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Exploring interaction design opportunities for remote robotic services

Master of Science Thesis

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Abstract

There is an emerging field within the robotics industry, where remote robotic services serve to aid people working in industrial factory plants by providing fast and proactive maintenance information. ABB Robotics seeked to accomplish these things by launching a remote service system called MyRobot. Customers bought the MyRobot service as part of a larger service agreement. It did however not meet the expectations ABB had, as several customers chose not renew their service agreements after expiration. The main reason being that MyRobot did not meet customers needs.

This thesis proposes an alternative remote service solution using interaction design methods to meet user needs. Robot manufacturers and robot end-customers were interviewed and observed within their work environments to gain an understanding of their daily activities. In total, four different robot end-customer companies were studied, the smallest owning two robots and the biggest approximalely two hundred. The information obtained from the empirical data colletion was analyzed and together with a brainstorming session, the data formed requirements for a new system called Pythia. Pythia is designed as a customizable system that incorporates all vital information in one place. The prototype was tested on all studied end-customers and the results suggest that the system have big potential for bigger companies with robot expertise.

The current robot market is conservative and many people do not realize the need and potential of using remote services. Nevertheless, there are endless possibilities yet to be explored.

Keywords: interaction design, user experience, usability, personalization, robotics, robot maintenance, remote robotic service

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Cecilia Boström and Varuna Mudumby

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1 Introduction

There is an ever increasing interest in automation in a range of industries as industrial robots provide companies the possibility to radically increase production rate, lower labor costs and increase revenue. Unlike humans, robots can work around the clock, all year round in tough and dangerous environments, performing activities such as heavy lifting, welding, packaging and cutting through metal, to name a few examples. As automation has made it possible to run a factory plant at a significant higher pace than it could using human labour, it is essential to minimize downtime. This is particularly important for companies who have automated big parts of the production with a high production pace, as unplanned stops can lead to a severe loss in revenue.

Modern industrial robots are able to store and send a range of data that can be used to analyze problems that have occurred, as well as to predict upcoming problems: a technology referred to as remote services. Remote robotic services make it possible for companies to work proactively and help reducing the risk of unexpected breakdowns. The regular streams of data offers vast possibilities of extracting useful information for both the robotics' industry as well as the robot owners and by designing ways to support people's understanding of the data, they could use it as a tool for decision making. A key challenge however, is to explore what data matters for the end-users and, even more importantly, figure out who these end-users really are. Interaction design is a discipline that involves users early in the process by exploring their needs and desires. This thesis will apply interaction design in the domain of robotics and answer the following research question:

> ***"What are critical aspects for a successful remote robotic service, from an interaction design perspective?"***

The question will be answered by examining a design case called MyRobot, an existing remote software service designed and developed by ABB Robotics. The thesis challenges this solution and provides an alternative system which results in a high-fidelity prototype based on requirements from end-user studies.

1.1 Industrial robots: a definition

The word robot has been in the English language since 1923 and derives from the Czech word 'robota', meaning servitude or forced labour (Robot 2011). A robot can be defined as any automated machine programmed to perform specific mechanical functions in the manner of a human (Robot 2003). The robots mentioned in this thesis only concern industrial robots. Appleton and Williams (2012) define an industrial robot as:

> *"An automatic servo controlled programmable multifunctional manipulator having multiple axes, capable of handling materials, parts, tools, or specialized devices through variable programmed operations for the performance of a variety of tasks."*
> *(Appleton & Williams 2012, p. 3)*

There are five major systems that make an industrial robot work: the manipulator, the end effector, the controller, a power supply and a means for programming. The manipulator is the arm of the robot which is used for moving material, parts, tools or special devices. It resembles the human arm in the sense that it consists of a series of joints and segments. Similarly, the end effector can be compared to a hand as it is the part of the robot that is attached to the wrist of the robot's manipulator. The movements of the robot is coordinated from a system called a controller. This works because of the power supply. Robots can run on hydraulic, pneumatic or electrical energy sources. Electrical power is the most common energy source for industrial robots. Lastly, the means for programming is used to teach the robot how to move. This can be done through a device called a teach pendant, which can be connected to the controller and used for recording a series of the movements that completes the robot's task (Schilling 2013).

1.2 Research problem

The industrial robots on the market are becoming both more robust and reliable, making robot customers able to reduce the need for expensive maintenance. Naturally the robotics industry strive for increased quality of their products, but at the same time seeks new ways of making revenue by offering other services along with robot purchases. An emerging trend is to sell remote service packages and in this study we explore ABB Robotics' approach who was pioneers in the area with their software application called MyRobot.

MyRobot helps ABB to remotely monitor and collect data about the productivity and wear and tear of the robots for fast communication and proactive maintenance for the customers (Blanc 2009). It indicates the health status of the robots, current problems, as well as upcoming issues that might occur. It also detects details of robot problems and helps identify what can be fixed in order to keep the production going, eliminating downtime. In its' current status, MyRobot only covers a small part of the information that is generated by the robots, whereas ABB Robotics has the rest of the data that has been collected from the customers' robots. What the end-users need however has not been studied. Furthermore, the end-users of MyRobot are not necessarily the same people who sign up for the remote service agreement where this application is included.

A main part of our research deals with understanding the customer value of MyRobot as well as exploring how the service can be improved. The research problem might however lie deeper and, as Tidwell (2010 p.2) argues: "the real art of interface design lies in solving the right problem". We therefore acknowledge that a solution might not necessarily result in an updated and enhanced version of the existing MyRobot service, but rather as a completely different service tool that meets the unspoken desires of the end-users based on data collected from them. To gain a wider perspective, we contrast ABB Robotics' approach with other robotic companies to examine why they have or have not developed a similar service such as MyRobot.

1.3 Research aim

The aim of this thesis has been to look beyond the robot industries' visions to find out what the real needs of their end-customers are in terms of remote services. To explore these needs, one part of the study aimed at targeting leading robot manufacturing companies so that their different takes on automation and remote services could be identified. The other part of the research aimed to understand how robot end-customers conduct their daily work too see what are they might be lacking or what could be improved from an interaction design point of view. For end-customers who are using the system MyRobot, a detailed feedback were to be obtained to see what works well and what does not. The overall research aim has been to get input from both sides, robot manufacturers and robot end-customers, to come up with a remote service solution that could work for all.

1.4 Scope

The scope of this thesis has continuously changed as it has dealt with a number of corporations who have been hard to reach, as each level of hierarchy has different information and visions regarding remote services. The thesis scope has for this reason been set to a higher perspective of how remote robotic services are beneficial to customers and why the service is not put into good use; instead of narrowing it down to studying the system of MyRobot and modifying it according to customer needs.

The research conducted in this thesis is seen through the lens of interaction design. This means the business model of robot manufacturers and remote services is not included in this perspective. This wholly includes only what and how remote services can be provided to improve the production performance for the customers. The interaction design part covers a brief introduction about the following subjects: visual interfaces, big data, design process perspectives, customer relationship management and a brief section about robotics and interaction design.

This thesis only focuses on remote services for industrial robots, that are used in production lines at manufacturing companies. Typically, these robots are caged as they can be dangerous for people. There is a wide range of other types of robots that is not covered in this thesis, which have fundamentally different types of use. For example, there are social robots used in healthcare such as PARO, a therapeutic robot resembling a baby seal which has proven to increase the activity levels of elderly (Sabanovic 2013). There are also humanoids, which are robots sharing human features with two legs and two arms, such as the teaching assistant called NAO. In war and emergency work, robots in the form of drones are sometimes used. Neither of these robots are however of concern for this thesis.

Moreover, this thesis focuses on the remote services, which are remote support systems typically provided by the robot manufacturers for robot customers to handle their work more smoothly, rather than the overall robotic work or interaction with the robots.

2. Background

This chapter provides an overall picture of the thesis project and its topic. It introduces the stakeholders perspectives of the project since the thesis started out as a company initiative. The chapter also covers how the research topic evolved as we discovered more information and discussed around the initial research task, which was to explore new design possibilities of a remote support system called MyRobot. The chapter ends with an overview of MyRobot seen through the lens of a design case.

2.1 Stakeholders

2.1.1 IT Consulting Firm

A Swedish IT consulting firm specializing in diagnostics lies behind the initiative to this thesis as they saw how ABB Robotics could potentially benefit from incorporating interaction design in their remote service solution MyRobot. The firm was convinced that exploring technological features of smartphones and tablets could be used to create better customer value for people investing in MyRobot. From their perspective of MyRobot, it was understood that it is a desktop bound system with little functionality. Hence it was proposed that interaction design could be used in order to enhance the customer value of the system.

2.1.2 Robot Manufacturers

ABB Robotics and KUKA Robotics are in the top charts of the multinational robot manufacturing industry. The robotics divisions of these two corporations are therefore of particular interest as they can provide vital information regarding their views of what to provide in remote services. The robots are used in all types of production lines as automotive, food, electronic, medical and several other industries. They are built for precision and to keep the production up and running, to increase the production rate to the maximum extent to cover the ever increasing needs and demands of people. To assist in the continuous uptime of robots, remote services have a lot of potential in nailing down the problems and diagnostics before the industry runs into costly downtime. Knowing the scope and potential of what remote services can offer for both the robot end-customers and manufactures, little has been said or ventured upon. This thesis investigates the users needs, and focuses to understand the manufacturers' business models and needs.

2.1.3 Robot Customers

There are several types of industrial robot customers. We have chosen to categorize customers into three groups depending on the size of the companies and number of robots they have. The first category is companies with small plants using fifteen or less robots. For this thesis two companies, Allard International and Pågen, are studied. The second category is where customers use about 50 robots. Here, SKF is dealt with. According to ABB Robotics, this is the prime category which they target for their current remote support system. The third category is customers who have more than 100 robots in a plant. These companies usually don't like to have their information given to their manufactures and prefer to have their own inbuilt system. Volvo Trucks is an example in the third category, which is studied in this thesis.

Most of the studied settings are customers to ABB Robotics, who have access to their remote system. KUKA, who does not offer any remote service package, is however still considered in this thesis as we believe it is relevant to contrast an existing remote service with KUKA customers' needs and viewpoints. The goal regarding the robot customers has been to understand how they work in the factories, how the actual factory plants look like and how the work with the robots is carried out. It is also of interest to study in what way customers use remote services and if not, why they are considering using it.

2.2 The unfolding of research focus

The initial main task given to us by the IT consulting firm, was to explore MyRobot by finding a way to please ABB Robotics' customers with an enhanced version of the system that truly understands their needs. The first research question that we formulated in collaboration with the firm was:

> *"How could the technological opportunities of smart mobile devices enhance customer value and features of existing tools in industrial applications, that is today limited by desktop thinking?"*

After trying to work with this question, we realized that it was built on assupmtions, and it became clear that neither we nor the IT consulting firm was properly situated in how the current version of MyRobot actually works. After continuing studies of the system it was found that ABB Robotics has already delved into the Internet of Things[1] (Titans of IoT, 2015) and that the latest version of MyRobot uses HTML5, making it web based and thus available in all devices. It was also revealed that ABB Robotics are considering merging MyRobot with another service called MyABB Customer Portal, which is a portal consisting of information such as service history, warranty status, product information, along with an order and pricing system (ABB 2015b). All these things made us unsure of the real intent of the thesis from the IT consulting firm's view, given that it was not at first clear what they could gain from the project. At first we assumed that they wanted to test whether interaction design could be valuable at the firm, using us as pioneers to pave way for future design work. As time passed however, it appeared that the firm was keen to make business deals with ABB Robotics, possibly using this thesis as a foundation for subsequent consultancy work. Overall, we felt that the firm's clear business perspective regarding ABB Robotics limited our research, and because of this we decided to radically change the research question. We also took the decision to take the research to a higher abstraction level, so that the results could be generalized across different robot manufacturers and robot end-customers. This we believe, will give the thesis a higher academic value.

1 **Internet of Things** "[...] a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network" (Uckelmann et al. 2011).

2.3 Design case: ABB MyRobot Remote Service System

ABB Robotics is a leading company in industrial robotics and they are currently the only company that provides remote services for the customers. In the light of studying interaction design possibilities in remote services, studying an existing solution by a lead company was useful in order to get a good start to understand their perspective on remote services and their take on what the customers need.

ABB Robotics has considered remote services in their business by implementing a software called MyRobot. MyRobot is a web-based remote service for ABB's robot customers that provides information regarding support, response, maintenance and warranty (Blanc 2009) pertaining to robots for an industrial assembly line setup. It is a 24-hour remote access service system to facilitate detection of malfunction and failures of robots to eliminate costly downtimes. MyRobot enables engineers and floor supervisors to 'talk' to robots remotely to enable smart, fast, and automatic analysis instantly (ibid.). Customers access MyRobot via a web browser by logging into a customer portal at ABB.com or by using the MyRobot URL as it is a stand alone page.

MyRobot is part of a package called ABB Remote Service which companies can sign up for to get added value for their robot purchases. It is primarily intended for factories with a small number of robots, which according to ABB Robotics is up to 50 robots. Bigger corporations, such as car manufacturers, can have up to 1000 robots in a plant and usually have in house expertise to develop robot overview systems of their own. Nevertheless, there are big corporations that purchase the remote service package from ABB with MyRobot included.

MyRobot is developed in HTML5 and is available in two views: mobile and desktop. The user can, independent of the device being used, change between these views by clicking a link in the footer. According to ABB (2015), the HTML5 has made it possible to access the service on virtually any platform.

The most prominent feature of MyRobot is the overview page, which shows a slider with four juxtaposed circle diagrams with robot information: alarms, last backup, diagnostics and last communication. Each circle diagram have sectors with numbers representing the total amount of robots in the plant system (see figure 2). The different diagram sectors are color coded according to the robot status that has been retrieved from the service box.

In the interface, color codings are used to convey information as follows:

- Red = Error
- Yellow = Warning
- Blue = Information
- Green = OK
- Grey = Value not available

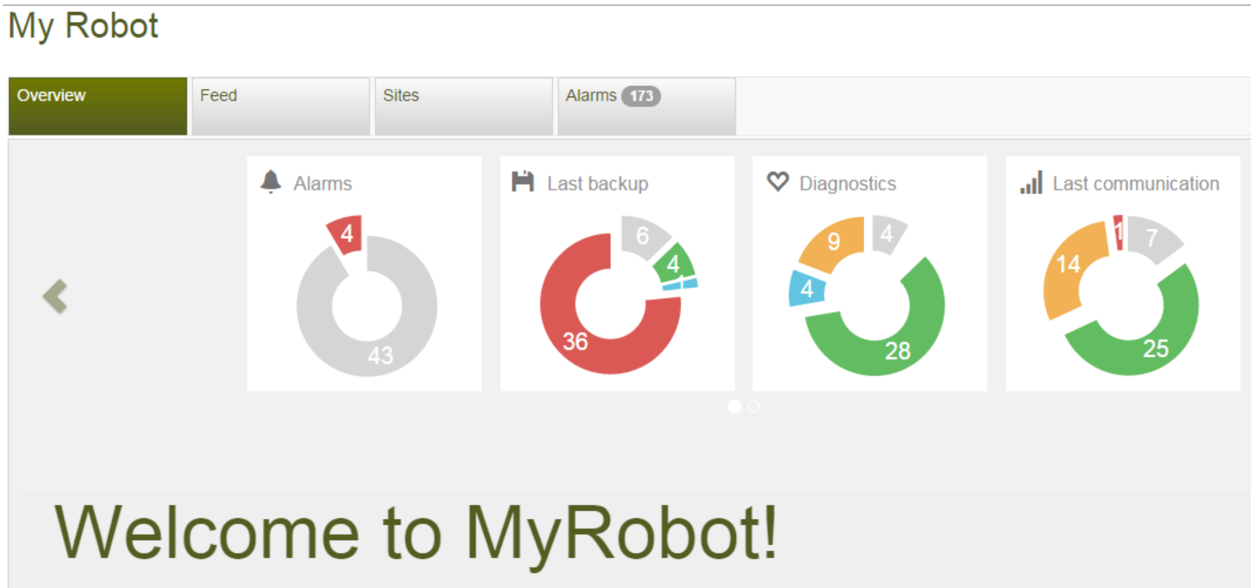

Figure 1. The numbers in each diagram sector all add up to 47 which is the total amount of robots in this system example, hence each diagram represents different aspects of the same robots.

The overview panel with the circle diagrams slide to the left after a couple of seconds, if the user does not click on anything, and get replaced with another view showing a bar chart of robot alarms (see figure 3). This only happens in desktop view. Both the bar chart and the sectors in the circle diagrams are clickable. When the user clicks on any of the colored sectors or the bar in the bar chart, further information is revealed. The extended information is presented in a list of data below the slider in desktop view and on top of the slider in mobile view (with the slider being translucent). The list has three columns that includes the name of each robot, the location of it and a number of indicators (see figure 4).

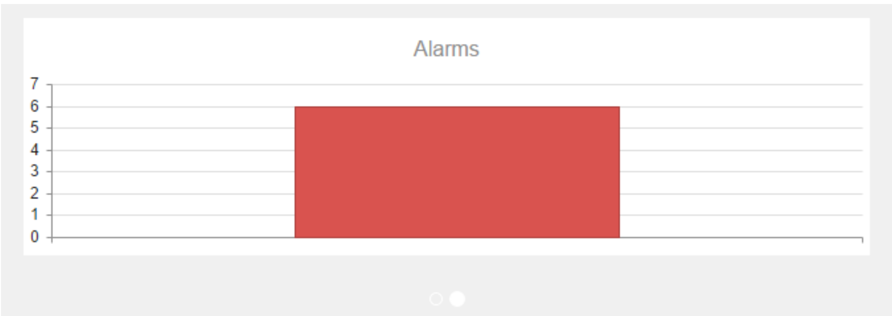

Figure 2. The above picture shows a bar chart of six robot alarms. The subtle dots in the bottom of the picture shows two navigational buttons to switch from the current view into the circle diagrams seen in figure 1. In the full view of the system, there are also two arrows that the user can use to switch views.

In the list view there is a column for indicators. These are represented by flat color coded buttons with icons and sometimes a number in front of the icon, representing the amount of indicators. When the buttons are clicked, a pop-up window appears next to it, revealing more information along with a link icon the user can click to open a new page with further information. This page can also be reached by clicking the robot name in the same list. The new window opens up in a new tab or a new window depending on the device being used.

Figure 3. This is an example of the extended information list view which appears when a user has clicked on a diagram sector.

The list of robots in the overview of the MyRobot page as shown in Figure 3 are clickable to get more detailed information. When for instance RS-12304 is clicked it leads to a whole new webpage in a different window with nine new tabs with a lot of information. As can be seen from the images below, figure 4 shows the overview (news feed) of the particular robot with time stamps, and figure 5 shows a long list of robot diagnostics with colored indicators. It is interesting to observe that the colored indicators in figure 3 are clickable to get further information but the icons in figure 5 are not. The whole system was explored and we ended up drawing a sitemap of the website (Figure 6) to get a clear picture of the basics and the navigation flow of the system. As can be seen in Figure 6, the information architecture points to difficulties in getting a clear overview of the system.

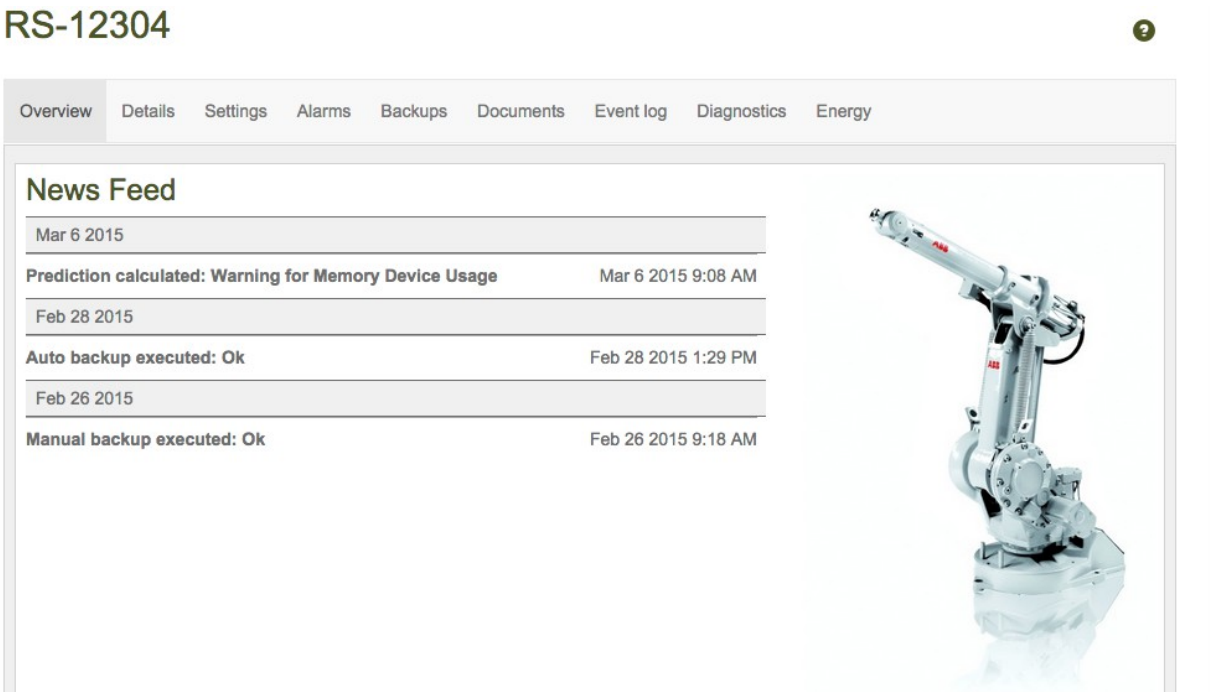

Figure 4. An example of a new stand alone page which appears when a particular robot has been clicked.

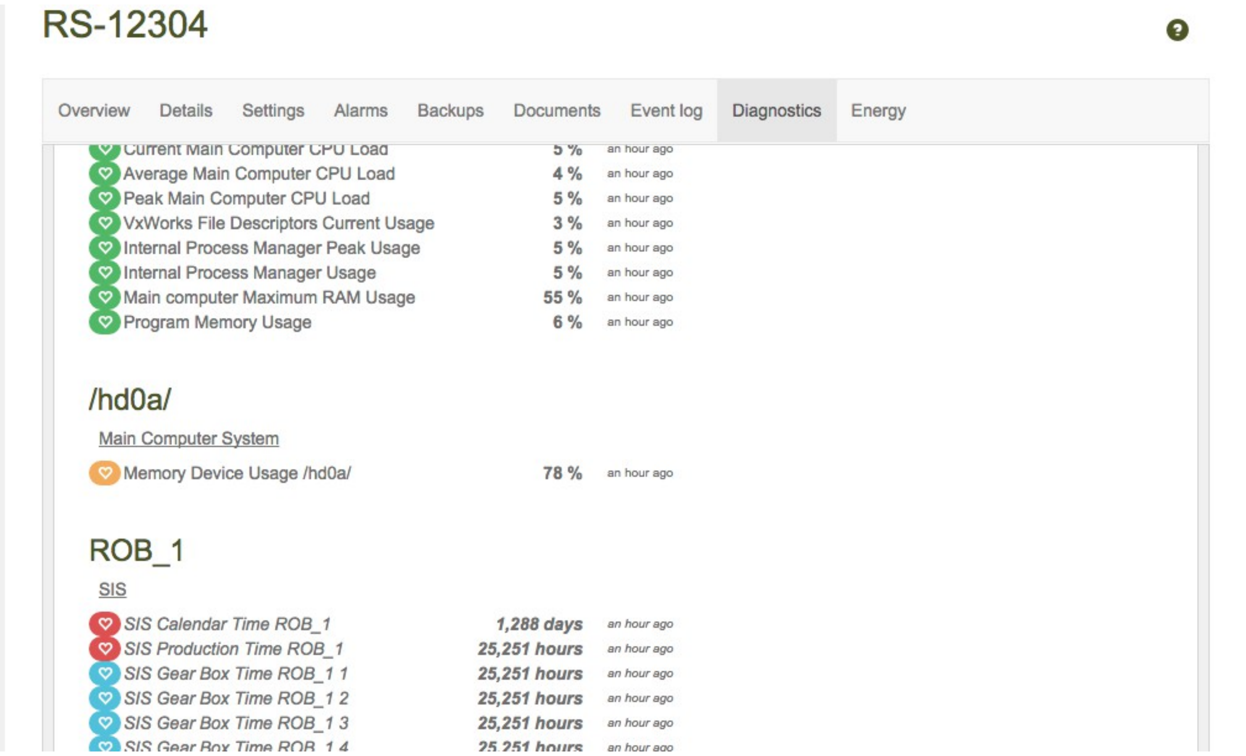

Figure 5. A list of diagnostics for the robot RS-12304.

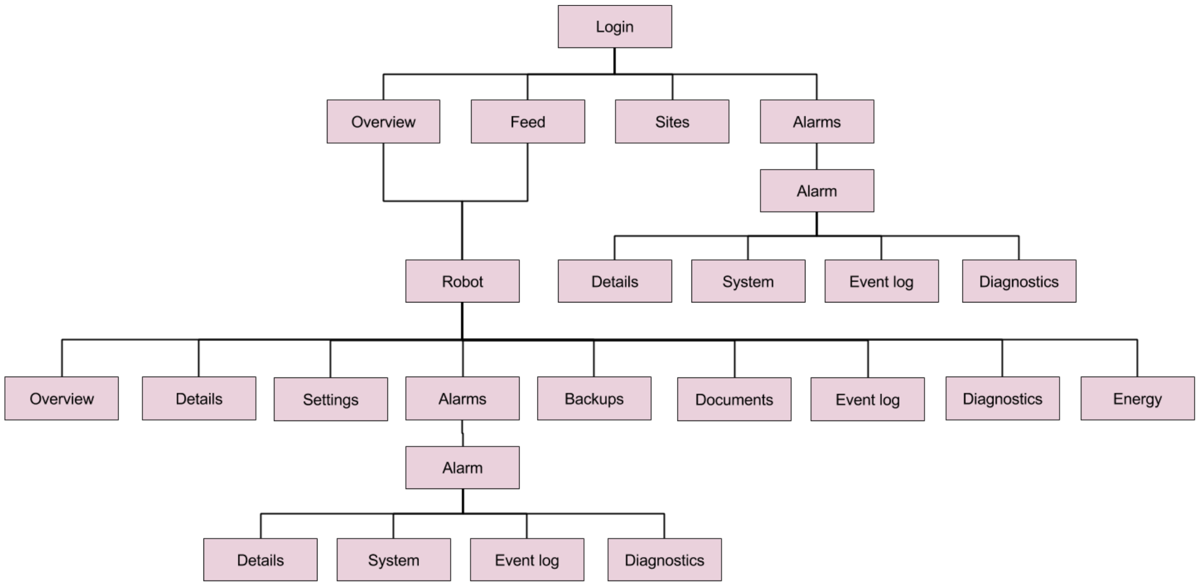

Figure 6. Sitemap of the existing MyRobot system.

The benefits of MyRobot that reach the customers from ABB's website states as follows:

> *"[...] ABB Robotics offers customers a powerful and truly versatile tool to help keep their operations running. Boasting a completely new dashboard, which provides instant general robot status, plus quick and thorough information with powerful filtering tools."* (ABB 2015a).

With this brief background of what goes into the interface along with ABB's own perspective of the service, we believe that MyRobot is a relevant design case to be used as a starting point to explore alternative remote service solutions in the robotic industry. MyRobot is also beneficial to have a point of reference to see what has already been made and to facilitate the process of finding out what is good and what is currently lacking in such a software.

2.4 The MyRobot Service set up

To make the remote services accessible to customers, the ABB robots have a communication unit called a 'service box' which is similar to the black boxes installed in airplanes. The service box transmits information about critical diagnostics that enables immediate support in the event of a failure. It also monitors and analyzes the robot's condition, thereby proactively detecting the need for maintenance. Using the data collected by the system also helps in predicting the health of the robots and show in advance if a particular part has to be replaced soon. This service box, using a built in modem and Global System for Mobile Communications (GSM) network, can transmit the data to a central server for analysis and display it on a dedicated website, MyRobot. Since GSM is used, they have good primary and backup electric power sources and hence it can collect data even when the power fails in the industries. Alerts and diagnostic issues are sent to the nearest ABB's remote robot service engineers who can analyze the data and provide rapid customer service remotely if possible, or can arrange the delivery of spare parts before an engineer can arrive at the site to solve issues. Whether the service engineer has to visit the site or not, with the help of this service box; the service is a lot faster and more efficient, thereby helping the ABB customers to keep the robots up and running (Blanc 2009).

The maintenance of robots is critical in assembly lines, as one faulty robot can affect the entire setup. Therefore constant lookout on the maintenance, service and support is needed to keep the production up and running. In this perspective the Internet of Things (IoT), as ABB Robotics has delved into, is a plus to keep devices and people connected all the time. The black box (service box) also plays an important role in constantly storing information from the robots. It was mentioned by ABB Robotics that once robots are connected through the internet to the remote services, it is possible to mine data and turn that into valuable information which can be used as a basis of new services. It was however not revealed to us how far the current data analysis is happening, but we believe it is an interesting field to study to find out more and try to formulate the real needs of customers. The MyRobot system right now is used to foresee what upcoming maintenance is needed so that problems can be solved before they occur. The idea behind MyRobot is also to help customers correct problems themselves without ABB Robotics having to send service personnel to the site which could save a lot of time and money for both parties. The system developers want to give what the customers want and in turn make the service meaningful and valuable (ABB Robotics 2014). On the contrary, information was gathered that out of about 140,000 robots only about 4000 robots are connected to this service and most customers do not renew their service agreements where MyRobot is included. This, we believe, is an interesting background and a starting point to see why the system is not delivering as much as it is claiming to do.

2.5 Initial reflections on the system MyRobot

MyRobot as it appears, is currently of main interest to ABB Robotics themselves, as they benefit from the information that is generated by connecting their customers' robots to the remote service. In the thesis however, the main stakeholder that is taken in consideration are the robot customers. This is because these are the people the remote service is developed for. Hence, our main focus is to be in constant touch with a different range of customers throughout the design process and to find out why or why not they use ABB's MyRobot system and get to know their experiences and thoughts on it.

Since MyRobot has been developed without involving users at any stage in the process, we suspect that the system might not be what the users actually need. Therefore, our focus was shifted from enhancing the existing MyRobot into staying open for designing a new remote service system from scratch, where real user data serves as a backbone to what the system should consist of. For a successful human-centric and user-centric approach, customers and other stakeholders should be involved throughout the process.

3. Theory

This chapter provides an introduction to interaction design as a field, practice and research, where key aspects such as user experience and visual interface design are clarified. This is followed by information visualization, a section which highlights some fundamental principles which relate to graphical interface design in terms of how people perceive figures visually. The theory chapter also includes previous research regarding design processes which form a basis to how design work can be carried out. Lastly, emerging research which combines interaction design and robotics is covered to show how design can be applied in the domain of industrial robots.

3.1 Interaction design

The term interaction design was coined in the mid 1980's by the industrial designers Bill Moggridge and Bill Verplank, as they were working on the first laptop computer, the GRiD Compass. But it was not until a decade later that the term started to get used by the mainstream (Cooper, 2007). Today, the term interaction design works as an umbrella term covering aspects such as interface-, software-, product-, and experience design (Sharp et al. 2011) and given the range of the term interaction design, there are several definitions and viewpoints regarding what it actually is. Cooper (2007) defines interaction design as "the practice of designing interactive digital products, environments, systems, and services" (Cooper 2007, p.xxvii). Similarly Sharp et al. (2011) defines interaction design as "designing interactive products to support the way people communicate and interact in their everyday and working lives" (Sharp et al. 2011, p. 9).

Patton (2008) compares interaction design with an architect, as an interaction designer typically designs the structure of an application and decides how the information should be placed at different site locations. The interface design can be correlated to interior design, how to enhance the look and feel of the interactive experience (Patton, 2008). Figure 7 provides an overview of interaction design in the larger scope of user experience design.

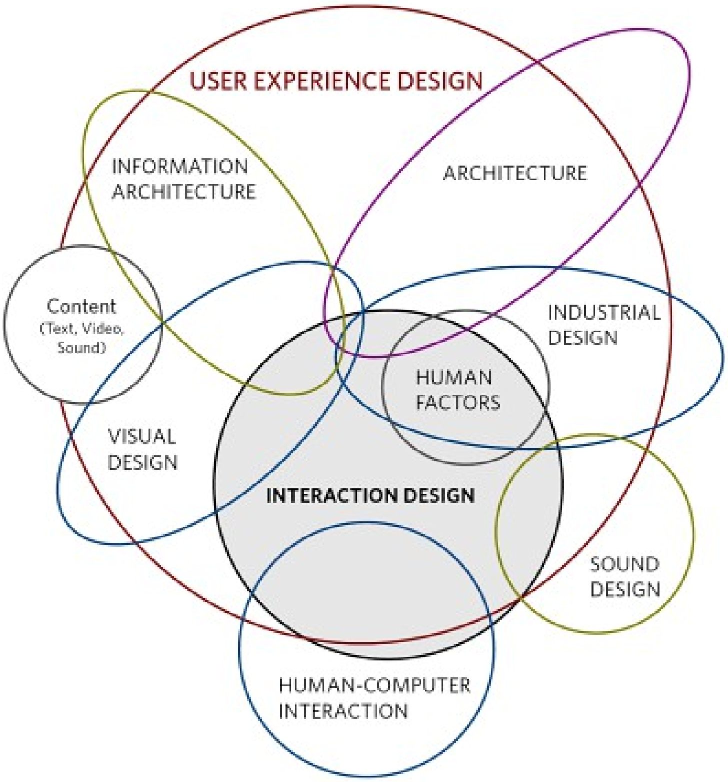

Figure 7. An illustration by Saffer (2010), showing the relation between interaction design and similar fields.

One of the key goals of interaction design is to provide users with positive experiences, by creating products and services that users think are pleasurable (Sharp et al. 2011). Saffer (2009) explains that as soon as the aspect of behavior is involved, such as how a product works, interaction design should be used to ensure a good experience.

3.1.1 Interaction through visual interface design

Remote robotic service solutions often involve visual interfaces, in order for the user to gain information in a easy way. Visual interface design is sometimes misunderstood as pure graphic design, in the sense that it merely deals with creating nice-looking interface skins. It is however a crucial discipline with the power of influencing a product to be more effective and appealing (Cooper 2007). A good design must balance beauty and usability, because when a product not just works well, but also looks and feels good, people overlook design faults and the interactions with it goes smoother. Hence if an interface has problems, these will be better tolerated if the interface looks appealing, as attractive things work better (Norman 2002).
In general, the interaction design of an interface can be thought of as a personality which, just like people having a conversation, adjusts to the situation. When talking to people in real-life, one constantly adapts to the other person based on one's understanding of her. For that reason it is important to adapt in order to avoid misunderstandings and make sure that the other person is interested in the conversation (Tidwell 2010). If one is not being perceptive in a conversation, other

people can easily feel annoyed or frustrated. Similarly, there are situations when computer interfaces can create user frustration just like in a human conversation. This particularly happens when an interface is supposed to be easy to use, but ends up being complex, such as remote controls and printers to name a few examples (Sharp et al. 2011). Moreover, depending on how people feel when interacting with an interface, the experience they get can greatly differ. Anxiety for instance, makes the mind less distracted and more focused, although too much of anxiety decreases performance. Positive affect on the other hand, makes people less focused but broadens the thought process (Norman 2002). Thus, the interaction with an interface is a two-way communication and the experience depends not only on the interface itself, but also on how the person interacting with it feels.

To be able to design a successful visual interface that provides the intended user experience, one has to first understand people (Tidwell 2010). This requires considering who is going to use the product being designed, how it is going to be used and where it is going to be used. Moreover, it is essential to understand the underlying activity that people do when interacting with a product to be able to support their needs. For this reason, interaction design can be applied across domains and is fundamental to all disciplines concerning computer-based systems that are intended for people (Sharp et al. 2011).

3.2 Visual interfaces

A large part of designing interfaces deals with determining how to lay out and present information to the user. Visualization is a key part of any service dealing with raw data, and acknowledging how to create information visualizations in a good way can help the users comprehend large amounts of data (Cooper 2007; Ware 2013). Given that remote robotic service systems are aimed as a tool to get a comprehensive overview for decision making, information visualization could be applied to aid the users in their process of understanding what is being displayed on the screen and to be able to make meaningful decisions based upon what they see.

3.2.1 Visual perception

How we perceive things visually is fundamental to information visualization. Knowing the fundamentals of perception is useful since it helps making conscious decisions when creating graphical user interfaces. Given the visually cluttered environment of the 21st century, our attention becomes more selective and we are forced to continuously make decisions on what interests us and keeps our attention (O’Connor 2015). When the human eye searches for something visually, it moves from fixation to fixation in a period of 200 and 400 milliseconds. These eye movements are called saccades and in order to minimize visual searches, it’s important to make visualizations as compact as possible. During a saccadic eye movement, we are less receptive to visual input (Ware 2013) and hence, it is relevant to know what catches the attention of the saccades. Previous studies have suggested that our eyes tend to look for focal points high in contrast, because they are more separable from their background (O’Connor 2015).

When designing visual interfaces, it is valuable to have the theory of visual perception in mind since it facilitates design decisions that need to be made in order to emphasize what is important. As an example, information regarding robot alarms could be very serious and hence it is important to have that information high in contrast in the interface to help viewers track it more easily.

3.2.2 Gestalt

In the early twentieth century, gestalt psychologists tried to determine how humans construct parts in our perceptive field to make up a meaningful whole (Passer & Smith 2009). They argued that the perceptive experiences we get depends on the patterns formed by stimuli and how our experiences are organized. This means that what we see relates to the background against which a figure appears. Hence the whole is different from the sum of its' parts, since the whole is dependant on the relations of the parts that builds it (Nolan-Hoeksema et al. 2009). This phenomena is illustrated in figure 8 where we tend to see a white square in front of four black circles, instead of the four black figures as separate units.

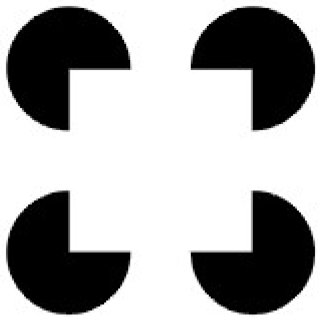

Figure 8. Kanizsa's figure.

The gestalt theory of perception is relevant in modern day design and especially in visual communication design as it clearly explains basic perceptual phenomena (O'Connor 2013; Ware 2013). The gestalt theory groups human perception into a set of laws. Some key laws of which are relevant in visual interface design are briefly explained below.

Proximity: Items placed close to each other appears to belong in a group. Because of this, spacing is relevant to consider to avoid unintentional effects. Graham (2008) argues that ignoring the law of proximity can result in an entire change of meaning as seen in figure 9.

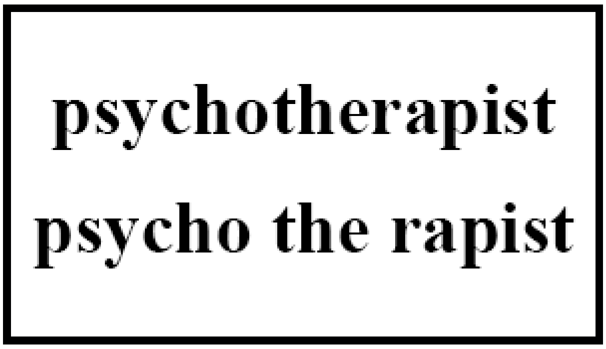

Figure 9. This figure illustrates how adding spaces in the word psychotherapist can drastically change its' meaning.

Similarity: Similar items appear to belong together and can therefore be used to draw visual attention (Chang et al. 2002). For instance, using a specific graphical style on clickable components in an interface can help people to distinguish them more easily.

Closure: We perceive figures as whole even though parts are missing, because our minds tend to fill in the blanks with familiar patterns, lines, tones etc. (Graham 2008). The law of closure can be applied onto decorative elements in an interface as incompletion can catch the eye and spark interest (Matz 2011).

Continuity: Our eyes tend to follow a line of similar items even though they cross over negative and positive shapes (Graham 2008).

3.2.3 Affordance

Affordance is a concept that became popular in the Human-Computer Interaction (HCI) community after Donald Norman discussed it in his book *The Psychology of Everyday Things* (McGrenere & Ho 2000). Cooper (2007) claims that affordances are invaluable to interface design. There is however a debate whether or not affordances make sense in visual interfaces, as flat design has become more prevalent.

The term affordance was coined by the perceptual psychologist James Gibson, who believed that people do not just see points of light in their surroundings, but that we perceive possibilities for action. In our environment we identify handles to pull, steps to climb, spaces through which we can navigate and so forth, and we do now need to form mental constructs in order to take action (Ware 2013). This theory of ecological psychology is known as Gibson's affordance theory. Norman built on this theory and introduced a concept called 'perceived affordances' into the field of HCI, which differs from 'real' affordances of physical objects (Hornecker 2012). Cooper (2007) describe affordance as a purely cognitive concept in the sense that we make mental connections to what we see and how we think we can interact with it and because of this. Windows and Mac for example, used to design acknowledging the concept of perceivable affordances in their systems, using simulated 3D-designs that relied on shadings, highlighting and shadows (ibid.). Whether or not simulated affordances actually help users comprehend how an interface could be interacted with is however a concept under debate, as some authors reject the idea that perceived affordances afford any action (Hornecker 2012). Norman argued that it is meaningless to try and design for real affordances in user interfaces, unless when designing physical things like devices for game controls (Sharp et al. 2011).

3.3. Big Data

According to the Oxford English Dictionary, the term big data is defined as:

> *"computing data of a very large size, typically to the extent that its manipulation and management present significant logistical challenges"* (Oxford English Dictionary 2008).

Modern industrial robots store a lot of data that is used today by robot manufacturers for big data analyzes. These analyzes can aid in providing hints on what can be changed to increase productivity and performance, as well as to identify problem patterns. A range of companies in the industry continually collect large amounts of data to measure every small detail in their factory plants to keep the machines up and running (Hagerty 2013). This facilitates nailing down problems before they occur, which is essential due to that some companies cannot afford production downtime (Blanc 2009).

Industries are looking deep into big data because of the ever increasing pressure and expectations from customers to eliminate automation defects. There is also pressure from stakeholders and regulators to squeeze out more cost and to trace safety problems respectively (Hagerty 2013). Big data is always a challenge to analyze as it is ever increasing, but when realized to its full potential it can have a lot of advantages in industries. In robot industries, the data currently collected is used for predictions and diagnostics of the robots in their primitive stages.

3.5 Design process perspectives

While designing a service, designers can research prospective users and their requirements using several methods. During the process it is difficult to merely use one set of rules and since design does not have any fixed formulae, it is wise to mix methods during each stage of the design process. In this case, three sets of design methods are used namely; human-centered design (HCD), activity-centered design (ACD) and user-centered design (UCD). HCD helps the design solution to connect better with the people and help to realize the needs and requirements of humans. This assists the designers to *hear* the needs of the people, *create* innovative solutions to meet the needs and *deliver* the solutions in a way it is feasible and usable to the target audience (IDEO 2011). This will be considered as the first stage of the design, to understand humans and what they need.

ACD focuses on the activities performed by humans. An activity in hierarchical form is at the highest level followed by tasks comprised of actions and actions in turn comprises of many operations that are performed by humans. Hence a deep understanding of humans is definitely a part of ACD but it also involves deep understanding of technology, tools and reasons why humans perform certain activities in a certain way (Norman 2005). In the initial stage the target users and their activities are unknown but once the potential of the service is known the activities come to place. So ACD will be considered as the next stage to HCD or overlapping partly with HCD where there is a shift from "understanding users as people" to "understanding them as participants in activities" (Constantine 2006).

UCD according to ISO definition is an approach to design that identifies four different basic principles:

i. an appropriate allocation of function between user and system,
ii. active involvement of users,
iii. iterations of design solutions and
iv. multidisciplinary design teams. (ISO 1998)

Participatory design (PD) is considered as a part of both HCD and UCD where the users' involvement is present throughout the design process and not just at the beginning and in the end. Users can actively participate in decision making along with designers (Gulliksen et al. 1999). Hence, both HCD and UCD can be considered as overlapping procedures where the stress on the first is more towards humans and the second on how specific users can use certain services. Hence UCD will be considered in a much later stage of designing when the target users are known and will be put into use after first understanding the humans and the activities performed by humans.

3.6 Customer relationship management

For a successful product in the market, industries should always have a good relationship with their customers and understand their requirements (Puschmann & Alt 2001). Remote robotic services have the potential to do this by providing fast and proactive maintenance information. Getting information directly from a system can be beneficial for staff working with maintenance as they do not need to wait for external service technicians from the robot manufacturers to identify problems. Therefore, robot manufacturers should understand how their customers use robots in their production plants and how they tackle different problems to be more effective. The perspective that robot end-customers may or may not know much about robotics should be emphasised to understand customer relationships better. For a successful business in any industry would be to have customer centric design, but most corporates prefer product centric design and good marketing. The customer contact is usually limited to just for support services and while purchasing the service. Customer relationship management (CRM) should increase revenues and profitability by coordinating, consolidating and integrating all points of contact enterprises have with customers. Doing this initially and during the design process saves a lot of time and integrates with increase in sales, marketing and service instead of spending a lot of money and investigation on marketing why a particular service is not used so much, as is the case with MyRobot. The goal of CRM is to use personal relationships of at least the most important customers to understand and elicitate their requirements better (Puschmann & Alt 2001).

3.7 Robotics and interaction design

Industrial robots are in most cases dangerous and are for this reason caged off from people in factory plants. Recent studies have however explored how robots can become less dangerous in order to open up for interaction with them. An emerging field in research has looked into how robots can work as co-workers alongside people. Sauppé and Mutli (2015) claim that the introduction of collaborative robots in manufacturing settings are going to revolutionize the way people carry out their work.

Interaction with robots is part of a field called human-automation interaction (HAI). For instance, this is the driving using a cruise control is HAI. Sheridan & Parasuraman (2005) divides HAI in three definitions: where people (a) specify the automation, (b) control the automation or (c) get information from the automation. An example for the first definition is when someone presses a button to initiate an automation, as when a person starts the microwave after setting the desired effect and time. The second definition deals with situations where a person might want to take control over automated task after a certain criteria has been met, such as when a particular temperature has been reached or a set time has passed. Examples of the third definition is when an automated system provides feedback in the form of alarms or simple decision aids. It can however also be the output of the automation as the movement of an automated car of aeroplane (ibid.)

3.7.1 Cloud robotics

Networked robotics communicate between robots about distribution of workload is currently through physical communications but this has several resource constraints such as the physical size, shape, computation units, memory, etc. These resource constraints, makes it technically infeasible to upgrade the existing configurations (Hu et al. 2012). To surpass the limitations of network robotics, ubiquitous cloud infrastructure comes in hand with its elastic resources (ibid.) National Institute of Standards and Technology (NIST) defines cloud computing as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” (Mell & Grance 2011). This allows a new paradigm in robotics that leads to exciting future development in robotics and remote services (Hu et al. 2012) with cloud computing’s promising characteristics of on-demand self service, broad network access, resource pooling, rapid elasticity and measured service (Mell & Grance 2011).

The main advantage of using cloud computing is to gain the ability to harness large amounts of computing resources into one package. It is an autonomous low maintenance infrastructure that is capable of providing resources based on supply and demand (Turnbell & Samanta 2013). The promising possibilities of this technology is definitely a boon for the future of robotics manufacturers and customers.

4. Methodology

4.1 The design process

The most common observations regarding design processes is that they essentially involve three stages: analysis, synthesis and evaluation (Jones 1992). These stages according to Jones model are named as Divergence, Convergence and Transformation.In simple words the stages can be described as 'breaking the problem into pieces', 'putting the pieces together in a new way' and 'testing to discover the consequences of putting the new arrangement into practice' (Jones 1992). This structure is not a fixed process to follow step by step, but is more of a suggestion of how to design effectively in a loosely based sequence. In this thesis the three stage process is used iteratively as a guidance to help understand design problems and to design better solutions.

4.1.1 Divergence

Divergence is the initial design phase where the focus is on extending the boundary of a design situation to create a large enough search space in which a solution can be sought (Jones 1992). This phase can be compared to Lewin's unfreezing step, where the stability of human behaviour is based on a quasi-stationary equilibrium[2] supported by a complex field of driving and restraining forces. So the equilibrium needs to be destabilised by unlearning and old behavior and to adopt a new one (Burnes 2004). The boundary of the situation is broadened by several studies to identify the target users, understand them and elicitate their requirements. This study of data collection can be done through several iterations of observations, interviews, literature research and questionnaires as explained in detail in section 4.2.

The objective of the divergent phase is to de-structure or to destroy the original brief while identifying the features of the design situation (Jones 1992). It is important to break open the shell of complacency and remove preconceived solutions and prejudice before diving into design phase. The process of unfreezing or divergence is a psychological dynamic process and identifies three processes necessary: disconfirmation of the validity of status quo, induction of guilt or survival anxiety and creating psychological safety (Burnes 2004). The problem boundaries here are unstable and undefined and nothing is discarded if it seems relevant to the situation. It is a starting point to investigate all the different stakeholders. The aim of this process is to end up in a more confused situation by deliberately increasing the uncertainty of the situation thereby reprogramming the brain to be more open minded and be more focused to the relevant issues and the target group (Jones 1992).

This phase starts with HCD as in the beginning stage it is difficult to pinpoint the actual users. Especially when dealing with multinational corporations and several stakeholders it takes a long time to find the right people and get access to them.

2 **Quasi-stationary equilibrium** is a state of equilibrium whereby the conditions of approximate equilibrium is established, in this case a state of almost stationary is established (Quasi-equilibrium 2003).

4.1.2 Transformation

Transformation is the stage of pattern-making, fun, high-level creativity, inspiration and everything that makes designing a delight. It is also a critical stage when big blunders can be made as narrow mindedness or wishful thinking prevails. This stage essentially consists of all kinds of brainstorming, interviewing, elimination of mental blocks, visual inconsistency search, data reduction, classification and the likes. Once a clearer picture has been obtained, the transformation stage essentially consists of ideation and prototyping from the results of the divergent search (Jones 1992).

The problems in the transformation stage are split into several subproblems (Jones 1992). The problems can all be grouped and iterated to have a deeper understanding. In the prototyping phase, the ideas can shape up better. It is an iterative approach of research, action and more research that enables people to move from less acceptable to a more acceptable set of behaviours (Burnes 2004). In the prototyping phase the ideas get more structured.

With the help of all the requirements from the divergent phase, focus can be shifted gradually from a human-centered to an activity-centered approach. Initially it is good to have workshops to make more relevant decisions and also to involve the people as much as possible to make it a more human centric design. Paper prototyping (IDEO 2003) in these sessions is useful for designers to quickly organise and visualize the interaction design concepts clearly to help the participants understand the situation better and iterate with the prototypes.

Through the workshops, onsite observations and interviews, the activities of the target group can easily be identified. A clear understanding and taxonomy of the activities done by the people will help in understanding the problem and hence make precise patterns. This ACD approach will help in getting a clear picture of the target group since a wholly HCD approach without considering activities could be disastrous (Norman 2005). Experience prototyping and quick-and-dirty prototyping (IDEO 2003) in this perspective will help in understanding the activities of the target users better and hence solve the design situation better by iterating them until satisfied with respect to the activities to be performed and how it should be executed.

4.1.3 Convergence

The last stage, convergence, is typically where the all designing takes place as all solutions from the previous stages are weighed down. Convergence occurs in the design process after designing the problem, identifying the variables and agreeing upon the objectives of the solutions (Jones 1992). This can also be considered as a refreezing phase to stabilize the group at new quasi-stationary equilibrium to ensure that the new service is safe from regression (Burnes 2004). This stage focuses on narrowing and scaling down the solutions developed in the transformation phase to make it relevant to the target users. This phase essentially shifts its focus from ACD to UCD to match with the user requirements and check the feasibility of the solutions.

The methods commonly used in this stage to evaluate and weigh solutions are KJ analysis, semantic differential, ranking and checklisting (Jones 1992). The main focus of evaluation will essentially be on user testing and feedback. The output of the previous stage will lead to several design solutions with semi working or just the quick-and-dirty prototypes. In this stage all these different solutions are converged to reduce the options to a final solution. This process is effective when the evaluation of the data and problems can be verified and narrowed down as quickly and cheaply as possible. Of the three stages this is the most mathematically logical and rational stage of evaluating the solutions (Jones 1992).

4.2 Data collection

4.2.1 Interviews

Using interviews is a strong data collection technique for exploring the complexity and depth of a topic (Cornford & Smithson 2006). Given the vast possibilities of remote services, interviews were chosen to be the prime data collection method. In this study, two categories of people have been subject for interviews: employees of robotics companies and end-customers of industrial robots and services. The interview questions for both parties were semi-structured, consisting of a mix of open and closed questions, where the majority of questions were open-ended. Semi-structured interview questions are advantageous when possible answers are not known in advance, because they enable the interviewee to mention issues that have not been considered beforehand (Sharp et al. 2011). The exploratory nature of the questions helped us to be flexible enough to shift research focus and led us to change perspective as more and more insights were revealed.

4.2.2 Bias

During interviews and observation, it is important to try and reduce bias, as people not always tell the truth for reasons such as not wanting to be shown in bad light, forgetting what they actually do etc. Fully eliminating bias is not possible, it could however be reduced by addressing aspects such as body language, prompts and probes (Sharp et al. 2011).

4.2.3 Observation

Sometimes, what people say they do and what they actually do can be completely different things. So instead of simply asking people what they do, observation is a good way to identify what is going on in the context of the design problem (Moggridge & Atkinson 2007). By observing how the end-customers of robotic services do their daily work, in their own surroundings (LUMA Institute 2012), an understanding of what they really need could be better understood. Additionally, just looking around in an organization will create a feel for how the work environment is, whether it’s chaotic, calm, well-organized and so on (Cornford & Smithson 2006).

An unobtrusive observation is useful because it lets one see how people behave without interfering them and disturb their daily activities. A method called ‘fly on the wall’ is effective for this purpose. It is an observation technique where the observer puts an effort in blending into the background to get an in depth details of the users and possible requirements (LUMA Institute 2012). When a clear picture has started to take form, a second iteration of observations can be done, which are more obtrusive. This can be useful to get a deeper understanding of how users think, by letting them talk aloud. Shadowing is a technique used for this, where one tags along with the users to get a feeling for their daily routines (Moggridge & Atkinson 2007).

5 Planning

5.1 Getting robot customer contacts

In order to collect useful data it was planned to first and foremost target actual users of MyRobot. It was clear from start that end-users of the service are customers of ABB Robotics, although it was not known what kind of positions, responsibilities and technical expertise these people have. Furthermore, it was not clear before the study if the users work closely with the robots, if they work off-site, or if they use MyRobot at all despite having paid for the service. To get a general understanding of who the users are for MyRobot, we planned to find people who had signed up for the service. Although we vaguely knew who to target, finding the right people to interview is sometimes difficult. Especially as some people, such as business managers, can be very busy and turn down an interview if they don't know what they can gain from it (Cornford & Smithson 2006). Several of the companies who make up the customer base for ABB Robotics are big corporations with employees in several countries. Reaching out to the right people, i.e. the people who could provide useful data for constructing requirements, is a challenging process which can be very time-consuming. Nevertheless, it is critical to find the real users of the system because a good interface design always starts with an understanding of people (Tidwell 2010).

To facilitate the process of finding the actual users, we planned to contact ABB Robotics who could point us in the right direction. In parallel, robot customers who don't use the MyRobot solution were also considered for the interviews, as they could offer new perspectives of features that they as future customers might want due to not being limited by what is possible in MyRobot. As a consequence of not conducting user studies, it was not clear from the beginning of the study what roles the current end-users of MyRobot have. Hence we stressed the importance of being open-minded as we might find potential users that ABB Robotics have not thought of.

5.1.1 Input from robotics company employees

To get a holistic view of remote robotic services we also planned to involve people from the robotice companies. Given the diversity of people working in the industry, we planned to chose to target staff with different roles ranging from software developers to project- and product managers. Furthermore, we considered it important to interview several people as the opinions of remote services might differ depending on the relationship the interviewee has with the solutions like that; i.e. a salesperson might promote it because of his or her role in the company, even though the personal opinion of the interviewee might be very different.

5.2 Applying design methods

We planned to record all interviews with permission from the interviewees to be able to transcribe them. The transcribed interview data was intended to serve as a base for further analysis and to refresh our memories, in case we missed out on important details. We believed this would happen as we might feel nervous during the interview situations and also, because we lacked basic understanding in the field of robotics, making it difficult to remember terminology that we have not encountered before. We planned to use the transcriptions, together with our overall impression of the interviewees and the factory sites, to pinpoint the needs for a new remote robotic system. Furthermore we planned to perform brainstorming sessions to spark new and innovative ideas, as we wanted to open up for more design possibilities while in the divergent phase of the design process. When moving on to the transformation phase, we wanted to blend the analyzed interview data together with the ideas we came up with, to start form meaningful requirements for a new system. Lastly, in the convergent phase our intention was to iteratively create prototypes until a final set of mockups for the new system emerged.

5.3 Societal and ethical issues in automation

This section addresses various societal and ethical issues that can be posed due to production automation and remote services in the industry. These issues are relevant for the planning of the thesis especially while dealing with the robot manufacturers and customers.

5.3.1 Replacing people with automation

Robot manufacturers deals with automation in several fields of assembly lines in factories. In such environments, there are several people involved with the machinery such as operators, floor supervisors, managers, etc. In the occurrence of a technical failure in the factories, the tendency is typically to blame the operator as he or she usually is present around the vicinity during the mishap. Blaming them and giving them such an unnecessary pressure is not right and unethical, before a thorough investigation occurs (Sheridan & Parasuraman 2005). Moreover, it is interesting to think about reliability and liability in terms of virtualness. In today's world where the dependency on technology and automation is so humongous, there is a growing issue and danger that the expectations of humans may not match the logic of the machines (ibid.).

Machines are programmed by humans, they do not have a brain of their own and hence the questions occurs as to how much can they process and understand in all scenarios. Typically, robots and computers lacks common sense to apply in unfamiliar situations, which humans can do. When everything around is robotic and automated, there is always a possibility for technical conflicts to arise during the flow in assembly lines. This is a major issue to be considered when factories become highly automated to avoid terrible large scale blunders. Also if there are several supervisors and operators in large scale systems, there could be issues of incomplete flow of information to different floor supervisors when an automation conflict occurs causing. This bifurcation of flows and pools in reality with different supervisors leads to what Hardin called 'tragedy of the commons'(ibid.). This looping of information can probably be made more transparent in this scenario by having an online remote service system available to all the different responsible personnels in the plant instead of having several different portals.

Another discussion here could be the complete elimination of humans in the automation industrial setting. People believe to avoid errors and have a fast and smooth working process, it is best to keep the humans to a minimum or even eliminate completely. But in retrospect the automation world was designed by the humans and the designer of this system could make human errors as well which are reflected on the equipments. So in a sense automation is also a human! (Sheridan & Parasuraman 2005). A mistake made by humans while making automation could lead to much higher consequences than a mistake made by a human without automation. This is a concern to be kept in mind with the increasing advent in technology.

5.3.2 Fear of technology

An important aspect to ponder upon could be the intimidation of technology as a greater power. Automation is much faster and error free when compared to humans, thereby the presence of supervisors and operators are reducing drastically and the robots increasing rapidly. This leads to employment security issues and unemployment. Another ethical issue in the world of automation being present everywhere is the possibility of being constantly noticed and recorded, this can cause anxiety in workers. Also there is always a possibility of sensitive information falling into the wrong hands (Sheridan & Parasuraman 2005). Big robot customers usually have a firewall system and hence use internal system for maintenance and spare parts stock and when a service guy from the manufacturers' turns up they are usually out of the loop. Not having a firewall can help in collaboration with other customers, manufacturers for detailed analysis and proactive maintenance.

5.3.3 Big Data issues

Big data from the industries, in this case ABB customers, are stored by ABB. Currently ABB uses big data analysis for prediction of diagnostics of their manufactured robots, which means that the data is public. Most often while analysing real time big data it tends to be public by intention or by accident of design (Kim et al. 2013). Hence the major concern of using big data is if the customers are willing to have the data public or even if they are aware of the data being public. Once public, it is very easy to misuse the data as well. Hence it is important to respect the rights and privacy issues of the owners and let them know of the potential risks.

6 The process: towards a new remote robotic service

This chapter explains in detail how the thesis was performed in order to get the final solution. It covers the findings which are divided into two main sections: robot manufacturers and robot end-customers. These consist of a combination of things that were seen in observations and interview excerpts. Several different design techniques and methods were used iteratively throughout the journey of finding the required results. Since each design task and customer is unique no set method or rules were followed through the thesis, rather the methods were tweaked to best suite the situation.

6.1 Workshop

While waiting for customer contact details, a small role playing workshop called *'What's on Your Radar?'* was conducted. The exercise aims to let people plot items according to how significant they are to them (LUMA Institute 2012). Employees of the IT consultant firm go to enact as different stakeholders of the thesis project. The roles played were: a project manager, robot software developers, a floor supervisor and a robot technician from a robot end-customer company. The employees were given fifteen minutes to come up with ideas of what might be useful to them, in their assigned roles and note down their ideas on sticky notes. Then they got to rate their ideas on a radar map onto a whiteboard. The radar consisted of four categories namely: problems, diagnostics, communication and feed. The categories were things that we thought could be important and that could spark idea generation.

The workshop did not work out as planned due to that the employees of the firm seemed to be uncomfortable in role playing and were silent most of the time. We realized that we had too high expectations on the participants since we hoped to obtain new insights from lively discussions and a current of new ideas. Nevertheless we learned that it is important to acknowledge that people who are not used to participatory design methods, do not automatically catch on.

6.2 Preparing for the interviews

Before conducting the first interview with end-customers, a small role-play session was carried out where we took turns in acting as the interviewee and the interviewer. By pretending to take part in the real interview setting, it was easy to spot what questions needed to be changed in order to get a good response from the interviewee. The fake interview sessions were recorded so that we could listen to ourselves and identify how we could get better in asking questions in a clear and understandable way. Moreover, when listening to the recordings, it was easier to spot what questions seemed to lead to bias and these were therefore rephrased in a more neutral manner before the actual end-customer interviews took place. We were aware that it is impossible to be completely unbiased, but we believed it important to be aware of bias in order to avoid it to the extent possible.

6.3 Interviews with robot manufacturers

Two robot manufacturers were studied for this project, namely ABB Robotics and KUKA Robotics who both specialize in factory automation. ABB Robotics has ventured into providing remote service solutions to the customers, whereas KUKA has not. To get a clear picture of what services the robot manufacturers offer and what they think about the current industry in terms of remote robotic services, five people in the industry were interviewed.

Company	Number of interviewees	Role of interviewees	Interview time
ABB Robotics	1	**M1:** Product Manager	30 min
ABB Robotics	1	**M2:** Technology Manager	30 min
ABB Robotics	2	**M3:** R&D Manager; **M4:** Software Developer	1 h
KUKA Robotics	1	**M5:** Director Automotive	1,5 h

Table 1. Statistics of interviews conducted with the robotics manufacturers.

6.3.1 ABB Robotics

ABB Robotics is a leading company that provides industrial robots and services to the help automate factory plants. MyRobot is their remote service solution and M1 explains that the software is a "proof of service that we deliver". He believes that MyRobot answers the question to why customers spend money on remote services. M1 further claims that MyRobot is "dead simple" in the sense that one could play with it for twenty minutes to comprehend the system. Informant M2 views MyRobot as a system consisting of pure information that can help customer improve their production and to understand the status of their robots. This view is also shared by developer M4 who said that MyRobot is more for reading, since only a handful of commands are possible.

Informants M1 and M2, who both work as managers, seemed to be under their own preconceived notions that the plants are in a certain way without actually investigating the customers and their daily activities in maintenance in the plants.

M1 emphasized the severity of downtime, he said that one could imagine a car factory which has a thousand of robots and if one robot stops, so does the whole line.

In conclusion, M1 pointed out that "we [ABB] are very open of new services that customers might want".

The developers of MyRobot, M3 and M4, had no say about the system per se and explained that they just came up with their own designs as they were no designers. Neither did they know much about remote services.

M3: *"Maybe the product [MyRobot] has not answered the question as well as it could have, because they haven't always been able to make customers renew their agreements. [...] it was easy to sell remote service, but it was not so easy to keep the customers."*

When being asked who is the typical user for the MyRobot system, what kind of expertise they have and so forth, it was revealed that the developers had no clue what people the system is intended for.

M4: *"We don't really know who is the typical user. We haven't done any benchmarking on it, so we don't really know"*

6.3.2 KUKA Robotics

KUKA Robotics is a competitor to ABB Robotics, who offer similar products and services. Unlike ABB Robotics, they have not explored in remote services yet as they believe that the customers are not ready. At the same time there is awareness from the KUKA's side that remote services could be useful to the end customers to predict maintenance and issues proactively.

M5: *"The service exists but we are not selling it because the market is not requesting. […] you can either create a service and create a market for it or there could be a market need and for this we have the [remote] service."*

M5 provided a distinct business perspective and made a point that a remote service system cannot cost anything, because then he believed it would not sell. According to KUKA, the GSM modem solutions has been in existence for more than 20 years to use in robotics remote services but the market does not use it for several reasons such as conservative industry mindset, privacy issues, virus and etc.

6.4 Interviews with robot end-customers

Finding companies willing to participate in our study turned out to be a more difficult and time consuming task than first expected. Early in the project a request of customer details of MyRobot was sent to ABB Robotics who in turn, offered a log file from MyRobot with raw user data from the latest month. The log file included information such as users' email addresses, IP-addresses, time of login, what pages have been viewed and what browser was used. No other robot end-customer information was provided to us and hence we had to set out looking for customer contacts ourselves by going through the log data. We searched for the company names online to get further information about them, such as where in the world they are located and their phone numbers.

As emailing customers proved to be a slow process, we started making phone calls. Surprisingly though, after talking to several different people in companies who use MyRobot according to the log, most of them appeared to be unaware of the existence of the system when asked. This suggest that MyRobot was not widely known within companies and that only a handful of people actually use it, if at all. Eventually four different robot end-customers accepted being interviewed, namely: Allard International, Pågen, SKF and Volvo Trucks. These companies work in widely different areas and contrast each other in terms of scale, productivity rate, years of experience in automation and robotic technical expertise.

The prime reason for interviewing a diverse set of robot end-customers was to find out if they would express similar needs that could be generalized for a new remote service system. From a previous phone call with a software manager in ABB Robotics, it was conveyed that the target customer for the MyRobot service use around fifty robots. The manager explained that companies with a greater number of robots usually have firewalls and security policies, making it difficult to connect their robots with ABB Robotics. l In order to find out whether a remote service system could be helpful for companies using a smaller or larger number of robots, we wanted to explore a wider range of customers. Furthermore, we considered including a robot customer with another brand than ABB Robotics to find out their opinions about the possibilities of remote robotic service systems.

Company	Number of interviewees	Role of interviewees	Number of robots	Main robot brand	Interview time
ALLARD International	1	**C1:** Service engineer	2	ABB	45 min
Pågen	1	**C2:** Chief of Distribution	14	KUKA	1,5 h
SKF	1	**C3:** Robot technician	50	ABB	1,5 h
Volvo Trucks	2	**C4:** Manager of Maintenance Development & EEM; **C5:** Robot technician	200	ABB	1,5 h

Table 2. Table showing statistics of interviews conducted with the robot customers.

6.4.1 Allard International

The company Allard International uses two robots and therefore falls under the first category of customers. They manufacture orthotic products and decided invested in robots to make their production line more efficient. The work in the production facility involves a lot of manual sawing and polishing which makes the facility dirty from the fine white dust. For this reason, the two robots are protected in boxes of glass. The automation only runs during the work hours and the facility is shut down every day when the workers go home.

> **C1:** *"We begin with starting up and then we run until evening and clean and fiddle."*

Allard does not have in house expertise regarding robots issues, nor are they allowed to fix the robots themselves according to their service agreement with ABB. If a robot problem occurs they need to call a local service person to help them fix the problem. In theory, a coordinator should be contacted first who then contacts the service contact. This is however not the case, as it goes faster and is more convenient for Allard to contact the local service person directly. Having an ABB facility located near the facility has for that reason come to advantage.

> **C1:** *"I don't know if I may say this, but we usually don't care calling the coordinator, but we call him [the local service person] directly. Or I do that and it works absolutely fine."*

Allard has one person to handle all the automation and robotic related issues in the plant. The environment appears rough as the blue overalls the interviewee were dusty and filled with lots of tools for hands on work. The interviewee wore special protective glasses which had cracks and he seemed to have lost a part of his finger at work. The work environment does not seem to be a safe setting. He prefers to use an old numberpad phone just for calling purposes, as it is safe and robust from drops and damages. Since it is a small company with just two robots, he sees it more of as a nuisance to get constant notifications about alarms and maintenance. He uses a Windows desktop computer stationed in a room adjacent to the plant, where he deals with the programming of the robots.

Allard has been renewing the MyRobot service package from when they bought the ABB robots, which was five years ago, but they have never seen nor used the MyRobot-system as the person responsible for signing the agreement is retired and the papers with the login-information are lost.

> **C1:** *"I think we bought these robots five years ago. And then this [MyRobot] was included as well, but he who took care of it is now retired and the papers no one knows where… and then, nobody talked to us regarding MyRobot. As said, this was pure news."*

After MyRobot was shown and potentials realized, C1 still did not see the point of the system. The only thing C1 wished for was to be able to store backups on his local server. When asked whether there was potential in using the system on a phone or a tablet, the service engineer replied:

> **C1:** *"Sure one can trudge around, but I don't see the benefit of it. I don't. I think that benefit is more theoretical. So I understand the benefit very well if we are talking big companies. But for small companies, I cannot see that."*

6.4.2 Pågen

Pågen is just like Allard International, a small robot customer and therefore falls under the first category of customers. The production facility in Pågen has invested in automation for the packaging section where they have a total number of fourteen robots. Since they deal with food they have strict rules regarding hygiene. The facility is divided into three zones: green, yellow and red. The automation takes place in the yellow zone. As a visitor, one has to first sign a health declaration stating that the visitor does not have cold, diarrhoea, fever and the sort, and before entering the yellow zone one has to take off all accessories such as rings and watches, wear disposable clothing and wash one's hands.

Robot stops occur frequently, around ten to fifteen times per hour, and it's usually caused by minor issues such as a box getting misplaced on the conveyor belt, making everything stop. When this happens, a worker in the plant needs to localize where the stop is, put the box in the right position and start up the assembly line again. As the robots run fast, it often happens that bags of bread are thrown onto the floor. In some cases, these are manually picked up and put back into the boxes. But if the bread looks too squashed, it is collected in a pile on the floor that will later go to Pågen's yeast producing facility.

> **C2:** *"We have between ten and fifteen stops every hour, so it's very short stop, you take out the bread, reset and start again from the operator."*

Pågen has almost no contact with KUKA as it has not been necessary; there have been no technical problems with the robots so far. In a span of four years, Pågen has only called KUKA twice and they don't see the necessity to have closer contact with them as they aren't specialized in software which is what Pågen claims they need. Instead, Pågen buys this expertise from a software company called Teamster who have developed a bespoke system for their plant. This software solution has a blueprint of the entire plant on two TV-screens in the control room from where the flow of packages and where problems occur easily can be seen. They also added a CCTV camera to get a constant feed from a location where a lot of stops occur to diagnose the issue and avoid future stops.

The chief distributor visits the plant around three to four times per day to see how the production is going and to make analyzes. He also receives reports from the shift managers in the plant with additional information. All these modes of communication usually happen through email, sms or telephone calls.

> **C2:** *"I use my experience and I look at the data, how fast we have produced and how many stops we have every hour. And then I'm sending a report every week to our director of logistic, how has it gone this week? Because if, in the legislation we have a problem, so he wants a report every week."*

Pågen currently calls an external company for help whenever a problem occurs dealing with the robots. They have weekly conferences with representatives from the external company to deal with the problems in the factory and go through the checkpoints of the equipments.

> **C2:** *"So far, we call they answer. Each time. But Teamster is a very small firm, so we are a little concerned that one they don't answer when we call, because they're maybe five or ten who work with us. And say, there are five and two is on vacation and two is ill and one is on honeymoon and then no one answers and then we have no production."*

During the big Swedish holidays, such as Christmas and Easter, Pågen has a lot higher production than normal. At these times Pågen makes sure that technical people from their external partner Teamster, who is located in another city, is readily available near the Pågen plant if something goes wrong.

> **C2:** "*[...] they're our lifeline, we don't have the space to call them in the middle of the night. Maybe they answer, maybe it take one or two or three hours. So we have them as assurance."*

The vulnerability of lacking technical in house expertise is acknowledged by Pågen, and for this reason they are considering to hire robot technical staff in the future.

6.4.3 SKF

SKF falls under the second category of customers, using about fifty robots. The production facility is spread out over a large area and hence has long distances between each building. The workers go by car or bike between the different parts in the company area. The robots are distributed into different halls and between each hall is a gate with a codelock.

The production plants are quite noisy and there is an evocative low frequency sound from the various machines at work. In occasional spots on the floor there is oil spill, which is why the factory workers need to wear protective work shoes. They also use blue wear and the workers who are in direct contact with the ball bearings need to wear light gloves to make sure that the bearings don't become stained with oil from their hands. Trucks are driving along the sides of the factory and the workers often make eye contact with the truck drivers to state their presence and avoid collisions.

There are many people at SKF who have maintenance expertise, but there is only one person (C3) for all the plants in the city who has the overall robot expertise. Since C3 does not have the possibility to deal with robot issues around the clock, ABB takes care of issues during the nighttime.

> **C3:** *"Since I'm only here daytime, ABB takes over the responsibility the rest of the time, because in the agreement it says we have six hours."*

C3 has used MyRobot before and thinks it can come in handy. He also feels that MyRobot can be used by several different people with different roles in the company. C3 conveyed that the system lacks categories and filters, and that it misses an area where the user can define his or her own information. In general, he easily gets lost in the MyRobot as he needs to go deep into the system when he is looking for something. According to C3 the communication part of the system is least useful, but the backups and restore is a very important feature for him to use recurringly.

> **C3:** *"I think it [MyRobot] is very useful, it's hard to define what you want to see. Configuring of the alarms so we have the same on every robot and that was not that easy."*

> **C3:** *"...also in the remote service I would like to have an area to define my own information: what I want to know and to connect it to the remote and see."*

Also one can not sit and look at the screen all day and there are a lot of alarms in the plants, not all are of interest to know. Some crucial alarms like collision are more desirable to know for him. Since the plant has more than 50 robots, having constant information from all can be overwhelming and maybe at a certain period only a certain number of robots interests him for further information.

> **C3:** *".. since I have fifty robots, I'm not so interested if I have five or ten alarms, I'm more interested in which robot has created the alarms."*

> **C3:** *"It is a little bit hard if we have a collision, maybe you want to see when just in real time when the collision is so you can go and check and you can connect to the robot in the program pointer."*

When an issue occurs there is usually a dialogue between the floor operators and a maintenance worker. If the issue can not be solved by the maintenance staff at SKF, ABB is called. When the issue does not need any spare part or mechanical changes in the robots, then the problems are solved remotely through instructions or otherwise technical people from ABB visit the plant to fix the issue. They visit the factory about sixty times in a year. Also ABB gets more information about the robots, alarms and maintenance. And sometimes a contact person from ABB calls SKF stating that they have a problem.

> **C3:** *"ABB looks at alarms every day and they contact us if they can see something."*

> **C3:** *"They [ABB] can see a lot of more than I can see. I know, as a customer you don't have access to all the information"*

He did not see the point of using a system like this on a mobile phone as it is too small. But he sees the potential of using a tablet for seeing documentations and the sorts. He also likes to have some kind of information exchange in the system for simple questions. The current system does not show the robots which are not connected and in manual mode or fault mode and he thinks it is crucial to know the ones. Since there are different models of robots, it would be convenient to write the serial number in the application and get the connection to the right documentation about the robots, the fault codes or some other kind of information. He wants to be free of choice as to what he can see and how he wants to see the different information.

> **C3:** *"A tablet is more protected than a computer, so that can be a very good idea to have that kind of remote service in an app in a tablet. And then also possibility to connect to a server to get information about the robot type."*

6.4.4 Volvo Trucks

Volvo Trucks falls under the third category of customers, who are using more than 100 robots. It is a large industry who employs a lot of young people. In the assembly area of powertrain where the observation took place, the majority of the workers were in their twenties. The noises from the robots and other machines were relatively low as it was easy to hear the radio that was playing pop music in the background. The workers seemed to have their fixed stations where they worked and the tasks appeared to be quite repetitive. It was clear as to when a worker needs to interact with a robot cell due to colored lights indicating the robot state. Every time a robot is idle, as when it has nothing to work with, a blue light is turned on next to the robot cell so that workers know that they need to manually load the machine with the parts the robots are about to work with to start up the production. This happens often and there are people constantly checking on the robot cells.

The robots in Volvo Trucks run in optimum phase and movement. There is a safety margin for the running robot capacity to avoid wear and tear increase the lifespan of the robots. Every robot cell is enclosed in a metal mesh and there is a light curtain sensing if anyone would trespass the space, making the robot stop immediately for safety reasons.

> **C4:** *"Some of the robots are more or less standing still most of the time, but that is their skill at that situation and then there are robots that really work on the edge, [...] we have specified that our suppliers should not use the robots up to 100%. We decreased that to have some safety levels also left in the robots.*"

At the Volvo Trucks plant there are a lot of automated vessels running across the factory floor. These have sensors and stops if someone comes too close. There are also people driving trucks in a fast pace and hence it's important to walk inside the drawn yellow line on the floor to avoid accidental collisions. Mobile phones are not allowed in the plant. However, it is ok to use laptops as those are needed for robot programming purposes.

> **C4:** *"The electrician will have his laptop with him all the time because they have to go online and check the PLC[3] very often."*

The robots at Volvo Trucks generate alarms when an error has occurred, but it is not until after 10 minutes of downtime have passed that an emergency failure starts to count. When problems occur, staff at Volvo Trucks try to fix them themselves to the extent possible to decrease the risk of financial damage. In a worst case scenario however, when problems cannot be fixed in house, there is a service agreement with ABB. The downside to that is that it can take a lot of time for ABB to come into place.

> **C4:** *"Most of the problems we fix by ourselves. We have to. The consequences here if you stop a site like this it costs a lot of money."*

At Volvo Trucks they work proactively by doing fake maintenance on a test robot which they disassemble, break, repair and perform calibration tests on. This is because they want to keep up the knowledge on how to do maintenance work as one easily forgets how to do it if it's not done often.

> **C5:** *"The most repair we do is about changing motors. So the motors on the robot is very important to have more information about."*

Volvo Trucks don't get any notification of when parts of the robot ought to changed, but have to figure out that themselves. When something needs to be replaced with a new part it is not always certain that that part is available, as new models are coming all the time. As an example, the robot motors from ABB change every month.

> **C4:** *"[...] when it comes to spare parts and ABB robots, they are not the best. It is a terrible area for us due to the fact that they change a lot. And this gives us a lot of headache."*

It was revealed that it's both cheaper and easier for Volvo Trucks to buy a complete new robot instead of changing all the parts for an old robot. Another benefit, as Volvo Trucks sees it, is that a

3 **PLC** is short for a "Programmable Logic Controller" and is a device used to automate monitoring and control of industrial plants (Programmable logic controller, 2003).

new robot with a new system also ensures quality. They do however keep a stock of spare parts, along with old robots within the company in case of emergencies, because it takes too long time to order a spare part from ABB. This is because the spare parts needed for Volvo Trucks is shipped from Germany.

6.5 Establishing requirements

After the interviews had been conducted, the audio recordings were transcribed in order to form a foundation for requirements analysis. As the transcriptions were complete, 158 notable quotes from the interviews were highlighted and later cut out (see figure 10) so that they could be arranged into different categories using a method called **affinity clustering**. Affinity clustering is a method for ordering large chunks of information into logical groups (LUMA Institute 2012) and we carried out the sorting by putting each piece of paper with tack onto the wall. Having the quotes on the wall provided a good overview due to the amount of information that had been collected. Furthermore it facilitated easy rearrangement of the quotes as categories emerged. After the sorting was done 13 categories were identified:

- Emergencies
- Problems
- Mechanics & maintenance
- In the plant
- Information exchange
- Business
- Human- automation interaction
- External support
- Externally developed systems
- MyRobot
- Robotics company services
- Robot network connections
- Devices

Some quotes were discarded as they were considered irrelevant. Later on it was discussed which categories made sense to consider when establishing requirements for the system. The categories which didn't matter for the system was however not discarded as they provided a good picture of the context in which the design solution is meant to exist in.

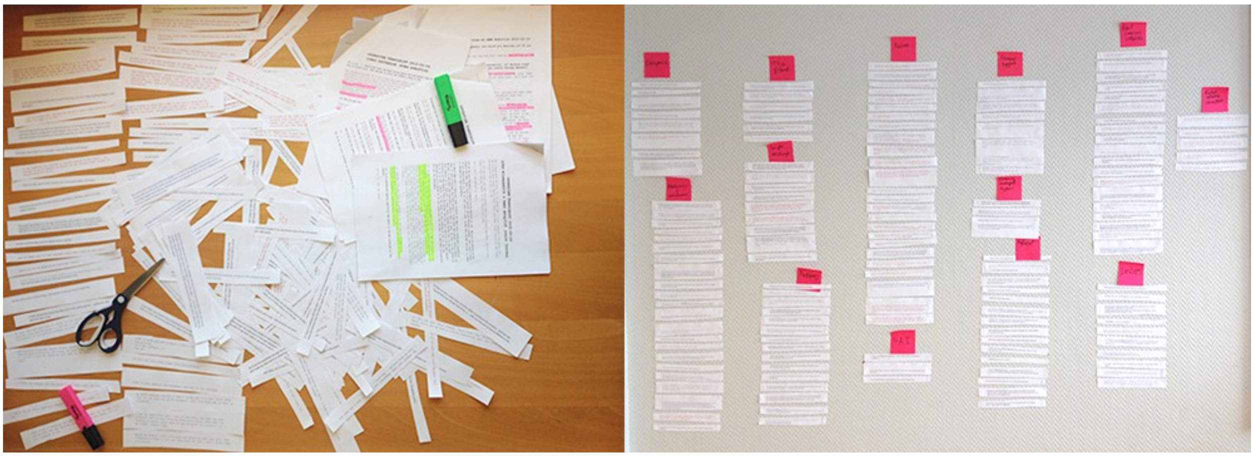

Figure 10. The image to the left shows the notable quotes that had just been cut out from the transcripts. The right image depicts how these were sorted into categories and put up onto a wall.

6.5.1 Brainstorming

Establishing requirements is a practice that usually involves innovation (Sharp et al. 2011) and as we did not want to constrain our solution to solely be based on the empirical data, a brainstorming session was conducted. The best ideas emerge from lots of ideas (Kelly 2000). We decided to come up with 100 different ideas within approximately one hour. Each idea was written or sketched on a sticky note and placed on a board in a grid of ten times ten (see figure 11). The primary goal of a brainstorming session after conducting user research is to get rid of all preconceptions and to go from an analytical state of mind into thinking of solutions (Cooper 2007). The pros of brainstorming are that it leads to come up with wild ideas and spark innovation without being judged or discouraged (Open IDEO 2011). It also helps in building on each other's ideas to get further immersed in the topic. Kelly (2000) argues that a limit 100 of ideas usually works to keep a good flow of the session.

Figure 11. One hundred ideas written down on post-it notes after the one-hour brainstorm session.

6.5.2 Kano Model

After the brainstorming session was finished, all ideas were sorted into the Kano model. The Kano model is a grid with two axes to help visualize and weight the ideas (The Kano Model, 2015) obtained from sorting. 100 ideas can be very tedious and taxing to sort, so to get a clear picture of these ideas they were sorted through a two dimensional axes, where customer satisfaction plays the major role on categorizing the needs. Customer satisfaction is important because when two requirements are fully implemented where one is more important than the other but in reality the one that is less important can cause more customer satisfaction than the other (ibid.).

The two axes used here to sort and select requirements was, a feasibility scale and customer satisfaction. For instance, a need that is not feasible today but produces high satisfaction is not a good need for designing a system (The Kano Model, 2015). It is important to strike a balance between the two parameters. The definition of feasibility was based on how practical and how easily the idea can be implemented in terms of the current situation and technology available through the perspective of robot manufacturers. The definition of satisfaction was based on ideas that was basic expected needs and ideas that would excite the future users. In other words this axis is sorting ideas based on how satisfying the ideas are in the near future.

From figure 12 it can be seen that the ideas sorted through the Kano model gives three broad categories of requirements. The ones above the performance scale can be broadly classified as ‘Excitement’ and the ones below as ‘Basic’. The ones in between along the Performance line are the Performance needs. Basic requirements are those which are needed and expected from the target users to be functional and usable. Since these needs are expected and basic they are usually taken for granted, when implemented well the customer satisfaction is neutral but when implemented poorly the satisfaction is very low (ibid.).Performance requirements are those that the customers can easily express that they need to assist their work. These are the most visible ones as the customers can easily mention and ask about these needs (ibid.), thereby they should form the base of the end system. Excitement requirements are those which are not expected from the target users but can still be very useable and make the system unique and desirable. These requirements are usually the selling points for a system, these needs can be the innovations for smoother running of the system (ibid.). For a system to be good and usable for the target users it should satisfy both the basic needs and the performance needs and it is good that majority of the ideas fall under these two sections. To make the system unique and beyond users’ expectations it is good to include some feasible exciters as well and give scope to not so feasible exciters as well for the future.

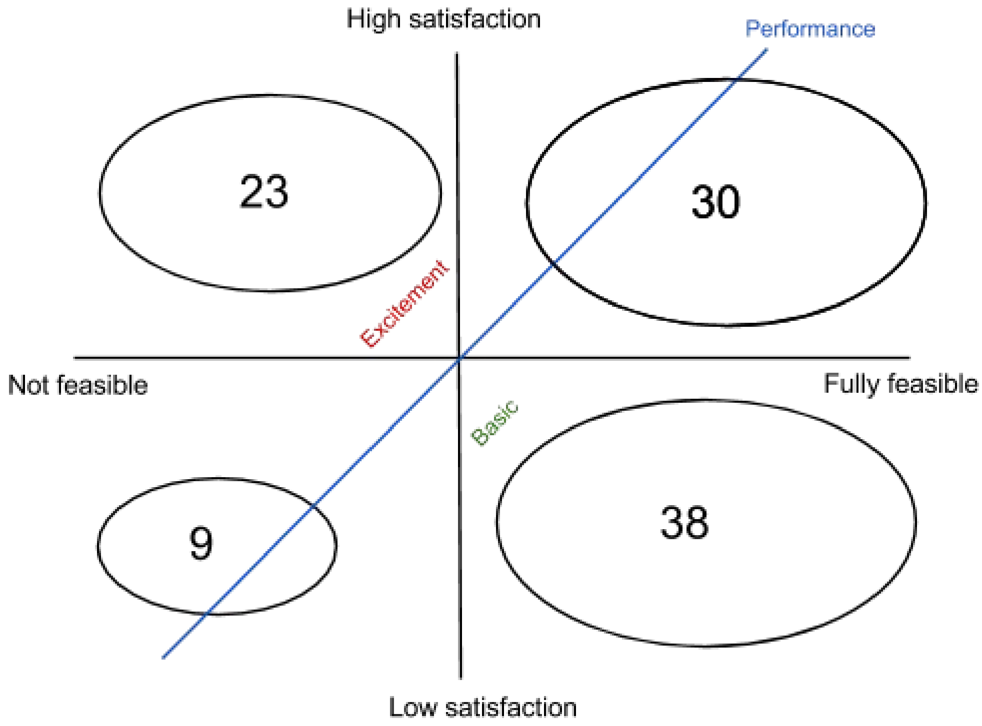

Figure 12. The distribution of ideas in the Kano Model.

6.5.3 Second iteration of affinity clustering

The brainstorming exercise produced a 100 ideas and even though Kano Model helped in sorting and highlighting the basic requirements, it is still a lot to work with. Hence affinity clustering was performed again with seven broad categories. After a couple of iterations of clustering post-it notes, the number of requirements boiled down to fifty. This not necessarily means that half the ideas were scrapped, some were merged and rewritten or some were too farfetched for the scope.

As can be seen from the table 3 below, the requirements were categorised into seven distinct clusters that can help in understanding the requirements and design an apt solution. The clusters and the final number of post its for each are listed down below to get an understanding of what was done. The number of requirements and the clusters are just a statistics for requirement analysis, and not to pinpoint that visualization cluster is more crucial than the help one. It is rather a suggestion that visualization was considered in depth to make it easier for the users to understand the system and make use of the system to the fullest. Personalization was an interesting and important category from these processes. The system can be used by more than one person in a company and then there are several shifts so having personalizable features and customization will help in selling the solution better and also making it more useable in several types of devices.

Cluster Names	Number of requirements
Visualization	16
Personalization	11
Maintenance	6
Big Data	5
Service Information	5
Exciters/Extras	4
Help	3
Total	**50**

Table 3. Table showing finalized cluster categories for requirement specifications.

6.5.4 Sitemaps

Before doing visual design work, a general sitemap of the system was drawn to provide a clear overview of the different pages that were to go in the system. A sitemap is a schematic diagram showing the structure of a site and are primarily used to reflect an understanding of a site as it keeps evolving and updating by the designers (Newman & Landay 2000). It can be very useful for designers, developers and clients to have a clear understanding and structure of the website or application. It is first and foremost an artifact of information design and as time progresses they will be revised to become increasingly detailed (ibid.).

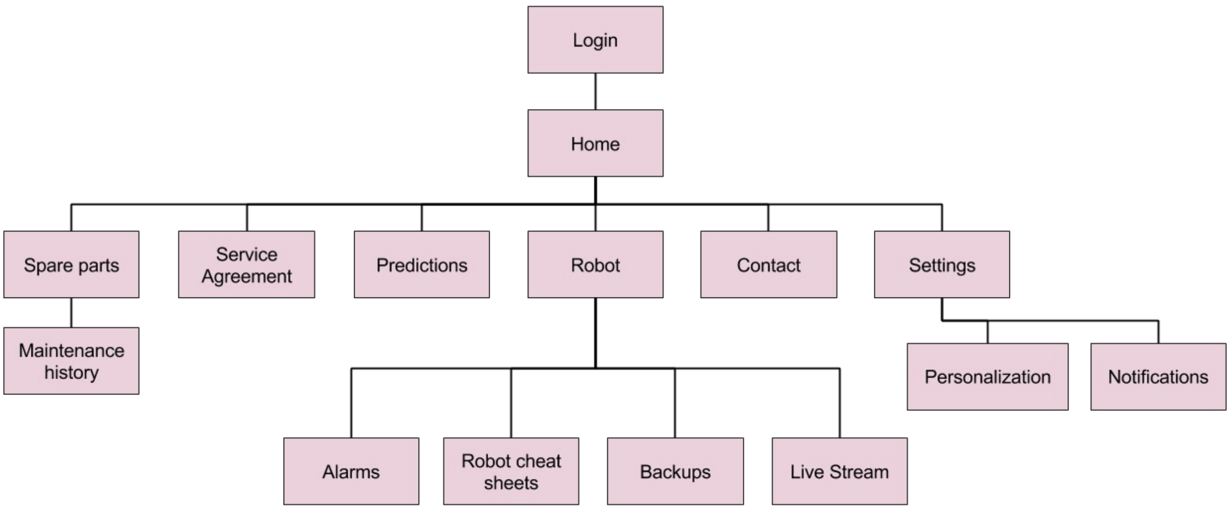

Figure 13. Sitemap for the proposed system.

The blocks in figure 13 represent individual pages and the lines represent the navigation flow between the different pages present in the site. From the sitemap below it can be seen that there are six main menu tabs with more subtabs meaning a lot of design decisions and prototyping. Information about the robots and spare parts, is most important for the customers. Informant C3 mentioned that, having a service history would be useful for analysis and also keep track of the services. Predictions would be useful for proactive maintenance, as downtime was very crucial for informants C2 and C4.

With the start of the prototyping phase, the sitemap went through a lot of changes. The initial sitemap in the above figure 13 was helpful to make the early prototypes but it was not a fixed map. While drawing the different pages in the sitemaps, the map evolved iteratively. For instance the Predictions was seen redundant to have a separate tab and seemed better placed along with robot details pages. After finalising the initial prototype, the designs were user tested with ABB's MyRobot developers to know more about the technical possibilities for the solution. It was realized that robot cheat sheets and error codes is very hard to implement as there is way too much information and several thousands of error codes. ABB themselves did not have the complete list for these particularities and hence it had to be scrapped.

The sitemap kept evolving during the entire prototype and initial user testing phase. The final sitemap is shown below in figure 14**.** As can be seen the number of tabs in the Home page was downsized to the four basic necessary tabs. The pages overall was downsized to only show what really interests the users and what is essential for the customers to keep the production up and running. Downsizing the number of pages also simplifies the interaction flow and eases the work for the customers.

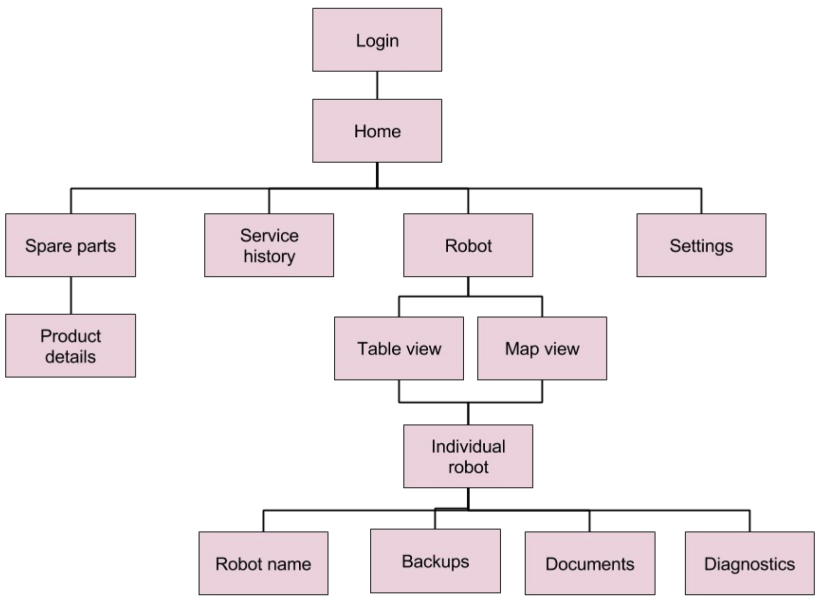

Figure 14. Final version of the proposed system sitemap.

6.5.5 User scenarios

To better understand the daily work of the intended end-users and to help shape understanding for the project stakeholders, user stories were written. A user scenario is an narrative text that describes a user activity in an informal way to facilitate analysis of user needs and requirements. It also helps form a picture of the users' context, as narratives are easy to relate to (Sharp et al. 2011). The scenarios help nailing down the requirements for the system by pinpointing the activities the users performs.

Down below are examples of short user scenarios for each of the interviewed end-customer companies.

> Allard International: *As a service engineer, I want to be able to do backups because I want them on the local company server.*
>
> Pågen: *As a chief distributor, I want to call Teamster when there are software issues or mechanical issues that we can't solv*e.
>
> SKF: *As a maintenance technician, I want to specify and filter what information I get from the system to stay focused on what's currently important in my work.*
>
> Volvo Trucks: *As a mechanical engineer, I want to make sure that someone in the plant calls me when an alarm has lasted for more than ten minutes.*

6.6 Prototyping

A prototype in the context of designing interfaces and interactions can be defined as 'a representation of a design, made before the final solution exists' (Moggridge & Atkinson 2007, p. 685). Prototypes can be made using different materials and techniques. The initial prototyping techniques are usually quick and dirty prototypes. Low fidelity prototypes helps in understanding thoughts and ideas better and to process visually. It also helps in discussing and iterating the sketches and ideas in the design team.

Interactive prototypes are usually produced late in the design phase (Newman & Landay 2000). In the later stages, more refined high fidelity prototypes are produced so that they can be used for testing outside the designer circle. The prototype here represents a combination of the way design looks, feels, behaves, and works (Moggridge & Atkinson 2007).

6.6.1 Wireframing

Wireframes define the overall layout of a page design by showing what content goes where (Snyder 2003). No graphical details such as font type and color are taken into consideration when sketching wireframes and because of that the focus is on the structure and the navigational flow. To be able to iterate fast on different design ideas, the wireframes were sketched on paper as seen in figure 15. In this context, the wireframes were used as a literal representation of how the different screens in the application would look like in structure. Wireframes can be very useful for initial user testing and feedback as the test subjects are forced to concentrate on the placement of things, interactions and the navigational flow, instead of the graphical appearance.

Figure 15. The above picture shows a selection of the final iteration of wireframes.

Using the sitemap as the starting point, several iterations of fast wireframes were made. After sketching several layout designs, the wireframes were discussed and a new set of low fidelity prototype was designed combining the best ideas and layouts.

6.6.2 Mockups

After the wireframes were finished, high-fidelity mockups of the system were created digitally in an image editing software. The mockups consisted of static images which aimed to resemble the final version of the system for each screen. When the wireframes were translated from paper format into detailed mockups, it was discovered that several design decisions had to be taken for each component in order to keep a graphical consistency. Sizes, colors, pixels, shapes and icons played an important role to design of the system. As an example, the size of the components had to be decided so that the sequence of screens in the prototype should look the same.

Due to the interest from the IT consulting firm to present the new system concept to ABB Robotics, we decided to adopt the official ABB concept and style guidelines. These gave the mockups a more polished appearance and ensured that they were relatable to ABB's existing branding. Some of the style guidelines were however reconsidered as they did not follow interaction design best practices, hence they served more as a support to do graphical design decisions. Although the ABB style guides were applied, the new system does not intend to be a redesign of the existing MyRobot system. It was a design decision solely based on work politics.

6.7 System testing

The proposed system tests were performed to evaluate and improve the system to design a more relevant and practical solution for the robot technicians. The testing was done in two phases, the first phase was internal user tests where software developers and the university supervisor tested the paper prototypes to just get a fresh perspective and get feedback in software technicalities.

After the initial feedbacks from the first phase of user tests, the paper prototypes was designed in a more polished manner using Adobe Photoshop. The prototypes were imported to an application called InVision to make it interactive and invoke the feeling of using a developed ready system. This system along with the paper prototypes was used for the second phase of external user tests.

6.7.1 Internal system tests

Software Developers

The polished paper prototypes showing the wireframes were initially tested by students in software engineering. Since they are competent with software development, the prototypes were just shown without explanations. A lot of valuable feedback and design decision questions were received, this helped in thinking further about the design to motivate the choices and decisions. They also helped in identifying some basic design flaws which we overlooked. The main idea was to get an outsider's perspective to the design.

Through this test it was realized that having a site view of the robots could be very hard to implement and confusing. Each customer has their own sitemap and sometimes the robot cells are relocated which could lead to unnecessary complications. Also got valuable input on several features such as news feed in home pages, search field, filters, etc.

Supervisor

The valuable and critical feedback from the prior test was considered and implemented before showing the designs to the supervisor. She pointed out that a person using a system regularly wouldn't want to be welcomed every time. It was realized that the menu names were very vague and had to be renamed to be clear. Also it was pointed out several times to work on scenarios to understand what the customers want and how would they want the information. It was realized that it was not the best to have the customers to enter service history. It was mentioned that having a sketchy prototype like this is very good to show it to the test subjects as it feels more flexible for changes and edits. It was also realized that from customer's point of view it is important to downsize to only the important things and hence reduce the steps a user has to do to the maximum extent possible. If the system had lots of steps, the user would just lose track of where he/she is and the purpose of this system to help in robot maintenance is lost.

Robotics' software developers

Informants M3 and M4 were met again, to get developers' feedback and their perspective. As developers they gave valuable feedback of what is possible to develop and what is not. We were informed that it was currently impossible to keep track off or calculate the downtime of the robots. It also came into notice that they currently do not store service history in any form but it was valuable information for customers. It was realized that they were quite surprised and interested to know what the customers wanted and did not want. Here we had to make a decision of either sticking to what ABB can provide easily today or develop something new and provoking and give a better design for the future. We decided to choose the later as the first one would only lead to a different variation of the existing MyRobot solution.

Workshop

A small workshop with developers and business analysts from the IT consultant firm were conducted in order to get feedback on the system. They got to try the semi-interactive prototype on a tablet and point out things that were unclear to them. During the session it was revealed that several people wanted icons in the design to make the possible interactions clearer. It was also mentioned that color is not enough to signify a specific category, but a combination of text and color, or an icon and color will provide better understanding. As the high-fidelity prototype was shown, several people believed the mockup more interactive than it actually was, hence the session had to be partly monitored in order to help the test people understand what parts could be clicked.

6.7.2 Robot customers user tests

SKF

Valuable feedback and suggestions for improvement was obtained from user testing the prototype with the robot technician. It was really good to start the user testing with this customer, as he was the only one who had used MyRobot before and has the basic idea of what to expect from remote services. The idea was to get input and feedback from him, iterate the prototypes again and then go back to him and other customers to show the prototype one final time.

The user test was started with the low fidelity paper prototype first, as this does not give the impression of a fixed complete design, thereby allowing the user to be very free and open to change things and give practical feedback. The most important input obtained was that he wanted everything connected with the robot details page, the robot specific service history, the spare parts, event logs, etc. It makes sense to get all the information related to the specific robot instead of the stand alone pages. But he also mentioned that it was good to have the information also in stand alone pages, to get a quick overview of all the history of the robots. There was also some minor changes to be done in all the pages. He mentioned several times that his only interest was mainly the robots and what alarms they generate. In the home page, he preferred the whole list of alarm information only so that he can scan quickly to understand the overview.
It was interesting to observe that he did not understand, nor get the point of the information visualization (see figure 16), that shows an overview of alarms and downtime over different days in a week or month. He preffered lists and tables, why it was realized that having interactive maps can look cool in a design, but does not necessarily have any value for the end users. Moreover, the robot that was included in the specifications list, appeared to be unnecessary as that space can be used for more useful information.

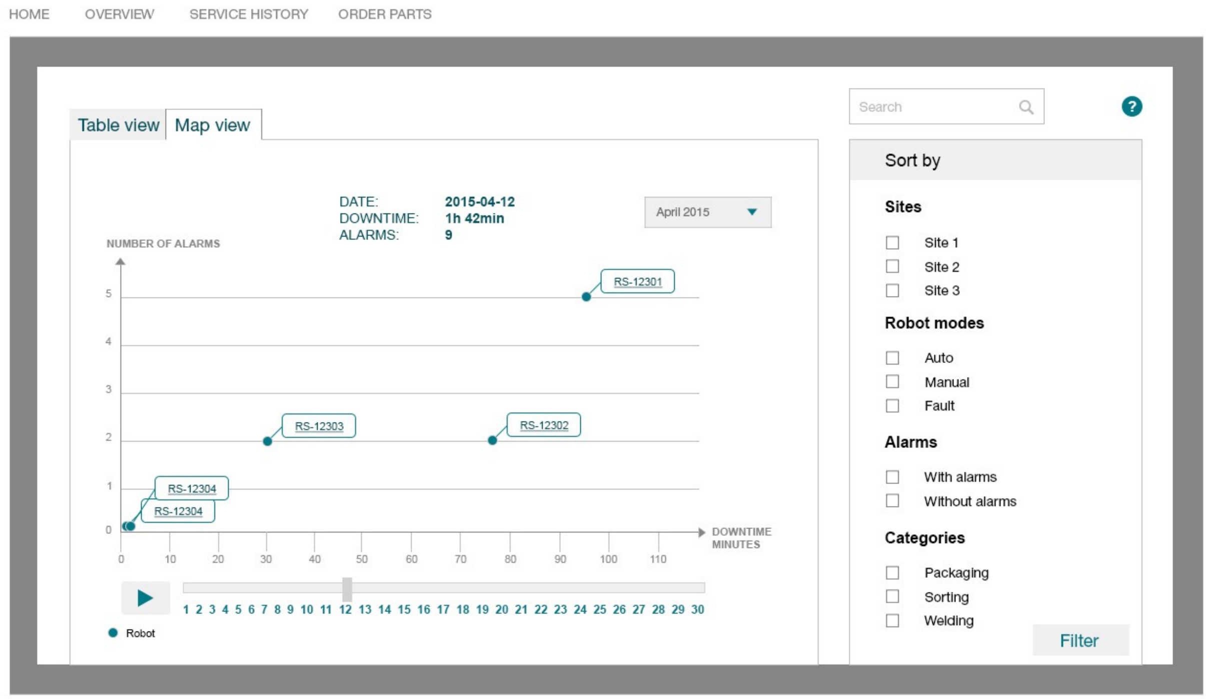

Figure 16. A screen showing a map view.

Allard

The final interactive prototype was sent as a link in an e-mail to Allard due to the company's geographical location. The service engineer, who also was subject for the interview, replied the following:

> *"I think it [the prototype] looks good except for some minor things. Can one have two servers in a backup? Can one change the interval of the backup?"*

From this reply, it was clear that he managed to explore the prototype on his own without extra help. This implies that the prototype of our proposed system, as originally intended, does not need extra clarification.

Pågen

When Pågen saw the proposed system, they instantly claimed that it is too theoretical for them, but that our solution might work well in other companies. Pågen shifted to robotics and automation very recently and they are still quite new to this field. They are also currently lacking in house robot maintenance staff, instead depend on external companies for maintenance. This is probably the reason why they don't find the system beneficial and think it is too theoretical.

Volvo

An online link with the system prototype was sent via e-mail and got tested by the manager of maintenance and develpoment. He stated that:

"I think [the prototype] gives a good picture over the facility and I like the heading 'predictions' even if it doesn't look like it's going to be used that way? To predict faults or necessary services, preferrable trigged by system solutions that evaluate needs, would be very good"

The reply suggests that the proposed system could be valuabe to a company of the size of Volvo Trucks, given that the system provides a useful overview. Hence, it is necessary to iterate on the details and be clear to what it means with 'predictions' as well as other terms that is used in the prototype.

6.8 Creative practices

As design is a creative practice, we stressed the importance of finding methods to keep a creative flow in our work. It was discovered that new perspectives were gained effectively when stepping out of the work environment and hence, a lot of discussions were held outside the office space. During the course of the project, we visited art museums, read books, watched movie clips and took long walks to shift our perspectives and to get inspiration. Positive emotions broadens the thought process and suits well for creative problem solving (Norman 2002).

Looking at similar experiences in different contexts is, according to IDEO (2011), one of the most effective ways to gain new insights. As an example, it was realized that our working methods have similarities with that of a crime investigation. In the case of a murder, policemen start out with fragments of information such as parts of evidence, be it a blood stain, a bullet, perhaps a body and so forth. Then they try to build up the entire picture of the event by exploring various areas of interest. This has been the case for our project, as the area of robotics was unexplored at the start of the project. Moreover, policemen make use of the workspace by putting up maps, papers and pictures on the wall to help everyone involved in the investigation to process the material. As this has been the case in our project as well, inspiration was gained from looking at crime investigation series, both fictional and real. By putting a lot of information on the wall, it was easy to invite people outside the project to see the progress and to make comments as the work progressed. So when people in the IT consultant firm came by our office space, we had the opportunity to ask for their perspectives and use the printed material as a mediating tool. This was helpful as some employees had previous experience in the robotics field.

7 Results

This chapter builds upon the findings presented in chapter six and aims to analyze what was found out from the robot manufacturers and end-customers to answer how interaction design can shed light on unspoken needs and be applied to improve the use of remote robotic services.

7.1 Pinpointing the users

In the beginning of the thesis, ABB's system MyRobot was provided to robot customers to increase the turnover of the system. From the first phase of interviews with the ABB project leaders and the software developers of the system, it was realized that nobody knew clearly who were the users of the system, how they use it and how often they use it. It was also unknown if this system really helped the production in keeping it up and running. Hence, as interaction designers, it was a journey through the industries to find out the real users of the system and finding out their daily activities and requirements. Every customer is unique in the way they use the robots for production and how much expertise they have regarding the use and maintenance of the robots. It has been a challenge to pinpoint that a certain group of people are the users with a certain skill set to design a solution. Therefore a spectrum of customers ranging from using two robots to two hundred robots were visited and analyzed to understand the potential users of a new remote service system better.

From the findings through interviews and observations, a consensus was arrived upon that the users are the robot technicians. In small companies there might be just one robot technician with limited knowledge on robots, whereas in large companies there are more than two robot technicians with different in depth knowledge on different sections of robots such as electrical expertise and mechanical expertise. In some cases the customers are dependent on expert help and services from the robot manufacturers when compared to other customers.

7.2 Identified user needs

To recap the research question posed in the introduction chapter of the thesis, we asked how interaction can improve the use of remote robotic services. From the findings, it has been clear that the interaction design methods applied have helped bring to light that there is a mismatch between the vision from robot manufacturers and what their customers really need. Interaction design also helped in identifying how to obtain information from the customers and how to use this to form requirements, and to create a suggestion of a remote service system that builds upon those requirements.

7.2.1 Personalization

Some companies have more than one person linked to robot services and maintenance, which was the case in Volvo Trucks. It was evident that in companies of that size, several people share the maintenance responsibility and are distributed across specific issues, such as, electrical-, mechanical- and software issues, etc. Given that each person's main interest could vary, we believe that a system that could be personalized may meet the needs for all kinds of technicians. This could be done by enabling user profiles so that each user can customize the system to their preferences.

For example, a software technician might want notifications only when there are issues related to the software, whereas a mechanical engineer only wants notification when problems such as robot arm failure occurs.

C3 explicitly said that he wished for an area where he can define his own information. By this, he meant that he wanted to choose what information retrieved from the robot that is valuable for him and adjust the interface to show that information. This also implies that C3 can benefit from removing the information he finds unnecessary.

7.2.2 Responsive design

From the interviews, it became clear that each individual has their own preferences. Informant C1 did not feel comfortable using a smartphone, but preferred a regular desktop computer, whereas informant C3 could imagine himself conveniently using a tablet in the plant. Hence, a new remote robotic service system ought to use responsive design in the sense that the layout is displayed gracefully independent of the device being used. This means that the layout is displayed differently in a smartphone as opposed to on a desktop screen. As an example, clickable links in the smartphone interface should be big enough for the user to be able to press them without accidentally pressing something else due to dexterity issues.

7.2.3 Information about robot downtime

Both informant C2 and C4 highlights the importance of avoiding robot downtime because of the financial damage that it can cause. From the observation in Pågen, it was found that a single robot stop in the packaging site causes the whole line of robots to stop as they are all dependent on each other. Therefore, it could be assumed that one robot can have negative consequences that affects other robots.

There is currently no technological possibility of telling whether an alarm has caused a robot to stop or not. Despite that, the users concern regarding downtime suggests that downtime information should be easily accessible to facilitate analysis.

7.2.4 Spare parts

Our findings imply that there is a need for a new way of handling robot spare parts. This is due to that customers today need to spend a lot of time and effort into keeping track of what spare parts are changing and decide whether to stock them in house or to rely on that the robot manufacturers will have the part the customers seek for. It is also cumbersome to find a spare part that is available in the market and check the compatibility with a particular robot, as mentioned by informants C3, C4 and C5. Moreover, spare parts cost a lot of money and can take a long time to reach a plant which can easily become an issue for robot customers.

The issue with spare parts could partly be handled by integrating an e-commerce solution within the remote service system, making the technicians able to browse for the desired part and check its' compatibility with the desired robot. The problem could also be solved by the robot manufacturers, who could work out a new business model that facilitates the change of spare parts. We suspect however that the incompatibility with new parts and old industrial robots could be part of a planned obsolescence, in the sense that the end-customers must make the choice between buying expensive parts or to buy a completely new robot. As C5 mentioned, it is many times cheaper to buy a new robot, which is why they prefer doing that.

8 Proposed system design: Pythia

A suggestion for a new remote service system was designed to show the results obtained from research on robot technicians and service engineers. We have chosen to call the system Pythia, a name which was used for the priestesses acting as an oracle in Delphi, ancient Greece. The reason this name was chosen was that Pythia provided essential information about what will happen in the future, which is the equivalent purpose of our proposed system: to provide useful hints on how to work proactively. The main intention behind the Pythia system has been to make it self-explanatory, so that robot technicians can understand it without any external help or training. To verify if the system met this overall aim of being easy to use and if the requirements of the users were met, the system was tested with the robot manufacturers and the customers, as seen in chapter 6.

Although the users preferred using the system in a traditional desktop setting, they recognized that there is a scope for the system to be more handy in tablets, simply because tablets are not exposed to industrial environmental damages as much as a traditional desktop setup. Phones were not considered to be practical devices in the near future for a remote service system, but there is still a scope for this market. Hence, the design was chosen in such a manner that it could be easily responsive in all devices and work smoothly in cross platform devices.

Ten screens were designed in detail for the final prototype in Photoshop. Data from the MyRobot demo system was used in most places instead of dummy text, so that the users get a better understanding of what information the screens convey and what can be interacted upon. As compared to the MyRobot system, the Pythia system omits redundant visualizations and welcome messages. Robot technicians would not want to be welcomed every time they open the system to check about alarms or services. Informant C3 mention that they want to get to the vital information immediately instant of welcoming. Similarly, tables were more descriptive and easier to understand according to informants C3, C4 and C5 to get a quick overview instead of donut charts and bar graphs.

The Pythia system aimed at incorporating everything related to service and maintenance of the robots in one place, making it easy for the customers. Today, MyRobot is used only to get basic information about robots such as specifications, alarms, diagnostics and predictions. The service history now is in the form of invoices and other paper documents that are filed, in a box file. The event log and alarm lists are filed similarly. There is no way to get spare parts within MyRobot and therefore ABB customers have to go the Enterprise Customer Portal, which is a separate system within ABB, to see spare parts details and then purchase if it is compatible with the robot. Hence, to avoid the hassle of having robot services information in different platforms and environments, these were all integrated together into the Pythia system so that they can be accessed anywhere in any device.

Figure 17 below shows the homepage of the system with the relevant tables for the user. This was the most difficult page to design, as it was not clear what was the most important information to be placed in the start screen and how it should be placed. The right side of the screen was denoted for the important contact details from the robot manufacturers to call for maintenance and problems.

The rest of the two thirds of the screen initially showed latest alarm overviews and maintenance history. Though it was later realized from ABB Robotics that predictions were more important to include in the home screen instead of the maintenance history. The alarms in the overview table are differentiated with the help of the colored indicators shown in the figure 17. The yellows indicate warnings and the reds serious alarms, as shown in the icons. The indicators have a number next to the icon to show the number of alarms or warnings the robot has. The redundancy of using both icons and colors were to eliminate the problem with color blindness.

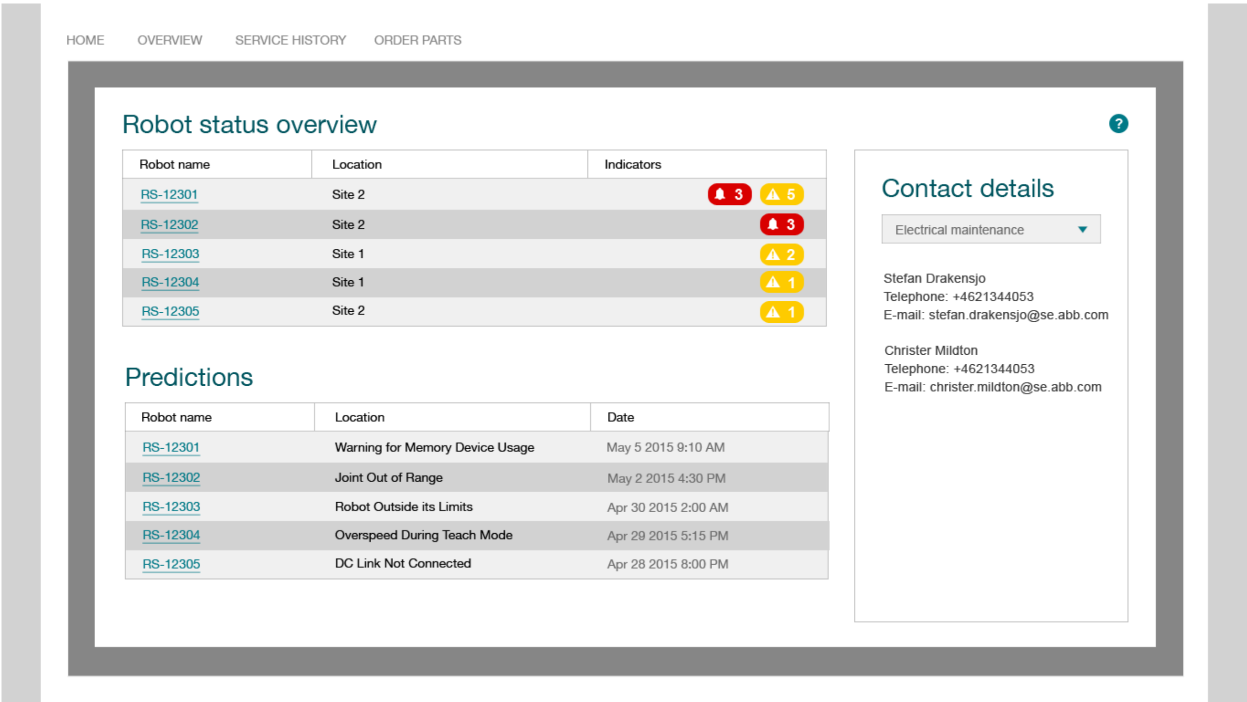

Figure 17. Home screen used for external user tests.

The system has four menu options on the top in gray, this helps the user to traverse between different overview information of all the robots using the remote services. The figure 18 below shows four tabs within the page, and these gives various detailed information about a specific robot in this case a robot called RS-12301. In the MyRobot application as shown earlier in figure 4, the specific robot information opens in a new window as a stand alone with nine tabs of information. Figure 4 has a picture of a robot, this just takes up lot of space and not useful for the users and the news feed in the screen is just a part of event logs and alarms. Figure 18 below shows the downsized version with just the vital information, the robot details in the page combines information from figure 4 & 5 into one screen. Diagnostics is just a lot of readings and specifications of the robot and hence it makes more sense to be combined with the robot details page. Based on information from the users, only what was really relevant and important for them to keep the production up and running was kept and the rest was scrapped.

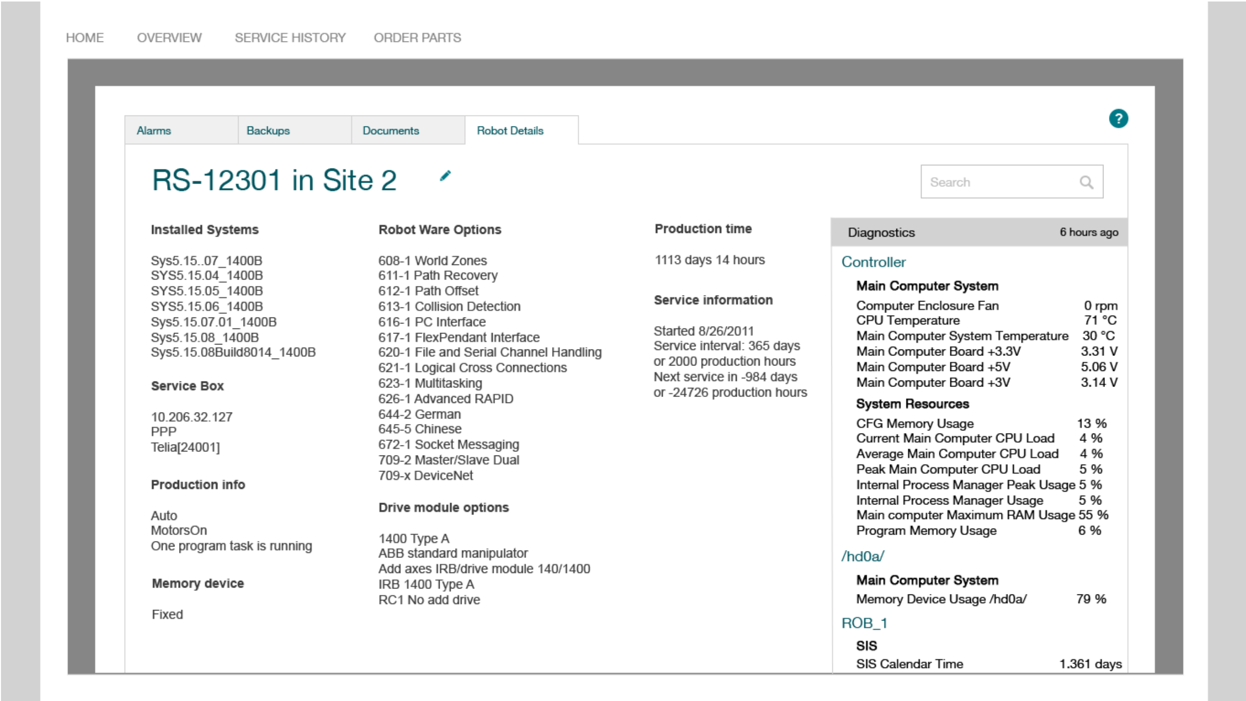

Figure 18. Robot details page of a specific robot.

The rest of the screens of the Pythia system can be seen in the **Appendix 2**. The Overview tab shows all the robots in the system with the latest information on location, alarms, last backup and so on that can be categorized and chosen by the user. The Service history shows all the information of various services and maintenance done by the robotic manufacturers in a list. The Spare parts, shows all the spare parts available in the nearest locations. Since the parts go obsolete so fast, they can be checked for compatibility with the robot before purchasing. All the pages shows information in the form of lists and tables to keep it consistent and clear for the users.

9 Discussion

The discussion chapter is divided into three parts. The first part is a reflection of the results gained from the study. The second part is a process discussion which reflects on the overall design process, the challenges faced and the things we believe could have been done differently. Lastly, the third part is a section suggesting future research that can be done in the field of remote robotic services.

9.1 Result discussion

9.1.1 Understanding the needs of robot customers

Our study shows that customers of remote services may not make use of them, even though they have been paid for. The system is usually lost in a package with several other systems and customers could just renew it regularly without realizing that they have it. Meaning, it was hard to find out the users of the MyRobot system even though the log was provided by the company. When the IP addresses were tracked for this system it was observed that most lead to just one number suggesting that probably an IT person sitting at the manufacturing company logged in to verify or set username and details. It was also interesting to note that the companies in the list was vast with companies ranging from a few tens of robots to over a 1000 robots as opposed by the claim of ABB that the typical users of MyRobot is companies with around 50 robots.

9.1.2 Handling alarms

Currently there is no way of finding out whether an alarm has caused a robot to stop or not. We believe however, that what is limited by technical possibilities today does not have to be considered to such an extent that it limits creative thinking. Today, alarms show up in MyRobot even if they are not relevant. There are several thousands of different alarms caused by robots and most of the alarms are not usually serious issues, nor causing stops. The companies have a whole compiled list of alarm and error codes, meaning there is definitely a possibility to sort them out based on the intensity of the alarms. Currently the system has too many alarms, and the robot technicians are not even concerned about most of the alarms. And to cancel these event logs, there is a team of employees outsourced in India, who patiently finish all the started alarms.

As interaction designers, the prior knowledge of robotic alarms and their codes was limited and hence it was difficult to design a system that could allow categorization of the issues. The Pythia system now allows robots to be sorted out based on the robots having an alarm or not. Nevertheless the future scope of this project could easily allow the sorting of robots based on the type of the alarm. Pythia was meant to be personalizable and hence in settings it should be allowed to change the alarm categories based on different customer needs and priorities on errors and stops. Such an ability to filter and track down the information that really interests the customers leads to more scope of using and analyzing big data to keep the production run smoothly day and night. This also leads to the scope of personalizing notifications, for instance a user might want to get notifications of just serious collision alarms on his phone instead of getting every single trivial alarm the robot gives. Today when such an intense alarm occurs, somebody down in the plant phone calls the technician to visit and fix the problem. So this new feature can lead to faster and smoother transition of information.

9.1.3 Ordering spare parts

Spare parts is another major hassle in the robotics world. The leading robotic manufacturers constantly come up with new robot models and there are new motors and other spare parts releasing every month. Such a fast pace of innovation leads to fast obsolescence. And to top this off, spare parts are usually expensive to stock and might end up being cheaper buying a brand new robot. Getting a spare part also takes a very long time for most customers. Due to so many issues and new models coming up all the time, there is always an issue of compatibility with the spare part and the robot. The bigger end customers due to high production demands tend to stock their spare parts whereas much smaller companies are dependent on the manufacturers when they need a new spare part. Having a spare parts pools based on proximity can really help solve the problem for all the different customers. Robot manufacturing companies arranging these warehouse pools would be the cheapest and efficient way of solving the problem for all in the future. This solution also promotes sustainability and reusability while making profits for both manufacturers and customers. Since spare parts are expensive, the readily availability of spare parts would lead the customers to servicing existing robots instead of purchasing brand new ones. Also for the customers fixing a spare part is definitely faster than ordering a new robot, setting it up and programming it.

9.2 Process Discussion

9.2.1 Difficulties setting a research question

When it was decided that the thesis should concern a system for remote service system in the field of robotics, a structure had to be worked out as we lacked prior knowledge of the field. Furthermore, as no supervision or guidance was provided from the companies involved, there was a need from our side to quickly form a research question to obtain something tangible that could serve as a starting point. The IT consultant firm who initiated the project, highlighted the importance in exploring different devices for the remote service system. We believe this emphasis was due to their current niche in the IT-field, as they focus mostly on the technological side of problems. They stressed that cross platform interfaces should be explored and that a lot of possibilities are opened up by using hand held devices such as smartphones and tablets. As the thesis progressed, we did however understand that just because something is technologically possible, does not mean it is useful or even needed. This insight dawned upon us when we had seen how the end-users actually work, what they think and what they feel they need.

9.2.2 Finding the right methods -methodological issues

There are is an abundance of methods that can be used within interaction design to generate ideas, structure requirements and so forth. It is nonetheless not always evident what method to apply and when to apply it. Even though a time plan had been set and it was clear what had to be done, it was easy to get lost in the process. There was a lot of trial and error when trying out various methods as the value of the outcome was not always anticipated. We realized that some of the work done had to be discarded. There were sketches that did not make sense, ideas that were good, but could not be realized and text written that was interesting, but did not add value to the thesis. Hence, we learned that it is important to sometimes kill your darlings in the sense that one has to swallow the pride and let go of what is not valuable to read in the end.

9.2.3 Getting to the right person

When reaching out for people to participate in the study, we encountered a lot of problems when it came to directly finding the people best suited for interviews. It appeared that most companies have hierarchies and that employees are not always aware of their colleagues' work. Additionally, it was in some cases discovered that it was precarious to call people in the wrong order. In one of the cases the CEO for the company was called directly, whereas a person in between should have been contacted first. This was problematic as it caused some anger from the person who were supposed to get the first call.

A similar problem relating to the same issue, is when companies are so big that the employees don't know the people who make decisions. In ABB Robotics software division team, it was clear that the work they conducted was a request from people they had no contact with. Moreover, the people working on the same things were spread across the world. For instance, one software development team was situated in Poland, whereas some other people working with the same software were located in India.

9.2.4 Unconventional data gathering

The thesis did not only involve a struggle in finding the right people, but also in finding the vital information that should serve as a backbone to the Pythia system. We realized that our data gathering techniques during the thesis started to resemble how Erin Brockovich in the movie *Erin Brockovich* (directed by Steven Soderbergh, 2000) used her charm and wit to get the information she wanted. During the period of interviews, we sensed that some interviewees did not take us seriously and hence might have given off more information than they would if they would feel threatened. We were aware of our presumable lack of power in the world of robotics and tried to use this to our advantage. This insight was also the driving force behind delving into competitors products and services.

9.2.5 Time lost transcribing

A significant part of the thesis work involved transcribing the recorded interview material. This was done carefully as we were afraid that we might miss out important details if not everything was written down. In retrospect, we could have been less accurate when transcribing as each and every spoken sentence in the interviews was not essential to note down. This would have saved us a lot of time which could have been used better in the prototyping phase.

9.3 Future work

There are several topics not studied in this thesis which could be explored more in the future. For instance, studies could be made to find out why the robotics industry is conservative in using remote services and try to find out how they could change in order to open up for the ever advancing technologies.

Several companies have extensive privacy policies and firewalls. Opening up to remote services with a healthy mindset could benefit both customers and manufacturers in data analysis and ensure a smoother system. The robot specifications information, event logs and the likes, are dependent on the robots and independent of what the customers manufacture in the plant. Hence, making this data public would not affect the customers negatively, but rather help in better data analysis and constructive feedback to keep the production running smoothly.

Providing a chat service system to help in remote maintenance of robots and other related issues, could turn out to be helpful in the future. This can particularly be useful for customers that are harder to access in person, due to their geographical location for instance. It also creates more opportunities to customers that have limited robotic knowledge to learn and clarify doubts effortlessly without depending on external physical help.

There are several different models of robots, and each robot has different specification sheets. Robot manufacturers provide guidance for how the robots should be taken care of, such as daily cleaning etc. and today this information comes in paper form. An idea generated from the brainstorming was to have this information more accessible, by using QR codes on each specific robot cell. This could facilitate for people working close to the robots to remember how to do things as well as to provide a help tool for people new to the work routines. In the interview with SKF, it was suggested that tablets could have a positive impact on the work due to the robustness and protection from industrial dust along with its screen size and portability. Hence, technicians walking in the plants with the help of a tablet or smartphone can scan the code on the robot cell to retrieve information about the details. This concept went beyond the time frame of this thesis. We believe it could be further investigated how QR codes could be of use in the industry.

The issue of buying spare parts or storing them, is another major issue for both robot manufacturers and their customers, as spare parts turn obsolete very fast. In the future, there is a scope to use technology and cloud networks to better deal with the spare parts problem. Having a shared proximity based warehouse for the manufacturers and customers near the facility can work for the near future. With the advent in technology today, the physical warehouse could turn to a virtual warehouse pool for spare parts, like the airbnb networks, to eliminate the waiting time. This could be realized by customers and manufacturers having spare parts in their company house for mutual sharing.

Another issue that is lacking now and can be touched upon in the future, is advertising. Our study points to that both robot manufacturers side and customers are not aware of the existence of remote robotic services, such as the MyRobot system. Making more people aware of this is a start.

Warehouse pooling and big data analysis of alarms, for proactive maintenance, could essential for the future of remote robotic services. What is impossible today, might be possible tomorrow and therefore, as interaction designers, it is important not to constrain the mind based on the current technical possibilities. We believe that by pushing the limits, innovation can be reached and that is how new business opportunities within the robotics field emerge.

10 Conclusion

This thesis has provided insight of the needs of industrial robot customers that use remote robotic services. Using ABB’s MyRobot as a case, a gap was found between what these services offer today, from what functionality robot end-customers wish to have. Our study revealed that no end-users was involved in any part of the design process before MyRobot was conceptualized and designed. The consequences of designing and developing using a top-down process resulted in a service that was not used as ABB Robotics intended as several customers did not renew their service agreement contracts. This study also points to that many customers do not currently see the benefit, nor the purpose of using a remote robotic service system. Due to widespread conservatism in the industry, both robot manufacturers and robot customers have not yet realized the full potential of remote service solutions.

To pinpoint the users for remote services, it is essential to conduct user research and gaining a proper understanding of how people actually work with robots in various factory plants. By designing through the lens of interaction design, both current, as well as the potential users for remote services were identified. The main user group has in this case proved to be robot maintenance technicians.

The maintenance technicians provided information that formed a requirements base for a new remote service system which we chose to call Pythia. In this alternative solution, essential information (alarms, robot details, backup information, service history and an e-commerce for spare parts) is collected into one place. The system lets the users define their own data and to decide for themselves what makes is important for them or not, as several features in the system are customizable. In the integrated e-commerce, Pythia allows for a compatibility check of spare parts so that the process of buying them becomes easier. The system also visualizes robot downtime as that is a crucial aspect to automation.

The feedback regarding the Pythia system was positive and seems promising, although the possibility to calculate robot downtime is not possible today. Nevertheless, Pythia points towards a future where a remote service system can support solving problems proactively to keep productions up and running. Not all robot technicians in companies are well versed with all the possible problems that could occur, hence the system is designed so that the information helps all the different levels of expertise, given that information can be defined and customized.

In summary, critical aspects that should be adressed when striving to design a successful remote robotic service from an interaction design perspective, is to recognize the users. Lack of user research makes it impossible to identify actual users and their needs, and vital user activities can be left concealed if they are not observed. Successful interaction design always begins and ends with people.

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Appendix I

Pythia system requirements

General [G]

- **G1** Filter search results by
  - Robot brand name
  - Defined time range
- **G2** Search function by text input
- **G3** Possibility to categorise all the different lists (eg. alarms, spare parts) by column
- **G4** Responsive scaling of the graphical layout
- **G5** Clickable breadcrumbs to help a user figure out where she is
- **G6** Function to retrieve lost password in an email

Service Information [SI]

- **SI1** A full list of robot error codes with explanations [cheat sheets]
- **SI2** Full access to robot specification sheets from robotics companies
- **SI3** Full agreement details of the system and remote services
- **SI4** List of backup history and options for restoring them
- **SI5** Full list of what data is collected and sent from the robots to the robotic companies (options for what data can be bought)
- **SI6** Remote maintenance history, providing a list of:
  - Time and date
  - Specification of the work conducted
  - Cost
- **SI7** A complete list of available spare parts for every robot model
- **SI8** Prediction of mechanical and technical issues for proactive maintenance
- **SI9** Complete list of spare parts history
  - Date of purchase
  - Cost

Notifications [N]

- **N1** Send push notifications in the user's mobile phone when one or several robot stops has lasted for longer than a user specified number of minutes
- **N2** Send notifications of when it's time to stock spare parts due to stop of production of them
- **N3** Allow easy customization of notifications
  - The users should be able to choose notifications in the form of e-mails or SMS
  - The user should be able to customize receiving notifications for particular shifts
  - The user should be able to receive selective notifications

Big Data [BD]

- **BD1** Generated robot data accessible for analysis
- **BD2** Statistics for improvement analysis
  - Average time to fix stops for each robot cell
- **BD3** Constantly get data and feedback from customers to improvise

Personalization [P]

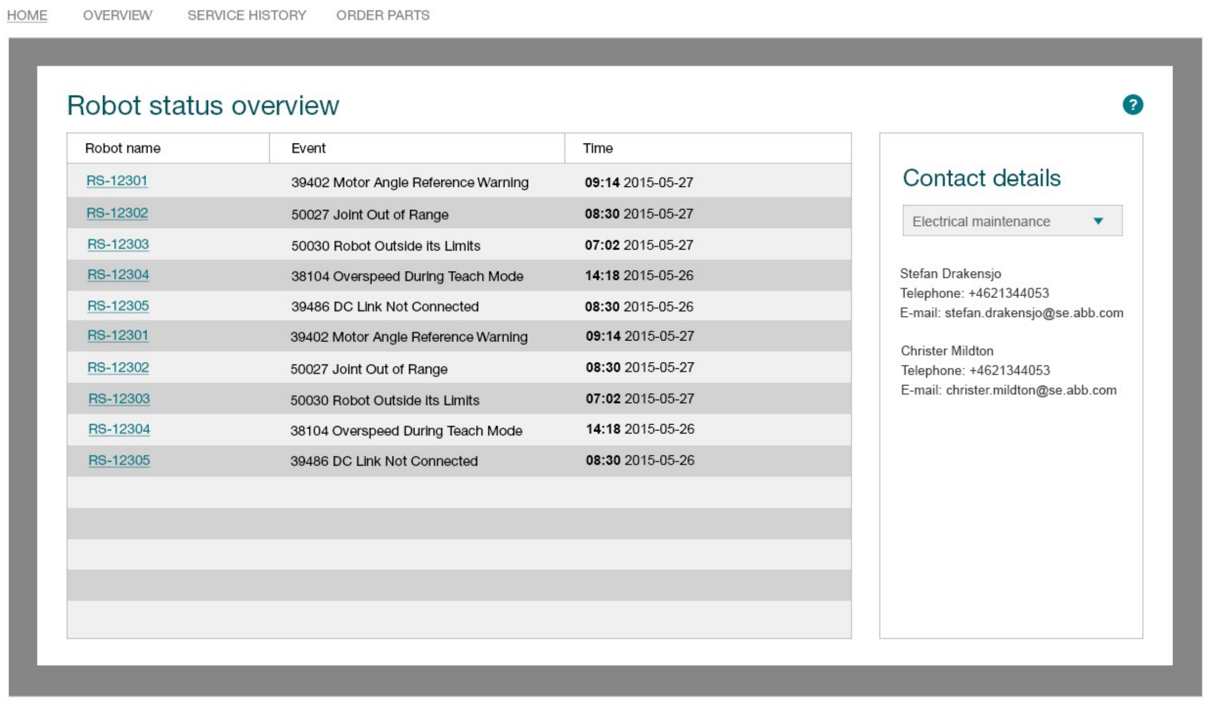
- **P1** The system administrator can manage what parts of the system other users have access to
- **P2** Customization option for what information to be displayed in mobile devices
- **P3** The user can choose what to display in the system dashboard startpage
- **P4** Allowing only certain alarms for notifications
- **P5** Contact details (phone number and email addresses) of
  - Primary contact people from nearest robot manufacturer
  - User specified people

Visualization [V]

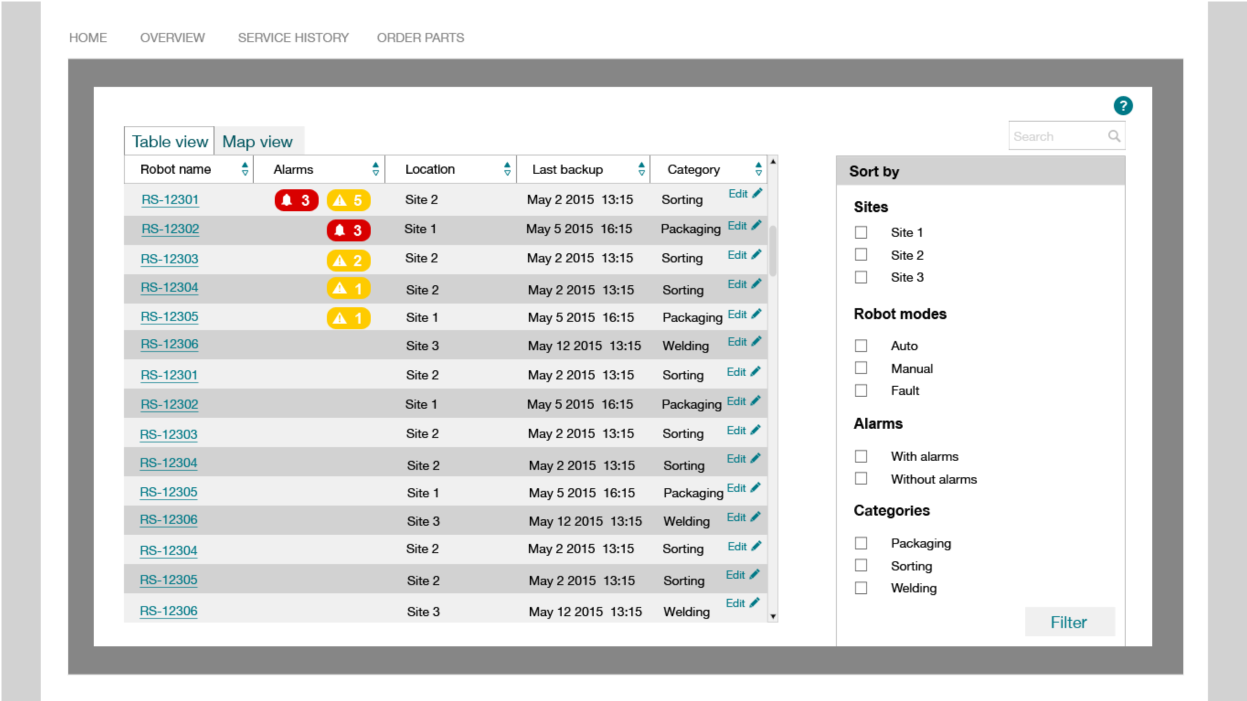
- **V1** Downtime (big) data visualizations
- **V2** Visual overview for the robot with most problems, i.e. problem chart (scatter plot)
- **V3** Visual overview of robot stops during a specified period of time (that can be chosen in the system)
- **V4** List of alarms which has crossed a user specified time (for future analysis)
- **V5** Ability to differentiate data if a company has several plants
- **V6** Show all modes of robot - whether connected or not
- **V7** Option for on demand live stream of specific robots (within CCTV range)
- **V8** Show robot connection status
- **V9** Checklist for daily maintenance when done, swipe phone close to robot and a visual indicates it has been checked
- **V10** Allow users to have or not of graphical representation and raw data

Appendix II

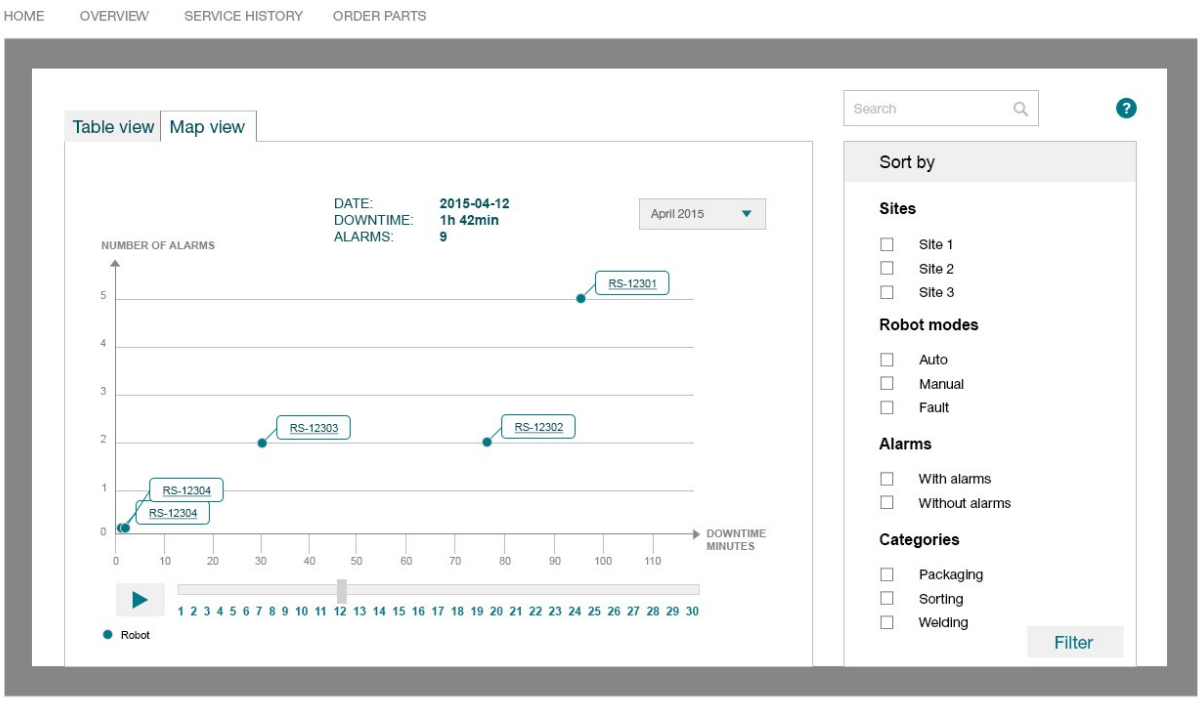
Pythia Mockups



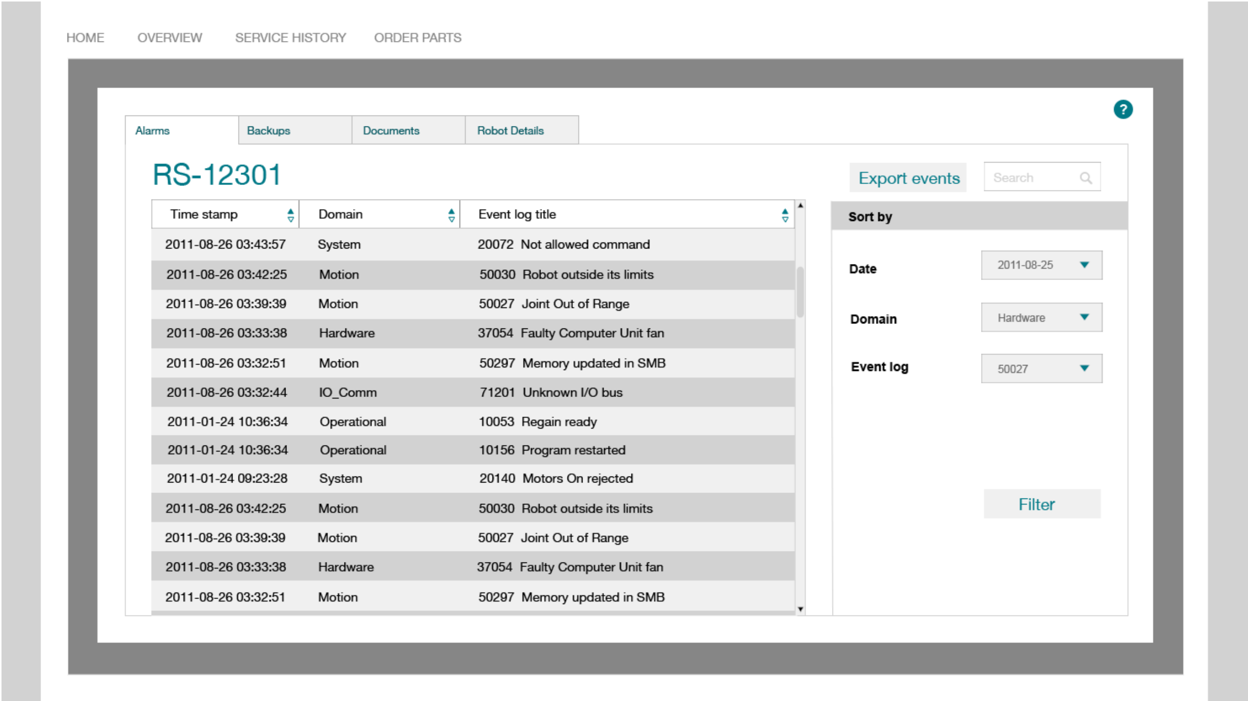
Screen 1. The home screen shows an overview of the latest events, together with the robot that has caused them. The robot names are links leading to a new page with more indepth information. To the right is a dropdown list with contact information to staff from the robot manufacturing companies.



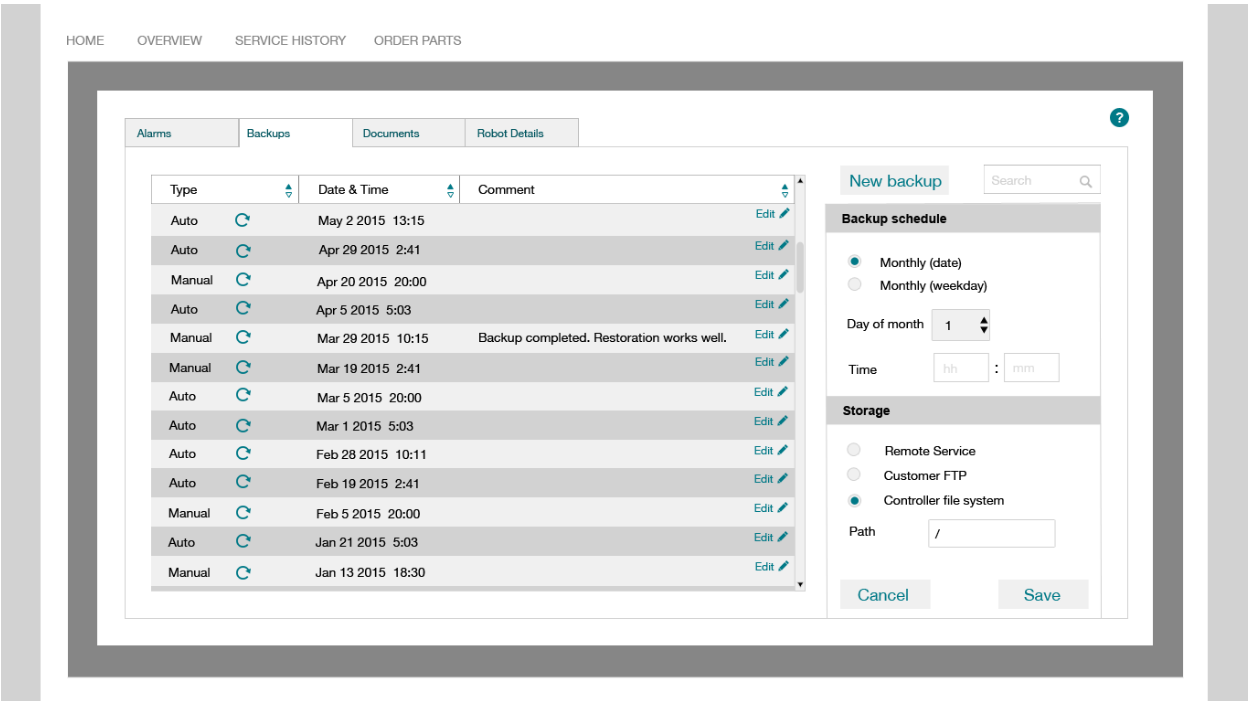
Screen 2. Overview screen showing the table view of all the robots in the system.



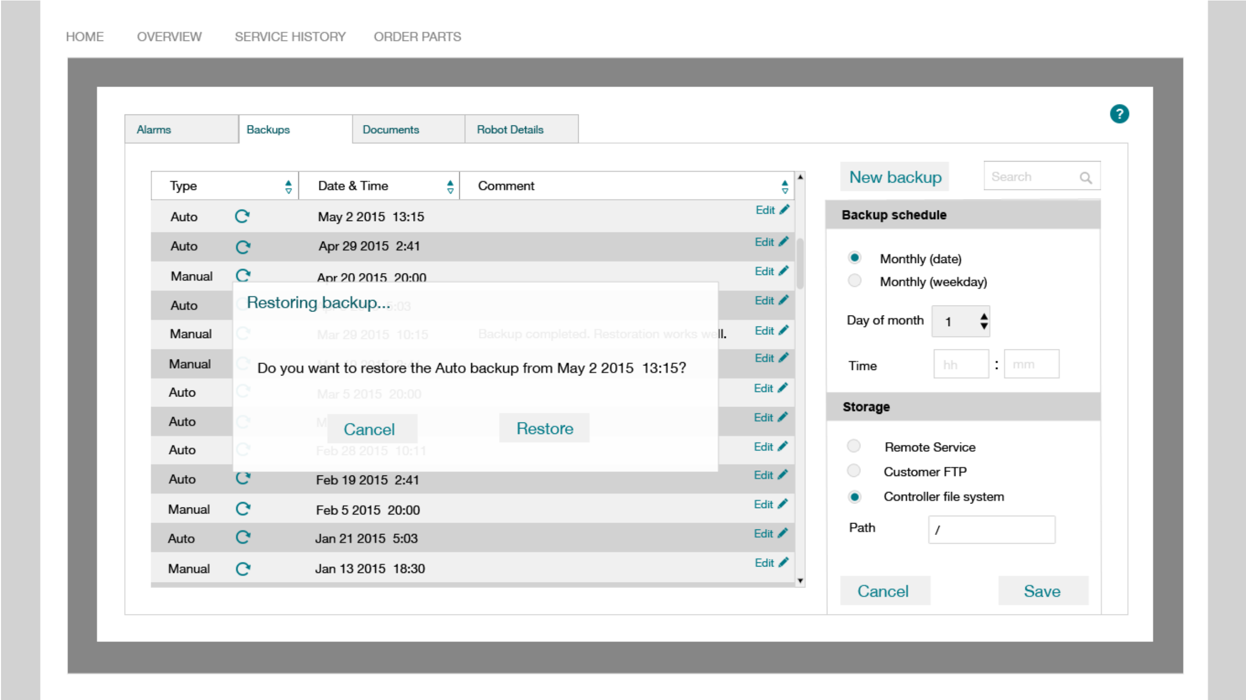
Screen 3. Overview screen showing the map view of all the robots in the system.



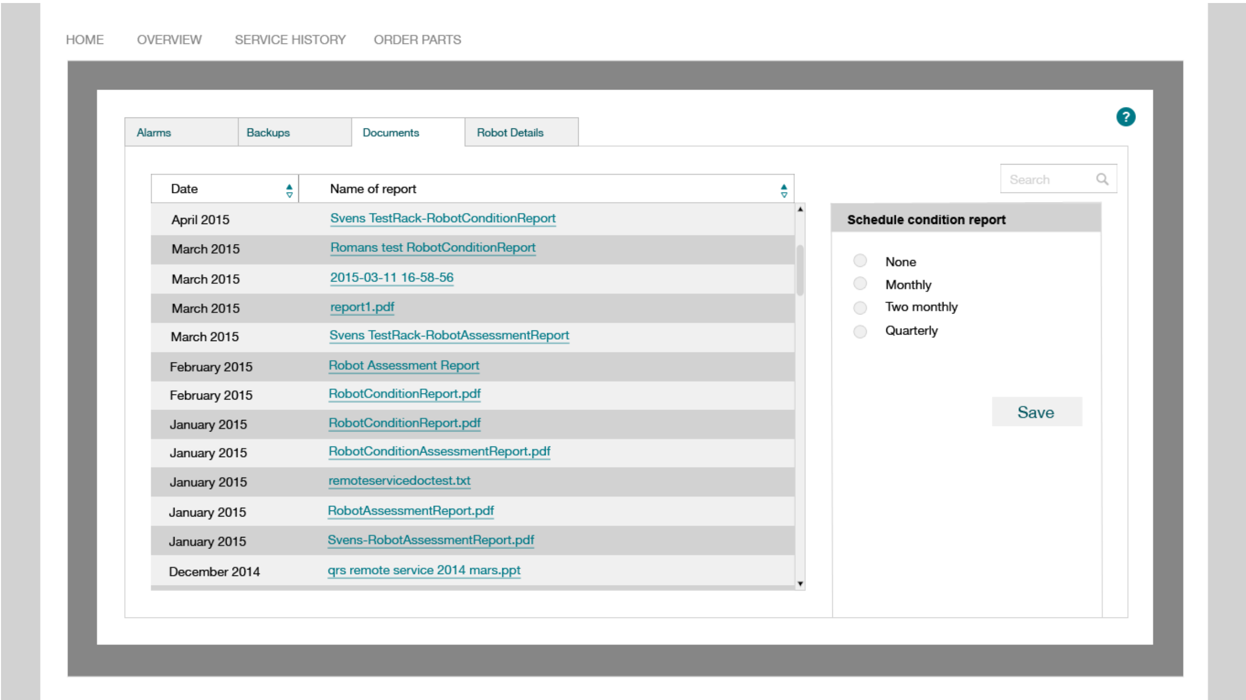
Screen 4. Robot specific page showing all its alarms.



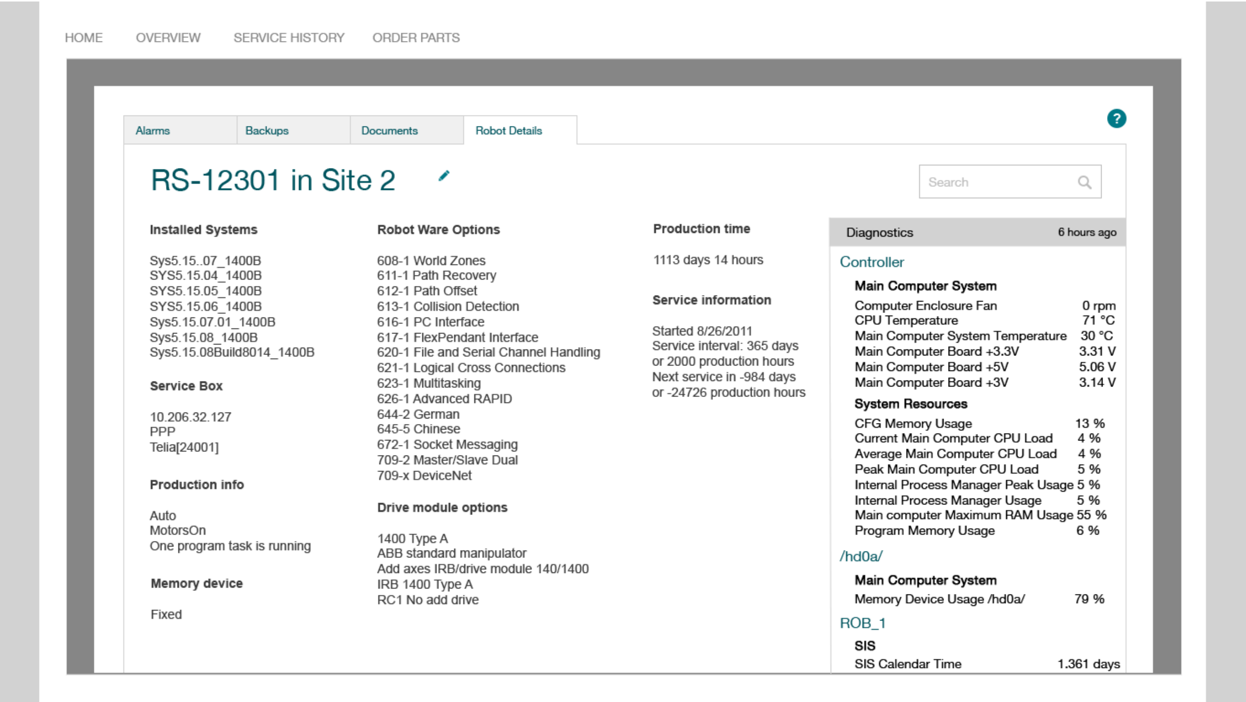
Screen 5. Robot specific page showing a list of all its backups.



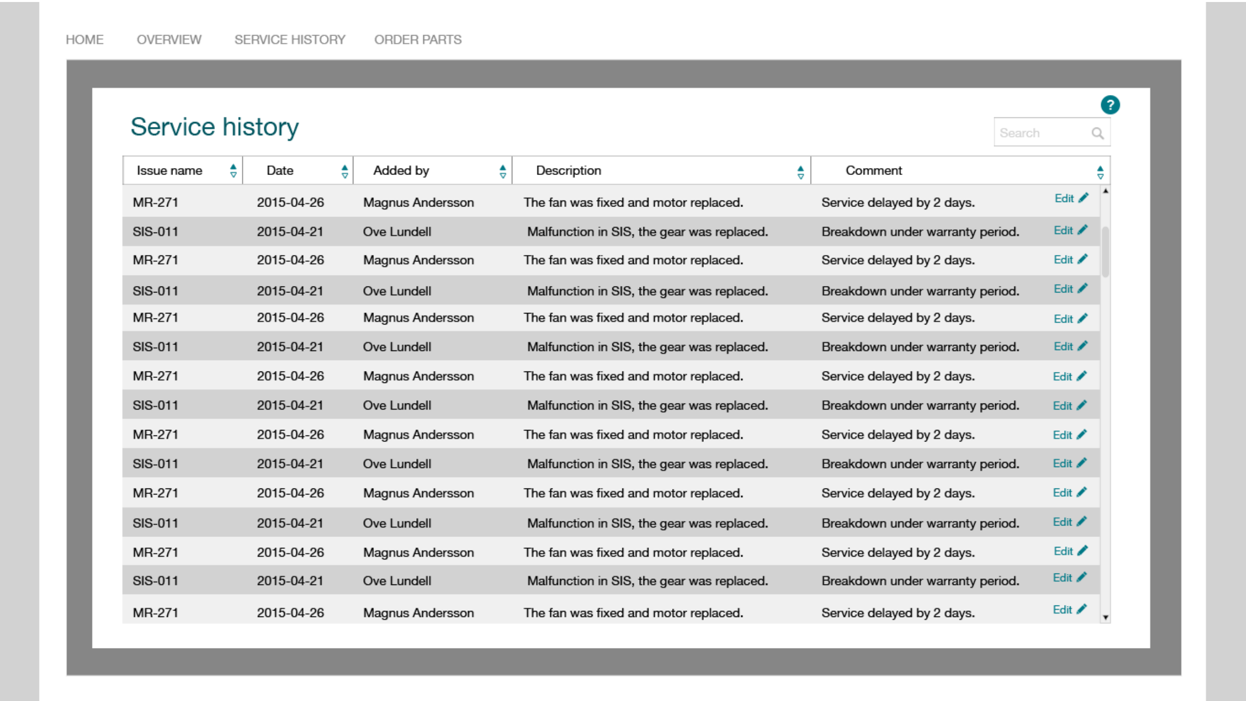
Screen 6. Robot specific page showing a restoration of a backup from its list of backups.



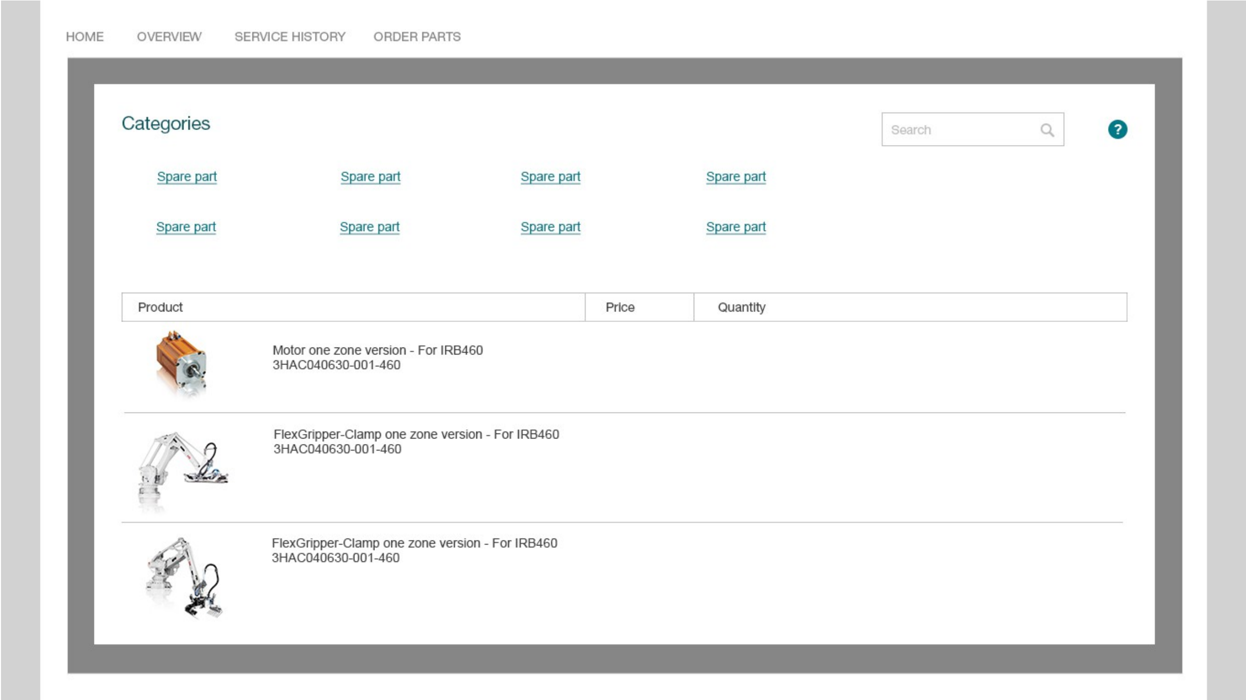
Screen 7. Robot specific page showing a list of all its related documents for view or download.



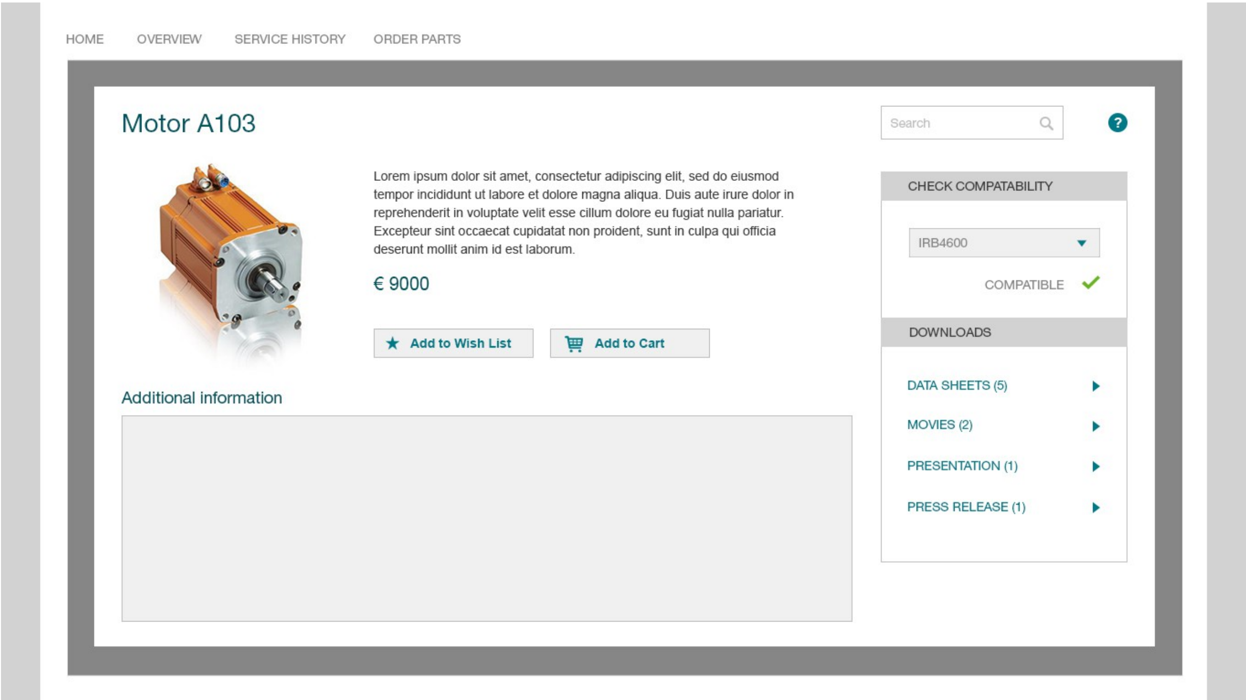
Screen 8. Robot specific page show the robot's specifications and diagnostics.



Screen 9. Service history page showing all the robots' service history in the system.



Screen 10. Spare parts page showing available spare parts sorted on categories.



Screen 11. Spare parts detail page displaying information on a particular spare part. It includes a compatibility check for different robot models in the dropdown list to the right. It also provides the user with an option to either store the spare part in a wishlist or to purchase it directly, by adding it to a cart.