MEASUREMENT OF POSTURAL HEAD ALIGNMENT IN NEUROLOGICAL PRACTICE

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Abstract: The paper describes a contactless method for measuring the postural head alignment using two digital cameras. The method is designed for use in neurology to discover relationships between some neurological disorders (such as disorders of vestibular system) and postural head alignment. There are first results measured on 31 non-patient subjects presented on this paper.

Introduction

Object was to develop a technique for accurate measurement of the head postural alignment 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 one or two degrees in case of tilt and rotation.

Similar technique has not been developed up to this time so that it could be widely and easily used in neurological clinical practice although it could have an important meaning in this field because there are a lot of neurological disorders that affect postural alignment of the head. These can be divided into several groups:

- Cervical blockades and diseases of cervical spine often cause abnormalities of the head position in the large range.

- “Movement disorders” from the group of dystonias. For them, the abnormal position of affected body segments is typical. Disorder of the head alignment that is known as torticollis is the most frequent dystonia at all. In this case, the abnormal position of the head corresponds to activation of affected muscles. See Figure 1.

- Pareses of eye muscles also often cause a compensative position of the head when the insufficient function is eliminated by a tilt of the head in direction of the affected muscle.

Figure 1: Head position affected by torticollis.

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 discovered.

Some similar studies, that have been published, are focused on differences of head postural alignment between genders and age categories [1] or compare means between a nonpatient sample and a sample of people who had cervical pain [2] but the techniques described in these studies are a little heavy-going and don’t allow measuring rotation of the head. We would like to present a new technique that allows us to get all needful values very comfortably and quickly by evaluating digital images and our study is focused on relation of the head position to neurological and eye disorders including relation to subjective perception of vertical by nonpatient and patient sample of people.

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Methods

The frontal photograph is used to evaluate the coronal head tilt (inclination). A digital camera is situated on a tripod so that its position corresponds to the physical horizontal. The anatomical horizontal can be defined by the following ways: If the measured subject does not suffer from an eye disorder that affects position of eyes, the connecting line between eye pupils can then be considered as anatomical horizontal. Otherwise, the anatomical horizontal is defined by exterior corners of eye lids. These points are designated by white circle marks. See Figure 2.

Figure 2: Anatomical horizontal defined by marks.

The position of eye pupils or attached marks is then evaluated in the digital image by using Hough transform. The angle between anatomical and physical horizontal is determined by angle between vector (1,0) (which is given by camera position) and vector that represents coordinates of points evaluated in the image. The angle is calculated as follows (1):

$$\varphi = \arccos \frac{u \cdot v}{|u| \cdot |v|}, 0 \le \varphi \le \pi, [rad], \qquad (1)$$

where u is the vector representing the physical horizontal and v is the vector representing the anatomical horizontal.

The same method is used for evaluating the tilt in sagittal plane (flexion) using a profile photograph. The flexion value is measured relatively as the inclination of the connecting line between tragus and exterior eye corner.

The circumvolution extent (rotation) of the head is evaluated from the difference between tragus coordinates in the left-profile and right-profile image. These images are captured at the same time using two cameras and the cameras are situated on the same optical axis which is the same or parallel with the frontal plane of subject. This is achieved by attaching specially designed devices on tripods. These devices allow the cameras to be set on the same axis using laser beam. See Figure 3.

Figure 3: Tripod attached with device for setting cameras on the same optical axis.

The laser beam emitter and the leaser beam detector are equipped with collimators. When the cameras are on the same optical axis, the right position is signalized by LED diode (the laser beam is detected).

The whole configuration is placed on an axis designated on the floor, each camera from each side. In the middle, there are marks for subject’s feet. In order to be photographed, the subjects are instructed to stand on the marks comfortably, in their “normal, loose or habitual” posture, with their weight evenly on both feet and looking straight ahead. When the subject is relaxed photographs are taken from both sides at the same time using remotely computer-controlled cameras to eliminate an error that would be generated by unconscious movement of the subject.

The following figures show how the coordinates of the left and right tragus are automatically evaluated by finding centre of the white circle mark attached on the tragus in the image, (Figure 4) using Hough transform. The tragus coordinates correspond to coordinates of the maximum in an accumulator from the Hough transform (Figure 5).

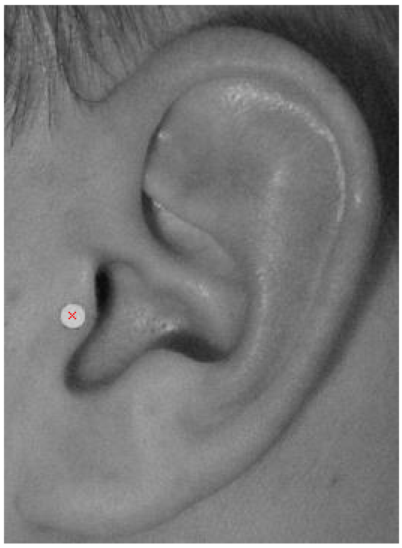

Figure 4: White circle mark on the tragus

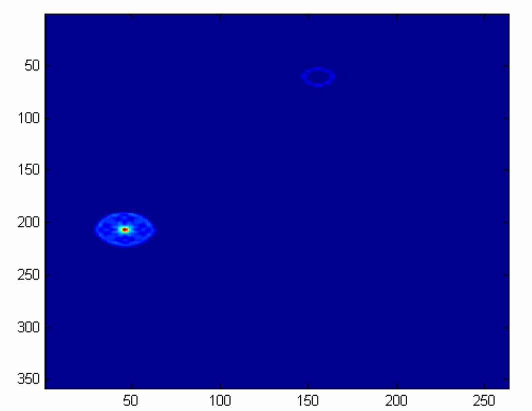

Figure 5: Maximum in the accumulator after performing the Hough transform corresponds to the coordinates of the tragus (the red cross on the Figure 4).

After evaluating coordinates of tragus in captured images, the angle of the head rotation is calculated as follows (2):

$$\varphi_c = \arcsin\frac{(a-(s-b))\cdot c}{d}, -\frac{\pi}{2} \le \varphi_c \le \frac{\pi}{2}, [rad], \quad (2)$$

where a[pixel] is x-axis coordinate of the tragus in the left-profile image, b[pixel] is x-axis coordinate of the tragus in the right-profile image, s[pixel] is x-axis size of the image, d[mm] is diameter of the head and c[mm/pixel] is a constant converting the distance between tragus coordinates from pixels to millimetres calculated as follows (3):

$$c = \frac{\frac{ccd\cdot z}{f}}{s}, [mm/pixel], \quad (3)$$

where ccd [mm] is width of the CCD sensor given by the camera's manufacturer, z[mm] is distance between the subject and the CCD sensor (camera), f[mm] is the focal length of the camera's lens and s[pixel] is the x-axis size of the image.

This method is based on circle movement approximation – see Figure 6, which shows the geometry used for measuring the head rotation (d[mm] is diameter of the head, x[mm] is distance between left and right tragus and φ[deg] is the result angle).

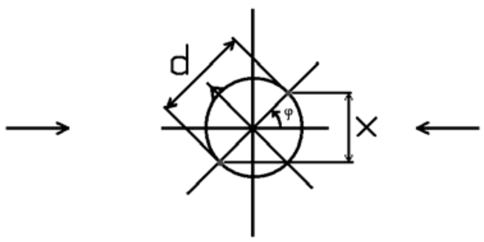

Figure 6: Geometry used for measuring the head rotation

It was experimentally checked by using a model of a human head and a smooth stepping motor that the accuracy of this approximation is about tenths of degrees in the rotation range of ±20 degrees. See Figure 7.

Figure 7: Verifying the method using a model of the head.

Results

The first set of data was measured on 31 volunteers recruited from students of CTU and CUNI in Prague. The measurement of the head position was completed with measurement of subjective perception of vertical (SPV). The subject tries to align a needle to vertical position when peering into white sphere. Final angle of the needle is measured. The measurement is separately done for left and right eye and then for both eyes. This is done because there can be potential relation between subjective perception of vertical and head position, especially inclination. There are results presented in Table 1.

Table 1: Mean (and SD) of Subject's head alignment and SPV

Data of	n	Mean	SD	Min-Max
Inclination	31	1.0	2.7	-5.3 – 5.5
Relative flexion	16	20.6	6.4	9.6 – 31.5
Rotation	31	-1.5	3.6	-6.7 – 6.0
SPV	22	0.9	1.0	-0.8 – 2.7

Values (mean, SD, SPV and min.-max.) given in degrees.

Conclusion

Data that has been measured up to this time shows that healthy man holds his head aligned with physical coordinate system in the range of c. ±5 degrees.

The results also predicate that there is a correlation between values of inclination and SPV.

Statistical analyses of this sample show that all values (inclination, flexion, rotation and SPV) are from normal distribution. Values of inclination and SPV are from the same distribution at the significance level of 0.05. However, these results can't be considered as final because of small data sample.

The rotation of the head is probably strongly related to the health state of eyes. We can observe a trend to move healthier eye more to the middle – compensation in the direction of the affected eye. In special case, when a volunteer was completely blind on his left eye, a rotation of 8.5 degrees to the left was measured. That represents the rotation that allows the visual field to be better covered by the health eye.

One of advantages of the whole method is option to get results online and all equipment can easily be installed.

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