Development of esMOCA RULA, Motion Capture Instrumentation for RULA Assessment

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Abstract. The purpose of this research is to build motion capture instrumentation using sensors fusion accelerometer and gyroscope to assist in RULA assessment. Data processing of sensor orientation is done in every sensor node by digital motion processor. Nine sensors are placed in the upper limb of operator subject. Development of kinematics model is done with Simmechanic Simulink. This kinematics model receives streaming data from sensors via wireless sensors network. The output of the kinematics model is the relative angular angle between upper limb members and visualized on the monitor. This angular information is compared to the look-up table of the RULA worksheet and gives the RULA score. The assessment result of the instrument is compared with the result of the assessment by rula assessors. To sum up, there is no significant difference of assessment by the instrument with an assessment by an assessor.

1. Introduction

An ergonomic assessment is conducted to ensure that the operator's work environment is ergonomically designed to minimize injury risk and maximize productivity. There are many methods of ergonomic assessment with specific objectives. Among the assessment tools for assessing musculoskeletal risk are Rapid Upper Limb Assessment (RULA). RULA provides an easily calculated rating of musculoskeletal loads in tasks where people have a risk of neck and upper-limb loading. The tool provides a single score as a “snapshot” of the task, which is a rating of the posture, force, and movement required. The risk is calculated into a score of 1 (low) to 7 (high)[1]

2. Related work

The limitations in the ergonomic assessment are the availability of qualified assessors. So some researchers developed a tool for conducting an ergonomic assessment [2,3,4,5,6,7] . Among the tools developed using motion capture-based cameras [2][8], and inertia measurement unit (IMU) based [3][9][10][11]. ergonomic assessment process automation always begins with capturing subject movement data. Furthermore, in computer applications built Digital Human Modeling (DHM) based on anthropometry data [4][7][11]. DHM receives body motion capture data and provides output data of the relative angle of the limbs, the force and moment at the joint, and the results of the ergonomic assessment.
Examples of motion capture system applications for posture reliability analysis work [12], for physiotherapy [13], for risk analysis on the shoulders and back [5]. The app is still in lab scale. However there are studies that apply ergonomic assessment to real activities. Golabchi uses his application for the assessment of construction workers [6]. Endo uses his application for the camera user’s hand analysis [14][15]. Sinden performs fire worker’s occupational assessment using the application it builds [8]. Even miller uses motion capture for analysis using a teleoperator arm [10]

3. Overview of system

The esMOCA RULA instrument is composed of two sub-systems, wireless sensor network subsystems and esMOCA RULA application subsystem (figure 1). The wireless sensor network subsystem consists of 9 sensor nodes and a wifi router to connect the sensors network to the computer. Sensor nodes have been built using MPU6050 sensor and wifi microcontroller ESP8266. The data communication between the sensor nodes and the computer runs through the UDP protocol on the IP network. The esMOCA RULA application is built using Matlab Simulink. Data capture to receive data from sensors is built using data acquisition toolbox while Digital Human Modeling (DHM) and inverse kinematic are built with simmechanic toolbox. The installation of 9 sensor nodes is schematically shown in Figure 2a. Figure 2.b shows the installation of each sensor on the low back, spine, head, hand, forearm, upper arm, and DHM illustration in Figure 2.c.

![Figure 1. block diagram of esMOCA RULA](image)

![Figure 2. (a). Sensors placement, (b). Sensors installment, (c). Digital Human Modelling.](image)

4. Experimental setup

This study aims to compare the RULA assessments performed by esMOCA RULA instruments with those done by RULA assessors. Three RULA assessors were involved in the study. They were asked to provide a simultaneous and independent RULA assessment of the two observed worker subject positions (figures 3, a and b). At the same time, the ESMOCA instrument captures the motion of the same observed subject and performs the RULA assessment. The ESMOCA instrument displays the
RULA score in real-time. After the subjects' observations were completed, the five assessors held a consensus of the RULA score. This consensus-based RULA score was compared with the RULA rating by the ESMOCA instrument.

5. Result and discussion

Assessment of the limbs by the three assessors performed independently so that will produce a different score as well. Then they consensus for the final value of their RULA assessment. Table 1 shows the results of the RULA score score for posture 1 by three independent assessors and the final consensus by the three assessors. In the same table also presented the results of RULA assessment by esMOCA RULA. The same consensus score as EsMOCA RULA score is the lower arm score and wrist twist score. While upper arm segment, wrist, neck and trunk have different score between esMOCA RULA with consensus of assessors. Assessment of RULA for posture 2 by three independent assessors and their consensus including assessment by esMOCA RULA is presented in Table 2. Rula score of three assessors are 5,6,6 respectively, and they agree on a score of 6 by consensus. the RULA score consensus by these assessors is identical to the RULA score by esMOCA RULA. Consensus RULES score that is identical to ESMOCA RULA score is lower arm score and wrist twist score. While upper arm segment, wrist, neck and trunk have different score between esMOCA RULA with consensus of assessors.

| Score                          | Assessor 1 | Assessor 2 | Assessor 3 | Consensus | esMOCA RULA |
|--------------------------------|------------|------------|------------|-----------|-------------|
| Upper Arm                      | 4          | 4          | 4          | 4         | 2           |
| Lower Arm                      | 3          | 3          | 3          | 3         | 3           |
| Wrist                          | 3          | 4          | 3          | 3         | 4           |
| Wrist Twist                    | 1          | 1          | 1          | 1         | 1           |
| Posture A                      | 5          | 6          | 5          | 5         | 5           |
| Muscle Use                     | 1          | 1          | 1          | 1         | 1           |
| Force/Load                     | 0          | 0          | 0          | 0         | 0           |
| Wrist & Arm                    | 6          | 7          | 6          | 6         | 6           |
| Neck                           | 3          | 3          | 3          | 3         | 4           |
| Trunk                          | 3          | 3          | 3          | 3         | 1           |
| Leg                            | 2          | 2          | 2          | 2         | 2           |
| Posture B                      | 5          | 5          | 5          | 5         | 5           |
| Muscle Use                     | 1          | 1          | 1          | 1         | 1           |
| Force/Load                     | 0          | 0          | 0          | 0         | 0           |

Figure 3. The two observed worker subject positions.
Neck, Trunk, Leg
RULA Score: 7

There are still differences in ESMOCA RULA score with consensus of RULA score of the assessors. This difference is encountered in the upper arm segment, wrist, neck and trunk. This difference comes from two causes are differences in perceptions of the assessors and the alignment sensor in the upper body limb arm, wrist, neck and trunk are less precise.

It was observed that esMOCA RULA instruments can perform real-time assessments with final RULA scores identical to independent assessors. Whereas independent assessors take 17 to 48 minutes to complete angle calculations and RULA assessments. From these results ESMOCA RULA instruments have the potential to be further developed into RULA assessment instruments or as a tool to train novice assessors in conducting RULA assessments.

| Score | Assessor 1 | Assessor 2 | Assessor 3 | Consensus | esMOCA RULA |
|-------|------------|------------|------------|------------|-------------|
| Upper Arm | 3 | 3 | 3 | 3 | 1 |
| Lower Arm | 3 | 3 | 3 | 3 | 3 |
| Wrist | 3 | 4 | 4 | 3 | 4 |
| Wrist Twist | 1 | 1 | 1 | 1 | 1 |
| Posture A | 4 | 5 | 5 | 4 | 4 |
| Muscle Use | 1 | 1 | 1 | 1 | 1 |
| Force/Load | 0 | 0 | 0 | 0 | 0 |
| Wrist & Arm | 5 | 6 | 6 | 5 | 5 |
| Neck | 1 | 1 | 2 | 3 | 4 |
| Trunk | 2 | 2 | 2 | 2 | 1 |
| Leg | 2 | 2 | 2 | 2 | 2 |
| Posture B | 3 | 3 | 3 | 4 | 5 |
| Muscle Use | 1 | 1 | 1 | 1 | 1 |
| Force/Load | 0 | 0 | 0 | 0 | 0 |
| Neck, Trunk, Leg | 4 | 4 | 4 | 5 | 6 |
| RULA Score | 5 | 6 | 6 | 6 | 7 |

6. Conclusion

The esMOCA RULA instrument has been successfully built and is capable of performing real time RULA assessments with high precision. The initial phase of this development has the potential to be further developed to become a standard instrument in the assessment of RULA or developed to assist the learning process of novice RULA assessors.

References

[1] N. Stanton, A. Hedge, K. Brookhuis, E. Salas, and H. Hendrick, *Handbook of Human Factors and Ergonomics Methods*, vol. 1, no. 1. CRC Press LLC, 2005.

[2] S. Duong and M. Choi, “Interactive Full-Body Motion Capture Using Infrared Sensor Network,” *International Journal of Computer Graphics & Animation*, vol. 3, no. 4, pp. 41–56, 2013.
[3] T. S. Young, R. J. Teather, and I. S. Mackenzie, “An Arm-Mounted Inertial Controller for 6DOF Input: Design and Evaluation,” in *IEEE Symposium on 3D Interfaces*, 2017, pp. 26–35.

[4] G. De Magistris, A. Micaelli, P. Evrard, C. Andriot, J. Savin, C. Gaudez, and J. Marsot, “Dynamic control of DHM for ergonomic assessments,” *International Journal of Industrial Ergonomics*, vol. 43, pp. 170–172, 2013.

[5] M. C. Schall, “Application of inertial measurement units for directly measuring occupational exposure to non-neutral postures of the low back and shoulder,” University of Iowa, 2014.

[6] A. Golabchi, S. Han, and A. R. Fayek, “A Fuzzy Logic Approach to Posture-based Ergonomic Analysis for Field Observation and Assessment of Construction Manual Operations,” *Canadian Journal of Civil Engineering*, 2015.

[7] M. Satheeshkumar and K. Krishnakumar, “Digital Human Modeling Approach in Ergonomic Design and Evaluation - A Review,” *International Journal of Scientific & Engineering Research*, vol. 5, no. 7, pp. 617–623, 2014.

[8] K. E. Sinden, J. C. Macdermid, T. R. Jenkyn, S. Moll, and R. D. Amico, “Evaluating the Reliability of a Marker-Less, Digital Video Analysis Approach to Characterize Fire-fighter Trunk and Knee Postures During a Lift Task: A Proof-of-Concept Study,” *Journal of Ergonomics*, vol. 6, no. 1, pp. 1–10, 2016.

[9] H. Fabian, R. Zhang, and L. M. Reindl, “A Wireless Micro Inertial Measurement Unit (IMU),” in *IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT*, 2012, pp. 1–17.

[10] N. Miller, O. C. Jenkins, M. Kallmann, and M. J. Mataric, “Motion Capture from Inertial Sensing for Untethered Humanoid Teleoperation,” *International Journal of Humanoid Robotics*, 2004.

[11] X. Li, S. Han, M. Gül, and M. Al-hussein, “Automated Ergonomic Risk Assessment based on 3D Visualization,” no. Isarc, 2017.

[12] R. Hough and R. Nel, “intra-rater reliability of the Posture analysis tool kit,” *SA Journal of Occupational Therapy*, vol. 43, no. 1, 2013.

[13] C. Lai, S. Tseng, C. Huang, C. Pei, W. Chi, L. Hsu, and T. Sun, “Fun and Accurate Static Balance Training to Enhance Fall Prevention Ability of Aged Adults: A Preliminary Study,” *Human Factors and Ergonomics in Manufacturing & Service Industries*, vol. 01, no. 0, pp. 1–11, 2012.

[14] Y. Endo, S. Kanai, N. Miyata, M. Kouchi, M. Mochimaru, J. Konno, M. Ogasawara, and M. Shimokawa, “Optimization-Based Grasp Posture Generation Method of Digital Hand for Virtual Ergonomics Assessment,” *SAE international Journal Passenger Cars - Electronic System*, vol. 1, no. 1, 2008.

[15] Y. Endo, S. Kanai, N. Miyata, and M. Kouchi, “Virtual Grasping Assessment Using 3D Digital Hand Model.”