FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Kinect-based Physical Pain Prevention System for Office/Home Use

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieur

im Rahmen des Studiums

Medieninformatik

eingereicht von

Bruno Tunjic
Matrikelnummer 0708079

an der
Fakultät für Informatik der Technischen Universität Wien

Betreuung: Univ.Prof. Geraldine Fitzpatrick, Phd.

Wien, 05.11.2013

(Unterschrift Verfasserin) (Unterschrift Betreuung)

FAKULTÄT
FÜR !NFORMATIK
Faculty of Informatics

Kinect-based Physical Pain Prevention System for Office/Home Use

MASTER'S THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieur

in

Media informatics

by

Bruno Tunjic
Registration Number 0708079

to the Faculty of Informatics
at the Vienna University of Technology

Advisor: Univ.Prof. Geraldine Fitzpatrick, Phd.

Vienna, 05.11.2013

(Signature of Author) (Signature of Advisor)

Erklärung zur Verfassung der Arbeit

Bruno Tunjic
Lorenz Müller Gasse 1a/5477, 1200 Wien

Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit - einschließlich Tabellen, Karten und Abbildungen -, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe.

(Ort, Datum)	(Unterschrift Verfasserin)

Acknowledgements

Abstract

Recent research indicates that excessive sitting in front of computer and inactivity in general, can cause neck, shoulder, wrist and back pain. Such disorders are summarized under the term musculoskeletal disorders (MSD). Rehabilitation systems and programs for such problems are available, but a more rewarding solution for employers and office workers would be prevention through exercising.

Therefore in this thesis a system for prevention of MSD-related pains is presented. Two key challenges when developing and designing such system are how to motivate users to exercise and how to track motion for feedback purposes. According to physical medicine specialists and physiotherapists, if office workers could be motivated to regularly perform exercises this group of disorders could effectively be prevented.

The system presented here incorporates a simple virtual agent which represents a guide and an exercise partner for a user. The integral part of the system is the Microsoft Kinect, a motion sensing device for which freely available drivers were released recently. Virtual agent should remind the user on when and how much to exercise, while the Kinect device is used to track users' movements and therefore provide feedback on correctness of executed exercises. Since the system should be used in everyday life, only sensible approach for design process is user-centered design (UCD) where users are constantly involved during the development. This constant involvement of users through interviews made it possible to adapt the design to users' needs and make the system practically applicable.

The resulting system provides exact navigation and guidance during execution of exercises by visualizing the user on computer screen and displaying static points through which the movement has to be performed. The approach with these guidance points minimizes incorrect movements drastically. In addition to that, system was positively evaluated by users, but also by physiotherapists who indicated that the system could ease their job and effectively prevent MSD-related pains. The system was also positively graded during the in-situ deployment in a home office. Main finding is therefore that by using a low-cost motion sensing device as Kinect and providing correct visual feedback, it is possible to create a system that can be used in prevention of MSDs in office or home environment. Future work would include longer deployment and extension of implemented features.

Kurzfassung

Mehrere Forschungen zeigen, dass übermäßige Sitzen vor dem Computer dazu führen kann, dass die Nacken-, Schulter-, Handgelenk- und Rückenschmerzen entstehen. Solche Erkrankungen werden unter dem Begriff "Muskel-und Skeletterkrankungen" (MSD) zusammengefasst. Rehabilitationssysteme für solche Probleme sind vorhanden, aber eine lohnendere Lösung wäre Prävention durch der Übung.

Deshalb wird in dieser Arbeit ein System zur Verhinderung von Schmerzen vorgestellt. Die wichtigste Herausforderungen bei der Entwicklung und Gestaltung von solchen Systemen sind wie die BenutzerInnen zu üben zu motivieren, und wie die Bewegungen zu verfolgen, so dass Feedback zurückgegeben sein kann. Laut Fachärtzte für Physikalische und Rehabilitative Medizin und Physiotherapeuten, diese Gruppe von Erkrankungen könnte dürch regelmäßig widerholten Übungen verhindert werden, nur wenn die Büroangestellte motiviert werden könnten.

Das hier vorgestellte System umfasst einen virtuellen Agent, der eine Führung und einen Übungspartner für die BenutzerInnen darstellt. Der integrale Bestandteil des Systems ist der Kinect-Sensor von Microsoft, der die Bewegungsverfolgung ermöglicht. Virtuelle Agenten sollten die BenutzerInnen daran erinnern, wann und wie viel zu üben. Dabei wird der Kinect-Sensor verwendet, um die Bewegungen zu verfolgen und Rückmeldungen über die Richtigkeit der durchgeführten Übungen zu geben. Während des Gestaltungsprozesses wurde der User Centered Design (UCD) Ansatz angewendet. Die Interviews und ständige Einbeziehung der BenutzerInnen machte es möglich, das Design an die Bedürfnisse der NutzerInnen anzupassen.

Das resultierende System bietet genaue Navigation und Führung während der Ausführung von Übungen durch die Visualisierung des Benutzers auf dem Bildschirm und Anzeigen von den statischen Punkten, durch die die Bewegungen durchgeführt werden müssen. Die Anzahl der falschen Bewegungen wurde dadurch drastisch verringert. Darüber hinaus wurde das System nicht nur von den BenutzerInnen positiv bewertet, sondern auch von Physiotherapeuten, die auch glauben dass diese Art von System ihre Arbeit erleichtern und Schmerzen großenteils verhindern kann. Die "In-Situ Deployment" wurde ebenfalls durchgeführt und das Feedback von dem Benutzer wurde einbezogen.

Hauptfeststellung ist daher, dass durch die Verwendung des Kinects und die Bereitstellung der richtigen visuellen Rückmeldung, die Gestaltung eines Systems für Prävention von Schmerzen möglich ist. Künftige Arbeit würde eine gründlichere Auswertung und Erweiterung von Funktionen umfassen.

Contents

CHAPTER 1

Introduction

The term *Musculoskeletal disorders (MSD)* can be used to describe any type of injury, damage or disorder of the joints or other tissues in the upper and lower limbs, as well as in the back. They manifest through pain in the muscles, tendons and nerves, which is caused by continuous, repetitive or unnatural movements [14]. All these symptoms can have a negative affect on the overall quality of life due to the fact that they cause difficulties in the performance of occupational or daily life activities [7]. Therefore, demographic and occupational factors can have an influence on the causes and risk amount for musculoskeletal symptoms. Aspects of daily life, such as sports or housework, can present physical stresses on musculoskeletal tissues. However, in this work the emphasis is on the relation of occupational work with MSDs.

Musculoskeletal disorders have been a subject of much research in the field of occupational medicine [34]. Accurate statistical data is very different across countries and while MSDs are present in many countries, they are not exclusively caused by work. However, a large percentage of work-related diseases can be categorized as musculoskeletal disorders. In the United States, Nordic countries and Japan it is estimated that one third of work related diseases are MSDs [57]. In Europe, the MSDs are characterized as the main occupational disease among workers, because of the fact that they account for over 50% of all occupational diseases [17]. There are certain industries and occupations where the risk factor is significantly higher compared to other occupations. Fast paced work, repetitive movements, insufficient recovery times, heavy lifting, incorrect and non-neutral postures, exposure to cold, and an unhealthy psychosocial work environment or demand, as well as any combination of these, are listed as the main causes [57].

In recent years, sedentary behaviour in general has emerged as an important factor for poor health [8]. Advances in technology are described as the primary reasons for increases in sedentary time, which is mainly accounted to the excessive use of computers. Although sedentary workers are less exposed to hazards that surround physically demanding occupations, the influence of sedentary behaviour should not be underestimated. The research by Parry and Straker [52] clarifies that regardless of measurement device, office workers are sedentary for a large number of work hours. According to their experiments, nearly half (48,5%) of the weekly sedentary time is accounted to the nature of office workers' jobs. Therefore, the conclusion is that office work can significantly increase sedentary behaviour and associated risks. The longer sedentary periods are only one aspect, the other being the fact that breaks from work have significantly decreased in length as well as frequency. Therefore Parry and Straker argue that low-risk nature of office work has correspondingly changed due to the fact that office workers are forced to spend more time in sedentary positions. Presented solutions for the problem are reduction of work in sedentary position and incorporating light intensity activities during work time.

1.1 Motivation

According to the United States Census Bureau [21], in 2011, 75.6% of households reported having a computer. This, compared to the data from 1984 (8.2%) and from 2003 (61.8%), proves that computers have become an in integral part of everyday life. This increase is however also noticeable in office environments. The *information and communication technologies (ICT)* have improved most of the occupations connected to office work in the sense of faster, easier and more reliable completion of tasks [6]. In this thesis, under the term computer work we understand work with video display units that include the use of a keyboard and/or mouse. In the United States, computers and computer work are an important part of the economy [21]. Since computing-related jobs are almost exclusively sedentary, the influence of computers on an increased risk of musculoskeletal disorders is directly observable. Moreover, the compensation costs, lost wages, and lost productivity, are between $45 and $54 billion each year due to musculoskeletal disorders [51]. Therefore minimizing the losses related to MSDs is of great economic importance.

In recent years, evidence of relation between musculoskeletal symptoms in neck and upper extremities and computer work has been mentioned more often than before. The studies concerning this relation between musculoskeletal disorders and computer use are mostly based on subjective measures. This, however, is scientifically not enough, and objective measures are needed. In the work by Waersted et al. [69], the limited evidence for the relation between computer work and some musculoskeletal disorders is presented. Tension neck syndrome is one of the disorders for which they found limited evidence. However, in an article by Tornqvist et al. [67] ,the high level of association of computer work with neck tension syndrome is presented. Waested et al. also presents evidence for a relationship between computer work and wrist tendonitis. A study that shows the influence of computer use on higher prevalence of self-reported musculoskeletal symptoms in Nigerian population was conducted by Ayanniyi et al. [6]. The large number of participants (472) in the study, and the significant difference between computer and non-computer users, proves that computer use has a strong influence on the occurrence of musculoskeletal disorders. It also important to note that neck pains had been reported as the most common symptom (33.9%) among computer users). In addition to that, the younger age, being male, and working longer hours daily, as well as increased time span of computer usage were significant factors that influenced the reporting.

The previously mentioned statistics show that use of computers and its effects on human health has increased in recent years in developed countries. The same is also applicable to developing countries according to Ranasinghe et al [55]. 2,500 participants were included in the research, which spanned over a period of 7 months. In 56.9% cases complaints of symptoms in arms, neck and shoulders were reported. The most reported regions are the forearm/hand with 42.6%, neck with 36.7% and shoulder/arm with 32%. 9.3% of the participants were reportedly absent from work due to complaints of their arms, neck and shoulders. It is however important to note that most of the workplaces were graded as ergonomically non-compliant. Other causes, such as body posture and insufficient ergonomic knowledge are also listed as additional factors. However, the study confirms that the prevalence of computer work related complaints of arms, neck and shoulders is also high in developing countries, which is comparable with the situation in developed countries.

The fact that the musculoskeletal symptoms among adolescents are related to computer use is examined by Hakala et al. [33]. The research is based mostly on finding out how much computer use affects the everyday life of adolescents. Therefore, the authors examine the relation of computer use with intensity of musculoskeletal pain, and level of problems caused by it in daily life. Based on the data obtained in the study, computer use of 14 or more hours per week is associative with moderate/severe pain in all body regions. However, the most affected regions that have influence on daily life are the head, neck and lower back.

1.2 Problem statement

Reducing computer use, or any other occupational sitting time at work can significantly improve worker's health [56]. Sedentary jobs present an important health risk, which can be avoided by simply reducing sitting time. Pronk et al. proposed a solution that takes advantage of a sit-stand device at work. The sitting times were reduced by up to 224%, which also reduced upper back and neck pain, and had great effect on mood states. However, due to space and financial constraints, such a device is not always obtainable.

As presented later in the text, during the interviewing phase of this research, the interviewed physical medicine and rehabilitation specialist put a lot of importance on overall physical activity and preventive exercise. There is a number of exercise programs on how to exercise in an office or at home available that are similar to what the interviewee presented [50] [23]. Research from Andersen et al. [4] claims that the importance of exercising in an office is significant, and that both resistance training and all-round physical exercise can give positive results. A similar conclusion is available in a study by Nikander et al. [47] where it is presented that a specific dose of neck, shoulder and upper-extremity exercises can reduce the neck pain related to office work. The effectiveness of exercising at a workplace is examined by Sjörgen [63], where the authors conclude that even 5 minutes of training per day, can reduce the prevalence of headache, neck, shoulder and lower-back pain. Furthermore, the conclusion is that physical exercise intervention can be very helpful in preventing impairment, and in maintaining work ability. Since preventive exercise has been well documented in the mentioned studies, and since the interviewees from the research related to this thesis emphasized the importance of preventive exercising, the topic chosen for further investigation in this thesis is pain prevention through exercise. The main emphasis is on prevention, which is proven to be a crucial factor in not only avoiding the occurrence of different diseases, but also thereby avoiding expensive treatments or rehabilitation processes. Based on interviews by experts that are later presented, fulfilling the conditions needed for successful prevention of MSDs, and all of the problems mentioned before could be solved. Moreover, the interviewed expert from the field of physical medicine and rehabilitation argues that costs related to treatments are significantly higher than costs of prevention.

In this work, the main idea is to take advantage of the fact that office workers in recent years mostly work on computers. Due to the fact that computers nowadays have become a very efficient and sophisticated technology, there is the possibility to adapt them for other purposes. Therefore, it is possible to create a computer supported system that would incorporate an exercise program for office workers for the purpose of physical pain prevention caused by computer work. By using motion tracking technologies, performed exercises can be traced and feedback can be provided to user.

1.3 Challenges

Two key challenges in designing a pain prevention system are motivating the individuals to exercise, and tracking movements in order to detect the correctness of the performed exercise. Berger et al. [9] show in their research that individuals drop out of exercise programs in 50% cases, despite the evidence that exercise affects the physical and mental state of humans. The challenge of motivating users is addressed throughout this thesis. Later in the text, the interviews with physiotherapist are presented, where they emphasize the importance of correctness of performed exercises. This presents a major technical challenge when designing a prevention oriented exercise system. The idea of having a motion-sensing device that could track movements of a person has been well received with physiotherapists, as well as the other medical workers with whom the interviews were conducted. Therefore, for this purpose, use of the low-cost motion-sensing device Microsoft Kinect is suggested in this thesis. The device and its features are described in detail in chapter 4.

1.4 Methodological approach

Aims of this thesis are finding best possible solutions for mentioned challenges. The technical part of the work is oriented mostly around finding suitable implementation solutions for the Kinect sensor. The process of finding solutions for technical part were time consuming, however due to the fact that the result of this research should be a system that is used by office workers in daily life, it was important to design the system according to users' needs. This is where user centered design (UCD) is very useful.

User centered design (UCD) [2] is a design process where users' opinions, suggestions, or limitations are taken in consideration from the beginning and during the whole design cycle. Following this approach, unintuitive design is prevented and user receives the power to influence how the end product will look like. Participatory design is the North American term for a practically identical concept [45]. There are different possibilities of how to include the user, but as Abras et al. claims, it is only important that users are involved in one way or another. For example, users can be involved at specific times or as partners with designers. The term itself originates from the book entitled: *User-Centered System Design: New Perspectives on Human-Computer Interaction* , written by Norman and Draper [48].

One has to note that there are more possibilities on how to interpret the term user. Broad understanding of the term would be users who will use the end product in order to accomplish a task. However, there are also other users affected by the design. Eason [20] defines three types of users. Namely, they are primary, secondary, and tertiary users. Primary users are the mentioned group of individuals that will directly use the end product, in this case the office workers. Secondary users are the individuals who use the end product occasionally, in this case they would be home users or people who work in offices for only limited amounts of time. And lastly, tertiary users are the individuals who will be affected by the use of the product and/or make the decisions of whether the product is worth purchasing. The tertiary users in this thesis can be defined as medical worker from the field of physical rehabilitation or a physiotherapist, since the proposed system reduces their work through prevention of MSDs. Furthermore, the employers could also be described as the tertiary users, since they would regulate the purchase of the system in companies.

Methods used to involve users were semi-structured interviews, and observation of behavior and interaction with the system. In addition to that, formative evaluation [11] of the system was conducted at each stage of the design process in order to follow the user-centered design approach. The users were constantly involved in testing procedures, where inconsistencies in motion detection or user interface problems were detected. The evaluation, however, was also conducted with experts from a medical standpoint. Furthermore, a short in-situation deployment was conducted.

The design process of the proposed system gave a strong confirmation that involving users in the process can provide efficient solutions to design-related problems in a short period of time. However, the key finding of this thesis is that by using Kinect as a motion recognition tool and providing visual feedback on screen, it is possible to create an MSD prevention system for office use. This thesis should help put more emphasis on the prevention of MSDs related to computer work. Since this topic has been less documented than home rehabilitation of patients, this research presents a building stone for further research in prevention of MSDs by taking advantage of low-cost motion sensing devices. The effectiveness of the system has not been fully confirmed due to the lack of resources and time. How much the system could contribute to prevention of MSD-related problems can only be determined by an evaluation over a longer period of time. However, according to physiotherapists and physical medicine specialists that were interviewed, the proposed solution, with minor improvements, could be a major step forward in prevention of mentioned disorders.

1.5 Organization

The remaining chapters of this thesis are organized as follows: a literature review of the related works is presented in the chapter 2. In chapter 3, the user-centered design is further explained. In this chapter details about interviews with users and experts are presented. Chapter 4 explains the system design and gives an in-depth description of Microsoft Kinect and software components of the system. Chapter 5 gives an overview on the technical details of implementation. In chapter 6, the formative and in-situation evaluation of the system is presented. Chapter 7 describes the future work that can be conducted based on this thesis, and chapter 8 gives a summary of the designing process and conclusions about the system.

CHAPTER 2

Related work

The topic of computer-based rehabilitation and exercising systems has been well documented in several researches in recent years. This is due to the fact that different aspects of rehabilitation process can be improved through *Virtual Reality (VR)* and computer support. There are many possible categorizations depending on devices and technologies that these systems use. Based on the types of technologies used for motion recognition, it is possible to categorize these systems into *marker* and *non-marker* based solutions. Marker based systems assume a use of markers placed on the user's body, while non-marker based solutions use different cameras in the motion recognition procedure. Furthermore, there are also systems that use inertial sensors and actuators. Others use several sensing devices and sensors in order to capture different aspects necessary for correct rehabilitation. Another classification of these systems is the distinction between systems that incorporate games as a motivation tool, and systems that do not include the gaming aspect. The games that initiate physical activity are referred to in literature as *exergames*.

However, for this thesis the most important differentiation is between systems that use Kinect as a motion-tracking tool, and systems that rely on other technologies. The reason for the presence of much research that uses Kinect sensors and underlying technologies is its low-cost nature and high accuracy in motion detection. The advantages of Kinect are presented in detail in section 4.1.

2.1 Non-Kinect based systems

Rado et al. [58] proposed a marker based rehabilitation system. Authors address specific needs of an *Anterior Cruciate Ligament (ACL)* tear, which is a common ligament injury. Aims of physical therapy in this type of injury are to strengthen the following muscles: quadriceps, hamstrings, and calves. For testing purposes only one exercise is chosen, namely *"squats"*. In order to check the correctness of the movement it is necessary to verify that both knees are bent in the correct angle and that they do not pass far to the side of the toes.

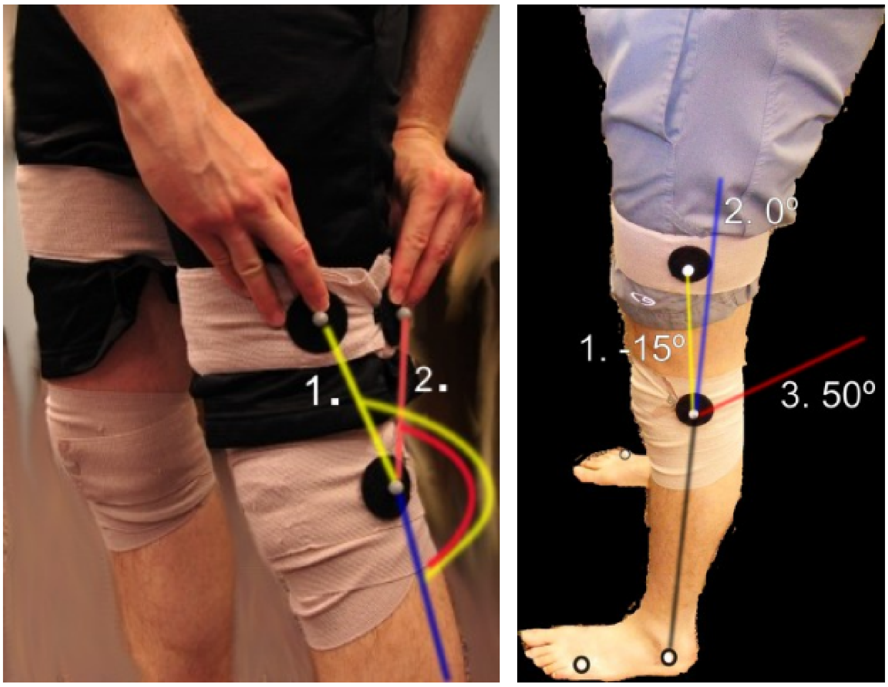


Figure 2.1: Placement of the markers for knee motion tracking proposed by Rado et al. [58]

The main design goals of this research are: demonstrating the correct motion, providing feedback on correctness of the motion, allowing small deviations in marker placement, and supporting the motion recognition in different distances from screen. The main disadvantage of the system is the need for markers that are placed on the outer side of the leg, above and below knee, as can be seen in Figure 2.1. The visualization consists of displaying the markers as ellipses that are connected by lines which should represent user's legs. When an incorrect movement of the knee is detected, the size of the ellipse representing the knee is increased and its color is changed from yellow to red. In addition to that, a red arrow is drawn next to the knee pointing in the direction in which one should move the knee to perform the movement correctly. Figure 2.2 represents a screenshot of the graphical user interface of the application.

Shchonauer et al. [62] presented a game-based rehabilitation system consisting of *full body Motion Capture System (MoCap)* and several other bio-signal acquisition devices. The system uses iotracker [36], a marker based infrared optical motion tracking system. Additional devices used are two bio-signal acquisition devices that have several different sensors which include *Electroencephalography (EEG), Electrocardiogram (ECG), Electromyography (EMG), Galvanic Skin Response (GSR)* and others. However the system primarily uses the EMG, while other sensors could also easily be activated. The data collected through iotracker and EMG is transformed, extracted and analyzed. This data is then sent as input to the proposed serious game. Since the system is aimed at assisting the rehabilitation of patients with chronic pain in the lower back and neck, three separate games are implemented. All games provide the user with visual and textual feedback on his/her performance. The system can be viewed in Figure

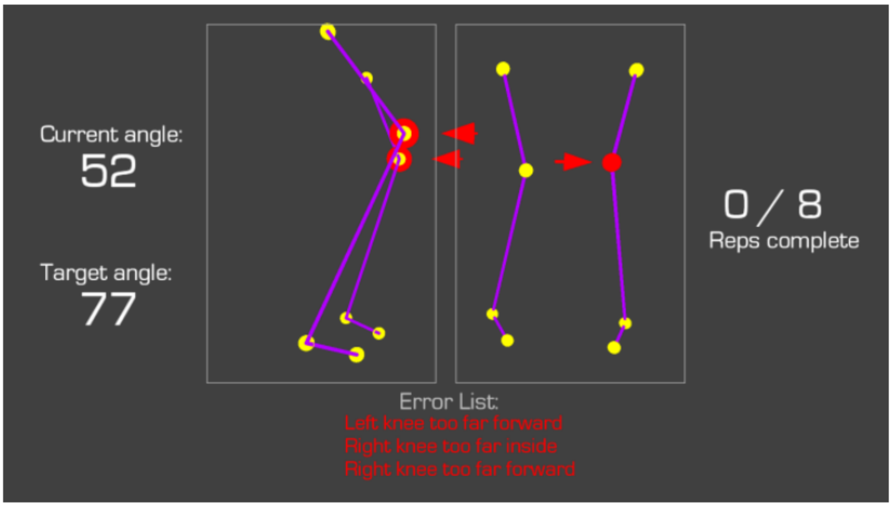


Figure 2.2: Visual feedback for knee motion tracking proposed by Rado et al. [58]

2.3.

Another game-based rehabilitation system that does not rely on Kinect sensor is presented by Geurts et al. [30]. Authors present four mini-games designed for people with motor disabilities. The key finding from this research is that the game parameters have to be adaptable to user's needs. More precisely the game has to be adjustable to player's skills and rehabilitation goals. Therefore Geurts et al. emphasize the importance of calibration when designing a similar system.

2.2 Kinect-based systems

Gama et al. [29] propose a virtual reality based system for motor rehabilitation and discuss the importance of *Natural Interaction* in this kind of systems. They argue that during the treatment the user should should not think about how the interaction works, but rather the interface should interpret user's intention. This makes it possible for user to focus more on the task. The main goal of the research is to use natural interface and improve the exercise execution by the patient, by providing movement guidance and correction according to instructions from physiotherapists.

Integral part of this system is a Kinect sensor, which is used for motion tracking tasks. A user receives visual feedback on the correctness of the executed movement. For testing purposes, shoulder and elbow movements are tracked. Visual feedback consists of messages on whether the movement is performed correctly. However, since visual feedback offered by this type of systems improves the efficiency of the exercising, showing a target which arm should reach to complete the movement provides additional feedback. The process is presented in Figure 2.4, and Figure 2.5 shows the additional movement status bar that loads gradually correspondingly to the completion status of the exercise.

The conclusion of the authors was that the implemented prototype provides more efficiency

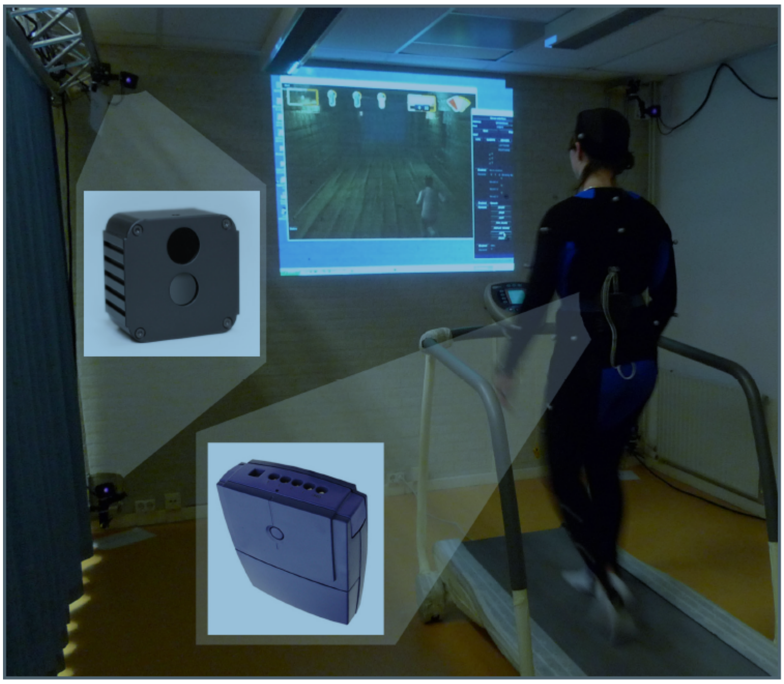


Figure 2.3: Full body motion rehabilitation system presented by Schonauer et al. [62], with magnification of iotracker device (top left) and a biosignal acquisition device (bottom right).

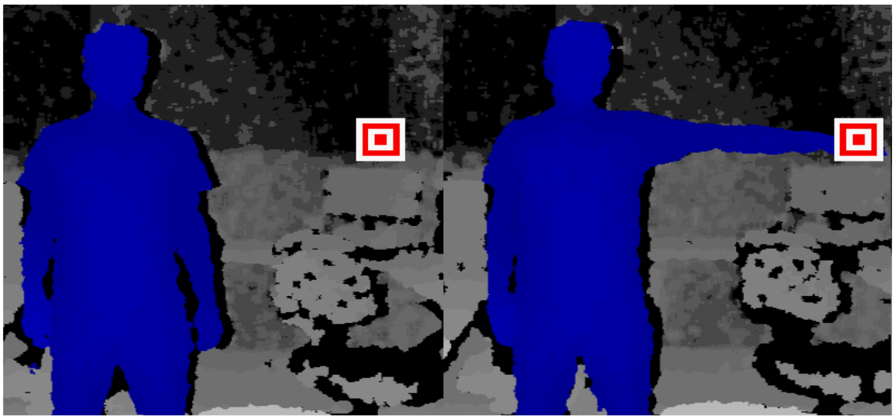


Figure 2.4: Target approach of system presented by Gama et al [29].

when checking the correctness of therapeutic exercises. Furthermore, visual feedback supplied by the system promotes better execution of the exercises. Based on positive reviews from users Gama et al. conclude that the future work will be to create a complete augmented reality rehabilitation tool.

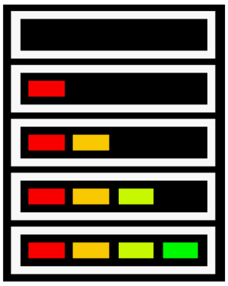


Figure 2.5: Status feedback of system presented by Gama et al [29].

Maurer et al. [41] propose a system that is to be used after the total knee replacement surgery. Since an extensive rehabilitation program is needed, common problems as communication problems between therapist and patient, and lack of motivation, stand out more than usual. A serious exergame with the focus on configuration and personalization as key challenges is presented in the research. Incorrect execution of knee exercises in this case is particularly dangerous. Therefore a number of parameters has to be determined by therapist during an early therapy session. The tracking tasks are performed by Kinect and stored in the system. These values can easily be adapted later as the patient's condition improves. The game itself is a prototype that consists only of simple visual feedback. If an exercise is performed incorrectly the feedback is correspondingly shown. Authors introduced a flashing indicator bar which is activated on overdoing an exercise, while telling the patient what exactly was done wrong. Beside the visual feedback, USB stick is used to store statistical data and exercise validity. USB is then provided to the physical therapist who based on this data modifies further rehabilitation process. Interdisciplinary process between developers, physical therapists and researchers is emphasized as an important approach in case of designing of such system. This is closely related to what is presented in this thesis, since researchers also included physical therapists in several stages of designing process and incorporated their opinions and suggestions.

Abdur Rahman et al. [1] propose an interactive multimedia environment that should complement the role of the therapist in rehabilitation of disabled children. Motion detection is provided by Kinect while the visualization interface used is an online virtual world *Second Life* [1]. A trainee can download or view a set of exercises presented by an avatar, whereas the exercises are recorded beforehand by physiotherapists. The movements of a child are traced and compared to those of a therapist. The authors also provide statistical analysis of the data recorded to display user's improvement. For testing purposes the authors also implemented a module that measures the mobility of the forearm. Figure 2.6 gives an overview of the system.

A system aimed at rehabilitation of post stroke patients is presented by Sadihov et al. [60]. In addition to the Kinect device, which is used for motion recognition, the system incorporates a haptic glove. The structure is created so that it is possible to design and develop different kinds of games and use rehabilitation setup for motion recognition. For use of haptic glove an

[1] http://secondlife.com/

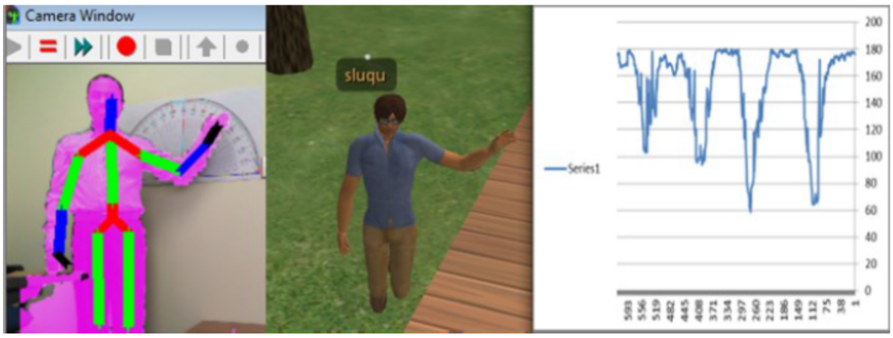


Figure 2.6: Second Life virtual environment (center) being mapped to physical environment (lef) with the graph of the angle at the elbow produced by moving the arm (right) [1].

interactive haptic rendering algorithm, which provides the patient with motion dependent haptic feedback is implemented. Authors implemented following simple games to test the concept: Wiping table game, Rope game, and Meteor game. For example in the Rope game, the users can train grasping reactions and grasping strength under different feedback conditions. The system received positive feedback from both the patients and the therapists.

System proposed by Pastor et al. [53] also focuses on rehabilitation of upper limbs in rehabilitation of stroke survivors. A patient has to sit in front of the table where a Kinect device is mounted pointing downward at the table surface. Due to the lack of strength in patients, they are often unable to hold their arms for excessive amounts of time in the required position. If they wanted to rest the arm on the surface of the table this might lead to wrong motion tracking by Kinect. To overcome this problem an arm support was placed parallel to and 15 cm above the table. The game itself is developed according to instructions of a team of physiotherapists. The main goal of the system is improving the movement in the impaired upper extremities.

The exercising procedure is conducted in the following way: a patient first calibrates the system by moving the hand to the left, right, away from and towards the body as much as possible. The game itself consists of controlling a cursor by hand movements and selecting the images that randomly appear on the screen. The whole screen is divided in a 6x6 grid, whereas the area of play is first 2x2 and then gradually increased. An image appears in the boundaries of this area of play and a patient has to navigate the cursor to the image. The area of play increases in each round and the positions of the area are carefully selected to provide equal amount of exercise for every movement and hand position. Rounds 5 and 7 are played in the areas where a patient had the lowest score, because it is assumed that the lowest scores correspond to the areas that require the most effort from a patient. Rounds 6 and 8 are also played in opposite areas of the screen to enable resting.

The system presents a solution that could be used for home rehabilitation of stroke survivors. High emphasis is given on personalizing the gameplay to the current patient by adapting to the range of motion of a patient. The system has been very highly accepted by the patient who tested the system. The patient was engaged with the game and graded the study as very enjoyable. Further work is still however needed in order to determine the reason for higher score, since authors do not know whether the system improved patients health or not, because no detailed evaluation of the system was conducted.

An exergame called JeWheels is a rehabilitation tool aimed at providing more physical activity to people in wheelchairs [18]. There are three key parts of the game that enable a successful gameplay. Pose recognition system consisting of partial body posture recognition is the first part. Since the game's targeted audience are people in wheelchairs, the body motion is limited to seated position. By using Kinect's skeletal tracking system, the system recognizes 16 joints of human body, which enables recognition of arm movements that are very important for the game. In the second part of game design, a set of configuration options is designed. This gives user the freedom to alter the gaming conditions. The configurable aspect of the game includes such options as changing camera angle in order to get a more complete view of a player, forcing the use of one arm, and choosing a different game mode, where a user can choose whether only one or both arms are used throughout the game. That way the game is easy to play in different conditions and by patients with different medical conditions.

The third and the most relevant part for the user consists of gameplay and interaction. Game objective is collecting coins that are randomly shown on screen. Difficulty is adjusted by specifying the number of coins to be collected and the collecting speed. The sooner the player collects the coins, the more points are awarded. The game supports only single player mode, due to the restrictions of Kinect's motion tracking algorithm for more than one user in the field of view. Figure 2.7 shows a screenshot of the gameplay.

2.3 Motivation

Since motivation to exercise presents one of the key challenges when designing computer-supported exercise systems, a short literature review on this topic was conducted. Kilpatrick et al. [37] compare motivation for sports activities with motivation for exercising among college students. Authors first identify that a cause of significant health problem in college population is lack of physical activity. One of the main findings is that people seem to be interested in participating in sports, without expectations on any outcomes. On the other hand, in exercising the motivation is centered mostly on desired outcomes. Authors argue that health promotion designed for increase of exercise behavior, might in fact demotivate people by creating social pressure. Therefore, key conclusion of the research is that motives for sport participation are more desirable than the ones for exercise.

Some of the abovementioned rehabilitation systems incorporate small games that guide a user during exercises. These games are often referred to as exergames. One of the underlying goals of such games is to help motivate people to do the exercise. Combining fun of video games with physical activity in order to motivate people is the main premise. Yim et al. [71] analyzed what makes an exergame successful, and thereby produced several requirements for successful exergames. Authors address the problems of poor exercise self-identity and low self-efficiancy by providing strong guidance, access to a group of peers, and a supportive environment. The

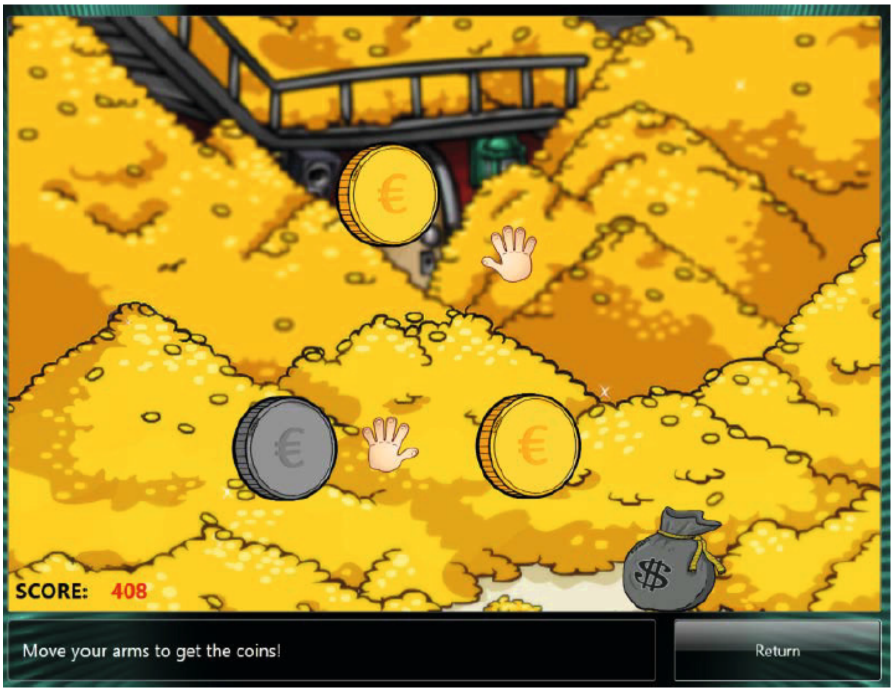


Figure 2.7: Gameplay of the JeWheels game presented in [18].

research presents a new exercise game which is used to illustrate how the requirements can be fulfilled. Inclusion of other physiological sensors can add additional features to the game, that can further increase the motivation, as presented by Fitzgerald et al. [22]. Additional motivation in exergames can be a rewarding system. Berkovsky et al. [10] propose a game that uses virtual rewards as a motivation tool. An evaluation of the impact of exergames on physical activity is presented by Macvean and Robertson [39]. Authors recommend longitudinal evaluations through which it can be ensured that the exercise intensity is appropriate and sustained.

Goal-setting is also as an effective strategy for changing behavior, as presented by Consolvo et al. [15]. Therefore, incorporating goal-setting tasks can help motivate people to change their behavior.

Virtual characters have been used in recent years to socially enrich the interaction with computer. Such characters have been proven to be beneficial for learning since they straighten the social dimension of computers. This has been proven in an research by Gulz [32]. In another article by Gulz [31], the author argues that if the goal of virtual characters is to motivate, engage and adequately impact users, visual appearance has to be carefully chosen. Ruttkay et al. [59] implemented a virtual trainer that presents specific exercises to the user and gives feedback on correctness of movements. They confirm that such approach can initiate more motivation and provide a fun interaction tool for users. Furthermore, these characters have to be designed so that they seemingly express emotion in order to relate to users better [49] [46].

2.4 Research gap

All the systems mentioned in the previous two sections are designed to represent a rehabilitation tool for people who are in need of it. Most of the research is concentrated on finding a way to provide a home rehabilitation system, as presented for example by Saini et al. [61], which is designed to support patients in the rehabilitation process while they are at home. The reason for that is the fact that physical therapists have limited time available to offer to each patient. The procedure of physical rehabilitation usually works in a following way: a physical medicine and rehabilitation specialist prescribes the physical therapy. Next step is then visiting the medical center where physiotherapists present the exercises and teach patients how to perform the exercises at home. Therefore, it is up to a patient to continue the therapy at home. The most systems proposed in recent years are aimed at helping a patient with this process. They usually provide correctional support and give visual feedback.

Following a literature review, and based on interviews with experts presented later, a research gap was identified. As explained in previous paragraph, most of the proposed systems available are aimed at assisting patients in rehabilitation process. Furthermore, as mentioned in the introductory chapter, the absence from work related to musculoskeletal disorders is well documented in several researches. Therefore the decision was made to design a system that represents a prevention tool that should help prevent computer work related Musculoskeletal Disorders (MSD)s. Since prevention is a key factor in medicine in general, the tool would represent a measure that is taken beforehand in order to avoid possible pain caused by MSDs. As shown in previous sections, Kinect motion sensing device has been graded as very powerful in detection of movements. In addition to that it is a low-cost device that is ideal for creation of prototype systems.

All these findings are combined and a new system has been proposed. Furthermore, related work shows that involving users and physiotherapists is of great importance for such design process. Based on this, the user-centered design approach has been chosen as an additional focus of this thesis.

CHAPTER 3

UCD

The research model for finding the exact focus of the thesis is presented in the 3.1. As can be seen, there are three main questions: *"What?"*, *"How?"* and *"With what?"* for which the answer should be found throughout the design process. First step is answering the main question *"What is the solution for the problem?"*. This initial phase is examined through interviews with experts, where ideas and opinions about possible solutions to the problem of computer work related musculoskeletal disorders are collected. Next step is finding out what users would find acceptable as a solution, or in other words answering the question *"How the solution to the problem should look like?"*. However, due to possible limitations of resources and device capabilities, a framing has to be set in sense of *technical possibilities*. Therefore technical possibilities have significant effect on what solution should be, and how it should be achieved. Main focus of the project is determined through interaction of all these aspects .

As mentioned in the introductory chapter, user centered design approach was followed during the entire design process. In order to keep users involved, and to follow the presented research model, a number of interviews with possible end users and physical medicine specialists and physiotherapists, was conducted. First informal talk with a physical medicine specialist can be categorized as an unstructured interview, where no predetermined questions were defined. All other interviews conducted can be defined as semi-structured [16] which means that the questions were partially pre-planned. One key advantage of such interviews is that standardization of at least some questions can increase the reliability of the data. Another advantage over informal and structured interviews is that the ability to ask spontaneous questions helps adapt how the participants want to express themselves. However, semi-structures are prone to being more time consuming, the spontaneous questions can be hard to quantify, they are not generalizable, and are very prone to possible bias [70]. Semi-structured interviews were chosen in order to follow the User centered design (UCD) approach, but also have some sufficiently focused research questions so that relatively similar answers would be provided by the participants [19]. Researcher's interview guide that was used as a reference in non-expert interviews can be viewed in Appendix A. An interview guide for interviews with experts was altered for each interview, since different aspects were discussed with different experts. However, for each

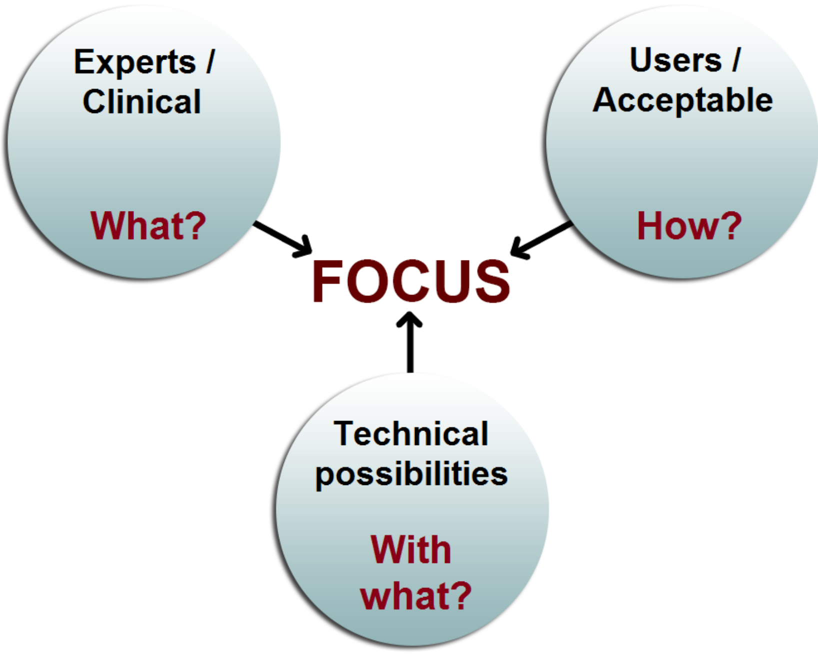


Figure 3.1: Research model.

expert interview an informal set of questions was used, if any guidance for the participant was needed.

Potential end-users, as well as persons that can give insights in the topic from expert's point of view, were identified as possible participants in interviews. The sample size was determined to be 3-4 non-experts and experts respectively. Interviewees are different acquaintances of the researcher, however many of them were later recruited through participants that were involved in the first interviews. A review by ethical research committee was not necessary due to the fact that collected data did not leave the ethical standards that do not require a review.

Users were involved in the designing process from the beginning, however there were two main phases of interviews. In the first iteration of the interviews 2 experts from the field of physical medicine and rehabilitation and occupational medicine respectively were interviewed. Furthermore, a group talk with physical medicine specialist and 2 physiotherapists was held at a medical center in Lukavac, Bosnia and Herzegovina. In the second phase of interviewing process 4 office workers were interviewed, and a group talk with physiotherapists from the first phase were conducted. All the interviews were audio recorded, except for the initial talk with a physical medicine specialist and one of the interviews with users, which was caused by a failure on the recording device. Several interviews that were chosen as the most relevant ones were also transcribed in their entirety. This is the case with two interviews with potential users, and the both iterations of interviews with physiotherapists. Written notes were used throughout each of these interviews, whereas they were a significant part of interviews with specialists, and less significant in the interviews with non-expert users. Most of the interviews for which the transcription was not performed were summarized and interpreted by listening to the audio recordings and following the notes taken during the interview. In addition to these interviews, informal talks took place every time the system was tested or presented to potential end users. During these sessions written notes were used as a data collection tool. It is also important to note that talks with experts were held in Bosnian language, while the interviews with non-expert potential end-users were held in English. Summary tables of all the interviews can be seen in Appendix B.

It is important to note that each of these interviews presented in this chapter represents a formative evaluation tool. The applied formative evaluation is later described in chapter 6.

3.1 First iteration of interviews

Interviews with medicine specialists

In the first phase of interviewing process, an informal talk with a physical medicine and rehabilitation specialist was conducted. The specialist in question is 53 years old and has a high level expertise in the field of physical medicine and rehabilitation grounded on almost three decades of medical practice. He works in the mentioned medical center in Lukavac, Bosnia and Herzegovina where all the experts involved in these interviews were recruited with his help.

An introduction to musculoskeletal disorders and its causes was provided by the specialist. The relation of MSDs with mental state of a person was mentioned as an important factor. A person's intellect can thereby be damaged, which causes limited overall functioning. Furthermore, expert clarifies that treatment for any disorder is a significantly more expensive procedure than prevention. Importance of exercising was presented as a key aspect in physical medicine in general. By exercising endorphins are secreted and physical and mental pleasure is induced. In addition to that, muscle tone is reduced, mobility of joints is increased and automatically better physical condition is achieved, and thereby also better mental condition.

The initial idea for the presented system in this thesis came from this informal talk. Due to the aforementioned lower costs of prevention compared to rehabilitation, a suggestion by the specialist was to create a MSDs prevention tool. He suggested a system which would control the operating system on the computer, where after a couple of hours of continuous work on the computer the worker is notified and any further work would require him to perform a set of exercises. Otherwise the system would block the computer and disable further work. This was presented as a great solution for adolescents who spend a significant amount of time in front of computers because of video games and other types of entertainment. He emphasized the importance of physical activity of children in puberty or before, due to intensive development of bones and muscles in this period. The specialist addressed the issue of excessive sitting in front of the computer as one of the leading causes for pain and therefore rehabilitation in practice. In addition to that, he claimed that this kind of a solution would be very useful for employers to keep track if their employees are exercising or not, which would help employers reduce losses related to absence from work. Furthermore, he expressed great interest in a system that would be the product of this research and therefore he arranged all the other interviews with physiotherapists and the interview with occupational medicine specialist.

Following this informal talk, an interview with an occupational medicine specialist was conducted. He is 49 years old and has been in the field of occupational medicine for over 20 years. The interviewee is a very physically active person that plays several recreational sports. He works at the same facility as the previously mentioned specialist, and was recruited by the expert from the first interview.

The expert was not informed on what the proposed system is, but rather it was more important to get objective opinions on ergonomics at workplace and information about possibilities of exercising at work. During the talk a number of rules regarding ergonomics was introduced and presented by the expert. Different criteria regarding ergonomics at office workplace were explained in detail. In addition to this talk a presentation from *Arbeitsmedizinischedienst der TU Wien (AMD)* was made available where ergonomic rules that apply in Vienna, Austria are also presented [3]. Types of chairs suggested for working with video displays should be appropriate height of 40-51 cm with the possibility to adjust it. The elbow and knee angles have to be 90, and enough space for legs has to be provided. The AMD suggests changing positions more times during a day, and possibly also periodically working in a standing position. The distance from keyboard, mouse and the screen is also strictly defined and can be viewed in the Figure 3.2 and 3.3. Other conditions mentioned by the occupational medicine specialist are lighting conditions, and that the keyboard and mouse have to be ergonomically designed. The AMD also defines a maximum of continuous computer work time being 50 minutes. After this period one has to make a short break and rest. Another for this thesis important aspect presented by the AMD is the positioning of the computers in joint offices. The correctness of positioning is shown in Figure 3.4. One of the questions posed for the expert was:

> *"Could exercising at workplace decrease or prevent the musculoskeletal symptoms?"*

The expert explained:

> *"Yes, but the exercise program would have to be created in compliance with physiotherapists or other experts, because the correctness of execution of exercises is a crucial aspect."*

The closing remark of the specialist was:

> *"The regulations regarding ergonomics at workplace are defined by law, and must be obeyed. If they are not, the employer or the parent company would have to be prosecuted. However, in practice it is also possible that there simply are not enough resources, and the office cannot satisfy the occupational medicine regulations, and the regulations are ignored in some amount."*

The conclusion from this interview was that aspects of ergonomics of workplace should not be taken into consideration when designing an exercising system for prevention, since offices should by law be ergonomically acceptable. However, an important factor for the system later turned out to be the amount of space available behind the worker.

Interview with physiotherapists

The last interview in the first phase of the interviewing process was a short group talk with two physiotherapists. First therapist is male, in his mid 30s and has a lot of experience in physical therapy, since he has been working in the same facility as two previously interviewed specialists in over 10 years. The other therapist is female, in her late 20s, and less experience in the field, however with a university degree in physical therapy. The two of them work in the same department with the physical medicine specialist, and were recruited also by him.

The suggested prevention system was presented and received as a good possible solution in general. The question from one of the physiotherapists was:

> *"How could the movements be tracked and how could we check if an exercise is performed correctly?"*

The physiotherapists were then informed that the project is in early stages and that the solution to this problem is not available. They were instructed to create an exercise program that one could perform in the sedentary position, and that would be suitable for pain prevention related to computer work. The limitations of Kinect were in this iteration not taken into consideration. The following program was created:

- Head tilt to left and right side
- Head tilt with addition of elevation of opposite shoulder
- Elevation and depression of shoulders
- Butterfly exercise with arms straight
- Butterfly exercise with arms slightly bent
- Asymmetrical butterfly
- Carpal tunnel syndrome prevention exercise
- Head rolls

The exercise program created was taken as a reference until the implementation phase started when a new exercise program was created in order to comply with Kinect limitations. The number of repetitions was set at 3-5 repetitions for the beginning, and the time needed for completion of the whole program was set to 5-10 minutes. The physiotherapists suggested that this amount of exercises, if repeated 2-3 times a day, could be enough for prevention of different pains related to MSDs.

3.2 Second iteration of interviews

In second phase of interviewing process, the interviews with 4 potential primary end users and a repeated interview with the two physiotherapists from the first phase of interviews, were conducted. The prevention system was already shaped throughout the process of interviews with experts in the first iteration of interviews, therefore the basic idea of what the system could look like was already existent. The interviews with 4 end users were conducted in order to answer the mentioned *"How?"* question.

Interviews with primary users

Two interviewees were told upfront what the system design might look like. The interviewees were asked more about their work habits, ergonomics at workplace, normal workday, pain that he/she might be experiencing, exercising habits, sitting time, and other for system more specific question. The following explanation was provided in the consent form:

> *"You are being asked to take part in a research study of how the Kinect-based exercising system for office or home use should be designed... The main goal of this project is to design a system, which should help overcome different back, neck, shoulder, arm, elbow and hand pains that are caused by excessive work time on the computer in an office..."*

The consent form can be viewed in its entirety in Appendix A.

Interviewee that gave the most information was a research assistant at the Vienna University of Technology, who is in her mid-40s, and has a shared office with two other colleagues. She has been working at the institute for 8 years and has a very limited amount of space in her workplace. As she explained none of them at the institute have an office for themselves, except for their boss. This limits their movement, because as she said:

> *"...And just have this bodily freedom to position yourself differently. That would be really nice. Putting your feet on the desk, this is something that I would never do with colleagues in my office. But I think this would be something that I would do if I was alone. And maybe have a chair when I am really tired so that I can close my eyes for 5 seconds, and distance myself from the situation for a little bit."*

She explained that working patterns are very different between all the employees. When asked if people there are always sitting at their desks, she explained:

> *"People do walk out to get some food, they might go and buy something, and then they might buy something for the others too. But that we all actually leave the building, that doesn't happen. So it's one or two colleagues a day, here that get out of the house."*

She herself experienced a lot of back pains before taking her sabbatical, and addresses this to the sedentary nature of her job. She does leave out the possibility that the pain was more related to something else, since she had to go through a very intense physical therapy in order to feel better in long term.

Despite being aware of health risks that are caused by extensive sitting, she still has problems, due to the fact that sometimes it is simply necessary to stay late at work or work extra hours. Simple exercises and stretching, in her opinion, would definitely be something that might be helpful.

The most important conclusion from this interview was that the initial idea of having the system block the computer work and report the summary of exercising to the employers would be something that users would not be happy about. She explained

> *"But my guess is it has to be in some level that you don't feel like being patronized now. If you start having this feeling that this system is patronizing you, you would say NNo thanksänd get rid of it."*

This indicated that the initial idea of system being an employer's tool to make the workers exercise would probably have a contrasting effect, where office workers would feel even more pressure. She suggested having simple *"Did you know?"* messages at the end of exercising procedure. She also claims that it should not become too repetitive and that a good solution for the notification would be an avatar or virtual agent. She also added that feedback on exercises should not be in negative form, but rather kept very simple in form of positive messages. Some example messages she mentioned were:

> *"I think I might not be so interested in myself if my neck motion was less good than yesterday. That would not be interesting for me. However this feedback would be nice: "You completed now the whole thing, and now it could be that in the next minutes you feel that blood flows better"."*

Second interviewee, who was told what the system was about upfront, was a computer scientist who works at the same institute as the previous interviewee. He is in his mid 40s and is a part time lecturer also at the Vienna University of Technology. He is very aware of the relation between sedentary jobs and MSDs, and therefore he keeps himself physically active by practicing different martial arts. After a short introduction in the idea for the system, he was skeptical if the Kinect sensor could be used for such purposes, since the number of its limitations is very high. He put the accuracy factor at first place and described how he personally did not think that it would be possible. He added:

> *"I am not sure if it could work exactly like that, but in general, I do like the idea of having an exercising guide."*

When asked how the motivation problem could be solved, he explained:

> *"Well this thing could really check if I am doing the training correctly."*

implying the motivation could simply lie in the fact that the system would help to get to know one's body better.

The last two interviewees were were not informed about the system and its possible use, but rather they were interviewed in order to get even more information about office work and work habits and patterns. The information gained was comparable to what the first two individuals mentioned. Both of them had experienced different pains that could be characterized as MSDs. Until they were told later in the interview what the proposed system idea is, they did not mention anything that might relate to a computer-based pain prevention system. When the system was explained at the end of the interview, the idea was received very positively, but just like the two previous individuals, they were against the idea of having a system that can disrupt the computer work completely. Furthermore, the suggestion of having summaries that an employer could control was identically to the previous interviews viewed as something that would turn the users away from the system. More about these, but also previously mentioned two interviews, can be read in Appendix B.

Repeated interview with physiotherapists

After the interviews with physical medicine and occupational medicine specialists, physiotherapists and 4 potential end users, first version of the system was designed. First implementation details were determined, with main purpose of discovering what obstacles or limitations should be taken into consideration. The actual design and implementation details are presented later in the text, and it is important here that after first tests with Microsoft Kinect the following limitations were discovered:

- The distance from Kinect, in order to track a person of average height, has to be approximately 1.5 meters.
- There is a limited number of joints that can be tracked in seated position. Figure 4.4 shows the comparison of traceable joints of Microsoft Kinect with tracking mode set to standing or seated.
- Joints that are behind the person's torso or belly are untraceable.

These limitations were presented to the physiotherapists, who nevertheless still supported the idea of having such system. One physiotherapist explained that people do not understand the importance of correctness of exercising. Therefore in his opinion, tracking movements and giving feedback would ensure that people do not exercise incorrectly. As he explained, the main goal of physical therapy is usually to teach patients how to perform the exercises. After this is done, patients are in many cases instructed to exercise at home. This is where, in his opinion, the potential of the presented system is great.

The conclusions from the talk with these two experienced physiotherapists were that despite the limitations the suggested system could still be very useful. The exercise program was altered and physiotherapists expressed a great wish to see the outcome of the research.

3.3 Interviews analysis

As mentioned before, the data was collected through audio recording and written notes in all the interviews. Audio recordings were a very important part of the analysis, however written notes were in some cases even more useful since researcher often noted things that cannot be perceived without seeing posture or gesticulations.

The recommendation of many experts is to conduct the data analysis concurrently with data collection [19]. This iterative process of data collection and analysis eventually leads to a point where same topics are discussed and no new themes appear. This is referred to as saturation in literature, and it is a sign that the data collection is complete [38]. Therefore the analysis of each interview was conducted immediately after the interview was finished. Due to time and resource constraints however the process could not be followed until the data is completely saturated, however upon completion of the two interviews with end-users the patterns were already identifiable. Interviews with two potential end-users that were marked as the most relevant ones were fully transcribed. The rest of the interviews were carefully examined and most important parts were transcribed.

Text segments were reviewed and identified in order to find patterns [43]. A common approach is to use codes to mark different sections of the text and then sort the text segments with similar codes into categories, which then represent separate themes [42]. To gain insights in the meaning of this data it is necessary to try to observe the connections and relationships between these categories. Naturally, since there were two basic categories of participants, experts and non-experts, the analysis was separated into two corresponding sub-tasks.

Analysis

The analysis was conducted separately for expert and non-expert interviews. A number of codes representing the relevant text segments of each interview were first determined. Both groups of codes contained more than 50 codes. Coding was done by hand or, in cases of transcribed interviews, by using the Atlas.ti[1] software. These codes were then closely observed and combined into greater categories, which represent the main themes discussed in the interviews. Example raw data and parts of analysis process can be observed in appendix C.

Some of the main topics in each interview were:

- Work routines - time spent in office, sedentary position time, work time, computer work time;
- Workplace - anything that is related to workplace environment, office space, ergonomics, other workplace conditions;
- Satisfaction - satisfaction with workplace, colleagues, pay, produced results;
- Concerns - for health and well-being, eating habits, validity of produced results;
- Physical in/activity - active or inactive, sports, hobbies, walking habits;

[1] http://www.atlasti.com/index.html

- Health improvement strategies - sports, stretching and exercising, leaving the workplace for specific amount of time, taking breaks;
- Motivation - motivation as an important factor in exercising, being active or working in general, motivation tools: virtual agents, fact messages, notifications, achievements;
- Including technology - computer as a rehabilitation or prevention tool, visual feedback, storing capabilities;

The relationships between these topics are very interlaced. Work routines, workplace and satisfaction are the first group of topics that could be identified as introductory. These themes, when combined, give an overview in what situation and how satisfied a person is. Next step is expressing concerns that persons have and its relation to the state of their health. Motivation is emphasized as the biggest challenge, since every interviewee is very aware of the need for more physical activity. And finally the technology inclusion in the process of motivating and being physically more active is given in every interview. This final topics was in each interview initiated by the researcher.

Similar coding and categorization was conducted on interviews with experts, whereas some interviews included topics that were not discussed in other interviews. For example, posture problems are mentioned in each interview, however the explanation on how workplace ergonomics effect these are only mentioned in interviews with specialists. Therefore, the categories produced are very similar to the ones derived from interviews with non-experts. Slightly altered is the "concerns" category, since experts only emphasize health and well-being as their concern. Furthermore, "work routines", "workplace" and "satisfaction" are irrelevant and almost never mentioned topics in an expert interview. The occupational medicine specialist did however also explain the topics as "workplace" and "working routines". An additional topic in these interviews is the "exercising". While this topic is mentioned in non-expert interviews, every expert emphasized the importance of exercise and more importantly the correctness of exercise execution.

3.4 Summary

Following the completion of the interviewing process, the three questions mentioned at the beginning of this chapter were answered. Answers can be seen in figure 3.5. Through interviews with experts a clear set of requirements was determined. MSDs can be prevented in a great amount if corresponding prevention steps are taken. One of the key aspects in this prevention is regular exercising and physical activity in general. However, exercising has to be correctly executed and in compliance with rules and guidelines determined by professionals.

Potential end-users expressed their disagreement with any kind of an computer-based exercising system that is intrusive or patronizing. They further emphasize that the motivation problems have to be taken in consideration and that the system and its approach towards users has to be kept positive.

Technical requirements for design of a prevention system are therefore motion tracking capability and the possibility to give corresponding visual feedback by the device that is to be used.

Due to limited resources in the research an ideal solution for a prototype is a low-cost device. As presented later in the section 4.1, Microsoft Kinect has these capabilities and is a low-cost solution.

Thereby all three research questions were answered and a very narrow focus on what the system should provide was determined.

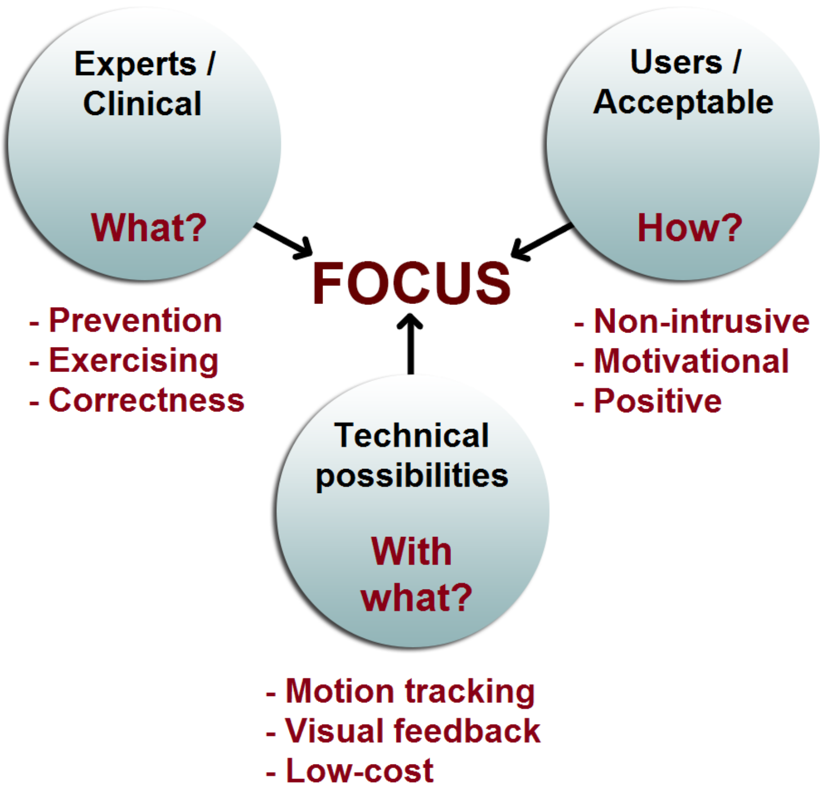


Figure 3.5: Research model upon completion of the interviewing process.

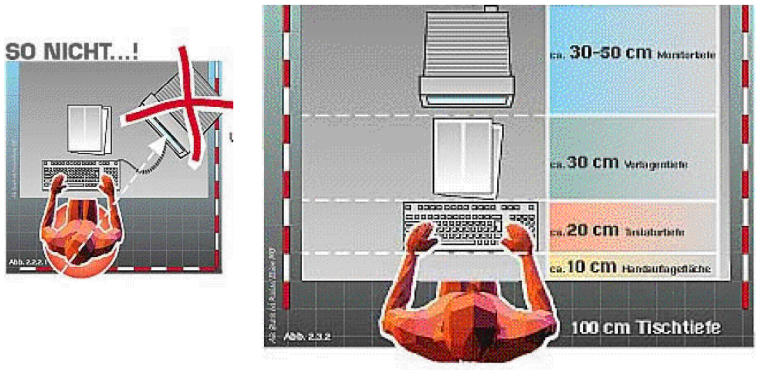


Figure 3.2: Defined distance from keyboard and screen [3].

Figure 3.3: Defined head to screen angle [3].

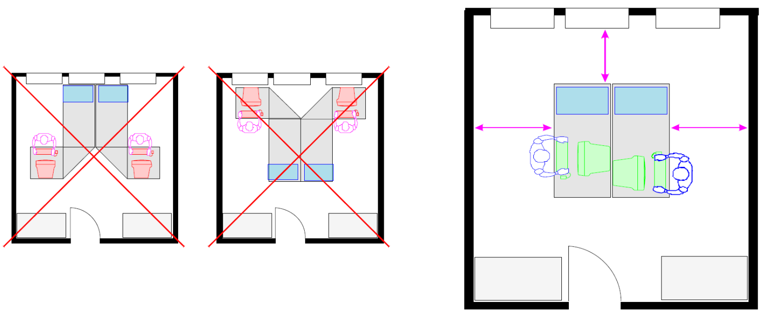


Figure 3.4: Room positioning [3].

CHAPTER 4

Proposed solution

Development of the proposed solution started when the first phase of interviews with physical and occupational medicine specialists was completed. First step was getting familiar with the technologies needed for the implementation of motion tracking. As mentioned in chapter ch:relatedwork of this work, Microsoft Kinect sensor is a device that is used in several researches with similar goal, due to its low cost and accuracy in motion detection tasks. The first sub-chapter is therefore dedicated to explaining the Microsoft Kinect device, while the rest of the chapter is dedicated to explanation of the design process.

4.1 Microsoft Kinect

Microsoft Kinect [24] is a motion sensing device designed primarily for the purpose of enhancing gaming experience. This web-cam style based peripheral device has been originally developed for use with XBOX 360 gaming console, in order to enable gaming without the use of game controllers. However, open drivers for Windows [25] became recently available, enabling the use of the device on personal computers. In addition to that, in 2012 a new version of the device, Kinect for Windows, aimed only for use under Windows OS became available. This version shares many of the capabilities of the XBOX version, and it is additionally optimized for use with computers and devices running Windows 7, Windows 8, Windows 8.1, and Windows Embedded OS.

Hardware specifications

The Kinect sensor incorporates a depth sensor, a color camera and an array of four microphones. These components provide full body motion capture, facial recognition and voice recognitions capabilities. The arrangement of the infrared projector, RGB camera and the *Infrared (IR)* camera can be seen in the Figure 4.1. The depth sensing technology is developed by PrimeSense company [54], and the exact details are disclosed. However, basic principle of work is known to be based on structured light principle. The IR projector is an IR laser that projects a number of

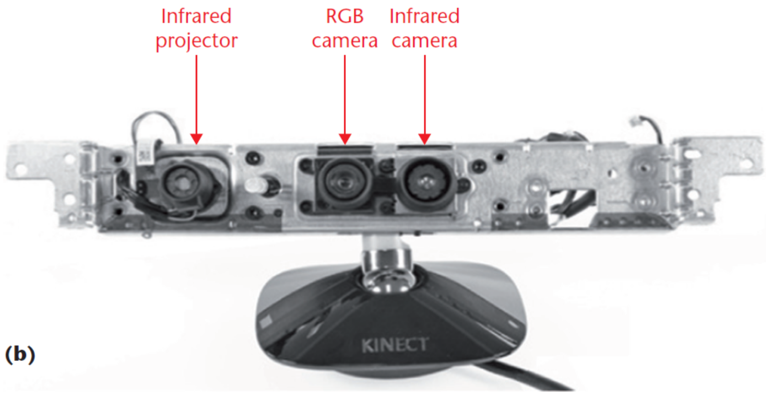


Figure 4.1: Arrangement of IR projector, RGB camera, and IR camera in Kinect [72].

Figure 4.2: Depth image produced by Kinect sensor [72].

IR dots. The IR dots are then captured by the IR camera. If it is possible to match the dot in an image and in the projector patter, the three-dimensional (3D) image can be reconstructed by using the triangulation. The comparison is performed by simply comparing a small neighborhood around the observed point [72].

A depth image (map) is then produced and depth values are encoded as grey values, as can be seen in Figure 4.2. The lower the grey value the closer is the point to camera. Black pixels represent the pixels for which the depth value could not be detected. This is the case if an object is too far away from the camera or if the surface does not reflect IR points.

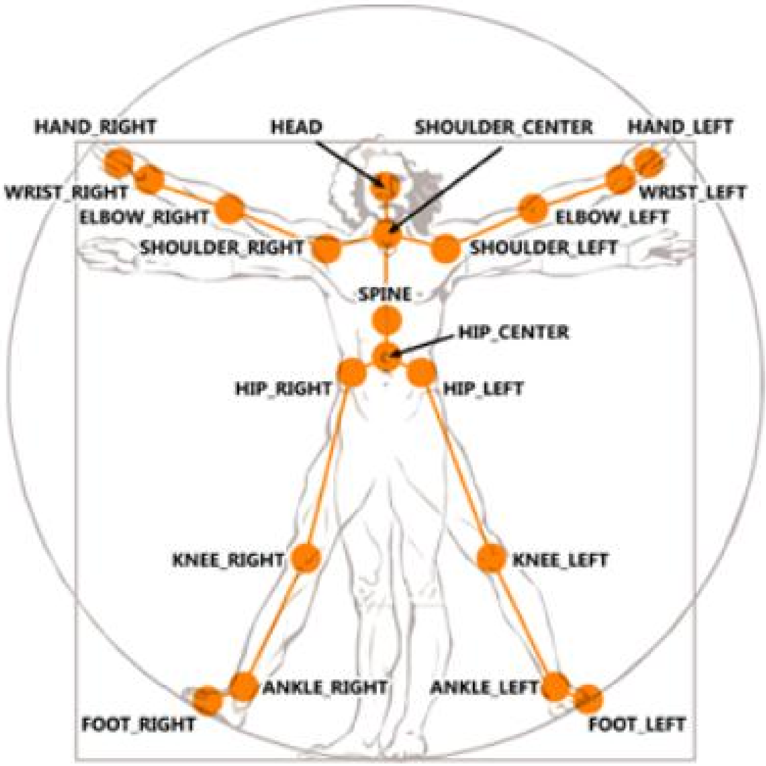


Figure 4.3: Traceable joints by Kinect [26].

Skeletal tracking

The most important feature for this thesis that the Kinect provides is skeletal tracking. Kinect sensor can track up to six people in its field of view, while two people can be tracked in detail. Body parts are represented by a number of joints as can be seen in Figure 4.3. Each body part has a joint assigned to it, which is represented by its 3D coordinates. This enables recognition of movements over time. Skeletal tracking can track positions of joints in standing or sitting position, as can be seen in Figure 4.4 [27]. In standing mode of skeletal tracking a total of 20 joints are tracked, whereas in the seated mode 11 joints are traced. In order for users to be recognized they need to be in front of the sensor, making sure that their head and upper body is in the field of view of Kinect.

An important aspect of Kinect for this thesis is its field of view. There are two range modes: default and near. As seen in the Figure 4.5, in the default range mode Kinect can see people standing 0.8 meters and 4.0 meters from the device. In near range mode, as shown in Figure 4.6, Kinect can detect people standing between 0.4 meters and 3.0 meters.

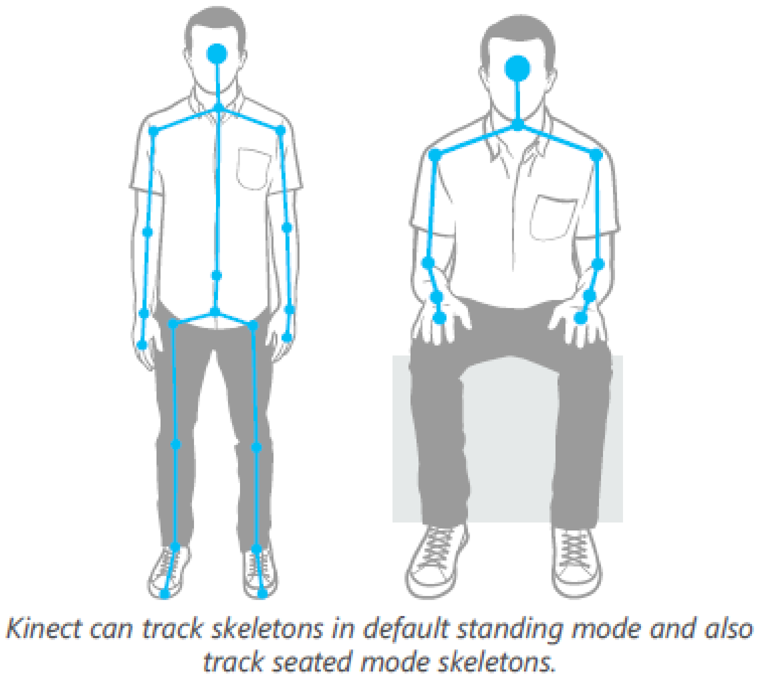


Figure 4.4: Skeletal tracking in standing (left) and seated (right) mode [27].

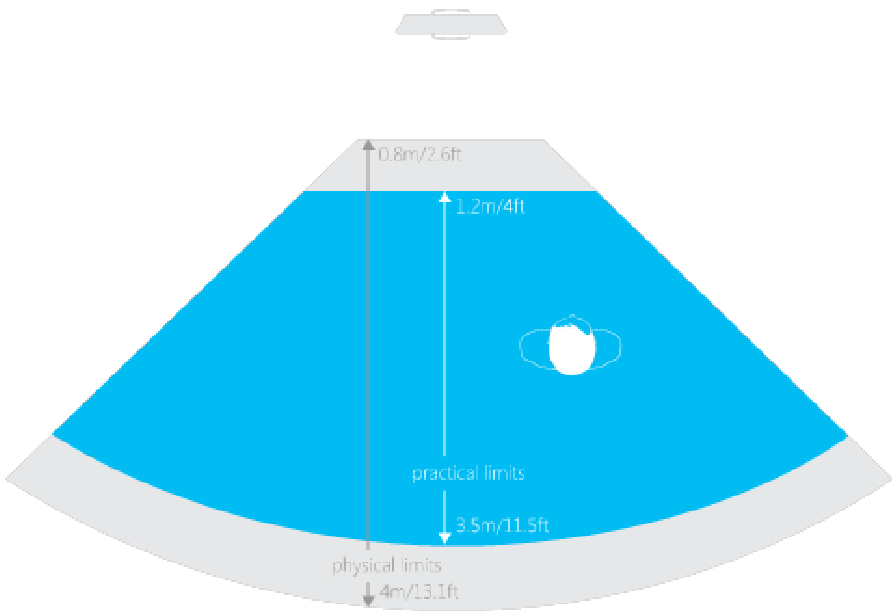


Figure 4.5: Default range mode of Kinect [27].

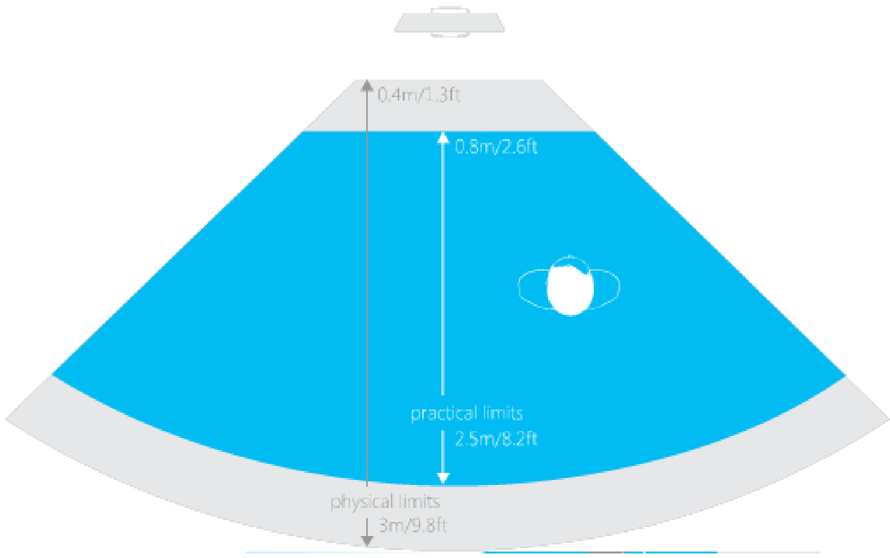


Figure 4.6: Near range mode of Kinect [27].

Available software

Kinect for Windows Software Development Kit (SDK) [25] gives full support for developing Kinect-based applications in C++, C# and Visual Basic. It includes drivers for using the Kinect for Windows sensor on computers running Windows 7, Windows 8 or Windows Embedded OS. In addition to that the SDK provides APIs and tools needed for development for Microsoft Windows. OpenNI Framework [64] provides also a set of open source APIs for Kinect. However, Microsoft recommends using the Kinect for Windows SDK due to better compatibility. Therefore to avoid any hardware related issues Kinect for Windows SDK 1.8 was used for accessing the device.

Advantages of Kinect

There are several advantages of Kinect sensor comparing to other available solutions. Some of these are following:

- it does not require a controller or markers,
- low-cost production and setup,
- easy integration with other systems,
- simple software implementation through APIs and freely available drivers

Tanaka et al. [65] presented a comparison of different motion sensing gaming interfaces available on the market. In addition to Kinect the comparison includes Nintendo's Wii Remote Plus with Sensor Bar and Sony's PlayStation Move Eye Motion Controller. Table 4.1 presents the main advantages and disadvantages of these devices. As can be seen Kinect has many advantages comparing to other motion sensing gaming interfaces, whereas the most significant one is the full body motion detection without the use of any controllers or other physical input devices.

Table 4.1: Comparison of different motion sensing gaming interfaces.

	Nintendo Wii Remote Plus & Sensor Bar	Sony PlayStation Move Eye & Motion Controller	Microsoft Xbox 360 Kinect sensor
Advantages	Hand motion detection with high temporal resolution.	3D hand motion recognition with high temporal and spatial resolution.	No need for a controller. 3D gesture recognition. 3D scene recognition.
Disadvantages	Limited detection of motion. Difficulty in detection of 3D hand position.	Only hand motion tracking available.	Low temporal resolution. Difficulty in occluded motion recognition. Difficulty in recognition of motion at the same depth.

Apart from these motion sensing devices that are used for gaming purposes, there are also other more expensive motion tracking systems available. OptiTrack V100:R2 [68] is a high performance optical motion capturing system that can be used for motion recognition. It is a marker-based system that is known for its high precision and fast processing capabilities. Table 4.2 gives an insight in comparison of OptiTrack's and Kinect's specifications, features and price as of the time of writing.

Table 4.2: Comparison of Kinect sensor with OptiTrack V100:R2 system.

	Microsoft Kinect	OptiTrack V100:R2
Resolution	640x480	640x480
FPS	30	100
Sensing range	1.2 – 3.5 meters	20 meters
Field of view	Horizontal: 57, Vertical: 43	360
Number of cameras	1	multiple
Markers	NO	YES
Price	Low (149)	High (599)
Open SDKs	YES	NO

Chang et al. [13] presented a detailed comparison of Kinect with OptiTrack. The outputs of Kinect are compared with outputs of OptiTrack, in order to determine whether this low-cost device can compete with a high performance system.

In trajectory comparison, the comparison of coordinate outputs is performed. For that purpose the coordinates of OptiTrack were translated in the Kinect coordinates. The trajectories were then compared in 3D space. Trajectories of joints in right hand, right elbow and right shoulder are illustrated in this paper. Movements in hand and elbow are very similar, however shoulder movements are less detectable by Kinect. The reason for this according to Chang et al. is that Kinect uses only one camera which is positioned in front of the user, and shoulder movements are not only distinguishable from front view. Overall Kinect performs very similar to OptiTrack system in detecting hand, elbow and shoulder movements.

The performance speed of Kinect and OptiTrack is also evaluated in this work. The conclusion is that OptiTrack system is 50 ms faster in creation of outputs. However, authors clarify that such difference is irrelevant for purposes of simple motion recognition used in rehabilitation.

4.2 Design

The design of the proposed solution is based on the outcomes of interviews with specialists, physiotherapists and potential end-users. Basic idea is to develop a system that navigates users during execution of simple office exercises by taking advantage of Kinect sensor and its skeletal tracking feature. The on-screen feedback for the user is what should help avoid the incorrect exercising. Main goal of the system is therefore to provide movement guidance according to therapeutic movement description. Although the core idea was to have a system that disables work on the computer, based on interviews with potential end-users, this feature would not be included. Instead, a more acceptable solution for users was a notification system. When a user is continuously working on a computer for a specific amount of time, a notification in form of a balloon appears and indicates that a set of exercises should be performed. This way, the patronizing effect mentioned by one of the interviewees is avoided.

Exercise program

The system has to include a set of exercises that can both help in prevention and stay within Kinect sensor's limitations. After getting familiar with the Kinect for Windows SDK, first step was presenting the limitations of Kinect sensor in skeletal tracking and adapting the exercise program. During the talk with physiotherapists the following exercise program was presented:

- Head tilt to left and right
- Clockwise and counterclockwise head rolls
- Shoulder elevation
- Butterfly with arms straight
- Butterfly with arms slightly bent

Physiotherapists concluded that if the system can track these five exercises, it should be possible to expand the exercise program and alter the exercises in future work. The exercises chosen include movements that are traceable when only observing the X and Y axis, or in other words in two-dimensional (2D) space. This decision was made, in order to simplify the implementation process for the first prototype of the system, since adding third dimension should not pose a problem. This is further explained in the chapter about further work.

Each exercise is started from the so-called initial position, where hands are placed on knees and sitting angle and knees angle are at 90. Correct breathing is emphasized as a crucial part of the exercising. As explained by physiotherapists, the person has to inhale through the nose while depressing the muscles and exhale through the mouth while executing an exercise. This correct breathing however cannot be checked by the system, therefore it is marked as out-of-scope of this thesis. The exercises are described in detail in the following sections.

Head tilt to side

This exercise consists of repeatedly tilting one's head to the left or to the right. From the straight position head should be tilted towards the shoulder, but not touch it with the ear, since this would be too much pressure on the neck muscles. When the maximum angle is achieved the position should be held for a second and then returned to the starting position. The exercise helps stretch the neck muscles. Figure 4.7 demonstrates how the exercise is performed.

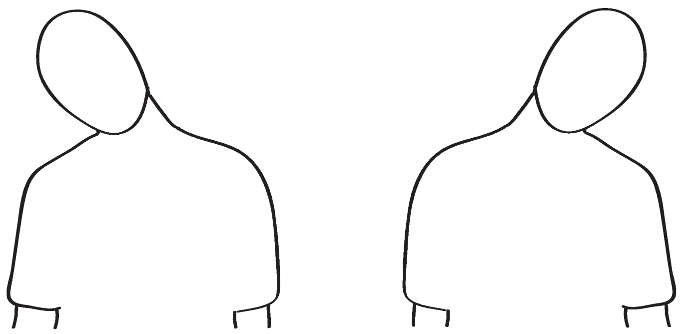


Figure 4.7: Head tilt to side exercise [44].

Head rolls

From the straight position head should be slightly tilted towards back by raising one's chin. From this position a person has to perform a head roll in a circular motion in clockwise or counter-clockwise direction until the initial position is reached, as shown in Figure 4.8. The exercise is aimed at preventing neck stiffness.

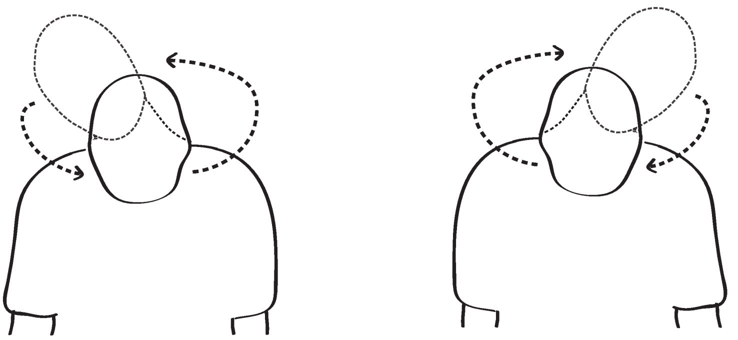


Figure 4.8: Head rolls exercise [44]..

Shoulder elevation

From initial position, shoulders are lifted up while keeping the head static, as can be seen in Figure 4.9. This posture is kept for a moment and the shoulders are returned to the starting position.

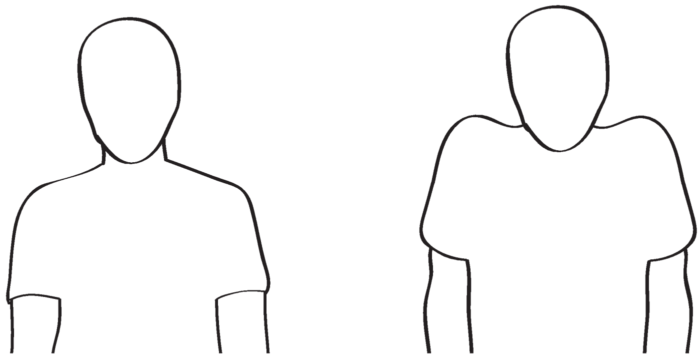


Figure 4.9: Shoulder elevation exercise [44].

Butterfly exercises

The exercise starts by lifting the arms off of the knees and moving them in circular motion above head as shown in Figure 4.10. The end posture is kept for a moment and arms are returned to the initial position. There are two variations of this exercise: One consists of raising arms above head while they are straight, the other is performed with slightly bent arms. In the version of the exercise where arms are bent, the end position is achieved by connecting the middle fingers and palms facing out, as can be observed in Figure 4.11.

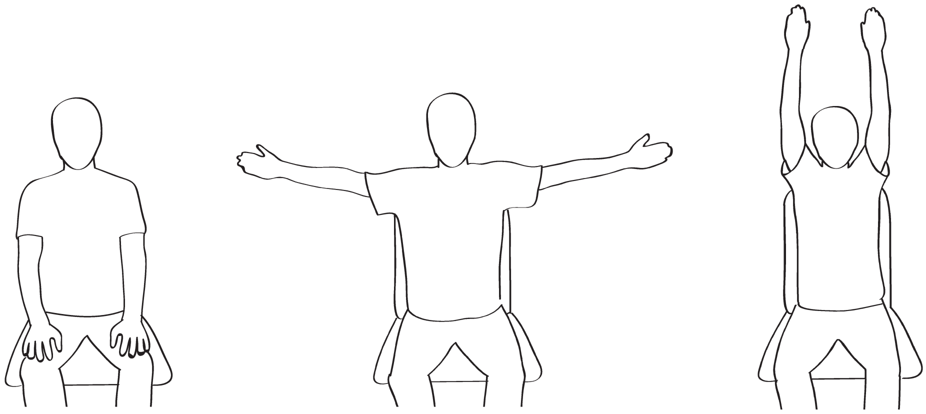


Figure 4.10: Butterly with straight arms [44].

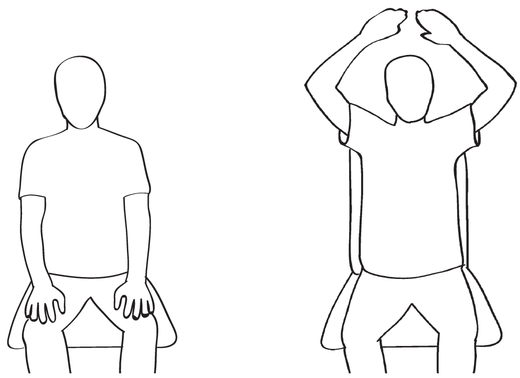


Figure 4.11: Butterfly with arms bent [44].

Kinect mounting and positioning

One of the crucial aspects of the design is the positioning and mounting of Kinect. Since every office is equipped with a working table, Kinect was for testing purposes in this research positioned on a table. Assumed table height is taken to be 70 centimeters, since this is a conventional height of an office table [35]. However, there are several factors that have to be taken in consideration. First and foremost, Kinect sensor has to be set at the optimal height in order to be able to track hands in initial position, but also in the most extended positions. The optimal height through testing was determined to be parallel to person's eyes, which is in the range of 1.0 meters and 1.3 meters. The elevation angle of Kinect has to be in the range of +/- 5 degrees. However, small calibration when Kinect is mounted might be necessary in order to adjust elevation angle according to the height at which the device is positioned. Important factor in height determination is the height of a person, but this can be regulated in most cases by adjusting the chair height.

Second most important factor is that Kinect sensor has to be placed so that the individual exercising is in the center of its field of view. Placing Kinect left or right of the computer screen would make users turn their head in order to be able to see the feedback on screen. Therefore, the suggestion is to position Kinect above screen, and lay it on a flat surface of 0. In order to lift Kinect above screen different approaches are acceptable, for testing purposes a simple stool was used and placed behind the screen.

Prototype

First prototype of the system included a simple user interface with a video of the tracked person being displayed on the right side, and on the left side an instructional video for the exercise. The user was displayed on the right side of the screen as a group of joints connected with lines, which represented bones of a user. A simplified version of the gesture recognition algorithm was implemented, where a user has to move a joint through specific points in space over specified time. This first version of the algorithm was aimed at making it possible to detect a performed movement anywhere in the Kinect's field of view.

Due to the user-centered design approach, two users were again involved in the testing of this first prototype of the system in several sessions. As the implementation process improved, users were brought in to test the on-going work. The users were instructed to stand at a specific distance from Kinect and perform simple head tilt exercises, and their behavior was logged. A short talk was also held after each session. By testing this simplified version of the system with two users several conclusions were made:

- Splitting the screen in two regions, where one on the left displays an instructional video and the one on the right shows the users movements, was graded as confusing. A user suggested having instructional video as a feature and not as something that is displayed by default.

- Since time for performance of an exercise was strictly defined, users could not repeat the exercise correctly. The system was graded as inaccurate, due to the fact that the speed at which the exercise is performed could not be exactly replicated each time.

- The users were not sure how to perform the exercise. Only when developer explicitly demonstrated how the exercise should be performed, then the exercise was completed correctly. Instructional video were not helpful either, but rather they were very distracting.

Based on the feedback received from users, several changes in the implementation and design were undertaken. The split screen approach was changed by removing the instructional video on the left side of the screen. Gesture recognition algorithm was altered so that instead of the strict time in which an exercise is performed, the maximum time for completion of an exercise is defined. However, the most important improvement of the design was the introduction of static on-screen points that should improve the guiding process.

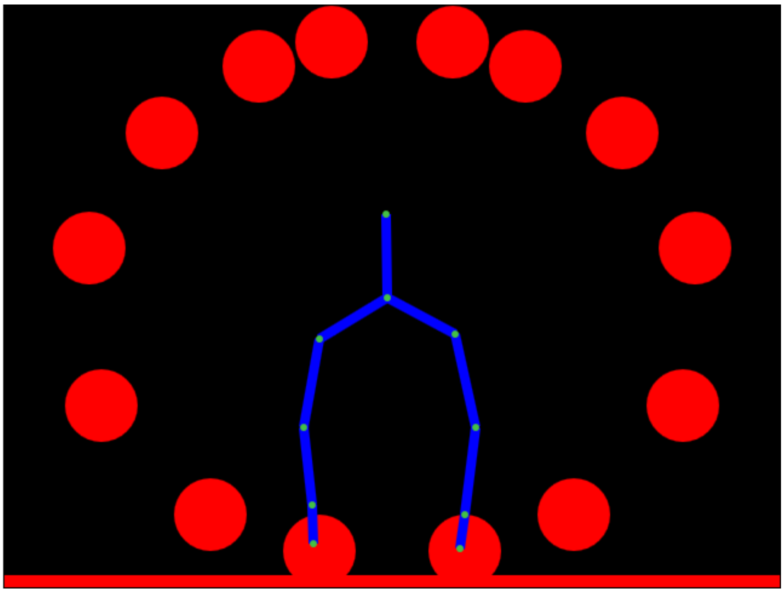


Figure 4.12: Static on-screen points.

Static on-screen points

Since prototype testing revealed that the gesture recognition is not accurate and consistent enough, need for a new solution has appeared. While users tried to replicate the exercises it was observable that they were looking at the video of themselves to see how their joints are moving. Therefore a new concept for guidance during exercising was created. As presented later in the implementation chapter, gesture recognition algorithm works by defining certain points in space through which a specific joint has to go through in a specific order and within specific timespan. The new proposed solution therefore includes visualizing these points on screen.

As can be seen in Figure 4.12, simple ellipses are drawn on screen and they represent the path for movement of a joint. First testing of this new concept gave significantly better results compared to the first design. More about the tests can be read in the formative evaluation section of the thesis. Only disadvantage of this approach is that the user has to position himself/herself so that the involved joints are at their starting positions.

Additional improvement to the concept of static on-screen points is the color coding. To distinct the starting from end position of the joint over time, different colors are used. As can be seen in Figure 4.13, the color scheme used is the following:

- Initial (starting) position of a joint in an exercise is represented by a red ellipse on screen.
- End position of a joint in an exercise is represented by a green ellipse on screen.
- Path or movement points through which a joint has to pass from starting to end position are represented by orange ellipses on screen.

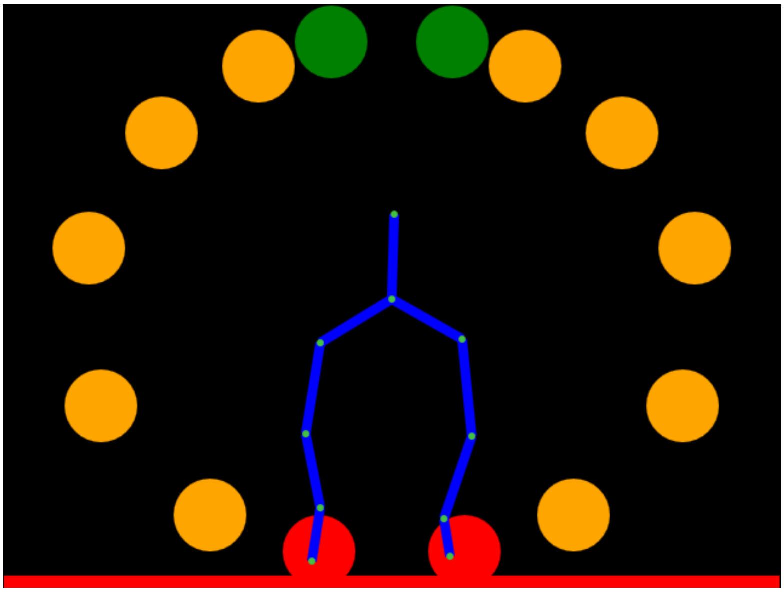


Figure 4.13: Color coded static on-screen points: red - initial position, green - end position, orange - path points.

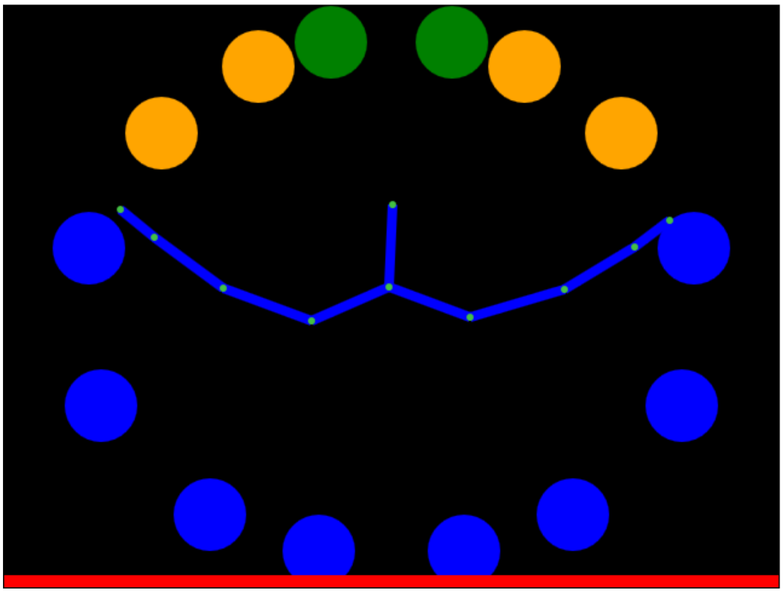


Figure 4.14: Blue color indicates that a movement in this point has been executed correctly.

It is important to note that later in the designing process also static on-screen points for static joints were added. This was done so that it can be checked whether joints that should not move are static. For example, in the mentioned "Shoulder elevation" exercise, the head has to be static.

Therefore, only one red ellipse is drawn at the area where the head has to be placed during the exercise.

Additional improvement to the static on-screen points is the coloring of the currently detected points. During one repetition of a single exercise it is important to give users feedback on where the mistake was made if it was made. For this purpose, every on-screen point that has been detected in the current repetition is color coded with another distinguishable color. In this case, for testing purposes, blue color was used for marking these points. Figure 4.14 shows how the exercise execution looks like after this approach has been implemented.

Calibration

Due to the fact that on-screen points are static, in order to start exercising all involved joints have to be placed in corresponding initial positions. In other words, each joint is placed in regions where red ellipses are drawn. To ensure that a user is standing in the right position throughout all the exercises, a short calibration is performed before starting the exercise procedure, so that the user is positioned at the correct distance from Kinect. By positioning the user correctly it is ensured that none of the joints are outside of Kinect's field of view. A very simple short movement is defined as shown in Figure 4.20, where a user spreads arms as much as possible parallel to the body. User then moves away from or towards Kinect while keeping arms straight until the initial positions for hand joints are reached. From this position the arms are raised above head until they reach the end positions. The calibration process is then over and exercising procedure can start.

Notification system

In order to exercise regularly a user has to be notified after specific amount of continuous computer work. Therefore it is necessary to have a timer running in the background that would activate the system when exercising is recommended. According to recommendations by physiotherapists and physical medicine and rehabilitation specialist, the exercising procedure should be performed 2-3 times a day. Suggested maximum timespan of not performing the exercises has been set at 4 hours. This time period was determined in an interview with physiotherapists. First prototype included a simple balloon notification as shown in Figure 4.17. The balloon would appear after 4 hours of inactivity and by clicking on it the exercising procedure would be initiated.

Recent research has shown that virtual agents that express emotion toward user can enhance the human-computer interaction [49]. Human or animal-like virtual agents are in general often used to represent a role that humans normally would perform. Moreover, user's perception of the agent is increased when the agent expresses emotion. Nass [46] discusses the politeness towards computers which is another aspect to take into account when designing interactive applications. In this research, the triggers listed for etiquette responses from user include voice, face, emotion manifestation, interactivity, attention to user, autonomy and the filling of roles normally filled by humans. Based on this research, in order to provide a better interaction with the system, a virtual agent is used as a tool for notifying, motivating and reminding the user. For the first version of

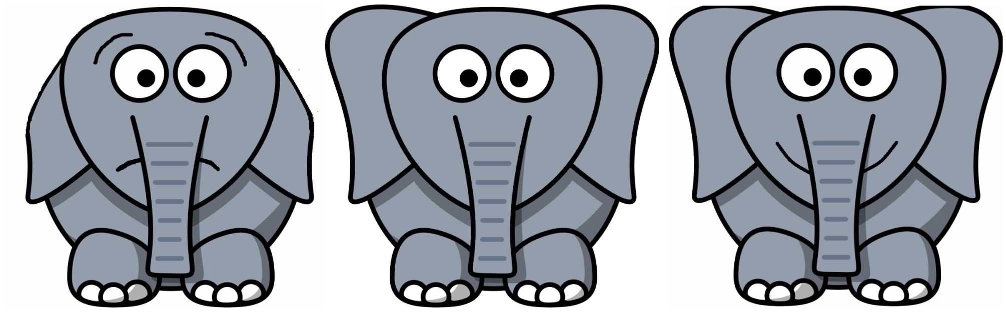


Figure 4.15: Virtual agent's health states: stiff (left), good (middle), fit (right) [5].

solution an agent with emotions and facial expressions was designed. However in future work there should be more of the Nass's triggers like voice and more interactivity taken into account.

Virtual agent

In addition to being an exercise guide, virtual agent is also meant to be a metaphor for user's physical state. To represent user's physical health states, the agent has three corresponding states: *"fit"*, *"good"*, and *"stiff"*. If a user has not exercised for more than 4 hours the state is set to "stiff". For inactivity of 2 up to 4 hours, agent's state is set to "good". If a user finishes a set of exercises or has exercised the last time before 2 hours or less, the state is set to "fit". In order to create more emotional empathy virtual agent's "emotions" change correspondingly as shown in Figure 4.15. In addition to that, a message explaining the state with last exercise time is displayed. The corresponding messages are:

- Since you recently exercised, I am feeling very fit right now. Thank you!
- I am fine now. But in a couple of hours I might get a little bit stiff and then I could use some exercise.
- Last time you exercised was XX hours/days ago, so I am feeling very stiff right now. Please perform these exercises and we will both feel much better.

4.3 Use scenario

To demonstrate the produced solution this section explains a simple use scenario of the proposed system by creating a persona. Let us assume our user's name is Alice. Alice works in an office approximately 8 hours per day. She is in her mid-40s and has experienced neck and shoulder problems related to excessive sitting and computer work.

In order to prevent neck and shoulder pain the proposed prevention system is installed in her office. Kinect is mounted just above her screen and the accompanying software is running in the background. The taskbar icon is shown in the tray and the application is active as can

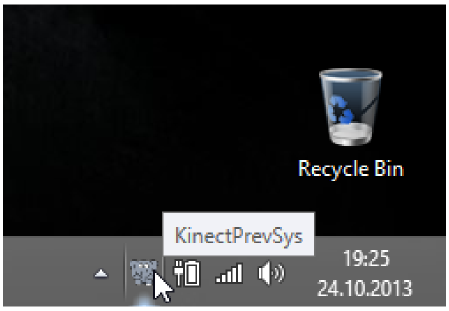


Figure 4.16: The system minimized to tray.

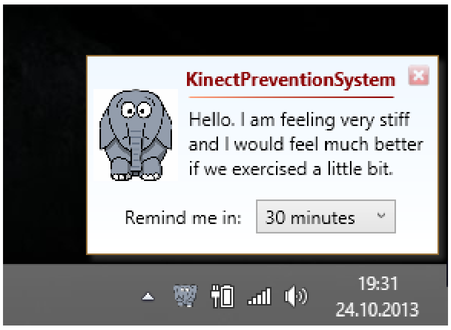


Figure 4.17: Notification to exercise.

be seen in Figure 4.16. After 4 hours of not exercising Alice receives the notification shown in Figure 4.17. Since she has a lot of work to do she postpones the exercising for 30 minutes. After 30 minutes have passed Alice is once again reminded. This time she decides to perform the set of exercises and therefore she double clicks the taskbar icon. The window shown in Figure 4.18 appears. Alice views the exercises she has to perform and starts the program by clicking *"Start exercising"*. The exercising window is then shown and Kinect sensor is started. First step is performing the aforementioned calibration. Static on-screen points for calibration appear as shown in Figure 4.19. Alice spreads her arms straight while keeping them at a same depth as her body, and moves her chair away from Kinect until her both hands and her head are in initial positions as in Figure 4.20. She then raises her hands and completes the calibration process 4.21. Then the exercise program is initiated and exercises are loaded in the order presented before in the text. Alice then performs specific number of repetitions for each exercise. After each correctly performed exercise the virtual agent displays a message congratulating the user. For example, Alice executes the "Butterfly with straight arms" exercise as shown in Figures 4.22, 4.23, 4.24. She receives a message from virtual agent saying "Good job", which means that one repetition was executed correctly. When all the repetitions for current exercise are finished, the system iterates to the next exercise. Alice is then instructed to perform the head rolls exercise, however she does not understand how the exercise should be performed correctly. Therefore she clicks on the help button which is located next to the exercise name in the upper left corner

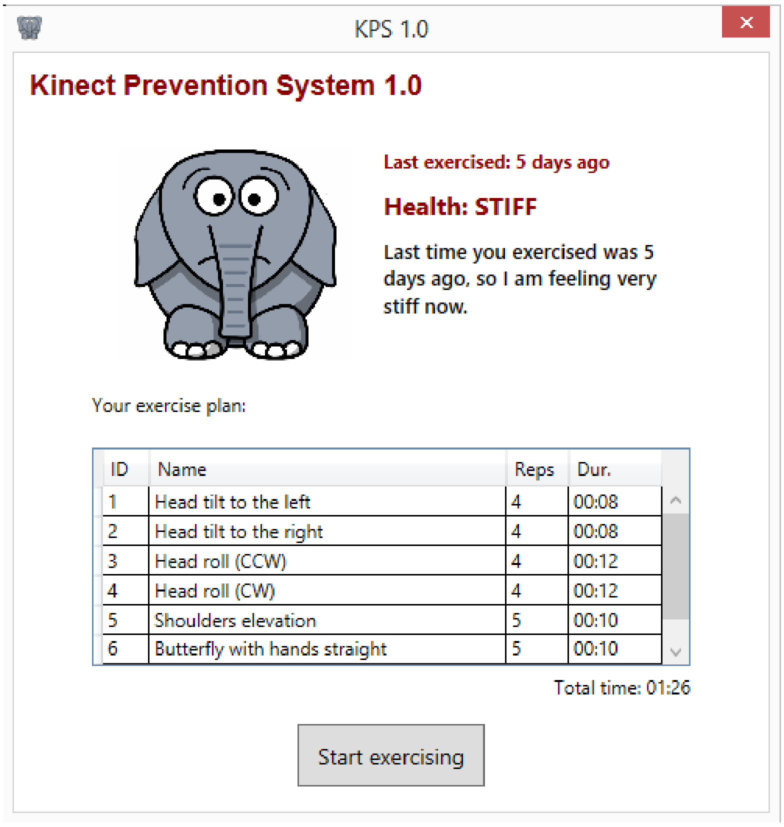


Figure 4.18: Start window.

of the window, which opens a new window with more detailed instructions and an instructional video. She then executes the exercise correctly after viewing the instructional video.

When all exercises are completed successfully the window can be closed and a window with now updated virtual agent is displayed, as shown in Figure 4.25. The window contains also a short tip about advantages of being in good shape. The background timer is reset, and again in 4 hours Alice will be notified to exercise.

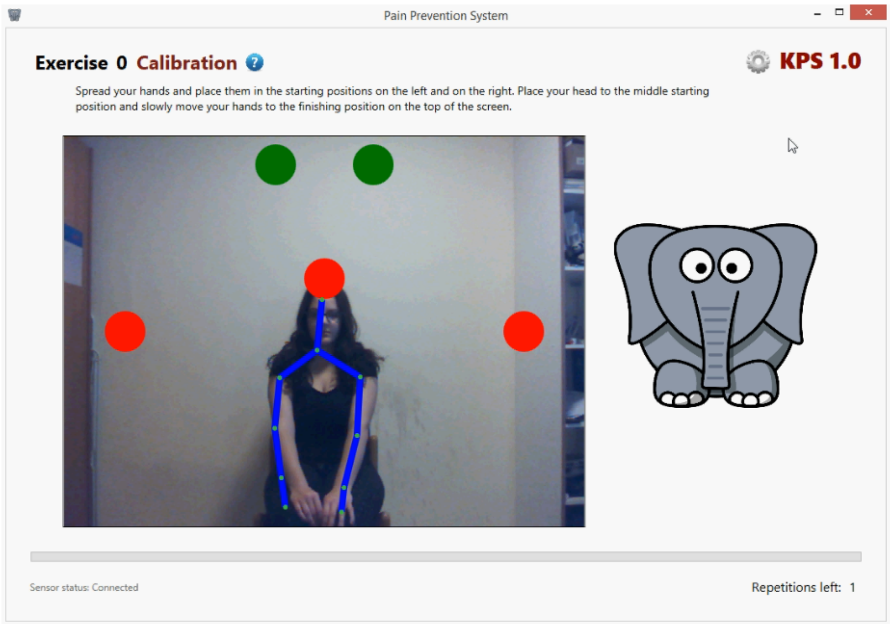


Figure 4.19: Static on-screen points for calibration.

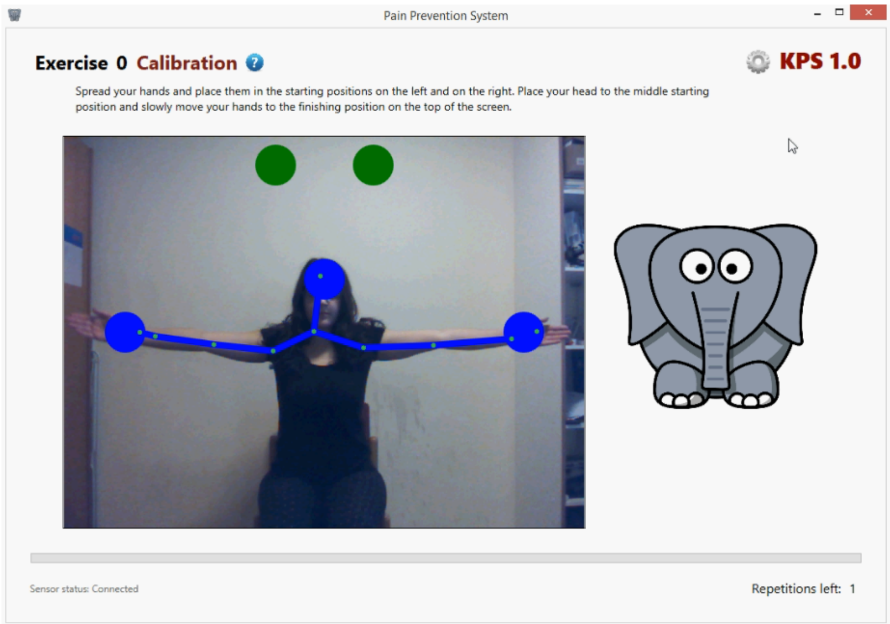


Figure 4.20: Initial position for calibration.

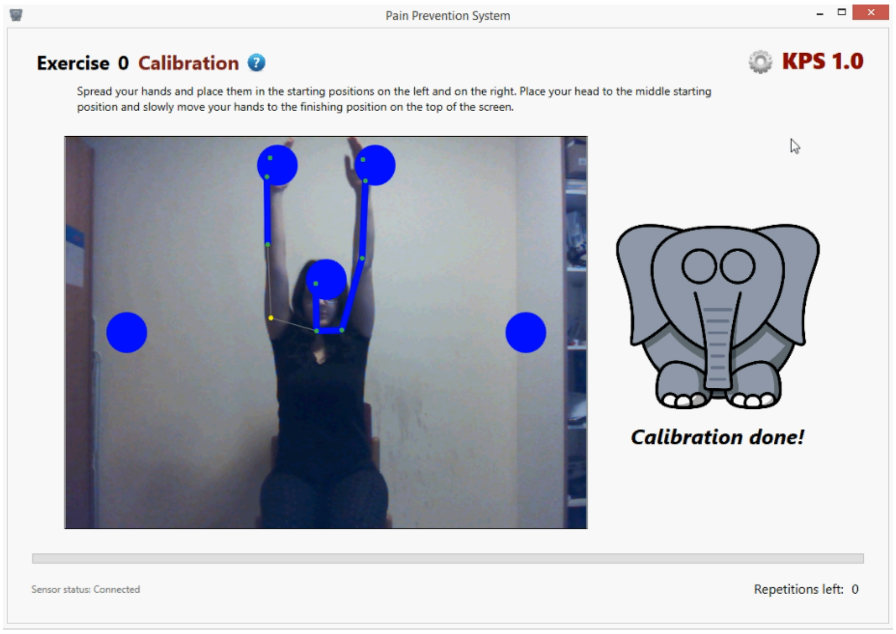


Figure 4.21: End position of calibration.

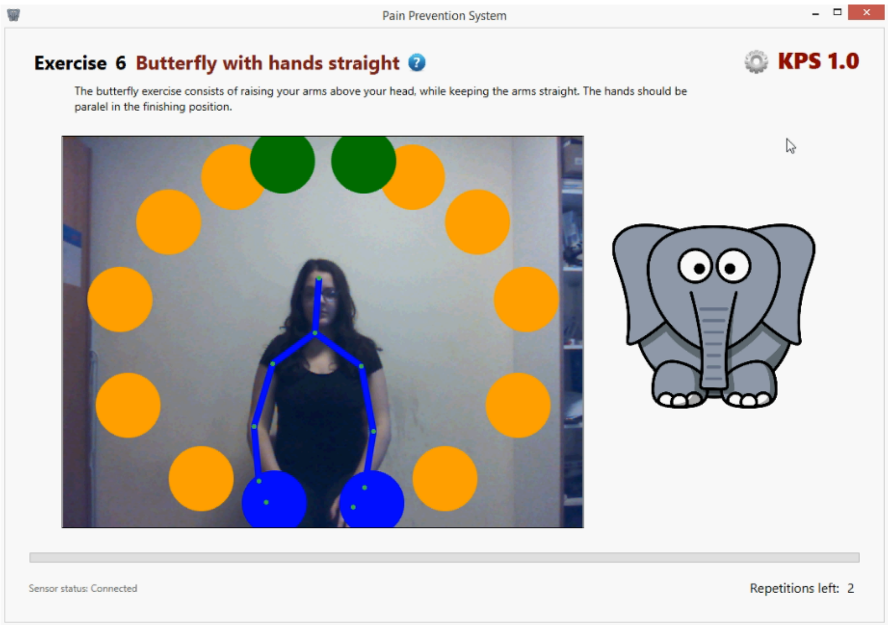


Figure 4.22: Detection of executed exercise (1).

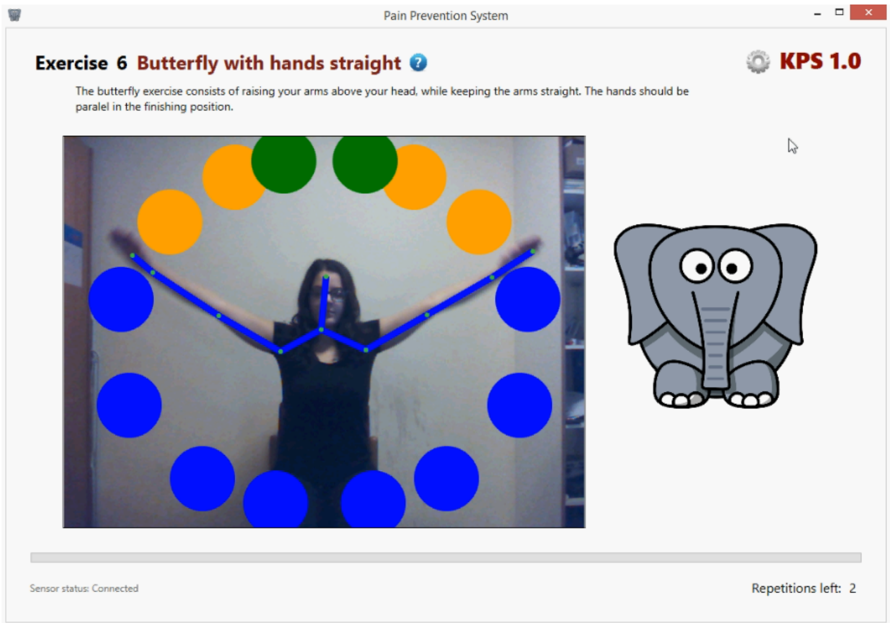


Figure 4.23: Detection of executed exercise (2).

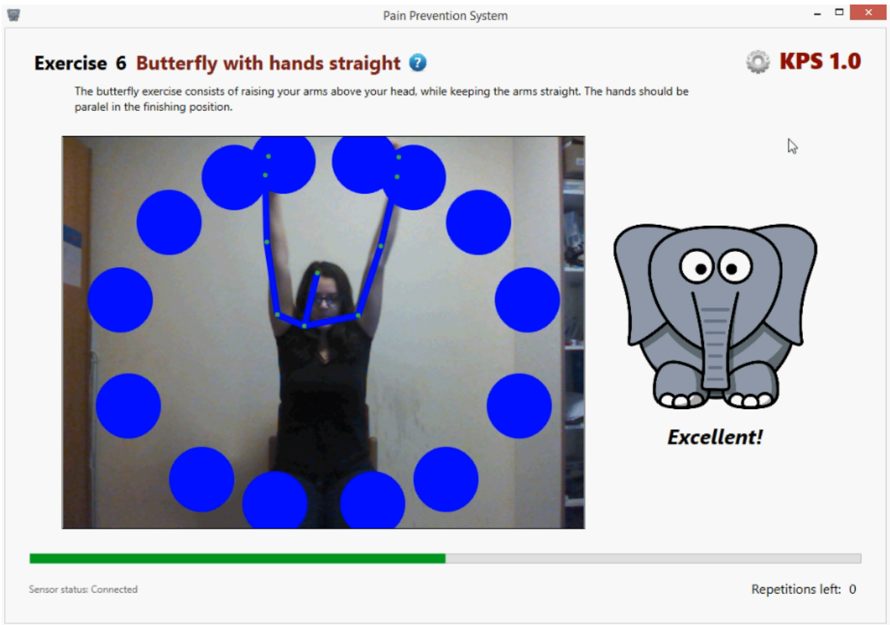


Figure 4.24: Detection of executed exercise (3).

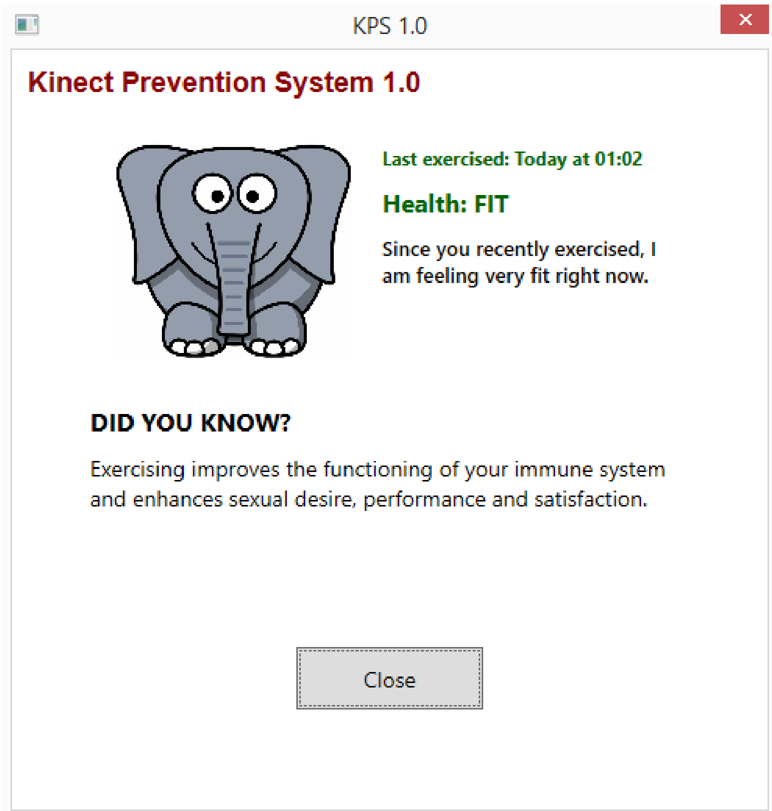


Figure 4.25: End window shown after all the exercises are performed correctly.

CHAPTER 5

Implementation

In this chapter the implementation of the proposed pain prevention system is explained. 5.1 provides a short introduction into technologies used in the implementation of the system. General structure of the implementation is presented in 5.2. Remaining sections describe the components in detail.

5.1 Technologies

The proposed system is implemented in *Visual C#* [12] programming language. *C#* is an object-oriented programming language designed for building applications that run on the *.NET Framework*. Visual C# is the implementation of the C# language by Microsoft. The development environment used is Microsoft Visual Studio Professional 2012.

Windows Presentation Foundation (WPF) [28] is a presentation system for building Windows client application. It is a part of *Microsoft .NET Framework*, therefore incorporation with other elements of the .NET Framework library is possible. WPF includes a set of application development features, some of which are *Extensible Application Markup Language (XAML)*, controls, data binding, layout, animation, styles, templates, media, text and typography. Great advantage of WPF is the fact that it is possible to develop an application using both markup and code-behind. While XAML markup is used to implement the appearance of the application, code-behind is used for the implementation of its behavior.

5.2 General structure

The structure of the system can be seen in Figure 5.1. WPF system offers developers the possibility to insert the main logic in the code-behind, while the corresponding markup is tightly connected to the class. The main logic of the implementation, as well as communication with Kinect sensor is implemented in the `MainWindow` class. Due to the use of WPF presentation system, the code behind `MainWindow` is written in `MainWindow.cs` file, while the

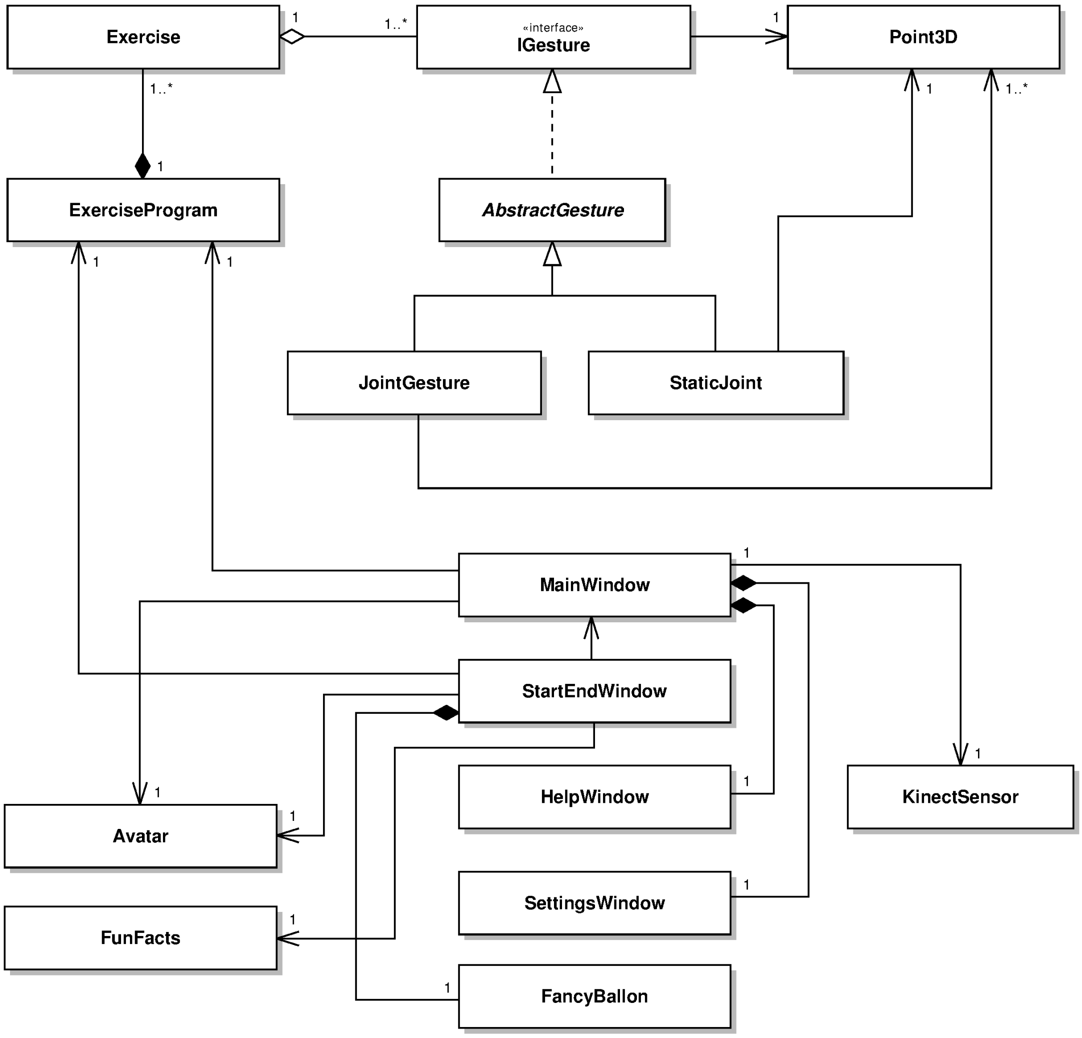


Figure 5.1: The structure of the system.

corresponding markup is located in an indivisible unit `MainWindow.xaml.cs`, where graphical user interface is defined. The same approach can be observed in `StartEndWindow`, `SettingsWindow` and `HelpWindow` clases. The logic needed for definition of exercises is implemented in `Exercise` and `ExerciseProgram` classes. The logic behind gesture recognition is accessed through the *`IGesture`* interface. Following sections describe each of these components in detail.

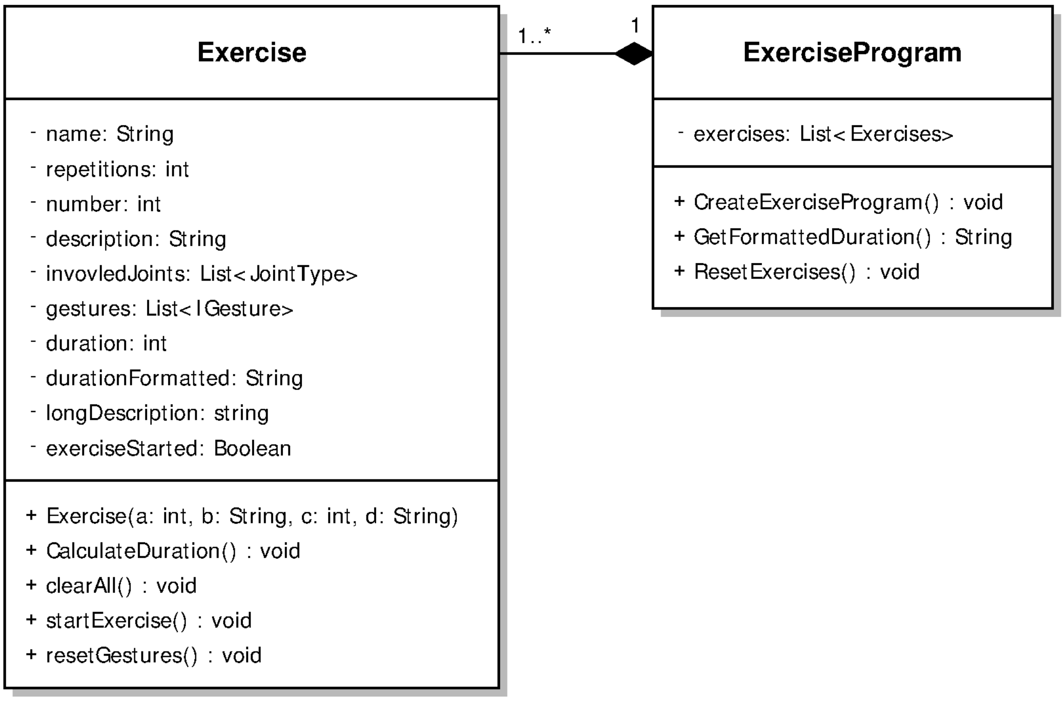


Figure 5.2: The structure of the exercises component.

5.3 Main logic

Start window

Code execution begins in the `StartEndWindow` class. First step during execution is the creation of an exercise program. Therefore, an object of class `ExerciseProgram` is declared and instantiated. To create the set of exercises, provided method `CreateExerciseProgram()` is called. The method creates a number of objects of type `Exercise` and stores them in a list. Each exercise has its recognizable and unique number, name, number of repetitions, duration, description, list of involved joints and list of gestures. Detailed overview of the class `Exercise` and `ExerciseProgram` is presented in Figure 5.2. The code for `Exercise.cs` is presented in Appendix D.1.

The markup of the start window shown in Figure 4.18 contains also the definition of the taskbar icon shown in Figure 4.16. For this purpose, WPF NotifyIcon[1] implmentation from Phillip Sumi is used. It is a independent control which enhances several features of the WPF framework, and enables use of rich ToolTips, Popups, context menus and balloon messages. In Listing 5.1 an excerpt of markup from `StartEndWindow.xaml` is presented. Line 2 of the

[1] http://www.hardcodet.net/projects/wpf-notifyicon

Listing shows how the XAML namespace is declared and in line 4 the taskbar icon is added with `<tb:TaskbarIcon>` tag. Line 8 and 9 define that on double click on the taskbar icon the a command `ShowWindowCommand.cs` is executed, which implements the code for showing the window. Since exiting by clicking on the close button on the window only minimizes the application to trey, this double-click command enables the reappearance of the window. In addition to that, a context menu which is activated by right clicking the icon is defined from line 11 to line 15.

Listing 5.1: StartWindow.xaml

```
1  <Window x:Class="KinectPreventionSystem.StartWindow"
2          xmlns:tb="http://www.hardcodet.net/taskbar"
3          ...>
4          <tb:TaskbarIcon
5              x:Name="TaskbarIcon"
6              IconSource="/Images/icon.ico"
7              ToolTipText="KinectPrevSys"
8              DoubleClickCommand="{StaticResource WindowCommand}"
9              DoubleClickCommandParameter="{Binding RelativeSource={
                   RelativeSourceMode=FindAncestor, AncestorType={x:Type
                   Window}}}">
10             <tb:TaskbarIcon.ContextMenu>
11                 <ContextMenu>
12                     <MenuItem Header="Show window" Click="
                           MenuItem_Click_1"/>
13                     <MenuItem Header="Close" Click="MenuItem_Click_2"
                           />
14                 </ContextMenu>
15             </tb:TaskbarIcon.ContextMenu>
16         </tb:TaskbarIcon>
17 </Window>
```

In order to regularly check if certain amount of time since last performance of exercises has passed, a timer from `System.Timers` namespace is implemented, as shown in Listing 5.2. The method `OnTimedEvent1()` re-initializes the virtual agent, so that the corresponding state of agent is shown. Another timer is defined to trigger the appearance of a notification balloon if the state of virtual agent is set to *stiff*, or in other words, if a user has not exercised in more than 4 hours.

When a user decides to exercise the *Start exercising* button is clicked and the *Main Window* is opened.

Listing 5.2: Timer in start window

```
timer1 = new Timer(refreshTime);
timer1.Elapsed += new ElapsedEventHandler(OnTimedEvent1);
timer1.Enabled = true;
```

Main window

Main window is shown in Figure 4.20 and Figure 4.21. The code-behind, which is located in MainWindow.xaml.cs class, is responsible for exercise coordination and iteration. If an exercise is performed correctly, that is if all gestures of current exercise are detected, the method NextRepetion() is automatically called. This method decrements the number of repetitions by 1, and when only one repetition is left the method NextExercise() is called. When the last exercise is completed the process is stopped and a *Close* button is shown to the user. At that time the gesture detection is paused and user input is expected in order to finish the exercising procedure.

Listing 5.3: An excerpt from MainWindow.xaml

```
<Window x:Class="KinectPreventionSystem.MainWindow"
        ...>
    <Viewbox Stretch="Uniform"
        HorizontalAlignment="Center">
        <Image Name="KinectImage" Width="640" Height="480"/>
    </Viewbox>
        ...
</Window>
```

The window markup contains an <Image> tag as shown in Listing 5.3. This element is a container for the video from RGB camera of Kinect. The skeleton and static on-screen points are also drawn on this image element. Following section explains how communication between Kinect sensor and proposed application is realized.

5.4 Kinect sensor

Kinect sensor is easily accessed from an C# WPF application in the Visual Studio Project Explorer by adding a reference to Microsoft.Kinect.dll. Naturally, Kinect for Windows SDK and accompanying drivers are a prerequisite for this to work.

The Kinect sensor communication with the proposed system is implemented in the code-behind of *Main window*. An object of KinectSensor class is declared and by using the Start() method the sensor is initialized. Since the implementation is in the MainWindow.xaml.cs class, this method is called in Window_Loaded() method that is executed after the window has been loaded. In order to ensure that the Kinect sensor is stopped when the window is closed a method Stop() is called in Window_Closing() method, which is executed when the window is closing. An instance of DrawingGroup and DrawingImage each are used to enable drawing of shapes and displaying source from RBG camera of Kinect. The source of KinectImage located in MainWindow is then set to receive the drawn shapes and video. Listing 5.4 shows simplified implementation of this process.

Listing 5.4: Excerpt from the implementation of Kinect sensor

```
private KinectSensor sensor;

private DrawingGroup drawingGroup;

private DrawingImage imageSource;

private void Window_Loaded(object sender, RoutedEventArgs e)
{
        this.drawingGroup = new DrawingGroup();
        this.imageSource = new DrawingImage(this.drawingGroup);
        KinectImage.Source = this.imageSource;

        foreach (var potentialSensor in KinectSensor.KinectSensors)
        {
                if (potentialSensor.Status == KinectStatus.Connected)
                {
                        this.sensor = potentialSensor;
                        break;
                }
        }

        if (null != this.sensor)
        {
                this.sensor.Start();
        }
}

private void Window_Closing(object sender, System.ComponentModel.
    CancelEventArgs e)
{
        if (this.sensor != null)
                this.sensor.Stop();
}
```

The three for this project most important streams available from Kinect sensor are: *Color Stream*, *Depth Stream* and *Skeleton Stream* . Color stream is used to access the color camera of Kinect. The camera can be optimized for different environments through the SDK. Color data is available in RGB, YUV and Bayer formats. Depth Stream gives access to depth data acquired by Kinect. Each frame of the depth data stream is made up of pixels that represent the distance from the camera to objects in Kinect's field of view. And the third stream mentioned, namely Skeleton Stream, is the most important one for this application. The sensor streams the data about detected skeletons by using `SkeletonFrame` objects. Each object contains one frame of the skeleton data. The provided method `CopySkeletonDataTO()` copies the skeleton data to an array of skeletons, where each `Skeleton` object contains a collection of `Joint` objects.

An object of type `Joint` contains data about joint type, position and whether the joint is tracked. For purposes of classifying the joints, the enumeration type `JointType` is used. For example, the left hand joint has the enumeration value of `JointType.HandLeft`. The list of all traceable joints was presented in Figure 4.3. The `Position` member of the `Joint` class, returns an object of `SkeletonPoint`, which contains the *X*, *Y*, and *Z* coordinates of the position of the joint in meters.

The code for enabling the Color Stream and Skeleton Stream is shown in Listing 5.5. To enable each of these streams the method `Enable()` is called before initializing the Kinect sensor. Tracking mode is set to seated, since the proposed solution is aimed at exercises performed in sitting position. Lastly, an `AllFramesReady` event handler is called whenever new frames are available for each of the sensor's active streams.

The simplified implementation of event handler `AllFramesReady` is presented in Listing 5.5. This event handler is responsible for drawing the on-screen static points and skeletons, but also the calling of methods related to gesture recognition.

Listing 5.5: Enabling Skeleton Stream and Color Stream

```
if (null != this.sensor)
    {
        this.sensor.ColorStream.Enable(ColorImageFormat.RgbResolution640x480Fps30);
        this.sensor.SkeletonStream.Enable();

        this.sensor.SkeletonStream.TrackingMode = SkeletonTrackingMode.Seated;

        this.sensor.AllFramesReady += this.AllFramesReady;

        this.sensor.Start();
    }
}
```

As can be seen in Listing 5.6, the event handler does the following:

- the skeleton data is copied to an `skeletons` array,
- the video from RGB camera is drawn on the `KinectImage` container,
- iterates through all gestures and draws corresponding static on-screen points,
- calls the `NextRepetion()` method if all gestures are detected,
- calls the `DrawSkeletonAndFindGestures()` method, which draws the bones and joints of a user and performs the gesture recognition.

Listing 5.6: Simplified AllFramesReady event handler

```
private void AllFramesReady(object sender, AllFramesReadyEventArgs e)
    {
        Skeleton[] skeletons = new Skeleton[0];

        using (SkeletonFrame skeletonFrame = e.OpenSkeletonFrame())
        {
            if (skeletonFrame != null)
            {
                skeletons = new Skeleton[skeletonFrame.
                    SkeletonArrayLength];
                skeletonFrame.CopySkeletonDataTo(skeletons);
            }
        }

        using (DrawingContext dc = this.drawingGroup.Open())
        {
            using (ColorImageFrame colorFrame = e.OpenColorImageFrame
                ())
            {
                Send source from RGB camera to KinectImage container
            }

            foreach (IGesture g in exercise.gestures)
            {
                for (int i = 0; i < g.getNumberOfPoints(); i++)
                {
                    // Draw on-screen exercise points
                }
            }

            if (AllGesturesDetected)
            {
                NextRepetition();
            }

            if (skeletons.Length != 0)
            {
                this.DrawSkeletonAndDetectGestures(skeletons[0], dc);
            }
        }
    }
```

5.5 Gesture recognition

`StaticJoint` and `JointGesture` classes represent a single gesture of an assigned joint. `StaticJoint` class defines joints that are static in an exercise, which means that this class is used for checking if a joint is located withing one specific region over the time of the whole exercise. Semantically an object of `StaticJoint` class cannot be categorized as a gesture. However, since static joints are also a part of an exercise, and since this saves a lot of code work, the `StaticJoint` class implements the `IGesture` interface, just like the `JointGesture` class.

The general structure of the gesture recognition component of the proposed solution is presented in Figure 5.5. As can be seen, `IGesture` interface provides a number of methods that are used in `JointGesture` and `StaticGesture`. However, since there are many field members that are defined in the same way in both of these classes, an abstract class *`AbstractGesture`* is introduced. This class implements the `IGesture` interface. Furthermore it contains the getters and setters for fields that are shared by both child classes, and defines the abstract methods provided in the interface. These methods are then in child classes overridden and implemented. The concept is presented in Listing 5.7.

Listing 5.7: Example of the usage of the gesture recognition structure

```
public interface IGesture
{
    void detectMotion(Point3D);
}

public abstract class AbstractGesture : IGesture
{
    public abstract void detectMotion(Point3D);
}

public class JointGesture : AbstractGesture
{
    public override void detectMotion(Point3D)
    {
        // the method implementation specific for this class
    }
}
```

Point3D

`Point3D` is a helper class for representing 3D coordinates of joints, as can be seen in Figure 5.3. The corresponding code is presented in Appendix D.2. Class is used for encapsulation of space coordinates and it provides methods needed for comparison of two points in 3D space. For this purpose each of these methods returns the *Sum of Absolute Differences (SAD)* between two points in specified dimensions defined by variable `dimensions`. For example if the `dimensions` field value is set to *"xyz"*, the `compareToXYZ()` method is called. This method then compares the X, Y and Z coordinates of two points in space in the following way:

$$SAD(p1, p2) = (p1.X - p2.X) + (p1.Y - p2.Y) + (p1.Z - p2.Z)$$

In addition to that, the class contains a field `Detected`, which is a `Boolean` value that stores information on whether the current point has been detected. The feature is only used when the point in question is the point with which the currently observed point is compared.

Gesture

A gesture is defined by a list of points of type `Point3D` in space. A gesture is linked with only one joint. The gestures are saved in `.ges` files, and are named after the `gestureName` field in `IGesture`. If an exercise includes movements of more joints, for each joint there has to be one `.ges` file. An example of how one gesture file looks like is presented in Listing 5.8. Each row represents a point in space, where first column is the X coordinate, second Y coordinate and third Z coordinate of the point.

Listing 5.8: An example of gesture (.ges) file with three static on-screen points.

```
320 175 1600
300 180 1600
285 190 1600
```

As mentioned before, semantically, *static gesture* is an incorrect term, however there are exercises where it is important to keep a joint static, which defines these positions as *static gestures* that are a part of an exercise. Therefore a `StaticGesture` object does not include a list of points in space but rather only one point of type `Point3D`. This point is however also saved in an separate `.ges` file that in this case includes only one row.

The gesture files are loaded by calling the `LoadGestureFromFile()` method. This information is then sent to the main window, where these points are visualized as static on-screen points.

Detection algorithm

When the method `DrawSkeletonAndFindGesture()` in main window is called, the skeleton is drawn and `DetectExerciseMovements()` method is called. This method sends the current position of the joint to the corresponding `IGesture` object by using the method `detectMotion(Point 3D)`, as shown in Listing 5.9. The current position of the joint is then compared to the first element of `points` list in `JointGesture` object. Each gesture has an `errorThresholdMax` field, which is an integer value that represents the maximum error threshold. This value is determined by-hand for each gesture. To check whether the current position of a joint is in the tolerable error region of the point in the list, the returned value of the comparison method is simply compared to the error threshold. If the SAD between current position of the joint and the first point in the `points` list is smaller than the

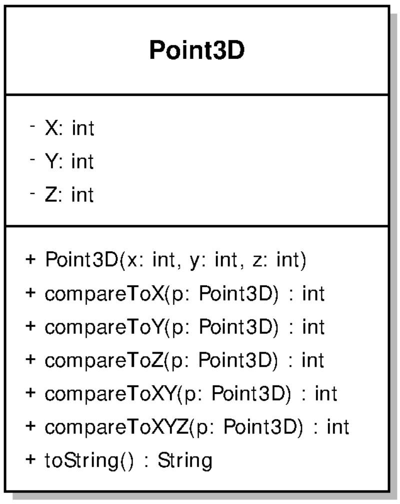


Figure 5.3: Point3D class overview.

value of `errorThresholdMax`, the current position of the joint is correct. If the value from `compareToXYZ()` is greater that the threshold value, the point is not detected.

If the first point is found, the value of its `gestureDetected` field is set to `true`. As soon as the region of this point is left, the field `currentIndex` is incremented and the timer for the gesture execution is started. Then the current position of the joint is compared to the next point from the `points` list. Therefore, if the user moves a joint through all the points in a correct order and reaches the end position (the last element in the `points` list), but the maximum gesture time defined in `gestureMaxDuration` is exceeded, the gesture is not marked as found. However, if a joint is moved through all the gesture points while not exceeding the gesture time, each point is marked as recognized and the gesture is marked as detected. This way, it is ensured that a user performs an exercise in the given amount of time, and not slower.

In case of `StaticJoint` the algorith is much simpler since there are no time limitations and there is only one point that has to be compared. If the current position of a joint sent by main window is within the tolerable region compared to the point in `StaticJoint`, the gesture (or in this case better word would be position) is marked as detected.

The detection procedure is performed almost simultaneously for all gestures, since the sensor sends new joint position information approximately every 100ms. If all gestures, static or non-static, are detected within each maximum gesture time, the exercise is marked as performed and the mentioned `NextRepetion()` method is called. This is observable in lines 30 to 32 in Listing 5.6.

Listing 5.9: Simplified excerpt of code responsible for gesture recognition in main window.

```
    private void DrawSkeletonAndFindGesture(Skeleton skeleton,
        DrawingContext dc)
    {
```

```
        // Draw bones
        foreach (Joint joint in skeleton.Joints)
        {
            foreach (IGesture gesture in exercise.gestures)
                if (gesture.jointType == joint.JointType)
                    DetectExerciseMovements(joint, gesture);
            // Draw joint
        }
    }

    private void DetectExerciseMovements(Joint joint, IGesture gesture)
    {
        Point3D pnt = SkeletonPointToScreen3D(joint.Position);
        gesture.detectMotion(pnt);
    }
```

5.6 Notification service

As explained in before in the text, the WPF NotifyIcon library is used to display the taskbar icon in the notification trey. In order to notify a user that the time to start exercising has been reached, a simple notification balloon from this library is implemented. `FancyBalloon.xaml` is the markup used for the notification balloon, whereas the interaction with the balloon is enabled by the use of WPF code-behind. The balloon appearance is initiated by a timer defined in the `StartEndWindow`, which is only enabled when the inactivity time is exceeded, or in other words when the virtual agent's health state changes to *stiff*.

5.7 Virtual agent

Virtual agent is implemented in the class `Avatar`. The agent is, as explained, a motivation tool that should cause emotional empathy and relate to users. However, the functionality of tracking when a user last exercised is also incorporated in the agent. Avatar class offers a method `SaveSummary()` which is called when a exercise procedure is finished in order to add an entry of current time in the `summary.sum` file. When the virtual agent is initialized the method `LoadSummary()` is used for loading the data from this file. Therefore, the agent is additionally a tool for detecting inactivity of a user. The class members and methods are listed in Figure 5.4

The displaying of the animated virtual agent is done by simply including an image of Graphics Interchange Format (GIF). The WPF presentation system however does not include a integration of images of this format, therefore an external library WpfAnimatedGif[2] is used. This library enable a simple integration of GIF images in the markup by adding the corresponding namespace in the window.

[2] https://wpfanimatedgif.codeplex.com/

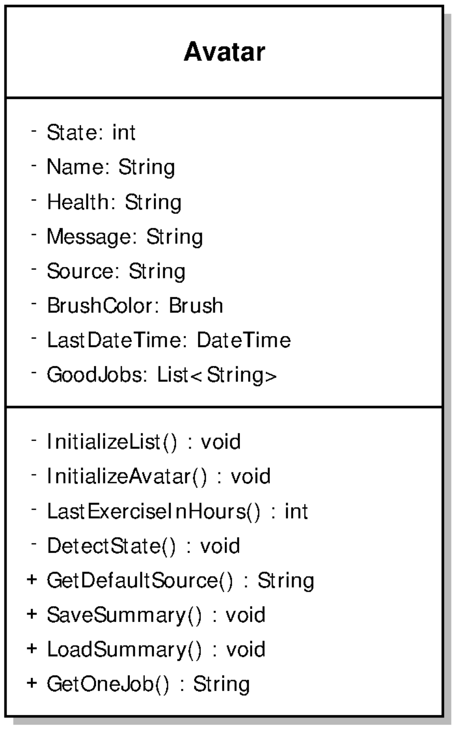


Figure 5.4: Class diagram of the Avatar class.

5.8 Settings window

Settings window is implmeneted in the `SettingsWindow` class and in the first version of the proposed solution it includes only a possibility to change the elevation angle of the Kinect device. The settings window represents a container for controls that are mentioned in future work and that would be added later.

5.9 Help window

`HelpWindow` class represents a help window that should provide additional information on the exercises as well as an instructional video on how the exercise is performed. In order to display the video, it is necessary to create a container for a *Windows Media Player (WMP)* plugin which is only available in *Windows Forms applications (WinForms)*. WPF presentation system however does provide a container for WinForms elements through the `WindowsFormsHost` field in the markup, which enables the hosting of an *ActiveX Control*. Thereby the playback of an instructional video on how to perform an exercise is achieved. The video can also be set to full screen by double clicking and use of all WMP controls is available.

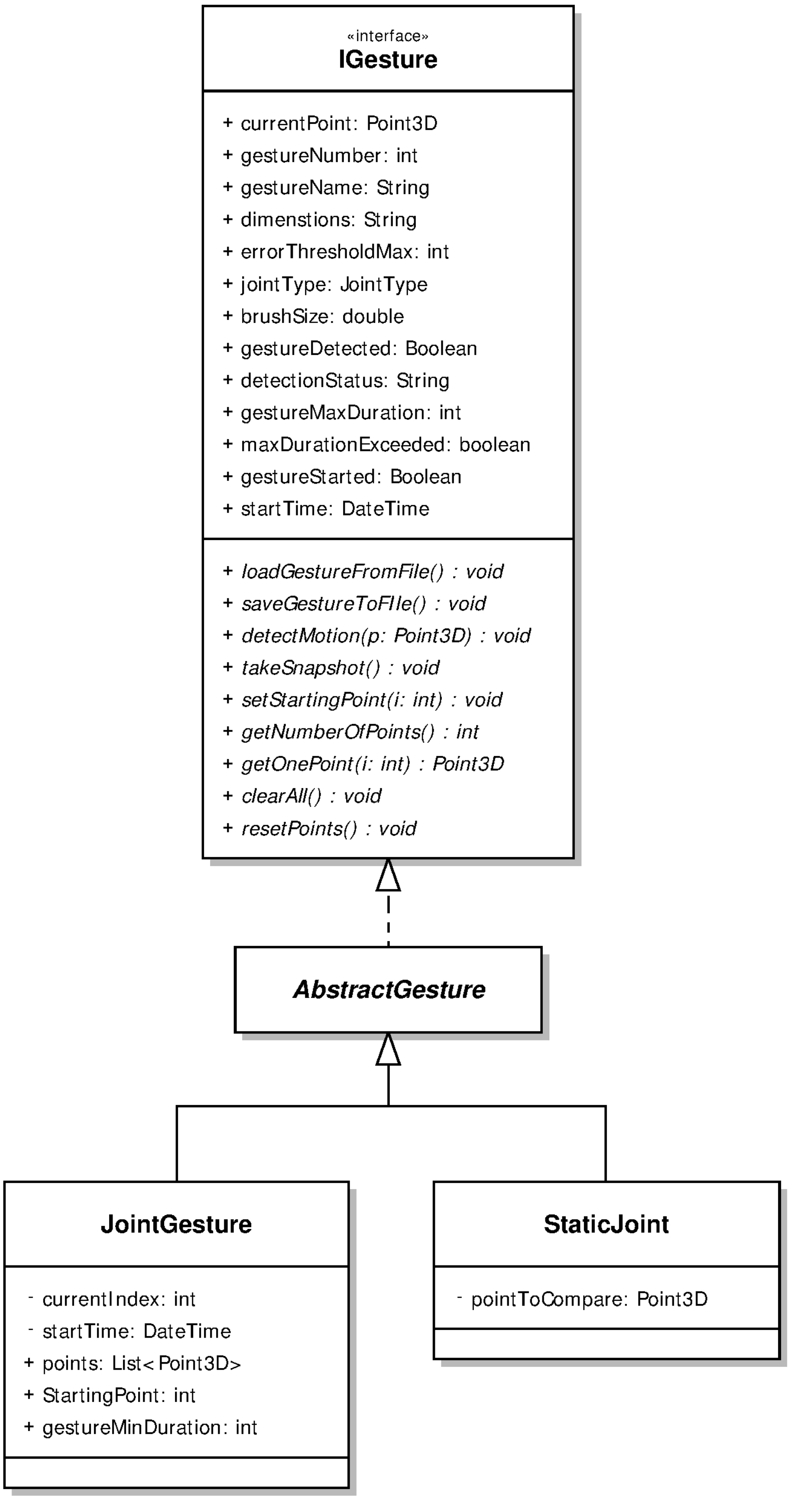


Figure 5.5: Gesture recognition component.

CHAPTER 6

Evaluation

Several evaluation methods were used in order to test the system. This chapter gives an overview of these methods and the results gained. Due to the user-centered design approach, the proposed system has been tested at several stages of development. Such constant evaluation at different design stages is in literature referred to as formative evaluation. Section 6.1 explains in detail this process. To evaluate performance of the system more thoroughly an in-situ deployment was also conducted with one user, which is presented in section 6.2. Furthermore, section 6.3 presents the outcomes of the evaluation with physiotherapists and physical medicine and rehabilitation specialist.

6.1 Formative evaluation

Formative usability evaluation [11] is any evaluation that takes place before or during development. Main goal is improving project design and system performance. Furthermore, the goal of formative evaluation is to detect and eliminate usability problems in early stages of development. Maner defines the formative evaluation in the following way [40]:

> *An evaluation of an unfinished user interface, done about three times during each iterative design cycle, which aims to expose usability problems that exist in the current iteration.*
>
> *Contrasts with "summative evaluation", which is done when the interface is complete, and with "human factors testing", which is done in a more carefully controlled research setting.*

This type of evaluation is in contrast to a *summative evaluation* which can only be started when a design is complete. However, formative evaluation can be observed as a complement to the summative evaluation.

As presented by Theofanos et al. [66], formative testing is testing with representative users and representative tasks on a representative product where the testing is designed to guide the improvement of future iterations. It is possible to work with any technique for working with users while working on any sort of a prototype or product. Any setting for evaluations is included, as long as it does not include working with non-representative users. In addition to that, according to this definition, surveys, focus groups, or other techniques in which the participants do have a prototype or product on hand is also excluded from the process. However, in this thesis the use of prototype for evaluation purposes was encouraged since it was necessary to ensure that the interaction with the system is solved correctly.

Users

As mentioned before, during the implementation phase two users were constantly asked to perform certain tasks. The informal nature of this evaluation process gave users more freedom to express their opinions and suggestions while talking to the designer. Special attention was given on having two physically different representative users. This was the case, since one user was female in mid 50s and with a smaller body type and the second one was male in his mid 50s with a larger body type.

Findings

The most important finding throughout this process was that the approach without on-screen static points used for guidance of exercise execution did not produce good results. Moreover, this initial design created a lot of frustrations for users, as they felt that they were making mistakes in the execution. Often times, they had to be instructed not to think of the process as something where they can make a mistake, but rather that it is the system that is not working properly. Several suggestions included things that would be impossible to implement due to the limited resources and time planned for implementation. One of these suggestions is the voice recognition system, where a user could navigate through exercises and control the process by voice commands. A more realizable suggestion that was solved differently in the initial prototype was to have the system automatically switch though exercises with a small pause after each exercise. The first prototype included a button that would have to be clicked in order to iterate to the next exercise.

The approach with detected points being colored differently from points that are still undetected was also one of the suggestions by a user. The problem here was that when a mistake in the execution of an exercise occurs, the user cannot determine where exactly the mistake was made. The new approach therefore solved also this problem.

Usability tests

Two usability tests were conducted where the execution mistakes were logged. One testing took place while the first prototype without static on-screen points was implemented. The second testing phase was conducted when the static on-screen points were used as a guidance for the user. Users were instructed to perform 3 repetitions of head tilt exercise to the left side and

Table 6.1: Motion recognition attempts while executing the "Head tilt" exercise.

User	First prototype	Second prototype
User 1	12	7
User 2	13	7

Table 6.2: Motion recognition attempts while executing the "Butterfly with arms straight" exercise.

User	First prototype	Second prototype
User 1	14	8
User 2	9	6

then three repetitions to the right side. The number of attempts was logged in order to evaluate the new concept. Table 6.1 shows the results of this test. As can be observed in the table, the new approach offers significantly higher level of accuracy, since users managed to perform 6 repetitions in 7 attempts as compared to 12 and 13 attempts in the first iteration. The same test was conducted for the "butterfly with arms straight" exercise. The results of this test can be seen in Table 6.2. As can be observed, more precise exercise execution with the on-screen points approach is confirmed.

6.2 In-situ deployment

After several usability tests and corrections in the user interface as well as in code, the system was deployed for 2 days in a home office. Person chosen as a tester is a 26 year old student who works at home for an architecture office. His tasks include drawing different plans on the computer and communicating with his manager. The system was installed beside the screen at a height of about 105 cm from the ground. The needed software was installed by the designer of the system and a short demonstration was given. A small glitch was detected when the user attempted to perform the calibration. For an unidentified reason Kinect sometimes renders the joints as if they were more distant than they really are. This problem however could not be solved, but was bypassed by simply restarting the application.

Logging was done inside the application by saving the time and date of the exercising procedure in the previously mentioned `summary.sum` file. The user was also given a small diary to write down any problems detected and was instructed to capture a fullscreen screenshot if a problem with user interface occurs. Additional information sheet was given in order to provide information if any of the instructions were not clear. A phone number of the researcher was given, and the user was also encouraged to call if any problems occur. An informal short interview with the user was conducted, where his work habits were discussed. In addition to that, several questions regarding the system were answered. Figure 6.1 and Figure 6.2 present the setup of the system in a home office where the in-situ deployment was conducted.

Figure 6.1: In-situ deployment of the system in an home office.

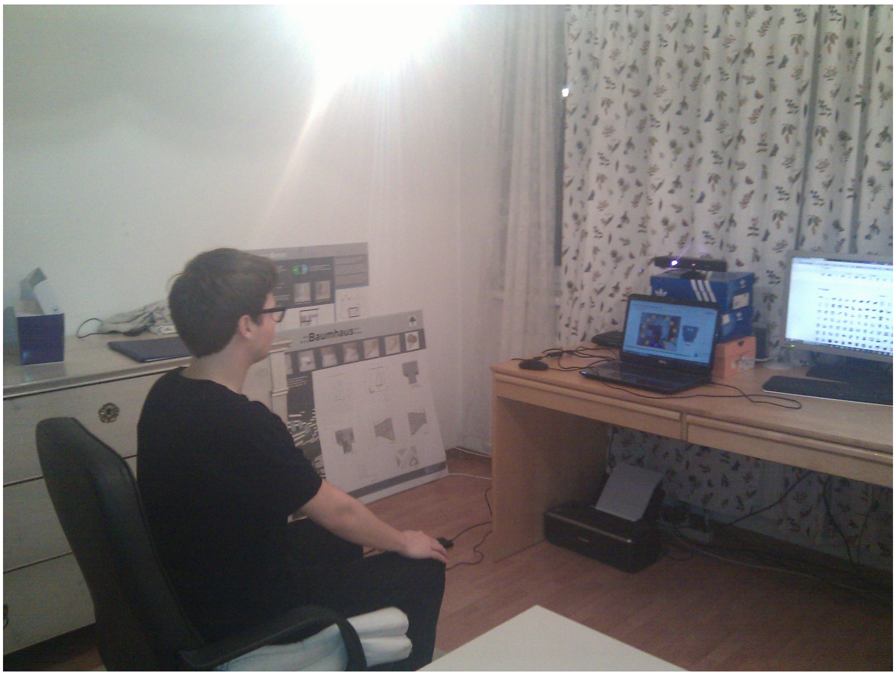


Figure 6.2: In-situ deployment of the system in an home office.

Findings

After two days of testing the user was visited in order to collect the data and the device. Before viewing the data and the diary, the user was shortly interviewed once again. Feedback was generally positive, however there were some minor problems. As one of the key problems mentioned is the exercises, which are not executed correctly if an office chair is used. Namely, side handles on the chair present a problem when performing exercises like the butterfly with arms straight. User usually therefore had to slide at the end of the chair, or even use another one that did not have side handles. Overall system did not fail, however since it has to be started manually in order to run in the background, when a computer is turned off the application is closed. This could be solved by adding the application to the "startup" folder of Windows OS.

The user also said that he tried to fake the movements and he provided proof that he succeed. The problem is that it is possible to stand closer to the device and execute exercises by making smaller motions. The solution for this problem is already implemented, since there are methods to compare the depth values in addition to X and Y coordinates. However, it would also be necessary to have this value stored for different body types beforehand so that the user cannot "cheat the system". Furthermore, some static joints are not marked in this version of the solution which enable users to do the motion in a different way. For example, the user showed that the head tilt exercise can simply be executed by moving head and neck. This could be solved by adding static joint points on screen for shoulders. Minor suggestion was to have longer timespans for the delay of the notification balloon, since sometimes he would simply not have the time for at least 2 hours to perform the exercises.

Shoulders elevation exercise however was very often not recognized. The problem here was that the movement is not easily definable since it consists of very small movements of shoulders that Kinect has troubles detecting. The cause for such behavior of the program lies in the fact that the solution was designed based on researcher's body type. In order to better adjust software to user's body type, several other steps in calibration are needed. This is explained later in the Future work chapter.

Logged data showed that the user performed the exercises 4 times during these two test days. Diary contained only short notes that the user used as a reminder for the problems explained in the previous paragraphs. Overall, the system was well received. When asked to rate the system from 1 to 10, the user graded it with a 7. He added that by changing some relatively minor details, the system would in his opinion something that he would use.

6.3 Experts evaluation

Last step of the study was a short evaluation with physiotherapists. Since the developer could not be present in the medical facility where the interviews were conducted at the beginning of the research, a Skype conference was organized with a physical medicine and rehabilitation specialist and three physiotherapists. They were shown a video of a person exercising with the system. Then a detailed explanation of the system was provided and they were all told to give some feedback.

Physiotherapists were asked if they thought that the device would be well received by people. One answer was:

> *"The system itself does look like something that we would like to see in use by our patients or everyone who excessively works on a computer. It could prevent many conditions. However, a simple problem would be that in developing countries people do not have a lot of money to begin with. The costs related to this device (Kinect) seem to be a possible problem."*

This was one of the aspects that was ignored when the initial idea was created. As shown in Table 4.1, price of the Kinect device is around 100, which is a significant amount of money. The information on whether users, or in case of office use, employers, would spend this amount in order to have such device, is missing due to the absence of the corresponding question in the interviews. Therefore it might be necessary to conduct a survey among potential users on whether they find that they would buy the device.

Apart from this comment, feedback from physiotherapists but also from the physical medicine specialist was positive. They were asked if they think that the device does guide users correctly. One therapist said the following:

> *"It seems all correct. However, due to limitations of Kinect, there is a number of important exercises that cannot be included. As can be seen in the video, the shoulders elevation exercise is not every time recognized despite being executed correctly. I am guessing that the system should be used with other things. As for example, maybe making a user stand up a little bit, walking around the room, stretching etc. Of course, everything that the system provides is also very good and could significantly decrease pain related to sedentary jobs."*

Physical medicine and rehabilitation specialist added:

> *"Secretion of endorphin and cortisol reduces the possibility of emergence consequences caused by stress, which is caused by secretion of adrenalin and noradrenalin. Moreover, pleasure is an emotion that emerges after physical work. Also, in practice we know that best exercises are the ones that are performed regularly, each day, or each 5 hours. That is the best exercise. One could make up the best exercise, but if it is not performed regularly there will not be any effect. Based on these facts the advantages of this system are obvious. It provides a tool that can remind users and guide them. This is a very important and great achievement."*

Finally, on question if he would prescribe the use of this system to someone, the physical medicine specialist replied:

> *"In developing countries, as ours, prescribing something that includes buying a computer software and a device that accompanies it seems unreasonable. Maybe in companies, when the financing is not coming from the workers' pockets there might be more possibility to really put the system in use. So, if money was not a factor,*

I would definitely prescribe following the exercises in this system in order to give people a more motivating tool for prevention of pains. And since the system already looks good, I am guessing that if improved, its capabilities might succeed even our predictions. Of course, it all depends on resources invested."

"On the other hand, prevention is the most important factor in every branch of medicine. Furthermore, in a long run, prevention is a much cheaper solution than rehabilitation or time lost due to absence. So if we take everything in consideration the proposed system is a solution that could provide the much needed prevention that is missing in this rapidly growing field of sedentary jobs."

He was told that the system does not work in the way he suggested, referring to the blockage of the computer work when exercising is required, due to the negative reception of potential end-users. He then explained:

"Well, that is a very subjective opinion. Workers on a construction site have to wear a helmet. This is a regulation by law. Each employer has to fulfill the security measures related to work. Due to excessive sitting in front of the computer in any branch of work, I expect to see new regulations regarding this in next 10-20 years. There is a concrete risk from this type of work, which increases the probability of physical pain. And each employer can insist that something becomes mandatory. Even though this is not regulated in law today, we entered the electrical age very fast, and regulations are coming late to the picture. I really think that in course of next few years, systems that make workers exercise or stand up will emerge. It is something that can be expected due to the capitalistic lifestyle that we all obey."

6.4 Discussion

Proposed system is aimed at preventing MSD-related problems by performing small exercises. Two crucial aspects taken into consideration were how to motivate people to exercise and how to provide feedback on correctness of the execution of exercises.

Despite the initial idea to ignore motivation and create a system that forces a user to perform the exercises, through interviews with potential end-users it was determined that such solution would not be acceptable. Therefore motivational aspects remained a crucial challenge throughout the design process. Suggestions from interviewed users regarding this part of the system were very similar. They saw the potential in reminding features of the system. Users claimed that an office environment can only include simple non-intrusive reminders about when the exercising has to take place. Notifications through simple pop-ups or balloons on screen were received as best possible solutions. In addition to that, several users emphasized the importance of facts or messages that are displayed to the user, which in their opinion have to be kept positive. Furthermore, it was additionally decided to include an virtual character that shows emotions and causes the user to create a relationship with it. This way the emotional empathy between the user and the character is initiated. The virtual character and notification messages were designed through talks with users during the design. The participant who used the system for 2 days gave a very positive feedback on system's notification component, as he graded it as not disturbing and non-intrusive. Further evaluation of this component is however necessary, but first reports indicate that this approach provides the right amount of motivation to exercise.

Second key challenge presented in this work was finding a suitable solution which can guarantee the correctness of movements performed during an exercise execution. Based on earlier work with Kinect, this motion sensing device was chosen as a tool for these purposes. Visual feedback was solved with static on-screen points that guide a user during the execution of an exercise. If a position of a movement is reached the points are colored differently and user can have real-time feedback on whether the current position of the involved body part is correct. All users who tested the system praised this guiding feature of the system. Physiotherapists were also very satisfied with this feature since it enables them to define exercises in detail and thoroughly check each gesture of an user. Overall satisfaction with visual feedback was very positive, due to the fact that each party involved saw advantages relevant for them. Physiotherapists saw great potential in the approach, while potential end-users found it very easy to follow the guidance points. However, calibration and Kinect mounting have to be simplified since these tasks are very time consuming in the current prototype.

Further evaluation is naturally needed in order to confirm effects that the system has on physical health. Due to limited resources and limited time available for the research, the evaluation was shortened. An in-situ deployment for a longer period of time with more users would be necessary to gain more reliable data. Other limitations were limited number of participants, as well as the fact that only one Kinect device was made available for in-situation evaluation. Implementation phase was also cut short due to time constraints posed by the thesis deadline. Next chapter describes what further improvements could be made to the system, as well as how the evaluation process could be continued.

CHAPTER 7

Future work

Since the proposed system incorporates many different functionalities and offers expansion possibilities, there is a lot of room for potential changes and additional features. Due to limited resources of this study, several suggested improvements made by interviewed users had to be ignored and only a set of most important features is implemented in the presented solution. This chapter gives a detailed look on what next steps in the development of the system would be in future work. Beside the improvements in software itself, there is also a lot of space for more detailed evaluation. This is explained also in this chapter.

The resulting proposed solution can be understood as a framework for a pain prevention system. Number of exercises, as well as any other options related to exercises are adjustable. Source code for the proposed system offers a possibility to input new exercises. This option was used in order to input the exercises created by physiotherapists after the implementation phase was over. Process of inserting new exercises is very simple. A user can press a "record" button and the recording process is started. Another button titled "Snapshot" provides the manual control of when to create a static on-screen point for selected joint. The involved joints are chosen from a list and one can differentiate between static joints and joints in movement. When the process of recording is finished the provided method for saving the exercise in a `.ges` file is called by clicking a button "Save gesture". Another possible feature would then be to import these custom exercises, and adjust the whole set of exercises, by changing the number of repetitions needed and minimum and maximum time for execution. Software can easily be expanded to include this feature in the deployed version of the system. Furthermore, even without making this feature open for public use, it brought many advantages to the system, since inserting exercises during development was not time consuming. Final deployment used in the evaluation did not include these features in order to prevent any errors since these were not tested.

A suggestion from a physiotherapist to have a possibility to track whether a user stands up and walks after a certain amount of time, has not been implemented due to limitations of the Kinect. However, solution might simply be detecting whether a user has stood up and walked away from Kinect. For this purpose, it would first be necessary to change Kinect's detection mode to standing position and then check if a user is standing. For purposes of simplifying the system, in order to stay within the frames of available resources, this feature is not included in the first version. Due to the same reason, an option to have a set of exercises in standing position is also excluded from the system. In future work, however, this feature would be integrated but only under the assumption that there is enough space in the office or home for execution of exercises.

Static on-screen points approach is suitable for detection of the most of the exercises. However, if an exercises relies on motion that is only detectable in depth values, this approach would fail. The points on screen can only be displayed in two dimensions, therefore visualizing that a movement contains movements of a joint in Z coordinate is impossible. Therefore, approach would have to be correspondingly extended to provide a visualization technique for exercises that are only observable in 3D space.

Current calibration process is a very simple procedure where a user simply moves away from the camera in until he or she is positioned correctly. This approach however makes it impossible to use the implemented methods for comparison of depth values. The taller the user, the more distant the user has to be in comparison to Kinect sensor. This causes that the distance from Kinect sensor is different for different body types. Therefore it is not possible to track the exercise in 3D space, since depth values for the same exercise are different for users with different body types. One possible solution in future work could be having several body types defined, and asking user at the initial start-up of the program to input some most important characteristics as height and weight. By defining these body types, each user would have a reference depth assigned, at which he or she would have to be positioned. In addition to that, for each exercise there would be more possible depth values that are correspondingly chosen based on the body type of the current user. Such implementation would then enable motion tracking of any kind of exercise in 3D space.

Another feature suggested by a user was the integration of voice recognition system that would enable voice control of the system. This would be useful particularly in case of the mentioned exercise motion recording. The user could also during the exercising manually instruct the system to increase the number of repetitions or skip an exercise.

Proposed solution does not have an algorithm for adjustment of the exercise program to user's needs. The system could first determine the optimal number of exercises and repetition for a particular user through several questions at the initial start-up. The system would then during time alter the exercise program by increasing the number of repetitions and/or exercises to accompany the physical health improvement of a user. Furthermore, a wish expressed by an interviewee is to have more exercise programs to choose from, and to be able to include self-defined exercises. Users could thereby even more adapt the system to their needs.

As suggested by an interviewed expert from field of physical medicine, future of this system might also be focusing on prevention of MSDs in adolescent ages. Due to intensive development of bones, sufficient physical activities are especially necessary in this age. Social networks and other features of the world wide web that are very attractive to younger population cannot be ignored. This fascination with interaction with computers is something that cannot be changed, but pain that can emerge from this can be prevented. Inclusion of exergames would then be something that would give additional motivation for this system. It is still only important that the system stays a prevention tool that is not too intrusive.

The most important aspect that has to be considered in future work is a more detailed evaluation of the system. The system should be deployed in several offices and information about usage would have to be logged in detail. It is necessary that the system is in use for several days or weeks with more users. The users would then have to be interviewed thoroughly and a questionnaire about the system could provide more objective data. Users would be asked to grade the proposed system based on different criteria. The grading from more users would be much more reliable than the single instance deployment that was conducted in this study. Furthermore, it is necessary to evaluate the motion range of a user before and after the deployment. Subjective data about satisfaction would be included in the questionnaire, however by checking the motion range of users, more reliable data about the influence of the system on physical health improvement could be gained. This motion range check should also be performed while having a physiotherapist on hand in order to incorporate his/her opinions on the improvement. Only then it can be confirmed that the system does help in prevention of MSDs caused by excessive computer work, and that the overall physical health of workers can be improved.

CHAPTER 8

Conclusions

This topic of this thesis was defining and developing a Kinect-based pain prevention system while following the UCD approach. Potential future users were incorporated in each stage of designing and development process. Initial idea came from an interview with an expert from the field of physical medicine and rehabilitation. Through repeated interviews and interviews with physiotherapists the scope of the work was defined.

Recent research indicated that MSDs are tightly related to sedentary jobs. Since computer work requires users to remain seated for most of their workday, the need for system for prevention of MSDs emerged. The systems presented in related work are aimed at people who are in special need of rehabilitation tool. They usually include a motion sensing device and a software component that can analyze the movements and provide corresponding feedback. Most of these proposed solutions take advantage of the Kinect sensor, due to its capabilities in motion recognition and its low-cost. However, a research gap was found, since none of these systems are aimed at prevention of MSDs.

Losses in companies due to the absence from work caused by MSD-related problems are well documented. Exercising is mentioned in several researches, but also by experts interviewed in this thesis, as the most important factor in physical medicine. Exercising causes physical and thereby also mental satisfaction, which enables a better performance and work results. After a literature review it was identified that there are no systems that can be used as a prevention tool available, but rather most of these are a rehabilitation tool for patients. Prevention was also mentioned by experts as a crucial factor in medical sciences in general. Therefore from the beginning of the research the main emphasis was given on prevention of MSDs. The solution proposed by a physical medicine specialist was a system that could track movements and provide feedback on correctness of exercises. Furthermore, the suggestion was to have a system that would force a user to exercise regularly. Physiotherapists were instructed therefore to create an exercise program that would be suitable for such purposes. However, due to limitations of Kinect sensor, these exercises had to be altered. This was also done in a session with the same therapists. Several interviews with potential users were also conducted, in order to get some insights in whether the system would be used and how users would design it. Main finding here was that the system must not be something that is another obligation for workers, since that might have a completely negative effect on exercising and motivation.

After the design of the system was specifically defined, the implementation process started. The system consists of Kinect sensor and accompanying software for Windows, that was programmed in Visual C# programming language. Mounting the device was presented as a first problem, where it was decided that there has to be a certain height at which the device is positioned. Implementation required constant involvement of users, who were instructed to provide critique and suggestions on the system. The first implemented approach based on simply gesture recognition produced very inconsistent and incorrect results. Users expressed their frustration with the device and the design was graded as unacceptable.

In favor of creating a gesture recognition platform that would produce better results, an approach with better visual feedback was developed. The new concept of static on-screen points that should guide the user while performing the exercises was presented to users, and it receive a very positive feedback. Several further improvements led to an overall very satisfying solution in users' opinions.

The proposed solution was tested in a controlled environment with users during the implementation. Performance of the system with static on-screen points for guidance was graded as an significantly improved solution through formative evaluation. The device was also tested over a period of 2 days in an home office. The feedback was also generally positive with some minor details concerning the actual implementation. Physiotherapists interviewed before also expressed their opinions on the system and gave positive feedback on its performance.

The conclusion is that Kinect sensor is a very powerful tool, that can be used in rehabilitation and prevention purposes. Furthermore, a pain prevention system based on Kinect, could in opinion of experts be a great step forward in fighting MSDs related to computer work and sedentary jobs. Crucial aspect when designing such tool is to integrate the users in its development. In addition to that, the findings are that visual feedback should be the focal point of the design.

However, there is a lot of space for future work on this type of a system. The thesis presents an extendable implementation of a pain prevention system that can be modified. Several features are partially implemented and extending them could be a topic of an further research. The most attention in future work on the system would have to be given on more thorough evaluation through longer deployment periods and more detailed feedback from users and physiotherapists.

List of Acronyms

2D two-dimensional

3D three-dimensional

ACL Anterior Cruciate Ligament

AMD Arbeitsmedizinischedienst der TU Wien

ECG Electrocardiogram

EEG Electroencephalography

EMG Electromyography

GIF Graphics Interchange Format

GSR Galvanic Skin Response

IR Infrared

MoCap Motion Capture System

MSD Musculoskeletal Disorders

SAD Sum of Absolute Differences

SDK Software Development Kit

UCD User centered design

VR Virtual Reality

WMP Windows Media Player

WPF Windows Presentation Foundation

WinForms Windows Forms applications

XAML Extensible Application Markup Language

List of Figures

List of Tables

List of Listings

APPENDIX A

Consent form and interview guide

Project Information and Consent Form

You are being asked to take part in a research study of how the Kinect-based exercising system for office or home use should be designed. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

Background

The main goal of this project is to design a system, which should help overcome different back, neck, shoulder, arm, elbow and hand pains that are caused by excessive sitting at the workplace. The study forms part of a Masters thesis under the supervision of Dr. Geraldine Fitzpatrick at the Vienna University of Technology.

The interviews

In this stage of the study, interviews with possible end-users, but also experts in the field of physical medicine and rehabilitation, are needed in order to get clearer set of requirements. Each session should not take more than one hour of your time if not arranged otherwise with the present researcher at the beginning of the session.

The main goal is getting new ideas and suggestions from end-users and experts from the field. All the data gained will be used to improve and expand the system in order to create a useful and fully functional prototype exemplar at the end of the project.

Since the project requires also participation in later stages of development, you might be asked to take part again in additional interviewing process. However, in the statement of consent part of this document you can decide on whether you want to be contacted later or not.

Data Recording

The interviews will be audio taped. The audio recordings will be transcribed, using pseudonyms instead of real names, and the transcript will be used for the research analysis. Use of recorded material will be strictly limited in accordance with the consent given on the consent forms.

Privacy and anonymity

Your answers will be confidential. The records of this study will be kept private. In any sort of report that is made public no information will be included that would make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records. The tape-recordings of the interview will be destroyed after the tape has been transcribed.

Participation

Taking part in this study is completely voluntary. You may skip any questions that you do not want to answer. If you decide not to take part or to skip some of the questions, it will not affect your current or future relationship with Vienna University of Technology. If you decide to take part, you are free to withdraw at any time.

Questions

The researcher conducting this study is Bruno Tunjic under the supervision of Univ. Prof. Geraldine Fitzpatrick, PhD. Please ask any questions you have now. If you have questions later, you may contact Bruno Tunjic at tunjic.bruno@gmail.com.

Statement of Consent

I have read the above information, and have received answers to any questions I asked. I consent to take part in the study and in addition to agreeing to participate, I also consent to having the interview tape-recorded.

In addition to that I wish to be contacted at later stages of the project when my opinion again might be helpful for the researcher.	YES / NO

Your name (printed): ______________________________

Your signature: ______________________________ Date: __________________

Witness name (printed): ______________________________

Witness signature: ______________________________ Date: __________________

Kinect-based Physical Pain Prevention System for Office/Home Use

Interview Guide

Time: up to 45 minutes (in cases where the interviewee can stay longer - 1 hour);
Data collection: audio record; scribe notes;
Personal notes: bring: tablet for audio recording, notebook and a pen, prepare a piece of paper and a pen also for the interviewee;

The interview should be conducted more as a conversation than an interview. The following example questions should help the researcher respond and keep the interview on the desired path. Therefore, these questions should also guide the researcher to cover all the important aspects with the interviewee. This interview guide is aimed for guiding a researcher during an interview with end-users or office workers. The questions are built based on context and should be very open ended.

General answers for some FAQs ("cheat sheet" for the researcher):

Interviewee....	**Answer:**
makes a comment that is not clear enough.	"Was there something that made you think that?"
is concerned that he/she is not helpful.	"You are giving us exactly what we need"
asks how something works.	"How do you think it works?"
has gotten entirely off question.	"Let's change gears a little bit!"

Intro: I would like to talk about your experiences with office work and exercises in general.

Aim 1: get opinions about workplace and exercising in general

- tell me about [show me, ideally] your office/work environment and working patterns?
- could you talk me through your normal workday?
  (also: where do you sit, how far is the computer, do you use special chairs, how are the input devices placed; how much sitting, do you walk, etc.)?
- what concerns if any do you have about where and how you work? and specific to your health and well being? physical and mental health?
- do you have any specific issues with [back, hands etc]?
- what strategies if any do you have to try to look after your (back, hands, etc)?

- can you talk me through what you know about the ideal workplace and ergonomic work environment and working patterns?
- do you have any suggestions or thoughts for how you (or others generally) could improve / have a better work environment / avoid problems with these pains etc.?
- can you explain me if you have any ideas on how you could exercise in order to prevent the mentioned pains?
- describe what you feel as the most rewarding exercises?
- do have any suggestions for how to use technology for such purposes?
- can you comment on motivation problems that you might see as a potential problem, please explain (what could motivate you etc.)?

Aim 2: check what opinions the interviewee has about the proposed system (explain what the idea for the system is)

- can I talk to you about some ideas and get your opinion on these; and if you have any other different ideas would be great to hear about these too
- in general, how do you feel about such a system (knowing that it will be designed in accordance to suggestions from professionals - if needed clarify who is involved)?
- if you did exercise before...what motivated you the most?...where did you exercise?...did you get bored with the exercises?...how often did you train?...did you feel any improvement?... how did you know if you were doing them right?
- what could you suggest as a motivation tool in this system (explanation that the employer can see the exercise summary, how would this affect a worker)?
- do you have any experiences with Kinect or other motion sensing devices, and what do you expect from it?
- how would you feel if while you're exercising in front of the computer someone sees you at the workplace?
- would you be willing to rearrange the furniture in order to use such device (not every time, just once in order to fit in the Kinect)?
- how would you place the Kinect (guidance important because there is only a limited number of positions that will be available)?
- could you imagine having a virtual character or some kind of reward for a great workout?
- how would you like to be notified when you should start exercising (suggestions, if not - explain that the notification can simply be on the computer - visual or auditory)? (tell me more about it!)
- how do you want to receive the feedback on whether the exercise is performed correctly (describe what you would ideally like to see)?
- how would you ideally design this device?
- other suggestions, complaints, feedback...

APPENDIX B

Interview summary table

Table B.1: Non-expert interviews summary table.

Participant profile	Interview date and duration	Workplace, routines, concerns and strategies	Suggestions / opinions on the system
Mid 40s, female, researcher at Vienna University of Technology	20.08.2013 56:02	Shared office and very limited space. She explains that people mostly do not go out of the office, only sometimes to get some food. She has concerns that the sitting position is causing her pain. However, she has different strategies to overcome these problems. She prefers walking as much as she can when going home or to work. She describes herself as an athlete and therefore she is very aware of the dangers of excessive sitting and therefore she tries preventing this as much as she can.	The participant suggest the use of virtual characters, and facts about human body to help overcome motivation problems. She immediately reviewed the initial idea of having a summary as unacceptable, since she feels that it would be just another portion of stress. She emphasized that the computer blocking feature is not something that she would support.
Mid 20s, male, programmer	23.08.2013 23:44	The participant explained that his work demands very excessive sitting, but that he simply does not have other option. They do not have tables with adjustable height, and only way to avoid sitting is to work at home for a day, when he can lie on his bed and work in other positions. He has been in the emergency room already once to receive an injection to help him with lower back pain. He says that he knows that his problem is that he does not exercise at all, and that this contributes to the problems in many ways.	Since this participant was one of the two interviewees that were not informed about the features or structure of the proposed system, the talk did not include any information that can directly be applied to the system. The interviewee did mention that he would use a mobile or desktop application that would remind him when he should take a break, since he often works for 2-3 hours without pauses. The talk mostly revolved around the fact that he is not active and should be, and that technology could help in motivation to be more physically active.

Mid 20s, architectural designer	24.08.2013 27:08	The designer works at home and spends most of his working hours sitting in front of a desktop computer. Since he is not in an office he explains that he personally stands up whenever he feels stiff. If he notices that he has been sitting for a long time, he simply takes a break and walks around his house a little bit. However, he explains that this is only the case at his job since he can work remotely from home. His working environment is not in his opinion in compliance with ergonomic suggestions from experts.	Since the interviewee was the second participant not informed about the proposed system, this topic was only barely touched. After a short explanation what the system might look like, the participant explained that he could imagine himself working out a little bit at home, but emphasized the problem of motivation. In his opinion there is no actual way to make someone exercise, because he did try to follow an exercise program but he dropped out very fast.
Mid 40s, researcher and a lecturer at Vienna University of Technology	26.08.2013 31:27	This participant presented a high expertise in ergonomics at workplace and explained that he knows a lot about it and therefore he keeps himself in movement the most of the time when he can. He practices different martial arts and in his opinion this is something that helps him a lot in prevention of work-related body pains.	The interviewee did not know how the technology could be put to use in sense of prevention of MSD-related problems. Since he knew how the proposed system should be designed, he tried to emphasize that he finds it impossible to accurately track movements and give feedback. However, in his opinion if tracking problems could be solved, correct feedback could be given thereby telling the user that he or she is doing the exercise correctly. This way, every user would get to know his/her body better. And in his opinion, getting to know one-self's body could be enough to motivate a user.

Table B.2: Expert interviews summary table.

Participant(s) profile(s)	Interview date and duration	Problems from medical point of view	Suggestions / opinions on the system
Male, 53, physical medicine and rehabilitation specialist	05.05.2013 not recorded	A detailed introduction to MSDs and what causes them was provided during this talk. The specialist explained how sitting affects posture and muscle tenderness, and how physical therapy helps in rehabilitation of such problems. Due to interest for this system, the specialist proposed to become a contact person for the researcher. Further recruitment of experts was provided by this interviewee.	The initial idea of proposed system was determined during this talk. A system that blocks work on computer and demands from a user to perform a number of short exercises was proposed. He mentioned problems of adolescents spending too much time on the computer. In addition to that, from his experience he said that physical inactivity is always a problem, and very often only 5 minutes of exercising a day could help prevent many MSD-related problems.
Male, 49, occupational medicine specialist	25.07.2013 28:20	The participant explained how ergonomics at the workplace can effect worker's health. Several working conditions were discussed, as well as regulations regarding work duration.	The expert emphasized that the proposed system would have to be designed in compliance with physiotherapists and experts in general, in order to be really effective. The main conclusion was that job conditions regarding ergonomics and space available should be ignored, since there are regulations that have to be fulfilled.
Female, late 20s, physiotherapist. Male, mid 30s, physiotherapist.	25.07.2013 27:08	In this group talk with 2 physiotherapists, several topics regarding physical therapy and rehabilitation were discussed. The importance of exercising and staying physically active was once again one of the main topics.	When the proposed system was presented, they had a lot of questions concerning the motion tracking and overall integration with the computer. An exercise program without taking Kinect's limitations was created. Interviewees confirmed that by correct exercising 5-10 minutes per day, many MSD related problems could be avoided. Their confirmation that the project could have a good result, was a great motivation for the researcher.

Female, late 20s, physiotherapist. Male, mid 30s, physiotherapist.	28.09.2013 17:55	The limitations of motion tracking component were presented and the experts were asked to explain if it is still possible to create an exercise program that would be suitable for such system. From medical point of view, they confirmed that there are till enough motions that can incorporated in the system, and that it still would be very helpful in prevention.	The participants suggested having an exercise program integrated in the system, that gradually increases the number of repetitions or even adds new exercises. Conclusion was once again that they would support this system.

APPENDIX C

Interview raw data analysis

C.1 Example of non-expert interview

Researcher: First thing is, I should just really hear about your office, routines and stuff like that. So just tell me about the environment and working patterns in your office. I saw that in your office there are three people that also are an aspect interesting for me.

Participant: Yes, yes, we don't have so much office space so we share offices; you've probably seen all the offices here of my colleagues, none of us except for our boss, have an office for ourselves. One of the guys now has, but it is a small room, so the rest of us share. We have 2-3 colleagues per room, and there are 3 workstations in my room. We work for 32 hours each, the two of us, and a third one comes every day for a couple of hours. He is usually in the workshop but comes regularly to check his mail. When he is with us, the two of us, the colleague and I, are pretty much together desk-bound. Sometimes we may work somewhere else for a few hours, but we are predominately at the desk. This is an office where we don't... it is hard to see where would there be an easy place to hold spontaneous the meetings, since this is a meeting room, and a kitchen and a multifunctional room, and is used quite bit, so meetings sometimes also take place in offices. And if it starts to take a little bit longer, we try to take the meeting into the library, of course if it is used, we have hallway discussions. It depends, we are all pretty much resistant to any kinds of interruptions and it doesn't really bother us if one colleague is having a conversation with the other. Sometimes also you need peace and write to write things down. We've learned to see in each other's behavior when we need peace and quiet and when not, when is it OK to hold conversations with others.

Researcher: So basically a lot of time is spent in the office? Even though meetings are for short time somewhere else, you are there pretty much the whole day.

Participant: Yes, and many of us are poor at taking breaks. That may be interesting for you. We are not good at taking lunch breaks. It is mostly like, once you're in your don't go out at all. I go out for my lunch dates, if I meet somebody or organize something. But it is mostly that I am here and I don't go out the whole day.

Researcher: And how is it, you work also 40 hours per week?

Participant: I work 32 hours.

(Short interlude)

Participant: Some people do get out you know, out of the office and just walk a little bit. I would need it myself, more of that.

Researcher: So you feel the need to make some kind of breaks or at least stand up a little bit, but you don't?

Participant: Yeah, I am an athlete, or I used to be. AN it is therefore very difficult for me to sit through a day, very difficult. But I do it. It is also a part of our work culture. That's how our work has been shaped. It is like that, and that we don't have lunch breaks is also bad.

Researcher: Usually you order some food or something like that?

Participant: Or you bring your own food or whatever. People do walk out to get some food, they might go and buy something, and then they might buy something for the others too. But that we all actually leave the building, that doesn't happen. So it's one or two colleagues a day, here that get out of the house.

Researcher: You have actually already answered my next question, or my next note. I was about to ask about the normal workday and how it all works. You're in the office the most of the time...

Participant: Yes, mostly in the office, and the airing in the office is bad, I don't have any idea why, but maybe it's because we have, no, actually we do have windows on two sides but the problem is that the on one side we have this courtyard so there is very little fresh air coming from there, so... Today is a really lovely day; I had a little breeze come in through the window, so that's great.

Researcher: There is no air conditioning here or?

Participant: No we don't have any, and it gets really hot during the hot days. So many of us decided that it would be more efficient to work at home. Because it got so hot here in the office. I've spent a couple of days working at home, it was much better that way, I mean it was really a reasonable and good decision to do that, because it was unbearable here. Especially my window, because the afternoon sun can directly beam into my workspace.
I don't know if this is important to you but I always choose the way of coming to work in the morning so that I can walk a bit. So even if I take the public transportation, or the bike, I always make sure to walk for a kilometer at least, so I either walk to the u-bahn from home and then walk a little bit extra from the station. I don't... I choose my way so that I am definitely fresh when I come to work. Fresh in the way that I have some fresh air in my lungs and my head and fresh thoughts in my head, and some minimal exercise, you can't call it exercise, when you walk to work, but it's better than getting straight to work. So that's my small strategy in the mornings just to be able to kind of come in a good mood and having, you know, fresh ideas in my head. And the other thing that I do when I choose my ways, I can choose between so many ways of getting home, in means of transportation, its great where I live you know, I can go by tram take a u-bahn, a bus, bike, I can walk almost. Of course it would take more time (to walk), but I always make sure that I have this buffer time also when I go home, to make sure I have the chance to walk some, a bit, before I get there.

Researcher: I think that is great, but I think there are a lot of people of don't actually do that either.

Participant: I've also had times when I had to rush back and forth and that doesn't do anyone good. So I started building this buffer times.

Researcher: Okay, that's what's interesting for me, are there any specific concerns during a workday. Do you feel pain? I mean physically or mentally, do you feel sometimes different? Do you feel some kind of concern sometimes?

Participant: About my health?

Researcher: Yes, your health or well-being. I mean you already said that you are an athlete so maybe it's a bit different now...

Participant: Well I used to be, but I took a year off for sabbatical, and when I came back to work I couldn't sit at all. It was really difficult to sit by my desk for the entire day. And I started to get a lot of pain and aches in my body, so I had to change the chair for a while. So I got one of those chairs so that I can kneel, instead of being seated in a chair. That's when I really realized how much I've done physically, because I had been running a lot, and being very active physically in the year when I was on my sabbatical. And I realized that there was such a great difference how I spent my time in the sabbatical and in the normal work time. And I actually had physical pains from sitting, so I had to stand up, also I was working partially standing up, because it was just impossible for me to sit down and work on these documents that I always work on. I mean the content was fine, I liked what I was working on, and it was very exciting to work on the things after taking a break. However, physically a great challenge. Because it just was so unusual to be seated six to eight hours a day. And that's where my body really said this is not good for me. Now I am back to, I am talking about eight months later, and now I am used to being seated again. But I actually don't quite like the feeling, I think that I should not be used to sitting so much. This is a concern of mine yeah. And now in the past couple of months I haven't been able to run so much, I am used to running, so you know I feel that you know I need to get back into this routine again. I find that very relaxing and very good for me. I used to be running up to 2 hours you know, get some fresh ideas in your head. You also lose your ideas while running, but that's also the part of the process, so you just have a really nice way of experiencing the city for instance. I am actually not running that much in the city, but I am really starting to like Vienna, during these long runs, because I discovered Prater and nature and all of this. And the city is really great for exercise. But I also realized that this sitting down cannot be doing us so good. Because I really had withdrawal symptoms too, from the impossibility to move around a lot.

Researcher: Especially what you said, if you get used to it, it's probably not good. If you get used to sitting so many hours it's probably not a good sign. Something is probably wrong.

Participant: I have never felt very good sitting down for a long time, but this was in particular difficult time to getting used to be seated so... yeah. Being still is something... Children would not choose sit down for six hours. If you ask them they would not do that. They would work intense on a drawing or something like that but after that they get up and do something else. Concentration is of course dependent on the age, they can be interested in something, but even so they change their postures far more often than we do.

Researcher: And their body can take much more than ours.

Participant: But they know that it is important to keep moving.

Researcher: Are there any specific pains that you have been experiencing form time to time?

Participant: I had a lot of back pains and I was not feeling very well. It was probably a combination of many things. It could be that these pains were not relegated just to sitting, but also to something that something didn't work well. I had actually gone through a physical therapy that helped a lot in long term. It could just be that something was not physiologically not quite correctly in place. Because once I got through that therapy the pain was gone. It was probably something that should've been taken care of before and did not have anything to do with posture work or similar. It might have been intensified with it though.

Researcher: OK. Are there any strategies that you personally have to avoid those pains? To you stand up from time to time?

Participant: I do. And I do my sports that are a very important strategy for me. Or these walks from and to work. We can all do this if we manage our time correctly. If you have some buffer time for yourself, that is very important. I actually have started to go and pick up some food or arrange these lunch dates with colleagues. Not every day, but there is this thing about leaving that helps. I was impressed once by this manager in Finland, she was in charge of many employees. And she said that when she sees her employees getting stuck with ideas, she gives them a ticket for the public transportation. And when they have this feeling that they cleared their had, and I was very impressed with this. She used to say it's time to change the scenery a little bit and the people could clear their thoughts. I think this helps definitely mentally but also physically. So sometimes I change the scenery a little bit. I also sometimes change the working atmosphere for myself and I sometimes go somewhere else, a coffee chop or something, just to change the environment. So I try to change scenery for myself. This way mi thought might be better.

Researcher: Do you ever find yourself stretching or exercising? `

Participant: Yes, I do. This small stretching and checking if everything is functioning. Yes of course.

Researcher: So you have any knowledge about heat would be an ideally ergonomically workplace? Would you prefer to be alone in the office etc.?

Participant: Yes. I would like to have my own office. I always did until I came to Vienna and this office. This is not very often the case in Austria. It takes a lot to; it was a big process to get used to this sharing. Because you have to share telephone calls of your colleagues, interviews that they do on telephone. To be honest I worked in a newspaper, where telephones were singing, TV and radio running, editors coming in, interrupting. So it's not that I never worked in such conditions, but there are ways that time to block that, by putting earphone or similar. Here however I haven't taken that approach, which I could maybe try. We have a lot of factors that influence your work, a lot of background noise. But I would prefer an office for myself, to have less office. I would love to have a desk where you could change the height, so that you can decide to work standing up if you want, or half a day standing half sitting. That would be nice to have. We can't actually always adjust our seats correctly, so I am not always sure if I am sitting correctly. We do have wrist pains and similar, and that might be that my hands are not at the optimal level, when I am typing. I would probably like to have an office for myself. One important thing is that you could decorate it yourself. Or if you want to take of your shoes. And just have this bodily freedom to position yourself differently. That would be really nice. Putting your feet on the desk, this is something that I would never do with colleagues in my office. But I think this would be something that I would do if I was alone. And maybe have a chair when I am really tired so that I can close my eyes for 5 seconds, and distance myself from the situation for a little bit. I could do it without someone thinking is I doing anything. That could contribute to possibly enhanced productivity, or having your own thought. This would be very nice.

Researcher: That is basically what everyone would say probably. I personally also cannot work like that. I really can imagine that it is not that cozy if you have more people.

Participant: On the other hand, I must say that I learned a lot from my colleague. We are almost as married couple, and we bath tolerating so much of each other. And we can read each other, and we can see if someone is in the mood or not. I've gotten to know someone very well, although we aren't in contact in our personal life. We are sometimes as an old married couple.

Researcher: How would you describe how you could motivate yourself for something more than stretching, or if the technology could be something that could help there? Virtual characters or?

Participant: It might not be that bad. If this avatar on screen would tell me "excuse me, you turned your computer an hour and a half age, it seems as you have been working non-stop. Do you think that you could use a break, or you might need a break later"? Also what's really important is to drink water during the day. And it's very important to remind people, because we can dehydrate. There could also be for example a little bottle of water on screen that should remind you drink water or something like that. You know just kind of reminding you to drink water, because we all drink a lot of water and yeah. You know something like this. Something that pops up sometimes that says "stand up a little bit" etc. It might also be useful to have lunch reminders, since we all have bad eating habits. Avatar could just give an hint to exercise. Not much just a little bit. Get up and stretch, stretch your arms and so on. But it certainly could be helpful an useful, and fun. But in my guess it has to be in some level that you don't feel like being patronized now. If you start having this feeling that this system is patronizing you, you would say "No thanks" and get rid of it.

Researcher: Of course, whenever you have to do something you don't want to do it.

Participant: And yeah. There might be something fun it.

(Short introduction of the system)
(Summary included & explanation that information storing could be interesting for employers)

Participant: Uh God. When you say that we all get nervous.

Researcher: Well because they could somehow take care of their workers, and recommend that they should exercise.

Participant: Well yeah, but that's exactly when we get to the patronizing effect. It gets very tricky there. Because most of us would then think "Oh no, now I have to on top of the work I have to do, there's another control thing, are they going to control me how much time I spend in front of the screen? Is my freedom going to be cutting in even smaller portions than now? "So this is something that I would not approve of. I think that an important thing is what could be motivating or I would be facts. For instance, I get the information on screen that "sitting in front of the screen for 3 hours causes these and these and these things. You could interrupt this process by every 45 minutes standing up. Taking few steps, stretch arms and neck, and this would reduce the possibility that your muscles will determinate today". So something like that, this kind of information where I get confronted with the fact, that my job is mostly sedentary and now I get reminded that this is not good for you. If I am confronted with this all, but then I would get the information that "For one minute exercising now you will prevent these ... harms later". So I think that this could work. But as soon as it becomes a tool that connect data about me and my working out, and provide this data to my employer, I think that most of us would think that this is counterproductive. And it becomes part of the stress. So I wouldn't do the exercises for myself, but it would become instrumental. Because I have to do it, because my boss will see that I didn't do the exercises, what am I going to do? But if you see an improvement, in the office atmosphere and people are better in work, and then the boss could say "Hey this tool does help". This quantification of us is fun for you, but as soon as you share with others. It becomes instrumental, because someone I know sends me this kind of quantified data about sports activity. I think to myself why you want me to see this. Do want praise of? What function does this quantified data have? I would then need to know what this data is needed. It would interest me. I have a GPS watch and I follow my running and its fun. I like having that kind of data for myself, but I would not like to share that anywhere. It's just for me.

Researcher: This part is where this idea could be problematic, also when I talked to my supervisor. Because people don't want more control.

Participant: Less control, and more self-control. For me, to control myself is good, but as soon as this tool becomes a control tool than it might not be for me anymore. I would also like to have more flexibility; I would like to have the opportunity to choose how often the tool gives me the notification. Is it 90 minutes, or maybe even random, could be fun. It pop ups not at 10:30 for example, but at 10:37. If it becomes too predictable, it might be something that I expect all the time. It might not suit my routine at that point. If it does every 15 minutes, that would be too much.

Researcher: It would only be few times a day. I had a talk with a physical medicine specialist and some other therapists that actually showed me the exercise that might be useful in those cases. And they all say that it can last for 5 minute, and if you do it 2-3 times a day it could have enough effect. From practice they think that it could be helpful.
There are some specific things about Kinect. It should be setup on the table and take up some space; I've seen you don't have that much office space. You would have to step away from the device also.

Participant: Yeah, I don't have that much space to pull back.

Researcher: Yeah, and so it wouldn't really be possible for Kinect to see your full body. Those some of the things that are going to be challenging. But basically what would you say, without all this, without all the limitations. There is an exercising program that works in a similar way. Would you say that it's too intrusive?

Participant: No I don't think so. If it gives me some facts... It could also be tailor-made for me. Knowing that I have some problems. There are people with severe back problems. I think this kind of tied up with knowledge could be in the beginning and it would say that "If you do these and these things you can prevent these things later".

Researcher: I like the idea, to have some short facts to motivate you.

Participant: Yes, and like you said "short". It could just be a little bubble you know a character, because we don't want to read even more. It could just say "This piece of information could interest you...“ You could have some questions when you start the system to adapt it to its user based on what the concerns are.

Researcher: Maybe choose the exercises that you want?

Participant: Yeah, exactly. It could even ask you do you feel like doing this today. Then OK, here are your three exercises for today. Or how are your arms today? Could you use some stretching? Here are then a few exercises that could help you improve your circulation. I am hypothesizing what could be interesting.

Researcher: We already mentioned it, but this kind of notifying and feedback are what are integral parts of this system. And somewhere in the middle is a set of exercises. What would you think what could be the feedback? If you have any ideas?

Participant: I think I might not be so interested in myself if my neck motion was less good than yesterday. That would not be interseting for me. However this feedback would be nice "You completed now the whole thing, and now it could be that in the next minutes you feel that blood flows better" or something liek that. I think that mindfulness people have good things like this. They say for example "Now you could thank yourself a little bit". So the feedback could be that you did something for yourself, be nice to yourself or something likes that. It doesn't have to be quantified but simple qualitative feedback. Think of the fact that you did something good to yourself, for example.

Researcher: And during the exercises there would have to be some kind of feedback, when your stretch for example, the system should tell you if you are doing it right. Would it be useful to see somehow a character, yourself or something?

Participant: Well it could be a character; it doesn't have to be you. He could simply do the same thing and then it could give you little feedbacks and guidance. It could also say "You reached the good position, hold it for a while etc."

Researcher: That's all what I almost expected; other people that I had informal talks with had similar suggestions.
Initial idea was also to stop work completely. It would make you exercise, and not ask you if you want to exercise. But I am guessing that this is not something that is too much, if it says "Now you have to exercise".

Participant: Yeah, it should not take command over me. It should be my pal, and not something that tells me what to do.

Researcher: That's probably the most important conclusion from this interview, since I was also concerned that this wouldn't be acceptable. Because the initial idea was to stop the work completely.

Participant: I would like to have more flexibility. It should be possible to choose maybe the level of exercises. My stretching comes from the time when I did sports, and I don't know what people may have come up with in recent years. I can do my stretching that I did long time ago when I was active in sports. So I could say, "I want to do my sport exercises", and then they would look different from my "I would like to do my gentle desktop exercises". So that I can do variety of things.

Researcher: I don't know in which direction it will go at the end, and we'll see what will be accepted by people. Basically I think that it will be something more optional, and not something you have to do. And with some kind of interesting interface and everything. Also, are computers here in your office running on Windows or Mac OS?

Participant: No, we are on Windows. Are you programming for Mac or?

Researcher: No, I am asking because in the other building they have Mac OS mostly installed. It will probably be implemented for use with Windows, because of the freely available Windows drivers for Kinect.

Participant: So if you need test persons you can come here, I would be interested to try it out. I am critical in a way that I will say if something really doesn't work. Might be good feedback for you.

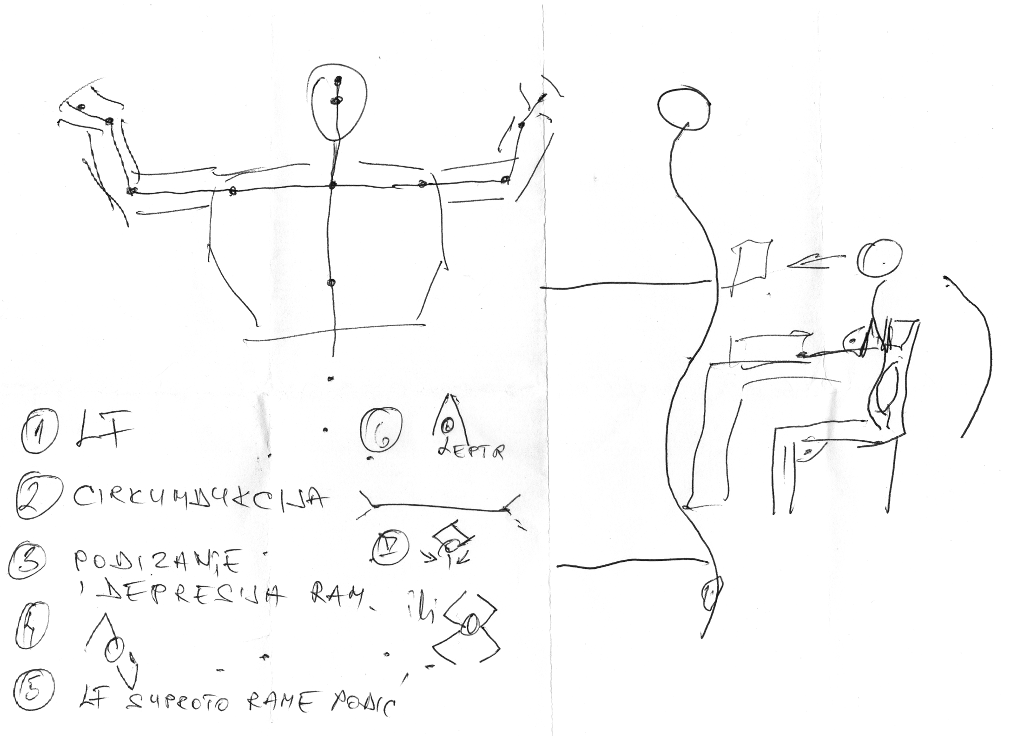
Researcher: Great, thank you. As you could've read in the consent form there will be a short in-situation evaluation. Probably couple of days. But I might also then contact you if you are here at the moment and if you have the time.

Participant: Yes, I would love to see that.

Researcher: That is it then what I needed. Thank you a lot.

Participant: No problem, thank you.

C.2 Examples of notes taken during interviews with experts



BILJEŠKE/NOTES **DATUM/DATE**

7:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00

- DUGO ISTI POLOŽAJ (REDUK. VENSKA KRV SE NE OKSIDIRA) — CEBA

- SYNDROM CERVICALE
- TORAKALNI SYNDROM
- LUMBOSAKRALNI SINDROM

- SINDROM RUKA-ŠAKA / KOMPJ. ŠAKA

- FILOGENETSKI NIJE TAKO ZAMIŠLJENO

- REGENERATIVNE SPOS. SLABE S VREMENOM
35:00 – ŠTA SU SVE PROBLEMI

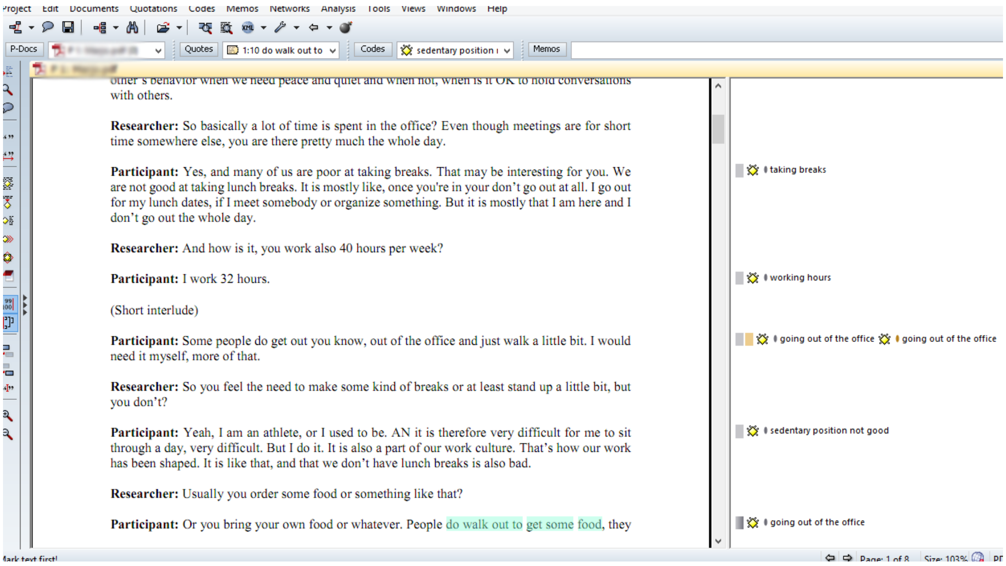
- PREVENCIJA BITNA ALI I KOD STARIH
(ne može se bas totalno prevencija)

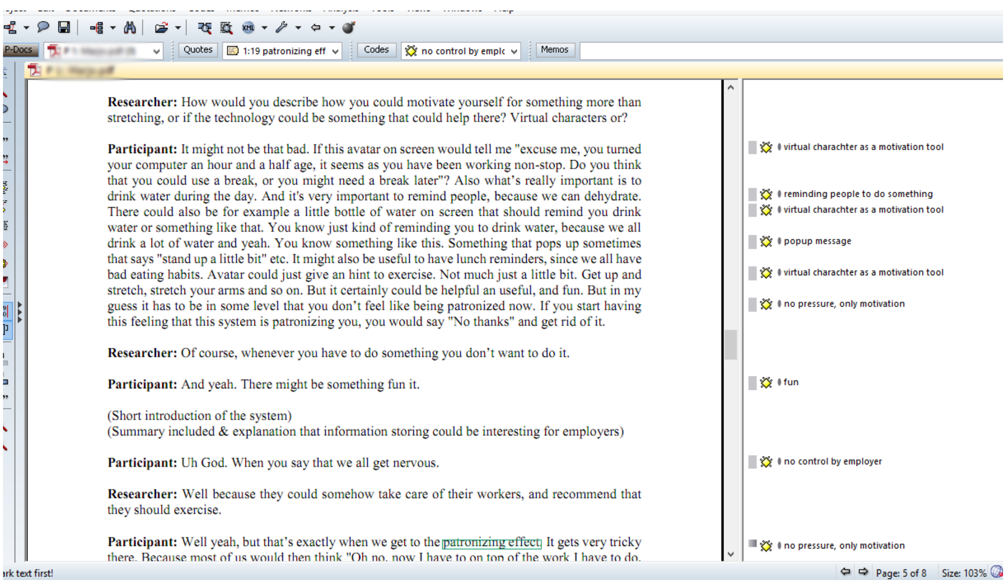
- pokretljivost stuba
- očuvat tonus mišića
- kod vježbanja luče se endorfini / enkefalin
 – lično jer zadovoljstvo

- ne mora bit dugo, bolje ikako nego nikako
- svaka vježba 3 ~~x~~ 5 x
- moraju bit uporno

BERLIN-CHEMIE MENARINI

C.3 Examples of data analysis in Atlas.ti software





APPENDIX D

Code

Listing D.1: Exercise.cs

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using Microsoft.Kinect;
using KinectPreventionSystem.Commands;
using KinectPreventionSystem.Entities;

namespace KinectPreventionSystem
{
    public class Exercise
    {

        public String name { get; set; }
        public int repetitions { get; set; }
        public int number { get; set; }
        public String description { get; set; }
        public List<JointType> involvedJoints { set; get; }
        public List <IGesture> gestures { get; set; }
        public int duration { get; set; }
        public String durationFormatted { get; set; }
        public String longDescription { get; set; }
        public Boolean exerciseStarted { get; set; }

        public Exercise(int number, String name, int repetitions, String
            description)
        {
            this.number = number;
            this.name = name;
            this.repetitions = repetitions;
            this.description = description;
            involvedJoints = new List<JointType>();
            gestures = new List<IGesture>();
        }

        public void CalculateDuration()
        {
            int dur = 0;
            foreach (IGesture g in gestures)
                if (dur < g.gestureMaxDuration)
                    dur = g.gestureMaxDuration;
            this.duration = dur * repetitions;
            durationFormatted = Converter.ConvertToMMSS(duration);
        }

        public void clearAll()
        {
            involvedJoints.Clear();
            gestures.Clear();
        }

        public void resetGestures()
        {
            foreach (IGesture g in gestures)
            {
                g.gestureDetected = false;
                g.resetPoints();
```

```
            }
            exerciseStarted = false;
        }

        public void startExercise()
        {
            exerciseStarted = true;
            foreach (IGesture g in gestures)
            {
                g.gestureStarted = true;
                g.startTime = DateTime.Now;
            }
        }

    }
}
```

Listing D.2: Point3D.cs

```
 using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace KinectPreventionSystem
{
    public class Point3D
    {
        public int X { get; set; }
        public int Y { get; set; }
        public int Z { get; set; }
        public Boolean Detected { get; set; }

        public Point3D(int X, int Y, int Z)
        {
            this.X = X;
            this.Y = Y;
            this.Z = Z;
        }

        public int compareToXY(Point3D p1)
        {
            int sad = Math.Abs(this.X - p1.X) + Math.Abs(this.Y - p1.Y);
            return sad;
        }

        public int compareToXYZ(Point3D p1)
        {
            int sad = Math.Abs(this.X - p1.X) + Math.Abs(this.Y - p1.Y) + Math.Abs
                (this.Z - p1.Z);
            return sad;
        }

        public int compareToX(Point3D p1)
        {
            int sad = Math.Abs(this.X - p1.X);
```

```
            return sad;
        }

        public int compareToY(Point3D p1)
        {
            int sad = Math.Abs(this.Y - p1.Y);
            return sad;
        }

        public int compareToZ(Point3D p1)
        {
            int sad = Math.Abs(this.Z - p1.Z);
            return sad;
        }

        public String toString()
        {
            return X + " " + Y + " " + Z;
        }
    }
}
```

Listing D.3: IGesture.cs

```
using Microsoft.Kinect;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace KinectPreventionSystem.Entities
{
    public interface IGesture
    {

        Point3D currentPoint { get; set; }
        int gestureNumber { get; set; }
        String gestureName { get; set; }
        String dimensions { get; set; }
        int errorThresholdMax { get; set; }
        JointType jointType { get; set; }
        double brushSize { get; set; }
        Boolean gestureDetected { get; set; }
        String detectionStatus { get; set; }
        int gestureMaxDuration { get; set; }
        Boolean maxDurationExceeded { get; set; }
        Boolean gestureStarted { get; set; }
        DateTime startTime { get; set;}

        void loadGestureFromFile();
        void detectMotion(Point3D point);
        void takeSnapshot();
        void saveGestureToFile();
        void clearAll();
        int getNumberOfPoints();
        Point3D getOnePoint(int index);
        void setStartingPoint(int index);
```

```
        void resetPoints();

    }
}
```

Listing D.4: JointGesture.cs

```
using KinectPreventionSystem.Entities;
using Microsoft.Kinect;
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace KinectPreventionSystem.GestureRecognition
{
    public class JointGesture : AbstractGesture
    {

        public List<Point3D> points { get; set; }
        private int currentIndex = 0;
        public int gestureMinDuration { get; set; }
        public int StartingPoint { get; set; }
        private DateTime startTime;

        public JointGesture(int gestureNumber, String gestureName, int
            gestureDuration, JointType jointType,
            int errorThreshold) : base(gestureNumber, gestureName, gestureDuration,
                jointType, errorThreshold)
        {
            points = new List<Point3D>();
            this.gestureMaxDuration = gestureDuration;
            this.StartingPoint = 1;
        }

        public override int getNumberOfPoints()
        {
            return points.Count();
        }

        public override Point3D getOnePoint(int index)
        {
            return points.ElementAt(index);
        }

        public override void loadGestureFromFile()
        {
            try
            {
                String line;
                using (System.IO.StreamReader reader = new System.IO.StreamReader(
                    "Gestures/" + gestureName + ".ges"))
                {
                    while ((line = reader.ReadLine()) != null)
                    {
                        String[] numbers = line.Split(' ');
```

```
                        Point3D pnt = new Point3D(Convert.ToInt32(numbers[0]), Convert.ToInt32(numbers[1]),
                            Convert.ToInt32(numbers[2]));
                        points.Add(pnt);
                    }
                }
            }
            catch (Exception ex)
            {
                Debug.WriteLine(ex.ToString());
            }
        }

        public override void detectMotion(Point3D point)
        {
            String ret = "";
            int calculatedError = 0;

            if (dimensions.Equals("xy")) calculatedError = point.compareToXY(points.ElementAt(currentIndex));
            else if (dimensions.Equals("x")) calculatedError = point.compareToX(points.ElementAt(currentIndex));
            else if (dimensions.Equals("y")) calculatedError = point.compareToY(points.ElementAt(currentIndex));
            else if (dimensions.Equals("z")) calculatedError = point.compareToZ(points.ElementAt(currentIndex));
            else calculatedError = point.compareToXYZ(points.ElementAt(currentIndex));

            if (calculatedError < errorThresholdMax)
            {
                ret = "Point " + currentIndex + " detected!";
                points.ElementAt(currentIndex).Detected = true;
                if (currentIndex != 0)
                    currentIndex++;
            }
            else
            {
                ret = "Point not detected!";
                if (currentIndex == 0 && points.ElementAt(currentIndex).Detected)
                {
                    startTime = DateTime.Now;
                    gestureStarted = true;
                    currentIndex++;
                }
            }

            if (gestureStarted && (DateTime.Now > startTime + TimeSpan.FromMilliseconds(gestureMaxDuration)))
            {
                resetPoints();
                ret = gestureNumber + "-false";
            }

            if (currentIndex == points.Count())
            {
                ret = gestureNumber + "-true";
                gestureDetected = true;
                currentIndex = 0;
                gestureStarted = false;
```

```
            }
            detectionStatus = ret;
        }

        public override void takeSnapshot()
        {
            points.Add(currentPoint);
        }

        public override void saveGestureToFile()
        {
            using (System.IO.StreamWriter file = new System.IO.StreamWriter("
                Gestures/" + gestureName + ".ges"))
            {
                foreach (Point3D point in points)
                {
                    String line = point.X + " " + point.Y + " " + point.Z;
                    file.WriteLine(line);
                }
            }
        }

        public override void setStartingPoint(int index)
        {
            StartingPoint = index;
        }

        public override void clearAll()
        {
            points.Clear();
        }

        public override void resetPoints()
        {
            currentIndex = 0;
            gestureStarted = false;
            gestureDetected = false;
            maxDurationExceeded = false;
            foreach (Point3D p in points)
                p.Detected = false;
        }

    }
}
```

Listing D.5: StaticJoint.cs

```
using KinectPreventionSystem.Entities;
using Microsoft.Kinect;
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace KinectPreventionSystem.GestureRecognition
{
```

```
public class StaticJoint : AbstractGesture
{

    private Point3D pointToCompare;

    public StaticJoint(int gestureNumber, String gestureName, int
        gestureDuration, JointType jointType,
        int errorThreshold)
        : base(gestureNumber, gestureName, gestureDuration, jointType,
            errorThreshold)
    {
        this.maxDurationExceeded = false;
    }

    public override void loadGestureFromFile()
    {
        try
        {
            String line;
            using (System.IO.StreamReader reader = new System.IO.StreamReader(
                "Gestures/" + gestureName + ".ges"))
            {
                line = reader.ReadLine();
                String[] numbers = line.Split(' ');
                Point3D pnt = new Point3D(Convert.ToInt32(numbers[0]), Convert
                    .ToInt32(numbers[1]),
                    Convert.ToInt32(numbers[2]));
                pointToCompare = pnt;
            }
        }
        catch (Exception ex)
        {
            Debug.WriteLine(ex.ToString());
        }
    }

    public override void detectMotion(Point3D point)
    {
        String ret = "";
        int calculatedError = 0;

        if (dimensions.Equals("xy")) calculatedError = point.compareToXY(
            pointToCompare);
        else if (dimensions.Equals("x")) calculatedError = point.compareToX(
            pointToCompare);
        else if (dimensions.Equals("y")) calculatedError = point.compareToY(
            pointToCompare);
        else if (dimensions.Equals("z")) calculatedError = point.compareToZ(
            pointToCompare);
        else calculatedError = point.compareToXYZ(pointToCompare);

        if (calculatedError < errorThresholdMax)
        {
            ret = gestureNumber + "-true";
            gestureDetected = true;
            pointToCompare.Detected = true;
        }
        else
        {
            ret = gestureNumber + "-false";
```

```
                    gestureDetected = false;
                    resetPoints();
                }
            }

            public override void takeSnapshot()
            {
                pointToCompare = currentPoint;
            }

            public override void saveGestureToFile()
            {
                using (System.IO.StreamWriter file = new System.IO.StreamWriter("
                    Gestures/" + gestureName + ".ges"))
                {
                    String line = pointToCompare.X + " " + pointToCompare.Y + " " +
                        pointToCompare.Z;
                    file.WriteLine(line);
                }
            }

            public override void clearAll()
            {
                pointToCompare = null;
            }

            public override int getNumberOfPoints()
            {
                return 1;
            }

            public override Point3D getOnePoint(int index)
            {
                return pointToCompare;
            }

            public override void setStartingPoint(int index)
            {
                /// DO NOTHING
            }

            public override void resetPoints()
            {
                pointToCompare.Detected = false;
            }

        }
}
```

Bibliography

[1] Mohamed Abdur Rahman, Ahmad M Qamar, Mohamed A Ahmed, M Ataur Rahman, and Saleh Basalamah. Multimedia interactive therapy environment for children having physical disabilities. In *Proceedings of the 3rd ACM conference on International conference on multimedia retrieval*, pages 313–314. ACM, 2013.

[2] Chadia Abras, Diane Maloney-Krichmar, and Jenny Preece. User-centered design. *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, 37(4):445–56, 2004.

[3] Arbeitsmedizinische Dienst (AMD). http://www.tuwien.ac.at/fileadmin/t/gut/fotos/sicherheit/amd/ergonomie Accessed: 2013-08-12.

[4] Lars L Andersen, Karl Bang Christensen, Andreas Holtermann, Otto M Poulsen, Gisela Sjøgaard, Mogens T Pedersen, and Ernst A Hansen. Effect of physical exercise interventions on musculoskeletal pain in all body regions among office workers: a one-year randomized controlled trial. *Manual therapy*, 15(1):100–104, 2010.

[5] Free Cartoon Elephant Clip Art. http://www.clipartlord.com/free-cartoon-elephant-clip-art/. Accessed: 2013-09-15.

[6] Olusola Ayanniyi, BOO Ukpai, and Ade Fatai Adeniyi. Differences in prevalence of self-reported musculoskeletal symptoms among computer and non-computer users in a nigerian population: a cross-sectional study. *BMC musculoskeletal disorders*, 11(1):177, 2010.

[7] Jin Wook Bahk and Sangchul Roh. Relationship between self-reported symptoms of work-related musculoskeletal disorders and health related quality of life. *Korean Journal of Occupational and Environmental Medicine*, 19(2):156–163, 2007.

[8] Adrian Bauman, Barbara E Ainsworth, James F Sallis, Maria Hagströmer, Cora L Craig, Fiona C Bull, Michael Pratt, Kamalesh Venugopal, Josephine Chau, and Michael Sjöström. The descriptive epidemiology of sitting: a 20-country comparison using the international physical activity questionnaire (ipaq). *American journal of preventive medicine*, 41(2):228–235, 2011.

[9] Bonnie G Berger, David Pargman, Robert Stephen Weinberg, et al. *Foundations of exercise psychology.* Fitness Information Technology, Inc., 2002.

[10] Shlomo Berkovsky, Mac Coombe, Jill Freyne, Dipak Bhandari, and Nilufar Baghaei. Physical activity motivating games: virtual rewards for real activity. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 243–252. ACM, 2010.

[11] Benjamin S Bloom et al. Handbook on formative and summative evaluation of student learning. 1971.

[12] Microsoft Visual C#. http://msdn.microsoft.com/en-us/library/vstudio/kx37x362.aspx. Accessed: 2013-10-15.

[13] Chien-Yen Chang, Belinda Lange, Mi Zhang, Sebastian Koenig, Phil Requejo, Noom Somboon, Alexander A Sawchuk, and Albert A Rizzo. Towards pervasive physical rehabilitation using microsoft kinect. In *Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2012 6th International Conference on*, pages 159–162. IEEE, 2012.

[14] Kyusik Choi, Jae-Hyun Park, and Hae-Kwan Cheong. Prevalence of musculoskeletal symptoms related with activities of daily living and contributing factors in korean adults. *Journal of Preventive Medicine and Public Health*, 46(1):39–49, 2013.

[15] Sunny Consolvo, Predrag Klasnja, David W McDonald, and James A Landay. Goal-setting considerations for persuasive technologies that encourage physical activity. In *Proceedings of the 4th international Conference on Persuasive Technology*, page 8. ACM, 2009.

[16] Zafra Cooper and Christopher Fairburn. The eating disorder examination: A semi-structured interview for the assessment of the specific psychopathology of eating disorders. *International Journal of Eating Disorders*, 6(1):1–8, 1987.

[17] Bruno R da Costa and Edgar Ramos Vieira. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. *American journal of industrial medicine*, 53(3):285–323, 2010.

[18] Zelai Sáenz de Urturi, Amaia Méndez Zorilla, and Begoña García Zapirain. Jewheels: kinect based serious game aimed at wheelchair users. In *Ambient Assisted Living and Home Care*, pages 391–398. Springer, 2012.

[19] Barbara DiCicco-Bloom and Benjamin F Crabtree. The qualitative research interview. *Medical education*, 40(4):314–321, 2006.

[20] Kenneth D Eason. *Information technology and organisational change*. CRC Press, 1989.

[21] Thomas File. Computer and internet use in the united states. *Population Characteristics*, pages 1–14, 2013.

[22] Diarmaid Fitzgerald, J Foody, D Kumar, D Kelly, T Ward, C Markham, and B Caulfield. Integration of kinematic analysis into computer games for exercise. 2006.

[23] Exercises for Office Workers. http://www.dfp.com.au/file.php?fileid=4939. Accessed: 2013-10-15.

[24] Microsoft Kinect for Windows. http://www.microsoft.com/en-us/kinectforwindows/. Accessed: 2013-09-30.

[25] Microsoft Kinect for Windows SDK. http://www.microsoft.com/en-us/kinectforwindowsdev/default.aspx. Accessed: 2013-10-01.

[26] Microsoft Kinect for Windows SDK: JointType Enumeration. http://msdn.microsoft.com/en-us/library/microsoft.kinect.jointtype.aspx. Accessed: 2013-09-28.

[27] Microsoft Kinect for Windows SDK: Skeletal Tracking. http://msdn.microsoft.com/en-us/library/hh973074.aspxid4eqc. Accessed: 2013-09-28.

[28] Microsoft Windows Presentation Foundation. http://msdn.microsoft.com/en-us//library/ms754130.aspx. Accessed: 2013-08-15.

[29] Alana Da Gama, Thiago Chaves, Lucas Figueiredo, and Veronica Teichrieb. Guidance and movement correction based on therapeutics movements for motor rehabilitation support systems. In *14th Symposium on Virtual and Augmented Reality (SVR), 2012*, pages 191–200. IEEE, 2012.

[30] Luc Geurts, Vero Vanden Abeele, Jelle Husson, Frederik Windey, Maarten Van Overveldt, Jan-Henk Annema, and Stef Desmet. Digital games for physical therapy: fulfilling the need for calibration and adaptation. In *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction*, pages 117–124. ACM, 2011.

[31] Agneta Gulz. Benefits of virtual characters in computer based learning environments: Claims and evidence. *International Journal of Artificial Intelligence in Education*, 14(3):313–334, 2004.

[32] Agneta Gulz. Social enrichment by virtual characters–differential benefits. *Journal of Computer Assisted Learning*, 21(6):405–418, 2005.

[33] Paula T Hakala, Lea A Saarni, Raija-Leena Punamäki, Marjut A Wallenius, Clas-Håkan Nygård, and Arja H Rimpelä. Musculoskeletal symptoms and computer use among finnish adolescents-pain intensity and inconvenience to everyday life: a cross-sectional study. *BMC Musculoskeletal Disorders*, 13(1):41, 2012.

[34] Oliver Hämmig, Michaela Knecht, Thomas Läubli, and Georg F Bauer. Work-life conflict and musculoskeletal disorders: a cross-sectional study of an unexplored association. *BMC musculoskeletal disorders*, 12(1):60, 2011.

[35] Back Designs inc.: Desk and work surface height. http://www.backdesigns.com/work-surface-height-w144c132.aspx. Accessed: 2013-09-20.

[36] Imagination iotracker. http://www.iotracker.com/. Accessed: 2013-10-07.

[37] Marcus Kilpatrick, Edward Hebert, and John Bartholomew. College students' motivation for physical activity: differentiating men's and women's motives for sport participation and exercise. *Journal of American college health*, 54(2):87–94, 2005.

[38] Anton J Kuzel. Sampling in qualitative inquiry. 1992.

[39] Andrew Macvean and Judy Robertson. Understanding exergame users' physical activity, motivation and behavior over time. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1251–1260. ACM, 2013.

[40] Walter Maner. Formative usability evaluation. Accessed: 2013-10-20.

[41] Bernhard Maurer, Fabian Bergner, Peter Kober, and Rene Baumgartner. Improving rehabilitation process after total knee replacement surgery through visual feedback and enhanced communication in a serious game. In *Proceedings of the 30th ACM international conference on Design of communication*, pages 355–356. ACM, 2012.

[42] Matthew B Miles and A Michael Huberman. *Qualitative data analysis: An expanded sourcebook*. Sage, 1994.

[43] William L Miller and Benjamin F Crabtree. The dance of interpretation. *Doing qualitative research*, 2:127–144, 1999.

[44] Aleksandar Mrkajic. Exercise sketches for kinect prevention system v1.0.

[45] Michael J Muller and Sarah Kuhn. Participatory design. *Communications of the ACM*, 36(6):24–28, 1993.

[46] Clifford Nass. Etiquette equality: exhibitions and expectations of computer politeness. *Communications of the ACM*, 47(4):35–37, 2004.

[47] Riku Nikander, Esko Mälkiä, Jari Parkkari, Ari Heinonen, Heli Starck, and Jari Ylinen. Dose-response relationship of specific training to reduce chronic neck pain and disability. *Medicine and science in sports and exercise*, 38(12):2068–2074, 2006.

[48] Donald A Norman and Stephen W Draper. *User centered system design; new perspectives on human-computer interaction*. L. Erlbaum Associates Inc., 1986.

[49] Magalie Ochs, Catherine Pelachaud, and David Sadek. An empathic virtual dialog agent to improve human-machine interaction. In *Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems-Volume 1*, pages 89–96. International Foundation for Autonomous Agents and Multiagent Systems, 2008.

[50] University of Southern California: Exercises for Computer Users and Office Workers. http://www.usc.edu.au/media/1000574/exercises-for-computer-users-and-office-workers.pdf. Accessed: 2013-10-15.

[51] Panel on Musculoskeletal Disorders, Commission on Behavioral the Workplace, Social Sciences, and National Research Council Education. *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities*. The National Academies Press, 2001.

[52] Sharon Parry, Leon Straker, et al. The contribution of office work to sedentary behaviour associated risk. *BMC public health*, 13(1):296, 2013.

[53] Isaac Pastor, Heather A Hayes, and Stacy JM Bamberg. A feasibility study of an upper limb rehabilitation system using kinect and computer games. In *Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference of the IEEE*, pages 1286–1289. IEEE, 2012.

[54] PrimeSense. http://www.primesense.com/. Accessed: 2013-10-01.

[55] Ranasinghe Priyanga, Perera Yashasvi, Lamabadusuriya Dilusha, Kulatunga Supun, Jayawardana Naveen, Rajapakse Senaka, and Katulanda Prasad. Work related complaints of neck, shoulder and arm among computer office workers: a cross-sectional evaluation of prevalence and risk factors in a developing country. *Environmental Health*, 10, 2011.

[56] Nicolaas P Pronk, Abigail S Katz, Marcia Lowry, and Jane Rodmyre Payfer. Peer reviewed: Reducing occupational sitting time and improving worker health: The take-a-stand project, 2011. *Preventing chronic disease*, 9, 2012.

[57] Laura Punnett and David H Wegman. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of Electromyography and Kinesiology*, 14(1):13–23, 2004.

[58] Danny Rado, Aswin Sankaran, Joseph Plasek, David Nuckley, and Daniel F Keefe. A real-time physical therapy visualization strategy to improve unsupervised patient rehabilitation. In *IEEE Visualization*, 2009.

[59] Zsófia Ruttkay, Job Zwiers, Herwin van Welbergen, and Dennis Reidsma. Towards a reactive virtual trainer. In *Intelligent virtual agents*, pages 292–303. Springer, 2006.

[60] Davud Sadihov, Bastian Migge, Roger Gassert, and Yeongmi Kim. Prototype of a vr upper-limb rehabilitation system enhanced with motion-based tactile feedback. In *World Haptics Conference (WHC), 2013*, pages 449–454. IEEE, 2013.

[61] Sanjay Saini, Dayang Rohaya Awang Rambli, Suziah Sulaiman, Mohamed Nordin Zakaria, Mohd Shukri, and Siti Rohkmah. A low-cost game framework for a home-based stroke rehabilitation system. In *Computer & Information Science (ICCIS), 2012 International Conference on*, volume 1, pages 55–60. IEEE, 2012.

[62] Christian Schonauer, Thomas Pintaric, Hannes Kaufmann, Stephanie Jansen-Kosterink, and Miriam Vollenbroek-Hutten. Chronic pain rehabilitation with a serious game using multimodal input. In *Virtual Rehabilitation (ICVR), 2011 International Conference on*, pages 1–8. IEEE, 2011.

[63] Tuulikki Sjögren. *Effectiveness of a workplace physical exercise intervention on the functioning, work ability, and subjective well-being of office workers: a cluster randomised controlled cross-over trial with a one-year follow-up*. University of Jyväskylä, 2006.

[64] OpenNI: Open source drivers for 3D sensors. http://www.openni.org/. Accessed: 2013-09-01.

[65] Kazumoto Tanaka, JR Parker, Graham Baradoy, Dwayne Sheehan, John R Holash, and Larry Katz. A comparison of exergaming interfaces for use in rehabilitation programs and research. *Loading...*, 6(9), 2012.

[66] Mary Theofanos and Whitney Quesenbery. Towards the design of effective formative test reports. In *Journal of Usability Studies*. Citeseer, 2005.

[67] Ewa Wigaeus Tornqvist, Åsa Kilbom, Eva Vingård, Lars Alfredsson, Mats Hagberg, Töres Theorell, Måns Waldenström, Christina Wiktorin, Christer Hogstedt, et al. The influence on seeking care because of neck and shoulder disorders from work-related exposures. *Epidemiology*, 12(5):537–545, 2001.

[68] OptiTrack V100:R2. http://www.naturalpoint.com/optitrack/products/v100-r2/. Accessed: 2013-08-15.

[69] Morten Wærsted, Therese N Hanvold, and Kaj Bo Veiersted. Computer work and musculoskeletal disorders of the neck and upper extremity: a systematic review. *BMC musculoskeletal disorders*, 11(1):79, 2010.

[70] Martin Woods. Interviewing for research and analysing qualitative data: An overview.

[71] Jeffrey Yim and TC Graham. Using games to increase exercise motivation. In *Proceedings of the 2007 conference on Future Play*, pages 166–173. ACM, 2007.

[72] Zhengyou Zhang. Microsoft kinect sensor and its effect. *Multimedia, IEEE*, 19(2):4–10, 2012.