The Head Posture System Based on 3 Inertial Sensors and Machine Learning Models: Offline Analyze

Conference Paper · December 2020

DOI: 10.1109/ISRITI51436.2020.9315418

1 author:

Severin Cristian Ionut
Gheorghe Asachi Technical University of Iasi

The Head Posture System Based on 3 Inertial Sensors and Machine Learning Models: Offline Analyze

Ionuț-Cristian Severin
Applied Electronics and Intelligent Systems
"Gheorghe Asachi" Technical University of Iasi
Bd. Carol I, No. 11 A, Iasi 700506, România
ionut.severin@etti.tuiasi.ro

2020 3rd International Seminar on Research of Information Technology and Intelligent Systems (ISRITI) | 978-1-7281-8406-7/20/$31.00 ©2020 IEEE | DOI: 10.1109/ISRITI51436.2020.9315418

***Abstract*—The current paper proposes and presents a new wearable system for head posture recognition, based on three inertial sensors used to prevent inadequate head posture during different office daily activities. During this experiment, 9 daily office activities were evaluated. The proposed model distinguished between bad or good posture with a high accuracy using the inertial time series's raw data. The performance of the proposed wearable system was evaluated offline with the help of machine learning algorithms. The advantage of the proposed approach is the possibility of transmitting data through the Wi-Fi connection, portability, low cost, and high performance. During this experiment, the best classification performances it was obtained with Decision Extra Trees Classifier, that was achieved an accuracy equal to 96.78 %.**

***Keywords*—Head Posture, Machine Learning algorithms, IMU, Wearable Wi-Fi system, Office worker posture, Posture correction system.**

I. Introduction

Today, modern human life is characterized more and more by the extensive use of technology (e.g., mobile phones, laptops, smartwatches, etc.). This was caused by the fact that technological progress has seen a significant increase in recent years. This has led to the emergence of many jobs requiring workers to sit in front of a computer for many hours in an improper body posture. This generates many cases of illness due to an incorrect position of the spine among office workers. This paper's focus is put on the analysis of head bad posture to determine and prevent the syndrome of forward-head posture (FHP). This syndrome is common among office workers because some adopt wrong neck postures with heads bent down for a long time. This leads to back pain, neck pain, leg pain, numbness, headaches, etc. [1, 2, 3, 4]. According to the survey performed on 200 people presented in [5], it is presented that 76 % of them do not practice good posture during the working day. While more than 90% experience back pain occasionally or permanently. This unintentional approach of posture, used during the day, can slowly change the body's structure for the long term. For this reason, the possibility of having a device that monitors head posture the entire working day is critical. This system should satisfy requirements as portability, low cost, low complexity, easy to use by any users, and high-performance. After a preliminary inspection of the technical literature, it was observed the fact that many approaches are based on contact sensors, such it is flex sensors [6], textile piezoresistive pressure sensors [7], force-sensing resistors [8], accelerometers [9], gyroscope [10], etc. Most applications used to monitor body posture based on the sensors mentioned above offer excellent performance on the rate of classification and detection of body position. However, almost all systems presented in the literature present limitations from the perspective of usability in daily life. Most prototypes were tested, and it can only be utilized within the confines of a laboratory [11, 12]. In this study, a wearable Wi-Fi system was designed to monitor head posture, based on 3 inertial sensors placed on a neck belt. The proposed system uses two 9DOF inertial sensors (MPU 9250) and a 6 DOF inertial sensor (MPU 6050). The computational step was performed using a NodeMCU development board that transmits data through a local Wi-Fi network station. For the classification side, in this study, it was used 8 classification methods to classify 9 daily office activities. Each set of activities was measured twice in order to simulate the good and bad head posture. For this experiment, a new database was created with acquired data from 3 volunteers ages 20 and 27. During the experimental trial, excellent obtained performances suggest the high potential of the presented approach. Although the number of measurements used in this experiment is relatively small, the results obtained in this paper can be considered as a starting point for further researches. The contribution of this paper to the HCI or medical field consists in the fact that a new portable system capable of being used by office workers has been proposed. The proposed approach also satisfied the condition of portability, cost, and performance, and from these reasons can be used the entire workday. The final contribution that can be considered is provided by the offline analysis based on the machine learning algorithms, which will be a subject of research for further studies.

II. Related Work

Because shortly, the number of jobs requiring the use of information devices, will increase significantly, spine illness will become a common problem for most people. This thing is also favored by the current conditions under which, in order to avoid the spread of the risk of COVID-19 infection, more and more people work from home. This thing increases the risk of spine complications that lead to headaches, back pain, etc., as a consequence of approaching an incorrect position and lack of movement for a long time. This thing highlights the topicality of the presented experiment and the importance of the contributions brought by this analysis in the current context. In [13], Han et al. proposed and introduce a system based on a three-axial magnetometer paired with a miniature permanent magnet. Their system is designed to detect the level of risk in the form of Normal, Warning, and Dangerous state. They suggest that this approach achieves an accuracy equal to ~95.6 %. Another solution provided by Dunne et al. [6] was based on a fiber optic sensor to determine the spine posture. Their solution offers a good accuracy equal to 96 %. In this case, the main limitation is related to the prototype itself, which has low portability and requires preliminary preparation. Zhang et al. propose a postural rehabilitation system based on Microsoft-Kinect technology [14]. This kind of sensor is more accurate than an inertial sensor, but the complexity and cost are significantly high. In their experiment was evidenced an overall accuracy of 99.14%. Another research, presented by Tanaka et al., suggests that their postural monitor system provides accuracy equal to 75 % in laptop use and 100% in mobile phone use [15]. Their design uses a front-facing camera, in the case of a laptop side, and a smart glass prototype to monitor the posture in the case of a mobile phone. In their research, Kim et al. had used 3 accelerometers placed on the front of the head, neck, and back [16]. They suggest that this approach provides accuracy equal to 94.5%. Although their system offers a good classification rate, the principal limitation is related to the prototype itself that is hard to be extended for daily usage.

This research aimed to determine and evaluate the newly proposed head posture system's classification performances based on 3 inertial sensors. For this study, the analyzes were performed offline with the help of Machine Learning algorithms. The current monitor system was designed in a previously published paper [17], where the focus was to propose and design a portable system to be used by an office worker. Compared to the previous work, in this paper, the proposed prototype was extended to have the possibility to transmit the data through Wi-Fi communication based on socket protocol. In the current paper, the proposed solution was evaluated with the help of machine learning algorithms, using a newly created database with data from 3 volunteers. Each volunteer who participated in this study had performed 9 predefined activity to simulate the real case. Each predefined action was executed twice. First, to simulate the normal posture, and second to simulate the abnormal posture. After evaluation, the machine learning algorithms' results suggest that the proposed postural monitor system can recognize the head posture with an accuracy equal to 96.98%.

III. Methodology

The back pain, neck pain, leg pain, numbness, or headaches [1, 2, 3, 4] is a common problem reported by office workers in the last decade due to long-time work in the front of the computer or adopting an inadequate posture. The primary intent of this paper is to acquire data from 3 inertial sensors and perform processing steps in order to be able to determine the quality of head posture from 9 daily activity. This paper's second scope was to select the best machine learning model to fit the acquired data. Our proposed system [17] is based on the 3 inertial sensors to determine the postural quality. Two of them are represented by MPU 9250, and the third is represented by MPU 6050 sensor. The MPU 9250 is a 9DOF inertial sensor with an accelerometer, gyroscope, and magnetometer sensor in its internal structure. In the current experiment, the MPU 6050 was used to determine the cervical angle. The 9DOF sensor was used to determine the tilting and twisting of the head. The sensors were placed on a neck belt, at an equal distance of 45 degrees between them. The computational step was performed with the help of the NodeMCU Wi-Fi development board. This device acquired data from all 3 inertial sensors and sent it to the windows python script through Wi-Fi protocol. In our case, all the 24-sample signals generated by the 3 inertial sensors (18 from MPU 9250 and 6 from MPU6050) were fused with the Kalman filter's help. This offers the possibility to reduce the number of sample signals from 24 to 9 through a 3D representation. The NodeMCU was able to acquire the inertial signals with a sampling period equal to 10ms. To send data in real-time, between NodeMCU and Windows script, in this experiment, the client-server model is used based on the socket approach. According to this approach, the NodeMCU was configured to work as a slave, while the python script that runs on the laptop was configured to work as a server. All data sent through the Wi-Fi network was automatically saved in an excel file. For this experiment, it was proposed and evaluate the quality of head posture from 9 human activity. The proposed activities are: reading a book from sitting on the chair position, using a mobile phone from stand up position, walking, relaxing position seated on the chair, writing on the notebook from the sitting position, writing on the laptop, stand up position, using a mobile phone from sitting position and watching a video movie from sitting position. The human activities listed above were chosen in such a way that to respect the main focus of the current research, where the proposed system should identify and prevent the wrong posture in the case of office workers. Also, an important point should be mention here. This is related to the fact that each human activity mentioned above was acquired from two perspectives. One is associated with normal posture, while the second one represents bad posture. For this reason, each involved volunteer in this experiment performed twice the measurement. For each motion, it was taken into consideration the normal stance of different activities as a reference, as presented in technical literature. This research involved 3 volunteers in all the experiments. Each of them was instructed to simulate normal posture and bad posture for the above-specified activities. Each involved volunteer had maintained each stance for 1.5 minutes. The intelligent computational step was performed with eight machine-learning algorithms. All the used intelligent computational algorithms are represented by: Random Forest Classifier (RFC), k-Neighbors Classifier (k-NN), Decision Tree Classifier (DTC), Extra Tree Classifier (ETC), Gaussian Naive Bayes (GNB), Logistic Regression Classifier (LR), Adaptive Boosting Classifier (ADAB) and Support Vector Machine (SVM). According to this, during the experimental trials, the best classification accuracy was obtained with the help of the Decision Trees Classifier, based on a 25% test set and a 75% training set. The classification rate, in this case, was equal to 96.98%. All analysis was performed in PyCharm 2017 Professional version. The computation tasks are performed on a Lenovo IdeaPad 700 laptop with an Intel Core i7 processor (CPU @2.59GHz, 4-cores, 8-logical Processors) and 8GB physical memory.

IV. Experimental setup

A. System layout

The postural system presented during this experiment is composed of 4 parts. The first part is represented by the inertial sensors that make possible the identification of head posture. The processing and filtering component represents the second part. At this level, the Kalman filter converts raw data into angles representation for each used inertial sensor. The NodeMCU development board performed all computational steps presented above. The Wi-Fi communication component represents the third part. At this level, it was created a socket communication channel between the NodeMCU development board and the Python application in order to send data between them. The Wi-Fi data reception and the classification system represent the last component of the presented solution. This step was done using a python application that took all of the data and pushed it automatically into an excel file. An offline analysis was performed based on 8 machine learning algorithms to determine the postural system's performance further. Fig.1 presents the block diagram of the proposed approach.

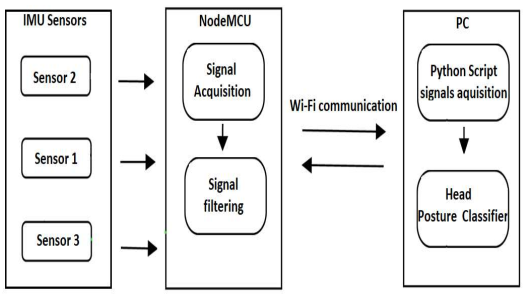

Fig.1. Block diagram of the postural system

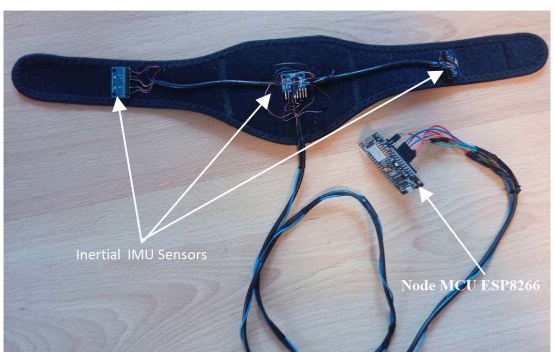

Fig.2. Head posture system

B. Hardware design

The proposed head postural system is based on the Node MCU ESP8266 wireless development board and three inertial sensors. This development board uses a Tensilica 32-bit RISC CPU Xtensa LX106 microprocessor. Also, this one operates between 80 MHz to 160 MHz adjustable frequency clock. The inertial sensors that were used in the postural system are represented by MPU 9250 and MPU 6050. The used components that compound this system provide a good balance between cost, portability, and performance. The experimental setup can be seen in Fig.2. In addition to the previously mentioned components, in this experiment, a 4400 mAh battery was used to power the system during the period when it was used.

C. Time series signal recording

During this research, 3 healthy volunteers were involved. Each of them had executed 9 predefined human activities from two points of view. The first approach focused on representing the normal posture, while the second was conducted to simulate the wrong posture. During the experiment, each of the three volunteers wore the proposed system and has executed the predefined activities. To mimic the incorrect posture, the published threshold from the medical literature suggests that a deviation of a cervical angle higher than 30 degrees is considered a dangerous stance. Taking into consideration this, in this experiment, the normal position of the head was supposed to be aligned with 90 degrees and a deviation of the cervical angle in a range of 0 to 20 degrees. Also, all deviation that is out of this range was considered to be a wrong posture. In order to define a standard reference (90-degree alignment), at the execution of each activity, was solicited to the volunteers to sit straight and look ahead to ensure that the head was on the same line with the body in the vertical direction. This position was maintained for 1.5 seconds. After that, to simulate a bad posture, the volunteers were solicited to bend the head forward with a deviation of more than 20 degrees. Also, this position was maintained for another 1.5s. The specified target activities, test the system from two points of view. This is represented by a static activity (e.g., writing, reading, etc.) and a dynamic activity (e.g., walking, stand up position, etc.). Through this, we tried to simulate real conditions in which the system is used in both static and dynamic office activities. During each measurement step, the data acquired from all 3 inertial sensors were saved into an excel file, located on the PC for subsequent processing.

D. Predictive Algorithms

In order to determine the classification performance of the proposed system, in this experiment, was used 8 supervised algorithms. These are represented by k-Neighbors Classifier (k-NN), Decision Tree Classifier (DTC), Gaussian Naive Bayes (GNB), Random Forest Classifier (RFC), Logistic Regression Classifier (LR), Adaptive Boosting Classifier (ADAB), Extra Tree Classifier (ETC) and Support Vector Machine (SVM). The used algorithms were trained with a 75% training set, while the test set was 25%. All the computational steps were performed in the python based on the "sklearn" library. The input data for the predictive model was used without any preparation (raw value) to determine the proposed system's initial performance.

E. Database

The final database used in this experiment to train and test all of the 8 predictive models include data from 3 volunteers. For each performed activity, in the final database, a target label will be used by the predictive model to classify it. The predefined activities are: reading a book from sitting on the chair position (A1 - Normal, A2 - Abnormal), using a mobile phone from stand up position (A3 - Normal, A4 - Abnormal), walking (A5 - Normal, A6- Abnormal), relaxing position sitting on the chair (A7 - Normal, A8 - Abnormal), writing on the notebook from the sitting position (A9- Normal, A10- Abnormal), writing on the laptop (A11- Normal, A12- Abnormal), stand up position (A13- Normal, A14- Abnormal), using a mobile phone from sitting position (A 15- Normal, A16- Abnormal) and watching a video movie from sitting position (A17- Normal, A18- Abnormal). In Fig. 3, it is illustrated the reading activity posture, from both approaches, good posture (a) and bad posture (b).

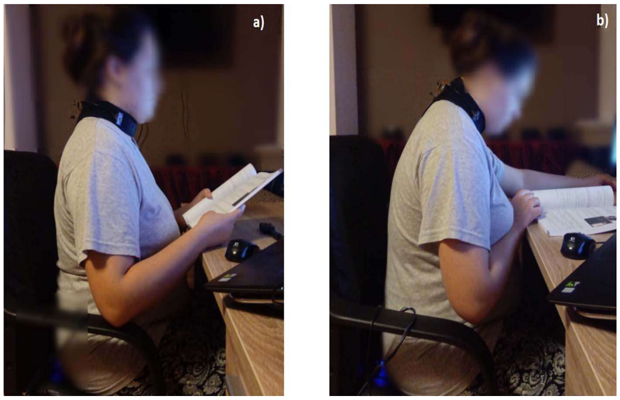

Fig.3. Reading book posture: a) Correct posture b) Incorect posture

V. Experimental Results and Discussion

The system's performance, for the current paper, was evaluated offline based on the predictive models. The best postural classification rate was obtained with the Decision Extra Trees Classifier (96.78 %). The results were obtained on a 25% test set. Also, another 4 algorithms did get a classification rate higher than 90%. These are represented by the Random Forest (96.62%), K-Neighbors Classifier (94.42%), Decision Tree Classifier (93.33%), and SVM (94.42%). The obtained results suggest that the proposed system can determine the postural risk level with high accuracy. The Decision Extra Trees Classifier's excellent performance is confirmed by the confusion matrix that suggests a min value of classification accuracy equal to 88.14% and an error rate equal to 11.86. Simultaneously, the max value is equal to 99.49 % and an error equal to 0.51 %. Table I presents the results based on a 25% test set, in the case of used predictive models.

The results presented in Table I highlight the proposed solution's capacity to determine the quality of the posture adopted in different daily activities. Also, in Table I, the information was presented both from the point of view of a correct position (odd-numbered labels) and an incorrect position (even-numbered labels). From Table I, it can be seen that the lowest performance was obtained with the help of the Gaussian Naive Bayes and Adaptive Boosting. In Table II, it was presented the classification rates got it for the best classifier algorithm represented by the Decision Extra Trees Classifier. High classification performance is also confirmed by Precision Factor, Recall Factor, and F1- Score evaluation metrics. The obtained results are excellent, and the proposed system could detect the quality of human posture from 9 different daily activities. This thing confirms the high potential of this to be used by the office workers, during their daily task, to prevent or correct the wrong posture. Comparing the obtained results to the technical literature, it was found that the system proposed in [13] is capable of achieving an accuracy equal to ~95.6 %, with a three-axial magnetometer paired with a miniature permanent magnet. The advantage offered by the system described in this paper is that it obtained a higher classification performance than in [13]. Another advantage is related to the system's portability and the possibility to be used without difficulties throughout the entire day, which is difficult to achieve with the help of the solution [13].

TABLE I. CLASSIFICATION PERFORMANCES USING PREDICTIVE ALGORITHMS (25 % TEST SET)

Classifier	RFC	k-NN	DTC	ETC	GNB	LR	ADAB	SVM
A1	96	90	91	97	62	84	0	99
A2	95	93	91	96	29	77	0	93
A3	96	87	89	97	32	85	37	95
A4	96	92	91	95	45	71	22	90
A5	97	91	92	98	40	62	0	98
A6	99	95	96	98	69	86	0	96
A7	99	93	96	99	58	88	100	96
A8	99	96	97	99	41	70	10	95
A9	97	95	94	99	52	88	0	99
A10	95	94	91	97	61	74	20	94
A11	98	92	98	95	10	79	62	97
A12	99	99	98	99	42	73	40	94
A13	85	87	76	100	75	65	14	82
A14	92	95	87	89	84	39	50	87
A15	98	95	93	92	25	75	86	97
A16	98	98	96	98	40	71	12	97
A17	99	97	97	99	89	97	0	100
A18	98	99	97	99	63	80	30	98

Another advantage of this study is provided to the fact that the postural condition was tested from two points of view: static posture (e.g., reading a book) and dynamic posture (e.g., walking). In their research, Kim et al., in order to detect and prevent Forward Head Posture, used 3 accelerometers placed on the front head, neck, and back [16]. They suggest that this approach provides accuracy equal to 94.5%. Although their system offers a reasonable classification rate, the principal limitation is related to the prototype itself that is hard to be extended for daily usage. Comparing our results to this solution, the accuracy was increased by 2.2 %. Also, the system proposed in this paper offers the possibility of easy use by any user without the necessity of preliminary preparation. Another important thing that emerges from the analysis is related to the system's performance, which was tested in different conditions of use. Although the proposed system offers high performance, this was done on a relatively small sample of participants. For this reason, for future research, it is considered to expand the database with a larger number of participants, this offering the consolidation of the results presented in this paper. This study's contributions to the HCI and medical field show that a portable head posture monitoring system based on the 3 inertial sensors was proposed as an alternative solution to the classical one (e.g., video camera, radar sensor, etc.). At the design of the system, it was considered that the system has a low implementation cost and high classification performance. The analysis was based on real situations in which people perform certain daily activities without maintaining a correct posture. Another focus of this study was to determine the best algorithm that can determine the quality of posture (normal or abnormal) from 9 different office workers' daily activities. The obtained results are competitive and make the current approach a very promising and feasible solution from both an economic and a constructive perspective. The proposed model is considered promising because based on the preliminary analyses presented in this paper, the classification rate's performance is up to 96 %.

TABLE II. CLASSIFICATION PERFORMANCES WITH EXTRA TREE CLASSIFIER (25 % TEST SET)

Activity	Precision Factor	Recall Factor	F1-Score
A1	97 %	94 %	95 %
A2	96 %	98 %	97 %
A3	97 %	94 %	96 %
A4	95 %	97 %	96 %
A5	98 %	96 %	97 %
A6	98 %	97 %	98 %
A7	99 %	98 %	99 %
A8	99 %	99 %	99 %
A9	97 %	97 %	97 %
A10	95 %	95 %	95 %
A11	99 %	99 %	99 %
A12	100 %	99 %	99 %
A13	89 %	87 %	87 %
A14	92 %	93 %	93 %
A15	98 %	98 %	98 %
A16	98 %	98 %	98 %
A17	99 %	99 %	99 %
A18	99 %	99 %	99 %

Another thing that suggests that the proposed system is feasible to be used in such kind of application is offered by constructive form of the prototype. Compared to the solutions proposed by other researchers, where the constructive form or complexity limits the portability and applicability, the current prototype was designed to avoid the constraints of the proposed solutions from the literature. Another thing that was taken into consideration is related to the fact that the use and applicability of the current system are not limited to special conditions of use, such as an experimental laboratory [6]. The total cost of the current prototype was around ~ 17 $ (NodeMCU: 4$, MPU6050: 1$, 2xMPU9250: 8$ and Neck Belt: 4$).

VI. CONCLUSION

This experiment investigated the performance of the previous proposed postural detection system [17], based on 3 inertial sensors. During this experiment, 9 office everyday activities were established to test the system's performance in the real case condition. For this experiment, the data were acquired from 3 healthy volunteers. The offline analyses suggest a high potential of this system to be used by the office workers in their daily office activity. The best classification performances were achieved with the help of the Decision Extra Trees Classifier. The proposed system provides the possibility to transmit data through the Wi-Fi connection, portability, low cost, and high performance.

The solution described during this paper was tried to highlight a new method of the postural monitoring system with a low cost of implementation and high performances based on 3 inertial sensors. It was also tried to highlight the classification performances based on intelligent computational algorithms as a consequence of using this system in a more complex and intelligent application (e.g., driver activity monitoring). The experiment presented during this paper proves the high potential and performances provided by the usage of IMU sensors as an alternative to those conventional ones (e.g., flex sensors, force-sensing resistors, etc.). For further research, it is planned to extend the current database with more data from different volunteers. Also, the number of monitor activities is desired to be increased. For the future, it is considered to check the system's online performance in normal usage conditions (e.g., wearing the prototype the entire day). For further research, it is considered to extend the applicability of the proposed system to other interest fields (e.g., automotive).

REFERENCES

[1] S. Kim and S. Koo, "Effect of duration of smartphone use on muscle fatigue and pain caused by forward head posture in adults", Journal of Physical Therapy Science, vol. 28, no. 6, pp. 1669-1672, 2016.

[2] Breen, Paul P., A. Nisar, and G. Olaighin, "Evaluation of a single accelerometer based biofeedback system for real-time correction of neck posture in computer users," International Conference of the IEEE Engineering in Medicine & Biology Society Conf Proc IEEE Eng Med Biol Soc, pp. 7269-7272, 2009.

[3] J. Kratěnová, K. Žejglicová, M. Malý and V. Filipová, "Prevalence and Risk Factors of Poor Posture in School Children in the Czech Republic", Journal of School Health, vol. 77, no. 3, pp. 131-137, 2007.

[4] R. Barrack, T. Whitecloud, S. Burke, S. Cook and A. Harding, "Proprioception in Idiopathic Scoliosis", Spine, vol. 9, no. 7, pp. 681-685, 1984.

[5] A. Alsuwaidi, WEARABLE POSTURE MONITORING SYSTEM WITH VIBRATIONAL FEEDBACK. ECCE Department: Khalifa University, 2016.

[6] L. Dunne, P. Walsh, S. Hermann, B. Smyth and B. Caulfield, "Wearable Monitoring of Seated Spinal Posture", IEEE Transactions on Biomedical Circuits and Systems, vol. 2, no. 2, pp. 97-105, 2008.

[7] L. Dunne, S. Brady, B. Smyth, and D. Diamond. Initial devel- opment and testing of a novel foam-based pressure sensor for wearable sensing. J NeuroEngineering Rehabil, 2(4), 2005. 5

[8] T. Fu, and A. MacLeod, "IntelliChair: an approach for activity detection and prediction via posture analysis," International Conference on Intelligent Environments, Jun 30- Jul. 4, 2014, pp. 211-213.

[9] R. M. Shubair and H. Elayan, "In vivo wireless body communications: State-of-the-art and future directions," in Antennas & Propagation Conference (LAPC), 2015 Loughborough. IEEE, 2015, pp. 1–5.

[10] W. Lin, M. Lee and W. Chou, "The design and development of a wearable posture monitoring vest", 2014 IEEE International Conference on Consumer Electronics (ICCE), 2014.

[11] Kang, Gu Eon, and M. M. Gross, "Concurrent validation of magnetic and inertial measurement units in estimating upper body posture during gait," Measurement 82, pp. 240-245, 2016.

[12] Inokuchi, Haruhi, et al, "Neck range of motion measurements using a new three-dimensional motion analysis system: validity and repeatability," European Spine Journal 24(12), pp. 2807-2815, 2015.

[13] H. Han, H. Jang and S. W. Yoon, "Novel Wearable Monitoring System of Forward Head Posture Assisted by Magnet-Magnetometer Pair and Machine Learning," in *IEEE Sensors Journal*, vol. 20, no. 7, pp. 3838-3848, 1 April1, 2020.

[14] Z. Zhang, Y. Liu, A. Li and M. Wang, "A novel method for user-defined human posture recognition using Kinect," *2014 7th International Congress on Image and Signal Processing*, Dalian, 2014, pp. 736-740.

[15] K. Tanaka, S. Ishimaru, K. Kise, K. Kunze and M. Inami, "Nekoze! - monitoring and detecting head posture while working with laptop and mobile phone," *2015 9th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)*, Istanbul, 2015, pp. 237-240.

[16] T. Kim, S. Chen and J. Lach, "Detecting and Preventing Forward Head Posture with Wireless Inertial Body Sensor Networks," *2011 International Conference on Body Sensor Networks*, Dallas, TX, 2011, pp. 125-126.

[17] I. Severin, "Head Posture monitor based on 3 IMU sensors: Consideration toward Healthcare application," *The 8-th IEEE International Conference on e-Health and Bioengineering- EHB 2020,* in press.