Improving Usability and Efficiency in Warehouse operation, using Smart Glasses

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Sammanfattning

Under senare år har flertalet intressanta personburna produkter, som härstammar ifrån smartphone-teknologin, blivit introducerade på marknaden. En av dessa teknologier som det vuxit ett stort intresse för, men ännu inte fått något kommersiellt genombrott, är smarta glasögon. Då teknologin är så pass ung, så har få aktörer gett sig in på marknaden och användningsområdet har inte hittills nått sin fulla potential och det finns mycket utrymme för förbättring. I detta examensarbete kommer ett specifikt användningsområde undersökas, detta område är lagerarbete. Tidigare inom lagerarbete finns det flera sätt att genomföra ett plock utav varor på; checka av på ett papper, skanna artiklar samt röststyrda lösningar. Consafe Logistics har utvecklat en röststyrd lösning, som går att använda hands-free, vilket frigör händerna så att de exklusivt kan användas till plocket. Deras lösning effektiviserade arbetet och var ungefär dubbelt så snabbt som bekräftelse av plock med skanner. I denna rapport kommer det undersökas om effektiviteten potentiellt kan förbättras ytterligare med hjälp av smarta glasögon och om ett framtida kommersiellt användningsområde finns inom lagerarbete. Fokus ligger också på att undersöka hur ett gränssnitt för smarta glassögon kan implementeras, för att göra det så enkelt som möjligt för användaren att förstå hur produkten ska användas. Därför är också användaren i centrum under hela projektet. Att produkten har stor användbarhet är något som är viktigt om effektiviteten ska kunna ökas. Projeket avslutades med ett proof-of-concept som visade tendenser att om smarta glasögon användes så utfördes arbetet snabbare och användarna kännde sig mer säkra på hur arbetet skulle utföras.

Abstract

In recent years, several interesting wearable products which originates from smartphone technology have been introduced on the market. One of these products which has increased in interest, but not yet received a commercial breakthrough, is smart glasses. As the technology is still young and undeveloped, few players have embarked on the market and there is still room for improvement. In this thesis, a specific usage area for smart glasses is explored: namely warehousing. This thesis is focused on the manual pick in a warehouse and how a user can confirm this pick. There are several different tools to help a user with this; confirming on a piece of paper, scan a barcode and voice recognition solutions. Consafe Logistics has developed a voice controlled solution which can be operated hands-free, which makes it possible for a user to use their hands exclusively for handling the pick.

With Consafe's solution, the work was about twice as fast as when using a scanner to confirm a pick. This thesis will examine if the efficiency can be improved further by using smart glasses and if commercial use of smart glasses could have a future in warehousing. A major goal for this thesis was to investigate how to design an interface for smart glasses in order to make a product as usable as possible. Information on how to design an interface for smart glasses is scarce and in order to design a user friendly product, a user centered design process is employed. This thesis resulted in a proof of concept application which showed a tendency that the work proceeded faster and that the user was more confident in their work.

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Chapter 1
Introduction

Among the novel interaction technologies introduced on the market lately, smart glasses are particularly interesting in a warehousing context. In a warehouse environment the workers depend on using their hands to perform different tasks. This could be driving a truck, pulling a trolley, putting items in the correct order box, et cetera. This thesis will mainly focus on the pick itself, which includes finding an article in the warehouse and place it in the correct order box, before shipping it out to the customer. Because workers need to use both of their hands, it is not preferable to use them for documenting the pick. Today this task is often completed by writing on a piece paper or signing on a tablet. This thesis will explore the possibility to use smart glasses when carrying out a pick, instead of more traditional methods.

1.1 Consafe

This Master Thesis was conducted at Consafe Logistics in Lund [1]. Consafe Logistics is a company which provides solutions in supplying software, hardware and services that aim at increasing efficiency. Consafe's solution can be anything from systems which calculates the best method to store articles, to the most efficient routes for picking up articles in a warehouse. The proof of concept that was developed in this thesis was based on Consafe's own voice controlled solution, described in 4.2.1.

1.2 Warehousing

In a warehouse you store a lot of different articles. It can be anything from cars to toothbrushes. The articles are stored in the warehouse until it is time to ship them to an retailer or directly to a customer. Employees at a warehouse can have a lot of different tasks to do throughout a regular day at work. More common tasks include, storing of articles and gathering articles in an order before shipping.

1.3 Purpose and goals

This thesis investigates how to implement an application for a pair of smart glasses in order to possibly increase the efficiency for employees. In summary the following areas will be investigated and compared with an exclusive voice controlled solution, without a graphical interface.

1. Will a display provide better efficiency?
2. Will it have better accuracy?
3. Will the user have a steeper learning-curve?
4. Will it increase the confidence of the employees?

With a relatively new product like smart glasses, not much research have been conducted and just a few similar applications have been created. Therefore it is important to investigate features which will provide good usability and ultimately see if this new technology could be of any use in a warehouse environment.

1.4 Target group

This concept is designed for workers at a warehouse environment, with different backgrounds. Implementation of the proof of concept, is in English. In a future product, language options should be implemented.

1.5 Approach

The work behind this thesis consists of three design iterations. The first iteration focuses on investigating the different interaction methods that can be used and the construction of a simple prototype. The second iteration explores the limitation of the technology and the implementation of an application. In the third iteration the application is improved to be a fully functional concept. In addition a user test session is held to investigate the possible advantages of using smart glasses in a warehousing environment.

Chapter 2

Theoretical background

This chapter contains the theoretical background behind the thesis, used when designing the proof of concept in the iterations.

2.1 User design

When designing a user interface, several different opinions on how it should be done exist. Some of the more recognized theories about usability and designing an interface are Shneiderman's eight golden rules and Norman's design principles. Shneiderman's golden rules provide guidelines when designing an interface and is more useful for a digital application. Whilst Norman's principles is used when designing everyday things.

2.1.1 Shneiderman's eight golden rules

To improve the usability of an application it is important to have a well designed interface. Shneiderman's "Eight Golden Rules of Interface Design"[2] provides guidelines when designing a usable interface.

1. **Strive for consistency.** When different actions resemble each other, the interactions should be done in a similar fashion. Formatting, colors, terminology, et cetera should be consistent throughout the system. The interface should not differ completely at the different states of a system, but they should resemble each other. This to avoid a user from feeling lost in the system.

2. **Enable frequent users to use shortcuts.** Experienced users could find that too many interaction steps are needed to achieve the desired result. As the experience of the system

increases, the user might want to speed up the process. Abbreviations, function keys and hidden commands all speed up the interactions and reduces the frustration that might occur with an experienced user.

3. **Offer informative feedback.** For each action the user takes, there should be feedback provided from the system. The magnitude of the feedback should be designed for each specific action. For frequent and common actions, the feedback should be subtle. If the action is less frequent and more complex, the feedback should be more distinct and easily noticeable.

4. **Design dialog to yield closure.** Without informative feedback of the completion of a group of actions, the user may feel that the task is uncompleted. A sequences of actions should have a beginning, middle and end. The informational feedback upon completion gives the user a signal to drop the task and mentally prepare for the next one.

5. **Offer simple error handling.** Best case scenario would be if no errors could occur, but that is not the case for most systems. If an error has occurred, the user should get comprehensive information about the error in question.

6. **Permit easy reversal of actions.** When the user knows that errors can be reversed, it encourages the user to explore unfamiliar options and not to be afraid of trying new functionality. The method of reversibility may be a single action, a data entry, or a complete group of actions.

7. **Support internal locus of control.** The user should have the sense that they are in control of the system and that the system responds to their actions. Design the system to make users the initiators rather than the responders.

8. **Reduce short-term memory load.** In order to reduce the short-term memory load and to better suit the limitation of human information processing, it requires that the presented information is minimal.

2.1.2 Norman's design principles

Norman's design principles is a set of guidelines when designing everyday things [3].

- **Visibility.** Show the relevant information so that the users will be able to know what to do. Users should easily get a grip of actions are possible in a certain state. The system should provide with indication of the states and should match the users expectations of the system [4].

- **Feedback.** The user should be confident that an action taken, otherwise the user could experience the lack of closure. With insufficient feedback the user could perform unnecessary and time consuming interactions. There are numerous types of feedback for interactions: tactile, audio-based, visual based et cetera [4].

- **Constraints.** In order to avoid for the user to make errors, the best way is to restrict the user from performing certain actions. The system can constrain the user with different methods, like properties of objects or logical assumptions [4].

- **Mapping.** In designing a user interface, this term refers to the relationship between two things. The mapping could closely relate to the desired outcome of the action taken. An example of this is a steering wheel, which when turned changes the direction of the car [4].
- **Consistency.** When designing an interface, similar interactions should be performed in a similar fashion and the artifacts that remains constant should be at the same position. This helps the user to quickly understand and learn how interactions are performed throughout the system [4].
- **Affordance.** Affordance refers to an attribute of an object that facilitates the user to know how to use it. The perceived properties of the object should be in relation to the actual properties, like the physical shape of the object, which should provide strong clues about how to use it. Good affordance could also be achieved with the material used; glass is for seeing through, wood for support [4].

2.2 Designing the interface

2.2.1 User-centered design

When designing with user-centered design, the focus should be around the user and their needs and goals. This should be the driving force behind the development of a product throughout the implementation; always put the user first. As a consequence of this, the system will work in unison with the user not against the user [4].

- **Early focus on users and tasks.** The first step is to identify who the user is, understanding their characteristics and involving these throughout the design process.
- **Empirical measurement.** Analyze the user's reactions and performance, with simulations and prototypes. Analyze the user's view of the product.
- **Iterative design.** When the user encounter problems, annotate these problems and correct them. Follow up with more tests and observations. The typical iteration cycle consists of design, test and evaluate. Iterate until the product is finished.

2.2.2 Brainstorming

The basic concept of brainstorming is to come up with as many functions and ideas possible for a product. Every input, however stupid or silly, is welcome and the process should be without any criticism. A result of this kind of idea generation is that some unrealistic functions will appear. But even these ideas can lead to something usable in the final product. During the brainstorming session all ideas are written down and presented for evaluation [4]. This process can be divided into four steps:

- **Background.** Setting up a context and clarify the purpose; what is relevant; focus on design or functionality.

- **Idea generation.** Writing down everything that comes to mind.
- **Discussion.** Asking questions about the ideas written down; How did you think? What if we did it like this instead? Evaluation and limitations.
- **Compilation.** Everything that has passed through the evaluation step is discussed in a separate step.

2.2.3 Prototyping

Low-fidelity prototype can be described as an independent artifact from the likely finished product. A low-fidelity is often made on paper, which makes it a fast way to draw up your own thoughts. A low-fidelity prototype is cheap to perform and change of the design is easy. A disadvantage is that you can not interact with it naturally. A high-fidelity prototype is usually created on a computer and looks more like the final product. The user can interact with it and should feel like the real product. A drawback is that it takes much more time and resources to develop, than a low-fidelity prototype. A usual step is to first use a low-fidelity prototype and later in the design process use the high-fidelity prototyping [5].

2.3 Test and evaluation methods

2.3.1 Heuristic evaluation

A heuristic evaluation is a usability inspection method that helps to find usability problems in the user interface. This method is developed by Jakob Nielsen [6].

When conducting a heuristic evaluation, a set of heuristics are written down and then the interface is evaluated by an expert with the set in mind. The heuristics are not mutually exclusive and they may cover the same aspects of the user interface.

The simplicity of heuristic evaluation is beneficial at the early stages of the design. This usability inspection method does not require user testing. Heuristic evaluation requires only one expert, reducing the complexity and the expected time for evaluation.

Using heuristic evaluation prior to user testing will reduce the number and severity of design errors discovered by users. The results are highly influenced by the knowledge of the expert reviewer and might not reflect the actual user [4][6][7].

The procedure of conducting a heuristic evaluation is as follows.

- Create common use cases
- Create or use an existing set of heuristics
- Categorize and prioritize the heuristics
- Apply the heuristics along the use case
- Incorporate the results in a re-design if needed

In this thesis Jakob Nielsen's set of heuristics is used, which is listed below.

- **Visibility of system status.**
  The users should be informed about what is going on, achieved by appropriate feedback.
- **Match between system and the real world.**
  Rather than system-oriented terms, the language in the system should match that of the user. Make the information appear in a natural and logical order.
- **User control and freedom.**
  The user should be in control of the system, if functions are used by mistake, it should be easy to reverse the action without the need of an extended dialog.
- **Consistency and standards.**
  Users should not have to wonder whether different words, situations, or actions mean the same thing.
- **Error prevention.**
  The optimal method for preventing errors to occur is to make them impossible to make. Or make the users confirm their actions before they commit.
- **Recognition rather than recall.**
  Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another.
- **Flexibility and efficiency of use.**
  The system should be able to satisfy both the novice and the more experienced user.
- **Aesthetic and minimalist design.**
  Dialogs should not contain information which is irrelevant or rarely needed.
- **Help users recognize, diagnose, and recover from errors.**
  Error messages should be expressed in plain language, precisely indicating the problem, and constructively suggesting a solution.
- **Help and documentation.**
  Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation.

2.3.2 Functional analysis

A functional analysis is performed by a group of people who normally have a stake in the development and design of the product or service. In preparation for this meeting, all participants have to be informed about the following [7].

- **Characteristics of the product or service**
- **Intended user group**

- **Intended purpose**
- **Circumstances for the product or service facilitation**

In the meeting itself the stakeholders discuss the functionality of the product or the service along with a set of suggested functions.

The discussion should be focused around the product and who the user is.

2.3.3 Cognitive walkthrough

Cognitive walkthrough is a usability inspection method. Cognitive walkthrough focuses on the learning aspects of a user interface and will provide usability problems that might occur, while step by-step learning the system.

This method is task-oriented and is typically performed by a designer or other persons involved in the project. A set of use cases which is expected for a future user is created. The user will then "walk through" the task and asking questions for every step [7].

- Will the user know how to solve the task?
- Will the user notice which interface element to use?
- Will the user understand the information received in the interface?
- Will the user receive appropriate feedback after the action?

If done correctly this method should provide a list of usability issues that need to be considered in the re-design phase.

2.3.4 Questionnaires

Questionnaires are a set of questions asked to the users, with the intention of gathering information on different aspects. The question format can include:

- "Yes" and "No" checkboxes
- Multiple choice checkboxes
- Likert rating scale
- Semantic scale
- Open-ended response

Questionnaires are used in both experimental and exploratory user studies. The questionnaires are focused around the research's objectives and hypotheses. A major advantage of questionnaires is that it provides quantitative amount of relevant data. When creating a questionnaire, some things should be considered[7].

- To provide a clear statement of purpose and guarantee participant anonymity

- Decide on whether phrases will be positive, negative or mixed
- Is the pilot test question clear and is there sufficient space for responses
- Decide how data will be analyzed

2.3.5 Interviews

Interviews are a method to gather background information about the requirements of the product. The general procedure for conducting an interview is that stakeholders are asked questions about the product. They will hopefully tell their needs, thoughts and provide a set of requirements. The structure of the interview can be more or less controlled or directed [7].

2.3.6 Controlled usability tests in a lab

When multiple designs of an application have been developed, it is important to compare them in a focused way. Controlled usability test is a good method to determine the usefulness of an application in a quantitative way. Lab based studies involve the user carrying out a set of constrained tasks with one or more variations of a system in a controlled environment. Advantages with a controlled usability test are the following[7].

- They allow study of particular aspects of a user interaction, in a way that cannot be done with less formal studies
- They are relative cheap to perform, and can be useful as a pilot test in a more long term studies, or more expensive off site evaluations
- They provide a concrete analysis of the performance of a system

Chapter 3

Technical background

In this chapter, all the technical details necessary for understanding this thesis are explained and discussed.

3.1 Augmented reality

Augmented reality can be described as a technology that enchants reality with virtual details. It is not limited to visual but can also involve other senses, such as hearing, smell and touch [8]. Augmented reality can be described as technologies which has the following properties.

- Combines real and virtual objects in a real environment
- Registers (aligns) real and virtual objects with each other
- Runs interactively, in three dimensions, and in real time

3.2 Smart glasses

There are no established definition of what smart glasses are, but in general it could be defined as a wearable computer which provide additional visual information usually in a pair of glasses [9]. In this thesis the Vuzix m100 smart glasses is used,seen in figure 4.3, which uses a small non-see-through display in contrary to the more well known Google Glass which uses a see-through display. A see-through display is an electronic display that allows the user to see through the display with information on it.

Figure 3.1: Vuzix m100

3.2.1 Problematics with smart glasses

Adapted vision

In the 1890's, a psychologist named George Stratton constructed and wore a pair of special glasses; these glasses turned everything upside-down and he wore them constantly for a period of time. George´s brain adapted to his new sight and only after a couple of days, he saw things normally again as if he did not wear the glasses. When the glasses were removed the world was not upside down as one could expect, instead he described it as: "a bewildering air". The readjustment period to normal eyesight when George removed the glasses, was longer than the time it took to get used to the upside-down world. In Steve Mann´s paper Vision 2.0 he claims that the required readjustment period is actually shorter when the brain adapts to dramatic distortion rather than a subtle one, like what George Stratton experienced with his experiment. Not much research has been conducted in this area, but it should be looked into especially when smart glass technology is an expanding market and insufficient long term usage research has been made [10].

3.2.2 Future

Even though the technology of smart glasses is new on the market for commercial usage, a numerous different but similar technologies are researched on. Some of the new technologies which could be classified as smart glasses, is Microsoft new holovision which uses "holograms" instead of a display [11].

3.3 Speech recognition

One of the most important tasks in this thesis is the interaction between the user and the glasses. The interaction with the smart glasses will be with speech and therefor a brief summary about how speech recognition works will be described in this section. Speech recognition implies only that the device can take dictation, not that it understands what is being said. There are many different types of speech recognition but they could be categorized into two types [2].

- **Discrete-speech recognition.** Discrete-speech recognition devices recognize words one-by-one spoken by a specific person. To increase the accuracy of choosing the correct word in this method, a common way is to use user-specific settings. This is done by letting the user say the vocabulary, which is used, so that the system learns how the user speaks [2].
- **Continuous-speech recognition**. Instead of recognizing words one-by-one continuous-speech recognition understands speech as used when talking with someone. This technique has still not been perfected and it is very difficult to recognize the boundaries between spoken words.[2]

When considering speech and auditory interaction, it is important to identify how speech works. Different users have different dialects and individual ways of speaking, which have to be considered when developing a speech recognition tool. An optimal system needs to learn how the user speaks and adapt itself around the individual.

Chapter 4

First iteration, information gathering

In this chapter the first of the three iterations is described, the goal is to get an overview of the project. The focus in this iteration are on what functions that is possible to implement, which design is suitable for the interface and how a basic navigation function should look like. The design principles that are used in this iteration can all be found in the chapter Theoretical background.

4.1 Method

4.1.1 Information gathering

In the beginning of the project, it was necessary to gather as much information as possible to get a better understanding on how to implement the application. Because the application will be used in a warehouse, some knowledge about logistics is vital to have before the designing of the product can start. Also it is important to get knowledge about Consafe's own products which will be used as a basis on the smart glass solution. Related work is researched.

4.1.2 Design

Interviews

Before entering the design phase some interviews were held. They were preformed by asking a couple of questions to people who has been working in warehouses and has experience with this kind of work. This was done to get an neutral view over what real workers experiences and what kind of problems they encounter when working in a warehouse. They also get the opportunity to say if they thought that a pair of smart glasses would help them with their daily work.

Brainstorming

Prior to designing the first prototype, a brainstorming session was held. The main purpose of the brainstorming was to provide suggestions of functionality, design and methods of interaction. It was held by the development team.

Functional analysis

All ideas generated during the brainstorming session were gathered and discussed as if they would have a part in the final application. The discussed items were either discarded, evolved or passed through for the prototype design.

Low-fi prototype

When all the functions were processed and passed through the functional analysis, they were used when designing the prototypes. The prototypes were discussed and after some consideration, the team decided on a final first prototype.

4.1.3 Test and evaluation

The test of the first iteration was different from a traditional low-fidelity test. Firstly, it was hard to perform a realistic simulation of how the product would actually work. Because when wearing a pair of smart glasses, the interface is always in-front of the user and the prototype would have to present the information the same way as in the glasses.

Instead the test was conducted by role playing a pick. The test area was narrow and not all interactions were tested in this iteration. The evaluation was done simultaneously as the test.

4.2 Result

4.2.1 Information gathering

Warehouse solution

Consafe has their own solution of how to store products in a warehouse. The solution provides coordinates for every article, Z-X-Y. Z is the row, X is the horizontal coordinate and Y is the vertical coordinate. A figure of an example row can be seen in figure 4.1.

Voice solution

Voice controlled systems enable workers to move freely around the plant or warehouse, guiding the operator on where to go and what to do. The system keeps full control of the tasks performed, as operators communicate with the system confirming the assignments they perform during the day [12][13].

A traditional warehouse solution for picking up articles, is that the workers have a list of articles that should been picked for a specific order. The list can be on a paper or a tablet/computer where

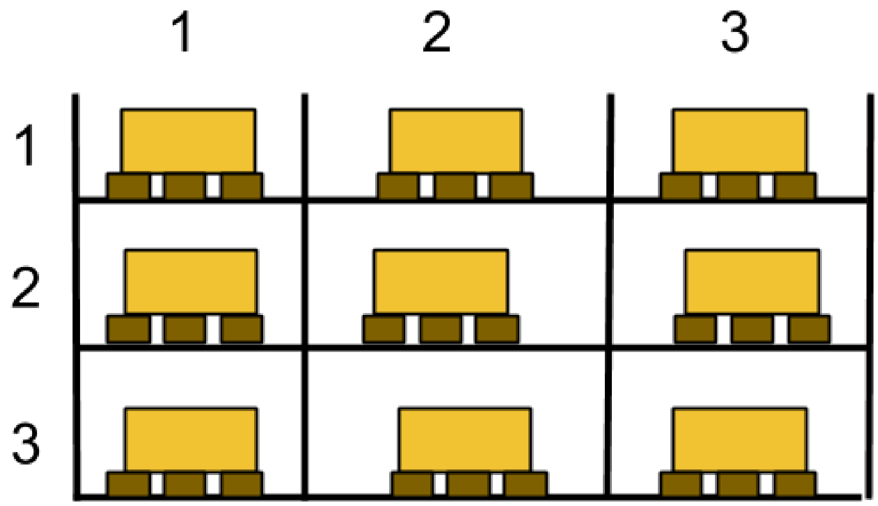

Figure 4.1: A rack with three X rows and three Y rows

the pick is confirmed by the user. The big disadvantage with these solutions is that when a user confirms a pick, they have to put down whatever they are carrying at the moment. One of Consafe's solutions uses a voice controlled system instead. This makes it possible to confirm a pick hands-free, by speaking to the device.

Additionally the system gives the user feedback by voice, allowing the user to avoid having to look on a paper or tablet to get the information about where the next article is located. Instead instructions are given by voice in the headset. Possible instructions could be: where to go, what is the current article, repetition of the instructions, et cetera.

Consafe's own testing shows that the voice solution is more than twice as fast than a system which uses a barcode scanner as confirmation instead of voice [12]. A pick-flow using Consafe's voice solution could look like the following [13].

1. Voice System: The round has 3 order lines
2. Operator: Ready
3. Voice System: Location 3-23-2
4. Operator: 32
5. Voice System: Take 3
6. Operator: 3 ready
7. Voice System: Location 2-1-32

8. Operator: 65
9. Voice System: Take 9
10. Operator: 9 ready

In step one the voice system simply tells the operator that in this specific round there are three picks, a round could consist of multiple orders. The operator confirms to start the round by saying "ready". The system then tells where in the warehouse the operator should go to by telling the Z-X-Y coordinates, explained in 4.2.1. When the operator is at the correct location, there will be a check number on the article location, the operator confirms the location by saying the check number. If the number matches the one in the system, the system tells the operator how many articles that should be picked and in which box it should be placed in. The operator confirms by saying the box number followed by ready. If there are more order lines for the current round the next location is stated.

A problem that could occur is if an operator forgets where to pick up next article, then the user has to ask the system for the details about the current state. It is because of this drawback that Consafe wants to look into the possibility of using smart glasses instead of just using a headset. To see if the efficiency can be increased by using a display in addition to voice.

Warehouse system setup

Consafe has several different warehouse managing systems, one of which is called Astro. Astro works with various picking technologies such as vehicle mounted computers or voice control [14]. It is easy to integrate Voice Control, RFID and similar tools with Astro. Could smart glasses be the next to be integrated as an picking technology that works with Astro as seen in figure 4.2?

To make the system as usable as possible, some requirements must be met. The system has to be able to communicate with the smart glasses without using hands, preferable with voice communication. The system had to be able to give feedback visually, be able to use both Wi-Fi and Bluetooth for connection. The glasses used in this thesis is the Vuzix m100 smart glasses, seen in figure 4.3. The reason Vuzix m100 was used is that they have a noise reduction technique like Consafe's voice solution and it would be preferred in the concept application as well.

Vuzix m100

Vuzix m100 is integrated with a wearable android based system that can be attached in front of the visual field with either a headband or on a pair of special protective glasses [15]. Vuzix m100 do not have a see-through display, instead a small regular display is used. What the user sees while using the smart glasses can be described as holding a smart phone at approximately an arms length from your eyes. This may seem a little disturbing but it is possible to change the location so it is not directly in front of the eye, but in the periphery instead. This is handy when the application running does not require the users attention at all time, all the information needed is just a glance away. One example on this is a direction application that shows the user where to go. Users do not want to have the display directly in the field of view, this could cause accidents to occur. The users attention should be on the environment, not on the display, especially when navigating around the warehouse

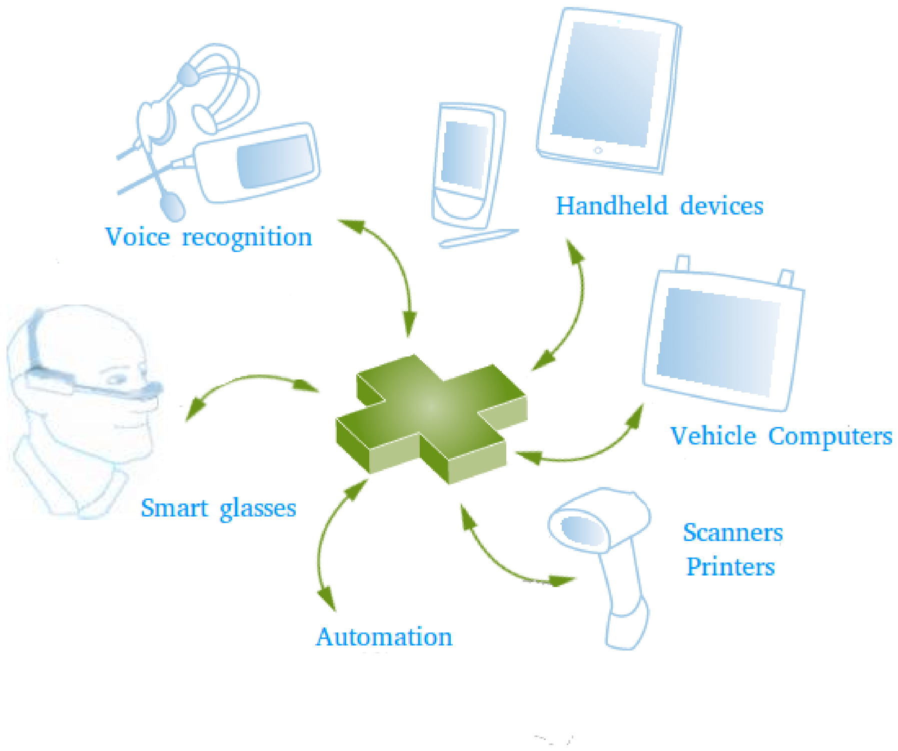

Figure 4.2: Smart glass and Astro

Figure 4.3: Vuzix m100

where hazards such as vehicles might be present. There are numerous ways of interacting with the Vuzix m100 [15].

1. Wi-Fi
2. Bluetooth
3. GPS

4. Buttons
5. Gestures
6. Camera
7. Voice

Wi-Fi connection makes it possible to send data to computers and mobile phones. This makes it possible to send information from a device to the glasses, so that the smart glasses can be configured from a distance.

The Bluetooth connection is the main way to configure the glasses and it is done with an application which is installed on a regular Android device. This speeds up the usage of the glasses, because it is hard to navigate and impossible to type using the glasses only. Therefore it is highly recommended to use a separate Android device with the application.

On the smart glasses there are four buttons that can be used for navigating in the interface. This is the main interaction method in the system. The four buttons have the following functions in default mode; back, forward, select and a power button. They can be seen in figure 4.4

Figure 4.4: Three of the buttons on a m100

In front of the buttons there are a sensor that can detect six different gestures, those are: back, forward, up, down, in and out. These commands can be used in the main menu as well in applications.

It is possible to interact with the camera, the camera can be used to scan barcodes and QR-codes. This would make it possible to scan barcodes in a warehouse.

The last interaction method, which is speech. This can be used in an application, but the user is forced to say "Voice on", before the smart glasses can take any voice commands from the user.

M100 Smart Glasses Manager

M100 Smart Glasses Manager is an application from Vuzix that makes it easier to configure the glasses, figure 4.5. The user connects with the Vuzix m100 with an Android device using Bluetooth. This is a vital tool, especially because the user can not type anything with the glasses alone because there are no keyboard implemented in them [15].

Figure 4.5: Vuzix Smart Glasses application

Android and M100 OS 2.0

Vuzix m100 is built on android API level 15 (Ice Cream Sandwich) and to be able to use the m100's own functionality, the provided library has to be used. Some of the Android functions are not implemented at the current state, and therefore they can not be implemented in the smart glasses. One example of a function that could not be implemented at the current state is Google's speech recognition [15].

4.2.2 Design

Brainstorming

Some of the ideas that were suggested during the brainstorming session were the following.

F1. Barcode scanning with the glasses, for confirmation of the location

F2. Locate articles with display

F3. Get instructions by both voice and text

F4. Get an image of the article presented in the glasses

F5. Use gestures to swipe through different alternatives

F6. Use position to make confirmations

F7. Have an overview of the round so the user can prepare for the pick

Functional analysis

F1. The barcode scanning The barcode scanning could be a function where the user can scan a bar-code or QR-code that is placed near or on the article with the camera. The barcode could be used for confirming the location and would be an efficient way of doing so, if it works fast enough. This functionality will be tested in the next iteration but will not be a part of the low-fidelity prototype [16].

F2. Location with the display Using the glasses for directing a user in the warehouse would be any easy way for a new employee to be efficient quickly. This function should maybe be hidden, because if an advanced user is familiar with the warehouse it might not be necessary. This functionality is not tested in this iteration.

F3. Voice and text interaction In one way or another voice interaction will be a part of the system. In the test, voice was used as the main navigation tool so the interface could be tested in the same way as the original voice solution. The display will provide with the information necessary for carrying through a pick, such as the location of the article, in what box the articles should be put in.

F4. Image of products One of the functions that came up early during the brainstorming was to give the user another kind of visual information by showing a picture of the product that they are supposed to pick up next. This will hopefully increase the users confidence about the current pick and maybe it will help them find it faster.

F5. Gesture as interaction Using gestures to confirm and navigate through the menus in the product were discussed, but it was uncertain if this interaction method was a good idea for the application, when it requires the user to use their hands.

F6. Position as confirmation It would be efficient to use position to confirm a pick, but hard to implement. The user could be at the correct row but still has to find which vertical and horizontal coordinate of the row to find the article. Combined with a barcode scanner this could be a powerful functionality.

F7. Have an overview of the round Use an overview of the round so that the user can better prepare for the upcoming pick. The display in the Vuzix m100 is relatively small and it might be hard to get a good overview of the pick round.

Low-Fidelity prototype

The low-fidelity was a bit different from a traditional low-fidelity process which is usually made on paper and then evaluated on test subjects. However in this case it was not that easy because the information is supposed to be in front of the user at all times and not on a tablet/phone or on a computer screen. The prototype was designed as it would be for a phone, and only the interaction with the system was tested [4].

The low-fidelity prototype resulted in a system where an overview of the pick was in focus, seen in figure 4.6. An alternative to the list overview was a fisheye overview, seen in figure 4.7. In this prototype the user navigated through these overviews with gestures. All other interaction was by voice.

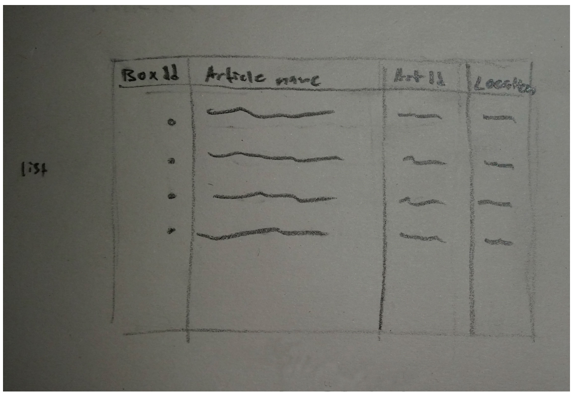

Figure 4.6: List overview

4.2.3 Test and Evaluation

The low-fidelity prototype was made on paper, but as stated earlier it could not be tested in a real environment. Instead the test was conducted in the same way as a tablet interface would be tested. The testing was performed by the developing team at a basic level. A discussion was held during the test session. The functions that tested in this iteration were **F3**, **F4**, **F5**.

The menu system was questioned, is it necessary for the user to see the up-coming and previous articles? This information was misleading and there would be too much information on the screen.

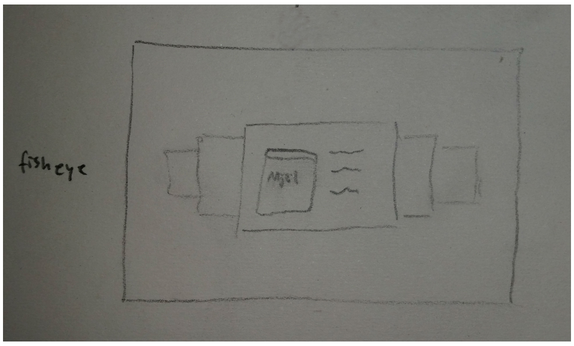

Figure 4.7: Fisheye overview

It appeared from the tests that it was strange to use gestures in a system with the main purpose to eliminate the use of hands. Also it was concluded that voice was a better solution in all aspects as the users have their hands free at all time.

4.3 Conclusions

The barcode scanning, locating articles with a position, the different confirmation methods were not tested in this iteration due to lack of a reasonable user study method. Instead these functions are explored in the next iteration.

It was decided that the menu system was confusing and unnecessary, as well as the gesture interaction method which did not conform with the design concept. Both of these ideas were discarded and were not further explored.

The main interaction method, was decided to be by voice and the hands will not be necessary to control the application. The hands should only have the responsibility to handle the picking of articles in the warehouse.

Chapter 5

Second iteration, first implementation

To know what kind of interface that would work on the smart glasses, details about how to implement an application for the Vuzix m100 were collected and a few concept application were created. When this thesis was written, Vuzix had not opened their appstore and only limited information about developing with the Vuzix m100 was available. The only applications that existed were some basic applications that came with the operating system; calculator, camera, barcode scanner, et cetera. This made it hard to determine what a good interface might look like on the smart glasses. After the research, two applications were developed in this iteration for the Vuzix m100; Voice only and Voice and text application.

5.1 Method

5.1.1 Exploration of the smart glasses

Before the implementation began, the Vuzix m100 smart glass functionality had to be explored. The different interaction methods of the application from iteration one, was implemented in standalone applications. The following applications for the m100 were implemented and tested.

Voice recognition

To make the application work as intended, a functional voice recognition service had to be developed. The recognition had to be able to listen continuously, but it would work as an discrete-word recognizer described in the technical background chapter, also it gives feedback as if the user was talking with someone.

GUI test
A basic GUI application was created in order to evaluate the resolution and size of the display. Also size and positioning of artifacts like text and images were explored.

Navigation
Multiple applications which took different approach on how to navigate.

Barcode scanning
An already existing barcode scanner was tested to see if a QR-code or a barcode could be used for confirming an article, instead of check numbers.

5.1.2 Design

The functionality that was decided to be tested and evaluated in iteration one was aimed to be implemented in this iteration. Still early in the design process, nothing was set in stone. But the major functionality of the applications was decided. The way of interacting with the product should remain consistent subsequent to this iteration step. The design was made with Shneiderman's eight golden rules and Norman's design principles in mind and evaluated with Jakob Nielsen's heuristics, described in the theoretical background. The interface was designed so the efficiency would increase for both a novice and an experienced user.

5.1.3 Test

Cognitive walk-through

A set of use cases were designed focused around a first-time user. The idea to understand what kind of usability problems might occur while step by-step learning the system. Each application was evaluated according to the following questions.

1. Will the user know what to do, in order to advance within the system?
2. Will the user get the information necessary to interact with the applications smoothly?
3. Will the user be confused by the provided feedback/information?
4. Will the user receive appropriate feedback after an action?
5. Will the user get confused when navigating through the interface?

5.1.4 Evaluation

Heuristic evaluation

As described in section 2.3.1 a set of heuristics were used to evaluate the applications in this iteration. Jakob Nielsen's heuristics were used and prioritized. The evaluation was performed by the developing team. The heuristics are as follows.

1. Consistency and standard
2. Error prevention
3. Recognition rather than recall
4. Aesthetic and minimalistic design
5. Visibility of system status
6. Match between system and the real world
7. Help users recognize, diagnose and recover from errors
8. Flexibility and efficiency of use
9. Help and documentation
10. User control and freedom

5.2 Results

5.2.1 Exploration of the smart glasses

In the beginning only static applications were created for the smart glasses, this to get an idea of how the display behaves. During this process, decisions were made to determine how the application would work and how the user would control it.

Voice recognition

The final application will use a discontinuous-speech recognizer, which is constantly listening. Otherwise it would not be possible for the application to be operated hands-free. Numerous applications were created for the Vuzix m100 with the intention of using the microphone in the glasses. This turned out to be impossible due to the intended functionality, because the voice recognition implemented in the Vuzix m100 had a limited dictionary and no additional words could be added at the time. Because Vuzix's own speech recognizing did not work well enough when this application was developed, Google's speech recognition was used instead [17]. Google's speech recognizer has some setbacks. The first problem was that it only supports speech recognizing after an action is performed. Google's speech recognition was not supported in the Vuzix m100, so the solution became two applications which communicates with each other. The voice recognition along with other functions, were implemented on a regular Android device. This turned out to work fairly well and a decision to move forward was made. The result can be viewed in figure 5.1, when the two devices were connected, the voice input was sent to the glasses and printed on the display in the GUI (Graphical User Interface). This application uses discontinuous voice recognition which was initiated with a push of a button. Two possible solutions were proposed to use the voice recognizer continuously.

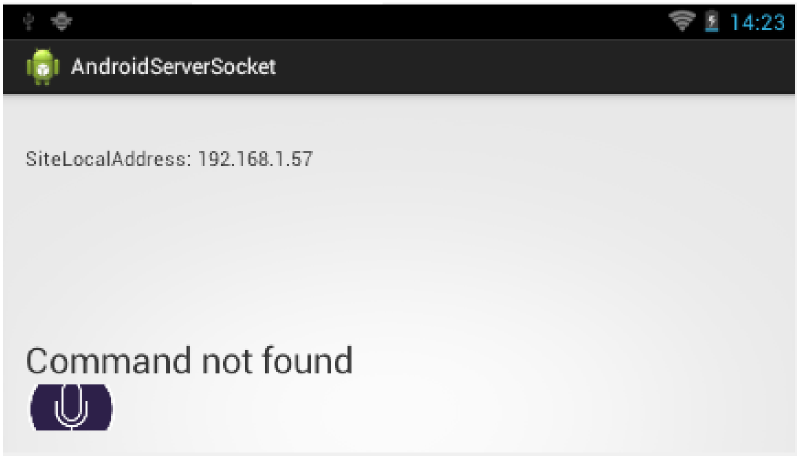

Figure 5.1: Voice test

1. **Listen at all time.** After receiving a result the recording starts again until another voice command is detected. The major problem with this solution is that it can not separate noise from speech, which means that if other noise is detected, it can easily be detected as a part of what the user just said. Another problem is that it can only send a few seconds of sounds at the time. This means if a user starts talking, the application can not guarantee that the whole command will be sent and therefore the user has to repeat the command.

2. **Energy level.** The second solution was to use a media recorder that captures sound at all times and checks the energy level of the sound. When the energy level rises above a certain level, the speech recording begins. This method allows the user to start the speech recording at anytime. A problem that can occur is if a user talks to another person, or if the background sound level is to high then the application try to detect a voice command wrongfully.

GUI test

During this step in the design process it was decided to use a database which powers the application, this would lead to a flexible application which can simulate a warehouse in a correct fashion. This means that the smart glasses can be tested separated from Consafe's systems. Details about the database can be seen in figure 5.2. To make use of the database, an application which tested its functionality was created. This application was used to test the display of the m100 as well and also to test a very simple pick round. An example of on how this interface looks like can be found in in figure 5.3.

Direction

Multiple possible solutions were discussed and tested.

- **GPS.** A GPS solution would only work in an outdoor environment, but indoors it would not work according to the requirements [17].

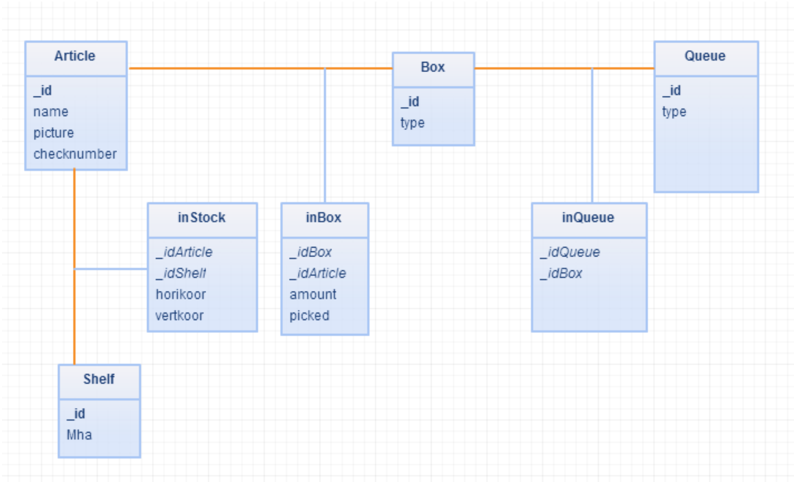

Figure 5.2: Database which is used in the application

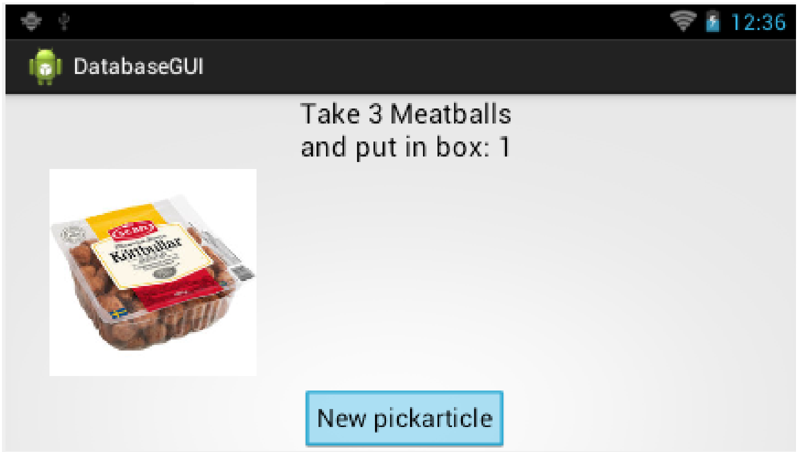

Figure 5.3: Database and GUI test, step 2

- **Wi-Fi triangulation.** Discussed, but decided to not be implemented due to time limitations [17].
- **Remote controlled.** When the tests are conducted the directions will be simulated from a control device. The interface of the remote control can be seen in figure 5.4.

Barcode scanning

The already existing barcode-scanner in the Vuzix m100, turned out to be not that useful due to the cameras slow focusing speed. Another problem was the size of the barcode, which needed to be too big for it to work in a warehouse.

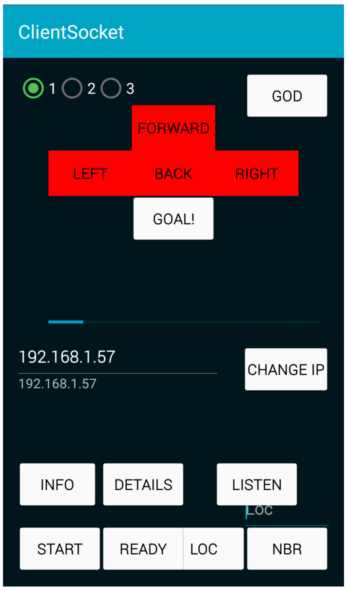

Figure 5.4: Database and GUI test, step 3

Limitations and conclusions

To make it work as intended, some functions could not be implemented in the smart glasses. Instead they had to be implemented in a second device. This device was a regular Android device that was connected to the smart glasses over Wi-Fi. The functions that were chosen to be implemented in the Android device were all the voice interactions and direction controls. The Android device works like a remote control which can be used to direct the user in future tests. To make the tests run as smoothly as possible a regular Android phone was used.

The communication between the devices is a server/client connection, where the client initiates the communication with the server and information can be sent between the two devices.

The white background on the display made it difficult for the user to perceive the information. To make it easier for the user, a black colour was selected as the background color and white colour for the text. This made it easier to find the information on the display.

5.2.2 Design

With the conclusions from the test applications in mind, implementation on the smart glass applications begun. To compare the application with the existing voice controlled solution that Consafe has, two different applications were created in this iteration. The first Application, which is only a voice based solution. The second application, which is the same as the first application but with additional information and feedback presented on the display. All the feedback will, when possible, be provided both on the display and with a voice reply. During the exploration of the smart glasses it was noted that it was difficult to see information close to the borders of the display, due to instability and adjustment issues. Approximately 15 % of the display, closest to the border, will not be used as the information area. The used display is presented in figure 5.5.

In the applications there are four different states depending on what task the user has ahead.

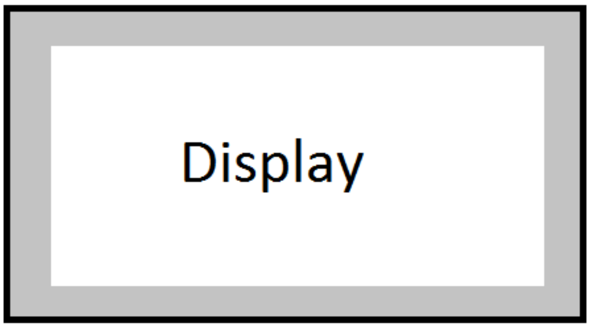

Figure 5.5: Display used, grey area approximately 15-20 % is not used

- **Standby**, the initial state. The system is waiting for the user and no pick round has been assigned.
- **Ready**, the state where a user has been assigned a pick round but the pick has not been initiated.
- **Location**, the state where a user locates an article.
- **Pick**, the state which handles the pick of an article and the placement in the correct box.

The user has to be able to get information of what to do at any time. So in addition to the basic functions, it is also necessary to have some help functions. Commands which are used should be short, logical and not similar to each other. The voice commands that were chosen are the following.

1. **Start.** Used only in the Standby-state. When performed, the user is assigned a pick round.
2. **Ready.** To start the assigned pick round.
3. **Info.** Information about how to advance to the next state. Feedback is provided by voice only.
4. **Details.** Detailed information about the current state. Feedback is provided with both voice and visible feedback on the display.
5. **0-99.** The user has to say a two digit check number to confirm the location of the current article that is to be picked. Numbers are also used to confirm that the article is placed in the correct box. This way both the system and the user can be sure that the article is placed in the correct box, so that the error ratio is minimized.

Feedback will be provided by voice in both applications. In the second application feedback will also be provided visually. The information on the display has to be minimalistic but still informative. Abbreviations were used so that the information would be visible.

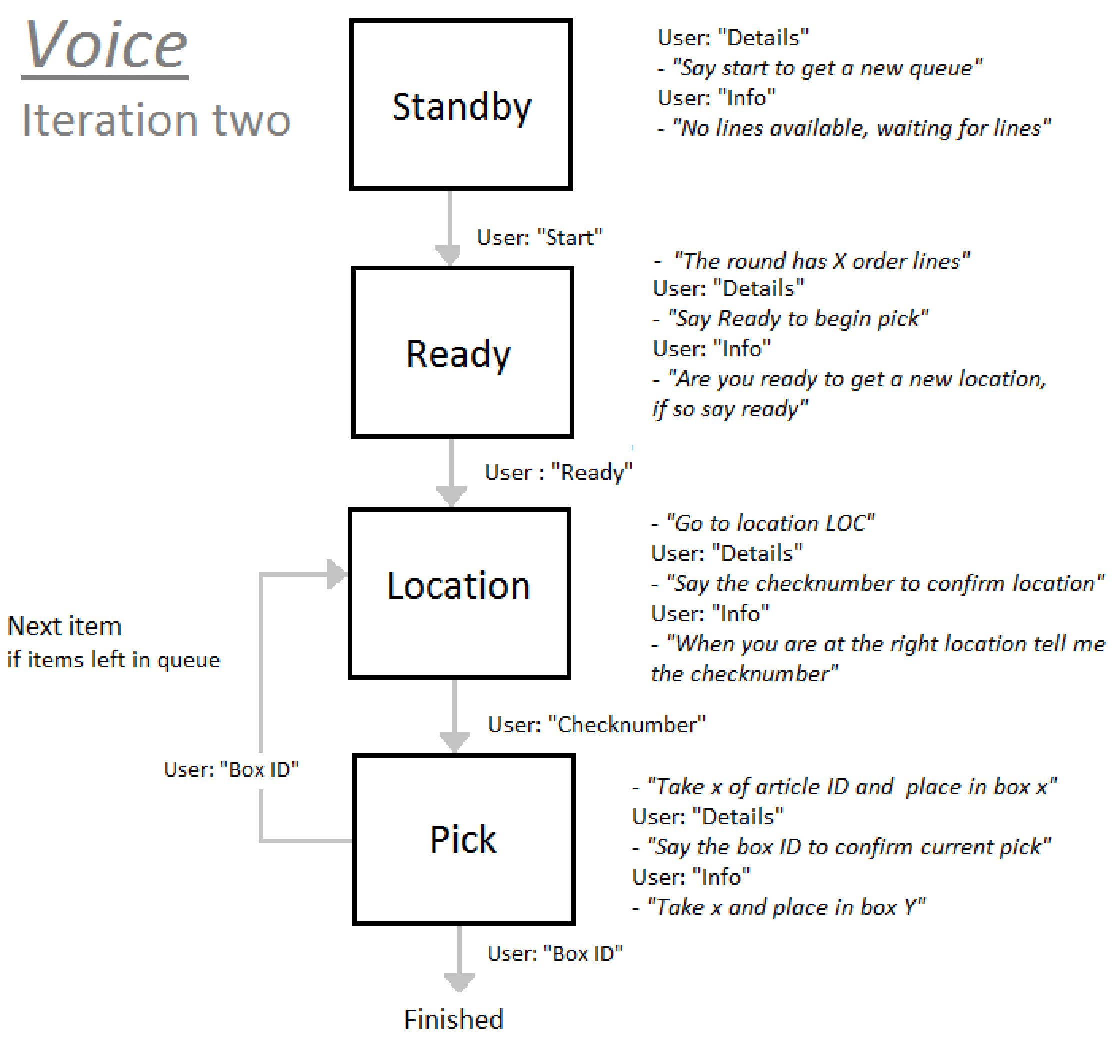

Figure 5.6: Voice control, iteration two

First application, voice only

The first application was created to have the same functionality as Consafe's voice solution. It was necessary to create an application which uses voice only to fairly compare usage with and without a display. With no display the user needs clearer feedback so that the user will not get confused. The complete voice interaction with the applications can be seen in figure 5.6.

Second application, voice and text

The voice interaction in the second application works in the same way as in the first application, but in addition to the voice feedback it adds text on the display which provides feedback on the system.

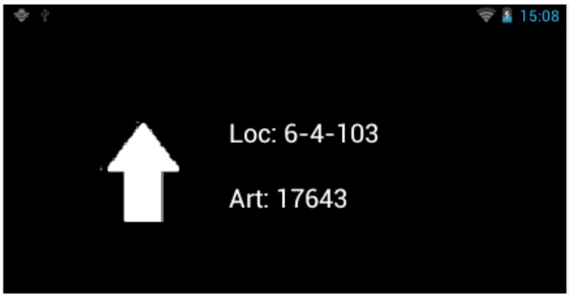

Figure 5.7: Location state

Figure 5.8: location state, details

A problem that may occur is that the screen could take away attention from the surroundings. Therefore it is important not to show redundant information, also this information has to stand out from the background which can be achieved by using high contrast between text and background color. Example of the location state can be seen in figure 5.7 and 5.8, an direction arrow was implemented to help the user to navigate in a warehouse. In 5.7 the original state is presented and in 5.8 the feedback provided with the details command can be seen. The pick state is showed in figure 5.9.
The screen on the Vuzix m100 can be adjusted, it can be placed right in front of the eye or in the periphery so that the user's regular vision will not be disturbed.

Phone application

In a final product, there will not be a separate device for controlling the pick. But in this thesis it was necessary to evaluate the proof of concept. Therefore an external application was developed to control what happens in the smart glasses.

5.2.3 Test

Cognitive walkthrough

1. Will the user know what to do to advance within the interface?

2. Will the user get the information necessary to smoothly interact with the applications?

Figure 5.9: Pick state

3. Will the user be confused by the information/feedback provided?
4. Will the user receive appropriate feedback after an action?
5. Will the user get confused navigating through the interface

The most severe problem noted during the testing was when using the details function, the original state could not be retrieved again. For example during the location state, when the user says 'Details' the location parameter disappears and is replaced with the detailed information. The location which the user should go to can not be retrieved and if forgotten, impossible to see again. This is a major flaw for both novice and advanced users. 'Info' and 'Details' commands should not override the necessary information otherwise it will become impossible to move forward in the interface.

For a novice user it would be hard to advance in the current system due to the feedback from the 'Info' and 'Details' functions which were not consistent. For the user to be able to learn the system as fast as possible, these functions have to be consistent. In the application, the 'Info' command sometimes gave the same information as the 'Details' command and sometimes not. The feedback from these should provide the same type of information, so that the user can anticipate what information that the different commands provide.

The positioning provided in the different states were inconsistent and during the pick state the picture of the article stole attention from the relevant information.

5.2.4 Evaluation

Heuristic evaluation

With the results from the cognitive walkthrough, the two applications were evaluated with the heuristics explained previously in 5.1.4. The heuristics were prioritized from 1-5 where 5 is the most important and 1 the least important.

1. **Consistency and standards**
   Severity rating: 5
   From a user's perspective the system often led to confusion. The system should provide

similar specifics when using the same commands. The positioning of the interface artifacts should be at the same location so the application does not feel 'jumpy'.

2. **Error prevention**
   Severity rating: 5
   In the current interface it is possible to get trapped if the user forgets the location and uses the 'Details' command in the location state. The command overrides the original view and the information there can not be retrieved again.

3. **Recognition rather than recall**
   Severity rating: 4
   The theory behind the commands 'Info' and 'Details', which provides additional information to the user is good, but the voice and GUI feedback needs to be improved and made more consistent.

4. **Aesthetic and minimalistic design**
   Severity rating: 4
   It is especially important to get all the information needed without involving redundant information for the advanced user. The advanced user wants as little information as possible so that the interactions are swift and smooth.

5. **Visibility of system status**
   Severity rating: 3
   In the application that uses a display, even a novice user will probably quickly learn the different states and know what to do next. But when it comes to the voice application the user will have to ask the system for the system status, to make it per say visible.

6. **Match between system and the real world**
   Severity rating: 3
   The system should speak the user language, not use system oriented terms. The current application is not too technical and the information should be kept in the same fashion.

7. **Help users recognize, diagnose and recover from errors**
   Severity rating: 3
   When the user tries to control the application and uses an invalid voice command, no feedback is given of what the user did incorrectly. In future iterations Error recognition should be a highly prioritized.

8. **Flexibility and efficiency of use**
   Severity rating: 2
   In this thesis the application was not able to adjust to more advanced users. But in a possible future application, the system needs to adjust according to the certain user preferences. Suggested features could be: faster speech, less speech, only the absolute vital information will be showed.

9. **Help and documentation**
   Severity rating: 1

The idea is for the user to start with only commands and through them, 'Info' and 'Details', get all the information necessary to learn how the system works.

10. **User control and freedom**
Severity rating: 1
This thesis focuses around developing a proof of concept. Hence, the application is somewhat linear and not designed as a working application. This step is not relevant. But as a product, the user must have the opportunities to cancel picks, go back and change picks et cetera.

5.3 Conclusions

In the next iteration some changes had to be made. The most severe problem was with the 'Info'- and 'Details' commands and how they affect the system. They should provide the same kind of information at all different states, so the user will not get confused. 'Info' should provide the user with instructions of which command that is expected and 'Details' should repeat the information necessary for the pick. For example in the Location state, when using the command 'Details' the system should answer with "Go to Location 'Z-X-Y'" not the current reply "Say the check number". The positioning should remain constant so the user can find the information easily and get a good overview of the interface.

Another problem was that the 'Details' command changed the GUI. The command should provide additional information for the current state in the interface but the old information should not disappear, as can be seen in figure 5.9 compared with the original state in figure 5.8. The suggested solution for this is to use a pop-up which disappears after a short period of time and the original state information is once again visible. The pop-up should be used for the 'Info' command as well. This functionality will allow the interface to be even more minimalistic. Advanced information which might not be needed often, is moved to the 'Details' pop-up instead.

The system should speak a user friendly language and not give too technical information that the user can not relate to.

The system did not provide the user with any information if an invalid voice command was used, which had to be thought of in the next iteration. When the user for example says 'Start' in the location state the system should inform the user that the wrong command was used and also tell the user once again what the system expects him or her to do.

Other things that were concluded, was that it could be hard to see information close to the borders and the information had to be centered in the display.

A minor problem experienced was that the direction arrow did not provide feedback when the user arrived at the location and that the design of the arrow was somewhat confusing. In the following iteration the arrows will be changed from this iterations more dynamic arrows to static directions where the user will not experience confusion about where to go.

One thing that made the application easier to implement was that it was made for experienced warehouse workers and it could therefore be assumed that they have at least a basic understanding of the warehouse system. Also in Consafe's earlier voice solution they have a training session where users learn how to use the product.

Chapter 6

Third iteration, a proof of concept

The third iteration was the last iteration of this thesis and resulted in the final prototype. It was implemented as a proof of concept from the goals in the beginning of the thesis. The iteration was concluded with a thorough test session. The test was held with test subjects that had not been involved in the project and had no knowledge about it, in order to see how well it works in an environment that is as realistic as possible.

6.1 Method

6.1.1 Design

From the second iteration some flaws in the interfaces were found and fixed. It was also decided to develop two different applications using the display, in order to be able to investigate which amount of information the users need.

6.1.2 User test

The final test will provide results which concludes the goals of this thesis. The test method chosen is a controlled usability test and the test subjects will afterwards provide feedback through questionnaires and an interview, the controlled usability test is explained in chapter 2.3.6. The test will focus on the following aspects.

1. Quality of the product
2. Necessity of the product
3. How much information that is needed for a user.

Controlled usability test

The purpose of the test session is to see how the applications created were used in a warehouse environment. Six different subjects tested the applications, all of them were students and some had previous experience of working in a warehouse environment. [6].

Test environment and setup

The test was conducted in the E building at the Faculty of Engineering in Lund. To simulate a warehouse with racks, horizontal coordinates and vertical coordinates, a rack was represented as a table and the articles were placed as if the table was standing up, can be seen in figure 6.1. In the simulated warehouse 81 different articles were placed and the stock was represented by matches. The articles were represented with a piece of paper with image, article name, article number and check number, as can be seen in figure 6.2. The test subject received a box with two compartments, where the articles were placed, each compartment represents a different box.

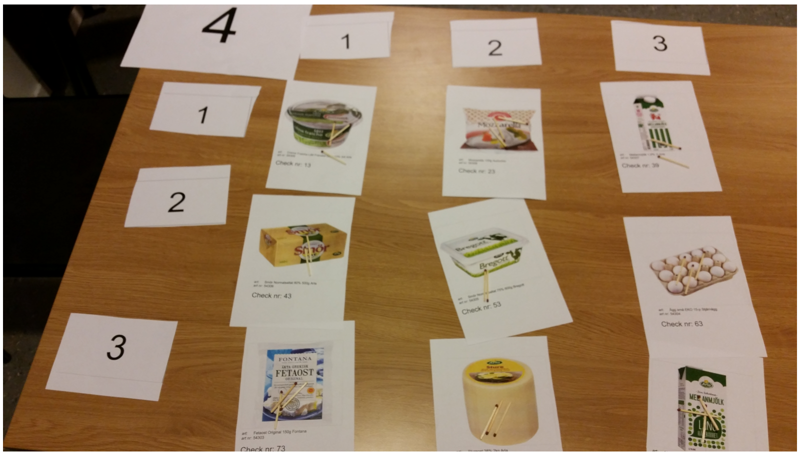

Figure 6.1: A simulation of a rack

Test structure

All three different applications were tested but in different orders so the results would be balanced and also so they would not affect the outcome. In the test there was three different rounds so the subject would not do the same pick twice. Every round contains of 10 articles, an example of a pick order can be seen below.

1. 1-3-3
2. 1-1-1
3. 2-1-2
4. 4-2-1

5. 4-2-2
6. 5-2-2
7. 7-2-2
8. 7-2-3
9. 8-1-3
10. 9-1-2

Figure 6.2: One of the 81 articles.

An overview of the round can also be seen in figure 6.3

The test session began with a short introduction about this thesis and the task that they would perform. The subject filled out a consent form and the test was commenced. The subject perform a test case followed by a questionnaire form, when the subject was finished with all three cases a short interview was held to get general comments and subjective feedback.

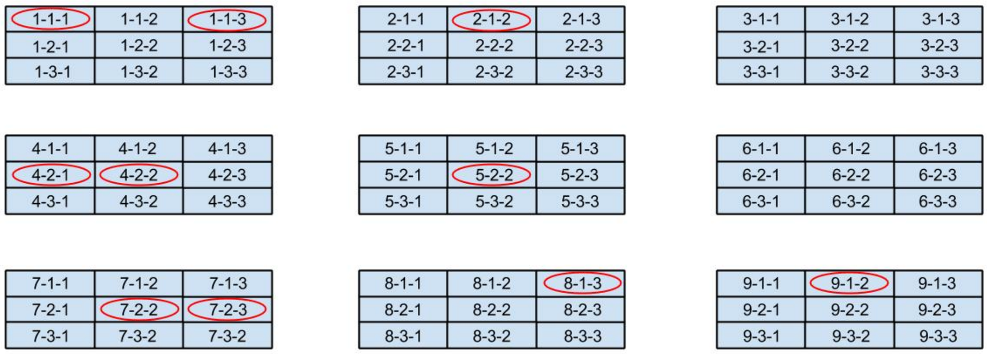

Figure 6.3: An overview over round one, showing where the articles that were to be gathered were placed

6.1.3 Evaluation

The evaluation in this iteration was short, because this was the last iteration and no new design was to be made. The only thing included in this section was a brief evaluation on what the test person said about the product.

6.2 Results

6.2.1 Design

It was decided to add one more application in the third iteration. This decision was taken so that it would be possible to see which information was necessary for a final product.

First application, voice only

The first application is just like in the second iteration, a voice only solution so the interface was only a black screen so that the user do not get any visual information. An example of the voice interaction in the different states can be seen in figure 6.4.

Second application, voice and text

The second application was voice and text. The difference from the second iteration was that the text in this iteration is centred and smaller so that it would be easier for the user to see all of the text and not just a small part of the information. An example from the Location state in this application can be seen in figure 6.5, where a user is locating an article to be picked. Additionally the information provided in this state is also repeated in voice, the user receives feedback both visually and auditory.

If a user wants additional information regarding the current state or help to advance to the next state of the system. There is now a pop-up that shows the information instead of just overwriting the text, this can be seen in fig 6.6.

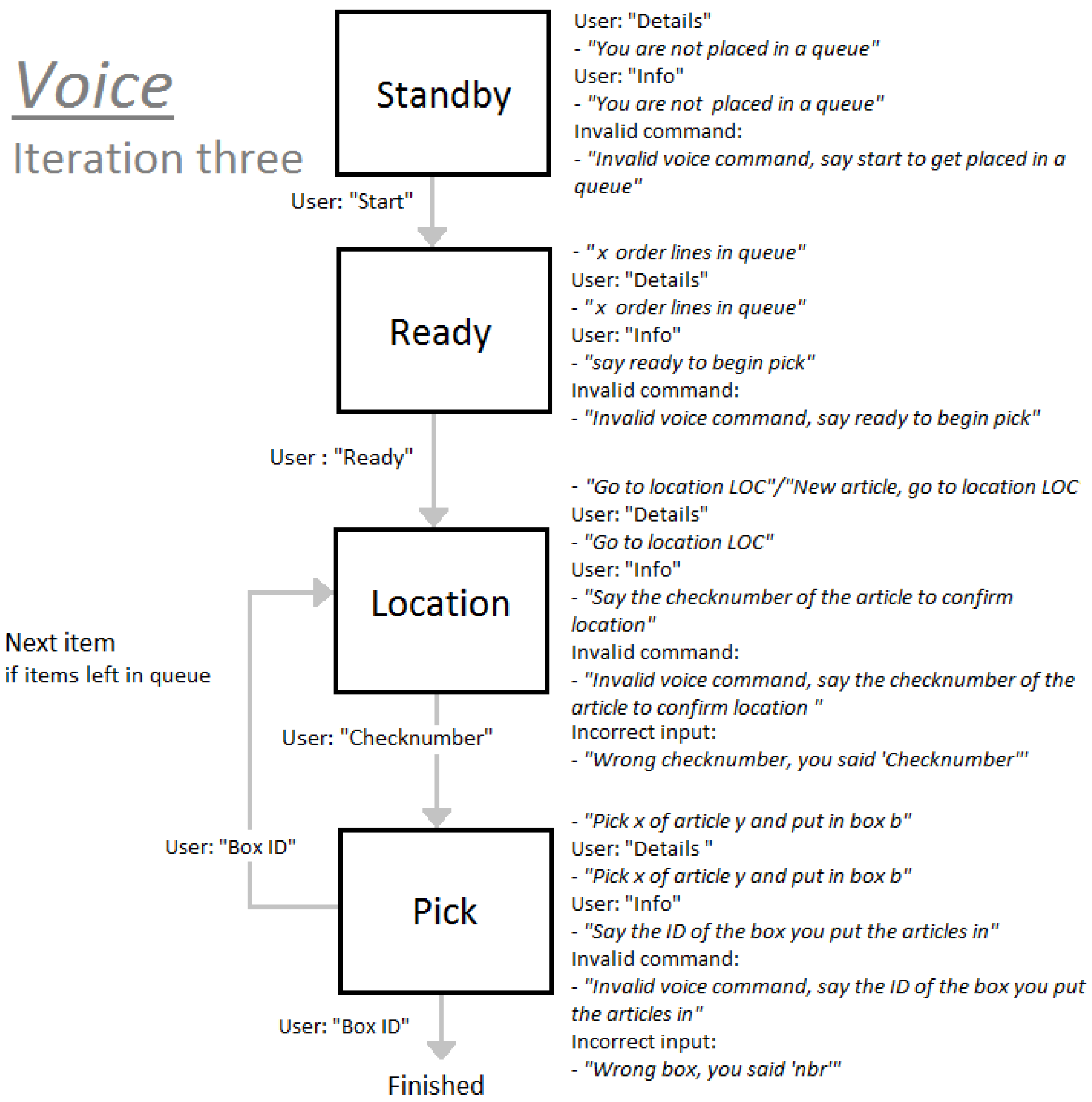

Figure 6.4: How a round work with the voice application

Third application, advanced voice and text

The third application is the most advanced of the three. In addition from the second application some new functionality were implemented, more information in the different states is provided. A picture of the article is shown when the 'Details' command is used in both the location state and the pick state, the difference between the second application an this application can be seen in figure 6.9 and 6.10. Instead of the dynamic arrow in the second iteration, the directions are now provided only with four static arrows; left, right, forward and turn around. When the user has arrived at the location of the article the forward arrow gets a circle around it and the user knows that they are

Figure 6.5: Example from the display when the user is supposed to go to location 1-3-3

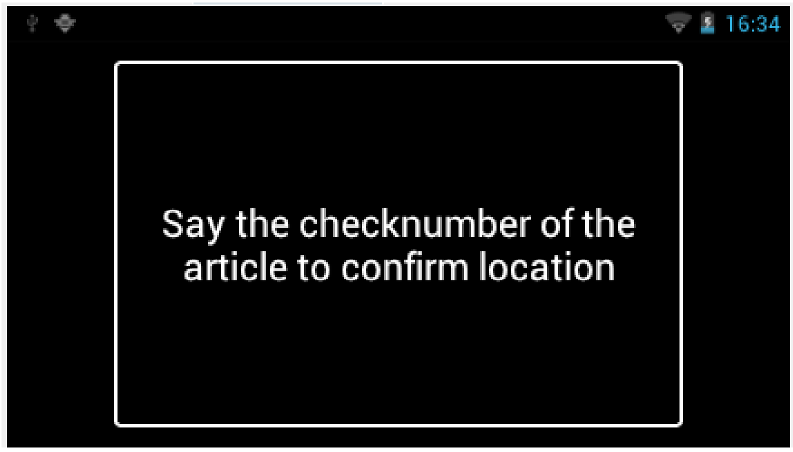

Figure 6.6: A user performs the 'Info' command and gets information about which action is needed to be performed to finish the task

at the correct location. Example of the static arrows can be seen in figure 6.7 and 6.8. Also the picture of the article is moved from the original state to the 'Details' pop-up.

6.2.2 User test

Task performance

All test subjects passed the three test rounds without any major problems. Most faults which occurred were when the test subjects were about to pick the first article. The problem was not to find the article, but how to confirm that the article was picked. All the subjects solved this by using the commands that they had been given prior the test, there was no correlation between not knowing how to confirm and which application that was used.

Some of the subjects had difficulties knowing whether to use the 'Details' or the 'Info' com-

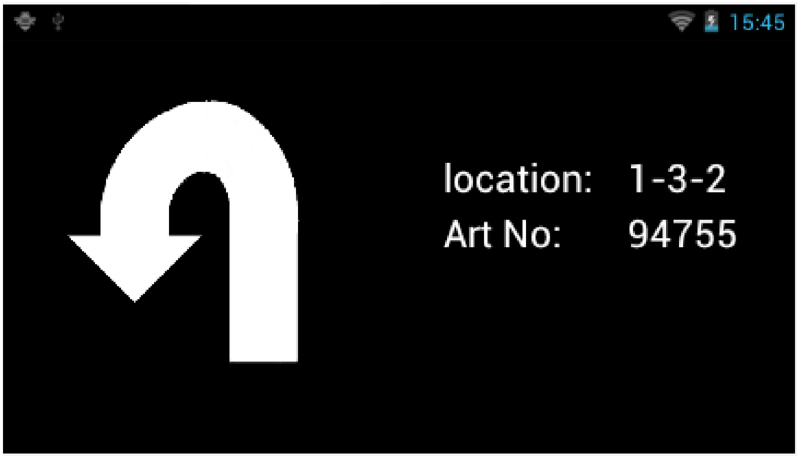

Figure 6.7: A user on the way to a new location and should turn around to find the right way

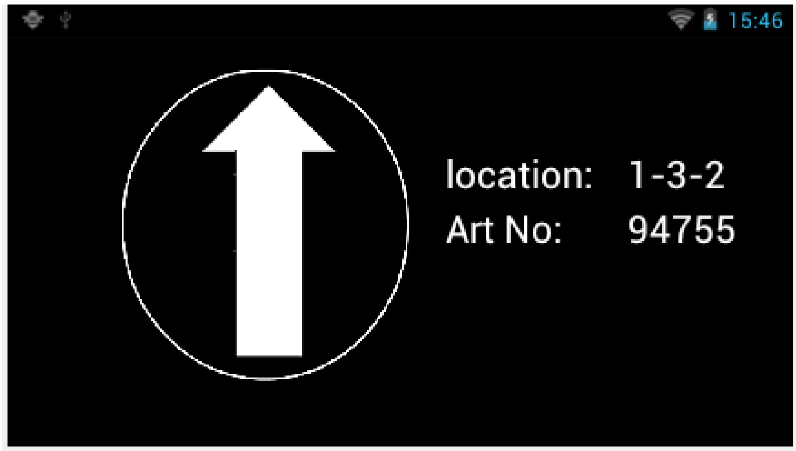

Figure 6.8: A user is at the correct location

mand. After the first two articles had been picked, almost no faults were made by the test subject. Some of the test subjects had to use the command 'Details' to get the information repeated about the location for the next pick. This problem only occurred when the first application was used.

The first round was always the slowest and the last round was always the fastest. The voice only application was by far the slowest of the three applications. The average time for each application was as followed.

1. **Voice only:** 5:29

2. **Text and voice:** 4:41

3. **Advanced voice and text:** 4:40

Figure 6.9: Details information in the second application, voice and text

Figure 6.10: Details information in the third application, advanced voice and text

Answers from the questionnaires

After each test round a brief questionnaires were answered by the test subject. The result of this was a disappointment because there was no significant difference between the applications, no conclusion could be drawn for this part of the test session.

Question from the last test. The subject chose on a likert scale ranging from 1 to 5, 5 is where the user could not agree more to the question.

Q1. The system was responsive

Q2. The application worked well and ran smoothly

Q3. I got the information I needed to complete the task

Q4. The application showed too much information too often

Q5. It was easy to to complete the task

Q6. The display was in the way

The results from the questionnaires on the different applications are presented in figure 6.11, 6.12 and 6.13.

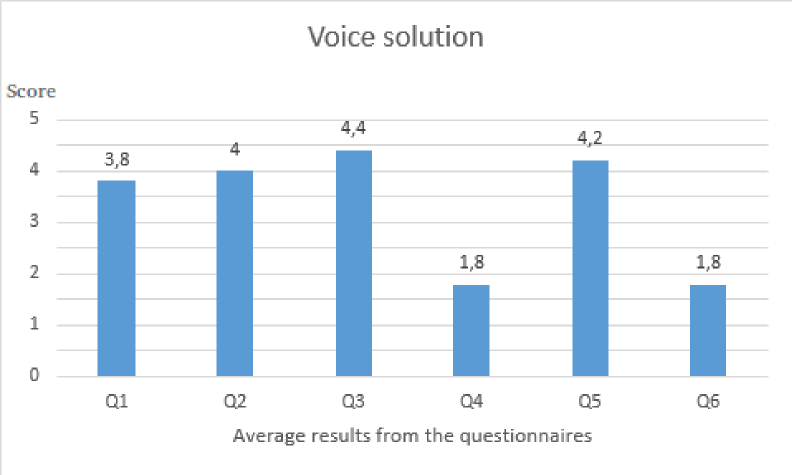

Figure 6.11: Average scores from the questions on the Voice application

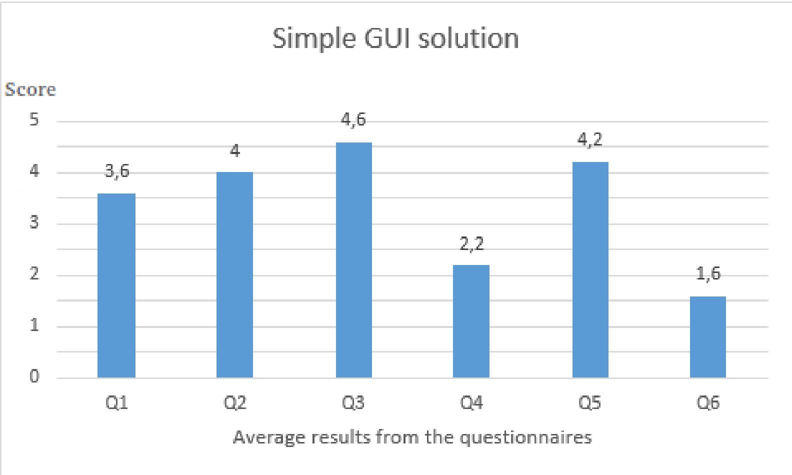

Figure 6.12: Average scores from the questions on the Text application

Interviews

In the interview the test person got some questions about how they felt about the test, using the smart glasses and about the applications. It was clear that all test subjects preferred an application

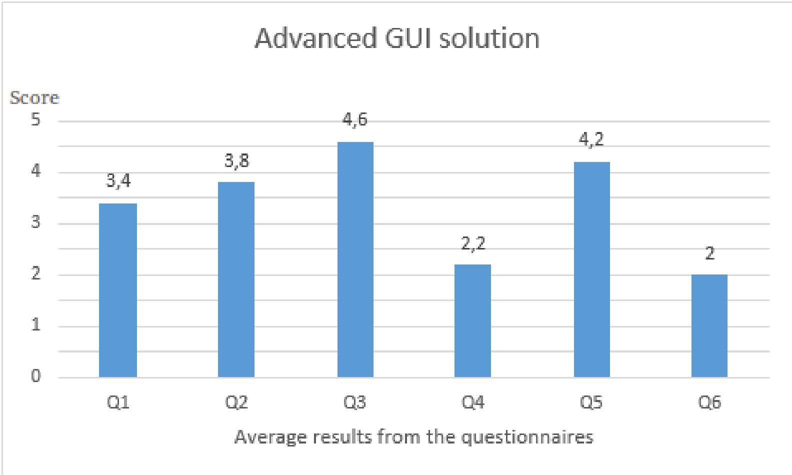

Figure 6.13: Average scores from the questions on the application with text and arrow

which used the display. Some of the test subjects preferred to have a arrow that guided them, whilst others thought that it was enough to just have the information by text.

It was also mentioned that an arrow would be more useful in a larger warehouse than in the simulated warehouse which was used in this test session with only 81 articles. It was mentioned that a new employee would probably feel more secure if they had access to an application that used an arrow for guidance.

During the interview, the background of the test subjects were discussed. All of the subjects were students at Lund University and some had previous experience with working in a warehouse environment.

The subjects with previous experience were asked some extra questions regarding the different methods of conducting a pick, and they had some interesting input regarding the concept applications.

- Easier to conduct a pick than using a scanner
- Felt more secure where to go
- Work went more smoothly without interrupts

There were different opinions about the color selections of the interface. Some subjects considered the contrast between black and white made it difficult for them to see the text while others considered the opposite. One of the test subjects thought that the applications contained too many different numbers, such as check number and box number, which made it hard to use.

6.2.3 Evaluation

From the results of the test, some conclusion could be drawn. The application which uses both a display and voice was preferred, both in terms of user experience and efficiency. To solve the problem with the contrast between the colours in the application, the user should be able to configure which colours that are used. The application as a whole should be configurable so it adapts to the specific users need, not the other way around.

Otherwise the feedback was very positive, the test subjects felt secure that they at all time could get help from the system by using only the smart glasses. The help function ’Details’, which provided information about the specific state, was the most commonly used. The ’Info’ function was especially useful the first time the application was used, when the user was unsure of what to do. Further investigation has to be done considering whether the names of these functions are good or not.

Chapter 7

Discussion and Conclusion

In this chapter, the result from the thesis is discussed and the conclusions which are drawn is presented. Thoughts about the future of smart glasses in a warehouse environment are discussed, where the focus is on whether they could be used efficiently in a warehouse environment in the near future.

7.1 Results from the iterations

The test from the third iteration, provided varied results. The following data was documented and evaluated.

- Round completion time
- Questionnaires
- Interviews
- Error ratio

The round completion time showed that the two application which used the display was faster, especially in the first pick round. The average time difference between the two application which used the display was insignificant, so no conclusions between the two could be drawn. The interviews held after the test session strengthened the results from the time measurement, where the subjects made it clear that the applications which used the display were preferred. The questionnaires on the other hand did not validate the claim that the applications which used the display were better in any aspect, where there was no significant difference between the applications according to the questionnaires. The reason of why no significant difference was noticed could be that the likert scale selected only went from 1-5 and the test only consisted of 6 test subjects. The test subjects answered a questionnaire after each application was tested and this could maybe affect the user's feedback due to previous experience. The results from the test was as expected, because for a first time user it is logical to assume it is easier to know what to do when instructions are given both visually and auditory. A more thorough test has to be conducted where the concept is tested in a real warehouse with real warehouse workers.

7.2 Designing for Vuzix m100 and limitations

When this thesis was conducted, there were some deficiencies regarding implementation with the Vuzix m100. The biggest flaw was with the included library, where the existing voice solution lacked the capacity to learn new words. To make it possible to implement a working proof of concept, the voice control functionality had to be moved from the smart glasses into a separate device, connected with a Bluetooth headset, which communicates with the glasses over a Wi-Fi connection. The use of two devices were not optimal and it was difficult to link everything together. In a final product, the voice control needs to be more flexible to make it usable in a real warehouse environment.

Another problem with smart glasses, is how long-term usage affects the user. A few experiments have been made which suggest that it might be harmful for the eyesight after long term use[11]. More research should be conducted in this area before a commercial product is released.

When this master thesis was conducted, the Vuzix m100 probably could not be used as the hardware in a final product, but the future still looks promising with the smart glass technology in warehousing.

7.3 Future work

In the proof of concept, only the vital functionality was implemented to investigate if there are a future with smart glasses in a warehouse environment. The result from the test indicates that there are a future, but certain aspects need to be considered. A future application has to be flexible for the user, so a specific user can tailor the system to suit their individual preferences. It is a requirement for the application to be designed for different types of warehouses, with different articles, size, et cetera. The system needs to be integrated with existing, or future warehouse managing solutions. The direction functionality designed in the proof of concept is just a simulation and if it should be implemented in a real product there are much work to be done.

A direction functionality was one of the first ideas that we had in the first iteration, although early in the design process it was clear that the functionality would take to much time and was not in the context of this thesis. Even though the direction function could not be implemented, it was still a functionality that needed to be investigated in the proof of concept, because the benefits using a display with directions could decrease the time for a user to get efficient and feel secure navigating through the warehouse.

Due to limitations in time and with the Vuzix m100, some of the functionality discussed in the first iteration was not implemented. The functionality using a barcode scanner for confirmation of location, was not implemented due to hardware limitation. Possible advantages with using a barcode scanner is faster verification of location.

Using a system built on Android has multiple advantages; support, flexibility and the nature of Android makes it cheap and easy to implement. All kind of functionality is already implemented in the Android OS and therefore it is easy to adapt Android based systems for many different usage areas. For example it is easy to implement a call support function with a live video feed so technicians can easily provide real time support. Although the integration between the smart glass hardware and Android does not have the support needed today to use all Android functions in the Vuzix m100.

7.4 Conclusions

The four goals that were stated in the beginning of this master thesis were the following.

1. Will a display provide better efficiency?
2. Will it have better accuracy?
3. Will the user have a steeper learning-curve?
4. Will it increase the confidence of the employee?

Did the proof of concept provide better efficiency?

Our results indicates that for a novice user this is the case, although if a user is experienced additional test has to be performed. The test session provided results that led us to believe that even for more experienced users the efficiency would at least not be worse, because the same information as in and only voice solution is provided above the visual feedback. Some concerns are if the user will focus too much on the display and interrupt the work flow. But the work flow for the test subjects were not interrupted, instead the pick went more smoothly compared to the voice only solution, where they stopped and listened to the voice information before continuing with the pick.

Will it have better accuracy?

No indications of if the accuracy differed between the different solutions, more tests are needed to investigate the error ratio.

Will the user have a steeper learning-curve?

The first application used in the test, no matter which of the three, was the slowest. This is not surprising because the user had no practical knowledge about how to operate the system. Although the average time of round completion was significantly faster using visual information in the first test round. This strongly indicates that the user will be efficient faster, using smart glasses.

Will it increase the confidence of the employee?

In the interviews held after the test session, the test subjects provided with information that they felt more secure about what to do, whilst using the visual applications than the voice only application. It is not that surprising, because the user has all the information which is needed to advance in the system at all time. In contrary to a voice only solution where the user has to preform a action to receive the same information.

Final words

As a final conclusion it is probable that smart glasses have a future in warehousing, but today the smart glass technology has to mature before a final product can be implemented. Looking how smartphones evolved it is likely to assume that in a few years the technology with smart glasses will go the distance and further improve the efficiency in warehousing.

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