11th International DAAAM Baltic Conference
"INDUSTRIAL ENGINEERING"
20-22 April 2016, Tallinn, Estonia

DEVELOPMENT OF COMPUTER VISION BASED FACE TRACKING MEASUREMENT FOR SITTING ERGONOMICS

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Abstract: *Sitting causes major health problems. Both bad sitting posture and prolonged sitting time increases the likelihood of back pain. The object of our research was to study if it is possible to measure sitting ergonomics using a webcam video. The webcam placed in front of a subject was tracking the movements of subject's face, which were used to derive the pose of subject's head. Different algorithms to detect bad posture based on head pose and movement were developed according to the physiological recommendations. The accuracy of these algorithms were investigated in a real environment testing. Although the results are promising, more research is needed to develop better algorithms for a more accurate and versatile detection of sitting ergonomics.*

Key words: 2d video camera, face detection, posture

1. INTRODUCTION

Poor sitting postures for prolonged periods of time increase the risk of development and perpetuation of stiffed neck and back-pain related conditions [1]. Office workers demonstrate high levels of sitting during both the working week and weekend [2]. Mostly people do not care about their posture while sitting, unless they are in pain. Not only the elderly but also teens and adults suffer from back pain as they spend a lot of time in front of a computer working, studying or playing games. Workers in pain cannot focus properly on their task and a longer effect cause sick leaves. The costs of sick leave daily allowances were 104.6 million euros in Finland year 2015 [3]. Measuring only sitting posture is not enough. It has been shown that discomfort when sitting is related to both biomechanics and fatigue factors that relate to sitting time [4].

According to physiotherapists a proper spinal curvature is essential to prevent back pain [5]. The correct curvature varies from country to country, though [5]. It is therefore a challenge to determine what sitting posture is good enough. According to a physiotherapist, in good posture it is important to maintain the ear-shoulder-hip line in a same vertical orientation (Fig. 1). However, it is shown that the largest factor to reduce the lumbar pain is to sit while maintaining neutral back; which means that there is a neutral flexion in lumbar spine i.e. lower back [1].

Numerous ways to measure posture has been investigated [6, 7, 8, 9]. Jaimes has studied the measurement of sitting posture

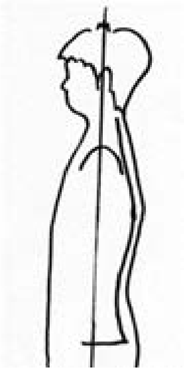

Fig. 1. The good posture comprises a vertical ear-shoulder-hip line.

from webcam video using geometric features [6]. Image processing based methods have difficulties with similar background color and loose clothes [7]. It is suggested that analyzing human posture by image processing should be done by looking at different joints [7]. The comfort level could be also determined by counting the movements of the human [8].

It is suggested that the scapular orientation and position can be measured more accurately, although also with more costs, with electromagnetic tracking than with image processing [8]. So it would be possible to connect an electromagnetic tracking system for example in some wearable to measure the posture. There are also smart cushion solutions which measure the sitting pressure distribution in a chair [9]. With these solutions it can be measured whether the upper body weight distribution is optimal or not.

The approach to track the sitting posture with a webcam was decided due to its vast potential. A lot of people have already an external webcam and also most of the laptops include one. Physical sensors to track the same thing could cost a lot. The method can be also accurate, if it is implemented properly.

The motivation for this research is to find an aid to the universal problem of bad sitting habits and sitting related back pain. The selection of webcam for a measurement system was based on its affordability and high prevalence among the computer users. The aim of this study is to determine a possible solution to asses sitting ergonomics using a frontal monocular webcam video. Some research on different algorithms to track a face from a monocular camera has been made. [10, 11] Some of those require a lot of processing capacity and might not be possible to run in real time, which is a requirement for this type of system. Here we use a simplified method to keep track on the position of the face. The effect of this simplified system is also to be analyzed.

2. TEST SYSTEM

According to a physiotherapist, the position of the legs, the spine and the head should be monitored to measure the sitting posture. We decided to try to measure the sitting posture only by measuring the position of the head as it affects also the position of the spine. The measurement would be based on incremental measurement of the position of the head, assuming that the initial position would be good.

The test system for measuring sitting ergonomics and giving feedback consisted of a desktop computer, a computer screen, a mouse, a keyboard, a notification light and a webcam (Fig. 2). External light notification system was used to notify the user to try to take a good posture. It was controlled by the test personnel. The webcam placed in front of a subject was tracking the movements of subject’s face. The software took video with a resolution of 640x480 pixels. A normal laptop, HP Pavilion dv6, was used to run the software.

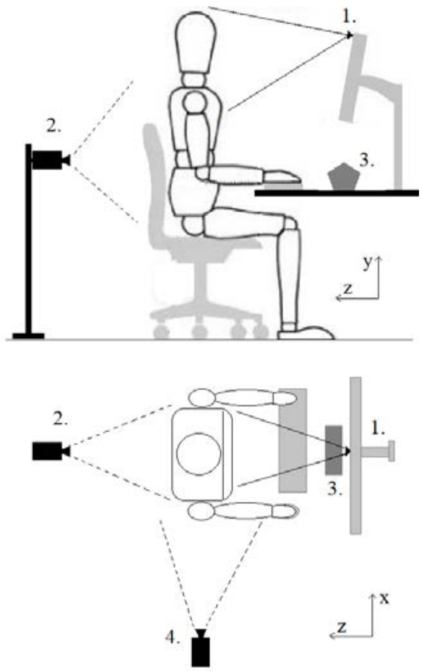

Fig. 2. Test setup: 1. webcam 2. video camera observing x and y movement 3. external notification light 4. video camera observing y and z movement.

The software was built with MATLAB and its Computer Vision toolbox. MATLAB was chosen as the coding platform for its wide user community and good sources of examples and ready functions. Our software uses functions for detecting a face with the Viola-Jones Method [12] and extracting corner points from the facial area with Shi-Tomasi-Kanade method [13,14]. With these methods, image coordinates of the center of the face and the width of the face can be derived. The software uses the width of the face and the known focal length of the webcam to estimate the distance. With these measures, it is possible to keep track of the face in three dimensions.

The program flowchart is shown in Fig. 3. In the beginning the software runs an initialization routine, during which the user is asked to take a good posture and start the session. The software saves the acquired coordinates as optimal place for the user. After that the location of the face is being tracked. If the face is positioned outside the optimal location for more than a threshold value longer than a threshold time, the software records that as an event and notifies user with the notification system. Leaning forward or on a side and slouching downwards is being tracked as well as the overall sitting time.

The software keeps track on what was the last position of the head before it disappears from the image. If the face disappears from the top of the picture, or if the face is moving upwards before it is lost, it is recorded as a standing up event, a good feature in sitting ergonomics.

Viability of the measurement system was examined in a real-environment experiment. 10 subjects were measured each for 15 minutes. The test persons were 20-29 years old university students. Their own estimated sitting habits varied from 4 to 6 hours of sitting per day at school/work and 2 to 5 hours of sitting per day in leisure time. Subjects were instructed to do normal computer tasks during the test. The system measured sitting ergonomics from

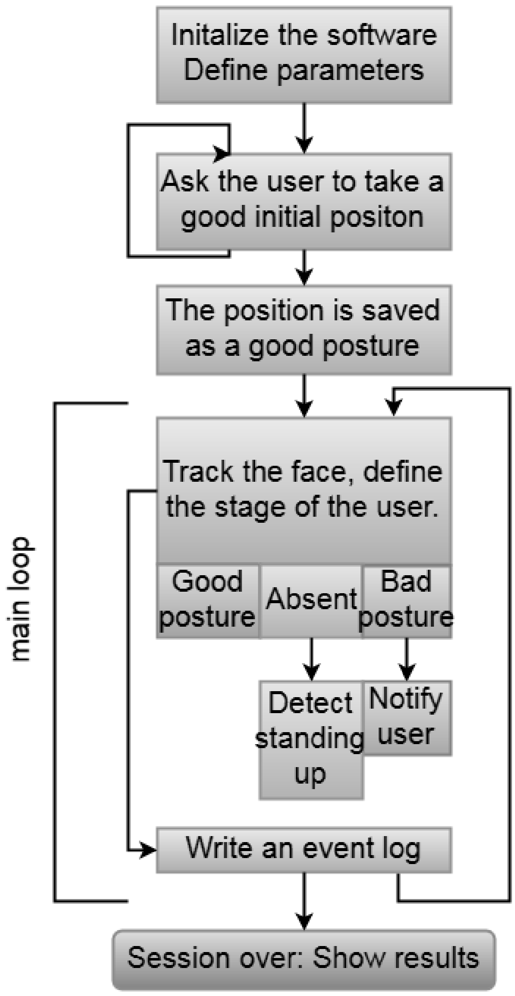

Fig. 3. The main functions of the measurement software.

webcam video and recorded an event log based on the test persons' postures, standing ups and overall sitting time. The test sessions were recorded with two external video cameras. Afterwards, a specialist in physiotherapy investigated the recordings and tried to define the same events as the software. The expert's findings were compared to what the software had recorded.

3. RESULTS

The physiotherapist's first notice on the experimental test videos was that the initial position in all tests was already out of the range of good sitting posture. Because of this issue we conducted one more experiment with the physiotherapist to get the initial posture right.

Four measurements were used to define, if the software can detect when the head has moved outside the initial position. Both the software and the expert physiotherapist measured when the posture changed from good to bad or vice versa. A margin of 10 seconds were allowed between the physiotherapist and software recordings. The physiotherapist recorded total of 27 events that the software did not recognize. The software recorded 24 events that the physiotherapist did not recognize. Both recorded same 9 events.

The method to track the distance to the face showed some problems. Distance was related to the width of the bounding box of the head. This width could change even by only rotating head in roll direction. Also the drift of the coordinate values along the measurement could be accused. Fig. 4 shows two cases of the tracked head positions during a 15 minutes test. From the test videos could be seen that the actual distance of the faces did not change as much as the Fig. 4 suggests.

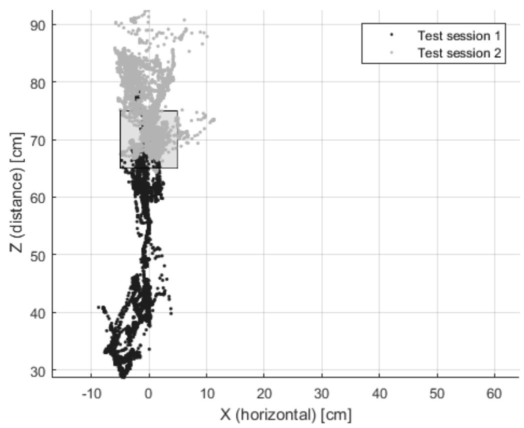

Fig. 4. The head coordinates in horizontal and distance direction. If the head is inside the square, the posture is defined as good by the software.

The time it took the software to detect the face was compared to the overall test time. The face was not detected by the software, if the user is not sitting or if there is some problem with the detection routine. In three tests out of ten the face detection percentage was considerably low, only 41-60 %. Excluding these tests, a total face detection percentage of 95 % was achieved, while the sitting percentage calculated by the expert in the videos was 98 %. During the tests, the subjects stood up total of 13 times. The software could not detect any of those as a standing up event, only that the face was lost.

4. DISCUSSION

The aim of this study was to examine, whether sitting ergonomics could be measured just by a frontal monocular camera. The measures were defined with the help of physiotherapists and literature research. Detecting standing ups is a good measure, because it is recommended that one should stand up after every 30 minutes. Also measuring the total sitting time is justified, because the overall sitting time should not be too long either. More questionable is, if measuring the slouching in all directions by the position of the head is enough. It can only describe if the user has moved from the assumed good posture. Slouching related to the distance to the webcam might be the one to look most closely.

The system could measure the head movement in horizontal and vertical direction accurately enough. The distance measurement was unreliable for this purpose. At least the initial distance should be updated from time to time. Some other method for tracking the pose of the head could measure the distance more accurately. Other methods could be tested in the same kind of test experiments to see their viability and ability to be run in real-time.

The proposed measurement system could detect 25 % of the events the expert observer detected. The software used strict thresholds of 5 centimeters to define, when the face had moved too far away from the optimal. This could mean that the expert recorded also smaller deviations than the software. Anyway, to develop the method further the thresholds for when the posture is too far away from optimal should be developed based on the expert analysis. Strict thresholds could have led to that the software recorded more events, when the face of the subject was wobbling on the edge of the threshold. In this analysis the software detected 24 events that the expert did not. Implementing soft thresholds could reduce this number.

There were problems with detecting standing up of the subjects. In many cases software lost track of the face and could not detect standing up. In the experimental study subjects stood up by first turning around in the chair and then standing up. Software detected this as losing track of the face by unknown reason, because face did not move upwards before losing it. This problem could be corrected with for example a method for tracking the whole head so that detecting standing up would not be dependent on the detecting of the face.

In three experiments the software had problems for tracking the face. The detection method might have tried to detect an inappropriate object as a face that the software had not accepted. The detection routine drew more computing time than the tracking routine which led to heating of the computer. The achieved frame rate of the images was also monitored. The actual frame rate dropped from the set 10 frames per second to 5,1-7,2 fps when the software had difficulties to detect the face. Overall, the computing time is a thing to consider in video-based measurements. A lighter software than MATLAB could ease the processor load.

In the seven tests where the software did not have major problems to detect the face, the overall sitting time could be measured within 3 % tolerance. This means that the proposed approach could be used to measure the overall sitting time, if the face detection can be made more reliable.

Major problems arose with the initial sitting posture. Many of the experimental study recordings were useless, because the initial posture was not good enough. This made the whole approach questionable. In the last experiment it took 5 mins for the physiotherapist to direct a subject to take a good initial posture. The physiotherapist paid attention especially to the spine curvature and ear-shoulder-hip line of the subject. This is something that the presented approach cannot handle. Could these instructions of the physiotherapist be replaced by a computer? That could be a topic for a further research. A camera viewing the user from a side could define more accurately the sitting posture. In this case the measurement would be absolute instead of incremental and there would be no need to initialize the posture in the beginning.

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