# Healthy sitting behaviour enhancement using a smart chair system

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**Abstract**

The aim of this paper is to present a smart chair prototype to monitor the sitting behaviour of people in wheelchair to re-educate them about long periods of time standing still and in the same position and giving them a feedback about this. The project is mainly focused on those who have been in a wheelchair for a short time. The sitting posture monitoring in the developed smart chair system can help or promote people to achieve and maintain healthy sitting behaviour, and prevent or reduce diseases caused by poor sitting behaviour, like bedsores (pressure ulcers).

**Keywords: S**mart Wheelchair, Postural behaviour, K-Nearest Neighbours, IoT.

## 1. Introduction

People's activities are strongly influenced by static behaviour in almost all activities. This may be the result of tasks that may require a high level of concentration or the use of complex user interfaces. In addition, the supply of entertainment in the form of multimedia content to be consumed statically has replaced other ways of using the population's leisure time. In addition, about 1% of the world's population has a disability that requires the use of a wheelchair for mobility, which means that 65 million people have strong mobility problems in their legs [11].

It has been shown that remaining in the same position for long periods of time, as well as poor posture, can eventually lead to problems related to pain and other complications such as pressure ulcers [7], cardiovascular disease [4] or diabetes [8]. Despite this, most people exceed the general recommendations for sedentary lifestyles [5, 6], [9]. In the case of wheelchair users, whose mobility is more limited, up to 33% have frequently experienced health problems coming from lack of movement [14].

Studies have shown how feedback from technological tools led to small or insignificant changes in the context of sedentary office life where most of the hours are linked to working time [13]. This, together with the type of work to be done and the concentration required, leads to a tendency to ignore warning signs. This is why our work focus on the creation of a non-invasive device to monitor and improve postural habits, mainly focused on wheelchair users, as this is the most vulnerable group and the one that can benefit the most. To achieve this goal, Internet of Things (IoT) tools based on sensors are used, as well as Artificial Intelligence (IA) techniques that analyse the quality of the users' posture.

## 2. Design and development Activity

The followed research methodology consisted in the creation and analysis of evolutionary prototypes that evolve guided by the identified requirements of the project. This type of methodology based on prototypes is widely accepted as it helps to clarify requirements [2]. Therefore, the design science research methodology (DSRM) proposed by Preffers et al [10] has been followed.

To develop the prototype, an architecture for IoT projects with 5 layers, established by Al-Fuqaha et al [1], was chosen. One of the advantages of using this architecture instead of the traditional 3 layers is that it adds more abstraction to the IoT architecture. Each of the layers that make up the system are detailed below.

### 2.1. Perception Layer

In this first layer, all the devices used to take information from the user are located. The main element of this layer is a 16x16 pressure sensor mat that will be in charge of collecting information about the user's posture. This mat can be easily placed inside the wheelchair cushion cover, adjusting and preventing unintentional movements. The information from the sensors is collected by an Arduino device that will adapt the information to send it to the next layer of the architecture. Figure 1 shows the appearance of the prototype where the mat connected to the Arduino can be seen, as well as the developed mobile application and the smart band used to inform users.

**Fig. 1.** Prototype

### 2.2. Object abstraction layer

The main objective of this layer is to share information between the perception layer, where the information is obtained, and the service management layer, which will be in charge of processing and validating data. The technology used in this abstraction layer is WIFI. The reason for using this wireless technology is to ensure connectivity with the server. Bluetooth and other short-range connections were tested and did not provide a framework that would fit all the situations in which the prototype was expected to work.

### 2.3. Service Management Layer

This layer is responsible for storing, analysing and processing the information provided by the abstraction layer. To store the data the project uses a real-time database provided by the Firebase platform. The main characteristic of this database is that it is a NoSQL database. Among the information stored there is the dataset used to train the algorithm, as well as the data collected by the sensors, having the anonymised historical data of each user with the data obtained from the sensors.

To detect the correctness of the users' posture, a K-Nearest Neighbours (KNN) algorithm [3] has been used for classification, using real data as input for training. Once trained, the model returns a k-nearest neighbour prediction to determine how close one value is to another. Euclidean distance is used as the method [12].

To train the algorithm it is necessary to obtain a dataset consisting on the values with their respective targets of the training values. The training sample was created from 15 users who have been sitting in different positions and setting the target on posture correction. In order to create a prototype that fits with most of users it is necessary to normalise the data according to the weight of the person.

Once the training was finished, it was necessary to choose the number of neighbours to be used by the algorithm. This choice depends on the amount of data and the reliability of the training set obtained [15]. To establish the number of neighbours, the algorithm was tested several times with the same input and with different numbers of neighbours. After analysing the results, it was found that the number of neighbours that provided the best results was 3.

### 2.4. Application layer

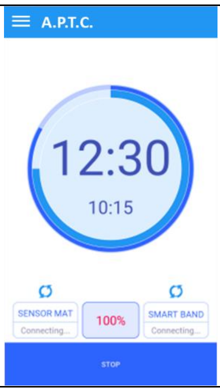
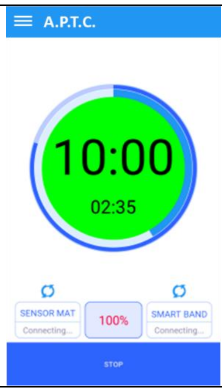
The designed prototype has an Android application that allows the communication with the user. The application gives the user the opportunity to adjust the weight in order to personalise the functionality. This is an important step to be sure that the system works correctly because the measurements are different for a person with low weight and small dimensions, such as a child, than for a heavier person with a larger measurement surface.

Once configured, the application offers three options to the user:

- *Chronometer* (table 1 left). The application calculates the time from the last change of position to prevent pressure ulcers. In case of exceed the time set without movements the application will play a sound to advise users. This mode of use is focused on those people that are in risk of suffer bedsores or pressure ulcers because they spend long hours without movement.
- *Monitoring* (table 1 centre). User will have the feedback about the correctness of its posture to avoid postural problems. In case of being sitting in an incorrect position the application will advise with an alert sound, and the application will display a red warning, while if the posture is correct, the application will display a green warning.. This mode is focused on improve the postural habits.
- *Complete mode* (table 1 right). This option presents a combination of the two previous options, so that it will warn both if the user has not changed his posture for a long time and if his posture is correct or not.

To increase the usability of the application in noisy environments, a smart band was incorporated so that it will vibrate to alert the user as a substitute for sound.

**Table 1.** Mobile application screenshot in different modes (a) chronometer, (b) Monitoring, (c) Complete

| a | b | c |
|---|---|---|
|  |  |  |

The application includes an additional tool which offers the possibility of sending periodic reports to an authorized user though a Telegram bot. This report incorporates a resume of the use of the application when the session is finished. This report can be very useful when the application is used in a professional healthcare environment, to follow the evolution of patients mainly in transitional stages in which the user must get used to a limitation of his mobility due to injuries.

### 2.5. Business layer

In order to improve the feedback in future versions, all information about the input and output of the evaluation is stored while maintaining the privacy of the users. This information will allow re-evaluating the results of the algorithm, as well as creating follow-up reports about the users' habits and validating if they improve their behaviour over time due to the use of this system.

## 3. Results

Throughout the development, different tests were carried out to train the algorithms, as well as to validate the results of the postural evaluation. However, to carry out a complete validation, it was necessary to have users who fit with the target audience of the project, and also to have the feedback of expert people. Therefore, once the development of the system was completed, a new validation stage was started in a health centre that works with people in wheelchairs, which fits with the target audience of the project, thus increasing the value of the tests carried out. In addition, a medical team was on hand throughout the validation process to evaluate the results. The tests were carried out in the care unit of the same health centre that works with people in wheelchairs.

The validation was split in 3 phases: the aim of the first one was to evaluate the usability of the mobile application and the physical device by medical practitioners to fill a form with their comments about the prototype. In the second phase, the application was adjusted with the recommendations presented in the previous stage. In the last phase, it was carried out a test with patients with mobility problems.

For the last stage of the validation the medical team chose a group of 5 users that fitted the target audience. The group was composed by 2 users who had suffer a recent accident and will be in a wheelchair permanently, 1 person who is temporally in a wheelchair because of an accident and 2 users who have been in a wheelchair for long time. The idea is to study the influence of the device in the wheelchair adaptation process in the first 3 users and evaluate the habits of usage thanks to the 2 last users. In order to make the evaluation of the tool as complete as possible, each user tested the 3 options of using the application.

After analysing the results obtained it was able to detect how the system was able to detect the correct sitting on 75% of times. Making a deep analysis of this results to check the possible problems, it was possible to check how in a 5% of times the incorrect evaluations was performed because of noise in the sensing procedure. These results reflect the need to increase the training process to a wide range of users, making the algorithm improve the precision.

Despite the results show a good analysis of the sitting behaviour of the users, the test has been done in a short time period. The main goal of this study is to provide a system that is capable of analysing user habits and helping to improve it, being able to detect behaviours that may be harmful to health. To check if the system is able of this task of re-educating the users, it is necessary to start a pilot where users use the system in their daily lives for at least 6 months. The results of this study would give more value to the system in order to be a useful tool to be incorporate in the daily life of the user.

## 4. Conclusion

This article presents a prototype, mainly oriented to wheelchair use, that allows the assessment of people's behaviour. To achieve the objectives, a DSR methodology has been followed, creating a prototype that evolves over time. As a result, the proposed prototype is able to adapt its behaviour to monitor not only the sitting time without movements, but also to detect the correctness of the user's position. These evaluations are mainly focused on helping to re-educate people who have been in wheelchairs for a short time so that they have a system that helps them to improve their postural behaviour in order to avoid problems such as pressure ulcers, among others. Although the usefulness of the project has not been analysed in the long term, the results obtained show that it can be used as a counselling tool to help correct posture in the event of incorrect posture. The influence of the system on the behaviour of the users will be studied in the future. In addition, its ability to warn of possible bad postures means that the project could be useful in other areas such as offices to look after the postural health of workers.

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