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Lightweight Scenario Planning for Human-Computer Interaction Technologies in the Next 5-7 Years

Bachelor of Science Thesis in Software Engineering and Management

ANITA BLAZHEVA
DAVID GIORGIDZE

University of Gothenburg
Chalmers University of Technology
Department of Computer Science and Engineering
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Anita Blazheva
David Giorgidze

Examiner: Lars Pareto, Antonio Martini

University of Gothenburg
Chalmers University of Technology
Department of Computer Science and Engineering
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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Anita Blazheva
Department of Computer Science and Engineering
University of Gothenburg
Gothenburg, Sweden
gusanibl@student.gu.se

David Giorgidze
Department of Computer Science and Engineering
University of Gothenburg
Gothenburg, Sweden
gusgiorda@student.gu.se

***Abstract*— Consumer-oriented technologies have continued evolving and drawn attention to human-computer interaction. Implementing such technologies in a company requires extensive future planning. This study presents scenario planning and investigates the possible future development of three of the current technology trends in human-computer interaction. We applied action research for identifying the most influential factors behind the technologies. The analysis revealed four categories of factors. Based on the two factors with highest impact and uncertainty level, four plausible scenarios were created. This study provides insights about the plausible future of human-computer interaction technologies, which can be used as input for a company's long-term planning.**

Keywords—scenario planning, human-computer interaction, augmented reality, speech recognition, gesture-based interaction

I. Introduction

Today's dynamic business environments have given rise to a new type of software development organizations, which continuously adapt their strategies in order to successfully accommodate new technologies. To gain a competitive advantage, many companies use strategic planning techniques to create flexible short- or long-term plans. In the last few years, scenario planning has proven to be an efficient planning method [1]. Thus, applying scenario planning for these new technologies would help to think creatively about their possible future. The central idea of scenario planning is to create a variety of possible futures, that include many of the important uncertainties in the system, rather than to focus on the prediction of a single outcome [2].

The new generation of technologies and services that are based on computer interaction, aim to improve the interaction between users and computers [3]. The long term goal of Human-Computer Interaction (HCI) is to design technologies, that can minimize the barrier between a designer's vision of what should be accomplished, and the computer's understanding of the user's task [4]. Although the keyboard and mouse are still the most popular ways to interact with computers, new HCI technologies that aim to simplify HCI are emerging. Technologies such as Speech Recognition (SR), Augmented Reality (AR) and gesture-based interaction are at the peak of their development, and their aim is to enhance the standard ways of interaction [5] [6].

There is a lack of academic research that has been carried out about scenario planning for HCI. In addition, there is a lack of research that focuses on the further development of HCI technologies in terms of the closer future. This study aims to address these gaps. The purpose of this paper is to increase the body of knowledge about the current trends in HCI, and present plausible scenarios for their future in the next 5-7 years. This timespan was chosen, because it refers to the expectations about the potential of these technologies to be on the mass market in the next 5-7 years [6]. Lightweight scenario planning was chosen due to the limited timeframe and resources of this research.

We applied action research approach to identify the most promising HCI technologies and evaluate the driving factors that shape their future development. In this sense, we investigated the following research questions:

- What are the driving factors that influence the future adoption of the current trends in HCI?
- What are the possible scenarios for the future of HCI technologies?

The data collection was carried out by applying literature review and conducting an interview. Therefore, we analyzed the extracted data by using thematic analysis. Furthermore, we used this data as input for the Two Axes Method of scenario planning in order to create possible scenarios for the future development of HCI technologies. The intended contribution of this study is:

- To increase the awareness about the current HCI trends.
- To provide insights to practitioners and researchers about the possible future of the HCI technologies.

A. Overview

This paper is organized as follows: Section two presents an overview of scenario planning and trends of HCI. Section three describes the research approach of the study and its limitations. The findings of the report are presented in section four. In section five, the scenario narratives are presented and discussed as an outcome of applying scenario planning. Lastly, section six concludes the study and gives suggestions for future work.

II. THEORETICAL BACKGROUND

To remain competitive, organizations invest in research and development of new technologies, which carry significant risk probability. Scenario planning is a robust way of managing this risk by understanding possible future events and circumstances that might affect the future adoption of these technologies, in both positive and negative way. As a result, organizations can prepare for the worst consequences and take advantage of the positive effects of the future events [7].

This section is divided into two parts: The first part gives a brief overview of scenario planning. The second part presents human-machine interaction (HMI) and its subcategories, and focuses on three of the current trends in HCI – AR, SR and gesture-based interaction.

A. Scenario Planning

1) Background

The first use of scenarios was during 1940s by Herbert Kahn from the RAND Institute, an independent research institute, working in close collaboration with the US military. Nevertheless, in the private sector Royal Dutch Shell, commonly known as Shell, was the pioneer, which during the 1970s used scenario planning to prepare for the upcoming oil crisis [8].

2) Main Characteristics

From a managerial perspective, scenarios can be seen as change agents, helping to identify risks, understand the possible chaotic future, and manage and reduce uncertainties. In this sense, scenarios have two common characteristics:

- A description of a potential future outcome or situation.
- An analysis of the impact of that potential future outcome on a company.

Therefore, the term ‘scenario planning’ represents the process of identifying, analyzing, and communicating the scenarios [7].

3) Differences between Forecast Planning and Scenario Planning

Forecast planning focuses on the best estimate from a particular method or model [2], and attempts to definitely predict a future outcome. However, scenario planning relies on scenario narratives about the plausible future, and on the assumption that a most probable future event cannot be determined [9].

Forecast planning aims to present the possible future by generating a scenario based on the known data about a future event. On the other hand, scenario planning generates different scenarios based on the uncertainties of this future event. In this sense, scenario planning addresses higher amount of possible scenarios [9].

4) Creating a Scenario Framework

a) Prerequisites

Before building the scenarios, the purpose of the work should be defined and how the scenarios would be used in practice should be clearly stated. The focal questions should be defined. Further, the timeframe that the scenarios would reflect and the methodology that will be used for conducting the scenarios should be clarified. In addition, scenarios are ideally developed during workshops including teams of 10-25 people that are subject-matter experts with different backgrounds such as stakeholders, policymakers, academics and professionals [8]. Some companies consider inviting analysts or consultants to do the scenario planning and discuss the findings of it on a workshop. However, in most cases the companies prefer to develop the scenarios during a workshop in collaboration with the stakeholders [8]. The analysis of key driving factors, trends and events, is initiated, which can be used as a preparation for the workshop. Scenarios add most value if they are communicated effectively and visualized for participants. This can be carried out by using diagrams, videos and presenting stories [8].

b) Methods to Develop Scenarios

There are many methods for building scenarios, such as Two Axes Method, Cone of Plausibility Method and Cause & Effect Scenario Generation. In this study, we applied the Two Axes Method, because the scenarios generated by this method are considered to be robust, illustrative, and can be particularly applied in a medium- to long-term period of time [8].

Two Axes Method

The Two Axes Method is based on one of the approaches used by Shell [1]. This method is usually performed in two-three workshops, or during a long-day session. The people participating in the workshops are divided into groups, and each group identifies the drivers and the trends that influence the focal questions. The drivers from all groups are clustered. The clusters are prioritized by group voting for identifying the drivers, that have highest impact and highest uncertainty level [8]. If the factors are closely related, they can be grouped and presented in a category. Based on the voting result, two of the factors are selected as scenario axes, which serve as a starting point to develop the scenarios. As shown on Figure 1, the method generates four contrasting scenario narratives, that describe how the plausible future might turn out [9]. To ensure that the created narratives are credible, the scenarios should be validated and verified.

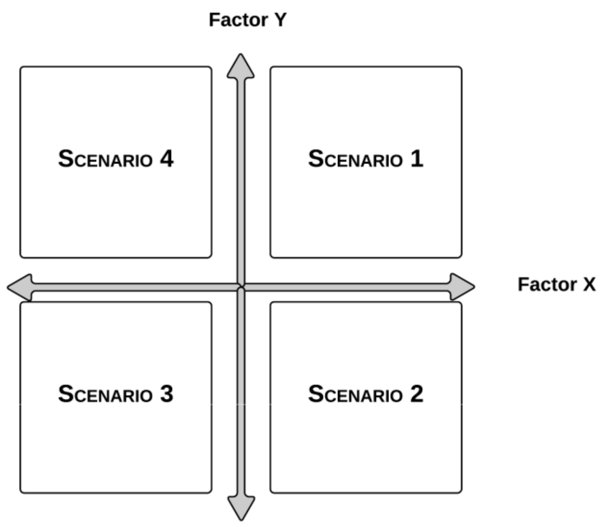

Fig. 1. Basic Overview of Two Axes Method

B. Human-Machine Interaction

HMI presents the interaction and communication between humans and a machine via a human-machine interface. The term "machine" refers to any kind of dynamic technical system [10]. HMI and Man-Machine Interaction (MMI) are used interchangeably and they define text- or graphic-based displays that are used by the humans to control, operate or monitor a machine. The application domain of HMI is very broad and includes all kinds of industrial, transportation, medical, service, entertainment and home-used systems [10].

1) Human-Computer Interaction

Technology has become a significant part of people's lives, and the impact of it is determined by the value that people derive from the technology. Therefore, businesses adopt appropriate technologies to address people's needs. This means, that business trends are influenced by the technologies and their users [5].

HCI is a discipline that focuses on the research, development, design and implementation of computer-based systems, which involves the interaction between a human and a computer [11]. The innovation and development of HCI technologies continues regardless the economic climate and thus, a diversity of technologies emerge, which aim for smarter, simpler and better HCI [5]. At present, the HCI technologies that are creating hype in the world are AR, gesture-based interaction, SR, 3D LCDs, gaze control, computer-brain interface and haptics [4] [6] [11]. The current research in the field of HCI leads toward possible adoption of these technologies in the next 10-15 years [6]. However, in terms of the closer future, our research leads us to believe that AR, SR and gesture-based interaction have the potential to be on the market in a period of 5-7 years [5] [6]. The following sections describe each of these technologies.

a) Augmented Reality

AR emerged from the field of Virtual Reality (VR). In VR, the user is completely engaged in a synthetic environment, without being able to interact with the real world. In contrast to VR, AR combines real world with the synthetic environment [12]. Thus, AR allows virtual and real objects to coexist at the same place. Therefore, AR superimposes graphics, audio and other computer-generated information on a live view of the real world [5] [6].

Main Characteristics - AR has existed for more than forty years, but the increasing availability of powerful devices provides a platform for future development. Currently, AR is particularly powerful for:

- Exploration - allowing the users to explore and discover areas of interest in their surroundings [6] [13].
- Navigation - providing user's position and showing the path to a certain destination [5].
- Suggestion - indicating and providing information about real-world objects of interest [5] [6] [13].

How Does AR Work? - A camera is used to display a real live view of the environment to the user. Location-based services can determine the location and its direction, which enables AR technologies to provide navigation. Further, by using mapping, the real-world objects are identified and annotated with additional information, such as descriptions, videos and images. AR applications can provide interactive menus, face recognition, and video/audio recording[13]. AR technologies consist of four major parts:

- Hardware – the underlying technologies such as camera, GPS, accelerometers, compass, battery, display and interaction devices [5].
- Recognition engine – identifies objects and faces. There are two types of recognition – based on location and/or objects. Location-based recognition uses spatial sensors to determine location and other attributes needed for navigation, while object-based orientation relies on the camera for input, either using the natural environment or artificial mark-ups to identify an object [13].
- Content – the content displayed within the AR application. It can be displayed by using private or publicly shared data [5].
- Viewer – the combination between all sensor data with the non-sensor data to identify, organize, and present context and objects to the user [5] [13].

The application domains of AR include manufacturing and repair, medicine, robot path planning, annotation and visualisation, military aircrafts and entertainment [12].

b) Speech Recognition

SR systems interpret human speech and translate it into text or commands. Technically described, SR presents the mapping of acoustic signals to a string of words [14]. Depending on the application, SR can be performed on a device, server in a network or a combination of both [6].

The application domains of SR vary from converting speech to text for desktop entries, user-interface control, and simple self-service dialogues for call center applications [5]. Further, SR is included in some other applications in combination with other technologies, as a way of providing input and control [5].

c) Gesture-Based Interaction

Gesture-based interaction presents the recognition and interpretation of human movements as a way of controlling and interacting with a computer system, without having direct physical contact [6]. Gestures can be captured either by using a camera or via a device with embedded sensors [5], which can be attached to the user. This can be performed by using magnetic field trackers, body suits or data gloves [15]. Further, gesture-based interaction involves the use of different input devices to provide either 2D movements or full 3D information. Thus, the input data requires data processing, which creates wire frame models of possible human-body positions and vector-based dynamics, responsible for the direction and speed of movement of the users [5] [6]. Therefore, the gestures are interpreted to commands to the computer system.

Gestures are often considered language- and culture-specific. They can be divided to hand and arm, head and face, and body gestures [15]. Further, the meaning behind a gesture depends on the place where the gesture occurred, its path, its sign and emotional value [15].

The primary application domains for gesture-based interaction are gaming and entertainment. However, the potential of having hands-free control can benefit other domains such as teaching, medical rehabilitation and sign language [15].

Gesture recognition can be also used together with other technologies such as SR and AR, in order to provide more features to an application. Such composite applications are considered having higher chances of mass adoption [5].

2) Human-Vehicle Interaction

Nowadays cars have become more than a way of transportation. Today's cars are equipped with different sensors, GPS navigator, audio and video players, and web browsers. Human-Vehicle Interaction (HVI) refers to the interaction between humans and computers in a vehicle [16].

HVI can be seen as a type of HCI, which is used in the automotive industry. Technologies that are emerging within different domains will eventually be implemented in vehicles [16]. However, the focus of this study is not on HVI, but rather on the current technology trends in HCI.

III. METHODOLOGY

This section describes the research approach used in this study. We applied action research and collected data in two steps – by conducting a literature review and an interview. Further, the data was validated and verified by conducting another interview, two workshops and a survey.

A. Research Approach

We applied action research approach to address the research questions. This approach was chosen, because it balances problem solving actions with theory in a future orientated way [17]. Thus, action research iteratively links the theory and practice, in a sense that a successful solution is based on analyzing the situation correctly, and providing knowledge about possible actions [18].

Based on Susman and Evered's [17] action research process, this study combined theory and practice as follows:

1) Diagnosing

During this phase we collected data by applying literature review [19] and conducting an interview. The review of the literature was split into two categories:

a) Research on HCI technologies that have potential to be on the market in the next 5-7 years.

b) Research on scenario planning.

The literature review was conducted in five distinct phases:

1. Search strategy development.
2. Identification of inclusion and exclusion criteria.
3. Research on relevant studies.
4. Data analysis.
5. Synthesis of the selected material.

2) Action Planning

During this phase, we reflected the prerequisites of scenario planning. Thus, we identified the purpose of the scenarios and their timeframe. We initiated the identification of key driving factors. Therefore, we validated the collected data by conducting two workshops and another interview.

3) Action Taking

We used the analyzed data to perform the phase of action taking. We identified the key driving factors and stakeholders, and prioritized them. The prioritization included a brainstorming session for discussing the uncertainty level of the driving factors and their impact on the future development of HCI. Further, the impact was validated by conducting a survey (See Section D3). This was visualized by using causal and prioritization diagrams. Based on the prioritization, we chose two of the factors that had highest level of uncertainty and impact. The two selected factors were used as input for creating scenarios by applying the Two Axes Method. Thus, four scenarios were created.

As shown on Figure 2, action research consists of five phases. Due to the short period of time for conducting this study, the phases of evaluating and specifying learning were not completed (See Section V- Validity Discussion).

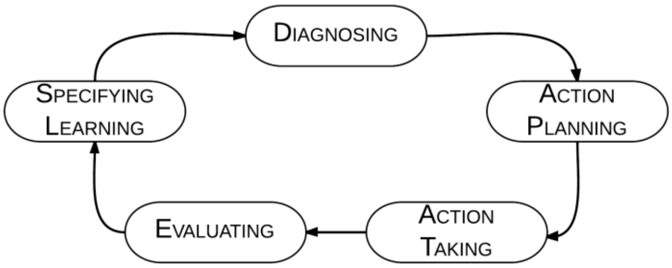

Fig. 2. Action Research Cycle

<u>Research Setting</u>

The research was performed in collaboration with Tech-Watch and Business Innovation Department of Volvo IT. Volvo IT is one of the eight business units of the Volvo Group and it has approximately 9000 employees and offices worldwide. The research was conducted in the Volvo IT office in Lindholmen, Gothenburg, Sweden.

In order to help us gather more data, Volvo IT organized an interview with an analyst from Gartner. Gartner is an American IT research and advisory firm, which provides technology related research to its clients within the IT industry.

B. Data Collection

1) Search Strategy Development

We developed a search strategy for collecting relevant articles [20]. We identified the important concepts of our research and created search terms that describe these concepts. We used electronic databases to perform the research.

a) Data Sources

As mentioned in section B1, electronic databases were used such as IEEE Xplore, Google Scholar, ScienceDirect, Elsevier, Chans, Libris, Scirus, Chalmers Library, Chalmers Catalogue, ACM Digital Library, and SpringerLink.

b) Search Terms

The following search terms were used during the phase of research:

- Human-computer interaction (HCI)
- Human-computer interaction trends
- Scenario planning
- Augmented reality
- Speech recognition
- Gesture-based interaction

We used Boolean operators such as AND, OR, and NOT to expand our research. In some cases, Boolean operators were used to combine several search terms into other search terms. In addition, such operators were used to exclude studies that did not respond to our quality criteria.

2) Quality Criteria

The quality criteria were created to confirm that the studies were relevant and could bring value to our research. The following quality criteria were developed to ensure that the identified studies were credible and reliable:

- The aim of the studies should be clearly stated.
- The studies should provide valuable information to our research.
- The studies should be closely related to our research questions.
- The methodology of the studies should be clearly presented.
- The findings, discussion, and conclusion should follow the methodology of the studies.

3) Inclusion and Exclusion Criteria

After applying the search strategy, we filtered the found studies, based on the following criteria:

- Studies were excluded based on their titles.
- Studies were excluded based on their abstract and conclusion.
- Studies were excluded if they did not match our quality criteria.

Therefore, we applied thorough filtering, based on our inclusion and exclusion criteria. The inclusion criteria were created to determine whether an article could provide value to our research or not. The studies had to match the following criteria:

- Studies that conformed our quality criteria.
- Studies written in English.
- Studies that provided empirical data on HCI and scenario planning.
- Scientific studies and studies that did not strictly follow the standard research conventions.
- Studies that contained information about the driving factors and/or stakeholders that affect the development of future HCI technologies.

Further, excluded from our research were:

- Studies that focused on scenario planning modified to the particular needs of a company.
- Studies that did not focus on scenario planning or HCI trends.
- Studies that focused on the development of a specific technology.

4) Interview with Gartner Analyst

We held a 30-minute phone session with a Gartner analyst for collecting data on the current trends in HCI and the driving factors behind the technologies. For that purpose we designed a questionnaire. The questions were sent in advance to Gartner and thus, we got appointed with one analyst that can address the questions from the questionnaire. This method allowed the analyst to prepare for the session and provide us with the most valuable information. We discussed the current trends in HCI and focused on benefits and limitations of AR, SR and gesture-based interaction. Further, the analyst gave prognosis whether each of the technologies would be available on the mass market in the next 5-7 years. Furthermore, the driving factors behind these three technologies were presented, and ranked based on their importance.

C. Data Analysis

The collected data was analyzed by following the guidelines for thematic analysis [21]. This approach allowed us to establish meaningful patterns that are related to our research questions. Braun and Clarke [21] describe thematic analysis as a coding process that consists of six phases for establishing meaningful patterns. They suggest the following phases:

- *Familiarization with data* – during this step we familiarized with the literature data and conducted the first interview. Therefore, we initialized the analysis of the data.
- *Generating initial codes* - we identified the most common recurring concepts of each study and listed them. Since thematic analysis is a cyclical process, we followed an iterative process of going through data, identifying driving factors, grouping them in sets and labeling the sets, which are closely related to our search aim and research questions. The labels included name and resource information. Organizing data in this way provided us with a better overview of the data, reduced the complexity and helped us compare the data.
- *Searching for themes among the codes* - According to Braun and Clarke [21] organizing data by labeling helps for themes to emerge. Therefore, we identified themes by looking for recurring patterns. The themes are presented in section IV Findings.
- *Reviewing themes* - Themes were created not only by checking for recurrence, but also by their relevance to the research questions.

- *Defining and naming themes* - Creating themes allowed us to reduce the amount of data and get a better picture of the possible findings. Thus, we identified data sets with important information, which helped for getting a better understanding of the topic and further, to answer the research questions.
- *Producing the final report* - During this phase, we focused on writing the final report, collecting feedback and addressing it.

D. Validation

To help us validate the findings, Volvo IT organized two workshops. Further, we conducted an interview with a university professor and a survey within Volvo IT.

1) Workshops

The first workshop focused on validating the findings from the literature review about scenario planning, and included a discussion on how scenario planning is used in Volvo IT. Further, scenario planning techniques and methods for prioritizing the driving factors were presented. The second workshop was conducted later in the process and included a session, where the findings were presented and discussed in order to confirm the validity of the themes that we identified.

2) Interview with a University Professor

We conducted an interview with a professor in HCI. We used the same questionnaire that we developed for the interview with the analyst from Gartner. Further, we used the analysis of the first interview to help us lead the conversation. This means that we touched upon every factor that the analyst mentioned, and discussed it further with the professor. We examined if the identified factors influence the HCI technologies in direct or indirect way. The stakeholders that might influence the future development of HCI were also discussed.

3) Survey

In order to validate the prioritization of the driving factors that we identified from the literature review and the interview with the analyst, we created a survey, administered online [22]. The survey was developed and tested at the University of Gothenburg before its usage in Volvo IT. The survey was sent to eight people - to seven employees of Tech-Watch and Business Innovation and one expert from Safety Analysis and Human Factors in Volvo Technology.

The survey focused on the impact that the driving factors would have on the current trends of HCI in the next 5-7 years. Thus, the survey tried to capture the general impact of the driving factors on HCI, rather than focus on each of the technologies.

The first question was designed to collect demographic data. We stated the main question how each of the driving factors influence the future development of HCI, and we listed every factor as a single question. Thus, the variables of the survey were the driving factors. We created a scale of impact consisting of six possible values – *very negative, negative, slightly negative, no impact, slightly positive, positive and very positive*. Therefore, we used this scale as a possible answer choice for every factor. Further, we included a "don't know" answer to every factor. The last question was an open question where the participants could add their thoughts about the factors or add a factor that was missing.

The data was analyzed and interpreted using the guidelines provided by Creswell [19]. The author suggests couple of analysis steps:

- *Reporting information about the number of participants that answered and did not answer* - the response time for the survey was four days and during this period of time seven participants replied.
- *Response-nonresponse bias* - we planned a nonresponse bias. Since only one person did not reply to the survey, we analyzed the data from the respondents of the survey and compared it with our findings. There was no significant difference, which means that the potential answers of the non-respondent would not significantly vary from the answers of the people that responded to the survey.
- *Plan for developing scales* – the answers' scale was coded, in a sense that to every answer there is a responding code number in a range from -3 to +3. As an example "very negative impact" had the value of -3 and "very positive impact" was coded with +3. "Don't know" was chosen only twice in the whole survey and there was a not significant difference in the percent distribution. Therefore, we excluded this answer from the analysis.
- *Statistics* – We calculated the mean values of each factor based on the answers' scale. Therefore, we compared the values with our prioritization values. The difference was not significant.

IV. Findings

In this section we present our findings based on the data analysis. As a result, we identified the most influential driving factors for the future development of HCI technologies and we grouped them into categories of related factors. Furthermore, we identified the key stakeholders behind the technologies and visualized their relationships with the driving factors. We prioritized the factors based on their impact and uncertainty level. Therefore, we chose two of the driving factors with highest impact and highest level of uncertainty to place on the axes of the Two Axes Method matrix. Thus, we identified four possible scenarios for the future development of HCI.

A. Driving Factors

The factors were derived from the challenges that should be addressed before mass adoption of the technologies. Some of the factors are related to a certain technology, while other factors are valid for more than one or all of the technologies. During the data analysis, we identified four sets of factors, which were highlighted by the literature, interviews and survey results: technological, business, user-related and political factors. The following sections present each of these categories:

1) Technological Factors

The most important technological factors are:

a) Maturity of the Technology

AR systems

The maturity of AR is strongly dependent of the maturity of the related technologies, included in AR systems [6] (See Section b) Maturity of Related Technologies).

SR systems

Accuracy levels of SR systems vary depending on the background noise, the size of the vocabulary of the application, the clarity of the voice of the speaker, the quality of the microphone and the available processing power [5].

Spoken language is different than written language, in a sense that written language is usually a one-way communication, while spoken language is dialogue-orientated. When speaking, people use gestures, repetitions or change topic, which cannot be registered by SR systems. Further, when speaking people take natural pauses between words, which is not always recognized by the technologies [23].

Moreover, the speaking style varies with the emotions of the speakers. Men and women have different voices with different vocal tracts. Further, different people have different speed of speech. In addition, the users of SR applications may have different accents or dialects, which might not be recognizable by the application [23].

b) Maturity of Related Technologies

AR systems

The device requirements for AR are very high in terms of GPS precision, battery capacity and screen resolution [13]. Brightness, focus, contrast and daylight issues exist when AR systems are used outdoors [12]. Always-on connectivity is required, which drains the battery. Thus, in a product like Google Glass the battery lasts about five hours [24]. In addition, GPS technologies lack providing perfect location data [6]. Besides, the newer AR systems include speech and gesture recognition technologies, which also encounter problems in terms of recognition.

c) Standardization

AR systems

There is an information incompatibility between different AR browsers. Thus, the data access should be refined and standardized [13].

Gesture-based interaction

Based on our interview data, we identified that standardization across devices is a challenge for gesture-based interaction. There is a need for widely accepted standards, which will address the problem of a gesture that means two different commands on different devices. Further, in order to be used in office environments, standardized gestures should be created to control business applications.

d) 3rd Party Functionality

Third party functionality includes other companies and developers besides the companies that develop AR, SR or gesture control systems. Based on the interview data we conclude that third parties, which use these technologies as a platform for developing applications, can contribute to their further adoption.

2) Business Factors

The business factors included in this category reflect the further adoption of each of the three technologies. The most important business factors that we identified are:

a) Financial Power of the Companies Behind the Technologies

The companies that have financial power usually have access to more resources and funds. Considering our interview data, we identified that such companies can invest in further development of a technology and put it on the market.

b) Competition Between Companies

As discussed during the interview sessions, the competition between companies is a factor. Competition leads to innovation and can be a reason for decreasing the price of the products.

c) Cost of Product

Research, development and hardware costs influence the final price of any technology. The higher the price level of the product, the lower the user adoption [13].

d) HCI Technologies as an Advertising Platform

The interview data showed that technologies such as AR systems can be used as an advertising platform. By showing advertisements while using AR, the companies gain profit. Thus, if a technology is profitable, its chances for further development are higher.

3) User-Related Factors

The key user-related factors are:

a) User Acceptance and Adoption

User acceptance and adoption can be viewed from two different perspectives - as a factor that can influence the development of new HCI technologies, and as an outcome of addressing all driving factors. In this study, user acceptance and adoption is seen as a factor that influences the development of the technologies. This factor is valid for AR, SR and gesture-based interaction. The following example illustrates one of the problems that can be encountered in terms of user acceptance and adoption.

SR systems

SR has been used for medical and legal dictation, but the main challenge that occurs is that in order to use the system, the users should either know how to dictate or obtain the skill [6].

b) Privacy and Security

AR systems

AR technologies can expose personal information about the users and their location for public usage [13].

SR systems

The analysis of the interview data showed that SR systems might not be suitable for office environment, due to privacy issues. Company information usually has protected value and by using SR, company secrets might be revealed.

c) Health and Safety

AR systems

The analysis of the interview data revealed that some AR systems can cause dizziness, neck pain or impairment.

Gesture-based interaction

Gesture control devices can be non-ergonomic and cause tiredness for the users [25].

4) Political Factors

The most important political factors are:

a) Government Interests

The analysis of the interview data showed that governments show particular interest in the future development of HCI for military use.

b) Laws and Regulations

Laws and regulations that are based on privacy issues can affect the availability of these technologies on the consumer market [26].

B. Stakeholders

Since stakeholders can also be considered as driving factors, we identified these stakeholders who might have impact on the development of the HCI technologies. We looked for stakeholders that influence the technologies both directly and indirectly. Thus, we concluded that users, privacy advocates and external contractors have high levels of interest, but not enough power or finances to push the innovation of the HCI field. In terms of power, governments can influence the future of HCI, but their interests are usually on military level. On the other hand, in terms of power and interest, major vendors, companies and research labs can influence the future HCI development.

C. Prioritization and Identification of Critical Uncertancies

Based on the data analysis, we investigated what impact the driving factors have on the HCI technologies and what their uncertainty level is. As shown in Figure 3, the factors situated in the top right corner of the diagram have the highest level of uncertainty and highest impact on the three technologies. Figure 4 shows a diagram of the relationships between these factors. The red arrows present the negative impact that some factors can cause, while the green arrows reflect on the positive impact. The thickness of the arrows refers to the level of impact of each factors e.g. "government interests, laws and regulations" have slightly positive impact on "standards"; "user acceptance and adoption" has very positive impact on "cost of product" or "privacy and security" have slightly negative impact on "user acceptance and adoption". Based on these relationships, we investigated that some of the factors are closely related and affect each other e.g. user acceptance, privacy issues, and health and safety. This indicates that these factors can be grouped into one bigger category as shown in section 3) User-Related Factors.

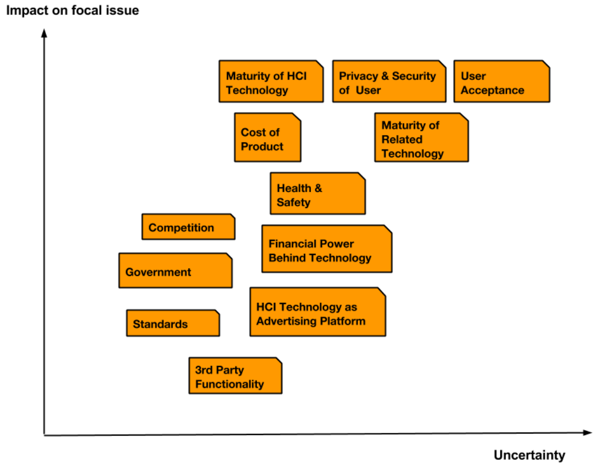

Fig. 3. Prioritization Diagram

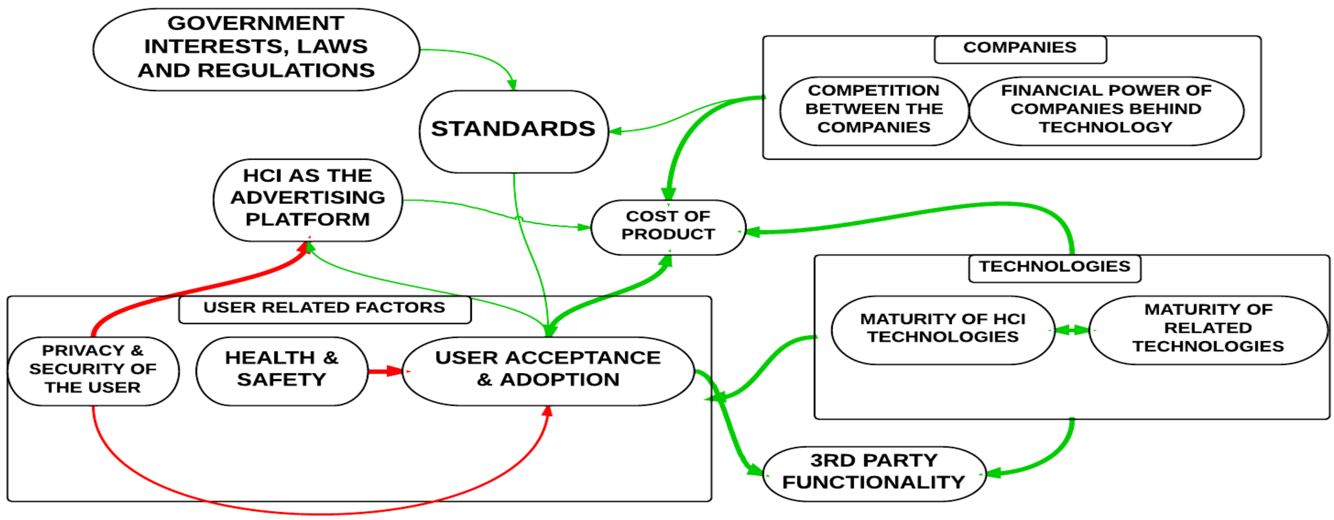

Fig. 4. Causal Diagram

The "user-related factors" group has the highest impact and uncertainty level. Therefore, we decided that this category of factors will be used as an axis for the Two Axes Method.

The another factor that we decided to include in the Two Axes Method is a combination of two factors that influence each other – maturity of the HCI technology and maturity of the related technologies. We named these factors "Technology Maturity".

Figure 5 shows the two extremes of each driving factor – inner- and outer-directed user values, and high and low technology maturity. Inner-directed user values refer to the values that are guided of user's own set of morals and standards. Outer-directed user values reflect on the set of user values that is derived by current trends or influences, rather than the thought and behavior by a user's own set of values. The four possible scenarios are:

- HCI revolution – the technology maturity level is high and the user values are outer-directed.
- Delayed innovation – the users are open to innovation, however the technologies are not mature enough.
- Technology deadlock – the technology maturity level is low and the users are concerned about their inner values.
- Unprepared for innovation – the level of technology maturity is high, but users' values are inner-directed.

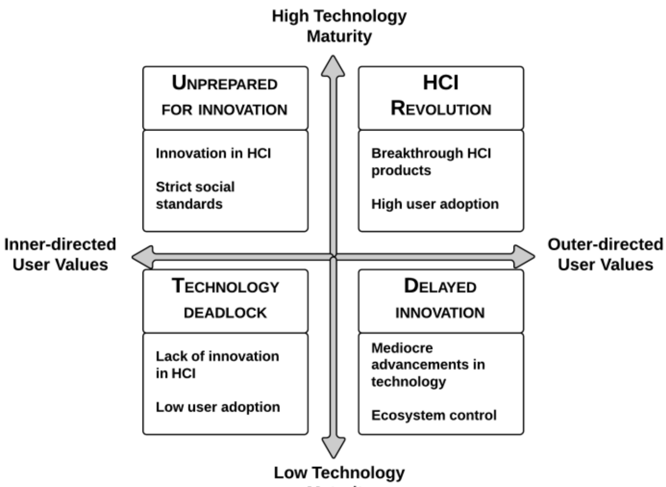

Fig. 5. Scenarios

V. Discussion

In light of the presented findings, this section discusses the four possible scenarios that were generated by applying the Two Axes Method of scenario planning. In addition, a scenario that reflects the authors' opinion of how the future of HCI might turn out, is presented. Lastly, this section presents a validity discussion.

The scenarios that follow are not meant to be exhaustive, but rather plausible and provocative. Each scenario presents a story about the possible future of HCI technologies in the next 5-7 years, with an emphasis on the maturity level of the technologies and the user-related values. The scenarios in this paper are stories, not forecasts, which means that some of the presented ideas might not happen. The reader should consider that the specific details are not necessarily conditions for any particular scenario to unfold. The driving factors in each scenario are discussed as themes, as presented in section IV. Thus, the scenarios include both the results of our research and discussion about the results.

The scenarios aim to initiate thoughts and questions on the possible future of the technologies. The scenarios can be used by practitioners and researchers as a base for further discussions, developing strategic vision or as indicators of potential future events. However, these scenarios are not mentioned in the literature, but reflect the collected and analyzed data.

A. HCI Revolution

This scenario narrative presents a possible view of the world in case of "HCI Revolution". Revolution is seen as a combination of high technology maturity level and outer-directed user values, which triggers an inevitable innovation in the HCI field. Thus, the further development of HCI is encouraged and the application domains of the technologies increase tremendously. Further, the technologies are stable, fully-functioning and well-established on the market.

1) Technological Factors

The high levels of technology maturity derive from the continuous development and improvements on technological level. The camera sensors are improved in terms of their size and power efficiency. Further, the battery capacity is increased without affecting the weight or size of it. Thus, stronger batteries trigger the development of a new generation of processors, which provide more processing power.

The microphone quality is adjusted for the purpose of SR systems. When speaking, the background noise can be determined and ignored without affecting the performance of the system. The vocabulary size increases and contains dialect words. The users can speak to the system as if they speak with another human, without taking into consideration the speed of speech and speaking style. Thus, the system recognizes spoken and written language style, pauses, different vocal tracts, accents and dialects, and modifies the spoken text into the particular needs of the user. All these improvements result in 100% speech recognition.

AR systems benefit from the camera and battery improvements. Therefore, the battery that is used for the devices can last longer than a day. When outdoors, the brightness, focus, contrast and daylight reflection are adjusted automatically. Thus, the users' sight is as it would have been without having an AR device. Further, AR systems effectively include other systems such as SR and gesture-based systems, which provide additional input to AR systems. In this manner, the maturity level of AR systems is high due to the advancements of the related technologies.

Due to the possibilities to experiment with the improved systems, the amount of third parties that develop new applications for the devices increase. In terms of standards, the major vendors together with the government, work for developing better standards that follow the necessary rules and regulations about health and safety. Further, the vendors agree upon a standard way of interaction with devices. Thus, gesture-control systems can provide a realistic experience, based on precise and standardized recognition.

Breakthrough in hardware technologies encourage the further development of context-based interaction systems, which aim to provide smarter products that recognize human behavior.

2) Business Factors

Due to high maturity level of HCI technologies, companies that have sufficient financial resources are investing in further development of these technologies, aiming to incorporate them in their products. Thus, the companies' intention is to increase the usability of their devices and attract more users. On the other hand, the availability of stable and mature related technologies attracts other companies to consider developing their own versions of the already existing products. Thus, competition between companies arise. Increased competition levels result in lowering the price of the devices.

3) User-Related Factors

Devices that both offer breakthrough HCI technologies and are cheaper, are quickly adopted by the users. Thus, the companies gain profit from selling user-related advertisements. This means that the technologies can be used as advertising platforms, providing advertisements based on the users' preferences.

As a result of the technology maturity, many organizations consider implementing these technologies in their office environments. SR and AR systems can be successfully implemented and used in offices. On the other hand, depending on the profile of the companies, SR systems might be in violation with the companies' privacy policy or inconvenient for the surrounding employees to perform their daily work.

The technology improvements contribute for developing safe and secure devices. Thus, the health issues such as tiredness, impairment and dizziness are addressed. Further, the major vendors aim to protect the privacy of the users. Thus, they do not provide sensitive data about people that do not own a device, nor present data without the users' agreement. Consequently, the users are not as concerned about the privacy of their data.

The new HCI technologies, being sold separately or as a product consisting of couple of technologies, promise to simplify the end-user's tasks and eventually replace the standard ways of interaction. The lower price of the products, combined with the higher maturity of technology result in higher levels of user acceptance. Therefore, the adoption rate increases. However, mass adopted technologies are exposed to higher risk of hack-attacks.

4) Political Factors

The growth of the technologies triggers the governments' support and investments. Thus, these technologies can be modified for military use. Further, laws and regulations for guaranteeing and protecting the privacy of the users are created.

B. Delayed Innovation

This scenario narrative presents a potential view of "Delayed Innovation". The users are open to innovation, however the technology maturity levels are low. In order to stay on the market, many companies oblige the users towards adoption of the technologies that are part of the companies' ecosystems. An ecosystem refers to the company, its product and services. The application domains have not changed.

1) Technological Factors

The development of AR, SR and gesture-control systems is delayed due to insufficient battery improvements, which do not address the always-on connectivity problems of draining the battery. Poor battery improvements reflect on less available processing power for handling vocabulary size and precise word recognition. Further, the SR systems still experience problems with background noise, and recognizing accents and dialects. Thus, these challenges limit the usage of the technology.

The low maturity levels limit the addressing of issues such as brightness, focus, contrast and daylight. Therefore, AR systems that are used outdoors might encounter performance problems. Due to these challenges, combining AR systems with SR and gesture-control results in creating insufficient devices. In terms of gesture control, in order to perform tasks the users need an additional device.

Low maturity levels attract less third party developers, who prefer to create applications for other fully-functioning technologies, which are already established on the mass market.

In order to decrease the effects of low technology maturity, the major companies initiate a standardization process, which would help for increasing the level of user acceptance and adoption. This process aims to solve the problem of steep learning curves.

2) Business Factors

In order to compensate on low technology maturity level and increase the user adoption, the major vendors are tightly integrating new HCI products in their existing ecosystems. Despite the high costs of research and development, device manufacturers sell their products at low prices to increase the levels of user adoption. The key component of every ecosystem is to limit the users to use only services that the vendor offers. Tightly controlled ecosystems provide possibility to fasten the customers to one company. This results in generating long-run profit, which eventually covers the research and development costs.

However, due to low technology maturity only few vendors are experimenting with new HCI technologies.

3) User-Related Factors

The outer-directed user values suggest that the users are willing to experiment with HCI technologies, despite that these technologies are not advancing and do not provide any new functionalities. The users are open towards innovation and due to the decreased prices of the devices, they still buy the products, which are available on the market. Despite their drawbacks, the technologies offer different way of interaction with the computers than smartphones such as basic speech commands like “Call Garry”, waiving hand gesture towards TV to change the channel and basic navigation using AR glasses.

Since the maturity level of the technologies is low, the users are not as concerned that technologies might violate their privacy. Health and safety issues still exist, but these are not considered as a major concern for the users.

4) Political Factors

Governments do not show much interest in HCI technologies, since the technologies are not mature enough.

C. Technology Deadlock

This scenario presents the possibility of “Technology Deadlock”. The technology maturity levels are low and the users apprise inner-directed values. This means that the technologies are in potential danger of not maturing or being abandoned.

1) Technological Factors

The existing problems within SR, AR and gesture-control devices are not solved. The SR devices cannot perform precise recognition, neither can be used as input for AR devices. Gesture control is not standardized and does not provide precise recognition. AR devices can be used for limited amount of time, due to poor battery performance. When outdoors, AR systems cannot perform well.

Due to poor technology maturity levels and low user adoption, there are no third parties that are interested in developing applications for these technologies. In terms of standardization, the major vendors develop gesture control devices, based on gestures that are particularly developed for their products. Thus, without having standardization, the users should learn gestures that are specific for every device, which might differ from the gestures used in another devices.

2) Business Factors

The HCI technologies that are on the market are not mature enough and the customers refuse to buy them, because of their inner concerns. Therefore, the major vendors are not interested in further development of these technologies. The competition levels are low and the price of each technology is high. Moreover, due to the high prices, research and development costs, the companies prefer to invest in further research and development of other technologies.

As a result of low user acceptance levels, the technologies are not used as advertising platforms.

3) User-Related Factors

The new technologies do not offer better interaction, therefore the user adoption rate is low. In inner-directed world the users are concerned about their personal values such as health, safety, security, and privacy. Therefore, they avoid using technologies, which can violate these values.

Despite of the technologies’ disadvantages and low adoption levels, there is a small group of users that can afford paying higher prices or is particularly interested of each of the technologies.

4) Political Factors

The technologies are not used in the military, due to their low maturity level. Thus, the governments do not influence their further development, nor create laws and regulations for them.

D. Unprepared for Innovation

The scenario “Unprepared for innovation” presents the “battle” between high technology maturity and inner-directed user values. The users are concerned about their personal values, which slow down the further adoption of the technologies.

1) Technological Factors

Camera and battery technologies are improved and can support full HD recording without using much power. Manufacturers create batteries with bigger capacity without increasing their weight or size. The problems that SR experienced, are addressed. Therefore, the recognition level is at 100%. Gestures are standardized and together with SR can be used in AR devices to provide input data.

Low user acceptance level limits the third parties, which might not consider developing applications for these technologies.

2) Business Factors

The competition between companies for developing better and stronger technologies is at high level. However, the competition is orientated towards technology advancements, rather than addressing the inner-directed user values. The major vendors focus on developing hardware and invest in further research and development of the technologies. The competition between vendors results in cheaper products.

The technologies have potential to be profitable advertising platforms, but due to low user adoption levels the advertisements are not fully used.

3) User-Related Factors

Despite of the advancements in HCI development, the users are skeptical about the technologies. The users are experiencing steep learning curves when using AR, SR or gesture control devices and therefore, they prefer to use the already existing devices that they are familiar with.

Despite that health and safety issues are addressed, the users are concerned about their personal values and the privacy of their data. Consequently, many companies experience problems with privacy advocates. Therefore, many users are doubting if vendors are respecting people’s values and privacy rights.

In office environments, technologies such as AR and SR systems are not adopted due to strict privacy policies. Furthermore, even if a company decides to implement a new device, which would bring fundamental changes to the way how employees perform their duties, it might take time and resources to address the steep learning curves that the employees experience.

Due to low adoption levels, using these technologies in public places might be considered inappropriate. Hence, the users that buy these technologies are a small group of enthusiasts that are not concerned about their privacy.

4) Political Factors

The advancements in these technologies trigger governments' interests in terms of military use. Hence, the technologies are adapted for the particular needs of the military and further, they do not violate the privacy and security that are required in the army. In terms of public use, government regulations might limit the usage of some technologies in public places due to privacy issues.

E. Authors' Scenario Proposal

The scenarios generated by the Two Axes Method present four possible narratives of the future based on the extreme values of the driving factors. This section proposes a scenario, based on the authors' view of how the most probable future of HCI technologies might turn out.

The authors of this study propose that the most probable scenario for the future development of HCI is closely related to the scenario, called "Unprepared for Innovation". However, this scenario is not stretched to an extreme level. The technologies will be slightly improved and will contain certain new features, but the adoption levels will be low, due to the price of the products and the privacy issues. The following sections present an overview on each category of factors and their relationship in this scenario.

1) Technological Factors

The maturity level of each of the technologies increases. In terms of SR systems, the recognition or different accents, languages, speed of speaking and natural pauses is working properly. The background noise is eliminated. However, despite of these slight improvements, there are still technological problems that need to be addressed such as battery capacity or issues that AR faces when used outdoors. The standardization process is almost completed. There are few third parties that develop applications for the new technologies.

2) Business Factors

In terms of business factors, the major vendors still invest in research and development, and there is slight competition between companies. The price of the products on the market is decreased, but still high for the average users.

3) User-Related Factors

AR systems are on the mass market, however the adoption level of AR is hindered by users' inner-directed values. The major vendors have not addressed the existing privacy issues and therefore, the users are concerned about their privacy.

SR systems are mostly used for medical and legal dictation purposes. Due to privacy issues, SR is not implemented in other office environments. The average users do not use SR on every day basis.

Gesture-based interaction is still used for gaming and entertainment. Products like Microsoft's Kinect and Sony's PlayStation Move are established on the market. However, in terms of office environments, gesture control technologies are not used.

There is still a group of users that buys the new technologies, despite the existing issues.

4) Political Factors

Laws and regulations based on privacy issues are established. The technologies are used for military purpose.

F. Validity

This section discusses the validity threads of this study.

1) HCI Trends

This study focuses on three of the current trends in HCI – augmented reality, speech recognition and gesture-based interaction. The researchers are open to the possibility that there might be other technologies, which have potential to be on the market in the next 5-7 years. Therefore, the driving factors might differ from the factors presented in this paper. Further, in case of different driving factors, the possible scenarios might not be the same as the presented scenarios.

2) Methodological Limitations

According to Susman and Evered [17] action research consists of five phases – diagnosing, action planning, action taking, evaluating and specifying learning. Due to the short period of time for this study, we applied the first three phases of the approach. Evaluating refers to examining the presented scenarios and studying their consequences. This phase will be performed by Volvo IT by the end of 2013, when the scenarios will be revised. Thus, Volvo IT will choose the most probable scenario as input for their long-term planning. Further, specifying learning refers to identifying the general findings after completing the previous four phases. Since the fourth phase has not been completed yet, specifying learning is not addressed in this study.

a) Literature Review Limitations

Due to our choice of search terms and strategy, we might have missed including some relevant papers. Some studies that did not follow the standard research conventions but merely reflect their author's opinion were included in the research. This might mislead the reader to case-specific conclusions. In addition, articles that focused on technologies that are not mature enough to be on the market in the next 5-7 years, were omitted. There was a lack of academic resources that focus on the current trends in HCI. Therefore, we included some restricted articles. In order to address these limitations, we conducted the interview with Gartner analyst.

3) Heavyweight vs. Lightweight Scenario Planning

Scenario planning is a heavyweight planning technique, which requires time and resources. The development of scenarios should be prepared during workshops with groups of experts, where the scenarios should be derived from a discussion between the different groups (Section II). In this study, two people were involved in the scenario planning process. The scenarios were not developed in a discussion within different groups of experts, but merely reflected authors' opinion based on the collected and analyzed data. The scenario planning applied in this study was conducted in a period of three weeks. Hence, there is a possibility that the presented scenarios might have been different from the scenarios, which would have been created by a group of experts within a longer period of time. Thus, the applied scenario planning refers to lightweight scenario planning.

4) Prioritization of Driving Factors

As shown on Figure 3, the prioritization of the driving factors is the same for all three technologies. In this sense, the presented prioritization gives more general overview of the factors. The researchers are open to the possibility that the prioritization diagram might look different if it focused on one technology at a time. Thus, the scenarios would be orientated towards one of the technologies, rather than providing a general overview of the future of the current trends in HCI.

VI. CONCLUSION

This study set to investigate the plausible future of three of the current trends in HCI in a timeframe of 5-7 years – augmented reality, speech recognition and gesture-based interaction. We initially presented a description of scenario planning and a review of the three technologies. Subsequently, we showed the most influential categories of driving factors – technological, business, user-related and political factors. We prioritized the factors and therefore, we selected "Technology Maturity" and "User-Related Values" as the factors with highest impact and uncertainty level. These factors were used as input for the scenario axes of the Two Axes Method of scenario planning. As a result, we presented four plausible scenarios, namely "HCI Revolution", "Delayed Innovation", "Technology Deadlock" and "Unprepared for Innovation". Each scenario narrative included discussion about the possible future of the four categories of factors. The main contribution of this study was to initiate thoughts and questions about the plausible future of augmented reality, speech recognition and gesture-based interaction and increase the awareness about these technologies.

A. Future Work

Due to the limited time of this research, the final two phases of action research were not conducted. A possible suggestion for future work is to complete the action research cycle by evaluating the scenarios and then, applying specifying learning.

More research should be carried out in order to validate the findings and investigate whether other technologies are more promising and suitable for the Volvo IT's needs. Further, the current scenarios are based on the two most influential driving factors and therefore, more research on the driving factors should be performed and more scenarios should be generated to address other possible futures.

Furthermore, implementing new technologies requires extensive testing and this is especially true for dynamic environments such as Volvo IT, where the conditions are constantly changing. Therefore, the next step for Volvo IT is to develop a prototype of the selected technologies, based on the findings of this report. The prototype should be tested under different scenarios and if the tests are validated, a complete implementation into the company's products should be attempted.

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References

[1] R. Bradfield, G. Wright, G. Burt, G. Cairns, and K. Van Der Heijden, "The origins and evolution of scenario techniques in long range business planning," *Futures,* vol. 37, pp. 795-812, 2005.

[2] G. D. Peterson, G. S. Cumming, and S. R. Carpenter, "Scenario Planning: a Tool for Conservation in an Uncertain World," *Conservation Biology,* vol. 17, pp. 358-366, 2003.

[3] M. Ziefle and E.-M. Jakobs, "New Challenges in Human Computer Interaction: Strategic Directions and Interdisciplinary Trends," presented at the International Conference on Competitive Manufacturing Technologies, University of Stellenbosch, South Africa, 2010.

[4] D. Sharma, "Toward a new foundation of human-computer interaction," in *Electronics Computer Technology (ICECT), 2011 3rd International Conference on*, 2011, pp. 395-397.

[5] S. Prentice and J. Fenn, "Hype Cycle for Human-Computer Interaction," Gartner, Inc.2011.

[6] S. Prentice and A. C. Ghubril, "Hype Cycle for Human-Computer Interaction," Gartner, Inc.2012.

[7] "Manage the Future Through Scenario Planning " KPMG Australia, Australia 2011.

[8] "Foresight Scenario Planning," UK Government Office for Science 2009.

[9] P. N. Finlay. (1998, Steps towards scenario planning. *Engineering Management Journal 8(5),* 243-246. Available: http://digital-library.theiet.org/content/journals/10.1049/em_19980510

[10] G. Johannsen, "Human-Machine Interaction," in *Encyclopedia of Life Support Systems (EOLSS), Control Systems, Robotics and Automation,* vol. XXI, ed, 2010.

[11] H. Rex Hartson, "Human–computer interaction: Interdisciplinary roots and trends," *Journal of Systems and Software,* vol. 43, pp. 103-118, 1998.

[12] R. T. Azuma, "A Survey of Augmented Reality," *Presence: Teleoperators and Virtual Environments,* vol. 6, pp. 355-385, 1997.

[13] T. H. Nguyen, "Innovation Insight: Augmented Reality Innovations Add Business Value," Gartner, Inc.2011.

[14] D. Jurafsky and J. H. Martin, *Speech and language processing : an introduction to natural language processing, computational linguistics, and speech recognition*, 2nd ed. Upper Saddle River, N.J.: Pearson Prentice Hall, 2009.

[15] S. Mitra and T. Acharya, "Gesture Recognition: A Survey," *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews,* vol. 37, 2007.

[16] D. Kern and A. Schmidt, "Design Space for Driver-based Automotive User Interfaces," presented at the First International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Essen, Germany, 2009.

[17] G. I. Susman and R. D. Evered, "An Assessment of the Scientific Merits of Action Research," *Administrative Science Quarterly,* vol. 23, pp. 582-603, 1978.

[18] B. Burnes, "Kurt Lewin and the Planned Approach to Change: A Re-appraisal," *Journal of Management Studies,* vol. 41, pp. 977-1002, 2004.

[19] J. W. Creswell, *Research design : qualitative, quantitative, and mixed methods approaches*, 3rd ed. Thousand Oaks, Calif.: Sage Publications, 2009.

[20] F. Naumann, "How to Develop a Search Strategy," Cochrane Haematological Malignancies Group 2007.

[21] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology,* vol. 3, pp. 77-101, 2006.

[22] D. Nesbary, *Survey research and the World Wide Web*. Boston: Allyn and Bacon, 2000.

[23] M. Forsberg, "Why is Speech Recognition Difficult?," Department of Computing Science, Chalmers University of Technology, 2003.

[24] S. Kovach. (30 April, 2013). *It Sounds Like Google Glass Will Have Awful Battery Life*. Available: http://www.businessinsider.com/google-glass-poor-battery-life-2013-4

[25] L. Garber, "Great Leap Forward in Gesture-Control Technology," *Computer,* vol. 45, pp. 21-23, 2012.

[26] I. Fried. (2013). *Congress Wants Answers From Google on Privacy Impact of Glass*. Available: http://allthingsd.com/20130516/congress-wants-answers-from-google-on-privacy-impact-of-glass/

Appendices

A. Abbreviations

AR	Augmented Reality
CBI	Computer-Brain Interface
HCI	Human-Computer Interaction
HMI	Human-Machine Interaction
HVI	Human-Vehicle Interaction
MMI	Man-Machine Interaction
SR	Speech Recognition
VR	Virtual Reality

B. Interview Guide

The following interview questions were used during the two interviews.

- What are the current trends in HCI development?
- What is the current research showing about Augmented Reality, Speech Recognition and Gesture-Based Interaction?
- What are the driving factors behind these technologies?
- What are the stakeholders that influence the development of HCI?
- Are there any other factors that influence each of the technologies?
- What is your prognosis for the future development of these technologies in the next 5-7 years?
- What do you think about the consumer market, what are the chances for future adoption of these technologies?

C. Survey Questionarre

This section presents the questionnaire designed for conducting the survey. The main question was "What impact the driving factors have on the development of HCI? Choose level of impact for each factor". The possible answers were: very negative, negative, slightly negative, no impact, slightly positive, positive, very positive impact and "don't know".

1. Name and position.
2. Technology maturity.
3. Maturity of related technologies (e.g. battery, context based interaction, pattern matching, camera)
4. Standardization (e.g. gestures for moving from one page to another should be same across all the vendors).
5. 3rd party functionality.
6. Financial power of the company behind the technology.
7. Competition between companies.
8. Cost of product.
9. Technologies as advertising platforms.
10. User acceptance/adoption.
11. Health issues and Safety.
12. Privacy and security of the user.
13. Government interests, laws and regulations.
14. Are there any other factors that have impact on the future development of HCI technologies?