58^{th} ILMENAU SCIENTIFIC COLLOQUIUM
Technische Universität Ilmenau, 08–12 September 2014
URN: urn:nbn:de:gbv:ilm1-2014iwk:3

An attempt to objectively determine part of the key indicator method using the Kinect® camera

Nuha Suzaly[1], Tobias Nowack[1], Sina Sprenger[2], Peter Kurtz[1]

[1]Technische Universität Ilmenau, Department of Work Science/ Ergonomics
[2]Technische Universität Ilmenau

ABSTRACT

It is important to evaluate the risk of musculoskeletal disorders related to repetitive or heavy lifting tasks. Thus, a method known as the key indicator method is recommended by the Federal Institute for Occupational Safety and Health (BAuA). The key indicator method (KIM) is used to assess manual material handling operations of employees in various fields. Through manual observation and assessment, certain key indicator parameters differ from one observer to the other. To help avoid variations in the results obtained, an objective method of assessment is here proposed using a motion-sensing input device from Microsoft, Kinect™. Using the Kinect™ camera, person recognition as well as a pseudo-skeleton model recognition is made possible. Data obtained from the pseudo-skeleton model can be used to objectively evaluate and classify the body posture. In this paper, we introduce the attempt to assess the body posture during manual work processes using the Kinect™ camera.

Index Terms – postural load, key indicator method, ergonomics, Kinect™, pseudo-skeletal recognition

1. INTRODUCTION

Discomfort in the back, neck, shoulders or upper limbs can be due to musculoskeletal disorders. Musculoskeletal disorder is one of the common cause of occupational illnesses [1] [3]. This is often due to repetitive tasks, awkward body postures and incorrect handling of loads. To assess the postural load on the back during manual handling operations (MHO), various methods such as questionnaires, logs or through observation, are used. These methods are subjective and the results obtained often lead to misclassification [4].

The key indicator method (KIM) is a method used to assess the manual handling of loads [5]. It considers the weights of certain parameters: duration of manual handling operations, type or weight of load, body posture during manual handling operations and the work condition. The assessment of the body posture is through observation. To avoid misclassification in the body posture weight, we suggest an objective method to evaluate this part of the key indicator method. With the help of the Kinect™ camera, it is possible to evaluate the body posture and sort it in specific weight categories suggested by the Federal Institute for Occupational Safety and Health (BAuA).

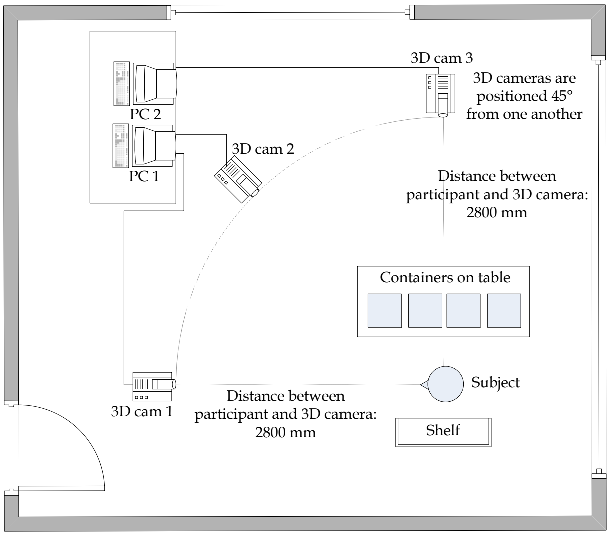
The Kinect™ camera incorporates an infrared camera and a video camera to create a 3D map of the area in front of it and uses an algorithm to determine anatomical landmarks on the human body, such as the joints in real-time. Thus, it does not require any markers. Moreover, it is an inexpensive and portable system and so makes it attractive for the application in performing body posture analysis [2]. Another camera used in the study is the Asus® Xtion PRO LIVE camera. The features of this camera are similar to the Kinect™ camera except for its size and mechanical stability. The cameras are addressed as 3D cameras later in this article.

To be able to objectively evaluate and classify various body postures, a study was carried out to investigate the validity of the 3D cameras at various angles and the viability in the detection of the anatomical landmarks on the body. The procedure of the study is explained in section 2. Besides that, section 2 desribes how the data collected from the study are analysed and used to develop a software tool that classifies specific body postures.

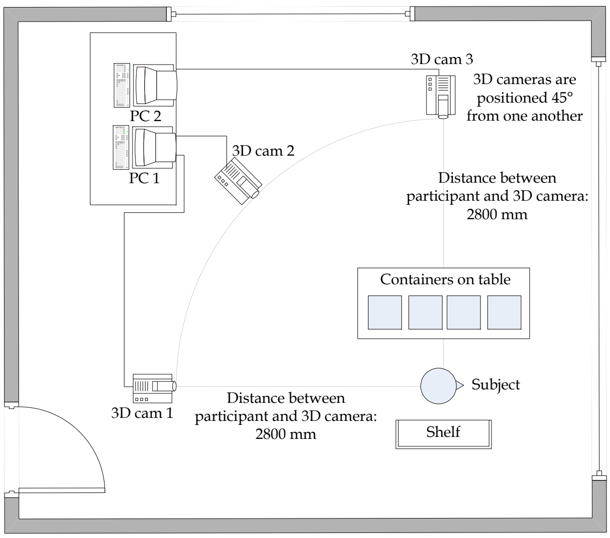
2. METHODS

2.1. Procedure

Twenty-four young injury-free individuals volunteered for the study (age: 24.3 ± 2.7 years, height: 1700.3 ± 109.8 mm, mass: 69.9 ± 12.2 kg, male:11). After carrying out anthropometry measurements with the subject, the subject is briefed about the study before performing the instructed tasks. Two scenarios were implemented for the assessment. The measurement setup for the scenarios 1 and 2 is displayed in Fig. 1. Two Kinect™ cameras and an Asus® Xtion PRO LIVE camera were used for the study to evaluate the validity of the cameras at three different angles. The trials were performed with the subject about 2.8 m away from the 3D cameras.



(a) Measurement setup of the study for scenario 1 with the subject facing 3D cam 1.



(b) Measurement of the study for scenario 2 with the back of the subject facing 3D cam 1.

Figure 1: Two scenarios from the measurement setup of the study on manual materials handling operations using two Kinect™ cameras and an Asus® Xtion PRO LIVE camera.

The body posture assessment was performed in order of the subject facing the 3D cam 1 (see Fig. 1a) and then with the back to the 3D cam 1 (see Fig. 1b). The subject is instructed to fill the shelf from top to bottom with the containers provided on the table opposite the shelf. After the shelf is filled, the containers are placed back onto the table. This is repeated 3 times for both scenarios to ensure a large collection of dataset from each participant.

2.2. Data collection

The relevant data were acquired from the OpenNI® library using a customized Java-software programmed in an integrated development environment (IDE) called Processing [6]. With Processing, a graphical user interface (GUI) is developed to display the pseudo-skeleton model (see Fig. 2) from the data acquired.

H — Head
N — Neck
T — Torso
RS / *LS* — Right/ Left shoulder
RE / *LE* — Right/ Left elbow
RH / *LH* — Right/ Left hand
RW / *LW* — Right/ Left hip
RK / *LK* — Right/ Left knee
RF / *LF* — Right/ Left foot

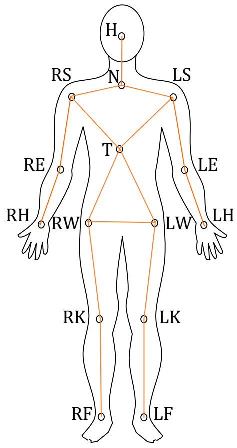


Figure 2: The pseudo-skeleton model made available by the OpenNI® library. The circles depict the anatomical landmarks detected.

The GUI is programmed to capture images from the 3D cameras and save the joint coordinates in a text file. Figure 3 shows the three camera perspectives taken from the second scenario.

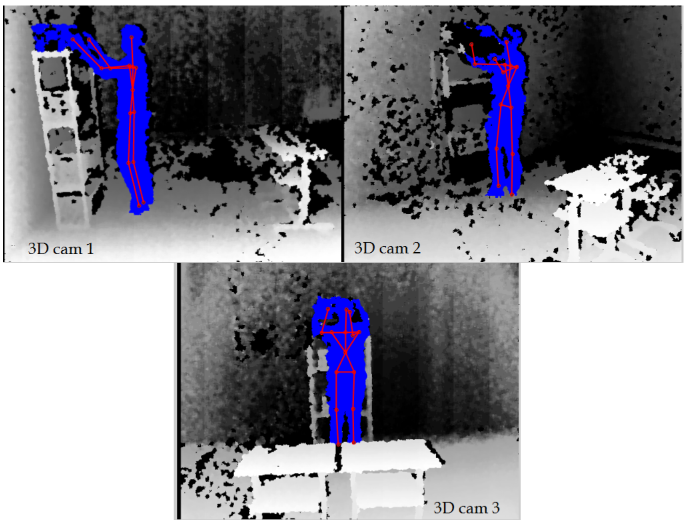


Figure 3: Depth images taken from 3D cam1, 2 and 3 respectively with the person and pseudo-skeletal recognition using the OpenNI® library.

The minimum and maximum range of the 3D cameras of 800 mm and 3800 mm respectively is to be ensured for a reliable person and pseudo-skeleton detection. The data acquisition was performed at an average frame rate of 15 Hz with the use of one camera connected to the PC. The average frame rate obtained when two 3D cameras are connected to one PC is 3 Hz. This is due to the simultanoeus use of two cameras and collection of data. The saved data are used for later evaluation and analysis.

Even with the simultaneous use of three 3D cameras, no significant interference between the infrared signals projected by the 3D cameras were noticed. Although, the container carried by the participant was often detected as a second person or as part of the participant as can be seen in Fig. 3. This problem also occurs when using only one 3D camera. The false detection caused false positive data to be collected along with the pseudo-skeleton data from the participant.

2.3. Data analysis

The collected data were analysed using MATLAB® before implementing the algorithm in Processing. False positive data collected from the study were sorted out prior to performing the data analysis. A colour range is used to categorise the risk ranges in low and highly increased musculoskeletal risk. Table 1 shows the classification of the body posture weight suggested by BAuA.

Colour range	Description of risk ranges	Posture rating weight
Green	Physical load unlikely to appear	1
Yellow	Physical overload is possible for less resilient persons	2
Orange	Physical overload is possible for normal persons	4
Red	Physical overload is likely to appear	8

Table 1: Classification of body postures in colour ranges and its corresponding posture weight according to the key indicator method suggested by the Federal Institute for Occupational Safety and Health (BAuA) [7].

An algorithm is developed to classify the body postures in the corresponding risk range. The flow diagram in Fig. 4 displays the steps taken to identify the risk range according to the colour range suggested by BAuA.

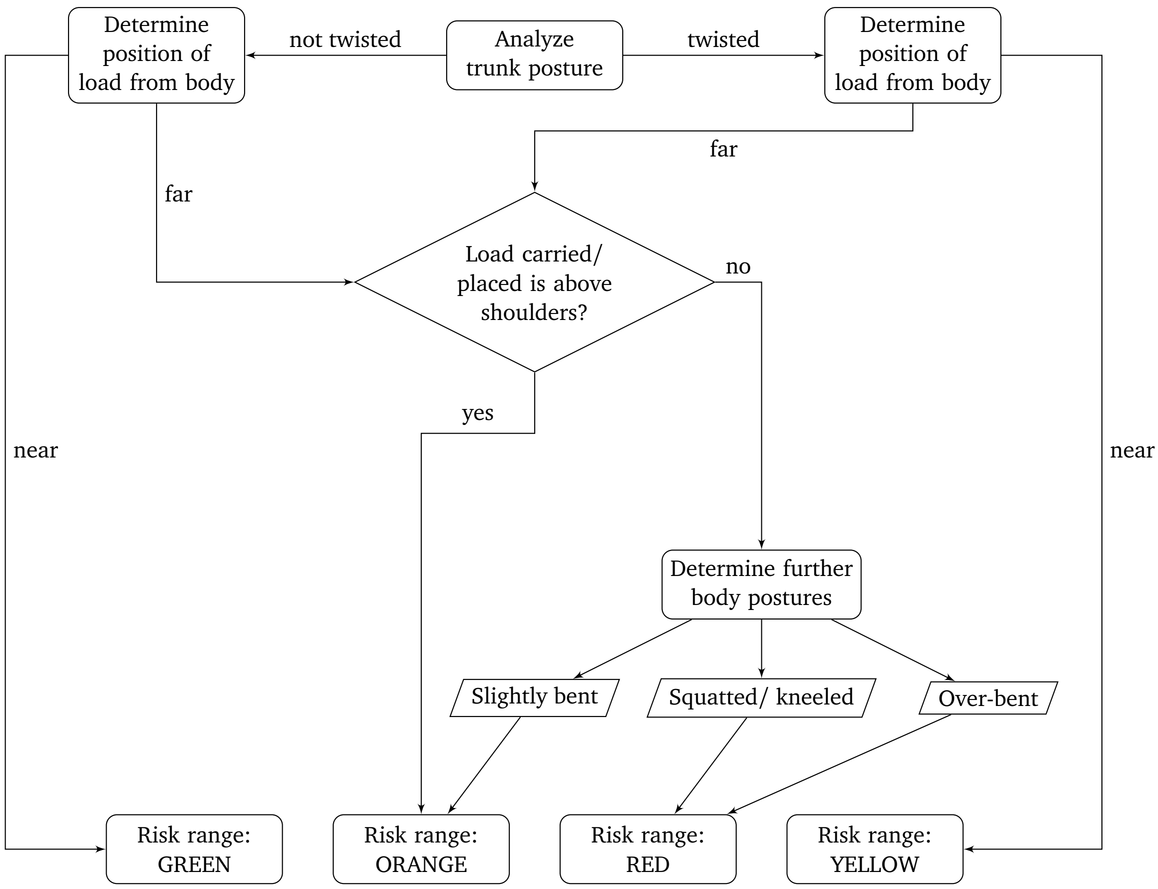


Figure 4: Schematic diagram on the classification of the body posture for the key indicator method.

The first step is to analyze the trunk posture whether it is twisted or not. After assessing the trunk posture, the position of the load from the body is determined. Less stress is imposed on the back, when the load is carried close to the body. If the load is positioned far away from the body, further assessment of the load position is performed. If necessary, further body postures are determined to identify the risk range. The pseudo-skeleton model is then displayed real-time in the colour of the risk range identified.

To classify the risk ranges of the body posture during manual material handling operations, the angles between the relevant joints shown in Fig. 5 provided by the OpenNI® library are taken into consideration. The classification of the risk range is carried out by setting thresholds. These thresholds are defined according to the anatomical limitations of the body [8]. The twist in the trunk is determined from the angle between the two normal vectors of the upper and lower body plane (see Fig. 5).

H — Head
N — Neck
T — Torso
RS / *LS* — Right/ Left shoulder
RE / *LE* — Right/ Left elbow
RH / *LH* — Right/ Left hand
RW / *LW* — Right/ Left hip
RK / *LK* — Right/ Left knee
RF / *LF* — Right/ Left foot
UP — Upper body plane
LP — Lower body plane

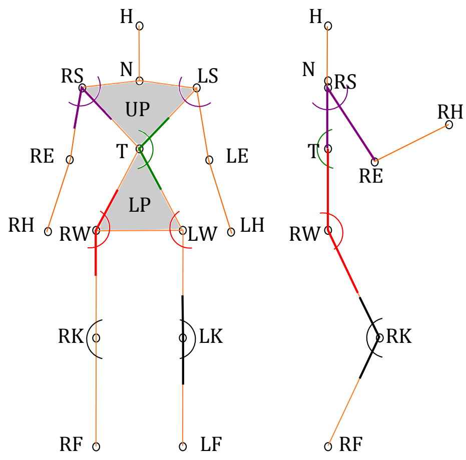


Figure 5: The frontal and side view of the pseudo-skeleton model with the relevant angles taken into consideration for the determination of the risk range.

A body posture is classified as slightly bent, when the hip angle which is between the vectors $(\overrightarrow{\mathbf{LS,LW}})$ and $(\overrightarrow{\mathbf{LW,LK}})$ or $(\overrightarrow{\mathbf{RS,RW}})$ and $(\overrightarrow{\mathbf{RW,RK}})$ respectively is smaller than 140° and greater than 60°. Whereas, squatting is identified when the knee angle between the vectors $(\overrightarrow{\mathbf{RW,RK}})$ and $(\overrightarrow{\mathbf{RK,RF}})$ or $(\overrightarrow{\mathbf{LW,LK}})$ and $(\overrightarrow{\mathbf{LK,LF}})$ respectively is lesser than 90°. According to the risk ranges described in Tab. 1, one of the threshold value used to define a posture rating weight is the evaluation of the shoulder angle between the superior arm $(\overrightarrow{\mathbf{RS,RE}})$ and the upper body $(\overrightarrow{\mathbf{RS,T}})$ (see Fig. 5). A posture rating weight of 4 is identified when this particular angle is more than 90° and the elbow is above the shoulder.

3. Results

Using the data collected, a program was then developed for the real-time assessment of the body posture. This program was then tested with 12 young injury free individuals. This program is contained in a GUI. Figure 6 shows the results from two participants carrying a load (the container) from the floor.

Figure 6: Results of the objective risk range classification using the Kinect™ camera and the algorithm developed.

The GUI can be run in real-time and assess the body posture during manual handling operations such as lifting or carrying.

Images are only saved when the GUI is clicked to increase the sample rate and the performance of the camera during person and pseudo-skeleton detection. The body posture of the participants were assessed during the lifting and carrying of the load. A warning tone is executed when the identified body posture is classified in the high risk range. This evaluation can also be applied with the other 3D camera, the Asus® Xtion PRO LIVE camera, as long as the OpenNI® library is installed.

4. DISCUSSION

It is possible to objectively determine the body posture during manual working processes using the Kinect™ camera. This can be used to analyse workplaces with manual material handling operations. The ability to differentiate various body postures may also help in objectively assessing the correct body posture and to help prevent awkward body posture during manual material handling. This in turn can reduce muskuloskeletal injuries in the working field. Further studies have to be carried out in order to improve and evaluate the accuracy and robustness of the developed program. This can be done by testing the program in different working places.

REFERENCES

[1] Andersen, J. H. and Haahr, J. P. (2007). Risk factors for more severe regional musculoskeletal symptoms: A two-year prospective study of a general working population. *American College of Rheumatology*, 56(4): 1355–1364

[2] Clark, Ross A. ; Pua, Yong-Hao ; Fortin, Karine; Ritchie, Callan; Webster, Kate E.; Denehy, Linda and Bryant, Adam L. (2012). Validity of the Microsoft Kinect™ for assessment of postural control. *Gait & Posture*, 36: 372–377

[3] Rempel, D. M.; Harrison, R. J. and Barnhart, S. (1992). Work-related cumulative trauma disorders of the upper extremity. *The Journal of the American Association*, 267(6): 838–842

[4] Burdorf, A. and Laan, J. (January 1991). Comparison of methods for the assessment of postural load on the back. *Scandinavian Journal of Work, Environment & Health*, 17(6): 425–429

[5] Klussmann, A. ; Steinberg, U. ; Liebers, F. ; Gerhardt, H. and Rieger, M. A. (2010). The key indicator method for manual handling operations (KIM-MHO) - evaluation of a new method for the assessment of working conditions within a cross-sectional study. *BMC Musculoskeletal Disorders*, 11: 272

[6] Processing 2. *http://processing.org/*, Last visited: 21 March 2014

[7] Bundesanstalt für Arbeitsschutz und Arbeitsmedizin - BAuA (2012). Gefährdungsbeurteilung mithilfe der Leitmerkmalmethode. *http://www.baua.de/de/Themen-von-A-Z/Physische-Belastung/Gefaehrdungsbeurteilung.html*, Last visited: 21 March 2014

[8] Man-Systems Integration Standards, Revision B, Section 3 (July 2005). Anthropometry and Biomechanics. *http://msis.jsc.nasa.gov/sections/section03.htm*, Last visited: 15 July 2014