

# Optimization of user interaction with DICOM in the Operation Room of a hospital

By

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## ABSTRACT

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### OPTIMIZATION OF USER INTERACTION WITH DICOM IN THE OPERATION ROOM OF A HOSPITAL

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In the UMCG (and every other hospital) speed and hygiene during surgery are very important. Currently a keyboard and mouse are used to access DICOM images during surgery. An assistant has to perform these interactions. The process of asking the assistant to perform these interactions takes too long.

In this report, the testing of a Kinect sensor for use in an operation room (OR) of a hospital has been described. The Kinect is a 3D camera and will be used for navigation through and interaction with DICOM images. A touchless interface can improve hygiene in the OR. Currently no touchless interface of this kind is available and the Kinect provides a possibly ideal platform to develop this. The Kinect has been tested for its accuracy and two different SDK's have been compared. Gestures for specific tasks were designed, compared and tested.

An interface was designed and built, a surgeon provided feedback to ensure that the methods used in this interface are usable in the operation room. The interface received positive feedback from a surgeon. Further development is required for use of live DICOM images.

## DECLARATION

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I hereby certify that this report constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

I declare that the report describes original work that has not previously been presented for the award of any other degree of any institution.

Signed,

Sander Wegter

## ACKNOWLEDGEMENTS

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This project and report would not have been possible without the help and support of several individuals.

First I want to thank Mr. Peter van Ooijen for his support during this project and the possibility to work at the UMCG. I would like to thank Mr. Jan Zijlstra for getting me into contact with Mr. Peter van Ooijen after the HDC (HIT Design Challenge).

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## LIST OF ABBREVIATIONS

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SDK	Software Development Kit
OR	Operation Room
UMCG	University Medical Centre Groningen
ECG	Electrocardiography
CT	Computer Tomography
MRI	Magnetic Resonance Imaging
DICOM	Digital Imaging and Communications Medicine
MSDN	Microsoft Software Development Network
ROI	Region of Interest
PACS	Picture Archiving and Communication System
MITO	Medical Imaging Toolkit

# 1 RATIONALE

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This chapter describes the background for this project. A general introduction is given into the current situation of the hospital operating room (OR). Furthermore the problem definition, scope of the project and research question are described.

## 1.1 INTRODUCTION

The UMCG (Universitair Medisch Centrum Groningen) is the largest hospital in the north of the Netherlands and the second largest in the country with over 1300 beds and almost 11.000 employees<sup>(1,3,4)</sup>. Like any other hospital, it relies on a clean environment. Hygiene is even more important in the OR of the hospital. The OR is an extremely sensitive and complex environment. All equipment which is used during the surgery needs to be sterilized in order to prevent contaminations and therefore help prevent infections or serious complications for the patient. However, during surgery the surgeon needs access to medical images and other patient data which has been recorded prior to the surgery. This data could include ECG's, CT or MRI scans, X-Ray images and much more. This data has to be available to the surgeon at all times during the surgery. One problem with this system is that it has to be separate from the sterile field around the patient and can therefore not be accessed by the surgeon self<sup>(19)</sup>.



*Figure 1 OR Assistant standing next to the computer used for medical images  
(Image courtesy of Sebastiaan Stuy)*

The surgeon has to ask the assistant to interact with the image or ask for another image on the screen which is needed during the surgery. This means that the surgeon has to give commands to the assistant. The situation is shown in figure 1. An observational study by Grätzel et al. in 2004 showed the case of a surgeon who needed approximately 7 minutes to explain to an assistant the exact location where to click. In a surgery where every minute counts, seven minutes is a lot<sup>(21)</sup>.

According to the UMCG's 2011 year report, over 3500 surgeries were carried out in the UMCG<sup>(1)</sup>. In total in the Netherlands in 2009 over 1.3 million surgeries were performed<sup>(2)</sup>. In almost all of these surgeries, one or more medical images were used. This shows the importance of medical images being used during surgery and why a hands-free interface would be preferred.

## 1.2 DESIRED SITUATION

The desired outcome of this project is to define and test a system which implements gestures to control an interface which in turn shows medical DICOM (Digital Imaging and Communication in Medicine) images on the screen. The surgeon should be able to control the interface himself with small gestures and as precise as possible. If the system works in a quick and efficient way, the surgeon will lose minimal time compared to ask the assistant to put a certain image on the screen. This project provides new insights into the use of gestures and touchless interfacing in the OR during surgery.

## 1.3 RESEARCH MOTIVATION

As has been described by the introduction hygiene in the OR is of utmost importance. All devices used in the OR for human computer interaction, like keyboards, will need to be decontaminated. At this moment the UMCG is testing a system which is able to do manipulations like zooming, contrast and selection on DICOM images with gestures. However at this moment the image has to be selected on the computer using a keyboard and mouse. An external device like a keyboard or mouse could pose a contamination risk.

## 1.4 PROBLEM DEFINITION, RESEARCH QUESTION AND SCOPE OF THE PROJECT

In order to be able to work as hygienically as possible, the surgeon should touch only the instruments used on the patient directly. Research needs to be done to find out what is the most suitable way to interact with a computer inside the OR to keep the OR environment as sterile as possible.

The UMCG has provided a Kinect for this project. Previous research with this device has been done using the Kinect SDK v1.0. Recently a new version of this SDK has been released and this will be compared to version 1.0.

The central research question for this project is:

“What technique is the most suitable way to interact with a computer showing DICOM images in the OR of a hospital based on the Kinect in order to maintain sterility?”

To answer the main research question, sub questions have been defined:

- Which SDK performs better when comparing selection methods and that ensures the user can perform the tasks fast and accurately?
- What is the ideal distance between the user and Kinect to get the best performance?
- What is the best method to determine who should be tracked by the Kinect?
- Which gestures or movements are preferred by the surgeon?
- What should the interface look like to be useful for a surgeon?

## 2 SITUATIONAL ANALYSIS

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In this chapter the situational analysis of this project is given. The current issues which have been briefly described in the introduction will be given more depth and explanation here.

For this chapter, information from various sources have been used. Questions and personal experiences from attending a surgery can be found in appendix A.

### 2.1 DICOM

DICOM stands for “Digital Imaging and Communication in Medicine”. Development started in the early 80’s and at this time is the standard for hospitals to store, process, display and produce medical images <sup>(5,6)</sup>.

More explanation about DICOM and its current use in the hospital is given in chapter 3.2.

#### 2.1.1 Image Usage

As said in the introduction, in almost all surgeries one or more medical images are used. The most frequent images used during surgery are X-ray, CT and MRI scans. These images are all stored in the DICOM database.

### 2.2 CLIENT SPECIFICATIONS

The client, in this case the UMCG, is investigating the possibilities of using a touchless interface in the OR. The client specified that there is a system available and being looked into which allows the user to interact with an image, however no touchless interface of some sort is present. Next to this, there is no device which has been approved yet for use in the OR. The UMCG is currently looking into the Kinect for use in the OR for gesture recognition.

### 2.3 INTERFACE

The system as it exists at the UMCG now does not have a touchless interface inside the OR. The user has to select the image on the computer and after this selection the software allows the user to interact with the image and the user will be able to change the contrast, rotate, zoom and do translations.

## 2.4 STAKEHOLDERS

Surgeries take place every day and there are several stakeholders which are involved in (a part of) the total process of this project. Table 1 gives an overview of the stakeholders which are involved in this process.

Stakeholder	Role
UMCG	The UMCG provides the materials for this project and is the location where the surgeries take place. Also a supervisor from the hospital is assigned to this project.
OR Staff	Responsible for carrying out the surgery and managing the entire process around it. For this project surgeons will also provide information.
Hanze University – Hanze Institute of Technology	Providing supervisors and therefore stakeholders from the educational side of this project. The supervisors will provide coaching and necessary support where needed throughout this project. The supervisors for this project are Mr. Bryan Williams and Ms. Adriana Mattos.
Patients	For patients, general safety and good healthcare is of the highest importance. Their safety needs to be ensured through the process of surgery and recovery.

*Table 1 Stakeholders*

## 3 THEORETICAL ANALYSIS

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In this chapter an overview is given on solutions and systems which are at this moment in research or already available regarding the use of a touchless interface in the OR. Using this information, a conceptual model can be developed.

### 3.1 SYSTEMS

At this moment there are several systems in development which are able to be used in the OR for image interaction. For surgeries carried out, an assistant controls the computer when asked to do so by the surgeon. Next to this there are other systems like the WiiMote, accelerometer, tablet and 3D cameras. Most of those systems have been tested for usability in the OR. These systems will be described in the next subchapters.

#### 3.1.1 Computer

The computer is a currently used system to control and display DICOM images during surgery. An assistant controls the computer on request of the surgeon. A DICOM viewer is used to display the image and do the necessary manipulations to it like brightness, ROI (Region of Interest), zooming, rotating, measuring and contrast.

This approach however requires the surgeon to ask the assistant to interact with the image and the keyboard / mouse will have to be sanitized before the next surgery takes place because this is not a touchless interface. To improve hygiene while still maintaining the use of a keyboard in the OR a self-cleaning keyboard has been developed. This keyboard moves itself inside a container and cleans itself with the use of UV lights. This light kills off all the contamination on the keyboard <sup>(7)</sup>.

#### 3.1.2 Tablet

The tablet is already a widely used device in the hospital environment. Doctors use it to access patient files and by using the tablet, they don't have to use paper clipboards anymore. All patient data is saved on the device. The smaller tablets are ideal for being able to be carried around easily in the pocket of a doctor's coat and can provide a quick way to access the patients' data. According to C. Cullinan carrying the tablet from patient to patient is a big risk. If the tablet does not get sterilized between patient visits, there is a chance for germ transmission <sup>(12)</sup>. Although it is a big risk, this is a risk with everything that is carried from patient to patient without sterilization.

Some hospitals are experimenting with the use of tablets in the OR. The tablet is then wrapped in a cover which can be sanitized after the surgery as is shown in figure 2. This way the tablet will not be contaminated <sup>(12)</sup>.

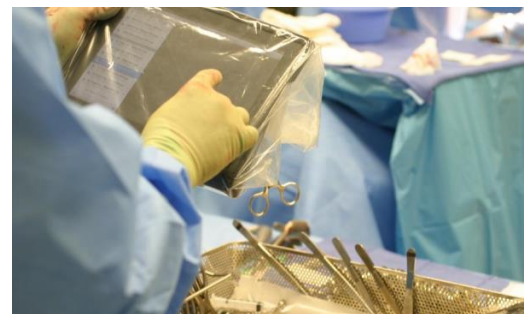


Figure 2 Tablet in use during surgery  
Image by Ximedica <sup>(12)</sup>

Another risk of using a tablet in the hospital is the risk of security. Since it is a mobile device and has wireless connections, it is relatively easy to get hold of the device or gain access through the wireless connection <sup>(13)</sup>.

### 3.1.3 Accelerometers

A way of controlling a screen without touching the screen or a remote is the use of accelerometers. A sensor device around the arm like a bracelet would be able to record the movement of the arm and translate this to gestures as explained by Kauppila et al<sup>(9)</sup>. Another possibility is to attach a sensor module to several joints of the body of the user as suggested by Deng et al. <sup>(25)</sup>. This type of system is able to recognise a wider variety of gestures compared to a wrist bracelet because the entire body can be used as a controller.

When the user wants to stop making gestures (the correct image has been reached), there needs to be a command like gesture to tell the system the user wants to stop navigating through the system and continue working without the system responding to every movement the user makes. If for some reason the user accidentally makes a movement which could trigger the start of recording measurements the system will respond to movements again and the state the screen was in could be lost. Next to this, like with all physical systems, care must be taken to clean the device and make sure it does not become contaminated during surgery.

A system has been made which records both directions of movement and muscle tension. This means that gestures can be used in combination with fingers for an even wider variety of gestures. But just like any other worn device, this needs to be sanitized as well if used in the OR <sup>(14)</sup>.

### 3.1.4 3D Camera

A camera system which uses two or more cameras (e.g. Stereoscopic) can be used to form a three dimensional image of what is in front of the camera. Another method is to use infrared to get a depth image. A detailed explanation of this method will be given in chapter 3.3. By using this, models can be made and the computer is able to recognize a person and its gestures, posture or other physical things. Examples of these cameras are the Microsoft Kinect and the Asus Xtion. The Xtion has the same specifications as the Kinect Xbox 360 <sup>(10, 15)</sup>. Both of these cameras are shown in figure 3.



Figure 3 (Left) Asus Xtion - (Right) Microsoft Kinect  
Images by Asus and Microsoft

Another system which implements touchless technology is the Leap. The sensor module developed by Leap Motion is capable of accurately displaying hands and other objects which are in range of the sensor. The accuracy of the sensor is 100<sup>th</sup> of a millimeter. According to a demo video released by Leap Motion the range of the sensor is limited <sup>(18)</sup>. If this sensor were to be used in the OR, the sensor would have to be placed well in range of the surgeon and therefore inside the sterile 'bubble' around the patient.



## 3.2 DICOM

Using a DICOM viewer enables the user to view the images, print them or manipulate the image like changing the contrast, rotate the image or zoom in on a special region of the image which is of interest to the surgeon or doctor.

### 3.2.1 DICOM Viewer

Currently during surgeries in the UMCG the DICOM viewer PoliPlus Web1000 viewer is used as shown in figure 4. This viewer is connected to PACS (Picture Archiving and Communication System). Images are loaded from the PACS database and then loaded into the viewer. This viewer is capable of loading several images or slices of images. Using that, surgeons are able to compare slices or other images. Another functionality is to measure the length between points (e.g. to measure the length of a tumour or the exact location of a region of interest (ROI)).

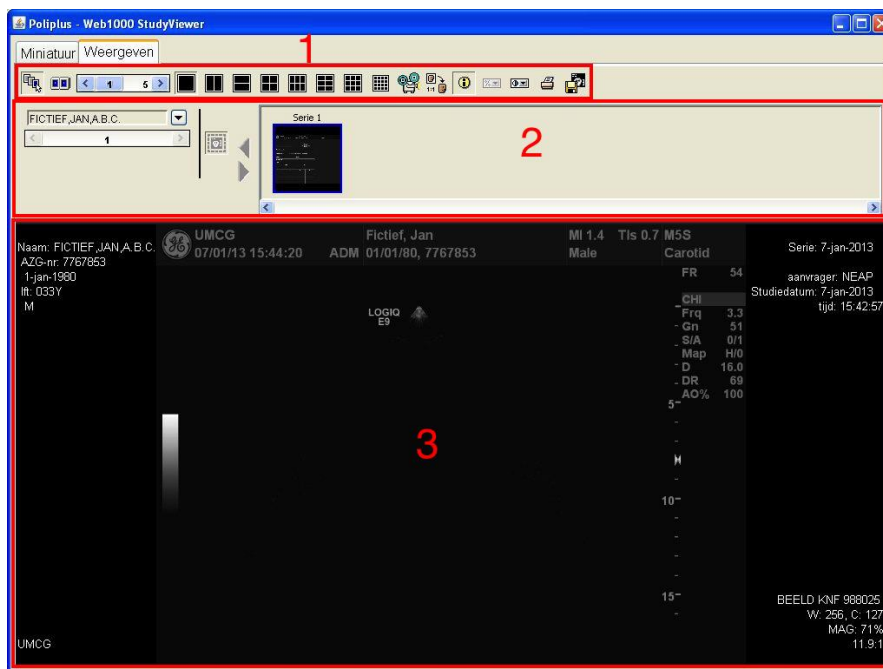


Figure 4 PoliPlus Web1000 DICOM Viewer.

1. A toolbar for selecting functions like viewports, layout and changing patient information
2. Selecting the patient and available thumbnails
3. The main window, this shows patient information and the selected image  
Image courtesy of Sebastiaan Stuy.

### 3.3 KINECT

The UMCG is currently focused on working with the Kinect sensor from Microsoft. This chapter will focus mainly on the workings of this sensor and gestures. The Kinect can provide a touchless interaction with the computer in the OR. This type of system makes the use of a keyboard and mouse in the OR unnecessary.

The Kinect is a camera system originally designed for the Xbox gaming console but at this moment widely used for development of all kinds of applications.

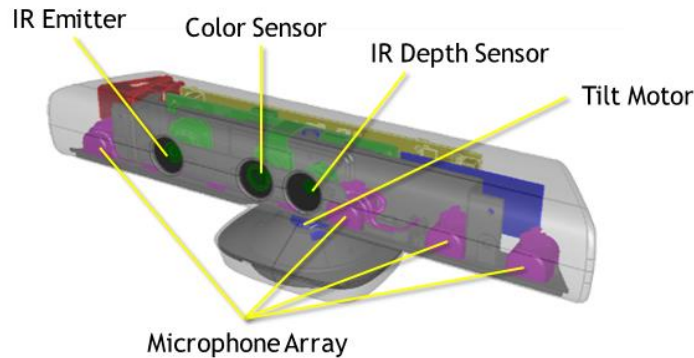
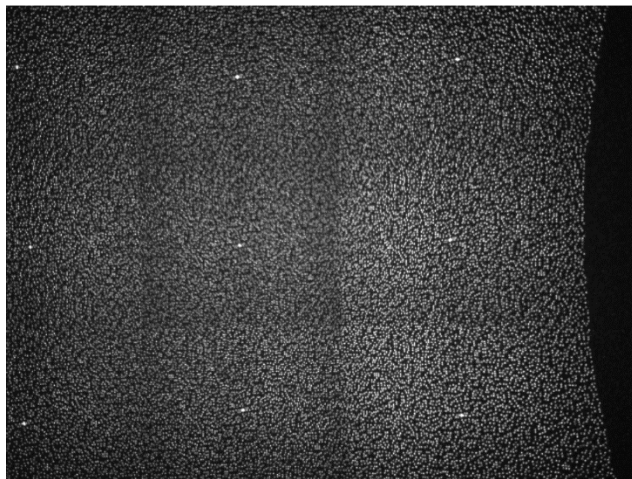


Figure 5 Inside view of the Kinect  
Image by Microsoft <sup>(10)</sup>

Figure 5 shows the internal side of the Kinect camera. The Kinect has 2 cameras, one in full colour and a sensor which records the IR pattern emitted from the IR emitter as shown in figure 6. This pattern is used to measure the distance to one or several objects, the size of the IR dots is measured as well as the shape. Shape indicates the angle of the object <sup>(10, 11, 16, 17, 20)</sup>.



The RGB camera has a resolution of 1280x960 and the IR depth sensor has a resolution of 640x480. The combined image from both sensors is used to form a 3D image of what is in front of the camera. The Kinect uses this 3D image to project a 'skeleton' on top of a user in front of the camera. Up to 20 joints are then tracked by the Kinect. To extend on functions, a microphone array has been added which is able to determine the exact location of the sound source. This can then be used for example to track a specific user after the user says a specific phrase. The Kinect can also adjust the angle of the camera due to a tilt motor (vertical direction) <sup>(11)</sup>.

Figure 6 Kinect IR pattern

The Kinect is also able to recognize voice commands and direction of those commands. This however will only work for short clear commands <sup>(11)</sup>.

### 3.4 TYPES OF INTERACTIONS

For this project a student has researched and compared two different kinds of gestures. Both of them use the right or left hand as a mouse cursor but the method to select is different. The first method uses a pause on a location to select (e.g. wait for 2 seconds to select where the cursor is pointing) and the second method is to use the other hand to 'click', move the hand forward as if a button were pushed.

As previous chapters stated, there are several ways to interact with the computer in the OR. However most of them require something physical to touch in order to interact. The solution which does not require any physical interactions and therefore is the most sterile solution is the use of a 3D camera and gestures.

### 3.5 MEDICAL IMAGING TOOLKIT (MITO)

The viewer mentioned before and currently undergoing tests at the UMCG is the Medical Imaging Toolkit (MITO). MITO is able to let the user interact with the DICOM images using gestures. The interface of the MITO resembles the PoliPlus Web1000 viewer described before <sup>(23)</sup>. However, this interface requires the user to select an image using mouse and keyboard before the gesture interaction can take place. After this selection, the user is able to interact with the image. The user can measure distances, change the contrast, do translations, rotate and zoom. Normally during a surgery, the surgeon has to ask the assistant to perform these tasks.

## 4 CONCEPTUAL MODEL

Based on research and gathered information through literature research and conversations with surgeons, a conceptual model can be set-up. This model is an outline for the research which will be conducted in this project.

At the time of writing the Kinect is already being validated and this project continues on this validation process. Previous research has shown the Kinect to be a more suitable method to use.

### 4.1 GENERAL CONCEPT OVERVIEW

Before the surgery, the surgeon or the assistant has already prepared an image which will be used during the surgery. They do this to prepare for the surgery itself so they know exactly what they have to focus on. However, if during the surgery another image is required, the surgeon will use gestures to change to a new image and optionally manipulate the image to suit the needs for this situation.

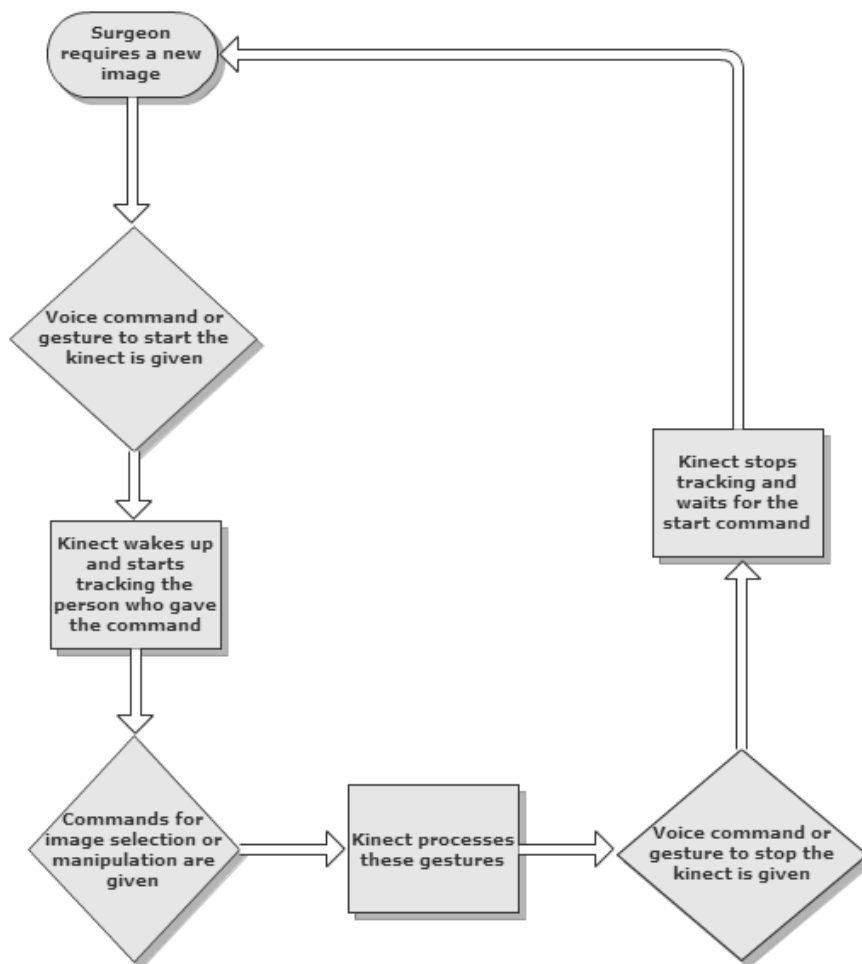


Figure 7 System flowchart

Figure 7 describes the flow of a system as it can be used for using gestures. In short, if the surgeon requires a new image, he or she will give a command or use a gesture to activate the Kinect. Next, gestures will be used to navigate to the desired image and optionally the image can be manipulated or a distance can be measured. Finally a command or gesture will be given to stop the Kinect. The Kinect will then wait for a new command to start tracking the user again.

## 4.2 GESTURES

There are several ways to navigate using the Kinect. Those different methods will be described in the following subchapters.

### 4.2.1 Pointer & Hold

The arm or hand can be used as a pointer. By moving the hand in a specific way the mouse pointer on the screen can be controlled. Clicking is done by keeping the hand steady on the button which needs to be selected for a specified amount of time (e.g. two seconds).

### 4.2.2 Pointer & Click

This method works the same as described in 4.2.1 but in this case instead of keeping the hand steady in one place to select an option, the other hand is used to click. By moving the hand forward in a clicking movement, the selection is made.

### 4.2.3 Gestures

This method is using specific gestures to perform actions. A swipe movement (moving the hand quickly from left to right or vice-versa) will select the next or previous item. Using this method requires the user to remember the set of gestures used in this interface and how to use them.

## 4.3 VOICE COMMANDS

For the navigations through the different patients, studies and series, the use of voice commands is a possibility. However Microsoft advises against the use of voice commands when this is used in sequence, asking the user to say 'next' to navigate through a list for example <sup>(11)</sup>. Another possibility is to have the user say the name of the selection he or she wants to make. But if the names are too complex (like ID numbers for studies), the Kinect is likely to make mistakes <sup>(11)</sup>. Therefore the use of voice commands for navigation will not be used.

## 5 RESEARCH DESIGN

The research design describes the setup of the experiments performed on the system and the development of the required interface. This design has as goal to create and test an interface which can be used by the surgeon in the OR of a hospital.

### 5.1 EXPERIMENTAL SETUP

The UMCG has provided a skills lab in which the OR setting is built. This can be used to test the placement and usage of the Kinect.

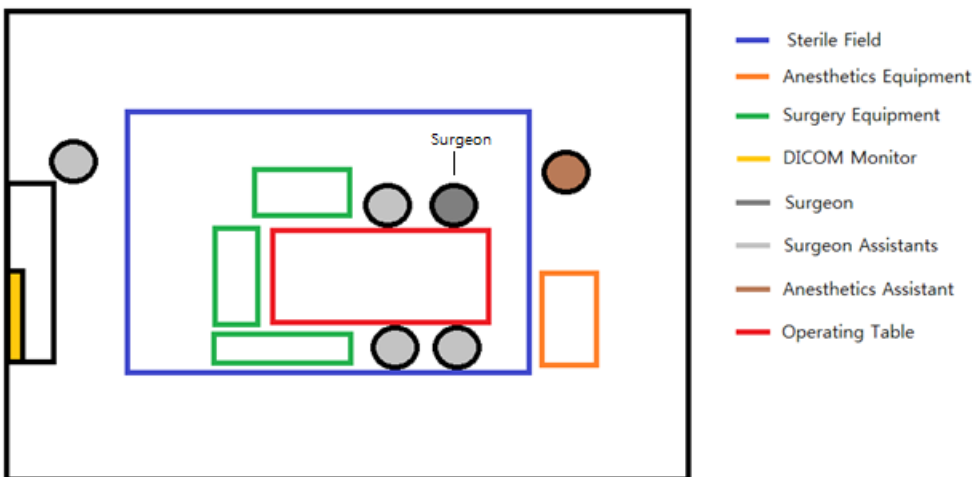


Figure 8 Top view of OR

Figure 8 shows an example of the top view of the OR, although this layout can change. At this moment the distance between the monitor and the surgeon exceeds the maximum range of the Kinect. Therefore the Kinect will have to be placed closer to the surgeon. The ideal location for this would be right in front of him, so he or she does not have to rotate his or her body to interact with the Kinect. The Kinect would then be placed on a flexible arm slightly elevated. This places the Kinect well within range of the surgeon and therefore it will be able to recognize gestures made by the surgeon.

### 5.2 KINECT VERIFICATION

Previous tests on the Kinect have been done with the 'old' SDK. With the release of the new SDK, some new functionalities and improvements have been introduced. This new SDK was compared by making a programme which is similar to the programme that is shown in figure 10. The outcome of this experiment helped decide which SDK will be used in further experiments.

The Kinect has a limited range between 1.2m and 3.5m <sup>(11)</sup>. To determine the ideal distance between the Kinect and the user, a number of tests have been performed. The user was placed in front of the Kinect at 1.2m, 1.9m and 2.6m. These distances were chosen in such a way that both the SDK's are able to track the user. The practical and physical limits of the Kinect are shown in figure 9. For this experiment five test subjects were used.

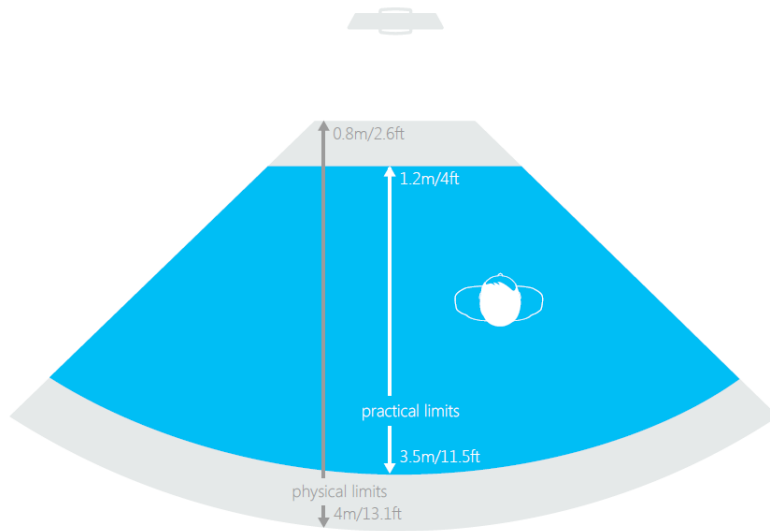


Figure 9 Kinect Setup  
Image by Microsoft <sup>(11)</sup>

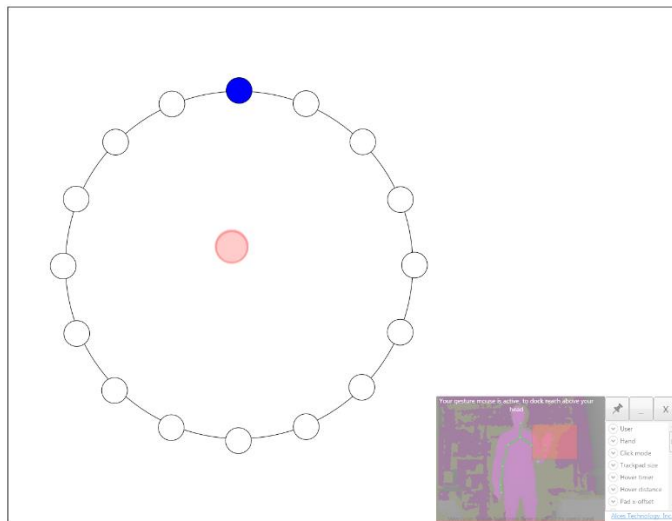


Figure 10 The test program used

These tests were done with a previously prepared programme by Sebastiaan Stuy and a Universal Gesture Mouse which is made by Alces Technology. The interface of both of these programmes is shown in figure 10. The programme records the accuracy and time taken for each sample. This was repeated three times

and with a big(x4) and small(x2) field in which the gestures are recognized (figure 10, the red square). To 'click' on the next button, the user has to hover the mouse cursor in place on top of the button. The sequence of the buttons is a set pattern. This method has been proved to be the more accurate method as is shown in figure 11. This figure shows the results of an experiment by Sebastiaan Stuy. He compared two different selection methods and two different sizes for the recognition of the gestures. After three trials the results show that the use of the big field (4x) and holding the hand in place (hovering) (in order to select) proves to be the more accurate method as the average error rate is the lowest after several trials <sup>(23)</sup>.

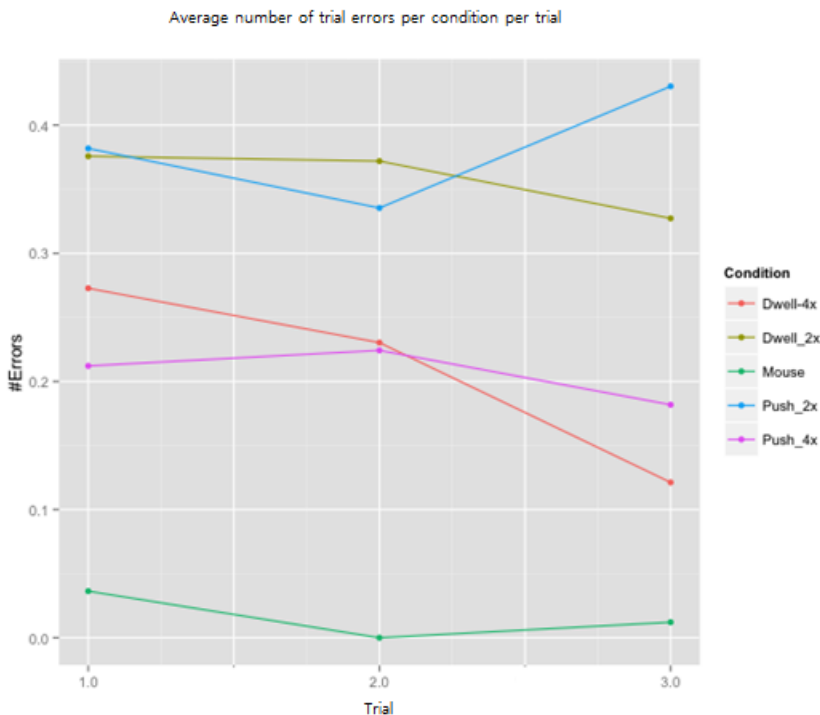


Figure 11 Comparison point test – Trials versus the average number of errors  
Image courtesy of Sebastiaan Stuy.

### 5.3 USER TRACKING

By default the Kinect will track the first user in the field of view. However, since several users will be in this field of view during surgery, a method has been developed which allows the system to track the surgeon only or the assistant who wishes to be tracked. For the Kinect to 'know' who to track there are several options; a voice command, marking the user by placing a coloured dot on his or her cap or the use of a specific gesture.



## 5.4 SMOOTHING PARAMETERS

When starting the Kinect, the program is able to set several ‘smoothing parameters’. These parameters influence the response of the Kinect to the movements of the users. Microsoft describes these parameters in more detail on their software development network (MSDN) <sup>(26)</sup>.

The parameters were tested for the specific effect the parameter has on the response of the cursor on the screen when moving the hand. A program was developed which counted the movements of the hand cursor over ten seconds when holding the hand completely still. It determines if the parameter causes the cursor to become unstable or not.

## 5.5 TRACKING MODES

The Kinect has two tracking modes. One mode is the ‘default’ mode which tracks the full body of the person(s) in front of the sensor. This full body then consists of 20 joints which are tracked by the Kinect. The other mode is ‘seating’. This only tracks the upper 10 joints of the person in front of the sensor. Figure 12 shows the joints tracked in default and seated mode.

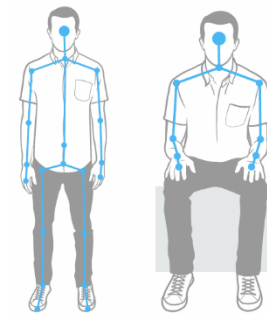


Figure 12 Default vs. Seated  
Image by Microsoft <sup>(11)</sup>

In the OR, the Kinect will be located in front of the surgeon. This means that the patient and operating table are in front of the surgeon and it is not necessary to track the lower body. An experiment was conducted to determine if there is a difference in performance for the two tracking modes. The default mode tries to draw a full body whenever the shape of a human body is detected. When part of the body is concealed (e.g. behind a table), it will still try to draw the missing part on top of the object in front of the user.

## 5.6 INTERFACE

In order to test the usability of a Kinect in the OR, an interface has been developed. This was done according to the design and usability of the previously described researched methods. The first step of this interface was selecting the correct image from a patient folder. The final step in designing and building the interface will be the implementation of the DICOM viewer. This means that the user will be able to select the correct patient and after which the user can select the correct image needed for the task at hand. However, for this research implementing the DICOM viewer into the interface is not the most important step and could be implemented at a later stage.

At the start of surgery, a patient will be selected on the computer. Then, during surgery it is possible to select the study, series and finally the image required for the surgery.

## 5.7 CONCEPT VERIFICATION AND VALIDATION

Of all previous described researches, a method was developed to record the usability of the method in the OR. If for instance the method using a gesture is accurate but it requires a gesture which uses a lot of space, it will not be usable in the OR and therefore not researched further.

## 5.8 USER VALIDATION

It is important for the surgeon to be able to work accurate and fast with this system. An interface was developed which could represent the final interface. In this interface the user, in this case the surgeon, will be able to select a patient before the surgery and during the surgery use gestures to interact with the image on screen.

After receiving feedback from a surgeon, the interface was finished and feedback from the surgeon was processed into the interface.

## 6 RESEARCH RESULTS

This chapter describes the results from the experiments conducted. The Kinect was tested for its accuracy to perform certain tasks on different ranges and the two SDK's available were compared for both accuracy and ease of use. The test plans used to perform these experiments can be found in appendix C.

### 6.1 KINECT ACCURACY

The Kinect is tested for the accuracy at different ranges and the performance of the two different SDK's. The tests performed recorded the time it took the user to perform the actions as described in the test plan. This time is compared over the two SDK's and the three distances. The results of these tests answered the first two sub-questions namely: "Which SDK performs better?" and "What is the ideal distance between the user and the Kinect?".

#### 6.1.1 SDK Results and recommendations

The main difference between the two SDK's is the method of selection. Version 1.0 uses the traditional mouse cursor. This cursor is hovered over the button for a pre-set amount of time after which it emulates a click with the left-mouse button. Version 1.7 has a built in hand-pointer. This pointer has the ability to click by physically moving your hand forward as-if the user is pressing a button. Another function is 'grabbing' a scrolling menu.

Figures 12-14 show the average time it took to perform the tasks of clicking or selecting all the buttons. Figure 12 is a comparison of the two different SDK's and their methods of selecting. The differences between the two versions are not big, however when we look at the maximum range, the older version has a significant increase in time. During the tests, the test subjects had difficulty selecting some buttons which resulted in this increase in average time.

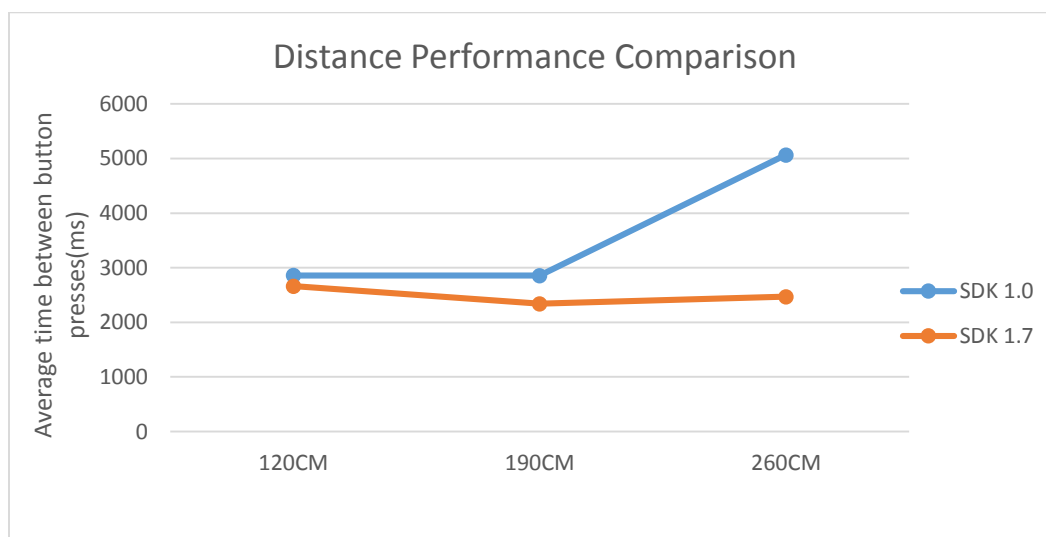


Figure 13 Distance performance comparison

In figure 13 and 14 the distances per SDK are compared and the three trials are compared. Because the experiment is a fixed pattern, it is expected that the average time (slightly) decreases after every test and

trial because the test subject can predict which button to press next. However, this is not the case for the 2.60m test on version 1.0. Because the test subjects had difficulty clicking on some buttons, the average time for this test was significantly higher compared to the other two distances.

For version 1.0 we can conclude that the two distances closest to the Kinect do not differ that much and up to 1.90m this will perform equally well. After 1.90m the average time increases and according to some test subjects they are not able to work well with this system.

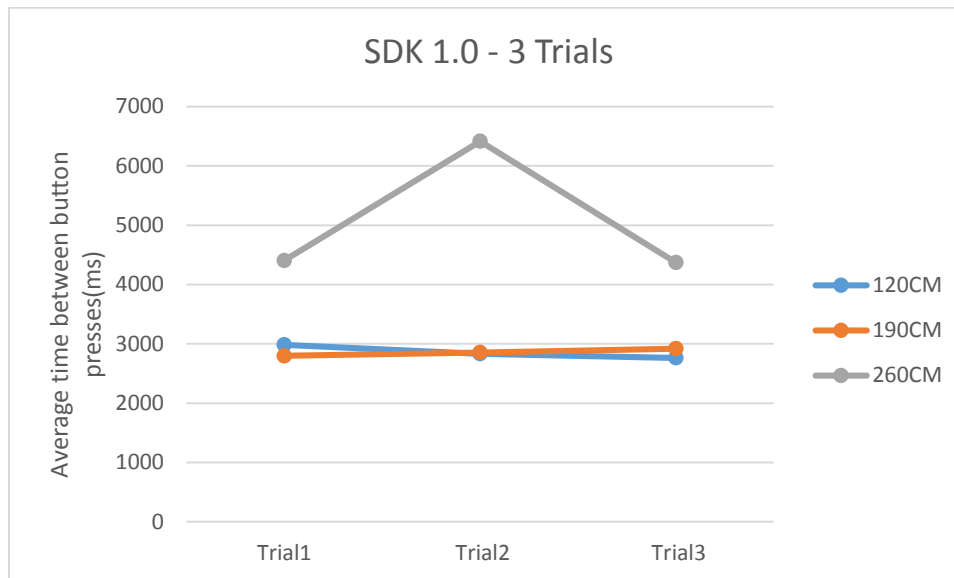


Figure 14 SDK 1.0 distance comparison

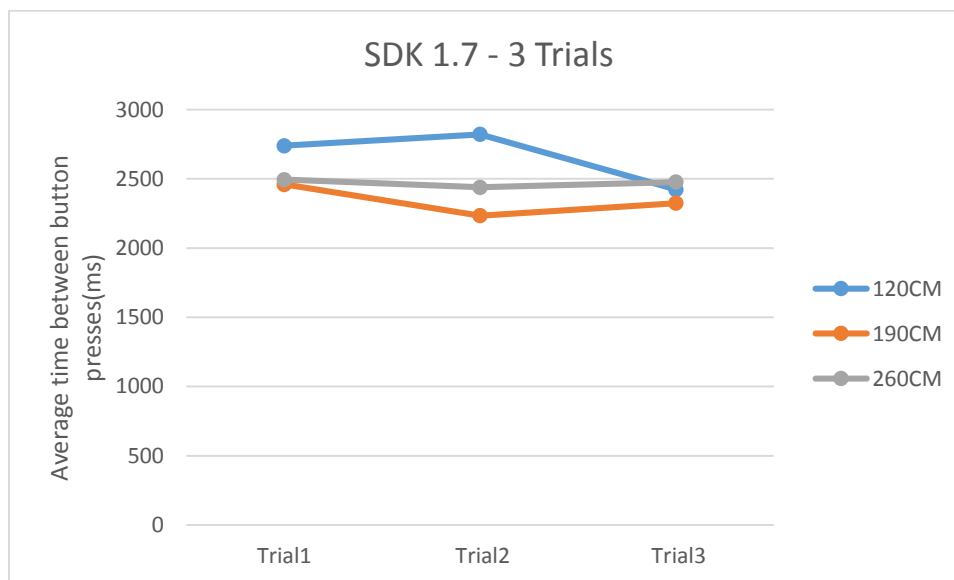


Figure 15 SDK 1.7 distance comparison

For SDK 1.7 the users take longest to complete the test at 1.20m. This is mainly due to the ‘pushing’ to click on a button. Because 1.20m is the minimum distance, it is possible that sometimes when pushing,

the hand is too close to the Kinect. This results in strange behavior of the hand cursor which makes the user unable to click the button and he or she has to try it again.

After having to click a lot in sequence, the test subjects complain about getting tired. Having to move the hand forward to push many times is exhausting. Therefore, in the final interface the user should not have to click a lot of times in a row.

Comparing the two SDK's gives a fair indication of the time it takes the user to click the buttons and on the accuracy of the clicking. However, because of the set pattern, the users 'learn' what the pattern is and in what sequence they have to press the buttons. This could result in the decreasing time the trial takes. However, the older and after this experiment least performing SDK, was done last. It is expected that the user knows the pattern and anticipates. The results do not show this.

After comparison between the two SDK's, version 1.7 has to lowest average time and the users confirm that they can use this selection method well at all the three ranges. For 1.0 it was too difficult to properly perform the task at the longer ranges. Therefore the better performing SDK for this project is SDK 1.7.

### 6.1.2 Kinect location

As version 1.7 of the Kinect SDK has the best results according to the time it takes to perform the tasks, it will be used in further testing and it will be used for the final interface.

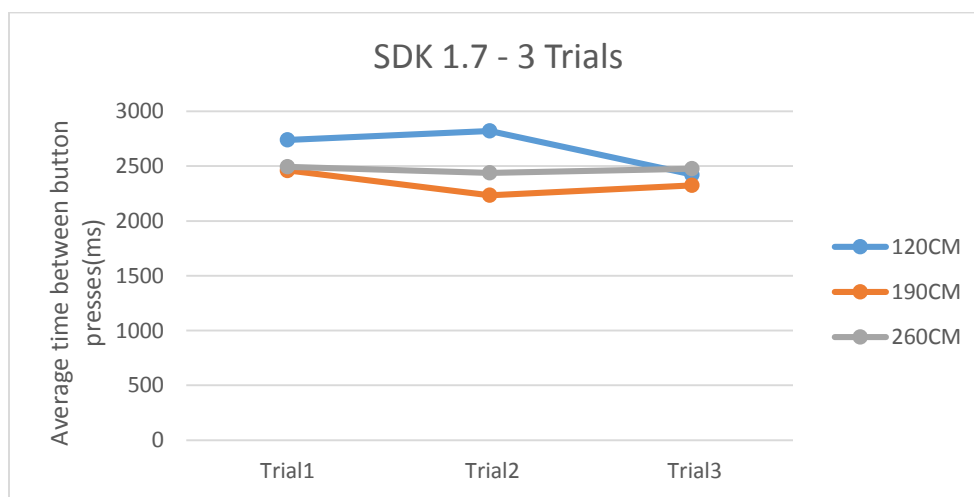


Figure 16 SDK 1.7 trial and distance comparison

If the distances from this SDK are compared, the distance somewhere halfway comes out best. This means that if the user is at 1.90m from the Kinect sensor, the user is able to quickly select items using the hand cursor.

At 1.20m most of the users started off slower compared to the rest of the tests. There are two causes for this. Firstly the test at 1.20m was the first test the user performs. In this case the user does not know the pattern yet and has to get used to the gestures to move the cursor around and click the buttons. Secondly, most of the test subjects had some difficulties clicking. When clicking, the users sometimes moved their hand in too close to the Kinect sensor. This resulted in the Kinect being unable to track the hand and therefore no clicking action was performed. After a few trials, the user gets used to the way the gestures are performed and the time to perform the actions decreases.

Most users confirmed after questioning that the distance around 1.90m was most comfortable to work with. The Kinect responded in a quick and accurate way to the gestures of the user.

### 6.1.3 Smoothing parameters

The Kinect has the ability to set several smoothing parameters. These parameters will smoothen the movement of the skeleton and its joints. This experiment describes the effects of the 5 different parameters at a low value (0), a high value (1) and at the default values. For a more detailed explanation about each of the parameters, please see Appendix B.

The test subject will sit in a comfortable position with his/her hand up. The jittering or movement of the hand cursor will be counted over a short period of time, every time the cursor moves the programme counts it. The amount of movements gives an indication on the stability of the cursor. Finally, the cursor movement will be tested. A high or low value of one of the parameters could mean the cursor is too slow or too fast to respond. See Appendix C for the test plan.

Parameter	Movements	Effect
All 0	19	Very vast response, slightly jumpy
Default values	13	Easy to keep on target, slight drift sometimes
Smooth	15	Smooth movement, Slow response
Correct	25	Moves a lot
Predict	25	Moves a lot, difficult to keep on target
Jitter	9	Very stable though sometimes 'jumps'
Maxdev	21	Jittery, drifts off target

*Table 2 Smoothing parameters comparison and effects*

The results from this experiment are shown in table 2. The default values described are: Smooth 0.5, Correct 0.5, Predict 0.5, Jitter 0.05 and MaxDev 0.04. These values are the default values as described by Microsoft's MSDN (Microsoft Software Development Network). The 'movements' column shows the times the cursor moved during the set time period of 10 seconds.

If the vales are all set to 0, the response of the hand cursor is very fast. However, trying to press on a specific target, like a button, the cursor is slightly jumpy which makes it hard to press on that specific button.

Using the default values, the cursor is easy to manage. Pressing a button can be done without any difficulty. If the user moves the hand quickly from left to right, the response of the hand cursor is slightly delayed. This however is of no problem in handling the cursor and using it to press buttons.

#### 6.1.4 Seated versus Default mode

SDK 1.7 has the ability to set the skeleton mode to 'seated' or 'default'. In seated mode, only the top half of the body is tracked. This is 10 joints compared to the 20 joints tracked in default mode <sup>(11)</sup>. This section focuses on answering the sub question "What is the best method to determine who should be tracked?".

The surgeon will be positioned behind the patient and the operating table. This means that the Kinect will not be able to 'see' the position of the lower joints. This could cause jittering and inaccurate joint placements. This experiment will determine if the use of seated mode increases the overall accuracy of the joints and cursor movement as well as the detection of skeletons on objects instead of persons.

While using default mode, the Kinect saw the table in front of the user as part of the user. If seated mode is used, only the upper part of the user is tracked. This reduces the fake skeleton effect where objects are seen as people or skeletons and it tries to track this.



Figure 17 Seated mode

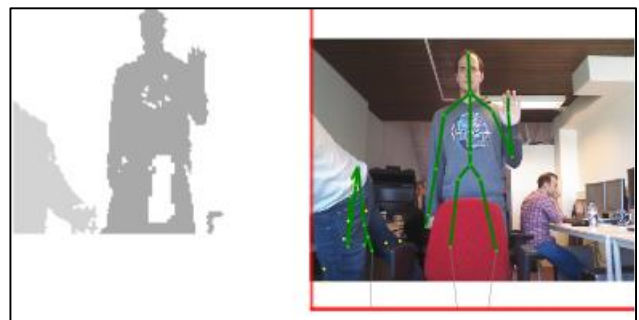


Figure 18 Default mode

As shown in figure 17 and 18, the Kinect tries to draw a full body and sees the object in front of the user as part of the body. When using seated mode, the Kinect does not try this and just looks for the upper half of the body.

A second advantage to using seated mode is the drawing of fake skeletons. Figure 18 shows a person in front of the camera and the Kinect somehow sees a person or body and tries to draw a skeleton.

The drawing of fake skeletons completely depends on the environment. If the user is the only object in front of the Kinect, there will not be any fake skeletons. However when there are a several objects, the chance of getting fake skeletons increases. This can be controlled by selecting the active skeleton which is described in the next chapter.

## 6.2 USER SELECTION

The Kinect is able to track up to 2 skeletons actively and the position of 6 skeletons in total. As there are multiple persons in front of the Kinect during surgery, the possibility of switching between the active skeleton has to be added. This means that if the assistant has his or her hands in a position where the Kinect tracks the hands, the surgeon will be able to override this tracking and make him or her the main user.

There are several possibilities to select a different skeleton. Those methods will be explained in the following subchapters.

### 6.2.1 Audio

The Kinect has the ability to record audio and (roughly) the direction from where the sound comes from. This means that short voice commands can be given which gives the surgeon or assistants the ability to decide which skeleton should be tracked. However, due to the limited time available for this project, using gestures for user switching was concentrated on.

### 6.2.2 Colour/Marking

Using a special colour mark for instance on the cap of the surgeon and assistant, it is possible to select the skeleton which belongs to this specific colour. The current version of the SDK does not have the ability to track a user by colour or by a special marking. Because of the limited timeframe, it is not possible to test this method of tracking for this project.

### 6.2.3 Gestures

By making a specific gesture it is possible to make the person who made this gesture the main and only person which is tracked by the Kinect. The gesture has to be simple and quick. The first gesture tested is raising the right hand to focus tracking on the person raising the hand and raising the left hand will track the two persons again. The second method to switch between users is to move the lower arms parallel vertically next to each other to become the focus for tracking and making a cross with the lower arms to track the two persons.

Both methods were tested by having several test subjects stand in front of the Kinect camera. At the start, the two first detected users are tracked. When one of the tracked users raises the right hand, the other user's skeleton is not tracked anymore and can move his or her hands freely without interacting. When the active user raises the left hand, the users who were previously tracked, are tracked again and can interact with the Kinect. The same goes for the second method of making the gesture with two arms.

To see who is being tracked, both users try to move the hand cursor. As only one of the users can control the cursor, the other user is not actively tracked. If however the other user raises his or her right hand, the Kinect immediately switches its focus to that user giving him or her the ability to control the cursor and interact with the Kinect.

When using 'default' mode, the Kinect draws fake skeletons, skeletons on top of inanimate objects which causes uncontrollable jittering and possibly movement of the cursor. Both methods for switching between tracking one or two skeletons worked in 100% of the cases.



Users total	Actively tracked	Passively tracked	"Fake" skeletons	Able to focus?
1	1	1	1	Yes
2	2	0	0	Yes
3	2	2	1	Yes
4	2	3	1	Yes

*Table 3 Kinect user switching test*

Table 3 shows the results of a simple test. Up to four users were placed in front of the sensor. The amount of users actively and passively tracked are counted as well as the amount of 'fake' skeletons. The appearance of 'fake' skeletons is completely random. Usually the Kinect detects a chair and tries to draw a skeleton on it. This could sometimes cause the Kinect to track this skeleton and a hand cursor will show. Because it is not a real skeleton, the hand will move wildly over the screen. In all cases the user was able to focus and therefore deny the 'fake' skeleton from interacting with the Kinect.

Finally the ability to switch between users was tested. One of the test subjects performed the gesture to become the only tracked person. This test showed that users are able to switch using this gesture. This works up to and including four persons.

## 6.3 INTERFACE

This section describes the interface and the feedback given by the surgeon. This is used to answer the sub questions “What gesture is preferred by the surgeon?” and “What should the interface look like to be useful for a surgeon?”.

### 6.3.1 Interface Clarification

The interface is built to incorporate built-in functions in the Kinect SDK. These functions include the buttons, the method to ‘grab and scroll’ and the way the user is tracked. The surgeon will be able to quickly and effectively select the next image or look between different studies and/or series of images. If the wrong person is tracked, an assistant has his or her hands above the waist which causes the Kinect to track him or her, the surgeon can perform a gesture to focus tracking on the surgeon. The program can be controlled by either the mouse or by using gestures. However, for hygienic purposes the use of gestures is advised.

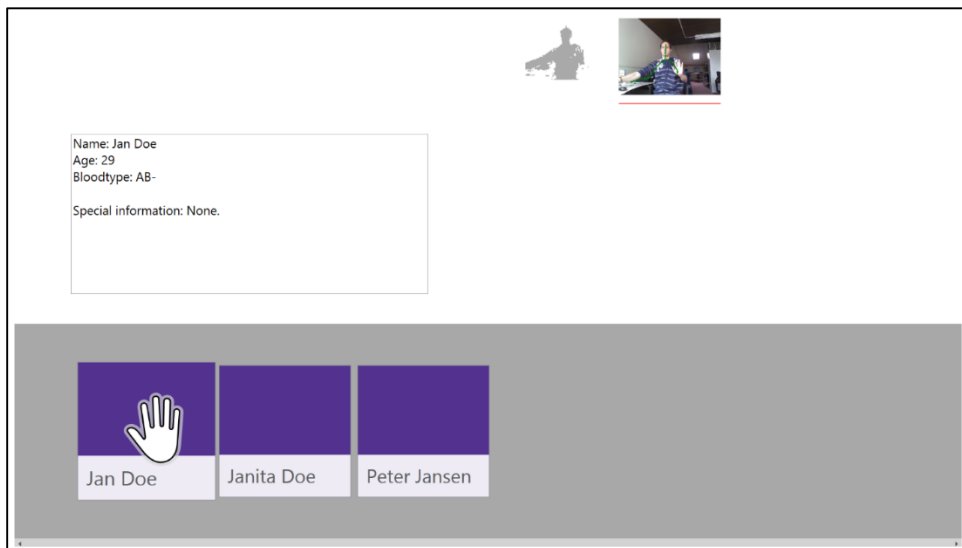


Figure 19 Interface layout

By using the interface (figure 19), the user is able to see patient, study and series information by hovering over the corresponding buttons. For a more detailed explanation about the interface please see appendix D.

### 6.3.2 Surgeon feedback

According to the surgeon, the methods used to interact with the interface are easy and accurate. The only comment was about the gesture to switch between users. The surgeon can only move the hands above the waist and below the shoulder. Moving the hands outside of this area could cause the surgeon to lose sterility. The other gesture suggested, to move the lower arms parallel vertically next to each other to focus and make a cross to track everyone, is a good solution. This gesture is not made naturally during surgery which means it cannot be done accidentally. This gesture has been implemented in the final version of the interface.

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## 7 CONCLUSIONS AND FUTURE RECOMMENDATIONS

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### 7.1 CONCLUSIONS

As has been confirmed by surgeons, not being able to interact with or change the image on the screen is something they would like to have solved. Currently they have to ask an assistant to perform these actions or just leave it as it is. If the surgeon can perform these actions themselves, they can improve the quality of the surgery. Previous research has shown that the Kinect is suitable to use in the OR. It provides touchless interaction with a computer and is therefore a hygienic alternative to the keyboard and mouse.

During this project the performance of the Kinect in an OR setting has been tested, taking into account the location, range and functionalities. Different settings have been tested and the complete system performs best when the Kinect is located at 1.90m from the user and using the seated mode. These settings have the least chance of producing fake skeletons improving overall performance.

If a user is tracked by the Kinect and another user needs to interact with the image on the screen, he or she can perform a gesture to focus tracking.

An interface has been developed using the functionalities of the SDK provided by Microsoft. These functionalities make it easy and intuitive for the user to select items and grab a list to scroll through the different items as patients, studies and series.

However due to limited time implementation of the DICOM viewer in the interface was not possible so a plain image was used to give an idea of the appearance of the final product.

### 7.2 FUTURE RECOMMENDATIONS

Due to the limited timeframe, other methods for switching between the skeletons as active user have not been tested. Using audio or a colour tag should be tested. Another possibility is to combine the use of, for example, audio and gestures. If the surgeon is unable to perform a gesture, he or she can give a voice command.

As mentioned in the conclusion, a connection with actual DICOM images has not yet been made. The program should retrieve the correct set of images belonging to the selected patient, extract the middle image as jpeg file for displaying as thumbnail and finally populate folders with the studies, series and images. The current location of the example DICOM image used currently in the interface can be replaced by the DICOM viewer. This then needs to be coupled to the Kinect to have functions similar to MITO.

Finally, if the DICOM viewer has been implemented, the Kinect is ready for live testing. The Kinect will be placed in an OR setting. Surgeons will test the performance of the Kinect during a practise surgery.

Development on the Kinect camera itself is also continuing. At the end of 2013, a newer version will be released which has a higher resolution and more functions <sup>(27)</sup>. This is likely to improve the accuracy and features of the interface described in this report.

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## 9 APPENDICES

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### APPENDIX A – SURGERY ATTENDANCE

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#### 9.1 SURGERY

This document describes the preparation and results of attending surgery on 05-03-2013. All things that are important for the project are written down in this document for later use. The surgeon who performed this surgery and to whom the questions were asked is Dr. Jutte.

##### 9.1.1 Preparation

###### 9.1.1.1 Surgeon

It is important to watch what the surgeon does with his hands. Especially occupation of one or both hands should be noted. This is important to see whether the surgeon can use one or two hands for gestures towards the system.

###### 9.1.1.2 Position and field of view

Noted should be the field of view from where the system could theoretically be placed. The camera on the system should have a free field of view towards the surgeon to be able to register his or her gestures.

##### 9.1.2 Questions

If possible, some questions can be asked to the surgeon, these questions are as following:

- 1) How often are the DICOM images used, what percentage of all surgeries performed?
- 2) How often is another image required during the surgery? (e.g. the image has to be changed by an assistant)
- 3) How much freedom does the surgeon have with his hands? What is the space in which he or she can use his or her hands?
- 4) What is preferred, one hand or both hands?
- 5) Any type of gestures preferred?
- 6) What types of images are used during surgery? What possibilities? (MRI, CT, ECG etc.)

## 9.2 RESULTS

### 9.2.1 Surgeon

Since the surgeon is not alone, he or one of the other surgeons is always able to use one or two hands for gestures. However, the surgeons do not want to move their hands below waist level. This in order to keep sterility. The range in which gestures can be made is not too large. The biggest movement possible is moving the arm straight up (e.g. to activate or deactivate tracking).

### 9.2.2 Position and field of view

If the Kinect is placed at the position the screen is placed now, there is a big chance an assistant or other surgeon stands in front of the camera or 'takes over' the tracking skeleton. Therefore it will be important to tell the Kinect who to track (e.g. say the voice command 'track me' so the Kinect knows who wants to perform gestures).

### 9.2.3 Questions

- 1) In most surgeries DICOM images are used
- 2) In about 1 in 4 surgeries images need to be changed. However, if the possibility of easy changing of the image is implemented, this will probably be done a lot more.
- 3) Hands cannot go below the waist and movements left to right are relatively limited. It is possible to move the arm up e.g. for activating or deactivating tracking.
- 4) 2 Hands is not a problem at all to use
- 5) Using the arm as a 'pointing device' is not a problem.<sup>(1)</sup>
- 6) Images used most during surgery are X-ray, MRI and CT scans.

<sup>(1)</sup> I will try to test both the mouse as a pointing device and specific gestures for selecting.



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## APPENDIX B – TEST PLANS

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### 9.3 KINECT SDK AND DISTANCE COMPARISON TEST

Since February 2013 a new version of the SDK for Kinect has been released. This new SDK has several new functionalities amongst which a new method to select or 'click' buttons. This method for clicking will be compared to the result of the previous experiment (which selection method is best) and results from this will determine the best way to select items.

The surgeon will have to be able to use the Kinect accurately for fast acquisition of new DICOM imagery. Therefore, the Kinect will have to respond accurately to the movements of the surgeon's hands.

The Kinect will be tested on its performance on different ranges. The ranges are chosen in such a way that it covers the minimum and maximum distance. For comparison, halfway will be measured too.

After fast testing with both the SDK's it turns out that for version 1.0 the minimum distance is around 1 meter and the maximum is around 2.60 meters. For version 1.7 these distances are 1.20 and 3 meters respectively. Therefore, the distances which will be used in this test are 1.20m, 1.90m and 2.60m.

A previous student has conducted a point experiment to determine what the best method for selecting or 'clicking' on an item is (between two different regions of interaction and between hover and clicking). This experiment did not include a ranged test, this will be performed in this experiment with the best method from the previous experiment.

To get an idea of what is the ideal range for placing the Kinect, the fastest time will be recorded.

The test program for version 1.0 looks as shown in figure 18. Figure 19 shows the test program for version 1.7 of the SDK.

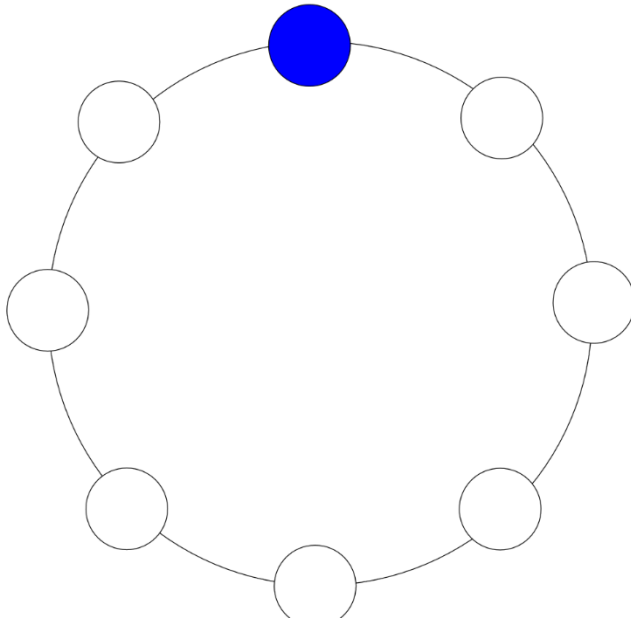


Figure 20 Point experiment for V1.0 - adjusted from Sebastiaan Stuy

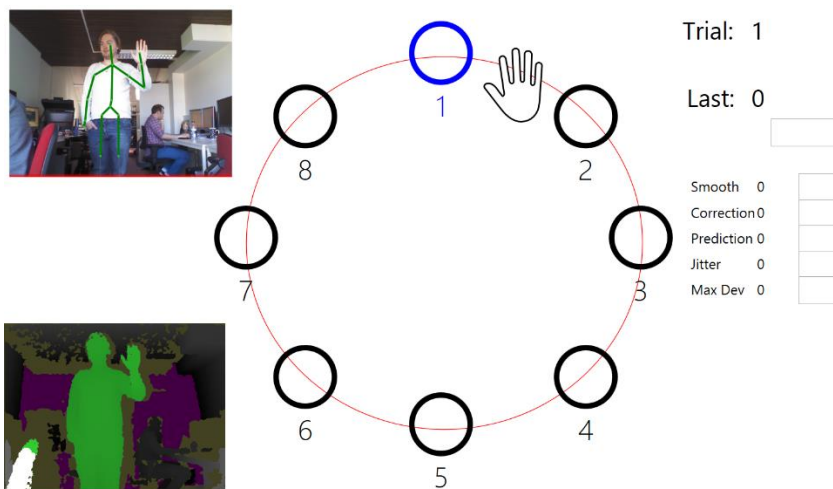


Figure 21 Point experiment for V1.7

On screen, the programs look similar and they have the same pattern to make comparison between the two fair.

## 9.4 PARAMETER TEST

The Kinect has the ability to set certain parameters (see Appendix B). To see the effect of these parameters and what they should be, a small test will be performed.

The test subject will lift his or her hand to about shoulder height and keep still. He or she has to try to keep his or her hand on the marked target on screen. Then, all parameters are set to 0 and for 10 seconds the movements of the hand cursor are counted. After this, the test is repeated for each of the parameters to be set to 1. Next to counting the amount of movements, the effects of the specific parameter are described (slow response, inaccurate etc.).

Finally the parameters will be set to the default values as described by Microsoft (see reference appendix B).

The results of these tests will be compared and the parameters will be chosen accordingly.

The software records for 10.000ms and records every 'HandPointerMove' event.

## APPENDIX C – INTERFACE

This appendix describes the different windows and components for the built interface.

### 9.5 PATIENT SELECTION

Figure 22 shows the first screen after starting the program. This window shows the list of available patients. If somehow the Kinect is disconnected, a window like figure 23 will be shown to inform the surgeon that the Kinect is disconnected or dysfunctional.

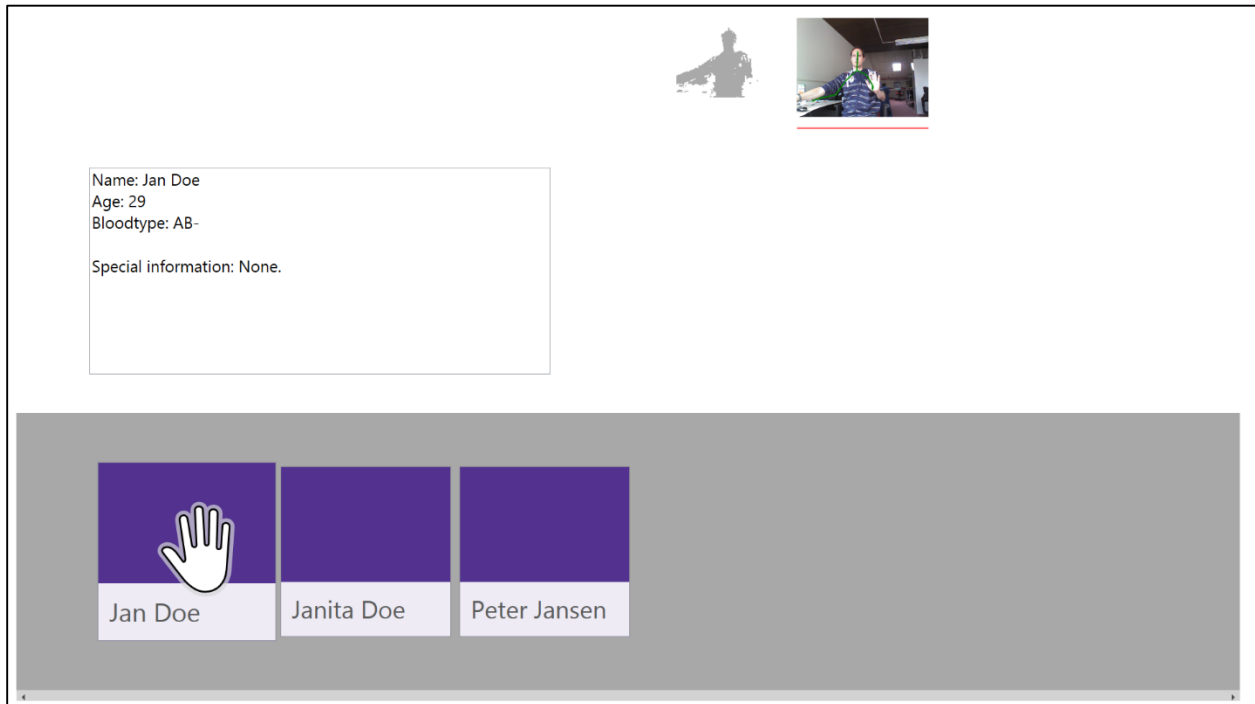


Figure 22 Patient selection screen



Figure 23 Kinect required

In this window the user can select the patient or get information about this patient by simply hovering the hand cursor or mouse cursor over the patients' button. By hovering, a pop-up window will show giving detailed information about the patient (as far as this information has been entered in the system).

## 9.6 STUDY SELECTION

After selecting the patient the user has the option to choose between studies as shown in figure 24. These differ in date or type of study done like CT or MRI. Again like when selecting the patient, the user can hover the hand cursor on top of the button to get information about the type of study and date.

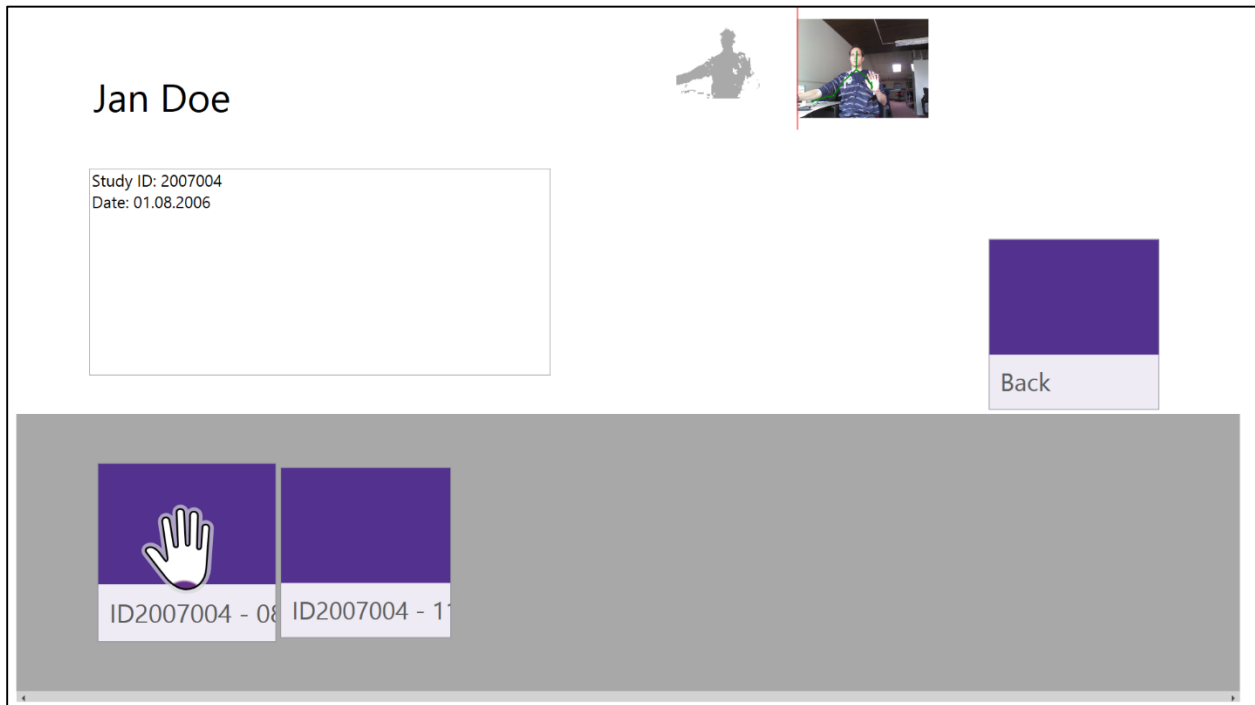


Figure 24 Study selection screen

## 9.7 SERIES SELECTION

Figure 25 shows the last selection window. This window gives the user the option to select one of the series. The series differ in settings like the use of contrast, position or brightness. The settings will be shown by simply hovering above the image thumbnail. This image is one of the images from the series.

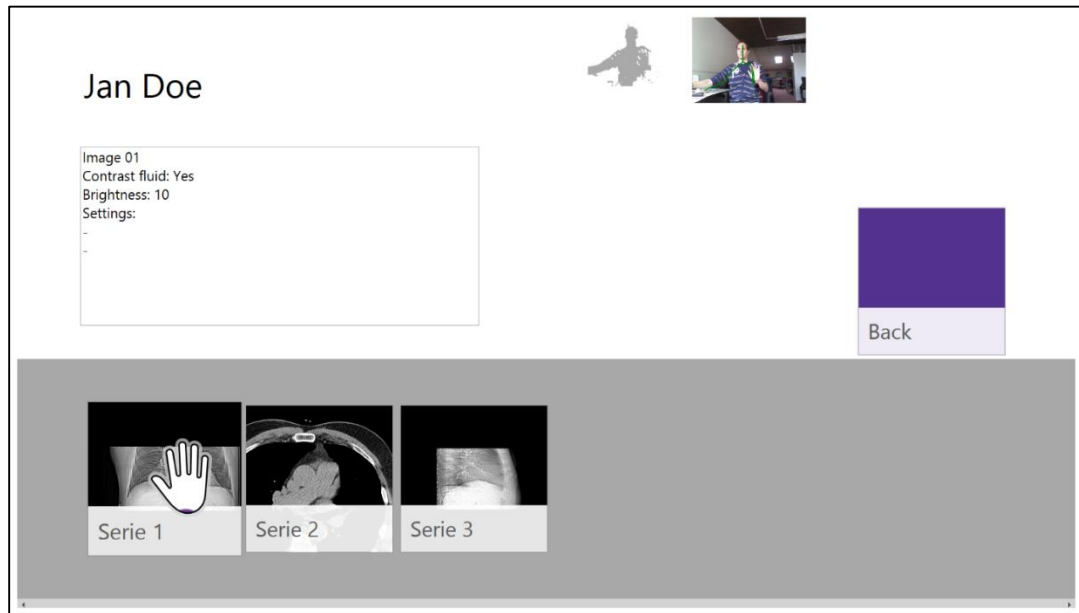


Figure 25 Series selection screen

## 9.8 IMAGE MANIPULATION

The final stage of the interface is showing the actual DICOM image. In this screen the user will be able to select different images in the current series and interact with these images as described in chapter 3.

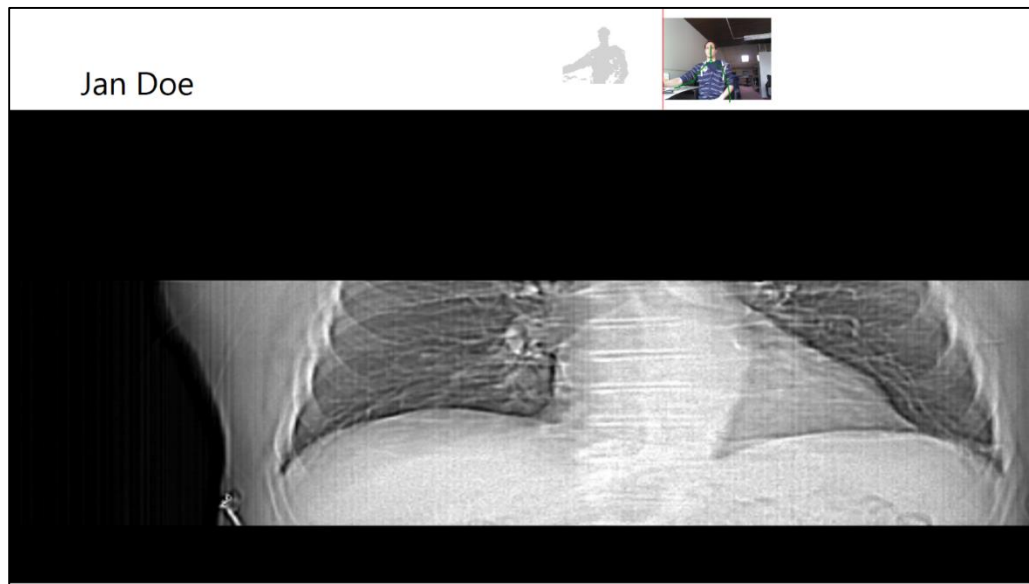


Figure 26 Image interaction screen

## 9.9 GESTURES

If a user wants to be the only one the Kinect should track, two sets of gestures to accomplish this were proposed.

The first set is raising the right hand above the head to become the focus. After this gesture, the Kinect does not track anyone else apart from the user that raised the hand. If the left hand is raised, the Kinect tracks all the users.

The second set is moving the arms parallel, vertically next to each other to have the Kinect track the user. To track all the users again, the arms are crossed in an 'X' shape.

Both of these sets of gestures are not naturally performed during surgery. This means that the gesture will not be done accidentally.