valid.

Eye gaze controller still have many research challenges, the detection process is not easy as it has two region of interest and requires complex calculations, webgazer.js showed high results and the implementation process requires less labor.

3.3 Employment of Artificial Mechanisms for Full Body Motion Controllers

Applications can be more interactive and accessible for users of different ages and types of disabilities. Taking in consideration the context of training and to facilitate the performance of physiotherapeutic tasks a controller that detects, hands, arms, legs, head and feet was used to answer the first research question of this investigation.

Based on the creation of AI Agents, like the creation of a Computer-generated Imagery (CGI) girl, the sensor which in this case is the webcam requires to capture the all body in order to associate geometries and bones. A virtual girl replicates the user movements on a projected Liquid Crystal Display (LCD) that aims to help in physiotherapeutic terms by providing movements and exercises that can help some motor disabilities. The prototype was developed in C# using the Game Engine Unity providing a Mixed Reality (MR) experience. On a perspective of virtual storytelling, this project uses a process of providing interactivity to the user for story creation.

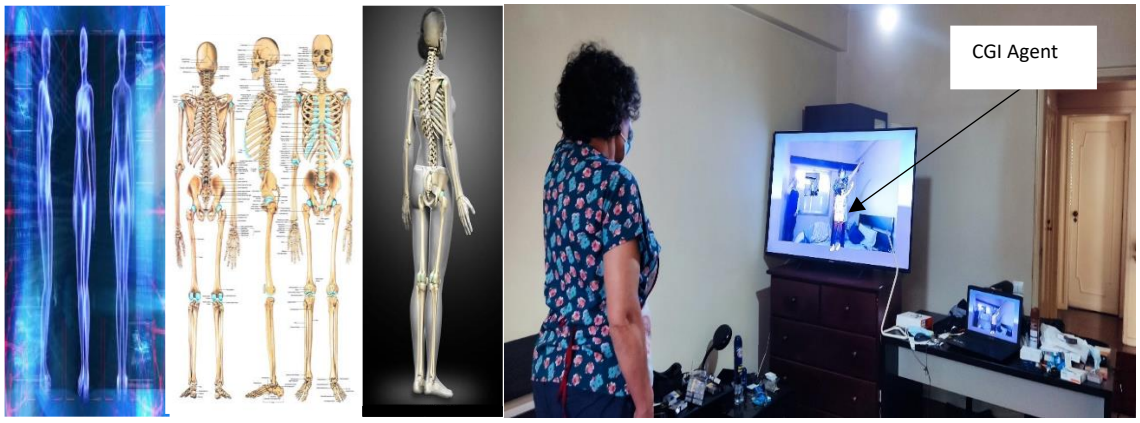


Figure 28. Full body motion controller and detector based on bones structure. Code adapted from (Chen, 2021).

The technology used can help people with visual problems to interact with the system with all parts of the body having the head, arms, body and legs more relevance concerning the detection process.

Via C# the developed prototype is able to associate the animations to the values detected by the camera.

Figure 29. Performing test with full body motion controller.

During tests it was noticed a high level of satisfaction from the users, mainly due to being a new technology. The MR system in cause allows to place virtual elements in the images captured by the camera, the objective was possible to achieve via the Unity game engine.

In order for the application to work the camera has to detect all part of the bodies, so users can not be close to the sensor and should be at a distance superior to 80 cms to perform better results.

There are other sensors like the Wii 2 that allow to interact with many parts of the body.

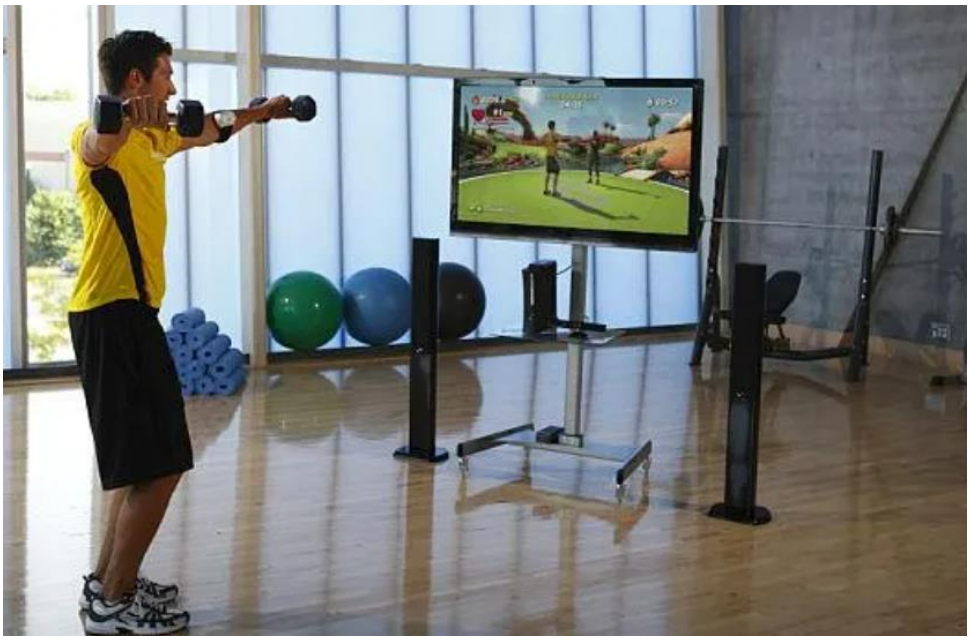


Figure 30. Wii 2 for full body tracking (Robertson, 2011).

3.4 The Drone Controller Prototype

This section describes the developed prototype, which in this case is a drone controlled via web that can be used by people with auditory, speech and learning disabilities.

The person being analyzed by the drone camera does not require to perform any tasks, being the system available for different types of incapacities. The proposed solution aims to provide geographic information, making the process simpler avoiding the current high costs on machinery required.

The section describes in more detail the development process used.

3.4.1 The Web Controller

The Droctor application developed is a prototype of a drone web controller that uses AI mechanisms and provides the location of the drone in Google maps.

On the web application appears eight buttons that allow to move the drone.

The prototype was tested more in indoor environments but can also be used outdoor.

For the drone in cause, DJI offers libraries that can be imported in the code allowing to implement controller mechanisms.

The UAV used has a short flight time of around 13 minutes, but other drones with higher capacities like cameras with more pixels, batteries that can last longer may show more efficient results.

Figure 31. Drone 720p Ryze by DJI Tello. Flight time: up to 13 min
Image transmission distance: 100m. HD 720p broadcast. Intel processor. Box Contents Accessories: Battery, Propellers, Propeller Guard, Compartment. Compatible with remote controls.

The drone application was done using a combination of several technologies like JavaScript, PHP, python, Flask among others, some operations required the importation of specific libraries like OpenCV and the DJI in order to let the implementation of functionalities.

The geo location used the Google Maps API that requires an account in Google Cloud and by IP is able to get the latitude and longitude coordinates which are presented in a map with a blue pointer, the type of map can be changed according to the possibilities supplied by Google Maps.

In order to start the drone, it is required that the drone has battery and that is connected to the computer which for the DJI model used was only possible via wi-fi. By pressing the button connect, the application will use the drone IP and after pressing the button take off, the drone starts flying.

During usage there is a map with the drone location, the controller and the images obtained by the drone camera.

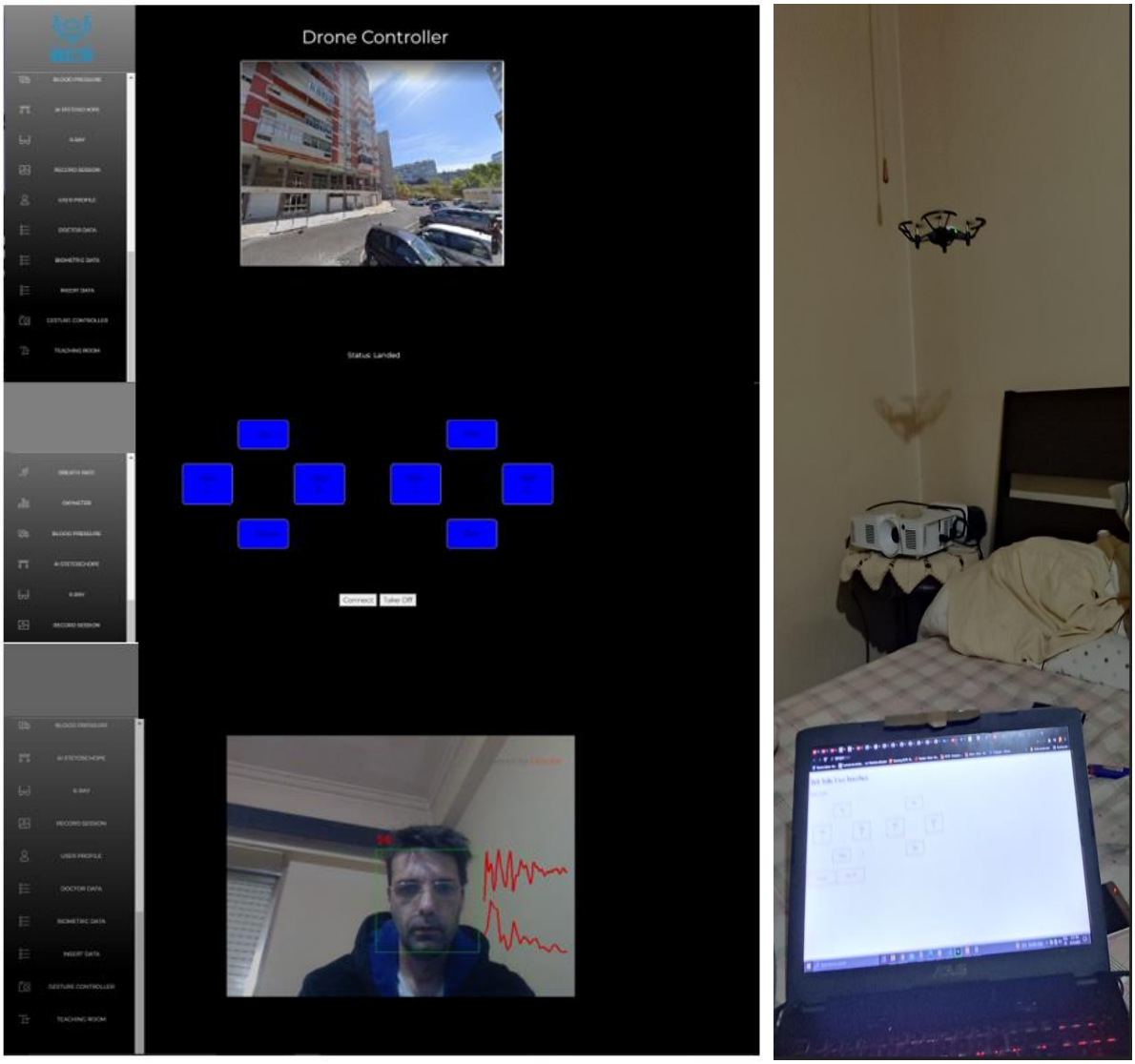


Figure 32. Developed prototype. Controlling a drone with geo location.

The drone is controlled by web buttons. In order to implement MR on the images obtained by the camera of the drone, the open CV library was used and most of the code was written in Python and JavaScript.

A DJI Tello drone was used to get physical data, although the flight time is not high, it was enough for the required tests and the quality of the images obtained by the camera was enough to perform the AI mechanisms, although other drones have better capacities and compatibilities with other technologies.

Figure 33. Drone 720p Ryze by DJI Tello and the mobile phone application controller. Flight time: up to 13 min. Image transmission distance: 100m. HD 720p broadcast. Intel processor. Box Contents Accessories: Battery, Propellers, Propeller Guard, Compartment Compatible with remote controls and virtual reality devices. Maximum speed of 8 m/s.

The implementation of AI mechanisms allows an improvement on the applications, providing more functionalities and answering problems that are not possible to achieve via traditional processes.

The connection of the used drone with the computer was done via wi-fi.

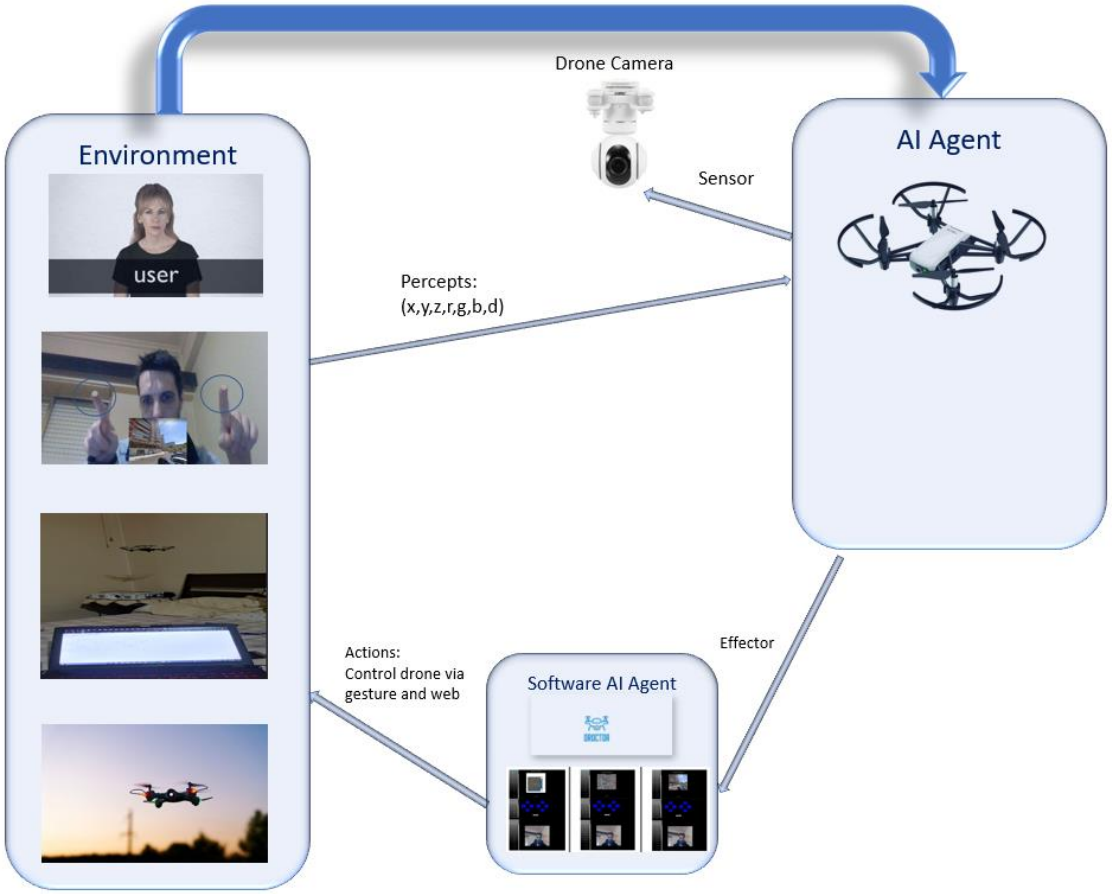


Figure 34. Perspective from the AI Drone agent (“Droctor”).

The web application that controls the drone was developed using the programming languages PHP, JavaScript, Python, Flask, among others, the database was developed with MySQL.

When the drone is active, the coordinates of latitude and longitude will be obtained from the IP of the UAV and will be displayed in a map on the application via the Google Maps API allowing to know where the vehicle is currently placed.

The presented AI system has several functionalities, like checking the surroundings, obtain the location of the UAV, among others.

The interaction between user and drone is made via an online system that allows to control the drone via buttons facilitating the accessibility for different types of people with different ages.

The use of virtualization technologies can also be applied to drones displaying the information obtained by the camera mixed with virtual elements with AI mechanisms.

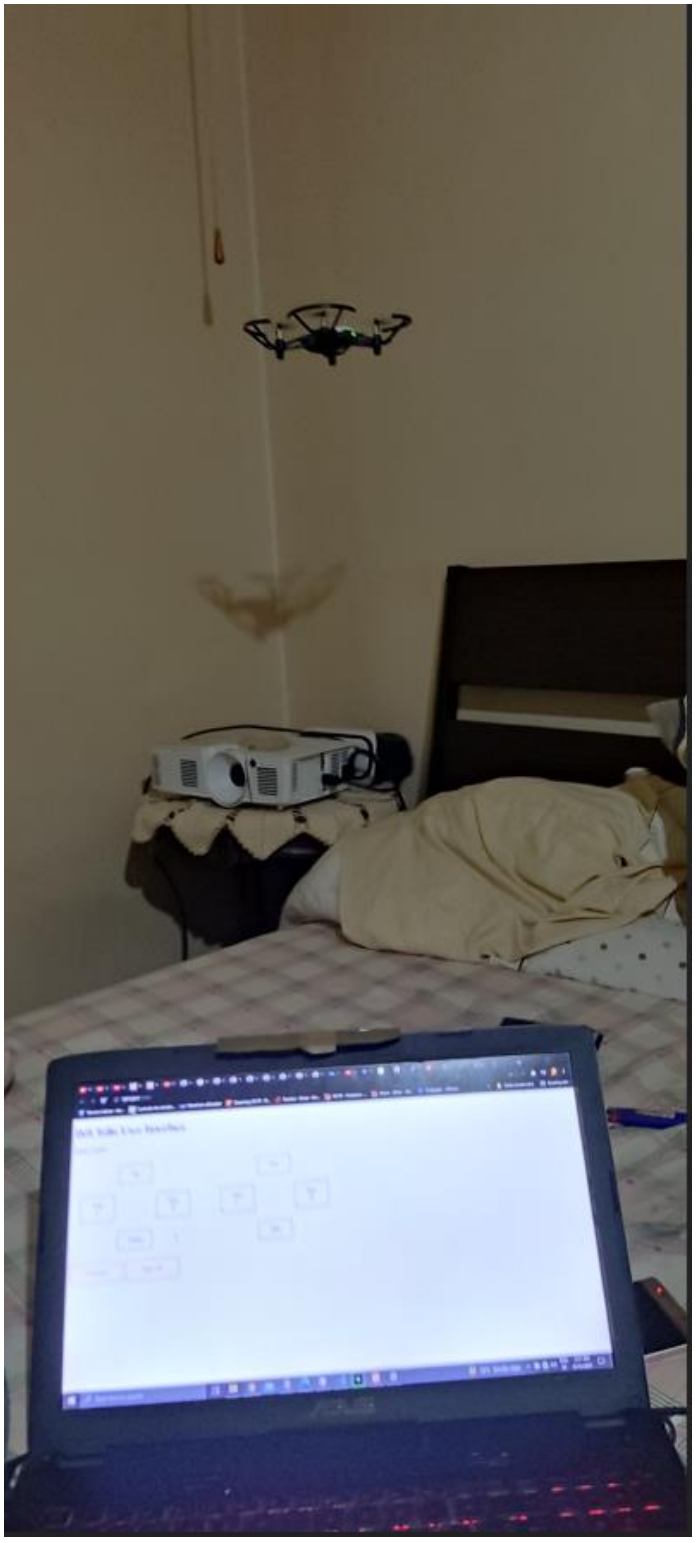


Figure 35. Performance of tests with the drone web controller.

The initial tests were done with web buttons to control the drone.

```
<!DOCTYPE html>
<html>
<head>
<meta charset="UTF-8">
<meta name="viewport" content="width=device-width, initial-scale=1">
<link rel="stylesheet" href="https://www.w3schools.com/w3css/4/w3.css">
<link rel="stylesheet" href="https://fonts.googleapis.com/css?family=Montserrat">
<link rel="stylesheet" href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/4.7.0/css/font-awesome.min.css">
 <meta charset="utf-8" />
  <link rel="apple-touch-icon" sizes="76x76" href="../assets/img/apple-icon.png">
  <link rel="icon" type="image/png" href="../assets/img/favicon.png">
  <meta http-equiv="X-UA-Compatible" content="IE=edge,chrome=1" />
  <title>
    Droctor
  </title>
  <meta content='width=device-width, initial-scale=1.0, maximum-scale=1.0, user-scalable=0, shrink-to-fit=no' name

  <link href="https://fonts.googleapis.com/css?family=Montserrat:400,700,200" rel="stylesheet" />
  <link rel="stylesheet" href="https://use.fontawesome.com/releases/v5.7.1/css/all.css" integrity="sha384-fnmOCqbT

  <link href="../assets/css/bootstrap.min.css" rel="stylesheet" />
  <link href="../assets/css/now-ui-dashboard.css?v=1.5.0" rel="stylesheet" />

  <link href="../assets/demo/demo.css" rel="stylesheet" />

    <script src="//ajax.googleapis.com/ajax/libs/jquery/1.9.1/jquery.min.js"></script>
    <script type=text/javascript>
        $(function () {
            $('button#TO_LAND').bind('click', function () {
                $.getJSON('/TO_LAND',
                    function (data) {
                                    });
                return false;
            });
            $('button#connect').bind('click', function () {
                $.getJSON('/connect',
                    function (data) {
                                    });
                return false;
            });
            $('button#button').bind('click', function () {
                $.getJSON('/button',
                    function (data) {
                                    });
                return false;
            });
        });
    </script>
     <script type="module" src="index.js"></script>
```

Figure 36. Html and JavaScript code with calls to the functions for controlling a Tello drone.

The HTML code shows the imported libraries and the call of functions via JavaScript to control the drone from a web page.

3.4.2 Collisions Avoidance

In order to avoid collisions of the drone with physical objects in the real-world environment several strategies were implemented like setting a maximum speed limit and defining a distance from which the unmanned aerial vehicle (UAV) will not move towards the defined direction, DJI Tello has a library that allows to program the control of the drone via Python, and the OpenCV Library was also used to treat images. The sensor in the proposed solution is the camera of the drone that films the surrounding and displays via the web application using the Internet Protocol (IP) and a Wi-Fi connection helping also to locate the controlled device.

3.4.3 Geo Location

The web application using the google maps API shows where the drone is located on the map, allowing also to facilitate the navigation when the drone is not physically visible to the pilot. The drone camera will show the place where the user is on the web application, providing important information about the environment. Via JavaScript is possible to locate based on Internet Protocol (IP) and calling APIs that will use the variables of latitude and longitude to show on the map where the UAV is placed.

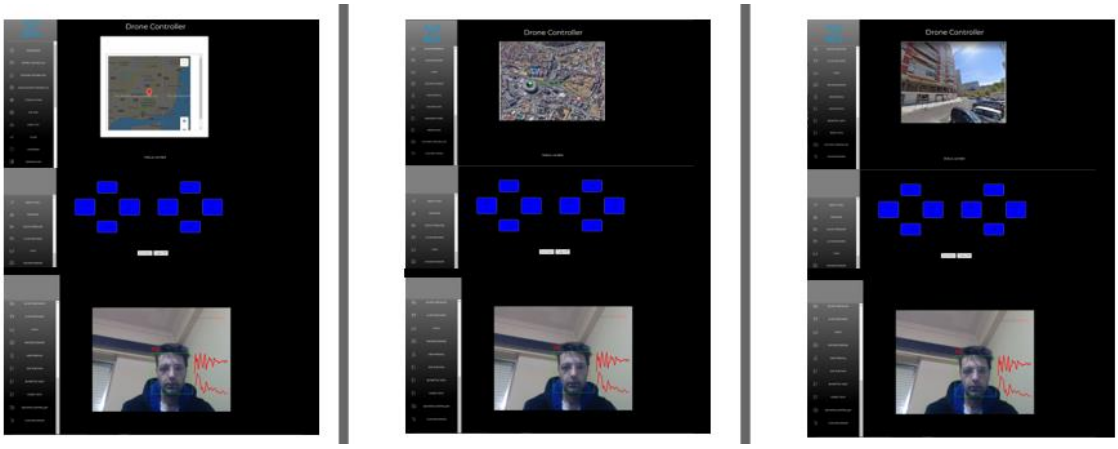


Figure 37. Locating and controlling a drone with a map with geo location.

```html
<html>
<head>
  <script async defer src="https://maps.googleapis.com/maps/api/js?key=AIzaSyDqT0Fw_IzDonpy4VpEFLlg1WmBOsbOlmM&callback=initMap"></script>
  <style type="text/css">
    #map {
        width: 400px;
        height: 400px;
      }
  </style>

  <script type="text/javascript">
      x = navigator.geolocation;

      x.getCurrentPosition(success, failure);

      function success(position)

      {
          var myLat = position.coords.latitude;
          var myLong = position.coords.longitude;
          var coords = new google.maps.LatLng(myLat,myLong);
          var mapOptions = {

              zoom:11,
              center: coords,
              mapTypeId: google.maps.MapTypeId.ROADMAP
          }

          var map = new google.maps.Map(document.getElementById("map"), mapOptions);
          var marker = new google.maps.Marker({map:map, position:coords});
      }

      function failure(){ }
  </script>

</head>

<body>
      <div id="map"></div>
</body>
</html>
```

Figure 38. Code used to display the location of an IP in Google Maps.

The google API was imported and via JavaScript the longitude and latitude coordinates were obtained to display the drone position in Google maps.

3.4.4 Drone System

In this multi-agent system, the camera of the UAV will treat the information. The level of light influences the usability.

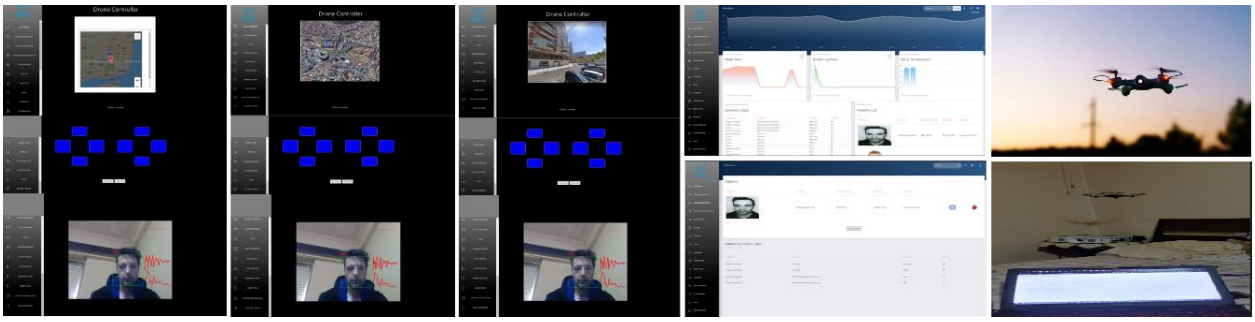


Figure 39. Drone controller via keyboard and gesture movements with geo localization.

The main technologies used on this project were: Python, Flask, PHP, MySQL, the Google Maps API, among others. A great part of the project was done using the programming languages Python and JavaScript.

AI Mechanisms may allow a better performance and add new functionalities to the current existing applications making some tasks easier.

By looking at the python code in the figure below, the Tello and Flask libraries were imported and used to connect to the drone and check if the drone is landed in order to allow the implementation of a web drone controller.

```python
from djitellopy import Tello
from flask import Flask
from flask import render_template
from flask import Response
import configargparse
import cv2 as cv
from gestures import *
import threading
from gestures.tello_gesture_controller import TelloGestureController
from utils import CvFpsCalc

from imutils.video import VideoStream


app = Flask(__name__)

drone_is_flying = False

@app.route('/connect')
def connect():
    global tello

    tello = Tello()
    tello.connect()
    tello.streamon()

    cap = tello.get_frame_read()
    return "nothing"

@app.route('/TO_LAND')
def to_land():
    global drone_is_flying
    global tello

    if drone_is_flying:
        tello.land()
        print("The Drone is landing")
    else:
        tello.takeoff()
        print("Take off")

    drone_is_flying = not drone_is_flying
    return "Not flying"
```

Figure 40. Python code to connect to the drone.

Considering the second objective of this research, the use of AI mechanisms can be applied to the applications allowing to control a drone.

Chapter 4

4. Tests, Results and Discussions

4

This chapter presents the results and tests of the applications in order to verify if the objectives are achieved and to validate the research questions. Concerning the first and second objective of this research a questionnaire process was used.

4.1 Questionaries to the Users

First was asked to sign a right grant form before proceeding with the questions and the use of the applications. The second test was based on using the prototypes, being the sessions recorded and the third step to fill an evaluation questionnaire. All the testers found important that the applications should use the real world data.

The tests were performed to a group of 8 people, being five females and three males with ages between 20 and 80 being some of them healthcare professionals.

The interrogations can be found in appendix D where it is asked the level of satisfaction after using the applications, if the applications achieve the objectives and if they will be used in the future, among other questions.

These questions were made to analyze and rate the work performed taking in consideration several aspects like satisfaction and if the objectives are fulfilled.

The questionnaire is focused on the research questions of this investigation and allows to appraise the proposed solutions to the investigation problem.

Concerning which of the motion controllers is the most important, in general all participants found them important, but none considered the hand motion controller the least important.

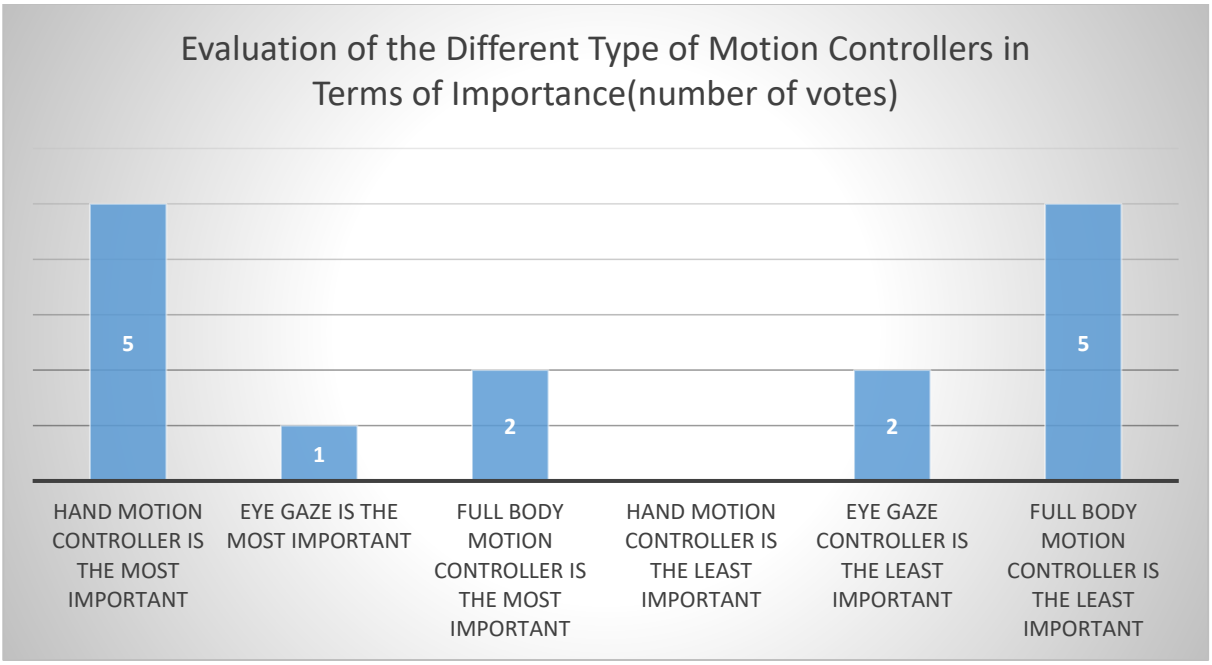


Figure 41. Results of the questionaries concerning the importance of each type of motion controller.

In general, all users considered the motion controllers an important feature and that will be useful in the future.

The use of AI mechanisms was considered important by all the testers and that may be more used in the future.

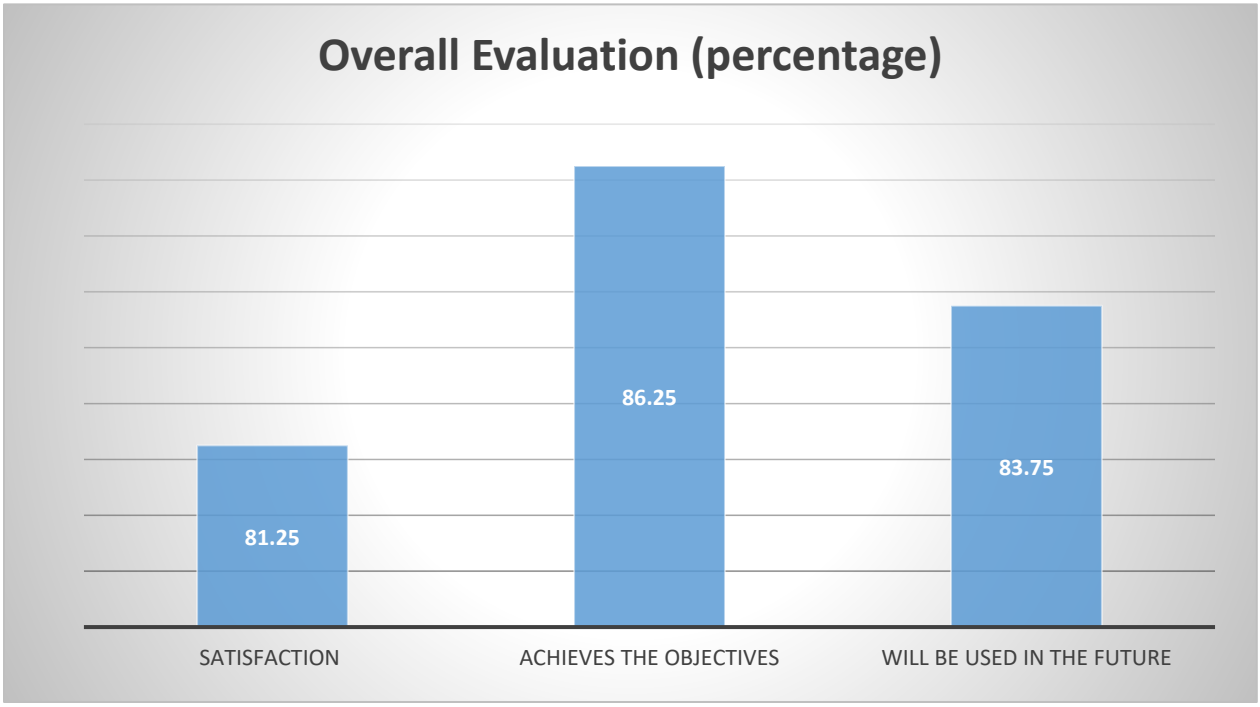


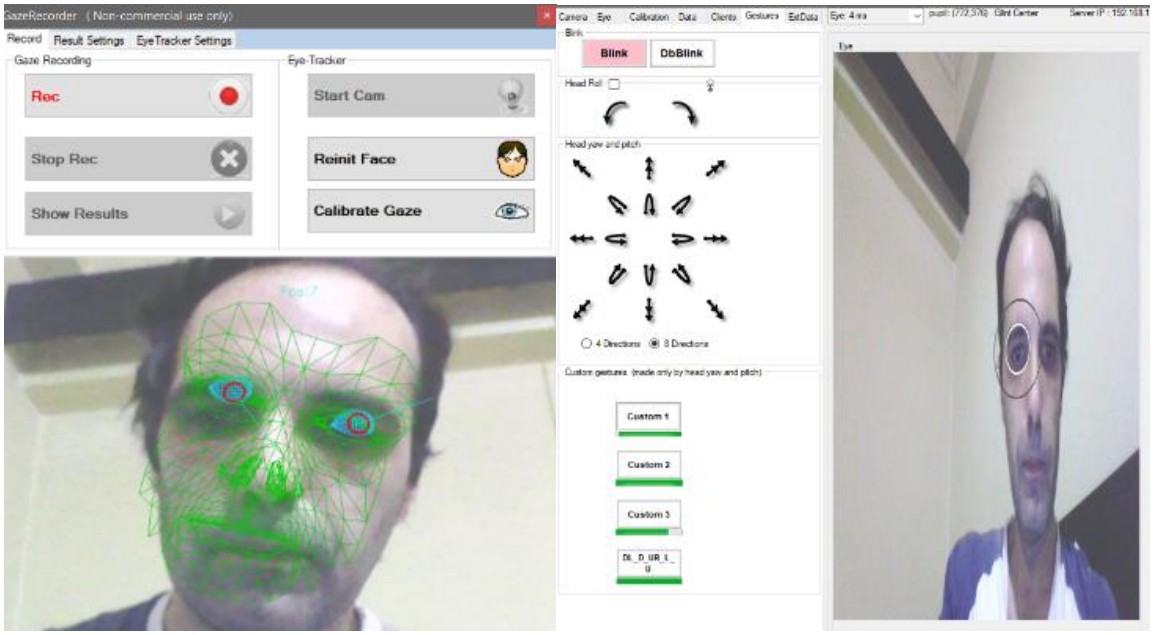
Figure 42. Overall evaluation results.

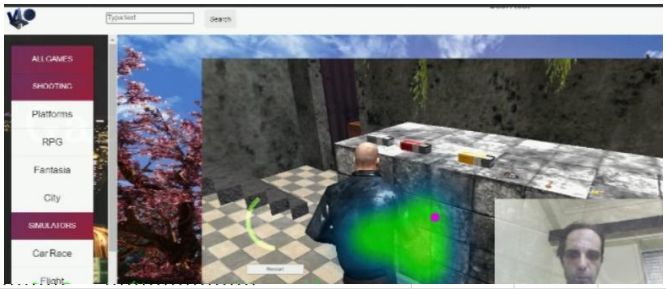
Concerning the motion controllers, it was noticed that the hand motion controller was not neglected and very appealing for cases of users with visual disabilities, something that was more highlighted for testers of older ages.

The questionnaire allowed to validate all the research questions of this investigation, allowing to retrieve qualitative conclusions.

4.2 Tests of Eye Gaze Motion

The tests were performed in indoor environments using in some cases artificial light and other cases natural light. The movement of the Iris was recorded and data was obtained like the coordinates of where the eyes are looking in the screen and predictions of emotional state.





#Gaze cordinates [0,0] : left top corner, [1,1] bottom right corner				
#[RespondentNr]	[StimulusNr]	[timestam	[Gaze x %]	[Gaze y %]
0	0	376	0.948	0.92
0	0	503	0.93	0.913
0	0	640	0.913	0.885
0	0	678	0.883	0.842
0	0	794	0.899	0.784
0	0	948	0.669	0.627
0	0	1081	0.699	0.619
0	0	1213	0.718	0.563
0	0	1347	0.767	0.547
0	0	1479	0.837	0.54

Figure 43. Recording sessions of eye gaze.

The data obtained during recordings can also be used to predict emotional states. The use of applications with motion controllers has been Increasing.

```
Time, Pupil Center X , Pupil Center Y , Glint Center X , Glint Center Y , Pupil Diameter , Blink , DbBlink , HeadGesture , GazeX , GazeY
67,921,630,0,0,53,,,,0,0
181,923,630,0,0,52,,,,0,0
250,926,631,0,0,53,,,,0,0
320,935,636,0,0,50,,,,0,0
385,948,650,0,0,52,,,,0,0
450,961,656,0,0,53,,,,0,0
504,0,0,0,0,0,,,,0,0
599,0,0,0,0,0,,,,0,0
708,0,0,0,0,0,,,,0,0
797,0,0,0,0,0,,,,0,0
912,0,0,0,0,0,,,,0,0
1089,0,0,0,0,0,,,,0,0
1244,0,0,0,0,0,,,,0,0
1399,0,0,0,0,0,,,,0,0
1531,817,669,0,0,46,,1,,0,0
1601,0,0,0,0,0,,,,0,0
1749,0,0,0,0,0,,,,0,0
```

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Recording	Computer	Sensor	Project na	Export dat	Participant name	Variable1	Recording	Recording	Recording	Recording	Recording	Recording	Timeline n	Recording	Recording	Recording	Recording	Recording
2	0	1.74E+11		Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
3	21731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
4	25731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
5	29731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
6	33731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
7	37731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
8	41731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
9	45731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
10	49731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
11	53731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
12	57731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
13	61731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
14	65731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
15	69731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
16	73731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
17	77731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
18	81731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
19	85731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
20	89388	1.74E+11	Mouse	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10
21	89731	1.74E+11	Eye Tracke	Project1	5/20/2021	Participant1		Recording	5/20/2021	5/20/2021	10:11:13.5	09:11:13.5	15664	Timeline1	Tobii I-VT (	1.162.324	1350	2400	10

Entire Recording

Duration of inter	Participan	Variable1	1	Average	Median	Count	Total Time	Total Recording Duration
Recording1	Participant		15.66	15.66	15.66	1	15.66	15.66
Average			15.66	15.66	15.66	1.00	15.66	15.66
Count			1					
Variance								
Standard Deviati								

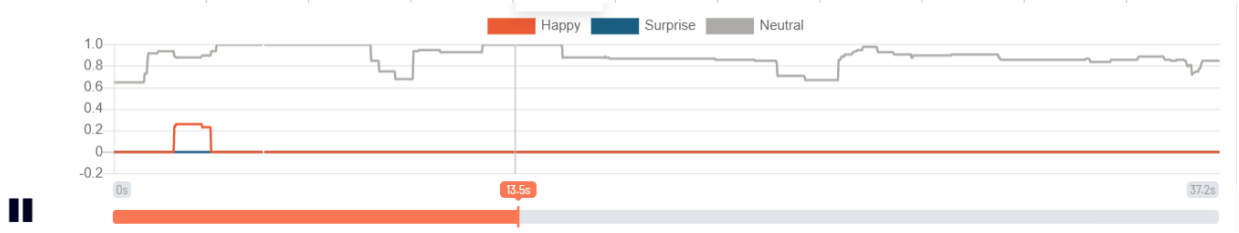


Figure 44. Prediction of emotions

4.3 Analysis of the Results and Discussion

The tests performed allowed to retrieve conclusions, concerning the satisfaction, the results obtained were high when measured via questionnaire or via AI mechanisms for emotional state prediction by recording the eye gaze.

From the several prototypes evaluated, it was noticed a preference for the hand motion controllers that can be used by people with certain disabilities like visual.

The study focused on different strategies to address the problem of usability and accessibility taking in consideration the degrees of incapacities.

Applications, especially the web based still have limitations concerning the access to certain handicaps offering many research challenges.

Via the tests, it was noticed that the objectives were achieved, most of the testers found that the applications developed achieved the objectives and that could be used for diverse types of disabilities. Concerning the full body motion controller, the hand tracker and the eye gaze there were some difficulties in obtaining the ROI mainly for the full body, the web camera has to detect the body parts that is going to interact, requiring in most cases to correctly place the users, with a distance of around 70 cms for the eye gaze and the hand controller and a distance of more than 1.5 meters for the full body, if the necessary body parts are not detected the applications will not work.

Most of the testers found that these type of applications with motion controllers will be used in the future.

The results obtained allowed to perform an overall evaluation and appraise if the investigation objectives were achieved and answer the research questions.

An assessment was done on the presented solutions for the problem of accessibility for people with disabilities like visual, auditory, physical, speech, cognitive, language, learning and neurological.

Most of the testers agreed that the implementation of AI mechanisms in softwares can provide more efficiency, control and functionality to the application.

The problem of accessibility can be approached via different perspectives being the systems focused to different body parts.

The drone controller showed high satisfaction results and in the future, there is a tendency that UAVs will replace some activities currently performed by humans.

Chapter 5

5. Conclusions, Limitations and Future Work

This dissertation presents a set of processes and prototypes to increase the usability of applications. The study took in consideration related work and theoretical concepts, certain aspects were given relevance, such as the implementation of responsive AI in order to make the applications more useful and easier to interact.

The project aims to answer the research questions by providing details of the AI mechanisms used and an implementation of different types of controllers to provide accessibility for different disabilities was implemented.

The accessibility problem was analyzed presenting different possibilities by using diverse types of motion controllers to facilitate the use for people with different sorts of disabilities and ages.

It was noticed difficulties concerning the process of obtaining the ROI, for some cases like low lightning or the user not positioning correctly in front of the camera.

Over the last years was noticed an increased utilization of motion controllers, allowing to help the interaction for several type of users and also reducing the dependency on a mouse and a keyboard.

Some of the processes described have low cost, are not so laborious and faster than traditional methodologies.

In order to present a possible solution to the presented problems, several programming languages, hardware and Interface Development Environments (IDEs) were taken in consideration and tested.

5.1 Answers to the Research Questions

The answers to the research questions are:

Research question 1: How motion controllers using artificial intelligence mechanics can facilitate the usability and accessibility of the applications for people with disabilities like visual, auditory, physical, speech, cognitive, language, learning and neurological?

Three different types of motion controllers, namely eye gaze, hand motion and full body were given more relevance in this dissertation. The applications can be accessible for different types of users, using the iris has a controller for example can help people with motor disabilities and hand controllers can facilitate the use to persons with visual difficulties, this question depends on the level of incapacity, the showed types of motion controllers are only able to be used for certain disabilities and for certain levels.

Research question 2: How can the implementation of AI mechanisms in softwares provide more efficiency, control and functionality?

The use of AI mechanisms allowed to perform several activities, like controlling drones, perform treatment of the image obtained by the camera and increasing the number of functionalities on the applications.

The interaction between user and an AI agent has been developing over the last years, adding more tasks to these agents allowing to make the applications more useful and provide more information that can be used in several areas like healthcare.

5.2 Limitations

The application of motion controllers to improve accessibility and usability still has some research challenges, for high degrees of incapacity and for some cases is very complicated to implement processes that allow the user interaction.

The collision avoidance process between objects still offers some difficulties. Some researchers were able to implement processes of interacting with UAVs using hand motion controllers, and processes like using drones to perform activities done by humans have been improving over the years but still have many limitations.

Concerning the use of hand motion controllers, it provides a possibility to be used by people with visual limitations, but people that have motor problems like Parkinson might not be able to use.

The eye gaze is not recommended for cases of visual disabilities and in some cases require high efforts of calibration.

The full body motion controllers have some difficulties of usage for people with motor disabilities and might require some efforts in order to obtain the ROI.

The implementation of web drone controllers should take in consideration the speed of the drone, the battery capacity, avoid collisions and should have functionalities that can help people with certain types of disabilities.

The AI mechanisms can be improved in order to provide more services and better interaction, facilitating the process of communication between human and machine.

5.3 Future Investigation

Artificial intelligence mechanisms are currently being used in different areas like mechanics, training, healthcare among others, but many research challenges are still open, there is an increase need to make these applications accessible to different types of disabilities and also a development of the AI mechanisms that allow to implement important functions like reading the vital signs via a sensor like a camera, or allowing to make predictions facilitating the process of detecting diseases in medical images.

Drones are being used in several areas of investigation and can have more functionalities reducing the human error, it is expected that cars will be able to drive automatically and some functions currently done by humans to be replaced.

The future of the applications has been followed by an increasing development of the correspondent hardware, CPUs have more memory capacity, it is possible to treat higher amounts of data at faster speeds, data science has been growing and answers to problems like predicting when a stock is going to be replaced or identifying a person by pointing a camera to the eyes or face from a huge dataset is being used, advanced algorithms in large amount of data can give information about a person identified via a drone camera, a situation that is currently being done in China, these technologies are being enhanced and having more functionalities.

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Appendices

Appendix A - User Questionnaire

Introduction and objectives

First, we would like to show our gratitude for the participation in these tests.

As mentioned previously this test is under the scope of the Master thesis of Information and Enterprise Systems, in which the objective is to test functional concepts to make the applications useful and easy to use.

This session is divided in 3 parts, the first in answering a questionnaire where some personal data will be asked, this will be used for an analysis and comparison between different uses of the application, the second part is the core of the test where it will be asked to use the application freely, and the third part a questionnaire about the evaluation and how you feel concerning the tested prototypes.

Appendix B - Right Grant Form

Consentment

I, _____, carrier of the Passport nº _____ authorize the audio the processing of my data for studying purposes.

_____, ___ of April 2022

_____

(Signature)

Appendix C - Pre-Test Questionnaire

Pre-Test Questionnaire

Initial questionnaire

Sex: ___ (M or F)

Age: ___

Professional situation: _____

District of residence: _____

Nationality: _____

Date of birth: ____/____/_____

Appendix D - Questionnaire after test

Final questionnaire

For the first eight questions, answer each affirmation with the value that more adjusts to your experience. It will be used a scale from 1 to 5 where 1 means “I totally disagree” and 5 means “I totally agree”. For question 9 use 1, 2 or 3, being 1 the one with higher priority and 3 the one with less.

1. The applications are easy to use.

   ○ 1 ○ 2 ○ 3 ○ 4 ○ 2

2. The several functions of the applications are well integrated.

   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

3. The applications show a lot of inconsistency.

   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

4. The users will learn quickly to control the applications.

   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

5. It was necessary to learn many new things to use the applications.

   ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

6. Rate from 0 to 100, being 100 the highest, the level of satisfaction with the applications.

   [ ]

7. Rate from 0 to 100, being 100 the highest, the level if the applications achieve the objectives.

   [ ]

8. Rate from 0 to 100, being 100 the highest, the level if the applications will be used in the future.

   [ ]

9. Which of the 3 motions controllers do you consider having more priority of use? (Fill the boxes with the values 1,2 and 3, being 1 the one you give more priority and 3 the one with less).

   Full body controller [ ]
   Hand motion controller [ ]
   Eye gaze controller [ ]