Facultad de
Ciencias Sociales y
Tecnologías de la Información
Talavera de la Reina. UCLM

UNIVERSIDAD DE CASTILLA-LA MANCHA

TRABAJO FIN DE GRADO

Diagnostico de patologias mediante el analisis de movimiento via inteligencia artificial

Carlos Rincón González

June, 2024

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Departamento tutor académico

Tecnología Específica

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June , 2024

*D*edicado a mi familia y a todos

aquellos que me apoyaron durante el camino

Yo, Carlos Rincón González con DNI 04235371J, declaro que soy el único autor del trabajo fin de grado titulado " Diagnostico de patologias mediante el analisis de movimiento via inteligencia artificial" y que el citado trabajo no infringe las leyes en vigor sobre propiedad intelectual y que todo el material no original contenido en dicho trabajo está apropiadamente atribuido a sus legítimos autores.

Talavera de la Reina, a 19 de Diciembre de 2023

Fdo: Carlos Rincón González

Resumen

Esta plantilla puede modificarse para adaptarse a las particularidades de cada Proyecto, tanto en contenido como en formato, siempre y cuando se respete las directrices básicas indicadas en la guía de estilo y formato para la elaboración de TFG del Grado en Ingeniería Informática de la Facultad de Ciencias Sociales y Tecnologías de la Información de Talavera de la Reina.

1-2 parrafos sobre el resumen general del proyecto

Abstract

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HTML Lenguaje de marcas de hypertexto

HCI Human Computer Interaction

TFG Trabajo Final de Grado

ML Machine learning

AI Artificial Intelligence

Chapter 1

Introduction.

When we were first discussing the possible themes of this project, we encountered papers that talked about the possible relation between depression and movement or posture. These studies were made using the Kinect as a tool to recognize the patterns of the movement of the afflicted people [34] [28] . This in conjunction with the sudden growth of the AI field at the moment sparked the idea that we could contribute to this field and make some development of our own. But before we get to depression there are many other problems that we could also address, one of which is very important to me as a person, back pain.

1.1 How back pain affects health.

Health is a problem that never can escape us, whether we want it or not, we get sick from time to time, and illnesses are a main cause of discomfort in your day-to-day life, but for many people, it's not only a discomfort, many people have chronic illnesses that don't allow them to have a normal life, and they don't deserve it. As many experts see it two main causes of illness affect people in today's world, mental illness and back pain.

As Gordon Waddell talks about in his book "The back pain revolution", back pain is a pervasive and often debilitating condition that affects millions of people worldwide, transcending age, occupation, and lifestyle. As one of the most common reasons for seeking medical attention, back pain poses a significant challenge to the well-being and functionality of individuals across diverse demographics. This book delves into the multifaceted nature of back pain, exploring its possible causes, far-reaching implications, and the profound impact it has on the daily lives of those who grapple with this condition.

Understanding the root causes of back pain is crucial in addressing and managing this prevalent health issue. From musculoskeletal imbalances and poor posture to more complex conditions such as herniated discs and spinal deformities, the variety of factors contributing to back pain is vast. By unraveling these causes, we can better comprehend the intricate web of influences that contribute to the development and persistence of back pain, thereby paving the way for more targeted and effective interventions.

Beyond the physical discomfort it causes, back pain goes through various aspects of individuals' lives. It enters professional life, limiting work productivity and potentially limiting career advancement. Simple daily activities become annoying tasks, demolishing the quality of life for those fighting with persistent pain. Furthermore, the emotional toll of chronic back pain can lead to anxiety, depression, and a sense of helplessness, creating a cascading effect on mental well-being.

Posture stands as a cornerstone in the intricate puzzle of back pain. Poor posture places undue stress on the spine, its supporting structures, and surrounding muscles, often leading to discomfort and pain. Sedentary lifestyles, prolonged hours spent hunched over screens, or improper ergonomics contribute to the prevalence of poor posture. This misalignment, whether subtle or pronounced, can over time lead to imbalances in muscle strength and flexibility, setting the stage for chronic back issues.

The way individuals walk, known as *gait*, is another pivotal factor influencing back health. An abnormal gait pattern can trigger misalignments in the spine, impacting the distribution of forces throughout the body. For instance, an uneven gait or excessive pronation of the feet can lead to compensatory movements in the spine, potentially causing strain and pain, this is a very well-known problem for those who have plain feet and the reason those people need to have prosthetics to help their posture.

Occupational demands and lifestyle choices significantly contribute to poor posture and walking habits. Jobs that require prolonged sitting or repetitive movements may contribute to muscular imbalances and faulty posture. Similarly, carrying heavy loads, whether at work or in daily activities, can strain the back and alter gait patterns, further increasing the risk of developing or exacerbating back pain.

This project will explore not only the physiological aspects of back pain but also its broader implications on society. By researching this condition, we aim to help the development of comprehensive strategies for prevention, management, and treatment. Through an understanding and research of back pain, we can empower individuals, healthcare professionals, and policymakers to collaborate in mitigating its impact and creating a healthier, more resilient society.

1.2 Mental issues and how they relate to posture.

This project will take part in a bigger research article related also to the importance of mental illness in society.

Mental illness poses a significant challenge to society, affecting people, families, and communities on various levels. Moreover, mental illness can disrupt social relationships and hinder effective communication, leading to social isolation and the destruction of a person's life from within itself. Depression, a common mental health disorder, affects millions of people globally, impairing their ability to function optimally in daily life. The repercussions of depression extend beyond individual suffering, where it can lead to harder and much worse consequences. Even if it doesn't go too far it can hinder your life in a very hard way making you not be a "proper" person even limiting you to a bed, as you don't have the strength to leave.

Alzheimer's disease, a form of dementia, is a particularly prevalent and devastating mental health condition. As populations age worldwide, the incidence of Alzheimer's continues to rise, placing immense emotional and financial strain on families. The progressive nature of the disease not only steals the cognitive abilities of the people who suffer it but also places a burden on the families and whoever is in charge of them. Personally, this has been a big issue in my family, where I've suffered several cases of Alzheimer's disease and it's been hard for us as a family to deal with.

The societal impact of mental illness also manifests in stigmatization, discrimination, and inadequate access to mental health services. The stigma surrounding mental health issues can lead to delayed or inadequate treatment, increasing the severity of conditions. Addressing mental health challenges on a societal level requires comprehensive strategies, including destigmatization, improved access to mental health resources, and increased awareness to create a supportive and inclusive environment for those affected by these conditions. Addressing mental health not only benefits individuals but also contributes to the overall well-being and productivity of society.

In the research this project takes part in, we aim to also establish a link between posture and movement to the discovery and prevention of mental health such as both we talked about, Alzheimer's and depression. Some articles correlate mental health symptoms to verbal but also non-verbal signs. Researchers have focused their attention on visual and linguistic indications for assessing depression. This project introduces related work on facial features, audio features, body features, and Kinect-based rehabilitation training and detection methods in particular.

1.3 Improving the medical field.

Technology, particularly advancements in computer science, has played a crucial role in revolutionizing the medical field, enhancing patient care, and driving improvements in the healthcare system. One of the most notable contributions comes from the utilization of electronic health records, which have simplified the management and accessibility of patient information. EHRs enable doctors to access detailed and up-to-date patient records instantly, facilitating more informed decision-making and coordinated care across various medical departments. This not only improves efficiency but also reduces medical errors which leads to a better healthcare system overall.

Moreover, artificial intelligence (AI) and machine learning (ML) applications have significantly impacted medical diagnostics and treatment planning. Advanced algorithms can analyze vast amounts of medical data, such as imaging studies, genetic information, and patient histories, to identify patterns and provide decisions that may escape the human eye. In fields like radiology, AI algorithms have demonstrated remarkable accuracy in detecting abnormalities, expediting diagnoses, and contributing to earlier interventions. Additionally, personalized medicine has gained momentum through genomic research, leveraging computational methods to analyze individual genetic profiles and create treatment plans for the specific genetic makeup of each patient.

Telemedicine, another technological advancement fueled by computer science, has transformed healthcare accessibility. Using video consultations, remote monitoring, and digital communication, patients can receive medical advice and monitoring without the need for physical visits to hospitals. This has proven particularly important as of late, following the events of the global pandemic that hit us a couple of years ago, even tho other parts of the world had been using it before that.

This project aims to tackle the previous points and merge them into one, allowing us the benefits of telemedicine and artificial intelligence to create a new diagnostic method for the biggest health issues of today's world. This is the goal, helping society to overcome what we see as the problems of the future and the present, that make life worse for so many people in this world.

#TODO mini resumen de la propuesta estructura del trabajo en cuanto a capitulos grafico del desarrollo

Chapter 2

Objectives.

We aim to create a way to analyze the human body that is more accessible for everyone so we can improve the lives of people who may not have easy access to doctors or specialists. The goal of this project is to make the world a better place using the technology of the future that we are starting to develop now. The project will start small by introducing a back problem as a means to develop the data model that will later be used for several other illnesses and even try to detect some non-physical problems using behavioral and movement-based analysis.

We don't want to substitute the medical professionals, that would be very irresponsible as peoples' lives may be at risk. This project aims to provide those professionals the tools to better do their job, to assess the patients beforehand and to have a better reach of patients who cannot access doctors due to physical restrictions.

2.1 Data obtenction via RGB camera and data validation.

We are going to consider the different types of cameras to be used to process the data, these cameras have different capabilities and characteristics. We are going to analyze the differences between them and we are going to see how we can make use of their data. In our case, we are going to use RGB cameras, which do not have depth perception by themselves, so we have to investigate how to transcribe depth to them. Not only is the camera we use relevant, but the software used to process what is seen by the camera is also relevant. Therefore we are going to investigate the different ways of data capture and processing.

In contrast to other types of cameras our choice, the RGB camera, is not a camera with previous scientific validation. This is why we have to investigate how the validation process of the camera and the data we obtain from it can be done. The data need to be validated not only scientifically, but also in terms of what parameters are going to be useful for the data model.

The aim of this is to help the medical field by setting a base for future development of medical applications using this type of camera, which will be very beneficial as it is the most common and and the most accessible for everyone. We think that if we come to conclusions and create a successful data model, the rgb camera will be able to be used in future research by other teams and developers. This is the reason why data validation is crucial for our project. It is not only necessary for the data model but also for the future of the medical field relating to the use of common-day smartphones for medical applications.

2.2 AI model training.

The data that we acquire from the cameras must be processed before being used for the data model and training. Also, this will help us determine what data is useful for future deployment of applications so the load on the devices is not as hard. With this, we aim to create a model that will be slim and powerful as it will have only the data that we require at a certain point in time. This will allow our project to be used by everyone and everywhere as part of our aim to expand the possibilities of helping people.

AI models are not that new anymore, which means that there are a lot of methods and services that help you train data models, we are going to dive into the different aspects of ones and others that have different characteristics between them. One may be more useful than others for our task. That also includes different methods of hosting these AI models and the research of different diseases to best choose the one that fits us the most and can be most of an improvement.

One big part of this project is also the image recognition software that we will be using, our objective is, as we mentioned, to use RGB cameras and therefore we need an image recognition software that translates the data into 3d from a 2d capture.

2.3 Validation of the diagnostic system for the pathology of the initial case study.

With this all in mind, we want to create more than one AI model in the future using the research we have done on the way. These other AI models would be trained for different pathologies of the human body and possibly the mind.

But before we can do that, we have another objective to reach, which is getting validation for our project from the medical field, as we are not doctors ourselves. This validation is key as it will serve as a precedent, as we have talked about before. The precedent is very important for the camera, the software and future models that we train, as would be backed by previous research and success.

Chapter 3

State of the art.

To know what can be done regarding our interests, we must look at what has already been done so far, so we don't waste our time doing something already done by someone else and also so we can use that research as a base to further improve our understanding and our work. Because of this, we are going to be looking at the state of the art on camera technologies, methods of extracting the data and different models of artificial intelligence.

3.1 Cameras.

RGB cameras, short for Red, Green, and Blue cameras, are imaging devices that capture color information by utilizing three primary color channels: red, green, and blue. These cameras mimic the way human vision perceives color by combining these three channels in varying intensities to produce a wide spectrum of colors. Each pixel in the image sensor of an RGB camera contains three sub-pixels, each sensitive to one of the three primary colors. The combination of these sub-pixels allows the camera to capture and reproduce a full range of colors, making RGB cameras essential for applications where color fidelity is crucial.

As told in the history of cameras by Amr Mohame [13]. The popularization of RGB cameras can be attributed to their widespread use in various fields. In consumer electronics, RGB cameras are a key component of smartphones, digital cameras, and webcams, enabling users to capture high-quality and realistic images. In the field of entertainment, RGB cameras play a key role in film and television production, making accurate color representation for a more immersive viewing experience. Even more so, RGB cameras are extensively employed in computer vision applications, such as facial recognition, object detection, and augmented reality, where precise color information is vital for accurate analysis and interpretation. This is the field we are going to be using them in, but as we will see, there are more complications to be dealt with when using

RGB cameras in the medical field.

RGB cameras have become necessary in modern society, finding applications in industries ranging from healthcare and automotive to agriculture and surveillance. Their ability to faithfully capture and reproduce color has made them indispensable tools in a wide array of technological advancements, contributing significantly to the way we perceive and interact with the visual world. This is the precise reason we chose to evolve on this type of technology, to make our outcome, the application that relies on the data model, the most accessible possible to all the possible public of our application.

- Infrared (IR) Cameras: Capture infrared light, which is beyond the visible spectrum. Used in night vision applications, thermal imaging, and scientific research [32].
- Ultraviolet (UV) Cameras: Detect ultraviolet light, which is also outside the visible spectrum. Applied in scientific research, forensics, and some industrial processes [11].
- Multispectral Cameras: Capture light in multiple bands across the electromagnetic spectrum. Useful in agriculture, environmental monitoring, and medical imaging [14].
- Thermal Infrared Cameras: Detect the heat emitted by objects. Commonly used in night vision, security, and industrial applications [33].
- X-ray Cameras: Utilized for medical imaging, security screening, and industrial inspection. Capture X-rays, which have shorter wavelengths than visible light [30].
- 3D Cameras: Capture depth information along with color. Used in computer vision, robotics, and augmented reality applications [5].
- Depth Cameras: Measure the distance of objects from the camera to create a depth map. Commonly used in computer vision, gesture recognition, and virtual reality [17].

These are just a few examples, and there are many specialized cameras designed for specific applications. Each type of camera serves a particular purpose, depending on the information required for a given task. In particular, we are going to take a look at Depth cameras, in particular Kinect, as it is a well-known and established camera within the medical community for a variety of applications, as we have talked about before.

RGB cameras and depth cameras, such as the Kinect sensor, serve distinct purposes in imaging technology. While RGB cameras focus on capturing color information, depth cameras are designed to measure the distance of objects in a scene, providing a three-dimensional representation of the environment. The Kinect sensor, for instance, utilizes a combination of infrared sensors and a depth-sensing technology called time-of-flight to measure the time it takes for infrared light to travel to an object and back. This information is then used to create a depth map, representing the spatial layout of the scene. [29]

One significant difference between RGB and depth cameras lies in their respective capabilities. RGB cameras are great at capturing detailed color information, making them suitable for applications like photography, video recording, and image analysis where color fidelity is essential. On the other hand, depth cameras are valuable in scenarios where understanding the spatial relationships and distances between objects is critical. This makes them ideal for applications like gesture recognition, virtual reality, and robotics, where depth perception plays a vital role.

Even more so, in the medical field, depth cameras have been used for many different purposes for years now. Here are some detailed examples of how depth cameras have been utilized in healthcare [9] [8] [10]:

- Rehabilitation and Physical Therapy: Depth cameras have been employed in rehabilitation settings to monitor and assist patients during physical therapy. Kinect-based systems can track body movements in real-time, providing quantitative data on a patient's range of motion, posture, and joint angles. Physical therapists can use this information to customize rehabilitation exercises and track the progress of patients recovering from injuries or surgeries. In some cases, they can even give output on how a patient is doing a particular exercise and correct them in the case they are doing it wrongly [23].
- Surgical Planning and Navigation: Depth cameras have been integrated into surgical planning and navigation systems to enhance the precision of procedures. By capturing detailed 3D models of a patient's anatomy, surgeons can visualize internal structures with greater accuracy. This technology assists in preoperative planning, allowing surgeons to better understand the space between organs and plan the optimal approach for surgeries. This has been used in combination with X-rays and in their replacement in cases where X-rays are not a viable option [18].
- Prosthetics and Orthotics Design: Depth cameras have been applied in the design and fitting of prosthetics and orthotics. By capturing precise measurements of a patient's limbs in three dimensions, doctors can create customized prosthetics that offer a better fit and improved functionality. This personalized approach enhances patient comfort and the overall effectiveness of prosthetic or orthopedic devices [16].

3.2 Tracking.

We not only need to talk about the way we are going to obtain the images for the purposes we are aiming at. Tracking is also a very important aspect of the design and the decision that we have to make. Human movement tracking involves capturing and analyzing the motion of the human body, often represented through skeletal models based on joints [15].

A skeletal model based on joints is a representation of the human body's underlying skeletal structure, focusing on key points or joints where bones articulate. This model is used in the context of human movement tracking and motion analysis. The skeletal model typically consists of interconnected joints, each associated with specific body parts, such as the head, shoulders, elbows, wrists, hips, knees, and ankles. These joints are crucial for capturing and understanding the intricate motions and positions of the human body during various activities. These joints are not only possible to be captured on a still image, but also on moving images of the body.

In the field of motion capture and tracking technologies, the skeletal model serves as a virtual framework that mirrors the actual movements of a person. The movement of joints is tracked and recorded using sensors or cameras, providing a three-dimensional representation of how the body is positioned and oriented in space over time. The accuracy and completeness of the skeletal model are essential for capturing natural and realistic human movements. The joints serve as key anchor points, enabling the reconstruction of the entire body's pose and facilitating a deeper understanding of biomechanics, kinematics, and human behavior. As technology advances, these skeletal models become increasingly sophisticated, contributing to the development of more immersive virtual environments, precise biomechanical assessments, and innovative applications in fields such as healthcare, sports, and entertainment.

Various technologies are employed for this purpose, each with its strengths and limitations.

- Inertial Sensors [25]: Inertial sensors, such as accelerometers and gyroscopes, are commonly used for motion tracking. These sensors measure acceleration and angular velocity, allowing the calculation of joint angles and movements. Inertial sensors are wearable and portable, making them suitable for applications like fitness tracking and sports analysis, but in our case, also the medical field.

- 2D Cameras [17]: 2D cameras or RGB cameras capture images in two dimensions and can be employed for human movement tracking using computer vision techniques. These cameras are cost-effective and versatile, making them widely used in applications like gesture recognition and video surveillance. However, they lack depth information, limiting their ability to capture the full three-dimensional nature of human movement. These are the ones we have been talking about before.

- 3D Cameras [29]: 3D cameras, such as depth-sensing cameras, provide depth information along with visual data. They use technologies like structured light or time-of-flight to measure distances, enabling more accurate skeletal modeling. 3D cameras are beneficial for applications like virtual reality, gaming, and biomechanical research, as they offer improved depth perception compared to 2D cameras. These cameras are the category that fits the

Kinect as we have talked about before.

- Infrared Cameras [35]: Infrared cameras capture infrared radiation, allowing them to work in low-light conditions. They are often used in conjunction with markers or reflective surfaces to track human movement accurately. Infrared cameras are employed in motion capture systems for animation, biomechanics research, and clinical applications. They offer high precision, but the setup can be complex and requires controlled environments.
- Marker-Based Motion Capture [12]: Marker-based motion capture systems use markers placed on specific body parts. Cameras, often infrared, track the movement of these markers to create a detailed skeletal model. This method provides high accuracy but may be intrusive, as markers must be attached to the subject's body. For example, Optitrack is a commercial solution for motion tracking using markers, OptiTrack's motion capture systems are used in the film industry for creating realistic animations, in the gaming industry for creating immersive experiences, in the VR industry for creating low-latency positional tracking, in the robotics industry for 6DoF tracking, and in the movement sciences industry for human movement analysis. The cameras are placed around the area where the motion capture is taking place, and they capture the movement of reflective markers that are placed on the objects or people being tracked.
- Markerless Motion Capture [22]: Markerless motion capture relies on computer vision algorithms to track and reconstruct skeletal models without the need for physical markers. This approach offers more natural movement and is less invasive than marker-based systems, making it suitable for applications like entertainment, sports analysis, and healthcare. OpenPose is a 3D markerless motion capture technique that uses multiple synchronized video cameras to track human poses or skeletons from images. It has been shown to have an accuracy of 30 mm or less.

3.3 Machine Learning Algorithms.

Machine learning is the practice of instructing machines on how to manage data more effectively. When it becomes challenging to extract information directly from data, machine learning techniques are applied. The increasing availability of datasets has led to a growing demand for machine learning across various industries, where it is used to extract pertinent information. The primary objective of machine learning is to enable machines to learn autonomously from data, a topic that has attracted extensive research from mathematicians and programmers seeking solutions for handling large datasets.

In an article by Azure they say@AzureML: "Machine learning is an application of AI. It's the process of using mathematical models of data to help a computer learn without direct instruction. This enables a computer system to continue learning and improving on its own, based on experience. One way to train a computer to mimic human reasoning is to use a neural network, which is a series of algorithms that are modeled after the human brain. The neural network helps the computer system achieve AI through deep learning. This close connection is why the idea of AI vs. machine learning is really about the ways that AI and machine learning work together."

Machine learning employs a variety of algorithms to address data-related challenges. Data scientists emphasize that there isn't a single, universally optimal algorithm for every problem. The choice of algorithm depends on factors such as the problem type, the number of variables, and the most suitable model. Here's a brief overview of some commonly used machine learning algorithms [3] [7]:

- Supervised Learning: Supervised learning involves training a model to map input data to output based on labeled examples. These algorithms require external guidance, and the dataset is typically split into training and test sets. The algorithms learn patterns from the training set and apply them to the test set for prediction or classification.

- Decision Tree: A decision tree is a graphical representation of choices and their outcomes organized in a tree structure. Nodes represent events or decisions, while edges represent decision rules. Each tree comprises nodes and branches, with nodes representing attributes to be classified and branches indicating potential attribute values.

- Naive Bayes: Naive Bayes is a classification technique based on Bayes Theorem, assuming independence among predictors. It assumes that the presence of one feature in a class is unrelated to the presence of any other feature. Naive Bayes is commonly used for text classification and relies on conditional probabilities.

- Support Vector Machine (SVM): SVM is a widely used machine learning technique for classification and regression analysis. It constructs linear or non-linear boundaries, known as margins, between classes. SVMs utilize a technique called the kernel trick to map inputs into higher-dimensional feature spaces, maximizing the margins between classes and minimizing classification errors.

These of course are not all the Machine Learning algorithms, but they are some of the most used. Machine learning is an ever-evolving field and with recent developments in the AI world, there is sure to be a huge influx of new ideas and changes to the field that will surely guide the path to improvements in Machine Learning.

3.4 MediaPipe.

Now that we have established a basis for motion capture through cameras and tracking systems and we talked briefly about what is machine learning, we have arrived at a very important part of the project, MediaPipe [20].

MediaPipe is an open-source framework developed by Google that provides a comprehensive solution for building real-time multimodal perceptual pipelines. It is designed to simplify the development of applications that involve various forms of sensor inputs, such as cameras and microphones. MediaPipe offers pre-built components and tools for tasks like hand tracking, face detection, pose estimation, and more.

MediaPipe provides a solution for human tracking through its Pose module, which is designed to estimate the poses of multiple people in real-time. This module can be used for applications such as fitness tracking, gesture recognition, and augmented reality experiences. It uses a pre-trained machine learning model for pose estimation. This model is trained on a large dataset of annotated images to learn the key points (joints) of the human body. The model predicts the positions of specific joints on the human body, typically including key points like the nose, shoulders, elbows, wrists, hips, knees, and ankles. These landmarks form a skeletal representation of the human pose.

The detected pose landmarks are then used as input data in a graph-based processing pipeline. Each joint becomes a node in the graph, and the connections between the joints define the edges. This structure enables efficient processing and tracking of human poses. It is optimized for real-time performance, allowing the pose estimation model to process video streams or camera input in real-time. This is crucial for applications where low-latency tracking is required such as ours.

Chapter 4

Image recognition and data extraction.

4.1 Landmarks and Joints.

The first thing to do is to create a code that can be used to obtain the information we need. Fortunately we know that the are going to be using MediaPipe since the begining of the project wich made a straight shot for us at the time of developing this simple tool in wich we can iterate the different requirements.

We start off by creating a module that obtains the image information from our camera and then we use mediaPipe to process the information. Using the Vision module we obtain the landmaks [4]. Landmarks are the name given to the visual representation of the human body joints that the model is able to track and reproduce.

For clarity, we colored different sections. The head section is colored green and the body is split into two sections, the right and the left hemispheres. Right side is red and the left is blue.

At this point, we draw the points that we obtained in the image in the picture frame and the connections between them that mediapipe also provides us. To draw the dots and lines, we have to normalize the data as mediapipe provides us with values in the range [1,-1] therefore we have to translate them into the canvas using the picture resolution as values for normalization.

By doing this we get a simple code that draws in the frame the data that is obtained and processed by mediapipe.

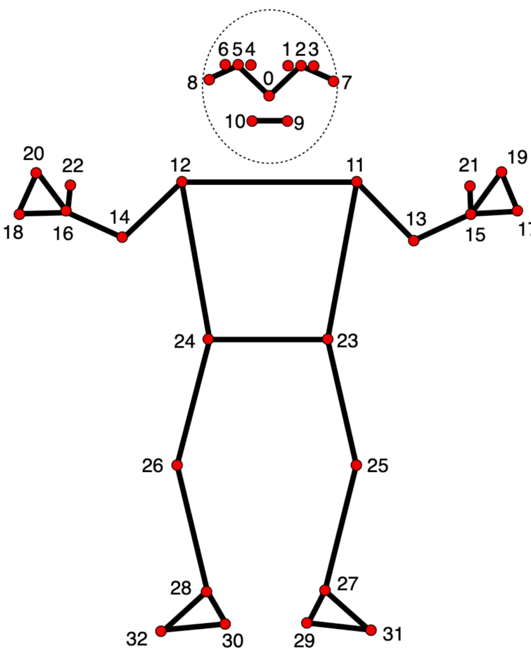


Figure 4.1: Pose landmarks

4.2 Human body planes.

There are numerous different papers that talk about ways in which we can study the human body analytically. The biggest part of the information came from medical articles that talk about how we can divide the body as if we took a photo from a different side [19] [2] [1].

In anatomy, understanding the concept of anatomical planes and axes is fundamental for describing the orientation and movement of the human body. Anatomical planes are imaginary flat surfaces used to divide the body into sections, aiding in the visualization and communication of anatomical relationships. These planes serve as reference points for describing the position of structures and organs relative to each other. The three primary anatomical planes are the sagittal, frontal (coronal), and transverse (horizontal) planes.

The sagittal plane divides the body into left and right halves, running parallel to the midline. It is further subdivided into median (or midsagittal) and parasagittal planes. The median sagittal plane precisely bisects the body into equal left and right halves, passing through the midline, while parasagittal planes are parallel to the median plane but offset to either side.

The frontal plane, also known as the coronal plane, divides the body into anterior (front) and posterior (back) portions. It is perpendicular to the sagittal plane and runs parallel to the coronal suture of the skull. Movement within the frontal plane includes abduction (moving away from the midline) and adduction (moving toward the midline) of limbs.

The transverse plane, often referred to as the horizontal plane, divides the body into superior (upper) and inferior (lower) portions. It is perpendicular to both the sagittal and frontal planes and is typically positioned parallel to the ground when the body is in the standard anatomical position. Rotational movements within the transverse plane include internal rotation (rotation toward the midline) and external rotation (rotation away from the midline) of limbs. Understanding these planes and their associated movements is essential for anatomical studies, medical diagnoses, and surgical procedures.

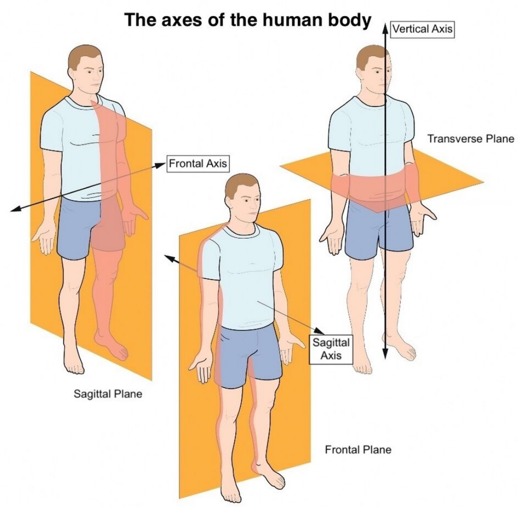


Figure 4.2: Axes of the Human Body

In our research, we are trying to establish a movement within these planes to be able to determine different parameters of the body's behavior and the direction of movement. For this precise reason, we are going to be using the data and we are going to normalize it in one of the different planes that we before mentioned using the angles of the joints for this process. The movement as described is considered to be an extension or a flexion seen by any of the axes of movement, therefore we can try to use this data to determine the direction of movement and the rate of it [24].

4.3 Stepping stones.

In terms of raw programming, I'm finding an issue with finding the normalization of a joint at a given time with the method previously used due to the fact that I cannot access the coordinates of the previous and next joint. For this precise reason, I proceed to create a new function that returns me a vector of the currently visible landmarks. This is key as we decided that an important point of reference that we could start measuring is when a step is taken, this is really important because since we don't have depth sensing cameras we cannot distinguish between floor and wall for example, we will have to use other much different approaches to know when a step is taken.

We are going to start trying to evaluate the height of the different landmarks that form a foot. We know as documentation tells us, that landmarks [27,29,31] and [28,30,32] form the left and right foot respectively. As we talked about before, we know that movement is a combination of extension and flexion [24], in this case, we assess that in order to take a step, one foot must flex and rise above the other, then proceeding to do the opposite, extending and causing the other foot to flex. This extension and flexion are reflected in our data as a change in the "y" variable of the joints, and normal steps commonly make the whole foot rise over the ankle of the other foot.

During testing, we also noticed and tweaked the variables as we noticed visibility as a parameter part of the landmarker function, which will be very useful for the assessment of false positives in the joint visualization. At this point, we also implemented several different features such as the ability to determine which landmarks are visible at a certain point in time and also the ability to extract the data that we collect to a csv file for future processing and easier visualization.

Chapter 5

Data validation

After creating our first piece of code that implements the mediapipe model as a way to extract the landmarks from a human body, we knew that we had to do something with that, because there are several different important data points to analyze.

The first step we took was to create some videos for two reasons:

- first we wanted to know if the data we are obtaining from our analysis was consistent, if we obtained diferent data each time we analyzed the same image, we would not reliably be able to trust the analisis that we would do after obtaining that data.
- Second, recorfing videos alows us the posibility of analyzing different types of body movements in an isolated manner. We will go more in depth later on, but there are some key factors or key movements that we woud have to look for as a indicative of a certain illness.

5.1 Data Extraction.

In the path to creating a tool for the healthcare system we need to asses their necessities. One of them is the data extraction and clarity. As talked about in this guide on how to create papers for medicine from the medicine research institue on the university of york [31]:

Healthcare decisions, both for individual patients and public policy, should rely on the most reliable research evidence available. It's important for practitioners and decision-makers to stay updated with the latest research and best practices to ensure that their decisions are grounded in sound knowledge. However, this can be challenging due to the vast amount of information generated by various studies, which may suffer from biases, methodological flaws, and contextual dependencies, leading to potential misinterpretation and misrepresentation. Moreover, individual studies may yield conflicting conclusions due to biases, differences in design or chance factors.

Consequently, determining the most reliable results or the ones to base decisions on isn't always straightforward.

Systematic reviews aim to address these challenges by identifying, evaluating, and summarizing the findings of all relevant studies, thus making the evidence more accessible to decision-makers. Combining results from multiple studies provides a more accurate and precise estimate of an intervention's effectiveness than relying on a single study. Systematic reviews follow a rigorous scientific design with explicit, pre-specified, and reproducible methods, ensuring that their conclusions are defensible. In addition to highlighting what is known about a particular intervention, systematic reviews also pinpoint areas where knowledge gaps exist, thereby guiding future research endeavors.

Healthcare decision makers increasingly rely on systematic reviews (SRs) of comparative effectiveness research (CER) to understand the benefits and risks of different healthcare interventions. SRs use explicit methods to identify, select, assess, and summarize relevant studies, sometimes including meta-analysis. However, the quality of published SRs varies widely, making it difficult for readers to evaluate them properly. Common issues include poorly documented methods, inappropriate use of techniques like meta-analysis, lack of assessment of underlying research quality, and failure to report funding sources. Additionally, diverse approaches to evidence hierarchies and grading schemes contribute to confusion in the field [21].

In this paper from the British Journal of General Practice [26], the computer databases were retrospectively examined for the recording of 10 major diagnoses in order to look for variations in recorded prevalence that might indicate incomplete recording. In all four practices the computer recording of four major chronic diagnoses was retrospectively assessed and compared with the prevalence of the four diagnoses found from manual medical records and the repeat prescribing system (all four practices used the EMIS integral repeat prescribing system) or found by crosschecking in the computer records for other related diagnoses. The diagnoses used for this diagnostic validation within each practice were: diabetes mellitus, glaucoma, asthma and coronary heart disease. The first two were chosen to assess cases that were not recorded on a computer or were inappropriately coded and the last two were chosen to allow examination of the ratio of active disease to overall recording of disease.

In our case, the data has to be contrasted by specialists in body movement and/or physiotherapy so our data has the validity we need in order to present this data used for a training model as a medical tool.

5.2 Data analisis. Angles.

During research we have found that a crucial part of the analysis of the human body is the angle in which the body is positioned relative to itself on certain points.

This paper [27] explores the impact of uncertainties in defining and constructing embedded axes on the estimation of joint angular motion during gait analysis. Using sensitivity analysis, the study assesses the effects of perturbations in the flexion-extension axis on joint angles, employing both Euler and helical angle definitions. Results show that errors in defining the flexion-extension axis significantly affect ab/adduction and rotation angles at the hip and knee joints, particularly in cerebral palsy patients with flexed knee gait patterns. The helical model demonstrates similar sensitivity to axis definition but may be less clinically interpretable compared to the Euler model. The findings underscore the importance of considering these limitations when interpreting joint motion data in pathological gait analysis.

This study [6] explores how the central nervous system simplifies control of the musculoskeletal system's redundant degrees of freedom (DoFs) by employing synergies in human arm movements. Using optical motion capture, researchers analyzed unrestrained catching movements, finding that three principal components (PCs) captured over 97% of variance in arm posture data. These PCs represent cardinal joint angle synergies, with three being sufficient to explain 80% of the variance across different catching positions. The study concludes that catching movements are characterized by strong kinematic couplings between joints, reducing kinematic complexity to three non-redundant DoFs, which vary systematically with target location.

At this point, we are interested in evaluating the extracted data and processing it in order to extract the angles making use of the previous knowledge of the body planes to project the skeletal representation of the landmarks and calculate the angles of the joints. The process would be:

- Calculating the vector between joints A, B and C on a certain plane.
- Calculating the product and the magnitude of the vectors.
- Applying the formula " cos(a) = (AB · BC) / (|AB| * |BC|) "
- The arccos would give us the angle of the B landmark so we can normalize its data.

We do this in the 3 planes and we obtain the angle of the joints for its analisys by the data model. The angles that we take into account are yet to be known from the data model, therefore we need to calculate every single angle of the joints. The joints in mediapipe's landmarks are referenced as a number and we know how they are joined as they give us the prescription on fig x

With this information we can construct a dictionary of the joints with it's connections as values and we can evaluate the data based on that every time. In this case:

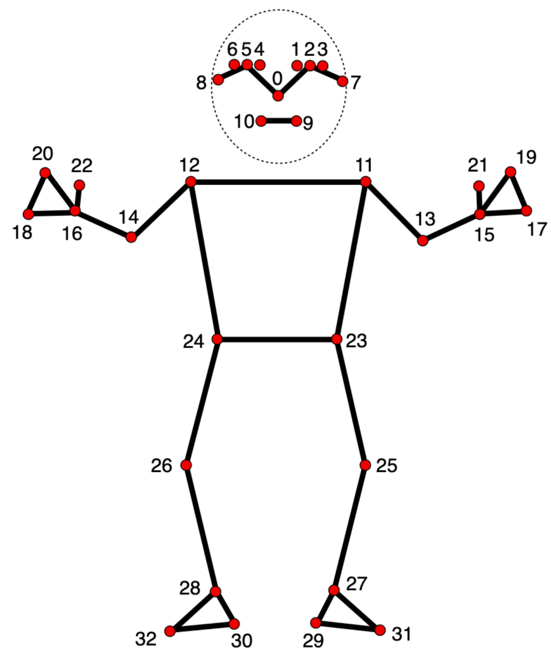


Figure 5.1: Pose landmarks

0: [1, 4],1: [0, 2],2: [1, 3],3: [2, 7],4: [0, 5],5: [4,6],6: [5,8],7: [3],8: [6],9: [10], 10: [9],11: [12,13,23],12: [11,14,24],13: [11,15],14: [12,16],15: [13,17,19,21],16: [14,18,20,22],17: [19,15],18: [20,16],19: [17,15], 20: [18,16],21: [15],22: [16],23: [11,24,25],24: [12,23,26],25: [23,27],26: [24,28],27: [29,31],28: [30,32],29: [27,31], 30: [28,32],31: [27,29],32: [28,30]

It is important to note that there are some landmarks that are only adjacent to one other point, and for an angle to be calculated, there has to be 3 points.

[1] 2024. Cardinal Planes and Axes of Movement. *Physiopedia*.

[2] 2023. Explicacin de los planos y ejes de la anatoma | Taxonoma bsica de la anatoma. *Fisiotutores*.

[3] 2024. Machine Learning Models: What They Are and How to Build Them. *Coursera*.

[4] 2024. Pose landmark detection guide. *Google for Developers*.

[5] Bleser, G. et al. 2005. Real-time 3d camera tracking for industrial augmented reality applications. (2005).

[6] Bockemühl, T. et al. 2010. Inter-joint coupling and joint angle synergies of human catching movements. *Human Movement Science*. 29, 1 (2010), 73–93. DOI:https://doi.org/https://doi.org/10.1016/j.humov.2009.03.003.

[7] Bonaccorso, G. 2018. *Machine learning algorithms: Popular algorithms for data science and machine learning*. Packt Publishing.

[8] Bonnechère, B. et al. 2014. Validity and reliability of the Kinect within functional assessment activities: Comparison with standard stereophotogrammetry. *Gait Posture*. 39, 1 (Jan. 2014), 593–598. DOI:https://doi.org/10.1016/j.gaitpost.2013.09.018.

[9] Chiu, C.-Y. et al. 2019. Comparison of depth cameras for three-dimensional reconstruction in medicine. *Proc. Inst. Mech. Eng. H*. 233, 9 (Jun. 2019), 938–947. DOI:https://doi.org/10.1177/0954411919859922.

[10] Dutta, T. 2012. Evaluation of the Kinect™ sensor for 3-D kinematic measurement in the workplace. *Appl. Ergon.* 43, 4 (Jul. 2012), 645–649. DOI:https://doi.org/10.1016/j.apergo.2011.09.011.

[11] Fulton, J.E. 1997. Utilizing the Ultraviolet (UV Detect) Camera to Enhance the Appearance of Photodamage and Other Skin Conditions. *Dermatol. Surg.* 23, 3 (Mar. 1997), 163–169. DOI:https://doi.org/10.1111/j.1524-4725.1997.tb00013.x.

[12] Furtado, J.S. et al. 2019. Comparative Analysis of OptiTrack Motion Capture Systems. *Advances in Motion Sensing and Control for Robotic Applications*. Springer. 15–31.

[13] Galal, A.M. 2016. An analytical study on the modern history of digital photography. *International Design Journal*. 6, 2 (2016), 203–215.

[14] Honrado, J.L.E. et al. 2017. UAV imaging with low-cost multispectral imaging system for precision agriculture applications. *2017 IEEE global humanitarian technology conference (GHTC)* (2017), 1–7.

[15] Huang, Y. and Huang, T.S. 2002. Model-based human body tracking. *2002 international conference on pattern recognition* (2002), 552–555.

[16] Krausz, N.E. et al. 2015. Depth sensing for improved control of lower limb prostheses. *IEEE Transactions on Biomedical Engineering*. 62, 11 (2015), 2576–2587. DOI:https://doi.org/10.1109/TBME.2015.2448457.

[17] Krishnan, C. et al. 2015. A low cost real-time motion tracking approach using webcam technology. *J. Biomech.* 48, 3 (Feb. 2015), 544–548. DOI:https://doi.org/10.1016/j.jbiomech.2014.11.048.

[18] Lacher, R.M. et al. 2019. Nonrigid reconstruction of 3D breast surfaces with a low-cost RGBD camera for surgical planning and aesthetic evaluation. *Medical Image Analysis*. 53, (2019), 11–25. DOI:https://doi.org/https://doi.org/10.1016/j.media.2019.01.003.

[19] Libretexts 2023. 1.4D: Body Planes and Sections. *Medicine LibreTexts*. (Jan. 2023).

[20] Lugaresi, C. et al. 2019. MediaPipe: A Framework for Building Perception Pipelines. *arXiv*. (Jun. 2019). DOI:https://doi.org/10.48550/arXiv.1906.08172.

[21] Morton, S. et al. 2011. Finding what works in health care: Standards for systematic reviews. (2011).

[22] Mündermann, L. et al. 2006. The evolution of methods for the capture of human movement leading to markerless motion capture for biomechanical applications. *Journal of neuroengineering and rehabilitation*. 3, 1 (2006), 1–11.

[23] Omelina, L. et al. 2016. Interaction Detection with Depth Sensing and Body Tracking Cameras in Physical Rehabilitation. *Methods Inf. Med.* 55, 01 (2016), 70–78. DOI:https://doi.org/10.3414/ME14-01-0120.

[24] Parklandcsit 2012. Axis Of Movement animation 2012. *YouTube*. Youtube.

[25] Ponciano, V. et al. 2020. Identification of Diseases Based on the Use of Inertial Sensors: A Systematic Review. *Electronics*. 9, 5 (May 2020), 778. DOI:https://doi.org/10.3390/electronics9050778.

[26] Pringle, M. et al. 1995. Assessment of the completeness and accuracy of computer medical records in four practices committed to recording data on computer. *British Journal of General Practice*. 45, 399 (1995), 537–541.

[27] Ramakrishnan, H.K. and Kadaba, M.P. 1991. On the estimation of joint kinematics during gait. *Journal of Biomechanics*. 24, 10 (1991), 969–977. DOI:https://doi.org/https://doi.org/10.1016/0021-9290(91)90175-M.

[28] Seifallahi, M. et al. 2022. Alzheimer's Disease Detection Using Comprehensive Analysis of Timed Up and Go Test via Kinect V.2 Camera and Machine Learning. *IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society*. 30, (2022), 1589. DOI:https://doi.org/10.1109/TNSRE.2022.3181252.

[29] Smisek, J. et al. 2013. 3D with Kinect. *Consumer Depth Cameras for Computer Vision*. Springer. 3–25.

[30] Szot, A. et al. 2004. Diagnostic accuracy of chest x-rays acquired using a digital camera for low-cost teleradiology. *International journal of medical informatics*. 73, 1 (2004), 65–73.

[31] Tacconelli, E. 2010. Systematic reviews: CRD's guidance for undertaking reviews in health care. *Lancet Infect. Dis.* 10, 4 (Apr. 2010), 226. DOI:https://doi.org/10.1016/S1473-3099(10)70065-7.

[32] Vandersmissen, R. and XenICs, N. 2008. Night-vision camera combines thermal and low-light-level images. *Photonik Int*. 2, (2008), 2–4.

[33] Waxman, A.M. et al. 1995. Color night vision: Fusion of intensified visible and thermal IR imagery. *Synthetic vision for vehicle guidance and control* (1995), 58–68.

[34] Yu, Y. et al. 2022. Depression and Severity Detection Based on Body Kinematic Features: Using Kinect Recorded Skeleton Data of Simple Action. *Front. Neurol.* 13, (Jun. 2022), 905917. DOI:https://doi.org/10.3389/fneur.2022.905917.

[35] Zappi, P. et al. 2010. Tracking motion direction and distance with pyroelectric IR sensors. *IEEE Sensors Journal*. 10, 9 (2010), 1486–1494.

A. Anexo 1 - Metodologia de trabajo Scrum.

Scrum is an agile project management framework that helps teams deliver high-value products. It emphasizes iterative development, collaboration, and customer feedback. The process is organized into time-boxed iterations called sprints, typically lasting 2-4 weeks. Scrum includes roles like Scrum Master, Product Owner, and Development Team, as well as specific events like Sprint Planning, Daily Stand-ups, Sprint Review, and Sprint Retrospective.

This is an altered version of the scrum methodology since there are only two parties involved in this project, the developer and the product owner. Carlos will be the developer and Felix and David will take part as the product owners. When adapting Scrum for a single developer and a single Product Owner, the structure can be simplified while maintaining key principles. Here's the modified version we are opting for: - Roles: - Developer: This is the individual responsible for all aspects of the product's development, from design to implementation and testing. Carlos Rincón González - Product Owner (PO): This person represents the stakeholders, defines the features, and prioritizes the work to maximize the product's value. Felix Albertos and David Carneros - Events: - Sprint Planning: At the beginning of each sprint (a development iteration), the developer and PO collaborate to plan the work for the upcoming sprint. These events will occur once every 2 to 4 weeks during the sprint meeting. - Daily Check-in: The developer has a brief daily check-in to review progress and plan the next steps. This is an opportunity to adjust plans based on feedback or changing priorities. This is not a necessary step and it's mostly used as a method of self-organization in the daily tasks of the developer - Sprint Review: At the end of each sprint, the developer presents the completed work to the PO. They discuss what was achieved and any adjustments needed for future sprints. Same as with the sprint planning, this will take part as part of the sprint meeting. - Sprint Retrospective: The developer reflects on the sprint, identifying what went well and what could be improved. This can be a brief self-assessment to enhance the development process. This will be a part of the sprint meeting as well.

- Artifacts:
  - Backlog: The Product Owner maintains a prioritized list of features and tasks, known as the backlog. The developer pulls items from the top of the backlog into each sprint.
  - The initial product backlog will consist of all the objectives set for the project in the beginning meeting. This objective will be stripped down into its crucial and more basic parts to be worked on and to develop a successful project

By simplifying the structure, a single developer can still benefit from Scrum's iterative and feedback-driven approach. The collaboration between the developer and product owner remains crucial for delivering valuable increments of the product.

For the management and monitoring of the project, we will make use of a tool called GitHubFor this workflow, we are going to use the tool within GitHub called Github projects. GitHub Projects is a collaborative project management tool designed to enhance the organization and tracking of software development projects on the GitHub platform. It provides a visual interface that allows teams to plan, track, and manage their work efficiently. GitHub Projects utilizes the concept of boards, where tasks are represented as cards that can be moved between customizable columns, such as "Product Backlog", "Sprint Backlog", "In Progress", and "Done". This flexibility makes it adaptable to various project management methodologies, including Agile and Kanban. Additionally, GitHub Projects integrates seamlessly with other GitHub features, such as code repositories and pull requests, providing a comprehensive ecosystem for collaborative software development, which is precisely the reason why we chose to use it, as we hosted our project on GitHub.

- **** #TODO Añadir product backlog inicial

A.1 Sprint 1 (20/09/2023 - 04/10/2023) - First Meeting.

- **Sprint meeting**
  - We stablish the bases of the project and the work methodology, and also we stablish a final name and theme.
- **Sprint Tasks**
  - **Tsk_01** Define the basics of the methodology and decide on an interface and a form to apply it **(1)**
  - **Tsk_02** Create the GitHub project and create the product backlog **(0.2)**

A.2 Sprint 2 (04/10/2023 - 22/11/2023) Project definition and configuration.

- **Sprint meeting**
  - Defining the project objectives and bullet points
- **Sprint Tasks**
  - **Tsk_11** Define and finalize the objectives of the project **(3)**
    - **Tsk_11.1** Define the objectives **(1)**
    - **Tsk_11.2** Write a description for each objective **(2)**
  - **Tsk_12** Create the constitution project document. **(2)**
  - **Tsk_13** Creation of the project based on Felix's template **(1)**
- **Sprint Retrospective**
  - The template works properly and has been filled
  - The project objectives seem clear and well-defined
- **Burndown Chart of the Sprint**

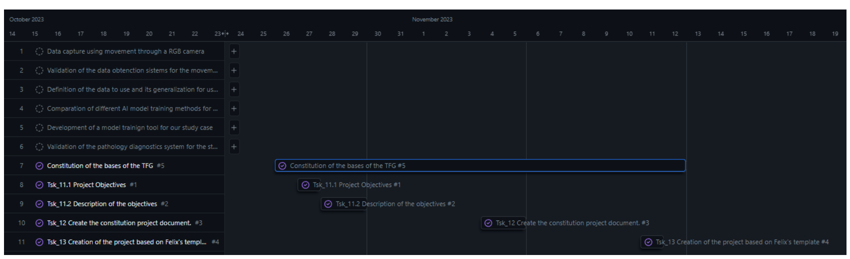


Figure A.1: Burnown Chart - Sprint 2

A.3 Sprint 3 (22/11/2023 - 05/12/2023) - Introduction.

- **Sprint meeting**
  - We start discussions about the project information itself and how to make the project´s memory.
  - We decided to start developing the introduction of the project so it is useful as a stepping stone for the rest of the project.
- **Sprint Tasks**
  - **Tsk_21** Research on back pain-related problems. **(4)**
  - **Tsk_22** Research How mental issues affect and relate to posture. **(3)**
  - **Tsk_23** Research How technology improves the medical field **(3)**
  - **Tsk_24** Explain the research **(5)**

    * **Tsk_24.1** How back pain affects life **(1.5)**
    * **Tsk_24.2** How mental health is affected by posture **(1.5)**
    * **Tsk_24.3** use cases of tecnology on the medical field **(1.5)**
    * **Tsk_24.4** ortography and references **(0.5)**

- **Sprint Retrospective**
  - The Introduction has started successfully but will need more work in the future.
  - The introduction may be split into different sections in the future as it may need more work
- **Burndown Chart of the Sprint**

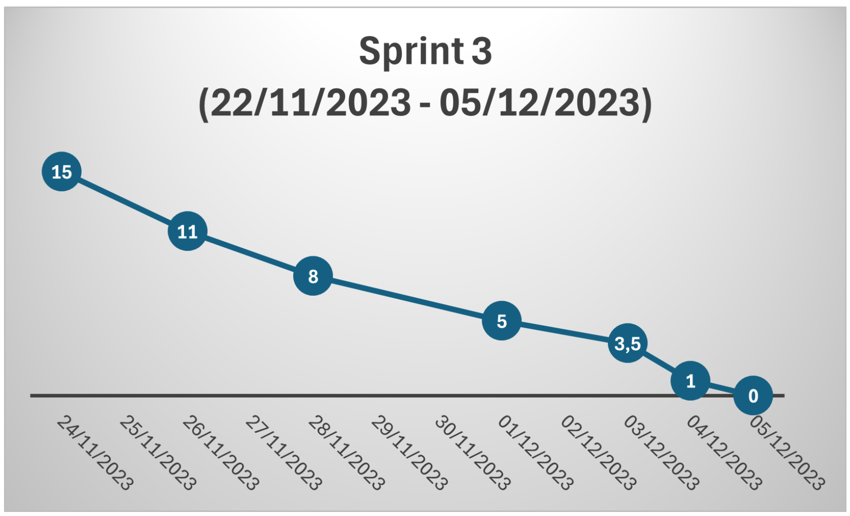


Figure A.2: Burnown Chart - Sprint 3

A.4 Sprint 4 (05/12/2023 - 19/12/2023) - State of the art.

- **Sprint meeting**
  - We agreed that the introduction art needed more development and we set ourselves on the path to research more about it in the future.
  - At this point, it was time to start working on the state of the art.
  - Also, we had to establish the motivations and objectives more clearly and develop a clear explanation of them in the project memory.
- **Sprint Tasks**
  - **Tsk_31** Further explanation of the introduction **(1)**
  - **Tsk_32** Research of the state of the art **(9)**
    * **Tsk_32.1** Types of cameras **(4)**
    * **Tsk_32.2** Tracking methodology **(3)**

        * **Tsk_32.3** Mediapipe definition **(2)**

- **Sprint Retrospective**
    - The points to iron out are the references, the orthography and use of the third person instead of the first person.
    - The sprint went well but i have to direct refference much more, even referencing every single example.

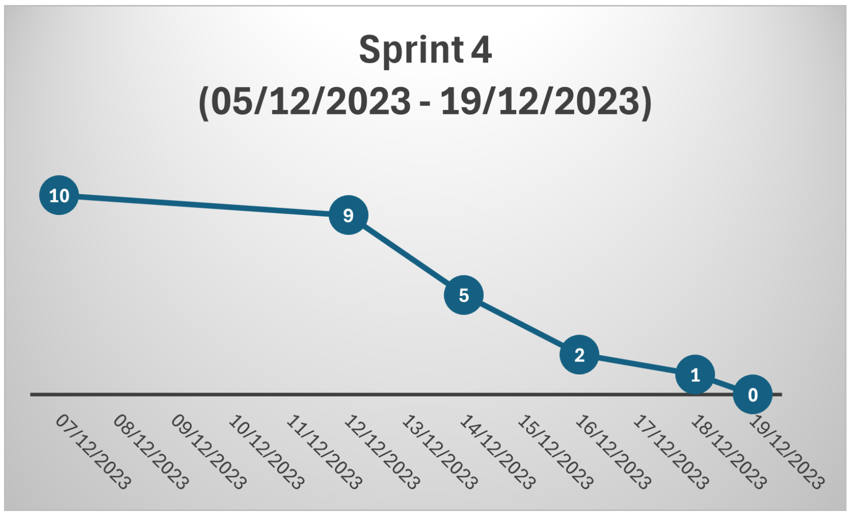


Figure A.3: Burnown Chart - Sprint 4

A.5 Sprint 5 (19/12/2023 - 16/01/2024) - Holiday Season Improvements.

- **Sprint meeting**
    - The previous sprint was successful in creating a beginning of a state of the art.
    - this sprint will take part during the holiday season and therefore will be lighter
    - we will use this time to further improve the work on the last sprints by improving the introduction and the state of the art research.
- **Sprint Tasks**
    - **Tsk_41** Research on the introduction **(3)**
    - **Tsk_42** Research on the state of the art **(3)**
    - **Tsk_41** Write compelling explanations and deeper knowledge **(4)**
- **Sprint Retrospective**
    - There was not much progress but we still did something in spite of the christmas vacation

  - There still needs to be even more references and the way references are made at some points are not correct.
  - We need to up the pace of the research so we can get into the real development of the ML model.

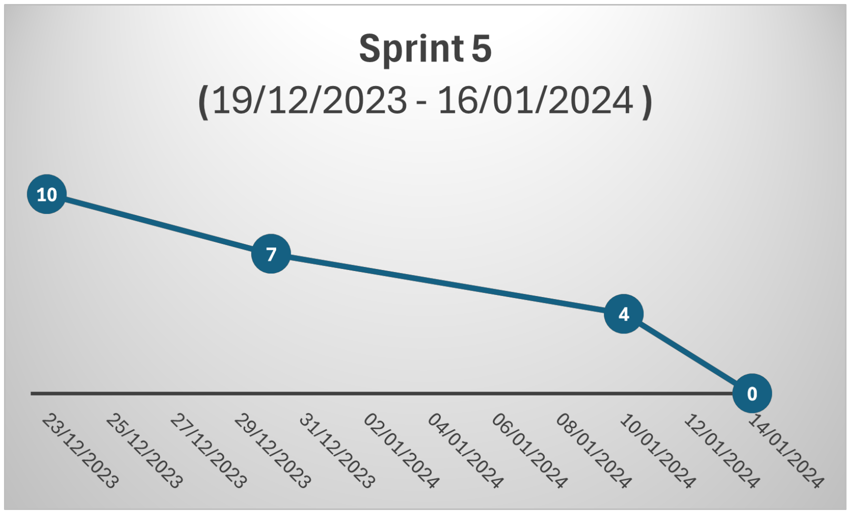


Figure A.4: Burnown Chart - Sprint 5

A.6 Sprint 6 (16/01/2024 - 02/02/2024) - Body planes and projections.

- **Sprint meeting**
  - we start to talk about the code and how we are going to aproach it.
  - Normalization of the data is a very important part of this process so we have to research a way of doing this.
  - This folowing weeks will set a base on some code to be used in image recognition and therefore we have to research on this very topic.
- **Sprint Tasks**
  - **Tsk_51** Burndown charts revised **(0.5)**
  - **Tsk_52** Data extraction for the x,y,z coordinates **(2)**
  - **Tsk_53** Creating a first script that uses mediapipe **(6)**
  - **Tsk_54** Research on body plane axes **(5)**
- **Sprint Retrospective**
  - Planes and projections are created from the coordinates obtained from mediapipe
  - The code works properly but needs more development

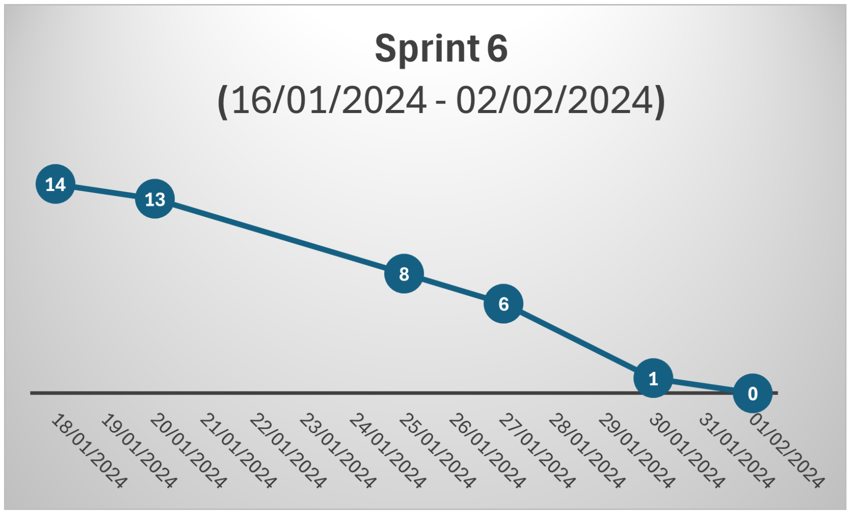
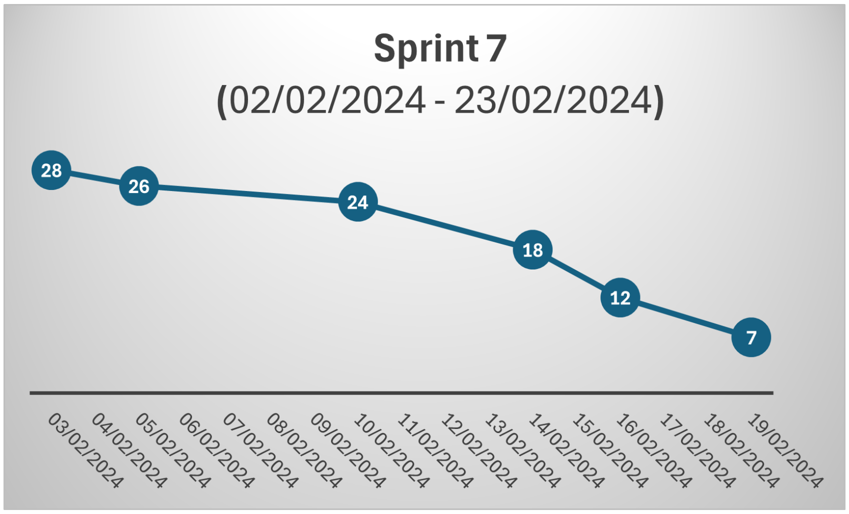


Figure A.5: Burnown Chart - Sprint 6

A.7 Sprint 7 (02/02/2024 - 23/02/2024) - Big steps into the code.

- **Sprint meeting**
  - we created a baseline code that extracts the data from the camera, we have to iterate and expand on this
  - we have to extract the data to csv in order to be processed
  - the code development has to continue by experimenting with the coordinates and seeing them change and what data we can extract from them
- **Sprint Tasks**
  - **Tsk_61** Data extraction for the x,y,z to csv **(7)**
  - **Tsk_62** Angle normalization of the coordinates **(9)**
  - **Tsk_63** Dection of steps taken **(12)**
- **Sprint Retrospective**
  - Angle normalization of the coordinates turned out to be harder than expected and is not finished.
  - Step detection is nearly done but not finished. Needs to be finalized.
  - Spent a lot of time in code development but left aside the document and that is not good.
  - focused on a visual representation of the data which is not at all relevant for us.



A.8 Sprint 8 (16/01/2024 - 02/02/2024) - Changes to the code and angles.

- **Sprint meeting**
  - have to fix the remaining problems on the document as they have been ignored for too long
  - the previous sprint was not very productive as the code took too much time and was way too complex
  - bring back to the beginning and start from scratch the code with a new focus
  - focus on the data extraction being correct and then proceed to angles and if we have enough time, distances.
- **Sprint Tasks**
  - **Tsk_71** Chapter 2 revised **(1)**
  - **Tsk_72** Annotations and titles corrected **(1)**
  - **Tsk_73** Recreate the data extraction algorithm using Pandas **(1)**
  - **Tsk_74** Angle extraction of the coordinates **(10)**
  - **Tsk_75** Research for chapter 5 **(3)**
  - **Tsk_76** Creation of distance measuring algorithm **(6)**
-

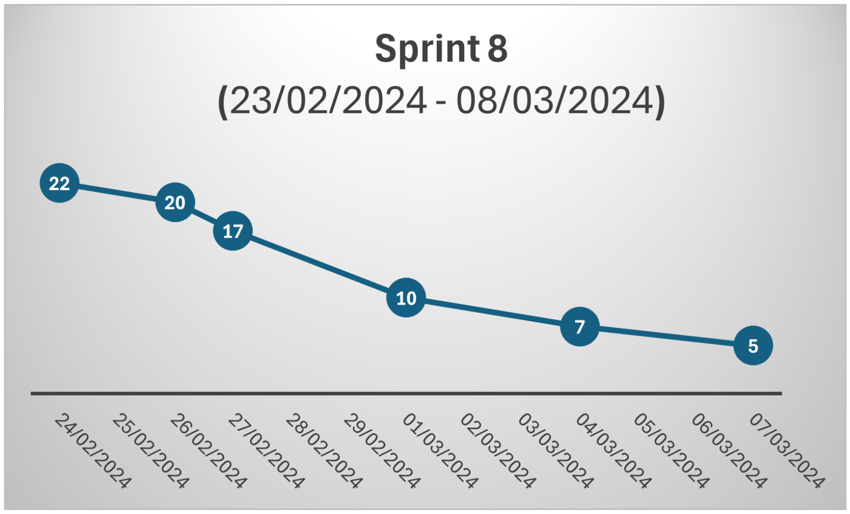


Figure A.6: Burnown Chart - Sprint 8

A.9 Sprint Retrospective

A.10 Sprint template (16/01/2024 - 02/02/2024) - Titulo del sprint (resumiendo el objetivo)

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A.11 Sprint meeting

- **Sprint Tasks**
  - **Tsk_81 ()**

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A.12 Sprint Retrospective