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Research article

Posture evaluation using real-time body tracking analysis

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Abstract: The exact position of certain segments of the human body can be easily inferred using the 3D video camera, this information can be processed by the body tracking modules to produce accurate estimates of the segments position in real-time. The present work aims to develop and apply a method for the recognition of large body joints using a body tracking device with dedicated software, without any other peripheral devices or sensors/markers applied to the patients. A number of 85 students participated in the study, who had their posture assessed from a standing position using two software designed for posture evaluation. This study focused on the assessment of postural alignment at the shoulder and hip levels. It is essential to assess the postural alignment in both the frontal and transverse planes in order to have a better perspective of the subject's posture. We found that in 58% of the subjects the right shoulder was projected forward. A mean difference of 12.32 mm was observed in people who had the right shoulder projected forward, while a mean asymmetry of 11.56 mm was observed in people who had the left shoulder projected forward. At the level of the hips, it was observed that a percentage of 56% of the subjects had the right hip projected forward, with an average difference of 6.31 mm. 3D video camera is a reliable instrument to assess transversal plane asymmetry from paired joints.

Keywords: posture analysis; body tracking; spinal deviation

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1. Introduction

In order to diagnose a deviation of the spine, after the clinical examination performed by the specialist, it is necessary to carry out an imaging investigation, i.e. to perform a frontal and profile X-ray of the entire spine. Once the diagnosis has been confirmed, the patient will undergo periodic X-ray examinations to monitor the evolution of the vertebral deviation. Rehabilitation specialists can not recommend periodic examinations due to the health risks associated with radiation. Therefore, the only way to follow the patient's progression remains the clinical examination, by observing the patient in different positions. Unfortunately, the clinical examination performed by the specialist doctor or physiotherapist is not always conclusive, requiring additional evaluation tools (for example: taking and analyzing photo or video images of the patient's posture).

In recent years 3D video cameras have been increasingly used in the field of medicine, robotics, and virtual reality [1]. Lange, B. (2012) used the somatosensory technique to create a limb recovery program for sports rehabilitation by combining digital skeleton data with virtual scenes [2]. Chang, Y.J. (2013) designed a mirroring system using a video camera by Microsoft and an augmented reality technique to allow users to try on clothes using gestures [3]. Cardo, A.L. (2018) designed an application using the Kinect device to detect when a person falls, which could reduce the falling risk when an elderly or medically impaired person is left unattended [4]. Li, K.F. (2011) created a web application that recognizes sign language using Microsoft's camera and displays the corresponding action meaning in the interactive interface

[5]. Xia, L. (2011) in his article used the depth camera of the same device that I used and the Canny operator to extract data related to the human body to detect and track it in motion [6]. Shotton, J. (2013) recognized human body parts by using depth images synthesized by the pixel difference method and Random Forest algorithm (machine learning algorithm) [7].

Other posture assessment methods have been tested over the years by different scientists [8,9]. Jansen et al. (2018) designed a sensor that can be applied directly to the skin, which could be used to monitor body position, which provides feedback that can be used in rehabilitation and sports activity [8]. Wang et al. (2019) conducted a study using computer tomography (CT) for automatic human posture recognition [9].

The present work aims to develop and apply a method for the recognition of large body joints using a body tracking device with dedicated software, without any other peripheral devices or sensors/markers applied to the patients.

2. Materials and Methods

We developed dedicated software for analyzing the static posture of patients before their inclusion in medical rehabilitation programs. A 3D video camera (Kinect Azure), developed by Microsoft for the video game industry, was used to acquire the video image. This same camera system was linked to a computer that analyzes and processes images obtained via this device.

We conducted a clinical study aiming to verify the accuracy of the Kinect Azure sensor in recognizing the position of the body's main joints. We assessed the position of the shoulders and hips and compared the results obtained from the Kinect Azure sensor with those obtained through the use of the Posture Pro software, a validated method used in several scientific studies for posture assessment [10].

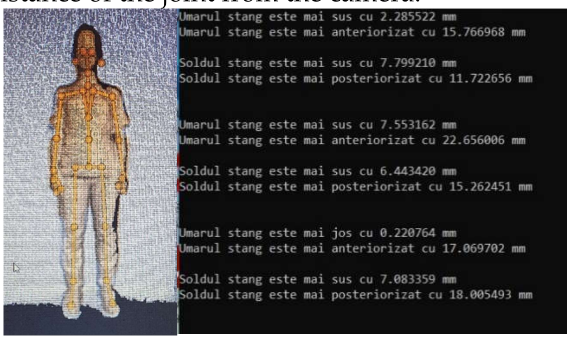
Initially, we approached a total of 102 students from the Physical Education and Sports Faculty, at West University of Timișoara. After presenting the details of the study, including its objectives and procedures, it was found that only 85 of these students expressed their willingness to participate and signed the informed consent. The subjects included in the study had an average age of 23.76 years, with 56 being male and 29 female. They had no diagnosed medical conditions related to the spine.

We needed certain materials to perform the posture assessment using the two proposed methods. For the first evaluation method, we needed a computer and an Azure Kinect 3D camera. We also used the open-source Microsoft software which was modified in order to capture and analyze 3D images. For the second evaluation method, we used a phone for image acquisition, a computer, dedicated software (Posture Pro), and colored markers attached to the investigated subject.

Both assessment methods were conducted simultaneously for each study participant, ensuring that all evaluations occurred under identical conditions. This simultaneous approach allowed for a direct comparison of the outcomes from each method. The assessments were carried out at a distance of 2 meters, which was determined to be optimal for evaluating posture effectively. By maintaining this specific distance, the researchers aimed to create a controlled environment that would minimize external variables and enhance the reliability of the results obtained from both assessment techniques.

Using the Microsoft Kinect Azure 3D video camera we created a digital model of patients' orthostatic posture. The posture image captured by the 3D camera is transformed into a digital skeleton of the individual without the necessity of attaching markers to the body. The proposed assessment system for patients' posture scanning is a non-invasive and non-irradiating optical system that can identify the major joints of the human body using an infrared (IR) camera. The system uses a structured light device based on an IR grating designed using an IR laser diode that detects the grid and creates a depth map of the surrounding space and the scanned human body. The system can separate the human body from the rest of the objects [11]. The image captured reflects the distance between the detected object/body and the camera in the visible range [12].

The proposed scanning system is capable of tracking 32 joints of the human body as in Figure 1 (a). Each joint is assigned a three-dimensional value that corresponds to its position in three-dimensional Cartesian space. For instance, the horizontal OX axis represents the left and right sides of the body, with negative values indicating joints located on the left side, and positive values indicating those on the right side. The Y coordinate, representing the vertical axis, has values less than 0 if the joint is above the level of the Kinect Azure camera, and values greater than 0 if the camera is below the joint. Finally, the OZ axis coordinate only has positive values, since it represents the depth distance of the joint from the camera.



(a) (b)

Figure 1. (a) Digital model of patients' orthostatic posture; (b) Example of the result obtained with Azure Kinect

To get accurate measurements, Kinect Azure must be configured as follows:

• The participant must be positioned at 2 meters from the visual camera,

• The sensor should be approximately 65 cm from the ground, perpendicular to the subject's hip. If the height of the subject exceeds 2 meters, the height of the sensor must be adjusted accordingly,

• The subject must be barefoot and wear tight clothes.

For the second evaluation method, we followed the methodology described by Senthil [10]:

• Participants were positioned at the same distance from the phone/camera, and was mounted on a tripod at a height of 115 cm

• Participants were informed before the assessment to adopt a relaxed standing position

• Markers were applied to subjects at the level of the acromion, bilaterally, and at the level of the two anterior superior iliac spines

• The captured photos were uploaded on the computer in the Posture Pro software to analyze the posture. Posture Pro by Ventura Design© (Overland Park, KS) was introduced in 1994 and claims to be the first posture analysis software. The latest version of the software (Posture Pro 8) includes image calibration features, the ability to zoom in, and the calculation of a Posture Number® that reflects the sum of postural deviations in the frontal and sagittal planes [13].

3. Results

The study comparatively analyzed the values obtained after applying both methods for deviations of large joints from the horizontal line.

At the level of the shoulders, it was observed that in 79% of cases, both evaluation methods using the Kinect Azure system and Posture Pro method detected the same shoulder as being elevated. Of the cases in which the assessment methods provided different results, in 72% of the subjects, the difference in asymmetry in the frontal plane at the level of the shoulders was less than 1 cm.

At the hip level, the two evaluation methods detected the same hip as elevated in 72% of the cases. Of the cases in which the assessment methods provided different results, in 76% of the subjects, the difference in asymmetry in the frontal plane at the hip level was the same as the shoulder measurement, less than 1 cm.

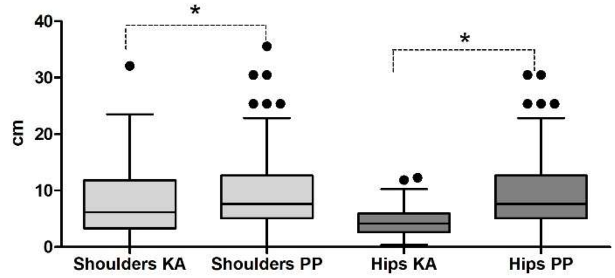


Figure 2. Mean difference of the evaluation methods. (KA= Kinect Azure, PP= Posture Pro, *=statistically significant)

Following the analysis of the data extracted by the two static posture assessment methods as illustrated in Figure 2, differences were observed regarding the assessment of shoulder and hip frontal asymmetries. KA showed marginally higher shoulder asymmetry than PP and less marginal hip asymmetry than PP, though differences were not clinically significant. A mean difference of 7.22 mm was observed between shoulders using the two assessment methods, while at the hips the mean difference was 6.51 mm.

SPSS software was used to analyze the recorded data and the statistical processing of the obtained results. Comparing the results of the two evaluation methods using the paired T-test, we determined that there are no statistically significant differences between them (mean difference between the KA method and the PP method at the shoulders 7.22mm ± 5.61 standard deviation, $p>0.05$ and at the hips 6.51mm ± 6.34 standard deviation, $p>0.05$) in assessing both the shoulder and hip, but a direct correlation was observed between the two evaluation methods, this being significant from a statistical point of view.

Compared with the Posture Pro method, the Kinect Azure can asses the potential asymmetry in the transverse plane using 3D technology. We noticed that in 58% of the subjects the right shoulder was projected forward, and in 42% it was the left shoulder. When the right shoulder was forward projected, the mean deviation compared to the left one was 12.32 mm, while the left shoulder was forward projected with a mean of 11.56 mm.

It was observed that in 56% of the subjects had their right hip projected forward at the hip level, with a mean difference of 6.31 mm. On the other hand, 44% of the subjects had their left hip projected forward, with an average difference of 6.21 mm.

4. Discussion

Prior research has indicated that the Kinect Azure system has not been utilized for clinical posture assessment, thereby positioning this study as the inaugural application of the proposed method for this purpose.

Kinect Azure device software can recognize the main joints of the human body. We improved this open source software written in the C++ programming language [14], by adding code lines to instantly calculate the frontal and transverse plans asymmetries. This modified software was uploaded to Microsoft Visual Studio [15] which is an integrated development environment used to create software for operating systems, websites, services, and mobile applications. We evaluated the software's functionality and data collection capabilities with the assistance of software engineers from the IT department at the Polytechnic University of Timișoara.

Previous studies have demonstrated that the Kinect sensor is a commercially viable and cost-effective device, widely utilized in gaming, capable of accurately detecting various body positions [16, 17]. The Kinect system serves as a complementary solution to established systems, which are primarily either two-dimensional detection systems or costly medical systems that emit radiation. [18].

Thanh et al. (2014) proposed the method of transforming joint information into a three-dimensional skeleton to facilitate posture analysis [19]. According to Chuan-Jun et al. [20], several Kinect-based recovery systems were developed to analyze patient-performed rehabilitation exercises. One of these systems compares the exercises performed by the patient with a video recording of a physical therapist performing these exercises to determine the accuracy of performing the rehabilitation exercises at home.

In the field of neuromotor recovery, there are several complex applications based on Kinect [3, 21, 22]. These systems are used to help the patient's upper limbs rehabilitation. Also in this field of neuromotor recovery, a set of recreational games "Kinect Adventures" developed by Microsoft has given very good results in the rehabilitation of patients with Parkinson's disease [23].

Two studies by J.A. Albert et al. and M. Tölgyessy et al. evaluated the motion tracking performance of the latest generation of Microsoft Kinect camera, Azure Kinect, compared to its predecessors Kinect v1 and Kinect v2 for treadmill walking as well as static posture using imaging comparison. Their results showed that the Azure Kinect camera's improved hardware and motion tracking algorithm led to significantly higher accuracy than its predecessors Kinect v1 and Kinect v2 [24, 25].

An experimental study evaluated the performance of the different existing versions of Microsoft Kinect Azure human body tracking device. A parametric analysis was conducted to assess the uncertainty in estimating body joint positions under varying conditions, including the resolution of the infrared camera, ambient light levels, the presence of obstacles that may obstruct the camera, and the distance between the human subject and the device. The findings of the analysis indicated that the estimation of hand joints consistently experiences uncertainty; specifically, as the subject moves beyond 2 meters from the device, the accuracy of joint detection diminishes. Furthermore, intense direct artificial lighting negatively impacts the quality of depth maps, thereby reducing the fidelity of digital skeleton generation. The presence of obstacles also contributes to increased uncertainty in joint detection [26].

A study published in 2023, which analyzed data from 30 subjects, demonstrated the accuracy of assessments conducted using the Kinect Azure. The study confirmed the device's potential for extensive application in high-quality and long-term monitoring of posture, balance, and gait across various environments, including medical offices, nursing homes, and community centers [27].

Key strengths of this study include the innovative nature of the methodology and the diverse applications of a non-irradiating device that does not require the use of applicators on the subjects.

Possible biases may be related to the fact that marker placement in the Posture Pro method is subjective and may suffer errors depending on the specialist performing the evaluation.

In future studies, we propose a comparison of the proposed method with a method considered the gold standard in posture assessment, namely the X-ray method. At this point we can say that a limitation of the study can be the reluctance of the subjects to perform an x-ray evaluation. At the same time, the two assessment methods will not be able to be performed at the same time.

In future research, we recommend conducting a comparative analysis of the proposed method against a recognized gold standard in posture assessment, specifically the X-ray method. It is important to acknowledge that a limitation of this study may arise from the subjects' reluctance to undergo X-ray evaluations.

The 3D posture assessment provides considerably greater accuracy compared to traditional 2D image assessment methods. This assumption is based on the enhanced capability of 3D technology to capture detailed and comprehensive information about a person's posture from multiple angles, facilitating a thorough evaluation of alignment and body dynamics. In contrast to 2D assessments, which confine the analysis to a two-dimensional representation, 3D assessments incorporate depth and spatial relationships among various body segments, thus providing a more comprehensive understanding of posture. This enhanced precision may facilitate more accurate evaluations of an individual's posture and overall body mechanics. As a result, the implementation of 3D assessment methods can substantially improve the effectiveness of posture evaluations, benefiting both evaluators and participants by obtaining more precise insights into postural characteristics. This provides a substantial advantage in creating the rehabilitation program aimed at improving posture. By incorporating this approach, practitioners can tailor the rehabilitation program to meet the specific needs of each individual, allowing for more effective strategies to address posture-related issues.

5. Conclusions

Based on the results obtained and their subsequent analysis, we conclude that the posture assessment method utilizing a body tracking device yields outcomes comparable to those of the widely accepted photogrammetric method. Furthermore, it was observed that body tracking enabled the evaluation of asymmetry in the major joints within the transverse plane, thereby enhancing the overall assessment of posture.

Kinect Azure is a viable clinical tool for assessing posture, particularly in terms of transverse plane asymmetry.

The study demonstrated that the body tracking method provides reliable results for posture assessment. Future research could be conducted to establish the utility of this method in clinical contexts for physical evaluations and the enhancement of rehabilitation programs.

Additional clinical studies are needed to explore the utility of 3D video cameras in dynamic posture assessment and to verify the accurate execution of physiotherapy exercises within rehabilitation programs.

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