Ergonomic Postural Evaluation System Through Non-invasive Sensors

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Abstract. The research consists in the study of cutting workplaces, in order to subsequently develop an ergonomic evaluation of the workers in this area and to obtain results of the ergonomic risks associated with the work. It could be determined that the appropriate method for the ergonomic evaluation was RULA. Once these workplaces had been evaluated in the traditional way, the postural risk evaluation system was developed and programmed. This system works with the Kinect V2 sensor, specifically with the depth, skeleton tracking, and color sensors; the system determines angles and measurement points between each joint of the body, each of them referenced to the value established in the RULA evaluation matrices at certain times.

Keywords: Ergonomic evaluation · Sensor · RULA

1 Introduction

Nowadays, the inclusion of ergonomic principles in the design of production processes is an important activity that is taking on relevant importance in companies; the main reason being to reduce the Musculoskeletal Disorders (MSDS) that are generated in jobs [1]. It is necessary to evaluate and measure ergonomic risk factors in order to obtain a comfortable workplace. There are ergonomic risk assessment methods classified [2], as observational or indirect and direct measurement methods that present disadvantages such as [3]: invasive, low precision, complex data analysis, being applied only by expert assessors, high cost, among others.

Several ergonomists find them unsuitable for measuring risk in the actual workplace. There are also semi-automatic assessment methods using 3D sensors and high-tech software [4], where more and more research is being developed for these methods. The use of sensors such as Kinect [5], can help to solve these problems because they collect data more reliably (see Fig. 1), avoid measurement errors, the sampling frequency can be increased due to the automation of data collection, making the risk estimation more accurate and non-invasive [6].

It is possible to track body parts through the manipulation, control and monitoring of a computer through the Kinect sensor applied to ergonomic risk assessment [7]. The use of the Kinect 2 sensor presents the results with measurement accuracy and efficiency in real time, being a real progress for computer vision tasks, allowing qualitative and quantitative evaluation models [8].

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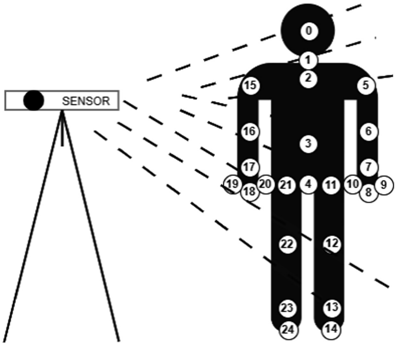

0 Head	5 ShoulderLeft	15 ShoulderRight
1 Neck	6 ElbowLeft	16 ElbowRight
2 SpineShoulder	7 WristLeft	17 WristRight
3 SpineMid	8 HandLeft	18 HandRight
4 SpineBase	9 HandTipLeft	19 HandTipRight
	10 ThumbLeft	20 ThumbRight
	11 HipLeft	21 HipRight
	12 KneeLeft	22 KneeRight
	13 AnkleLeft	23 AnkleRight
	14 FootLeft	24 FootRight

Fig. 1. Person in the evaluation environment with sensor location

The capture of people's movements and even manage a computer program with total independence of cables or special clothes mounted with multiple sensors at different points of the body [9], make all these movements are captured by the sensor in real time, at the lowest cost, allowing subsequent analysis of the data obtained and therefore determine the level of ergonomic risk to which workers are exposed in the production of footwear [10].

In the business environment, the aim is to determine some musculoskeletal disorders [11], for example, the evaluation of the workplace in driving a car, where it depends primarily on the repetitive movements of the driver and response times in each activity [12]. On the other hand, there is the evaluation of jobs in general, since people use the computer daily and the sitting position is not adequate, these symptoms are created called "Office Workers Syndrome" [13]. Which is analyzed if a position of the worker is inadequate this thanks to the non-invasive sensor of evaluation. Because the data are taken from people in their respective activities and different trades or professions such as: medicine, driving, office, industry, etc. These data are used as a means of analysis to determine potential risks at work [14], in addition to being able to decide whether an activity should be changed or eliminated from the worker. Going further to data mining it has to be that the data taken from a worker can serve as a database of training movements. Either for a rehabilitation system or send that data to robots and thus be able to improve the activity in an appropriate mechanism of work [15].

Taking into account that the industry seeks the best interaction of the worker with the job, methodologies such as RULA, REBA, OWAS, etc. are a case study [16]. Which seek to evaluate each job or activity in certain times of repetition. Now the evaluation depends on the equipment used for data collection, which are classified in two groups [17]: invasive and non-invasive devices. The disadvantage of invasive devices is the discomfort of the worker at the time of being evaluated and the data may not be accurate. On the other hand, if a worker in an assembly industry is evaluated with a non-invasive sensor, the person will perform their activity normally, thus presenting the real problems in the activity or improvements in it.

2 Methods

The purpose of the research is to develop a tool that facilitates and optimizes technical management in the evaluation of ergonomic risks of occupational origin [18], in this sense was taken into account, for the development of this work, the footwear companies specifically in the area of cutting each of their activities.

2.1 Development Study

The first phase of this project is the development of initial planning to determine the procedure and ergonomic assessment method to be used by applying an indirect methodology. With this, the decision was taken to carry out an analysis of the cutting workplace in the production of footwear, in which it was evident that most of the repetitive efforts and movements during the working day were in the upper limbs. For this reason, the Rapid Upper Limb Assessment (RULA) method [19], and the Rapid Entire Body Assessment (REBA) method [20], are the methods initially selected to be used as standardized ergonomic assessment techniques.

The traditional evaluation of work postures is based fundamentally on observation, which is why the following is a list of the various cards applied for the study of work and postural evaluation of cutting activity in footwear companies.

2.2 Convenience Sampling

The evaluation within the system is planned to work with 25 companies is met with the evaluation sample of 25 cutting jobs in footwear companies, where the total population evaluated participant in the research project was 70 people. The type of sampling carried out was intentional or convenient, because for the study only the exclusive personnel in manual cutting workstations were required.

2.3 System Systematization

The first execution parameter is the determination of the base Operating System, within the specifications of Kinect V2, Windows 10 is established in its Pro version. Requirements for Kinect V2: 64-bit (x64) processor, 4 GB memory, USB 3.0 controller dedicated to the Kinect sensor for Windows v2, Graphics adapter with DX11 capacity for Microsoft Kinect v2 sensor [21].

The requirements are the basics for the initial operation of Kinect. For the initial tests of the sensor commercial and free access programs were used such as: Brekel Pro Body v2 [22]; Kinect capture software with a maximum of 6 people within a programming environment with Unity. Kinect Studio and Visual Gesture Builder [23]; Kinect own applications, which analyze and record pre-established movements of the body postures.

These programs and most Kinect applications have the ability to capture the person in a frontal way. This poses a research problem of being able to obtain data from a person in a lateral way (sagittal plane) [24]. The bibliographic research is based on the types of sensors that Kinect has such as Depth, Skeleton and Color (see Fig. 2). The data that can be had with the Skeleton sensor are 25 joints of the body, while the depth sensor allows to save data in captures of 3D frames [25]. The combination of these two sensors makes it possible to obtain data based on the programming of a complete rotation of one of these joints [26].

Fig. 2. System implementation in workplaces with different environments.

2.4 System Systematization

Initial Kinect tests, the initialization of the sensor has a procedure of physical recognition of the Kinect, until the ignition of the same within the SDK (see Fig. 3).

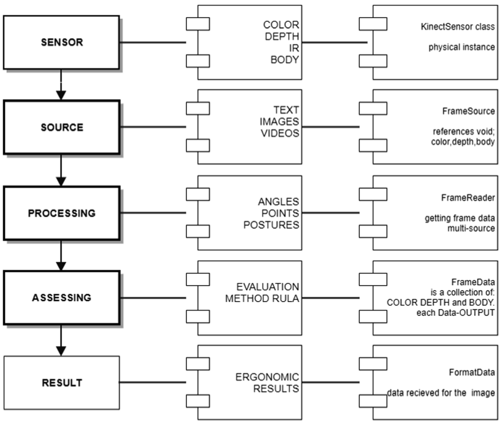

Fig. 3. Sensor processing stack.

Implementation of the system modules with a non-invasive sensor for the evaluation of the workplace [27], to determine the Kinect processing and to improve the use of the GPU a study is made with Kinect V2 and NVidia CUDA [28]. Therefore, for the detection of people and the follow-up of RGB-D data, obtaining as a result that the rates of obtained tables are better with respect to the use of CUDA in the processing. This group of data is processed by different classes (see Fig. 4), which allow from the capture to the evaluation and generation of the reports of each of the participants.

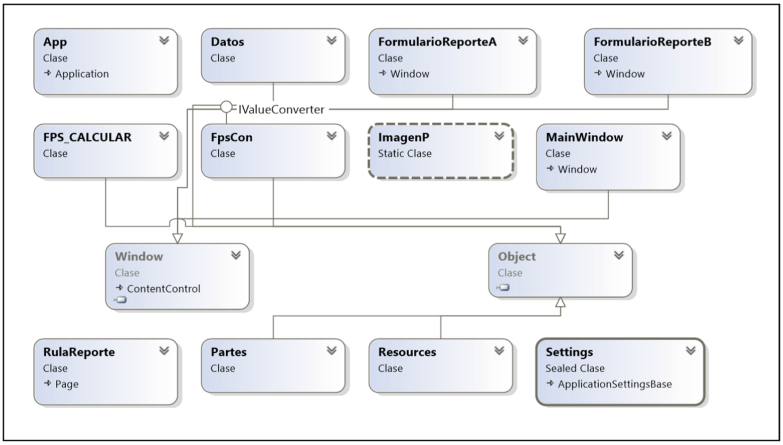

Fig. 4. Sensor processing stack.

The data obtained from each articulation is stored for each frame captured, at certain times. The averages are 52 columns and 1000 records (in rows) that are recorded in Excel, this for an evaluation of 5 min. Each one of these data allows to determine the position and the value to be obtained according to the RULA valuation matrices. In addition, each group of rows is congruent with the frame that belongs to it, the process of evaluation of RULA values [29].

The operation of the depth camera allows to determine the person in a workspace obstructed by objects and different types of lighting. The skeleton sensor completes the depth sensor, which determines the analysis points specified by RULA [30]. This means that the skeleton sensor is mapped over the depth sensor. For the first versions of the system with Kinect, it was used libraries and parameterization between Vitruvius [31] and investigation of angles to obtain points in the axes x, y, z, which allows the determination of the angles of evaluation of certain articulations of the frontal plane.

The interface model is based on a process of switching on the sensors (color, depth, skeleton), the process of rapid analysis is contemplated, accuracy depends on the evaluation time. The signals (green box) that a person is within the capture focus of Kinect depends on a value of >1, correctly traced and <1 outside the evaluation range of Kinect (see Fig. 5).

In the development process each Kinect procedure is based on the division of the data into CSV with each corresponding frame. Having too much information in plain text leads to implement a database in PostgreSQL for better response time in the query of each frame with each of the output data capture sensor.

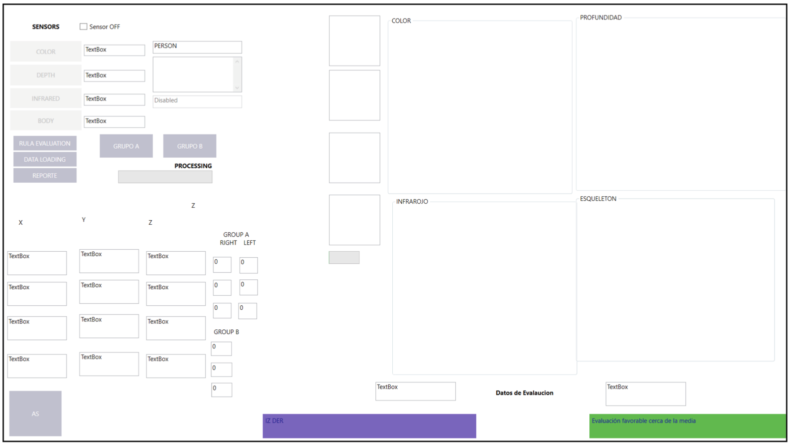

Fig. 5. Prototype implementation schema.

3 System Performance Tests

Initial tests of the system (see Fig. 6), are based on the detection of postures in determined times, each evaluation counts on a sequential one that analyzes the points of each participant until the activity is determined as repetitive or of inadequate posture.

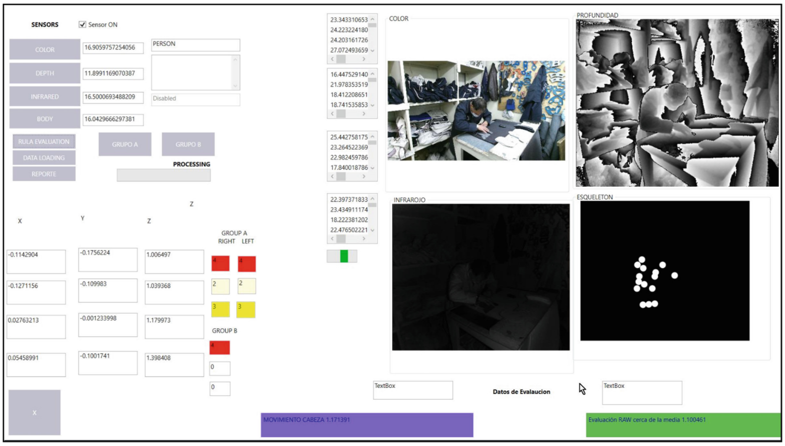

Fig. 6. Implementation of a system in workstations of a cutting company.

The reports are generated based on the highest risk frames, for which the RULA comparison tables are loaded, establishing a score for the final valuation. There are two forms of reports for both group A and group B established by RULA [29] (see Fig. 7), the final generation of the report depends on the evaluation time of the participant.

For group A it is determined according to the RULA methodology that the extremities of the body evaluated are the arm, forearm and wrist. On the other hand, for group B it is determined according to the RULA methodology that the extremities of the body evaluated are the neck, trunk and legs (static value). It must be taken into account that the values obtained are a comparison between body and depth sensor data. These data allow to establish an analogy of the capture for each frame which is created for each second of the repetitive activities.

The system contemplates obtaining three frames that come from the n postures evaluated in certain times. These three frames are managed internally by the data, i.e. each capture entails the depth data that the body adjusts to the mean of evaluation of the inadequate posture. Each inadequate posture or evaluated by the method entails the study of the angles that exceeded for this posture in addition to the time of repetition in the activity.

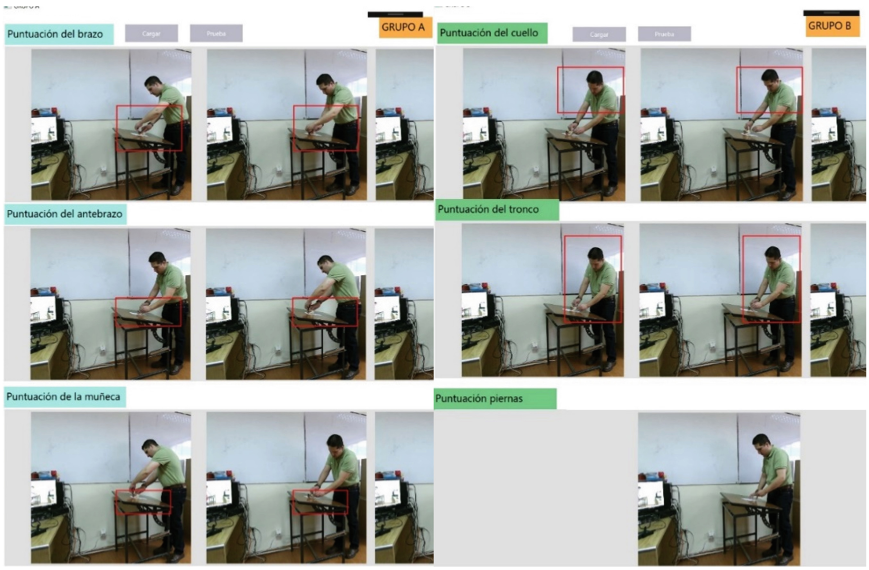

Fig. 7. Implementation of a system in workstations of a cutting company.

As a previous point of investigation, it was established that the data obtained in the assessment of the wrist may contain errors, due to the distance of evaluation of the sensor with the person. In order to parameterize these values and obtain data closer to reality, it was decided to use an additional evaluation sensor which through stable programming a deeper approach to the hands of the person evaluated. In projection the turns of the wrists are determined by a rotation matrix which determines data in depth of the person.

Once the evaluation is completed, we proceed to the creation of reports which, with generated by the system, taking into account that, if there are additional data in the methodology tells us that, if there is any kind of load, if the limb is on one side of the body, if there are forced flexions, if abduction data, and so on. These data allow us to determine the risk level of the posture or activity that the person is performing.

4 Results

The method of development of dynamic systems, allows a restructuring based on the requirements of evaluation of the postures of each person and the type of activity performed (see Fig. 8). These activities are based on a previous study of the RULA methodology, the valuation times are determined by the precision required by the data. As it is a non-invasive system, it allows the worker to perform his task normally. In addition to the evaluation of the system, an expert in evaluation by means of an angle measurement instrument corroborates the data obtained with the sensor in the system.

Fig. 8. Development of dynamic systems (real-time evaluation method).

The results are divided into two phases: The first phase, seeks to obtain the joints of the person in a CSV configuration file, the saves an approximate 8000 tuples (rows) of information. Each stored data is processed and tied with the frames corresponding to the evaluation activity. The second phase, analyzes the data based on the tuples of the CSV as an internal process, each frame of the 1000 that can be extracted from each evaluation in a time of 5 min, is saved for the final report and the valuation belonging to the positions determined by RULA [29].

The results were validated in the laboratory tests comparing the direct measurements versus the measurements that the developed system took in the same position and instant of time.

Taking the result of group A, the rating of the arm is 4 for the right side and 3 for the left side. These values are obtained by the frame that establishes that the angle of the arm was 41°, or; this means that the values of the evaluation angle in the methodology exceeds 20° of extension giving a value of 2, after that is added 2 additional points because there is abduction and has the shoulder elevated (see Fig. 9).

Taking the result of group B, the value of the neck is 3. This value is determined by the degree of flexion that the worker evaluated has which for this case is 57°; this

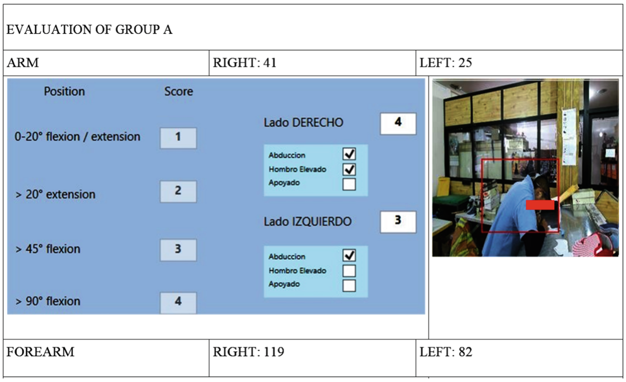

Fig. 9. Scheme of results produced by the system, group A.

means that the values of the evaluation angle in the methodology exceed 20° of flexion giving a value of 3, this is determined by a certain time of valuation that is contemplated in the RULA methodology as repetitive activity (see Fig. 10).

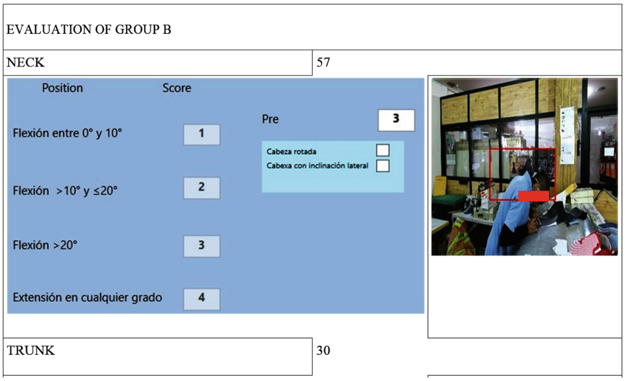

Fig. 10. Scheme of results produced by the system, group B.

For more detailed information, the evaluation parameters of the system are presented. The data obtained from the neck within the template is determined by (see Fig. 11); the activity performed by the person, the evaluation side with respect to the sensor, the percentage time of the frames, the time that the activity lasted with that working angle, the total number of frames within a range of 1 to 5000, time and date of evaluation, the angle, the most representative frame for the report and finally is determined based on the percentage of type and the most inappropriate posture with the frame selected for a previous result of the risk level.

Therefore, the final score of the RULA assessment method within the system tells us that for the right side we have a risk level 4 and for the left side we have that the risk level is 3 (see Fig. 12). These determinations and values are born from the RULA score

NECK					

ACTIVITY:	CUT _M	ACTIVITY:	CUT _M	ACTIVITY:	CUT _M
SIDE:	RIGHT	SIDE:	RIGHT	SIDE:	RIGHT
TIME FR(%):	69	TIME FR(%):	44	TIME FR(%):	79
MIN/SEG:	7 / 08	MIN/SEG:	6 / 39	MIN/SEG:	8 / 01
PHOTOGRAMS EVALUATED (5000):	3777	PHOTOGRAMS EVALUATED (5000):	3587	PHOTOGRAMS EVALUATED (5000):	4877
TIME:	2018-04-05 10:52:26	TIME:	2018-04-05 10:57:14	TIME:	2018-04-05 10:54:10
ANGLE:	55	ANGLE:	36	ANGLE:	57
NUM_ PHOTOGRAM:	1992	NUM_ PHOTOGRAM:	6444	NUM_ PHOTOGRAM:	3549
NUM_ PHOTOGRAM SELECTED:					3549

Fig. 11. Summary of results after valuation.

tables. Each value was from the systematization of the data corresponding to each person evaluated. Once the results are presented, they are validated with respect to the visual perspective of the frame found with the highest level of risk, which additionally allows access to the other frames obtained in that evaluation time.

SCORES FOR GROUPS A AND B				
GROUP A				
ARM R	4		ARM L	3
ANTEBRAZE R	3		ANTEBRAZE L	1
WRIST R	2		WRIST L	1
TURN	1		TURN	1
SCORE A ON THE RIGHT SIDE	4		SCORE A ON THE LEFT SIDE	3
ACTIVITY _M	1		ACTIVITY _M	1
LOAD / FORCE	0		LOAD / FORCE	0
SCORE C RIGHT SIDE	5		SCORE C LEFT SIDE	4
GROUP B				
NECK	3			
TRUNK	4			
LEGS	1			
SCORE B	5			
ACTIVITY _M	1			
LOAD / FORCE	0			
SCORE D	6			
FINAL SCORE RULA				
RIGHT	7	LEFT	6	
	LEVEL: 4		LEVEL: 3	
Se requieren cambios urgentes en la tarea		Se requiere el rediseño de la tarea		

Fig. 12. Format of the report of the result of the evaluation and ergonomic risk assessment

5 Conclusions

The semi-automatic system of ergonomic evaluation with the developed sensor proves to be a non-invasive method that allows the worker to carry out his activities in a natural way making the data more real and reliable, allowing also the discovery of the ergonomic risk associated to the postures in a task with precision, thus reducing the errors of estimation of measures taken by the evaluators with a direct measurement; in addition that reduces considerably the time in the development of an ergonomic evaluation.

The ergonomic evaluation method recommended for the development of the software in the cutting activity is the RULA method, because the activity has a high level of repeatability and requires the movement of the upper extremities, in addition its application in real working environments is more recommended.

In manual cutting, of the companies studied with this type of cut, 33% have level of critical risk in the workplace, so it is recommended according to the methods of postural evaluation that changes are made in the task urgently. And 67% of the companies have a high level of risk in the work area, which indicates that a redesign of the task or job is required. Determining based on these results that manual cutting activity is riskier than die cutting activity. Therefore, the ergonomic evaluation system with the non-invasive sensor found performance levels of manual jobs at 13% for jobs that may require task changes, 65% for jobs that require task redesign and 22% for jobs that require urgent changes in the task of 23 evaluated manual cut jobs.

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