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Enhanced communication support between control room and field operation

Human communication and interaction

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Master of Science in Engineering Cybernetics

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Problem Description

The objective is to implement a functional prototype of a mobile device for enhanced communication support based on selected theories and models of communication between humans, human information processing and/or human-machine interaction.

The focus of the project is to study technical solutions for a mobile device based on requirements from the human users and the environment (process plant) within which it will be used.

The work consists of a theoretical and a practical part. Initially a review of the state of the art for cognitive models for human communication and collaboration will make the basis for a mobile communication device to improve communication between the control room and the field. Based on this work, a functional prototype will be developed to overcome problems with today's limited two-way radio communication.

Assignment given: 08. January 2007
Supervisor: Charlotte Skovrup, ITK

Abstract

Communication between the field operator and the control room operator is vital for successful operation in the process industry. By reviewing models for human cognition and interpersonal communication and collaboration together with appropriate technology, concepts for enhancing the field operator/control room operator communication are developed. These concepts constitutes the basis for design and implementation of a working prototype. The prototype is utilizing a mobile device with wireless networking abilities.

Evaluation of the concepts concludes that they most likely will enhance communication and decrease erroneous decisions because of higher system awareness and better mental models. This is achieved by introducing data to an operator from the system context of the other operator. The prototype also increases the communication abilities by allowing the operators to interact with each other through pointing and drawing.

Preface

This thesis constitutes the final part of my Master of Science degree in Engineering Cybernetics at the Norwegian University of Science and Technology (NTNU). Considerable parts of the work was carried out at the ABB Strategic R&D for Oil & Gas group in Oslo.

First of all I would like to thank my advisor at ABB, Håkan Silfvernagel and my supervisor at NTNU, Charlotte Skourup. Without their assistance, guidance, discussions and inspiration this thesis work would not have been possible. I would also like to thank the researchers at ABB Strategic R&D for Oil & Gas for their accommodating attitude and will to discuss and share ideas. The working environment has been highly inspiring.

Håkon Nergaard Berg

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Chapter 1

Introduction

In process industry, communication between control room operators and field operators is crucial for successful operation. Today, communication is done mainly using two-way radios. This causes misunderstandings and misinterpretations due to noise and other disturbances, as well as challenges with different mental models among the operators.

Development in communication technology and solutions has been tremendous over the last years, and the process industry has now taken action for utilizing this growth with the Integrated Operations initiative, among others. Integrated Operations (IO) is

a program for improvement of the value creation potential on the Norwegian Continental Shelf (NCS) by improving the quality and the speed of key work processes onshore and offshore. [1]

The objective of this thesis is to focus on the collaboration between control room and field, and investigate the possibility of using new technology to enhance the communication between them. The prototype should consist of a mobile device on the field operator side. This mobile device supports wireless technologies for networking.

First a brief analysis of the system, its boundaries and members is given. Secondly, an overview of human communication and cognition is explained, introducing well established models as well as new thoughts on the subject. Finally, the design and implementation of a prototype demonstrating concepts for enhanced operator communication are thoroughly presented.

Chapter 2

System Analysis

Chapter 2 performs an analysis of the system in this thesis. A model of the system contents is presented confining what the specific system actually is. Further, a task analysis describes what typical field operator tasks are. Scenarios are introduced to give an impression of how collaboration between the field operator and control room operator and tasks are handled.

2.1 System Model

The essential part of system analysis is to define and confine the system borders. A system may be defined as:

A part of the world that a person or group of persons during some time interval and for some purpose choose to regard as a whole, consisting of interrelated components, each component characterized by properties that are selected as being relevant to the purpose [2].

In this thesis, the system is defined and limited to all relevant/inter-relating components in the communication process between a field operator and a control room operator. The main components of the system are a process plant, a field operator, a control room operator and a control system, as illustrated in Figure 2.1. The control room operator is responsible for managing the process from the control room. The control room gives the control room operator access to a wide range of information such as measurements, analyses, historical trends, piping and instrumentation diagrams, manuals, maintenance and repair documentation and logbooks. Compared to control room operators the field operator has a very limited access to information. Situated out in field, he has direct contact with the process and the instruments. Instrument readings are his primary source of information, together with what his senses tell him of the situation (hearing, smelling, touching) [3].

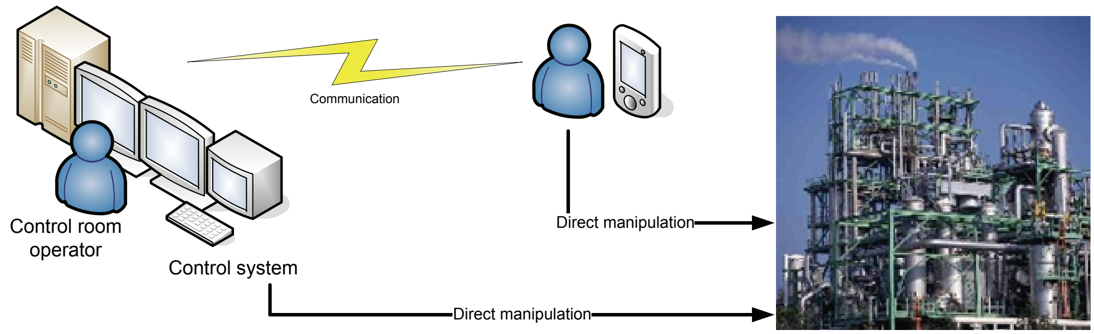


Figure 2.1: *The original system model*

2.2 Current Communication System

Almost all communication between control room and field operation is today done by two-way radio, also known as walkie-talkies. Walkie-talkies are now a well-established means of communication. They were essentially created for military use, but the industry has adopted them because of the ease of use when sharing information and as a discussion device. Such a system usually supports broadcasted half-duplex communication, meaning that only one person can talk at a time, and all messages are available to everybody.

Two-way radio's maybe biggest weakness is its quite limited bandwidth. With modern digital radio, this ability has been improved, but compared to other modern wireless technologies, it is still weak.

2.3 Task Analysis

The field operator's work tasks are by Skourup and Reigstad [3] suggested divided into four categories:

- **Routine operations:** Routine operations are tasks required for the daily operation of the process, and is typically communication between the control room and field to get data from the automated system.
- **Special operations:** Special operations include start-up and shut-down of process sections. The field operator adjusts set points on equipment, and monitors the process, assuring that everything is in order. Special operations often require extensive communication between the control room and field to secure safe operation.

- **Maintenance and repair:** Maintenance and repair is a divided task. They have to plan what working orders they need, collect instrument documentation and get a security clearance. The field operator performs the actual maintenance or repair following procedures and checklists, reading the documentation, and communicating with the control room and experts.

- **Inspection:** Inspections are quite similar to maintenance and repair, but does generally not require the same amount of interaction with the control room. As with maintenance and repair, the field operator gathers documentation and work orders, and gets the correct security clearance. The actual inspection is done in the same fashion as with maintenance and repair; he follows procedures and checklists, and reads and understands the documentation and work orders.

2.3.1 Visit to Tjeldbergodden Industrial Complex

As a part of the system understanding, a visit to Tjeldbergodden industrial complex was scheduled. Tjeldbergodden industrial complex is one of Statoil's onshore production facilities in Norway. It consists of four plants[1]:

- A methanol plant
- A gas receiving station
- An air separation plant
- A gas liquefaction facility

During the visit, the main source of information gathering was to follow and observe a field operator during a shift. This gave a good impression of common communication between the control room and other field operators. A field operator is the jack-of-all-trades in process industry. He is responsible for assuring that the production is going non-stop. His tasks include debugging, maintenance, repairing, adjusting and monitoring the actual production lines and appurtenant instruments. The control room operators have the overall responsibility of the production facility, and the field operators are their eyes and ears in the field, together with the control system, see Figure 2.1.

2.4 Scenarios

Three scenarios are given, illustrating typical operations that need collaboration between field operators and control room to be solved.

[1] More information on Statoil's web pages http://www.statoil.com

1. The field operator contacts the control room operator to ask which pump is positioned next to the inlet to a tank out in the process. The field operator provides the tag-number of the pump. The control room operator looks at the control application at the specific area described by the field operator, but can not locate the pump. They discuss where the pump may be located, and what the function of the pump is. The control room operator discusses the situation with the other control room operators, without identifying which pump it is. A separate system containing all P&ID drawings for the process is used by the control room operator to locate the pump on the original diagrams, but the pump is still not found. The conversation between the field operator and the control room operator continues until they finally agrees upon which pump is has to be, and that this pump is drawn in the wrong place in the P&IDs and the control application. The control room operator writes an error report to get the P&IDs and the control application corrected.

2. The control room operator discovers a parameter change not according to the state of the process. He calls the field operator and asks him to do a reading of the instrumentation and the general situation at the current location. The field operator and the control room operator collaborates about status, readings and the general situation in the process section. From complementary instrument readings in the process and a stable situation, the control room operator concludes that the initial parameter value was wrong.

3. The control room operator gets an alarm from the safety system on a separator. He uses the CCTV camera to detect changes in the process. No changes are discovered, and he calls the field operator to ask him to check out the separator. The field operator and the control room operator go structured through pipes in/out, valves and instruments located around the separator. They discuss possible causes to the alarm, and checks consecutively for potential symptoms, but do not find any. They conclude that the field operator should check the instruments and pipes at designated time lags. The control room operator will pay specific attention to the separator and its surroundings. The field operator and control room operator communicate in a casual normal tone with suggestions, questions and answers from both parties.

Chapter 3

Human Communication and Collaboration

The chapter introduces theory on cognition, communication and collaboration. Starting with mental models, it explains to some extent how humans make an internal interpretation and comprehension of the real world, and how this influence their interaction with it. Further, a brief explanation of the term situation awareness is given and its importance when designing and analyzing systems. Situation awareness is a tool for understanding how system information and state should affect the decision process. A few influential models for human communication are also introduced. These focus on the exchange of information and interplay between humans when communicating. Together, the sections give a good starting point for understanding important elements of human communication and collaboration.

3.1 Mental Models

Studies show that mental models influence problem solving as well as collaboration, see e.g. [4]. A mental model is the cognitive representation of human understanding. When humans think and reason they manipulate these internal models. Human beings understand the world by constructing working models of it in their minds. Being incomplete, these models are simpler than the entities they represent and just mimics their behavior [5]. The idea of mental models is believed to be first introduced by Kenneth Craik:

> *If the organism carries a "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and the future, and in every way react in a much fuller, safer, and more competent manner to the emergencies which face it.*

Quote of Craik by P. N. Johnson-Laird [6].

Johnson-Laird explains that since these models represent only certain aspects of the situation, there exists a many-to-one mapping from the real world to the mental models.

The introduction of mental models leads to the fact that interaction with two models is required when a system is to be manipulated; first, the internal mental model created by the human mind as a representation of the system, and second the actual real world system. As Craik explained, the internal model allows for various approaches for solving a problem; input may be applied to the model, and a response is received. If the response is desirable, the same input may be applied to the real world model. The closer these models match, the better will the understanding and utilization of the real system be. The further apart they are, the bigger is the risk of making an error.

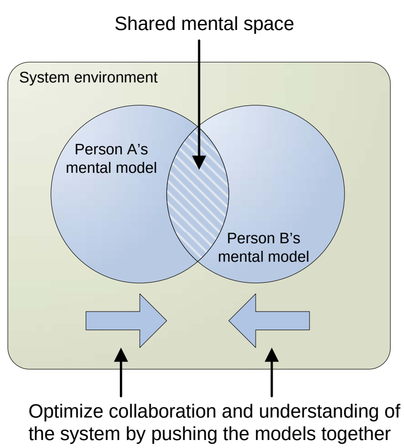


Figure 3.1: *The mental models of two persons collaborating in and about an environment*

Since all people create their own mental models, it is likely to believe that a system as shown in Figure 3.1 is created while collaborating. Hence, to successfully solve a problem, the mental models should be as similar to the real system as possible, but also resemble each other; collaboration issues occur, among other factors, due to different mental models, causing the participants to misconceive. Not resembling the real system may cause them to agree on a potentially wrong decision.

3.2 Situation Awareness

The term Situation Awareness (SA) was created in the 1990's. The most influential definition of SA is that of Endsley [7] regarding large, complex and dynamic processes:

> *"The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future."*

In other words, SA is a measurement on how well the system design supports the operator's ability to get the needed information under dynamic operational constraints.

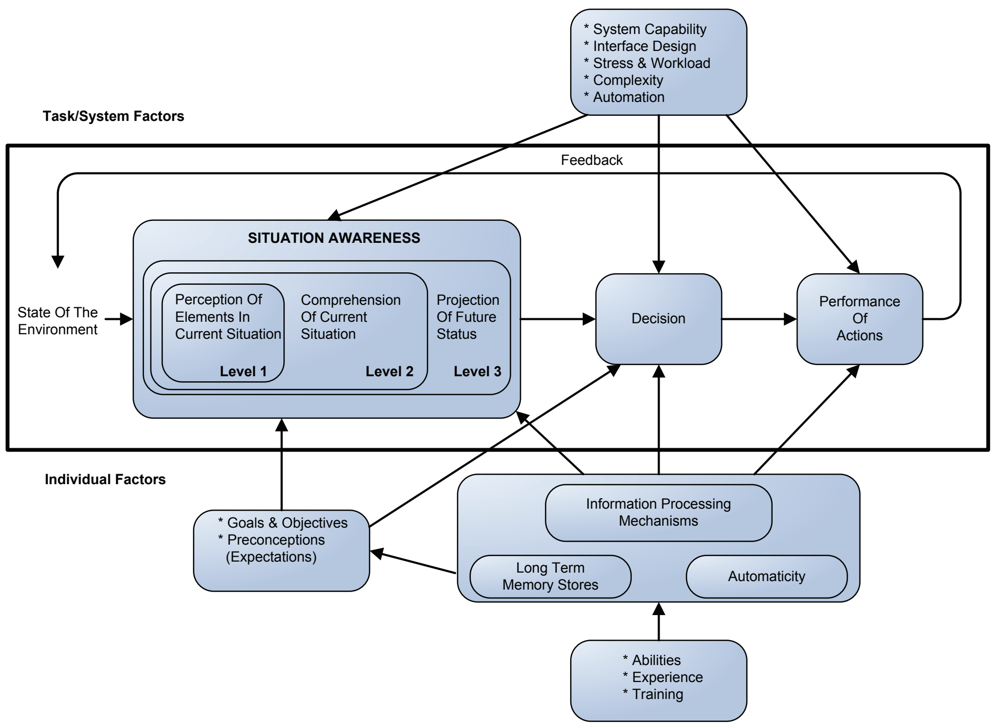


Figure 3.2: *Endsley's model of Situation Awareness in dynamic decision making*

Figure 3.2 [8] displays Endsley's model on SA decision making. Endsley describes the three levels of Situation Awareness:

- **Level 1 SA** explains the need to perceive important information. Without this ability, the probability of creating an incorrect picture of the situation will increase dramatically.
- **Level 2 SA** describes the need for comprehension; combining pieces of information, and evaluating their relevance.
- **Level 3 SA** explains the ability to forecast future states of the system. This level requires the highest knowledge and understanding of the system.

This situation awareness model can be used for understanding which factors, information and processes influence the decision making process. It focuses on mechanisms important for making the correct decisions in a particular situation.

3.3 Human Communication Models

The aim of communication models is to describe communication and make a good representation of it in a definite fashion. Communication has always been a topic of interest for researchers ranging from philosophers to system theoreticians and mathematicians. The first models recorded date back to the Antiquity. Aristotle is one of the Greek philosophers concerned with human communication. The model is fundamental in Greek rhetoric and his work is still of importance in today's rhetoric theory.

This section introduces a selection of influential communication models in this thesis. Human communication is a very complex process, and to see it from multiple models is crucial for achieving an appropriate understanding of it.

3.3.1 The Shannon-Weaver Mathematical Model

The Shannon-Weaver Mathematical Model of communication is the first widespread model of newer time [9]. Figure 3.3 illustrates Shannon's model. The model is based on probability theory developed by Norbert Wiener, and is, as the name indicates, a mathematical approach to communication. Shannon defines that the fundamental problem of communication, is *"...that of reproducing at one point either exactly or approximately a message selected at another point."* The model explains how important informational aspects lies not only in the message itself, but also in the fact that this message was selected from a set of available messages. This gives the message *meaning*. The model consists of five parts:

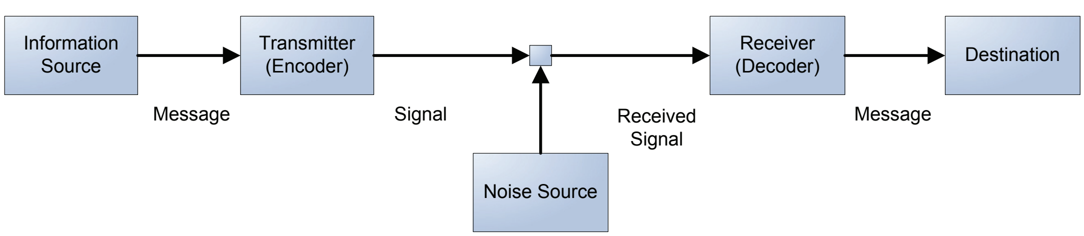


Figure 3.3: *Shannon-Weaver's Mathematical Model*

1. **The information source produces** the message to be communicated. The model is not limited by the type of message: it may vary from a simple array

of letters, $a[n]$, to several functions with several variables; $f(x, y, t)$, $g(x, y, t)$, $h(x, y, t)$.

2. **The transmitter** encodes the message in some way to make it suitable for transmission.

3. **The channel** is located between the transmitter and the receiver. Its only purpose is to transport the message.

4. **The receiver** performs the opposite task of the transmitter; it decodes the signal transported over the channel.

5. **The destination** is the part which the message was intended for.

As an example person A wants to share an idea with a person B. Person A's idea is not available to person B since person B does not have access to A's mind. Hence, if person A wants to share his idea, he has to encode his idea into a signal suitable for transmission if his idea is to be shared. In this case, person A's mind is the information source, the transmitter is person A's mouth and the message is encoded as words. On the other side of the model, person B will have to interpret the received signal. The difference between the sent signal and the received one is due to the noise source located in the middle of the model. The message from person A will probably be given orally through the air. Noise will in this case be represented as other people speaking, distant traffic noise and so forth; basically all sounds except that of person A. Person B interprets (decodes) the signal, hence revealing the message.

The Shannon-Weaver model is very popular due to its simplicity and definite fashion. The communication model is described in a very technical, but accurate way; communication needs a sender and a receiver and is exposed to noise. The noise factor is in particular interesting; it is not always considered a part of communication, but will in many cases be the reason why communication fails.

3.3.2 The S-M-C-R Model

David K. Berlo developed a communication model named S-M-C-R, short for Source-Message-Channel-Receiver [10], as illustrated in Figure 3.4. This model is an adaption of the Shannon-Weaver model, but with a psychological view rather than a mathematical. The model consists of four main parts:

1. **The source** initiates the communication. How the source will operate is dependent on several qualities that the source holds; his communication skills, his attitude towards the subject of communication and the receiver, his knowledge about the topic, and so on.

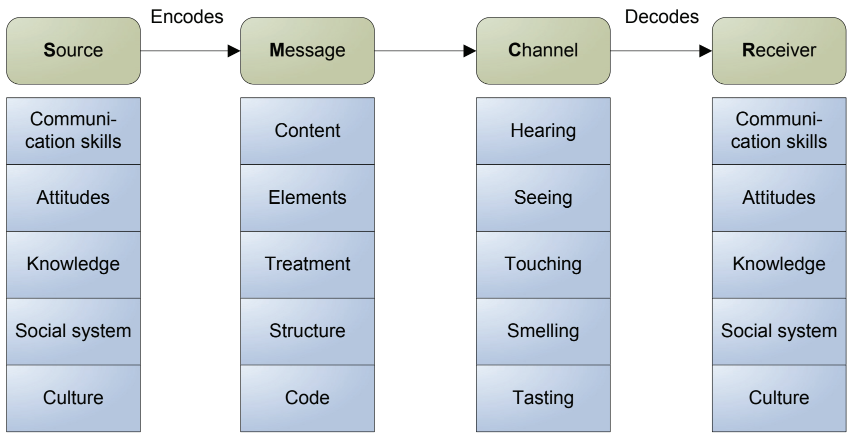


Figure 3.4: *Berlo's S-M-C-R model*

2. **The message** is the representation of the information the source wants to give the receiver. The message's quality is given by its content, how it is treated by both participants and how the source developed it (structure and code).

3. **The channel** is more a human sense in Berlo's model compared to Shannon-Weaver. How is the message transported from source to receiver? In theory, rancid butter gives a person trying to eat it a message about it being old. In this case there are three channels; seeing, smelling and tasting.

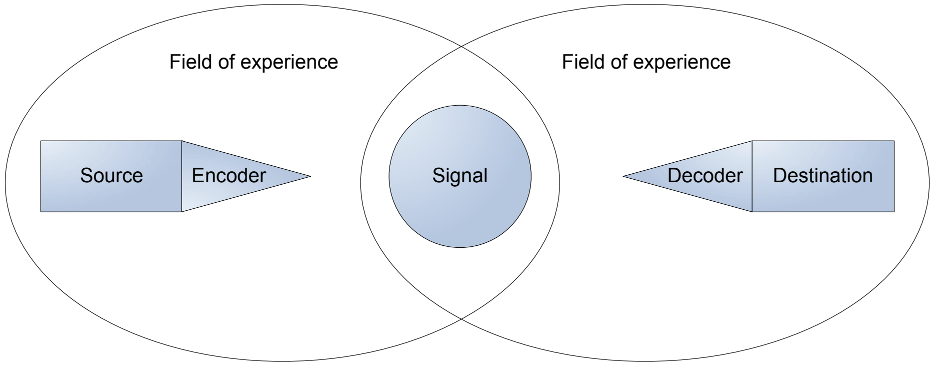
4. **The receiver** is the last segment of the model. His ability to understand the message depends on the same qualities as that of the source.

While the Shannon-Weaver model is accurate and simple, the S-M-C-R model is more diffuse and open. It focuses more on the human factors when communicating; how are they feeling when the communication takes place? How close are they emotionally, how well do they understand each other? These are all questions that will affect the quality of the communication according to Berlo's model.

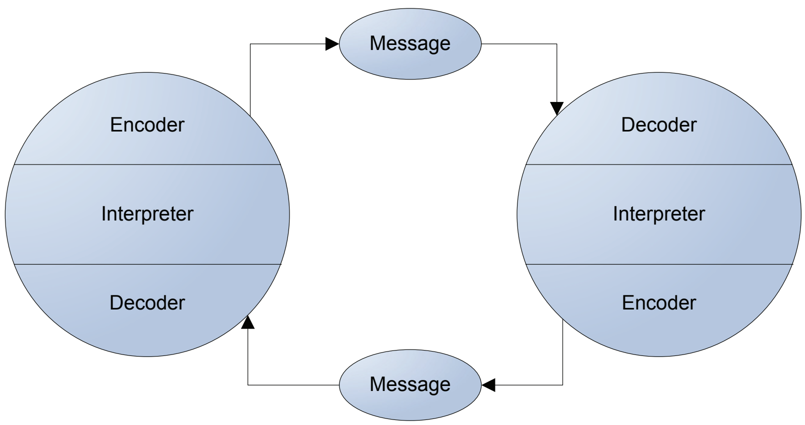
3.3.3 Wilbur Schramm's model

Professor of communication, Wilbur Shramm, further includes the concept of *field of experience* in his model, as illustrated in Figure 3.5(a) [11]. People gain experience through background and culture, and this will widely affect their ability to communicate. For a message to be received and understood as intended by the sender when communicating, it is essential that the sender's and receiver's fields of experience overlap.

"If an African tribesman has never seen or heard of an airplane, he can only decode the sight of a plane in terms of whatever experience he has had. The plane may seem



(a) *Schramm's communication model illustrating field of experience*



(b) *Schramm's communication model illustrating feedback*

Figure 3.5: *Schramm's communication model*

to him to be a bird, and the aviator a god borne on wings."

In addition, Schramm introduced the importance of feedback to overcome noise when communicating. This is shown in Figure 3.5(b). One advantage of feedback is that the sender has the ability to adjust his message depending on the response he gets from the receiver. This represents the natural setting for face-to-face communication, where the sender continually sees and hears the receiver's response. The sender can easily see from the receivers facial expressions that he does not understand a message, and will use this information to adjust his message accordingly.

The introduction of feedback increases the complexity of the communication model. The distinct sender/receiver architecture is replaced by a model where both parties act as sender and receiver.

3.3.4 Kincaid's Convergence Model

The convergence model has a more mental approach to communication than the previous presented models. The model represents communication as a process of dialogue, information sharing, mutual understanding and agreement as well as collective action [12]. In the convergence model, there is no distinct transmission of

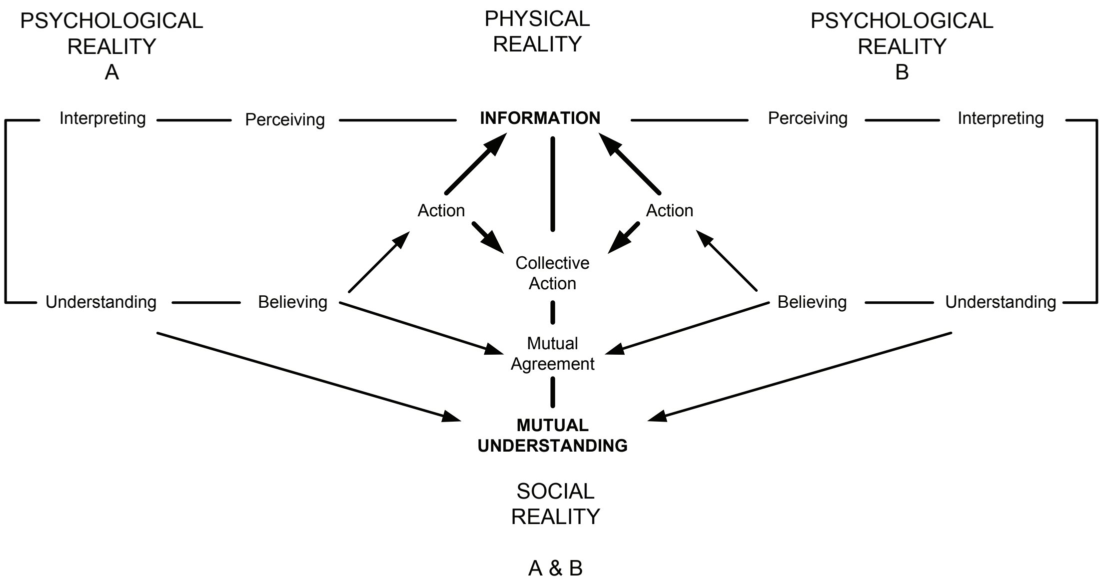


Figure 3.6: *Kincaid's model of convergence.*

information as is the case of the preceding models; information is shared/exchanged between them, not creating a sender/receiver architecture. As information is processed, individual outcomes like *perceiving*, *interpreting*, *understanding* and *believing* are achieved, as well as social outcomes, the *mutual understanding*, *mutual agreement* and *collective action* parts in Figure 3.6. Participants take turn creating information to share, and they interpret and reinterpret this information until they achieve a sufficient level of agreement and understanding. At this point, the participants are ready to make a collective action.

The convergence model shows that communication is a common action between multiple parties. It incorporates difficult concepts like interpreting, perceiving, understanding and believing. Communication itself creates information. The model is quite different from the other models, and gives the last approach to communication in this chapter.

Chapter 4

Technology

The prototype is supposed to include a mobile device with wireless networking abilities. This chapter introduces technology necessary in development of the prototype together with aspects concerning mobile device development in general.

4.1 Wireless Network Technologies

Wireless network is an explosively growing technology platform; it has been one of the driving forces of technology growth the last 15 years. As the need for communication and data transfer increases in the industry, so does the use of wireless technology. This section describes the basics of wireless technology, and serves as an introduction to the network technology to be used in the creation of the prototype.

4.1.1 Wireless Local Area Network

Wireless Local Area Network (WLAN) is the standard for wireless networking. IEEE named it 802.11. WLAN is also known as WiFi. WLAN works in two different modes:

1. In the presence of a base station.
2. In the absence of a base station.

In the former case, all communication goes through an access point, in the latter communication is sent directly, known as ad hoc networking [13].

Currently, there are five subgroups in the 802.11 family using different modulation techniques, but the same protocol. These are:

- 802.11 legacy
- 802.11 a
- 802.11 b

- 802.11 g
- 802.11 n

For a typical WLAN user the important difference between the subgroups is the data rate they can achieve, see Figure 4.1.1.

Protocol	Release Date	Op. Frequency	Data Rate (Typ)	Data Rate (Max)	Range (Indoor)	Range (Outdoor)
Legacy	1997	2.4-2.5 GHz	1 Mbit/s	2 Mbit/s	?	?
802.11a	1999	5.15-5.35/5.47-5.725/5.725-5.875 GHz	25 Mbit/s	54 Mbit/s	~25 meters	~75 meters
802.11b	1999	2.4-2.5 GHz	6.5 Mbit/s	11 Mbit/s	~35 meters	~100 meters
802.11g	2003	2.4-2.5 GHz	25 Mbit/s	54 Mbit/s	~25 meters	~75 meters
802.11n	2007 (unapproved draft)	2.4 GHz or 5 GHz bands	200 Mbit/s	540 Mbit/s	~50 meters	~125 meters

Figure 4.1: *A summary of the different subgroups in the 802.11 family [14].*

4.2 Over IP Technologies

The Internet Protocol has over the last years introduced new services. As an example of such a service, the birth of Voice over IP (VoIP) is explained.

By 1999, the data traffic had catched up with the voice traffic in telecommunication networks. And while the volume of data traffic kept growing (exponentially), voice traffic growth was almost flat [13]. Since the extra bandwidth required to carry voice was small, the operators of the data networks (packet switched networks) realized that they could also offer this service, making additional money with the fibers they already had in the ground. Voice over IP was born.

In its simplest form, VoIP records an audio signal from a recorder, converts it to digital data, that in turn may be transmitted as datagrams over a packet switched network. On the receiving side, the digital data in the datagrams are converted to analog audio signals to be played by a speaker, Figure 4.2.

Other real-time data can be transmitted in the same fashion as with voice; this could be live video or other kinds of interaction. An advantage gained by using IP for this kind of transmittal, is its flexibility regarding what is to be transmitted; the same procedures are used when sending voice or a file, the only difference is perhaps in the topmost protocol layer.

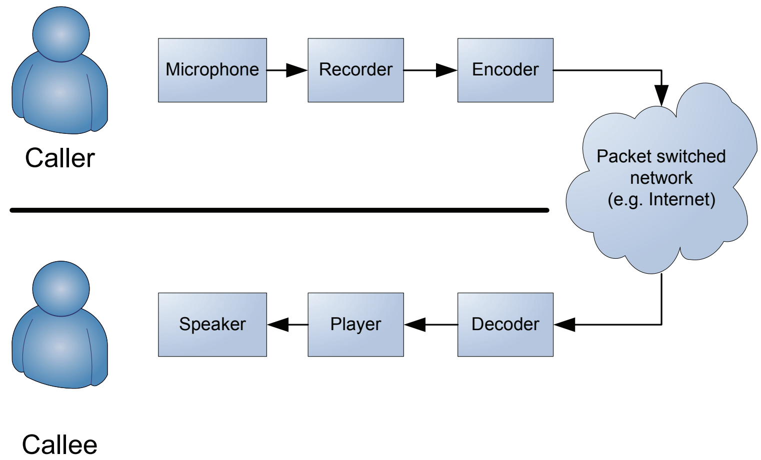


Figure 4.2: *A simplified diagram of the principles behind voice over IP.*

4.3 Mobile Devices

One of the objectives of this thesis is designing a working prototype for a mobile device. Mobile devices are generally small, and requires special attention to usability. The mobile device is also to be used in an industrial setting, which in turn strictens the requirements.

4.3.1 Touch

The main input methods on mobile devices utilize touch; either through buttons or directly on the screen. As screen technology has gotten better, devices with larger screens has been developed with fewer buttons, relying more on their touch screens for user input. One may also see fully QWERTY-equipped mobile devices for better writing abilities.

These mobile devices may work brilliantly for a business man in an airport, but the environment of an industrial facility provides some challenges. A field operator often has to wear gloves while working. This limits the usability of touch screen input. He may also need one or both of his hands for maintenance work, limiting his ability to interact with the device even further.

4.3.2 Speech Recognition

Speech recognition is the process of converting a speech signal to a sequence of words using a computer algorithm [15]. If these words represent different commands, a hands free user input is achieved. Voice is probably the most common method for human interaction, and should therefore be well suited for mobile device interaction.

A problem with speech recognition is that it from time to time misinterprets commands [3]. Training increases accuracy, but it will still remain an issue.

4.3.3 Issues and Constraints

Designing for mobile devices requires knowledge about the constraints a mobile device inflicts. It is also important to understand the differences between mobile design and conventional computer design. Following is a list of important differences:

- **Screen size and resolution:** The screen size of a mobile device is very limited compared to a desktop computer. While today's desktop computers at least supports a resolution of 1024x768 with almost limitless display size (» 20"), a mobile device *may* have a resolution of 480x640 on a 3-4" screen.

- **Screen visibility:** Screen visibility is a concern when working outside. Sunlight will make it hard to read the screen. Newer screens work better, but these are yet to be implemented on a mobile device.

- **Battery:** A desktop computer is connected to the power grid, so power is not an issue. A mobile device is powered by batteries, and battery-life is therefore a major concern.

- **Processor:** The processor in a mobile device and a desktop computer are quite different. This has mainly to do with power consumption and size. The differences are most noticeable when doing large calculation work, like video processing or 3D graphics. Though the differences still are big, a lot of development on mobile devices the last years has to some extent minimized the gap.

- **Memory:** Memory on a mobile device is a fraction of that of a desktop computer. Where a desktop computer may be able to design complex 3D models, a mobile device may only display a simplified snapshot of it. A PDA has typically 64 megabytes, while a desktop computer has 2 gigabytes of RAM.

- **Input:** The size of the mobile device is a concern when user input is required. There is no room for a large keyboard or a mouse. Smart-buttons, scroll wheels and small joysticks are used for input. The last years more touch-sensitive screens have also been introduced in the market. This gives the user the ability to interact directly with the screen.

Chapter 5

Mobile Devices for Process Industry

This chapter introduces solutions for use of mobile devices in process industry. Two solutions, the Redback Pocket and the Pocket Portal, are based on wireless networking and used for process data access. However, the focus in this thesis is to enhance communication support between the field- and the control room operator which is a rather different approach to mobile devices. The ability to access data will affect system awareness which in turn is likely to influence the quality of potential collaboration. Figure 5.1 shows the difference between the focus of this thesis and the

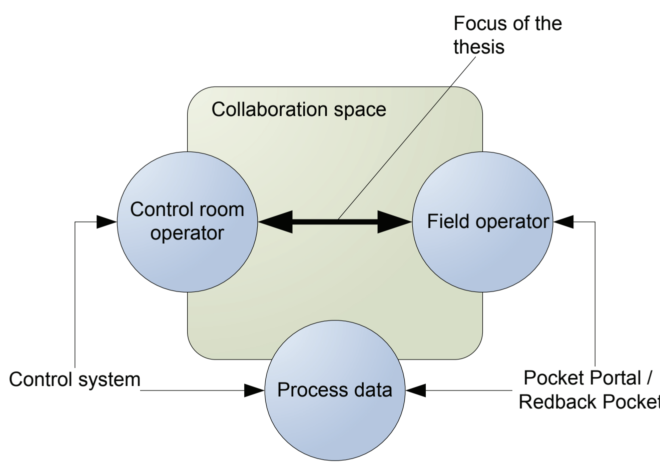


Figure 5.1: *An overview of the collaboration space*

general purpose of the Redback Pocket and the Pocket Portal. The arrow in the center of the figure indicates the communication/collaboration between the two operators. Process data can be accessed either through the control system, available for the control room operator, or a pocket solution, available for the field operator.

The Redback Pocket and the Pocket Portal were not created to enhance the communication/collaboration in specific, but may definitively have an impact on it. Neither Redback Pocket or Pocket Portal are at the moment part of ABB's product portfolio.

5.1 Redback Pocket

The Redback Pocket is an initiative by ABB Denmark for wireless and mobile access to process data. Figure 5.2 shows screen prints of the solution. Redback Pocket uses IEEE 802.11 for communication with an ABB Data Server (ADS) [16]. The idea behind Redback Pocket is that enabling process data access to maintenance people reduces the workload on the control room operators. Redback Pocket may be used for:

- Data collection
- Alarm viewing
- Maintenance work
- Commissioning

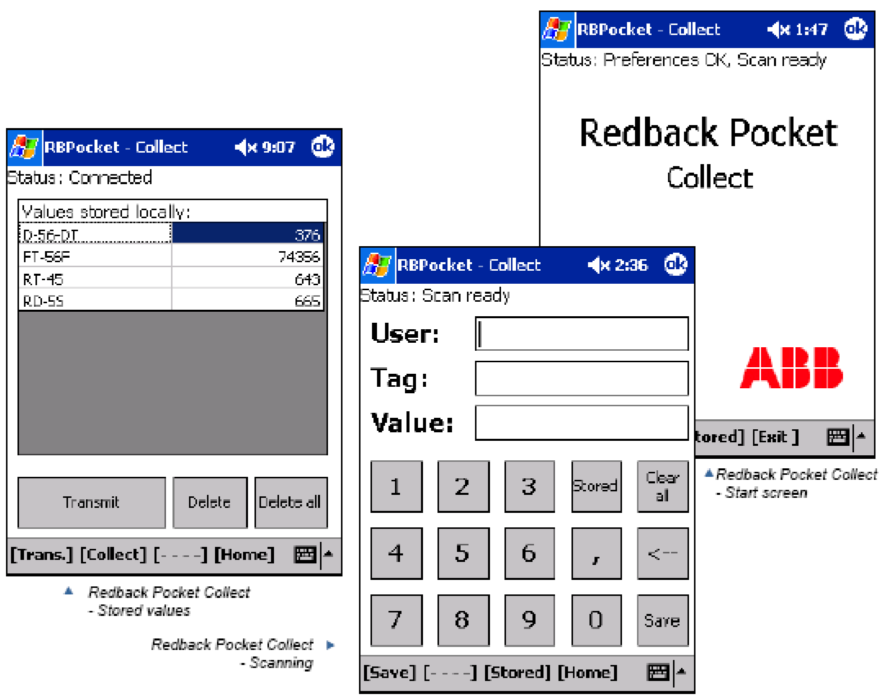


Figure 5.2: *Screen prints of the Redback Pocket*

A meeting was scheduled with Bo Sundahl, an electrical engineer participating in the Redback Pocket development. One of the topics for the meeting was his inputs about development of mobile devices used in an industrial setting. His main advice was that a successful mobile device has to be custom-made and intuitive to operate for the users; *"PDAs work best with dedicated solutions for dedicated problems"*. Some of the design guidelines of the Redback Pocket team concerned:

- **Stylus pen:** The stylus pen was disregarded as an input device.
- **Favourite lists:** User-dependent lists to store individual user-setup.
- **Scanner function:** The Redback Pocket contains a bar-code scanner for instrumentation readings.

The guidelines have a clear trend; user-input has to be kept to a minimum, and be as simple as possible, when working in an industrial environment. The field operator often wears gloves, which will, for instance, make the use of a stylus pen very difficult.

5.2 Pocket Portal

The Pocket Portal is another ABB product for wireless process data access. The concept is much like Redback Pocket, but has some different functionality. As with Redback Pocket, a meeting was scheduled to get experiences on the product. Jan Burstedt is an engineer at the Swedish mining and smelting company Boliden, and has experiences both from the Pocket Portal and Boliden's own mobile development.

Burstedt thinks that the Pocket Portal is a good product, but with some signs of not being completely finalized. It is especially useful when real-time feedback from the instruments are needed onsite. This may include:

- **Fault localization:** No need to contact control room, feedback is provided by the Pocket Portal.
- **Operation issues:** Calibration of instruments, running test functions, and so on.

Using the Pocket PC for sound recording had also been used for debugging.

The main problem with the Pocket Portal is, according to Burstedt, its lack of flexibility in the user interface. More specifically, he missed the possibility to trend signals over time and overview images of the process.

When developing new solutions, it is important to consider how it fits in to the organization; if a mobile solution is to succeed, the organization must be supportive to mobile solutions. Further, a new solution can not be pushed on users; the users must find it useful and necessary.

Chapter 6

Concept development

6.1 Model of Communication

From the different communication models discussed in chapter 3, a model for understanding the specific communication between a field and a control room operator was created, as shown in Figure 6.1. The model is meant to be used as a visualization of some of the issues which one encounters in this specific setting. The field requires

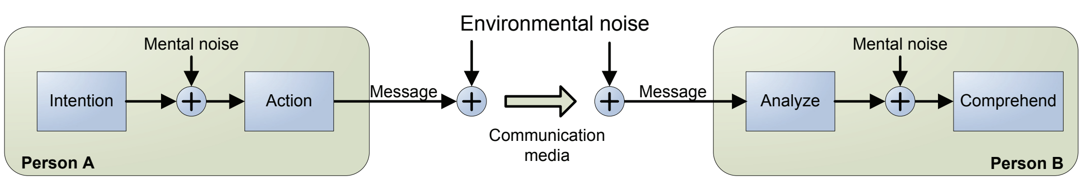


Figure 6.1: *A diagram of typical noise issues when communicating*

special attention to disturbances. This includes audio, environmental (temperature, dust, wind, rain) and restriction due to explosion protection (EX). The idea of noise on the communication channel is in accordance with the Shannon-Weaver model. The mental noise is supposed to represent issues that may occur when the input transfers to the person's mental model. The quality of the mental model will affect the understanding of the input. The transfers from intention to action and analyze to comprehend represents the encoder/decoder paradigm in the communication models in chapter 3.

6.2 Enhanced Communication

When considering the quality of remote communication, it is reasonable to compare it to face-to-face communication. Combined with equal understanding of the system they are communicating about, the model will presumably become as close to optimal communication as possible[1]. This is illustrated in Figure 6.2. People will never have the exact same understanding of a system, so this figure is just meant to give a theoretical understanding of what could be considered optimal communication. The

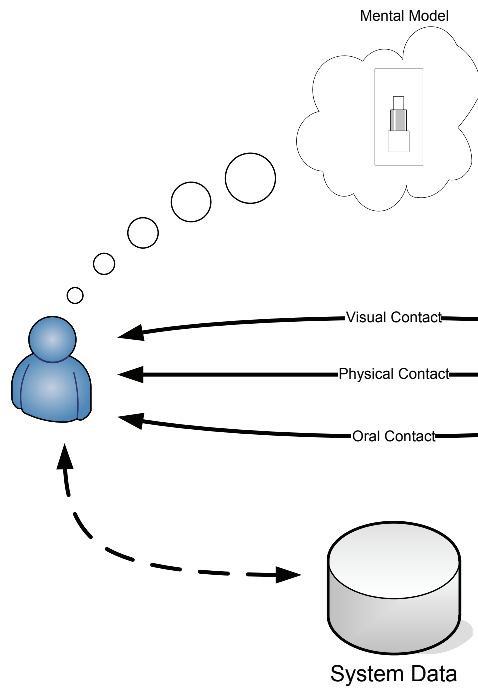


Figure 6.2: *A suggested model of optimal collaboration*

figure displays:

- **Visual Contact:** The collaborators can see each other, giving them a better understanding of to whom they are talking. Facial expressions and gestures enriches the communication session.
- **Oral Contact:** The main mean of normal communication is voice. Loosing oral contact would significantly damage the ability to communicate.
- **Physical Contact:** Physical contact is in this context meant as the other possibilities being (physically) in the same place gives. This may for instance be hand gestures (e.g. pointing on a map) or showing the other collaborator a document you are carrying.
- **System Data:** For the best possible collaboration, the participants have to be able to access the same system data. This makes them better suited for collaboration, since they at all time get the same inputs from the system.

[1]One could argue that with equal understanding of the system, or identical mental models, the need for communication could possibly disappear, hence it is not optimal communication.

In today's solution, visual and physical contact are completely missing. The access to system data is also weakened; the control room operator has good access, while the field operator needs to contact the control room operator or do a manual instrument reading to get data.

Since the control room operator has access to process data, it would be logical that he brings this data to the collaboration with the field operator. What the control room operator does not have access to, is the process hardware; this is what the field operator can contribute to the collaboration. By introducing process data to the field operator and real-time field experiences to the control room operator, their awareness of each other as well as the interaction they are doing will increase. Both parties will take advantage of being more aware of the context of the other collaborator and the roles they are playing. It is desirable that this increases the quality of their team-work, making them better suited for solving complex and sometimes unexpected problems.

6.3 Concepts

In this section, more specific definitions of the concepts for enhancing the communication and collaboration are given. Figure 6.3 illustrates the concepts of the prototype.

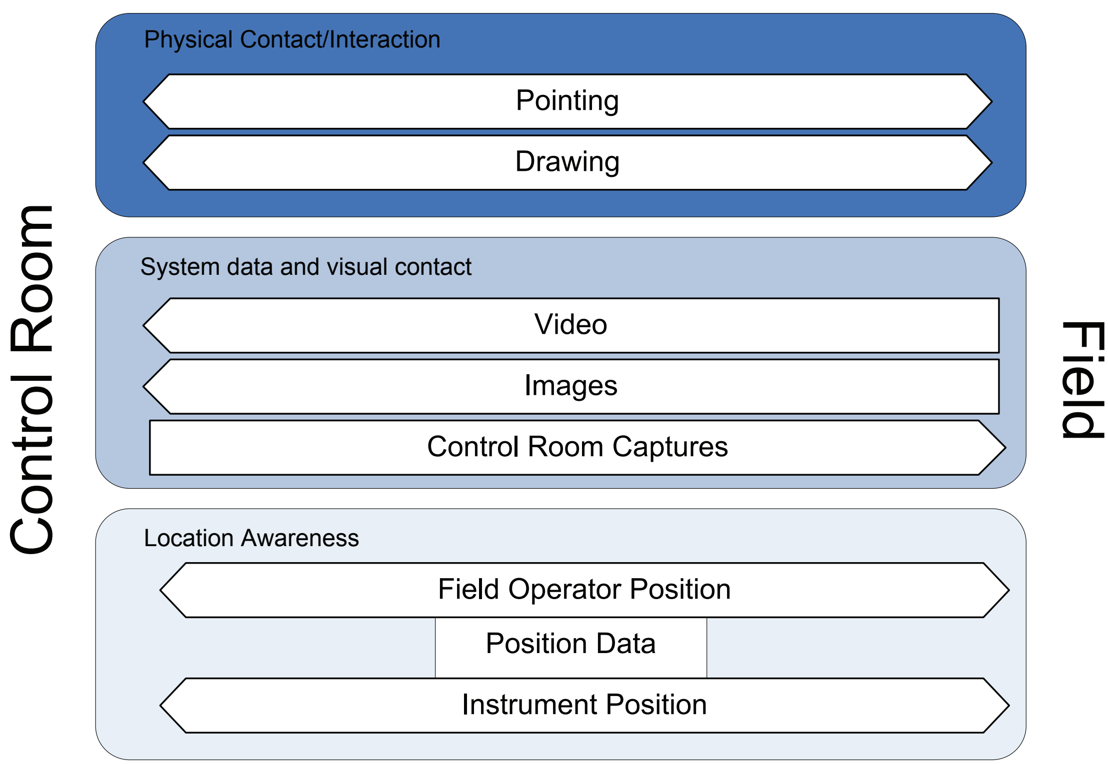


Figure 6.3: *The concepts developed, and their properties in collaboration*

6.3.1 Physical Contact/Interaction

The physical contact arrow shown in Figure 6.2 is in today's solution completely missing. There is no support for typical face-to-face communication attributes, like pointing. The prototype will try to implement this support by introducing a common interface. This could be a whiteboard where both parties can draw, an image of the process where they can discuss a problem with drawing and pointing abilities, or a section of the control room application with the same abilities. The idea is to increase their interaction with each other by introducing important concepts lost in typical remote communication.

6.3.2 System Data and Visual Contact

As previously mentioned, the intention of the prototype is to increase awareness of the other parties, as well as the system. Video and images from the field will give the control room operator understanding of the field operator's situation. In the same way, by sending real-time images from the control room application, in a sensible resolution, the field operator will get an increased awareness of the control room operator's environment. This will hopefully enhance the communication and teamwork, since they are sharing a tighter bound than regular radio communication gives. To make the concept feasible, an application at the control room side should be developed to represent the field operator's mobile device. This application will be their common interface, and help them to comprehend what they are watching.

6.3.3 Location Awareness

Location awareness will in the prototype be used to get the position of the field operator. Combined with position data of the instruments, a system for locating the field operator in the process, as well as getting the relation between instrument position and field operator position, can be created. This will minimize the possibility of the field operator choosing the wrong instrument, and is a tool for the control room operator and the field operator to be certain that they are talking about the same instrument.

6.3.4 Additional Concepts

This section discusses other concepts that came up during the initial design phase. These concepts were not implemented due either to their mismatch with the initial objective, or that they were unsuitable for the final prototype. Still, the concepts are part of the work done, and may also be suitable for prototypes to come.

Video-conferencing is definitely a means to creating better visual contact, but is not a focus in this thesis. This has multiple reasons:

1. There already exists a great amount of implemented systems, thus creating a new one for this prototype would be unnecessary work.
2. Although some research show increased communication effectiveness, others show no increase [17]. The cost of broadband may not be worth it.
3. The concept of seeing the other collaborator has more to do with interpersonal awareness, which has not been a focus in this thesis.

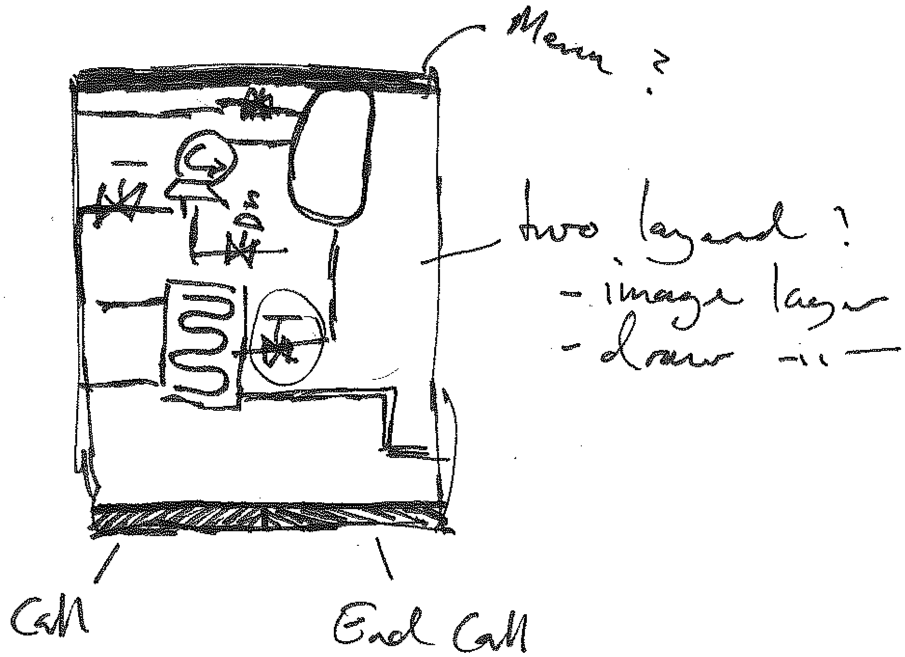
Digital communication, like Voice over IP, will increase the flexibility in the communication. Where two-way radio just offers a half-duplex one-to-many communication, digital communication supports multiple setups:

- Normal one-to-one calling
- Multicast, one-to-many
- Specialized, one-to-some, where the caller decides whom to call from a phonebook, and the recipient decides if he wants to be part of the call.

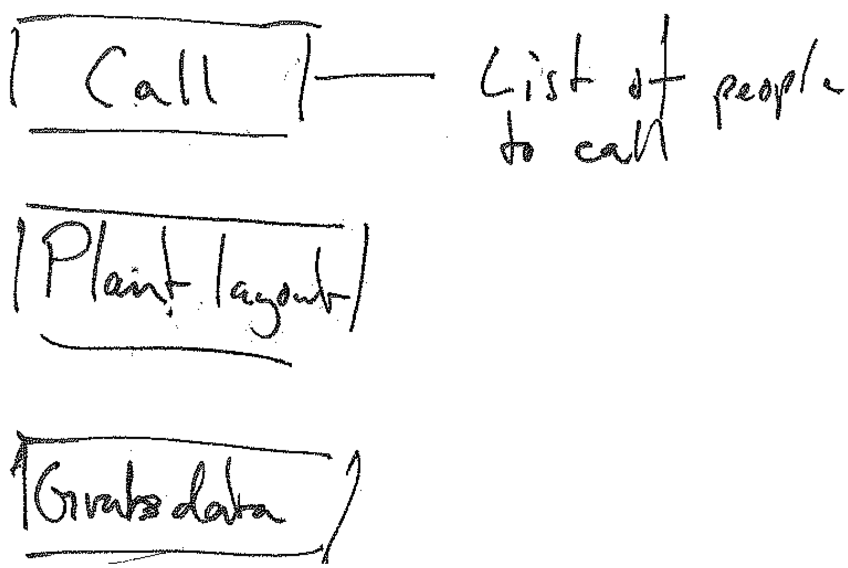
Digital voice communication introduces new abilities to communication without loosing the properties of the old two-way radio technology. The reasons why digital voice communication is not to be implemented are similar to those of video-conferencing; there already exists professional solutions for it and it is not the main focus for this thesis. There is new radio technology implementing the functionality of digital voice communication that may be implemented in a prototype at a later stage.

6.4 Paper-prototyping

The phase just before actual design and implementation are begun can be crucial for the outcome of a concept. The ideas tend to be all over the place, so structure is needed for them not to be lost. Paper-prototyping is a good tool for structuring ideas. Two of the first design drafts of the prototype are shown in Figures 6.4(a) and 6.4(b).



(a) *The concept of interaction on a process image*



(b) *The first layout of the menu*

Figure 6.4: *Two simple paper prototypes*

Chapter 7

Prototype Design

This chapter describes the design of the prototype. The prototype needs two sides; the actual mobile device, and a control room application. The mobile device application is for convenience named `FieldPocket`, representing it being a PDA (pocket) for the field operator.

7.1 FieldPocket

7.1.1 MainMenu

`FieldPocket` needs a menu to access the different concepts implemented. This is the purpose of `MainMenu`. It is equipped with easy-to-push buttons for the user to interact with. Pushing a button makes `MainMenu` change its state, remembering which button and concept that has been chosen by the user. Figure 7.1 illustrates the

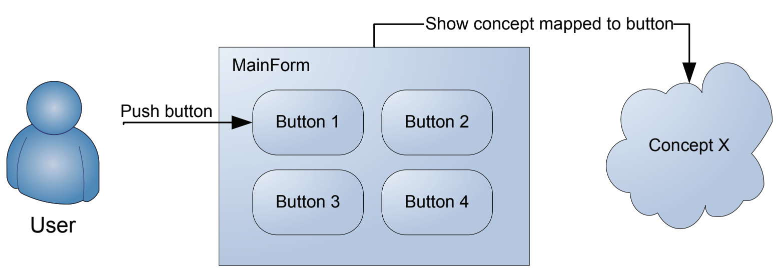


Figure 7.1: *Design drawing of MainMenu*

design of `MainMenu`.

7.1.2 Media

The media concept illustrated in Figure 7.2 will include support for video capture and taking pictures. The functionality should be as intuitive as possible and easy to operate for the user. When a picture is taken or video is captured, it should be transmitted to the control room side without needing any more inputs from the user.

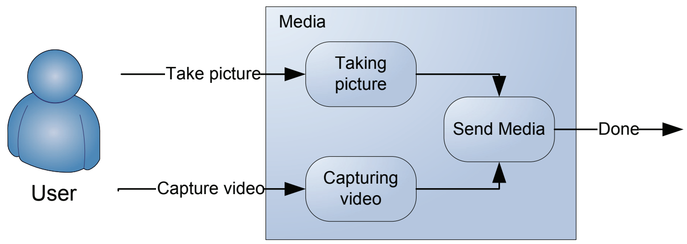


Figure 7.2: *Design drawing of Media*

7.1.3 Location

The location concept design is a bit more complex than the previous two. It consits of a map that should either show the position of the field operator in the process, or the location of a specific instrument from the field operator's point of view. Figure

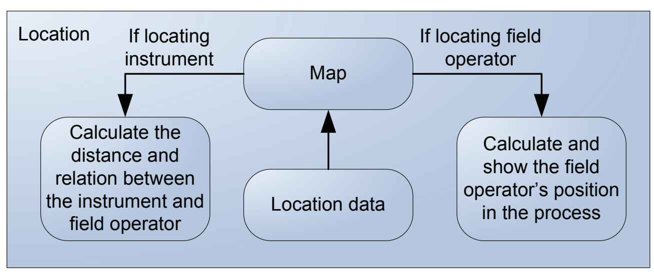


Figure 7.3: *Design drawing of Location*

7.3 shows the design. The map receives the location data of the field operator. It then calculates the position of the field operator on the map, or calculates the distance to and the position of the instrument.

7.1.4 Call

`Call` is used to contact another operator. It should consist of some sort of phonebook where the user can select to whom he wants to speak. `Call` then connects him to the operator he chosed, and the communication session may start. Figure 7.4 illustrates the design.

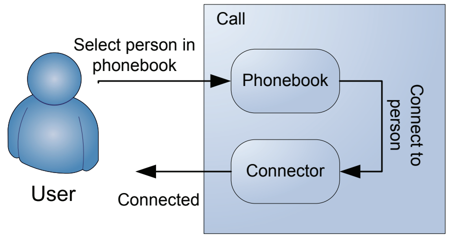


Figure 7.4: *Design drawing of the Call*

7.1.5 Interaction

Interaction is not a visible concept alone; it gives `FieldPocket` the ability to draw and point, but needs a foundation to do this on, like a picture or a white form. How it should work, more than that it should draw and point, is implementation dependent, and the interaction concept will therefore not be mentioned more in the design phase. `Interaction` should be used both by `FieldPocket` and `ControlSystem`.

7.2 ControlSystem

`ControlSystem` consists of two applications:

1. **InteractionUnit:** An application representing the field operator's application

2. **ControlRoom:** An simple application resembling a control room system

7.2.1 InteractionUnit

`InteractionUnit` is a common interface between the field operator and the control room operator. It enables the control room operator to see what the field operator sees on his mobile device. Because of its property as an interface between the operators, it needs to contain a substantial part of `FieldPocket`'s functionality. Moreover, it should be able to capture what the control room operator is looking at, and send it to the field operator. The design of `InteractionUnit` is shown in Figure 7.5.

An important aspect of the `InteractionUnit` is that it can relieve a lot of user input from the field operator. A major concern when field operators are to use mobile devices is how they should interact with them in a harsh environment. This was one of the concerns of the Redback Pocket design team. `InteractionUnit` moves a lot of the control of what the field operator sees to the control room operator. This reduces the need for user input from the field operator, but may make him feel too dependent on the control room operator.

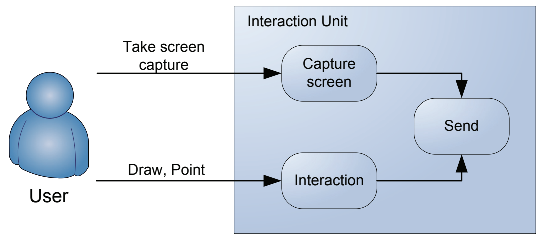


Figure 7.5: *Design drawing of InteractionUnit*

7.2.2 ControlRoom

`ControlRoom` is a mockup of a real control room system. It is to be kept as simple as possible, and should contain only two elements; a background image displaying the process, and instruments that can be dropped into `InteractionUnit` to trigger `Location` on the field operator's device. Because of its simplicity, a design drawing was not created.

Chapter 8

Implementation

8.1 Implementation tools

The following section introduces the tools that are used for creating and implementing the final prototype. ABB Strategic R&D for Oil & Gas has provided a PDA which has, together with programming preferences, made the basis for the choices of implementation tools.

8.1.1 Fujitsu-Siemens LOOX T830

The PDA has an Intel(r) PXA270 416 MHz processor. It contains 64 MB Random Access Memory (RAM) and 128 MB Read Only Memory (ROM). The screen is a 2.4 inch transflective TFT screen with 240x249 pixels and 65,536 (16-bit) colours and LED background lighting. For connectivity, the PDA offers a USB 1.1 port, 802.11 b/g wireless LAN and Bluetooth 2.0. Furthermore, it contains a SiFR Star III GPS unit, a complete QWERTY keyboard, and a Secure Digital I/O slot. The lithium-ion battery gives the PDA an operating time of up to 4 hours of GSM talk time, or up to 150 hours of standby.

Figure 8.1: *Advert photograph of the LOOX T830 (http://www.fujitsu-siemens.com)*

8.1.2 Windows Mobile 5.0

Windows Mobile is Microsoft's compact operating system to be used on mobile system. The OS is built in a fashion that makes it relatively easy for Windows desktop developers to jump over to mobile development. Windows Mobile 5.0 is powered by Windows CE 5.0, and supports the .NET Compact Framework 1.0 and 2.0, enabling .NET development.

8.1.3 Microsoft Visual Studio 2005

Visual Studio is Microsoft's IDE for software development. The primary target of Visual Studio 2005, is .NET development. The 2005 version of Visual Studio also include better mobile device support, making mobile development very easy.

The good support for mobile development together with the strong .NET support makes Visual Studio 2005 a very well suited IDE for prototyping. The .NET framework possesses a multitude of basic functions, enabling much more rapid programming than the corresponding programming in e.g. plain C++ would.

8.2 Initial Framework

To be able to implement the design as wanted, a quite extensive framework with basic functionality had to be created. This concerned among others, video, data and location demands. For the device to be location aware, the built-in GPS functionality was used.

8.2.1 Networking

`Networking` is a library utilizing the Microsoft .NET Framework's `System.Net` namespace for easy communication over networks. For this project two protocols are used: Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). These two protocols were chosen to enable flexibility in data transmission. TCP and UDP are both a part of the transport layer, but with some prominent differences. TCP provides an end-to-end data stream, guaranteeing reliable data transfer in the correct order. But this functionality comes with the cost of decreasing its real-time properties; packet arrival may become indeterministic. This protocol works well for transmission of larger data amounts, like documents and video files (not video streaming). UDP has, in contrast to TCP, no guarantee for reliable transfer. This makes UDP considerably faster and suitable for real-time purposes. For more information about either protocol, see [13].

Both TCP and UDP have excellent support in the .NET environment. For ease of use, two classes were constructed for both protocols; a communicator class and a data class. During prototyping, there will often be necessary to change the way data is transmissioned, and separating transfer dependencies and data makes it quite easy to do changes.

Class Diagram

Details on how to do networking is not part of this thesis, and will therefore not be examined in detail. A diagram of the classes is provided to give a simple overview. For more extensive information, see the source code.

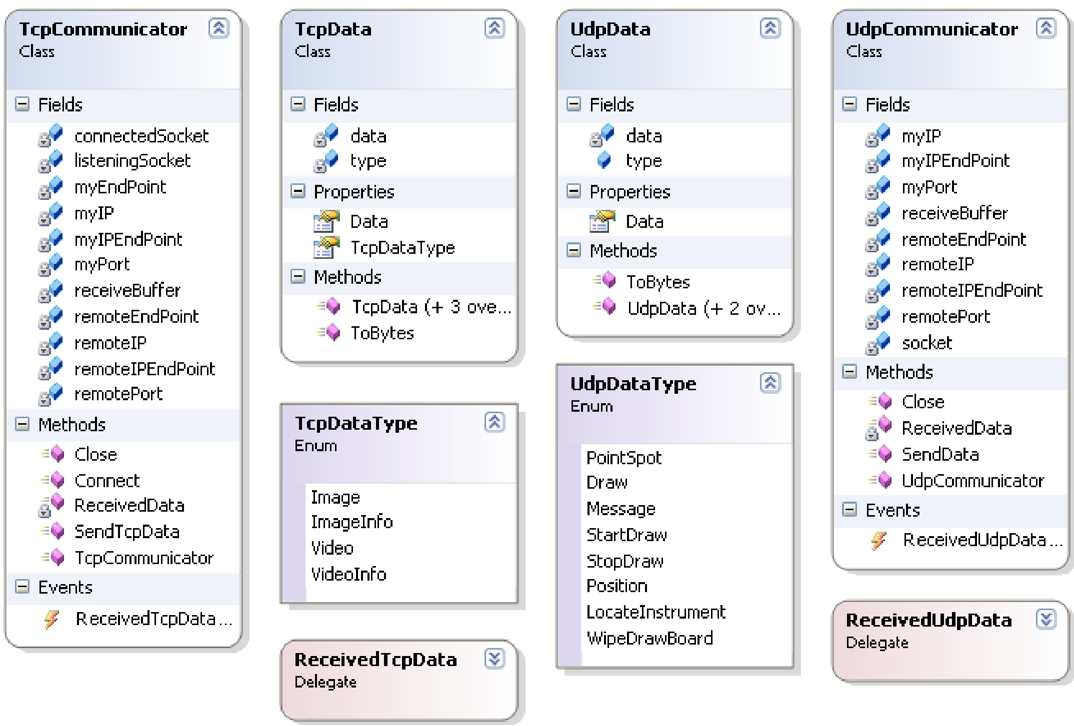


Figure 8.2: *Class diagram of the most important classes in the Networking library*

8.2.2 MediaCapture

The Windows Mobile SDK includes the `Microsoft.WindowsMobile.Forms` namespace, which contains the `CameraCaptureDialog` class. The class is made ease the work for developers utilizing cameras on mobile devices, and supports both still image and video capture. Since it should only be possible to take a picture or capture video in the prototype, the `CameraCaptureDialog` class contains too much flexibility for the field operator. By creating a new class, `MediaCapture`, a cleaner interface was created. This class will in turn be connected to the

Networking library, so images and video can be transferred seamlessly and without user interference. A Class diagram of the MediaCapture class is displayed in Figure 8.3.

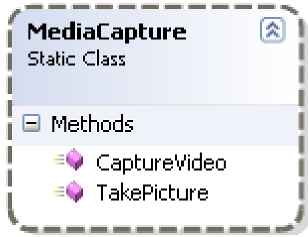


Figure 8.3: *Class diagram of the MediaCapture library.*

8.2.3 GPS

A GPS is used for introducing position data to the prototype. The GPS classes are strongly based on the Windows Mobile SDK sample for wrapping the native GPS Api to C#. The GPS does return location data, but this data can only be used, with special

Figure 8.4: *Class diagram of GPS library*

maps supporting the latitude/longitude position scheme. In the prototype an industrial drawing is to be used which do not support latitude and longitude, and another use of latitude and longitude had to be thought of. The drawings are given in pixels, while the position is given in degrees on the earth sphere. This demands a derivation from sphere coordinates to the distance between them. From [18], an equation for calculating the distance between the points (ϕ_1, λ_1) and (ϕ_2, λ_2) is given:

$$\begin{aligned} \gamma &= \sin^2 \frac{\Delta\phi}{2} + \cos\phi_1 \cdot \cos\phi_2 \cdot \sin^2 \frac{\Delta\lambda}{2} \\ d &= 2R \arctan(\sqrt{\gamma}, \sqrt{1-\gamma}) \end{aligned} \tag{8.1}$$

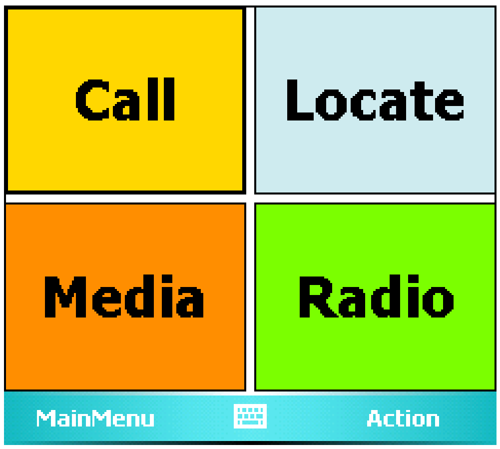
Where R is the radius of the earth, ϕ is latitude and λ is longitude. The implemented version of the equation is displayed in Appendix A.

8.3 FieldPocket

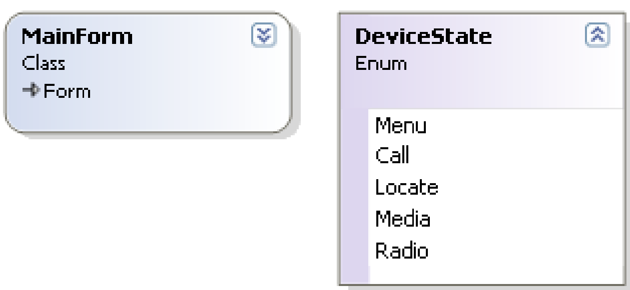
FieldPocket has been implemented as an application containing the `MainMenu`, and five libraries, `Location`, `Interaction`, `MediaCapture`, `Networking` and `PhoneBook`.

8.3.1 MainMenu

`MainMenu` is the main form of the application. It displays the choices the user has, and contains all the concepts implemented mapped to the buttons shown in Figure 8.5(a). When the user pushes one of the buttons, the concepts mapped to that button is opened inside the `MainMenu` form. Figure 8.5(b) shows the class diagram.



(a) *Screen print MainMenu*



(b) *Overview of the classes in MainMenu*

8.3.2 Interaction

The classes in the `Interaction` library are illustrated in Figure 8.5. The main class is the `DrawBoard`, which also is the most important class for the interaction between the operators. This class handles all drawing and pointing inputs, as well as receiving the `DataReceived` events from the `Networking` library, see Appendix A for source code. The `HandDrawing` class are used inside `DrawBoard`, one array of objects for the hand drawings made locally, and one array of objects for the hand drawings received from the other operator. These are created dynamically from either mouse input events (locally) or when drawing data is received from the `Networking` library. The `PointSpot` class is a control that is created dynamically

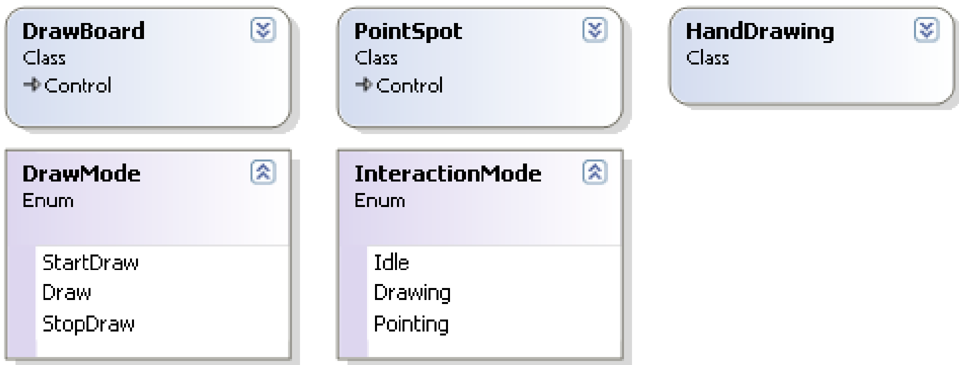
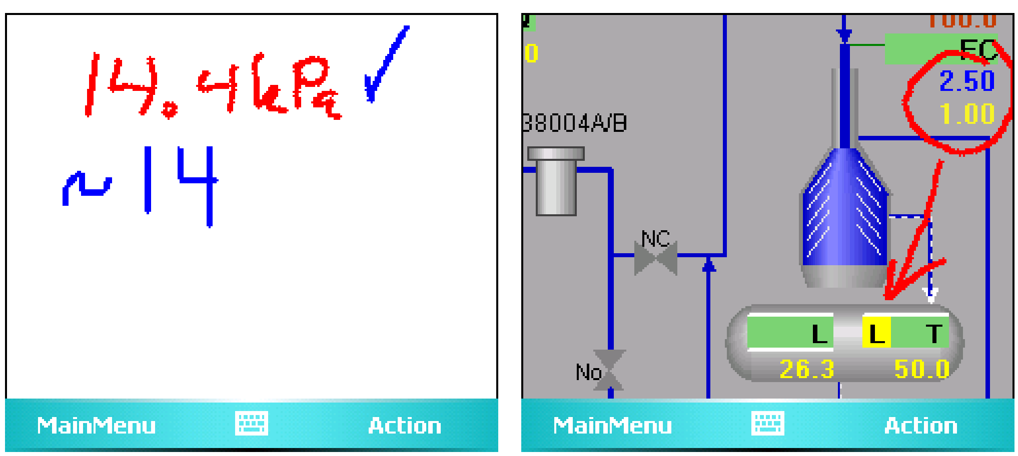


Figure 8.5: *Overview of the classes in Interaction*

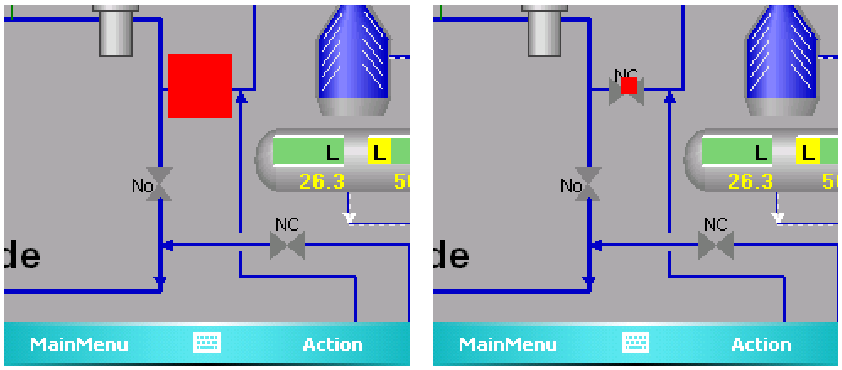
in the same fashion as with hand drawings. The major difference between them is that a `PointSpot` has a much more temporary existence, closing after a specific period of time. The `PointSpot` is supposed to resemble finger pointing. It has a dynamic shape, first quite big to get the attention of the user, and then shrinks gradually to one point, so the user can see exactly where the other user is pointing. Figure 8.7(a)



(a) *Drawing on a white surface* (b) *Drawing on a process image*

Figure 8.6: *Screen prints of DrawBoard in the Interaction library*

and 8.7(b) shows the `PointSpot` in action. It first grows to a large square before shrinking into a pixel.

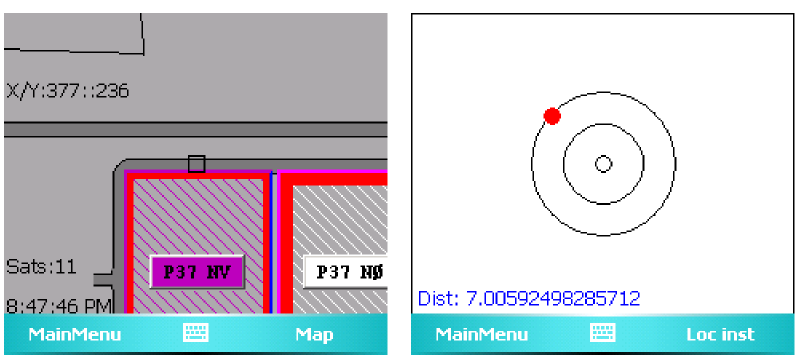


(a) *Screen print of the early phase of PointSpot* (b) *Screen print of a later phase of PointSpot*

Figure 8.7: PointSpot

8.3.3 Location

The `Location` library consists of the GPS classes already mentioned, and the `Map` class. `Map` is responsible of turning the location data to a sensible output on screen. This is done by mapping the position to equivalent pixels. A customized paint method draws the desired graphics at the calculated pixel position. Appendix A contains source code of the paint method. Figures 8.8(a) and 8.8(b) show screen prints of the `Location` library in use.

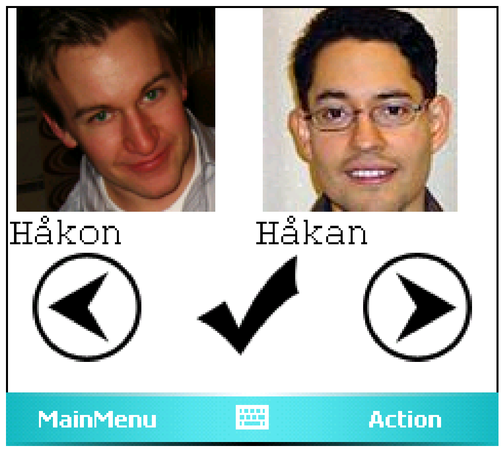


(a) *Screen print of Map when locating the field operator* (b) *Screen print of Map when locating an instrument*

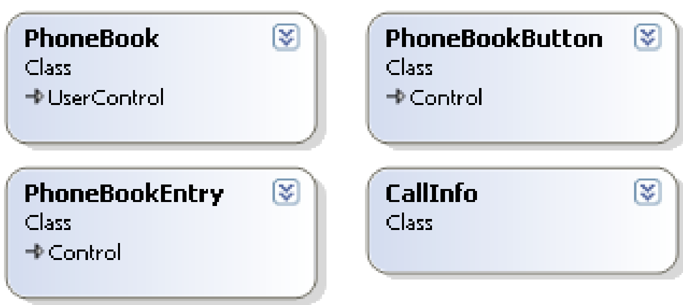
Figure 8.8: Screen prints of Map

8.3.4 PhoneBook

Since it should be possible to communicate with different operators, a phonebook had to be made. It contains a picture and the name of all operators, and the entries are touchable; you choose whom to talk to by pressing the image or name. Figure 8.9(a) illustrates `PhoneBook` in action, while Figure 8.9(b) shows the classes in the `PhoneBook` library.



(a) *Screen print of PhoneBook*



(b) *Overview of the classes in PhoneBook*

Figure 8.9: PhoneBook

8.4 ControlSystem

As designed, contains `ControlSystem` two applications. A short description follows.

8.4.1 InteractionUnit

`InteractionUnit` contains much of the same functionality as `FieldPocket`, but can use the `.NET Framework 3.0` instead of the `.NET Compact Framework`, which makes it somewhat simpler to implement. Figure 8.10 illustrates the main classes of `InteractionUnit`. It consists of a form with input support through regular buttons and radio buttons. The main part of the form is covered by `DrawBoard` which is the interface to the field operator. The `DrawBoard` class is the same as the `DrawBoard` class in `FieldPocket`. A screen print of `InteractionUnit` is displayed in Figure 8.11.

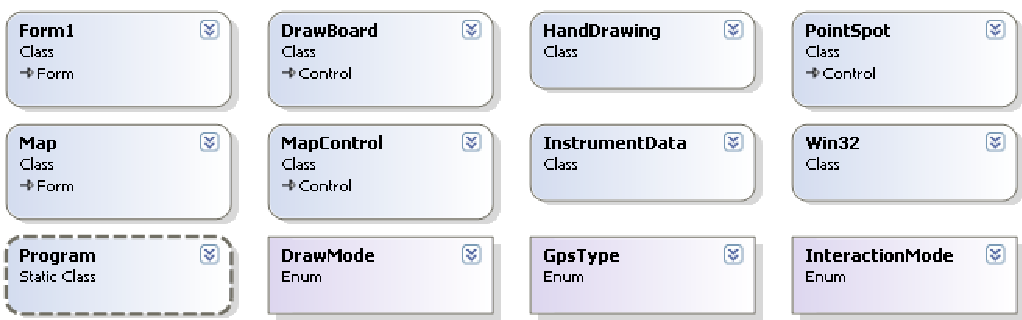


Figure 8.10: *Overview of the classes in InteractionUnit*

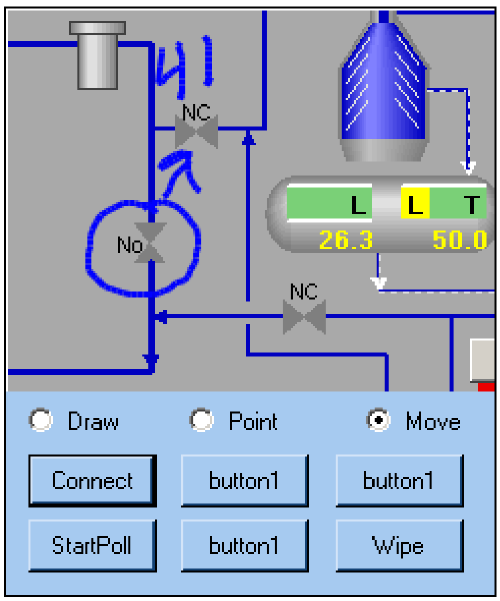


Figure 8.11: *Screen print of InteractionUnit*

8.4.2 ControlRoom

A screen print of `ControlRoom` is illustrated in Figure 8.12. `ControlRoom` is the smallest part of the prototype. It consist of a form with a background image of a process screen. The main feature of the application, except for looking like a control room application, is that it contains instrument objects that can be dropped into `InteractionUnit`. `InteractionUnit` recognizes the instrument, and sends a message to `FieldPoket` that an instrument is to be located, using `Location`. This functionality is implemented using Drag and Drop feature supported in `.NET Framework 3.0`. Figure 8.14 illustrates the concepts. An instrument is selected, illustrated by the arrow numbered one, and dropped into the `InteractionUnit`, shown by the arrow numbered two. For more information about Drag and Drop, see [19].

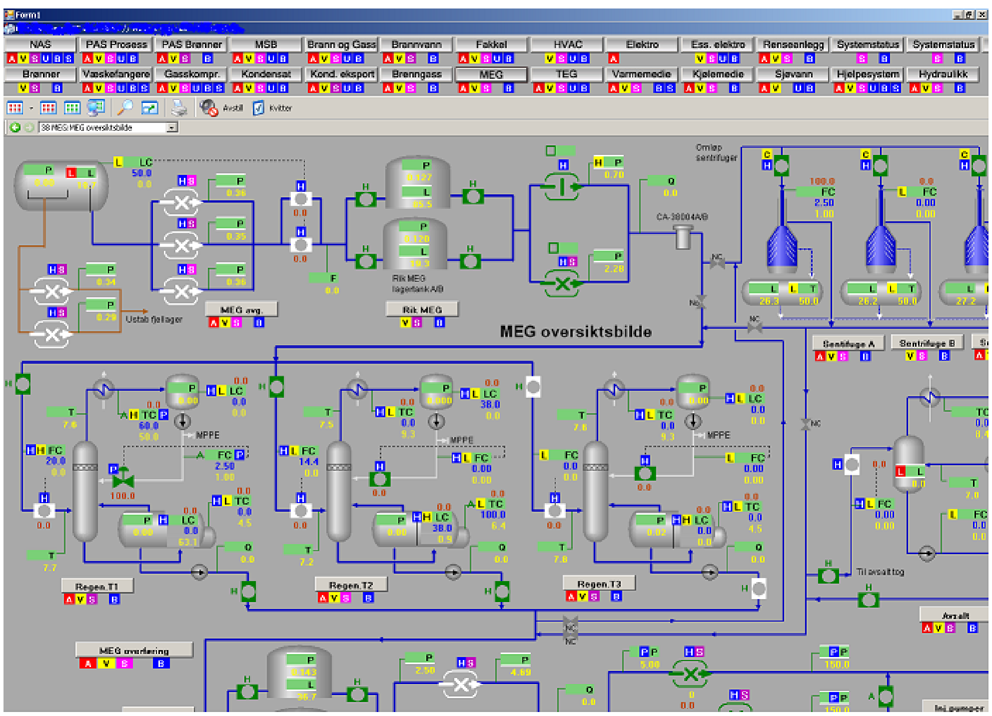


Figure 8.12: *Screen print of ControlRoom*

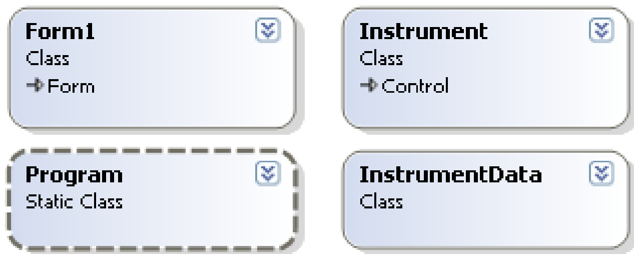


Figure 8.13: *Overview of the classes in ControlRoom*

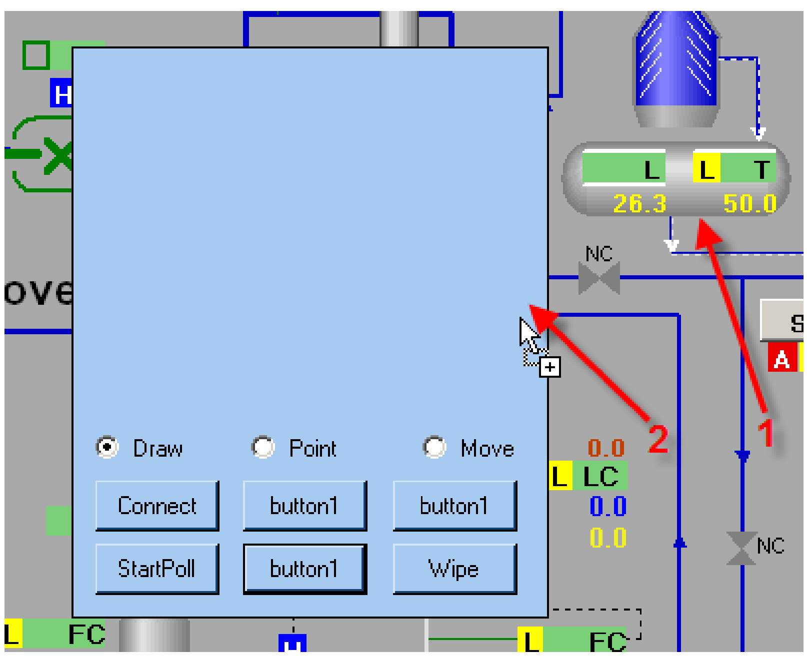


Figure 8.14: *Screen print of an instrument (1) being dropped into InteractionUnit (2)*

Chapter 9

Discussion

In chapter 3 mental models, situation awareness and communication models are introduced as important aspects for understanding the issues of communication. Through chapters 6, 7 and 8 a prototype which goal is to enhance communication between operators is designed and implemented. Because of the complexity of the prototype and the fact that the prototype needs real location data to work fully, the setup for a test of it became to extensive to be part of the thesis. Instead, tests concerning general technical functionality was conducted together with a concept evaluation.

9.1 Technical Evaluation

The prototype consists of two parts that need much of the same functionality, but use different frameworks. This means that a lot of the software could be reused, with some minor changes. During implementation, considerable time was spent testing that the functionality actually worked on both frameworks. When all the concepts were implemented and tested individually, more overall testing could be done.

9.1.1 Input Response

Most commercial PDAs on the market are meant for a business office environment. The main input device is the stylus pen together with a varying number of buttons. To get the most out of the small screen, the standard on-screen buttons (for the stylus to push) tend to be quite small. For this prototype however, the buttons where made as big as possible for the specific situation in which they occur. An example of this is that the buttons in the `MainMenu` fill up the entire screen, since nothing else is to be displayed. These buttons can easily be used with finger input.

9.1.2 Network Speed

Network speed has not been a special concern when creating the prototype in this thesis, but will certainly affect the user's impression of its performance. The network traffic contains of two types of data; small UDP packages and larger TCP packages. The UDP data is fast and the responsiveness of the prototype when UDP data is sent is more than sufficient. However, with TCP data the user will experience some dead time from the time data is sent to it is received on the other side. This is especially noticeable when images taken by the field operator is to be transmitted.

9.1.3 User-friendliness

During design and implementation of the prototype, focus has been put on ease of use. For instance, when a field operator wants to take a picture for the control room operator to see, he should just have to take the picture with no more actions. Further, the control room operator should not need to do any specific work for the picture to arrive; when the field operator tells him that he is sending a picture, the picture should arrive automatically. Using events, this is in fact what happens in the prototype; when the picture is taken, `Networking` sends the picture as TCP data, and when arriving at the control room operator, an event is triggered that saves the picture and displays it for the control room operator to see.

9.2 Evaluation of the Prototype Compared to the Models

According to the theory of mental models, a system which increases similarity of the mental models of the communicators, will lead to better understanding between the communicators, hence achieving better communication. The prototype tries to do this by introducing some of the data each side possesses to the other side. This data will then affect the mental models on the respective sides, and to some extent make the parties understand the system in a more unified way.

Schramm's communication model states that common *fields of experience* between the parties communicating, in Figure 3.5, is necessary for effective communication. It is reasonable to believe that these fields will increase when using the prototype, because of the introduction of data from the other party. This data is already a part of the other's field of experience, so the growth of the fields will be inside the intersection of the respective fields.

The interaction aspect of the prototype with drawing and pointing, attempts to enhance communication according to the communication models. By introducing common human interaction functions it broadens the channel for communication, which is the hearing, seeing, touching part of the S-M-C-R model, as illustrated in Figure 3.4.

The prototype also implements location awareness. Location is used both for the relation between the field operator and a specific instrument, as well as the field operator's location relating to the field in general. This will certainly help avoiding misconceptions about which instrument the operators are talking about. It will possibly also increase the situation awareness on both sides, since it will help the operators conceive the field operator's situation; some of the qualities of visual contact in Figure 6.2 are achieved.

Although the prototype does not implement audio communication, a final solution should without a doubt contain it. Voice is crucial for human communication. Combining voice with the drawing and pointing will decrease possible misunderstandings because of multimodality. The control room operator may say the name of an instrument, and point at it, thus giving the field operator two inputs for understanding which instrument the control room operator is talking about.

Chapter 10

Conclusion

By utilizing knowledge about human cognition and communication, factors that define important aspects of interpersonal communication and collaboration are emphasized. Concepts based on these factors for enhanced communication were suggested. These concepts constitute the basis for the design and implementation of a working prototype. Evaluation of the prototype suggests that it enhances the communication among the control room and field operation, because of conformity between the concepts implemented and definition of communication according to the models of chapter 3.

10.1 Further Work

First of all, more elaborate user tests need to be performed to further evaluate the appropriateness of the concepts. Because of the nature of the concepts, the best test would be a complex scenario in a real test environment where all concepts could be tested at once.

Further development of the concepts should focus on:

- **Robustness:** The prototype suffers somewhat of being rapidly developed in a quite short amount of time. The data transmission could be optimized for better performance and stability. Preparation for an industrial PDA should also be considered as a step towards a final solution.

- **Functionality:** Even though user input has not been a major focus in this thesis, further work should consider looking more into it . Speech recognition is an especially interesting means of user input for the field operator. Combining the prototype with the data collectors introduced in chapter 5 could also result in interesting findings.

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Appendix A

Source Code

Some of the core functions from the prototype implementation are presented. All source code is available on CD. If no CD is available, contact ABB Strategic R&D for Oil & Gas in Oslo.

A.1 Calculating Distance from GPS Position

```
private double calculateDistance
(double lat1, double lon1, double lat2, double lon2)
{
    // The radius of the earth in meters
    private const int R = 6367000;
    // Convert to radians
    lat1 = deg2rad * lat1;
    lon1 = deg2rad * lon1;
    lat2 = deg2rad * lat2;
    lon2 = deg2rad * lon2;

    // Calculate the difference
    double dlon = lon2 - lon1;
    double dlat = lat2 - lat1;

    double a =
    (Math.Sin(dlat / 2)) * (Math.Sin(dlat / 2))
    + Math.Cos(lat1) * Math.Cos(lat2) * (Math.Sin(dlon / 2))
    * (Math.Sin(dlon / 2));

    return 2 * R * Math.Atan2(Math.Sqrt(a), Math.Sqrt(1 - a));
}
```

A.2 UDP Data Receival

```
// Received UDP data from Networking
void udp_ReceivedUdpDataEvent(UdpData args)
```

```
{
    UdpMousePosition udpData;
    switch (args.type)
    {
        case UdpDataType.StartDraw:
            udpData = (UdpMousePosition)args.Data;
            remoteDrawings[remoteDrawingsIndex] =
            new HandDrawing(udpData.X, udpData.Y,
                           this.CreateGraphics(), Color.Blue);
            break;
        case UdpDataType.StopDraw:
            udpData = (UdpMousePosition)args.Data;
            if(remoteDrawingsIndex < numberOfDrawings -1)
                remoteDrawingsIndex++;
            break;
        case UdpDataType.Draw:
            udpData = (UdpMousePosition)args.Data;
            remoteDrawings[remoteDrawingsIndex].
                AddPoint(new Point(udpData.X, udpData.Y));
            break;
        case UdpDataType.PointSpot:
            udpData = (UdpMousePosition)args.Data;
            pointSpotPoint = new Point(udpData.X, udpData.Y);
            this.Invoke(addPointSpotEventHandler);
            break;
        case UdpDataType.LocateInstrument:
            this.Invoke(startMapEventHandler);
            break;
        case UdpDataType.WipeDrawBoard:
            this.Invoke(wipeDrawBoardEventHandler);
            break;
    }
}
```

A.3 Customised Paint Method in Location

```
protected override void OnPaint(System.Windows.Forms.PaintEventArgs e)
{
    Graphics g = e.Graphics;
    // Are we locating an instrument or the field operator?
    switch(type)
    {
        case GpsType.Map:
            if (initiated)
            {
                Rectangle srcRect =
                    new Rectangle(this.x, this.y,
                        this.Width, this.Height);
                g.DrawImage(bitmap, rect, srcRect,
                    GraphicsUnit.Pixel);
```

```
                g.DrawRectangle(pen,
                new Rectangle(distCenterX - 5,
                    distCenterY - 5, 10, 10));
            }
            g.DrawString("X/Y:" + x+"::"+y, locationFont,
                brush, 2, 40);
            g.DrawString("Sats:" + this.satellitesInView,
                locationFont, brush, 2, 150);
            g.DrawString(time, locationFont, brush, 2, 175);
        break;
        case GpsType.FindInstrument:
            Rectangle rectObject =
                new Rectangle(objectX - 5, objectY - 5, 10, 10);
            g.DrawEllipse(pen, circ1);
            g.DrawEllipse(pen, circ2);
            g.DrawEllipse(pen, circ3);
            g.FillEllipse(redBrush, rectObject);
            g.DrawString("Dist: " + distance, locationFont,
                blueBrush, 5, 170);
            break;

    }
}
```

Appendix B

Interviews

The writings from the informal interviews with Bo Sundahl and Jan Burstedt is presented.

B.1 Interview with Bo Sundahl - 14.02.2007

- Purpose of the Redback Pocket: Lower load on operators in the control room by transfering data to maintenance people
- Uses 802.11 wireless technology
- Initiated by customers
- Uses a EX verified PDA from Symbol
- The stylus pen used on many PDAs was considered impossible to use in field, the Redback Pocket is equipped with buttons only together with a bar-code reader
- Problems with using the PDA considered among other factors:
  - Layout / Screen space
  - Navigation
  - Key input
- The instruments can be easily read with the bar-code reader
- The Redback Pocket is not meant as an extended operator panel, it is a tool for special occasions
- Trend: Operator will have flexibility, but not many devices - a combined mobile phone and security phone?
- Experience from the users: Easy to use, Nice features

- Hardware issues: when fuses blew, the PDA had to be sent back to the manufacturer.
- Dedicated solutions for special problems

B.2 Interview with Jan Burstedt - 27.03.2007

- Thinks it is unfortunate that the Pocket Portal is no longer in the ABB portfolio
- Pocket Portal is a good product, but suffers from not beeing completely finalized
- Very useful when one needs feedback in the field
- Faultfinding: need no one in the control room, the control room is with you
- Operation start/stop: calibration, test functions, testing
- Sound recording: valuable fourier analysis for fault localisation
- Interface: weak, only face plates are supported - no process section images or trends
- Functionality for recording analog signals with trending abilities would be a nice feature
- A solution should incorporate all the functionality that the equipment the operators are wearing today has - operators will not carry more than they need
- The stylus pen is a bit too small
- Writing text is too hard
- There should be more than just one level in the menu –> the menu becomes too long with just one level
- There should be some sort of overview images for easy access to specific sections of the process
- The solution must fit in to the organisation – do not push technology on people who do not want it
- Wireless networks have been underestimated – achieves good bandwith
- PDA interaction with gloves is a problem