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Vision system to obtain spatial coordinates in bony protuberances of the human body through ArUco markers

Sistema de visión para obtener coordenadas espaciales en protuberancias óseas del cuerpo humano a través de marcadores ArUco

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Abstract

Actually, the vision systems have a great impact in technological innovation, since they represent the eyes of any device or machine, therefore the importance of this is paramount. On the other hand, in one of the branches of biomechanics studies are carried out to diagnose disorders in the gait cycle of patients, normally a physiotherapist performs specific exercises to determine if there is an abnormally during the gait cycle, however, the accuracy of the diagnosis can become uncertain if the physiotherapist has carried out several continuous studies and factors such as lighting of the place or eye fatigue cause alterations in its diagnosis, therefore, with the development of this project it is intended to make a vision system that, from markers positioned on bony protrusions on the lower part of the human body, get the spatial coordinates (X, Y and Z), information that adding a post processing would allow obtaining data such as angular movements, angular velocities and custom gait cycles, fundamental data in the development of prostheses, orthoses or exoskeletons, and considering that the project is carried out in free software, its implementation becomes more accessible.

Vision systems, Spatial coordinates, Python

Resumen

En la actualidad los sistemas de visión tienen un gran impacto en innovaciones tecnológicas, ya que representan los ojos de cualquier dispositivo o maquinaria, por lo tanto, la importancia de éste es primordial. Por otro lado, en una de las ramas de biomecánica se realizan estudios para diagnosticar padecimientos en el ciclo de marcha de las pacientes, normalmente un fisioterapeuta realiza ejercicios específicos para determinar si existe anormalidad en el ciclo de marcha, sin embargo, la precisión del diagnóstico puede llegar a ser poco certera si el fisioterapeuta ha realizado varios estudios continuos y factores cómo iluminación del lugar o fatiga ocular provocan alteraciones en su diagnóstico, por lo tanto, con el desarrollo de este proyecto se pretende realizar un sistema de visión qué, a partir de marcadores posicionados en protuberancias óseas de la parte inferior del cuerpo humano, se obtengan las coordenadas espaciales (X, Y y Z), información que agregando un post procesamiento permitiría obtener datos cómo movimientos angulares, velocidades angulares y ciclos de marcha personalizados, datos fundamentales en el desarrollo de prótesis, ortesis o exoesqueletos, y considerando que el proyecto está realizado en software libre, su implementación se vuelve más accesible.

Sistema de visión, Coordenadas espaciales, Python

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Introduction

The study of the movement of the human body, as well as its causes, has been the subject of research throughout history in cultural, scientific or medical fields. Currently, there are areas such as bioengineering or biomedicine that require studies of the kinematics of the human body to solve different problems related to human gait, mainly due to vascular diseases that could cause transfemoral, knee, transtibial or ankle amputations; some other factors that alter the normal gait cycle are trauma, mainly the rupture of one or more bones, causing patients to require rehabilitation and special adaptations in their lower extremities to recover the greatest possible mobility [I-IV].

The boom in this area is so great that the number of laboratories and equipment that exist is not enough to meet the demand of patients who require these services, since it is known that annually in the country there are more than 27 thousand amputations and 80% of these are of lower limbs, it is also known that only 10% of patients receive a passive prosthetic equipment, On the other hand, existing vision systems such as VICON [IX], which is currently the most widely used due to its wide variety of applications, is a technology that most people cannot access due to its high cost.

There is another field of application of vision systems in the monitoring of the gait cycle, the area of sport, where, from the study of their physical abilities that the patient performs during their gait cycle, applied to activities such as cycling or walking, routines are diagnosed to strengthen their physical activity [IX].

The objective of this project was to obtain the spatial coordinates of specific points of the human body, mainly of bony protrusions, located from the hip to the feet, using computer vision, and developed in free software using a Perfect Choice PC-320494 camera, with the purpose of a post processing that would allow to obtain data how angular movements, angular speeds and personalized gait cycles, fundamental data in the development of prosthesis, orthosis or exoskeletons [X].

Methodology to be developed

The development of the vision system was with the intention of obtaining a technological innovation capable of extracting the movements of a patient's gait cycle through the monitoring of ArUco markers.

The programming was done in Python version 3.7 [XI], some libraries that were used are openpyxl, numpy, imutils, math, datetime, pathlib and OpenCV (opencv-contrib- python), in order to detect and process ArUco markers, these are mainly used in areas of augmented reality, their characteristics and the way of being processed were perfectly adapted to the needs that were presented.

The first procedure performed was the camera calibration, which is performed only once, the calibration algorithm requires at least 20 photographs with different view of the pattern shown in Fig.1, the photographs must be equal in dimensions (width and length).

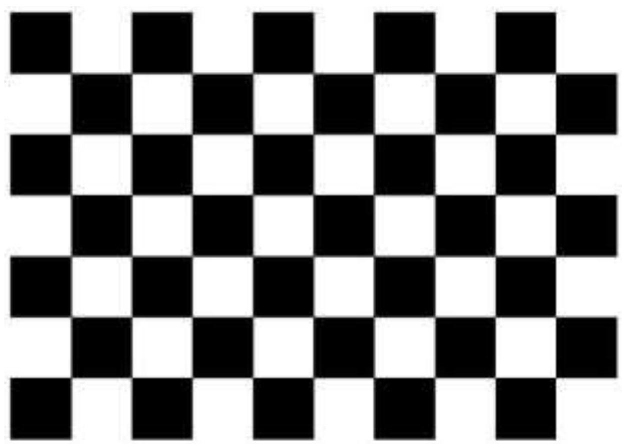

Figure 1 Calibration pattern

Aruco markers can be created with the function cv2.aruco.drawMarker of the OpenCV library, generating files with parameters such as: dictionary, Id, contour pixels and contour line. Additionally, there are sites on the Internet that allow to generate graphic markers and download them as PDF files.

To detect the markers in each frame we used the cv2 and cv2.aruco packages of the OpenCV library and a programmed function to save the parameters of the intrinsic matrix and distortion coefficients, followed by a conversion to grayscale of the frame. With these features the coordinates of the 4 corners of each marker are detected, as well as its id and objects rejected by the algorithm.

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The drawDetectedMarkers and drawAxis functions of the OpenCV library were used to visualize the markers on the screen. For the acquisition of coordinates the aruco.detectMarkers function was used, considering that the dimensions of the photographs with which the camera was calibrated are 5 times larger than the frames that make up the video, the value used for the size of the marker will be 2 (considering that each marker physically has a dimension of 10 x 10 cm).

The markers have different positions on the human body, mainly on the hip, sacrum, knees and ankles, to identify the body position the description of R (right), L (left), K (knee), A (ankle), H (hip) and SA (sacrum) were added, additional letters of JC were added to describe a kinematic joint, hence the acronym. Thus, if the acronym RKJC is described, it refers to the kinematic joint of the right knee.

Data storage was performed using math, datetime and openpyxl libraries, each record is made from a displacement greater than 7 pixels and was calculated using the Pythagorean theorem for a three-dimensional system.

Results

The vision system has the ability to detect up to 7 ArUco markers and draw a skeleton from given points.

1. Camera calibration

Figure 2 shows how the calibrate_chessboard function of the OpenCV library successfully finds the corners of the squares that make up the calibration pattern.

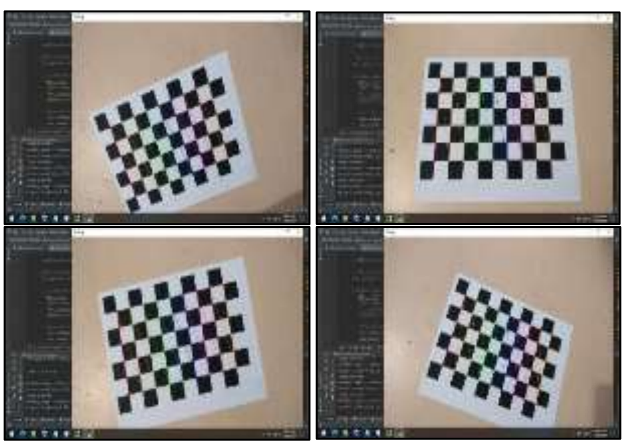

Figure 2 Calibrate_chessboard

This ensures that the intrinsic matrix calculation and distortion coefficients are calculated correctly.

2. ArUco markers

Seven markers were generated in PDF format from the web page https://chev.me/arucogen/, printed and adhered to a firm base to obtain better readings by the webcam. Fig. 3 shows some of the generated markers, ready for use with the mink system.

Figure 3 ArUco markers generated

3.- Detected Arc Markers

The program was able to calculate the orientation and position of each marker, being the illumination the only factor that produces erroneous values. In Fig.4 it can be seen that in the center of each marker a spatial coordinate axis is drawn, describing in order the colors red, green and blue, representing the X, Y and Z axes respectively.

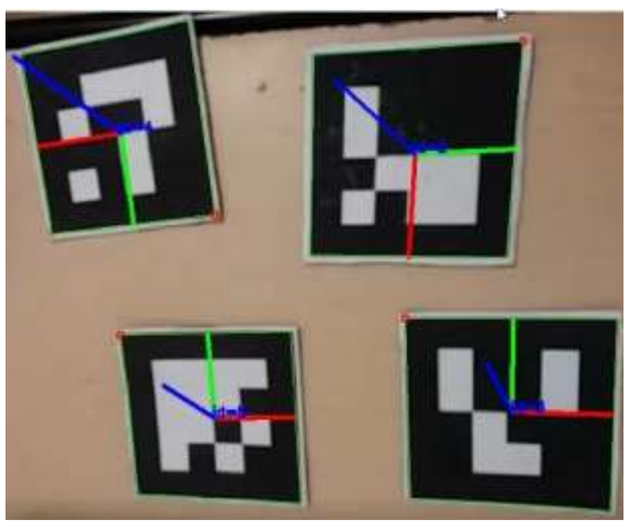

Figure 4 Coordinate axes on ArUco markers

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4. Acquisition of coordinates of ArUco markers

In addition to the generation of coordinate axes, the mimic system identifies each marker by ID and attributes a description to it in order to identify the position on the human body where it is located and draw the skeleton, as shown in Fig. 5.

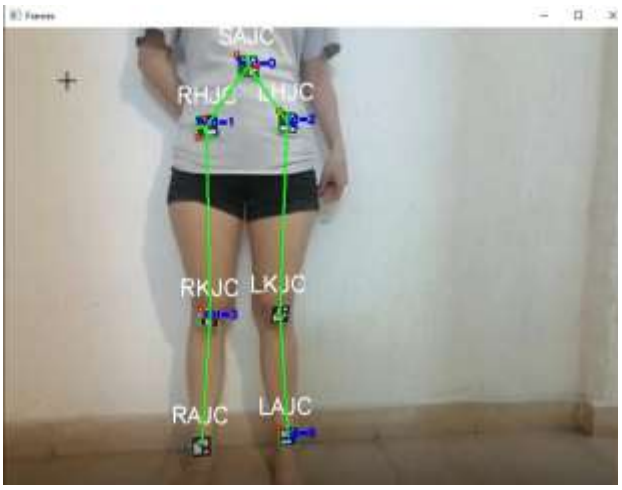
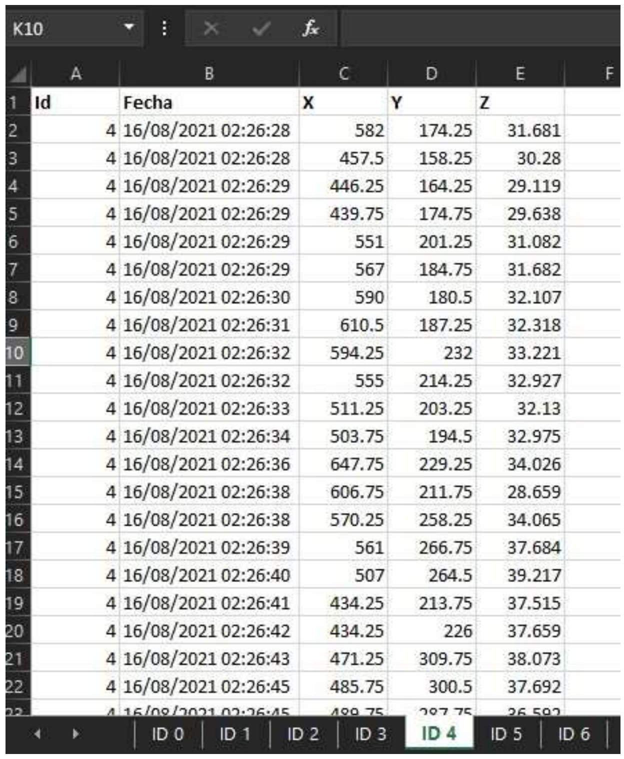


Figure 5 Skeleton drawn from the markers Arc

To corroborate the data obtained for the z coordinate, tests were performed to check the real distance with the value obtained in the vision system. The results showed a 3% error with respect to the real value in the z coordinate.

5.- Coordinate Storage in Excel

The storage was done individually, that is, for each different marker a new sheet was added in the Excel file, the data that were saved for each marker are: Id, Date, X, Y and Z coordinates, as shown in Fig.6.



	Id	Fecha	X	Y	Z
2	4	16/08/2021 02:26:28	582	174.25	31.681
3	4	16/08/2021 02:26:28	457.5	158.25	30.28
4	4	16/08/2021 02:26:29	446.25	164.25	29.119
5	4	16/08/2021 02:26:29	439.75	174.75	29.638
6	4	16/08/2021 02:26:29	551	201.25	31.082
7	4	16/08/2021 02:26:29	567	184.75	31.682
8	4	16/08/2021 02:26:30	590	180.5	32.107
9	4	16/08/2021 02:26:31	610.5	187.25	32.318
10	4	16/08/2021 02:26:32	594.25	232	33.221
11	4	16/08/2021 02:26:32	555	214.25	32.927
12	4	16/08/2021 02:26:33	511.25	203.25	32.13
13	4	16/08/2021 02:26:34	503.75	194.5	32.975
14	4	16/08/2021 02:26:36	647.75	229.25	34.026
15	4	16/08/2021 02:26:38	606.75	211.75	28.659
16	4	16/08/2021 02:26:38	570.25	258.25	34.065
17	4	16/08/2021 02:26:39	561	266.75	37.684
18	4	16/08/2021 02:26:40	507	264.5	39.217
19	4	16/08/2021 02:26:41	434.25	213.75	37.515
20	4	16/08/2021 02:26:42	434.25	226	37.659
21	4	16/08/2021 02:26:43	471.25	309.75	38.073
22	4	16/08/2021 02:26:45	485.75	300.5	37.692
23	4	[illegible]	[illegible]	[illegible]	[illegible]

Figure 6 Excel file with essential information of each ArUco marker

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Conclusions

The use of the OpenCV library was undoubtedly the best option for image and video processing, since excellent results were obtained without affecting the performance of the equipment. On the other hand, the ArUco markers allowed to facilitate the detection of specific points because they are easily recognizable in an image regardless of the background or the environment in which they are located, and their features such as having a unique identifier (id) or the facility they provide to locate them in a three-dimensional space with a single camera were perfectly adapted to the needs of the project.

Although it was necessary to have good lighting, a good camera and to keep the markers fully extended during motion capture, using ArUco marks to identify the various points of the human body presented a great advantage over the other options that were considered, since other identifiers based on color or shapes were highly limited by the environment.

Finally, it is necessary to emphasize that the three-dimensional coordinates obtained for each marker from a two-dimensional system are accurate as long as the appropriate environmental conditions are present.

Although the current software has much room for improvement, the way has been marked for its correction, implementation and possible future expansion.

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