**Monitoring of body posture during computer use**

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# Introduction

We live in a time where more and more jobs require either full or partial computer work. An intensive computer work often means that we stop focusing on proper posture and forget about taking regular breaks. Many people are starting to experience various medical conditions, which are directly related to the sedentary type of work. The most frequent problems caused by the slouching and leaning for long hours using computers are back problems, headaches, visual impairment, or carpal tunnel syndrome.

In recent years, quite a few sitting posture monitoring systems have been developed to prevent back pain related to the bad sitting posture. In this work, we will focus on proper sitting and posture when working with a computer and will review some available systems for posture monitoring. We will have a look at different technologies and methods used, to help us design our own posture monitoring system. We will then describe a process of designing a network of IoT sensors that will be attached to the back of the chair and will be used to monitor the posture of the computer user. The data we collect will then be processed and annotated so that it can be used for the artificial intelligence model that we will use in this work.

# Existing posture monitoring systems

In this section we describe the different existing systems for posture monitoring. We will have a closer look at the technologies used for each system because initially we must decide what sensors would be suitable for our system. Our other focus will be on the machine learning models used in a different works.

## Vision cameras

The basic and easiest way to monitor people is to use vision cameras. Authors in [1] used specially installed webcam, which was positioned at a 90 degrees on the side, where the worker held the mouse while using the computer. The picture of a correct posture was taken. The camera was used to photograph workers every 20–25 minutes. The system randomly selected a time from this interval. The workers were then showed a pop-up window on their computer showing the photo of the ideal position and the current position so they can adjust their posture accordingly. No machine learning model was used in this paper, as workers received the information about their posture only from the picture. Authors used Rapid Upper Limb Assessment (RULA) measuring tool, which is used to quantify the grade of musculoskeletal risk of the sitting posture. The RULA grade is calculated based on the degree of angles between various body parts and recommended postures. The semi-automated software was built to access a database and calculate the RULA score from the photos. This model using a vision webcam improved the sitting posture of the workers, however, the vision-based systems can face privacy problems.

Another approach using only simple depth camera placed on a desk was proposed by Kulikajevas et al [2]. Authors did not use a single photo but a time sequence with four frames and decided on deep convolutional recurrent neural network based on *MobileNetV2* as their machine learning model (shown on Figure 1). To collect the date, they filmed each subject in each position deliberately to label the data, and then they let subject get into their usual bad position. The model firstly classified sitting postured into eight categories with accuracy of 68.33 %. After additional analysis they changed the classification, and created three categories with the accuracy of 91.47 %.

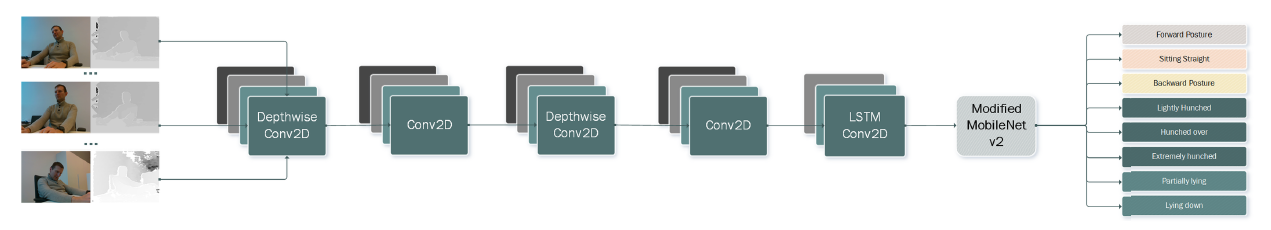


Figure 1 The recurrent hierarchical ANN architecture using MobileNetV2 as the main backbone

## Pressure sensors

There are different approaches of how to use pressure sensors when building a posture monitoring system. Jongryun et al [3] in their work used four pressure sensors, that were placed on the seat plate of the chair. Authors tried to classify six seating positions shown in Figure 2.

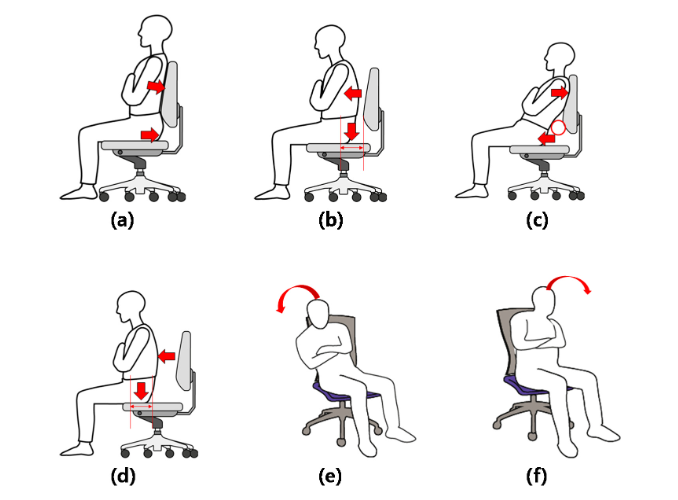


Figure 2 Types of sitting postures : (a) upright sitting with backrest; (b) upright sitting without backrest; (c) front sitting with backrest ; (d) front sitting without backrest ; (e) left sitting ; and (f) right sitting

The study used seven machine learning methods for the posture classification, and eventually chose the best one (SVM with RBF kernel) with an accuracy of 97.20 %, which is a very good result considering they used only four pressure sensors.

Authors in [4] created a system of six force sensitive resistors placed on the chair seat, then used neural network architecture for classifying seven different seating position with an accuracy of 81 %. The problem was that their system could not distinguish between the correct upright position and the one with the back not resting on the backrest.

A similar system was designed by Matuska et al [5] who used 6 force-resisting sensors, four of them were place on the seat and two of them at the backrest of the chair. Authors defined nine sitting postures, first one was a correct sitting posture, next four represented bad sitting posture, and last four postures were heavy load for the backbone. These sensors were connected to the mobile application, where the user could see the information about correctness of the posture. No machine learning model was used in this work, authors just tried to create a simple rule based on calculating the standard deviation, to distinguish between different posture categories.

Another approach of using pressure sensors were proposed in [6] where authors placed pressure sensors under each leg of a normal office chair shown in Figure 3. Authors of this study showed that with their approach it is possible to detect 7 different postures with the accuracy of 78.3 % based only on calculation of date collected by sensors.

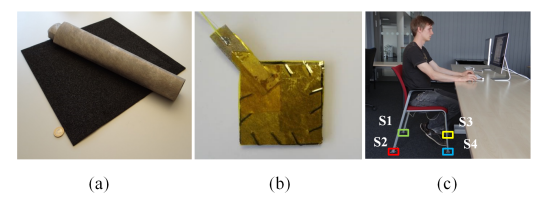


Figure 3 System Design; a) raw materials for the pressure sensor; b) a sensor prototype; c) a chair equipped with sensors

## Inertial sensors

The inertial sensors provide information about the tilting angle relative to the gravity and linear acceleration. They can be easily integrated into people clothes due to their small size and high portability. However, the system measurements accuracy is sensitive to the sensors position and some people might find those systems invasive as the sensing devices must be stuck to the human body.

Authors in [7] developed a portable trunk posture analysis system to monitor a daily posture habits of a user. They used three inertial triaxial accelerometer sensors attached onto the back of the subjects at the upper trunk(T1/T2), middle trunk (T12) and pelvic (S1) levels. These devices monitor the spinal curvature during the trunk movement. The parameters of the trunk posture measurement were calculated based on several axis systems.

A Smart Rehabilitation Garment (SRG) for posture monitoring was introduced in [8] consisting of two inertial measurement sensors embedded in the person clothes. Sensors were placed at C7-T1 spinal segment and at T4 and T5 vertebrae. Evaluation of the garment was dome by measuring the thoracic angle. The purpose of this garment was to prevent the spinal pain and avoid compensatory movements during arm-hand training. The posture feedback was directly provided on the jacket using vibration motors and graphically on a connected Android smart phone app.

Azin Fathi and Kevin Curran [9] designed an intelligent wearable system for the displacement of the spine detection. The system continuously monitors a user’s posture using three sensors. Sensor 1 was placed on Cervical spine; second sensor was placed in between all Thoracic spine and sensor 3 was placed on lower Lumbar spine. Authors analyzed collected data using the SAX (Symbolic Aggregate approXimation) method for posture classification to identify the hunched and slouching back posture. A user interface was created to send feedback signals when an incorrect posture is detected.

# Sensor network design

First, we needed to define what we considered to be the correct posture and what is the wrong one. To be able to do this, we needed to obtain appropriate information from a reliable source – domain expert. Figure 4 is showing how spine is divided into groups of vertebrae. Cervical spine has 7 vertebrae, thoracic spine has 12 vertebrae, lumbar spine has 5 vertebrae, sacrum has 5 vertebrae and coccyx has 4 vertebrae.

Obrázok, na ktorom je mapa

Automaticky generovaný popis

Figure 4 The vertebral column [10]

## Correct posture

We made an appointment with the domain expert, an orthopedist, and he helped us to have a better understanding of the posture problem. He explained and showed us a correct sitting posture, told us all about the mistakes, people usually make when sitting behind the computer for a long period of time. Figure 5 shows what is the correct sitting posture (on the right), and what is a bad posture when using computer for a long time (left). When people come to work and sit behind the computer, firstly they tend to be sitting correctly, as it is something, they are focusing on. However, after spending some time sitting, their attention and focus is drawn towards work tasks, and they stop keeping the correct upright posture. Another problem is that because of busy work, people tend to forget taking regular breaks, which help stretching tighten muscles and regain their focus on correct sitting when coming back to the table. That is why, when sitting correctly, one should have all the surface of one’s back pressed against the back of the chair, because it does not require as much focus to keep the back straight. One’s sacral spine should be as far back as possible; this will make sure that the lumbar and the rest of the spine will be upright. Arms should be bent in elbows in 90 degrees, supported by a table. Legs are supposed to be relaxed, also bent in about 90 degrees angle, feet situated on a small pad. We can call this posture the correct sitting posture no. 1.

These are the rules for an ideal posture, that most people do not follow. The correct sitting posture is also considered an upright posture, displayed in Figure 5 on the right, not necessarily with the back pressed against the back of the chair. One can sit correctly without leaning on the chair back, even though it is harder without a back support, as it requires much more focus to stay in a correct position. This position would be called the correct sitting posture no. 2.

Two positions described above will be considered a correct sitting posture in our work. All the other positions will not be correct. The most common wrong sitting posture are sitting with a hunched or slouched back with the head tilted forward, another position would be sitting at the front part of the chair, with the top of the back resting on the backrest.



Figure 5 Wrong vs. correct posture

## IoT sensors network

After meeting the domain expert, we took into consideration all his recommendations, and based on those, we proposed a model of IoT sensors shown on Figure 6.

Obrázok, na ktorom je sedadlo, nábytok, stolička

Automaticky generovaný popis

Figure 6 Initial proposed model of IoT sensors

For our experiment we will be using ergonomic chair. We decided to use two types of sensors, the Time-of-Flight sensors, used for a distance measurement (green dots), and the pressure sensors (yellow dots). Time-of-Flight sensors [11] contain very small invisible laser source and a matching sensor. Those sensors use the time that it takes for photons to travel between two points to calculate the distance between them, that is what “time of flight” means. We decided to use VL6180 sensor (shown on Figure 7), which can measure 50 - 1200 mm and VL53L0X with 5mm to 200mm of range distance. As pressure sensors we are using Force Sensitive Resistors SEN-09375 (shown on Figure 8) [12] with combination with 3.3 ohm resistors to create a voltage that can be read by a microcontroller's analog-to-digital converter input. Depending on the chair, if there is a headrest, we could place another Time-of-Flight sensor there, to monitor, if a person does not tilt his head forward too much.

Obrázok, na ktorom je elektronika

Automaticky generovaný popis

Figure 7 ToF sensor VL6180

Figure 8 Force sensitive resistor SEN-09375

Sensors would be placed at the tops of the curves of the ergonomic chair, specifically on the levels of the C3 vertebrae of the cervical spine, the T7 vertebrae of the thoracic spine and the L4 of the lumbar spine. This layout should be suitable for an average person’s height.

To collect a data, we initially used Arduino Uno R3 microcontroller with 32 kB of memory. After connecting different types of sensors, we found out, that memory was not sufficient, therefore we had to find an alternative. We researched some available options and decided to use Arduino Mega 2560 + Wi-Fi R3 which has sufficient memory of 256 kB. Since this microcontroller also has a Wi-Fi, it would make it easier to transfer our data into the database, as we will not have to use any additional cables.

After connecting all the sensors to the microcontroller and testing their functionality, we found out, that our force sensitive resistors do not respond well to a light pressure, which can cause a problem while measuring pressure on the bottom of the chair backrest. This realization led us to reconsider our initially proposed model of sensors. We agreed that better option would be to place those two pressure sensors at the back of the chair seat, one on the right side, and one on the left, to obtain better results.

## Correct posture measurement

The idea of the proposed system of sensors is, that pressure sensors would provide us information about the correct sitting posture no. 1. It means that two pressure sensors on the chair seat would be activated, and two pressure sensors on the backrest of the chair. Another correct sitting position is the correct sitting posture no. 2. To determine this position Time-of-Flight sensors come to use as indicate Figure 9.



Figure 9 Distance measurement

## Data collection

The next step in our work is to collect data. After we assemble all the sensors together and fasten them on the chair, we can start with the measurements. The data would be stored in a database, the most probably it will be MongoDB database. Some experiments might take place to determine what is the best way to gather date, what time series to use and so on. We would use few volunteers to sit on the chair prototype under a supervision and take measurements of both correct sitting postures to be able to label the data. Then we were discussing two options. We could either classify postures into two categories – correct posture or incorrect posture, or we can decide on more posture categories, as it was done by some monitoring systems we researched.

# Machine learning models

The goal of this work is to create some machine learning model to classify correct and incorrect sitting posture, alternatively make a classification into more sitting positions. Machine learning [13] is a subset of artificial intelligence which allows a machine to automatically learn from past data without explicitly programming an algorithm. The goal of artificial intelligence is to create computers which would be able to simulate human cognitive functions and behavior and solve complex problems. Machine learning has dramatically progressed over last few years, and it has been used in different fields like science, technology, even in healthcare, education, manufacturing, or financial modeling. It helped develop different practical software for computer vision, speech recognition, natural language processing, robot control, and other applications. We can see machine learning software all around us without even realizing it.

Machine learning can also be described as the scientific study of algorithms and statistical models that computer systems use to perform a specific task without being explicitly programmed [14]. That is why decided to take advantage of this discipline. Figure 10 illustrates different algorithms possibility that machine learning can provide. We would like to point out that there is not one universal algorithm that is suitable for all the problems. It always depends on data and a problem we want to solve.

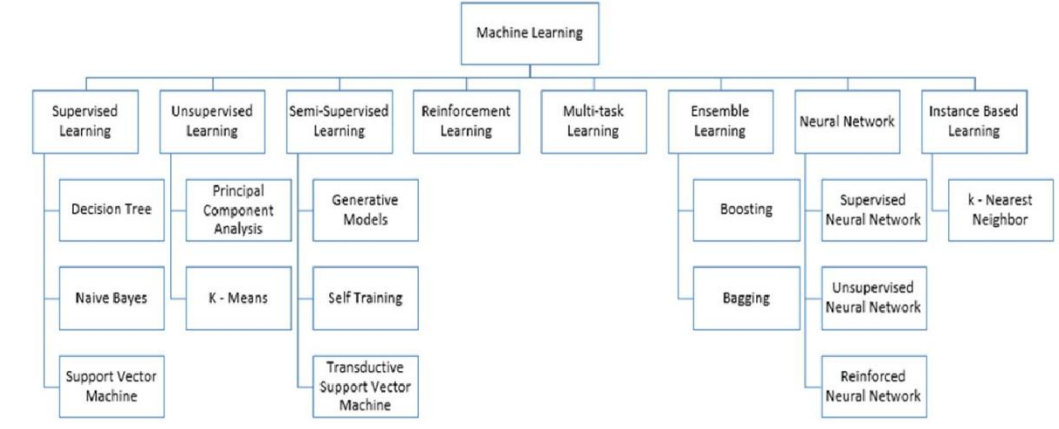


Figure 10 Machine learning algorithms

## Supervised learning

Supervised learning algorithms need an external assistance, and it is based on predicting labels of new data learnt on a set of training data. Input dataset is divided into training and testing samples. Firstly, the algorithm is trained on training dataset, where it learns some pattern, which is then applied to testing samples to predict correct labels. The workflow of supervised learning is shown on Figure 11.

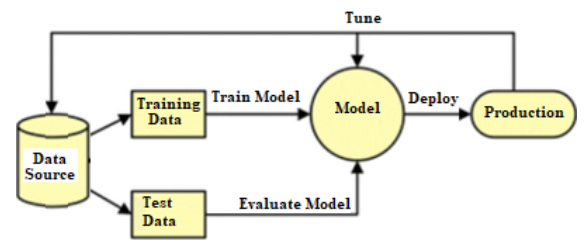


Figure 11 Supervised learning workflow

The most known supervised learning algorithms are Decision tree, Naïve Bayes, and Support Vector Machine.

### Decision tree

Decision tree is classification algorithm which is represented in form of a tree graph. The nodes in the graph represent an event or choice and the edges of the graph represent the decision rules or conditions. Each node represents attributes in a group that is to be classified and each branch represents a value that the node can take.

### Naïve Bayes

It is a classification technique based on Bayes Theorem with an assumption of independence among predictors. In simple terms, a Naive Bayes classifier assumes that the presence of a particular feature in a class is unrelated to the presence of any other feature. Naïve Bayes mainly targets the text classification industry. It is mainly used for clustering and classification purpose depends on the conditional probability of happening.

### Support vector machine

In machine learning, support-vector machines are supervised learning models with associated learning algorithms that analyze data used for classification and regression analysis.

It basically, draw margins between the classes. The margins are drawn in such a way that the distance between the margin and the classes is maximum and hence, minimizing the classification error.

## Unsupervised learning

The unsupervised learning means that there are no correct answers and there is no teacher. Algorithms are left on their own to find a data classification or discover some interesting structure in the data. The unsupervised learning algorithms learn few features from the data. When new data is introduced, it uses the previously learned features to recognize the class of the data. It is mainly used for clustering and feature reduction.

### Principal component analysis

PCA is a statistical procedure that allows you to summarize the information content in large data tables by means of a smaller set of “summary indices” that can be more easily visualized and analyzed. The most important use of PCA is to represent a multivariate data table as smaller set of variables (summary indices) to observe trends, jumps, clusters and outliers. This overview may uncover the relationships between observations and variables, and among the variables.

### K-Means clustering

K-means is one of the simplest unsupervised learning algorithms used for solving clustering problems. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters. The main idea is to define k centers, one for each cluster. A cluster refers to a collection of data points aggregated together because of certain similarities. The algorithm then allocates every data point to its nearest cluster.

## Semi-Supervised learning

Semi-supervised machine learning is a combination of supervised and unsupervised machine learning methods. It combines a small amount of labeled data with a large amount of unlabeled data during training. With more common supervised machine learning methods, you train a machine learning algorithm on a “labeled” dataset in which each record includes the outcome information.

### Generative models

A Generative model is the one that can generate data. It models both the features and the class (i.e., the complete data). If we model P (x, y): I can use this probability distribution to generate data points - and hence all algorithms modeling P (x, y) are generative. One labeled example per component is enough to confirm the mixture distribution.

### Self-training

In self-training, a classifier is trained with a portion of labeled data. The classifier is then fed with unlabeled data. The unlabeled points and the predicted labels are added together in the training set. This procedure is then repeated further. Since the classifier is learning itself, hence the name self-training.

### Transductive support vector machines

Transductive support vector machines algorithm (TSVM) has been widely used as a means of treating partially labeled data in semi-supervised learning. It is used to label the unlabeled data in such a way that the margin is maximum between the labeled and unlabeled data.

## Reinforcement learning

Reinforcement learning is an area of machine learning concerned with how software agents ought to take actions in an environment to maximize some notion of cumulative reward. It is a technique that enables an agent to learn in an interactive environment by trial and error using feedback from its own actions and experiences.

## Multi-task learning

Multi-Task learning is a sub-field of machine learning that aims to solve multiple different tasks at the same time, by taking advantage of the similarities between different tasks. Rather than training independent models for each task, we allow a single model to learn to complete all the tasks at once. Formally, if there are *n* tasks, where these *n* tasks or a subset of them are related to each other but not identical, Multi-Task Learning (MTL) will help in improving the learning of a particular model by using the knowledge contained in all the *n* tasks.

## Ensemble learning

Ensemble learning is the process by which multiple models, such as classifiers or experts, are strategically generated and combined to solve a particular computational intelligence problem. Ensemble learning is primarily used to improve the performance of a model or reduce the likelihood of an unfortunate selection of a poor one. Other applications of ensemble learning include assigning a confidence to the decision made by the model, selecting optimal features, data fusion, incremental learning, nonstationary learning, and error-correcting.

### Boosting

The term „Boosting‟ refers to a family of algorithms which converts weak learner to strong learners. Boosting is a technique in ensemble learning which is used to decrease bias, not variance. In boosting, a random sample of data is selected, fitted with a model, and then trained sequentially—that is, each model tries to compensate for the weaknesses of its predecessor. With each iteration, the weak rules from each individual classifier are combined to form one, strong prediction rule.

### Bagging

Bagging is used when the goal is to reduce the variance of a decision tree classifier. Here the objective is to create several subsets of data from training sample chosen randomly with replacement. Each collection of subset data is used to train their decision trees. As a result, we get an ensemble of different models. Average of all the predictions from different trees are used which is more robust than a single decision tree classifier.

## Neural network

A neural network is a series of algorithms that is used to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, either organic or artificial in nature. Neural networks can adapt to changing input; so, the network generates the best possible result without needing to redesign the output criteria. The concept of neural networks, which has its roots in artificial intelligence, is swiftly gaining popularity in the development of trading systems. An artificial neural network behaves the same way. It works on three layers. The input layer takes input. The hidden layer processes the input. Finally, the output layer sends the calculated output.

### Supervised Neural Network

In the supervised neural network, the output of the input is already known. The predicted output of the neural network is compared with the actual output. Based on the error, the parameters are changed, and then fed into the neural network again. Supervised neural network is used in feed forward neural network.

### Unsupervised Neural Network

The neural network has no prior clue about the output the input. The main job of the network is to categorize the data according to some similarities. The neural network checks the correlation between various inputs and groups them.

### Reinforced Neural Network

Reinforcement learning refers to goal-oriented algorithms, which learn how to attain a complex objective (goal) or maximize along a particular dimension over many steps; for example, maximize the points won in a game over many moves. They can start from a blank slate, and under the right conditions they achieve superhuman performance.

## Instance Based learning

Instance-based learning refers to a family of techniques for classification and regression, which produce a class label based on the similarity of the query to its nearest neighbors in the training set. Instance-based learning algorithms do not create an abstraction from specific instances, but rather, they simply store all the data, and at query time derive an answer from an examination of the queries nearest neighbors.

### K-Nearest Neighbor

The k-nearest neighbors (KNN) algorithm is a simple, supervised machine learning algorithm that can be used to solve both classification and regression problems. It is a non-parametric, supervised learning classifier, which uses proximity to make classifications or predictions about the grouping of an individual data point. It is typically used as a classification algorithm, working off the assumption that similar points can be found near one another.

# Conclusion

In this work we addressed the problem of keeping the correct sitting posture while working with a computer which has a become a worldwide problem. We researched this topic and had a look on different machine learning techniques to help us design a posture monitoring system of our own.

In the first chapter we described different posture monitoring systems, we compared different sensors used and reviewed various machine learning models that authors used in their work.

The second chapter was devoted to the posture monitoring system we want to design. We described the anatomy of the spine, we provided the information we obtained from an orthopedist, the domain expert, and based on that information we defined two correct sitting posture. We proposed a design of the system with an appropriate layout of IoT sensors for data collection and described other technology used in our system. The process of measurement and data collection was mentioned in this chapter as well.

The last chapter focused on machine learning, its meaning and importance in today’s world. Different types of machine learning were introduced along with the most known algorithm for each type of learning.

Our work is still in relatively early stages. The next step would be data collection and annotation. The most important thing will be the decision on what type of model is the most suitable for our data for classification of correct an incorrect sitting posture of our subjects.

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