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TRABAJO FIN DE GRADO

Diagnostico de patologias mediante el analisis de movimiento via inteligencia artificial

Carlos Rincón González

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Diagnostico de patologias mediante el analisis de movimiento via inteligencia artificial

Carlos Rincón González

Félix Albertos Marco

David Carneros Prado

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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Contents

Contents

List of Figures

List of Tables

Listings

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 [30] [25] . 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

añadir un objetivo global #TODO

2.1 O1: Data obtention via RGB camera

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.

2.2 O2: Validation of the data acquisition system for motion analysis in a clinical setting

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.

2.3 O3: Definition of the data to be used and their generalization for 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.

2.4 O4: Comparison of different methods for training AI models for the diagnosis of the pathology of the initial case study

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 on 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.

2.5 O5: Development of a tool for training AI models for the initial case study

We not only aim to research everything in this field, we are going to develop a data model that fits our needs and gives us our desired outcome.

2.6 O6: Validation of the diagnostic system for the pathology of the initial case study.

HEURISTICA DE EXPERTOS #TODO

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 [13]

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.

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 [28].
- 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 [29].
- X-ray Cameras: Utilized for medical imaging, security screening, and industrial inspection. Capture X-rays, which have shorter wavelengths than visible light [27].
- 3D Cameras: Capture depth information along with color. Used in computer vision, robotics, and augmented reality applications [6].
- 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. [26]

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 appli-

cations 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 [22].

- 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 [24]: 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 [26]: 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 [31]: 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 [21]: 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 Azure's words [1]: "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 [4] [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.

3.5   Data extraction and compilation

Análisis de movimiento Lo primero que deberías entender aquí porque te va a ser muy necesario es el ciclo de la marcha humana, junto con sus fases. Una vez entendido eso verás que hay 2 tipos de parámetros: Parámetros espacio-temporales Aquí los espacio-temporales que son algunos como longitud de paso, longitud de zancada, tiempo de paso, tiempo de doble apoyo, etc. Parámetros cinemáticos Para entender estos primero debes entender que el cuerpo está dividido en 3 planos: Sagital, transversal y frontal. Con esos planos se pueden obtener los parámetros cinemáticos (ángulos) de las diferentes articulaciones. Por ejemplo: - Flexion/extension de la rodilla - Abducción/aducción de la rodilla - Rotación interna/externa de la rodilla.

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 [5]. 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 conections 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] therefor 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.
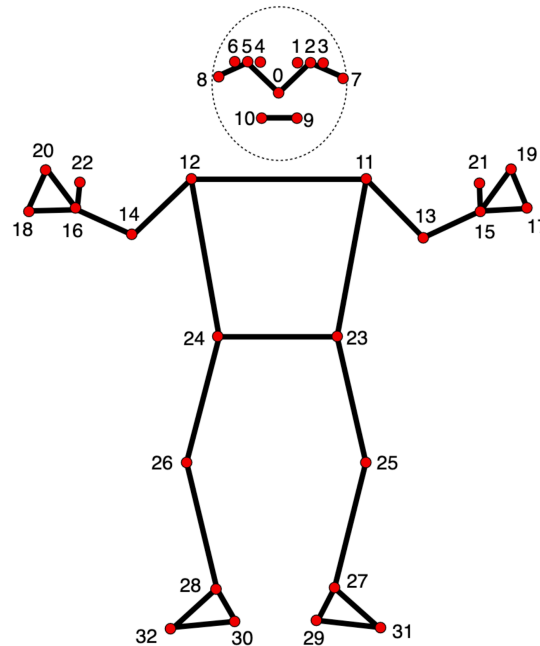
Figure 4.1: Pose landmarks

4.2   Human body planes .

[19] [3] [2]

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.
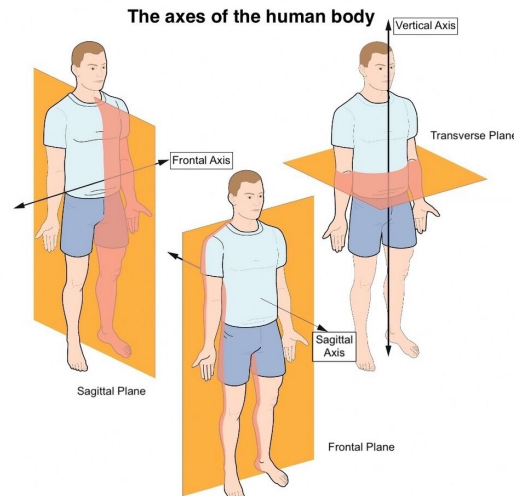

Figure 4.2: Axes of the Human Body

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 [23].

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 " $\cos(a) = (AB \cdot BC) / (|AB| * |BC|)$ "
- The arccos would give us the angle of the B landmark so we can normalize its data.

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 [23], 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.

IGNORAR TODO LO SIGUIENTE SON ANOTACIONES
Info recavada de mediapipe y el codigo de david
El dodigo de david usa dos clases, una detecta la pose y la otra dibuja el frame

pose: Utiliza 3 modelos que están en una carpeta separados (pregunter por ellos) utiliza la task de vision en media pipa para elegir los parametros basicos en el modelo. inicializa el objeto con los valores pasados en la creación para la detección de imagen usa la libreria de mp con la función image. landmarker es la función que usa para la detección de los puntos esto es lo que sale en la documentación de mediapipe y por eso lo referencian tanto en el paper. devuelve el resultado de la pose del landmarker draw: llama al objeto de la pose toma como configuracion los colores para los parametros. tiene unos condicionantes que colorean los joints dependiendo de la posición, como se ve en la imagen unos son la cara y otros son el lado izquierdo o derecho del cuerpo. (preguntar los enteros pero supongo que serán los numeros de los landmarks que ya están definidos por mp) los dibuja usando cv2 notar que en este dibujado accede a .poselandmarks, lo cual parece ser la lista de los landmarks que hay en el frame. investigar ka función circle pero parece "simple" en su función usa line para las conexiones haciendo referencia a las coords x e y de ambos puntos en el main solo hace un bucle infinito con las dos funciones se definen los valores para el objeto de la pose usa cv2 para la captura del video

La función de convolución realiza el filtrado de los valores de píxel de una imagen, lo que se puede utilizar para aumentar su nitidez, difuminarla, detectar sus ejes u otros realces basados en el kernel. Los filtros se ut ilizan para mejorar la calidad de la imagen de ráster al eliminar datos falsos o mejorar las entidades de los datos. Estos filtros de convolución se aplican a un

kernel móvil o superpuesto (ventana o vecindad), como 3 x 3. Los filtros de convolución actúan calculando el valor de píxel en función de la ponderación de sus vecinos

---

Viendo la forma en la que funciona el codigo no encuentro la forma de calcular dinamicamente el angulo de una joint Tampoco veo la forma de como se puede ver los pasos. Pasos para stepcounter> Los pies son los landmarks [27,28,29,30,31,32] segun la guia. Para detectar un paso ambos tienen que ser visibles para poder decir cual esta por encima al hacer print de lo qye hay en "pose_landmarker_result" veo que están tanto las coordenadas como la visibilidad creo una clase que me enseñe los landmarks visibles en un punto determinado en el tiempo.

```
[def getVisibleLandmarks(pose_landmarker_result):
visible_landmarks = []
if pose_landmarker_result.pose_landmarks: <---Copiado del modulo de dibujo
    for normalized_landmarks in pose_landmarker_result.pose_landmarks:
        for i, landmarks in enumerate(normalized_landmarks):
            if landmarks.visibility > 0.5: <----- implementar en el modelo
                ↪ general y jugar con el valor
                visible_landmarks.append(i)
return visible_landmarks]


lo muevo a una funcion porque no necesita ser una clase.
para hacer el stepcounter primero checkeo que los pies estan en un momento
    ↪ dado en la imagen siendo visibles


[def stepCounter(visible_landmarks):
    feet = [27,28,29,30,31,32]
    if set(feet).issubset(set(visible_landmarks)):
        print ("both feet")]


una vez que he detectado los dos pies los separo para poder detectar pie izq
    ↪  de derecho para dar el paso
como vi imprimiendo el poseLandmarker antes, los landmarks tienen metidas
    ↪ las coordenadas
cuando el tobillo de uno de los lados sube por encima del otro es un "paso"
problema, hacer un limitador para que no cuente todo el rato el tobillo de
    ↪ encima y que solo cuente cuando haga un cambio de altura
```

```
implementar un rango de error porque el modelo es impreciso y el jitter
    ↪ cuenta pasos que no son.
las alturas previas las necesito guardar entre ejecuciones porque obviamente
    ↪  la altura no cambia en la misma snapshot
lo cambio a una clase para poder usar el self y almacenarlo ahí
ademas aprovecho a guardar en el self el contador de los pasos dados (porqué
    ↪  no)
creo el getter para que me imprima los pasos dados a la hora de hacer el q
[
    if (min(leftFeet_heights) > (max(self.prev_heights[1])) and
            max(rightFeet_heights) < (min(self.prev_heights[0]))):
        self.steps += 1
        print ("StepCounted")
]
```

https://docs.aws.amazon.com/machine-learning/latest/dg/types-of-ml-models.html https://docs.aws.amazon.com/mach
learning/latest/dg/training-ml-models.html   https://datagen.tech/guides/data-training/model-
training/

https://www.youtube.com/playlist?list=PLOU2XLYxmsILr3HQpqjLAUkIPa5EaZiui

https://www.tensorflow.org/guide

redes neuronales trabajan entre 0 y 1

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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. - *** Explicar el porque de GitHub - **** 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
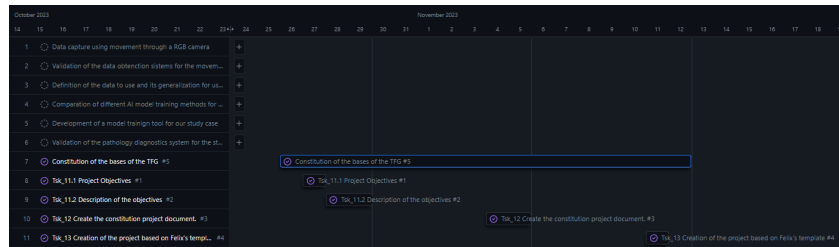- **Burndown Chart of the Sprint**

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)**
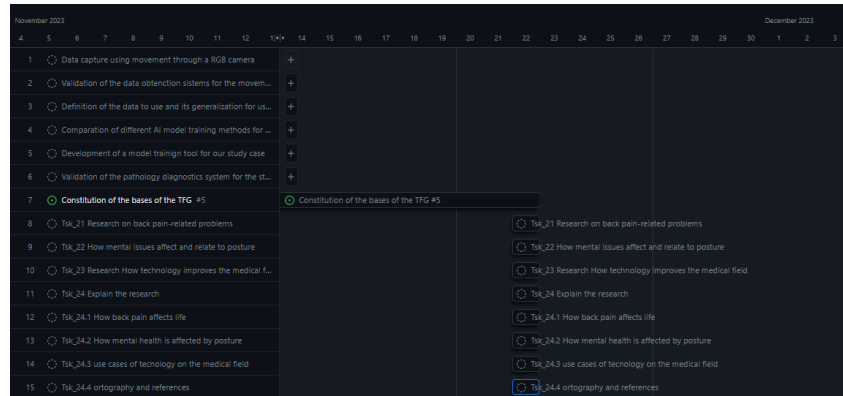* **Tsk_24.4** ortography and references **(0.5)**

Figure A.2: Planing - Sprint 3

- **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
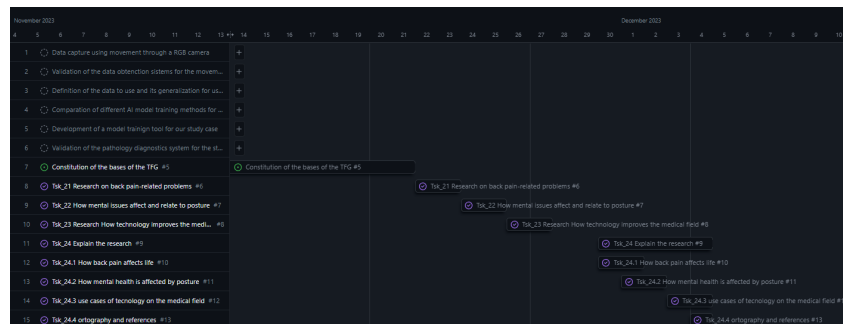- **Burndown Chart of the Sprint**

Figure A.3: 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 stablish 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.

A.5   Sprint template (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.

A.6 Sprint template (16/01/2024 - 02/02/2024) - Titulo del sprint (resumiendo el objetivo)

- **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 to csv **(2)**
    - **Tsk_53** Angle normalization of the coordinates **(5)**
    - **Tsk_54** Dection of steps taken **(4)**
    - **Tsk_55** Research on body plane axes **(2)**
- **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.