Open Visual Guidance System for Mobile Senior Citizen

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Master’s Thesis
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Abstract
The elderly citizen’s health care need some radical changes and improvements to alleviate the situation where the quality of service must be enhanced without overburdening the caregivers under the weighty workload. Much of research is done and many researchers all around the world emphasize the importance of assistive technologies. Current technological advancements in communication allow us to build systems which could be useful tools for the caregivers and allow the elderly to live more autonomous and active life. Offering stimulus to the elderly to experience with the technology could lessen the feel of social isolation and ameliorate the quality of service significantly. Shrinking electronics, mobiles and sensors do not bound the use only in homes or facilities, but allow the use in many different environments. While using technology of this kind, the caregivers could give guidance or follow the health status of a mobile elderly citizen in remote fashion and give help if needed. This thesis is also immersing in the matter by producing a Visual Guidance system that utilizes current mobile technology, actuators, sensors and uses a virtual reality as a communication medium between the caregivers and elderly citizens.

The system consists of two different parts combined together to form a real-time communication system between caregivers and elderly citizen. The system uses Android smart phone’s built-in sensors to track the movement of the elderly. Those sensors are location based sensors such as GPS and acceleration and magnetometer sensors. This system provides an open map view of the world where the elderly citizen move. Also to improve the communication between the elderly and caregiver, video and audio communication has been used as one of our research aims. The caregiver can remotely use the smart phone to open video and audio communication with the elderly if needed. The system has been integrated with indicator base smart glasses so that when the elderly citizen are on the move, the caregiver can give directional advices on where and when to go.

The authors used integration testing to evaluate the system and comparing the current system functions with the requirements of the system. Also the authors made sure that the delay with communication was small enough so it would be safe for the caregivers to communicate with the elderly citizen.

For future work we suggested various actions such as integrating indicator based glasses with the Pupil Pro glasses, finding the most appropriate security solutions for the system and testing the system with real-life caregivers and elderly citizen.

Key Words
Senior citizen, Smart phone, Sensors, Old Birds, GPS, Virtual Reality

Supervisors
University Lecturer Ari Vesanen, Professor Petri Pulli
Foreword
This research will continue previous studies made by Siitonen, (2011); Pulli et al., (2012); Ponrasa et al., (2014). The open visual guidance system for mobile senior citizen project aims to research and implement services for senior citizen which provides more autonomous life for elderly citizen and reduces the workload of the caregivers. We deeply thank our Supervisors University Lecturer Ari Vesanen and Professor Petri Pulli.
Abbreviations

TCP (Transmission Control Protocol) Protocol used to create connections between devices.

HMD (Head- mounted display) Display device which is worn on the head.

IP (Internet Protocol) Communication protocol that delivers the packets in the network.

UDP (User Datagram Protocol) Protocol that can be used in data transfer. Can also be used to send DNS- queries and usually used in real- time video and audio transfer.

DNS (Domain Name System) Naming system for computers and services. Translates the domain names to the numerical IP- addresses.

HTTP (Hypertext Transfer Protocol) Protocol for data delivery used by web- servers and browsers.


RTSP (Real-Time Streaming Protocol) Network control protocol used to control streaming media servers in entertainment and communication systems.

RTCP (Real-Time Control Protocol) Provides statistical information about the RTP-session. Also provides QoS (Quality of service) in media distribution.

QoS (Quality of Service) Measures the overall performance of a telephony or computer network.

Interoperable – Referred also to as Interoperability in the literature, this combines the communication and the control functions.

Old Birds – A web application prototype for caregivers for observing and monitoring elderly people.

VoiP (Voice-over-internet protocol) Protocol for voice-communication and multimedia sessions over the IP (Internet protocol).

Teleguidance – Caregiver remotely assisting the elderly people.

Telepresence – Feel of presence in remote environment.

Augmented Reality – Direct or indirect view of a real world physical environment.

Semantic reality – A concept to connect the virtual world into the real world.

Caregiver – Helps individuals with their daily living.

Mobile Senior Citizen – Citizen having disabilities with active lifestyle.
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1. **Introduction**

The health care for the elderly people as it exists today, needs more sophisticated solutions. The current birth rate and increasingly growing life expectancy has accelerated the aging of the population. This leads to challenges concerning the current methods of elderly people’s health care all around the world (Winblad et al., 2010). Measured by the number of employees, this means that alone in the Finland with the current rate and consumption the growth in the health care and social services should almost double by 2035. (Hyry et al., 2011). The current trend is showing directly in the wellbeing of the elderly people and their caregivers.

Studies of new kind, combined with the recent technology advances in the telecommunication and information are used to confront the challenges and match the needs of the society. Following the footsteps of Remote Caregiving or Remote Assistance, which is a concept made by Ikeida et al., (2012), this study takes the research further in the field by using teleguidance combined with augmented reality. With current technology it is possible to give assistance from a remote location by administering telepresence technologies. The objective of this study is to gain new knowledge about assistive technologies by creating a teleguidance application utilizing a virtual reality system as a communication medium. While trying to enhance the communication between the caregivers and the elderly people by integrating the real world and virtual reality by exploiting the modern information and communication technologies, we try to find a solution for the weighty workload of the caregivers and offer an opportunity for the disabled to live more autonomous life.

The contributions of this research are done by two researchers. Tapio Korvala has the responsibility of the Android tool and Hannu Raappana has the responsibility of the Communication tool. The chapters 1, 5, 3.2, 4, 4.1 and 6 are written jointly by the authors and the chapter 2 is divided between the authors. The chapters 2.1, 2.2 are written by Tapio Korvala and the chapter 2.3 by Hannu Raappana. Chapters 3.1, 3.3, 4.2 were written by Hannu Raappana and Chapters 3.4, 3.5, 3.6, 4.3 were written by Tapio Korvala.

1.1 **Purpose of the study**

Today, the miniaturization of the electronics and communication networks going viral, new technologies have been embraced and they are affecting in our everyday lives. The integration of computer technology, sensing and actuating is an emerging research field (Kukka et al., 2014.)

Purpose of this study is to gain more knowledge about the teleguidance for senior citizens, and study the current technology that could be harnessed to elderly people's health care. This study concentrates on integrating the real world with virtual reality to improve the connectivity between the caregivers and the senior citizens.

1.2 **Motivation**

A study of Nakamura et al. (1999) shows that effects of using telecare would improve the quality of service significantly. After this the society and technology have been
progressing at vast speed, but the goals of providing more efficient health care services still remain the same. Information and communication technologies play increasingly large role in our daily lives today and tomorrow. At the same time the aging of the population has increased dramatically due to the current birth rate and life expectancy. This leads to challenges in the elderly people's health care and we need more efficient solutions to alleviate the situation all around the world.

The recent technological advancements allow us to build systems than could contribute to the elderly people’s health care. As the care of the community is more preferable than the institutional alternatives for the most of the patients, a system that could give support at home would be much appreciated. With modern electronic sensors of different kind, it is possible to build systems like video monitoring, remote health monitoring and equipment like fall detectors to assure safety for the elderly people. The systems of this kind could benefit the patients along with their care providers. (Miskelly, 2001.)

Motivation for this study is to attain information about the feasibility of combining the virtual and real world environment in elderly people's health care. Innovating new information systems based on new telecommunication technologies that could help in the elderly people's health care are crucial. “Communication technologies are a critical means to ensure safety and independence of older adults with disabilities through providing access to health care providers and caregivers.” (Rogers & Mynatt, 2003.)

The information gained by this study can be used to build information systems that can be exploited in the elderly people's health care.

1.3 Prior research

The idea of providing remote assistance for the elderly people is not new. There have been multiple studies about the “telecaring” of the elderly people even before the 21st century. In the literature “telecare” is defined as the combination of information and communication technologies to facilitate the delivery of social and health care services for individuals in their homes. (Barlow et al., 2006). The studies have been made for improving the elderly people's quality of life by improving their autonomy and social life through information and communication techniques of various kind.

Two basic modes of assistance (personal assistance and technological assistance) are required when coping with the limitations that the elderly people face when completing their daily tasks. Personal assistance can be considered as help that the elderly citizen might get from a relative or paid caregiver. On the other hand, help from the others doesn’t enable the disabled to live more independently, but it may facilitate the difficulties when performing tasks of various kind. Whereas technological assistance refers to the use of equipment that can enhance the performance during daily activities that could help the disabled to live more independently. A potential outcome when trying to reduce the task demands by using the technological assistance is to lower the workload of the caregivers and provide more autonomous life for the disabled. (Hoenig et al., 2003.)

Some studies have burrowed into the assistive technologies and techniques like teleservices and their ethical and social issues and we already have knowledge about elderly citizens as the users of these new technologies. Abascal (1997) conducted research that was based on former studies which were concerning telecaring the elderly people, and discussed issues like teleservices and their impacts on the users. To assist the people with disabilities of various kinds and offering them an experience of more autonomous life, the studies described teleservices like telealarm, telecare,
teleinformation services and interpersonal telecommunication services. The definitions were as follows:

- **Telealarm**: “The user is equipped with a device that automatically or manually generates a call to a remote surveillance centre when he or she suffers an emergency due to an accident, disease, security problem, etc.”

- **Telecare**: “Distant medical attendance service. In some cases care is limited to health advice by the means of speech or/and written communication. More complex systems may include tele-exploration, and diagnostic and therapeutic advice. Remote patient monitoring and transmission of physiological signs may be required in this case.”

- **Teleinformation service**: “Information database for the elderly people providing valuable information about diverse aspects of everyday life. The information can consist of public transport, emergency telephone numbers, relatives' addresses etc. In some cases they can include advice about everyday tasks, developing and agenda planning (Schedules of medical treatment, doctor's appointments, and special days like birthdays.)”

- **Interpersonal telecommunication services**: “Service that can provide speech, image and text transmission like video-telephone, telefax, or electronic mail.”

Dahl & Holbø (2012a), state that without offering services of this kind for the dementia patients may lead to reduced physical activity and social isolation, but on the other hand according to Abascal & Civit (2000) there are also concerns that these services in itself could lead to social and ethical risks and ultimately worsen the situation in the means of social isolation, loss of personal autonomy and privacy. Also the economic barriers should be taken into account. Users may have varied disabilities with special requirements that would imply more workload on the system which could mean a higher price for the same service.

One big concern has been the assumption that the elderly people are not very fond to accept new technology, but the studies have pointed out the contrary. National Science Foundation sponsored the study of SeniorNet (www.seniornet.org) where the researchers study the Internet community and disclosed that the senior citizens are willing to learn new computer skills and most of all capable of creatively using the Internet tools, like newsgroups or home pages to support social exchanges and interaction. (Mynatt & Rogers, 2001; Mynatt et al., 2002). The earlier findings also suggest that the experience with the technology may change the initial assumptions and encourage the user toward a technology. (Dahl & Holbø, 2012a). Also the technology itself may be one of the pitfalls. There may be technological problems of various kinds, like user interface problems and other technical problems. Nowadays safety and confidentiality are also big concerns and they should be taken into account. (McLean et al., 2011).

Application and learning of new technologies did not seem to be troublesome for the elderly people if they were properly informed about the benefits of the new technologies and adequately trained to use them. (Rogers et al., 1996). The studies pointed out that if the design of the system is based on the user needs assessment and the user learn to efficiently interact with the system, he is more enthusiastic about using it and the approval towards the new technology become smoother. “The best assistive
technologies are those that have become invisible to the user – tools that people use to accomplish a goal without thinking about the technology itself, such as the telephone or a radio.” (Rogers. & Mynatt, 2003.)

After years of the studies of the impacts of mobile telephony and in the light of new emerging technologies there have been arguments that the needs of the disabled and elderly people would only be possible to fulfill within integrated intelligent environment along with interoperable systems. This would be achieved by a wearable computation, ubiquitous and mobile computing along with the future networks. (Abascal, 2004.)

More recent studies about the matter for example are Pulli et al., (2012) “Mobile Augmented Teleguidance-based Safety Navigation Concept for Senior Citizens”, where they studied a safety navigation systems for the elderly people. This study was concentrated on providing telepresence assistance by using built-in mobile sensors of different kind. Later on Pulli et al., (2013) in their article “Canderoid: A mobile system to remotely monitor the travelling status of the elderly with dementia”, introduced a new system called “Canderoid”, a mobile application made for android that can exploit the built-in sensors in smart phones. With this application it is possible to send sensor data, like GPS coordinates and snapshot images from the elderly citizen’s mobile phone to the caregiver’s end point.

This research is also related to the “Attention Control and Eyesight Focus for Senior Citizens” by Lääkkö et al. (2014), where they proposed Smart Glasses as an assistive technology in elderly people's health care. To design feasible solution for combining the virtual reality within the real world, we gather information about the virtual and augmented reality technologies. We need proper knowledge how to process this semantic information and represent it in the augmented reality. We also need to gain more information about the ubiquitous computing and telepresence techniques including video and audio telecommunication. The research provides a brief review in these technologies and techniques via narrative literature review.

1.4 Research questions

Intention of this study is to find out whether it is possible to enhance elderly citizen’s activities by using modern communication technology to provide real time assistance. From this we derive our research questions:

- Is it possible to implement a visual guidance system consisting of smart phone, smart glasses, an Android tool and a Communication tool that would enable communication between user and operator?

- Is it possible to implement the system such that it provides a safe user experience for the senior citizen?

With Android tool, we mean an application residing on a smart phone that communicates with the Communication tool and with a Communication tool, we mean a tool that is used by an operator to communicate with the Android tool.

The safe user experience is defined here as a experience where the user will not be exposed to any harm during the usage of the system due to latency between the devices.
1.5 Research methods

The research is done by utilizing Design Science Research (DSR) method to establish and evaluate a visual guidance system. DSR is a research paradigm which can be used to answer questions related to real human problems via creating innovative artifacts and evaluating their performance. (Hevner et al., 2004; Iivari, 2007). The DSR method is explained in more detail in the chapter 3.

1.6 Main contribution

The main contribution of this research is to alleviate the situation in the health care of senior citizens. This research focuses on helping caregivers to monitor the activities of a mobile senior citizen and providing a flexible way of communication between the caregiver and the senior citizen. The contributed artifact is a system that provides a graphical user interface for the caregiver where the senior citizens can be monitored. The caregiver can contact senior citizens by using a voice communication with video feed to assist the seniors in their everyday activities. To conclude, our main contribution is to create a "proof-of-concept" of a working real time system addressed in the elderly citizen’s health care which also could be useful in real life situations in the future.

1.7 Structure

The structure of this research is following the DSR framework. In the first chapter, the problem domain is identified and an introduction to prior research is presented. Next, in Chapter 2 the research method is introduced and then in Chapter 3 the knowledge database is formed and a brief review of the current technology is made with narrative literature review. In Chapter 4 the implementation of the system is explained in detail and in Chapter 5 we discuss our findings and finally, in Chapter 6 we conclude the study.
2. Research methods

In this thesis the authors will create a solution by following the guidelines of Design Science Research (DSR) methodology. First, the basic concept of design science research will be introduced. Next, the authors will discuss the framework of information system research and the guidelines for design science research will be introduced. Finally, we describe how those guidelines are applied to this thesis.

2.1 Introduction to Design Science Research

Hevner & Chatterjee (2010) proposed DSR is a research paradigm, where the designer answers questions via creation of innovative artifacts that are relevant to human problems and for creating new knowledge to scientific community. Design science research is based on understanding the underlying problem and resolving the problem with artifacts.

We found many different process models for Design Science Research methodology, but here we present only the one made by Peffers et al. (2008) in Figure 1, since it is clear and easy to understand. In the first step of this process model, the researchers must define the problem at hand and explain why the solution will be valuable. Also it is a good idea to divide the problem into a set of problems so the problems can be dealt more specifically.

Next in the process the researchers will define the objectives for the solution to the problem that was defined in the previous step. Also it is important to use knowledge to see what is possible and feasible to do. The objectives can create a solution which provides a better solution to the problem or the objectives can create a solution to a new problem that has not been addressed before. (Peffers, 2008.)

In the third step the researchers will create the artifact. These artifacts can be constructs, models, methods or instantiations and so on. Artifacts can be any objects that have been designed with using the research contribution in it. In this step the researchers will first determine the functionality of the artifact and the architecture for it and after that they can proceed with the actual creation of the artifact. After creating the artifact, it needs to be demonstrated. The demonstration can be done by using the artifact to solve the problem partly or entirely. (Peffers, 2008.)

In the fifth step the artifact will be evaluated by observing and measuring how well the artifact provides the solution for the problem. This can be done by comparing the objectives with the results of the demonstration. The final step is to communicate the problem and to inform how it would be important to solve the problem. After this the researchers need to tell the community about the artifact and why it is useful and new, how it was designed and also how effective it is for other researchers and for other relevant parties. It is not needed to actually do these steps in order and in fact it is possible to start in any step which seems more useful in the situation, but all steps must be completed in order to provide a real design science research solution. (Peffers, 2008.)
2.2 Design Science Framework

Organizations and their supporting information systems are most often complex, artificial and designed on purpose. These systems include people, structures, work systems and technologies of different kind. The design of a purposeful organization with specific goal in mind arrogates great effort from the IS practitioners and managers in general. The essential alignments between business and information technologies and organizational and information systems infrastructures are outlined in Figure 2. Extensive design activity is required to make the transition of strategy into the infrastructure on the both sides of Figure 2. (Hevner et al., 2004.)

An effective organizational infrastructure requires organizational design and an effective information systems infrastructure requires information systems design. These design activities are interdependent and central to the IS discipline and hence the interplay among the information technology strategy, information systems infrastructure, business strategy and organizational infrastructure as displayed in Figure 2 must be addressed. Nowadays the interplay is considered more important because in the business strategy and organizational infrastructure the information technologies are seen as enablers. (Hevner et al., 2004.)

Figure 1. Design Science Research Methodology Process Model. (Peffers et al., 2008.)

Figure 2. Organizational Design and Information Systems Design Activities. (Hevner et al., 2004, Figure 1, p 79)
According to Hevner et al. (2004) an important dichotomy must be made before achieving true understanding and the appreciation of the design science as an IS-research paradigm. The design consists of both an artifact and a process, where the world which is acted upon and the world as sensed is described as processes and artifacts, respectively. This platonic view of the design is supporting the problem solving paradigm which is constantly shifting perspectives between design processes and artifacts that are designed for the same problem at hand. The design process of producing an innovative artifact consists of a sequence of expert activities. To improve the design process and the quality of the artifact a feedback information about the product is gained by evaluating the artifact afterwards and a better understanding of the problem is obtained. This so called build-and-evaluate loop is then iterated until a satisfactory creation of the design artifact is achieved.

The design science research in IS identifies two design processes (build and evaluate) and four design artifacts (constructs, methods, models and instantiations). These purposeful artifacts are built to address unsolved problems and then evaluated the respect to the utility provided to solve those problems. The language in which the problems and their solutions are defined and communicated is provided by the constructs. Constructs are also used in models to represent the design problem and its related solutions space, a situation from the real world. Models facilitate the comprehension of the problem and its solution. Also the connections between the problem and its solution components are frequently represented by the model. This enables the exploration of effects that design decisions result in the real world. Processes are defined by methods and give guidance how to explore the solution space, in other words solve the problems. The guidance can range between formal mathematical algorithms to informal textual descriptions or some of their combinations. Instantiations show that the models, constructs and methods are applicable and could be implemented in a working system. These can be used to demonstrate feasibility and to prove that the artifact is suitable solution to the purpose it is intended in. Furthermore, it allows the researchers to make observations about user behaviour and how the artifact conducts in the real world. (Hevner et al., 2004.)

In Figure 3, Hevner et al. (2004) presents a conceptual framework in IS research for understanding, executing and evaluating. The framework combines both behavioral science and design-science paradigms.
Figure 3. Information System Research Framework (Hevner et al., 2004, Figure 2, p. 80).

The problem space is where reposes the phenomena of interest and it is defined by the environment. The environment consists of people, organizations, and the technologies that are already available or planned. It also includes the problems, tasks, goals and opportunities which define the business needs of the organization. The business needs are assessed and evaluated within the organizational context, such as strategies, processes, culture and structure. When these are positioned next to their relative technologies, applications, communication architectures and development capabilities the researcher may define the business needs or the problem. The research relevance is assured when the business needs are framed by addressing them with research activities. (Hevner et al., 2004.)

After the business need is defined, the IS research is conducted in two complementary phases in behavioural (development / justification) and design science (building / evaluation). The knowledge base includes all the raw data that are there for accomplishing the IS research. It includes a basis for the research in the forms of foundations and methodologies. Foundations are used in the develop/build phase and the methodologies in the justification/evaluation phase. The rigor can be achieved by applying these existing foundations and methodologies in the research. Empirical analysis and data collection are used in the behavioural sciences and in the design science, mostly mathematical methods are used to evaluate artifacts and their quality and effectiveness. (Hevner et al., 2004.)

The design activities of design science (Fig. 4) are presented as design cycles, as Hevner, (2007) stated that the design science research is in fact an embodiment of three design cycles of activities that are closely related.

Figure 4. Design Science Research Cycles (Hevner, 2007, Figure 1, p. 88).

The “Relevance Cycle” acts as a bridge between the application domain and the design science research activities. The “Rigor Cycle” connects the knowledge base with the design science activities. The “Design Cycle” in the middle iterates between the building and the evaluation of the artifacts.
2.3 Design Science Research Guidelines

Hevner, March, Park & Ram (2004) proposed seven guidelines for design science research in order to help people to understand the requirements for effective design-science research. These guidelines in Table 1 are used in our research as basis to meet these requirements and also to help us provide quality research.

Table 1. Seven Design-Science Research Guidelines by Hevner et al. (2004)

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Description</th>
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<tbody>
<tr>
<td>Guideline 1: Design as an Artifact</td>
<td>Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.</td>
</tr>
<tr>
<td>Guideline 2: Problem Relevance</td>
<td>The objective of design-science research is to develop technology-based solutions to important and relevant business problems.</td>
</tr>
<tr>
<td>Guideline 3: Design Evaluation</td>
<td>The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.</td>
</tr>
<tr>
<td>Guideline 4: Research Contributions</td>
<td>Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.</td>
</tr>
<tr>
<td>Guideline 5: Research Rigor</td>
<td>Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.</td>
</tr>
<tr>
<td>Guideline 6: Design as a Search Process</td>
<td>The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.</td>
</tr>
<tr>
<td>Guideline 7: Communication of Research</td>
<td>Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.</td>
</tr>
</tbody>
</table>

Guideline 1: Design as artifact

Hevner et al. (2004) state that the result of Design Science Research is an artifact which has been created to resolve an important problem. The artifact must be relevant to the problem and it must be described effectively and the implementation and application must be used in the problem area.

In this thesis, the research will deliver a visual guidance system as the artifact in order to support the independence of out-door travelling senior citizen. The artifact handles the communication between smart phone, smart glasses and the monitoring tool.

Guideline 2: Problem relevance

Design science research problem must be relevant to the practitioners which plan, manage, design, implement, operate and evaluate information systems or to those who use technologies to their development and implementation. (Hevner et al., 2004). In this research, the problem relevance comes from real world problems in elderly citizen’s health care using information technologies.
Guideline 3: Design evaluation

The utility, quality and efficacy of the artifact will be evaluated during the construction process as Hevner et al. (2004) instruct. The evaluation consists in our research of testing the artifact against the requirements. Integration testing is also done in order to ensure the compatibility of the components.

Guideline 4: Research contributions

Hevner et al. (2004) state that the design science research must provide contributions to the area which the artifact, foundations or methodologies belong. This research provides new ideas on how to use real-time communication between multiple devices. The contributions in this research come from combining the Pupil Pro smart glasses, Indicator-based smart glasses, Android tool with smart phone and Communication tool.

Guideline 5: Research rigor

Design Science Research requires rigorous methods to be used in the construction of the artifact and in the evaluation of the artifact as Hevner et al. (2004) state. The rigor for construction and evaluation of the artifact are gathered from the knowledge base, but it is important not to overemphasize the rigor of the methods because it can lessen the problem relevance.

In our research the construction of the artifacts will be evaluated in different phases of the research and evaluation will be planned separately and carefully to ensure the rigorousness. The researchers used TDD when constructing the system.

Guideline 6: Design as a Search Process

Hevner et al. (2004) inform that the design-science research process is iterative since the progress is made iteratively by creating solution for the problem and testing it against the requirements. Alternative solutions can be created based on the test results of the previous alternative solutions.

In our research the artifact will be created in an iterative process until it satisfies the problem at hand. The artifact will be evaluated in laboratory environment and will be refined based on the results of the evaluation.

Guideline 7: Communication of Research

Hevner et al. (2004) state that design-science research must be presented to the technology-oriented and management-oriented audiences. This way the technology-oriented audiences can gather detailed information to construct their own artifact and use it appropriately. Management-oriented audiences on the other hand need information from the presentation to assess properly, if their organization should construct the artifact and use it.

This research aims at reporting the findings in scientific format for the academics and presenting the artifacts as practicable as possible.
3. Related research

In this section, the related research is introduced with narrative literature review. The section offers the insight of the technology that could be harnessed to the elderly people's health care.

First we burrow in the world of augmented reality and ubiquitous computing with related wearable computation. Later telepresence with virtual reality and virtual reality application Old Birds is introduced. At last the technology behind the platform and location based sensing is explained.

3.1 Augmented Reality

Augmented reality (AR) has roots back in the 1950’s. Cinematographer Morton Heilig got an idea of drawing the viewer into the screen by encompassing all the senses in an effective manner. After a decade in 1962 Heilig built the first prototype of the system named Sensorama which he had described earlier. Sensorama was a motorcycle simulator and this was the first known example of multimodal technology. Following the idea of Morton Heilig, Ivan Sutherland invented a head mounted display (HMD) in 1966 and constructed an AR system which used an optical see through HMD later in 1968. This can be considered as the first AR System that has been ever created. In the following years, the AR was being exploited more and more, also in the Boeing aircraft company for assisting the employees in the building of airplanes in the 1990’s. (Kipper & Rampolla, 2012.)

The definitions and concepts of AR between the researchers may vary lightly, but mostly they are the same. Milgram et al. (1994) introduced a concept Reality - Virtuality Continuum (Figure 5) which embodies taxonomies Augmented Virtuality (AV) and Mixed Reality (MR) which are closely related to the AR. Fig. 5 clarifies the relation between these taxonomies to the real, and virtual environments in a continuum.

![Figure 5. Reality - Virtuality Continuum. Adapted from Milgram et al. (1995).](image)

The left corner of the continuum in Figure 5 defines an environment which consists of exclusively real world objects. It can be anything that an observer might see directly or through a window or a display when viewing a real world scene. The right corner of the continuum defines an environment which consists solely of pure virtual objects that are computer generated, like graphical computer simulations that are presented on a monitor.
(nonimmersive) or a head mounted display (immersive). The space between the extrema of the continuum demonstrates the mixed reality which encompasses a presentation of the real world and virtual world objects wrapped together. (Milgram et al., 1994.)

By the definition of Azuma (1997), the Augmented Reality is an amendment of Virtual Environments (VE) and the real world. Pure VE technology immerses the user completely inside a synthetic environment and when immersed, the user cannot directly see the real world around him. In contrast in Augmented Reality, the user can observe the Real World surroundings with Virtual Objects that are superimposed upon, or mixed within the view of the real world. In an ideal case according to Azuma (1997) the user cannot distinguish difference between the real-, and virtual objects and it may appear that the objects coexist in the same space. AR could be imagined as the space between the synthetic, which is completely virtual and telepresence, which is completely real. The definition also includes the widely accepted characteristics of AR system:

1. Combines real and virtual.
2. Is interactive in real-time.
3. Is registered in three dimensions.

While some researchers allow the use of the term augmented reality only when using head mounted displays (HMDs), this definition doesn’t make limitations to only specific viewing techniques as long as they have these three characteristics. (Azuma, 1997). After a few years Azuma et al. (2001) expanded these characteristics and made a suggestion that AR would no longer be limited to the sense of sight, but it could be applied to all senses including hearing, touching and sense of smell. (Azuma et al., 2001). In outdoor locations, the AR systems like HMDs provide more challenges, but could also induce new opportunities for the telecare of elderly people. The challenging issues are also ergonomic, but the biggest difficulties has been with the tracking. These challenges may occur especially when determining the user’s position and orientation with a sufficient level of accuracy. (Azuma et al., 1998). Building a virtual environment which is connected with the real world, a technology or combined technologies are needed to accurately measure the locations and orientations of the users when they are interacting with the real world environment. According to this location and orientation information, we can display the user in the virtual environments coordinate system. This refers to tracking in the literature. (Rolland et al., 2001.)

Also other studies promote the importance of accuracy, low jitter and low latency in systems of this kind. (Rolland & Fuchs, 2000; Ribo et al., 2002). The kind of tracking where we are measuring the position and orientation of real 3D objects (like humans) that are located in indoor or outdoor environment is called “six degrees-of-freedom” (DOF) tracking. (Liarokapis & Newman, 2007). In some cases the normal tracking with only one technique is not enough for providing decent accuracy so we need to establish a system which combines multiple techniques and utilizes them together to get results that are precise enough. This kind of tracking is called “hybrid- tracking” in the literature. (Zhou et al., 2008.)

Regardless of the challenges, several mobile tracking systems already exist which use Global Positioning Systems (GPS), gyroscopes, electronic compasses and other sensors that are applicable. In the past 20 years AR systems like “touring machines” have been developed that provide information for the user from the surrounding environment. Those systems can offer spatial information about the viewed scene and give guidance directly displayed upon the view of the user. An AR system may also be helpful for a group of users which interact with each other, especially when the users are geographically separated. The users could also see the whereabouts of their friends, or
unfriendly areas of some kind. This could come handy when providing guidance for other users of the system. An instruction telling a member of the user group to go into a specific location might be worthless because of the different vantage points from which the users view the environment. (Azuma et al., 1998.)

Also in the more recent studies augmented reality is defined as a real-time indirect or direct view of a physical environment. AR can be used to enhance the user's perception, and provide a better way to interact with the real world. The view from the environment can be enhanced and modified (augmented) by adding a computer generated virtualized information (Semantic information) and thus give more information to the user. Augmented reality can be exploited in many different applications, from medical applications to entertainment. The aim of the augmented reality is to simplify user's life by providing an indirect view of a real world environment and giving information such as live video stream not only from the user's immediate surroundings. (Carmigniani et al., 2011). Also the supervision of patients using camera based surveillance is important in assistive environments. (Lalos et al., 2009.)

The most ideal case of AR system is when the system is able to mix virtual information with real in such a way that it allows the users to interact naturally in a user friendly way. In some specific cases, the participants should not notice the difference between the real and augmented, but not in all cases. Each type of information should be designed for specific purposes which also may alter the outcome. In some cases of communication, a textual explanation can be more efficient than an auditory description, but on the other hand, pictures and images can work better than text (i.e. 2D digital maps). When describing a procedure or sequence of events, a video could be the most convenient technique, but also combining the information using these techniques of various kinds may eventually prove to be beneficial. (Liarokapis & Newman, 2007.)

Advances in the mobile technology, in particular in the electronic tracking using GPS have raised interest among the caregivers and in the care and technology oriented research. Application of the GPS devices in the dementia care has been envisioned as a tool for helping caregivers to maintain awareness of health and security of a demented person. By offering a tool for the caregivers to help in their work we could extend the time that the dementia patient could perform home and outdoor activities. However, this can be a controversial issue. Major concerns have been the infringement of privacy, reduced human contact and dignity. (Dahl & Holbø, 2012b.)

Along with the pedestrian outdoor navigation, which has become ubiquitous via GPS enabled smart phones, also the demand for indoor navigation and localization system is increasing. It could be an enabler for multiple of applications like guidance for passengers at the airport and the visitors of shopping malls. The traditional GPS technology is not applicable indoors, but there are lots of other native technologies which could be exploited indoors. The technologies, such as infrared, radio based or sensor technologies could be used, but they need specific environmental architecture and augmentation. (Möller et al., 2012.)

3.2 Ubiquitous Computing

Urban computing in the science fiction is most often described as a very bleak and dominating force. Often people are somewhat integrated into the network of computers and can traverse between virtual and real worlds. These virtual worlds and real worlds can be parallel in the means that getting hurt in the virtual world may also be harmful to you in the real world. These virtual worlds in the science fiction literature can also be
compared with today’s Internet into some extent, where there can be harmful places in web-pages that can infect your computer with viruses that can have tedious effects. Although researchers may use these cyberpunk narratives as materials to gain information about human technology themes such as globalization, embodiment, feminism, and urbanism, in the research growing body of the literature in the domain of ubiquitous computing and urban computing is described very differently. (Kukka et al., 2014.)

Mark Weiser who can be considered one of the founding fathers of ubiquitous computing depicted the technology in his visions to be benevolent, friendly, useable and most of all always there if you need it, but otherwise not disturbing. This leads to Weiser's description of ubiquitous technology to be “calm” technology. This vision is not to let people to live in the virtual world, but to let the computers to live in the real world. The early vision of the ubiquitous computing according to Weiser (1991) was that the ubiquitous technology should be used to aid people to live their lives and work in a very smooth and effective way. All the possible obstacles that could lead to frustration should be avoided by using technology of this kind and make the user’s life very calm and easy.

After Weiser's vision of this intelligent environment there have been concerns that this kind of technology could ultimately lead into problems concerning people's autonomy and privacy. Although after Weiser’s proposition there have been a lot of advancements in the technology, and the vision could be feasible at least to some extent, this may not be what the people want or need. As the technology doesn't necessarily work and think just like the “human mind”, it can also lead into frustration when it is not working properly due to some miscalculations. More information about human behaviour should be used when designing and conducting this kind of technology and it should be considered more carefully where and when to use it. (Rogers, 2006.)

The new agenda and kind of thinking in the research is not to let the computers live on behalf of the people, but to give the people stimulus to experience things of a new kind, extend their learning and generate innovative ideas for problem solving. Instead of offering a tool which makes decisions and thinking on behalf of the people we should study new ways to enhance the people's own thinking and help them to be more proactive in their environment. The idea that the technology should be so weaved into human lives and using it should be as natural as breathing needs more rethinking. The computer – human interaction should be more carefully balanced to give people more stimulus and excitement. (Rogers, 2006.)

Some concerns in UbiComp are to fathom out what would be the most feasible way to present and represent information, what kind of tools would be the best way to give access to this information and to provide more information about the activity at hand. How to provide this new technology for the users and how to help them to use it more efficiently. This knowledge could be achieved by experimenting with the new technology and studying human behaviour and practices with their current tools in their surrounding environments. Rogers named the three most promising areas where the ubiquitous technology could be used and harnessed to enhance the human practices of various kinds. These are “Playful and Learning practices”, “Scientific practices”, and “Persuasive practices”. The goal is to design and implement “tool-kits” for the users for example to enhance learning and provide more applicable complex problem solving capabilities. (Rogers, 2006.)

New movement called “in the wild” is emerging to dominate the research in the HCI field. Researchers are now rejecting the old habits making studies only in their stale usability labs and moving in to the “wild”. Decamping their research setting in the real-
world, taking the sampling experiences, in situ user studies in real homes and on the streets. The emphasis is to gain better understanding about ordinary living and extend it by creating novel technologies. In the wild approach differs from the earlier methods of observing existing practices and then suggesting a generalization to the design and requirements, by more preferably focusing on creating and evaluating new technologies in situ. (Rogers, 2011.)

Novel technologies are made to augment people, places and settings without focusing on some special user need. A key concern is how the people adapt these new technologies, and how they are going to react and change their habits in their everyday lives. Designing in the wild has been made possible by the new and affordable plug-and-play technologies and tools such as Arduino, mobiles, actuators, sensors, displays of various kinds. Also the new user friendly programming languages and wireless connection techniques play a big part in the change from the lab to the wild. By combining these new techniques offer the designers and researcher more possibilities to innovate and create new artifacts. The evaluation of these new artifacts is also made in the wild in situ. Involving observing and recording the user behaviour and how this changes over a time. (Rogers, 2011.)

The outcome of conducting in-the-wild studies may differ significantly from the basic lab studies. It may enlighten the human behaviour with the artifacts more because they are using the new technologies with their own terms and the user’s own situated purposes. The user testing is conducted in a more complex environment and there may be no assistant or researcher to tell you what you should do, when to do it, or where you should sit when doing it. In the wild it can be more difficult to find out what is causing the observed effect. Nevertheless, according to Rogers because of the earlier empirical lab findings and the theories do not seem to fit, we need to conduct user testing in a more complex environment than a laboratory. With a more complex environment, Rogers means a situation where the outside distraction is not cut off. Earlier, most of the studies have been made in a closed, isolated rooms, with a minimum distraction. On the other hand in the wild studies, people behave more unpredictably. Users may be distracted by other people, they may be constantly interrupted and so on. Without forgetting the old knowledge of the interaction design and theories, Rogers suggests that we should import the theories into the interaction design that have been developed to explain behaviour as it occurs in a real world. Furthermore, according to Rogers we need to reconceptualize how a theory will have utility in the wild and develop new theories based on the findings emerging from in-the-wild studies. (Rogers, 2011.)

Privacy is a hot topic nowadays, but its impacts have not yet fully reached the ubiquitous computing where you would think its relevancy is really high. Although some of the projects explicitly address privacy, they are most often ad hoc and system specific. One of the reasons could be that the ubiquitous computing as a concept is still an infant, but it might also be that computer scientists have a hard time to approach this matter which can be considered as social, or even ethical issue. The first data protection law was made in Germany in 1970, but the most influential pieces of legislation were the US privacy act of 1974. The principles of fair information practices were introduced by governmental advisory committee and included practices like openness and transparency, individual participation, collection limitation, data quality, use limitation, reasonable security and accountability. These principles were incorporated into all major pieces of privacy legislation worldwide, but they were no success at home. What makes it different in ubiquitous computing is that communications between these small devices happen in more dynamic environment, and it is most often wireless. There have been lots of opinions about the privacy, and some of us even think that it is not very important aspect. Some people have argued that life would be better without privacy.
They say that we have never had total anonymity, so why would we have it now in the time of bits. (Langheinrich, 2001.)

According to Park & Jayraman (2003), it is possible to improve the quality of life of people of all ages with technology, when we can for example monitor the life of elderly citizens and support it for easier lifestyle. With technology rapidly improving and changing, we can affect the health-care and the field of medicine constantly to provide safer place for patients. Any technology that can minimize the loss of human life or improve the quality of life is priceless.

Starner et al. (1997) state that the acceptance of multimedia and Internet is growing constantly. This is enabling the usage of personal computers with everyday devices such as telephone, fax or television. Also Park & Jayraman (2003) informs that a need for portable devices has been growing in the field of medicine, because devices need to be moved rapidly from one location to another for different patients. Starner et al. (1997) also say that personal computers still have a flaw as they are located at the desk and cannot be with the users most of the day. This issue can be resolved by designing a multimedia computer which can be worn as clothing. The wearable computer connected to a network, could possibly replace every portable device which users use such as wristwatch, cellular phone, compact disk player, camera and other things. Heads-up displays and earphones integrated to the wearable computer could provide more interactive interface with the user and thus give a new range of applications.

Using different kind of sensors with wearable computation could possibly make the device see and hear the surrounding environment and also sense the user’s physical condition and see what the user is trying to do. With the mentioned information combined, the wearable computation could possibly predict the task the user is trying to accomplish and assist the user with the task. Although augmented and virtual reality focus on expanding the human-computer interface with 3D graphics and have made a significant change in computing, the word processing is still dominating the use of computer. With the heads-up display the wearable computer can display messages to the user in meaningful situations, when the computer is aware of the user’s location. When the computer understands the task at hand when the user is doing word processing, it can assist the user to remember and access information because word processing does not require much processing power and then the remaining power can be used to search relevant information for the user. (Starner et al., 1997.)

When attaching a video camera to the wearable computer, it allows many different kinds of user interfaces. The video camera system can be used to replace the conventional mouse and use user’s movements as guidance for the system and the system can provide view of the problem to a remote user. These “over the shoulder” telepresence sessions can be applied in repairing, maintenance, medicine, security and many other fields. The wearable computing system can also digitize the video cameras input and process the images thus making the camera a sensor which then can send data to the remote user and shown on the remote user’s user interface. Wearable computing gives as a chance to create physically placed information which allows the users to use their wearable computers to download information from specific place, for example from museum the user could acquire information about the exhibition taking place. Wearable computing also gives us the chance to help visually impaired people’s sight. It is possible to take the visual input of the camera and display it on the heads-up display with magnification which could possibly help visually impaired people. (Starner et al., 1997.)

In an article by Azuma et al. (2001), head-worn display is defined as user mounting to their head a display head which will then display image in front of their eyes. There are
optical see-through and video see-through head-worn displays. The video see-through head-worn display uses camera input as a background for augmented reality overlay and the optical see-through head-worn display provides augmented reality overlay to the transparent display. Displaying information on head-worn displays can be achieved with either using an LCD display where the information is drawn or using a virtual retina display where low-power lasers draw the information directly on to the retina. The ideal head-worn display would look just like a pair of sunglasses which are light and durable.

### 3.3 Telepresence and Virtual Reality

In the year 1941, new communication medium was introduced to the people, a television which could give vision at a distance. Very quickly this medium was not only a novelty in the research labs, but it was flickering in homes. In the year 1988, another new communication medium was introduced, a virtual reality. This new technology presented HMDs, new kind of television that is wrapped on our heads and expands or immerses our view of the real world. This also becomes to change our thinking about the ways of ordinary communication. (Biocca & Levy, 2013.)

Virtual Reality (VR) in the literature is usually defined in terms of technological hardware rather than experiential, because of the technological hardware it consists of. The technology may vary, but usually it is thought to include computers, HMDs, headphones and motion sensing gloves. One different definition for the VR is a variable based definition which could be used to classify the VR in relation to other media. The definition of VR is based on “presence” and “tele-presence”, which are concepts that arise from the sense of being in an environment which has been generated either in the means of natural or mediated. Nowadays VR can be portrayed as a medium, such as a television or a telephone. (Steuer, 1992.)

The key concept when defining VR not in the technological terms, but in terms of human experience is presence. Steuer (1992) defined the presence “Presence can be thought of as the experience of one’s physical environment; it refers not to one’s surroundings as they exist in the physical world, but to the perception of those surroundings as mediated by both automatic and controlled mental processes.” Various factors in perception contribute when generating this sense. Not only can it include input from all sensory channels of perception or just from some of them, but also from other mental processes.

Presence is taken for granted in unmediated perception, but when mediated by communication technologies, two separate environments become forced to be perceived simultaneously. This includes the physical environment the one is perceiving and the environment which is presented by means of the medium. This extends the dimension of the perceiver’s feel of being present in the immediate physical surroundings also to the mediated environment. This leads to definition of telepresence, “telepresence is an experience of presence in an environment by means of a communication medium”. The environment can vary from real world distant environment which is viewed through video camera or computer generated virtual environment. It also leads to the definition of virtual reality, “virtual reality is a real or simulated environment in which a perceiver experiences telepresence”. (Steuer, 1992.)

Semantic Reality (SR) is used to connect the virtual world into the real world. In the literature, SR is defined as an information space in a machine understandable form. The information space is constructed by integrating the physical world and computers in real-time using sensor technologies of various kind. In this way it is possible to represent the physical world in the cyberspace and the information will be ubiquitously
available on the Internet. Applications built for monitoring, manufacturing, health, tracking and planning can then exploit this integrated information space. (Hauswirth & Decker, 2007.)

Virtual reality application used in this research as a communication medium is Old Birds, which is a web-application prototype that that gives the caregivers a novel way for observing, monitoring, communication and guidance. Old Birds has started as a student project VESC (Value Creation in Smart Living Environment for Senior Citizen) in University of Oulu, Department in Information Processing Science. The VESC projects are made for developing and analyzing smart technologies and services which could be used to support elderly people, their daily life and health care. Old Birds is a smart tool for caregivers run by a game engine that is originally build for remote caregiving from the concept made by Pulli et al., (2012) and implemented by Firouzian & Nissinen (2013) in Oulu University. The prototype could offer detailed information about the elderly citizen’s whereabouts and their health condition. This prototype could also come in handy when considering other user groups, like people suffering from memory illnesses of different kind. In addition it may give other caregivers like the relatives of the elderly the possibility to attend the caretaking of their kin.

Old Birds utilizes Unity game engine (Unity3D), which includes capabilities, such as support for workflow and multiplatform. Workflow can be used in interactive media and software development to improve the process of development (Roudaki & Doroodchi, 2009). The reason for using workflow in the Old Birds is that software features could be tested before implementing them in the real world. A workflow database has been designed earlier to predict probable life situations of various kinds. With the current state of the prototype it is possible to make simulations about everyday life scenarios. The simulations are presented in an isometric 2.5D environment, which can make it more interesting for the user. This is also due some tools and features which may be implemented in the future. Some scenarios have already been implemented for hypothetical senior citizens in the prototype. One scenario for example is the outdoor environment where the senior citizens may roam. A map can be used to pinpoint senior citizen’s whereabouts according to the GPS coordinates coming from the workflow database (Fig. 6). As the monitoring just one senior citizen might be a time-consuming task, the Old Birds provides a way for monitoring and assisting multiple seniors at a time. (Firouzian & Nissinen, 2013.)

Old Birds uses avatars to represent the elderly citizens in the simulations (Fig. 6). Although a human like model might be an interesting option for the representation of the hypothetical characters, it may pose some serious privacy issues. To avoid these privacy issues which may arise, the avatars are designed to have cartoonish appearance. The monitoring tool also includes an information box for every avatar. The information box includes personal information such as living status, age, medical information and technical skills that the elderly citizens have. The information box appears when the caregiver hovers the mouse over an avatar. (Firouzian & Nissinen, 2013.)
It is also possible to simulate indoor locations of various kinds. The main shopping mall of city of Oulu, Finland, for example, is designed and included in the simulation scenarios (Fig. 7). (Firouzian & Nissinen, 2013.)

Home environments should be designed separately and accurately to match the real environment at home. The walls must have low opacity so they don't block the view of the caregiver. (Fig. 8). (Firouzian & Nissinen, 2013.)
All of the views are combined so that the avatars can move from inside to outside view and vice versa. When moving outside, the original game coordinates can be replaced to real map coordinates coming from the Global Positioning System (GPS) to pinpoint the elderly citizen location on the map (Fig. 6). This is only applicable when the user is wearing a GPS device. (Firouzian & Nissinen, 2013.)

For the latest version of Old Birds, new features were designed and for example a communication tool for the caregiver was implemented. The tool allows the caregiver to send a text message or make a phone call to a senior citizen in a simulated situation. The tool could be useful when the caregiver needs to make a contact. The communication tool allows the caregiver to make a call to multiple seniors at a time. This might come in handy when an urgent announcement for a specific group of elderly is needed. The user interface includes caregivers phone panel that have a button for bringing forth the caregiver's phone tool. (Fig. 9). (Ponrasa et al., 2014.)
3.4 Technology behind the platform and smart glasses

The mobile communication technology and hardware has enhanced to the level where the smart phones are used by majority of the citizens in Finland. Smart phones contain many useful sensors such as GPS that can be used by the caregivers to track elder citizen. In this chapter the following topics will be introduced: Communication platform and Pupil pro smart glasses and Indicator-based smart glasses.

3.4.1 Communication platform

Mobile communication technology involves different operating systems. The main smart phone operating systems are: Android, IOS, Symbian, Windows Phone and Blackberry OS. (Anderson & Hall, 2009.) In this thesis the Android platform has been selected because of the researchers former knowledge of developing with Android.

The era of Google began in the year 2005, when Andy Rubin was asking Google for a start-up money, but in the end Google bought the company and the developers working there. Android differs from other manufacturers because Android’s source code is mostly released under an open source license but other manufacturers release their operating systems as closed source. This means that anyone can use and modify Android operating system and also developers can create applications for it without any complications because of licensing. (Marziah, 2001.)

Android’s architecture is built on Linux kernel and is composed of different layers forming together a software stack which includes applications, application framework, libraries, Android run-time and Linux kernel. Android comes with a set of applications that are essential for users nowadays such as email client, SMS program, calendar,
maps, browser and many more. All applications in this application layer are written in Java and every application that is made will be placed in this layer. (Saha, 2008.)

The application framework in the Android component stack makes component reuse possible in Android. This means that all applications have access to other applications capabilities which enables the reuse of components. For example, if you have a calendar program on your mobile and want to get your events from your email you could just use the email application to add those events in to the calendar instead of switching applications back and forth. (Saha, 2008.)

There are various components in the Android system, which use libraries that are written in C/C++. The functions of these libraries can be used through the Android framework by developers. Android also is included with core libraries that provides almost all features of the Java programming language. (Saha, 2008.)

Each Android application is started in a new process with an instance of Dalvik virtual machine. This virtual machine has been designed to support running multiple virtual machines concurrently in one device and it uses the Linux kernel for threading and low-level memory management. Dalvik is not the only component relying on Linux kernel since Android uses Linux kernel to abstract software and hardware from each other and it is also been used with security, memory management, process management, network stack and driver model. (Saha, 2008.)

![Android Software Stack](image)

**Figure 10.** Android Software Stack, (Android, 2015d.)

### 3.4.2 Pupil Smart Glass Platform

Bulling, Kassner, & Patera (2014) informs that head-mounted eye tracking devices are useful for customers in research and industry, but they are usually closed source and are...
expensive to purchase. A problem arrives from this, where the experts are the only real customers.

Bulling et al. (2014) introduce Pupil which is accessible, affordable and extensible open source platform created for mobile eye tracking and gaze-based interaction. Pupil consists of a headset which has camera for eye tracking and a camera to capture the view of the holder, open source framework for developing software that uses Pupil and a software for using recording and using the data from the cameras.

Pupil headset cameras use USB interface to communicate with other devices and support UVC standard. Because of this the cameras can be used with devices that support UVC standard and vice versa cameras that support UVC standard can be used with the Pupil software. Pupil eye tracking system can be used with laptops, computers, or mobile devices but may require additional setup from both the user and the developer. Pupil can be used with mobile for lightweight applications and for applications which use streaming, geo-tagging, multi-user synchronization. (Bulling et al., 2014.)

Pupil software source code is licensed with an open source license and two main parts of it are Pupil Capture and Pupil Player. Pupil Capture can capture and process images from two or more camera video streams in real-time. Pupil Player is used to playback video that were captured with Pupil Capture and it can also provide useful data in a visualized manner which can be visually inspected. (Bulling et al., 2014.)

Figure 11. Pupil Pro headset. (Bulling et al., 2014.)
3.4.3 Indicator-based Smart Glasses

Indicator-based smart glasses are introduced here because they will be integrated to our system, which then uses the glasses to give instructions to senior citizens about where they should be headed next.

Firouzian (2014) states that senior citizens that suffer from dementia are the main users of head mounted display systems. These systems are created to assist demented citizens with tasks for everyday life, but developing these systems requires designers to consider factors such as quality of life and safety.

Firouzian (2014) informs that there were first two prototypes for the Smart Glasses and the indicators were positioned differently to the frame in each device to see which one could provide more meaningful navigation clues for the user. After testing these prototypes, it appeared that neither of the prototypes was not able to provide optimal navigation clues. This made the researchers create another prototype which is a mixed version of both prototypes and it contains fourteen LED indicators that are placed on the frame of the glasses. Figure 12 shows the prototype with the fourteen LED indicators implanted to the frame.

![Figure 12. Sketch of Indicator-based Smart Glasses. (Firouzian, 2014.)](image)

The LED indicators placed on the Smart glasses can change their color to red, green and yellow based the electrical signal received. The indicators together can be given instructions to blink with specific frequency and brightness. The Microcontroller embedded in the Smart Glasses can receive 32-bit array data from the Android application using Bluetooth. Figure 13 shows the front-side view of the constructed prototype of Indicator-based Smart Glasses. (Firouzian, 2014.) These LED indicators are used in the research to help the guidance of the elderly citizen. The LED indicators can blink with different patterns to show directions for the elderly citizen. The LED indicators can be used to give directions such as forward, left, right, stop, back and so on.
The first 28 bits of the array data contain the colors settings for each LED indicator. These bits are divided into pairs which are used to indicate the color of a specific LED. When the first bit of the pair is set, the LED is blinking with color red and if the second bit of the pair is set the LED is blinking green. The color yellow can be achieved with setting both bits of the pair. The last four bits of the array are used to define the brightness of the LED indicators. (Firouzian, 2014.)

3.5 Location based sensing

In this chapter we jump in to location based sensing. Which includes location sensors and how to acquire the location of the citizens, magnetic field and acceleration sensors and how they will be used to determine the heading direction of the elderly and lastly the open-source will be introduced and explained why it has been selected as an approach for this thesis.

Milette & Stroud (2012) informs that Android devices are just like conventional computers but they have sensors embedded which you cannot normally see on a computer. These sensors make Android devices able to locate themselves, see around and listen and understand speech.

With these sensors Android devices can sense radio signals and detect orientation, movement and environmental properties. Because of these versatile sensors, it is possible to use them to make life easier. For example, sensors can help user to input text to the device by just speaking to the Android microphone. (Milette & Stroud, 2012).

Milette & Stroud (2012) also informs that sensors will continue to be part of Android platform, because when the hardware of the devices improve it will also increase the number and quality of the sensors. Because of this, the users will continue to expect that applications will use sensors when possible.
To be able to create Android applications, you must know at least the basics of sensors. In our research we will be using camera and microphone to help the communication between caregiver and elder. Also locations sensors and physical sensors will be used together to achieve good tracking capabilities.

3.5.1 Location Sensors

According to Kushwaha & Kushwaha (2011), sensors used for determining the location of the phone are called location providers. Location providers have become extensively used in applications because these providers can be used to determine the phone’s surroundings. This means that with the phone the users can see if there is something interesting in the area such as a restaurant.

Applications that are depended on the location of the mobile phone are called location based services. These services are used together with mobile Internet access for entertainment and information gathering, hence the two main actions these services include are to pin point the location of the user and to use this information to provide a useful service. Typically these services are used to improve some aspect or make something easier for example in health, work or personal life. Location based services can be categorized into two different services: triggered location based services and user-requested location based services. (Kushawa & Kushawa, 2011.)

Triggered location based services locate the user’s position when a certain condition has been triggered for example if the user is currently in an area where a hurricane is about to come, the application could then warn the user about the upcoming bad weather. User-requested location base services do not automatically pull the user location but instead the user decides when to retrieve the location. These services are usually used in navigation applications to find the location of the user or nearby restaurant which the user wants to visit. (Kushawa & Kushawa, 2011.)

The location based services do not work alone, but instead they consist of at least these components: mobile device, application, communication network, positioning component and service server. The mobile device is not always a mobile phone, but it can also be for example personal data assist device or some kind of a navigation device. These devices are used to access the location based services by users which are sending requests and retrieving results. (Kushawa & Kushawa, 2011.)

The application is typically developed by an outside party and then later on installed by the user to the device. The application acts as an interface to access the location based service and these applications are developed to be very lightweight and battery efficient in general. (Kushawa & Kushawa, 2011.)

When the user requests information from the location based service there is a need for some kind of communication network, which can transfer the user requests from the mobile device to the service provider, and then the information back to the user. Global System for Mobile (GSM) standard is currently the most used by mobile networks and mobile phones. These networks are controlled and maintained by the operators which provide and charge the users for using the mobile network connectivity. (Kushawa & Kushawa, 2011.)

The location based service application can work without positioning component, but then the location must be set manually to work. Most of the location based services do not require the user to manually give the current location. The user’s location can be tracked with a positioning technology such as satellite positioning or cellular network
positioning. Service servers handle the calculation of positions, determine route to a location, or search information based on the user’s position. The service providers do not store or maintain the information requested by the user but content providers store and gather geographical data and location-based information and other related data which can be then requested by the service servers and forwarded to the user. Figure 14 shows the typical information flow and process of location based services. (Kushawa & Kushawa, 2011.)

![Figure 14. Flow and process of location based services. (Kushawa & Kushawa, 2011.)](image)

### 3.5.2 Physical Sensors

According to Milette & Stroud (2012), before the smart phones started blooming people interacted with devices with a single purpose, single sensor in their daily life such as tire pressure sensor. When the smart phones came available for the general public, the number of sensors around the people increased. This started a trend where multiple sensors were in a single device and the device had more than one meaningful use.

Android software stack was first introduced with sensors in Android 1.5 (API 3). Later on in Android 2.3 (API 9) more sensors were added to the hands of developers and methods which supported these sensors. The standard sensors in Android currently include the accelerometer, gyroscope, magnetometer, light sensor, proximity sensor, relative humidity sensor and pressure sensor. These sensors provide a wide range of options for developers in navigation, gaming control, augmented reality, and many other uses. (Milette & Stroud, 2012.)

Sensors can be classified to raw and synthetic sensors. Raw sensors give raw data from a sensor which is only one physical component in the Android device. Synthetic sensors have an abstract layer between the source code and physical component. The abstraction layer modifies the sensor raw data to make it easier to use or it combines raw data from multiple different sensors and before releasing the data to the application it might be altered. In this research only accelerometer and magnetometer will be introduced from the physical sensors because they are used in the artifact. (Milette & Stroud, 2012.)

Global coordinate system and device coordinate system are defined in Android when using orientation and movement sensors. Both coordinate systems are shown in the Figure 15.
Global coordinate system is used by all sensors and methods which are dealing with absolute orientation with respect to Earth. In the global coordinate system the $Y_E$ coordinate points toward the magnetic north, which is approximately true north. The coordinate $X_E$ points approximately east and is parallel to Earth’s surface but 90 degrees from $Y_E$. Lastly the $Z_E$ coordinate points away from the center of the earth. (Milette & Stroud, 2012.)

Device coordinate system use the values gathered from the accelerometer, magnetometer and gyroscope. Part of the device coordinate system is the default orientation which changes depending on the type of the device. Smart phones for example use portrait default orientation and tablets use landscape as default orientation. When the device is in its default orientation the x-axis is horizontal with positive values to the right. The y-axis is vertical with positive values upward and the z-axis has positive values in front of the screen. (Milette & Stroud, 2012.)

There are three different representation type of rotation matrices: 3-vector, rotation matrix and quaternion. For example with 3-vector gyroscope reading (0.3, -0.5, 0.0) tells us that the rotation rate around the x-axis is +0.3 radians per second, -0.5 radians per second around the y-axis and the rotation rate around z-axis is zero. The direction of angular three-vectors is determined with the right-hand rule. When your right hand thumb is pointing to the positive direction of the axis, your fingers will curl around in the direction of positive angle. (Milette & Stroud, 2012.)

### 3.5.2.1 Accelerometer Sensor

According to Kwapisz, Weiss & Moore (2011), Android phones contain accelerometer sensors which measure the acceleration of the device. These sensors makes it possible to detect the orientation of the device with the help of earth’s gravity which can be used in our research together with magnetic field sensor to determine the heading of the elderly.

When accelerometers were created their purpose was to support game play and enable automatic screen rotation, but they can be used for many other purposes. For example...
with these sensors we could monitor the activity level of the user and report the results back to the user at the end of a week in the users sport application. (Kwapisz, Weiss & Moore, 2011.)

Acceleration sensor contains springs which have a mass attached to them. This enables the measurement of acceleration by watching how far the mass deviates from its original position. In figure 16, the picture A represents a device which is placed on a table and picture B is a picture from a situation before the phone leaves the user’s hand when throwing the phone to the right. Picture C is from a situation where the phone is free-falling. (Milette & Stroud, 2012.)

Figure 16. Acceleration sensor springs affected by gravity. (Milette & Stroud, 2012.)

From this we can see that accelerometers can measure the force of gravity and linear acceleration. We can also determine that acceleration is zero in the picture C, because it is subjected to Earth’s gravity and this makes both the mass and the frame to get same acceleration so the springs do not deform. (Milette & Stroud, 2012.)

The sensors masses are pulled downward because of the force of gravity which makes the tiny springs deform and giving the possibility to measure the acceleration of gravity. In conclusion when the sensors are resting the force of gravity can be measured, when the device is shaken or moving, the acceleration of the force applied to the device can be measured and when the device is free-falling the acceleration sensor gives acceleration as zero. The acceleration in Android is reported in m/s2 so in free-fall the sensors z-value is +9.8 m/s2, because z-axis reports positive values for downwards acceleration. (Milette & Stroud, 2012.)

3.5.2.2 Magnetic Field Sensor

Milette & Stroud (2012) inform that magnetic field sensors do not always use the same methods, because the manufacturer and architecture but most of the magnetometers in the market use Hall effect. The manufacturers might also use magneto-resistive materials or Lorentz force in place of Hall effect.

Hall effect sensors pass a current though a wire and magnetic field component attached to the wire, makes the wire on the other side to be more dense. A voltage goes through the width of the wire which is proportional to the magnetic field. Lorentz force sensors measure the mechanical deflection of the wire but is very similar to the Hall effect. In
the end the magnetic field result is given in the same form with using x,y,z axis by having one sensor on each axis. (Milette & Stroud, 2012.)

Magnetic field is reported typically in range around 2000 in Android with microtesla units and the resolution for magnetic field sensor is 0.1 microtesla units. The earth’s magnetic field can change from 30 microtesla units to 60 microtesla units, but the value does not need to be so exact and in fact the magnetometer are not very accurate and will fluctuate depending on environmental and hysteretic effects such as the presence of a nearby metal or magnet and even some nonmagnetic materials might affect the results. Hysteresis effects is a situation where the sensors history of the environment is taken in to the calculation and then the calculation is not using the values the user wants to measure. (Milette & Stroud, 2012.)

When and if better accuracy is needed Android provides a GeomagneticField class, which estimates the magnetic field magnitude and direction at given point on Earth when provided with latitude, longitude, altitude and time variables. Magnetometers calculate the absolute magnetic field of Earth always, but in reality the values measured change because of the local magnetic environment and device history. Because of the sensors react in nearby metals, people have used the sensors as metal detectors. (Milette & Stroud, 2012.)

When the magnetometer is used to make a compass, the heading might start jumping around. Waving the device in a figure of eight will usually make the magnetometer provide more stable results. The figure of eight ensures that the magnetometer gets a wide range of data changes which then helps the magnetometer to start working again. The figure eight waving should be done in a way that all three axes are put to work and thus they are getting accurate data again. (Milette & Stroud, 2012.)

3.6 Open-source implementation

According to Raymond (1999), Moody (2001), & Sharma et al. (2002) open source software’s creation is done by freelance developers which are working together over the Internet. The source code of open source software can be freely distributed. On the other hand Perens (2005) states, that a patent or a license protects proprietary software and source code which the software holds. Barahona et al. (1999) says, that outsiders can’t normally access the source code of a software. The source code can be accessed by requesting a permission from the company, but this cannot be guaranteed because they do not have any obligations regarding this. Onetti & Verma (2009) describe proprietary software as a software that has the source code hidden and locked and it belongs to an individual or a company. Also the source code is not distributed with the software.

Open source software is the other end of the spectrum because open source software includes the source code and allows distribution of it in source code and executable form. Open source software also has open source licenses and the source code might be under one or multiple open source licenses. The developers of the source code can choose a proper license from a list of pre-approved licenses. When to software projects source code is made available for everyone, it might create some interest in the open source communities and thus creating more developers to focus on the project and develop it further. (Onetti & Verma, 2009.).
4. Implementation

In this chapter the implementation of the visual guidance system will be explained in more detail. Our main purpose of this research was to facilitate interworking for existing Old Birds networked virtual communication environment with existing indicator based smart glasses guidance navigation interface. Later on it was decided to include Pupil Pro glasses into the visual guidance system to ponder the possibilities of camera based smart glasses in elderly citizen’s health care.

The visual guidance system consists of three components: smart phone, smart glasses and communication tool. The implementation is divided in two parts: Communication tool and Android tool which in as whole include these three components. The Communication tool consists of client and the web server and the Android tool at the smart phone, smart glasses and Pupil Pro.

4.1 Requirements

Requirements for the system derive from the initial brainstorming meeting with Prof. Pulli and from earlier studies Siitonen, (2011); Pulli et al. (2012); Ponrasa et al. (2014). With the system it should be possible to track whereabouts of the users and pinpoint the location and orientation of elderly citizen on a map. It should offer the caregivers a possibility to make a contact in the elderly citizen’s end point including real time audio and video feed. The system should utilize smart glasses and pupil pro smart glasses. The system must be robust and reliable. The Android tool should be automatic and built so that it doesn’t hinder the use of the smart phone. Table 2 summarizes the requirements.

<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Real-Time GPS Tracking</td>
<td>The system must enable real-time GPS tracking of the elderly citizen.</td>
</tr>
<tr>
<td>2</td>
<td>Real-Time Heading Tracking</td>
<td>The system must be able to get the heading of the elderly citizen in real-time.</td>
</tr>
<tr>
<td>4</td>
<td>Video communication</td>
<td>The system must be able to initiate video calls between the Communication and Android tool.</td>
</tr>
<tr>
<td>5</td>
<td>Voice communication</td>
<td>The system must be able to initiate voice calls between the Communication and Android tool.</td>
</tr>
<tr>
<td>6</td>
<td>Map</td>
<td>The system must include a map to pinpoint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7</td>
<td>Indicator based smart glasses</td>
<td>The system must be able to use indicator based smart glasses with the system to help guide the movement of the elderly citizen. The smart glasses should be operable from Old Birds.</td>
</tr>
<tr>
<td>8</td>
<td>Pupil pro smart glasses</td>
<td>The system must be able to use the Pupil pro smart glasses in order to feed the Communication tool the video feed in the video calls.</td>
</tr>
<tr>
<td>9</td>
<td>Hidden and automatic</td>
<td>The system must be automatic and without user interface in the Android smart phone.</td>
</tr>
<tr>
<td>10</td>
<td>Robust and reliable</td>
<td>The system must not overuse the phone so that it can be used for other purposes as well.</td>
</tr>
</tbody>
</table>

To fill the requirements with regard to the real time audio and video feed an existing VOIP (Voice Over Internet Protocol) solution was decided to integrate within the Old Birds and Android environments. VOIP enables the use of the Internet as the transmission medium when initiating telephone calls. It allows the sending of voice packets over the IP (Internet Protocol) instead of traditional circuit transmissions which is used in PSTN (Public Switched TelePhone Network). (VOIP, 2015.)

When selecting existing VOIP solutions Skype was our first option, but it turned out that Microsoft had terminated the public API (Application Programming Interface) in 2013, which would hinder the usage in both environments. (Microsoft, 2013). The other option was Linphone, which is GPL v2 licensed SIP (Session Initiation Protocol) phone that is available on multiple environments, like Android, Windows and Mac. Linphone offers the user a GUI (Graphical User Interface) for the phone that rests on the top of Liblinphone. Liblinphone is the core engine of the Linphone and includes all the functionalities of the system. In Figure 17, the architecture of the system is illustrated.
Mediastreamer2 is an open source library which can be used for streaming video or audio in Linphone. Mediastreamer2 supports various operating systems such as Android, iOS, Windows, Linux (http://www.linphone.org/technical-corner/mediastreamer2/overview).

Belle-sip is an implementation of the RFC 3261 protocol which is Session Initiation Protocol (http://www.linphone.org/technical-corner/belle-sip/overview). SIP is an protocol made for creating, modifying and terminating sessions which can include multiple clients. (RFC 3261.)

ORTP is an implementation of the RFC 3550 protocol. This protocol is Real-time Transport Protocol (RTP) which can be used for transporting data such as video or audio in real-time applications (RFC 3550).
The visual guidance system consists of five different sections which are shown in Figure 18. Smart phone includes the Android tool and its functionalities. The Android tool communicates with the smart glasses and web server. Web server includes the web service that operates between the Android tool and Communication tool. It also includes a database which can be used to store persistent data. Client includes Old Birds that is used as a communication medium between the caregivers and elderly citizens.

![Architecture of the visual guidance system for mobile senior citizen.](image)

Here in Figure 19 is presented one of the sequence diagrams for the visual guidance system. In Figure 19, the Admin presents the caregiver which decides to send turn directions for the elderly citizen. From the figure we can see that the caregiver first uses the turn direction function in the OldBirds user interface and after that the LED command is sent to the phone. From the phone the command is routed to the service which handles the command and creates the actual LED command for the smart glasses and then calls the function for the smart glasses which then lights up the LED indicator.
Figure 19. Sequence diagram of sending a LED command to the indicator based smart glasses.

Other diagrams about different situations are included in the Appendices A, B, C and D.

Some restrictions for this research were set at the start of this project. It was decided that the smart phone operating system is Android, since with it we can keep everything open source. Also the indicator based smart glasses are still a prototype that are used in this research, so this project will evolve after our research. In order to keep everything as real-time as possible, it was decided that communication from Android phone will be done using UDP or UDP based technology such as RTP.

4.2 Communication tool

The requirements define that the Communication tool must have a feature for making a contact to elderly citizen’s end point including real time audio and video feed. There should also be a possibility to track and pinpoint an elderly citizen on a map according to the GPS coordinates from the real world. In addition it should present the orientation of the elderly citizen according to the compass data and to send control messages into the elderly citizen’s end point. First we explain the implementation of GPS based tracking with control message sending and after that, the proposed implementation of communication is illustrated.

It was decided to implement an already existing map for this purpose and OpenStreetMap was selected. The selection was based mostly on the license and the fact that there were earlier implementations on Unity3D that were exploiting the OpenStreetMap. Google Maps was also one of the options we had, but it dropped out because of the tight restrictions and fees that might occur on heavy usage and hinder the use later on. Furthermore at the time of implementation the usage of Google Maps would have required the pro version of Unity3D which is commercial.
OpenStreetMap is licensed under the Open Database License and the cartography as CC BY-SA (http://www.openstreetmap.org/copyright). To integrate OpenStreetMap with the Old Birds project UnitySlippyMap (https://github.com/jderrough/UnitySlippyMap) was used. UnitySlippyMap is an open source project that is made for Unity3D and it utilizes OpenStreetMap. Some of the features in UnitySlippyMap were modified to fit the need and new ones created to fulfill the requirements of the project. UnitySlippyMap is licensed under the LGPL 3.0 license.

With UnitySlippyMap it is possible to place markers on the map in Unity3D environment according to the real world GPS coordinates. Utilizing this feature the avatars of the Old Birds can be placed on the map as markers. The marker's location and rotation have to be transformed according to the GPS coordinates and the compass data from the GPS device. The GPS coordinates and the compass data can be fetched from the web service which is explained later in more detail. UnitySlippyMap had all necessary features except the feature for handling the rotations of objects according to their orientation in the real world when using a compass. In addition a feature for the fetching of the GPS data from a web service or device is missing.

In Figure 20, OpenStreetMap is integrated into the Old Birds project. It includes controls from UnitySlippyMap for zooming the map in and out. It also includes controls for switching between 2D and 3D to help the usage of the map when tracking. The “control” panel was added for the user controls. By clicking “Forward”, “Stop”, “Left” and “Right” the control messages are sent to the elderly citizen's end point. The message format of the control messages are specified in the chapter 4.3.

![Controls for using the map and sending control messages to the elderly citizens.](image)

To represent an orientation of a rigid body, we can use Euler angles. The Euler rotation theorem states that any rotation is possible to describe by using three angle parameters, if they are written by the means of rotation matrices (X, Y and Z). While using these parameters it is then possible to write formula for the general rotation:
These three angles that produce the rotation matrices are called Euler angles. The next matrices are so called basic rotations (aka Elemental rotations) and they can be used in three dimensional space to rotate a vector using the right hand rule. In the right-handed coordinate positive X is pointing right, positive Y up and negative Z into the view.

Rotation about the x axis:

$$R_x(\alpha) = \begin{bmatrix}
1 & 0 & 0 \\
0 & \cos(\alpha) & -\sin(\alpha) \\
0 & \sin(\alpha) & \cos(\alpha)
\end{bmatrix}$$  \hspace{1cm} (2)

Rotation about the y axis:

$$R_y(\beta) = \begin{bmatrix}
\cos(\beta) & 0 & \sin(\beta) \\
0 & 1 & 0 \\
-\sin(\beta) & 0 & \cos(\beta)
\end{bmatrix}$$  \hspace{1cm} (3)

Rotation about the z axis:

$$R_z(\gamma) = \begin{bmatrix}
\cos(\gamma) & -\sin(\gamma) & 0 \\
\sin(\gamma) & \cos(\gamma) & 0 \\
0 & 0 & 1
\end{bmatrix}$$  \hspace{1cm} (4)

Figure 21 illustrates rotations around X, Y and Z axis:

Figure 21. Rotation around X, Y and Z axes.

To represent the orientation of the user according to the compass data, we need to rotate the avatar only around the Y axis because in Unity3D the rotation about Y axis represents the heading. (Eberly, 2003). The heading matrix is a $[3 \times 3]$ matrix representing the rotation:
Next matrix shows how the points \((x,y,z)\) are rotated by multiplying the heading matrix in the original coordinate system to obtain the points \((x', y', z')\).

\[
H_t(\theta_h) = \begin{bmatrix}
\cos(\theta) & 0 & \sin(\theta) \\
0 & 1 & 0 \\
-\sin(\theta) & 0 & \cos(\theta)
\end{bmatrix}
\]

In Unity3D, the world coordinates are left-handed where positive \(Y\) is pointing up, positive \(X\) is pointing right and positive \(Z\) is pointing into the screen. The matrices introduced were intended for right-handed coordinates so conversion is required between these different coordinates. To switch between left- and right-handed coordinates we only need to flip the direction of one of the axes and it doesn’t matter which one. (Eberly, 2003). Every object in a scene of the Unity3D has a ‘Transform’ to store the object attributes position, rotation and scale. By manipulating these values, it is possible to manipulate the object’s position, rotation and scale respectively. All of the Transforms may have a parent so it is also possible to handle them hierarchically. In Unity3D, the rotations are internally stored as Quartenions and Euler angles must be transformed. Luckily there was a dedicated function in Unity3D to do this:

```csharp
public static function Euler(euler: Vector3): Quaternion;
```

Figure 22 is presenting the class diagram of the system including classes that are responsible of transforming objects position and rotation on the map, JavaScript (UnityScript) for sending and receiving data between the Old Birds client and the web service.
The Map class is responsible of all map related functions, like loading the map tiles from the OpenStreetMap server.

MainController class includes functions such as transforming the GameObjects positions that are placed on the map.

LocationController class creates connection to the web service and fetches location based information of the elderly citizens.

GlassController class is used to send messages to the elderly citizen’s end point.

To establish a way to exchange information between the Old Birds and elderly citizen’s end point, it was decided to build a web service for this purpose. Web services consist of application components and communicate together with open protocols, mostly using XML (Extensible Markup Language) and HTTP (Hypertext Transfer Protocol). These web services are accessible via network by other applications that can exploit these services ubiquitously. While there are different ways to build a web service, the one that is used in the research was decided to build in ReSTful manner.

ReST (Representational State Transfer) is based on ROA (Resource Oriented Architecture) and is a lightweight alternative for mechanisms like RPC (Remote Procedure Call), CORBA (Common Object Request Broker Architecture) or web services like WSDL (Web Service Description Language) which can be accessed via SOAP (Simple Object Access Protocol). WSDL is an XML based language that can be used to describe web services and SOAP is an XML based protocol that is used to access these services. ReST is used over HTTP protocol and while making usual requests like reading data (making queries), posting data (create / update), all of the CRUD (Create, Read, Update, Delete) operations can be used by ReST. (Richardson & Ruby, 2008; Webber, Parastatidis & Robinson, 2010.)

The service should contain a login for the users to log in the service. It should have user object to represent the current user that is logged in and using the service. Furthermore

---

**Figure 22.** Class diagram of the controllers.
there should be a way for handling location data and send control messages to the users of the service. Table 3 lists all the resources and bound actions that are included in the service.
Table 3. Resources of the web service.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Login</td>
<td>PUT, POST</td>
<td>Represents the user’s registering or log in in the service.</td>
</tr>
<tr>
<td>User</td>
<td>GET, PUT, POST</td>
<td>Represents a registered user of the web service.</td>
</tr>
<tr>
<td>Users</td>
<td>GET</td>
<td>Represents the users that are registered on the system.</td>
</tr>
<tr>
<td>User_profile</td>
<td>GET, PUT, POST</td>
<td>Represents the user information like health status of a user.</td>
</tr>
<tr>
<td>Location</td>
<td>GET, PUT</td>
<td>Represents the location of a user.</td>
</tr>
<tr>
<td>Control</td>
<td>POST</td>
<td>Represents the control message that is sent to a user.</td>
</tr>
</tbody>
</table>

The incoming messages follow the next JSON format:

```
{
    "User": {
        "Id": "value"
    },
    "Location": [
        {
            "Latitude": "value",
            "Longitude": "value",
            "Heading": "value"
        }
    ]
}
```
The implementation is made by using Python programming language following the guidelines of TDD (Test Driven Development) and utilizing Flask. TDD was selected because it was a convenient way to test the web service with “dummy” clients and furthermore it is performing well with the agile development and when utilizing the pair programming. In the TDD, the code is implemented so that the tests are written first and then the actual program code is produced and worked on until it passes the tests. The programming is done in iteration cycles of testing, writing and developing until the task is finished. (Beginning Test-Driven Development, 2015.)

Flask is a BSD licensed micro web development framework for Python that uses Jinja2 (Template Engine) and Werkzeug (WSGI library). (Welcome to Flask, 2015). The WSGI (Web Server Gateway Interface) ensures that the applications on all of the clients can communicate with the web server. The next code snippet presents a basic “Hello World” application using WSGI and Werkzeug. In the example the query string (‘name’ parameter) is taken from the request and substituted against another word.

```python
def application(environ, start_response):
    request = Request(environ)
    text = 'Hello %s!' % request.args.get('name', 'World')
    response = Response(text, mimetype='text/plain')
    return response(environ, start_response)
```

With WSGI application it is possible to call and pass a dictionary object (environ dict) and start_response callable. All of the incoming information is included in the dictionary object and the start_response function is used to indicate the start of the response. While using Werkzeug the request and response can be accessed as objects which makes their handling much easier. (Werkzeug Tutorial, 2015). Figure 22 shows the class diagram of the web service.
Figure 23. Class diagram of the web service.

The Login class includes functions for registering, session handling like verifying the username and password and logging in the user and storing the session data in the database.

User class represents the user and includes all the necessary functions for storing user related information, like response_ip which is stored in the database at initialization phase.

Users class represents all the users in the system. It can be used to retrieve the online users or just one specific user.

User_profile class can be used when storing and retrieving user related information, like the health status of an elderly citizen.

Location class is used to initialize UDP (User Datagram Protocol) socket for listening incoming location related information. The packets are excepted to be in JSON (JavaScript Object Notation) format for proper decoding.

Control class is used to initialize TCP socket and to send JSON format packets in the elderly citizen’s end point. The packets can include messages like guidance controls.
For storing persistent data like user information, the service uses MySQL. MySQL is an SQL (Structured Query Language) database server, which is dual licensed. It can be either used as an Open Source product under the terms of GNU (General Public License) or the standard commercial license that can be bought from Oracle. Figure 24 presents the ER (Entity-relationship model) diagram of the database.

User table consists of id, name, pwdhash, status, response_ip and contact_person. The id is the primary key of the table, name is the username, pwdhash is a hash presentation of the password, status presents the user state which can be either “online” or “offline” and response_ip is the IP of the client which is stored at the handshake process in the beginning. Contact person is the foreign key and it is pointing at the Id in the Caregiver table.

User_location table consists of id, longitude, latitude, heading and userid. They id is the primary key of the table. Longitude, latitude and heading are string expressions of the GPS coordinates and compass data. The userid is the foreign key and it is pointing at the id in the User table.

User_profile table consists of id, profile_text and userid. The id is the primary key of the table, profile_text stores the health status of the user and userid is the foreign key and it is pointing at the id in the User table.

Caregiver table consists of id and sip_address fields. The id is the primary key of the table and the sip_address is a string presentation of the caregivers sip address.

Sessions table consists of id, access, data and userid. The id is the primary key, access is the current timestamp, data is current session data and the userid is foreign key pointing at id in the User table.

Figure 24. Entity relationship model of the database.
For integrating Liblinphone in Old Birds environment we need to use the existing libraries from the Linphone project which are written in C programming language. In Unity3D it is possible to use functions that are written in native languages like C and compiled in libraries. To use these functions from the Unity3D we need to create a script in C# programming language that calls the functions from the native libraries. Next is a very simple example of a native library written in C with a single function and the C# script for Unity3D for accessing this code.

Native C library with one function:

```c
extern "C"
{
const EXPORT_API char*  PrintHello()
{
    return "Hello World!";
}
}
```

C# script for accessing the library:

```csharp
[DllImport ("PluginName")]
private static extern IntPtr PrintHello();

console.WriteLine(PrintHello()); //Would print "Hello World!"
```

By applying the possibility to import external libraries, it is possible to use Liblinphone libraries from the Unity3D and so it is usable in the Old Birds project. While searching for information about the external plugins in Unity3D, it was found out that there already is a solution for wrapping Liblinphone with C#. Following the earlier experiences with the software Liblinphone is integrated in the Old Birds environment by utilizing sipdotnet [https://github.com/bedefaced/sipdotnet](https://github.com/bedefaced/sipdotnet). Sipdotnet is a .NET wrapper for Liblinphone library and it is licensed under LGPL 3.0 license. Figure 25 presents the class diagram of sipdotnet. Sipdotnet was somewhat modified to fit the requirements of Old Birds. For example the UpdateCallState was added from the Liblinphone libraries to change the ongoing call state while a call was active. This allows changing from a voice call to a video call without terminating the current call and initiating a new one.
Linphone class handles the “wrapping” of Liblinphone libraries and functions as described earlier. Phone class is used when accessing these wrapped functions and events. Account class represents a SIP account, which is required when placing and receiving calls. Call class represents the calls, their types and states which are explained in the Linphone documentation in more detail. Figure 26 presents an ongoing video call from the Old Birds environment to the elderly citizen’s end point.

Figure 25. Class diagram of sipdotnet.

Figure 26. Ongoing video call from Old Birds.

The code will be available from Github in the future.
4.3 Android tool

The second part of the visual guidance system is the Android tool. The Android tool consists of an Android phone, indicator-based smart glasses and Pupil Pro smart glasses. In the Android tool implementation, there are multiple classes where each class provides various functions for the main service. These functions enable the caregivers to keep track of the elders, communicate with them and see what they are seeing which allows the caregivers to make the mobile senior citizen’s life easier and safer. Below is a class diagram of the Android tool.

Figure 27. Class diagram of the Android tool.

The class diagram contains a class called BootReceiver. This class is essential in our research because one of the requirements was that everything should be automated and there is no need for user interaction. This requirement meant that it was important to make a class which monitors the state of the smart phone and when the smart phone has completed booting, onReceive function is called and then the visual guidance system is started automatically which means that the VGSActivity is started.

Below is a code snippet containing source code from the BootReceiver class. This snippet is to show how applications can be started when phone has completed booting to the operating system. Be aware that if using similar code in other projects, the users might not like the behavior of applications starting without user’s consent.
@Override

public void onReceive(Context context, Intent intent) {
    if (Intent.ACTION_BOOT_COMPLETED.equals(
        intent.getAction())) {
        Intent i = new Intent(context,
            VGSActivity.class);
        i.addFlags(Intent.FLAG_ACTIVITY_NEW_TASK);
        context.startActivity(i);
    }
}

In Android every program needs an activity for it to run and next in our class diagram we can see the VGSActivity which is a class that extends the Activity class. The only purpose of this activity is to start the MainService service and it is done in the onStart function and after this it has to end itself by calling a finish function. The VGSActivity must be ended every time in order to achieve application without a user interface.

MainService is the heart of the application because it manages everything in the application and connects other classes together. MainService class implements two interfaces which are ConnectionObserver and AreaObserver. Both of these interfaces are implemented in order to use the Observer design pattern.

According to study by Alencar et al. (1995) design patterns are a collection of good practices in object-oriented programming. With design patterns we get re-usability into object-oriented programming since with design patterns we can use approaches used by the best programmers in our own applications.

When the Model-View-Controller (MVC) model started to become popular the design patterns were inspired from this since it is a programming model and it enables separating the user interface from the application. This does not mean that all design patterns separates the application from the user interface. (Alencar et al., 1995.)

Gamma, Johnsson, Helm, Vlissides (1994) categorize design patterns into three different groups. These groups are creational patterns, structural patterns and behavioral patterns. Creational design patterns make the system have more control over how its objects are created, composed and represented. They are used when the system starts to depend more on how objects are composed so the system cannot anymore rely on fixed source code but instead needs more flexible code. Structural patterns affect the way a large group of classes and objects can create structured forms. Structural patterns use inheritance to create these structural forms. Lastly the behavioral patterns affect objects responsibilities in the system, algorithms and communication between classes and objects. Observer design pattern belongs to the behavioral patterns group.

Gamma, Johnsson, Helm, Vlissides (1994) state that Observer design pattern is useful when there are situations where one object state is important to other classes. In
Observer pattern, one class is the class that will be observed and other classes can register to it as an observer. After registering, when the state of the observable class changes, it will notify all classes registered to it. Below is a UML class diagram of the Observer pattern where Observer1 and Observer2 are notified by Observable using notifyAll function.

Figure 28. Observer design pattern.

Code snippet example of the above introduced Observer pattern in Java without Observer2:

```java
public interface Observer {  
    public void notify();  
}

public class Observable {
    private List<Observer> observers = new ArrayList<Observer>();

    public void addObserver(observer) {
        observers.add(observer);
    }

    private void notifyAll() {
        for (int i = 0; i < observers.size(); i++) {
            list.get(i).notify();
        }
    }
}
```
public class Observer1 implementsObserver {
    public void notify() {
        System.out.println("incoming");
    }
}

In the Android tool the MainService and MsgHandler classes are observers and the CompassSensor, GPSTracker and MessageServer classes are subjects. Interfaces ConnectionObserver, AreaObserver and MessageServerObserver are used to make the Observer design pattern work.

In the Figure 27 above, only the relevant variables are mentioned. These variables are mCompass, mGps, mMsgHandler and mLinListener. The variables are objects created from classes CallHandler, MsgHandler, GPSTracker and CompassSensor. These objects are initialized in the onCreate command of the service, but these objects start working only when the handshakeReceived function has been called. The only exception for this rule is MsgHandler which needs to be running as soon as possible so that the handshake can be received. The handshake mentioned here only means at this point of development that a datagram package has been sent to the communication tool with user id and sip address for Linphone calls.

For the class MainService three functions are introduced in the class diagram. The function newDegree is called after the heading of the phone has changed. The newLocation function is called if the location of the phone changes for example if the gps location changes. Lastly the handshakeReceived function is called after the Android tool’s server has sent a handshake message to the communication tool server.

CallHandler class implements LinphoneCoreListener and Runnable interfaces in order to implement Linphone functionality to the application and make the class run in a separate thread in order to not interfere with the rest of the application functionality. This class also fulfills the requirements for video and audio communication. CallHandler is responsible for accepting and managing the Linphone calls from the caregiver.

When CallHandler class is initialized it adds default caregiver addresses to the allowedContacts which means that only the calls coming from the addresses in the list are accepted automatically and others are ignored. When the CallHandler’s startLin function is called, first the LinphoneCore object is initialized with pre-existing files which can be altered in order to change the Linphone settings. After this it is needed to create authentication information for the LinphoneCore so it can be used for creating and receiving calls. The authentication information is composed of username, password, realm and domain. Normally the realm variable can be left null and domain and username can be created from the LinphoneAddress. After this the function initializes LinphoneProxyConfig which is needed in order to register into the Linphone servers. After registering with the LinphoneProxyConfig it is placed into the LinphoneCore. Now the LinphoneCore is ready to be used and the startIterate function can be called. The startIterate function must call LinphoneCore’s iterate function periodically which handles the main functions of the Linphone such as authentication retries and receiving of SIP messages.

The second function shown in the class is callState which is called every time when the Linphone client is running and a state of the call has changed. There are many different
states for Linphone call, but in the Android tool it was only needed to monitor the states IncomingReceived, CallUpdatedByRemote, CallEnd. When a LinphoneCall is in the state of IncomingReceived, an incoming call has been received and this is when it is possible to see who is the caller and should the call be answered or not. In the application the function checks if the caller is in the pre-approved list of contacts and accepts or declines the call based on this. When the call’s state is CallUpdatedByRemote, it means that something has been changed by the remote party and this is used in the Android tool to check if the remote party wants to start a video call and if so then the camera is activated. Lastly the call state CallEnd is monitored in order to see if the remote party has closed the call thus we should also terminate it.

One of the requirements was that there must be a way to track the whereabouts of the elderly citizen. In order to achieve this the GPSTracker and CompassSensor classes were created into the Android tool. GPSTracker class implements the LocationListener interface so that whenever there are changes in the smart phone’s location this class is informed. GPSTracker has two important variables which are mLatitude and mLongitude. Every time a change has occurred in the GPS location the MainService is informed. GPSTracker class has also two important functions which are essential for this class. The onLocationChanged function is called when a change has occurred in the location and in the function the mLatitude and mLongitude variables are set with new values and the MainService is informed that a location has changed. Below is a code snippet from the onLocationChanged function.

```java
@Override
public void onLocationChanged(Location location) {
    mLocation = location;
    mLatitude = mLocation.getLatitude();
    mLongitude = mLocation.getLongitude();
    if(mIsRunning && mObserver != null) {
        mObserver.newLocation();
    }
}
```

The onStatusChanged function is called when the location provider’s state has changed for example if the current location provider is no longer available. This function re-registers listeners for the location provider so that the most accurate location is accessed every time.

The CompassSensor class implements the SensorEventListener interface in order to monitor the states of sensors and detect if the accelerometer or magnetic field sensors have new values. This class has mDegrees variable which always contain the latest compass heading degree value. When either accelerometer or magnetic field sensors values have changed the onSensorChanged function is called where the new heading values are calculated and inserted into the mDegrees variable. After this the MainService will be informed that the compass heading has changed.
In onSensorChanged function, there is a need to determine which sensor called the function. Example code snippet on how to determine the calling sensor is accelerometer:

```java
@Override
public void onSensorChanged(SensorEvent event) {
    if(event.sensor.getType() == Sensor.TYPE_ACCELEROMETER) {
        // Your code here
    }
}
```

The MsgHandler class implements the MessageServerObserver interface which contains the functions messageReceived and handshakeReceived. These functions are used to communicate between the MainService and the MessageServer. MsgHandler has an object called mLedService which represents the package uni.oulu.firstprotocol and is created from the FirstProtocolMain Activity. The object can be used to manage the indicator based smart glasses by using the function sendDirections. The function messageReceived is called by the MessageServer after receiving a message which then triggers the MsgHandler to process the messages using the function processMessages. This function parses the message and according to the message sends appropriate directions for the indicator based smart glasses. The handshakeReceived function is called also by the MessageServer after a handshake message has been sent to the Communication tool. This function only calls the MainService’s handshakeReceived function. MsgHandler has a function sendMessage which takes the location data as parameter and sends the message to the Communication tool’s server.

The package uni.oulu.firstprotocol contains classes which are developed by Aryan Firouzian, but some modifications were made. The original source code can be retrieved from [https://github.com/aryan-firouzian/FirstProtocol](https://github.com/aryan-firouzian/FirstProtocol). All the modifications were done in order to remove the user interface from the existing code. The package is used to manage the indicator based smart glasses and it contains source code for creating bluetooth connection with the smart glasses and functions for sending directions to the smart glasses.

MessageServer is a class which is used for sending and receiving packages between the communication tool’s server and the Android phone and peripherals attached to it. MessageServer class contains two inner classes which are DownloadMessageTask and UploadMessageTask. DownloadMessageTask is a class which creates a socket and listens to a specific port until a package has been received and after receiving the package it checks the type of the message that was in the package and based on that either calls for the function handshakeReceived or messageReceived.

The control messages downloaded by the DownloadMessageTask follows the next JSON format:
Above JSON example message makes the Indicators based smart glasses LEDs blink at the left side indicating to turn left.

The class UploadMessageTask takes a string as a parameter and creates a package out of it and then sends it to the Communication tools’ server. Below there is an example code snippet of the class where package is sent in background. Catch block is removed to simplify the source code.

```java
@Override
protected Void doInBackground(String ... text) {
    byte[] sendData = text[0].toString().getBytes();
    senderAddress = InetAddress.getByName(ipAddress);
    DatagramPacket sendPacket = new DatagramPacket(sendData, sendData.length, senderAddress, Integer.parseInt(serverPort));
    dSocket.send(sendPacket);
    return null;
}
```

In the function, first the parameter is placed in a byte array and after this server address is created from a String variable to form an InetAddress. After this a DatagramPacket is created from the bytes and the server address and port. After this the package is sent by using DatagramSocket’s function send. The code is available from github (https://github.com/korvatap/VGS4MSC).
5. Findings

In this chapter we summarize the research findings, problems and the evaluation of the system.

The first design cycle consists of the background research in order to build the knowledge database and to gain a proper knowledge about the problem. We started to design the system and it was decided that in order to make the visual guidance system to support audio and video communication between the elderly and the caregiver, an integration of VOIP application to the system was required. We started by gathering information about already existing VOIP solutions that could also be applicable in our project. In the first design cycle we inspected Skype and its properties, but it turned out that after Microsoft had terminated the public API it would not be suitable for our purpose. After discovering this fact, we examined Linphone and decided to choose it as our VOIP solution. Also already existing map solutions were inspected in this cycle. First option was Google Maps, but it dropped out because of the tight use restrictions and usage fees which might occur if the application goes viral. The second choice was OpenStreetMap which turned out to be suitable for our project.

In the second cycle, after designing initial diagrams utilizing the practices from object oriented programming, the next step was to start implementing the system. In the Android tool implementation the first step was to create source code to fulfill part of the requirements real-time GPS tracking and real-time heading tracking. The implementation was rather straightforward, but when testing trackers a problem occurred. Every time the smart phone’s screen went to standby the sensors stopped working and when the screen was turned on again sensors started working again. After a while of searching through the forums of the Internet, we found out that it was common among Android devices. Here is a link to a web site where is a list of Android devices that receive sensor events in standby and a list of devices that do not receive events in standby: [http://www.saltwebsites.com/2012/android-accelerometers-screen-off](http://www.saltwebsites.com/2012/android-accelerometers-screen-off)

Later on during work with the Pupil Pro smart glasses we had problems with getting the glasses working with the Android phone. After researching this particular problem it was discovered that it was due to the fact that the USB Host function was not supported by the current device used in testing the application. This took some time from our research but in the end we got a new Android smart phone which supported USB Host function.

If an Android device supports USB Host function it means that it can communicate with USB devices. The USB Host function consists of USB host controller and root hub with USB port and the operating system must enable the device drivers for the USB device in order to communicate with low-level drivers which can use the USB hardware. With USB Host function it is possible to detect USB devices, manage the data flow on the bus, check errors from the transferred data, provide and manage power for the USB devices and exchange data with other devices. (Axelson, 2009). In order to use Android USB host function, the device needs to be equipped with at least version Android 3.1. (Android, 2015a.)

The aforementioned problem was not the only one with the Pupil Pro glasses, since when it was time to integrate the Linphone into the application everything worked as
planned until the moment we tried to make Linphone to use the Pupil Pro glasses as camera device. Below is a code snippet of the function Linphone uses for setting the camera in Android.

```java
static public AndroidCamera[] probeCameras() {
    List<AndroidCamera> cam =
        new ArrayList<AndroidCamera>
            (Camera.getNumberOfCameras());

    for(int i=0; i<Camera.getNumberOfCameras(); i++) {
        CameraInfo info = new CameraInfo();
        Camera.getCameraInfo(i, info);
        Camera c = Camera.open(i);
        cam.add(new AndroidCamera(i,
            info.facing==
            Camera.CameraInfo.CAMERA_FACING_FRONT,
            info.orientation,
            c.getParameters().getSupportedPreviewSizes()));
        c.release();
    }

    AndroidCamera[] result = new AndroidCamera[cam.size()];
    result = cam.toArray(result);
    return result;
}
```

As we can see from this the Linphone uses Android’s own support for cameras which creates a problem because the glasses cannot be detected with this since it can only be used to detect the phone’s own internal cameras.

Now that everything was working for the most part except the Pupil Pro glasses with the Linphone, it was time to test the system as whole. Everything worked when the software was tested in home environment using wireless local area network connection with the Android phone. After this it was time to redo the tests in a laboratory settings in University of Oulu and when the tests revealed to problems: First one was that the bluetooth device detecting source code had trouble when dealing with multiple devices but it was fixed without much effort. The second problem which caused a lot of mess was that the Android phone could not receive any messages from the Communication tool.

In the third cycle, after trying to get these problems solved, we found out that the Internet service provider changes the mobile connection IP address using network address translation so the mobile device then would have a nonpublic IP address. This causes a situation, where UDP packets cannot be sent to the mobile phone’s IP address directly. After pondering the situation we came to the conclusion that it would be in fact better to use TCP instead of UDP since the amount of messages per minute coming from the caregiver is not high and TCP is a more reliable way of sending packets.

Most of the troubles with the communication tool were caused by problems with Unity3D and earlier tools that were implemented for the simulations. After the map was implemented the features intended for the simulation stopped working appropriately. This was mostly because the map has very different coordinate system from the earlier solution. After implementing the Linphone and making a call in elderly citizen’s end point Unity3D v. 4 started to crash occasionally. The problem was traced on the
libgcc_s_dw2-1.dll library which came with Linphone libraries, but there was no specific reason for this and the information messages about the crash presented by Unity3D were weak at the best. After searching the web it was found out that this was somewhat common with the current Unity3D version.

Generally we did not have that much problems during our research, but what slowed us down considerably was waiting for third parties. For example at the start before getting our hands on the Pupil Pro smart glasses, it was used by course provided by University of Oulu thus we did not have access to the glasses during that time. Another time when we had to wait was when the Indicator based smart glasses stopped working and those had to be returned to the original component assembler. There were also other times where we had to wait because of third party and this limited our study to some degree.

The visual guidance system built in this research strongly advocates that it could be usable in the elderly citizen’s health care, but must be further developed to fill the gaps this research left behind. The observations about the functionality of the system made by the researchers show that it works decent enough to use safely in some extent. Observations about the latency show that there is approximately 1 second delay when sending messages from the Communication tool to the Android tool and vice versa. The latency was not too high to hinder the usage in usability tests, but it can be decreased with further development if it becomes an issue in the future. The electrical compass has a small jitter which causes problems with the avatars spinning without the movement of the Android tool, but this problem could be addressed with the use of other sensors alongside the compass. Without comprehensive user testing the system cannot be said to guarantee the safety of the users, but it can be used as a “proof-of-concept” to demonstrate that system of this kind has potential and it should be researched more.
6. Conclusions

The studies of current situation in the elderly people’s health care point out that there will be problems in the future because of the current birth rate and life expectancy. To alleviate the situation lots of researchers and caregivers emphasize the need for assistive technology. Following the earlier studies and information gathered in the initial meeting, the purpose of this study was to build a system that could be used to facilitate the activities of the elderly citizen’s by offering a visual monitoring tool in the elderly citizen’s health care.

The tool could be used by the caregivers to give guidance for the elderly in remote fashion and reduce the workload of the caregivers. This could also aid the elderly citizens to live more autonomous life and give them stimulus and possibility to experience with the current technology which might reduce the feel of social isolation. In this study, we use virtual reality application Old Birds as a communication medium between the caregivers and the elderly citizens. We make use of the current technological advancements of mobile phones and communication technologies to build a system which could alleviate the situation in elderly citizen’s health care.

The study is made by utilizing DSR (Design Science Research) method and following the guidelines of Hevner et al. (2004). The design science framework was the most applicable approach to conduct this study because of its nature and the fact that it has been widely been used in IS research field before. The expected result of design science research would be a novel artifact addressing problems that are related to real human problems, which in this case are the current problems in elderly people’s health care. The evaluation of the artifact was done by conducting usability tests to demonstrate the feasibility of the system. Further development ideas and findings gathered by doing the study are also reported for future use.

This research tries to point out problems and pitfalls that are expected if a system of this kind would be implemented for example in commercial fashion. It gives a brief introduction to the prior research on the field along with the technical solutions behind the system. The research tries to offer the reader a general knowledge about the current technology that could be harnessed in elderly people’s health care. The outcome is evaluated by comparing the requirements with the product in all of the cycles. The requirements drawn from the chapter 4.1 define that with the system it should be possible to track whereabouts of the users and pinpoint the location and rotation of elderly citizen on a map. It should offer the caregivers a possibility to make a contact in the elderly citizen’s end point including real time audio and video feed. The system should utilize smart glasses and pupil pro smart glasses. The system must be robust and reliable. The Android tool should be automatic and built so that it doesn’t hinder the use of the smart phone. Looking at the requirements and comparing them to the system it can be seen that the system does fulfill the requirements except the pupil pro smart glasses had to be left out from the final artifact in the end.

Because the system was implemented in multiple parts, integration testing had to be done to ensure interworking between components. Each cycle typically ended in integration testing after finding some problems in the code. Not all of the problems were related to modules not working together, but there were also problems while different approaches were used for communicating between the Android tool and
Communication tool. The integration testing was done in parts by testing how each individual parts of both tools work with together. For example both of the clients including Communication tool and Android tool were tested with the server to ensure they could communicate with each other as planned. When a problem arose we did not immediately stop testing the system but instead we continued testing with other parts so we could gather as many problems as we could find and then in the next cycle the first thing was to fix these problems.

In order to make the system safe enough for the senior citizen, we tested that the delay in communication between the caregiver and senior citizen was small enough. This was done by timing every communication scenario individually and deciding from the time whether it is too slow. Testing was done with an Android smart phone which had 1 Mbps connection and that is not particularly high speed connection when comparing to the available mobile connection speeds which can range from 10 to 100 Mbps.

To answer our research question “Is it possible to implement a system consisting of smart phone, smart glasses, an Android tool and a Communication tool that would enable real time communication between user and operator?” we built a system following the guidelines of DSR which consists of all those components mentioned and the implemented system strongly advocates that by building a system of this kind would enable real time communication between the user and operator.

To analyze the second research question “Is it possible to implement the system such that it provides a safe user experience for the senior citizen?” The user experience with the senior citizen is comprised of seeing led indicators flash on the smart glasses and talking to the caregiver. The system provides real-time communication between the caregiver and the senior citizen with small enough delay for the usage of the indicator based smart glasses to be safe.

For future work we have a couple of ideas from where to start. Firstly the most important factor would be to implement some kind of library which would make Pupil Pro glasses to be identified by the Android camera functions. Another way of solving the video communication problem would be to combine for example UVCCamera library (https://github.com/saki4510t/UVCCamera) and libstreaming API (https://github.com/fyhertz/libstreaming) so that they would work together and this would then enable us to use the feed from the UVCCamera and streaming it with libstreaming which uses real-time streaming protocol. In the research the Pupil Pro smart glasses were tested with UVCCamera library and the streaming capabilities with the libstreaming successfully which means that the underlying concept is possible.

After this work it would be a good idea to make a research using different encrypting technologies for the communication between the Android tool and Communication tool. Currently the security in this version is nonexistent and should only be used for testing and for future work. As the web service is located on an HTTP server which is insecure and so at least all of the sockets should be qualified to accept HTTPS connections. Furthermore the location based messages send from the Android tool to the server and control messages for the smart glasses are sent over the Internet unencrypted, which is bad for the security so also the messages should be encrypted to avoid security issues.

Another future issue could be to make performance evaluation of the system. After doing the evaluation one could enhance the performance from the results thus making the interaction between the caregiver and the elderly citizen smoother and having a better user experience. Current implementation is based on client - server model where the client is polling the server inducing overhead. The system could be changed so that the clients get the address information of other clients from the server after a successful
login and after that the UDP packets containing location data and control messages could be sent directly between the clients reducing latency and not overburdening the web server.

We also recommend that someone would integrate both Indicator based smart glasses and Pupil Pro smart glasses together or to make smart glasses which has led indicators and camera’s embedded into the glasses.

For the tracking it was noticed that while the map covers the whole earth, it is quite tricky to find someone specific on it if you don’t know the coordinates or location where he or she might be roaming. The system should have a feature which allows the caregiver to search for users that are online just by making a search with the username which would transform the camera position according to the user’s coordinates. Furthermore when zooming very far out from the map or very close it would be preferable if the size of the avatars would change a bit accordingly. Also the features that were implemented for the simulations in the earlier versions should be imported and modified to match the new coordinate system.

After completing all this, it would be a good time to test the whole system with actual elderly citizens in order to actually see how the system works in real life with real caregivers. The overall success of this research was enough to provide answers for the research questions so in that area it was a success. It would have been better to finish the Pupil Pro support for the Android but it would have taken too big an effort for the scope of this research and thus we present it as a future work. To conclude, we managed to get enough proof for the concept and this shows that this kind of a system could be used in real life with real persons.
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Appendix A. Sequence diagram for video call
Appendix B. Sequence diagram for phone call
Appendix C. Sequence diagram for handshake and GPS message sending
Appendix D. Sequence diagram for general flow of the application