UNIVERSITATEA **POLITEHNICA** DIN BUCUREŞTI
Şcoala doctorală de Automatică şi Calculatoare

TEZĂ DE DOCTORAT

Monitoring and improving workers body posture and physiological parameters via an unconventional user interface

Monitorizarea și îmbunătățirea poziţiei corpului și a parametrilor fiziologici ai angajaților folosind o interfaţă utilizator neconvențională

Autor: Paruyr Harutyunyan

Conducător de doctorat: Prof. Dr. Ing. Florica MOLDOVEANU

COMISIA DE DOCTORAT

Preşedinte	Prof. dr. ing. Adina FLOREA	de la	Universitatea POLITEHNICA din Bucureşti
Conducător de doctorat	Prof. dr. ing. Florica MOLDOVEANU	de la	Universitatea POLITEHNICA din Bucureşti
Referent	Profesor dr. ing. Vasile MANTA	de la	Universitatea Tehnică „Gheorghe Asachi” din Iași
Referent	Profesor dr. ing. Ion Smeureanu	de la	Academia de Studii Economice din București
Referent	Conferențiar dr. ing. Irina Mocanu	de la	Universitatea POLITEHNICA din Bucureşti

Bucharest, Romania, December 2015

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF CHARTS

ACRONYMS

HCI – Human Computer Interaction

EEG – Electroencephalography

SCD – Spinal Cord Dysfunction

SDI – Spinal Cord Injury

WHO – World Health Organization

MPMS – Mobile Patient Monitoring System

SPSS – Statistical Package for the Social Sciences

IEA – The International Ergonomics Association

ILO - International Labour Organization

MMO – Massively Multiplayer Online

MSI – Musculoskeletal Injuries

MSD – Musculoskeletal Disorders

WMSD – Work-Related Musculoskeletal Disorders

VR – Virtual Reality

MIT - Massachusetts Institute of Technology

LBP – Lower Back Pain

COP – Center of Pressure

ETS – Eye Tracking Systems

USB – Universal Serial Bus

Acknowledgement

Although this research paper carries my name, it is not solely my work. Many people have had their valuable contribution to this work to whom I'd like to extend my sincere thanks for bringing to me the opportunity to write this thesis. We've done together an important and serious work; it was quite a new life experience for me that will guide me through my life.

I would like first of all to express my deepest gratitude to my thesis supervisor, Prof. Florica Moldoveanu, for giving me the freedom to work on independently, meanwhile guiding and supporting me where necessary. From her I learnt to put questions correctly and present them in such a way as to be clear to the audience. Thanks to her patience and support I could overcome all difficulties encountered on my way and complete this work.

My special thanks to my thesis assistant, Alin Moldoveanu, for his readiness to listen to me any time, to have discussions for long hours, to provide technical and non-technical support, to go through this work for many times and make references, as well as to advise correct literature.

My sincere thanks are also extended to Victor Asavei, Anca Morar and my fellow student Alexandru Butean. As a foreign student studying in Romania, I never felt as a stranger thanks to these nice people.

And finally, thanks to my family and friends for their support during these years. Their support and care helped me overcome all difficulties and focus on my work. I appreciate my family and friends, as well as their trust in me.

1 Introduction

The development of computer technologies made our jobs easier to conduct, but on the other hand causes new but serious health associated problems. Work at the office typically means to spend particular amount of time sitting in an office chair, which in its turn adds stress to spine. As it is well-known back pain is one of the most common work-related health problem and is mostly caused by particular work activities, such as heavy lifting or sitting in an office. Office work related pain in neck is also very common nowadays and is agreed, that the ethology of neck pain among office workers is a multidimensional and is associated with complex factors with individual, physical and psychosocial components. We will show all components in Virtual Reality environment, and each time when the worker deviate from normal posture program will react in most realistic way.

Virtual reality refers to computer or other hardware-simulated reality that is perceived by humans through senses, including sight, hearing, etc. Virtual reality is replicated in real life.

The term "artificial reality" first introduced by an American computer artist Mayron Krueger has been in use since 1970s. Virtual reality in its modern usage was popularized by Jaron Lanier in 1989. Virtual reality is otherwise known as electronic reality or computer-based model of the reality. One has the feeling of being part of the reality replicated on a computer. The virtual reality developed for training and educational purposes is capable of simulating any situation that takes place in real life.

Different types of communication formats are available in 3D virtual reality, including text, audio and video. Communication via virtual reality becomes more interesting when users thereof use avatars, as well as avatar groups that communicate and cooperate with others(in our case avatar groups can be chair, office table, computer, etc).

Virtual reality is also used for scientific purposes, to represent objects with different sizes. For example, scientists have developed programs that enable to see on the screen how the atoms augmented to giant sizes join together and form chemical compounds. Virtual reality has also penetrated into many other disciplines.

Virtual reality has also positively impacted the educational process. Many education experts have begun reckoning with virtual reality and take urgent actions to use virtual technologies for the benefit of education.

It is not news that spending extended periods of time in front of the computer and doing sedentary work adversely affects human health. However, human health is mostly affected by the negligent attitude of people towards their sitting posture and health. Following our study among more than 300 workers, we found out that most of them had a feeling of discomfort caused by the work they were doing and almost all of the interviewees did nothing to improve the situation.

Virtual reality has poorly penetrated into workplaces so far. As already stated, virtual reality is the human presence in a computer-generated environment in real time.

With a view to helping workers to take care of their health, we have decided to consider human health in the context of virtual reality and to develop such computer-based interfaces that will enable to monitor human health in real time and based on certain physiological parameters help to create a healthier working environment.

1.1 Purpose and Motivation

The number of chronic diseases caused by IT technologies is growing increasingly all over the world [Matthews, 2003] [Brownson, 2005]. Sedentary behavior is one of the main factors contributing to degradation of health and, in some cases, to death [Bauman, 2011]. Here is why many researchers and young scientists are encouraged to take the challenge and get involved in solving health issues. To note that chronic diseases can be only controlled, but not healed [Thorp, 1996]. Here a question arises: how to protect humans against more serious health problems and complications in future? Health problems caused by IT technologies and widely spread all over the world are spinal curving, visual disorders, diseases of the limbs, slowdown of blood flow, many diseases caused by poor blood circulation, etc. Problems are many and various. To go on living and not to pay attention to all these diseases will have a serious impact on the quality of human life and on the society we live in. As people age, the possibility of diagnosing such diseases is increasing. According to the World Health Organization (WHO), unless solutions are found to problems listed above in years to come, such problems may be a serious cause of disabilities in two decades [WHO].

A new trend in the development of Mobile Patient Monitoring Systems (MPMS) is observed in the world. The method of remote controlling of patient's physiological state was first introduced in 1997. Based on this method, a Home Monitoring (BIOTRONIK) technology was developed says in [Schaldach, 1998]. In clinical context this technology was first used in 2000, when the first GSM-powered testing model, equipped with an external device, was developed, which received the information on patient's general state from implant and transmitted to service center for further processing and analysis. In 2003, a web platform was developed to enable physicians to get online data about patient's physical state from the service center. The progress of mobile telecommunication systems and information technologies has considerably enlarged the capacities of implantable devices, which have a great potential to provide a premium healthcare intervention, thus making it much easier to solve the most complicated issues relating to this domain.

Being one of those many, who lead a sedentary lifestyle, and feeling the increasing threat such lifestyle might have to human health, I have decided to have my own contribution to the solution of this very complicated issue. The tools presented herein are widely applied in different domains, both in developed and newly developing countries. More details on the study conducted, problems revealed and solutions offered to come further.

In the scope of the study 300-400 workers of different companies were interviewed. The evaluation questionnaire was reviewed by an internationally reputable organization. As a result, certain questions were reformulated and some questions and sections added, thus developing the final evaluation questionnaire. The study conducted by us revealed many people with various mild and serious physiological problems, the latter requiring urgent medical intervention. It also revealed a problem (systems for monitoring worker fatigue at work do not exist) that had not been thoroughly examined and solved so far. To find a solution to the mentioned problem, a system was developed to track human physiological state in non-clinical context. Detailed description of the principle of operation and the architecture of system will follow later.

To evaluate system efficiency, a testing was conducted. Up to 5 workers from initial workers were selected, based on the following criteria:

- workers doing mainly sedentary job
- workers partly in motion
- workers with mild health problems

After a one-week ongoing testing, the mentioned 5-10 workers were interviewed again with a view to comparing initial and testing results, in order to evaluate system efficiency.

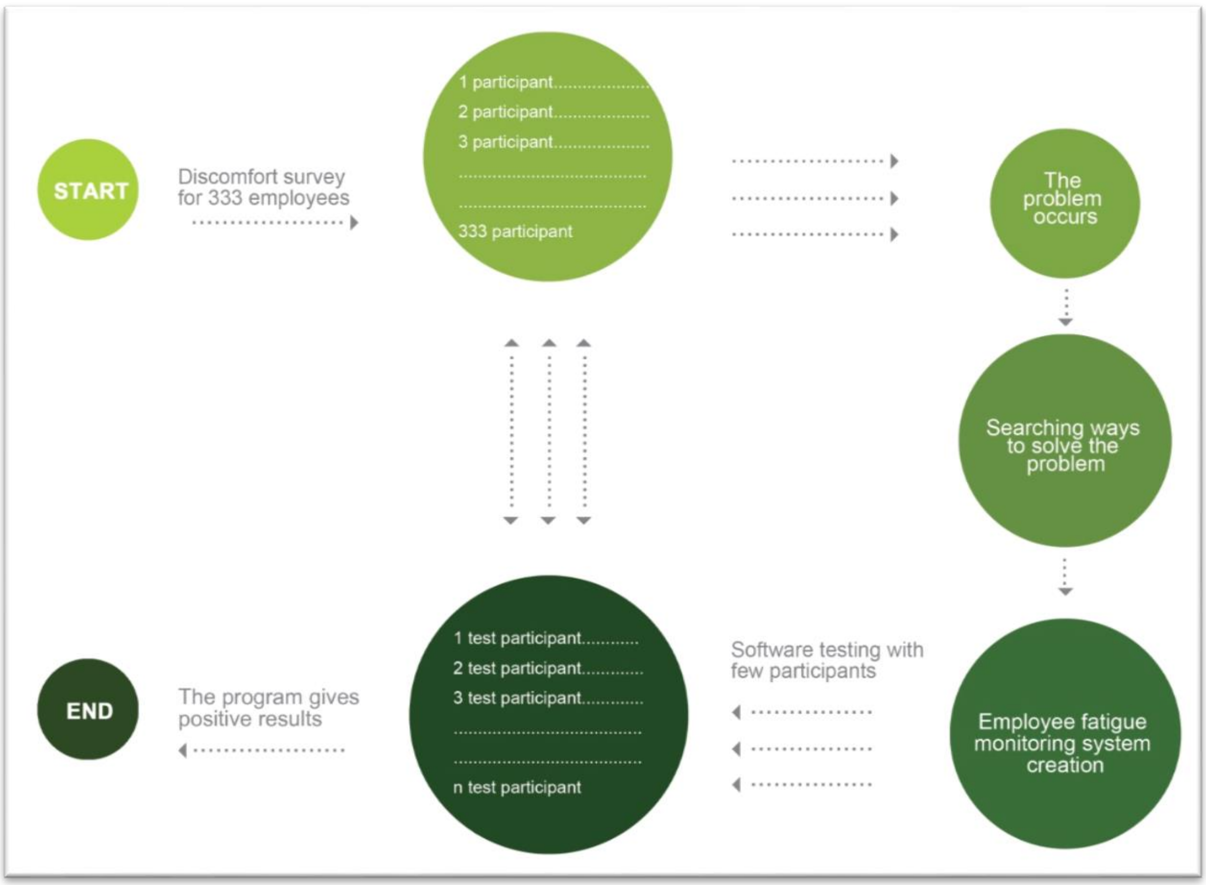


Figure 1.1 - Research steps

The present research aims at revealing the problem, offering a solution, conducting testing and proving system efficiency based on testing results (figure 1.1)

1.2 Thesis Outline

Every scientific work or research begins with an **introduction**. This thesis also contains an introductory part (Chapter 1), which gives the general outline of the main reasons for the occurrence of problems in question. The rest of the thesis is structured in 9 chapters, as follows:

Chapter 2 covers the research topic, the goals and objectives, the methods and approach, as well as the study of works relating to the topic in question.

Chapter 3 describes the study carried out among 333 workers of different companies, in order to evaluate their health status at work. The study targeted three focus groups of workers. The first group consisted of physically active workers, the second group was represented by partly active workers and the third one was the group of passive workers. Workers' answers to questionnaires were statistically analyzed. The analysis results were then discussed and took into consideration for prototype development.

Chapter 4 consists of two parts. As far as the present scientific work targets the workplace, worker and worker's health, this chapter is fully dedicated to the topic of healthy working environment. As for the part 2, it reveals the health problems caused by poor working environment.

Chapter 5 covers the systems already exists in the world. As examples, virtual monitoring systems existing in the world are shortly presented. Some studies about the effectiveness of using virtual environment for human monitoring are also discussed.

Chapter 6 defines the main understanding of "Virtual reality" and the features of virtual world.

Chapter 7 introduces the system developed by the author of the present thesis, with a view to solving the problem in question. It describes the "Unity 3" web-based development framework, having been used to develop the system and to get information from 3 devices (Microsoft Kinect V2 sensor, Tobii eye tracker and Microsoft Band smart watch) for further processing. This chapter also covers all system characteristics.

Chapter 8 covers the system tests and the evaluation of test results.

In the **conclusive part** of the present thesis, which again is an inseparable part of every scientific work, two main points are introduced. Firstly, a conclusion on the work performed, i.e., what problem we had in the beginning and to what extent it has been solved, and secondly, the desirable development trends that need to be set to achieve much better results in future. **Last point** summarizes the main contributions of the author and also some recommendations and suggestions.

2 The research of this thesis

2.1 The addressed issue

Nowadays economy has made serious scientific and technological progress. Our society has been very quick to adopt and apply state-of-the-art computer, as well as mobile technologies as an inseparable part of our everyday life. As said in [Paruyr et al, 2015] innovative technologies have integrated into our lives in a way that most of us do not even realize their being relatively new technologies, and today it is just impossible to imagine everyday life without these technologies. In fact, the IT technologies create lots of conveniences for human life, but at the same time, it can be definitely stated that they also negatively impact physical, mental and psychological state of humans. The medicine and education are the two main disciplines mostly influenced by the technological progress [Konsbruck, 2013].

Where does this progress lead to? What will be the consequences for the society? Here are two main questions that need to be carefully and thoroughly considered. Today almost all office workers, e.g., telephone operators, remote sales specialists, back-office workers among others, spend most of their working day sitting. If we search for the terms “healthy working environment” or “ergonomics” via search engine, we’ll find thousands of related articles, researches and studies. Tens of thousands researchers are concerned in a study of this rather important issue. The comparison of current and 20-year-old working styles reveals that parallel to the upgrade of computer technologies, workers’ sitting time is continuously increasing, which, in its turn, results in the increase of the number of diseases of people leading passive, sedentary lifestyle. Human brain is incapable of concentrating on work for hours and, what’s the most important, working for 8-9 hours daily in a sitting position is harmful for health. It is necessary to have regular breaks (every 30 minutes), to walk away from computer, to have a walk, to talk to colleagues and perform certain physical work/exercises [Parry, 2013]. Prevention or improvement of an unconsciously wrong attitude of humans towards their posture, whether sitting, standing or lying, will help to create a healthier working environment and to increase workers’ productivity. The present research covers the right ways of working.

Parallel to penetration and development of computer technologies and systems, employers and workers become more and more concerned about reviewing the processes, objectives and means of organization of work.

The researches and studies have revealed that rather many workers apply to medical institutions on a yearly basis with health problems caused by work. To note that such health problems are not supposed to be caused by heavy physical work.

The results of many researches [Ortiz-Hernandez, 2003][OSHA Ergonomics] have shown that humans are rather poorly “protected” from IT technologies at work. Our study (see Chapter 3) have revealed that most workers do not even realize the scale of damage caused to their health at work, which, in its turn, negatively impacts workers’ productivity. In the scope of study I had face-to-face interviews with over three hundred workers I defined that the huge part of them didn't know the cause of health problems. Worker’s physical and psychological state first of all depends on the worker himself/herself and only then on his/her management. After having been working for over 3 years on this thesis, I found out that most people were not aware of possible damages that could be caused to their health at work. Like robots, they do their job unconsciously, and the organizations they work for are not interested in changing anything in the organization of work at all, so that to give priority to workers’ health issues. By the end of this thesis it would be clear that preventing or improving incorrect postures and physiological other parameters with the help of special programs will lead to less musculoskeletal disorders.

Romania and Armenia are considered to be rather progressive countries, in terms of application of innovative technologies. However, it is not the case with health culture, which is poorly developed in these countries. The Governments make attempts to help workers take care of their health, but still it is impossible to fully control the situation in all the domains of economy and assist people in taking care of themselves during their everyday work.

Considering the modernity of this research, we should carry out a number of other researches and compare this one with others, in order to determine the effectiveness hereof.

Being a worker of rather a large company, by my own experience I became convinced that sedentary and passive work was rather quickly and negatively affecting physical health of humans. So, understanding the great importance of this issue, and also that it has not been yet fully studied, I decided to carry out this research and based on the results of tests to prove that it is necessary to use relevant means and tools to protect workers against health risks.

2.2 The importance of this research

This research is of great importance to different concerned parties:

- For the management: workers should be productive at work and satisfied with their job. It is natural that the productivity coefficient of workers satisfied with their job is much higher than that of workers who are not satisfied with their job.
- For workers: work-related stresses should be kept under control. The phenomenon and concept of "stress" has been largely circulated in recent years, causing serious concern for the management. "Stress" is deemed to be one of those most "expensive" risks negatively affecting both workers' health and organizations' profit.
- For further development: a work-health balance should be maintained. For most people finding this balance has become extremely difficult. When work takes most of their time, working without breaks and other problems that workers have cause overstress and finally they get sick. One should reasonably make work planning, by learning to say "No", adopting healthy practices and thus reaching work-health balance.

2.3 Research Goals and Objectives

The present research work represents a study of a method, which helps to reveal early signs of fatigue, sleepiness, tension and incapability to work. If the variables, such as those depending on biological and environmental influence, are studied, it will be possible to reveal the cases of loss of alertness and mental load at their early stage. It is a rather complicated phenomenon and cannot be simply measured using ordinary tools, and based on the results to determine worker's health status. If all the necessary data is collected in one system and studied and reasonably processed from a medical point of view, we can get a clear picture of worker's health status in real time. In case of complete study and design of the method, we'll get a system, which will help to determine whether or not the worker is capable of working or doing other necessary actions at the moment (this system will have a great demand among workers leading sedentary and passive lifestyle).

As necessary parameters for making the analysis of this issue can be, for example, person's visual behaviour – eye movements, gaze, blink rate, as well as the viewing angle and distance from the computer screen. As for other parameters, e.g., physiological parameters, such as heart work, brain activity, spine position can be considered. Also, it is necessary to study and consider the environmental influence on human body, such as temperature in the workplace and, why not, other factors controlled by workers, such as monitor placement, chair placement in front of the desk, room illumination, etc. In a word, the system will collect and process all the parameters necessary to organize the working process properly.

There are certain measures that could be taken to minimize the scale of damage caused to human health at work, such as doing physical exercises, avoiding same sitting positions, walking away from the workstation on a regular basis, doing special exercises to relieve eye strain, etc. [Dunstan, 2013]. All these actions should be done regularly, so to become an inseparable part of everyday work. However, at work people are sometimes so much engrossed in doing their everyday tasks that they forget about other things (it is not a secret how attractive it is to work with computer or just surf the internet). And so, these are the factors that urge us to create such a system, which will help to monitor the physical state of workers at work. Thanks to that system it will be possible to fix any changes in the physical state of workers and to offer possible solutions, in order to prevent negative consequences.

The global and main objective of this research and of development of a special system is to constantly monitor the physical state of workers without any interference with their life and to evaluate the general state of workers, having spent an extended period of time in an awkward position. The system will collect all the possible biological data via special devices and various sensors. It should be equipped with all necessary devices, in order to enable the system to collect all the biological and non-biological data and to derive a systemized algorithm based on the results of data processing.

The system will collect and process the data and derive a systemized algorithm in real time. The final result that represents a special algorithm will help workers take relevant steps in their workplace, in order to enable them to avoid further serious health problems caused by sedentary, passive workstyle. This system is intended for use in large companies with over 100 workers, as in such companies workers are subject to busy work schedule and it will be possible to get the most accurate picture.

The objectives of this research can be summed up as follows:

1. to show the possible impacts of computer systems and to develop safe work practices among workers via a virtual reality environment;
2. to reveal early signs of fatigue and inability to work through virtual reality;
3. to create a number of virtual reality based programs that can be used to educate workers in implementing safer work practices, as well as to evaluate efficiency of such programs during work.

2.4 Research methods and approaches

The methods and approaches used in this research are mainly for test purposes and by their nature correspond to the domain of human-computer interaction. When measuring any parameter of medical intervention and using the results in any domain, we have relied on professional literature and taken into consideration opinions of different specialists. Brief description of innovative devices used in the system, their manner of operation and the purposes of their use in the system is given below.

Now briefly about Kinect: it is a special tool released by Microsoft Corporation. It is controlled without any physical interaction, using only gestures, and tracks movements of objects and people in three dimensions [MsKinect]. In other words, Kinect enables the user to control it through verbal/oral commands, gestures and through other objects.

There is a great potential all over the world to use Kinect in different domains. For example, it is widely and efficiently used in medicine – in operating rooms, at home or in hospitals for the purposes of physical therapy. As far as the newly-developed system will be used to monitor the physiological state of workers in the working environment, the above-mentioned logical approaches are in direct proportion to all healthcare norms.

In 2014, Microsoft Corporation launched Microsoft Band smart device. Microsoft Band, the first device powered by Microsoft Health, helps to achieve wellness goals by tracking heart rate, body temperature, physical activity, as well as sleep duration and other similar parameters [Agelink, 2001][MsBand]. The device tracks user’s movements, considering the distance and speed, measures body temperature, heart rate and calorie burn. One of the more interesting sensors on the Microsoft Band is the UV sensor. It helps to get a snapshot of the current UV level and avoid too much UV exposure, thus enabling users to lead a healthy lifestyle and to work efficiently. It is composed of 10 sensors – an optical sensor to measure heart rate, a triaxial accelerometer/gyroscope, air humidity, GPS, illumination, body temperature, UV sensors, etc.

Microsoft Band has a great capacity to collect the parameters of human physiological and physical activity. It provides many parameters from which the necessary ones will be included in the system. Each parameter necessary to give a solution to the problem in question will be specifically processed and presented in the designed system. The next special feature of Microsoft Band used in the scope of this research measures the physiological phenomenon of variation in the time interval between heartbeats. Small-scale recorders are intended to collect data on heartbeat acceleration rate. Pulse is a numeric average of a person's heart rate during one minute [Agelink, 2001]. 60-80 beats per minute are considered to be an average heart rate, but it does not mean that the time interval between heartbeats makes 1-1.3 seconds: it may range between 0.5-2 seconds [Agelink, 2001]. The factors affecting the heart work may be as follows: age, genetics, body position, time of the day and health status. These are the main factors to pay special attention to. More details will be discussed in the relevant chapters of this thesis.

The level of progress of IT technologies plays a very important role in the lives of both healthy/disabled and old people. People with hearing or visual impairments, as well as with motor disabilities, such as spinal cord injury or dysfunction and other problems, very often face many obstacles in human-computer interaction, which they overcome with great difficulty. People with physical disabilities experience difficulties in using computer accurately and effectively, which usually hinders their integration into the society, as well as limits communication with the world around them without additional aids. Tobii Eye Tracker [TobiiEye] is an ideal solution for people with such disabilities. It helps to work with the computer using eye movements. I have used this device in the designed system, in the following way: using eye behavior we determine some parameters, such as, blink rate, duration, viewing angle and the distance from the monitor.

There is also one device which we consider to use in our system, but because of lack of knowledge such as brain electroencephalography (EEG) measurement, as well as normal rate of brain activities, we made half of work and leave it for further development. The device used for brain activities is Emotiv, which is a more innovative solution used to control computer with one’s brain. Emotiv Systems [Emotive] is an Australian electronics company developing brain-computer interfaces based on EEG technology. EEG is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp (14 electrodes in our case). It is one of the most reliable sources helping to reveal signs of sleepiness and fatigue.

All devices used in the scope of this research are presented and interpreted in more details in the chapter six.

This research is not based on hypotheses and opinions. It refers to concrete tests, which do not need to be proved and has been done based on different physical parameters taken from a number of workers. Chapter 8 of this research work describes the test done in the scope hereof in all details and contains the results of such test. It also describes (chapter 7) the program developed by the author.

2.5 Research Delimitation

As already stated in the beginning of this research, we have set ourselves a goal and started looking for possible ways to reach that goal. The first step to take towards reaching our goal is to give the right definition of that goal. And so, the first thing to do is to create a prototype. A demo version was developed and presented in the scope of the testing. Based on the results of pilot test, we got the general picture of what we have and what we had to do to develop it further and to have a more user-friendly interface. This solution was warmly welcomed by many users and we got their positive feedback, as well as suggestions which we took note of. The interview with users is a proven method to find out the factors interacting with human spectrum. Multiple tests of the prototype and discussions with users help to achieve the final result.

In the scope of this research we now have a modern and functional system, which is rather flexible and which uses the latest IT devices and approaches. Considering the highly progressive trends of the IT industry, we should do our best to always maintain all devices and software used to operate this system up to date. The hardware used in the system is intended to evaluate the physiological state of humans.

The experiments on which is based the research described in this thesis are delimited by place, time and content.

First stage

1. Place: several large and medium-sized companies in the Republic of Armenia.
2. Period: the study was conducted during the 2014-2015 academic year.
3. Content: a study was carried out among 333 employees through the validated questionnaire, to reveal their health status in different working conditions.

Second stage/Experiment

1. Place: Republic of Armenia, company with huge number of employee.
2. Period: November 2015.
3. Content/Results: a ready-made “Worker Monitoring” system was tested(the test results are described in Chapter 8).

3 Study of the discomfort for office workers

The present research was carried out using the method of prospective cohort study. Such studies widely vary in terms of size and complexity. A cohort study is mainly used in medicine, social science and business analytics, as well as in other disciplines. In this specific case it is used for health evaluation purposes. A prospective cohort study is a study that follows patients over particular time, by performing permanent or repeated monitoring of risk factors or health status of patients or both of them [Mana, 2008]. A cohort is a group of people sharing a particular characteristic and tracked for a particular period of time.

In the scope of this research work the main objective of cohort study was to get exhaustive quantitative data to help us in decision-making with regard to further development and upgrade of our system. A non-random sample selection method was used to select the participants of the study. Workers having shared the same workplace for the targeted period of time were selected to participate in the study. The use of such method enabled us to have a representative sample of workers from Armenia.

Source data collection was performed in January-February of 2015 and medium-term data collection - in April-June of 2015.

3.1 The target population

The target population was represented by a group of workers, which worked during the 3 years of my research, the period from 2012 to 2015.

The target group members were selected based on the following criteria:

- bank workers, whose work agenda is much stricter as compared with others;
- workers of multinational organizations doing their business based on international standards;
- workers doing part-time active job.

Those eligible for participation had to meet the following criteria:

- to work in the same organization throughout the research period (2012-2015);

- to do different types of job (e.g., active, partly active, sedentary);
- to be a Republic of Armenia citizen;
- to speak Armenian, English;
- to wish to participate in the study.

The exclusion criteria for participation were as follows:

- workers with physiological problems (as the results of study would be drastically impacted);
- workers always doing a physically active job.

We have also excluded workers over age 50, as the likelihood of occurrence of health problems conditioned by age is rather big at that age. Whereas, the main objective of the study carried out by us was to reveal health problems conditioned by poor organization of work.

3.2 Study instrument

The first thing done in the scope of the study was to filter the organizations according to the type of business they do and only after that make final selection of organizations and workers. Following the selection process, we made a phone call to those organizations to verify certain information and only after that meetings were organized to conduct interviews with workers.

EQ-5D-3L instrument applied in the study is a verified, approved and reliable tool used to evaluate the quality of life (QoL) [EuroQOL] of people. The QoL Commission has studied the problem in advance and offered a questionnaire consisting of several questions. Parallel to this questionnaire we also used the Cornell Musculoskeletal Discomfort Questionnaires (CMDQ) developed by Dr. Alan Hedge [Cornell] from Cornell University.

The final questionnaire was reviewed (Appendix 1A English version, Appendix 1B Armenian version), certain questions were reformulated and several new questions and sections added, based on the experience of evaluation of other similar studies.

Initially the questionnaire was in Armenian, later it was translated into English. With the help of 10 volunteers the questionnaire was tested and with a view to eliminate the shortcomings found as a result of testing, relevant changes were made therein.

The final questionnaire consisted of the following sections:

- General information about worker
- Job description
- General information about worker's health status
- Environment
- Study of highly vulnerable aspects

3.3 Sample Size calculation

A sample size is an important component of every study. It is highly important to understand that different studies require different sample sizes and that it is not acceptable to use the same formula for all of them. A sample is a part of anything that is representative of a whole. Hence, a question arises: how many persons should our study sample be composed of? The sample size and the result achieved after the study should best and accurately represent the whole from which the sample is taken. In order to decide on how much accurate results we want to achieve after the study, we must carefully calculate the sample size. There are several reliable online tools to calculate the needed sample size, which need several parameters for that particular study. Firstly, the chosen tool must correspond to the design of the study, also the power and confidence level should be mentioned, which is assumed to be 80% and 95% appropriately. Then the prevalence rate of the particular outcome among the exposed and non-exposed groups must be found based on literature review of previous studies, which can also be used to calculate either assumed relative risk or odds ratio.

Thus, the sample size for our study was calculated with the confidence level of 95%, power 80%, assumed relative risk of 1.7 and expected incidence in unexposed group of 19%, which is based on the results of previously conducted study [Devereux, 2002]. So the needed sample in the scope of this particular study which will best represent Armenian population is 332 [EpiTool].

3.4 Statistical considerations

Before entering the data into the SPSS (Statistical Package for the Social Sciences) database, we reviewed all questionnaires completed by interviewees. At that stage a unique data entry was performed by us with further cleaning, which was rather a time and effort consuming process. During the medium-term evaluation, in order to avoid mistakes and to improve the quality of the database, a double data entry was performed, which took us almost 4 weeks. Data analysis was conducted via the SPSS and STATA software packages.

Categorical variables were presented as counts and percentages compared by *by-item analyses* and continuous variables were presented as means and standard deviation. As far as we have used categorical data we have used bivariate and multivariate logistic regression analysis.

P-values are used to define the statistical significance level in testing the hypothesis. As the null hypothesis refers to a statement that no significant difference is observed between the groups, so in our study, the null hypothesis is considered to be the lack of difference between the groups (active, partly active, sedentary). In other words we consider the null hypothesis to be true if there is no difference between our groups. The p-value shows how compatible are the data with the null hypothesis. So the higher p-values assume that hypothesis under consideration is true and lower p-values assume that the data observed is not consistent with the null hypothesis to be true, so it must be rejected. In our study we considered the significance level (α) to be 5%. So if the p-value is less than 0.05 we reject the null, in other words our data is inconsistent with the assumption that null hypothesis is true and we reject it. The p-value does not measure the support of any other hypothesis, it only interprets whether the hypothesis we are currently testing is true or it must be rejected.

3.5 Study variables

The dependent variable of the study was quality of life of workers divided in the three work categories: active, partly active and sedentary. Based on a few studies of regression analyses the dummy variable was created for this variable. These types of variables (dummy) are used mainly in regression analyses to represent subgroups in a study. The investigator recoded the options of the variable and defines passive as “0” and partly active and active options as “1”, based on other studies being done previously. The independent variables of the study were gender, time of working (months), sought or received medical assistance, changes performed at workplace to improve quality of workplace, variables experiencing ache, pain and discomfort, including options of never, 1-2 times last week, 3-4 times last week, ones every day, several times every day/uncomfortable feeling when experiencing ache, pain and discomfort/ache, pain and discomfort interfering ability to work, with options of slightly, moderately and very. It is worth to mention that for regression analyses score was generated for these variables. For the neck, all options were summed and the maximum value was 8 and minimum 0, for shoulders 16 and 0, for upper back 8 and 0, for upper arm 12 and 0, lower back 8 and 0, forearms 14 and 0, wrist 16 and 0, hip buttocks 7 and 0, thigh 16 and 0, knee 16 and 0, respectively maximum and minimum values.

3.6 Ethical considerations

This study corresponds to local and international ethical standards. All participants were informed about their rights (participation was on a voluntary basis and participants could refuse to further participate in the study and answer the questions; anonymity and confidentiality was fully ensured). Before the interview, all interviewees had read the notification agreement (Appendix 2), which contained general information about the objectives and conditions of the study, rights of interviewee, confidentiality clause, as well as information about the group of researchers/interviewers. The main language of the study was Armenian. However, whenever preference was given to English, the English version of the notification agreement and questionnaire was provided to interviewees (Appendix 1A and Appendix 2A).

3.7 Results

3.7.1 Administrative data

10 organizations were contacted, of which 4 organizations refused to participate in our study and 6 were included in it. All together in those organizations were 834 employees, of which 590 met our inclusion criteria. So, 485 employees were contacted, from which 112 employees refused to participate, 24 were on vacation and 349 completed our in-depth

interviews. After data collection and cleaning, 16 persons' data were excluded from the analysis due to missing values.

So, the final sample available for the analysis was 333, which fully corresponds to the needed sample size calculated previously.

3.7.2 Baseline and procedural characteristics of the patients

Employees' baseline characteristics are presented in the Table 1. Of 333 employees included in the sample 65 (19.52%) had active, 71 (21.32%) partly active and 197 (59.16%) sedentary working conditions. More females were in sedentary group (55.33%) than in the partly active (49.30%) or active (35.38%) groups (p=0.020). Less people were working more than 61 months (approximately 5 years) in each group (29.23% versus 70.77%, 43.66% versus 56.34% and 35.53% versus 64.47%, p=0.210). And in all the groups people were less likely to sought or receive medical assistance.

3.7.3 Quality of life for employees

The by-item analysis of the questionnaire showed significantly worse results for the sedentary group regarding ache, pain or discomfort in neck (Table 2). And people with active lifestyle had more chances to never experience neck pain (68.25% versus 46.48% or 34.01%, p=0.000). Regarding shoulders, 81.54% of people working with active conditions never experienced shoulders' pain ache or discomfort compared to people from partly active (64.79%) or sedentary group (64.47%) (p=0.011). The groups also differed significantly in the rates of lower backache, pain or discomfort. And employees in the sedentary (75.63%) or at least partly active (66.20%) group experienced lower part of back pain, ache or discomfort at least once a week compared to people from active group (43.08%, p=0.000).

There is also significant difference in hip/buttocks, as people from sedentary group had worse results, experiencing ache, pain or discomfort more often than those from partly active or active groups (35.53% versus 21.13% or 4.62%, p=0.000). And it is also worth to mention that people experience pain, ache or discomfort in lower parts of legs more frequently with active work than people with sedentary working conditions (29.23% versus 25.38%, p=0.006). No differences were found regarding shoulders, upper back, upper arms, wrists and thighs.

The quality of life of employees regarding the uncomfortable feeling when experiencing ache, pain or discomfort is shown in Table 3. The most significant differences are found in neck, shoulders, lower part of back, forearms, hip/buttocks and knees. The by-item analysis showed worse results for employees with sedentary working conditions compared to the ones with partly active and active working conditions, showing very uncomfortable feeling in neck (25.89% versus 14.08% or 4.62%, p=0.000), shoulders (15.25% versus 5.63% or 0.00%, p=0.007), lower back (26.40% versus 23.94% or 10.77%, p=0.000) and hip/buttocks (3.55% versus 0.00% or 1.54%, p=0.000). No significant differences were observed regarding the other parts of the body.

The analysis was also conducted regarding the ability of employees to work, as they experiencing ache, pain or discomfort (Table 4). Significant differences were found showing substantially worse results in ability to work when experiencing ache, pain or discomfort in neck, lower part of back, wrists and hip/buttocks. Employees' neck pain, ache or discomfort substantially interfered their ability to work for the ones with sedentary working conditions compared to the ones with active or partly active work (25.89% versus 4.62% or 9.86%, p=0.000). People from sedentary group also had higher chances to have lower part of backache, pain or discomfort that substantially interferes their ability to work if compared to people from partly active or active groups (28.93% versus 15.49% or 7.69%, p=0.000). No significant differences were observed in domains of upper back, upper arms, forearms, thighs or knees.

3.7.4 Bivariate analysis: simple logistic regression

Table 5 presents the results of the simple or bivariate logistic regression analysis for the associations between the dependent variable and other independent variables. It is worth taking into consideration that the regression coefficient is the obvious increase in the log odds of the dependent variable's per unit increase in the value of the independent variable.

From the table 5 it is obvious that period of working, upper arm problems, forearms problems, wrist problems are not associated with any odds of the dependent/outcome variable, meaning that when the OR=1, the independent variable haven't any association with dependent variable. In the case of thigh problems, knee and leg problems OR is marginally higher for 1 (OR>1) meaning that those variables are associated with higher odds of the dependent variable. In the other cases, when OR<1, independent variables are associated with lower odds of the dependent variable.

3.7.5 Multiple logistic regression

Multiple logistic regression analyses was carried out to identify factors associated with the outcome/dependent variable while controlling for other significant variables. In the table 6, the final model was described and only significant variables from the bivariate analyses were included in this model to control potential confounders. The independent variables from this model were shown to be significantly associated with the dependent variable (p-value=<.001). As it was seen only gender (OR=0.76), neck problems (OR=0.78), lower back problems (OR=0.90) and hip buttocks problems (OR=0.67) were associated with lower odds of the dependent variable, that means these above mentioned variables were associated with a passive lifestyle of the employee.

Table 1 - Baseline characteristics

Characteristics	Active n=65	Partly active n=71	Sedentary n=197	p-value
Gender				**0.020**
Male	**42 (64.62)**	**36 (50.70)**	**88 (44.67)**	
Female	**23 (35.38)**	**35 (49.30)**	**109 (55.33)**	
Time of working (months)				**0.210**
<61	**46 (70.77)**	**40 (56.34)**	**127 (64.47)**	
≥61	**19 (29.23)**	**31 (43.66)**	**70 (35.53)**	
Sought or received medical assistance				**0.680**
Yes	**21 (32.31)**	**19 (26.76)**	**53 (26.90)**	
No	**44 (67.69)**	**52 (74.24)**	**144 (73.10)**	
Changes performed at workplace to improve quality of workplace				**0.151**
Yes	**12(18.46)**	**6 (8.45)**	**35 (17.77)**	
No	**53 (81.54)**	**65 (91.55)**	**162 (82.23)**	

*Results are presented as frequencies and percentages, unless specified otherwise.

Table 2 - Experiencing ache, pain and discomfort

Characteristics	Active n=65	Partly active n=71	Sedentary n=197	p-value
Neck				**0.000**
Never	43 (68.25)	33 (46.48)	67 (34.01)	
1-2 times last week	10(15.87)	16 (22.54)	52 (26.40)	
3-4 times last week	7(11.11)	8 (11.27)	26 (13.20)	
Ones every day	3(4.76)	7 (9.86)	35 (17.77)	
Several times every day	0 (0.00)	7 (9.86)	17 (8.63)	
Shoulders				**0.011**
Never	53 (81.54)	46 (64.79)	127 (64.47)	
1-2 times last week	10 (15.38)	12(16.90)	32 (16.24)	
3-4 times last week	2 (3.08)	4 (5.63)	23 (11.68)	
Ones every day	0 (0.00)	1 (1.41)	7 (3.55)	
Several times every day	0 (0.00)	8 (11.27)	8 (4.06)	
Upper back				**0.493**
Never	49 (75.38)	43 (60.56)	134 (68.02)	
1-2 times last week	10(15.38)	17 (23.94)	31 (15.74)	
3-4 times last week	3 (4.62)	5 (7.04)	10 (5.08)	
Ones every day	1 (1.54)	3 (4.23)	15 (7.61)	
Several times every day	2 (3.08)	3 (4.23)	7 (3.55)	
Upper Arms				**0.736**
Never	60 (92.31)	62 (87.32)	180 (91.37)	
1-2 times last week	3 (4.62)	5 (7.34)	12 (6.09)	
3-4 times last week	2 (3.08)	2 (2.82)	2 (1.02)	
Ones every day	0 (0.00)	2 (2.82)	2 (1.02)	
Several times every day	0 (0.00)	0 (0.00)	1 (0.51)	
Lower Back				**0.000**
Never	37 (56.92)	24 (33.80)	48 (24.37)	
1-2 times last week	13 (20.00)	11 (15.49)	49 (24.87)	
3-4 times last week	6 (9.23)	14 (19.72)	38 (19.29)	
Ones every day	4 (6.15)	3 (4.23)	40 (20.30)	
Several times every day	5 (7.69)	19 (26.76)	22 (11.17)	
Forearms				**0.157**
Never	64 (98.46)	63 (88.73)	186 (94.42)	
1-2 times last week	1 (1.54)	5 (7.04)	5 (2.54)	
3-4 times last week	0 (0.00)	3 (4.23)	2 (1.02)	
Ones every day	0 (0.00)	0 (0.00)	2 (1.02)	
Several times every day	0 (0.00)	0 (0.00)	2 (1.02)	
Wrists				**0.092**
Never	63 (96.92)	63 (88.73)	183 (92.89)	
1-2 times last week	1 (1.54)	3 (4.23)	6 (3.05)	
3-4 times last week	0 (0.00)	4 (5.63)	1 (0.51)	
Ones every day	1 (1.54)	1 (1.41)	4 (2.03)	
Several times every day	0 (0.00)	0 (0.00)	3 (1.52)	
Hip/Buttocks				**0.000**
Never	62 (95.38)	56 (78.87)	127 (64.47)	
1-2 times last week	3 (4.62)	14 (19.72)	52 (26.40)	
3-4 times last week	0 (0.00)	0 (0.00)	2 (1.02)	

Ones every day	**0 (0.00)**	**1 (1.41)**	**12 (6.09)**	
Several times every day	**0 (0.00)**	**0 (0.00)**	**4 (2.03)**	
Thighs				**0.146**
Never	**56 (86.15)**	**67 (94.37)**	**184 (93.40)**	
1-2 times last week	**5 (7.69)**	**2 (2.82)**	**8 (4.06)**	
3-4 times last week	**2 (3.08)**	**0 (0.00)**	**0 (0.00)**	
Ones every day	**2 (3.08)**	**1 (1.41)**	**3 (1.52)**	
Several times every day	**0 (0.00)**	**1 (1.41)**	**2 (1.02)**	
Knees				**0.052**
Never	**59 (76.92)**	**48 (67.61)**	**161 (81.73)**	
1-2 times last week	**4 (6.15)**	**8 (11.27)**	**21 (10.66)**	
3-4 times last week	**5 (7.69)**	**4 (5.63)**	**7 (3.55)**	
Ones every day	**3 (4.62)**	**7 (9.86)**	**3 (1.52)**	
Several times every day	**3 (4.62)**	**4 (5.63)**	**5 (2.54)**	
Lower legs				**0.006**
Never	**46 (70.77)**	**49 (69.01)**	**147 (74.62)**	
1-2 times last week	**6 (9.23)**	**9 (12.68)**	**29 (14.72)**	
3-4 times last week	**8 (12.31)**	**0 (0.00)**	**6 (3.05)**	
Ones every day	**2 (3.08)**	**6 (8.45)**	**7 (3.55)**	
Several times every day	**3 (4.62)**	**7 (9.86)**	**8 (4.06)**	

Table 3 - Uncomfortable feeling when experiencing ache, pain or discomfort

Characteristics	**Active n=65**	**Partly active n=71**	**Sedentary n=197**	**p-value**
Neck				**0.000**
Slightly	**48 (73.65)**	**34 (47.89)**	**71 (36.04)**	
Moderately	**14 (21.54)**	**27 (38.03)**	**75 (38.07)**	
Very	**3 (4.62)**	**10 (14.08)**	**51 (25.89)**	
Shoulders				**0.007**
Slightly	**53 (81.54)**	**46 (64.79)**	**73 (61.86)**	
Moderately	**12 (18.46)**	**21 (29.58)**	**27 (22.88)**	
Very	**0 (0.00)**	**4 (5.63)**	**18 (15.25)**	
Upper back				**0.105**
Slightly	**53 (81.54)**	**43 (60.56)**	**135 (68.53)**	
Moderately	**10 (15.38)**	**22 (30.99)**	**46 (23.35)**	
Very	**2 (3.08)**	**6 (8.450)**	**16 (8.12)**	
Upper Arms				**0.417**
Slightly	**60 (92.31)**	**63 (88.73)**	**179 (90.86)**	
Moderately	**5 (7.69)**	**6 (8.45)**	**17 (8.63)**	
Very	**0 (0.00)**	**2 (2.82)**	**1 (0.51)**	
Lower Back				**0.000**
Slightly	**37 (56.92)**	**27 (38.03)**	**50 (25.38)**	
Moderately	**21 (32.31)**	**27 (38.03)**	**95 (48.22)**	
Very	**7 (10.77)**	**17 (23.94)**	**52 (26.40)**	
Forearms				**0.031**
Slightly	**65 (100.00)**	**63 (88.73)**	**189 (95.94)**	
Moderately	**0 (0.00)**	**6 (8.45)**	**7 (3.55)**	

Very	0 (0.00)	2 (2.82)	1 (0.51)	
Wrists				0.476
Slightly	63 (96.92)	64 (90.14)	185 (93.91)	
Moderately	1 (1.54)	5 (7.04)	10 (5.08)	
Very	1 (1.54)	2 (2.82)	2 (1.02)	
Hip/Buttocks				0.000
Slightly	62 (95.38)	59 (83.10)	139 (70.56)	
Moderately	2 (3.08)	12 (16.90)	51 (25.89)	
Very	1 (1.54)	0 (0.00)	7 (3.55)	
Thighs				0.332
Slightly	56 (86.15)	67 (94.37)	184 (93.40)	
Moderately	8 (12.31)	3 (4.23)	11 (5.58)	
Very	1 (1.54)	1 (1.41)	2 (1.02)	
Knees				0.001
Slightly	52 (80.00)	49 (69.01)	164 (83.25)	
Moderately	7 (10.77)	14 (19.72)	31 (15.74)	
Very	6 (9.23)	8 (11.27)	2 (1.02)	
Lower legs				0.155
Slightly	46 (70.77)	49 (69.01)	149 (75.63)	
Moderately	16 (24.62)	14 (19.72)	41 (20.81)	
Very	3 (4.62)	8 (11.27)	7 (3.55)	

Table 4 - Ache, pain and discomfort interfering ability to work

Characteristics	Active n=65	Partly active n=71	Sedentary n=197	p-value
Neck				0.000
Not at all	51 (78.46)	41 (57.75)	94 (47.72)	
Slightly	11 (16.92)	23 (32.39)	52 (26.40)	
Substantially	3 (4.62)	7 (9.86)	51 (25.89)	
Shoulders				0.053
Not at all	56 (86.15)	50 (70.42)	139 (70.56)	
Slightly	7 (10.77)	16 (22.54)	34 (17.26)	
Substantially	2 (3.08)	5 (7.04)	24 (12.18)	
Upper back				0.089
Not at all	58 (89.23)	53 (74.65)	150 (76.14)	
Slightly	7 (10.77)	13 (18.31)	30 (15.23)	
Substantially	0 (0.00)	5 (7.04)	17 (8.63)	
Upper Arms				0.309
Not at all	64 (98.46)	64 (90.14)	180 (91.37)	
Slightly	1 (1.54)	5 (7.05)	14 (7.11)	
Substantially	0 (0.00)	2 (2.82)	3 (1.52)	
Lower Back				0.000
Not at all	45 (69.23)	38 (53.52)	65 (32.99)	
Slightly	15 (23.08)	22 (30.99)	75 (38.07)	
Substantially	5 (7.69)	11 (15.49)	57 (28.93)	
Forearms				0.276
Not at all	65 (100.00)	66 (92.96)	190 (96.45)	

Slightly **Substantially**	**0 (0.00)** **0 (0.00)**	**3 (4.23)** **2 (2.82)**	**5 (2.54)** **2 (1.02)**	
Wrists **Not at all** **Slightly** **Substantially**	 **64 (98.46)** **1 (1.54)** **0 (0.00)**	 **64 (90.14)** **4 (5.63)** **3 (4.23)**	 **191 (96.95)** **1 (0.51)** **5 (2.54)**	**0.033**
Hip/Buttocks **Not at all** **Slightly** **Substantially**	 **62 (95.38)** **3 (4.62)** **0 (0.00)**	 **67 (94.37)** **4 (5.63)** **0 (0.00)**	 **166 (84.26)** **27 (13.71)** **4 (2.03)**	**0.048**
Thighs **Not at all** **Slightly** **Substantially**	 **61 (93.85)** **2 (3.08)** **2 (3.08)**	 **69 (97.18)** **1 (1.41)** **1 (1.41)**	 **187 (94.92)** **8 (4.06)** **2 (1.02)**	**0.635**
Knees **Not at all** **Slightly** **Substantially**	 **54 (83.08)** **5 (7.69)** **6 (9.23)**	 **57 (80.28)** **9 (12.68)** **5 (7.04)**	 **174 (88.32)** **18 (9.14)** **5 (2.54)**	**0.139**
Lower legs **Not at all** **Slightly** **Substantially**	 **49 (75.38)** **12 (18.46)** **4 (6.15)**	 **57 (80.28)** **6 (8.45)** **8 (11.27)**	 **162 (82.23)** **29 (14.72)** **6 (3.05)**	**0.051**

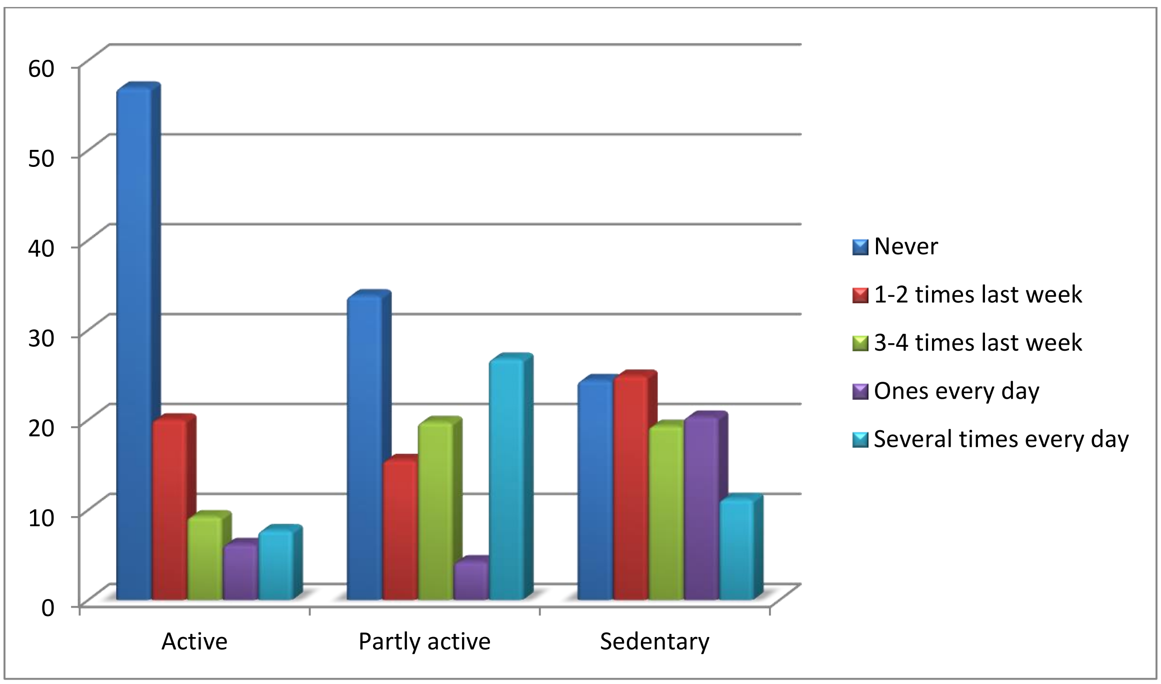
Table 5 - Bivariate logistic regression analysis

Variable	Crude OR	p-value	CI (95%)
Independent variables			
Gender **Male**	**.60**	**.023**	**(.38; .93)**
Period of working	**1.00**	**.700**	**(.99; 1.00)**
Neck problems	**.80**	**<.001**	**(.73; .88)**
Shoulder problems	**.95**	**.046**	**(.89; 1.00)**
Upper back problems	**.95**	**.327**	**(.85; 1.05)**
Upper arm problems	**1.00**	**.897**	**(.91; 1.11)**
Lower back problems	**.85**	**<.001**	**(.78; .92)**
Forearms problems	**1.00**	**.960**	**(.89; 1.13)**
Wrist problems	**1.00**	**.948**	**(-.91; 1.10)**
Hip buttocks problems	**.63**	**<.001**	**(.51; .78)**
Thigh problems	**1.03**	**.486**	**(.94; 1.13)**
Knee problems	**1.10**	**.004**	**(1.02; 1.15)**
Leg problems	**1.05**	**.071**	**(.996; 1.10)**

Table 6 - Multivariate logistic regression analysis

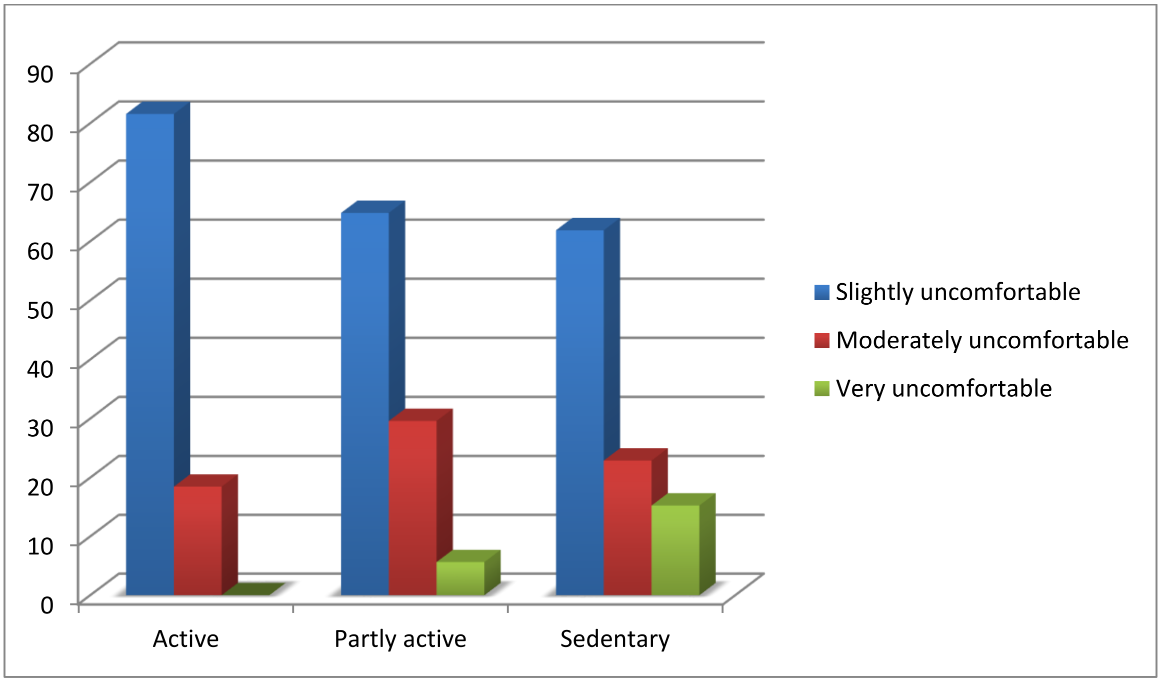
Variable	Crude OR	p-value	CI (95%)	Pseudo R2	p-value
Independent variables					
Gender	*.76*	*.299*	*(.45; 1.27)*		
Neck problems	**.78**	**<.001**	**(.68 ; .89)**		
Shoulder problems	**1.06**	**.100**	**(.99 ;1.15)**	**.1417**	**<.001**
Lower back problems	**.90**	**.042**	**(.82; .99)**		
Hip buttocks problems	**.67**	**.001**	**(.54 ; .85)**		
Knee problems	**1.11**	**.004**	**(1.03; 1.19)**		
Leg problems	**1.07**	**.038**	**(1.00; 1.14)**		

Chart 1 - Ache, pain and discomfort in the lower back



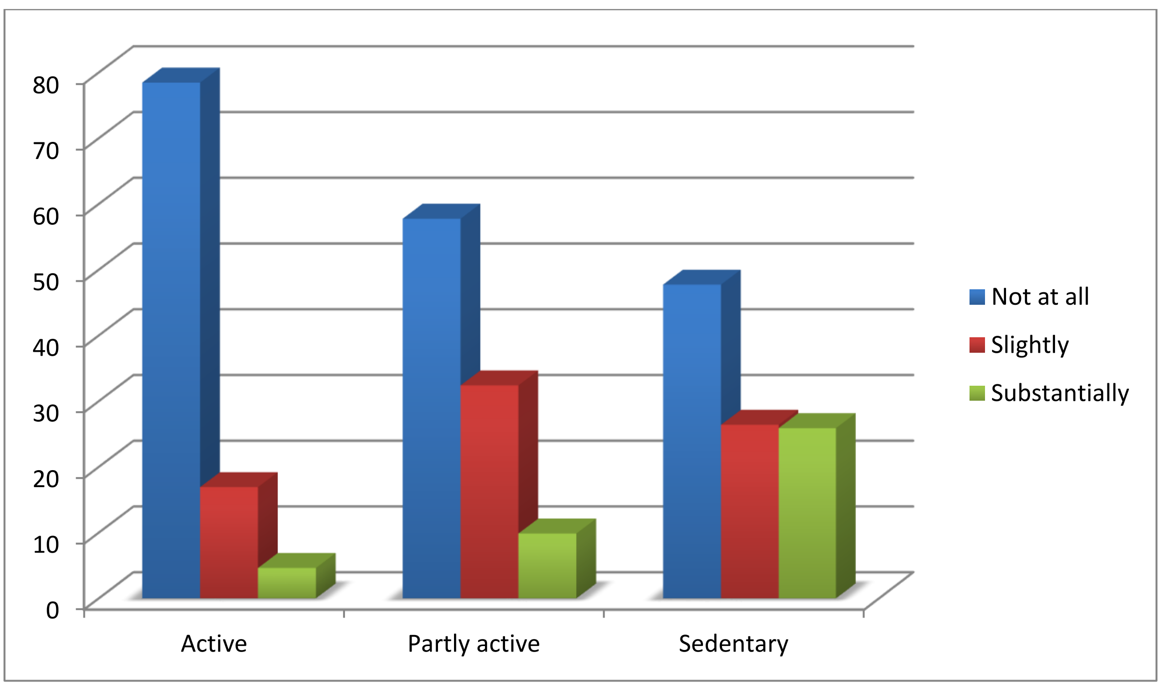
As it is seen from the chart above, active workers experience ache, pain or discomfort in the lower part of the body less than workers from partly active and sedentary groups. It is also obvious, that workers from partly active group experience ache, pain or discomfort more frequently than those from active group.

Chart 2 - Uncomfortable feeling of ache, pain and discomfort in shoulders



As shown on the chart above, the uncomfortable feeling of ache, pain and discomfort is increasing from active lifestyle to sedentary.

Chart 3 - Ache, pain and discomfort in the neck interfering with the ability to work



It is obvious that ache, pain or discomfort in the neck affects the ability to work in different groups of workers doing different jobs and especially workers doing sedentary job, as compared with workers doing active or partly active job.

3.8 Conclusions

The results of this study indicate that sedentary working conditions may cause pain, ache or discomfort in different parts of the body resulting to uncomfortable feeling in neck, shoulders, lower part of back, forearms, hip/buttocks and knees, but the more important finding is the ability of working, which decreases with experience of ache, pain or discomfort especially in neck and lower back. Significant association was found between gender, neck problems, lower back problems, hip/buttocks problems and passive lifestyle of the employees. These findings suggest opportunities for intervention strategies as to stimulate an ergonomic setting in the workplaces.

4 Healthy workplace and Computer Ergonomics

4.1 Why develop a healthy workplace?

As describes in [Joan, 2010], to answer the question “why develop a healthy workplace?”, perhaps another and no less important question should be answered first: why bother with healthy workplaces at all? While it would be logical, if it is self-interest for workers to want to have a healthy workplace, why should employers care?

We can answers to that in several ways. First of all, creating a healthy workplace that does no harm to the mental or physical health, safety or well-being of workers is a moral imperative of our days. In recent years, more attention has been paid to business ethics and the norms deriving therefrom. The second reason that creating healthy workplaces is important is the business argument. It looks at the hard, cold facts of economics and money. Companies do business to make money, and to make money healthy workplaces should be created. These workplaces require workers in order to achieve their goals, and there is a strong business case to be made for ensuring that workers are mentally and physically healthy through health protection and promotion [Joan, 2010]. Figure 4.1 summarizes the workflow diagram for the business case.

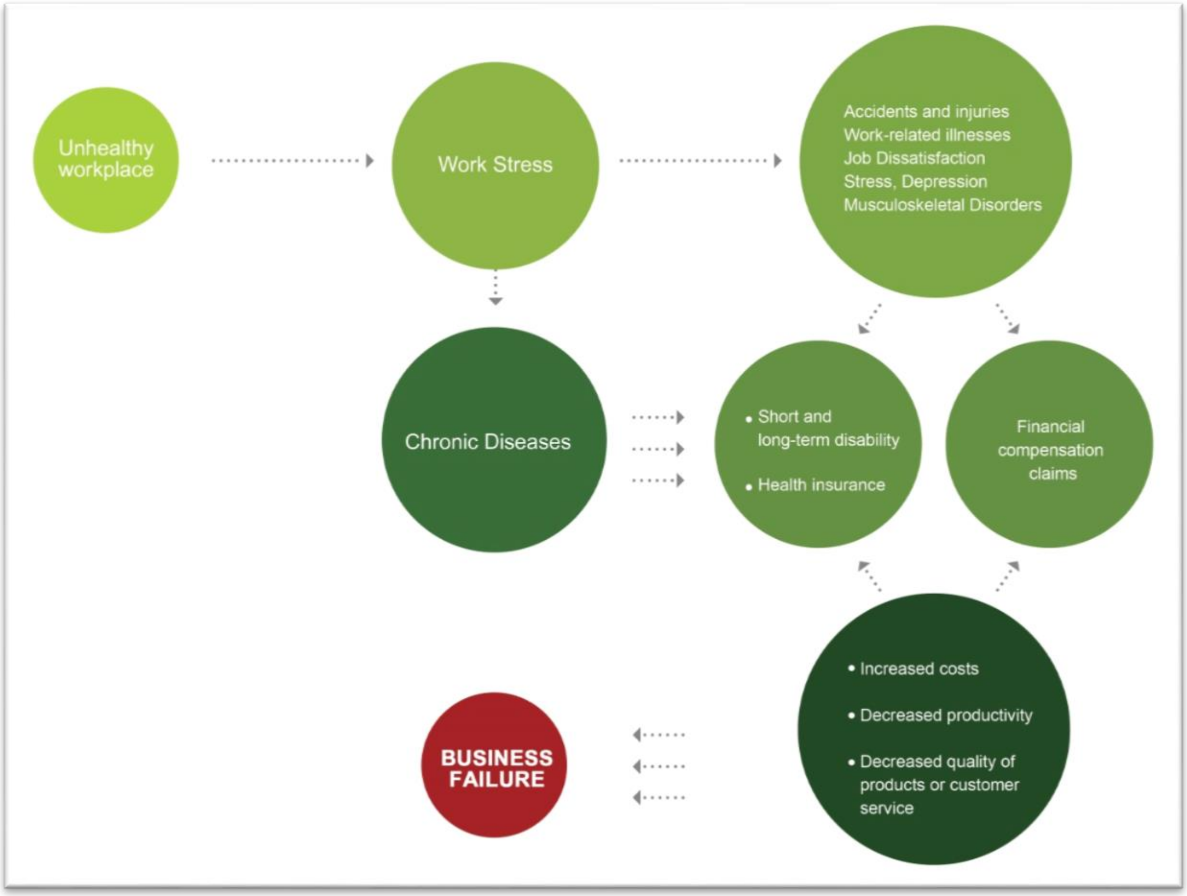


Figure 4.1 - Business case workflow diagram

Here a logical question arises: given the ethical and business reasons for creating healthy workplaces, why then is a global guidance required? A look at the global situation reveals that many or almost all organizations and even governments have not understood the advantages of healthy workplaces, or do not have the knowledge, skills or tools to improve things. The European Union stresses that the lack of effective health and safety at work not only has a considerable human dimension, but also has a major negative impact on the economy. The enormous economic cost of problems associated with health and safety at work inhibits economic growth and affects the competitiveness of businesses [EU, 2007].

Sharp increase in the number of work-related deaths or occupational accidents and illnesses urged the International Labour Organization (ILO) and World Health Organization to focus efforts on developing a preventive safety and health culture.

According to new estimates by the ILO, the number of occupational accidents and illnesses, which annually claim more than two million lives, appears to be rising because of rapid industrialization in some developing countries. Hence, despite many advantages industrialization also has disadvantages, which result in rapid increase in the number of work-related deaths and occupational accidents and illnesses, which, of course, could not but make part of our research [Labour Org].

In [Joan, 2010][Leka, 2008] are listed the main factors having serious impact on workers' health:

- **work content** – lack of variety, sedentary work;
- **workload** – work overload, time pressure;
- **work schedule** - shiftwork, inflexible schedules, unpredictable hours, long hours;
- **ergonomics** – lack of ergonomic conditions in the workplace;
- **lack of information** – workers lack knowledge and skills necessary to create a healthy workplace.

The aforementioned fully covers the social perception of the importance of having a safe and healthy workplace, as well as how the working conditions impact workers' health and the latter, in its turn, company's productivity.

This, of course, motivates both employers and workers to take relevant measures to create healthy workplaces. Have you ever thought about the possible solutions to the problem in question? How should we understand whether or not such solutions are effective? The following section will give an answer to these questions. What is ergonomics? Where and how is it used?

4.2 What is Ergonomics?

In our everyday life we very often use the term "ergonomics". The present section describes the ergonomic conditions in the workplace. What is ergonomics and why do we need to have ergonomic conditions in the workplace? Here we will find the answers to these questions. Ergonomics is the science of studying people at work and then designing tasks, jobs, information, tools, equipment, facilities and the working environment so people can be safe and healthy, effective, productive and comfortable [Alexander, 1998]. It is the science of studying general activities of people, means of activity and human-environment interactions. Its main objective is to ensure the productivity, safety and comfortability of production processes, i.e., to create such conditions that will help to reduce fatigue and contribute to health.

The success of every organization depends on human factors. The productivity of organizations highly depends on job satisfaction of workers at workplace. Ergonomics tries to harmonize things that interact with people in terms of people's needs, abilities and limitations. Ergonomics is the scientific discipline concerned with the study of changes of functional state of human body, and the profession that applies theory, principles, data and methods, in order to optimize human well-being [Alexander, 1998].

Comfort in the workplace is reached with the help of ergonomics and rational planning of the office area. According to the definition of the International Ergonomics Association, ergonomics is a scientific discipline concerned with design of objects, systems and environments for humans [Int. Ergonomics]. In terms of ergonomics the main principles of organization of workplace are comfort and minimum load. Unfortunately, modern society is dominated by a sedentary lifestyle and people doing sedentary work forget about maintaining a correct sitting posture. In the context of ergonomics, micro ergonomics is the study of human-machine interactions; it also focuses on the design of workplaces. If a worker fails to fully perform the scheduled work during the working day, it does not always mean a bad worker. The reason for such failure can be the uncomfortable workplace, causing early fatigue, as well as making the worker spend much time and energy on doing unnecessary things. Every year almost 1 million people use part of their working time to treat or recover from work overload, musculoskeletal pains or other functional disorders [Bls].

Working in awkward positions or work overload may cause muscle fatigue/strain. Under such working conditions muscles, tendons, ligaments, nerves and blood vessels can be damaged. They generally affect the back, arms, shoulders and neck. Such injuries are called locomotor disorders. Moreover, sitting at a desk for extended periods of time increases the likelihood of occurrence of muscular injuries. This risk is increasing parallel to the time spent in front of the computer. Very often the reason for muscle strain or discomfort is the awkward position of worker in the workplace (chair placement in front of the desk, uncomfortable office furniture, etc.).

Computer operators may experience both muscle and visual discomfort and strain. Symptoms vary from eye strain, eye burning sensation and blurred images to headache. Depending on the placement of computer, new visual demands, such as illumination and brightness level, can be presented by computer operators.

The present research studies the physical and visual factors, affecting people working with the computer. It focuses on the placement of workstation, computer and its accessories (keyboard, monitor, mouse, etc.), office furniture and other objects, as well as on workplace illumination and design of computer-related tasks.

Firstly, the encountered problems were studied and based on the results the system was developed. Although numerous researches [Karin, 2008] [MICHIEL, 2003] have revealed the right working postures, such as the sitting depth, spine and waist positions, seat height adjustment, eye strain control and other physical parameters, there does not exist any such system that would not only constantly monitor human behavior during the work and fix any deviations from normal behavior, but would also offer solutions to problems and help to prevent the reasons for the occurrence of such problems.

A question arises: how can we examine different people, as well as people having different postures by applying the same method? The physical abilities of different people may vary depending on age, physical preparedness, sex, height, etc. The system developed by us considers all these factors case by case, and responds accordingly to the deviations in human behavior. More details about the system operation will be described in the Chapter 7.

4.3 Benefits of ergonomics

If we consider a workplace as a unit of production process, we'll see that at all times workplaces were fully at the disposal of workers and ergonomics was used by them personally to customize the workplace to their needs.

Individual ergonomics

The features listed below best characterize individual ergonomics:

- workplace can be customized to the specific physical needs of the worker and the technical processes required to create the most comfortable working conditions, considering the impact on worker's health;
- workplace is a modular structure consisting of many components, which enable to build an appropriate configuration and change it quickly, if necessary;
- workplace is universal in its modules, but if fully configured, it will strictly meet the specific objectives and technical processes, if applicable;
- all associated conditions should be customizable. It refers to illumination (both general and local), room temperature, workstation configuration, placement in the room, organization of storage areas, etc.

The benefits of individual ergonomics in the workplace are obvious:

- to bother with worker's health, thus reducing fatigue, treatment costs and the risk of occupational illnesses;
- to increase business productivity by increasing individual productivity of a particular worker: an opportunity to constantly optimize the workplace;
- to strengthen worker's concentration in the workplace, thus improving product quality and reducing defects.

Individual ergonomics: future or the past?

For centuries, individual ergonomics in workplaces has enabled to develop innovative solutions, thus contributing to progress. There are many such examples. Most of the major projects in the world were launched in garages, rooms, private workshops and laboratories. The world has changed thanks to the innovators, who were self-employed in their own workplaces. Those workplaces were individual and had a set of features that enabled to achieve results in the most efficient manner, i.e., they had individual ergonomics.

Workplaces are everywhere, where there are people. In the industrial domain such workplaces are deemed to be warehouses, workshops, all possible clean and office premises, etc.

Every workplace should have its specific characteristics corresponding to the domain of human activity it is intended for. Every such workplace can and should create an opportunity for innovations, and the only way to innovate is to create favorable conditions for that.

Today the need for individual customization of workplaces, as well as for innovators is more than topical, and innovators do not come without the desire for personal, and most importantly, for overall efficiency. Efficiency, in its turn, is impossible without high concentration, which can be only reached in comfortable conditions, when nothing distracts attention: neither a squeaky chair nor blinking lights nor a shaky desk, etc.

You may ask: what can our organization do to reduce or prevent the injuries of the locomotor apparatus requiring enormous treatment costs and to help avoiding the problems listed above? One of the answers will be to use proper ergonomics in the workplace. It is more important to treat the health problems relating to locomotor apparatus at an early stage of their occurrence, as at that stage they can be treated and are less costly. Unfortunately, it is not the case with the later stages.

Everything is highly interrelated, so the answer to the above question is: **individual ergonomics, which is undoubtedly the future, as ergonomics contributes to the development of the engine of progress – the man.**

4.4 Worker fatigue

4.4.1 What is fatigue?

In this subchapter I'd like to give the outline of the main health problems that occur in human-computer interaction, as well as of consequences and progress thereof. The studies of this topic provide deeper understanding of these problems, as well as of their impact on human health. The most important thing to do at this stage is to reveal the critical problems that we'll need for further development of our system prototype, as through that prototype we should monitor workers at work and offer them right solutions from a medical point of view.

Fatigue can be defined as an increasing decline in alertness and ability to work, thus causing sleep. Fatigue is a daily phenomenon and in an ideal world it would not have posed a serious risk to human health and safety. Nonetheless, the society we live in is a living organism, which is in motion 24/7, without week-ends, and, correspondingly, most people are forced to work "non-standard" hours. Hence, this chaos leads to severe fatigue. Shift work, long hours, business trips among others can be a serious cause of fatigue. Other causes of fatigue are medical disorders, such as sleep disorder, drugs, etc.

People are different by their nature and physical and physiological characteristics. For example, the same action done by different people may cause different degrees of fatigue. As far as our research mainly targets office workers doing sedentary jobs, we'll focus on office workers' health problems, as well as on negative impacts suffered by them as a result of fatigue.

Nowadays we spend extended periods of time in front of the computer. Such lifestyle has rather an aggressive and irritative effect on human brain and organism, in general. Let's consider several aspects of computer exposure.

Firstly, it is the unimaginable and large amount of information that our brain has to absorb every second. Humans have never been exposed to such a large amount of information before. In addition, we need to instantly analyse, make decisions and take other necessary actions with regard to the information we receive every second. To do this, our brain loses a lot of energy. That is why, after spending many long and tense hours in front of the computer, whether for learning, working or for other purposes, many people feel tired and exhausted. Secondly, it is the same body position that not only affects our posture, but also our organism. Human spine has several curvatures that normally ensure the good physiological state and wellness of human body. The curvatures of chest and spine are of greater importance [Rudakewych, 2001] and especially these curvatures are affected as a result of spending extended periods of time in front of the computer. Another important problem is the impact of computer on human eyes and sight. Interaction with the computer, whether for learning, working or for other purposes, makes us blink eyes six times less [Bacher, 2004] than necessary. As a consequence, the cornea does not get enough moisture, thus resulting in sight degradation.

As far as today we cannot imagine our everyday life without information technologies, we can say for sure that it exerts positive or negative effect on everybody, whether a child or adult. There will come a time when we'll live in an age richer in information technologies. In the meantime, however, we will have a society with different health problems entailed by negative impact of such technologies.

How to prevent these problems from occurring and how to protect human health? That's the main question, as it is as easy as ABC to understand that it is impossible to imagine the future without the computer. As far as the topic of this research paper is the workplace, office worker and his/her health, as well as the means thanks to which all negative impacts on office worker's health can be prevented, the present subchapter is fully dedicated to the working environment and health problems caused by wrong working conditions.

4.4.2 Computer without harm to health

Do you know how much time the children of Bill Gates, Microsoft founder, spend on computer entertainments? No more than 45 minutes daily in one press conferences said Bill Gates. On weekends this time reaches 1 hour and 45 minutes with every 15-20 minutes break. What should be considered, in order to avoid too much computer exposure?

Human health effects of exposure to the computer are as follows:

1. Electromagnetic radiation
2. Muscle and joint strain
3. Eye strain

4. Psychological strain

Electromagnetic radiation

This is the most common reason why parents fear for their children's health. It is true that the pathogenicity of electromagnetic radiation has not been fully proved so far; it is mainly doubts. X-rays emitted from a computer monitor are very weak; it doesn't emit radioactive particles at all. But electromagnetic radiation of the computer and its electrostatic field are equivalent to those of toasters and microwaves. Another thing is that people spend very little time, usually few minutes next to these appliances when they are turned on, i.e., significantly less time than in front of the computer. One thing, though, can be deemed as a proven fact – it is the low content of negative ions in the air around the computer. And it is because of that the following symptoms, such as sore eye or dry skin appear after sitting long hours in front of the computer.

Muscle and joint strain

Remember how we were taught to sit right at the desk when in the first class? All this is true for the posture we maintain while sitting in front of the computer. An uncomfortable chair, too high or too low desk and absence of a backrest may lead to osteochondrosis or scoliosis.

Eye strain

Over the years the eyesight of people, who spend extended periods in front of the computer, can be seriously affected. So, it is very important that computer monitor doesn't cause additional problems. The properties of the equipment used, as well as how the workplace is equipped play an important role here. We have touched upon this topic when speaking about ergonomics in the workplace.

Psychological strain

The less you are exposed to stress, the less you feel fatigue. It is a proven fact [Harkness, 2005].
The topic of computer addiction is rather a complicated one and so far the experts have not reached a consensus on why and how this type of addiction is formed and whether or not it is formed at all. Currently it makes sense to consider it as one of the varieties of addictive behavior, such as gambling, tobacco or alcohol addiction.

4.4.3 Work-related musculoskeletal disorders

Injuries and disorders are mainly due to uncomfortable positions, repeated movements, strong strain and a range of other risk factors for health. Very often such injuries or disorders cannot be observed easily due to their being not grave. So, besides grave injuries or disorders there are also cumulative trauma injuries or disorders that are observed not at once, but after some time. Such types of injuries are known as musculoskeletal injuries or disorders.

Depending on the work we do, work-related musculoskeletal injuries or disorders may vary. In the scope of this research we'll study the injuries or disorders caused by sedentary jobs, as well as the methods of avoiding such problems. This study, however, is not developed to handle specific injuries. Weakness, tremor, sleep disorder, numbness of limbs, pain in different parts of the body, the difficulty in doing any action or moving any part of the body can be deemed as signs or symptoms of musculoskeletal injuries. And, why not, also eye sore, as the eyes are mostly exposed to computer. All separate body parts we include in survey and you already see the most vulnerable parts.

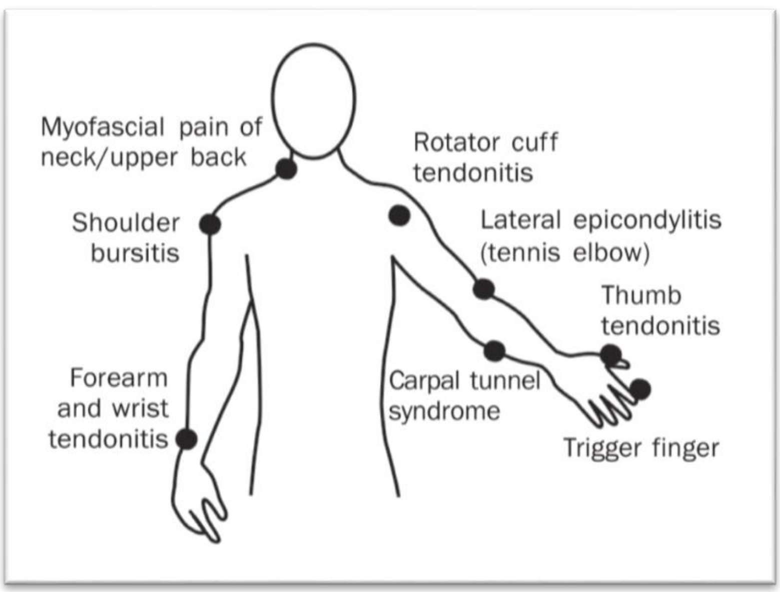


Figure 4.2 - Body parts where some WMSDs occur [WMSD]

4.4.4 Symptoms of WMSDs and risk factors

Almost all health problems can be prevented from further progressing. Necessary actions should be taken to keep them under control and not let them pose a threat to our health. As a first step the following risk factors can be identified:

- occurrence of pain;
- intensity of pain;
- spreading pain, i.e., when pain spreads from one part to another;
- a feeling of discomfort due to pain and nonstop pain at the end of the working day;
- impossibility of relieving the feeling of discomfort with ease.

Generally, it can be stated that the gravity of risk factors depends on three main points: duration, intensity and frequency.

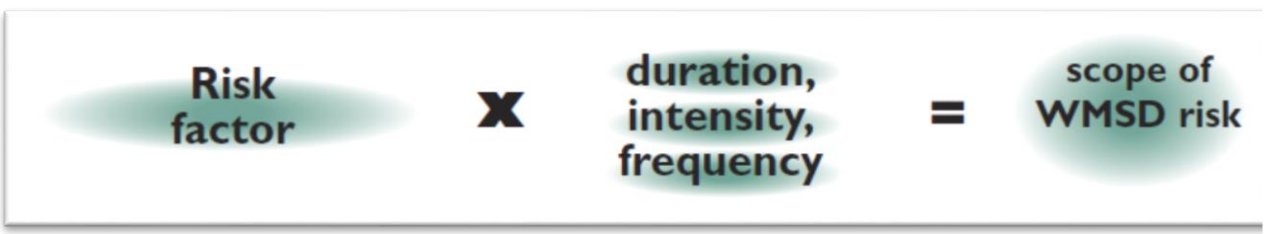


Figure 4.3 - Characterization of most risk factors [Serge, 1996]

The five risk factors affecting human health and most encountered in our everyday life situations are as follows:

- uncomfortable position;
- use of physical force;
- work, causing muscle strain;
- sedentary job;
- organizational factors.

Generally, none of these factors acts separately to cause Work-Related Musculoskeletal Disorders. WMSDs commonly occur as a result of a combination and interaction among them.

4.4.5 Sitting and back discomfort

While doing a sedentary job many unpleasant feelings, such as numbness of limbs, pain in the back, neck or in other parts occur. These unpleasant feelings may be symptoms of serious diseases. The most dangerous sitting position is when shoulders are slightly raised, neck muscles strained and head tilted forward. If maintaining this position for extended periods of time, the functioning of vertebral arteries will degrade, resulting in disruption of blood flow to the brain and, thus, causing headaches, memory degradation, high pressure and fatigue. Heartache and arrhythmia are also possible, if intercostal nerves are under pressure for an extended period. In order to avoid the aforementioned problems the following actions should be taken:

- to change sitting positions as often as possible;
- to always control muscle strain and prevent its occurrence. Every 10-15 minutes one should make sure that the back and hands are not strained and shoulders are not raised, as well as one should do some physical exercises, in order to reduce physical tension.

4.4.6 Back physiology while sitting

This part of research will focus on the physiological structure of the human body while sitting. Physical discomfort in the back, having an expression of pain, may occur as a result of absence of ergonomic conditions or those risk factors, which cause musculoskeletal disorders. Approaching the problem from a medical point of view, we can say that in our everyday life very often we unconsciously open possibility for problems connected with the back. Long-time motionless position may reduce blood circulation, which is mainly observed in the extremities of the body. In the first stage it may only cause discomfort, but in case of aggravation it may become rather a serious problem. Another factor causing physical discomfort in the back is uncomfortable or improper vertebral posture, which can squeeze or even rupture the cartilaginous discs between vertebrae. Complications may occur especially when one fails to take regular breaks or do physical exercises on a daily/weekly basis.

Ignoring the factors described hereinabove, employees at work, students at university or pupils at school more often face health risks. Nowadays there is a tendency to simplify all processes, as a result of which human mobility is restricted. Today almost all conditions are created to manage all processes sitting at the desk/in front of the computer. Whereas, a couple of years ago rather serious physical efforts were needed to manage all the mentioned processes.

In order to have general understanding of how the sitting posture affects the body, it is necessary to analyses interaction of the parts of the body while sitting. The interaction takes place among 5 important parts – vertebral column, intervertebral discs, pelvis, muscles and the skin.

Vertebral cord is a column composed of 24 vertebrae. It's one of the most important structures of the human body especially while sitting. The arrangement of 24 vertebrae composes 3 natural curvatures. Upper part of the vertebral column is composed of 7 vertebrae and forms the primary curvature of the vertebral column and begins from the neck (cervical region). Next is thoracic region, composed of 12 vertebrae and forming the curvature (kyphosis) of the rear part of the vertebral column. Lower part of the vertebral column, i.e., lumbar region, is composed of 5 vertebrae and forms the next external curvature.

Intervertebral discs are formed from cartilaginous tissues and filled with thick liquid. Thanks to these discs vertebrae are separated from each other. Besides, intervertebral discs give flexibility to the vertebral column and ensure its amortization in positioning.

Pelvis, sacrum and ischial tuberosities: the base of the vertebral column is called sacrum. It's a triangular bone in the lower back formed from 5 fused vertebrae and situated between the two hip bones of the pelvis. These 3 bones together are called lumbar region. Two main bones of the hips on which we sit are called ischial tuberosities. Hips may turn to right or left, thus changing the curvature of the lumbar region of the vertebral column.

4.4.7 Healthy posture

As previously stated, numbness of lower limbs or extremities and eye strain are among those factors that risk human health. Another risk factor is psychological factor, which is no less serious than others. We already know that computer addiction is rather a serious psychological problem with no less serious consequences.

How to sit right in front of the computer?

- As far as desks are not height-adjustable, it would be preferable, if office chairs are height-adjustable for comfortable sitting.

- Backrest should enable to slightly lean back against while sitting (only to several degrees); it removes pressure on the spinal cord.
- While sitting at the desk arms and elbows should rest on the desk; hence, it is preferable that the chair is close to the desk as much as possible. If elbows don’t rest on the desk while working, then extended periods spent in front of the computer may cause pain in the hands or wrists, as well as result in nerve inflammation.
- Hips should rest at a right angle to the trunk and knees should be bent at a right angle too.
- Legs should rest completely on the floor or on a stand.
- Head should not be tilted forward. Forward-tilted head position while sitting may cause strong pains in the upper part of the back and in the neck,
- Very often office workers sit in front of a notebook, instead of a desktop computer. Notebook monitors are usually lower than that of desktop computers, which make a worker to stoop down. To avoid this, it is preferable that the notebook monitor is adjusted to a right angle. The monitor should be positioned so that its center is slightly below eye level (at an angle of about 10 degrees), in order to avoid neck strain.

How to protect eyes from the computer screen?

It is already a long-known fact that computer screen has a harmful effect on human sight. After spending few hours in front of the computer our eyes become tired, red and watery followed by headaches. Spending systematically long hours in front of the computer leads to sharp deterioration of sight. As time passed, physicians and engineers revealed how computer deteriorates human sight. If, for example, we look at an old black-and-white TV screen from a close distance, it won’t be too dangerous for our eyes, as blinking takes place not from a too close distance. It is not the case with computer screen, as here the distance between the eyes and computer is less. One can even adapt to weak fluctuations of text or image, but eyes automatically react to such fluctuations. As a consequence, eye nerves and corresponding nerve centers of human brain become strained, inevitably resulting in reduction in visual acuity. A set of independent tests have revealed that safe intensity of fluctuations of monitors starts from 75 Hz, which is the minimum necessary intensity. In order to protect our eyes from the computer screen, we need to buy a monitor manufactured after 1995. No matter how cheap the computer is, we should avoid buying it, if the screen is flickering. It is better to increase intensity of fluctuations to 75-85Hz at the expense of permissible zoom out of computer screen. Otherwise, working with the computer will pose a threat to human health.

The distance between the eyes and computer screen must be at least 50cm, or, in other words, our hand should hardly reach the screen when extended towards it. As for the minimum permissible distance, from a scientific point of view, human eyes can clearly see an object from top to bottom at an angle of 17 degrees. Hence, the minimum permissible distance between the eyes and computer screen should be the length of the diagonal of the computer screen. The monitor should be positioned about 10 degrees below the conventional horizon, which is at eye level. Hence, we should look at the screen from top to bottom. It is recommended to tear the eyes away from the screen every 30 minutes and look far into the distance. This exercise helps to protect eyesight. Sometimes it is useful to close the eyes for some 2-3 minutes. It helps to remove eye muscles strain, recover visual receptors sensitivity, thus providing clarity and brightness of sight.

On top of the above-mentioned recommendations, it is also recommended not to forget about blinking eyes frequently. It will help to avoid eye strain and sight degradation.

Dry eye syndrome is also known as “office eye syndrome”. Symptoms thereof are redness and dryness of the eyes; one has the feeling of sand in the eyes. This is because of spending extended hours in a room full of computers.

- The distance between the eyes and computer screen must be at least 50-65cm, and its center should be positioned slightly below eye level (10-20 degrees).
- If one needs to combine the work on the screen with the work in a printed text format, one should place the text on the left side of the screen and at a distance of at least 33cm from the eyes.
- While working with the computer, one should have breaks every 30 minutes.

One should use a monitor, software and settings that are safe for the sight; the picture should not flicker or be too small or too bright.

5 Workers monitoring systems

There are many opinions regarding monitoring of workers' health status at work. However, almost all authors of these opinions have come to the same conclusion that the mentioned domain is rather poorly developed and that it is necessary to control and protect workers' health in the workplace to the greatest degree possible.

In this section I'll present several monitoring systems that already exist and are in use, and through comparison thereof I'll try to clearly showcase the importance and seriousness of the work done. Having studied different research materials and works for already three years in the scope of this research, with difficulty I can bring some examples related to the topic in question, due to the modest quantity of such research works.

Kortuem [Gerd, 2007] defines that ubiquitous tracking and monitoring technologies are now routinely used in industrial environments, but very rarely with the goal to improve occupational health and safety.

The authors of [Parry, 2013] indicate that interrupting sustained sedentary time with short rests result in improved glucose metabolism in overweight individuals and increased energy expenditure, suggesting that relatively small changes in activity level and pattern have the potential to modify adverse health risks.

The authors of [Eleni, 2009] add that first is the issue of privacy: patients, although they may appreciate the increased sense of safety that comes with the monitoring infrastructure, are leery to have their every move monitored.

The paper [Moeslund, 2006] provides an overview of researches done with a view to detecting human body movements and estimating human body postures through video monitoring.

Some other examples of image estimations are described in [Lee, 2006][Zhao, 2007][Loke, 2007][Bernhard, 2013], including the ones based on video monitoring from the same or multiple points, and monitoring using static images.

The paper [Lee, 2006] introduces an algorithm, which based on a static image helps to determine human body posture. Lee and Cohen [Lee, 2006] also states that, if the algorithm detects all body postures, whether sitting or standing, then such algorithm can be useful to detect different sitting postures.

The research described in [Zhao, 2007] aims to create a three-dimensional human body model based on an image sequence taken by one camera.

A most useful and effective method is described in [Loke, 2007], where human body images are received in a three-dimensional space using different video cameras. This monitoring method also detects movements of eyes, hands and fingers.

Schwartz and others [Bernhard, 2013] have introduced the "active chair" solution for workers doing sedentary work. They aimed to evaluate and develop a special device with integrated sensors, which could be used for every office chair.

A common office chair is usually a swivel chair with a set of wheels and four independent, especially designed force transducers for mobility and adjustable height (Figure 5.1). Force transducers signals are digitized and transmitted through a microcontroller using wireless protocol. Four force sensors are situated in each corner under the chair, thus enabling to compute the coordinates of the center of pressure (COP).

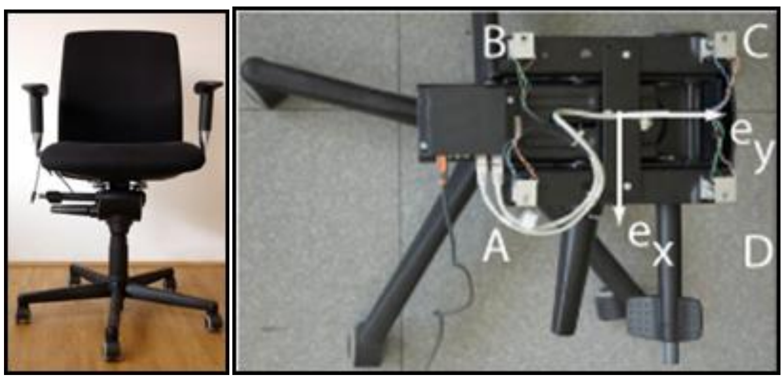


Figure 5.1 - Office chair and support frame of the chair [Bernhard, 2013]

The four sensors are marked with the letters A-D in Figure 5.1. The COP coordinates vary according to the person's posture on the chair, which allows classifying the sitting posture and the time spent in the corresponding position. For further analysis the mean values of the positions are computed and normalized. Additionally, the normalized deviations of the positions from the mean values are computed and provided for further analysis.

Related to the monitoring subject is the driver fatigue detection. The research described in [Rogado, 2009] refers to early detection of the signs of fatigue and sleepiness while driving. It states that the analysis of certain biological and physiological variables may detect the signs of loss of alertness before the driver falls asleep. Thanks to such analysis the system can determine whether or not the driver is able to continue driving. Visual facts, such as, eyes movement, head movement, facial expression, or non-visual facts, such as HRV, ECG, pressure, exercised over the steering wheel, relative humidity, as well as temperature difference between the inside and outside of the vehicle, make possible to estimate in an indirect way the driver's fatigue level. Detection of the signs of fatigue based on a single physiological parameter is impossible, that is why, different devices and various sensors were used to detect the above-mentioned parameters (Figure 5.2), as well as an algorithm was developed to detect human heart rate variability (HRV).

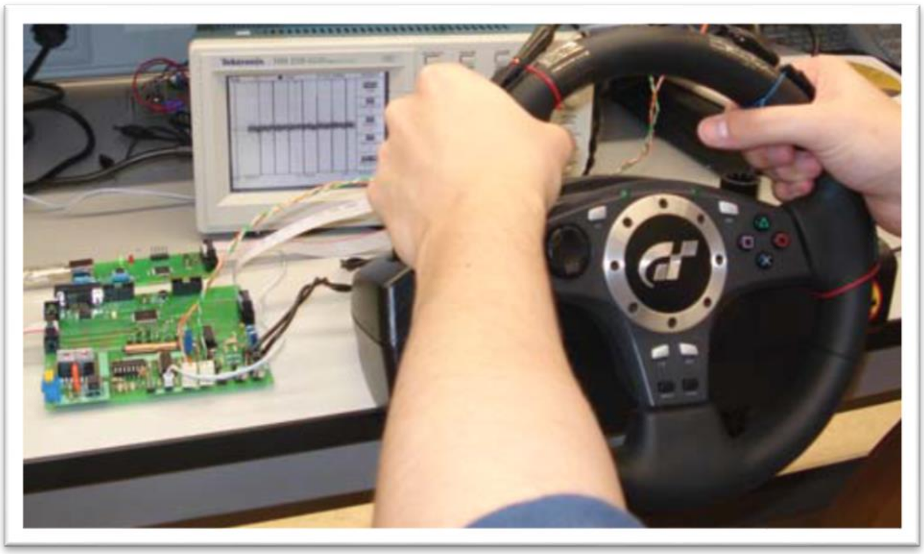


Figure 5.2 - Driver fatigue detection prototype [Rogado, 2009]

It is true that the above prototype differs with its usability from the ones used for office workers. However, the mentioned prototype may serve as a basis for a research on workers monitoring.

Very few of the above mentioned solutions are integrated systems that estimate workers' health status and physiological parameters. It testifies to the conviction that workers are poorly protected from modern technologies in the workplace and everyday life.

Our study revealed that almost all participants responded negatively to the question on whether their employer has taken any actions to improve their working conditions (environment, ergonomic conditions, etc.). And the overwhelming majority of interviewees (280 workers, i.e., 84% of 333 interviewees) gave positive consideration to the idea of monitoring of their health status at work.

6 Using Virtual Reality for workers monitoring

6.1 Virtual Reality characteristics and advantages

Virtual reality is a fast growing environment that uses computer power to replicate real conditions and situations with enhanced realism and interactivity [Etienne van Wyk, 2009]. It is the combination of computer graphics and "human-computer" interaction. The usage of computers requires from us study of a new culture rather than of a new language. Cyberspace is usually perceived through the window or screen. Today, however, virtual reality technologies have made it possible to transform that bio-dimensional perception directly into a three-dimensional one [Grigore, 2003]. A cyberspace is a notional environment, where information is received through electronics. Nowadays, we are surrounded by an ocean of facts, which can be perceived not only as a numerical series, but also as a text, image, voice and music. Virtual worlds, like applications, represent interactive three-dimensional environments containing animated characters, the so-called, avatars. On top of that, these are environments, where various actions are performed and which have specific features and links that connect people from all over the world. In 2000, Di Carlo developed a virtual reality tool allowing users to simultaneously work with different three-dimensional representations of the same data in an immersive environment [DI CARLO, 2000].

The notion of virtual world is not new. It has been already used in object-oriented programming, in "mouse" manipulation for creating images, in graphical user interfaces or computer simulators for "painless" testing of new devices. The idea of using virtual objects or graphical representations instead of real world makes "human-computer" interaction more user-friendly and accessible to us. The most popular example of this (which has its roots in pre-computer technology) is the simulation of flight to the space or on a plane.

The thing about virtual reality is that virtual interfaces should not just be the representation of real world, but should also fully replace it in all senses; a user should not simply pull a "mouse" or other means of control, but also manipulate virtual objects just like real ones. This not only involves use of the organ of sight and, most probably, of hearing, but also sensory perception. Moreover, a virtual reality user interface should be able to pick up and move virtual objects, as well as move his/her body or part thereof in cyberspace. For example, you look at the screen and see two slightly different images of the same object. Your brain combines these images into one three-dimensional representation. When turning your head, the image will change correspondingly, just as in real life.

Traditional input devices, such as joysticks, keyboards and “mouse” are replaced by contactless sensory devices, gloves or other sensors, the receptors of which not only respond to human body postures, but also to the shape and bending of body, hands and other body parts. You look at the representation of your hand, move your hand and realize that, in fact, it is the same object [DENBY, 1999][ORR, 2002]. Like real world, virtual reality is a dynamic object in interaction with the user in a tree-dimensional environment. A virtual user has all the rights to freely explore the virtual reality with the help of the computer, as well as to directly interact with it just as in real life. We find our way with difficulty through this new, strange world consisting of bright polygons.

According to some sources, the term “virtual reality” was coined in the Massachusetts Institute of Technology (MIT) in late 1970s, in order to express the idea of human presence in a computer-generated environment; the idea of interactivity has already been in the focus of many experiments held in the MIT. Later it moved to Atari Lab, where many graduates of the MIT worked in early 1980s, followed by its penetration into computer games industry.

The first instrument that helps us to penetrate into the virtual reality is given to us from birth; it is our brain and its sensory receptors. Our visual system is the main tool of perception. Other senses make our perception of the world around us more complete. The seven major senses are sight, hearing, touch, smell, taste, equilibrium and intuition. Our perception is influenced by the combination of the above-mentioned senses, for example, the sense of movement (gesture) is not only perceived by eyes, but also by body itself. Our brain responds to all signals received from all receptors, comparing the new data with those already existing in our mind. In a virtual reality the principle of perception is the same, in the latter case, however, receptors are replaced by different virtual recorders and human brain - by computer, which compares human actions with different patterns and turns them into virtual actions. One of the most important features of virtual reality is that in real life it is supposed to be real, but at the same time, it is the presence in virtual reality, i.e., it exists in real life, but ensures the presence in a virtual environment. It is a modelling concept using advanced hardware and software.

There are different types of "virtual worlds". One of the most popular features thereof is the Massively Multiplayer Online Game (MMO or MMOG). The MMO is a multiplayer video game, which is capable of supporting a large number of players simultaneously, who interact with each other in real time through virtual representations of themselves - avatars. The most popular MMO game is "Second Life", which is a three-dimensional virtual world with the elements of social life, played by over 1 million active users. This game was developed and launched in 2003. Second Life is not a game in its usual sense, but a virtual space with certain properties [SecondLife].

In 2009, the number of active users of online virtual worlds reached about 136M users. In three years, this number grew eight times and reached about 1139M in 2012 [KZero] (Figure 5.1).

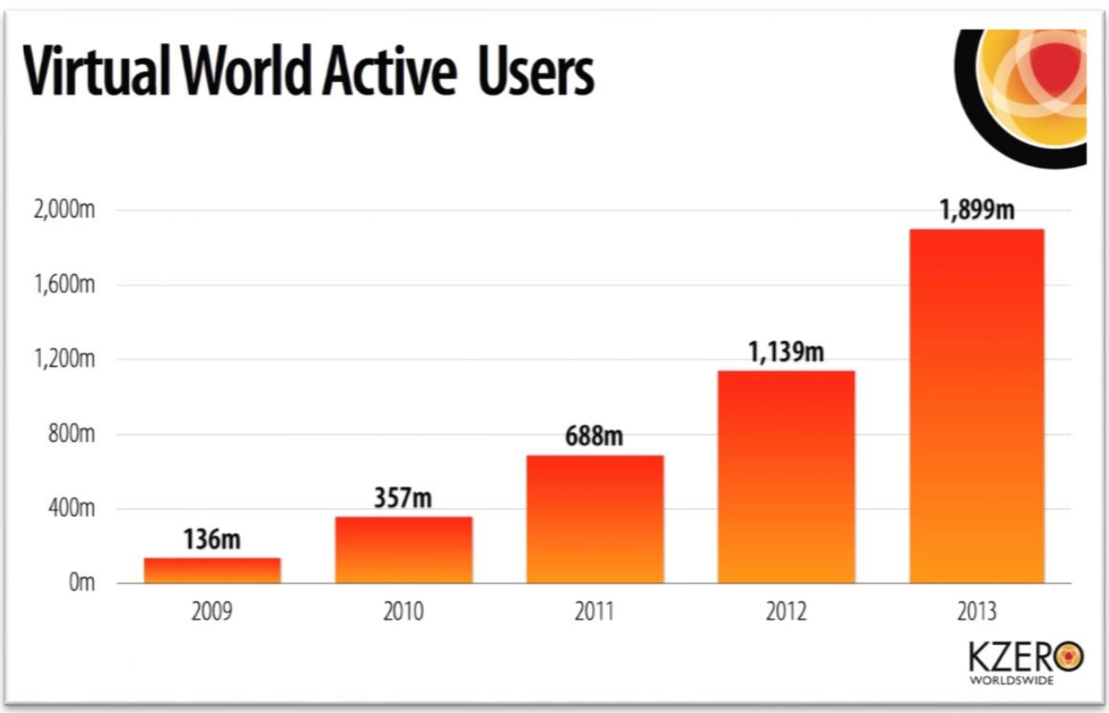


Figure 6.1 - Virtual world users [KZero]

Virtual reality has significantly changed over the past two decades. It is still confirming its position among innovative technologies, and it is an undeniable fact that in future virtual realities will have their stable role in education, science, medicine and in other domains [DE STRULLE, 2004].

The meetings and discussions with representatives of different domains revealed the following advantages of using virtual reality:

- safety of untrained workers in the process of training;
- no language barriers;
- no territorial barriers;
- no time limit;
- lack of sufficient interactivity in traditional classroom-based learning;
- more effective learning progress monitoring.

Virtual environments are deemed to be perfect environments for exploring real fenomena, which may be too costly or too important in physical reality.

6.2 Hardware and Software tools used in the development of the proposed system

Based on the results of all studies we have done and experimental data processed so far, we developed a system for workers monitoring, which uses virtual reality and special devices. The system is described in the next chapter.

In this section we present the hardware and software tools used in the implementation of the system. The devices provide various data necessary to measure both ergonomic conditions and worker's health status in the workplace. The user's body is visualized by an avatar in the virtual environment of his/her workplace. For the design and implementation of the virtual environment we used the Unity 3D framework. For monitoring, we used the following tools: Microsoft Kinect V2 for measuring worker's body posture (neck, shoulders and back); Tobii Eye Tracker for monitoring worker's eye behavior, as the eyes are especially vulnerable to computer exposure. The necessary parameters for eye behavior monitoring are: eye blink rate (we all know that when tired we keep our eyes closed a bit longer when blinking), distance between the eyes and computer screen, viewing angle and worker's head motion. The third tool that helped us to have a better and useful system was Microsoft Band. It enables to measure human heart rate at a particular moment of time, as well as physical activity on a daily basis, as physical activity is one of the first prerequisites to creation of healthy work environment.

Experimental results have shown that the system, developed in the scope of this research work, provides recommendations without prejudice to productivity. Moreover, prospective estimations show that it contributes to improvement of worker's health. Worker's health status is in direct proportion to the work done by him/her, i.e., the better is worker's health status, the higher is his/her productivity.

In this part of the present research the devices and framework used by the author to develop the system will be presented. It's only a brief presentation of some innovative technologies about the performance and usefulness of which we may talk long hours.

6.2.1 Unity 3D framework

Unity 3D is a game engine that allows developing games for PC, smartphones and tablets, as well as game consoles. Using the same framework one can develop an application that will run on almost all conceivable devices with color display. Unity 3D enables to use all the possibilities of multiplatform development of a whole cycle.

Unity Editor has a user-friendly and easily adjustable Drag&Drop interface, consisting of different windows that enable to debug games directly in the Editor. Unity 3D supports 2 scripting languages: C# and JavaScript (modification).

A Unity project is divided into scenes (levels), i.e., separate files consisting of their own game worlds with a set of objects, scenarios and settings. Scenes may contain both objects (models) and empty game objects ("dummies"). Objects, in their turn, consist of a set of components that interact with scripts.

Collisions can be applied to objects (in Unity, the so-called, colliders). There are several types of colliders:

- Character controller - a type of physical model created especially for using it for game characters;
- Box collider (physical model of a cube, where physical collisions are detected);
- Sphere collider (physical model of a sphere, where physical collisions are detected);
- Capsule collider (physical model of a capsule, where physical collisions are detected); unlike the previous one, this collider is resizable - its sizes can be changed by 1 or 3 axes at once;
- Mesh collider (physical model that repeats fully the actual geometry of an object);
- Terrain collider – a type of a physical model created especially for using it on an object of a type Terrain, i.e., a terrain generated by Unity Editor with terrain sculpting and painting features.

Unity Editor has a component for creating animations. Also, animations can be created preliminarily in a 3D Editor and imported together with the model and then divided into files.

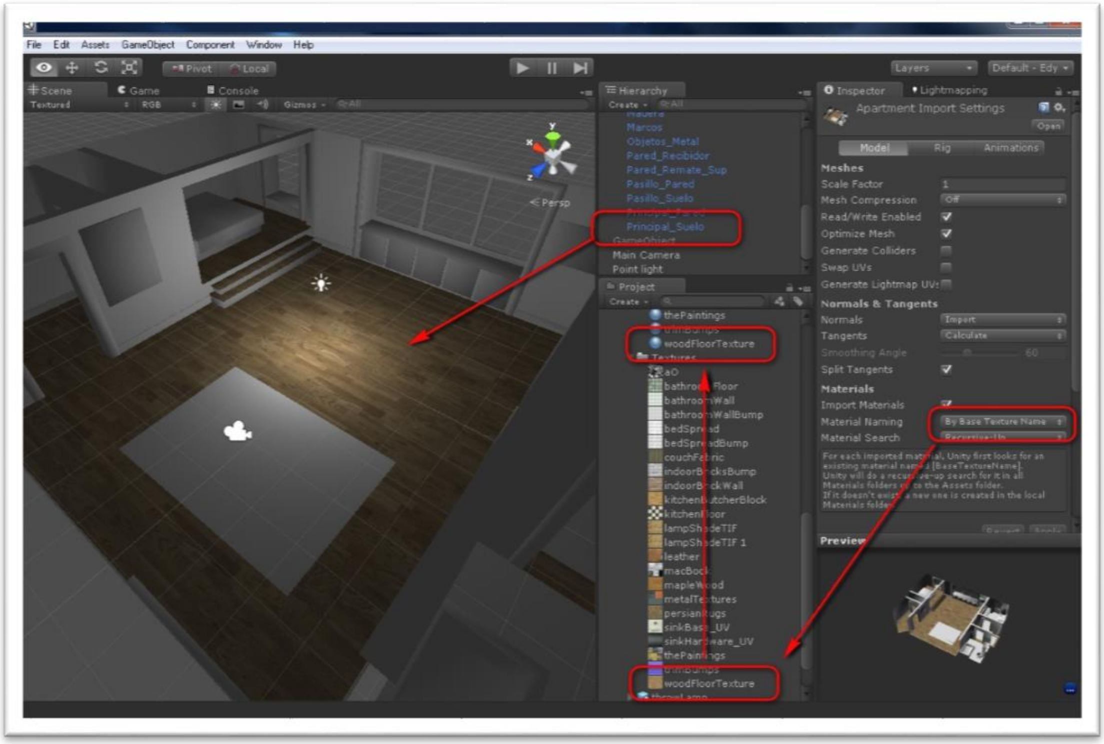


Figure 6.2 - Unity 3D model example [Unity3D]

In addition to dummies and models, objects like GameObject can be added to the scene: Particle system, Camera, GUI text, GUI texture, 3D text, Spot light, Directed light, Terrain illumination, Light source, Sun imitator, Standard primitives, Trees, Terrain.

In this particular case we have set ourselves a goal to imitate an office room with all its accessories, e.g., desk, chair, computer and other accessories important for us. With the multifunctional Unity platform we created an imaginable 3D environment, which was the representation of work environment in a virtual reality.

Unity 3D supports Level Of Detail (LOD) feature that involves decreasing the complexity of 3D object representation as it moves away from the viewer and vice versa, as well as Occlusion culling feature that disables rendering of objects when they are not currently seen by the camera because they are obscured (occluded) by other objects. Thus, the load on the central processor is reduced, enabling to optimize the project.

Version Control System

Unity resource center is a full-featured solution of version control for all game scripts and resources. Like everything else in Unity, it's user-friendly.

Server with an open source code

Unity resource server is administered by PostgreSQL database. PostgreSQL is known for its reliability, data integrity and ease of administration and perfectly copes with the workload of large projects.

Competitors

Unity3d and Unreal Engine 4 are the most popular game engines now available. Although both are big game engines, user's choice depends on what he/she wants to have, whether a user-friendly interface or a programming language. In this particular case we needed to have such a solution that would perfectly operate with the 4 devices selected to measure worker's health status.

Unity game mode is an extremely powerful development tool in respect of fast iterative editing during the game. User should press Play button and immediately find himself/herself in the game.

6.2.2 Microsoft Kinect V2 for Windows

Kinect was first announced in 2009 under the code name "Project Natal". Two factors served as a basis for the choice of the project name: Microsoft's tradition of using cities as code names for projects and project chief developer's wish to honour his birthplace – the Brazilian city of Natal. However, before the 2010 E3 Global Expo it was announced that the system would officially be called Kinect, a portmanteau of the words "kinetic" and "connect", which describe key aspects of the initiative. Thus, Kinect was first introduced to the world.

Figure 6.3 - Microsoft Kinect V2

How does it work?

Kinect is a new generation device developed by Microsoft for its Xbox 360 home video game console. Kinect’s principle of operation is similar to that of radar. Infrared projector emits light beams towards a player, which then reflect back to the device, where they are perceived by the camera and analyzed. This enables the system not only to build user’s body outline on the display and track his/her movements in a 2D vertical plane, but also to respond to approaching/moving off of the player, thus forming the 3D image of player and making the game character fully imitate player’s behavior. Kinect allows playing and having fun in a completely new way, by using player’s body parts – arms, legs, feet and hands. With Kinect no controllers are needed. The player is the controller. When technologies become invisible and intuitive, amazing things happen – player becomes one with the game. No more barriers, borders, gadgets, accessories, learning curve! With Kinect the user is his/her own controller. Thanks to Kinect the user becomes a real magician; with own movements, voice and facial expressions the user can manage games effortlessly, naturally and beautifully. Microsoft Kinect can support more than two active players.

With Kinect the user can manage the entire interface – press buttons, switch modes, calibrate and communicate. The camera tracks user’s movements around the room and the built-in microphone allows giving commands to Kinect.

Kinect v1, a sensory game controller by Microsoft, has been well positioned in the technology market. But time is passing and Kinect v1 was soon upgraded to Kinect v2. The latter can detect and track 20 joints from 6 people's bodies, including thumbs, as compared with Kinect v1, which could only track 20 joints from 2 people (Figure 7.3).

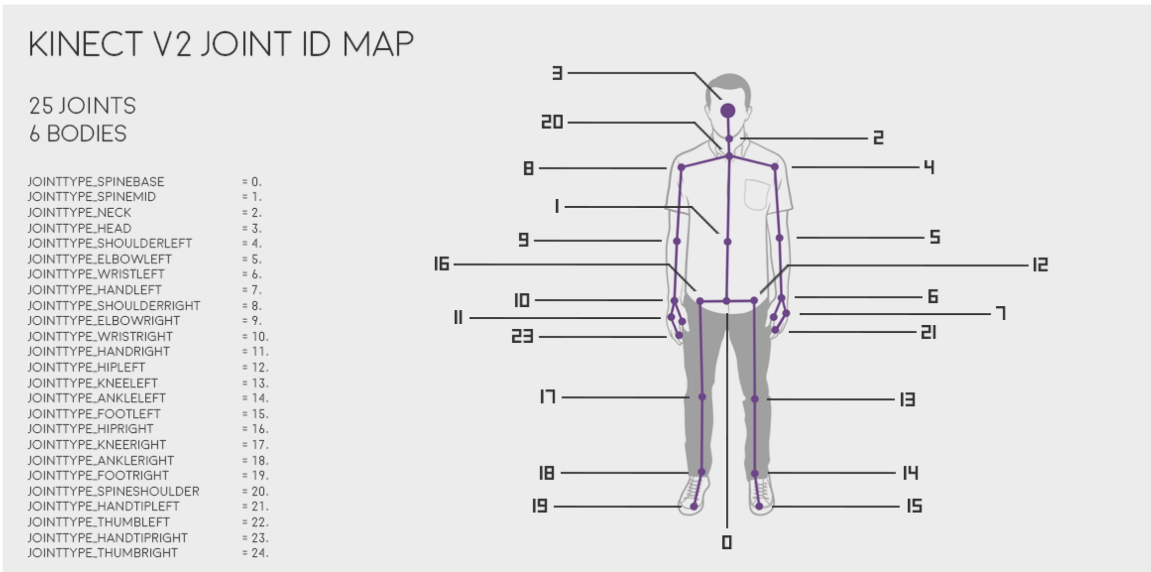


Figure 6.4 - 25 identification points for Kinect v2 [Microsoft Corp.]

Several advantages of Kinect v2 are: increased viewing angle; more sensor pixels and enhanced resolution, allowing identification of motion; several new view modes, which can be very useful in improving the accuracy of movement tracking and reducing errors. For example, Infrared View Mode and new human body modelling tools can be used to track muscle motion and mutual orientation of body parts. And Deep Image Mode, which acts as a radar, where each of 220K pixels of sensors records data independently, allows creating a surprisingly precise and detailed mapping. Thanks to Kinect v2 we succeeded in developing our system most precisely and getting positive results.

When processing the data generated by Kinect, one should not need to worry about the room illumination and the data won't be corrupted due to unexpected changes in the room illumination. The minimum size of the object recognized by Kinect v1 is 7.5cm. Kinect v2 with 60% increased viewing angle recognizes objects ranging in size from 2.5cm. The number of people in the room monitored by Kinect v2 simultaneously is increased to 6, as compared with Kinect v1, which could only monitor 2 people simultaneously.

So, what's now?

Now we have a fundamentally new type of human-computer interaction. What has been depicted by dozens of science fiction writers is finally becoming a reality. So, what awaits us next? Full rejection of physical interaction with computer, i.e., virtualization. Thanks to this non-physical interaction we could detect and get in touch with different parts of human body and bring our project to life.

6.2.3 Tobii Eye Tracker

Initially, teletypes were used by specialists to measure the productivity and potential of human-computer interfaces [JOHN, 1997][Jonathan, 2005]. Another group of specialists focus on the method of gaze direction measurement through assistive technologies used in human-computer interfaces [Shuo, 2011]. Electro-oculographic techniques is other example from eye-tracking systems, electrodes mounted on the skin around the eye will measure differences in electric potential so as to detect eye movements [Andreas, 2010].

Eye gaze is a potentially powerful tool, if used accurately. Eye movements as well are an important research topic, as they help to measure the productivity and potential of user interfaces. One of the methods of measurement of iris color is to use the high contrast between the sclera, which is the white of the eye, and the dark color of iris. This method is more effective when applied in horizontal direction, and less effective for vertical, as in case of the latter certain upper and lower parts of the eye are covered by eyelids. Many specialists use eye pupil direction, in order to avoid problems and ensure smooth operation of systems.

Currently the Eye Tracking Systems (ETS) are widely applied. These systems fall into the following 3 groups, depending on the nature of issues solved with the help of such systems:

- stationary tooling systems for labs;
- portable devices for games and virtual reality systems;
- built-in systems for human-computer interfaces.

The best and fastest way to measure the productivity and potential of human-computer interfaces is to use the method of eye direction measurement. Systems based on this method do not require head movements and can be applied for people with weakly developed muscular system. The most preferable method is to track eye gaze and determine eye direction using cameras. Nowadays, almost all eye-tracking systems use cameras and infrared laser.

Tobii Eye Tracker enables new functions that revolutionize in daily HCI. It enhances the experience for any users to point with their eyes naturally and intuitively. Users can then avoid cumbersome and unnecessary movement of having to reach for their mouse or drag a finger several times on a touchpad to move the mouse cursor to where he/she is already looking. This caters for a much more natural and intuitive interaction with the device. Thanks to Tobii Eye Tracker now it is possible to identify the points the user is looking at.

Figure 6.5 - Tobii eye tracker

Figure 6.4 pictured the Tobii Eye Tracker used in our system. The objective of a Tobii-based eye tracker is to identify gaze direction through infrared images.

6.2.4 Microsoft Band

When Microsoft announced its new product – the Microsoft Band tracker, end of October 2014, it did not make a flamboyant show of that, like its main competitors Apple, Samsung or Google. Maybe it's because this fitness tracker was not remarkable and worthy of such efforts? Let's have a closer look at it.

Figure 6.6 - Microsoft Band v1

Microsoft Band is rich in functions. It has various built-in sensors, e.g., heart rate sensor, accelerometer, gyroscope, GPS, light sensor, UV sensor, etc. Moreover, a vibrometer and microphone are embedded in the bracelet and connectivity is ensured via Bluetooth Low Energy. The user can control the functions of Microsoft Band by flipping the screen through simple gestures.

Microsoft Band tracks such standard things like travelled distance, quality of sleep and similar activities. GPS helps to precisely control the distance. One of the additional features worth mentioning is the possibility of measuring skin temperature online.

Of course, Microsoft Band shows the information regarding the travelled distance or heart rate, but it cannot advise when the user should have rest and in no case motivate him/her to physical activity.

The heart rate sensor embedded in Microsoft Band differs from similar sensors built in fitness trackers by other manufacturers, which reflect only sample data, e.g., not very accurate and less informative. Microsoft claims that the sensor built in Microsoft Band tracker is much more accurate.

7 Developed Employee Monitoring System

From previous chapters we already know that there are other tracking methods, such as through a standard camera or multiple cameras, in order to receive a more detailed graphical representation of human body. These methods, however, are not very accurate and cannot represent human body while sitting. Considering the aforementioned, we have used Microsoft Kinect in our system with a view to collecting information regarding the ergonomic conditions in the workplace and monitoring worker's posture. Microsoft Kinect provides more precise information regarding the worker's presence in the room, his/her movements and attention. The collected data enable to create the graphical representation of the worker. For any deviations from predefined norms, the system sends a warning to worker in a form of a pop-up window opening on the computer screen, or signal or animation. Also, additional warnings are provided, aimed at reminding the worker to maintain safe distance from the computer screen, or to do eye exercises in order to relieve eye strain, or to take a break. In this proposed system each type of notification warnings are already installed. All data is processed locally, so the privacy of the worker is respected.

7.1 System overview

As understood from different researches, virtual reality is a computer-simulated reality perceived by humans through sight and hearing, e.g., eyes and ears. Virtual reality is represented in real time. Our system is a completely virtual reality based system. Like applications, virtual worlds represent three-dimensional interactive environments with animated characters, called avatars. In this specific case, an avatar is attributed to the worker, through which the worker acts in the virtual reality. The virtual reality may contain different objects, which we can manipulate as we wish. In this case we have created a 3D room model similar to the office room. And when the worker works at his/her desk in the office, the same is done by his/her avatar in the virtual reality. Thus, we aim to create such an environment, which will help workers monitor their own behavior at work and follow predefined health rules and norms. Figure 7.1 showcases the virtual office room and avatar.

Figure 7.1 - Virtual office room and avatar

Our system consists of different types of sensors, designed to monitor workers at work. They are installed at a certain distance from worker and do not interfere with the latter's work (only Microsoft Band is worn around worker's wrist as a wristwatch).

Now, one by one about the data collected by each device, usage thereof in our system and all this represented in a given virtual environment.

7.2 Microsoft Kinect processing

Let's start with Microsoft Kinect. We are already familiar with this device from subchapter 6.2.2. Now about its usage in the system and on how it supports the system performance. In Chapter 4 we have revealed all important points that should be the focus of attention of workers at work. One of the most important points was worker's sitting posture at work (head not tilted back or too forward, or too right, or too left). Another important point was the spine position, which should not be curved (this does not refer to people suffering from scoliosis or with inborn spinal deformity). We all may be tired, or on the contrary, ready to work hard and be highly productive at different times throughout the day. Kinect starts monitoring workers, whether sitting or standing, since the beginning of the working day (let's assume it's 9 a.m).

Now a little about how Kinect identifies people, i.e., about its principle of operation. Prior to the application of the proposed action recognition approach, the depth maps captured by the Kinect sensor are processed by a skeleton-tracking algorithm. It is also used for detecting the performing subject and tracking a set of joints of human body. For determination of body position several actions are taken. First, the Depth Map is considered, followed by development of the skeleton. The first step to take is to send and receive infrared beam. Based on this principle the skeleton image is created, encompassing the head and other parts of human body.

Thanks to Kinect V2, values for 25 joints are received every second. Figure 7.2 showcases the varying distance between the pairs of 25 joints, thus making interaction with virtual reality clearer to the user.

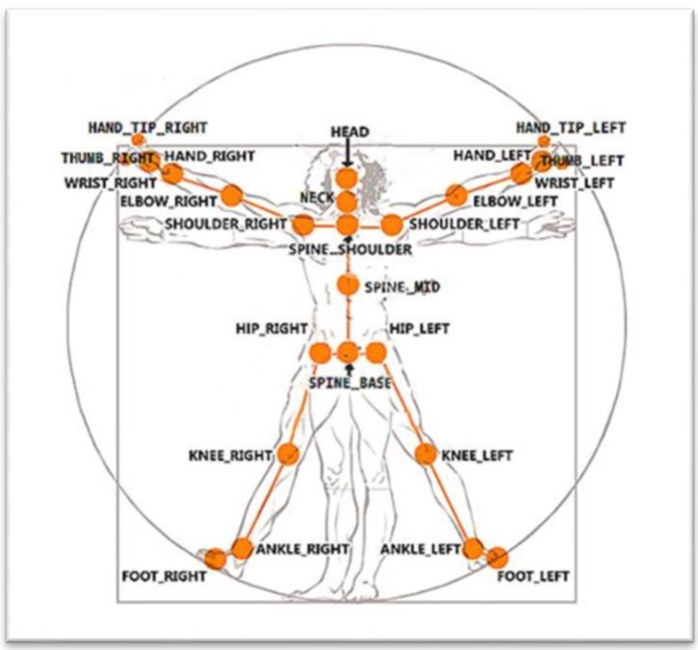


Figure 7.2 - 25 skeleton joints [Microsoft Corp.]

With the help of Vector3 of pairs or triplets we can derive the deviation value thereof.

Kinect v2 provides Vector3 (x, y, z) coordinates of 25 joints showcased in Figure 7.2 in a three-dimensional space. In order to measure the JointType.Neck, we consider X and Z coordinates of Vector3. These coordinates are then filtered and brought to a common unit measure. As worker's neck goes forward, coordinates grow positive (1,2,3,...16,17,…,n) and as the neck goes back, coordinates become negative (-1,-2,-3,…,-16,-17,…,-n). In this specific case (-15; 15) are assumed as normal values. In the event that these values are exceeded, the worker will be notified thereof.

The same principle is applied for determination of JointType.SpineBase value. Here X coordinate of Vector3 should be considered. In this specific case (-15; 15) value will be considered as an acceptable norm, as, in fact, the user cannot tilt his/her spine the way he/she does with his/her neck. Appendix 3 showcases some parts of the programming code.

Here we present the pseudocode of the used algorithm:

Set all parameters to zero
if Kinect is running and it detects the worker then
    Start to monitor the worker
else
    Notify "no user was found"
if the Neck and/or Spine is not in correct position
    Notification "You hold your neck in an awkward position"
    Notification "You hold your spine in an awkward position"
else
    Continue to monitor
Add the coordinates average rates for every 5 minutes into file

In order to have a better understanding of the situation, let's have a look at the skeleton, which showcases the body parts discussed hereinabove (neck and spine). The coordinates of joints in blue allow determining neck position and those of joints in red allow determining spine position.

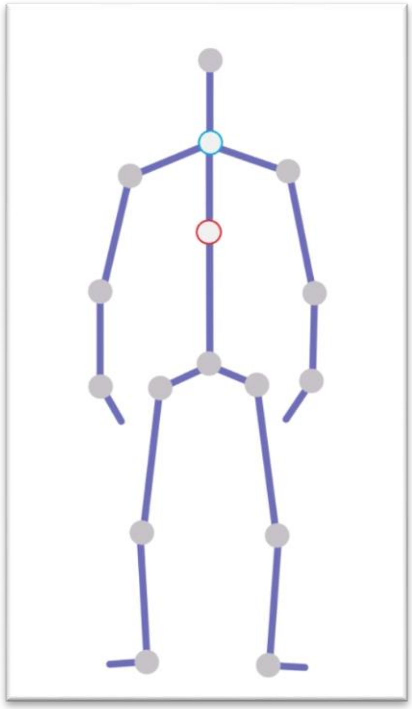


Figure 7.3 - Neck and spinal joints

All data on every single movement is recorded and stored in a corresponding file or database. Regardless of worker's sitting position, whether right or wrong, he/she can continue working without paying attention to the system. Thus, the system does not interfere with his/her work or personal life. Moreover, this system provides maximum level of confidentiality and does not provide data without user's approval. Users of our system do not explicitly interact with the system, it is designed to passively compute and present data.

It is assumed that worker's working day begins as soon as he/she turns on his/her computer, and beginning from that moment our system starts monitoring the worker. Any moment workers can allow deviations from predefined posture norms, but such deviations are not dangerous and cannot be fatal. But if it is done regularly, the system sends a warning and recommends taking corresponding actions. The recommendations may be as follows:

- You hold your neck in an awkward position.
- You hold your spine in an awkward position.

There may be cases when the worker ignores these warnings and continues to work holding the same awkward position. Regardless of the ignored status, the system continues recording the data. In this case as well the computing is made based on algorithm and, if the total number of deviations exceeds the acceptable norm within the last 30 minutes, another type of warning is sent to the user. This type of warning already contains a variable value showing the percentage rate of awkward and normal positions. This refers to human-computer interactions only in real time. Regardless of anything, the system stores all data of monitoring conducted throughout the day in a corresponding .CSV file for further statistical analysis.

The system also envisages graphical representation of monitoring data, which, however, will be presented later, as long as other parameters thereof are not familiar to the audience.

7.3 Tobii Eye Tracker processing

Eye gaze is a potentially powerful tool, if used accurately. Eye movements are also a very important research topic that enables to measure the productivity and potential of user interface as an input device [Duchowski, 2002]. Traditional methods of gaze tracking have used specialized hardware, typically consisting of multiple cameras and/or infrared sensors [Zhu, 2007] [Ning, 2007]. In our proposed system we use Tobii Eye tracker, already discussed in this chapter.

The flexibility of tracking human face in various positions is crucial for our system, as workers do not always look directly at the monitor, especially when busy doing other tasks at the desk. The front facing, built-in device in the user's personal computer extracts eye related attributes of the user, including gaze direction (eye angle from monitor), distance from the screen, eye blink, as well as duration and frequency of blinking.

In our application, we wish to extract the eye behavior of the user, as well as head position and orientation. This is slightly rough approximation, however, using the data extracted from eye tracker we can determine user's coordinates and identify head direction and orientation through analysis. Based on head position and orientation we can find a vector representing the head direction as a proxy for the gaze direction. We then project the estimated gaze vector onto the computer monitor and calculate gaze angle. According to ergonomic rules, user's gaze angle (α) in human-computer interaction should be 15-17 degrees (Figure 7.4).

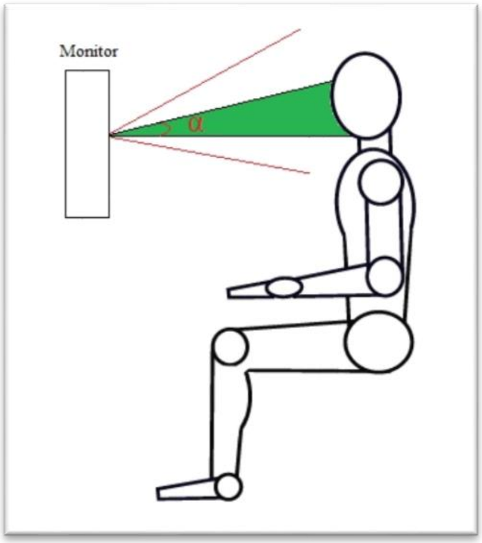


Figure 7.4 - α gaze angle

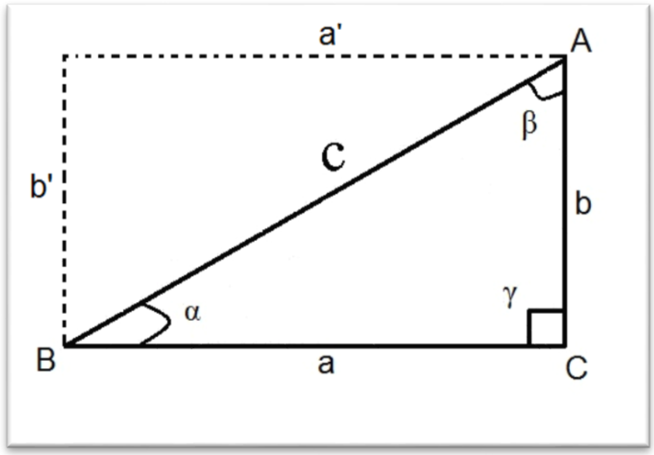


Figure 7.5 - Geometric gaze image

Now let's have a look at how α angle is determined. As already mentioned hereinabove, Tobii Eye Tracker is used to track eye and head movement directions. It is installed on the monitor, right in the center of horizontal axis, so to capture user's gaze, when the latter is looking at the monitor, and provide values (variables). In this specific case, as a necessary value we may need to have the hypotenuse (c) of the triangle showcased in Figure 7.5, which is the distance between user and monitor. Point A is the viewing source point. It's a combined value, as human eyes move parallel to each other and there is no need to determine the angle for each separately. Exceptions are squint-eyed people; in this case quite other logic should be applied to determine gaze angle. The next variable is b', which is the coordinate of the point the worker is looking at.

$$\sin \alpha = \frac{b'}{c} \Rightarrow \alpha = arcsin \frac{b'}{c}$$

Here we present the pseudocode of the used algorithm:

Set all parameters to zero for each time program starts

if Eye Tracker is running and it detects the worker on the front of computer then

    if the worker already accustomed to the system

        Start to monitor the worker's eyes behavior

    else

Start Tobii Eye Tracker Software to install individual users' eyes parameters

Start to monitor the worker's eyes behavior

else

Notify "no user was found"

if the Eye Distance and/or Viewing Angle is out of normal values

Notification "Please correct the distance between you and monitor"

Notification "Your viewing angle is incorrect"

else

Continue to monitor the worker's eyes behavior

Add the parameters average rates for every 5 minutes into file for further statistical analysis

*Hence, having this angle we ca*n track gaze angle every second. Should the standard gaze angle be violated, a corresponding warning is sent to worker. Through collection of the data recorded throughout the day or for the given period of time, it'll be possible to perform statistical analysis per worker and provide individual advice.

It is very important to maintain proper distance from the monitor, in order to avoid eye fatigue in the workplace [OSHA, 2012]. Using the data received as a result of face tracking, we can easily determine the distance between user and computer. A user's distance can suggest possible changes to a user's computer viewing habits when compared to ergonomic guidelines. Tobii Eye Tracker identifies user from a distance of 45-75cm. We should send three infrared beams to identify human eyes. If the distance is <45cm or >75cm, the system will be unable to identify human eyes and will send a corresponding warning to user with the following text: "Please keep proper distance from the computer". However, if the user is within the range of 45-75cm, it does not mean that he/she follows the ergonomic rules. According to these rules the proper distance should be 55-65cm. In this case the system double checks the location of worker and if the latter is within the range of 55-65cm, such distance is considered normal and the worker may continue working, but if the distance varies between 45-55cm or 65-75cm, the worker is warned about it. The warning text contains the following information: "The permissible distance is exceeded, please maintain the correct distance”. Distance variable helped us to determine gaze angle.

Eye fatigue is a term used to designate a state, which is commonly known as “eye strain”, pain in the eyes, weakness or heaviness in the eyes due to hard work.

Common signs and symptoms of eye strain include:

- Pain in the eyes
- Dry eye
- General heightened fatigue
- Feeling of heaviness in the eyes

All these 4 factors can be identified through eye behavior tracking. Tobii Eye Tracker helps to record all data regarding the eyes, e.g., eye blink rate, i.e., how long user keeps his/her eyes closed or open when blinking. A question comes up: how can this tracking method be helpful to us in this specific case? If we pay attention to our eyes behavior during the day, we’ll find out that when we are tired our eyes close spontaneously, against our wish; it’s a sign of eye fatigue. Measuring the milliseconds between blinking frequency and duration and establishing a logical link with predefined norms, we can identify indicators of fatigue. Absence of blinking or a blink rate decrease may lead to the rupture of the tear film and cause discomfort, eye strain, burning sensation, excessive lacrimation, willingness to keep the eyes closed, pain, keratitis, visual alterations and decrease in vision capability.

The average eye blink rate in humans is 25 times ±5 per minute [Carney, 1982]. Involuntary blinking takes place spontaneously, and as for voluntary blinking, it depends on each person’s habits. Blinking is divided into spontaneous, which takes place at constant intervals, and reflex, resultant from external factors in corneal stimulus [Lavezzo, 2007]. Based on study done involuntary blinking lasts from 290 to 750 milliseconds as an average, it is influenced by several conditions, among them the illumination, temperature, air draught speed, ocular pathologies, and attention levels [Dumery, 1997]. The research done in [Dumery, 1997] showed that one blink took 572 ± 25 ms and was accompanied by asymmetric motion with much faster closing action compared with opening action of the eye [Kyung-Ah, 2013].

Now about the solution proposed by us in this respect. Number of worker's eye blinks in 5 minutes is measured. If the average norm is 25±5 per minute, then the number of blinks in 5 minutes will make 125±25. Should this threshold be exceeded by ≤100 and ≥150 respectively, worker will be warned about it, for example, "You've violated the blinking norm", for further consideration. This, however, does not mean that if worker fails to blink, he/she is tired. The system just keeps warning the worker to blink eyes, in order to avoid eye pain or discomfort.

Another question comes up: How to identify fatigue, having these data at our disposal? The answer to this question is rather simple. As far as we have already succeeded in obtaining all data regarding eye behavior, we can measure blink duration (means closing-phase, closed-phase, early opening-phase, late opening-phase collectively) and based on the predefined norm, we can identify whether or not there are deviations from the norm. If, however, there are deviations, the mean value per hour should be calculated and worker should be notified of the result.

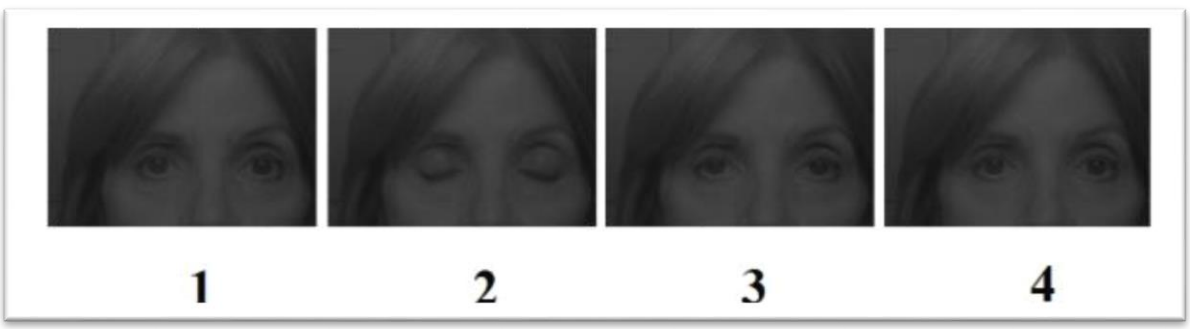


Figure 7.6 - 1, 2, 3 and 4 refer to closing-phase, closed-phase, early opening-phase, late opening-phase, respectively

7.4 Microsoft Band processing

The last device used in our system is Microsoft Band – the latest thing in personal comfort-saving devices. More details of this and other devices used in our system have already been presented hereinabove. Now about the features of Microsoft Band that we need to know, in order to collect and process the data we are interested in. The role of this device is vital to our system performance, as with Microsoft Band we can collect data on physical activity of humans, e.g., number of steps, travelled distance, etc. Thanks to this device the system not only collects data, but also reminds worker from time to time to do physical activity, in this specific case, to walk. Sleep time should also be considered, as the role of sleep is also vital to worker's productivity at work. Also, two other very important parameters that can be received from Microsoft Band are heart rate and skin temperature.

How the data received from Microsoft Band is processed by the system? Every 60 minutes the system measures the data on physical activity of worker for the last 1 hour received from Microsoft Band. Generally, we compute the number of steps, as not all offices provide the possibility of walking long distances. We could also develop such a system that would force the worker to follow the clearly predefined norms, but we refrained from doing it, as in a fast-paced working environment not all the norms can be respected by all. Unfortunately, this also refers to health norms. The number of steps, however, is not as important, as the fact of tearing the worker away from the computer and making him walk for a while. Thus, we can have our little contribution to human health at work and to help workers respect the ergonomic and health norms fully described in Chapter 4 of this thesis.

So, if the system can tear the worker away from the computer even for a second and make him/her walk, it already means a success. The worker will be notified of any necessary action to be taken via notifications popping up on the computer screen. Regardless of the calculations done by the system, the distance (km) travelled by the worker will also be displayed on the screen.

Just for worker's information, data on worker's sleep duration for the previous night will be displayed on the screen as well.

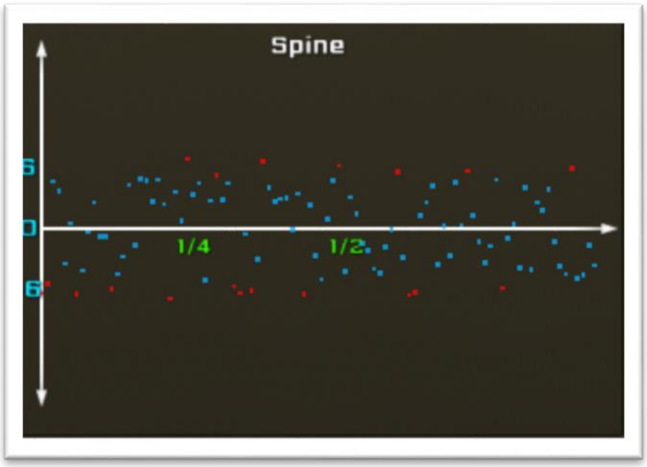
Two more very important parameters to be dealt with in the scope of this research are heart rate and skin temperature.

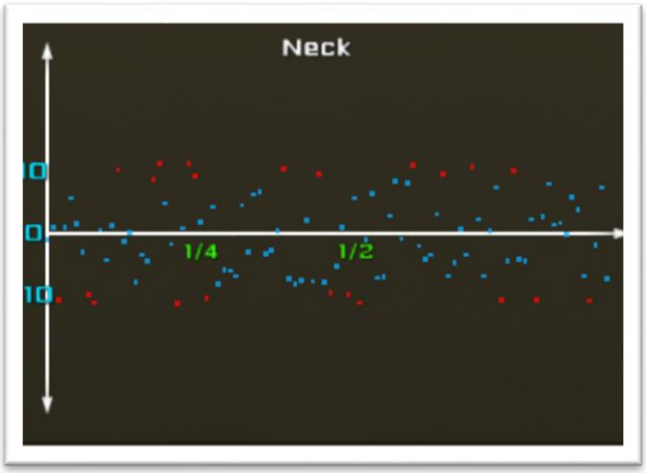
It is true that this research refers to information technologies, and notably, virtual reality systems, but it also requires having certain knowledge in medicine. Different studies reveal that heart rate among people vary between 60-80 beats per minute. In this specific case, the system measures heart rate every 30 seconds. If the abovementioned threshold is exceeded, the system sends a warning to the worker and gives corresponding recommendations, such as, "Go outside and breathe some fresh air." But if the deviations from the aforementioned norm are greater, the following recommendation is given: "Consult a doctor". The next parameter directly relating to human health is skin temperature. In normal conditions human skin temperature during the day varies between 36-37°C. Skin temperature does not depend on environmental factors thanks to internal heat generation center that ensures the balance between heat generation and heat transfer. If in unit time skin temperature remains constant high, it means that something is wrong and urgent actions should be taken. Data on skin temperature, exceeding the predefined norm, are available on the computer screen every second via specially designed software. Based on the result, the worker will be recommended by the system to consult a doctor.

In any case, one should always remember that early detection of diseases is the earnest of full recovery. Our system will help to deal with this issue.

7.5 Graphical representation

Throughout the day it is necessary to record and maintain all data on worker's physiological state for both the workers and for those who'll need them later for statistical analysis. The system allows creating the graphical representation of all data on worker's physiological state throughout the working day, e.g., body position, eye behaviour, heart rate, physical activity, etc. (Figure 7.7).





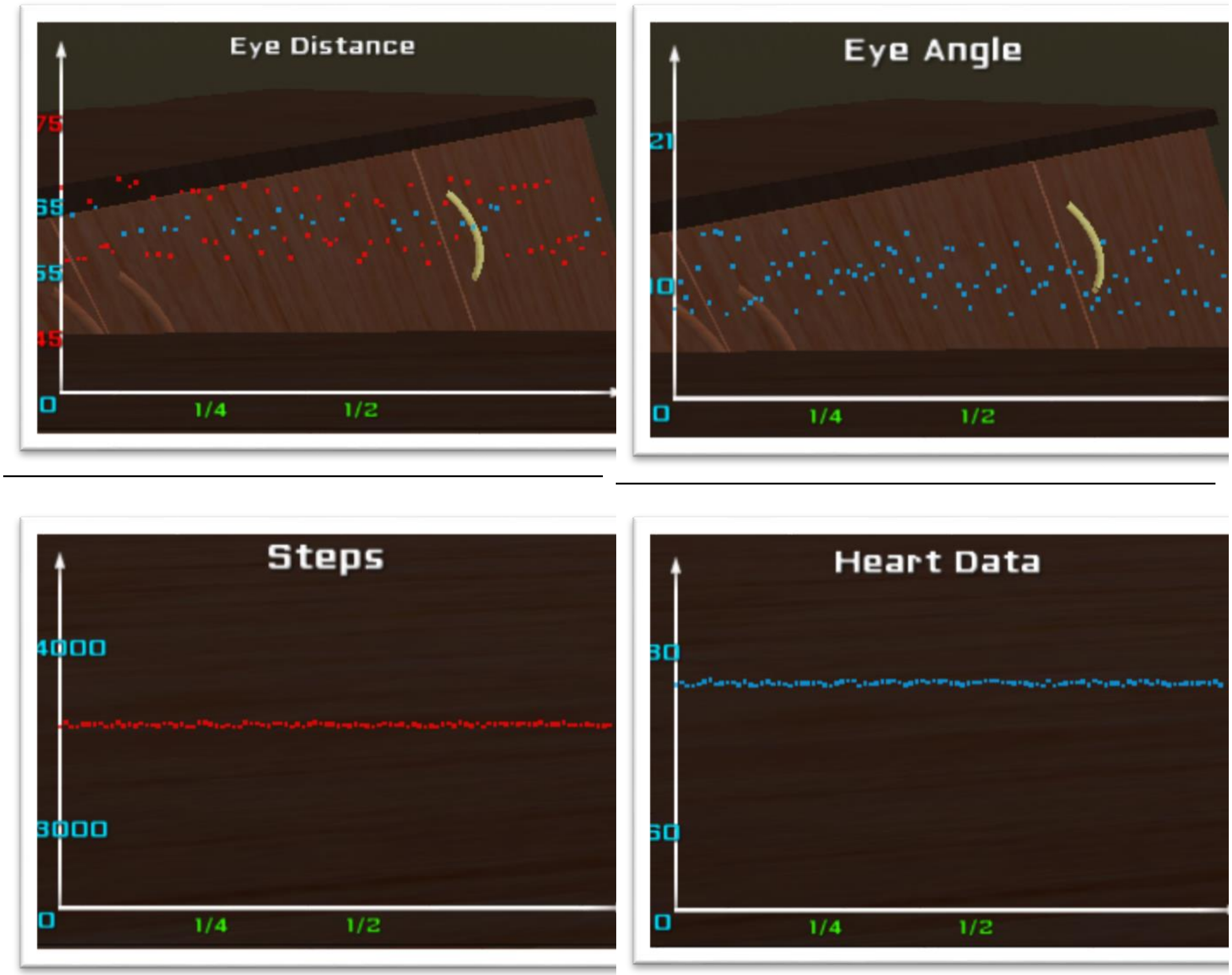


Figure 7.7 - Graphical representation of data on a daily basis

It has been mentioned so many times already in the scope of this research that the system is designed for office workers to monitor their behavior at work. They usually work 8 hours daily and during this period they receive a large amount of information. And as the technologies used by them are capable of transmitting data instantly, it means they may receive thousands of lines of data every second. Conditioned by this, we have grouped all values for every 5 minutes. As a result, if we exclude 1 hour break, we'll get mean values equivalent to 96 (96x5min=8 hours) and will be able to measure worker's state throughout the day. The possibility of further data analysis will enable us to determine at what time of the day the worker is overtired and based on that give individual advice.

7.6 Data transferring

The system sends the collected data LIVE, i.e., in real time. But it is not the case with Microsoft Band, which updates data every 30 seconds following data collection. However, we won't be mistaken, if we say that Microsoft Band as well is functioning LIVE, as we do not need to have the data collected by Microsoft Band every second.

In the beginning we store all data in the database, but after receiving first range of data from three devices we saw that it is not effective as millions of data transferring every second and computer capacity goes down. So the structure was changed, and all data the system store in CSV (comma-separated values) files. Such file formats are used to store tabular data, such as a spreadsheet or database. In the experimental part the tabular data will help us analysis the data, and it is easy to imported and exported from programs that store data in tables, such as Microsoft Excel.

The USB standard supporting information exchange between computer and output devices has been widely and successfully applied in computer technologies for already 10 years. Initially, USB 1.0 was widely used, later it was upgraded to USB 3.0. In the scope of this research the latter version is used. These versions of USB standard mainly differ from each other with their speed. USB 3.0 theoretically supports data transfer speed of 5Gbit/sec. In fact, we need such a high speed to receive a large amount of information every second from different devices and to process them accurately in real time. Microsoft Kinect and Tobii Eye Tracker use USB 3.0 for data exchange, and Microsoft Band is connected to the data acquisition module via Bluetooth 4.0 Low Energy, which consumes less energy as compared with Bluetooth devices of previous generations. Like USB 3.0, Bluetooth 4.0 Low Energy is distinguished with high speed.

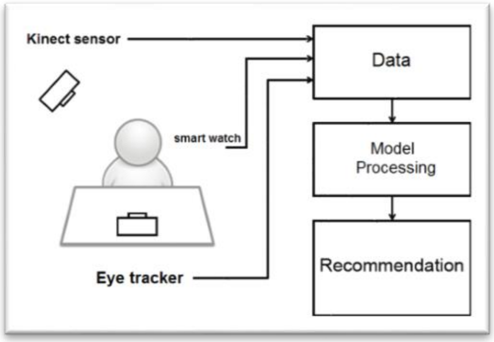


Figure 7.8 - System overview

Figure 7.8 shows the workflow logic overview. The data received from different devices are sent to the model processing module. The latter is responsible for making all logical calculations. It compares the data received from different devices with predefined values entered in the system as normal values. These values are the norms that should be respected in the workplace (sitting posture, distance from the computer, etc.).

8 Experiments and evaluation

This sub-chapter is dedicated to the pilot prototype testing in an organization, where standard hours of work for employees are 8 hours. The experiment was conducted in November 2015. Let's see how it works.

8.1 Technical equipment and design of experiments

The sample group of the experiment consisted of 3 workers (2 females and a male) with an average age of 27, height – 168-175 and weight – 57-75kg. All participants were informed in advance about all details of the experiment, and, of course, they signed a consent form. After having obtained their consent, the whole process was explained to them and they were asked to use the system during normal office hours. As far as not all organizations and their management would allow embedding any software or hardware in their systems, we had to use our own laptop to ensure system performance. With the experiment we had set ourselves a goal to evaluate (i) worker' body posture while doing a sedentary job, as well as (ii) more critical behaviors and when exactly they reach the critical point during office hours.

According to our plan, for the experiment a full working day (09:00–18:00) was provided to each worker, lunch time (13:00–14:00) excepted.

Received data were computed within subsequent time-windows of five minutes. As a result, for standard hours of work, i.e., 8 hours, we received 96 different samples of sedentary behavior of one worker. According to the predefined plan, our experiment consisted of 2 parts: the first part was fully dedicated to the familiarization of workers with the system (1 full day) and the second was fully dedicated to the process of monitoring of workers during office hours.

In order to evaluate our system efficiency, enormous amounts of data were collected. The experiment started in mid-November of 2015, and data collection ended at the end of the same month. It took us much more time to process the collected data and clear useless data. As a result, over 2500 lines of value and date-time pairs were processed.

8.2 Results

Here are presented system experiments and discussion for three employees (User A, User B and User C). Because of time limit and also resources we run the experiments for “neck monitoring” and “eye distance” functionality. And here we will represent some results in graphical mode. In charts you can see user A, user B and user C, with Blue, Red and Green colored accordingly.

A. Neck monitoring

Our developed system is capable of transmitting data instantly, meaning that it may receive thousands of lines of data every second. Conditioned by this, we have grouped all values for every 5 minutes. Especially, the system give as an average value each 5 minutes. As a result, if we exclude 1 hour break, we’ll get mean values equivalent to 96 (96x5min=8 hours) and will be able to measure worker’s neck state throughout the day. Chart 4 and Chart 5 shows neck monitoring data from three employees. As we know from Chapter 7 the conventional normal coordinates for neck we consider is (-15; 15). See Figure 8.1 for each back and forward posture.

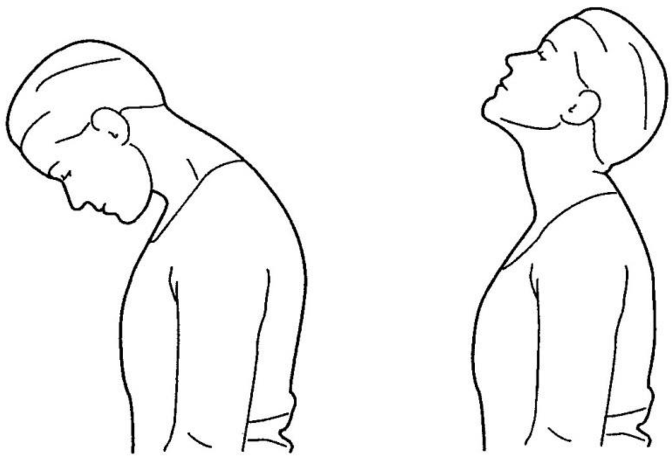


Figure 8.1 - Neck bending forward and back [MSI]

So, if we compare the data from our test users we will see that each user passed the acceptance range of coordinates many times. We can see that with minus value in the graphic are few, and it is normal, because in position of bending back the head worker can't work normally. If we compare all three users we'll see that almost all have the same behavior.

Based on our test results if we compare three users data, we will see that User B for each five minutes average value have more wrong positioning than User A and to User C. But even in that case there are no very precise differences between them. User B has 15 before lunch and 20 after lunch time, User A and User C has 16(12 after lunch) and 15(19 after lunch). Further experiments will allow us more clearly imagine critical hours during full working time.

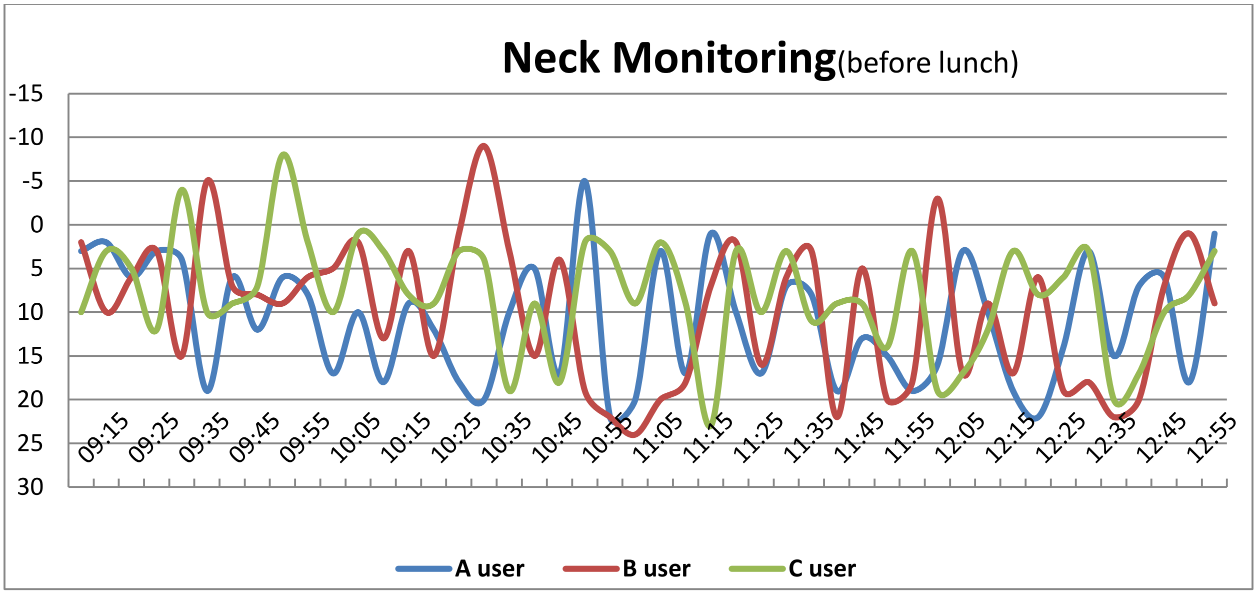


Chart 4 - Neck monitoring before lunchtime (User A, B and C)

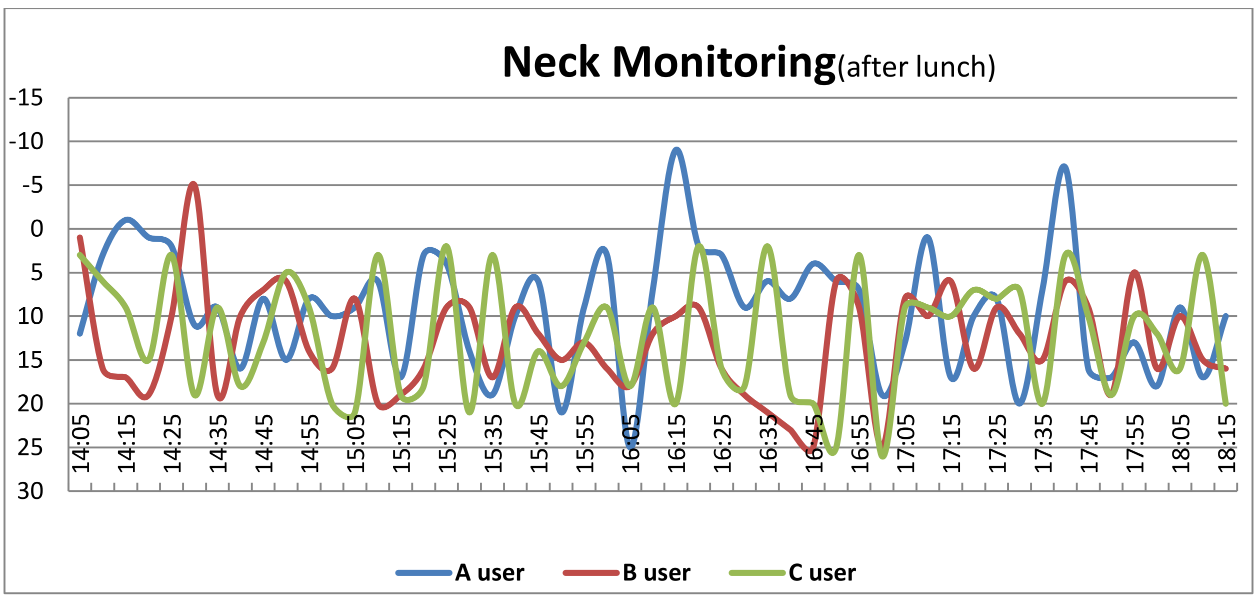


Chart 5 - Neck monitoring after lunchtime (User A, B and C)

B. Screen Distance Analysis

The graphic of the screen viewing distance for our three test users are shown in Chart 6 and Chart 7. Here also we divide all data charts into two parts, before lunchtime and after. The difference in average viewing distance between the users can be explained by User A's and User C's, as only they has 0 value in some place. It means that they go out from front of monitor (and also eye tracker device), and they value was 0. We account the distance when a user's face was in view, and he/she is looking directly at the screen, but when the worker is on the front of office table but not looking thought monitor the eye tracker can't track his/her eyes gaze, so the distribution of viewing distances could be a little bit skewed. As you can see in Chart 6 and Chart 7, zero value was registered for user A and user C. As in this case the test refers to the distance of the employee from the monitor, zero value can be registered in two cases: the employee has either been so close to the monitor that he touched it or the system has not registered employee's look (if the employee has not been in front of the monitor) and has printed the zero value. Taking into consideration also that cases we choose the way to combine the values every 5 minutes.

A user's distance can suggest possible changes to a user's computer viewing habits when compared to ergonomic guidelines. Our system identifies user from a distance of 45-75cm. However, if the user is within the range of 45-75cm, it does not mean that he/she follows the ergonomic rules. According to these rules the proper distance should be 55-65cm. In this case the system double checks the location of worker and if the latter is within the range of 55-65cm, such distance is considered normal and the worker may continue working, but if the distance varies between 45-55cm or 65-75cm, the worker is warned about it.

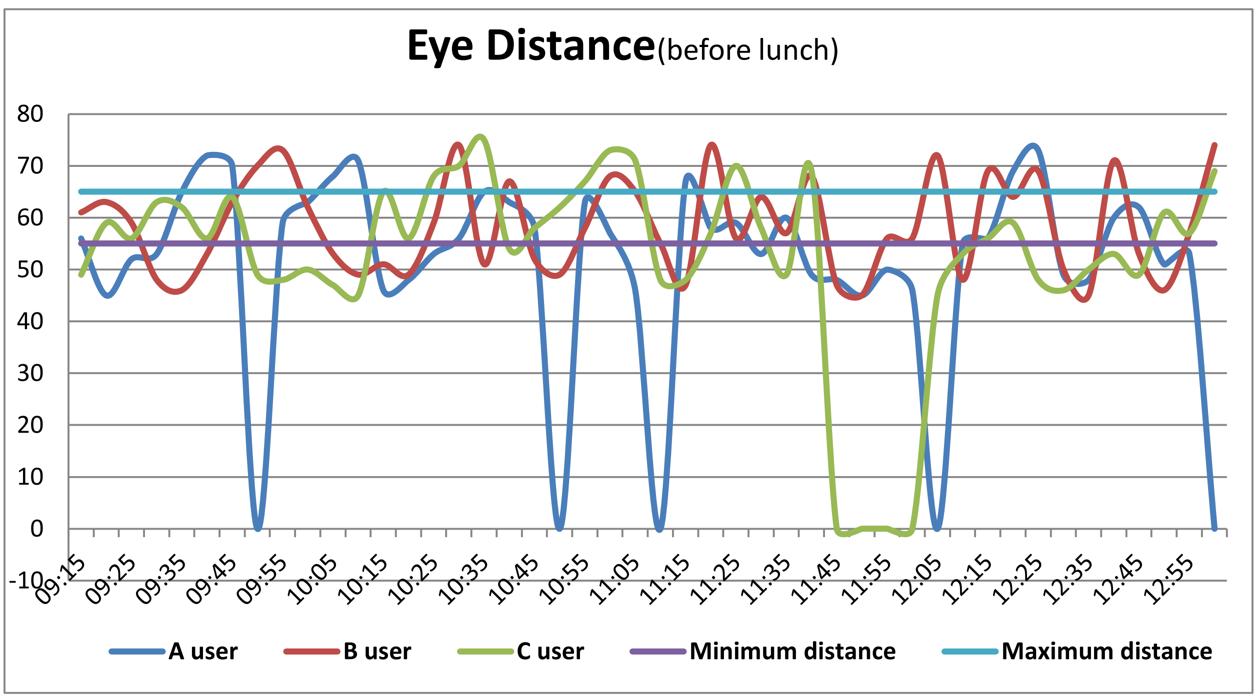


Chart 6 - Eye Distance for three users (User A, B and C)

In Chart 6 and Chart 7 we marked with Purple and Light Blue the normal minimum and maximum range as a normal value. Here is very clean underlined that all three users has the problem with keeping distance when they are in front of the monitor. So continuously using our system will train them keep normal distance without supporting devices.

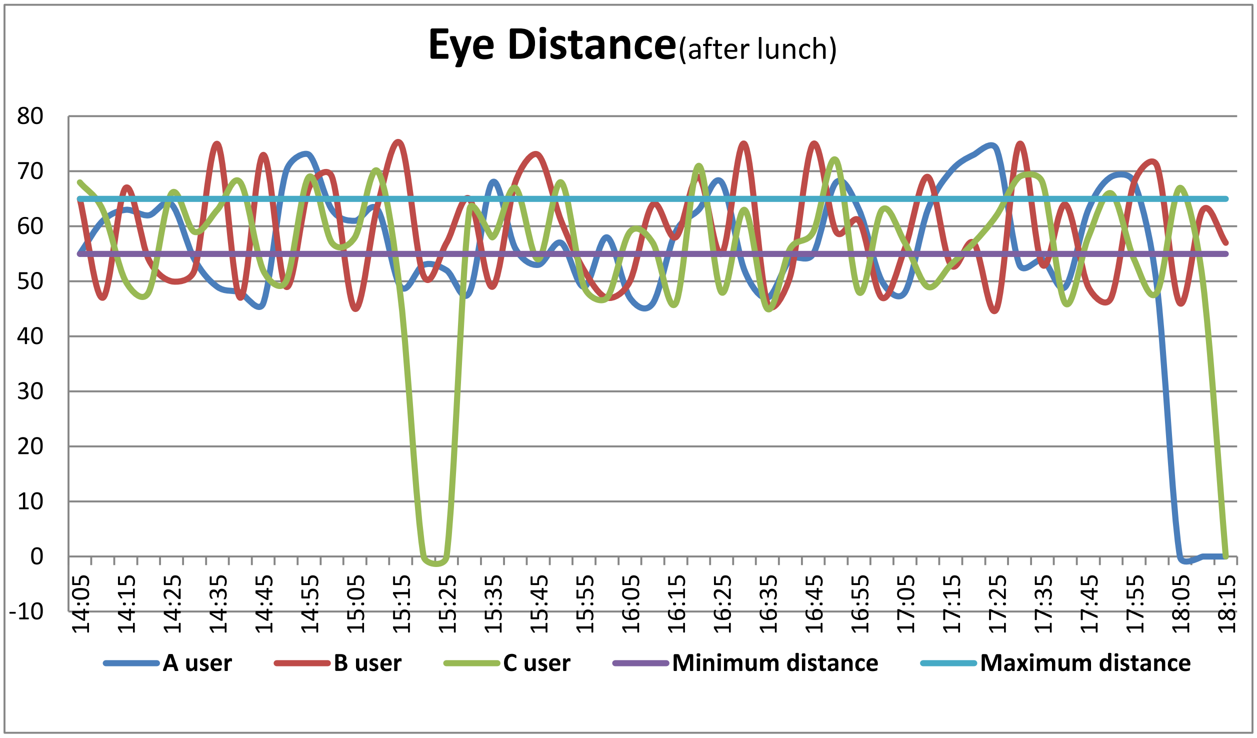


Chart 7 - Eye Distance for three users (User A, B and C)

As a conclusion I can say that we need to test it with up to 10 users and 6-12 months continuously. To record the entry data in the first days and compare them after 12 months. In that case I am almost sure that for some users we will have positive progress. And if we append also some workers who had already work-related musculoskeletal disorders (neck pain, eye strain, etc) we will achieve great results.

9 CONCLUSIONS and FUTURE WORK

9.1 The original contributions of this thesis

The technological development, and particularly the development of computer technologies provided humanity a great range of tools for facilitation and speeding up the accomplishment of daily work tasks and duties. With development of computer technologies we got unique possibilities and advantages in our professional development processes, but unfortunately, with all the range of possibilities and advantages it provided also a variety of disadvantages – serious health associated problems.

A study of the discomfort for office workers was carried out, to prove the existence of a real problem for sedentary workstyles employees. The study was carried of three groups of workstyles - active, partly active and sedentary. As shown on the results, the uncomfortable feeling of ache, pain and discomfort is increasing from active lifestyle to sedentary.

As seen from the previous part of this research, working at the office with advanced computer technological tools, which is doubtlessly the inseparable part of modern working process, affects office workers health extremely negatively, causing a variety of spine, neck and other problems the reasons of which are multidimensional and are associated with complex factors with individual, physical and psychosocial components. In this research, with the help of virtual reality tools, which are largely used nowadays in almost all extra important fields of educational and scientific processes and activities, we have tried to indicate all the negative aspects of sedentary work and to focus our attention on latest developments and studies of this problem. And also, what is more important, with the help of virtual reality, which, as stated above is the human presence in a computer-generated environment in a real life.

As discussed in previous research publications, nowadays almost all office workers spend the most of their working day doing sedentary work – telephone operators, remote sales agents, customer care agents, etc. With advancement of computer technologies time spent by employees in a sitting position continually grows. Thanks to the state-of-the–art technologies it has now become possible to do any type of working activities in a virtual environment thus “impeding” human mobility.

As stated in a Department of Labor Bureau of Labor Statistics, about 1 million of people annually devote time to treatment of musculoskeletal disorders caused by sitting at work.

Various other surveys of ergonomic intervention have been conducted which show that by preventing or improving human unconscious approach to his/her sitting position will help to create a healthier ergonomic environment, as well as will increase work efficiency and, of course decrease time and means for employees spent on treatment of disorders caused by above mentioned factors.

The International Labor Organization (ILO) even proposed to move on four-day workweek in order to improve employees health and somehow decrease the stress, sedentary lifestyle and overworking that inevitably lead to disorders. First tangible symptoms are weakness of fingers, elbows, knees and toes, back pain, uncomfortable postures etc. In our research we discussed methods for preventing such health-harming developments – to do exercises, do not sit in same position for a long period, often walk away from the computer and do eye exercises in order to reduce tension in eye muscles etc. And this should become integral part of a work process.

The present research aims at revealing the problem, offering a solution, conducting testing and proving system efficiency based on testing results.

To summarize, the original contributions of this thesis are:

1. A study of the discomfort for office workers. The study aims at revealing the problem of office workers who spend most working time in office and don’t have enough mobility during work. The target population was employees in Armenia and was carried out using the method of prospective cohort study. Statistical considerations, study variables and results are presented in chapter 3 of this thesis. The study and its results were accepted to be publish in [Paruyr, 2016]. Preliminary results of this research were published in [Paruyr et al, 2015].

2. Using Microsoft Kinect V2, Tobii Eye Tracker and Microsoft Band devices for monitoring employee’s posture, head position, eyes behavior, as established in the study from chapter 3. The monitored parameters are: head position (especially neck), spine

position, distance from monitor, eye blinking parameter, as well as Heart rate variability and physical activity during day. Details about processing of data from these devices are presented in chapter 7 and will be published in [Paruyr bUPB, 2016]. Preliminary results of this research were published in [Paruyr, 2014] and [Paruyr, 2015].

3. Using Virtual Reality tools for helping office employees to improve their health, based on the data acquired from the above mentioned devices. These contributions are highlighted in chapter 7 and will be published in [Paruyr bUPB, 2016].

4. Development of a system for employees monitoring, using parameters established in chapter 3, and helping them to improve their health, through presentation of the monitored data analysis using virtual reality, voice and text.

5. The experiments and tests of the system prototype, made in an organization, with 3 participants. These and their results are described in chapter 8. They will appear in [Paruyr bUPB, 2016].

9.2 Future work

The main issue considered in the present thesis relates to all activity domains, however, it got a solution thanks to IT technologies and advanced solutions that develop and upgrade every second. Hence, parallel to making a step forward, we should focus on development trends and upgrade our system and devices used therein. The main goal we'd set to ourselves in the scope of this research was to monitor human behavior during office hours. Hence, as a step forward, we may consider new parameters for further monitoring, such as physiological and ergonomic parameters.

As a new psychological parameter we may consider the factor of human fatigue revealed through EEG study, as well as changes in the electrical resistance of the skin caused by emotional stress through new sensors. As for new ergonomic parameters, desk placement, chair height, room illumination, air humidity and others can be considered.

Considering the aforementioned development trends, our system should be continually upgraded, in order to keep abreast with those trends, but before adding any new features to the system, we should first of all test it for a long period of time. It means that we should monitor workers' behavior for months long, in order to find out if positive changes are observed in their behavior during office hours or see if workers have given up bad habits and adopted good ones.

Author's publications in connection with this thesis

[Paruyr, 2014] - Paruyr HARUTYUNYAN, Alin MOLDOVEANU, Florica MOLDOVEANU, Vasile-Alexandru BUTEAN. Technologies for monitoring students body posture and physiological parameters during learning. In eLSE 2014 - 10th International Scientific Conference "eLearning and Software for Education". vol. 1, ISSN 2066-026X, pp. 67-72, April 2014

[Paruyr, 2015] - Paruyr HARUTYUNYAN, Alexandru BUTEAN, Anca MORAR, Alin MOLDOVEANU, Florica MOLDOVEANU. Improving ergonomics for sedentary jobs through body-posture monitoring. In eLSE 2015 - 11th International Scientific Conference "eLearning and Software for Education". vol. 3, pp. 549-556, April 2015

[Paruyr et al, 2015] - Paruyr HARUTYUNYAN, Alin MOLDOVEANU, Florica MOLDOVEANU, Victor ASAVEI. Health-related impact, advantages and disadvantages of ICT use in education, compared to its absence in the past. In eLSE 2015 - 11th International Scientific Conference "eLearning and Software for Education". vol. 3, pp. 557-563, April 2015

[Paruyr, 2016] - Paruyr HARUTYUNYAN, Alin MOLDOVEANU, Florica MOLDOVEANU. Study of the health problems and work-related musculoskeletal disorders caused by IT technologies, accepted for publication, in "Proceedings of national polytechnic University, information technologies, electronics, radio engineering of Armenia, 2016, vol. 1.

[Paruyr bUPB, 2016] - A SYSTEM FOR IMPROVING IT OFFICE EMPLOYEES HEALTH USING AN UNCONVENTIONAL USER INTERFACE, submitted to Scientific Bulletin of University POLITEHNICA of Bucharest.

10 Appendices

Appendix 1A. Employee questionnaire (English)

Questionnaire #___________ ID #___________

Day of the interview (day/month/year) ___/___/______ Start and end time of the interview (hours/minutes) ______/______ ------ ______/______

DISCOMFORT SURVEY for Employees

Full Name____

Job title ____ Male__________ Female __________

Job description _______ Active ☐ | Sedentary ☐ | Partly active ☐

1. How many years or months have you been working in this particular job or set of tasks?

   ___________years __________months

2. Which body part rated above represents the one in which you feel the most discomfort?

   ____

3. Have you sought or received medical assistance or treatment or other for specific body part?

Yes _____ No _____ If yes, please specify:

____

4. Have there been any changes made to your job, workstation or activities that you must perform to do your work? If yes, please specify:

   ____

5. What do you think what kind of changes could improve your job quality?

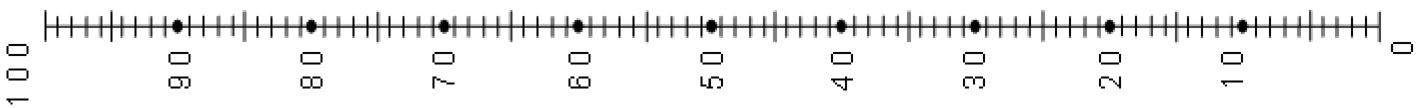
   ____
   ____

		During the last work week how often did you experience ache, pain, discomfort in:					If you experienced ache, pain, discomfort, how uncomfortable was this?			If you experienced ache, pain, discomfort, did this interfere with your ability to work?		
		Never	1-2 times last week	3-4 times last week	Ones every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantiall interfered
Neck		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hip/Buttocks		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Knee	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. Would you like to say how good or bad your health state is, we have drawn a scale on which the best state you can imagine is marked 100 and the worst state you can imagine is marked 0.

Scale __________



Appendix 1B. Employee questionnaire (Armenian)

Հարցաթերթիկ #____________ ID #____________

Հարցման ամսաթիվ (օր/ամիս/տարի) ___/___/_______ Հարցման սկիզբ և ավարտ (ժամ/րոպե) _______/_______ ------ _______/_______

Աշխատակիցների անհարմարությունների հարցում

Անուն, Ազգանուն____

Աշխատավայր____Արական_______ Իգական ___________

Աշխատանքի նկարագիր ________ Ակտիվ ☐ | Նստակյաց ☐ | Մասամբ ակտիվ ☐

1. Քանի տարի կամ ամիս եք աշխատում տվյալ աշխատավայրում?

   ____________տարի ___________ամիս

2. Մարմնի որ հատվածն է, որում դուք առավել շատ անհանգստություն եք նկատում? ____

3. Դուք ցանկանում եք ստանալ կամ ստացել եք բժշկական օգնություն տվյալ կամ այլ մարմնի հատվածի համար? Այո ______ Ոչ______ Եթե այո, ապա մանրամասնեք.____

4. Ձեր աշխատանքային պայմաններում արդյոք կատարվել են որևէ փոփոխություններ առօրյա աշխատանքային որակը բարձրացնելու նպատակով?

Այո ______ Ոչ______ Եթե այո, ապա մանրամասնեք.____

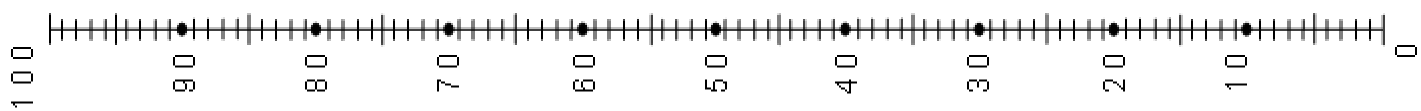
5. Ինչ եք կարծում, աշխատանքային միջավայրի ինչպիսի փոփոխություն կարող է բարելավել Ձեր աշխատունակությունը?
____

		Վերջին աշխատանքային շաբաթվա ընթացքում որքան հաճախ եք դուք ցավ կամ անհանգստություն զգացել տվյալ հատվածում.					Եթե դուք ունեք ցավ կամ անհանգստություն, որքան անհարմարություն է դա Ձեզ պատճառում?			Եթե դուք ունեք ցավ կամ անհանգստություն, արդյոք դա ազդում է ձեր աշխատելո ունակության վրա?		
		Երբեք	1-2 անգամ	3-4 անգամ	Օրը մեկ անգամ	Օրը բազմաթիվ անգամներ	Թեթև անհարմարություն	Չափավոր անհարմարություն	Շատ անհարմարություն	Բացարձակ	Քիչ է ազդում	Բավականա ափ ազդում
Պարանոց		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ուս	(Աջ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Ձախ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Թիակ		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Բազուկ	(Աջ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Ձախ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Մեջք		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Նախաբազուկ	(Աջ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Ձախ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Դաստակ	(Աջ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Ձախ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Նստատեղ		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ազդր	(Աջ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Ձախ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Աջ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Ծունկ	(Ձախ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ստորին ոտք	(Աջ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Ձախ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. Կցանկանաինք, որ այս սանդղակով նշեիք, թե Ձեր կարծիքով ինչպիսին է Ձեր առողջական վիճակն այսօր: 100-ը համապատասխանում է Ձեր պատկերացրած լավագույն առողջական վիճակին, 0-ն՝ վատագույն առողջական վիճակին:

   Սանդղակ __________



Appendix 2A. Consent form (English)

University Politehnica of Bucharest

Consent form for *DISCOMFORT SURVEY* for Employees

Title of research project: *Monitoring and improving employees body posture and physiological parameters via an unconventional user interfaces*

Hello, my name is Paruyr Harutyunyan. I am a PhD student at University POLITEHNICA of Bucharest, Faculty of Automatic Control and Computers. As part of my thesis project, and with the support of the faculty members, I am conducting a study to examine the health status of employees during working time for appropriate active, partly active and sedentary behavior. You have been contacted because you are working in the organization in which I am doing my research.

If you are willing to participate in this study I will ask you some questions concerning your health and your working behavior. Your participation in the study is voluntary. You may skip any question you think is inappropriate and stop it at any moment you want with no further negative consequences. The interview will take place once at any time that is convenient for you and will last no more than 5 minutes.

There will be no monetary benefits for you if you participate in this project. The information provided by you will be very helpful for science and for other workers as well. There is no penalty for refusing to participate. Whether or not you are in the study will not affect on your future working environment. The information provided by you is fully confidential and will be used only for the study. Only aggregate data will be reported.

Contact information will be destroyed upon completion of the research. If you have more questions about this study you can contact Paruyr Harutyunyan, the member of the research team – (+374 77) 73-79-07.

If you agree to be involved in this study, could we continue?

Appendix 2B. Consent form (Armenian)

Բուխարեսի Պոլիտեխնիկական Համալսարան

Իրազեկ համաձայնության ձև Աշխատակիցների անհարմարությունների հարցման համար

Հետազոտության վերնագիրը. *Աշխատակիցների մարմնի կեցվածքի և ֆիզիոլոգիական պարամետրերի մոնիտորինգ և բարելավում նստակյաց աշխատանքի ժամանակ ոչ ավանդական վիրտուալ իրականության ինտերֆեյսի միջոցով*

Բարև Ձեզ, իմ անունը Պարույր Հարությունյան է: Ես Բուխարեսի Պոլիտեխնիկական համալսարանի, Ավտոմատ կառավարման և ինֆորմատիկա ֆակուլտետի, ասպիրանտուրայի ուսանող եմ: Ես, որպես իմ ավարտական գիտական աշխատանքի մի մաս, հետազոտական խմբի անդամ դասախոսների աջակցությամբ իրականացնում եմ հետազոտություն ուսումնասիրելու աշխատակիցների առողջական վիճակը ակտիվ, մասամբ ակտիվ և նստակյաց աշխատանք կատարելու ժամանակ: Դուք ընտրվել եք, որովհետև աշխատում եք այն կազմակերպությունում, որտեղ ես կատարում եմ հետազոտությունս:

Եթե Դուք համաձայն եք մասնակցել այս հետազոտությանը, ապա ես Ձեզ կտամ որոշ հարցեր Ձեր առողջության և աշխատանքի կատարման վերաբերյալ: Ձեր մասնակցությունը այս հետազոտությանը կամավոր է: Դուք իրավունք ունեք չպատասխանել այն հարցերին, որոնք Ձեզ կարող են տհաճություն պատճառել կամ դադարեցնել հարցազրույցը ցանկացած պահին՝ առանց որևէ հետագա բացասական հետևանքների: Հարցազրույցը տեղի կունենա մեկ անգամ, Ձեզ առավել հարմար ժամանակ, և կտևի ոչ ավելի քան 5 րոպե:

Այս հետազոտությանը Ձեր մասնակցության դեպքում որևէ դրամական խրախուսանք նախատեսված չէ: Ձեր կողմից տրամադրված տվյալները կլինեն շատ կարևոր գիտական տեսանկյունից և օգտակար կլինեն թե Ձեր հետագա աշխատելաձևի համար, և թե այլ աշխատակիցների: Հետազոտությանը չմասնակցելու դեպքում Ձեզ ոչ մի բացասական հետևանք չի լինի: Անկախ նրանից Դուք կմասնակցեք այս հետազոտությանը թե ոչ, ոչինչ չի ազդի Ձեր հետագա աշխատանքի վրա: Ձեր կողմից տրամադրված ողջ տեղեկությունները գաղտնի կպահվեն և միայն ընդհանրացված արդյունքները կներկայացվեն զեկույցում:

Ձեր անձնական տվյալները անմիջապես կոչնչացվեն հետազոտության ավարտից հետո: Հետազոտության հետ կապված հետագա հարցերի համար կարող եք զանգահարել հետազոտական թիմի անդամ՝ Պարույր Հարությունյանին, (+374 77) 73-79-07:

Եթե համաձայն եք մասնակցել այս հետազոտությանը, կարող ենք շարունակել:

Appendix 3. Source code

Microsoft Kinect – Neck variable checking source code

```
if (joint == JointType.Neck)
        {
            if (neck_write_in_file_boolean == true)
            {
                using (StreamWriter stream_writer = new StreamWriter(path_name_neck,
append: true))
                {
                    var x =
(Mathf.FloorToInt(kinectManager.GetJointOrientation(userId, iJoint,
true).eulerAngles.x));
                    var z =
(Mathf.FloorToInt(kinectManager.GetJointOrientation(userId, iJoint,
true).eulerAngles.z));
                    if (x > 300 && x <= 360)
                    {
                        stream_writer.WriteLine(-(360 - x) + " " +
DateTime.Now.ToString("HH:mm"));
                    }
                    else
                    {
                        stream_writer.WriteLine(x + " " +
DateTime.Now.ToString("HH:mm"));
                    }
                    if (z > 300 && z <= 360)
                    {
                        stream_writer.WriteLine(-(360 - z) + " " +
DateTime.Now.ToString("HH:mm"));
                    }
                    else
                    {
                        stream_writer.WriteLine(z + " " +
DateTime.Now.ToString("HH:mm"));
                    }
                }
            }
            if (    ( ( Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.z) >= 310
                       && Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.z) <= 356)||
                       (Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.z) >= 6
                       && Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.z) <= 50)
                    )||
                ( Mathf.FloorToInt(kinectManager.GetJointOrientation(userId, iJoint,
true).eulerAngles.x) >= 310
                       && Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.x) <= 356)||
                       (Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.x) >= 6
```

```
                       && Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.x) <= 50)
                    )
            {
                if(WarningPicture.activeSelf == false)
                {
                    WarningPicture.SetActive(true);
                    WarningMessage.text = "Correct Your Head";

                }
            }
            else
            {
                if( WarningPicture.activeSelf == true)
                    WarningPicture.SetActive(false);
            }
        }
```

Microsoft Kinect – Spine variable checking source code

```
if (joint == JointType.SpineBase)
{
      using (StreamWriter stream_writer = new StreamWriter(path_name_spine, append:
true))
          {
             var x = (Mathf.FloorToInt(kinectManager.GetJointOrientation(userId,
iJoint, true).eulerAngles.x));
                    if( x > 300 && x <= 360 )
                    {
                    stream_writer.WriteLine(-(360 - x) + " " +
DateTime.Now.ToString("HH:mm"));
                    }
                    else
                    {
                    stream_writer.WriteLine( x + " " +
DateTime.Now.ToString("HH:mm"));
                    }
            }

if (( Mathf.FloorToInt(kinectManager.GetJointOrientation(userId, iJoint,
true).eulerAngles.x) >= 356
      && Mathf.FloorToInt(kinectManager.GetJointOrientation(userId, iJoint,
true).eulerAngles.x) <= 360) ||
      (Mathf.FloorToInt(kinectManager.GetJointOrientation(userId, iJoint,
true).eulerAngles.x) >= 0 &&
      Mathf.FloorToInt(kinectManager.GetJointOrientation(userId, iJoint,
true).eulerAngles.x) <= 4))
{
      SpineDeviation.text = "OK";

}
else
```

```
{
   SpineDeviation.text = "Correct Your Spine";
}
}
```

Monitoring and improving workers body posture and physiological parameters via an unconventional user interface

REFERENCES

[Matthews, 2003] Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, Troiano RP. Amount of time spent in sedentary behaviors in the United States, 2003–2004. Am J Epid 2008, vol.167, no.7, pp. 875–881.

[Brownson, 2005] Brownson RC, Boehmer TK, Luke DA. Declining rates of physical activity in the United States. Annu Rev Public Health 2005, vol. 26, pp. 421–443.

[Bauman, 2011] Bauman A, Ainsworth BE, Sallis JF, Hagstromer M, Craig CL, Bull FC, Pratt M, Venugopal K, Chau J, Sjostrom M. The descriptive epidemiology of sitting - a 20 country comparison using the International Physical Activity Questionnaire (IPAQ). Am J Prev Med 2011, vol. 41, pp. 228–235.

[Thorp, 1996] Thorp A, Owen N, Neuhaus M, Dunstan D. Sedentary Behaviours and subsequent health outcomes in adults - A systematic review of longitudinal studies 1996–2011. Am J Prev Med 2011, vol.41, no.2, pp. 207–215.

[Schaldach, 1998] Schaldach M, Hutten H. Telecardiology - Optimizing the diagnostic and therapeutic efficacy of the next implant generation. Prog Biomed Res. 1998, vol. 3, pp. 1-4.

[Paruyr et al, 2015] Paruyr HARUTYUNYAN, Alin MOLDOVEANU, Florica MOLDOVEANU, Asavei Victor. Health-related impact, advantages and disadvantages of ICT use in education, compared to its their absence in the past. In eLSE 2015 - 11th International Scientific Conference “eLearning and Software for Education". vol. 3, April 2015

[Konsbruck, 2013] Konsbruck Robert Lee. Impacts of Information Technology on Society in the new Century, Route de Chavannes, 27C CH-1007 Lausanne-Vidy Switzerland, 2013, Last access 28 November 2015: http://www.zurich.ibm.com/pdf/news/Konsbruck.pdf

[Parry, 2013] Parry S, Straker L, Gilson ND, Smith AJ. Participatory Workplace Interventions Can Reduce Sedentary Time for Office Workers - A Randomised Controlled Trial. PLoS ONE vol. 8, no. 11: e78957. doi:10.1371/journal.pone.0078957, 2013

[Dunstan, 2013] David W Dunstan, Glen Wiesner, Elizabeth G Eakin, Maike Neuhaus, Neville Owen, Anthony D LaMontagne, Marj Moodie, Elisabeth AH Winkler, Brianna S Fjeldsoe, Sheleigh Lawler, Genevieve N Healy. Reducing office workers' sitting time, BMC Public Health, December 2013, vol. 13, no. 1, p. 1057

[Agelink, 2001] Agelink MW, Malessa R, Baumann B, Majewski T, Akila F, Zeit T, Ziegler D. Standardized tests of heart rate variability: normal ranges from 309 healthy humans, and effects of age, gender, and heart rate. Clin Auton Res 2001, vol.11, pp. 99-108.

[Mana, 2008] Mana Rafik Loutfy, Sheila Macdonald, Terri Myhr, Heather Husson, Kanice Du Mont, Shannon Balla, Tony Antoniou and Anita Rachils. "Prospective coort study of HIV post-exposure prophylaxis for sexual assault survivors" 2008 International Medical Press. Last access 27 November 2015: http://www.intmedpress.com/serveFile.cfm?sUID=036e1d48-66b7-40de-8040-227f2ab95eeb

[EU, 2007] European Union.Community strategy 2007-2012 on health and safety at work, Last access 28 November 2015: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:l10114

[Joan, 2010] Joan Burton. WHO Healthy Workplace Framework and Model, Geneva, Switzerland, February 2010, Last access 28 November 2015: http://www.who.int/occupational_health/healthy_workplace_framework.pdf

[Leka, 2008] Leka S, Cox T, Eds. PRIMA-EF. Guidance on the European framework for psychosocial risk management: a resource for employers and worker representatives. Protecting Workers' Health Series #9. World Health Organization 2008.

[Alexander, 1998] Alexander, D. Ergonomic Design Guidelines, Auburn Engineering, Inc., 1998

[Rudakewych, 2001] Rudakewych M, Valent-Weitz L, Hedge A. Effects of an ergonomic intervention on musculoskeletal discomfort among office workers. Proceedings of the 45th Human Factors and Ergonomics Society Annual Meeting. Santa Monica, CA; 2001, vol. 1, pp. 791–795.

[Bacher, 2004] Bacher, L. F., and Smotherman, W. P. Spontaneous eye blinking in human infants: a review. Developmental psychobiology vol. 44, no. 2, March 2004, pp. 95 -102.

[Harkness, 2005] Harkness A, Long B, Bermbach N, Patterson K, Jordan S and Kahn H. 'Talking about stress at work: Discourse analysis and implications for stress interventions', Work and Stress, vol. 19, no. 2, 2005

[Etienne van Wyk, 2009] Etienne van Wyk, Ruth de Villiers. Virtual Reality Training Applications for the Mining Industry, Afrigraph 2009, Pretoria, South Africa, February 2009, ACM 978-1-60558-428-7/09/0002

[Grigore, 2003] Grigore Burdea, Philippe Coiffet. Virtual Reality Technology, Presence: Teleoperators and Virtual Environments, December 2003, vol. 12, no. 6 , pp. 663-664 (doi: 10.1162/105474603322955950)

[DI CARLO, 2000] DI CARLO, W. 2000. Exploring multi-dimensional remote sensing data with a virtual reality system. Geographical & Environmental Modelling 4, pp. 7–20.

[DENBY, 1999] DENBY, B., and SCHOFIELD, D. 1999. Role of Virtual Reality in Safety Training of Mine Personnel. Mining Engineering, 1999, pp. 59-64.

[ORR, 2002] ORR, T.J., FILIGENZI, M.T., AND RUFF, T.M. 2002. Desktop Virtual Reality Miner Training Simulator

[DE STRULLE, 2004] DE STRULLE, A. 2004. Differentiation of the Causal Characteristics and Influences of Virtual Reality and the Effects on Learning at a Science Exhibit, PhD Thesis, University of San Diego.

[Bartelds, 2004] G. Bartelds, J.H. Heida, J. McFeat, C. Boller. Health Monitoring of Aerospace Structures: smart sensor technologies and signal processing, ISBN 0-470-84340-3, 2004

[Gerd, 2007] Gerd Kortuem, David Alford, Linden Ball, Jerry Busby, Nigel Davies, Christos Efstratiou, Joe Finney, Marian Iszatt White, Katharina Kinder: Sensor networks or smart artifacts? an exploration of organizational issues of an industrial health and safety monitoring system, UbiComp 2007, Proceedings of the 9th international conference on Ubiquitous computing, pp.

465-482, 2007

[Eleni, 2009] Eleni Stroulia, David Chodos, Nicholas M. Boers, Jianzhao Huang, Pawel Gburzynski, Ioanis Nikolaidis: Software Engineering for Health Education and Care Delivery Systems The Smart Condo Project, SEHC'09, May 18-19, 2009

[Moeslund, 2006] T. Moeslund, A. Hilton and V. Krüger. A survey of advances in vision-based human motion capture and analysis. Computer Vision and Image Understanding vol. 104, no. 2, pp. 90-126, 2006.

[Lee, 2006] M.W. Lee and I. Cohen. A model-based approach for estimating human 3D poses in static images. IEEE Transactions on Pattern Analysis and Machine Intelligence vol. 28, no. 6, pp. 905-916.

[Zhao, 2007] X. Zhao and Y. Liu. Generative Estimation of 3D Human Pose Using Shape Contexts Matching. Lecture Notes in Computer Science 4843, 2007, pp. 419-429.

[Loke, 2007] E. Loke and M. Yamamoto. An Active Multi-camera Motion Capture for Face, Fingers and Whole Body. Lecture Notes in Computer Science 4843, 2007, pp. 430-441.

[Bernhard, 2013] Bernhard Schwartz, Andreas Schrempf, Michael Haller, Kathrin Probst, Josef Glöckl: RECOGNIZING STATIC AND DYNAMIC SITTING BEHAVIOR BY MEANS OF INSTRUMENTED OFFICE CHAIRS, Conference: BioMed 2013, DOI: 10.2316/P.2013, pp. 791-142

[Rogado, 2009] E. Rogado, J.L. García, R. Barea, L.M. Bergasa: Driver Fatigue Detection System, Proceedings of the 2008 IEEE International Conference on Robotics and Biomimetics Bangkok, Thailand, February 2009

[Duchowski, 2002] A. T. Duchowski, "A breadth-first survey of eye-tracking applications." Behavior research methods instruments computers a journal of the Psychonomic Society Inc, vol. 34, no. 4, pp. 455 - 470, 2002.

[Zhu, 2007] Z. Zhu and Q. Ji, "Novel eye gaze tracking techniques under natural head movement," Biomedical Engineering, IEEE Transactions on, December 2007, vol. 54, no. 12, pp. 2246 –2260.

[Ning, 2007] C. C. Ning, O. Shunichiro, and C.-S. Lin, "Development of an active gaze tracking system in unrestricted posture," in Control, Automation and Systems, 2007. ICCAS '07. International Conference on, October 2007, pp. 1348 – 1353.

[OSHA, 2012] OSHA, "Laboratory safety ergonomics for the prevention of musculoskeletal disorders in laboratories," January. 2012, Last access 28 November 2015: http://www.osha.gov/Publications/laboratory/OSHAfactsheet-laboratory-safety-ergonomics.pdf

[Carney, 1982] Carney LG; Hill RM. The nature of normal blinking patterns. Acta Ophthalmol. 1982, vol. 60, pp. 427-33

[Lavezzo, 2007] Lavezzo MM; Schellini AS; Padovani CR. Avaliação comparativa do ritmo de piscar em crianças normais em idade pré-escolar. Arq. Bras. Oftalmol. 2007, vol.70, pp. 481-486

[Dumery, 1997] Dumery B, Toi VV. Relationship between blink rate, ocular discomfort and visual tasks. Invest Ophthalmol Vis Sci. 1997, vol.38, no. S, pp. 68.

[Kyung-Ah, 2013] Kyung-Ah Kwon, Rebecca J. Shipley, Mohan Edirisinghe, Daniel G. Ezra, Geoff Rose, Serena M. Best, Ruth E. Cameron. High-Speed Camera Characterisation of Voluntary Eye Blinking Kinematics. DOI: 10.1098/rsif.2013.0227, June 2013.

[Ortiz-Hernandez, 2003] L. Ortiz-Hernandez, S. Tamez-Gonzalez, S. Martinez-Alcantara, and I. Mendez-Ramirez. Computer use increases the risk of musculoskeletal disorders among newspaper office workers. Archives of Medical Research, 2003, vol. 34, no. 4, pp.331-342.

[Karin, 2008] Karin Reinhold, Piia Tint, Viiu Tuulik, Silver Saarik, Innovations at Workplace: Improvement of Ergonomics. ISSN 1392-2785 ENGINEERING ECONOMICS vol. 60, no 5, 2008.

[MICHIEL, 2003] MICHIEL P. DE LOOZE, LOTTIE F. M. KUIJT-EVERS, JAAP VAN

DIEEN, Sitting comfort and discomfort and the relationships with objective measures, ERGONOMICS, AUGUST, 2003, vol. 46, no. 10, pp. 985 - 997

[Serge, 1996] Serge Simoneau, Marie St-Vincent, Denise Chiocoine, Work-Related Musculoskeletal Disorders(WMSDs), A BETTER UNDERSTANDING FOR MORE EFFECTIVE PREVENTION, 1996, Accessed on June 2015: https://www.irsst.qc.ca/media/documents/PubIRSST/RG-126-ang.pdf,

[Devereux, 2002] Devereux JJ, Vlachonikolis IG, Buckle PW. Epidemiological study to investigate potential interaction between physical and psychosocial factors at work that may increase the risk of symptoms of musculoskeletal disorder of the neck and upper limb. Occup Environ Med. 2002, vol. 59, no. 4, pp. 269-277.

[JOHN, 1997] JOHN M. CARROLL, Human-computer interaction: psychology as a science of design, Int. J. Human-Computer Studies,1997, pp. 501-522

[Jonathan, 2005] Jonathan Grudin, Three Faces of Human–Computer Interaction, IEEE Annals of the History of Computing, 2005

[Shuo, 2011] Shuo Samuel Liu, Andreq Rawics, Siavash Rezaei, Teng Ma, Chenq Zhang, Kyle Lin, Eion Wu, An Eye-Gaze Tracking and Human Computer Interface System for people with ALS and Other Locked-in Diseases, Journal of Medicine and Biological Engineering, vol. 32, no. 2, March 2011, pp. 111-116

[Andreas, 2010] Andreas Bulling, Jamie A. Ward, Hans Gellersen and Gerhard Troster, Eye Movement Analysis for Activity Recognation Using Electroculography, IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, 2010

Web References

[WHO] World Health Organization,
Available: http://www.who.int/en/

[MsKinect] Microsoft Corporation: Kinect for Windows,
Available: https://dev.windows.com/en-us/kinect

[MsBand] Microsoft Corporation: Microsoft Band,
Available: http://www.microsoft.com/microsoft-band/en-us

[TobiiEye] Tobii: The world eye tracking leader,
Available: http://www.tobii.com/en/eye-experience/

[Emotive] Emotiv: Brain activity tracker,
Available: https://emotiv.com/epoc.php

[EuroQOL] EuroQol Research Foundation,
Available: http://www.euroqol.org/

[Cornell] Cornell Musculoskeletal Discomfort Questionnaires: Human Factors and Ergonomics Laboratory at Cornell University,
Available: http://ergo.human.cornell.edu/default.htm

[Labour Org] Facts on safety at work. International Labour Organization.
Available: http://www.ilo.org/global/about-the-ilo/media-centre/press-releases/WCMS_005161/lang--en/index.htm#1

[Int. Ergonomics] The International Ergonomics Association (IEA),
Available: http://www.iea.cc/whats/index.html

[Bls] Injures, Illnesses, Fatalities [US Dept, of Labor, Bureau of Labor Statistics website]. Washington, D.C. US Department of labour Bureau of Labor Statistics, 1999.
Available: http://www.bls.gov/iif/home.htm

[SecondLife] Second Life: Virtual World,
Available: http://www.secondlife.com/

[KZero] KZero Worldswide: analytics of the Virtual World/MMO,
Available: http://www.kzero.co.uk/

[Unity3D] Unity Technologies, Unity game engine,
Available: http://www.unity3d.com/

[OSHA Ergonomics] OSHA. OSHA Ergonomic Solutions: Computer Workstations eTool,
Available: http://www.osha.gov/SLTC/etools/computerworkstations/

[WMSD] Work Related Musculoskeletal Disorders, Occupational Health Clinics for Ontario Workers,
Available:
http://www.ohcow.on.ca/uploads/Newsroom/Work_Related_Musculoskeletal_Disorders__WRMSDs_.pdf

[Microsoft Corp.] Microsoft Corporation Website,
Available: https://www.microsoft.com/

[EpiTool] EpiTools, Sample Calculation
Available:
http://epitools.ausvet.com.au/content.php?page=cohortSS&P1=0.19&RR=1.7&Conf=0.95&Power=0.8

[MSI] Module 2 - Guide to employee education on Musculoskeletal Injuries (MSI),
Available:
http://www.esdc.gc.ca/en/reports/health_safety/ergonomics/module2.page