Feasibility of Team Training in Virtual Reality for Robot-Assisted Minimally Invasive Surgery

Worksheets

GROUP 743
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Aalborg University

Contents

Chapter 1

Problem Statement

Motivation

Robot assisted minimally invasive surgery (RAMIS) is used for many medical procedures. It allows for more precise surgery and lowers the risk of injury while reducing recovery time for patients [1]. Traditionally, the surgical performance has been measured in terms of surgeons' visuo-motor skills and dexterity, however a shift in the conceptualization of competencies is emerging in new literature [2][p. 83]. One of these competencies is teamwork in the operating theatre [3].

Lingard et al studied communication in the operating theatre and found that 36% of errors affected the teamwork negatively [4]. From this study, five key points of communication in the operating theatre were found: time, resources, roles, safety and sterility, and situation control.

To counter human errors, and to reduce critical events, simulation based training has become increasingly popular over the years [5]. This applies to multiple professional and high risk contexts such as aviation and surgery. As the goal of simulated training is to involve all members of the surgical staff and to enhance their performance, R. Aggarwal suggests that the method can also be applied to other procedures such as robot surgery. As robot surgery is also a high risk context, virtual simulations of high risk procedures is also beneficial. This project will explore the possibilities of simulating surgery training in virtual reality (VR) and assess the viability in context.

Based on the information above and focusing on the impact of recent virtual reality technology, this project aims to answer the following problem statement:

"Is virtual reality a viable addition to RAMIS team training?"

Chapter 2

Field Studies

Purpose

The purpose of the studies was to understand how nurses and surgeons train to operate a da Vinci robot and perform robot assisted minimal invasive surgery (RAMIS), as well as to asses what must be included in a surgery scenario.

Method

We observed training sessions and a real surgery at Minimally Invasive Education Centre (MIUC) followed by a semi-structured interviews with Jane Petersson, First Nurse Assistant and Nurse Specialist in Robot Surgery, and Johan Poulsen, Head Surgeon at Aalborg Univeristy Hospital, to get an understanding of RAMIS and how surgeons practise. We conduct a contextual inquiry, which requires observations of the context, in this case both the training room and operating room, and the interviews with the two experts provide information about important procedures and tools. They also clarify observations, in case of ambiguity.

The observation team took both pictures, notes, and recording video from the operation. Notes from this study are found in Appendix A. These illustrate the tasks and teamwork necessary to perform such an operation and were used to create different models; a physical model showing the layout of the room, a sequence model to clarify the work flow, and an artefact model showing objects used during the procedure.

Results

The results are split into three sections; surgeon training at MIUC, team training focused interview at MIUC, surgery observation.

Surgeon Training at MIUC

The training sessions at MIUC varies depending on the skill level of the participants. In cases with skilled participants, the students take on the role as instructors to help guide during the training session. This is beneficial as the surgeon often will be in charge during surgery.

During the interview, Jane Petersson explained that during team training a surgeon will operate the robot while making calls for the nurses in training. The individual tasks for the nurses depend on their current role. For instance, a first assistant nurse is the one who assists the surgeon inside of the patient. In general, the training focuses highly on getting familiar with the robot and how it operates during surgery. One particular task is important for the nurses to learn - how to dock the robot. As stated by both Jane Petersson and Johan Poulsen, ensuring that the robot is correctly docked is key to enable full movability of the robot. Johan Poulsen also expressed the importance of sterility of staff and tools.

Team Training Focused Interview at MIUC

One of the most important things during surgery and training is the emergency handling, however this requires extensive knowledge of the robot and tools. Another very important task is the placement of the robot arms because collisions during surgery can be very dangerous. Sometimes the surgeons adjust the arms manually. In general, the training is for hands on experience with the robot and individual instruments, in preparation for a real surgery.

Teams during surgery, from which roles during team training are practised, consist of:

- First assistant nurse - Sterile, assists the surgeon inside the patient's body.
- Scrub nurse - Sterile, prepare unpacked tools for the first assistant nurse.
- Circulating nurse - Not sterile, unpacks tools, and can go outside the sterile area.

During training, on the first day Jane Petersson starts by introducing the robot and showing how tasks are done, while students observe. They also get hands-on experience with docking and moving the robot arms. On the second day, students are expected to do most of the tasks themselves. At the end of the second day, Jane Petersson sabotages some of the equipment and the students have to find and fix the errors. Any mistakes done by the students are used for learning purposes. At the beginning of the training, Jane Petersson makes most of the decisions, however later the students are expected to take the lead.

Surgery Observation

The physical model shows the layout of the operation room and the staff's workspace. The figure includes doors and their movement as well as other objects. The layout is shown in Figure 2.1.

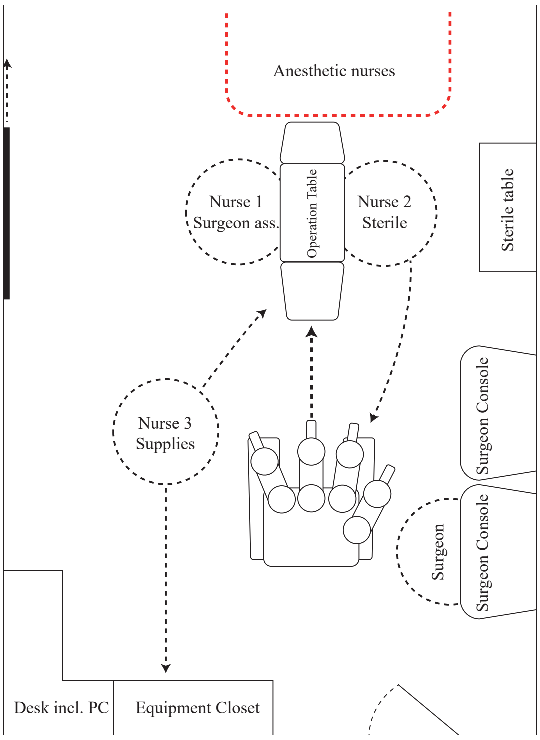


Figure 2.1: The phyiscal model showing the layout of the operation room

The physical model enables the development and design of the room when creating the simulation.

The sequence model is based on Jane Petersson's worksheet used in team training at MUIC. The sequence model is shown in Figure 2.2.

The sequence model describes the actions necessary to both start the operation and to end it. This enables the design of the tasks which should be included in the simulation and their order of appearance to the user. The model shown is for an

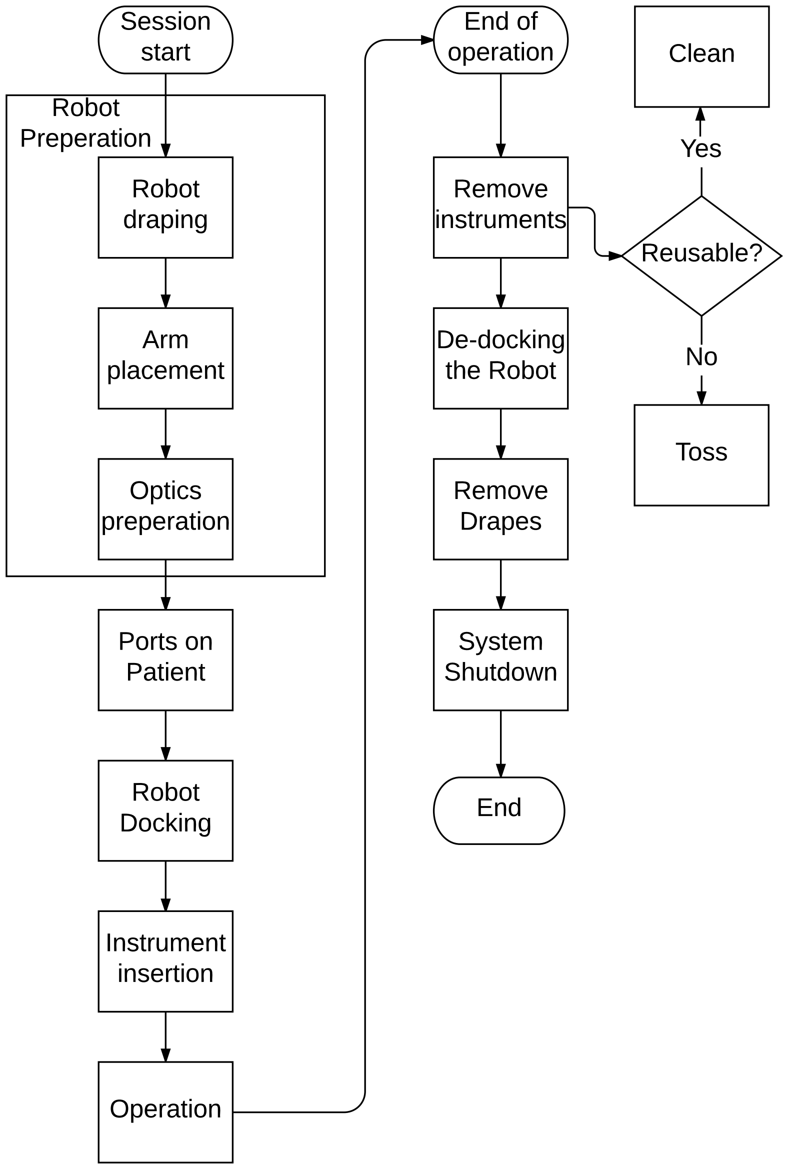


Figure 2.2: Flowchart of the sequence model showing how the operation preparation and debrief is carried out

operation without any complications. Complications can lead to undocking the robot in an emergency.

The Artefact models are shown in Figures 2.3, 2.4, 2.5, 2.6, and 2.7. These are created from pictures taken during the observation. Figure 2.3 shows the plastic drapes used to cover the arms of the robot sterilising it. Figure 2.4 shows the endoscopic camera during calibration. Figure 2.5 shows the endoscopic camera up close. Figure 2.6 shows one of the ports used to insert the tools into the patient. Figure 2.7 shows the tools used with the robot.

Figure 2.3: The drapes used to cover the arms of the robot, sterilising them

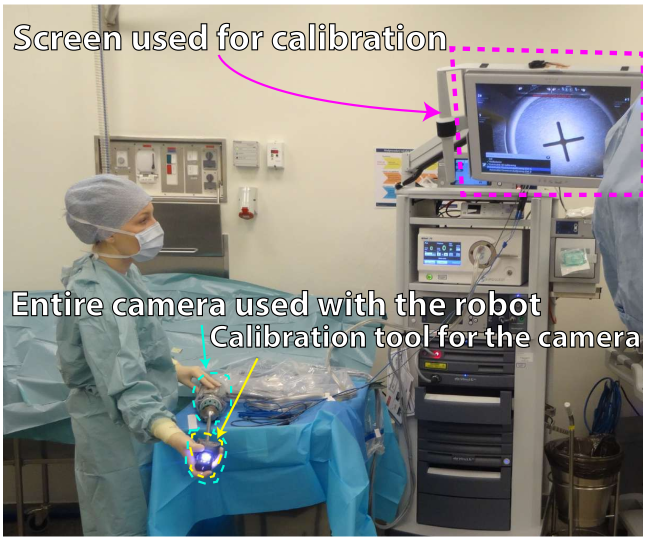


Figure 2.4: The camera used with the robot and a calibration tool

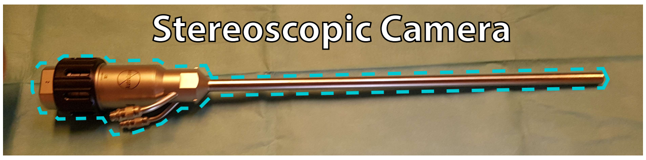


Figure 2.5: The endoscopic camera up close

Figure 2.6: One of the ports used to insert the tools in the patient

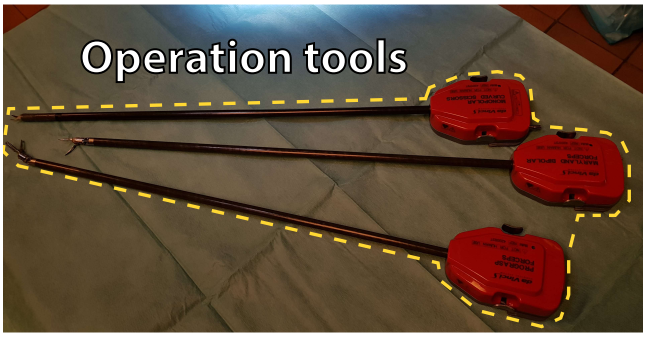


Figure 2.7: The tools used with the robot

Conclusion

The observations and interviews have given an insight as to how both the surgeons and the nurses train and work with the da Vinci Surgical System. Furthermore, critical procedures have been explained by Jane Petersson. These procedures are a must know as failures within these could prove critical or even fatal. The contextual inquiry has been used to determine implementation requirements and key considerations for the expert review. The script for this interview is shown in Appendix B.

Chapter 3

Rules

Designing Rules for a VR Environment

To ensure realism and to estimate functionality of the virtual reality simulation a set of rules for the system should be established. The core rules can be separated into three primary groups; the system, the users, and the virtual equipment. However, these rules are set prior to implementation but are based on observations made in the training room as well as interviews with Jane Petersson. The mindmap of these rules is shown in Figure 3.1.

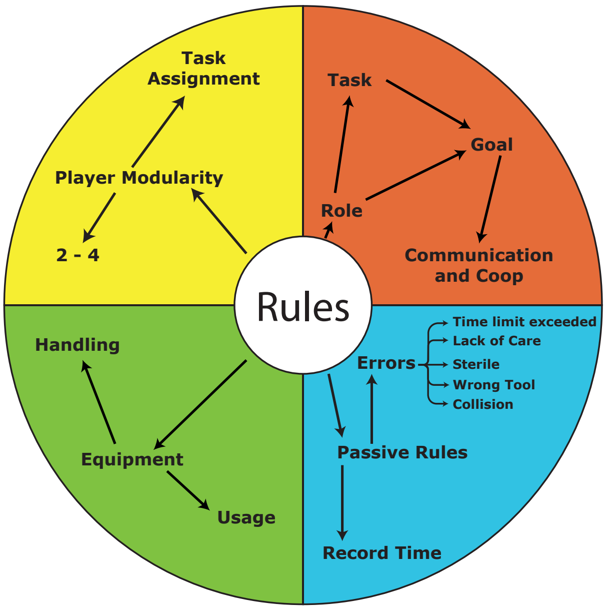


Figure 3.1: Mindmap

The System

The rules set for the system can be considered passive. These rules primarily exist to accurately recreate the environment and ensure the proper functionality of the surgical equipment. These rules also track any errors that might be done by the users, such as poor positioning of the robot arms or incorrect tool placement.

The User

The users in the scene should be designated a specific role which entails different tasks, but they should not be limited by that role. Completing a task as a group, rather than multiple individuals should be the primary focus for the users, since communication is vital to team training.

The Equipment

The equipment's rules should primarily focus on their specific use and how they should be handled by the users. Furthermore it should also include how the equipment should respond to certain user actions or other objects within the scene.

Chapter 4

3D Modelling and Animation

3D Modelling

The 3D model of the da Vinci robot was created in Autodesk 3DS Max. The robot needed to be modelled as realistic as possible and as such the program was chosen based on it's level of detail and built-in functions. However, due to the location and observation limitations of the da Vinci Si System it was not possible to capture every detail of the robot. As such, the robot is modelled partially from images taken, images on the internet, and memory. The robot was modelled with box modelling and was compared to a human model to ensure somewhat realistic sizes of the individual parts. The workspace for 3DS Max is shown in Figure 4.1

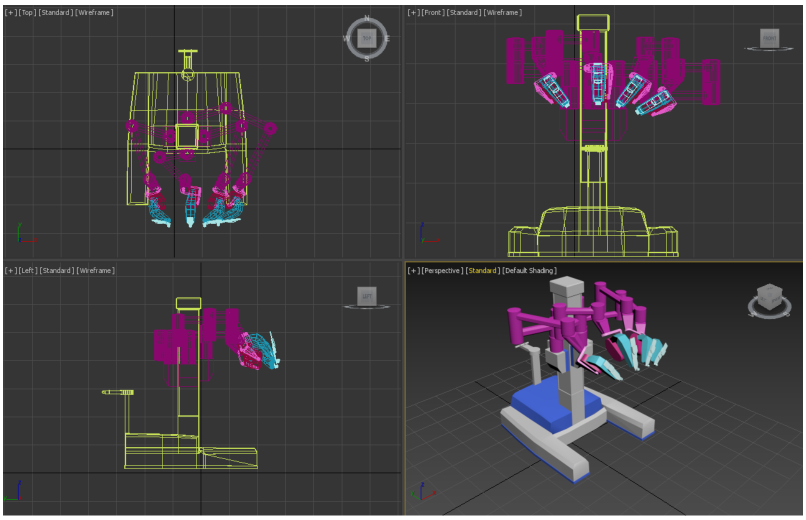


Figure 4.1: The robot shown in Max' default workspace separated into four perspective views

Upon completion, the model was imported into Autodesk Maya which allows for easier rigging and animation. The model was rigged according to the joints of the real robot. The workspace for Mayas' workspace can be seen in Figure 4.2

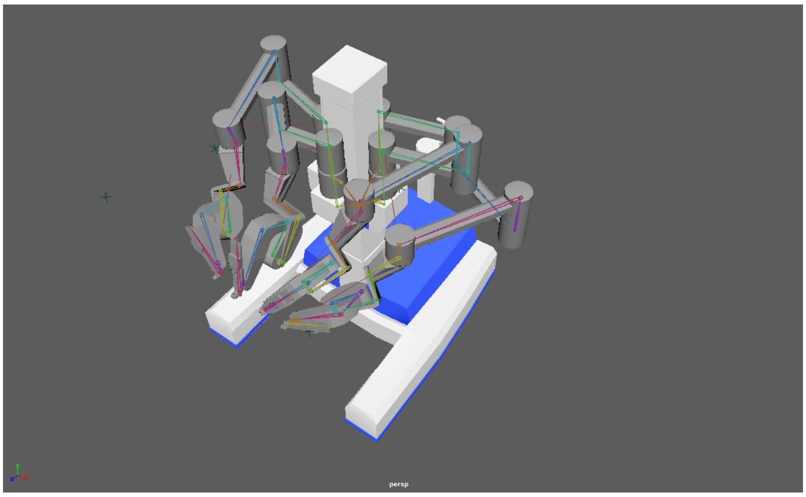


Figure 4.2: The robot shown in Maya's default workspace indicating bones

3D Animation

A 3D animation was created to ensure that pseudo-realistic docking procedure could procede as a backup for the real-time interaction due to time constraints. In the case of using animation instead of interaction, a button would have to implemented in the scene to start the animation. This animation could then be reversed to simulate undocking.

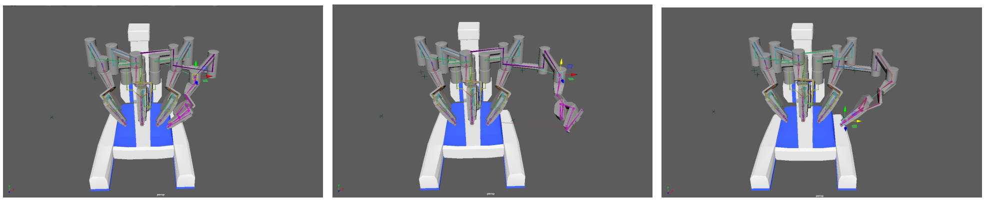


Figure 4.3: IK handles in Maya's workspace

Maya has two different inverse kinematic (IK) solvers, named *Single Chain IK solver* and *Rotate Plane IK solver* (RP). This solution uses the RP IK solver as it's end effector only tries to reach the position of the IK handle and not the orientation. This makes the bones' rotation more reliable. This can be seen in Figure 4.3.

Chapter 5

Shaders

Purpose

The purpose was to create an outline that indicates to users whether the object they are nearing is interactable. The important objects in the scenario are the laparoscopic tools, the robot arms, and other items such as scissors and scalpels. Indicating that items can be interacted with is important in Virtual Reality (VR) and in many other graphical environments such as games.

Method

Two different outlines were created using different techniques; inverted normal meshes and post processing. Inverted normal meshes, or front face culling, are applied over the regular mesh and upscaled slightly. They are normally easy on GPUs compared to many post processing effects, but lack in customisability and accessibility during runtime. They also get increasingly visually disruptive when applied to detailed meshes. Post processing outlines are usually computationally expensive compared to the previous method since they require at least an extra depth render, but they perform better in edge cases (such as overlapping), and are very customisable even during runtime. This was implemented using Unreal Engine 4 post processing stack, a custom depth render on important objects, and a global custom material. In the case of overlapping, for example when users grab the objects, inverted normal meshes work as any other mesh in that it renders to the depth buffer, whereas post-processing requires an extra check for depth at each position.

The post-processing effect was implemented using edge detection. This means that colour differences at edges are detected, and a linear interpolation from normal colours to a chosen outline colour decides which to render based on a parameter *called edge angle falloff.*

Results

Figure 5.1: Comparison between methods. Left: Post processing, line width 3. Right: Inverted normals mesh, upscaled 1.1 times

Figure 5.1 shows the two methods compared to each other. The inverted normal mesh is upscaled to 1.1 times and uses black for both its main colour and its emission (meaning it is independent from light source blending). The post-processing effect uses texel width 3 and edge angle falloff -100 (which appears to only detect outer edges).

The post processing outline is a part of the mesh, whereas the inverted normals mesh extends over the regular mesh. The right side also shows some differences in line width, as well as some irregular lines around the eyes. On the left side, the lines being part of the monkey head mesh is also very obvious, as some of the detail is lost.

Conclusion

Based on these results, we implemented the post-processing effect on the interactable objects in the scene. These were easily accessible and customisable, and provided a consistent look on all objects and at all angles without creating new meshes. The problem with detail loss from the outlines extending into the mesh was not an issue since the effect only appeared once users were close enough to grab the objects.

Chapter 6

FABRIK

Forwards and Backwards Reaching Inverse Kinematics (FABRIK) is an algorithm that efficiently solves inverse kinematics (IK) for a number of joints in a system. Being a heuristic model, FABRIK avoids solving rotational matrices as conventional IK solvers, and instead translates the joints to a point on a line. This results in low computational requirements. A table comparing FABRIK to other IK solvers is shown in Table 6.1.

	Number of iterations	Matlab exe. time (sec)	Time per iteration (msec)	Iteration per second
FABRIK	15.461	0.01328	0.86	1164
CCD	26.308	0.12356	4.69	213
FTL	21.125	0.02045	0.97	1033

Table 6.1: Average results from different IK methods for a system with 10 joints [6]

The following section describes how FABRIK have been implemented and applied to the virtual da Vinci robot. It also describes the current problems with the algorithm and its implementation in Unreal Engine. The algorithm have been implemented according to Andreas Aristidou and Joan Lasenby [6].

FABRIK is implemented in Unreal Engine's Animation Blueprint, but as this only allows to define preset animation sequences, it cannot be used to interact with in real-time. Standard Blueprints does not allow for bone or joint transformations and therefore a Poseable Mesh has to be created from the Skeletal Mesh of the robot in order to program bone behaviour.

FABRIK Algorithm Example

Figure 6.1 shows an example of a system consisting of four bones and an end-effector. The goal of the algorithm is to get the outermost bone (P_4) as close to the end effector (t) as possible and maintaining the original distance between each bone. The FABRIK algorithm starts by adding all bone lengths together to determine if the target is reachable or not. As FABRIK is a heuristic bone translation algorithm it starts at the end effector P_4 and sets its position to the target's position as seen in Figure 6.1. The new heuristic joint is called P'_4

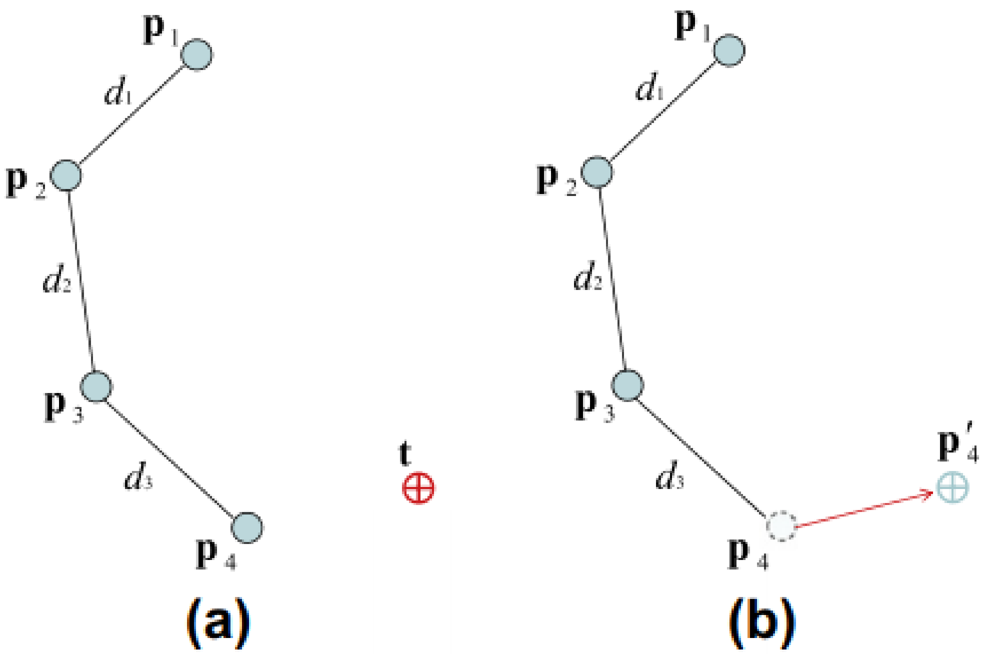


Figure 6.1: First two stages in FABRIK; calculating positions based on end-effector position and bone lengths

A line is then drawn from P'_4 to P_3, and since the original distance have to be maintained, P'_3 is translated to somewhere on that line as seen in Figure 6.2. The position on the line is calculated using Equation 6.1

$$P'_3 = (P_3 \hat{-} P'_4) \cdot d_3 \tag{6.1}$$

This procedure is then repeated for each bone in the system, creating a heuristic position for all joints, as seen in Figure 6.2. This results in the root bone (P_1) being translated as well.

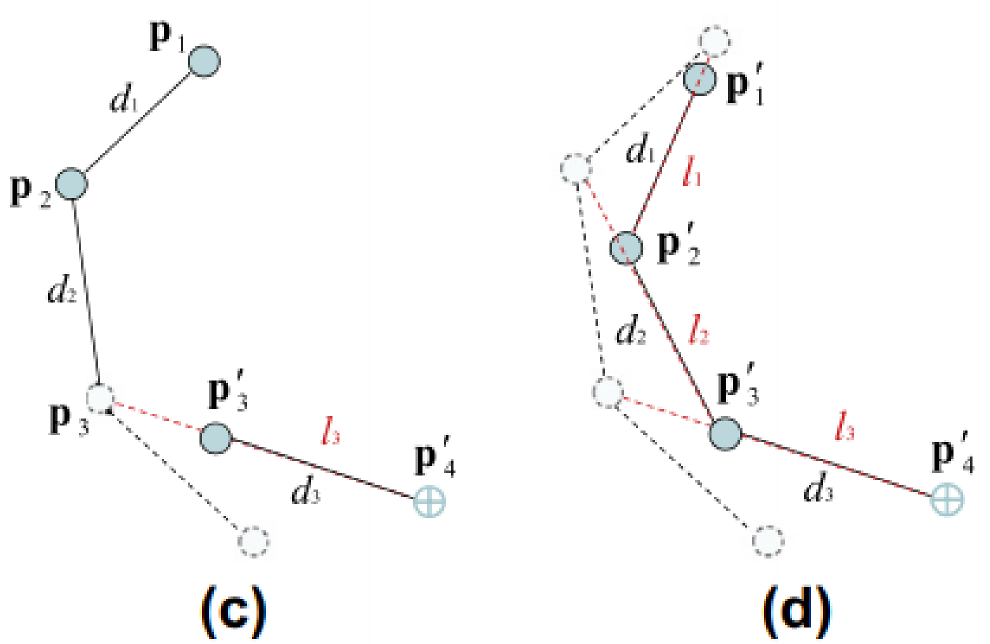


Figure 6.2: Position of all joints are being recalculated, resulting in a slight offset from the root bone's original position

The root joint is then moved back to its initial position and the same process now repeats in the other direction (root to outer joint) as seen in Figure 6.3.

Variable Name	Type	Use	Static
Arm1	Array of Bones	Contains all the bones of the robot arm. Used to reference.	Yes
BoneLocations	Array of Positions	Contains all the bones' positions in world space. Used in the start to calculate the original distances between joints and updated later when new positions are calculated.	No
Lengths	Array of Bone Lengths	The array of bone lengths is constant and is needed to calculate positions.	Yes
Target	Object	The actual object that the end effector will try to reach. This is a red semi transparent cube used to set the end-effector's position to the target and to calculate proximity.	Yes
Origin1	Position	The root's original position. Used in the start of the "Forwards" part where the root's position is set to its original position.	Yes

Table 6.2: Table of the important variables of FABRIK

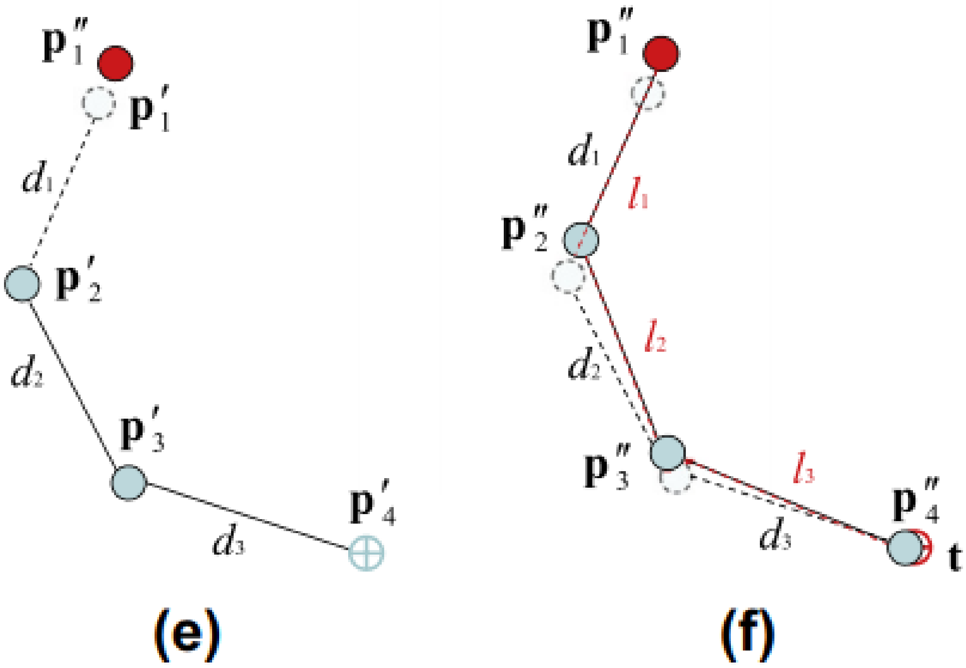


Figure 6.3: The same process now repeats, now where the root bone is moved back to its original position. These processes repeat until the end effector is within a predefined distance to the target

Implementation in Unreal Engine

For implementation purposes, Unreal Engine's Poseable Mesh Blueprint was used to translate the bones toward the target. Table 6.2 shows the variables used by the Blueprint with a description of its use.

The code is split up in four main parts:

- BeginPlay
- OutOfReach
- Backwards (Heuristics)
- Forwards (Positioning joints)

BeginPlay initializes and calculates all of the variables in Table 6.2. OutOfReach determines if the target is out of reach and, if so, stretches all bones in the target's direction. Backwards handles the heuristics of the algorithm and the flow of this program can be seen in Figure 6.4. Forwards then calculates the real position of the joint and sets the position of the joints in world space. Forwards look like the flow in Figure 6.4 the only difference being a positive for loop and the order in the "pos" calculation.

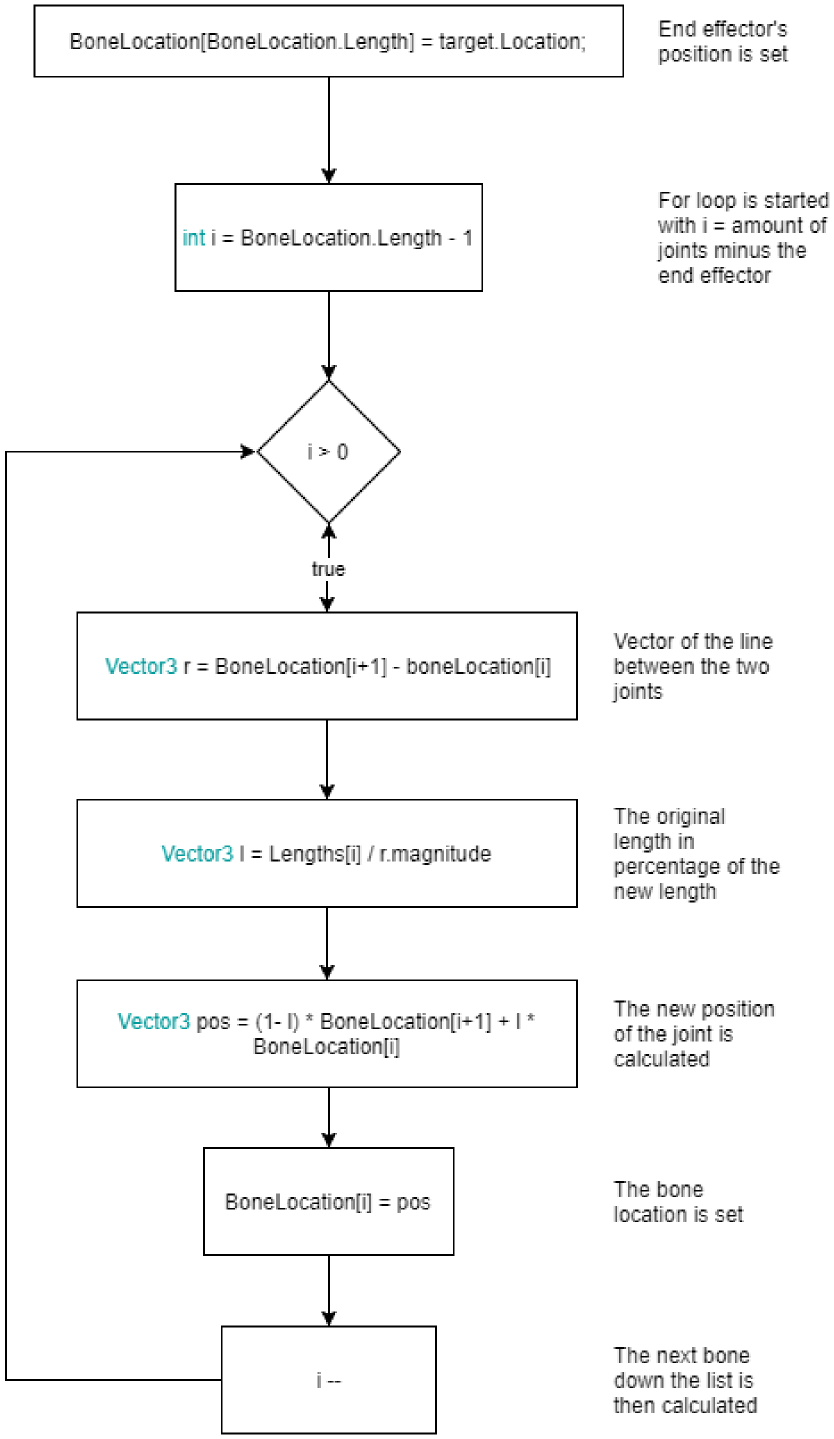
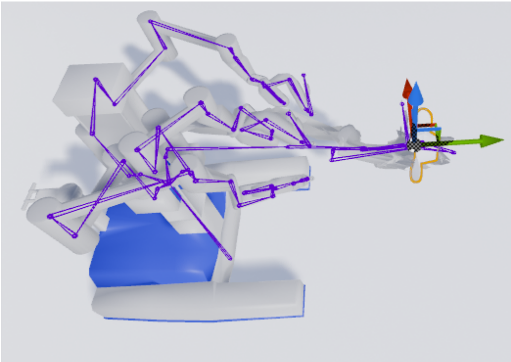


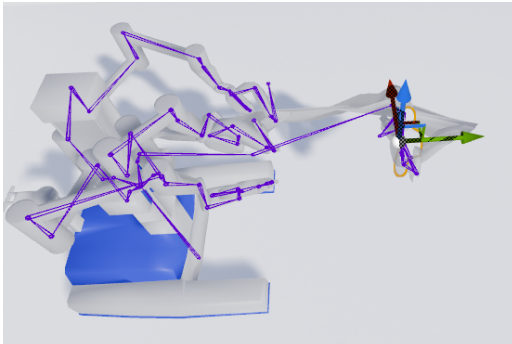
Figure 6.4: Flowchart showing the Backwards part of the FABRIK algorithm

Results

The results of this implementation is shown in Figure 6.5b. It is clear that the implementation did not work as intended, as a small movement of the target transforms the bones with this magnitude. This is the case no matter what direction the target is moved.



(a) The robot and its bones in one state with the target visible



(b) The robot in another state where the target has moved slightly

Looking at the target out of reach as seen in Figure 6.6, the IK acts as expected and only points towards the target without any radical movements.

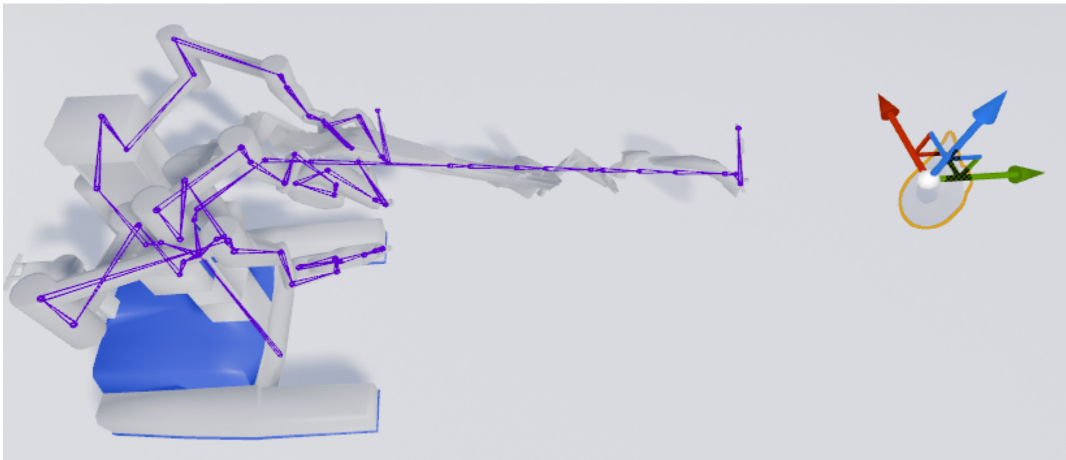


Figure 6.6: The arms when the target is out of reach

One of the reasons the FABRIK acts radically when the target is in reach might be because of the Blueprint implementation. Blueprints lack several basic features such as reverse for-loops. This leads to more complexity of the code, since these have to be programmed in Blueprints. As complexity increases debugging also gets more difficult. Due to time constraints the Cyclic Coordinate Descent algorithm was implemented instead.

Chapter 7

Cyclic Coordinate Descent

For the implementation of the da Vinci Surgical System in the operating theatre simulation a Cyclic Coordinate Descent (CCD) inverse kinematic (IK) method is used. The IK finds values for all connected joints so that an end-effector reaches a desired position and orientation. Chin et al compares different solutions to the IK proble [7]. CCD is an optimisation method for minimising a nonlinear cost function. The method iterates through a list of variables and adjusts the values to minimise the cost. The use of CCD to solve the IK problem is documented by Wang and Chen [8]. CCD iterates through all joints one at a time starting from the outermost one. For each joint an angle is chosen which moves the end-effector closest to the desired position.

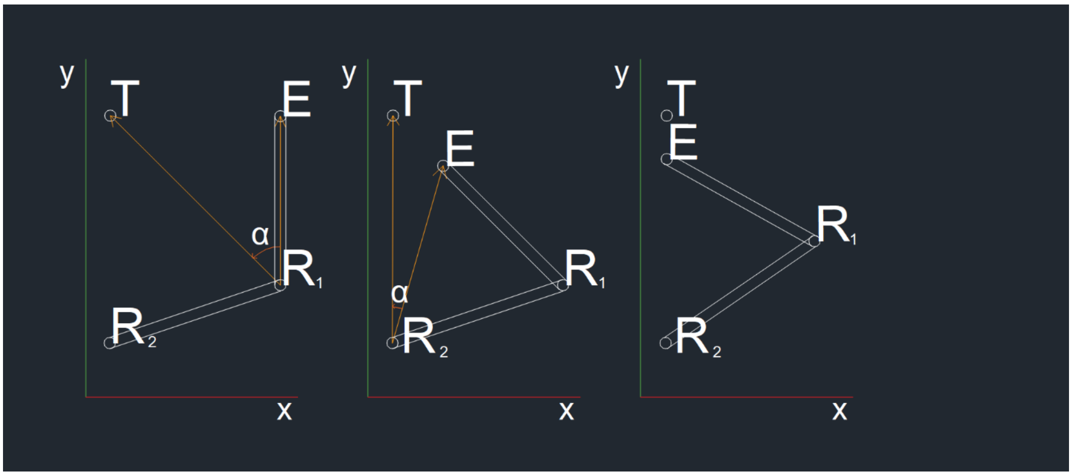


Figure 7.1: Visual example of IK using CCD

In Figure 7.1, a desired position T, end-effector position E and position of the current joint R1 is shown. Calculating the rotation for R1 is achieved by calculating the dot product R1 $\overline{R_1T} \cdot \overline{R_1E}$ and the cross product $R1_T \times R1_E$, in both cases the vectors should be normalised. Using inverse cosine of the dot product, it is possible to get the angle between the two vectors, and the cross product is used to show the direction in which the root (In this case R_1) needs to be rotated. In 2D the sign of the cross product is used, however in 3D the normalised cross product vector is multiplied by the angle between the two vectors providing three new angles, for each of the three axes respectively. Those angles are directly added to the current rotation of the root joint. This process is repeated for each joint in the list.

One addition to the algorithm is the implementation of a restriction vector. The restriction is a unit vector (for example [0,0,1]), when multiplied by the new rotation vector it effectively removes any rotation from two of the axes, allowing rotation to happen only around one. This allows for more realistic movement by not allowing joints to rotate in unnatural ways.

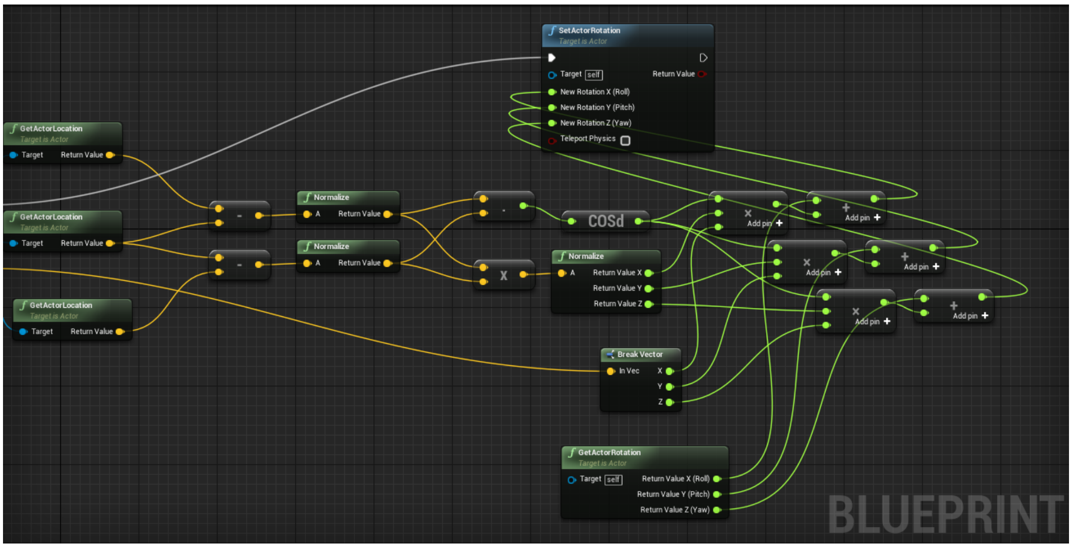


Figure 7.2: Blueprint that changes the rotation of an object to position the end-effector closest to the desired target

Figure 7.2 shows the implementation in Unreal Engine. Because Unreal Engine does not allow for easy manipulation of dedicated bone structures in real time a hierarchical joint system was used instead. Each joint shares a parent-child relationship with other joints in the chain, and any changes made to the transform of a parent joint affects all of its children.

Chapter 8

Internal Test

Purpose

The purpose was to test the system used in the expert review, including hardware load and frame times. This was done to determine whether potential issues could be attributed to physical limitations. Since the review and system test were both performed over LAN, no latency testing was performed.

Method

The test was performed at Aalborg University's Audio-Visual Arena using the computers described in Table 8.1.

	Computer A	*Computer B*
CPU	Intel Core i7-4770	Intel Core i7-6700
GPU	Nvidia GTX 980	Nvidia GTX 980
RAM	16GB	16GB

Table 8.1: Specifications of the computers used

Two players and two observers were present. The players moved around in an introduction scene and in the final scene used in the system review. The observers recorded data using MSI Afterburner and Fraps to measure CPU and GPU load as well as framerate.

Results

The results from the hardware monitoring are shown below. The range indicates roughly 10 minutes of play. The top graph shows GPU usage, the bottom shows CPU usage.

Figure 8.1: Hardware usage of Computer A

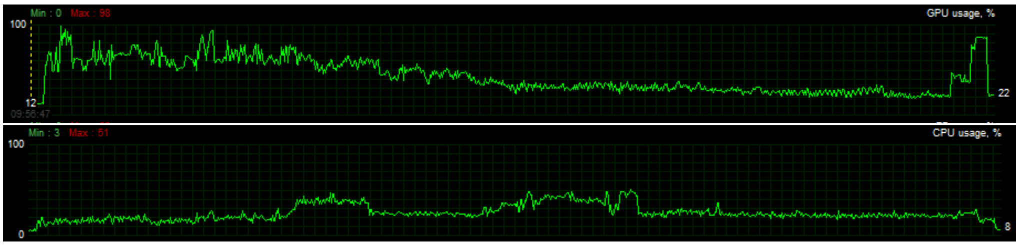


Figure 8.2: Hardware usage of Computer B

The results from recording framerate are shown below.

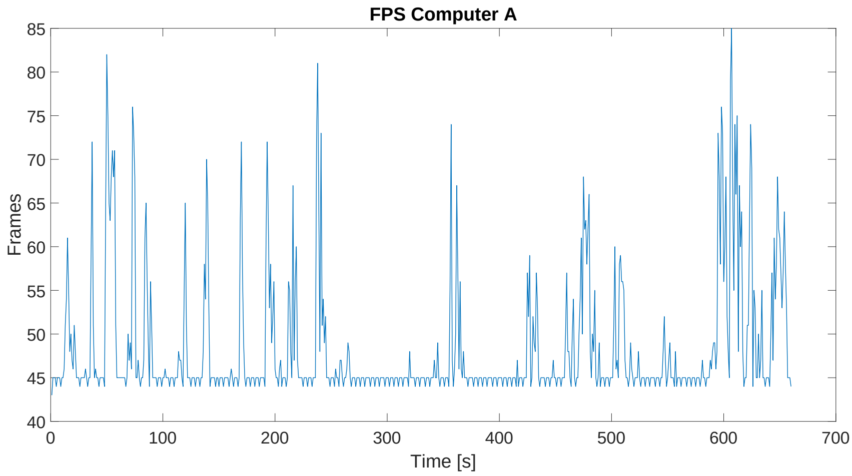


Figure 8.3: Results from recording framerate in Computer A. Y-axis: Framecount, X-axis: Time in seconds

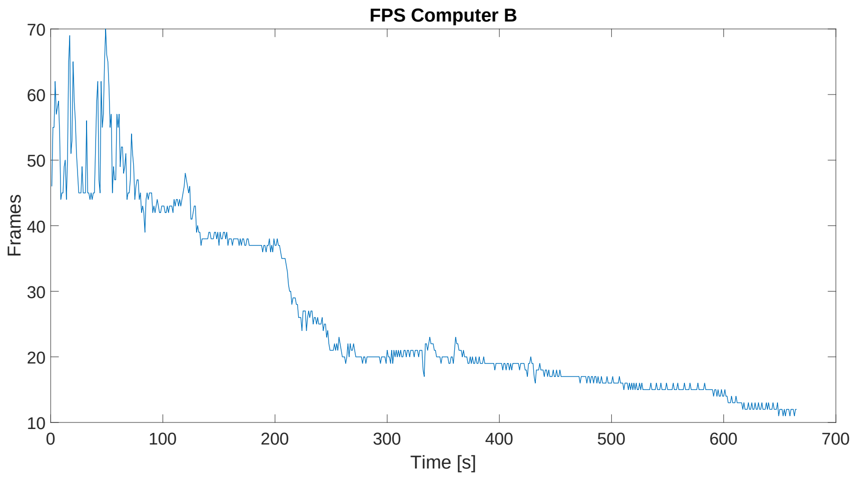


Figure 8.4: Results from recording framerate in Computer B. Y-axis: Framecount, X-axis: Time in seconds

Conclusion

The framerate results show a line at 45 frames per second, however monitoring in the same scene before beginning the recording showed a steady 90 frames per second. We hypothesize that the recording software is at fault, and cannot accurately record framerate in virtual reality applications. This was, however, the only possible solution since no native software that can log it was found.

The results show a steady decline in framerate for the client computer. This was confirmed in several tests to be the case for any computer used as client, but does not seem to be caused by overheating. The client's GPU usage steadily drops while CPU usage seems to jump. This may be the fault of the Proteus multiplayer template for Unreal Engine, and the issue could be writing to a file or otherwise adding data to an array that must be processed at each frame. The issue can be fixed by starting the scene using "25 minutes play time" instead of 10 minutes.

Chapter 9

Final System

Description

The purpose of the project is to develop a simulation environment for robot assisted minimally invasive surgery (RAMIS) team training. A top-down comparison can been in Figure 9.2. The simulation needs to allow trainees to practice different tasks and scenarios that might occur during real surgery. The simulation should allow up to five trainees and an instructor to be simultaneously in the same virtual operating room. In the room, trainees should have access to all the tools and equipment that would be available to them during real training. The simulation allows trainees to move on short distance by walking or teleport for long distance movement. Objects in the simulation, such as tools and the robot, can be grabbed to carry and interact with. A comparison between the modelled robot and the real one can be seen in Figure 9.1. Post processing was used to create a outline to indicate interactibility as seen in Figure 9.3. There are two types of Tools; hand tools and laparoscopic tools. The hand tools are used mainly by the first nurse assistant. The laparoscopic tools includes the camera and tools that can be attached to the arms. Trainees can interact with the robot by moving its arms to achieve optimal placement, which is required for proper functioning of the robot. Additionally, voice over IP service is implemented to support communication between the trainees.

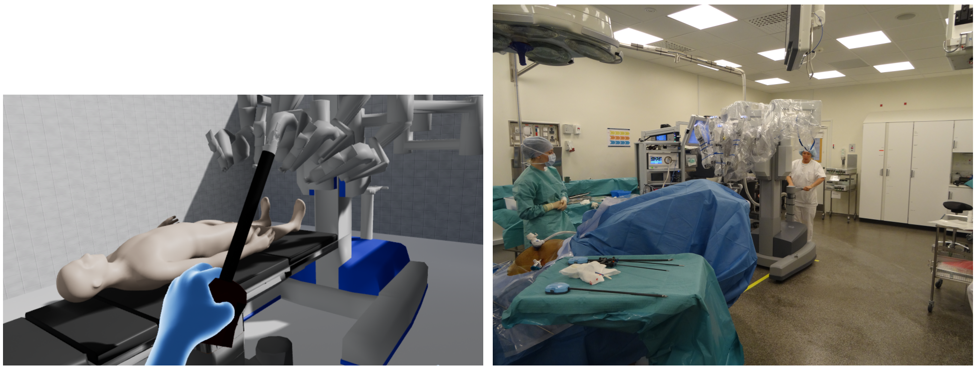


Figure 9.1: Left: Robot in the scene. Right: Robot in real life

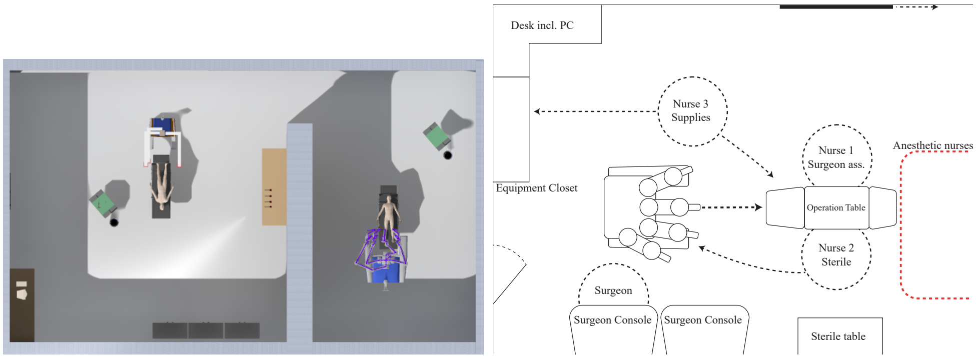


Figure 9.2: Left: the scene in VR. Right: the physical operating room

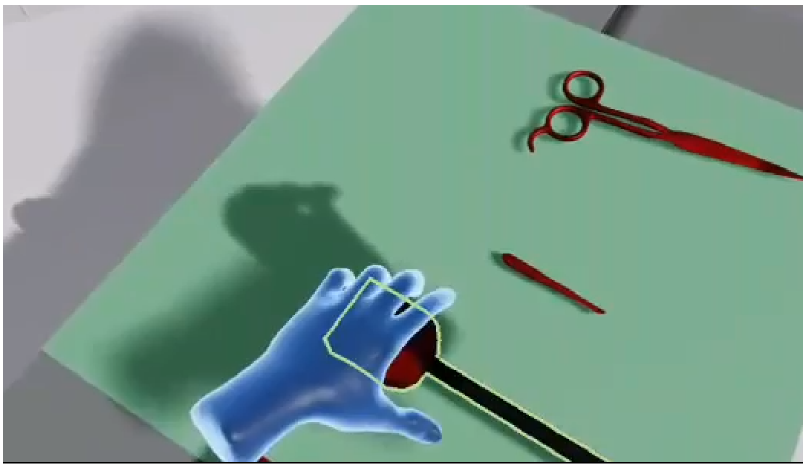


Figure 9.3: The highlight feature when the user is within reach of an object

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Appendix A

Notes Taken During the Observation

- If you are not sterile, you have to stand at least one meter from sterile objects.
- The tables covered in green paper blankets are sterile.
- When preparing tools and unpacking, two nurses works together. One non-sterile nurse unpacks while the other, sterile, nurse grabs and places the tools on the sterile table.
- The sterile nurse sterilises the robot.
- When the patient enters the room he is firstly laid down on the operating table and then prepared for surgery.
- The stereoscopic camera is wrapped separately from the robot and other tools.
- When all sterile tools are placed, the sterile table is covered.
- The camera is calibrated by the sterile nurse. This is done using different kinds of end pieces and rotating them around scopes.
- The arms of the robot must be placed in a specific order. This is to avoid any kind of collision of the arms. Furthermore, the placement of the arms is as important as the order. This is done before the robot is docked.
- Before the robot is docked, the nurses taking part in the operation are sterilising.
- When the robot is docked the arms are once again placed, this time around the ports inserted on the patient.
- A time out is taken before any cutting securing everyone and everything is ready and in place.

- The first cut done on the patient is to expand his stomach using air, easing the operation as this will yield more space.
- Before docking the camera on the robot it is used hand held to insert the other instruments and afterwards docked on the dedicated robot arm.
- When the camera is docked the robot arms are placed as far apart as possible. This is done to avoid collision.
- Each arm has three buttons enabling arm movement in two different ways.
- Cleaning of the optics is done several times during the operation. it may even be changed for another if it is too dirty.
- Communication during operation is somewhat an issue as the original speaker system made for this kind of surgery is broken. Instead, a small speaker and bad microphone is used.

Appendix B

Interview Script Including Notes

We firstly introduce Jane and Johan to the simulation. They will get to watch one from the group "play around", while being explained how the controls work etc. The robot will be in un docked position, but the patient is still on the table. The 4 ports, camera and 3 tools are presented on the tool table, they can insert these and "play around". Afterwards they will be able to try the simulation themselves and evaluate the scene.

Simulation Feasibility

Which aspects of the simulation works well?

- The basic functionality is working well.
- The squares which was used to control the robot may need an indication of the orientation
- Nice that the instruments could be socketed
- The room itself worked well

Which aspects of the simulation does not work well?

- The cart needs to be moved closer to the patient.
- The arms didn't work properly, as they weren't moving in the same as the real robot did.
- The instruments should be able to move instead of just pointing down.

Is anything crucial missing from the simulation?

- More realism in general.

- You should be able to see the other “players” with each their dedicated roles.
- Working together.
- Being able to go from the nurse position and docking the robot to sitting at the console and operate the robot. – A full simulation of the surgery.
- Even expanding with anaesthetics and information hereof.
- Implementing disaster/accidents as well, which you would need to adept to.

Is anything in the simulation redundant/superfluous?

- No

How would you describe the realism of the simulation? How did it affect the experience?

- Nice and spacious.
- Needs more realism to be considered a useful simulation

What details did you find missing/lacking in the scene?

- The console is missing from the simulation
- Ports in the patient, to give an end goal for the. Maybe attach the arms to the ports and make insertion of the tools in the ports.
- When the arms are docked they should still be movable, but around the port socket of course.

Further Work

What is the next step for us to implement?

- 5 ports and making the arms' endpoints socket to the ports.
- Results of too much force
- It is too basic, but the idea has great potential.
- Refinement and realism are key points.

What would you use this kind of simulation for? Opportunities, purposes, direction of development.

- As of right now, it may be able to give a basic idea to a completely new user. But it's not detailed enough. People will not be able to train with this simulation. It has a lot of simulation.

- It's too basic right now, but with further development, it can yield enormous possibilities.

Could it be used for showcasing?

- As before, it should be refined and more realistic, but it is a possibility to use it to showcase what is going on, how the team work together and what is going on.

Do the controls suit your needs? How?

- The two control options are good.
- A reset button for a "mentor"/admin/supervisor.
  - A laser pointer which should be visible for everyone.
  - Regular controls as well.
- Admin controls to switch pre-set scenarios and the different kinds of operations/setups.

Which scenarios are important as well?

- Role designation

What would be nice to have later on?

- A complete simulation of a surgery where you're able to do everything which is done in real life.
- Tactile feedback would be nice – but you use your eyes and compensate as you know the visual signals.
  - We could use the vibration in the controllers

Appendix C

Consentforms

Samtykkeerklæring

Jeg giver hermed samtykke til at deltage i projektet af gruppe VGIS743 fra Aalborg Universitet.

Jeg er indforstået med at deltagelse i dette projekt er frivilligt og at jeg til hver en tid har mulighed for at stoppe interviewet hvis jeg føler det nødvendigt.

[X] Jeg giver hermed samtykke til at alt indsamlet information må blive anvendt i studierelateret sammenhæng. Lydoptagelser bliver slettet ved projekts afslutning, med mindre andet er aftalt.

Underskrift: ____________________

Dato: 4/12/17

AD NYE VEJE
AALBORG UNIVERSITET

Samtykkeerklæring

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Underskrift: Jan Petersen

Dato: 4/12'17

AD NYE VEJE
AALBORG UNIVERSITET

Appendix D

Peer Reviews

Review of: Introducing Virtual Reality in Robot Assisted Minimally Invasive Surgery Team Training

Overall assessment

In general a decent paper with a nice and clear progression throughout the paper. The overall language used is clear and is well written and formally formulated, though with some inconsistencies. The overall goal is clear, but in a few places the line of thought or the argumentation could benefit from some revision or further elaboration.

A good investigation of an area of application of VR, make sure to emphasize the scientific contribution of the work.

General Comments

GC1: The comparisons between surgery styles presented seem to compare only between open surgery and RAMIS. Would it not be more interesting to compare between RAMIS and normal Minimal Invasive Surgery in the cases where it is applicable?

GC2: The switch from the introduction to methods seem somewhat abrupt, maybe it would help with a small clear outline in the end of the introduction of what the work strives to achieve and what the main contributions are.

GC3: The paper in general includes a reasonable amount of figures, which also supports the written text well.

CG4: Make sure to include units on axes, legends etc. in the figures.

CG5: In general the language is clear but occasionally sentences seem incomplete or it could be formulated in a more elegant way. Considering your general style you brobably will spot this when you review your article again before hand-in.

Specific Comments

SC1: In regard to the statistics provided about deaths related to RAMIS it is a bit unclear whether the information in the table represents deaths or not and whether the 410 injury reports correspond to the 17.4% of deaths(that occur during operations). Also, what about people who die *after* the operation due to complications caused by the RAMIS?

SC2: In Figure 1 you have a nice caption to each of the subfigures, therefore the text in the subfigures seems redundant. Only put text in the figure if it is very important that it is there as opposed to in the caption.

SC3: In the beginning of the section context study you have a wall of text. Maybe try to break it for better readability.

SC4: Figure 3 is a great way to present the actions that are occurring simultaneously, however, the flow with the blue background is a bit difficult to read.

SC5: In the Section context study a point is made of the importance of and experienced user of RAMIS being present to answer questions. Where any considerations done in regard to how to incorporate that in a VR application (especially in respect to the training at non certified locations)

SC6: The SUS is a more less generally know scale. You can write that you calculate an average score for the participants and that u further more calculate the SUS score in the way that is specified by the developers of the SUS, but explaining it in detail and showing the formula seems a bit redundant. Also, usually the sus score is just provided as a number between 0 and 100, Is there a specific reason why you provide it as a percentage?

SC7: It should be clearer what information you gain from plotting the mean scores of the sus against the age (especially as your age span is so small).

Introducing Virtual Reality in Robot Assisted Minimally Invasive Surgery Team Training

Group 743

Overall:

Overall the user experience test and references to the study about your project are really nice and useful for the reader to understand where your product is useful and why it can be useful. However it is not clear what your product is about, since it didn't get described very well. For your Introduction segment it seems to follow the “Why and what for (four)” somewhat, but is severely lacking the last what, as it is about explaining what will be presented in this paper.

The Discussion stated that the product was made for multiplayer use in a procedure - second paragraph - but this was not made clear enough through your paper as it was not stated anywhere else. You should at least describe what you are implementing and go more into details what RAMIS and Da Vinci is.
Overall your Discussion segment should be split into 3 sections, Discussion, Conclusion and Future work where the Discussion needs to include a discussion of your results, if they went well or not and why. You made some good points in your introduction and it would be nice if you write a conclusion and conclude if a nurse was/wasn’t better trained using your product.

General comments:

- Your abstract is very well written and easy to understand.
- The introduction is very long and shouldn't have any subsection.
- The context study seems to belong under methods and not in the introduction.
- When you reference to an image, use numbers and letters like Figure 3.a not “top image”.
- When giving a random number like a price you need to reference where it is from.
- Good idea to use the SUS to evaluate the usability of the system.
- The discussion seems to be a mix of a conclusion, discussion and future work.
- The discussion should discuss your results. What went right, what went wrong and what should be improved and what was good enough.
- Make a conclusion to conclude on the introduction you set up. (we’re guess you didn’t do that because you don’t have enough results to conclude on your product yet, but it would still have been nice to see an indication that you planned to implement it).

Specific comments:

See attached PDF-file for detailed comments.

Review of Introducing Virtual Reality in Robot Assisted Minimally Invasive Surgery Team Training

Title

The title is okay. Maybe find another way of saying minimally invasive or use “collaborative training” instead of “team training”, but the title is already good as it is.

Layout

The introduction is too long. Maybe a “Context” section could replace part of it. Besides, there may not need to put an “A” subsection is there is no “B”. There again, this could maybe fit in a “Context” Section.

However, the Method section has no subsections. This could be improved by separating the description of your approach, the actual protocol used in different subsections.

Content

In the abstract you mention usability score. What kind of metric is that? What is is based it on?

The median score was 67.5, with the first quartile scoring 45 and the third scoring 86.25.

You should consider reporting your test results in a more structured way, like having important values in one table, instead of mid-text. All your graphs need to have their axis labeled. I couldn’t figure out what 0-4 on the y axis represents since you’re talking about sus scores which are in the range of 0-100.

Why did you choose to use SUS as the method to measure your results. Was there other approaches to it ?

This paper lacks some maths.

Figures

The figures at the end of the paper are not aligned and without captions. It’s not even mentioned what they are showing.

Graphic doesn’t makes sense. You need to label your axis:

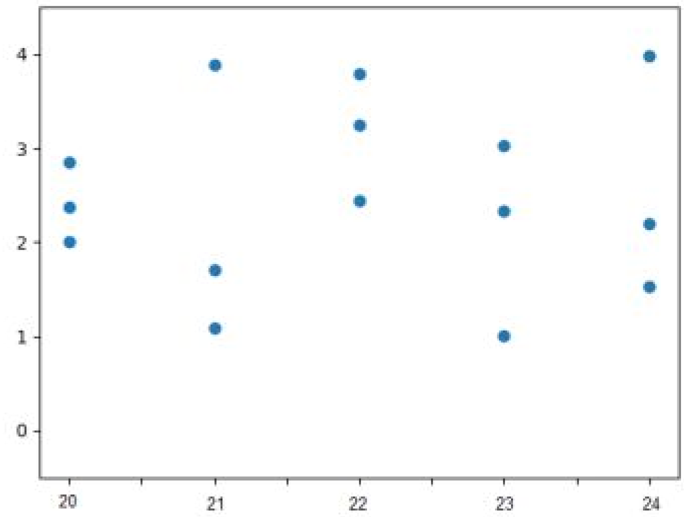

Fig. 5: Mean scores plotted as a function of participant age

Figure 5 shows the participants' scores plotted as a function of their age. Linear regression returns $y = 0.03x + 2.06$. R^2

- It looks like you're performing regression on figure 5, but the y-axis looks categorical and not continuous. Seems a little weird.

General notes:
You should consider reporting your test results in a more structured way, like having important values in one table, instead of mid-text. All your graphs need to have their axis labeled. I couldn't figure out what 0-4 on the y axis represents since you're talking about sus scores which are in the range of 0-100.