DEVELOPMENT OF A HEAD MOTION TRACKING SYSTEM

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Abstract: Head motions are rarely studied due to the complexity of this evaluation. Optoeletronic systems become possible an accurate measurement for each situation. However, the majority of video systems are expensive or present errors in 3D motion reconstruction. This work uses two synchronized digital video cameras and a specific software to become more practical the biomechanic analysis of head motions in physiotherapy clinics. The 3D coordinates of two passive white markers positioned on the volunteer`s forehead and chin were analysed to calculate the motions path and the rotation angle of the head. The system presented maximum error of 0.8 % calculated in the head's initial and final positioning. The extension and flexion motions to the right as to the left presented a maximum error of 3.7 %. The method allows to develop aid devices for professional inclusion of tetraplegics, to evaluate the muscle-skeletal dysfunction of the cervical spine, which could cause neck pain, muscular tension, chronic headaches, and to analyse the relationship among the directions of the head and eyes motions when these are stimulated, evidencing and quantifying oftalmologic problems.

Key-words: Biomechanics, synchronized cameras, head tracking, upper limbs motion analysis.

Introduction

Analysis of human motion is of great importance in different areas of medicine and human science. In clinical gait analysis, for example, the temporal information about position and orientation of the patient's joints may be useful in determining abnormalities. In orthopedics, the range of motion information helps in the evaluation of the prosthetic join replacement and physical therapy of joint disease. In neurology, the early diagnosis of cerebral lesions appears to be possible by detecting a slight deviation from normal patterns which could not be evident by a simple visual inspection [1]. However, the minority of researchers have studied head motions due to the complexity of this evaluation. These movements depend on motion at the atlantooccipital and atlantoaxial joints and to a variable, but lesser, extent at other cervical joints. Disease, degeneration and trauma often affect these regions and their results could have consequences on functions. Motions of the cervical spine are moderately extensive, compared to other regions of the vertebral spine and take place as rotation in three principal planes (flexion-extension, axial rotation and bilateral flexion, which is lateral bending to the left and right, as defined by the American Academy of Orthopedaedic Surgeons). Besides, motions through the full range in one plane alone is not always possible (e.g. lateral flexion and rotation are mutually dependent) [2].

Optoeletronic commercial systems could be divided into active and passive, depending whether they use active or passive markers. The approach of such systems for tracking considers dedicated hardware implementing basic computer vision techniques. Systems based on active markers, such as Selspot, Optotrack and Costel use a certain number of light emitting diodes (LED) attached to the body. Passive infrared systems such as Elite, MaxReflex and Vicon operate through the recording of reflected light, using wireless retro-reflective markers in combination with infrared illumination. These systems could become possible a precise measurement for head tracking. The main advantage is the real-time processing capability, on the other hand, they are very expensive. Thus, some researchers have developed systems for this application. The Camera Mouse was developed by [3] to provide computer access to people with severe disabilities but this system does not allow 3D head motion reconstruction. The analysis of head motion was done by [4] using stereo systems, but the results presented errors when the image is too close and the model of body could not be acquired or whether the subject's arms occlude the head and shoulders.

Fastrak was used by [5] to measure the range of active cervical rotation in a position of full head flexion. Although this electromagnetic device presents accurate results, your cost is still highest.

Therefore, the aim of this work is to develop a system with two synchronized digital video cameras and a specific software to become more practical the biomechanic analysis of head motions in physiotherapy clinics. The method allows to develop aid devices for professional inclusion of tetraplegics, to evaluate the muscle-skeletal dysfunction of the cervical spine, which could cause neck pain, muscular tension, chronic headaches, and to analyse the relationship among the directions of the head and eyes motions, when these are stimulated, evidencing and quantifying oftalmologic problems.

Materials and Methods

Our head tracking system involves a scenery defined with area of 6 m^2, a pair of digital video cameras with automatic shutter speed set up in stereometric mode and mathematical tecnhiques to reconstruct 3D head motions. Based on these considerations, the centre of six black control points were calculated using (1) and (2) (figure 1).

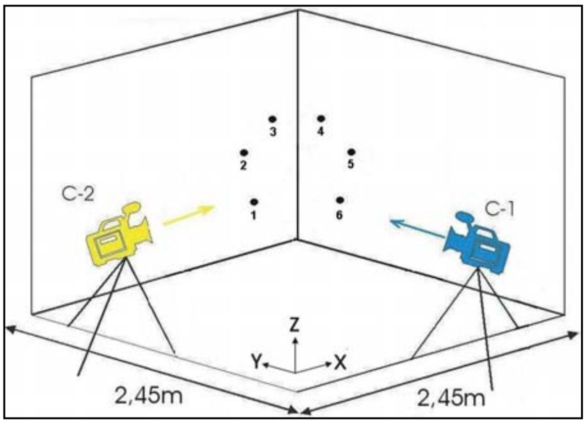

Figure 1: Black six points inside of scenery.

$$x_c = \frac{\sum x}{\varphi} \tag{1}$$

$$y_c = \frac{\sum y}{\varphi} \tag{2}$$

Where:

x_c and y_c are central coordinates of each black control points.
Σx is the sum of all x coordinates for each black control point.
Σy is the sum of all y coordinates for each black control point.
φ is the quantity of black pixels encountered for each black control point.

Two passive white markers were positioned on the volunteer`s forehead and chin to calculate the motions path when there is lateral inclination, rotation, extension, flexion and inclination with rotation (figure 2). These markers were aligned to capture any head motions.

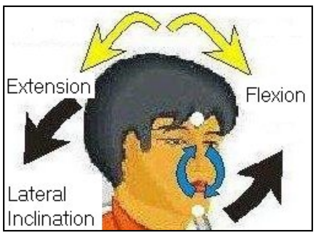

Figure 2: Head motions.

In order to obtain the head motion in the space we need at least two views of the same motion and also that each point of interest be simultaneously observed by both cameras. The main problem in use of standard digital video cameras is the lack of synchronization between registers that is caused by:

1 - The registers do not start at the same time.
2 - The possible frequency mismatch between the cameras.

This lack of synchronization could be corrected using a luminous signal inside of scenery (figure 3). Generally, the velocity of head motions is small if compared with gait analysis. Besides, the time of filming for each analysed motion is usually shortest. Therefore, this signal could indicate the beginning and the end of the motions for each camera.

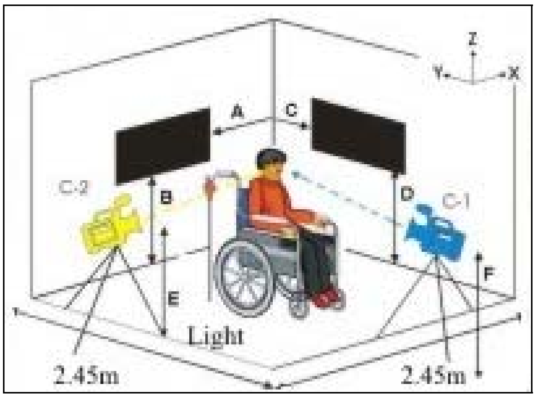

Figure 3: Light signal inside of scenery.

The camera C-1 is turned on before than camera C-2. After few seconds, the light switches on and off indicating the beginning for each camera. Thus, the motion is achieved during a period of time followed by light which switches on and off again determining the end. The algorithm analyse the kind of motion between the first and the second luminous signal.

The position of each white marker is determined by Direct Linear Transformation (DLT). This technique was applied two times using (3) and (4). The centres of each black control points and their real 3D coordinates should be used to calibrate each camera and become possible the reconstruction of 3D head motion path.

$$x_c + \frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1} = 0 \tag{3}$$

$$y_c + \frac{L_5X + L_6Y + L_7Z + L_8}{L_9X + L_{10}Y + L_{11}Z + 1} = 0 \tag{4}$$

Where:

x_c and y_c are central coordinates for each white marker or black control points.
X,Y and Z are the real 3D coordinates for each black control points or white markers.

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L_1 to L_{11} DLT standard calibration parameters for each camera.

Two mechanical supports were developed (figure 4). Their extremities have 3D knownledge coordinates inside of the scenery. The error of this system was evaluated comparing the calculated 3D coordinates by the algorithm with these extremities using (5) when the head was initial and final position.

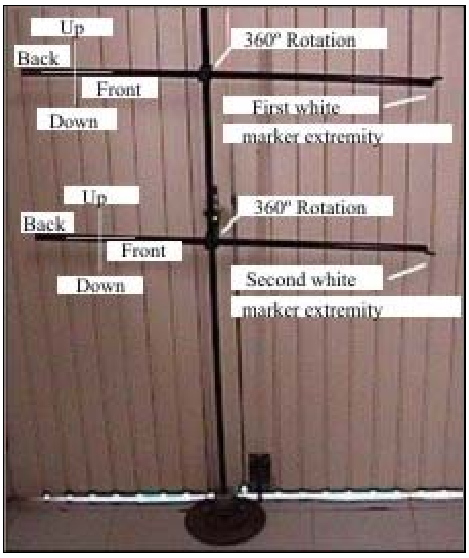

Figure 4: Developed mechanical support

$$E = \left(\frac{|X_e - x_c|}{X_e} \right) \times 100 \qquad (5)$$

Where:

E is the position error.
X_e is the real spatial coordinate for each marker.
x_c is the spatial coordinate calculated by the algorithm.

The rotation angle of the head was evaluated using (6) in relation to figure 5.

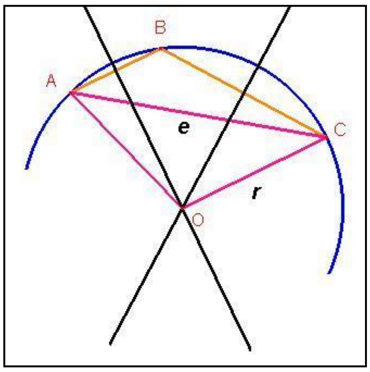

Figure 5: Rotation angle of the head.

$$A\hat{O}C = 2 \times \left(arcsen\left(\frac{e}{2 \times r} \right) \right) \qquad (6)$$

Where:

AÔC is the rotation angle of the head.
e is the distance between the initial and final head position.
r is the radius of the head.

Results

Two head motions are presented.

1 - Right extension.
2 – Left extension.

Figure 6 shows right extension head motion achieved by the volunteer.

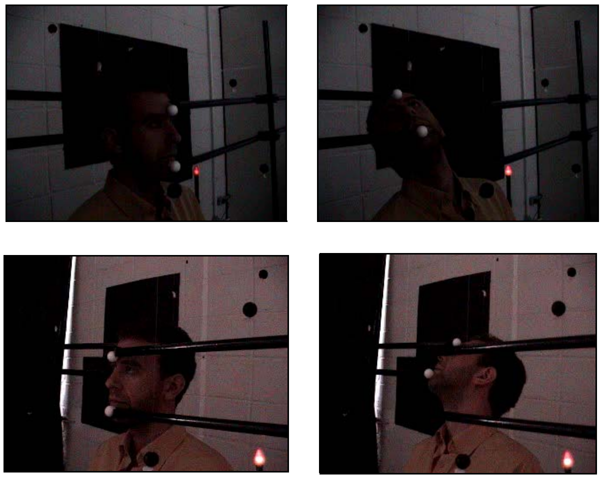

Figure 6: Right extension head motion.

Figure 7 shows the 3D right extension path of the head.

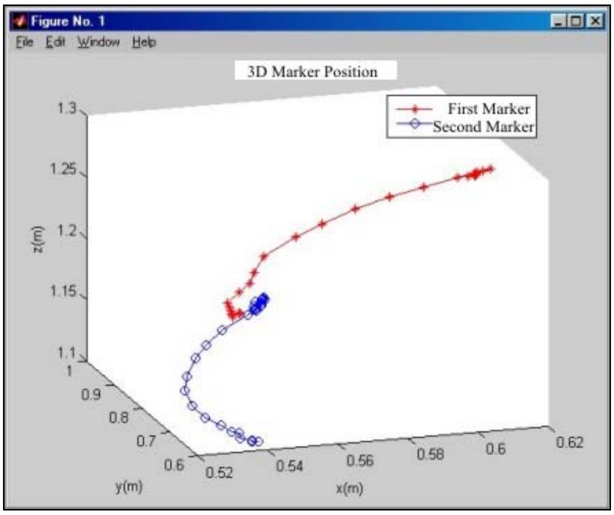

Figure 7: 3D right extension path of the head.

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Figure 8 compares the real initial and final head position with the positions evaluated by the algorithm when the volunteer achieved right extension motion.

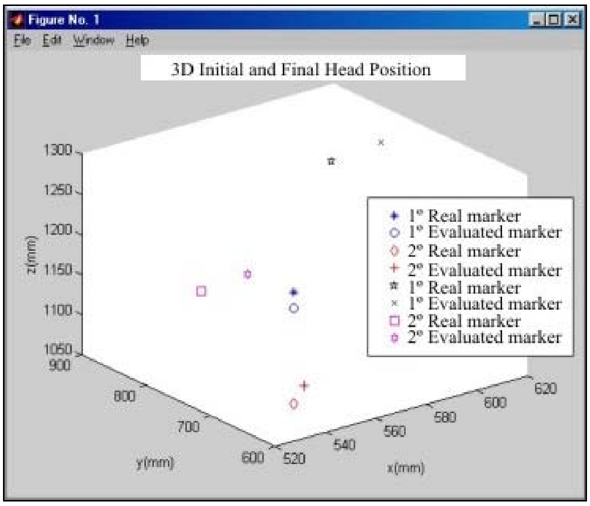

Figure 8: 3D Initial and final head position

Figure 9 shows left extension head motion achieved by the volunteer.

Figure 9: Left extension head motion

Figure 10 shows the 3D left extension path of the head.

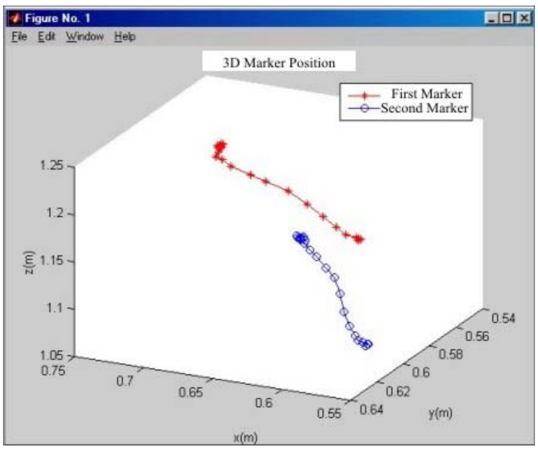

Figure 10: 3D left extension path of the head.

Figure 11 compares the initial and final real head position with the positions evaluated by the algorithm when the volunteer achieved left extension motion.

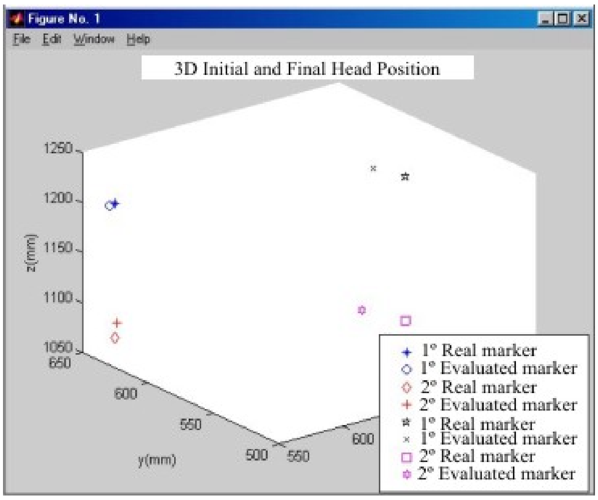

Figure 11: Initial and final head position

The rotation angle of the head was measured by the physiotherapist. Table 1 shows the values encoutered between the goniometry and the developed system.

Table 1: Comparison among the rotation angles.

Rotation to the right	Goniometry	System	Deviation
1º Volunteer	40º	40.7º	0.7º
3º Volunteer	60º	50.3º	9.7º

Discussion

The results demonstrated that the developed system has maximum error of 0.8 % calculated in the head's initial and final positioning. The extension and flexion motions to the right as to the left presented a maximum error of 3.7 %. The evaluated angles of rotation presented deviations of 0.7º for the first volunteer and 9.7º for the third volunteer in relation to the measurements done by the physiotherapist.

The synchronization using a luminous signal is simple and effective. The frequency deviation between the two cameras is not outstanding because the time of filming is very small, only 5 seconds. In this period, there are not significant errors while the 3D motion is being reconstructed. However, a frequency synchronization method between the cameras should be implemented for other motions which require a long period of filming as gait analysis.

Conclusions

The acquisition of this system is viable for rehabilitation clinics due to your low price. Besisdes, the method allows to develop aid devices for the professional inclusion of tetraplegics, to evaluate the muscle-skeletal dysfunction of the cervical spine, which could cause neck pain, muscular tension, chronic headaches, and to analyse the relationship among the directions of the head and eyes motions when these are

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