Measurement of Head Position by Cameras and Accelerometers

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Abstract: In this paper we describe advanced methods for the precise posture head measurement by cameras and accelerometers. The methods we designed for use in neurology to discover relationships between some neurological disorders. The main goal of this study is to compare possibilities of the methods. The results are presented for rotation and flexion of head. It was experimentally checked that the accuracy is tenths of degree and therefore this method satisfies the general physicians´ requirement for the accuracy of the measurement about 1-2°.

1 Introduction

Head posture can be influenced negatively by many diseases of the nervous system, visual and vestibular systems (Fig. 1). In many cases, the abnormalities of the head position can be small and hard to be observed. In clinical practice, it has been possible to quantify only those deviations that are well visible (up to this time). Despite the fact that an accurate method for measuring the head postural alignment could contribute to diagnosis of vestibular and some other disorders, this issue has not been systematically studied.

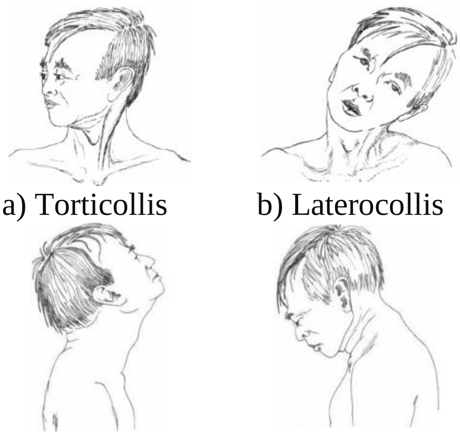


Fig 1. Examples of head position abnormalities.

At the present time, the use of an orthopedic goniometer is the standard way how to evaluate angles simply and rapidly in clinical practice. But there are some limitations, especially in the case of head posture measurement. Because of the combination of three components of movement, it is problematic to use only the goniometer.

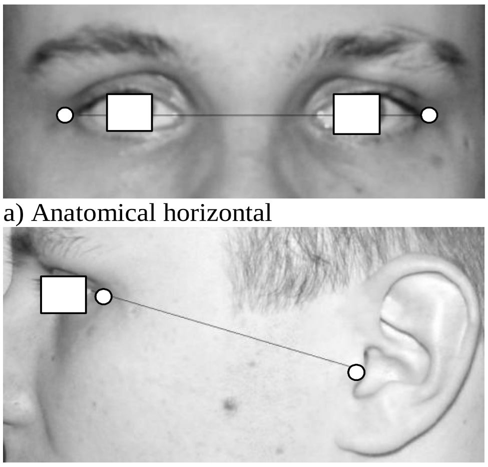
The first advanced method based on modern technique, that means application of cameras, was developed in 1988. The method uses a three mirrors and special patient´s head markers (bands). The resulting images are taken with the camera. After this a set of lines is drawn with respect to the reference points and adjacent known vertical or horizontal line. The last step is measurement of the relevant angles with a protractor.

The second main method based on application of cameras was developed by Ferrario V.F. in 1995 [1] the new method was developed as method faster than conventional photographic analysis. The subject's body and face were identified by the 12 points. All subjects were pictured using a standardized technique for frontal views of the total body and lateral views of the neck and face. After 20 seconds of standings, two 2-second films were taken for each subject. Based on the image analysis program the specified angles were calculated after the digitization of the recorded films.

In Galardi, G. et al, 2003 [2] objective method to measure posture and voluntary movements in patients with cervical dystonia using Fastrack was developed. The Fastrack is an electromagnetic system consisting of a stationary transmitter station and four sensors.The head position in the space was reconstructed (based on the sensor signals) and observed from axial, sagittal, and coronal planes.

2 Methods

In this part we describe in more detail our contribution and our proposed methods of head position measurement. Hozman, J. et al, 2004 [3] proposed new method based on the application of three digital cameras with stands and appropriate image processing software. The new method of non-invasive head position measurement was designed for use in neurology to discover relationships between some neurological disorders and postural alignment. Objective was to develop a technique for precise posture head measurement or, in other words, for measurement of the native position of the head in 3D space. The technique was supposed to determine differences between anatomical coordinate system and physical coordinate system with accuracy from one to two degrees in case of tilt and rotation. Pictures of the head marked on tragus and outer eye canthus are taken simultaneously by three digital cameras aligned by laser beam. Similar technique has not been developed up to this time such that it could be widely and easily used in neurological clinical practice. Head position was measured with precision [3] of $0{,}5^{o}$ in three planes (rotation-yaw, flexion-pitch and inclination-roll).



a) Anatomical horizontal

b) Anatomical axis

Fig 2. Defined anatomical horizontal and axis.

In the last our designed method [5], only two cameras are required for determination of head positions. The rotation and inclination of the head is evaluated from the difference between tragus coordinates in the left-profile and right-profile image (Fig.2). The coordinates of the left and right tragus are automatically evaluated by finding the centre of the rounded mark attached on the tragus, using Hough transform. The images were captured at the same time using two cameras and the cameras were situated on the same optical axis which is parallel with the frontal plane subject.

The method which was used for evaluating the tilt in sagittal plane (flexion/extension) using a profile photograph. The flexion value was measured relatively as the inclination of the connecting line between tragus and exterior eye corner (Fig.2). By described way we can avoid an influence on patients during the time of measurement of the inclination (roll), flexion (pitch) and rotation (yaw) of the head. This is very important advantage for medical doctors because they can apply various examinations which need open space in front of a face.

The problem of deviations of CCD sensors and the problem of deviation of optical axes of both cameras can be excluded by scanning of correction mark on a transparent mask [5]. By these we find differences of coordinates of this point in both frames. These differences represent the deviations that will be used for the calculation of correction. At present, a test version uses the software correction based on the MatLab Camera Calibration Toolbox. This software enables the accurate detection of mutual positions of the optical axes. Software provides information on the mutual displacement and the mutual rotation of the axes. The exact values of displacements and rotations of optical axes can be added to the calculation of correction of displacements or to refine the angles. It appears, however, that the angle correction software is time consuming and impractical for medical practice and for this reason is used only the correction of displacement of optical axes and the CCD sensors.

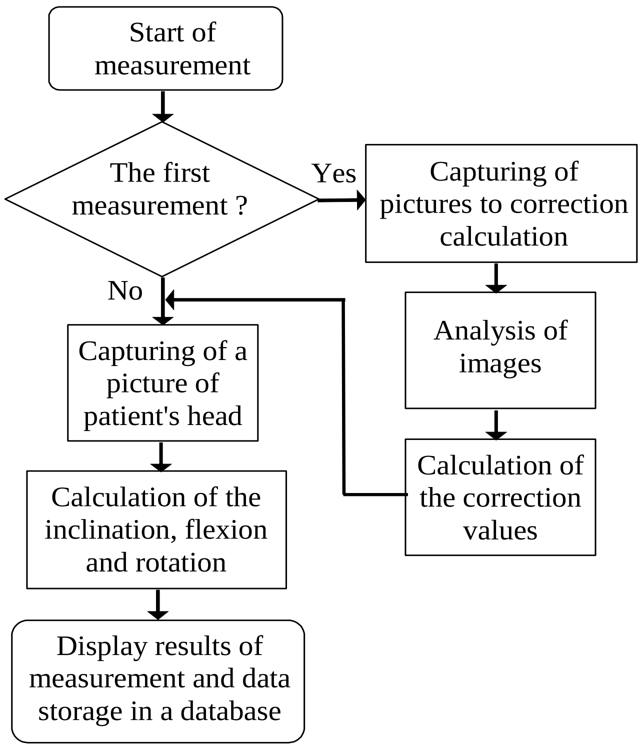


Fig 3. Flowchart of clinical measurement by our camera system.

The second main area of designed methods we tested for application in neurological practice uses accelerometers [6]. The headtracker in the eMagin Z800 3DVisor® personal display can measure head position in the 3D space. For the acquisition of the head motion we programmed software FBMI SPH in C# language based on Z800 3DVisor® SDK 2.2. The SW (software) retrieves position of the head from the build-in headtracker through the USB connection and save the measured results in to the CSV (comma-separated values) file.

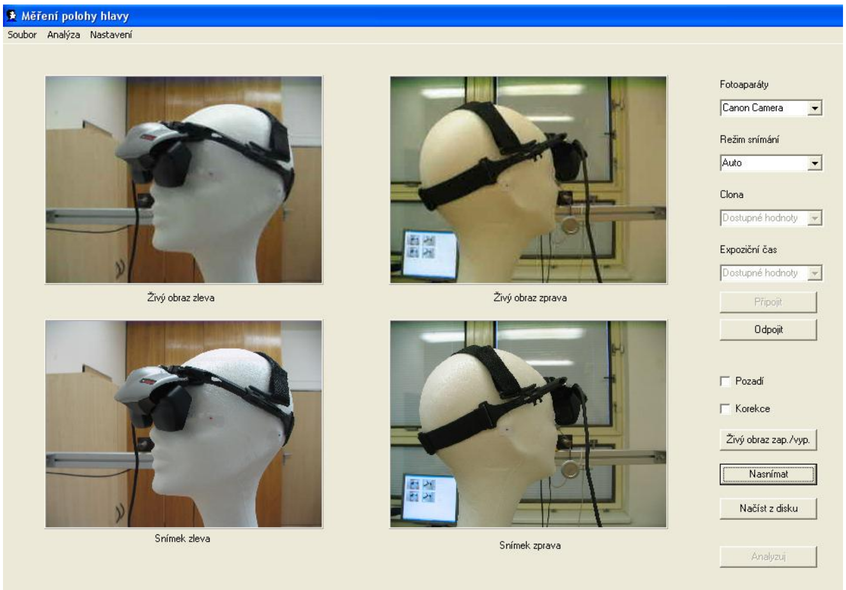


Fig 4. User interface of developed software during the comparative measurements with accelerometers.

The main goal of this study is to compare possibilities of the methods. Above all, we compared application of system based on cameras and system based on accelerometers for measurement of head position. To assess the quality of measurement position of the head and comparison of the two proposed methods we use the model of a human head with accelerometers positioned as well as with colored markers to identify the position of the head with two cameras. Results of the comparative measurements are given in Tables 1 and 2. The method is based on the rotation model, in accordance with a precise goniometer, on which the model is located. By this way we can make accurate comparisons between the two methods. We performed several measurements to obtain average values of measured angles for each method. The first measured values were used as initial, i.e. zero and were used as correction for all subsequent values.

Approximate value of the flexion angle [^{o}]	Angle identified by cameras [^{o}]	Change of angle of flexion measured by cameras [^{o}]	Angle identified by accelerometers [^{o}]	Change of angle of flexion measured by accelerometers [^{o}]	Differences in changes of angles of flexion [^{o}]
0	13,2	-	1,2	-	-
-5	9,0	4,2	-2,9	4,1	0,1
-10	4,0	5,0	-8,0	5,1	0,1
-15	-0,5	4,5	-12,6	4,6	0,1
-20	-5,3	4,8	-18,3	5,7	0,9

Tab 1. Differences in changes of angles of flexion measured by cameras and accelerometers.

Approximate value of the rotation angle [°]	Angle identified by cameras [°]	Change of angle of rotation measured by cameras [°]	Angle identified by accelerometers [°]	Change of angle of rotation measured by accelerometers [°]	Differences in changes of angles of rotation [°]
0	-1,0	-	-0,6	-	-
-5	-5,4	4,4	-6,9	6,3	1,9
-10	-9,7	4,3	-11,5	4,6	0,3
-15	-14,6	4,9	-16,0	4,5	0,4
-20	-18,9	4,3	-21,2	5,2	0,9

Tab 2. Differences in changes of angles of rotation to the right measured by cameras and accelerometers.

3 Results

The system based on two identical digital cameras is a sufficiently accurate system for determination of inclination, flexion and rotation of head in neurological practice. Advantage of the system is easy to determine angles between anatomical horizontal and axis and the physical coordinate system defined by cameras position. The cameras measure with precision of 0,05° ideally if there are not large abnormalities of the head position [4].

Disadvantage of cameras system is the increasing of error of detected angle in the case of increasing of abnormalities of the head position / measured angles. The reason of that is a large deviation of head position from the optimal location in the middle distance between the two cameras and it causes large differences of distances between the CCD sensors (cameras) and the measured head [5].

The special glasses – headtracker does not allow to determine information about angles between anatomical horizontal and axis and the physical coordinate system. Nevertheless, this measurement method is portable and faster way to measure motion of head.

Head position was measured with precision of 1,0° in three planes (rotation, flexion and inclination) [6]. The result is that the accuracy of the method alone is in eights of degree per the ten measurements. This is the dynamic error thanks the low-cost headtracker which has long stabilize time after the previous measurement.

Disadvantage of cameras system is the increasing of error of detected angle in the case of increasing of motion of measured subject. We can not measure position/angles of fast moving patients. For example in the case of a tremor. On the contrary, the advantage is measuring all angles/head positions with a constant error. This means that we can measure the high abnormalities of the head position as well.

It was experimentally checked that the accuracy of the method satisfy the general physicians´ requirement for the accuracy of the measurement about 1-2°. The cameras measure with precision of 0,05° ideally and headtracker with precision of 1,0° in three planes. A result of study is a recommendation to use the headtracker with lesser dynamic error (less than 0.3°/s) for the measurement of head position. The whole accuracy of the method could be this way markedly increased.

From the above mentioned description of both systems it shows the possibility of a combination of advantages of cameras and accelerometers. Most useful modification of these systems could allow the clinical measurement of head and shoulder posture [7]. Generally, combination of identification of positions of specific anatomical markers by cameras and motion by accelerometers can provide many uses, not only in medicine.

4 Discussion

From the above mentioned description of both systems it shows the possibility of a combination of advantages of cameras and accelerometers. Most useful modification of these systems could allow the clinical measurement of head and shoulder posture. Generally, combination of identification of positions of specific anatomical markers by cameras and motion by accelerometers can provide many uses, not only in medicine.

5 Conclusions

We designed two methods for evaluation of head motion and position for application in neurological practice. Both systems are cheap in comparison with sophistic 3D motion capture systems. Mentioned ways of measurement of head posture could be applied within another engineering, medical and science areas as well.

Acknowledgement

This is the work of the Department of Biomedical Technology, Faculty of Biomedical Engineering, Czech Technical University in Prague in the frame of the research program No. MSM 6840770012 "Transdisciplinary Biomedical Engineering Research II" of the Czech Technical University sponsored by the Ministry of Education, Youth and Sports of the Czech Republic.

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