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by Iwan Iwan

Real Time Floor Sitting Posture Monitoring using K-Means Clustering

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ABSTRACT

The production of *Emping Melinjo* is one of cottage industries in *Cilegon, Banten*, which has a great potential to grow because of the high demand of the product. The major workforces in the production are females who do the labor at home. However, due to the traditional practice in the activity, workforces conduct their activities while sitting on the floor and this turned to be a potential health problem during work, such as LBP (Low Back Pain). In this paper, we proposed to build the data acquisition system for working posture and build the monitoring system that can prevent static postures. This proposed system is based on positioning posture with data clustering method using pressure measurement by 4 position sensors. Based on these 5 clusters, we defined the tracking postures as: in the middle position, backward position, forward sitting posture, and laterally tilted left or right sitting posture.

CCS Concepts

•Computing methodologies→Machine learning→Learning paradigms→Unsupervised learning→Cluster analysis

Keywords

Low Back Pain; Sensor; Static Sitting Posture; Data Acquisition; Clustering.

1. INTRODUCTION

The production of *Emping melinjo* is one of agroindustry-products which have a great potential to be developed since it contributed more on economic growth by creating job opportunities and alleviating poverty. In the current situation, this industry appeals well as a family economic activity in which it is easily implemented, can be done as part-time job and does not require any special skill so that rural women or housewives can run both public role and domestic role at the same time. Commonly, this production activity is performed manually on the floor and this job was classified as a repetitive task, implying that it has major risk factor that is associated with musculoskeletal symptoms. As a nature of traditional, cottage industries, on-floor or ground sitting postures are unsurprisingly popular, as portrayed in Figure 1. References often assume such awkward sitting postures, if maintained for prolonged period, would likely be a risk factor for low back pain (LBP)[1][2]. Thus, the purposes of this study are to assess the movement of body postures in real-time on-floor work and to identify the static and awkward sitting postures during work in definite interval.

The optimal occupational sitting position and sitting behavior has been extensively discussed in the literature during recent years. They discussed about the thought of an ideal sitting position with upright posture has been strongly questioned [3] and has been slowly replaced by the concept of "Dynamic Sitting". A literature review conducted by Pynt et al.(2001) [4] suggests that there is no ideal sitting posture. According to these authors, some regular movements and a good seated posture is essential for preventing LBP [5][6].

In this case, pressure sensors have been widely used to identify the working posture in real time. In previous research, many systems tended to use components like force sensitive resistors (FSR) that connected to circuit boards (PCBs) [7]. Furthermore, all this sensors are attached to microcontrollers such as Arduino to get real time data acquisition using laptop.

Recent advances in real time measurement and data mining problems have proposed the use of machine learning algorithms in many researches. In this case we are agree that machine learning algorithms have the advantage of minimizing errors by training the problems through optimization and tuning and have recently been used in various practices, such as classification of sitting postures [8–12]. However, in the classification of sitting postures, the system needs to be calibrated (trained) well. In this study, we would like to propose another perspective of machine learning by using clustering method to analyze the on-floor sitting position and classify data with identical characteristics into certain classes in which the similarity of intra-class is maximized or minimized [13]. The limitation of this study is the data was obtained from female worker only and ruled out the environmental factors.

2. METHODS

2.1 Definition of Floor Sitting Posture

The initial step in this research was analyzing the posture of workers during approximately 5 hours of working a day. The

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workers did their activity in on-floor sitting position as presented in Figure 1. This step included the analysis of the relation between sitting posture to LBP, which was completed by questionnaire spread to random female workers in the cottage industry area and by using SPSS to process the data.

Figure 1. The on-floor working posture

The results of SPSS are as shown in Table 1, indicating that there was a significant correlation between working posture, particularly static posture, to the LBP. In detail, the LBP was correlated to static position with a correlation efficient of 0.786 by Kendall's test and 0.870 by Spearman test.

Next, based on the observation to the working posture, we assumed the classification of the on-floor sitting postures were as follows: middle position, backward position, forward sitting posture, and laterally tilted to the left or right sitting posture. From this classification, we analyzed the number of objects in the clusters which were considered to be representing the working postures in the process of *emping* production

Table 1. Correlation analysis between LBP and static position

Correlations

			LBP	Static Position
Kendall's tau_b	LBP	Correlation Coefficient	1.000	.786**
		Sig. (2-tailed)	.	.000
		N	20	20
	Static Position	Correlation Coefficient	.786**	1.000
		Sig. (2-tailed)	.000	.
		N	20	20
Spearman's rho	LBP	Correlation Coefficient	1.000	.870**
		Sig. (2-tailed)	.	.000
		N	20	20
	Static Position	Correlation Coefficient	.870**	1.000
		Sig. (2-tailed)	.000	.
		N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

2.2 System

This research was developed based on concept that the pressure sensing interfaces have demonstrated a good accuracy in the detection and tracking of posture for research purpose. In our work, we used the fabric based pressure sensor namely FSR Interlink 406 Square form; with the advantages of its flexibility in placement position, not expensive and easy to connect with microcontroller [14]. Due to the fabric nature of this sensing method, it has vast potential to be embedded into several common objects that we daily interact with. We used conductive fabric-based sensors on a chair to monitor real time movements in a user's sitting posture. The positioning of sensors S1, S2, S3 and S4 is shown in Figure 2.

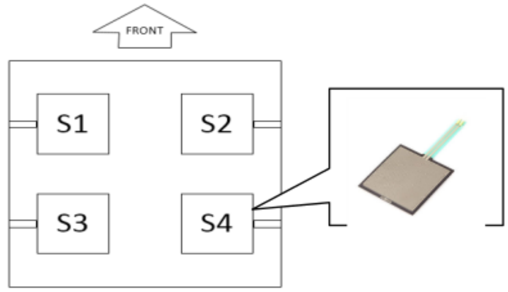


Figure 2. The arrangement and structure of FSR pressure sensor

In this study, we divided our system into 2 phases. Firstly, we set the system as real time data acquisition to collect the posture data during all-day work using Excel PLX-DAQ. Next, we designed the system to monitor the good practice of ground-sitting working postures and movements by using 4 sensors to collect the data within 3 minutes interval. This arrangement is unique to our system.

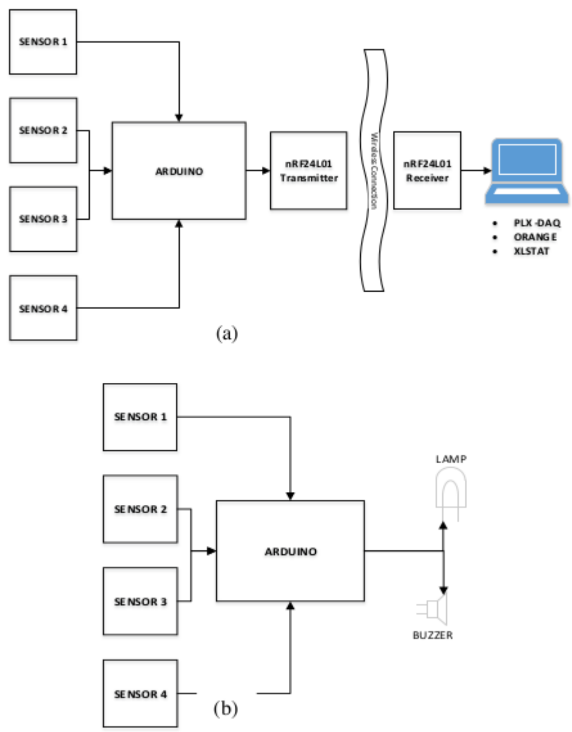


Figure 3. The structure of two modes of proposed system (a) Data acquisition mode, and (b) Monitoring mode

The main components of the sensor cushion are described in Figure 3 as data acquisition then applied for monitoring mode, using seat (foam cushion) that attached the four square-formed pressure sensors FSR Interlink 406, NRF24L01 wireless communication and a power bank for power supply. All components were connected to Arduino Uno Microcontroller that encased in the lower left side of the seat cushion. The encased panel has lamp to notify the user about the connection and power status, and the alert for work posture.

3. RESULT AND DISCUSSION

3.1 Clustering

It is necessary to get real-time data during the working time for initial step of clustering, thus the system was set as a data acquisition system. Additionally, we have developed the system using wireless data acquisition system to improve the convenience in the time-consuming data acquisition process.

In real-time we set the real-time data collecting with interval of 1 minute while the working hour was 4 hours a day, resulting the dataset obtained was 240 data of work postures for each female worker. To obtain proportional data within each posture, we have briefed the female workers to move their body in five certain ways in each interval.

Next, we analyzed these data using Orange data mining software to find the optimal cluster of the data as schemed in Figure 4.

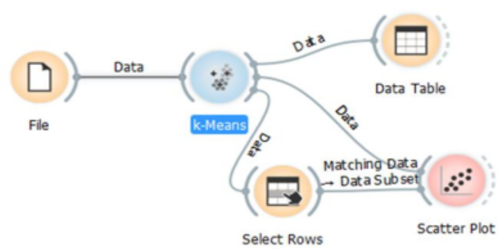


Figure 4. The model of K-Means Algorithm in Orange

In this work, we used scoring with Silhouette (heuristic) to find out the optimal cluster while for distance measurement we employed Euclidean method and random initialization. Data analysis performed using Orange resulted in output showing the optimal cluster for 4 working-hour data was 5 Cluster (k=5), as shown in Figure 5.

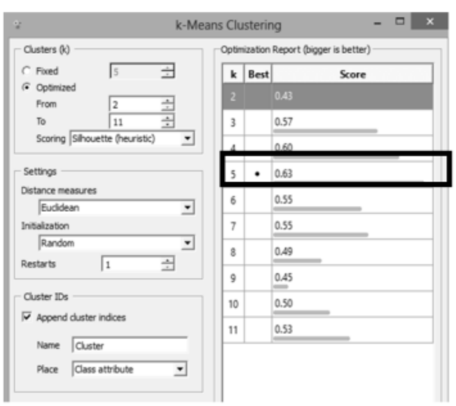
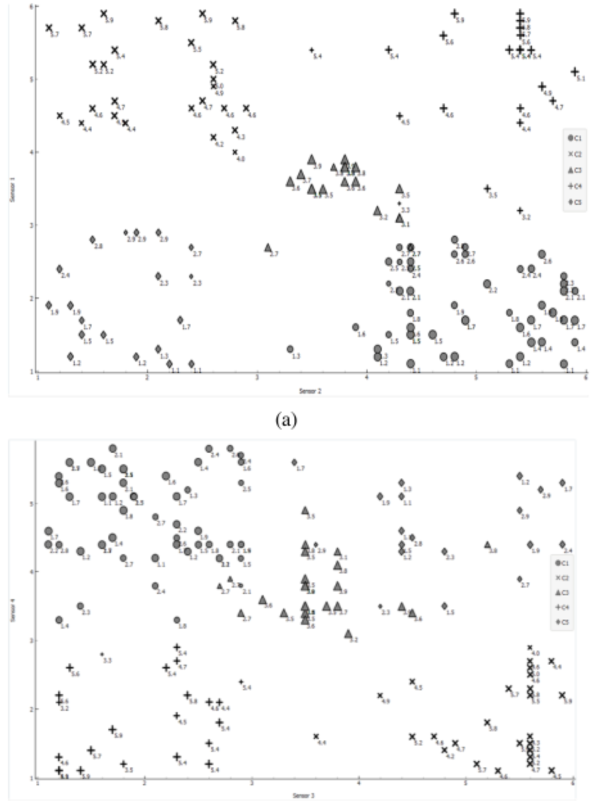


Figure 5. The number of cluster optimization report

3.2 Tracking postures

For tracking posture monitoring, we determined the most optimal number of cluster was 5 (k=5). The optimal cluster obtained from Orange data mining software and as well the output of the scatterplot is shown in Figure 6.



(a)

(b)

Figure 6. The Scatterplot of (a) Sensor 1 and 2 , (b) Sensor 3 and 4

Based on these 5 clusters, we defined the tracking postures as: in the middle position, backward position, forward sitting posture, and laterally tilted left or right sitting posture.

Next, we run the K-means algorithm in XLSTAT to discover the centroid of each cluster, shown in Table 2, and some results from each class are shown in Table 3. These centroids were set into the rules in Arduino to track the posture movement.

Table 2. Centroid Coordinate of each cluster

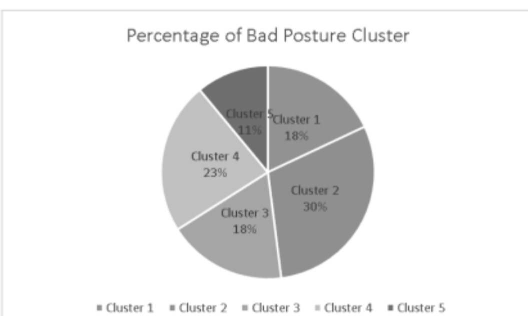
Class	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Within-class variance
1	4.875	2.150	5.319	1.869	1.326
2	1.921	5.095	1.979	4.747	1.676
3	5.004	5.113	1.965	1.883	1.703
4	1.963	1.811	4.795	4.637	1.594
5	3.609	3.774	3.696	3.770	0.535

Table 3. Clustering by good posture class

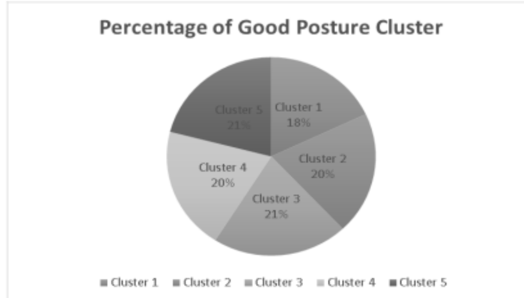
Class	1	2	3	4	5
Objects	44	47	51	47	51
Sum of weights	44	47	51	47	51
Within-class variance	1.326	1.676	1.703	1.594	0.535
Minimum distance to centroid	0.682	0.592	0.831	0.557	0.277
Average distance to centroid	1.074	1.225	1.224	1.196	0.640
Maximum distance to centroid	1.953	1.903	2.131	1.764	1.644

Table 4. Clustering by bad posture class

Class	1	2	3	4	5
Objects	44	72	42	55	27
Sum of weights	44	72	42	55	27
Within-class variance	1.323	1.461	0.664	1.703	1.594
Minimum distance to centroid	0.706	0.475	0.312	0.831	0.557
Average distance to centroid	1.097	1.161	0.707	1.224	1.196
Maximum distance to centroid	1.908	2.058	1.758	2.131	1.764



(a)



(b)

Figure 7. (a) The pie chart of bad posture clustering ,(b) The pie chart of good posture clustering

3.3 Discussion

In this study, we proposed a system to monitor five on-floor sitting positions by mounting only four low-cost load cells onto the seat cushion to obtain real-time data during all-day working time using clustering method. The system consisted of two modes: data acquisition mode and another mode for tracking or monitoring the working posture in real time basis.

The results of K-means optimal clustering using Orange data mining software disclosed that five position (k=5) was the most optimal number for clustering the pressure sensors data with highest silhouette score of 0.63. With this 5 clusters of: middle position, backward position, forward sitting posture, and laterally tilted left or right sitting posture, we proposed the system monitoring to prevent bad work posture using Arduino that was supplied with lamp and buzzer.

As a result of tracking the working position using clustering method, by assessing the number of objects in each cluster and comparing it to the other clusters, this system has succeeded to recognize the differences of working postures between each worker. When the number of objects of each cluster is relatively uniform, it represents that the operator conducted good working postures, and vice versa. Furthermore, this system was connected with buzzer to inform the working condition of bad postures. After we tested the system during real working time in this *emping melinjo* cottage industry, the system has succeeded in reducing the occurrences of bad postures, especially static working postures within the time interval of 3 minutes..

4. SUMMARY

To summarize, this present study has demonstrated the ability of sensor technology along with machine learning analyses to accurately cluster the various on-floor sitting positions. The appliance of such novel approaches, namely performing direct assessment with real time system with buzzer, could be a promising option for development as to prevent bad working posture due to on-floor sitting during work, which may cause LBP specially for repetitive working type. Future studies will also explore how the reliable of related measures correlate with operator performance or injury.

5. ACKNOWLEDGMENTS

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