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Time-variable scene quality – perception tests

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Problem Description

Plan and carry out perception tests of time-varying scene composition, spatial and temporal resolution of scene objects, respectively, as defined in DMP. Base the time-variation on short time intervals of only tenths of milliseconds. Use and extend test setup as in 'The Hems Lab - Perceptual test of scene objects with variable temporal resolution' project, autumn 2008.

Find an economic model that can be used to help businesses assess market potential of new technology (software, hardware) and show how this can be used in a DMP setting.

Assignment given: 15. January 2009
Supervisor: Leif Arne Rønningen, ITEM

Preface

This report is a result of a master thesis published by The Norwegian University of Science and Technology (NTNU) in Trondheim. The master thesis is a part of the 10th semester of the Master of Technology education at NTNU.

I would like to take this opportunity to thank my teaching supervisor Leif Arne Rønningen for all the help he has provided, both as a counselor and for the help he provided when assessing the experiment in the project.

Disclaimer

All research in this project has been conducted by me alone. All work done by other people has been referenced. Images and tables without any reference have been produced by me. This project continues some of the work done by me fall 2008, because of this some content is similar to the work done in the project “The Hems Lab – Perceptual test of scene objects with variable temporal resolution” but has been adapted to suit the needs of this project.

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Abstract

In this project the goal has been to find out how time variable quality of scene objects affects the viewers perceived quality of a video clip. Two experiments have been conducted; the first experiment looked at two different frame drop patterns using two different temporal resolutions, 29.97 and 59.94 frames per second. Experiment 1 tried to identify the best way to combine frames of low and high spatial resolution to see what yielded the best perceived quality for different objects in the scene. The second experiment used different frame drop patterns and different spatial resolution on the low quality frames. The data gathered in experiment 2 has been used to find out whether a higher bitrate of a video always gives better perceived quality, or if there are ways to combine different resolutions and frame drop patterns to achieve quality that is perceived to be better than what a video using higher bitrate has.

The assessment of the video clips in the two experiments has been conducted using five assessors; the research has been performed in a qualitative way but with an action research approach. Adopting an action research approach has allowed me to guide the participants to focus on specific qualities in the video clips and it has also allowed me to ignore some of the small error sources that could affect the outcome of the assessment. The experiments have however been slightly limited by the equipment used and because of the limitations of the best equipment available on the market.

From the experiments conducted it is clear that how different frame drop patterns and spatial resolution on low quality frames are combined has a large impact on the perceived quality of a video clip. Some combinations can give a perceived quality that is almost as good as watching video of original quality without any frame drops or resolution reduction, while being able to save large amounts of network bandwidth.

Further work in this area will have to be done, especially when it comes to improving spatial interpolation and applying edge correction to the video clips. The possibilities of Quality Shaping in terms of saving bandwidth while maintaining a good perceived quality of video looks promising.

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Abbreviations

AVI	Audio Video Interleaved
CCD	Charge Coupled Device
CMOS	Complementary Metal Oxide Semiconductor
DMP	Distributed Media Plays
DPI	Dots Per Inch
FPS	Frames Per Second
GIF	Graphics Interchange Format
HDTV	High Definition TeleVision
HQ	High Quality
IC	Integrated Circuit
ISO	International Organization for Standardization
JPEG	Joint Photographic Experts Group
LCD	Liquid Crystal Display
LZ	Lempel-Ziv
LZW	Lempel-Ziv-Welch
MHP	Multimedia Home Platform
MHS	Multimedia Home Space
MP3	MPEG-1 Audio Layer 3
MPEG	Moving Picture Experts Group
PDA	Personal Digital Assistance
PDF	Portable Document Format
PNG	Portable Network Graphics
RAID	Redundant Array of Independent Disks
RGB	Red-Green-Blue
SS	Single-stimulus
VGA	Video Graphics Array
VO	Video Object

1 Introduction

Electronic equipment is continually becoming more advanced. Processors are getting faster, storage capacity is increasing and people's internet connections are becoming faster. In addition, the price of this equipment and these services are decreasing which makes the technology more common and available to more people. This gives new possibilities to software developers, and the complexity and possibilities for the average user is increasing.

1.1 DMP – Distributed Media Plays

Distributed Media Plays is a system architecture which is meant to provide near-natural communication between two or more players. It was introduced as a proposal for an extension to the coming digital TV system, Multimedia Home Platform, MHP, in a Telenor project in 1996-1999, but the focus has now been changed to a long-term project that is to present a system architecture that can handle Multimedia Home Space (MHS) distributed services and other services that may be introduced in ten year's time. [1]

Some of the goals of DMP are to be able to provide:

- Stereoscopic multiview video
- 3D sound
- A guaranteed end-to-end delays of 10-20 ms
- Near-natural video and sound quality
- Should be simple to use
- Guarantee privacy

With near-natural video and sound we mean that reality and a representation of it should be impossible to distinguish. This demand a lot from the resolution (both spatial and temporal), color, contrast, brightness and all other parameters that affect the picture, and to be able to realize these demands we require both recording- and display devices with technology far more advanced than what is available today. In addition to new recording- and display devices we are talking about a bitrate that is much higher than what the Internet and most local networks are

capable of today. DMP will require a bitrate at the gigabit level while the norm today is a few megabits for the normal households, nor does today's networks give any guarantee for end-to-end delays, which is very important for real-time communication. [2]

The DMP architecture is not meant to be realized in the next couple of years, but it will have to be done gradually over many years as the required technology becomes available.

Some examples of scenarios where this architecture can be use is: [3]

- A virtual book device that is loaded with information from the book you select in your virtual bookcase
- A living room that you can change the appearance of by selecting the ceiling to show the weather outside, and you can choose to have green décor on the walls one day and blue the next
- Virtual dinner, you can eat dinner with your family even if you are in Tokyo and they are in Oslo (any two set of locations as long as the propagation delay is not to large)
- Virtual game room
- Virtual conferences and meetings

1.2 Background / Motivation and approach to the problem

The three main goals of DMP are 'near-natural virtual collaboration', 'simple-to-use' and privacy. This implies that the 'service providing system' has to be intelligent and responsible so that it can track and interpret user behavior and take action that will benefit the users the most.

[1]

As a part of this, optimal usage of available bandwidth is important. If there are only a few users that e.g. look at a stream of High Definition video material, then it is likely that they could all look at the video with maximum resolution and bitrate without it exceeding the maximum capacity of a link. But if there were a lot of people connected to the network we could fast approach the maximum available capacity. For the users to still have a good viewing experience it will then be needed to reduce the quality (bitrate) that is sent to each user so that the maximum capacity of the stream is not exceeded.

The solution to this problem, as presented in DMP, is the concept of Quality Shaping [4]. Quality Shaping is introduced to give graceful degradation of quality when traffic overloads the network or if a system component fails. This concept again builds on controlled dropping of sub-objects from selected packets, and scaling of scene resolution/composition and coding parameters. This also guarantees a maximum user-to-user delay without any reservation of resources. To guarantee a minimum quality level, admission control is also needed. This report will look at controlled dropping of sub-objects as part of Quality Shaping. Dividing scenes into sub-scenes, objects and sub-objects is fundamental in DMP (as seen in Figure 1-1), because it is the basis for making multimedia content packets independent. [5]

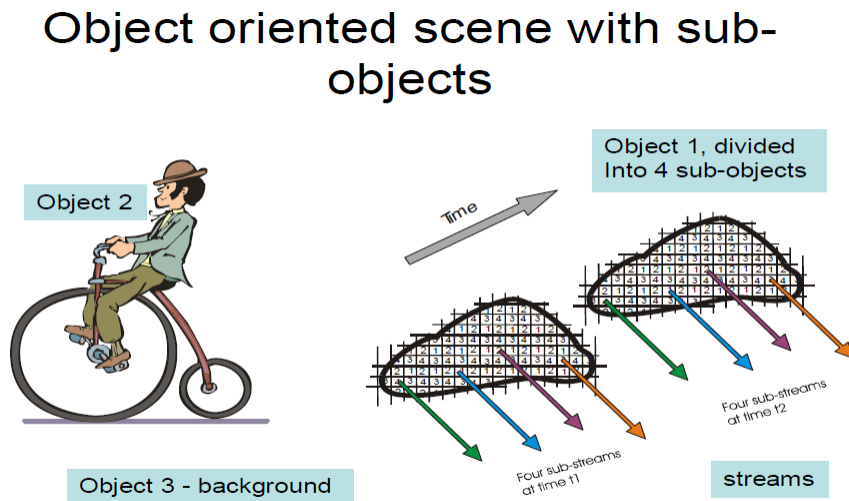


Figure 1-1: Object-oriented scene with sub-objects [5]

This report continues some of the work done in Leif Arne Rønningen and Erlend Heiberg’s paper on “Perception of Time Variable Quality of Scene Objects” [6] and Håvard Berge’s report “The Hems Lab – Perceptual test of scene objects with variable temporal resolution” [7].

Rønningen and Heiberg’s paper was based on quality variation of the video clip on intervals of 8-10 seconds while in a practical system the interval time will vary randomly between a few milliseconds and several seconds depending on the traffic characteristics and the traffic load. This report will focus on perception of video clips with quality variation on short time intervals of only tenths of milliseconds.

1.3 Originality

The aim of this project is to look at the perceived quality of scene objects when time variable quality is applied on short time intervals, and to identify parameters that have a large effect on how quality is perceived when time variable quality is used. This is research that to my knowledge has not been conducted before on this scale.

1.4 The organization of the report

This report is divided into ten chapters.

In Chapter 1 the background and motivation for writing the report is explained. Related work, research and assessment method, and limitations will also be addressed.

Chapter 2 describes some of the problems with streaming multimedia on a network and looks at ways to solve this problem.

Chapter 3 explains different parameters that affect the look and quality of digital images.

Chapter 4 introduces the equipment that has been used and the limitations of this equipment, while Chapter 5 explains how the equipment has been used.

Chapter 6 describes how the experiments have been conducted.

Chapter 7 looks at the error sources that may have had an impact on the results of the experiments.

Chapter 8 looks at the questionnaire and explains the reason for its structure and what data it aimed to record.

Chapter 9 is a discussion of the results from the experiments

Chapter 10 consists of a conclusion and suggestions for further research.

1.5 Related work

1.5.1 Time variable quality

Research has been done by Leif Arne Rønningen and Erlend Heiberg in [6] on how visual quality is perceived in video clips when time variable quality of scene objects is applied. In this paper the authors conduct tests using different types of video material and apply quality variation on intervals of 8-10 seconds. They conclude that regeneration of dropped sub-objects by means of linear interpolation in many cases is a very good approach when it comes to regaining visual quality. It also showed that applying edge correction in most cases further increased the perceived quality.

1.5.2 Dividing scenes into objects

There are different ways to extract objects from a scene so that they can be applied different spatial and temporal resolutions. Moving object classification from videos is an important issue in image processing and video analysis, and it is an essential part of DMP. As the authors of [8] state, collecting training data for all kinds of conditions and labeling them all manually is tremendous work. Using training data to teach a DMP system to recognize objects would be a never-ending task. Instead the authors have developed an algorithm with three main properties [8].

- Practical: The algorithm should be real-time and achieve high classification accuracy (real-time is a requirement for DMP)
- Robust: The algorithm should be robust in all kinds of conditions and perform well in different environments (In DMP there will be many different environments from all kinds of situations)
- Automatic: The algorithm should avoid any supervised learning and manual labeling of large samples of training data (needed in DMP as the amount of different scenarios is limitless)

The results from this research showed that using this algorithm with a subregion strategy and Gaussian Assumptions, 2D features are effectively organized and the suggested approach achieved good performance. The algorithm suggested is effective and robust to condition changes, which means that it can be applied to many systems [8].

Another possibility to divide a scene into objects is introduced by the MPEG-4 standard. The MPEG-4 standard understands a visual scene as a composition of Video Objects (VOs) characterized by their shape, motion, and texture. Each VO is individually coded and corresponds to an elementary bitstream that can be individually accessed and manipulated, while composition information is sent in a separate stream. [9]

The independent representation of each object provides coding flexibility, allowing to focus on the subjectively more important objects, e.g. in quality, error protection, or resolution. The distribution of the available resources can even be guided by the application's user himself depending on his specific interest.

By finding the Target Number of Bits, which could be the maximum bitrate per user in DMP, the objects that make up the scene can be assigned a specified bitrate. The available bitrate every VO receives will be dependent on characteristics such as [9]:

- The normalized VO priority – reflecting the subjective importance or the need of additional error resilience.
- The normalized VO size – reflecting the size of the object
- The normalized VO activity – reflecting the motion of the object
- The normalized VO complexity – reflecting the texture complexity

The authors of [9] use these possibilities of MPEG-4 on a scene of a news studio TV broadcast with good results.

In [10] the authors also look at the possibilities introduced in MPEG-4. They use an algorithm for face detection and tracking and develop a constant-quality variable bitrate (CQ-VBR) control algorithm that guarantees the quality specifications for each object in the scene. The face detection and the constant quality algorithms both run in real-time on a low-cost media processor, testing in various indoor environments have shown great promise. The authors of [10]

achieved significant reduction in overall bitrate, while maintaining the same visual quality of the foreground/face object.

1.6 Research method

This part explains quantitative and qualitative research. The choice of research method for this project will also be explained and discussed. Concepts like reliability and validity will also be addressed.

1.6.1 Quantitative and qualitative research

In general we can say that research can be divided into four fields [11]. These can be seen in Figure 1-3 below, where each quadrant represents one of the four fields. The two methods above the x-axis are empirical methods; this means that they are based on observation and experience. The methods under the x-axis are based on rationality, that things make sense and are logical.

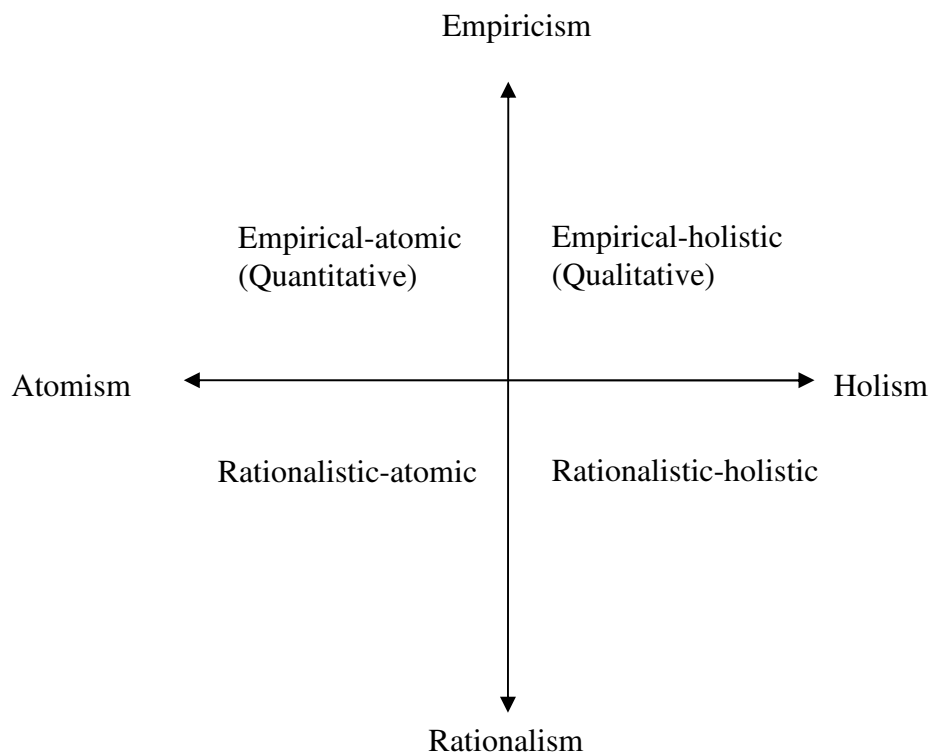


Figure 1-2: Four different fields/methods of research [11]

The empirical-holistic quadrant represents a view where all parts as a whole is greater than the sum of all the parts individually. Because of this the result can be misleading if you limit yourself to only look at some of the parts. The empirical-atomic quadrant represents the opposite; the whole is the sum of all the parts. Even if most people agree that the whole is more than the sum of the parts, this view is of the opinion that studying some of the parts, a part of the whole, will give a good understanding of reality. Simplified we can say that the empirical-holistic view represents a qualitative method and that the empirical-atomic view represents a quantitative method. [11]

A characteristic with the qualitative (empirical-holistic) method is that you normally do not know exactly which results you will get. What you want to study is more about qualities and not about numbers, distributions and exact values. The result can be a number of new aspects of the problem. When collecting data for qualitative research one would normally not give categories for the research subject to select, but towards the end of the research different categories should be defined reflecting on how the test subjects answer. This is how you can get new qualities of reality that were not known beforehand. This is different from quantitative research where the categories will often be defined and the test subjects are confronted with a limited number of categories to place himself/herself in. Methods of collecting information can be [12]:

- Oral interviews, either half-structured or open
- Observations, either with participating subject or without, the observer can also be hidden or in the same room as the subject

Quantitative research is characterized by that you know approximately what the results will be and what the likely conclusions will be. It is often normal to have predefined answer alternatives, and the data collection is used to get concrete numbers that can be used for a statistical analysis. Some examples of methods of collecting data can be [12]:

- Direct measurements of temperature, speed, distance etc. which can be done with different sensors
- Indirect measurements of IQ or knowledge in a particular subject. This can be done with structured interviews with yes/no questions or other specified answers

If we compare the two research methods it is obvious that qualitative research requires more involvement from the researcher. This means spending more time with each research subject. Given a limited timeframe quantitative research will allow the use of more research subjects than qualitative research. The number of research subjects is also more important for quantitative research to get reliable data for a good statistical analysis.

1.6.2 Action Research

Action research can be seen as a supplement to the two methods described earlier. In [13] action research is described as a research method that “can include many research methodologies, which pursue action and research outcomes at the same time”. It has some similarities to consulting and change management in organizations.

It is often used in a cyclical process where action and critical reflection is used in turn. What is learned from the early stages is taken into consideration to improve in the later stages. According to [13] most people involved in this field agree on four basic themes that need to be present

- The empowerment of the participants
- Collaboration through participants
- Acquisition of knowledge
- Social change

When we look at action research in the light of quantitative and qualitative methods, action research often leans towards a qualitative method. It is possible to use action research in quantitative research, but because of the deep involvement with each research subject this will be very time consuming.

1.6.3 Choice of research method

For choosing a method for this project it is useful to have a comparison of qualitative and quantitative research like the one found in Table 1-1.

This project is, to my knowledge, one of the first to be done on testing how quality variations over short periods of time affect the viewer’s perception of quality. As this is preliminary research I found it best to focus on a relatively small number of test subjects, and spend some time to really understand how they perceived it. There are many ways to vary quality over time, and to find the best way of doing it, every test subject would have to view a number of different video clips.

As reliable quantitative data would be difficult to obtain, and because of the limited number of test subjects, to focus on a qualitative approach seemed to be the best option. To me it seems like reliable data, even qualitative data, could be hard to obtain by just having the participants filling in a questionnaire, and I felt that a better way to gather the data was if I was an active part in the test of every participant. That way I would understand properly what everyone felt about the quality of the clips they were shown, and the number values given in the questionnaire would be more precise. This choice takes the form of action research where I can through the interview process improve how it is performed if anything is unclear or difficult to understand for the participants. It can also be difficult for the participants to understand exactly what I am looking for during the process and being an active part of it allows me to better describe what they should look for, and if there are any irregularities or aspects of the video clips they can ignore.

The main research method in this report will because of this be a discussion between the test subjects and myself where I will guide them so that they know what to look for and what to comment on.

		Quantitative Method	Qualitative Method
1	Holistic view / Context	Looks at what is studied isolated and restricted/without context. The more restricted, the easier to study	Looks at the whole where context often is significant
2	Historical relation	Rarely interested in historical relations	Often interested in the relations between past, present and future
3	Goal	Tries to describe and explain relations or to prove a hypothesis. Looks for universal truths	Tries to understand the specific human nature
4	Research plan	A specified research plan that rule out sources of error beforehand. Data is input and statistics is output	Dependable on data, can be changed underway. Better methods of question the subject can be found during the process, or a better way to interpret data can be found
5	Researchers role	The researcher stays objective and can in principle be changed during the	The researcher has a more familiar relationship to the subject and cannot be

		process	changed during the process
6	What it studies	Studies things that can be quantified and measured	Studies things that are specific to human nature. Often based on experiences and peoples way to give experiences meaning and content
7	Choice of sample	Representative selection which give information of the population	Research subjects are chosen because they have knowledge about the phenomenon. Often tries to get an even distribution of age and experiences
8	Size of sample	Preferable with a large number of subjects	Not necessary with a large number of subjects
9	Collected data consists of	Well defined variables. Definitions of them are called operational definitions	Uses abundance as data. Describes essences, themes, patterns and apprehension
10	Possible / imaginable results	Decided in advance which imaginable results one can get	Openness for what the results can be
11	Transferability	The results from the sample can often be generalized to the rest of the population	Looks for repeating patterns and similarities. Some transferability, but cannot be generalized
12	Good research quality is	<ul style="list-style-type: none"> • Reliability • Validity • Reproducibility 	<ul style="list-style-type: none"> • Conscious of perspectives • Intern logic • Good quality of data • Legitimacy

Table 1-1: Comparison of quantitative and qualitative method [11]

1.6.4 Validity and reliability

Reliability means trustworthiness (can we trust the results we are seeing) and is often defined as the likelihood that you will get the same result when using the same measurement tool multiple times for measuring the same thing [14]. Measuring water temperature by using your finger as a thermometer will most likely give low reliability, while measuring water temperature with multiple thermometers will give a high reliability.

Validity tells us about whether or not the measurement measures what it is meant to measure. If one wants to measure peoples TV habits, it is not relevant to ask them about what they normally eat for dinner, but asking if they own a TV is very relevant. [14]

1.7 Assessment method

ITU-R BT.500-11 [15] lists different suggestions for assessing the quality of television pictures. The methods that were best suited for my experiment was the Single-stimulus adjectival

categorical judgment method (SSACS) and the Stimulus-comparison adjectival categorical judgment method (SCACS).

1.7.1 Single-stimulus adjectival categorical judgment method (SSACS)

In SS methods, a single image or sequence of images (video) is presented and the assessor provides an index of the entire presentation.

The test session consists of a series of assessment trials. These should be presented in random order and, preferably, in a different random sequence for each observer. A typical assessment trial consists of two displays: the reference and a mid-grey post-exposure field and then followed by the video that is to be assessed. The duration of the exposure can be varied depending on viewer task, material and the opinions or factors that are considered, but 10 and 5 seconds are generally suggested.

The assessment for the Adjectival categorical judgment method is categories that are typically defined in semantic terms. The categories may reflect judgment of whether or not an attribute is detected. Categorical scales that assess image quality and image impairment have been used most often; the ITU-R scales are given in Table 1-2 below. [15]

Five-grade scale			
Quality		Impairment	
5	Excellent	5	Imperceptible
4	Good	4	Perceptible, but not annoying
3	Fair	3	Slightly annoying
2	Poor	2	Annoying
1	Bad	1	Very annoying

Table 1-2: ITU-R quality and impairment scale [15]

1.7.2 Stimulus-comparison adjectival categorical judgment method (SCACS)

In stimulus-comparison methods, two images or sequences of images (video) are displayed and the viewer provides an index of the relation between the two presentations.

The assessment trial will use either one monitor or two well-matched monitors and generally proceeds as in SS cases. If one monitor is used, a trial will involve an additional stimulus field identical in duration to the first. In this case, it is good practice to ensure that, across trials, both members of a pair occur equally often in first and second position. If two monitors are used, the stimulus fields are shown simultaneously.

Stimulus-comparison methods assess the relations among conditions more fully when judgments compare all possible pairs of conditions. However, if this requires too large a number of observations, it may be possible to divide observations among assessors or to use a sample of all possible pairs.

In adjectival categorical methods, observers assign the relation between members of a pair to one of a set of categories that, typically, are defined in semantic terms. These categories may report the existence of perceptible differences (e.g. same, different), the existence and direction of perceptible differences (e.g. less, same, more), or judgments of extent and direction. The ITU-R comparison scale is shown in Table 1-3. [15]

-3	Much worse
-2	Worse
-1	Slightly worse
0	The same
1	Slightly better
2	Better
3	Much better

Table 1-3: ITU-R Comparison table [15]

1.7.3 Adapting the assessment methods

The duration of the reference video clip and the video clips that were evaluated made assessment according to the recommendations difficult, so the methods described above have been adapted to fit the needs of my experiment.

The duration of the video clips in my experiment were slightly longer than what is recommended (21 seconds per video clip) but there was no practical way of reducing the duration of the video clips while keeping the repetitive behavior. As I wanted the assessors to look for specifics in the videos I also looped the videos so the total duration of a video clip was as long as was seen necessary for the assessor to evaluate all the specifics of it. Another practical problem was that only one Samsung 46" LCD HDTV (Chapter 4.3) was available so both the reference material and the video clip that was assessed had to be shown on the same display device. Because every video clip had to "buffer up" before the playback was how it should be (without any fps delay) it also caused a 30 second delay between when the assessor saw the reference video to when they saw the video that was assessed. Because of these limitations the ITU-R recommendations could not be followed in full. The ITU-R also recommends that the participants are not experts, or experienced in assessing video quality, but as this was the first time research of this type was conducted I wanted participants that had some experience to be able to rule out some error sources. Five participants were selected that all, to a certain degree, had experience in assessing video quality, this can also be seen by the way they completed part 1 of the questionnaire. All participants had e.g. looked at stereoscopic video material before.

During the first experiment with the first participants I quickly discovered that only having five number values to grade by was proving problematic as the differences between the video clips in some cases were small but clear. As the result from a discussion with the participant we agreed that assessing the video clips using ten values instead of the initial five would make it much easier to give an accurate assessment, but that it would still be difficult in some cases. As a result I decided to use ten values instead of the five recommended by the ITU-R. Assessing proved to be difficult for experiment 2 as well, so instead of just using the values from -3 to +3 I allowed the participants to use decimal numerals when assessing experiment 2.

Because I informed the participants about the frame drop patterns and the resolution of the low quality frames for every video clip there was no need to show the video clips that were assessed in a random order.

1.8 Scope and limitations

There are a lot of factors that can affect picture quality. To not make this project too comprehensive I have limited myself to look at finding the optimal way to vary quality over short time intervals of about 17 – 84 milliseconds:

$$\frac{1 \text{ second}}{59.94 \text{ frames}} = 0.01668 \frac{\text{seconds}}{\text{frame}} = 17 \frac{\text{milliseconds}}{\text{frame}}$$
$$5 * \frac{1 \text{ second}}{59.94 \text{ frames}} = 5 * 0.01668 \frac{\text{seconds}}{\text{frame}} = 84 \frac{\text{milliseconds}}{\text{frame}}$$

A more thorough explanation of the calculations can be found in Appendix 3.

Throughout the testing I will focus on using a spatial true HD resolution of 1920x1080, and two temporal resolutions, 29.97- and 59.94 frames per second. This allows me to test both the highest spatial and temporal resolution that is used on public TV broadcasts today. This will be displayed on the Samsung LE-46A656 HDTV (Chapter 4.3) which is a 46” monitor capable of showing a spatial resolution of 1920x1080 and a temporal resolution of 60 frames per second.

In a DMP environment it is to be expected that especially the spatial resolution would be much higher, but also the temporal resolution would be increased. Due to the technical limitations of today’s equipment it is not possible to do these tests according to the specifications of DMP, but it is to be expected that tests done using the highest public TV standards will give results that are a good indication of how the situation will be in the future as well.

Initially, as can be seen from the project description, it was the aim of this project to also introduce an economic model to show how economic models can be used to help make decisions when it comes to how to best deliver new technology to the market, whether it is software or hardware. This included a scenario that was used to show how this can be applied in a DMP setting. Using a generic economic model in a setting like this has not been done before. The

project description was meant to be vague when it came to the economy part. The reason for this was that we did not know which economic model that would suit the needs for DMP, and because of this we did not know how complex it would be either. As the economic model was chosen we (Leif Arne Rønningen and I) understood that explaining the model and its use would not be possible in this report because of its scope and complexity. Instead the model and how it can be used for DMP is briefly described in Appendix 7. The model presented should fit the needs of DMP well, and more research should be done on this in a later project.

2 Time variable quality of scene objects

The demand on bandwidth is increasing all the time and traffic can overload the network. As streaming of multimedia is increasing it is likely that network overload will be an even more common occurrence. In this chapter I will look at some of the complications that are introduced when the network gets overloaded and explain some alternative ways that can help to solve these problems.

2.1 How can we reduce network overload when streaming multimedia?

When a network reaches its bandwidth capacity it results in packets being dropped, which again results in data loss, low response and a decrease in overall usability of the network.

In general we can say that there are three ways to reduce the possibility to overload a network when streaming multimedia content. These three are to:

- Increase the capacity of the network to handle increase in demand
- To find new and better ways to compress the data that is being streamed
- To shape the traffic so it does not exceed the capacity of the network

These three solutions should all be worked on simultaneously as they all have a positive effect on network overload. When you increase the capacity of the network, there is less need for traffic shaping as the network can handle more connections without the need to reduce the bitrate received by each person connected. The same is the case with better compression of the data being sent, better compression results in a lower need in total capacity, and allows less traffic shaping to take place.

When it comes to increasing capacity of networks there are some disagreements as to how the future will be. The author of [16] predicts that the user demand for the Internet could outpace network capacity as early as 2010. Others state that there should be no concern that technical limitations to fiber-optic data transmission could become severe in the foreseeable future. In [17] the author argues that the fact that data transmission capacities can evolve faster data storage and computational power, has lead to some people to predict that any transmission limitations will

become obsolete. In [18] they have successfully developed a dense multiplexing technique that is implemented by polarization division multi- and demultiplexing technology, when they combined this with a newly developed thulium doped fiber amplifier (TDFA) they achieved a 100-km transmission of 10.9 Tbps as well as a 40 Gbps transmission over 9000 kilometers. In addition they developed a low cost switch IC (integrated circuit) module that contains optical input/output interfaces with a port speed of 10 Gbps per channel. The low processing speed of routers lead to a bottleneck when connecting backbone and access networks, but it is believed that this problem will vanish with the production process refinement of ICs, however the connection between the IC and the external circuit and the interfaces between boards continues to pose problems in terms of increasing speeds, but with the use of the developed high-speed optical interconnection technology these problems are expected to be resolved. The theoretical maximum optical transmission speed using this technology is 50 Tbps.

This development leads one to believe that the capacity of networks will be high enough in the future, and that the authors of [16] might be wrong when it comes to capacity shortage. It is impossible to know when this new technology will be available and when it starts to get used, so until then we have to treat network capacity as a limited resource.

When it comes to compression of information sent on the Internet there exists several compression techniques at different levels, such as Huffman coding (used in MP3 and JPEG etc.), LZ, LZW (used in GIF, ZIP, PDF, PNG etc.), JPEG, JPEG2000, MPEG, H.261, H.263 and H.264 which are available for text, image, audio and video compression [19].

Traffic shaping, controlled dropping of sub-objects as part of Quality Shaping will be treated in this report, the more advanced parts of Quality Shaping will not be looked at in this report, but can be found in [4] for better understanding.

2.2 Quality Shaping

The aim when streaming video is to allow maximum resolution all of the time, but with a high amount of users this will cause network overload. To prevent this, Quality Shaping can be used. By controlled dropping of packets we can reduce the resolution of objects or sub-objects in a scene so that the overall size sent to every user is lowered (an object can be any part of the scene,

some examples are the background, a football or the face of a person). For this to happen in a controlled manner and to have a guarantee of the minimum quality of the video every user receives the way this dropping happens has to be controlled using different QualityShapingProfiles [4]. How the QualityShapingProfiles perform and which parameters they include will not be addressed in this report. The focus here is to look at different way of combining original resolution frames with frames with reduced spatial resolution so that the total needed bandwidth is reduced. In DMP this will done on a object and sub-object level, while in this report I will look at how this controlled dropping will perform when applied to the entire scene. The reason for this is that the process of dividing a scene into objects and sub-objects is advanced and would take too much time in a report such as this. As this is preliminary testing of how quality variation work on short time intervals, looking at how it performs on the scene as a whole will give good indications to how it will perform when the scene is divided into smaller objects as well. A pseudo separation of objects will be done during the experiment as the participants will be asked to focus on how it performs on a moving object, the background and on a stationary object.

2.2.1 How Quality Shaping helps save bandwidth

If we imagine a scene as the one pictured below in Figure 2-1 we can see that a lot of the scene is made up by the background. The moving (dynamic) object is the cassette tape cover on the top of the diagonal single axis conveyor belt, and the single axis conveyor belt and the cassette tape under the conveyor belt are stationary (static) objects. If the background can be displayed with a lower temporal resolution than the moving object and the stationary objects, without this causing the viewing experience to be degraded significantly, this can be used to save large amounts of bandwidth. As the background makes up such a large part of the total scene, reducing the temporal resolution of it will make the total amount of data that is needed to represent the scene much lower. This can also be applied to static objects because there is less need to update them over time because they do not move. By intelligently choosing objects in a scene that should be shown with the highest available resolution and which objects, in this example the background, that can be shown with reduced temporal resolution we can use this as a mechanism of choosing which packets to drop. We can also choose to reduce the spatial resolution of objects that are out

of focus or objects that do not have a lot of details without it reducing the perceived quality, which again reduce the total bandwidth needed to represent a scene. These two techniques can be combined to reduce the bandwidth needed for streaming multimedia.



Figure 2-1: Example of a scene

In general we can say that objects that are in focus and move around should be shown with the highest possible resolution, while objects that are out of focus and often stationary can be shown with a lower spatial and temporal resolution without there being a big loss in perceived quality of the scene. This is consciously used in movies where the objects the directors want the viewer to look at are in focus, while the background and other parts of the scene are unfocused. This can be used when reducing spatial and temporal resolution so the perceived loss of quality is as small as possible.

As this report focuses on quality variation of the scene as a whole and not on every object we can show the bit rate needed by introducing different QualityShapingProfiles in a table as the one shown in Table 2-1.

I will throughout this paper use kilobyte/kilobit, megabyte/megabit and gigabyte/gigabit where kilo means 1000 and not 1024, the abbreviation b is for bit and B is for byte. Note however that 1 byte is still 8 bits. For referenced papers I will use the same abbreviations as in the source material.

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	996.66	996.66	996.66	996.66	996.66	996.66
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	996.66	945.90	923.99	904.38	877.80	872.08
1:1:1:1:2:1:1:1:1:2	20.00%	996.66	935.75	909.45	885.92	854.03	847.16
1:1:1:2:1:1:1:2	25.00%	996.66	920.53	887.65	858.24	818.37	809.79
1:1:2:1:1:2	33.33%	996.66	895.15	851.31	812.09	758.94	747.50
1:2:1:2	50.00%	996.66	844.39	778.64	719.81	640.08	622.91
1:2:2:1:2:2	66.67%	996.66	793.64	705.97	627.53	521.22	498.33
1:2:2:2:1:2:2:2	75.00%	996.66	768.26	669.63	581.39	461.79	436.04
1:2:2:2:2:1:2:2:2:2	80.00%	996.66	753.03	647.83	553.70	426.13	398.66
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	996.66	742.88	633.29	535.24	402.36	373.75
2:2 (only frames of reduced quality)	100.00%	996.66	692.13	560.62	442.96	283.49	249.17

Table 2-1: Bitrate needed in Mbps for a video stream using different QualityShapingProfiles

In Table 2-1 above in the Frame pattern column “1” indicates a frame with high spatial resolution (1920x1080) and “2” indicates a frame with reduced spatial resolution (the resolution of low resolution frames is given by the “Resolution of low quality frames” row). So 1:2 indicates a cyclic pattern where one original quality frame is followed by one frame with reduced spatial resolution. The way the values in Table 2-1 have been calculated is to take the total image size of a video file shown with the original 1920x1080 resolution and the total video file size of the same video with reduced resolution and then see how much of the resulting video file that consist of original frames and how much of it contains frames of reduced resolution. As we can see the final video files where we have dropped packages are much smaller, which results in much less bandwidth needed to stream them. These values are calculated for a video clip using the Uncompressed Microsoft AVI format with 29.97 frames per second.

$$\frac{(1920 * 1080) * 0.001261687MB}{21s} * 8bit = 996.66Mbps$$

More information about these calculations can be found in Appendix 3.

As we can see from Table 2-1 a video clip sending all frames in a 960x540 resolution saves $1 - \frac{249.17Mbps}{996.75Mbps} * 100 = 75\%$ of the bitrate compared to sending a video in a resolution of 1920x1080. By intelligently combining different resolutions and frame drop patterns we should be able to reduce the overall bitrate needed to stream video while keeping the quality high.

As an example we can use the scene presented in Figure 2-1 and say that it consist of 60% background, 25% static objects and 15% dynamic objects (this are all approximate numbers and may not be fully accurate to the scene presented). If we then choose to send the background using 2:2 frame pattern with the 1280x720 resolution, the static objects with a 1:2 frame pattern using the 1600x900 resolution and the dynamic object with a 1:1 frame pattern using the 1920x1080 resolution we will get an average bitrate of:

$$0.60 * 442.96Mbps + 0.25 * 844.39Mbps + 0.15 * 996.66Mbps = 626.37Mbps$$

For a scene composition like this we would need 37.15% less bandwidth:

$$1 - \frac{626.37Mbps}{996.66Mbps} * 100 = 37.15\%$$

So by intelligently dividing the scene into objects and sub-objects we could potentially save large amounts of network bandwidth. A big challenge in doing this is how to divide scenes into objects when the scene changes continuously and this will be looked at in the discussion in Chapter 9. To be able to save bandwidth when reducing the resolution of some frames in the video stream it will be necessary for the receiver to use spatial interpolation techniques to increase the resolution back to the original resolution after the frames has been transported over the network.

3 Picture Quality

In this chapter I will highlight some of the most important parameters that affect how a picture looks. The purpose of this chapter is not to go in depth on every parameter, but to give the reader a good overview of the parameters affecting image quality. For this project it was important to get good quality video material to work with, so this has been an important part of the process when I recorded my video material.

3.1 Digital cameras

The visual properties of an image can be improved by editing the picture after it has been taken, but the most important when it comes to getting a good picture is what is done before the picture is taken. Most new cameras can automatically adjust most settings that affect image quality, but with varying results. Good knowledge of the camera and setting the parameters manually will usually yield the best results. Good lighting conditions are also very important to get a picture with good technical quality.

In this project the purpose is to look at the quality of digital pictures, because of this, this section will only describe digital cameras. Just like conventional cameras a digital camera consists of series of lenses that focus light to create an image of a scene. Instead of film, a digital camera has a sensor that converts light into electrical charges. The sensor in most digital cameras is a charge coupled device (CCD), but some cameras also use a complementary metal oxide semiconductor (CMOS). Both CCD and CMOS image sensors convert light into electrons. When the sensor converts light into electrons, it can read the accumulated charge of each cell in the image (how the charge is read is what differentiates CCD and CMOS). There are a number of differences between the two sensors, but they both play the same role in the camera, they turn light into electricity, and for the purpose of understanding how a digital camera works we can think of them as nearly identical devices. [20]

3.2 Capturing Color

It is important to note that cameras can be considered to be colorblind, what is meant by this is that they only keep track of the total intensity of the light that strikes its surface. To get a full color image sensors use filtering to look at the light in its three primary colors. Once the three primary colors are recorded they are combined to create the full spectrum (Figure 3-1).

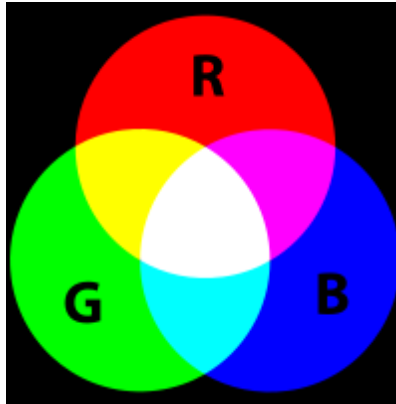


Figure 3-1: The RGB color spectrum [20]

The most economical and practical way to record colors in digital pictures is to use a color filter array. By breaking up the sensor into a variety of red, green and blue pixels it is possible to get enough information to make accurate guesses about the true color at the location. The process of looking at neighboring pixels to make educated guesses is called interpolation. The most common pattern of filters is the Bayer filter pattern as can be seen in Figure 3-2 [20].

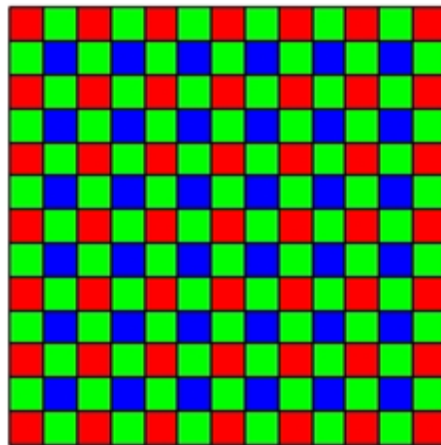


Figure 3-2: The Bayer filter pattern [20]

The pattern is made by alternating a row of red and green filters with a row of blue and green filters. The result of this is that there are as many green pixels as there is blue and red combined. This however, is not a disadvantage since the human eye is not equally sensitive to all three colors. For the eye to perceive a “true color” it is necessary to include more information from the green pixels. The advantage with this is that it is only necessary to use one filter in the camera.

The output from a sensor with a Bayer filter is a mosaic of red, green and blue pixels of different intensity, so the digital cameras have to use a demosaicing algorithm to convert the RGB mosaic into a true color mosaic.

Other ways of capturing colors is to use more than one filter, or by using a spinning disk filter, but this is mostly used for expensive studio cameras, and will not be addressed further in this report.

3.3 Exposure and focus

To control the amount of light that reaches the sensors two components are used, the aperture and the shutter speed.

- **Aperture:** Is the size of the opening in the camera, and controls how much light passes through at any given time. This component is automatic in most digital cameras, but some allow manual adjustment to give professionals more control over the final image.
- **Shutter speed:** Is the amount of time that light can pass through the aperture.

These two aspects work together to capture the right amount of light needed to make a good image, they set the exposure of the sensor [20]. If the camera is hand held, it is very hard to keep it still and get a clear picture (without motion blur) if the shutter speed is low. To get a clear picture with a hand held camera, the normal solution is to increase aperture to allow for a higher shutter speed.

In addition to controlling the amount of light, the camera also has to adjust how the light is focused on the sensor, this is done by lenses. Lenses on digital cameras are very similar to lenses on conventional cameras, but the focal length is one important difference. The focal length is the

distance between the lens and the surface of the sensor. The focal length is normally shorter on digital cameras because the sensors are normally smaller than a piece of 35mm film. The focal length also determines the magnification, or zoom, when you look through the camera. [20]

3.3.1 ISO value

As mentioned, increasing the aperture allows for a higher shutter speed. Another way to increase shutter speed is to adjust the ISO setting. The ISO number can range from 25 up to 3200. A high ISO value indicates that less exposure to the light is needed, so that the shutter speed can be increased. Using a high ISO value is however not only beneficial, because it introduces digital noise in the picture. Grain, or digital noise, can be seen in Figure 3-3. [21]

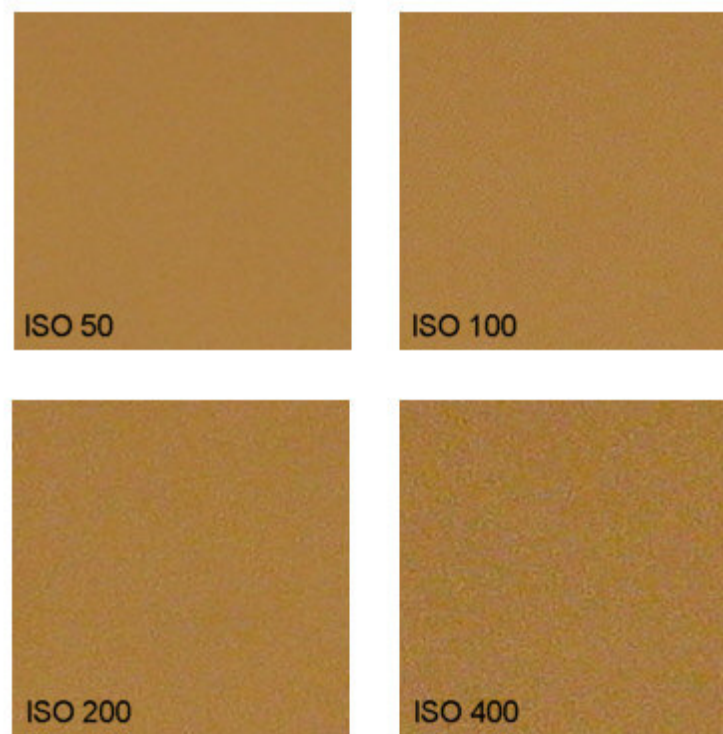


Figure 3-3: Digital noise at different ISO levels [21]

The best way to use ISO values is to use the lowest setting you can for the situation you are in when taking pictures.

3.4 Color depth

As mentioned, sensors only record the amount of light that hit the surface. The number of intensity levels is described by the number of bits of color depth. Most of the digital world operates at 8 bit images, which means that 8 bits of information are used to create the image that you see. 8 bits is used to represent each color (red, green and blue), so this gives a total of 24 bits per pixel. These 24 bits can then be used to represent approximately 16.7 million colors.

$$2^{24} = 16.777.216$$

Instead of using 8 bits to represent one color, more expensive cameras can use 12 and even 16 bits, but since most screens and printers are only able to represent 8 bits per color the advantage of using 12 or 16 bits are limited. The main advantage of using more than 8 bits to represent each color is that the picture will deteriorate slower if post processing work is done to the picture. Post processing on images with low bit depth can lead to posterization [22]. Posterization manifests itself when continuous gradation of tone is replaced with several regions of fewer tones as can be seen in Figure 3-4.

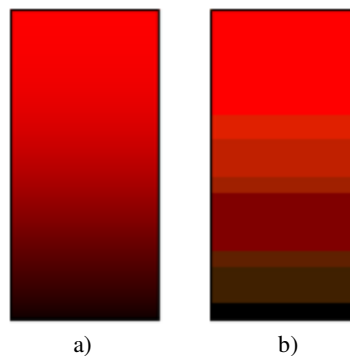


Figure 3-4: The Posterization effect.

Image a) and b) shows an image before and after posterization

One of the disadvantages with using a high color depth is that the image will require more resources for storage, and that more resources are required to work with the picture.

3.5 White Balance

In photography and image processing, color balance is the global adjustment of the intensity of the colors. For digital cameras the normal way to adjust color balance is to adjust the white balance. We can “tell” the camera which object in the room is white and suppose to come out white in the picture. This can be done by pointing the camera at a white or gray card and filling the screen completely with it. The camera can then calculate the color temperature of the environment we are working in, and will take pictures that, as close as possible, reflect the colors that we are observing [23]. Figure 3-5 shows two pictures, one with correct white balance and one with wrong white balance.



Figure 3-5: Picture showing wrong white balance on the left and correct white balance on the right [24]

White balance can also be adjusted in post processing, but it is better to do it before taking pictures. When adjusting white balance before taking pictures most cameras have an option to do this automatically or have presets of color temperature for different environments. Selecting the appropriate preset for the conditions that you are taking pictures in or having the camera

automatically adjust the white balance can be successful to a certain degree, but the best result is achieved by adjusting it manually.

3.6 Resolution

The resolution of an image tells us how many ‘dots’, both horizontally and vertically the image consists of. These ‘dots’ are called pixels. To know more about the quality of a picture it is important to know the size of the picture. This is because a picture with 640 x 480 pixels (VGA resolution) will look horrible on a cinema screen, but it will look good on a cell phone or a PDA. This resolution is described as the spatial resolution of an image. Because the size of the display devices vary so much, we have to see resolution in relation with the size of the image or the size of the display device. Generally speaking we can say that a high spatial resolution allows for a greater amount of details in a picture. A good way to describe the quality of a picture that takes this into consideration is dots per inch (DPI). [25]

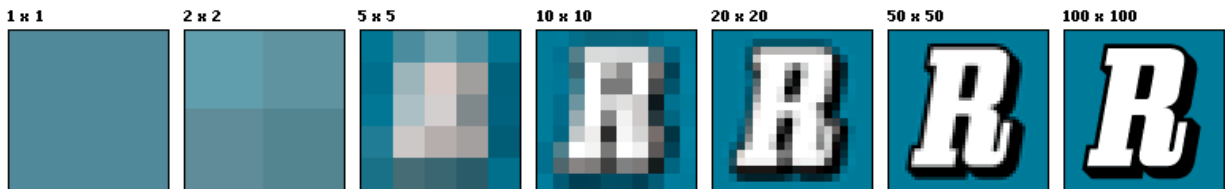


Figure 3-6: Picture of an ‘R’ at different resolutions [26]

If these things were not complicated enough, another important parameter when looking at an image is the distance it is viewed from. The distance from e.g. a digital TV set is an important part of the total viewing experience. Pixels cannot be too big, because then the viewer will be able to see them, and the viewing experience is worse than what it should have been.

When considering video, we also have to consider another type of resolution, the temporal resolution. The temporal resolution is given by how many different pictures that are displayed every second, this is also known as frames per second (FPS). A low temporal resolution gives an impression of stuttering to the observer.

3.7 Moiré

In some situations we can experience that a strange pattern appear in a digital image that we cannot observe in reality. This effect is called moiré and it is caused when a fine pattern in the subject matches the pattern of the imaging chip [27]. In Figure 3-7 we can see that a circular pattern is created when the two grids are combined. The moiré effect can be reduced by

- Changing the angle of the camera
- Changing the position of the camera
- Changing the focus point
- Changing the lens focal length
- Remove with software like Adobe Photoshop, or other third-party software

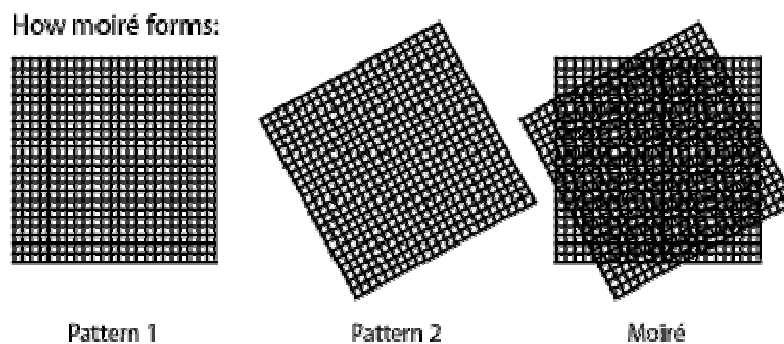


Figure 3-7: How moiré forms [27]

3.8 Interlaced and progressive scanning

Interlaced and progressive scanning are two options we have when we look at how an image is displayed on the monitor. Interlaced scanning divides the picture into two fields. One field contains line 1, 3, 5 etc while the other field contains line 2, 4, 6 and so on. When the image is displayed it is displayed in alternating order, first field 1 then field 2 (as can be seen in Figure 3-8 below). Progressive scanning on the other hand contains all lines in every frame. This means that the entire image is displayed for every frame which gives a better overall picture. [28]

The advantage of interlacing is that it saves bandwidth because only half of the information is sent compared to what a progressive image would need. Most new LCD screens and projectors support and use progressive scanning.

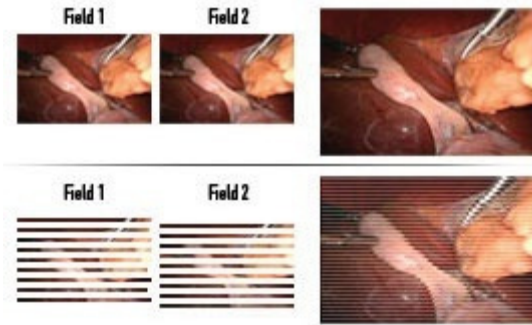


Figure 3-8: The difference of interlaced and progressive scanning [29]

4 Equipment and testing environment

This part describes the equipment that has been used in preparation and when carrying out the experiments. I will also try to explain some of the work done prior to deciding what equipment to use. Problems related to the equipment that arose during the process will be described in Chapter 7.

4.1 Research done before deciding on what equipment to use

For the comparisons that was going to be done in this project a good visual quality is important both when recording and when displaying the material. Because of a limited budget it is not possible to buy “top of the line” equipment; because of this the choice of equipment has been primarily based on already available equipment and some purchases where available equipment would not suffice.

As displaying the material is an important part of the experiments that are part of this project the choice of display device was a 120 Hz LCD HDTV from Samsung. The Samsung LE-46A656 is a 46” 120 Hz LCD TV that has a continuous refresh rate of 120 Hz which was chosen because of the size of the display. With a 46” LCD TV it should be easy to identify pixels in the video material during the experiment when the spatial resolution is reduced (more information about the TV can be found in Chapter 4.3).

For recording the video material, what was viewed as the most important was to be able to record in a 1920x1080 progressive resolution. There were no cameras available on the laboratory with this capability, but the Sony PMWEX1 XDCAM EX Compact Full HD Camcorder was available on the Midgard media lab on NTNU so this was borrowed and used when recording (more information about the camera can be found in Chapter 4.2).

The equipment that would be used for the model that was recorded was already available in the laboratory and this was also the case for the software needed for the project.

The computers available were not fast enough to play 1920x1080 video using the Uncompressed Microsoft AVI format at 59.94 frames per second, so a new computer was bought to be able to properly play the video material without it suffering from dropping of frames or uneven playback

as this would have an impact when comparing the different video clips in the experiment (more information about the computer and the storage solution can be found in Chapter 4.4).

4.2 Camera

The camera that was used for recording was the Sony PMWEX1 XDCAM EX Compact Full HD Camcorder [30] seen on Figure 4-1. This camera can record at 1920x1080/59.94i/29.97P/23.98P, 1280x720/59.94P/29.97P/23.98P where the ‘i’ means interlaced and the ‘P’ means progressive.



Figure 4-1: The Sony PMWEX1 XDCAM EX Compact Full HD Camcorder [30]

Recording with this type of camera is very straight forward if you are not too considered with the quality of the recording or if it is only for general private use. For recording with the high requirements to visual quality that was needed in this project many manual adjustments were necessary. These adjustments were done according to the parameters described in Chapter 3.

The recording was done using the HQ 1920x1080/29.97P setting which gives frame rate of 29.97 frames per second. In this project I also wanted to compare video at 59.94 fps, and although the camera could not record at HQ 1920x1080 at 59.94 fps this could be circumvented by using a playback setting in the media player used for showing the video material so that recording in 29.97 fps was not a problem. The HQ signals are compressed in MPEG-2 format. This was a good starting point for the comparisons I wanted to do in this project. [30]

For storing and editing the recorded material it was transferred to a computer using the cameras IEEE1394 (FireWire) connection. The recorded material is following the HQ standard and record pictures at the image bit rate of about 35 Mbps. For editing the material Adobe Premiere Pro CS4 was used.

4.3 Display device

The display device used in the project was the Samsung LE-46A656 [31] which is a 46" LCD HDTV that continuously displays at 120 Hz. One of the main reasons for choosing this display device over one of the projectors available in the laboratory was that the projectors were not capable of displaying a spatial resolution of 1920x1080. As both the highest spatial and temporal resolutions that were selected for the experiments reflect the highest available on public TV broadcasts in Norway this TV, which supports those resolutions, seemed like the perfect choice.



Figure 4-2: Samsung LE-46A656 120 Hz 46" LCD TV

Another benefit of using a LCD TV compared to a projector is that it gives a better visual quality when the light is not optimal. For this project that means that even if the material is not viewed in a room that is very dark, the image will be affected less than what it would have been using a projector. This is important since the lighting conditions should be the same in the room when

doing the recording of the model as they are when looking at the recorded material. Because a lot of light is needed to be able to make recordings of satisfying quality the room has to be well lit.

4.4 Storage

The video was copied to a computer and stored on a RAID 0 setup with two Samsung SpinPoint F1 750GB SATA2 hard drives.

RAID or Redundant Array of Independent Disks is a system that helps distribute data over multiple hard drives. There are many different levels of raid, the standard schemes are:

- RAID 0 – “Striped set without parity” or “Striping”
- RAID 1 – “Mirrored set without parity” or “Mirroring”
- RAID 2 – Hamming code parity
- RAID 3 – Striped set with ‘dedicated parity’ or ‘bit interleaved parity’ or ‘byte level parity’
- RAID 4 – Block level parity
- RAID 5 – Striped set with ‘distributed parity’ or ‘interleave parity’
- RAID 6 – Striped set with dual distributed parity

The hard drives were set up in RAID 0 which is the setup that gives the best read and write speed to the disks. The benefits of RAID 0 is that operating system sees the disks as one large disk and when a file is read or written to the disk the information is spread over the number of disks.

Theoretically this means that when 2 hard drives are connected $\frac{1}{2}$ of the information is recorded to each hard drive so the speed is doubled, with 4 hard drives $\frac{1}{4}$ of the information is stored on each drive so the speed is quadrupled, and so on.

To test the speed of the RAID setup I ran a comparison test using HD Tune Pro 3.00 [32]. The test showed that the average read speed was 147.5 MBps which could be a too low to play the Uncompressed Microsoft AVI video files at 59.94 fps:

$$\frac{2 * 996.66Mbps}{8bit} = 249.17MBps$$

Because a video using the Uncompressed Microsoft AVI format with 59.94 fps uses as much as 249.17MBps it was necessary to test how the playback would be. To do this I did a practical test and tried playing one of the recorded video clips in VLC Media Player (Chapter 4.6) at 2x speed and found that after playing through the video once while having it on repeat the playback did not lose any frames and played successfully at 59.94 fps. It seemed like the media player could buffer up the video file and that after that was done the playback was good.

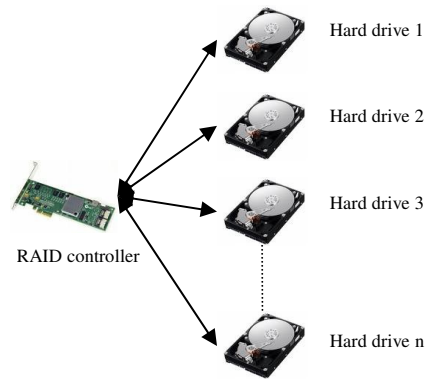


Figure 4-3: Hard drives connected to a RAID controller

The write speed is not so important in this project because the amount of data written is limited by the camera (it only allows the computer to record in real-time which is about 35 Mbps for the MPEG-2 standard that the video is recorded in on the Sony PMWEX1), so the write speed was not benchmarked.

Figure 4-3 shows how hard drives are connected to the raid controller, in my case the raid controller was a part of the motherboard in the computer.

4.5 Linear actuator (Compax3 Single axis device)

The basis of the model in this project is an object moving diagonally across the field of view. To realize this, a linear actuator has been used. This linear actuator used is delivered by Parker Motion Control Systems [33]. The Compax3 Single axis device consists of the Compax3 Servo Drive which is the controller for the device, a motor to generate the movement, a single axis

conveyor belt, a Laboratory Power Supply to supply the motor with power, and a computer using the C3 ServoManager 2 software. How these components are connected can be seen in Figure 4-4 below.

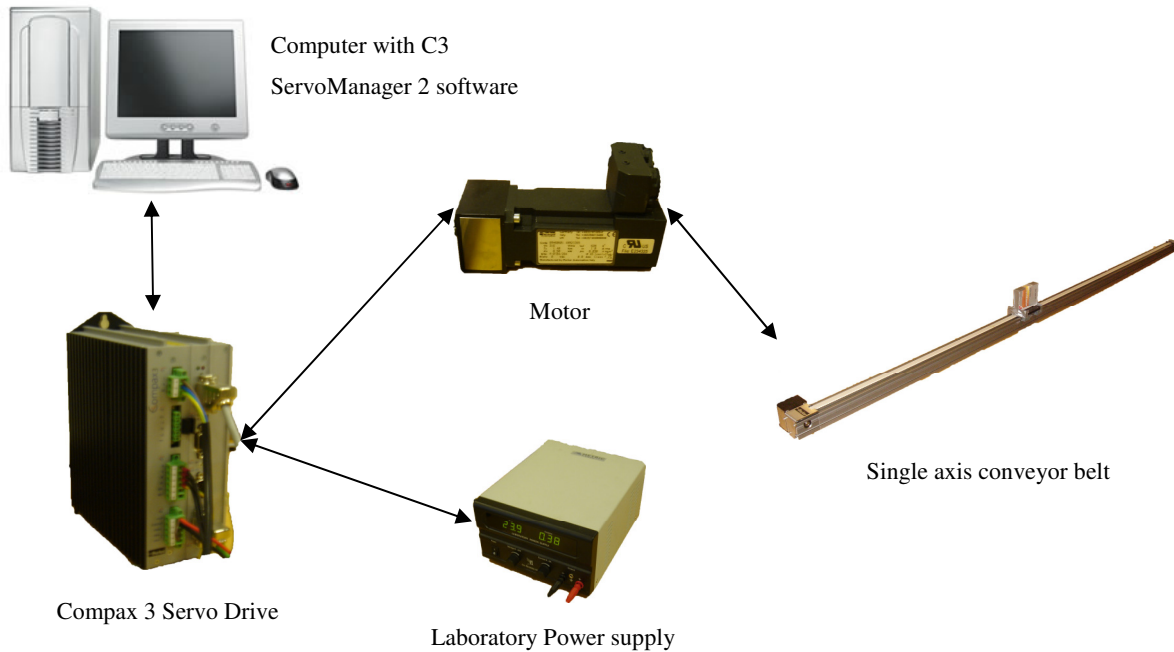


Figure 4-4: Linear actuator. All Components and how they are connected

After connecting the Compax3 system according to the installation manual supplied by Parker all the configuration is done in the C3 ServoManager 2 software. The software version used was V 2.0.2.11 and was released December 16, 2005. The software is designed to help the user set up and configure the motion of the system. It is designed for people that have good knowledge of motors and servo systems which make it less intuitive and user friendly for a person without detailed knowledge about these things. The examples of different setups that are given in the START UP brochure are very specific and they did not work for the system that was to be used in this project. Because of this a lot of time was spent trying to find a configuration that would behave the way I wanted for this project. More information and a step-by-step guide for setting up the C3 ServoManager 2 software can be found in Appendix 4.

4.6 Software

The software used for copying the recorded material to the computer was the Sony XDCAM EX ClipBrowser V2.00.01 [34], and the video editing was done using Adobe Premiere Pro CS4 [35]. More information about how the editing was done can be found in Chapter 5-3 and in Appendix 5.

For controlling the motion of the model C3 ServoManager 2 was used. A more detailed description of this software can be found in Appendix 4.

VLC media player [36] was used for showing the final edited material. The VLC media player has the benefits of being able to do video playback at 1x, 2x, 3x, and 4x speed etc. which makes it an ideal media player for this type of project.

4.7 Lighting

As mentioned in Chapter 3 a lot of light is important to make good recordings. Professional lighting equipment was not available, so 500W halogen task lights were used. These 500W lights gave a warm light of approximately 3000K. Typical daylight has a temperature of 5000K and candle light has a temperature of about 1000K. The higher the temperature of the light is, the more enhanced blue colors get and the more dulled red colors get, we say that the light is cold in this case. At 3000K red colors are enhanced and blue colors are dulled, which is the case when using these 500W halogen task lights, this is called a warm light. The light setup is closer described in Chapter 4.8.1. [37]



Figure 4-5: 500W halogen task light with stand

4.8 Experiment scenario

The goal of this project was to find different ways of combining frames with different spatial resolution to reduce the bandwidth needed to stream video over a network while keeping the perceived video quality as high as possible.

The experiment setup was simple and consisted of a chair for the test subject to sit in and the Samsung LCD HDTV. According to [38], for a person with perfect 20/20 vision the best pixel size is the distance the viewer is from the TV divided by 3400. In this case, this means that for a resolution of 1920x1080 (which is the resolution of the highest quality frames) the best distance to view from is:

$$\frac{1.06\text{meters}}{1920} * 3400 = 1.88\text{Meters}$$

Where 1.06 meters is the horizontal size of the LCD TV and 1920 is the number of horizontal pixels in the recording. This shows that the best distance to sit away from the TV screen for this experiment is 1.9 meters. The reason why the highest resolution that was going to be used in the experiment was used is that it is this resolution you would expect the viewers to position themselves for when using DMP. For this experiment the 1920x1080 spatial resolution is the

reference, so we are trying to find out what makes the viewing experience worse. Based on this the chair where the test subject was sitting was placed 1.9 meters away from the TV.

4.8.1 Light setting

A normal way to use lights when recording is to use a 3-point setup. This setup uses three light sources, one key light, one fill light and one back light. By using three light sources you minimize the shadow of the most important object in the recording. This light setup can be seen in Figure 4-6. The key light creates the subject's main illumination, and defines the most visible lighting and shadows. The fill light softens and extends the illumination provided by the key light, and makes more of the subject visible; it should preferably come from the opposite side of the key light. The back light creates a bright line around the edge of the object, to help visually separate the object from the background. [39]

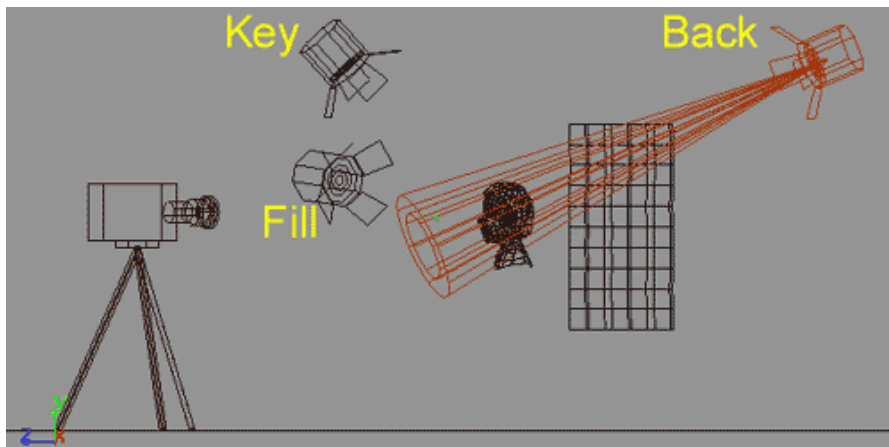


Figure 4-6: Three point lighting [39]

Because of the limited types of light available (only used the 500W halogen task lights) a perfect 3-point setup was not used. Instead the key light and the fill light were placed on the same side of the object. The key light was directed toward the object while the fill light was directed so that light was reflected of the wall and ceiling to reach the object. The back light was placed behind

the object as to light it up from behind as well as possible. The light setup used can be seen in Figure 4-7 below.



Figure 4-7: Light setup used during recording. a) key light, b) fill light and c) back light

As we can see from Figure 4-7 the key light and fill light were placed behind a filter screen that helped soften the light, this was done because the 500W halogen task lights gave a warm light (see Chapter 4.7) without this filter which made the object appear redder than it should. The setup gave good lighting of the object without too much shadow on the background. Another important factor when setting up the light was to not create any unpleasant ‘hot-spots’ where the object reflected light directly back at the viewer or the camera when it was recording, as this did not happen, I feel that overall the lighting worked well.

4.8.2 The Model: Object and movement pattern

The object can be seen on Figure 4-8 below where it is attached to the conveyor belt that was used to produce the movement in the model.

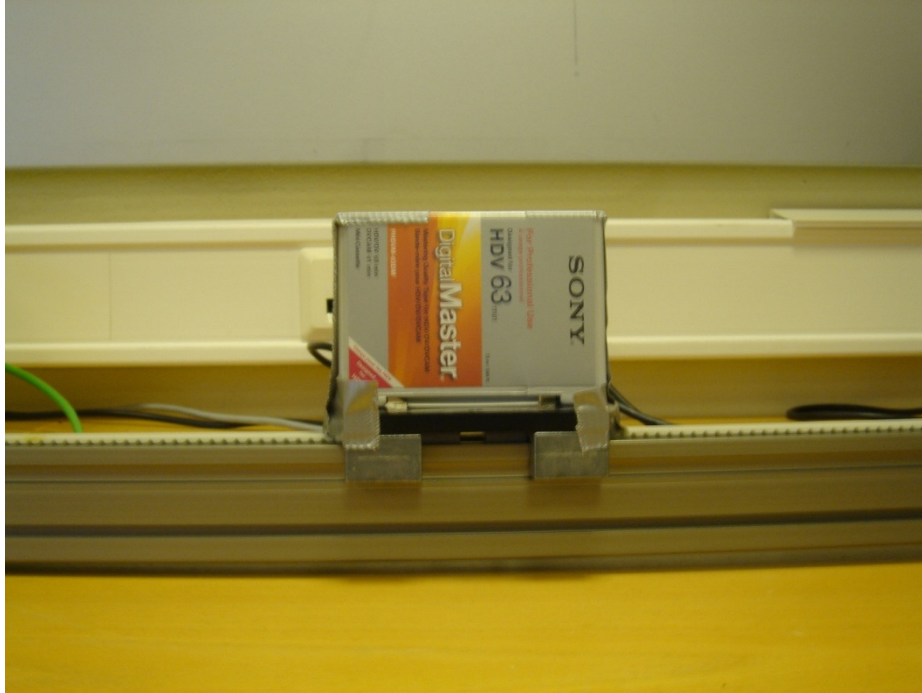


Figure 4-8: The object that was recorded

To generate the movement the Compax3 Single axis device described in Chapter 4.5 was used (Figure 4-9). The part that was visible on the recording was the conveyor belt that the object was connected to.

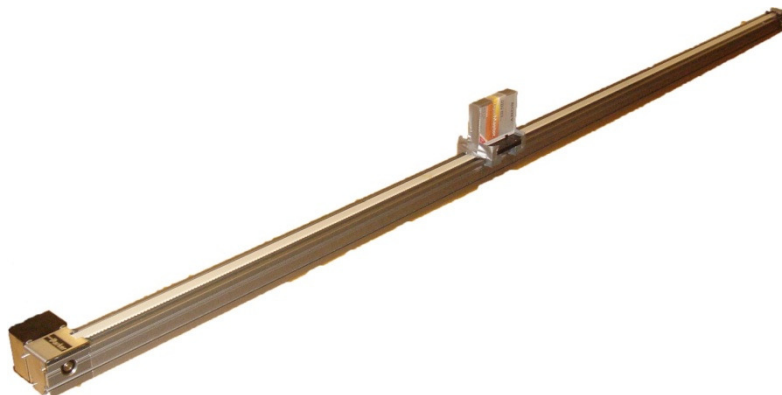


Figure 4-9: The Compax3 conveyor belt

The movement pattern was a simple back and forth movement of the object on the conveyor belt. Only using two dimensions was a choice made because I did not want to complicate things by using stereoscopic recordings and display devices.

5 Recordings and preparations for showing the material

This part describes the entire process from setting up the equipment, recording the material, editing of the material and preparing for showing it.

5.1 The room

Figure 5-1 shows a picture of the room that was used for recording and comparison between the model and the recording. The room was big enough to place the chair from where the comparison would be done 1.88 meters away from the model and the LCD TV.



Figure 5-1: The placement of chair, screens, lights and model

5.2 Camera placement and recording

The recording was done with the zoom setting set to 6. It is at that level of zoom the recorded object was the same size on the TV screen and in the model. The reason for wanting the same

size of the object in the recording and in the model was that in a scenario like a virtual dinner in DMP you want to look at objects using the same size as they have in real life. There were no problems with adjusting the focus at this level of zoom, so this was found to be a good setting. The camera was placed at a distance so that the frame around the model was not visible, but was perfectly aligned with the edge of the recorded material.

The recorded video was to be used as reference material, so the recording was done using the maximum spatial and temporal resolution (while still recording progressive video). The recording was done using a 1920x1080 spatial resolution at 29.97 frames per second.

The movement speed of the object in the model was adjusted using the C3 ServoManager2 software and the selected speed was 0.5. This speed was selected to get the best possible individual images of the moving object.

The background that was chosen was mostly grey and this felt like a good choice because it did not draw the attention away from the dynamic object and the static objects which was the most important part of the scene. The background also let the objects “stand out”, by not making them hard to see.

5.3 Editing

After the recording was done the video material was copied to the computer using Sony XDCAM EX ClipBrowser V2.00.01 (Chapter 4.6). The video was then imported in Adobe Premiere Pro CS4 (Chapter 4.6). In Premiere Pro CS4 the original video was exported using the Uncompressed Microsoft AVI format. The reason for using this format was to not have any interpolation between the frames in the video as this could change how the frames would look when combining high and low resolution frames in the videos that were used during the experiment. The uncompressed video material was then again imported in Premiere Pro CS4 and exported with the different resolutions. The resolutions selected were those that were to be used as low quality frames in the final video clips. These new low resolution videos were then imported in Premiere Pro CS4 and sequences were made using a video track that contained individual frames from the original quality video and the low resolution video. One video sequence was made for each of the videos that were used in the experiment and these were again

exported using the Uncompressed Microsoft AVI format. Editing the video material to fulfill the needs of this project was a long process and detailed information of how the editing was done can be found in Appendix 5. The appendix also explains some of the choices that was done while editing when it comes to edge correction and similar techniques.

5.4 Presentation the video material

The computer was connected to the Samsung LCD HDTV and all the video files were played through to see that there was nothing out of the ordinary with them. The video playback when using 2x playback speed in VLC Media Player (Chapter 4.6) was uneven until it had played through the video file once, but was good after that. The videos were to be shown in a well lit room, and the LCD TV was calibrated to give a good representation of the color and light in the room. The original video recording was used during the calibration to make the image on the TV look similar (color and light) to the model that had been recorded.

6 Experiment: Time variable quality of scene objects

6.1 Procedure

This chapter describes the procedure every assessor went through. An overview over the different elements can be found in Figure 6-1.

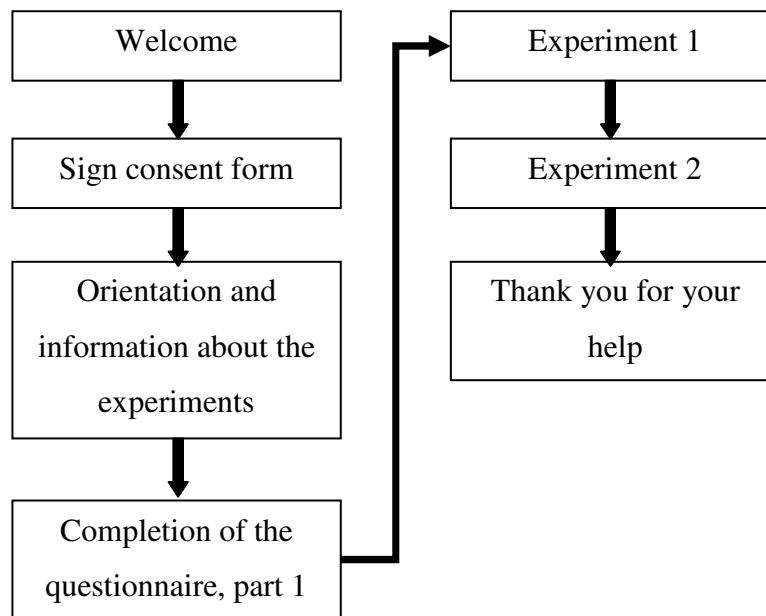


Figure 6-1: Procedure for the experiments

6.1.1 Information and consent

Before the experiments were conducted all the participants were presented with an information document which in short described who I am, what the project was about and how the experiments would be conducted. Before the experiments were started the participants had to sign a form of consent which gave me the right to use the results in my project. The form of consent and information was written in Norwegian so that all participants had a full understanding of what they were supposed to do and knew what the collected data would be used for. The information and form of consent can be found in Appendix 1.

6.1.2 Completing part 1 of the questionnaire

Before the participants started completing this part of the questionnaire they were informed that if they had any questions they should always ask them straight away. This way I could improve the questionnaire along the way if there was anything that was unclear to the participants.

Because of this, the questionnaire was under a continuous revision to be sure that the questions were as accurate as possible if the experiments were to be conducted later on a larger scale.

6.1.3 Experiment 1

The assessors read the information concerning experiment 1 and were asked whether anything was unclear. In the same way as with part 1 of the questionnaire the participants were told to notify me if anything was unclear so it could be improved for the next participant. According to the experiment scenario described earlier, the participants were placed in a chair in front of the LCD TV and the reference video clip was then shown. In accordance with the action research approach I explained some of the characteristics of the scene on the video and explained what parts were considered the background, the static objects and the dynamic object. I also explained what the participants should look for when assessing the video material.

After the reference clip had been shown for a while, and the participants understood the qualities of it, one of the video clips that were to be assessed was shown. Since the project had an action research approach it was me that filled in the questionnaire for this experiment with information that the participants gave me and we discussed. I asked the participants to first look for specific qualities and variation in the quality of the background, the static objects and the dynamic object and in the end a general impression of the video clip they had just observed. The video clips that were assessed in this experiment used two different frame drop patters (1:1:2:2 and 1:2:1:2) a temporal resolution of 29.97 and 59.94 fps, more information can also be found in Chapter 9. This experiment was conducted according (with some adaption) to the Single-stimulus adjectival categorical judgment method (SSACS) described in Chapter 1.7.1.

After assessment of one video clip was completed the reference video was shown again before the next clip that was to be assessed was shown. This was done until all the video clips had been evaluated.

The objective of experiment 1 was to find the best way to combine frames of low and high resolution to see what yielded the best perceived quality for different objects in the scene.

6.1.4 Experiment 2

As in experiment 1 any questions about the experiment information was answered and taken notice of so it could be improved for the next participants. This experiment followed the Stimulus-comparison adjectival categorical judgment method (SCACS) described in Chapter 1.7.2 but was conducted in a similar way as experiment 1. The main different between the two experiments is the way the assessment was done when it comes to semantic terms and the scale on which they are judged.

Experiment 2 continued to build on what was perceived as the best result in experiment 1. The reference video for experiment 2 was a video using a similar frame drop pattern as what was found to give the best result during the first experiment. During experiment 2 the temporal resolution was kept at 59.94 fps for all video clips, while the resolution of the low quality frames and the frame drop patterns were different in all video clips.

The results observed in experiment 2 has been used to see if a higher bitrate of a video always give a better viewing experience, or if there are ways to combine different resolutions and frame drop patterns to achieve quality that is perceived as better than what a video using a higher bitrate does.

7 Error sources

This chapter will describe possible sources of error that may have had an effect on the outcome of the project. To describe the severity of each source I have classified the impact of them as small, medium and large. A small error source will have had no, or a very small impact on the result, a medium error source may have had some effect on the outcome while a large error source will probably have had a large effect on the outcome, or made it impossible to test some aspects of the project.

It is important to remember that the participants were experienced in, or had done some sort of video quality assessment before, which reduce the severity of most error sources considerably. Another tool I used to reduce the severity of error sources was to adopt the action research approach since this gave me the possibility to “train” the participants during the experiments so they knew what could be ignored and what they should look for. Because of this the only sources of error that would have a big impact on the outcome of the experiment were pure technical error sources that made it impossible to consider some aspects during the assessment of the video clips.

7.1 Test environment

7.1.1 Light conditions in the room

The fluorescent light in the ceiling flicker at the net frequency which in this case was 50Hz. This flickering, although usually not very visible to the naked eye, can be easily recorded on a video camera if the frequency is not synchronized, it is the difference between the two frequencies that introduces this problem. This is very noticeable when e.g. using a video camera to record the picture of a CRT monitor, but can also be seen when the room is lit by fluorescent light. This effect was tried removed using the 3-point light setup with the halogen task lights but the flicker was not fully removed. The assessors were informed about this effect and it was shown on the reference video material. Error source severity: SMALL

7.1.2 Suggestions to changes and improvements

To remove the flicker from the fluorescent light completely only other light sources should be used. The recording can either be done in a room where there are specialized light for video recordings, or more task lights can be used. If task lights are used, different power should be used for the halogen light bulbs so that there is not a lot of shadow in the model which tends to be created using too strong light sources.

7.2 Technical equipment

7.2.1 The camera

The camera could only record at 1920x1080 at 29.97 frames per second while the experiments assessed video displayed at 59.94 frames per second. This was achieved by doubling the playback speed in VLC Media Player which in itself was not a problem, but the image quality of the individual frames during the recording would have been higher if the camera was able to record at 59.94 frames per second directly. Error source severity: MEDIUM

7.2.2 The computer

The computer that was used for video playback had hard drives that were too slow to play video using the Uncompressed Microsoft AVI format at 59.94 frames per second without having to buffer the video first. This meant that there was a 21 seconds delay (length of the video clips) before the participants could compare the reference video and the video that was to be assessed. This may have led to the assessors not being fully able to remember all the details of the two video clips that were compared. This was tried circumvented by allowing the participants to ask to see the reference material again during the assessment whenever they wanted to check for some details, but the time delay will still have had some impact. Error source severity: SMALL

7.2.3 The display device

The display device (Samsung LCD TV) performed as expected, but having access to one additional display would make it possible for the assessors to compare the videos directly to each other and eliminate the need to switch between displaying the reference video and the video that was assessed. Error source severity: SMALL

7.2.4 Suggestions to changes and improvements

Using a camera that was able to record at 59.94 frames per second would have given better image quality of the individual images in the videos. Especially is this the case for the dynamic object that did not have readable writing even in the reference video. Having a video camera able to record at the same frame rate as the video will be displayed at will be necessary for large scale testing in an experiment like this.

Having a computer with faster hard drives would eliminate the need for the computer to buffer up each video clip. As two of the hard drives used had a read speed of 147.5 MBps and the need for playback at 59.94 frames per second using 1920x1080 resolution with the Uncompressed Microsoft AVI format is 249.17 MBps (Chapter 4.4) it would theoretically require four hard drives similar to those used in the experiment. It has not been tested whether four hard drives would double the performance of two hard drives, but supported by the theory in Chapter 4.4 we can assume that it would suffice.

If another display device similar to the Samsung LCD HDTV was used there would also be need for another computer similar to the one used in this project, with the exception of adding four hard drives instead of the two that has been used (as discussed above).

7.3 The model and carrying out the experiment

7.3.1 Linear actuator

The linear actuator used to generate the movement in the model has a jerky movement which is noticeable when the object moves at low speed. At the speed setting used in this project (0.5) this was noticeable, but only to a small degree. Because of my research approach I was also able to inform the participants about this problem. Error source severity: SMALL

7.3.2 Edge detection

When editing the video edge detection was not used. This may have caused a higher quality loss on edges than what we would have seen if this effect was used. The severity of the error source of not using edge detection is hard to assess, but it is likely that at least some of the pixels that were identified by the participants could have been removed. In [6] it was discovered that edge detection can give a significant improvement in perceived quality. Error source severity: MEDIUM

7.3.3 Image scaling

When reducing the resolution of the 1920x1080 video and then scaling the video clips back up to original size (1920x1080), an operation that would be done with video player software as discussed in Chapter 2.2.1, something that looked like a shift in the pixels in the picture was introduced. The way the spatial interpolation is performed when up-scaling resolution in Adobe Premiere Pro CS4 was the cause of this, and this is likely the reason for some of the perceived quality loss in especially the static objects. Error source severity: MEDIUM

7.3.4 Suggestions to changes and improvements

A more accurate actuator could be used to get a smoother motion. It might also be possible to do this experiment using a higher speed on the actuator as the jerky movement is less noticeable

then, but this makes the individual images in the recordings worse and can make it even harder to recognize text and graphic on the dynamic object.

Edge detection has had many proposed implementations since the 1960s; some examples are Marr-Hildreth, Canny, Local Threshold and Boolean Function Based, Color Edge Detection using the Canny Operator, and Depth Edge Detection using Multi-Flash Imaging. In [40] a comparison between these edge detection implementations has been done and the Color Edge Detection using the Canny Operator performed best. Using edge detection on a scene from the reference video gave the results seen on Figure 7-1 below:



Figure 7-1: Scene with and without edge detection

As we can see using edge detection on the scene above gives a good representation of the edges. If this could be used when reducing the resolution of the videos so that the edges kept their original resolution it would probably have been harder to notice pixel artifacts along the edges and the perceived quality of the assessed video clips would probably have been closer to the reference clip.

Using a different spatial interpolation technique than the one that is default in Adobe Premiere Pro CS4 might give better results so some research can be done on this if this experiment is to be replicated. I will look at some different spatial interpolation techniques in Chapter 9.

7.4 Summary of error sources

The error sources discussed are summarized in Table 7-1 below.

Type of error	Severity		
	Small	Medium	Large
Light conditions	X		
Camera		X	
Computer	X		
Display device	X		
Linear actuator	X		
Edge detection		X	
Image scaling		X	

Table 7-1: Table of error sources

It can be discussed whether or not image scaling (Chapter 7.3.3) and edge detection (Chapter 7.3.2) in themselves should be perceived as error sources, but I have chosen to include them as they most likely had an impact on how the assessors perceived the video material. With those included we can see that there are four small and three medium severity error sources associated with this project. The medium error sources may have had an impact on the results of the project. The results gained have validity for what the experiments aimed to test; overall I feel that the error sources did not have a major impact on the reliability of the results and that some conclusions can be drawn from them. I will discuss this in more depth in Chapter 9.

8 Questionnaire

In this chapter I will describe the structure of the questionnaire and explain the basis and reasoning behind the questions that were asked. I will look at some of the data that was collected and consider the validity and reliability of these. The questionnaire can be found in Appendix 2.

8.1 Structure

The questionnaire consists of three parts. The first part consists of a series of questions to record the participants TV and computer habits. Part two was used to assess the first experiment which aimed to find the best way to use frame drop patterns to give the best possible perceived quality of a video clip given a specific bitrate. Part three was used to assess the second experiment which aimed to identify possible ways to combine different frame drop patterns and spatial resolutions to see if a higher bitrate always meant better perceived quality, or if there were intelligent ways to combine these two to give better results even at reduced bitrate.

I was available for questions and guidance throughout the process each participant took part of, and I encouraged discussion about the views of each assessor. By doing this every participant partly became co-scientists which the action research methodology encourages.

8.2 Part 1

- **Age, gender, occupation and eye sight**

The age of the participants varied between 25 and 62 years. One out of the five used contact lenses and no one suffered from being colorblind. Two were students and three were employed at the university. All the participants were male.

- **How many hours do you spend in front of a computer every week?**
- **What kind of monitor do you usually use?**
 - **Screen size?**
 - **Screen format?**

The reason for the questions was to judge how the participants’ knowledge about computers was, although this is not directly relevant to the experiment, it is a good indication of whether they are knowledgeable about computers and are used to be around them. Screen size and format is not relevant in itself, but data gathered can be used to show that the participants are experienced users and not without knowledge about computers. The results are summarized below:

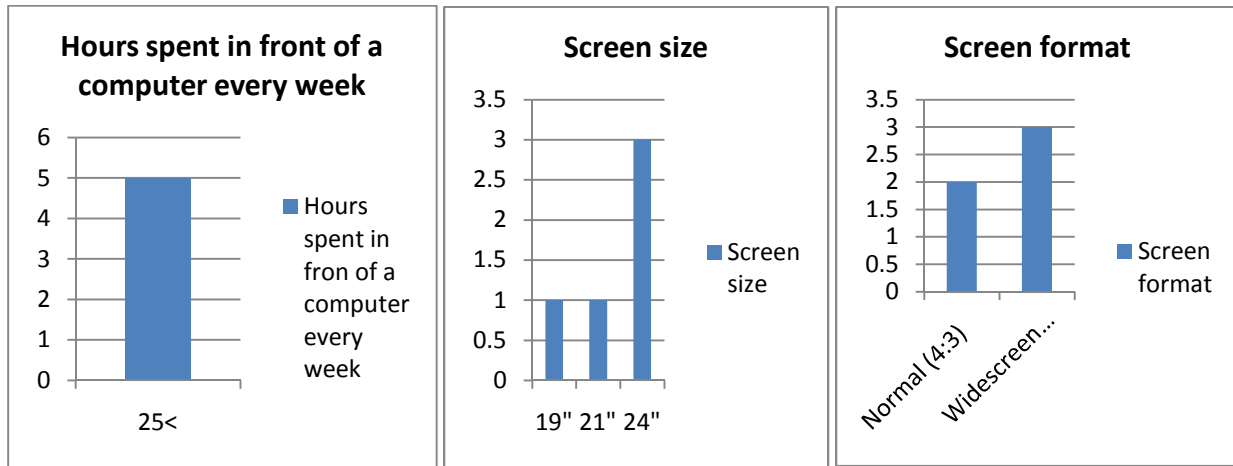


Figure 8-1: Computer habits

As we can see from Figure 8-1 all the participants used more than 25 hours in front of a computer screen every week which was to be expected as all participants were either students or were working at the university. They all used what can be seen as normal sized screens, between 19” and 24”, two used normal (4:3) format screens while 3 used widescreen (16:9) monitors. The most important information for me was that they all knew what kind of monitors they were using and that they were all accustomed to sitting in front of computer screens.

- **How many hours do you watch TV every week?**
- **What kind of monitor do you usually use?**
 - **Screen size?**
 - **Screen format?**

The TV habits of the participants were examined with the same goal as those for computer habits, to see how experienced the participants were with using this equipment. The numbers themselves are not very interesting, but the knowledge the participants had about the equipment they were using. The results are summarized below:

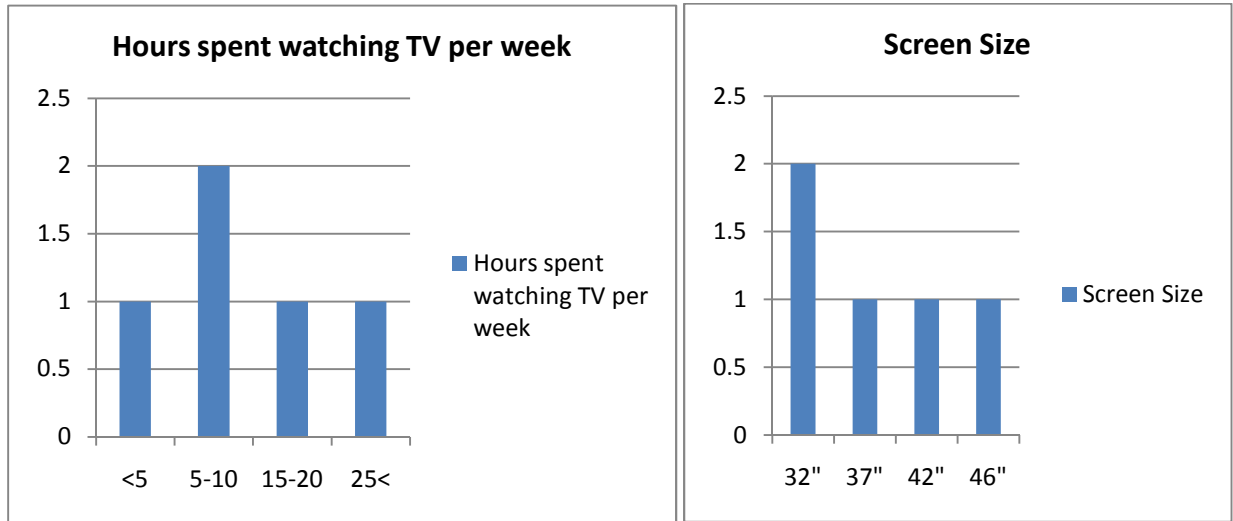


Figure 8-2: TV habits

All participants also answered that they had widescreen (16:9) format on the TV sets. As we can see from Table 8-2 all participants were used to watching TV every week, but the hours spent doing so varied a lot. The size of the TV screens varied from 32” to 46”.

- **How far away from the TV do you usually sit?**

This question coupled with the size of the TV screen can be used to see if the participants sat the “right” distance away from the TV according to the BBC recommendations described in Chapter 4.8. Four out of five people answered that they usually sat between three and four meters away from the TV. As we saw in Chapter 4.8 the right distance to sit away from the TV when looking at 1920x1080 resolution with a 46” TV was 1.88 meters, so we can say that most of the participants were sitting further away from the TV than what is recommended. This causes the viewer to lose the ability to see some of the details in the picture.

- **Have you ever watched “High Definition” video material or broadcasts in HDTV format?**

This question was mostly meant to check if the participants knew what HDTV was and had heard about High Definition. All participants had watched HDTV or High Definition video material before which further shows that all participants were somewhat experienced when come to, if not assessing, at least watching HD material and had knowledge about how video and TV material was displayed.

- **Have you ever watched stereoscopic (three-dimensional) images/video/games using specialized glasses?**

All the participants had knowledge about stereoscopic imaging and had watched some form of stereoscopic images.

- **Have you ever watched stereoscopic (three-dimensional) images/video/games without using specialized glasses?**

Only one person had watched auto-stereoscopic images, but the other participants knew what this meant and had knowledge about the technology.

8.2.1 Part 1 summary

As has been shown through the answers given by the participants they all showed that they had knowledge about technology used in computers/TV and how video was displayed, this impression was further enhanced by the conversation I had with every one of them. I wanted people experienced with video material in this project because it allowed me to eliminate some error sources and get results which were relevant for the aim of the experiments. All the above questions were meant to make the participants more comfortable and get a dialogue going between them and myself. They were also made aware about their own knowledge and it made them think about their own situation. The data gathered in Part 1 of the questionnaire is not

relevant to the results in Part 2 and Part 3, and should be disregarded when interpreting the results from the two last parts, it is only meant as a confirmation, both for myself, and others that the participants had some basic knowledge about video material and display devices.

8.3 Part 2

This part was used to assess different video clips in experiment 1 and was meant to find the best way to use frame drop patterns to give the best possible perceived quality of a video clip given a specific bitrate. The results from Part 2 will be examined and discussed in Chapter 9.

8.4 Part 3

The last part was used to assess video clips in experiment 2 and the gathered data was used to try to identify possible ways to combine different frame drop patterns and spatial resolutions at slightly different bitrate to see if a higher bitrate always meant better perceived quality, or if there were intelligent ways to combine these two to give better results even at reduced bitrate.

This part used a video clip which resembled what was discovered to give best results in the first experiment as reference, and can be seen as a continuation of the first experiment. The results from Part 3 will be examined and discusses in Chapter 9.

9 Results and discussion

In this chapter I will examine the data gathered in Part 2 and Part 3 of the questionnaire.

9.1 The participants

All participants were males between the age of 25 and 62; one used contact lenses while the others had normal vision. It is important to note that because of the low number of assessors we cannot use this data for to draw quantitative conclusions, but as this is preliminary research gathering quantitative data was never the purpose of this project.

9.2 Part 2, experiment 1

All the video clips that were assessed in this experiment were shown with a 1920x1080 resolution on the high resolution frames and 960x540 resolution on the low quality frames. The resulting video clips' size was 37.5% smaller than the reference clip.

To describe frame drop patterns I will use the number '1' for frames with original quality while '2' represents a frame with reduced spatial resolution. As an example a drop pattern of 1:1:2:2 represents two high resolution frames followed by two low resolution frames and this pattern is repeated over and over.

Table 9.1 shows the results of experiment 1.

	Experiment 1															
Participant	General				Background				Static objects				Dynamic objects			
	Video clip number															
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	7	8	8	9	8	8	8	10	7	7	8	9	8	9	8	10
2	3	4	4	7	6	7	7	9	2	2	2	4	4	5	6	7
3	5	6	6	9	6	8	8	10	3	4	4	9	8	10	8	10
4	5	6	5	9	5	6	6	10	4	4	4	9	6	7	6	10
5	5	7	6	8	7	7	7	9	4	6	6	7	5	7	7	9
Average	5	6.2	5.8	8.4	6.4	7.2	7.2	9.6	4	4.6	4.8	7.6	6.2	7.6	7	9.2

Table 9-1: Results from experiment 1

9.2.1 Experiment 1, clip 1

This clip was shown with a 1:1:2:2 frame drop pattern and 29.97 frames per second as temporal resolution. This clip would theoretically give the worst results of the four.

The general consensus of this clip was that it was much worse than the reference clip with an average general score of 5. The video clip had small, in search of a better word, “jumps” as it shifted between the high and low resolution frames, and this jumping was most clear on the static objects (the “jumping” is described in detail in chapter 9.3 and Appendix 6). The quality of the background also suffered a little from this jumping, but it was not as clear as it was with the static objects. The dynamic object was not influenced by the jumping as clearly as the other parts of the scene which most likely is because the movement to a large degree made the jumping impossible to see. The biggest decrease in perceived quality on the dynamic object was that the movement was not as smooth as it was in the reference clip which is an expected result as the video clip used a 29.97 fps temporal resolution compared to the 59.94 fps temporal resolution of the reference clip.

9.2.2 Experiment 1, clip 2

This clip was shown with a 1:1:2 frame drop pattern which was the same as in clip 1, but used a temporal resolution of 59.94 frames per second.

This clip was generally better than the first clip. The issues with the image jumping were much less noticeable, but still clearly there. The reason for the jumping being less noticeable is that every frame only had half the duration it did in clip 1 because of the double frame rate. Instead of frames shifting between high and low quality every $2frames * \frac{1000ms}{29.97fps} = 66.73 ms$ like it did in clip 1 it shifted every $2 * \frac{1000ms}{59.94fps} = 33.36 ms$ which makes it harder to see the changes for the eye because they happen so fast. The dynamic object had a smoother movement than clip 1 and one participant stated that he could now not see any difference when compared to the reference video.

The most disturbing part of the scene was still the static objects in which it was still a clear disturbance due to the image jumping. The jumping was less noticeable on the background which is likely because it does not have the clear contrasts and graphic the static object has; there are fewer details that noticeably change place when the jumping occurs.

9.2.3 Experiment 1, clip 3

This clip was shown with a 1:2:1:2 frame drop pattern using 29.97 frames per second.

Theoretically this would give results similar to those we saw in clip 2 as the change between low and high quality frames happen at the same frequency. The change between high and low resolution frames happens every $1 * \frac{1000ms}{29.97fps} = 33.36 ms$ as was the case for clip 2.

From the results in Table 9-1 we can see that the general impression of clip 3 is slightly lower than that of clip 2 which most likely is the result of the dynamic object not moving as smooth at 29.97 fps as it does at 59.94 fps. We can also see from the table that the static objects scored slightly higher on clip 3 compared to clip 2, the difference however is so low that we can say that the perceived quality was similar, this is also backed up by the fact that only one person gave the static objects a different value in clip 2 and 3.

Again it was the noise introduced by the jumping of the static object that was most noticeable when comparing the overall quality compared to the reference clip.

9.2.4 Experiment 1, clip 4

This clip was shown with a 1:2:1:2 frame drop pattern as clip 3 but used a 59.94 fps temporal resolution. The change between high and low resolution frames for this clip happened every $1 * \frac{1000ms}{59.94fps} = 16.68 ms$. The results seen in this video clip was much better than what was achieved with the other clips. Three people said they could not see any difference for the dynamic object and the background when compared to the reference clip. Three people also gave a value of 9 for the static object showing that it was very close to the quality of the reference. The jumping in the static object was very hard to see, but some noise could still be noticed. Overall this clip was very close to the quality of the reference clip which is impressive since it uses 37.5% less bitrate than the reference.

9.2.5 Experiment 1 summary

From the results it shows a clear indication that when the duration of the low resolution frames becomes shorter the perceived quality increases. In clip 4 the duration of a low quality frame is $1 * \frac{1000ms}{59.94fps} = 16.68 ms$ which seems to be so low that the human eye has a problem with perceiving the change between low and high resolution frames. Clip 4 gave much better results than the other assessed video clips especially when it comes to the background and the static objects. The main reason for this was that the “jumping” was almost impossible to notice.

The “jumping” that caused the most perceived quality loss when clips are compared to the reference is caused by the way pixels are interpolated when the resolution is increased. Below, in Figure 9-1, we can see six different images of the “S” in “Sony” on the static object.

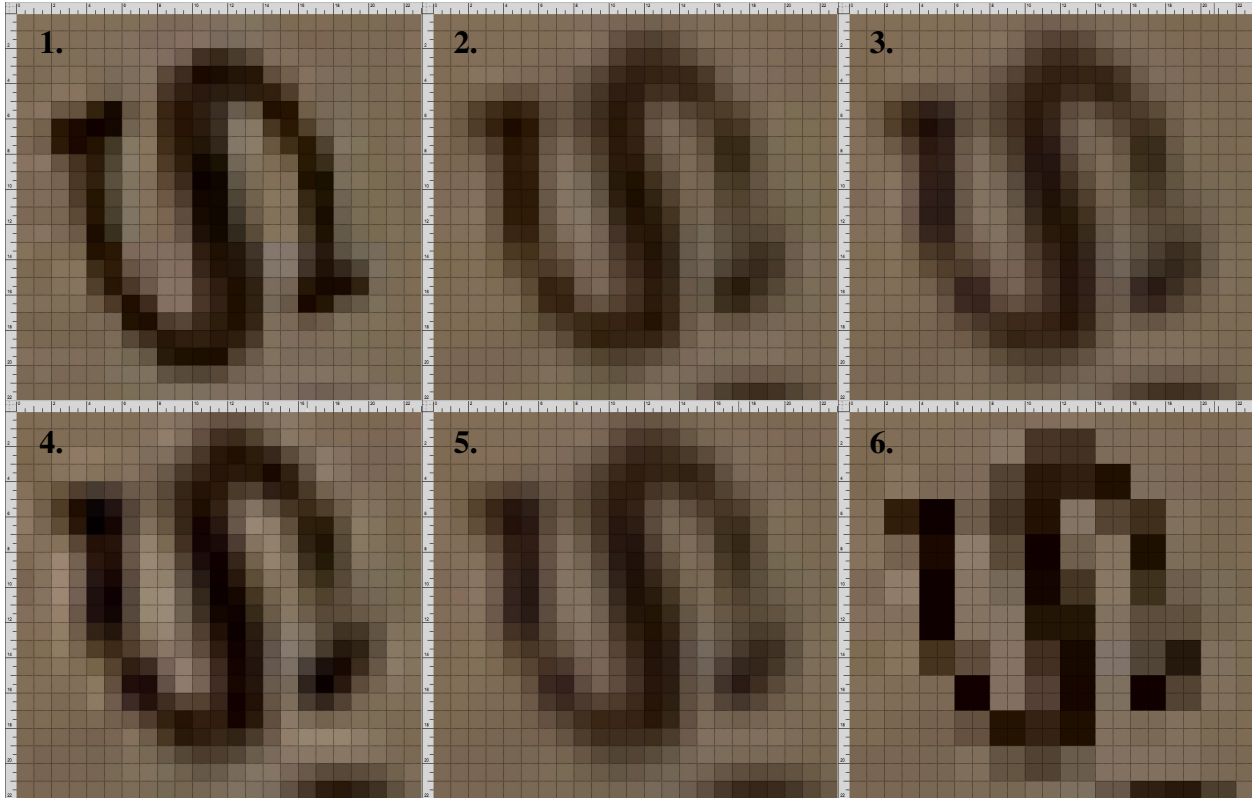


Figure 9-1: Comparing different interpolation algorithms

These images have been zoomed by 3200% so that it is easy to identify every pixel in the image. More detailed pictures can be found in Appendix 6. Image 1 is taken from the reference video and has a resolution of 1920x1080 pixels without any form of interpolation applied and can be seen as the reference image for the comparison done here. Image 2 is the result of the way Adobe Premiere Pro CS4 scaled a 960x540 pixel image up to 1920x1080 pixels (this is the interpolation technique used on all the low resolution frames in the video clips that has been assessed). Efforts to find the exact interpolation algorithm used in Premiere Pro CS4 has been unsuccessful, but judging from the images above it looks very similar to Image 3 which uses Bilinear interpolation. Bilinear interpolation is the default spatial interpolation technique used in other Adobe software like Adobe Fireworks CS4 and Adobe Photoshop CS4 so it is likely that Adobe Premiere Pro CS4 also uses this interpolation technique by default.

The reason for the “jumping” observed when combining high resolution and low resolution frames in the assessed video clips can be identified in the images above. If we look at Image 1 we can see that the two upper rows of pixels are not used to draw the “S” at all. The same is the

case for the three rightmost columns of pixels. When we compare this to the interpolated image produced by Adobe Premiere Pro CS4 in image 2 we can see that the second upper row of pixels as well as the third pixel column from the right is used to draw a part of the “S”. In Image 1 we can also see that the third pixel column from the left is used to draw clear black pixels in the “S” as well as second pixel row from the bottom. In Image 2 the “S” is not drawn in clear black until the fourth and fifth pixel column from the left and not until the third and fourth pixel row from the bottom. The results of this is that the pixels that are used to draw the “S” has been shifted one pixel column to the right and one pixel row up. When this is shown in a video clip it results in the pixels shifting back and forth between these two locations and hence it is perceived as if the image is “jumping” between two positions.

This effect is also clear if we look at the bottom row of pixels in Image 1-6, in Image 1 we can see that this pixel row is not used to draw any other text (the “O” in Sony in this case) while on Image 2-6 we can see that a part of the “O” has drawn.

For Image 4-6 other interpolation algorithms has been used (4: Bicubic interpolation, 5: Soft interpolation, 6: Nearest Neighbor interpolation), and as we can see the shift in pixels has happened when using these algorithms as well.

9.3 Part 3, experiment 2

The video clips that were assessed in this experiment were shown with a 1920x1080 resolution on the high resolution frames, but they had different resolution on the low quality frames. The frame drop patterns were also different in all video clips. The reason for doing this was to keep the bitrate of the video clips in a set interval to be able to see if a higher bitrate always meant higher perceived quality, or if there were intelligent ways to combine different resolutions and frame drop patterns to achieve quality that was perceived as better than what a video using a higher bitrate would give.

Time-variable scene quality – perception tests

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	996.66	996.66	996.66	996.66	996.66	996.66
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	996.66	945.90	923.99	904.38	877.80	872.08
1:1:1:1:2:1:1:1:1:2	20.00%	996.66	935.75	909.45	885.92	854.03	847.16
1:1:1:2:1:1:1:2	25.00%	996.66	920.53	887.65	858.24	818.37	809.79
1:1:2:1:1:2	33.33%	996.66	895.15	851.31	812.09	758.94	747.50
1:2:1:2	50.00%	996.66	844.39	778.64	719.81	640.08	622.91
1:2:2:1:2:2	66.67%	996.66	793.64	705.97	627.53	521.22	498.33
1:2:2:2:1:2:2:2	75.00%	996.66	768.26	669.63	581.39	461.79	436.04
1:2:2:2:2:1:2:2:2:2	80.00%	996.66	753.03	647.83	553.70	426.13	398.66
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	996.66	742.88	633.29	535.24	402.36	373.75
2:2 (only frames of reduced quality)	100.00%	996.66	692.13	560.62	442.96	283.49	249.17

Table 9-2: Resulting bitrate given different QualityShapingProfiles

Table 9-2 shows the different combinations of resolution of low quality frames and the frame drop patterns selected for experiment 2. The reference video clip for experiment 2 used the same frame drop patterns as the one found to be best in experiment 1 but used a higher resolution on the low resolution frames. For this experiment 1280x720 was used as resolution on the low quality frames for the reference. As we can see from Table 9-2 the bitrate of the reference clip was the second lowest of all the clips at 719.81 Mbps with the video clip bitrate varying between 705.97 Mbps for the lowest and 809.79 Mbps for the highest.

All video clips in experiment 2 used a temporal resolution of 59.94 frames per second which means that the bitrate given in the table above have to be multiplied by two as it gives bitrates using a temporal resolution of 29.94 fps.

Table 9-3 shows the results of experiment 2.

Experiment 2																
Participant	General				Background				Static objects				Dynamic objects			
	Video clip number															
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	-2	-1	-1	-0.5	-0.5	-0.2	-0.2	-0.1	-2	-1.5	-1.5	-1	0	0	0	0
2	-2	-1	-1	0	-1	0	1	2	-2	-1	-1	-1	-1	-1	0	0
3	-1	-0.5	-0.5	-0.5	-1	0	0	0	-2	-1	-1	-1	0	1	1	1
4	-3	-1.5	-0.5	-1	0	0	0	0	-3	-2	-1	-2	0	0	0	0
5	-1	-1	-1	-0.5	-1	-0.5	-1	-0.5	-1.5	-1	-0.5	-0.5	0	0	0	0
Average	-1.8	-1	-0.8	-0.5	-0.7	-0.14	-0.04	0.28	-2.1	-1.3	-1	-1.1	-0.2	0	0.2	0.2

Table 9-3: Results from experiment 2

9.3.1 Experiment 2, clip 1

This clip was shown with a 1:1:1:2 frame drop pattern where 960x540 was the resolution of the low resolution frames.

Overall this clip gave the worst overall perceived quality of the clips assessed in experiment 2 which is surprising as it had the highest bitrate of all the clips that were looked at. The most noticeable reduction in quality was for the static object which suffered from the same jumping that had been so noticeable all along. It was also easier to see the pixels in this clip compared to the reference.

9.3.2 Experiment 2, clip 2

This clip was shown with a 1:1:2 frame drop pattern where 1024x576 was the resolution of the low quality frames.

This clip had less noticeable jumping on the background and the static object, but it was more much more noticeable than it was on the reference clip. The general consensus was that it was far from the quality of the reference clip, but that it was slightly better than clip 1. One participant

felt that the dynamic object was better in this clip and one said the quality was lower than the reference.

9.3.3 Experiment 2, clip 3

This clip was shown with a 1:2:2 frame drop pattern where 1440x810 was the resolution of the low quality frames.

The jumping in this clip was about the same as what was experienced in clip 2, and the overall quality was below that of the reference clip.

One participant felt that the dynamic object was better in this clip while the other participants said that the quality was the same as the reference. The only explanation for this could be that the dynamic object could give better representation of details when the frames did not change between low and high quality so often. As the other participants did not notice this, it could also just be a problem with the playback of the reference video, or that the delay between showing the reference video and the assessed video was so long that it gave this impression.

9.3.4 Experiment 2, clip 4

This clip was shown with a 1:2:2:2 frame drop pattern where 1600x900 was the resolution of the low quality frames.

This clip gave the highest overall quality impression, but it was still not as good as the quality of the reference clip. One participant gave the background a high score and felt that it was better than the reference, but two participants felt that it was not as good as the reference. The quality of the background can have been hard to assess as the jumping is not as noticeable for this element. The static object got a lower score again than what it received in clip 3, which is the result of more jumping.

9.3.5 Experiment 2 summary

As we can see from Table 9-3 none of the assessed videos gave an overall impression of higher quality than the reference video. The reason for this was that the issue with the static object jumping was again more noticeable when the frame drop pattern changed away from the 1:2:1:2 pattern. Whenever the change between high and low quality frames happens in intervals where one type of frame lasts longer than the other this problem is more noticeable, even if the majority of frames are of high quality as was the case for clip 1 where 75% of the frames have a 1920x1080 resolution. The jumping is less noticeable when the duration of low and high quality frames are almost equal as was the case for clip 2 and 3 where 66.6% of the frames were of either high or low quality, and it became more noticeable again for clip 4 where 75% of the frames were of low resolution. It is surprising that for clip 4, which had 1600x900 as the low resolution frames, that the jumping was so noticeable, but the cause was again that the pixels were shifted up and to the right as described in Chapter 9.2.5.

As we can see from these results, increasing bitrate of a video clip does not necessarily increase the perceived quality of a video clip. The way low and high resolution frames are combined has a big impact on the resulting perceived quality of a video when Quality Shaping is used.

9.4 Practical application

The use of QualityShapingProfiles (Chapter 2.2) can have a big impact on how many users we can allow access to a media stream without them experiencing degraded quality as a result of package loss and network overload.

9.4.1 Reducing quality of the whole scene

In Chapter 2.1 it was shown results where researchers had successfully developed technology and carried out tests where a transmission of 10.9 Tbps was achieved over a distance of 100-km, which could be the size of a large metropolitan city. This technology could theoretically be used for a transmission speed of 50 Tbps, but using the transmission speed they had achieved we can

generate some numbers based on this to find numbers of users that would be allowed to this network.

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	1,993.32	1,993.32	1,993.32	1,993.32	1,993.32	1,993.32
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	1,993.32	1,891.81	1,847.97	1,808.75	1,755.60	1,744.16
1:1:1:1:2:1:1:1:1:2	20.00%	1,993.32	1,871.51	1,818.91	1,771.84	1,708.05	1,694.32
1:1:1:2:1:1:1:2	25.00%	1,993.32	1,841.05	1,775.30	1,716.47	1,636.74	1,619.57
1:1:2:1:1:2	33.33%	1,993.32	1,790.30	1,702.63	1,624.19	1,517.88	1,494.99
1:2:1:2	50.00%	1,993.32	1,688.79	1,557.28	1,439.62	1,280.16	1,245.83
1:2:2:1:2:2	66.67%	1,993.32	1,587.27	1,411.94	1,255.05	1,042.43	996.66
1:2:2:2:1:2:2:2	75.00%	1,993.32	1,536.52	1,339.26	1,162.77	923.57	872.08
1:2:2:2:2:1:2:2:2:2	80.00%	1,993.32	1,506.07	1,295.66	1,107.40	852.26	797.33
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	1,993.32	1,485.76	1,266.59	1,070.49	804.71	747.50
2:2 (only frames of reduced quality)	100.00%	1,993.32	1,384.25	1,121.24	885.92	566.99	498.33

Table 9-4: Bitrate in Mbps given different drop patters and resolutions

Table 9-4 gives bitrates needed in Mbps for video using the Uncompressed Microsoft AVI format at 59.94 frames per second.

To find the number of users that can use the network we use the bitrate achieved by the scientists.

$$10.9Tbps = 10900000Mbps$$

This allows a maximum number of users of $\frac{10900000Mbps}{1993.32Mbps/user} = 5468$ users when streaming video at 1920x1080 resolution continuously. Table 9-5 below gives the maximum number of users depending on frame drop pattern and resolution of low quality frames. The maximum number of users has been rounded down to ensure that there is no network overload.

Time-variable scene quality – perception tests

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	5468	5468	5468	5468	5468	5468
1:1:1:1:2:1:1:1:1:2	16.67%	5468	5761	5898	6026	6208	6249
1:1:1:1:2:1:1:1:1:2	20.00%	5468	5824	5992	6151	6381	6433
1:1:1:2:1:1:1:2	25.00%	5468	5920	6139	6350	6659	6730
1:1:2:1:1:2	33.33%	5468	6088	6401	6711	7181	7291
1:2:1:2	50.00%	5468	6454	6999	7571	8514	8749
1:2:2:1:2:2	66.67%	5468	6867	7719	8684	10456	10936
1:2:2:2:1:2:2:2	75.00%	5468	7093	8138	9374	11802	12498
1:2:2:2:2:1:2:2:2:2	80.00%	5468	7237	8412	9842	12789	13670
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	5468	7336	8605	10182	13545	14582
2:2 (only frames of reduced quality)	100.00%	5468	7874	9721	12303	19224	21873

Table 9-5: Maximum possible number of users of a media stream

As we can see the maximum numbers of users changes from 21873 when streaming a video with a resolution of 960x540 to only 5468 users when using a resolution of 1920x1080. The additional number of users allowed when using different frame drop patterns and resolutions is given in Table 9-6 below.

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	0	0	0	0	0	0
1:1:1:1:2:1:1:1:1:2	16.67%	0	293	430	558	740	781
1:1:1:1:2:1:1:1:1:2	20.00%	0	356	524	683	913	965
1:1:1:2:1:1:1:2	25.00%	0	452	671	882	1191	1262
1:1:2:1:1:2	33.33%	0	620	933	1243	1713	1823
1:2:1:2	50.00%	0	986	1531	2103	3046	3281
1:2:2:1:2:2	66.67%	0	1399	2251	3216	4988	5468
1:2:2:2:1:2:2:2	75.00%	0	1625	2670	3906	6334	7030
1:2:2:2:2:1:2:2:2:2	80.00%	0	1769	2944	4374	7321	8202
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	0	1868	3137	4714	8077	9114
2:2 (only frames of reduced quality)	100.00%	0	2406	4253	6835	13756	16405

Table 9-6: Additional number of users allowed by the network

16405 additional users can use the network stream when streaming at a resolution of 960x540 which is a 400% increase in the number of users compared to when streaming at a 1920x1080 resolution.

As we have seen from the experiments performed however, the perceived quality of video of reduced resolution is much lower than when the video is shown at 1920x1080 which was the resolution of the reference video in experiment 1. If we look at video clip 4 (1:2:1:2 frame drop pattern and 960x540 resolution on low quality frames) from experiment 1, which gave a perceived quality that was very close to that of the reference video, we can see that it allows 3281 additional users of the media stream which is a 160% increase in number of users.

9.4.2 Introducing objects in the scene

The possibility to divide a scene into objects is a part of DMP, and even though this has not been a part of this project data has been collected about objects through the way the questions were asked during the experiments. This data can be used to look at how the resulting bitrate of the entire scene would be if it was divided into objects.

Using the scene from the video clip that has been used during the experiments (Figure 9-2) we can say that the background is about 75% of the total scene, while the static objects make out 15% and the dynamic object make out the reminding 10%.

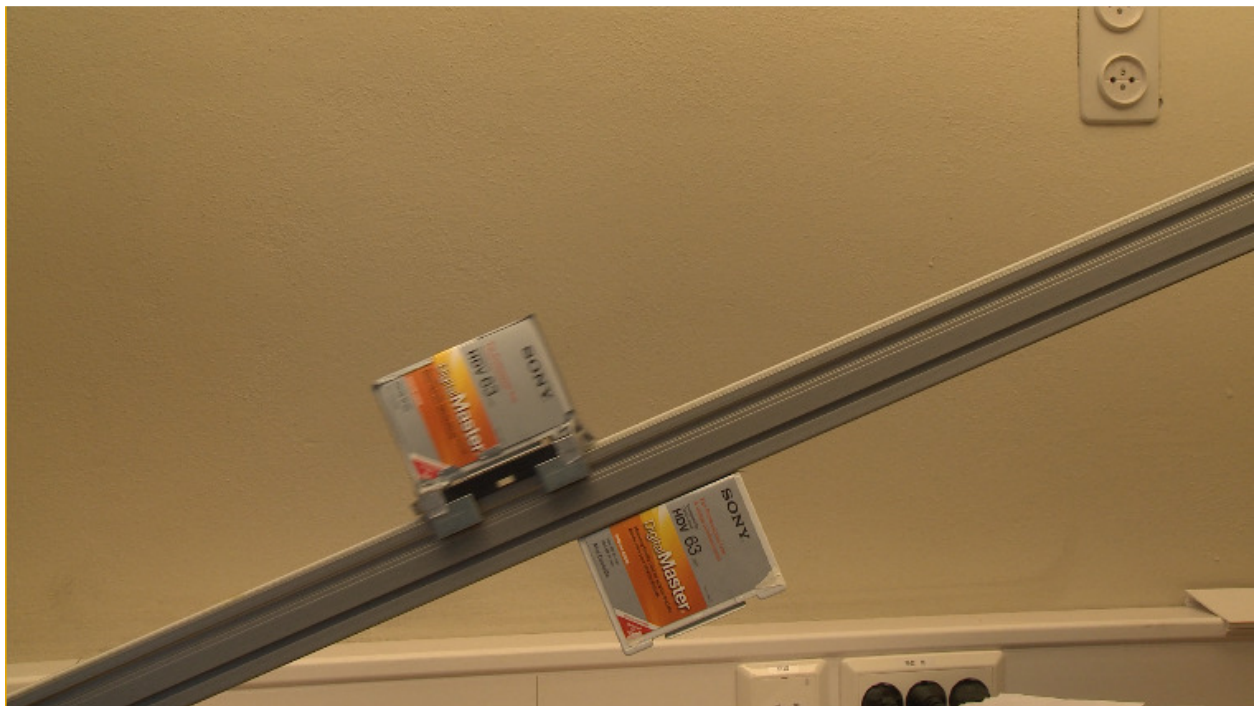


Figure 9-2: Scene from the video clips

From the results of the experiments it is clear that it is very important that the static objects are shown properly, as it was the static objects all participants noticed the biggest degradation in quality when resolution and drop patterns changed. For the background the participants mostly commented on a degraded quality when it was jumping as a cause of the changing between high and low quality frames. The dynamic object was usually perceived to have close to the same quality for many different drop patterns and resolutions, but this is likely because it had an image quality that was a bit lower than that of the static objects (as discussed in Chapter 7.2.1). The dynamic object is often an important part of the scene so the quality of it should be high.

Taking these thoughts into consideration the selected parameters for the different objects are:

- Background: 2:2 frame drop pattern at 1280x720 resolution
- Static objects: 1:2:1:2 frame drop pattern with a 960x540 resolution on the low quality frames
- Dynamic object: 1:2:1:2 frame drop pattern with a 1280x720 resolution on the low quality frames

The resulting bitrates would then be (from Table 9-4):

- Background: 885.92 Mbps
- Static objects: 1245.83 Mbps
- Dynamic object: 1439.62 Mbps

And the resulting video stream would have a bitrate of:

$$75\% * 885.92Mbps + 15\% * 1245.83Mbps + 10\% * 1439.62Mbps = 995.277Mbps$$

The total number of users allowed to the network would be $\frac{10900000Mbps}{995.277Mbps/user} = 10951 users$

while, from the results we have seen from the experiments, keeping the perceived quality very high.

By dividing the scene into objects as done above we can increase the number of users that can access the network stream from 5468 to 10951 which is an increase of 200.3%.

9.5 Eye tracking

In [41] the author explains that because of the eye's physical structure humans experience the external world with different levels of sharpness. The human vision's ability to focus is halved only 2 degrees away from the point of fixation. This property can be used so that only areas that are focused on are displayed with high quality, while unfocused areas can be displayed with reduced quality as you are unlikely to notice it anyway.

The project [41] concludes that if a background is out of focus, it can be displayed at low resolution without this being observed by the viewer. It also showed that about 90% of the time was used to look at only 7.3% of the total scene which further enhances the possibility to show large parts of the scene with low resolution.

For eye tracking to be usable in a DMP scenario it is important that the feedback from the user to the network is very fast. This is supported in DMP which has a guaranteed end-to-end network delay of less than 10-20 milliseconds (Chapter 1.1), and as we could see from the experiments when a change happens in 17 milliseconds (1:2:1:2 using 59.94 frames per second) it is very hard to notice.

Any exact numbers using eye tracking is hard to produce, but judging from the numbers above this technique should be able to save a large amount of bandwidth especially when combined with the other techniques discussed earlier.

10 Conclusion and recommendations

From the results in Chapter 9 some things are clear:

- Quality Shaping introduces good possibilities for saving bandwidth in a network and allows many more users to connect to the network or, when few users are simultaneously active they can obtain highest quality. A contract with the user could e.g. be: When a user pays a specified amount of money they shall experience a certain ‘quality – distribution’ over time guaranteeing a minimum quality.
- There is still a lot of work that needs to be done when it comes to spatial interpolation so that the image is not “jumping”. This project looked at four different interpolation techniques, but the shift in pixel position was evident in all of them. Edge correction has proven [6] to give good results, and can also be used to reduce the pixel artifacts.
- Some frame drop patterns give much better perceived quality than others. The network traffic behavior may force certain drop patterns, and an oscillation effect can happen when the network cannot stabilize itself. The different drop patterns that have been researched in this project can represent such oscillation patterns.
- Experiment 2 showed that a high bitrate does not always equal high perceived video quality. Intelligent combinations of resolution and frame drop patterns should be found and be used instead of just finding combinations that fulfill the bandwidth needs of the network.
- Combining the possibility to divide a scene into objects and sub-objects with the possibilities of eye tracking could possibly save large amount of network bandwidth while presenting video of very high perceived quality to all users of a network media stream.

The research on new fiber optic technologies and how to increase network bandwidth increases the maximum numbers of users that can connect to a network. As it is still unclear if the network bandwidth increases faster than the storage capacity of hard drives and the processing power of processors there is a large need for intelligent ways to reduce the network capacity needed by users connected to the network. This report has looked at the specific need of multimedia streaming, and shown that there are big advantages in using Quality Shaping.

This report shows that it is possible to save as much as 37.5% of total bandwidth by only alternating high and low resolution frames without it causing a noticeable reduction in perceived quality. The possibility of saving bandwidth is even larger when you can divide the scene into objects and sub-objects which is an important part of DMP.

Controlled dropping of packets in the network allows us to reduce the resolution of objects in a scene so the overall size of the media stream is reduced. Even with an increase in network capacity, intelligent use of the available resources will always be necessary. For this to happen in a controlled manner and to have a guarantee of the minimum quality of the video every user receives Quality Shaping is needed.

10.1 Further research

This has only been a preliminary study of the benefits of Quality Shaping when looking at time variable quality of scene objects. It has been conducted by me with the help of Professor Leif Arne Rønningen which has assisted both in the work and in evaluating the results. To get a better view of the perceived quality when using time variable quality of scene objects, a qualitative study should be performed when a solution is found to how one can vary between high and low quality images without experiencing the “jumping” that was so noticeable during my experiments. A good place to start would be to find a good way to use edge correction on video clips so that the edges are kept at high resolution throughout the video, research on this has been initiated by Erlend Heiberg and Leif Arne Rønningen in [6]. Using participants without any experience when it comes to assessing video quality should also be focused on as the largest part of users of a multimedia stream would, most likely, consist of “none experts”. Given a large enough number of participants, quantitative data should also be collected.

This work will continue to have importance as new technology is developed and new spatial and temporal resolutions become available.

If a study, using none experts, is to be conducted some changes have to be made to the method and procedure used in this project. Using participants that had some experience with testing like this allowed me to ignore many of the small error sources that would have been present if the material was to be evaluated by none experts.

Further research should also look at dividing a scene into objects and sub-objects to get more accurate data on the possibilities of saving bandwidth by doing this. My theoretical scenario shows that this method has great possibilities, but more research is needed.

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Appendix 1: Informasjon og samtykkeserklæring

Time-variable scene quality – perception tests

Jeg skriver en masteroppgave om hvordan vi oppfatter tidsvariabel kvalitet av objekter i en scene. Gjennom dette skjemaet vil du hjelpe meg å samle informasjon om hvordan variasjon av kvalitet over korte tidsintervaller blir oppfattet.

Oppgaven gjennomføres på instituttet for telematikk ved NTNU i samarbeid med professor Leif Arne Rønningen.

Prosjektet er basert på frivillig deltagelse, og du kan når som helst underveis trekke deg og be om at data samlet om deg blir slettet uten noen begrunnelse. Du er ikke pliktig til å gjennomføre forsøket, og en eventuell avbryting vil ikke få noen konsekvenser. Dataene som blir samlet inn vil bli behandlet konfidensielt, og kun undertegnede vil ha tilgang til dem. Eventuelle resultater fra undersøkelsen vil bli behandlet anonymt.

Undersøkelsen gjennomføres på Carusolaben ved instituttet for telematikk på NTNU og vil ta ca. en halv time. Før selve forsøkene begynner skal du, i tillegg til å svare på noen enkle spørsmål, og få se ett videoklipp for å gjøre deg vant til testmiljøet. Under forsøkene vil du få se en rekke videoklipp med varierende kvalitet, som du skal vurdere i forhold til et originalt videoklipp. En mer utfyllende muntlig forklaring får du før forsøket begynner.

Forskningen utføres i henhold til retningslinjer for action research som betyr at jeg vil være den som fyller ut spørreskjemaet, og jeg vil være med å diskutere dine synspunkter slik at jeg bedre kan forstå hva du synes. Jeg vil være tilgjengelig for spørsmål og kommentarer både før, under og etter gjennomføringen av forsøkene så hvis det er noe du lurer på underveis er det bare å spørre.

Håvard Berge

SAMTYKKEERKLÆRING

Prosjekt tittel: Time-variable scene quality – perception tests

Jeg har lest informasjonen og er villig til å delta i prosjektet.

.....

Sted

.....

Dato

.....

Underskrift

Appendix 2: Questionnaire

This questionnaire is divided into three parts. The first part should be completed before the experiments are carried out. Part 2 will be completed by me during the first experiment. Part 3 will be completed by me during the second experiment. During the entire process I will be available for questions if something should be unclear.

What is the size of the monitor you use the most when you watch TV (in inches)?

- < 28 28 32 37 40 42 46 50 56 56 < Don't know

Screen format:

(If you use both types approximately the same check both boxes)

- Normal (4:3) Widescreen Don't know

How far away from the TV are you usually sitting (in meters)?

- <1 1 – 2 3 – 4 4 – 5 5 <

Have you ever watched “High Definition” video material or broadcasts in HDTV format?

(If you do not know cross no)

- Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games using specialized glasses?

(If you do not know cross no)

- Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games without using specialized glasses?

(If you do not know cross no)

- Yes No

Part 2

After looking at the 1920x1080p video clip at 59.94 fps, evaluate the following clips using the video just shown as reference.

The scale given is 1 – 10 where 10 describes a video clip of excellent quality which is close to the quality of the reference clip and 1 is a clip with bad quality where the viewing experience is so severely degraded that it is unwatchable.

If you at any time during the testing process want to watch the reference clip again you can just ask. I will, via discussion, help evaluate the different video clips so that I better gain an understanding of your views. I will also at times during this test ask you to look for specifics in the video shown. This could e.g. be that I want you to focus on the background and evaluate that compared to the background on the reference clip. By doing this, learning will be a part of the experiment because I direct you to look for specific qualities in the video clip.

Clip 1

Video clip 1 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1:1:2:2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	Bad		Poor		Fair		Good		Excellent	
	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1:1:2:2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	Bad		Poor		Fair		Good		Excellent	
	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1:2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	Bad		Poor		Fair		Good		Excellent	
	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1:2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	Bad		Poor		Fair		Good		Excellent	
	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Part 3

This part of the experiment will evaluate the quality of video clips with approximately the same bitrate against each other. The clips will have varying frame drop patterns and different spatial resolution of their low quality frames.

The video clips chosen have a bitrate between 705Mbps and 810Mbps and we will try to find out if increased bitrate always increase the quality of the video clip, or if there are intelligent ways of combining frames that increases the quality, as the viewer experiences it, even when using a lower bitrate. All clips will be shown at 59.94 fps.

The scale in this experiment is -3 to 3 where 0 indicates same as the reference, a negative value indicates that the video clip is worse than the reference and a positive value indicates that it is better than the reference.

The reference video clip for this part is shown with a 1:2 frame drop pattern which showed to be the best combination during the first experiment with a quality drop of 55.56% which gives the low resolution frames for this video clip a resolution of 720p (1280x720).

Clip 1

Video clip 1 is shown with 75% reduction in spatial resolution 25% of the time using a cyclic 1:1:1:2 frame pattern (Three original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	Much worse	Worse	Slightly worse	The same	Slightly better	Better	Much better
	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown with 71.56% reduction in spatial resolution 33.33% of the time using a cyclic 1:1:2 frame pattern (Two original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	Much worse	Worse	Slightly worse	The same	Slightly better	Better	Much better
	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown with 43.75% reduction in spatial resolution 66.67% of the time using a cyclic 1:2:2 frame pattern (One original quality frame will be followed by two frames of lower quality and this will be repeated over and over)

	Much worse	Worse	Slightly worse	The same	Slightly better	Better	Much better
	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown with 30.56% reduction in spatial resolution 75% of the time using a cyclic 1:2:2:2 frame pattern (One original quality frame will be followed by three frames of lower quality and this will be repeated over and over)

	Much worse	Worse	Slightly worse	The same	Slightly better	Better	Much better
	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Appendix 3: Calculations

This appendix explains the calculations done in this project. Calculations for 29.97 fps video using the Uncompressed Microsoft AVI format and calculations for 59.94 fps using the Uncompressed Microsoft AVI format are included, and the last part of this appendix contains the formulas used for the calculations (all formulas are not included because of the length of some of them, but it shows how the most important parts have been calculated).

Because this was calculated using Microsoft Excel 2007, the formatting of the text in this document is not as good as it was using Excel, but for the purpose of including it in this appendix it should give a good enough overview. Because of the formatting, captions and table references are not included.

The Excel 2003 Worksheets can be found in “Digitale vedlegg” on DAIM.

Time-variable scene quality – perception tests

Uncompressed Microsoft AVI 21 seconds duration
 For 29.97 frames per
 second

Resolution	Exact size MB	MB per pixel
1920x1080	2,614.37	0.00126078 79
1600x900	1,815.71	0.00126091 23
1440x810	1,471.22	0.00126133 37
1280x720	1,162.86	0.00126177 99
1024x576	744.81	0.00126277 42
960x540	654.50	0.00126253 42
Average MB per pixel		0.00126168 70

Table 1: Size of 21 seconds video clip given by different resolutions and different frame patterns

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	2,616.23	2,616.23	2,616.23	2,616.23	2,616.23	2,616.23
1:1:1:1:1:2:1:1:1:1:2	16.67%	2,616.23	2,483.00	2,425.47	2,373.99	2,304.22	2,289.20
1:1:1:1:2:1:1:1:1:2	20.00%	2,616.23	2,456.35	2,387.31	2,325.54	2,241.82	2,223.80
1:1:1:2:1:1:1:2	25.00%	2,616.23	2,416.38	2,330.08	2,252.87	2,148.22	2,125.69
1:1:2:1:1:2	33.33%	2,616.23	2,349.77	2,234.70	2,131.75	1,992.21	1,962.18
1:2:1:2	50.00%	2,616.23	2,216.53	2,043.93	1,889.50	1,680.20	1,635.15
1:2:2:1:2:2	66.67%	2,616.23	2,083.30	1,853.17	1,647.26	1,368.19	1,308.12
1:2:2:2:1:2:2:2	75.00%	2,616.23	2,016.68	1,757.78	1,526.14	1,212.19	1,144.60
1:2:2:2:2:1:2:2:2:2	80.00%	2,616.23	1,976.71	1,700.55	1,453.46	1,118.59	1,046.49
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	2,616.23	1,950.06	1,662.40	1,405.01	1,056.18	981.09
2:2 (only frames of reduced quality)	100.00%	2,616.23	1,816.83	1,471.63	1,162.77	744.17	654.06

Time-variable scene quality – perception tests

Frame drop pattern is presented with 1 as a original frame with the highest resolution (1920x1080) and 2 represents frames with reduced resolution (the resolution is given in the table)

MBps 124.5825834
 Mbps 996.6606674334

Table 2: Bit rate of clip given by different resolutions and different frame patterns (in Mbps)

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	996.66	996.66	996.66	996.66	996.66	996.66
1:1:1:1:1:2:1:1:1:1:2	16.67%	996.66	945.90	923.99	904.38	877.80	847.18
1:1:1:1:2:1:1:1:1:2	20.00%	996.66	935.75	909.45	885.92	854.03	829.16
1:1:1:2:1:1:1:2	25.00%	996.66	920.53	887.65	858.24	818.37	789.79
1:1:2:1:1:2	33.33%	996.66	895.15	851.31	812.09	758.94	717.50
1:2:1:2	50.00%	996.66	844.39	778.64	719.81	640.08	591.29
1:2:2:1:2:2	66.67%	996.66	793.64	705.97	627.53	521.22	498.33
1:2:2:2:1:2:2:2	75.00%	996.66	768.26	669.63	581.39	461.79	436.04
1:2:2:2:2:1:2:2:2:2	80.00%	996.66	753.03	647.83	553.70	426.13	398.66
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	996.66	742.88	633.29	535.24	402.36	373.75
2:2 (only frames of reduced quality)	100.00%	996.66	692.13	560.62	442.96	283.49	249.17

From the paper 10.90 Tbps over 100 km
10,900,000 Mbps over 100 km
 With maximum resolution 10,936 user

Time-variable scene quality – perception tests

Table 3: Maximum numbers of users allowed by network stream without overload given by different resolutions and different frame patterns
(Rounding down)

	Resolution of low quality frames	1920x1080	1600x 900	1440x 810	1280x 720	1024x 576	960x5 40
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	10936	10936	10936	10936	10936	10936
1:1:1:1:1:2:1:1:1:1:2	16.67%	10936	11523	11796	12052	12417	12498
1:1:1:1:2:1:1:1:1:2	20.00%	10936	11648	11985	12303	12763	12866
1:1:1:2:1:1:1:2	25.00%	10936	11841	12279	12700	13319	13460
1:1:2:1:1:2	33.33%	10936	12176	12803	13422	14362	14582
1:2:1:2	50.00%	10936	12908	13998	15142	17029	17498
1:2:2:1:2:2	66.67%	10936	13734	15439	17369	20912	21873
1:2:2:2:1:2:2:2	75.00%	10936	14187	16277	18748	23604	24997
1:2:2:2:2:1:2:2:2:2	80.00%	10936	14474	16825	19685	25579	27341
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	10936	14672	17211	20364	27090	29164
2:2 (only frames of reduced quality)	100.00%	10936	15748	19442	24607	38448	43746

Table 4: Additional number of users allowed by network stream without overload given by different resolutions and different frame patterns

	Resolution of low quality frames	1920x1080	1600x 900	1440x 810	1280x 720	1024x 576	960x5 40
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	0	0	0	0	0	0
1:1:1:1:1:2:1:1:1:1:2	16.67%	0	587	860	1116	1481	1562
1:1:1:1:2:1:1:1:1:2	20.00%	0	712	1049	1367	1827	1930
1:1:1:2:1:1:1:2	25.00%	0	905	1343	1764	2383	2524
1:1:2:1:1:2	33.33%	0	1240	1867	2486	3426	3646
1:2:1:2	50.00%	0	1972	3062	4206	6093	6562
1:2:2:1:2:2	66.67%	0	2798	4503	6433	9976	10937
1:2:2:2:1:2:2:2	75.00%	0	3251	5341	7812	12668	14061
1:2:2:2:2:1:2:2:2:2	80.00%	0	3538	5889	8749	14643	16405
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	0	3736	6275	9428	16154	18228

Time-variable scene quality – perception tests

2:2 (only frames of reduced quality)	100.00%	0	4812	8506	13671	27512	3281 0
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This can be used to find how much bandwidth you can save on a scene, by looking at how many % of the scene consists of the background, dynamic objects and static objects. E.g. If the background is 60% of the scene, by testing we can say that 1280x720 with 100% drop works best for the background. This can be used to find the totale bitrate, it will consist of 60% of 885.92 Mbps (from table 2)

If the static objects is 25% of the scene and uses 1600x900 with 50% drop and dynamic object is 15% of the scene and uses 1920x1080 with 0% drop, this can be used to find an example of the total bitrate of the scene:

Background	442.96
Static objects	844.39
Dynamic object	996.66
Total bitrate for this example	626.3735445

Total number of users in the network	17401
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Which is	6465	More users than the original video stream
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Table 5: Percentage decrease in bit rate compared to original video stream

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	0.00%	5.09%	7.29%	9.26%	11.93%	12.50%
1:1:1:1:2:1:1:1:1:2	20.00%	0.00%	6.11%	8.75%	11.11%	14.31%	15.00%
1:1:1:2:1:1:1:2	25.00%	0.00%	7.64%	10.94%	13.89%	17.89%	18.75%
1:1:2:1:1:2	33.33%	0.00%	10.19%	14.58%	18.52%	23.85%	25.00%
1:2:1:2	50.00%	0.00%	15.28%	21.88%	27.78%	35.78%	37.50%
1:2:2:1:2:2	66.67%	0.00%	20.37%	29.17%	37.04%	47.70%	50.00%
1:2:2:2:1:2:2:2	75.00%	0.00%	22.92%	32.81%	41.67%	53.67%	56.25%

Time-variable scene quality – perception tests

			%	%	%	%	%
1:2:2:2:2:1:2:2:2:2	80.00%	0.00%	24.44 %	35.00 %	44.44 %	57.24 %	60.00 %
1:2:2:2:2:2:1:2:2:2:2	83.33%	0.00%	25.46 %	36.46 %	46.30 %	59.63 %	62.50 %
2:2 (only frames of reduced quality)	100.00%	0.00%	30.56 %	43.75 %	55.56 %	71.56 %	75.00 %

Uncompressed Microsoft AVI 21 seconds duration
For 59.94 frames per second

Resolution	Exact size MB	MB per pixel
1920x1080	5,228.74	0.00252157 57
1600x900	3,631.43	0.00252182 46
1440x810	2,942.44	0.00252266 74
1280x720	2,325.71	0.00252355 99
1024x576	1,489.63	0.00252554 84
960x540	1,309.00	0.00252506 84
Average MB per pixel		0.00252337 41

Table 1: Size of 21 seconds video clip given by different resolutions and different frame patterns

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	5,232.47	5,232.47	5,232.47	5,232.47	5,232.47	5,232.47
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	5,232.47	4,966.00	4,850.93	4,747.98	4,608.45	4,578.41
1:1:1:1:2:1:1:1:1:2	20.00%	5,232.47	4,912.71	4,774.63	4,651.08	4,483.64	4,447.60
1:1:1:2:1:1:1:2	25.00%	5,232.47	4,832.77	4,660.17	4,505.74	4,296.44	4,251.38
1:1:2:1:1:2	33.33%	5,232.47	4,699.53	4,469.40	4,263.49	3,984.43	3,924.35
1:2:1:2	50.00%	5,232.47	4,433.06	4,087.87	3,779.01	3,360.41	3,270.29
1:2:2:1:2:2	66.67%	5,232.47	4,166.60	3,706.33	3,294.52	2,736.39	2,616.23

Time-variable scene quality – perception tests

1:2:2:2:1:2:2:2	75.00%	5,232.47	4,033. 36	3,515. 56	3,052. 27	2,424. 38	2,289 .20
1:2:2:2:2:1:2:2:2:2	80.00%	5,232.47	3,953. 42	3,401. 10	2,906. 93	2,237. 17	2,092 .99
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	5,232.47	3,900. 13	3,324. 80	2,810. 03	2,112. 37	1,962 .18
2:2 (only frames of reduced quality)	100.00%	5,232.47	3,633. 66	2,943. 26	2,325. 54	1,488. 35	1,308 .12

Frame drop pattern is presented with 1 as a original frame with the highest resolution (1920x1080) and 2 represents frames with reduced resolution (the resolution is given in the table)

MBps 249.1651669
Mbps 1,993.3213348668

Table 2: Bit rate of clip given by different resolutions and different frame patterns (in Mbps)

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	1,993.32	1,993. 32	1,993. 32	1,993. 32	1,993. 32	1,993 .32
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	1,993.32	1,891. 81	1,847. 97	1,808. 75	1,755. 60	1,744 .16
1:1:1:1:2:1:1:1:1:2	20.00%	1,993.32	1,871. 51	1,818. 91	1,771. 84	1,708. 05	1,694 .32
1:1:1:2:1:1:1:2	25.00%	1,993.32	1,841. 05	1,775. 30	1,716. 47	1,636. 74	1,619 .57
1:1:2:1:1:2	33.33%	1,993.32	1,790. 30	1,702. 63	1,624. 19	1,517. 88	1,494 .99
1:2:1:2	50.00%	1,993.32	1,688. 79	1,557. 28	1,439. 62	1,280. 16	1,245 .83
1:2:2:1:2:2	66.67%	1,993.32	1,587. 27	1,411. 94	1,255. 05	1,042. 43	996.6 6
1:2:2:2:1:2:2:2	75.00%	1,993.32	1,536. 52	1,339. 26	1,162. 77	923.5 7	872.0 8
1:2:2:2:2:1:2:2:2:2	80.00%	1,993.32	1,506. 07	1,295. 66	1,107. 40	852.2 6	797.3 3
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	1,993.32	1,485. 76	1,266. 59	1,070. 49	804.7 1	747.5 0
2:2 (only frames of reduced quality)	100.00%	1,993.32	1,384. 25	1,121. 24	885.9 2	566.9 9	498.3 3

Time-variable scene quality – perception tests

From the paper 10.90 Tbps over 100 km
 10,900,000 Mbps over 100 km
 With maximum resolution 5,468 user

Table 3: Maximum numbers of users allowed by network stream without overload given by different resolutions and different frame patterns (Rounding down)

	Resolution of low quality frames	1920x1080	1600x 900	1440x 810	1280x 720	1024x 576	960x 540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	5468	5468	5468	5468	5468	5468
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	5468	5761	5898	6026	6208	6249
1:1:1:1:2:1:1:1:1:2	20.00%	5468	5824	5992	6151	6381	6433
1:1:1:2:1:1:1:2	25.00%	5468	5920	6139	6350	6659	6730
1:1:2:1:1:2	33.33%	5468	6088	6401	6711	7181	7291
1:2:1:2	50.00%	5468	6454	6999	7571	8514	8749
1:2:2:1:2:2	66.67%	5468	6867	7719	8684	10456	10936
1:2:2:2:1:2:2:2	75.00%	5468	7093	8138	9374	11802	12498
1:2:2:2:2:1:2:2:2:2	80.00%	5468	7237	8412	9842	12789	13670
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	5468	7336	8605	10182	13545	14582
2:2 (only frames of reduced quality)	100.00%	5468	7874	9721	12303	19224	21873

Table 4: Additional number of users allowed by network stream without overload given by different resolutions and different frame patterns

	Resolution of low quality frames	1920x1080	1600x 900	1440x 810	1280x 720	1024x 576	960x 540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	0	0	0	0	0	0
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	0	293	430	558	740	781
1:1:1:1:2:1:1:1:1:2	20.00%	0	356	524	683	913	965
1:1:1:2:1:1:1:2	25.00%	0	452	671	882	1191	1262
1:1:2:1:1:2	33.33%	0	620	933	1243	1713	1823
1:2:1:2	50.00%	0	986	1531	2103	3046	3281
1:2:2:1:2:2	66.67%	0	1399	2251	3216	4988	5468
1:2:2:2:1:2:2:2	75.00%	0	1625	2670	3906	6334	7030
1:2:2:2:2:1:2:2:2:2	80.00%	0	1769	2944	4374	7321	8202
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	0	1868	3137	4714	8077	9114
2:2 (only frames of reduced quality)	100.00%	0	2406	4253	6835	13756	16405

Time-variable scene quality – perception tests

This can be used to find how much bandwidth you can save on a scene, by looking at how many % of the scene consists of the background, dynamic objects and static objects. E.g. If the background is 60% of the scene, by testing we can say that 1280x720 with 100% drop works best for the background. This can be used to find the totale bitrate, it will consist of 60% of 885.92 Mbps (from table 2)

If the static objects is 25% of the scene and uses 1600x900 with 50% drop and dynamic object is 15% of the scene and uses 1920x1080 with 0% drop, this can be used to find an example of the total bitrate of the scene:

Background	885.92
Static objects	1,688.79
Dynamic object	1,993.32
Total bitrate for this example	1252.747089

Total number of users in the network	8700
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Which is	3232	More users than the original video stream
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Table 5: Percentage decrease in bit rate compared to original video stream

	Resolution of low quality frames	1920x1080	1600x900	1440x810	1280x720	1024x576	960x540
Frame pattern	% of frames dropped						
1:1 (only original frames)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1:1:1:1:1:2:1:1:1:1:1:2	16.67%	0.00%	5.09%	7.29%	9.26%	11.93%	12.50%
1:1:1:1:2:1:1:1:1:2	20.00%	0.00%	6.11%	8.75%	11.11%	14.31%	15.00%
1:1:1:2:1:1:1:1:2	25.00%	0.00%	7.64%	10.94%	13.89%	17.89%	18.75%
1:1:2:1:1:2	33.33%	0.00%	10.19%	14.58%	18.52%	23.85%	25.00%
1:2:1:2	50.00%	0.00%	15.28%	21.88%	27.78%	35.78%	37.50%
1:2:2:1:2:2	66.67%	0.00%	20.37%	29.17%	37.04%	47.70%	50.00%
1:2:2:2:1:2:2:2	75.00%	0.00%	22.92%	32.81%	41.67%	53.67%	56.25%
1:2:2:2:2:1:2:2:2:2	80.00%	0.00%	24.44%	35.00%	44.44%	57.24%	60.00%
1:2:2:2:2:2:1:2:2:2:2:2	83.33%	0.00%	25.46%	36.46%	46.30%	59.63%	62.50%
2:2 (only frames of reduced quality)	100.00%	0.00%	30.56%	43.75%	55.56%	71.56%	75.00%

Time-variable scene quality – perception tests

The following is meant to give information about how the values on the previous pages were calculated. Because of the size of these tables every column is not included

Uncompressed Microsoft AVI 21 seconds duration
For 29.97 frames per second

Resolution	Exact size MB	MB per pixel
1920x1080	=2614369704/1000/1000	=B9/(1920*1080)
1600x900	=1815713736/1000/1000	=B10/(1600*900)
1440x810	=1471219654/1000/1000	=B11/(1440*810)
1280x720	=1162856392/1000/1000	=B12/(1280*720)
1024x576	=744814536/1000/1000	=B13/(1024*576)
960x540	=654497734/1000/1000	=B14/(960*540)
Average MB per pixel		=SUM(C9:C14)/6

Table 1: Size of 21 seconds video clip given by different resolutions and different frame patterns

	Resolution of low quality frames	1920x1080	1600x900
Frame pattern	% of frames dropped		
1:1 (only original frames)	0	=(1920*1080)*\$C\$15	=(1920*1080)*\$C\$15
1:1:1:1:1:2:1:1:1:1:1:2	=1/6	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B23)+D\$32*\$B23
1:1:1:1:2:1:1:1:1:2	=1/5	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B24)+D\$32*\$B24
1:1:1:2:1:1:1:2	=1/4	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B25)+D\$32*\$B25
1:1:2:1:1:2	=1/3	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B26)+D\$32*\$B26
1:2:1:2	=1/2	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B27)+D\$32*\$B27
1:2:2:1:2:2	=2/3	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B28)+D\$32*\$B28
1:2:2:2:1:2:2:2	=3/4	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B29)+D\$32*\$B29
1:2:2:2:2:1:2:2:2:2	=4/5	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B30)+D\$32*\$B30
1:2:2:2:2:2:1:2:2:2:2:2	=5/6	=(1920*1080)*\$C\$15	=(\$C\$22*(1-\$B31)+D\$32*\$B31
2:2 (only frames of reduced quality)	=1/1	=(1920*1080)*\$C\$15	=(1600*900)*\$C\$15

Frame drop pattern is presented with 1 as a original frame with the highest resolution (1920x1080) and 2 represents frames with reduced resolution (the resolution is given in the table)

Time-variable scene quality – perception tests

MBps = $(D22/21)$
 Mbps = $B40*8$

Table 2: Bit rate of clip given by different resolutions and different frame patterns (in Mbps)

	Resolution of low quality frames	1920x1080	1600x900
Frame pattern	% of frames dropped		
1:1 (only original frames)	0	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(1920*1080)*\$C\$15}{21*8}$
1:1:1:1:1:2:1:1:1:1:1:2	=1/6	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B48)+D\$32*\$B48)}{21*8}$
1:1:1:1:2:1:1:1:1:2	=1/5	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B49)+D\$32*\$B49)}{21*8}$
1:1:1:2:1:1:1:2	=1/4	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B50)+D\$32*\$B50)}{21*8}$
1:1:2:1:1:2	=1/3	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B51)+D\$32*\$B51)}{21*8}$
1:2:1:2	=1/2	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B52)+D\$32*\$B52)}{21*8}$
1:2:2:1:2:2	=2/3	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B53)+D\$32*\$B53)}{21*8}$
1:2:2:2:1:2:2:2	=3/4	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B54)+D\$32*\$B54)}{21*8}$
1:2:2:2:2:1:2:2:2:2	=4/5	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B55)+D\$32*\$B55)}{21*8}$
1:2:2:2:2:2:1:2:2:2:2:2	=5/6	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B56)+D\$32*\$B56)}{21*8}$
2:2 (only frames of reduced quality)	=1/1	$=\frac{(1920*1080)*\$C\$15}{21*8}$	$=\frac{(\$C\$22*(1-\$B57)+D\$32*\$B57)}{21*8}$

From the paper 10.9 Tbps over 100 km
 = $B59*1000*1000$ Mbps over 100 km
 = $\text{ROUNDDOWN}(B60/B41,$
 With maximum resolution 0) user

Table 3: Maximum numbers of users allowed by network stream without overload given by different resolutions and different frame patterns (Rounding down)

	Resolution of low quality frames	1920x1080	1600x900
Frame pattern	% of frames dropped		
1:1 (only original frames)	0	$=\text{ROUNDDOWN}(\$B\$60/C47,0)$	$=\text{ROUNDDOWN}(\$B\$60/D47,0)$
1:1:1:1:1:2:1:1:1:1:1:2	=1/6	$=\text{ROUNDDOWN}(\$B\$60/C48,0)$	$=\text{ROUNDDOWN}(\$B\$60/D48,0)$
1:1:1:1:2:1:1:1:1:2	=1/5	$=\text{ROUNDDOWN}(\$B\$60/C49,0)$	$=\text{ROUNDDOWN}(\$B\$60/D49,0)$
1:1:1:2:1:1:1:2	=1/4	$=\text{ROUNDDOWN}(\$B\$60/C50,0)$	$=\text{ROUNDDOWN}(\$B\$60/D50,0)$
1:1:2:1:1:2	=1/3	$=\text{ROUNDDOWN}(\$B\$60/C51,0)$	$=\text{ROUNDDOWN}(\$B\$60/D51,0)$

Time-variable scene quality – perception tests

		/C51,0)	0)
1:2:1:2	=1/2	=ROUNDDOWN(\$B\$60 /C52,0)	=ROUNDDOWN(\$B\$60/D52,0)
1:2:2:1:2:2	=2/3	=ROUNDDOWN(\$B\$60 /C53,0)	=ROUNDDOWN(\$B\$60/D53,0)
1:2:2:2:1:2:2:2	=3/4	=ROUNDDOWN(\$B\$60 /C54,0)	=ROUNDDOWN(\$B\$60/D54,0)
1:2:2:2:2:1:2:2:2:2	=4/5	=ROUNDDOWN(\$B\$60 /C55,0)	=ROUNDDOWN(\$B\$60/D55,0)
1:2:2:2:2:2:1:2:2:2:2:2	=5/6	=ROUNDDOWN(\$B\$60 /C56,0)	=ROUNDDOWN(\$B\$60/D56,0)
2:2 (only frames of reduced quality)	=1/1	=ROUNDDOWN(\$B\$60 /C57,0)	=ROUNDDOWN(\$B\$60/D57,0)

Table 4: Additional number of users allowed by network stream without overload given by different resolutions and different frame patterns

	Resolution of low quality frames	1920x1080	1600x900
Frame pattern	% of frames dropped		
1:1 (only original frames)	0	=C67-\$C\$67	=D67-\$C\$67
1:1:1:1:1:2:1:1:1:1:1:2	=1/6	=C68-\$C\$67	=D68-\$C\$67
1:1:1:1:2:1:1:1:1:2	=1/5	=C69-\$C\$67	=D69-\$C\$67
1:1:1:2:1:1:1:2	=1/4	=C70-\$C\$67	=D70-\$C\$67
1:1:2:1:1:2	=1/3	=C71-\$C\$67	=D71-\$C\$67
1:2:1:2	=1/2	=C72-\$C\$67	=D72-\$C\$67
1:2:2:1:2:2	=2/3	=C73-\$C\$67	=D73-\$C\$67
1:2:2:2:1:2:2:2	=3/4	=C74-\$C\$67	=D74-\$C\$67
1:2:2:2:2:1:2:2:2:2	=4/5	=C75-\$C\$67	=D75-\$C\$67
1:2:2:2:2:2:1:2:2:2:2:2	=5/6	=C76-\$C\$67	=D76-\$C\$67
2:2 (only frames of reduced quality)	=1/1	=C77-\$C\$67	=D77-\$C\$67

This can be used to find how much bandwidth you can save on a scene, by looking at how many % of the scene consists of the background, dynamic objects and static objects. E.g. If the background is 60% of the scene, by testing we can say that 1280x720 with 100% drop works best for the background. This can be used to find the totale bitrate, it will consist of 60% of 885.92 Mbps (from table 2)

If the static objects is 25% of the scene and uses 1600x900 with 50% drop and dynamic object is 15% of the scene and uses 1920x1080 with 0% drop, this can be used to find an example of the total bitrate of the scene:

Background =F57
 Static objects =D52
 Dynamic object =C47
 Total bitrate for this example =0.6*B103+0.25*B104+0.15*B105

Time-variable scene quality – perception tests

Total number of users in the network = $\text{=ROUND}\text{DOWN}(\text{B60}/\text{B10},0)$

Which is = $\text{B108}-\text{C67}$ More users than the original video stream

Table 5: Percentage decrease in bit rate compared to original video stream

	Resolution of low quality frames	1920x1080	1600x900
Frame pattern	% of frames dropped		
1:1 (only original frames)	0	= $\text{1-C47}/\text{\$C\$47}$	= $\text{1-D47}/\text{\$C\$47}$
1:1:1:1:1:2:1:1:1:1:1:2	= $\text{1}/\text{6}$	= $\text{1-C48}/\text{\$C\$47}$	= $\text{1-D48}/\text{\$C\$47}$
1:1:1:1:2:1:1:1:1:2	= $\text{1}/\text{5}$	= $\text{1-C49}/\text{\$C\$47}$	= $\text{1-D49}/\text{\$C\$47}$
1:1:1:2:1:1:1:2	= $\text{1}/\text{4}$	= $\text{1-C50}/\text{\$C\$47}$	= $\text{1-D50}/\text{\$C\$47}$
1:1:2:1:1:2	= $\text{1}/\text{3}$	= $\text{1-C51}/\text{\$C\$47}$	= $\text{1-D51}/\text{\$C\$47}$
1:2:1:2	= $\text{1}/\text{2}$	= $\text{1-C52}/\text{\$C\$47}$	= $\text{1-D52}/\text{\$C\$47}$
1:2:2:1:2:2	= $\text{2}/\text{3}$	= $\text{1-C53}/\text{\$C\$47}$	= $\text{1-D53}/\text{\$C\$47}$
1:2:2:2:1:2:2:2	= $\text{3}/\text{4}$	= $\text{1-C54}/\text{\$C\$47}$	= $\text{1-D54}/\text{\$C\$47}$
1:2:2:2:2:1:2:2:2:2	= $\text{4}/\text{5}$	= $\text{1-C55}/\text{\$C\$47}$	= $\text{1-D55}/\text{\$C\$47}$
1:2:2:2:2:2:1:2:2:2:2:2	= $\text{5}/\text{6}$	= $\text{1-C56}/\text{\$C\$47}$	= $\text{1-D56}/\text{\$C\$47}$
2:2 (only frames of reduced quality)	= $\text{1}/\text{1}$	= $\text{1-C57}/\text{\$C\$47}$	= $\text{1-D57}/\text{\$C\$47}$

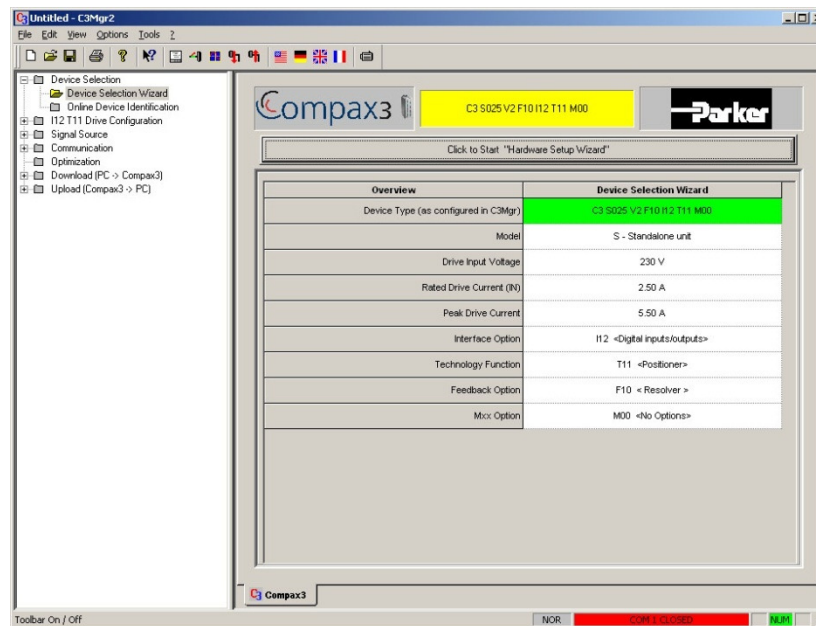
Appendix 4: The C3 ServoManager 2 Software

This appendix is a step-by-step guide to setting up the C3 ServoManager 2 that is used to controlling the motion of the linear actuator. The software has a lot of settings that adjust the motion of the actuator that can be hard to understand for someone that does not have good knowledge about motors and servos.

This is only a guide to the setup used in my own project work, and adjustments may have to be made for realizing other motions in other projects. The settings used can be stored in configuration files, and my settings can be found in the C:\Documents and Settings\bruker\Virker.C3P file on the computer connected to the linear actuator on the Caruso lab. This configuration can be accessed by clicking File → Open in the menu of the software.

Step 1: Getting Started

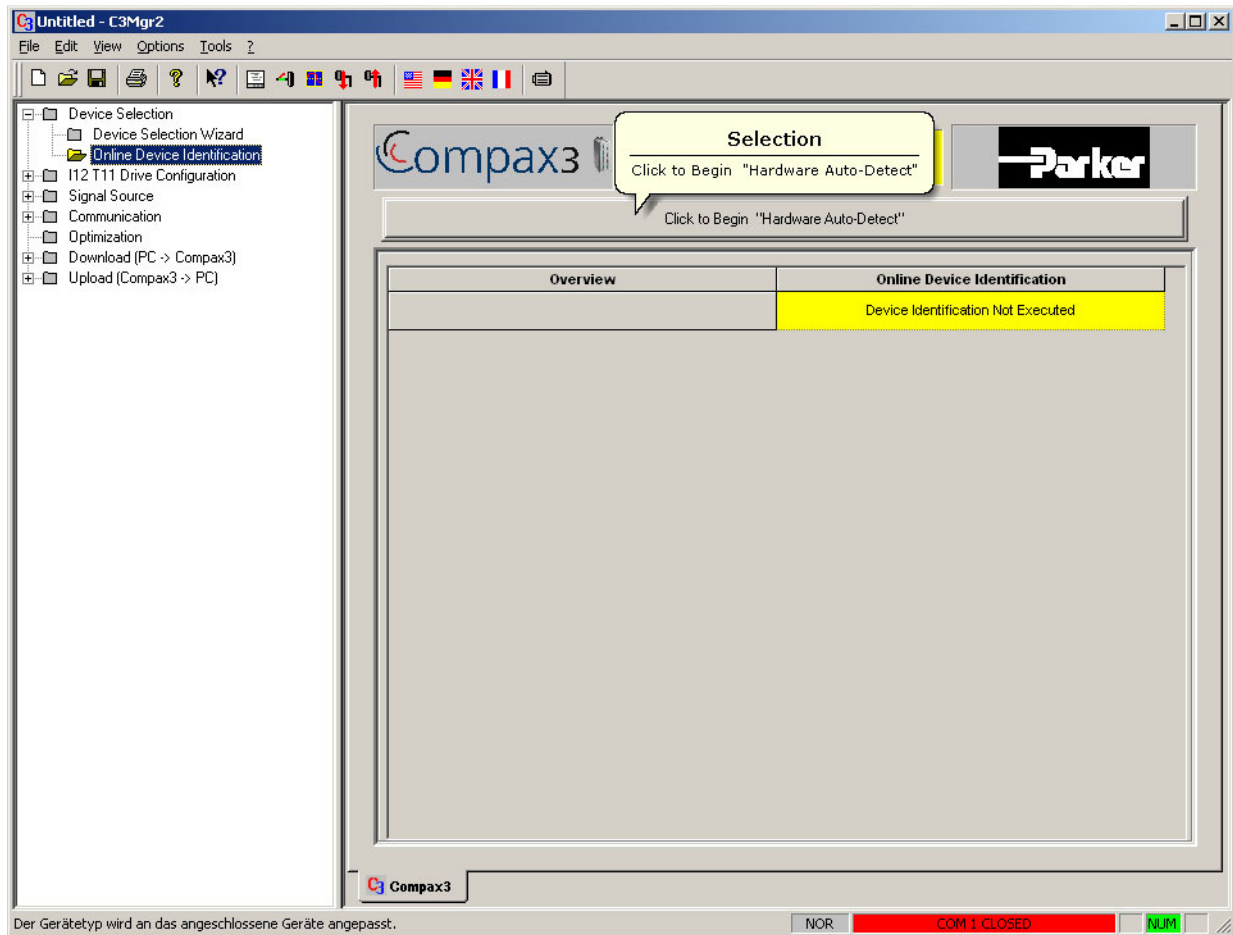
First off you have to locate the C3 ServoManger 2 software on your computer. For the purpose of this lab, it is already installed on the computer connected to the linear actuator and a shortcut can be found on the Desktop. When starting the software you will get a screen looking like this.



Appendix 4 Figure 1: C3 ServoManager 2 startup window

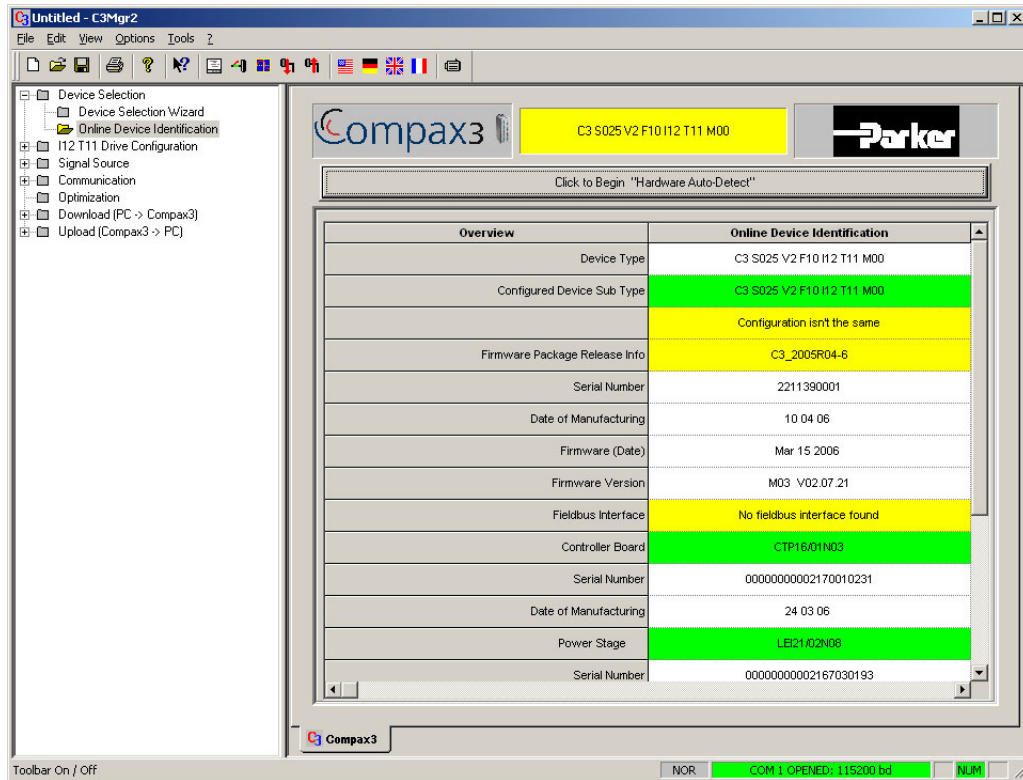
Step 2: Identifying the device

The software can auto-detect the connected device, this is done by clicking ‘Online Device Identification’ in the menu on the left and then clicking ‘Click to Begin “Hardware Auto-Detect”’ on the right side of the screen.



Appendix 4 Figure 2: Online Device Identification

After the auto detect is done you should see a screen looking like Figure 3.



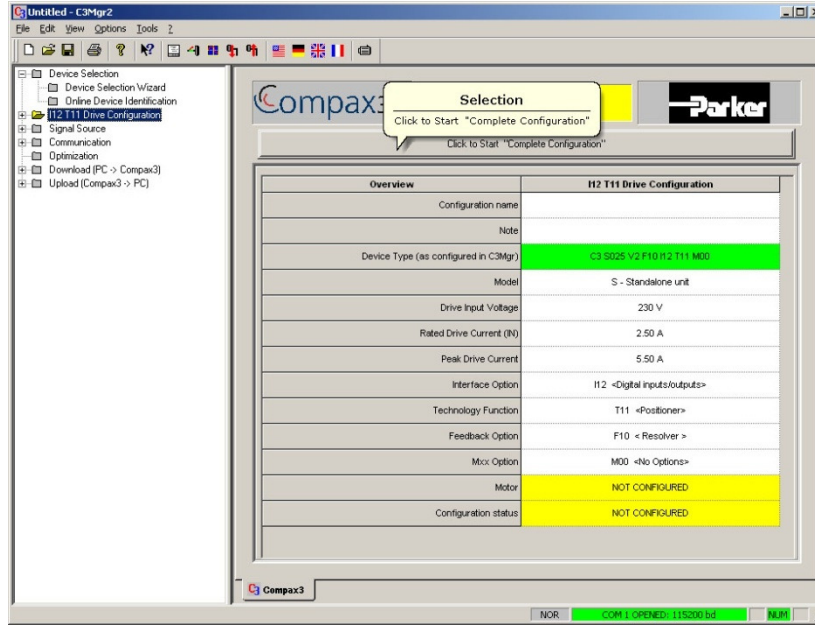
Appendix 4 Figure 3: Auto Detection completed

If you get any error messages at this stage, control that you have connected the power supply, and that it is turned on.

Step 3: Completing Configuration

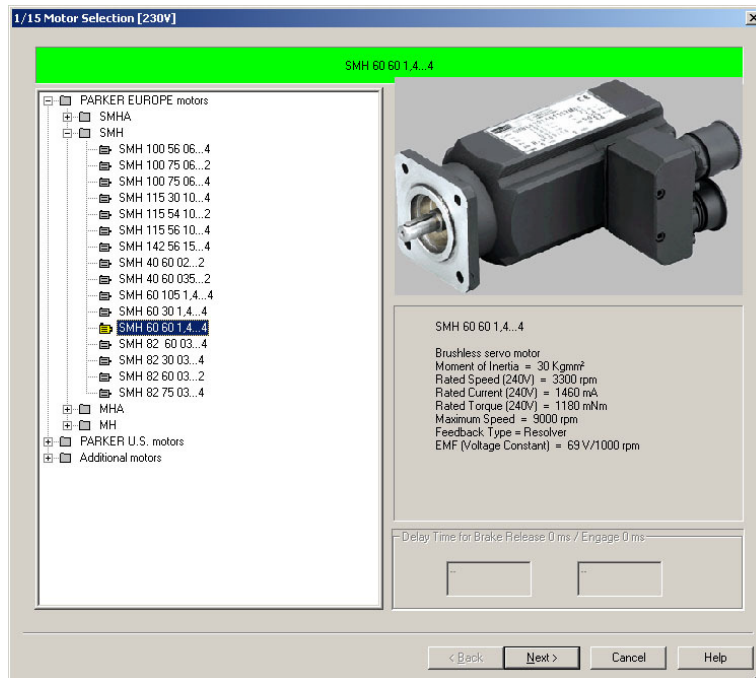
Now it is time to configure the device so that it behaves the way we want it too. I will not explain every setting in detail, but I will quickly go through the most important ones.

To access the configuration settings, click 'I12 T11 Drive Configuration' in the menu on the left and then click 'Click to Start "Complete Configuration"' on the right.



Appendix 4 Figure 4: Complete Configuration

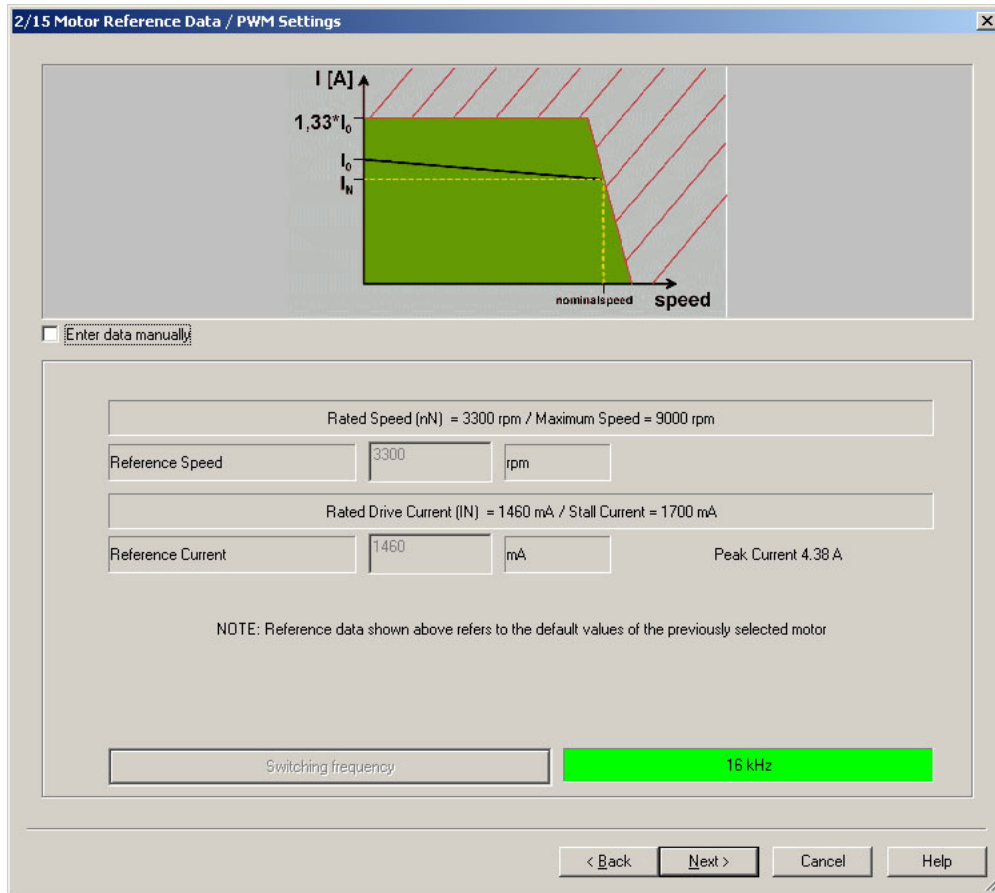
A window should now open that looks like Figure 5



Appendix 4 Figure 5: Monitor Selection

Click your way and select the ‘SMH 60 60 1,4...4’ motor under ‘PARKER EUROPE motors’ → ‘SMH’. After the correct motor is selected, click ‘Next’.

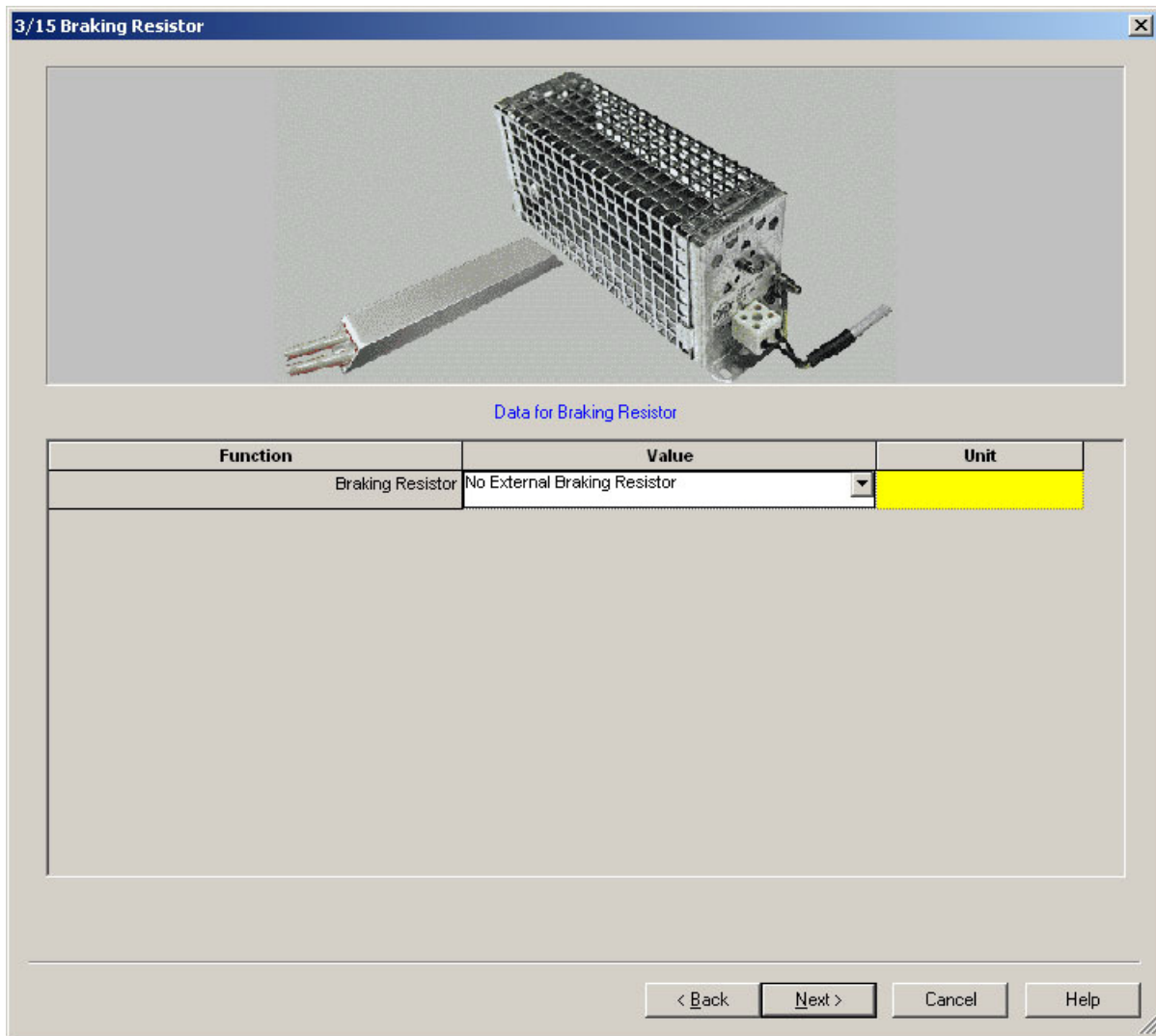
The next window we leave with its default settings, it should look like Figure 6 below. If the box for ‘Enter data manually’ is ticked then click it off.



Appendix 4 Figure 6: Motor Reference Data / PWM Settings

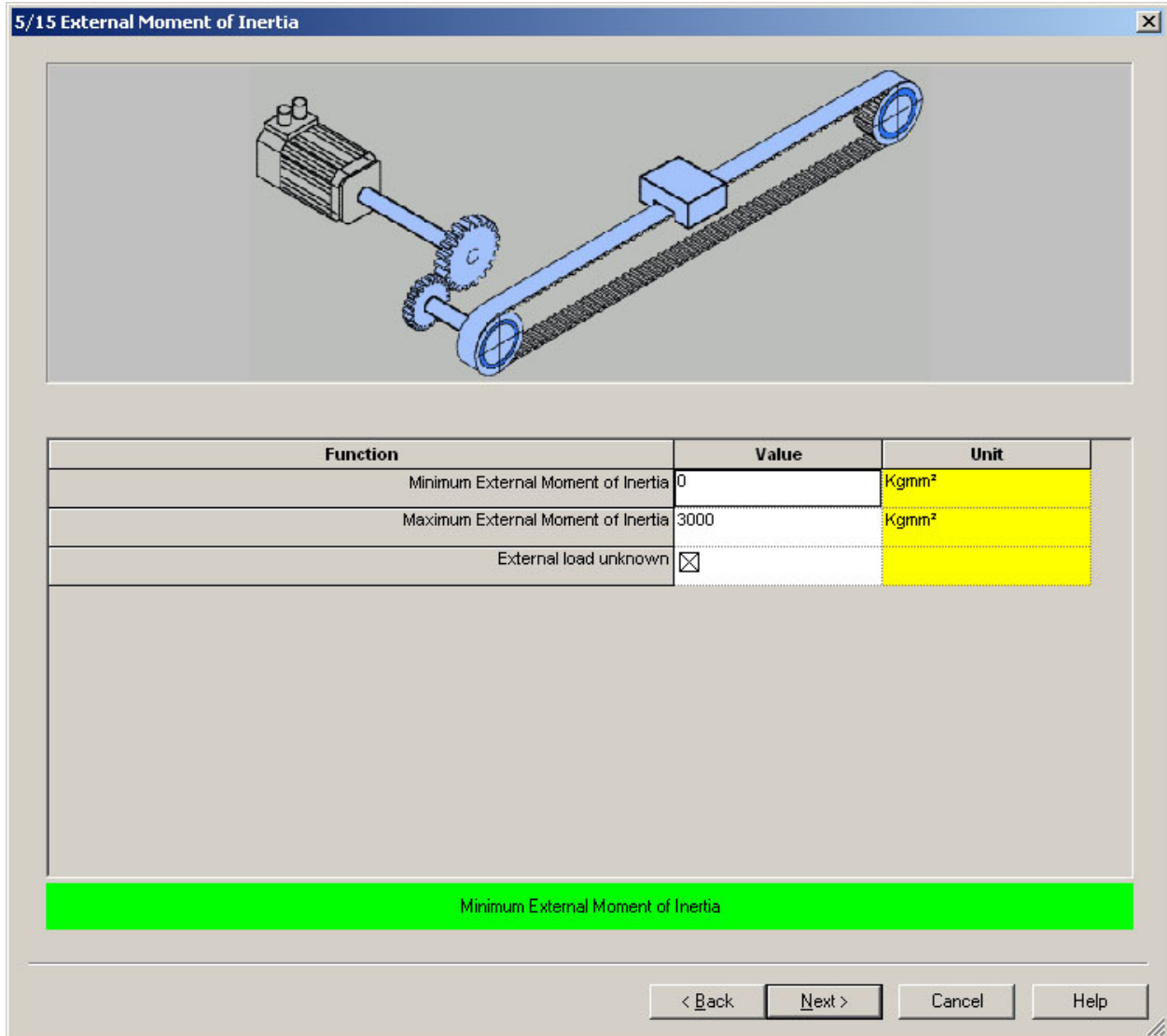
After this is done click the ‘Next’ button.

The next page should also be left unchanged, but check that the ‘Braking Resistor’ is set to ‘No External Braking Resistor’ and click the ‘Next’ button again.



Appendix 4 Figure 7: Braking Resistor

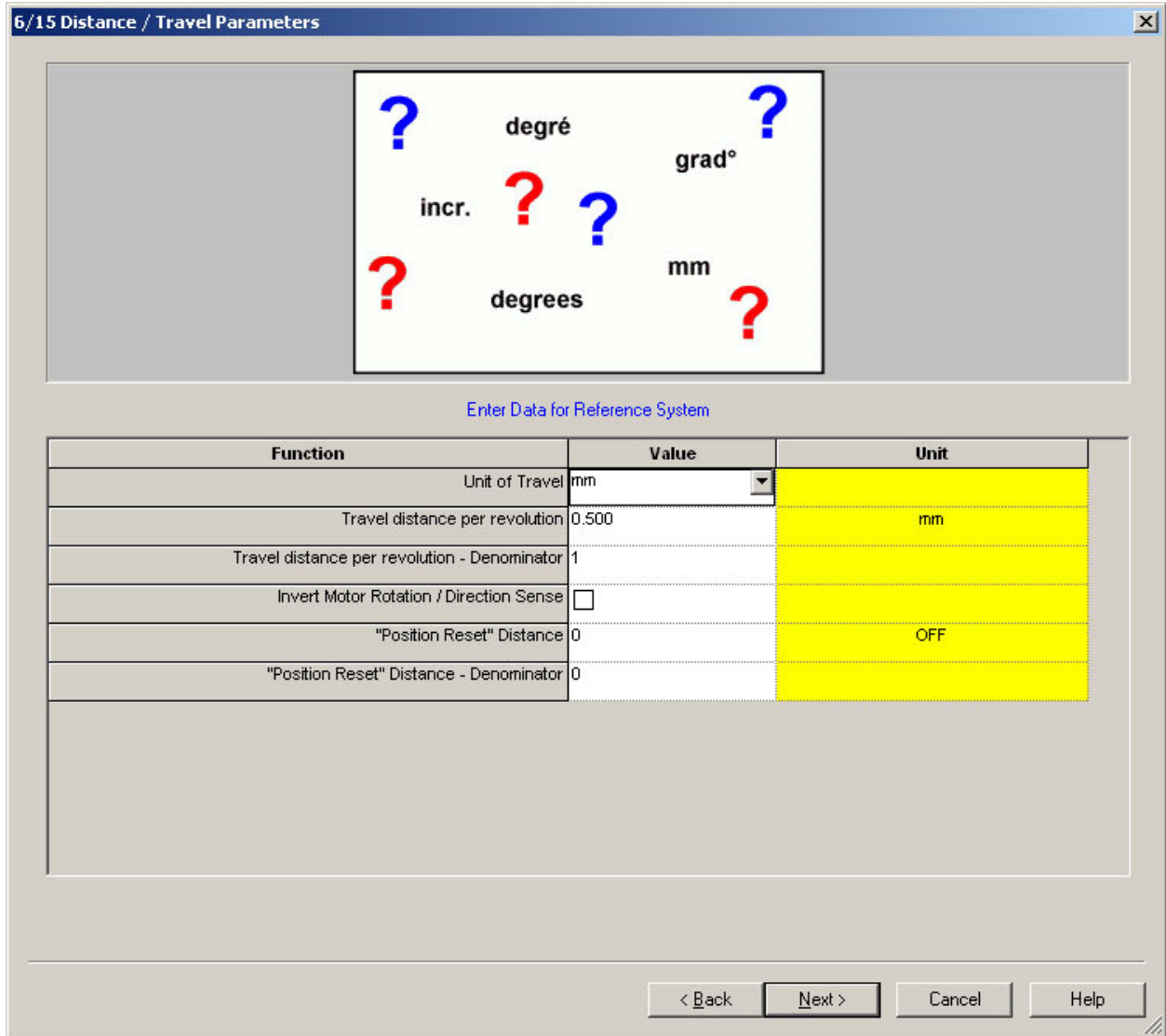
In the next window change the maximum according to the maximum load that will be on the system, the more accurate the value, the more accurate the stability and the behavior of the motion. This value does not need to be exact, but it should be higher than zero. I used 3000 Kgmm^2 , which is a value that will never be used, but the motion accuracy did not seem to change with a lower value so I left it at that and no further testing was done.



Appendix 4 Figure 8: External Moment of Inertia

After the ‘Maximum External Moment of Inertia’ is set click the ‘Next’ button.

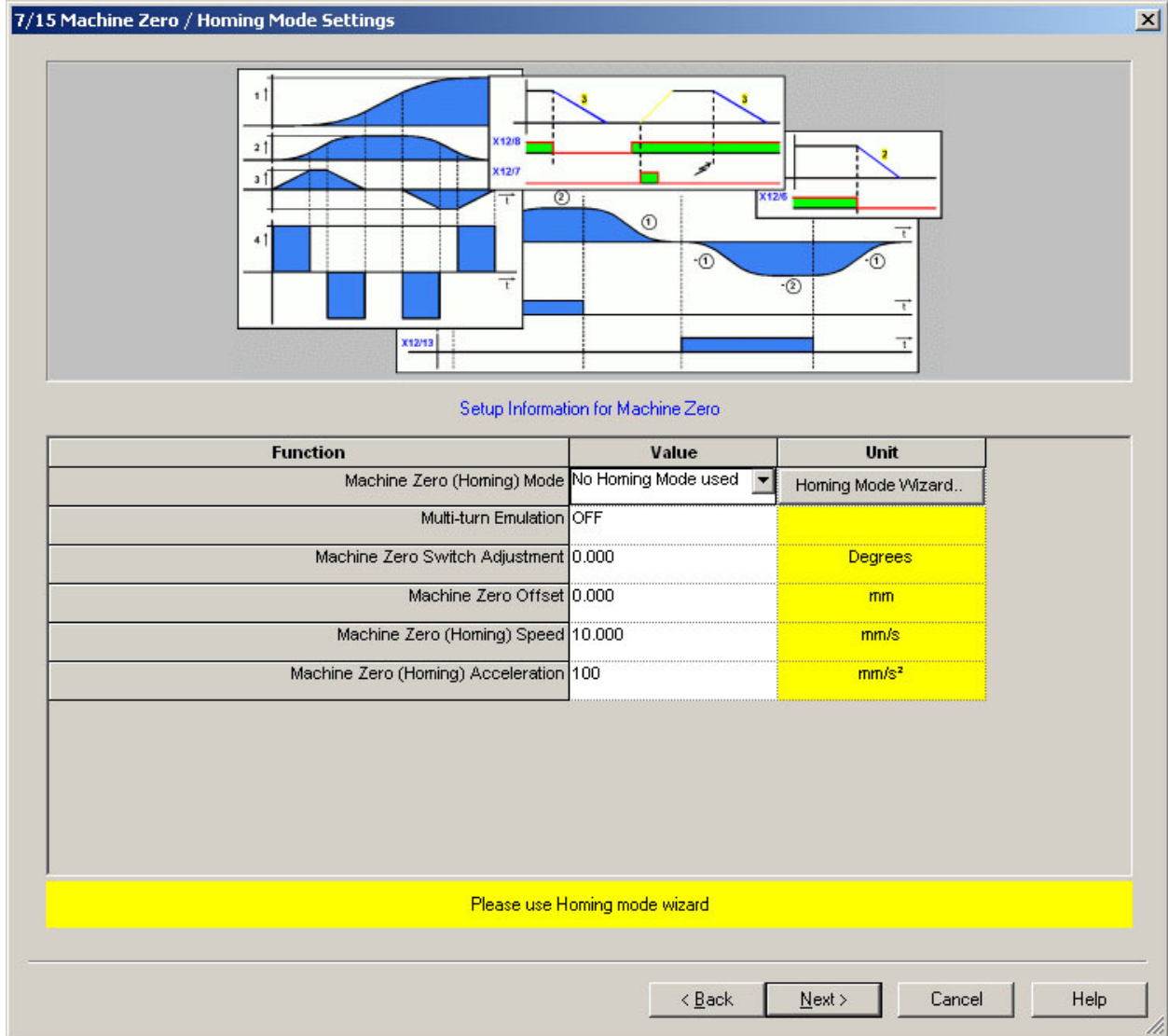
The next page is very important in controlling the speed of the motion. This is what caused the most problems for me. The example setups that can be found in [1] were very specific (and complex) and did not work for the system I used. This caused very irregular movement and controlling the speed of the motion was hard. Using 0.5 in the nominator (‘Travel distance per revolution’) and using 1 in the denominator (‘Travel distance per revolution – Denominator’) seemed to be the best setting because it gave good control of the speed of the motion.



Appendix 4 Figure 9: Distance / Travel Parameters

When this is set according to Figure 9 click the 'Next' button.

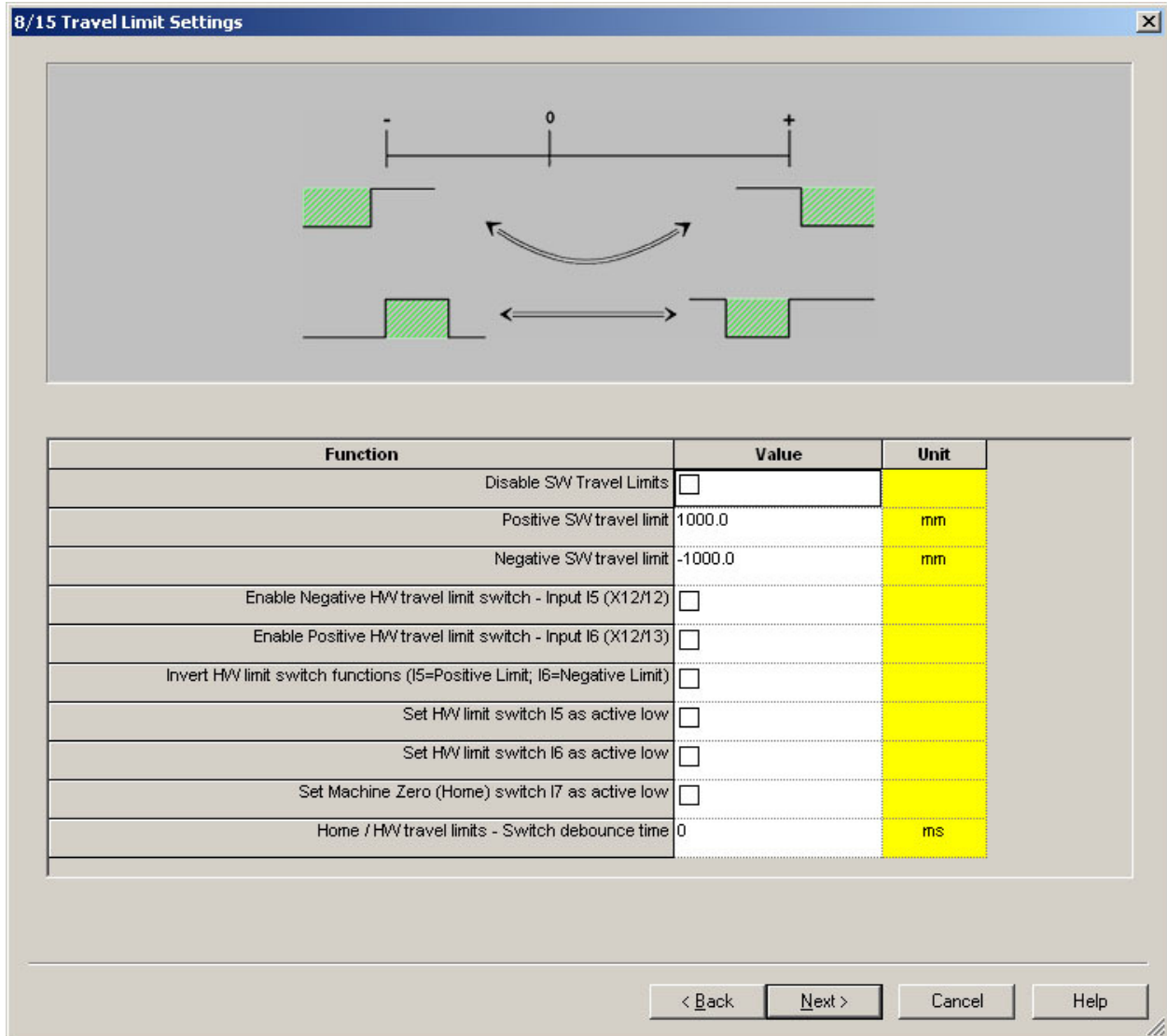
The next page can help setup 'Homing Mode' for the system. This allows the user to click 'Homing' to make the device return to a specific position. This was not needed for my project, so this setting was left with the default values and not used further.



Appendix 4 Figure 10: Machine Zero / Homing Mode Settings

If 'Homing Mode' is needed more information about this setting can be found in [1].

The next page sets the left and right limits of the movement along the actuator. This setting can be left at default because we are operating at low speeds and the limits can be changed during 'Optimization' later.

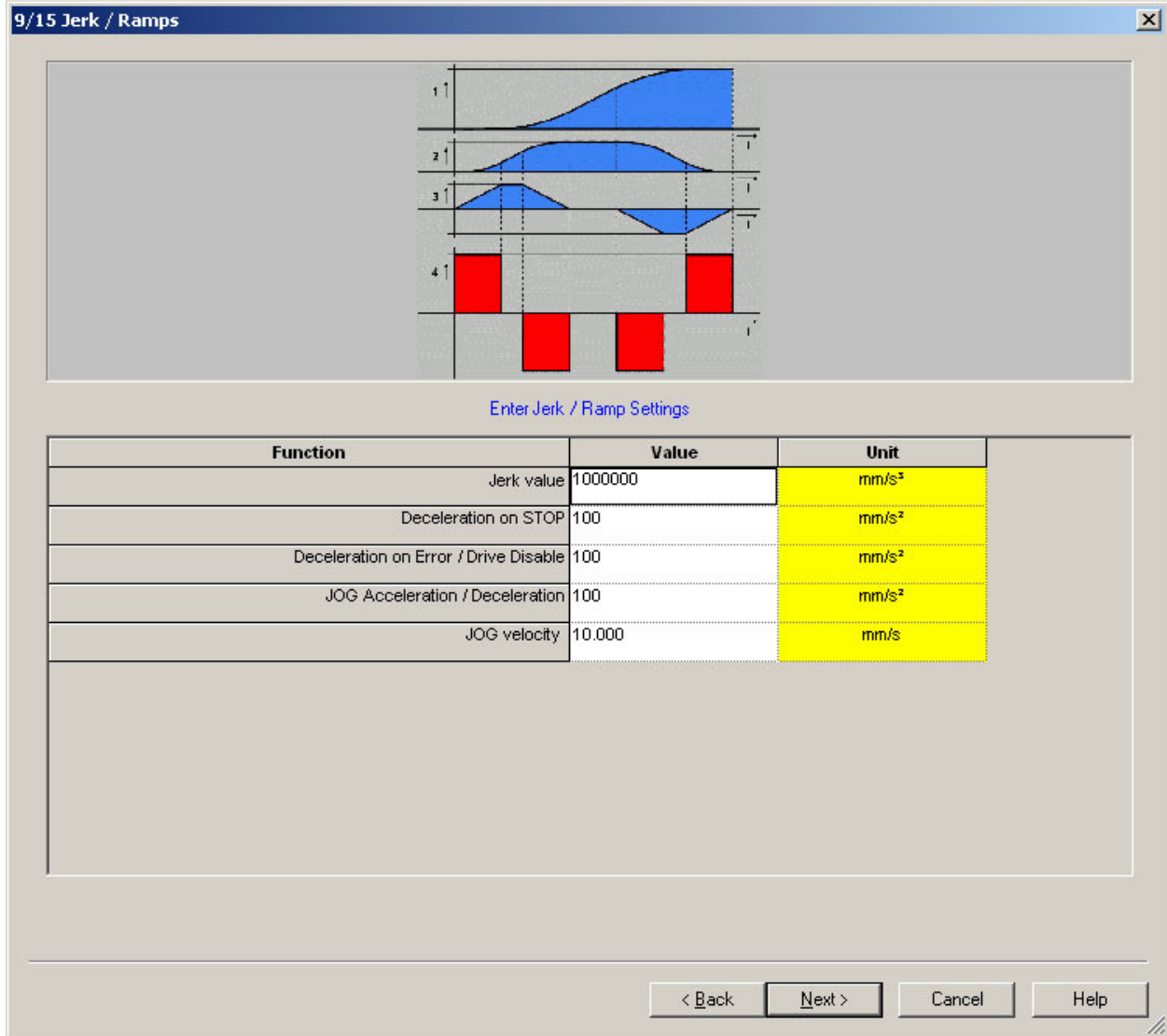


Appendix 4 Figure 11: Travel Limit Settings

Click the 'Next' button to continue to the 'Jerk / Ramps' page.

This page controls the acceleration and deceleration speed of the motion. The 'Jerk Value' limits how fast the motion can accelerate and decelerate and can be left at a high value (1000000 mm/s² in the picture below). The different acceleration and deceleration values set how fast the motion will stop and start on special events, and can be left at 100 mm/s² so that the motion stops quickly if something goes wrong.

The JOG setting is not something that will be used significantly, and can be left at the default value. This controls the speed of the motion when using JOG (fast way of moving the object from one spot on the actuator to another).

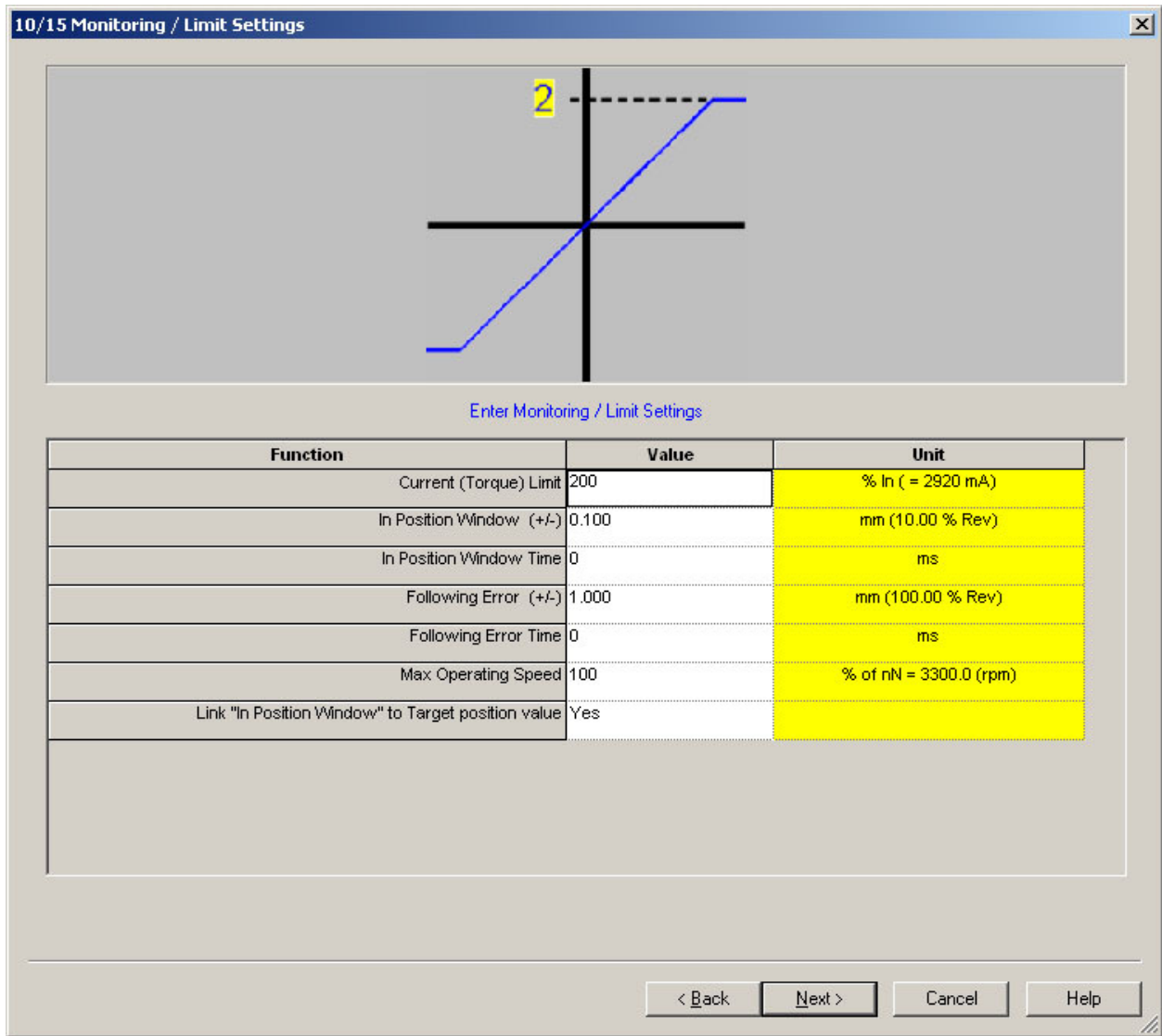


Appendix 4 Figure 12: Jerk / Ramps

When this is set, again click the 'Next' button.

The next window helps set the maximum speed of the motion. If you are unsure about the speeds you will be using, leave the 'Max Operating Speed' high, 100 in my case, to not limit the speed

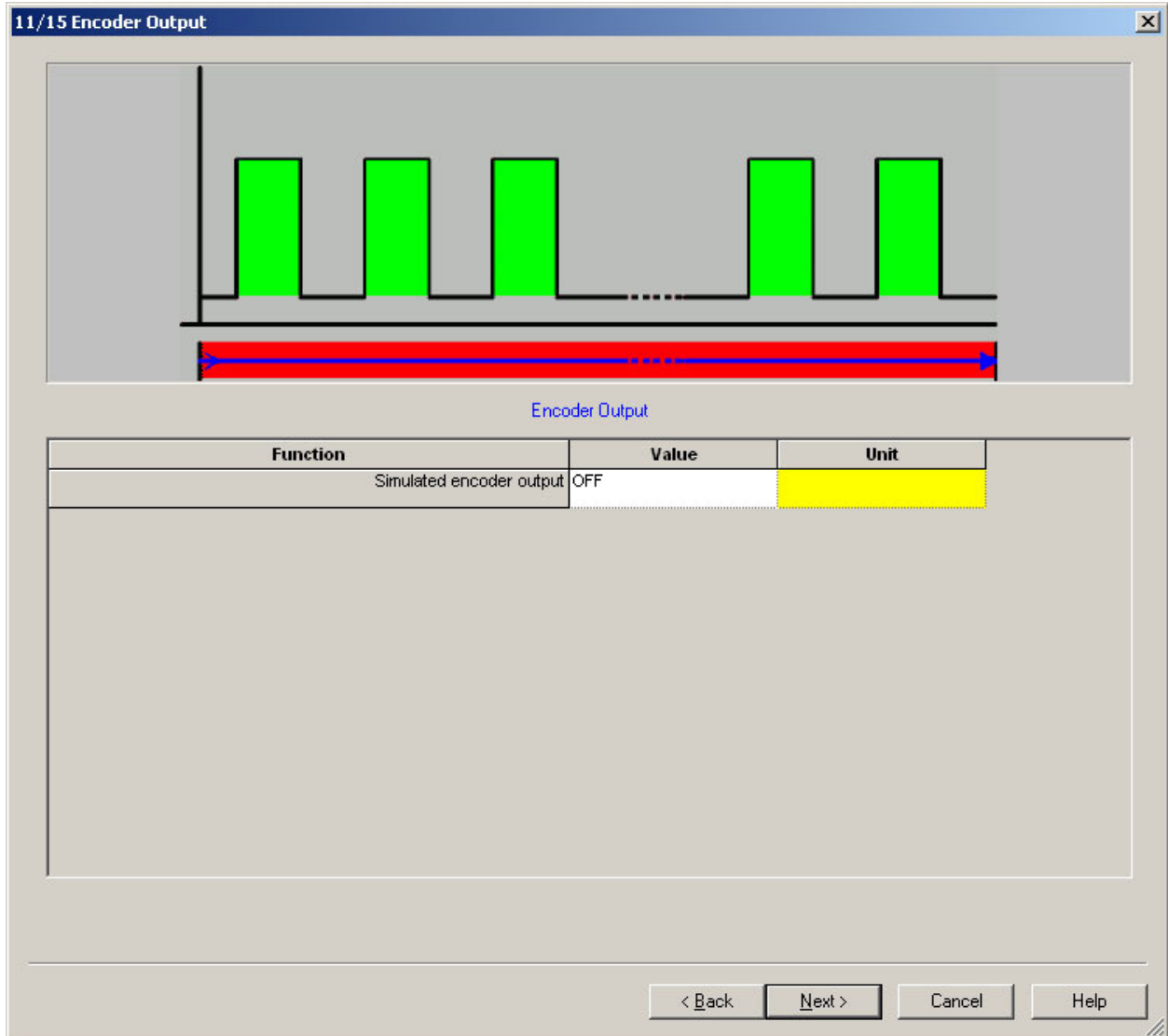
you are able to use when controlling the motion later (note that I used a maximum speed of 10, which is very fast so this can be set lower than 100 if wanted). Leave the other settings at default.



Appendix 4 Figure 13: Monitoring / Limit Settings

Click the 'Next' button to continue.

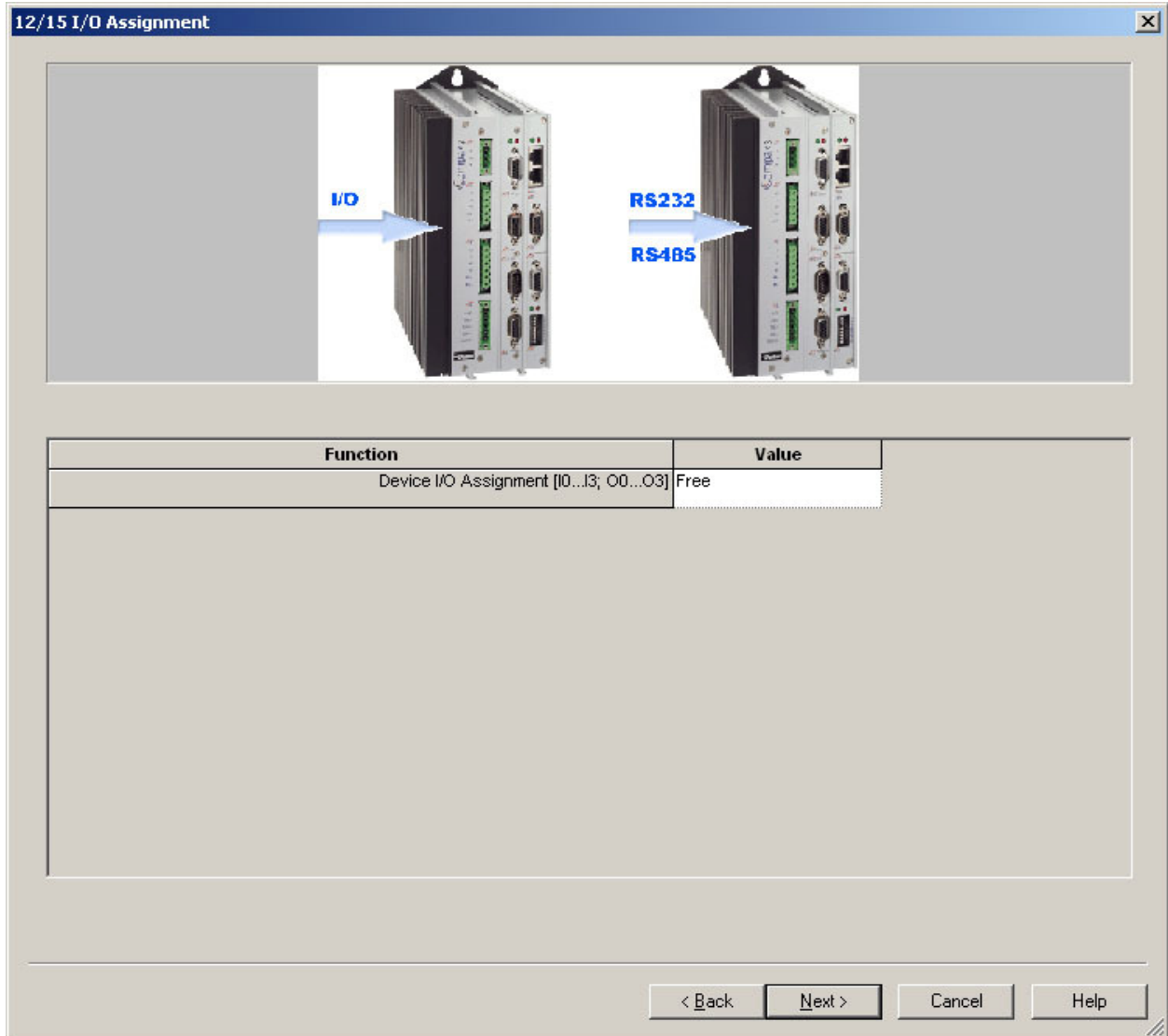
On the next page, leave the 'Simulator encoder output' in its 'OFF' position.



Appendix 4 Figure 14: Encoder Output

Click 'Next' again to continue.

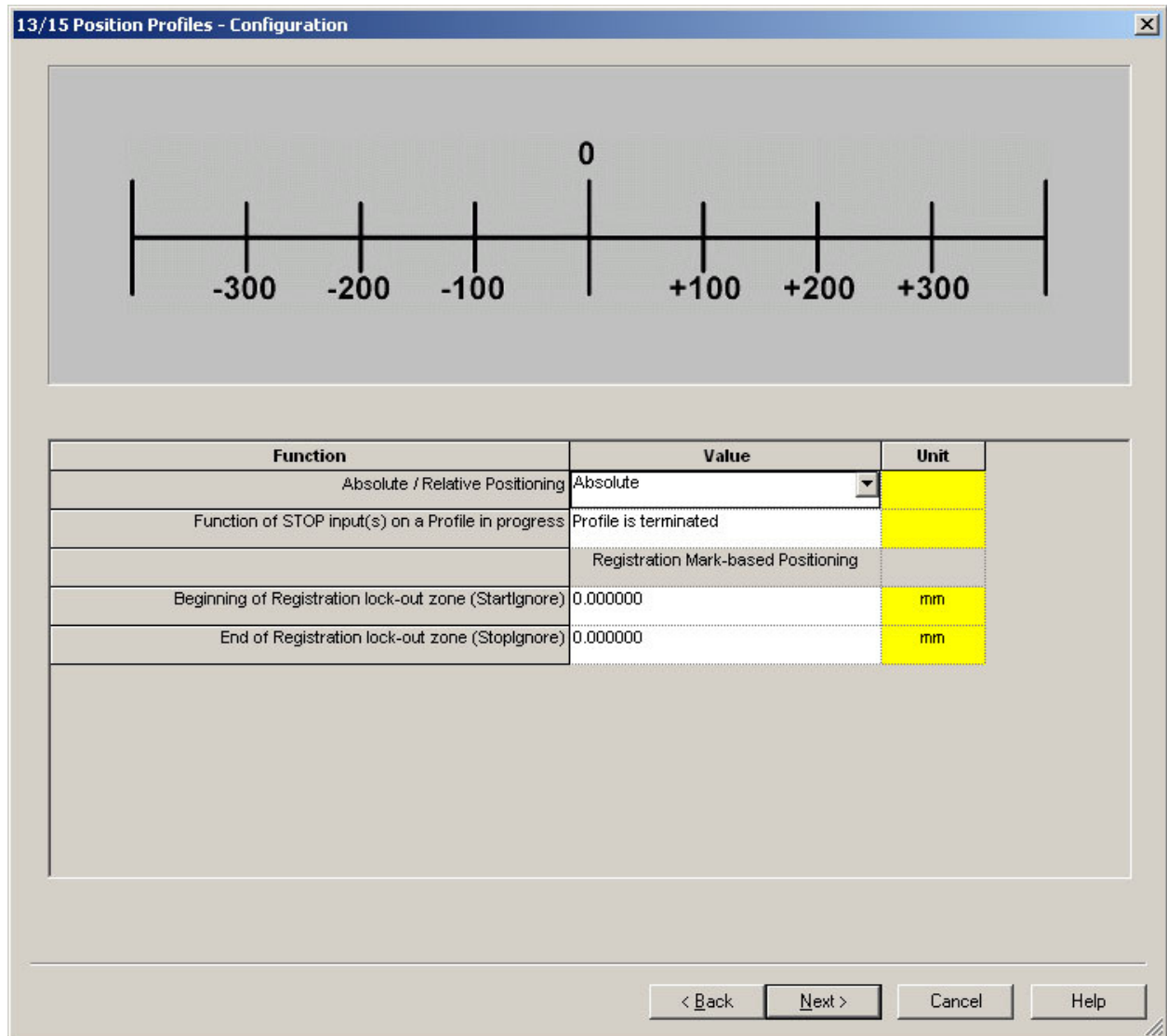
On the next page leave the 'Device I/O Assignment' off.



Appendix 4 Figure 15: I/O Assignment

Click 'Next' to continue.

The next window controls the absolute position of the motion and is used in combination with the 'Homing' and 'Machine Zero' settings that I did not use, and it will not be looked into further in this appendix.



Appendix 4 Figure 16: Position Profiles - Configuration

Leave settings at default and click 'Next' if you are not going to use 'Homing' and 'Machine Zero'.

This next page allows you to predefine movement of device. For my case this was not needed since I only wanted a motion that went back and forth between the left and right limits.

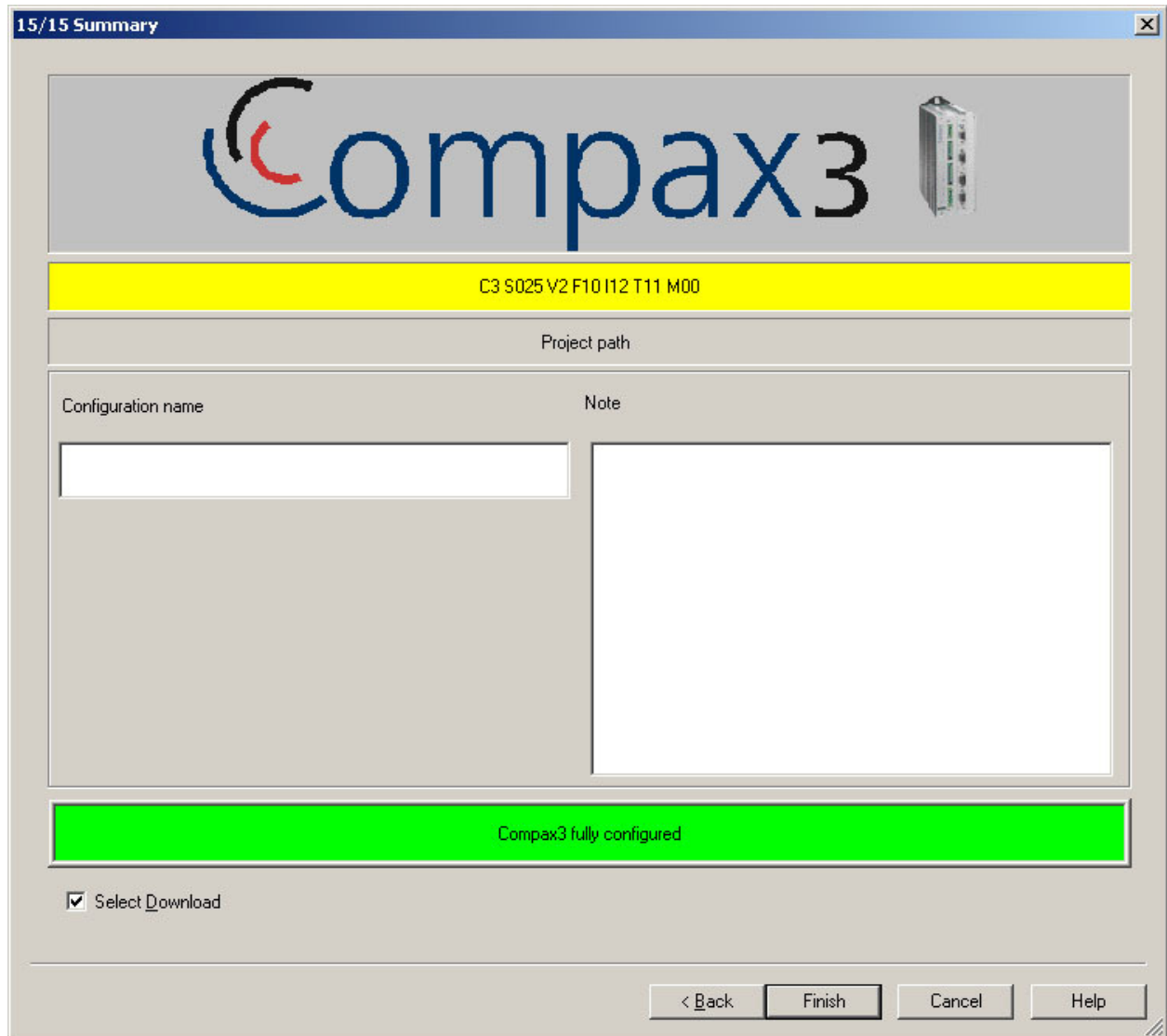
Set	Mode						
0	Homing	Mode=0	V=10.00mm/s	A=100mm/s ²			000
1	Empty						
2	Empty						
3	Empty						
4	Empty						
5	Empty						
6	Empty						
7	Empty						
8	Empty						
9	Empty						
10	Empty						
11	Empty						
12	Empty						
13	Empty						
14	Empty						
15	Empty						
16	Empty						
17	Empty						
18	Empty						
19	Empty						
20	Empty						
21	Empty						
22	Empty						
23	Empty						
24	Empty						
25	Empty						
26	Empty						
27	Empty						
28	Empty						

Appendix 4 Figure 17: Profile Table

Click ‘Next’ to finish the configuration.

This next screen is where you download the configuration settings to the Compax 3 Servo. You can store your configuration in a file by typing in a name and writing a short description if you want to. Configurations can be stored later by clicking File → Save in the main window, so this might be a better solution since you will know if the configuration works for you.

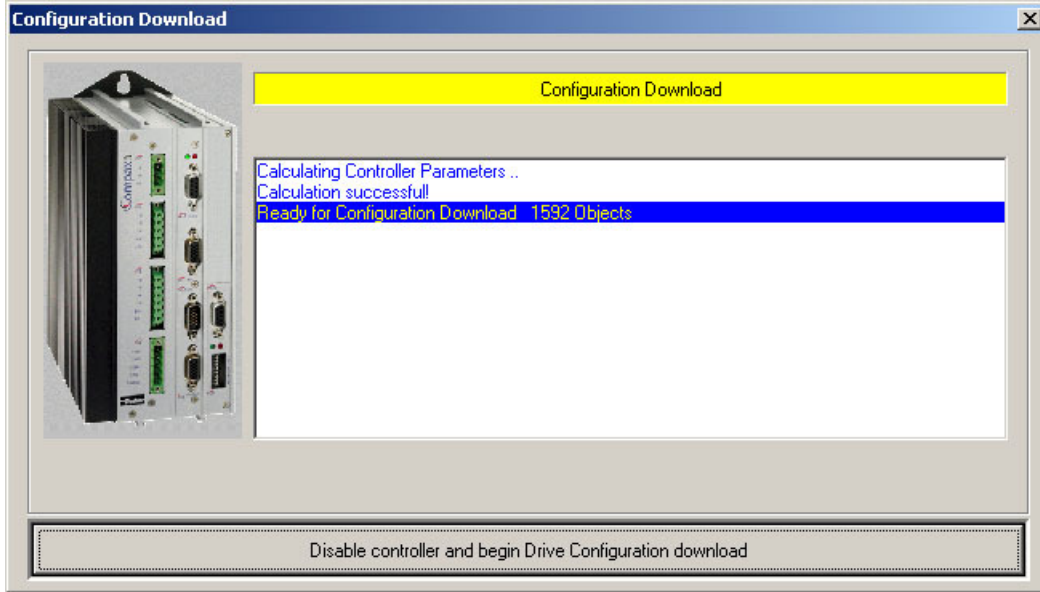
Make sure the ‘Select Download’ button is ticked before continuing.



Appendix 4 Figure 18: Summary window

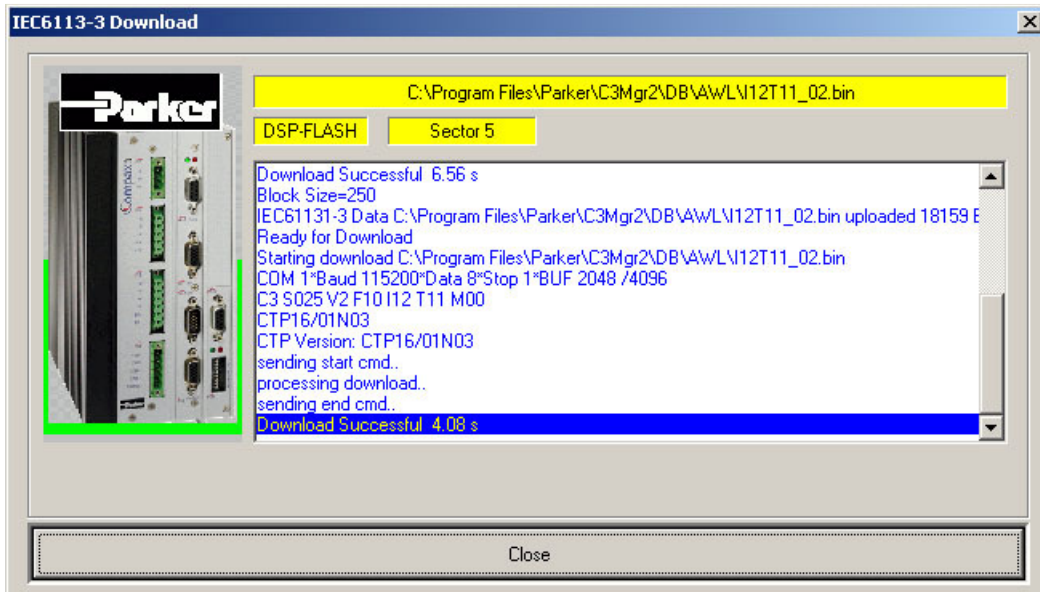
Click the 'Finish' button to continue.

On the next page click the 'Disable controller and begin Drive Configuration download' to continue. The settings will now be stored on the Compax 3 Servo. To change setting now you have to configure it again and download the changes for them to take effect.



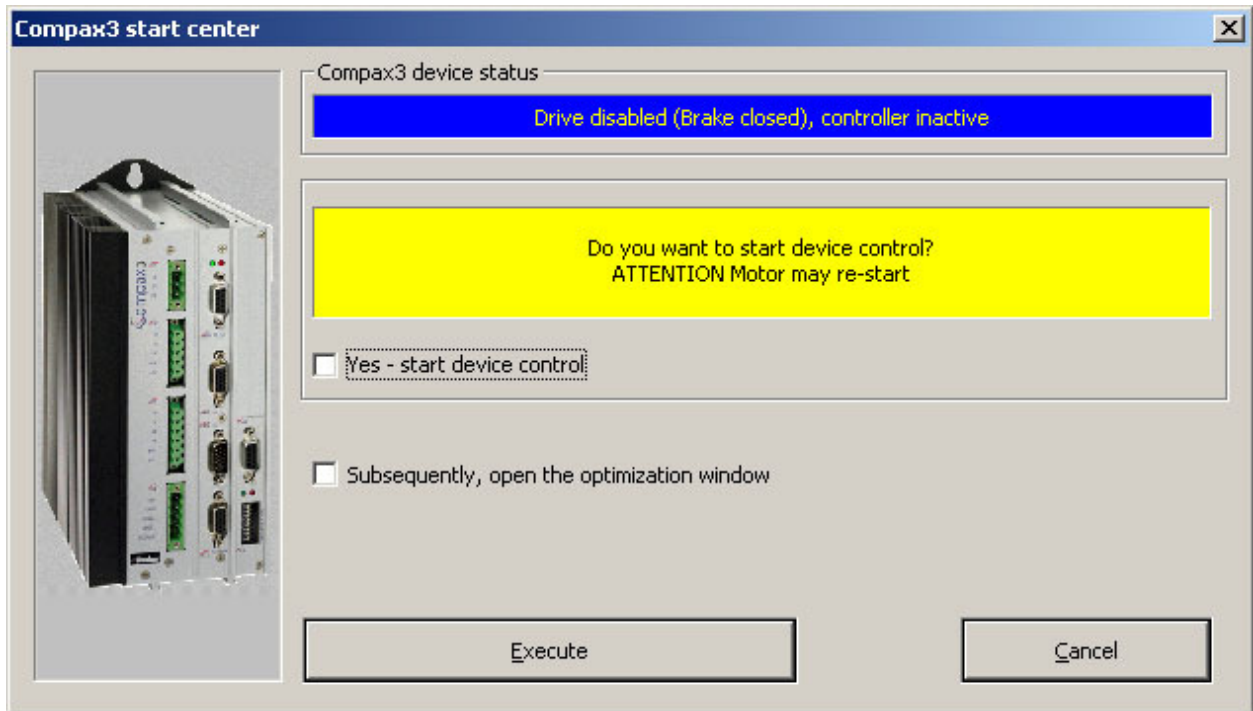
Appendix 4 Figure 19: Configuration Download

When you see the ‘Download Successful’ message you know that everything is working. Any other message at this point will usually mean that something has been done wrong, so if that is the case start over from the beginning of the configuration and check that all values are correct.



Appendix 4 Figure 20: Configuration Download Successful

When the next window opens, make sure that ‘Yes- start device control’ and ‘Subsequently, open the optimization window’ is unticked.

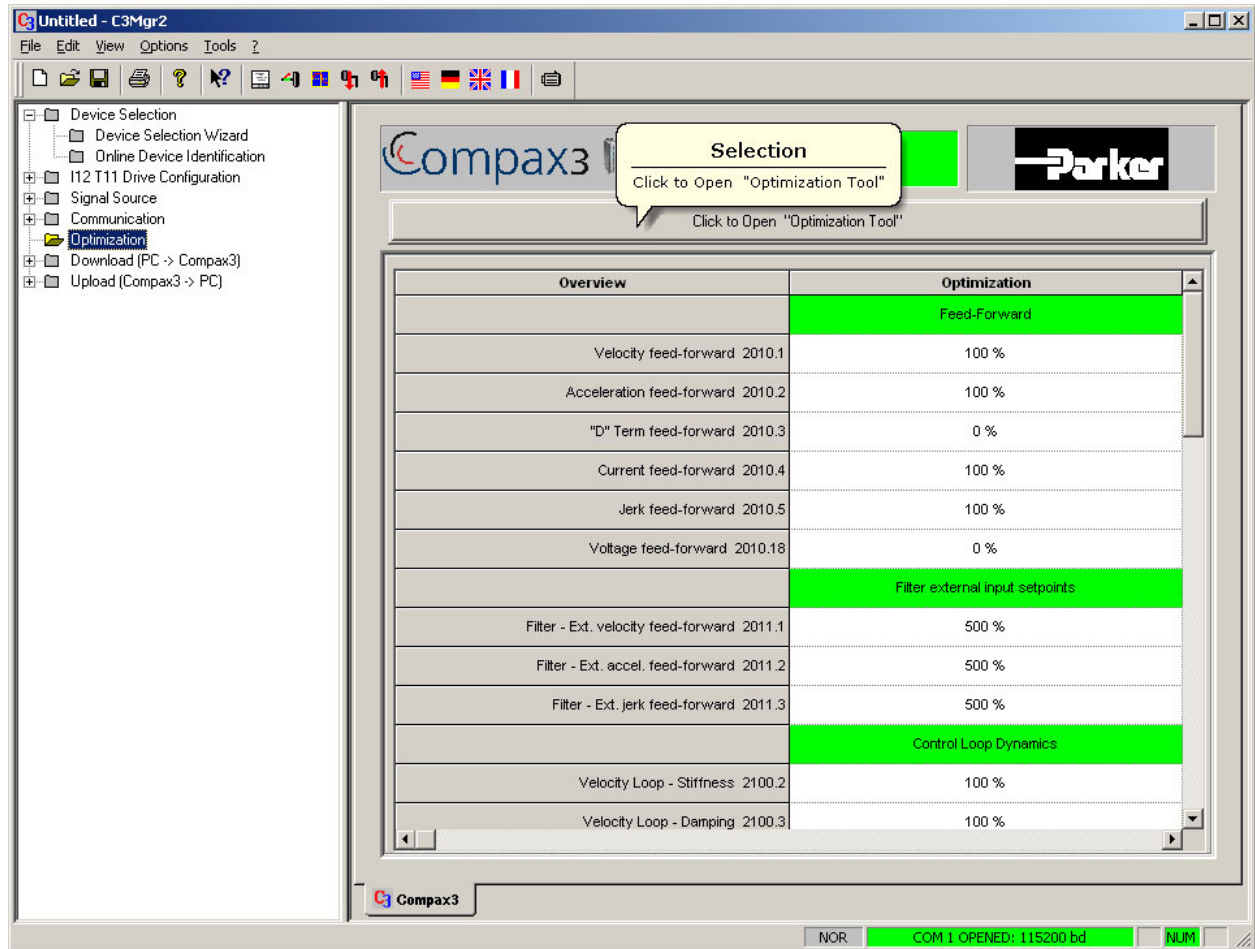


Appendix 4 Figure 21: Compax3 start center

Press the ‘Execute’ button and you will be back at the main C3 ServoManager 2 window.

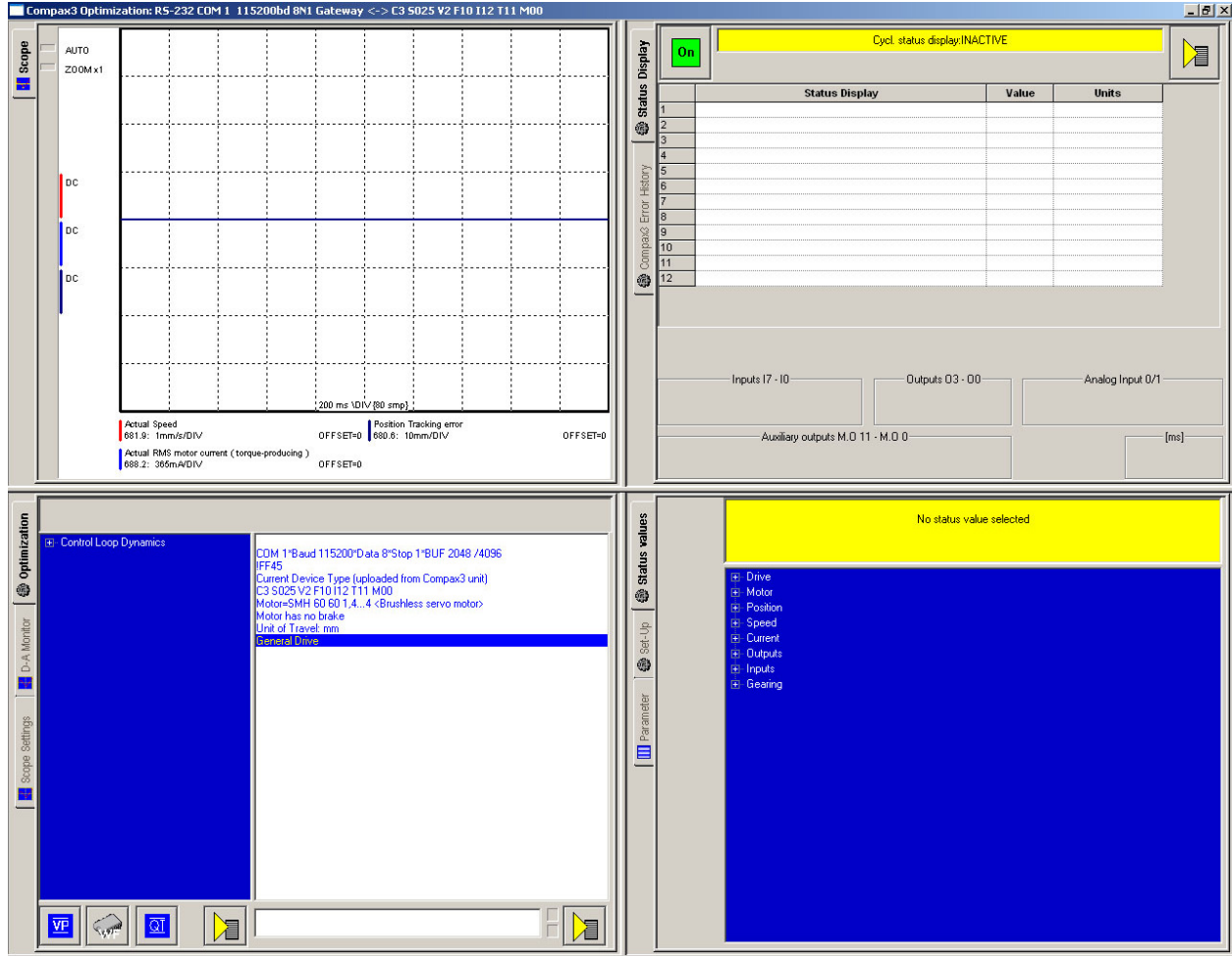
Step 3: Optimization

The next step is to optimize the movement of the model. The optimization is done by opening the ‘Optimization Tool’, select ‘Optimization’ on the menu on the left and then click ‘Click to Open “Optimization Tool”’ on the right.



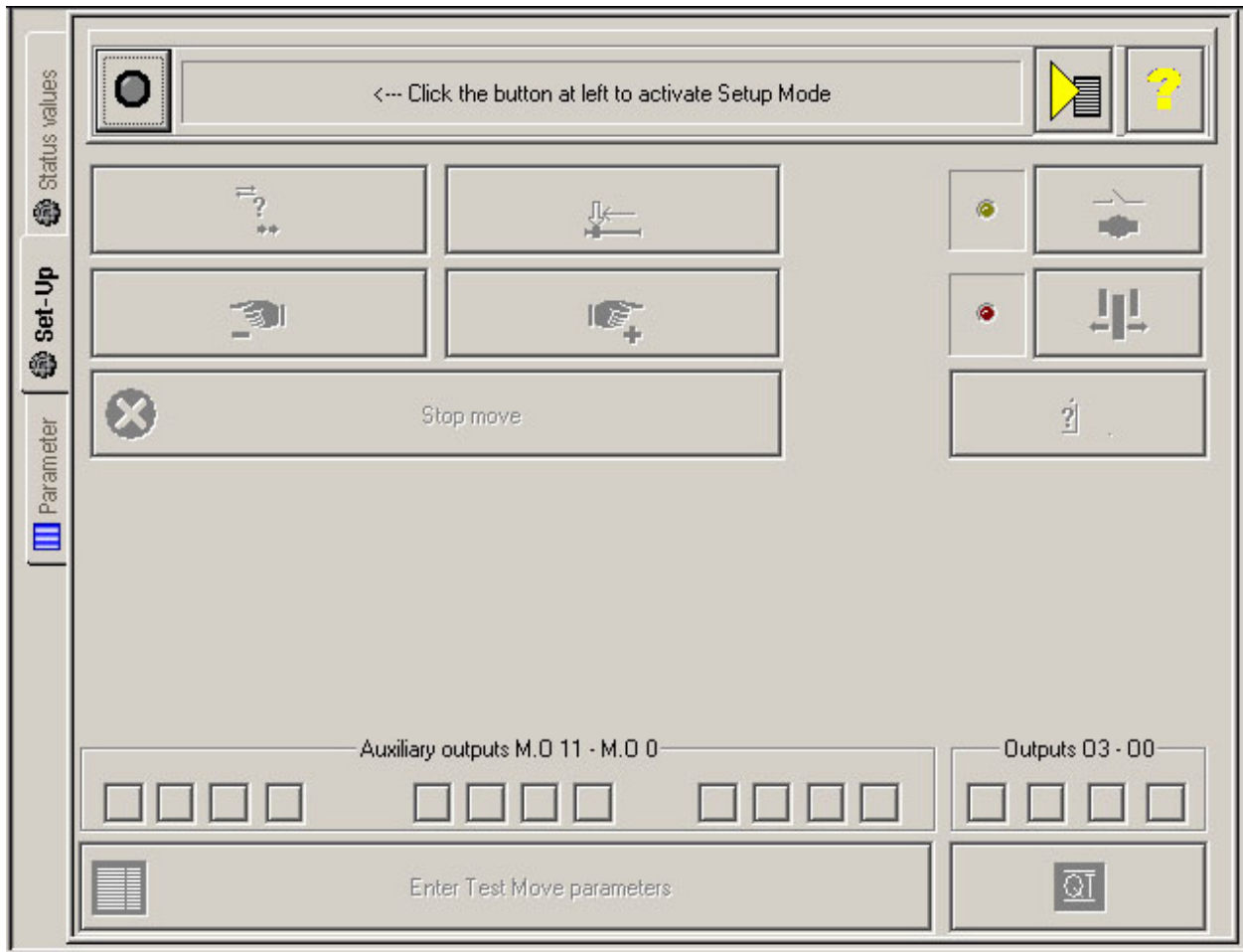
Appendix 4 Figure 22: Starting the Optimization Tool

This opens the 'Optimization Tool' which consists of 4 separate windows. The window we need to do changes to, the one that controls the movement pattern, is the one on the bottom right.



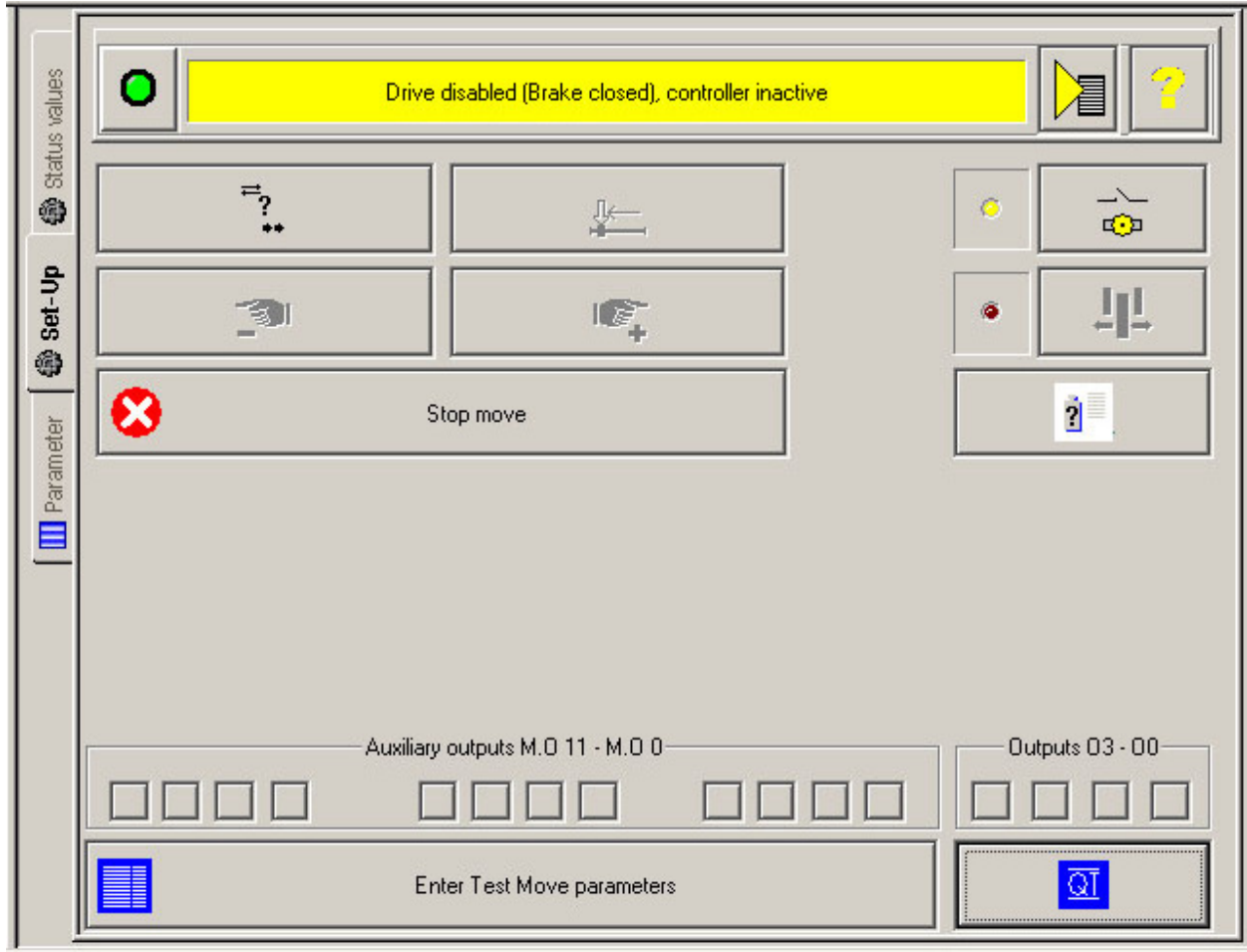
Appendix 4 Figure 23: Optimization Tool main view

The first thing that has to be done is to click the 'Set-Up' button which should result in the bottom right window looking like Figure 24.



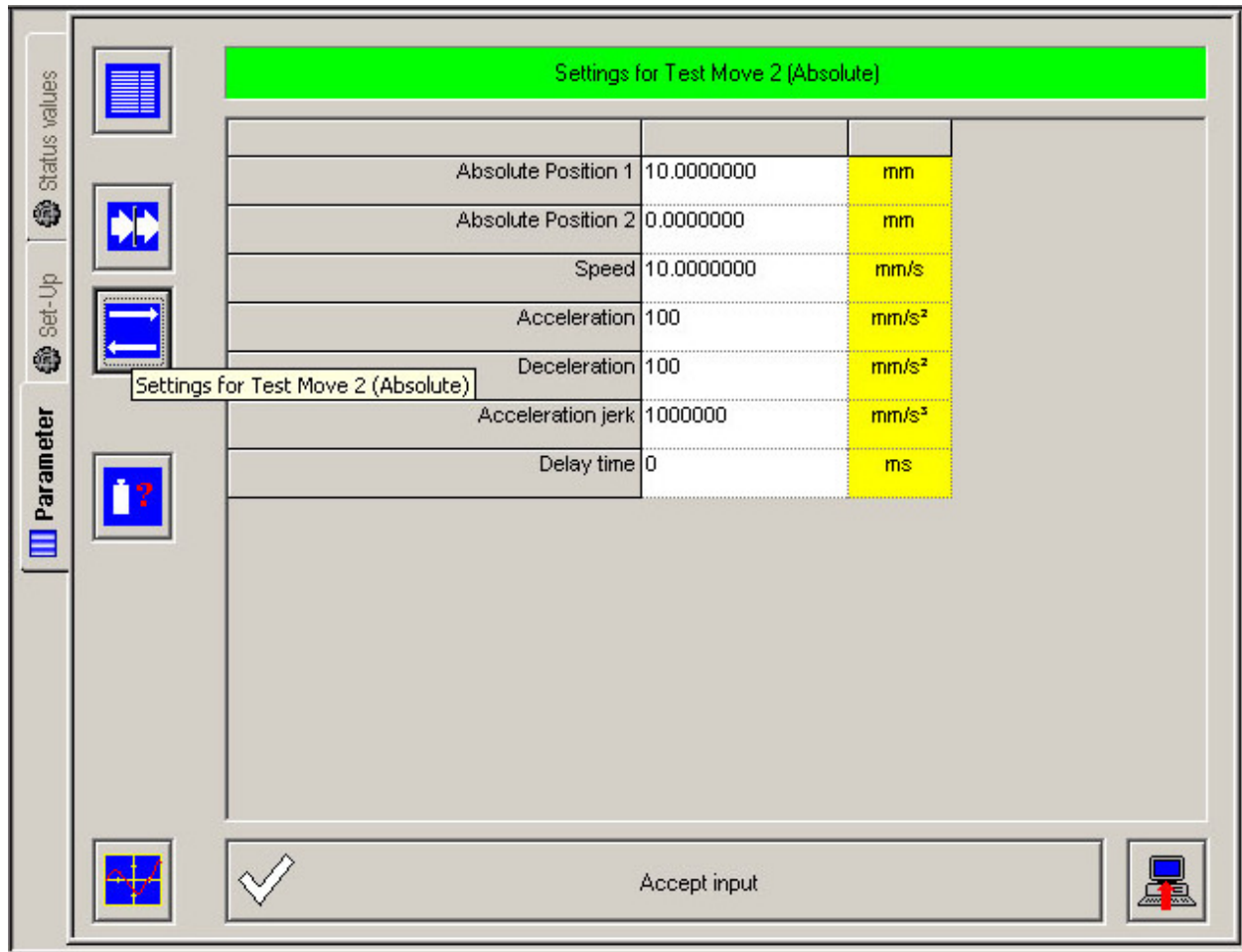
Appendix 4 Figure 24: Activate Setup Mode

Now click the button on the left of the '<--- Click the button at the left to activate Setup Mode' message. It should then turn green and you should have a window looking similar to that in Figure 25.



Appendix 4 Figure 25: Setup Mode activated

The next step is to click the 'Enter Test Move parameters' on the bottom. From this window click the 'Settings for Test Move 2 (Absolute)'. This test move allows the motion in two directions (back and forth) while 'Settings for Test Move 1 (Relative)' only allows for motion in one direction. This should give you a window looking similar to that in Figure 26 below.



Appendix 4 Figure 26: Setting Test Move parameters

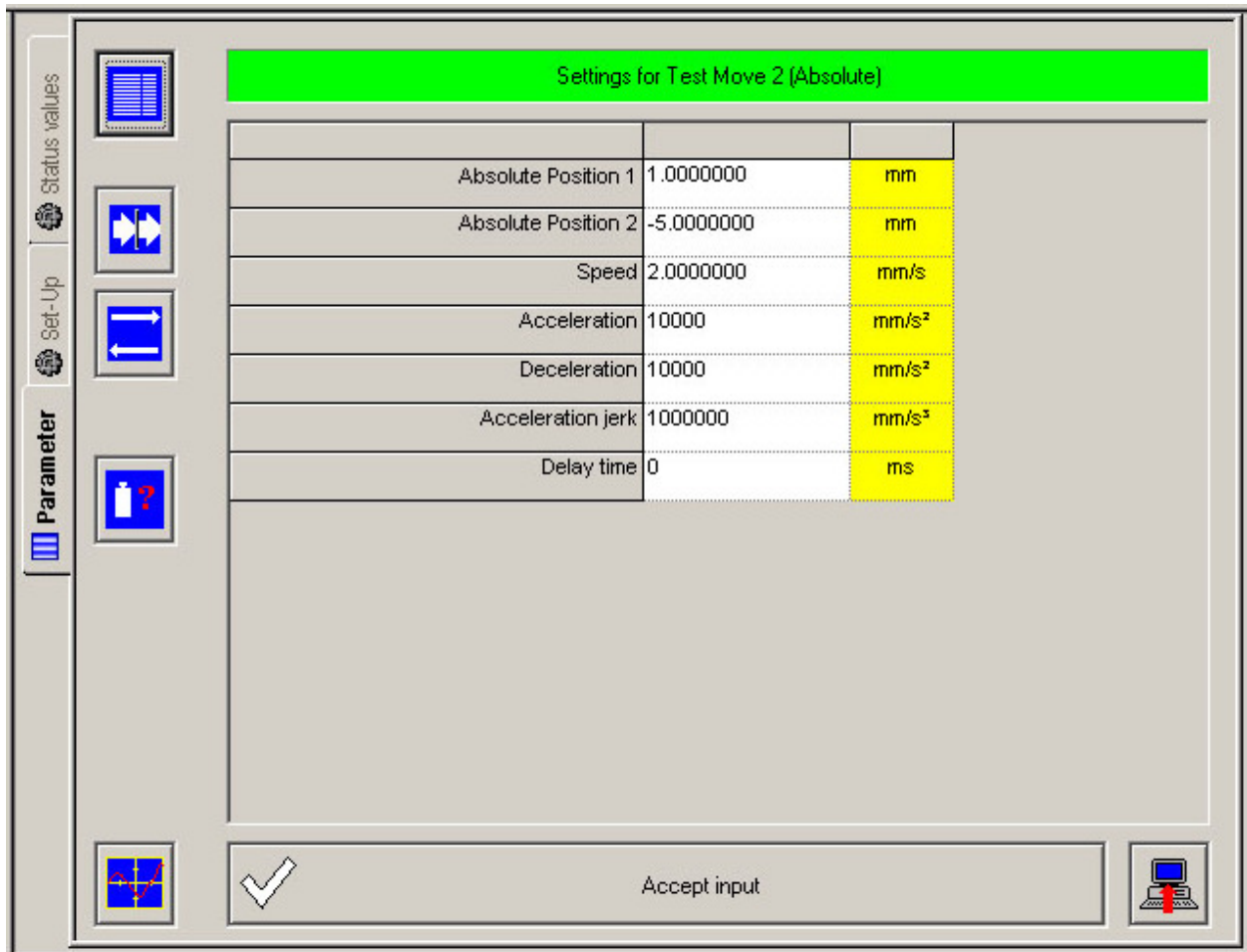
This is where the left and right position of the motion, the top speed and acceleration/deceleration of the movement is set. Speed should be set very low to start off with to check if your configuration has been successful. Setting ‘Speed’ to a value of 1 or lower should be good to begin with. ‘Acceleration’ and ‘Deceleration’ can be set high, as these settings only control how fast the motion should reach maximum speed, and how fast the speed is slowed down before stop and return motion begins.

The ‘Absolute Position 1 and 2’ gives the left and right boundaries of the movement. These should be set low to start off with using 1 as a value for ‘Absolute Position 1’ and -1 as a value for ‘Absolute position 2’ is good way to start. To increase the right absolute position, increment ‘Absolute Position 1’ with 1 until the right boundary is correct, and decrement ‘Absolute

Position 2' with 1 until the left position is correct. The 'Delay' value tells the Servo how long the motion should pause at each absolute position before starting to move again.

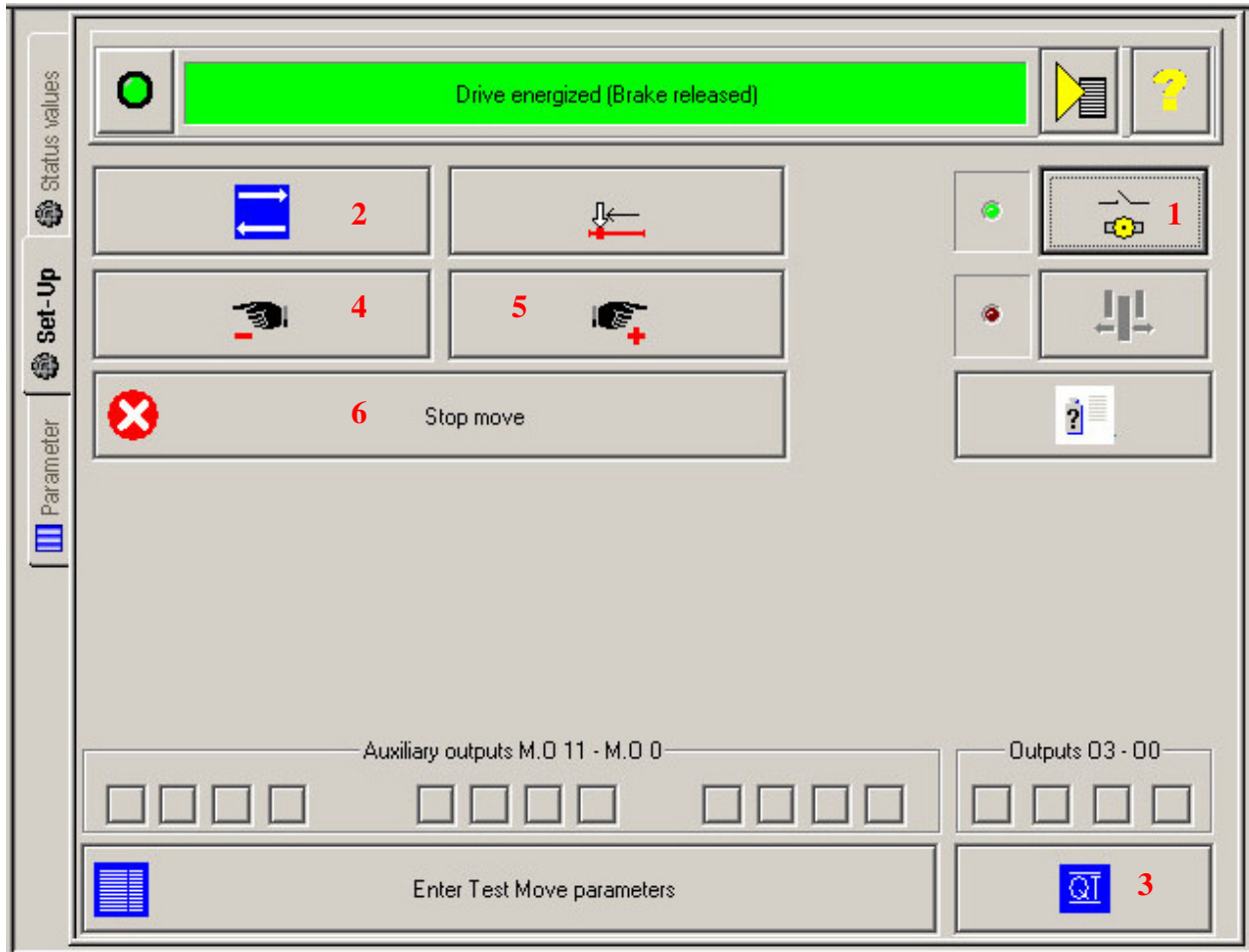
The 'Acceleration Jerk' can be left high because it is just a limit for how fast the acceleration and deceleration can be.

In Figure 27 below you can find the values that were used in my project. For some reason the 'Absolute Position' values had to be changed almost every time the C3 ServoManager 2 software was used even when a configuration preset was saved and loaded. This most likely have to do with me not initializing a 'Machine Zero' which gives the Servo a default starting point of the motion.



Appendix 4 Figure 27: Adjusting Test Move parameters

When these settings are completed click the ‘Accept input’ and you will see a window looking like Figure 28.



Appendix 4 Figure 28: Power the motor and start Test Move

Click Button 1 (seen in Figure 28 above) on the top right so that the light turns green to power the motor. We are now ready to start testing the movement. Click Button 2 to initiate to movement.

Button 3 can be used to clear errors if they should occur. Clearing errors has to be done to continue using the optimization tool.

Button 4 and Button 5 can be used to quickly move the device to a position on the actuator.

Button 6 can be used at any time to stop the movement.

To make changes to the test move parameters click the ‘Enter Test Move parameters’, when changes are done remember to click the ‘Accept Input’ button again as can be seen in Figure 27.

If the movement is “out of control’ click button 1 to cut motor power so that everything stops. This may have to be done because Button 6 not always responds if the device has been configured wrong.

References:

- [1] Parker, “*Positioning via digital I/O & RS232/RS485*” August 4, 2005. Parker Hannifin GmbH & Co. KG EME, Germany

Appendix 5: Editing in Adobe Premiere Pro CS4

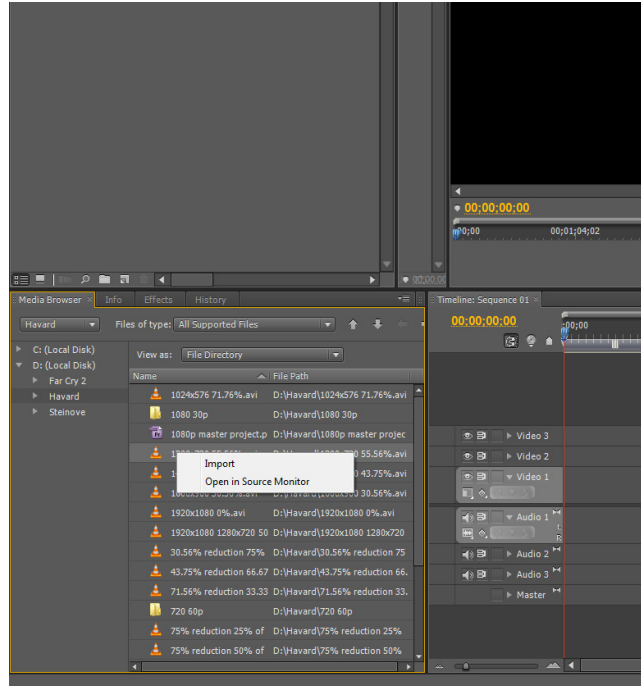
This appendix is a step-by-step guide to how the video material used for this project was edited in Adobe Premiere Pro CS4. The reason for writing this guide is to help other researchers to be able to continue the work I have done if they want to perform it in similar ways. It will also give others a possibility to see what I have done in order to improve the method.

Step 1: Getting started

When Adobe Premiere Pro CS4 is started you will have to start a new project, when the new project is started you get to choose a Sequence Preset. The Sequence Preset should be of the type you want the output video to have. For me the Sequence Preset chosen was ‘XDCAM EX 1080p 30p (HQ)’ because this was the type of video recorder the video was recorded on and I wanted the output video to keep have the same qualities. The video sequence is the video clip we will be working on, so no changes will be done to the original video material.

Step 2: Importing video material

To make a video that combines data from two video clips like I have done the two video files first have to be imported. This is done by locating the video clips in the media browser on the bottom left and right-clicking them and selecting Import. If the video clips are not of the right format (video codec e.g. they will first have to be exported to the right codec. Exporting will be covered later in Part 6).

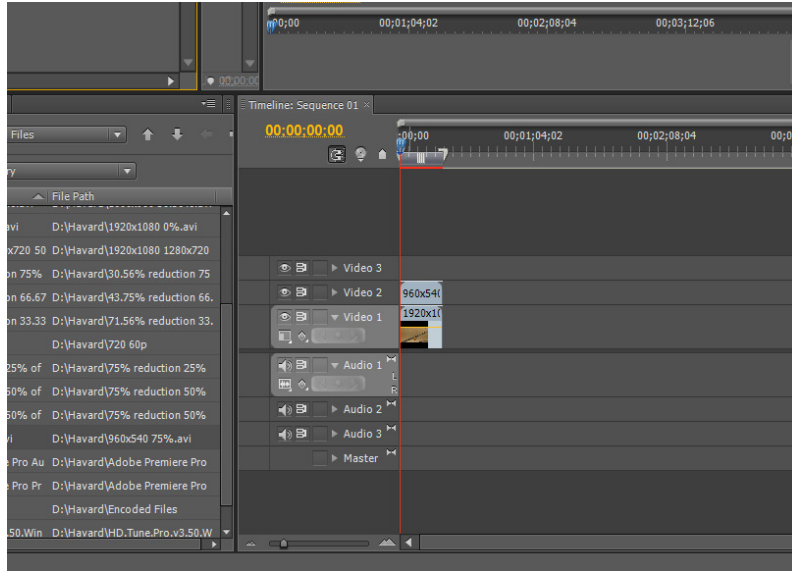


Appendix 5 Figure 1: Import video clip

After the video clips are imported, they will show up along with the sequence on the upper left side of the screen.

Step 3: Editing video tracks

After the video clips have been imported they can be applied to the sequence. This is done by simply dragging them down to a video track in the timeline view of the sequence located on the lower part of the screen. One of the videos should be placed on video track 1 and the other video should be placed on video track 2. The screen should now look as Figure 2 below.



Appendix 5 Figure 2: Applying video clips to tracks

After the video clips have been placed on the timeline for the sequence different effects can be applied to them.

The ‘Sharpen’ effect was tested and gave clearer edges in the video material, but it also introduces more noise in the picture so overall the quality was lower. Because of this ‘Sharpen’ was not used. The ‘Find Edges’ effect extracts the edges in the scene, but I found no way to use this as a mask so that the resolution of the edges was not changed.

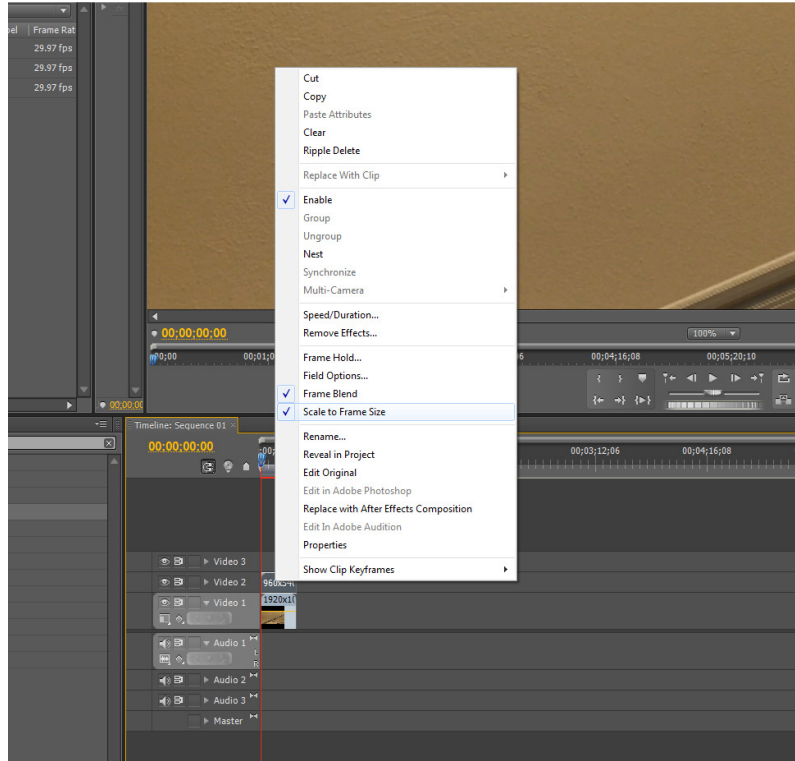
I could not find any other effect in Premiere Pro that made the edges look better without decreasing the quality of the rest of the scene, so no effects were used.

Step 4: Dividing a video clip into frames

Before using the ‘Razor Tool’ to divide video clips into frames all effects should be applied first if the effect is to be used on the entire video clip.

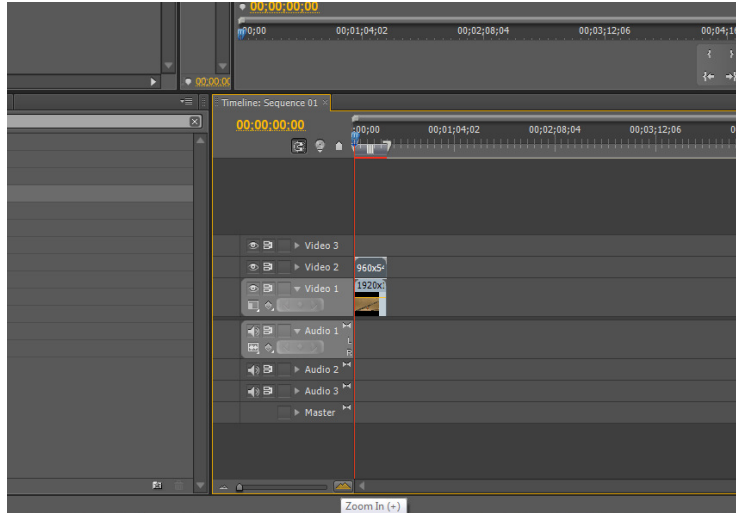
In my case I wanted the video clip of reduced resolution to be scaled up to have the same resolution as the high resolution video clip. This is done by right-clicking on the video clip that should be scaled up in the sequence timeline and selecting ‘Scale to Frame Size’. This forces

Adobe Premiere Pro to use spatial interpolation to scale the low resolution video clip up so it has the same resolution as the highest resolution video clip (960x540 scaled up to 1920x1080 in my case).



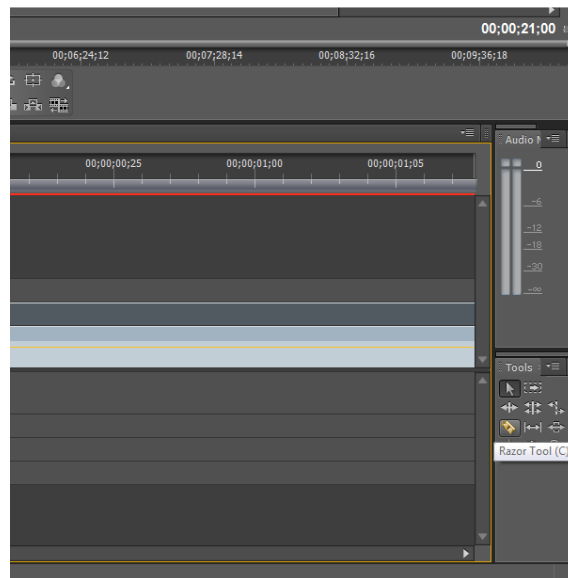
Appendix 5 Figure 3: Scale to Frame Size

After this has been done you can zoom in the timeline so it is easier to use the ‘Razor Tool’. This is done by clicking the ‘Zoom In (+)’ button on the bottom of the timeline window.



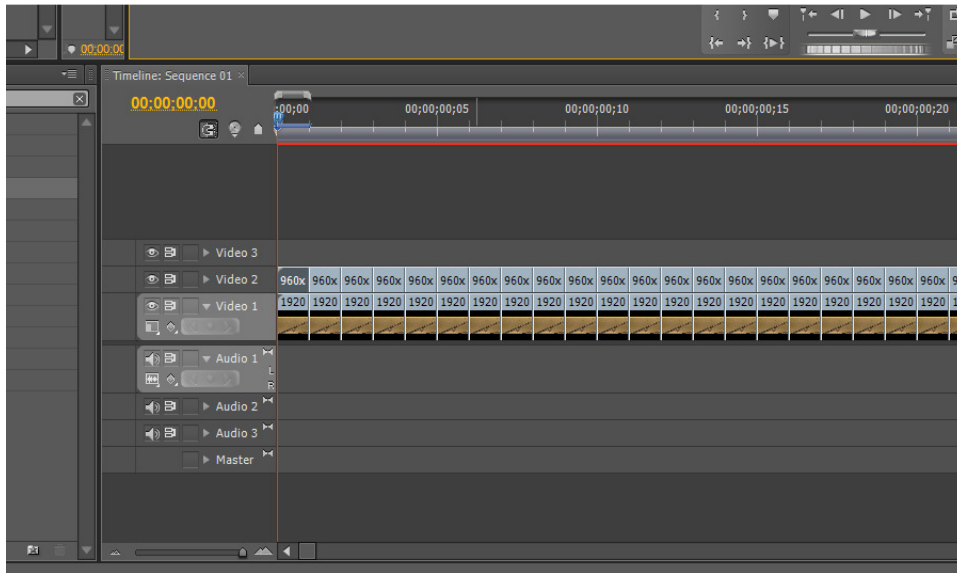
Appendix 5 Figure 4: Zooming the timeline

If you zoom in as far as possible it is easy to use the ‘Razor Tool’ to divide the video clips into individual frames. Doing this requires a lot of mouse clicking, so finding a script or a plug-in for Adobe Premiere Pro CS4 that can help performing this would be helpful, but I was unable to find a better way to do this. The ‘Razor Tool’ is located on the bottom right side of the screen as seen in Figure 5 below.



Appendix 5 Figure 5: The Razor Tool

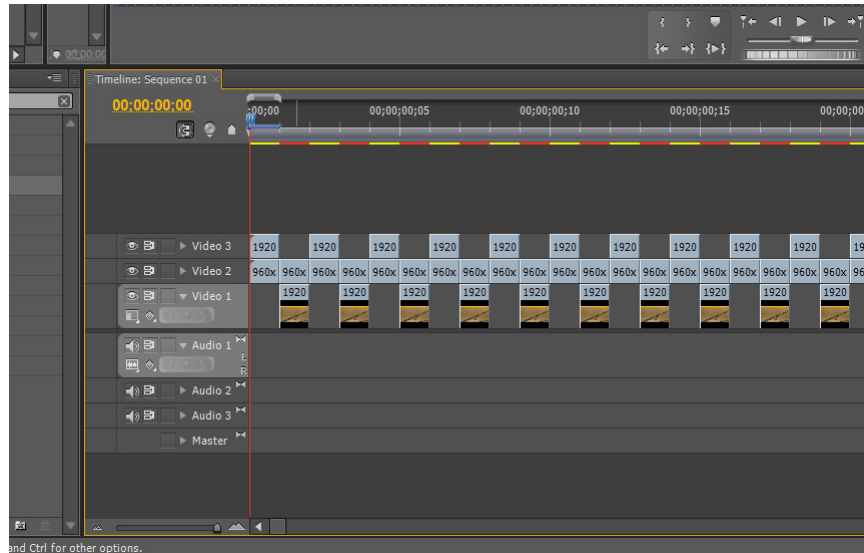
After the 'Razor Tool' is selected you can start cutting the video clips into individual frames. This is done by clicking on the video track, the 'Razor Tool' will automatically cut where the closest frame is located, so there is no chance of cutting at the wrong position in the video clip (dividing a frame in two e.g.). One click is needed per frame, so after a lot of cutting the video tracks in the timeline should look like on Figure 6 below.



Appendix 5 Figure 6: Video clips divided into individual frames

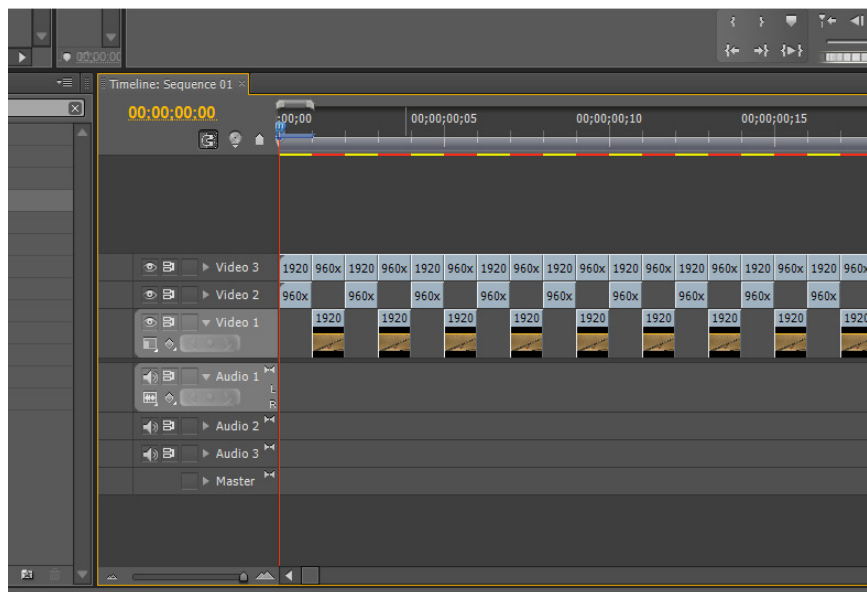
Step 5: Combining frames together to make a new video clip

After both the video clips have been divided into frames it is time to combine the frames together as a new video clip. In this guide I will show how this will look when using the 1:2:1:2 frame drop pattern I have used in my experiments. To do this, click and drag the frames from one video timeline up to a new video timeline in the sequence. In Figure 7 below you can see how this looks when frames from the video 1 timeline is placed on the video 3 timeline.



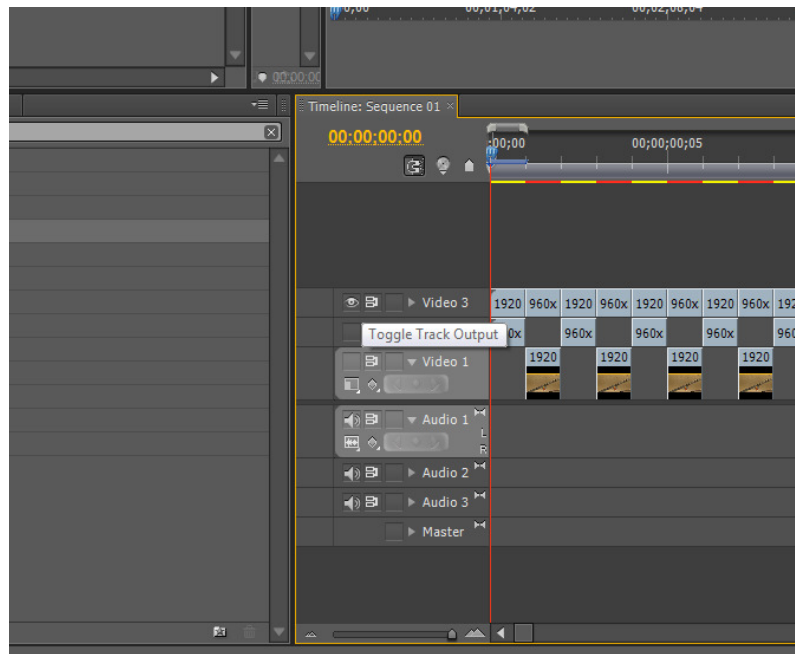
Appendix 5 Figure 7: Frames from clip 1 put on new video track

As we can see only every other frame is selected and dragged up. This is to create the 1:2:1:2 drop pattern. The empty frames slots will be filled with frames from video 2. This is done in a similar way as when dragging the frames from video 1. The result should be as shown on Figure 8.



Appendix 5 Figure 8: Frames from clip 2 put on new video track

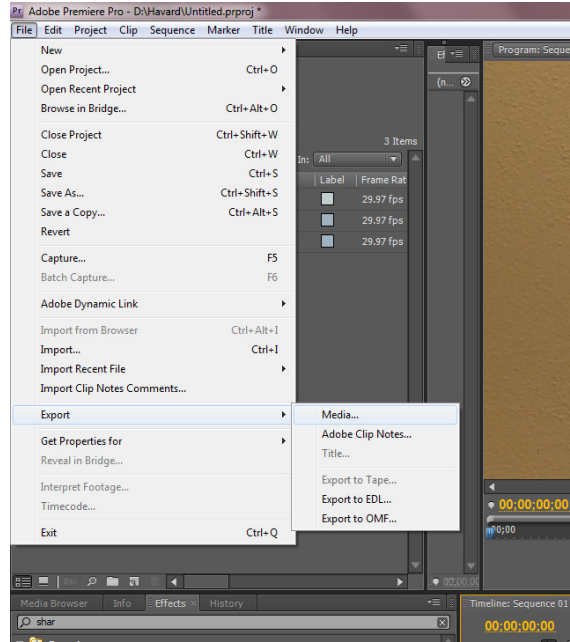
Now that we have combined the two video clips together on a new video track (Video 3) we have to select track 3 as the output track. This is done by clicking the ‘eye’ on the left side of the video tracks. Only track 3 should have an ‘eye’ visible while track 1 and track 2 should not. It should now look like it does on Figure 9.



Appendix 5 Figure 9: Selecting track output

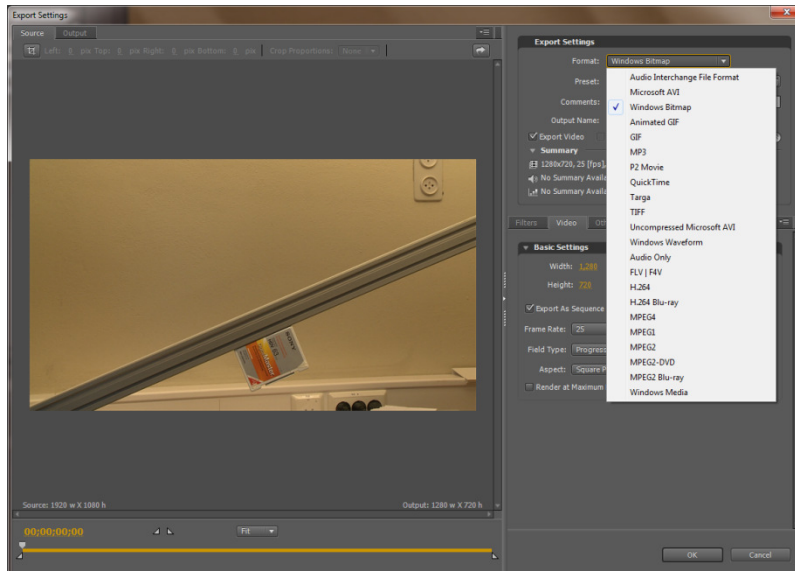
Step 6: Exporting

The video clip is now complete and can be exported. This is done by clicking on the ‘File’ menu on the top and selecting Export -> Media...



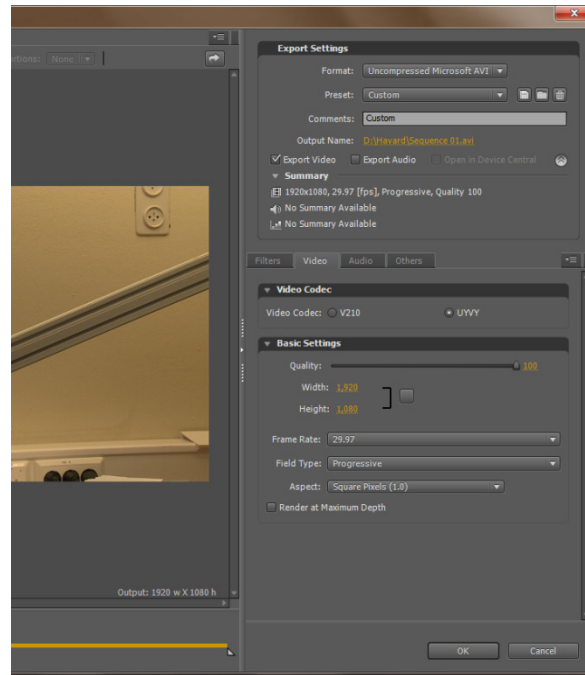
Appendix 5 Figure 10: Exporting the video

After that a new window should open and the format of the video can be selected.



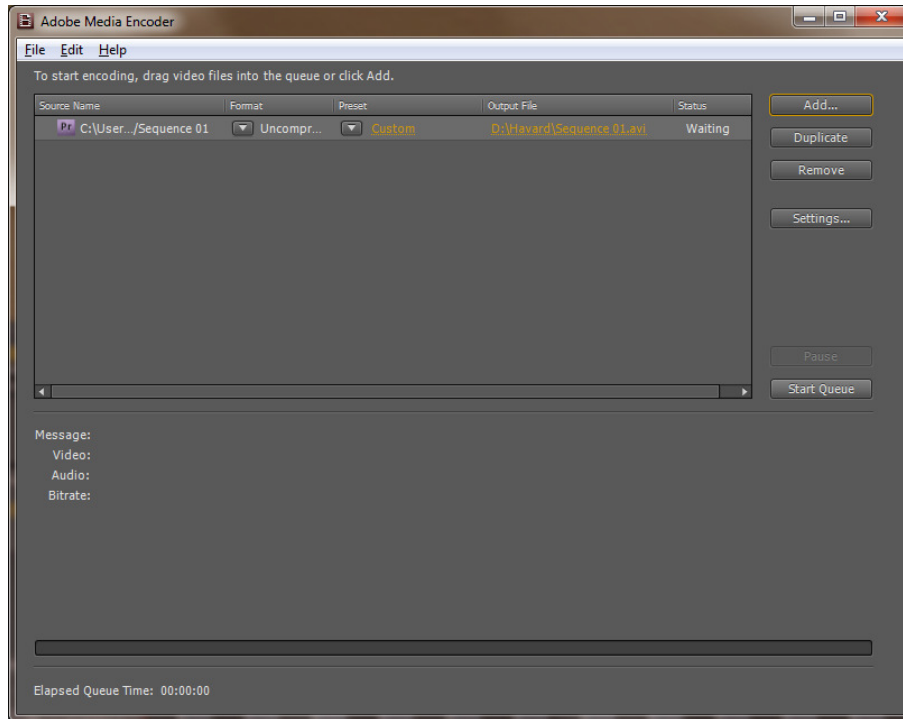
Appendix 5 Figure 11: Choosing video format

In this project I used the Uncompressed Microsoft AVI format. I did not export audio, so that checkbox was unchecked. Video codec was chosen to be UYVY, resolution was set to 1920x1080 and frame rate 29.97. This can be seen below.



Appendix 5 Figure 12: Export settings

After all parameters have been selected click the ‘OK’ button. A new window should now open called the Adobe Media Encoder. When it is done loading click the ‘Start Queue’ button on the right.



Appendix 5 Figure 13: Adobe Media Encoder

The video clip should now be complete. To see the results open the video clip in a media player of your choice.

Appendix 6: Pixel shifting

On the next page you can see large images showing the problem that was introduced when low resolution video material were applied spatial interpolation algorithms. There is a clear indication that the pixels describing the edges of the letter “S” in “Sony” on the static object in the scene have been shifted to the right and up.

In search of a better word this occurrence have been described as “jumping” in the report as it describes well the impression the viewers get when they look at video material where this is a problem.



Appendix 6 Figure 1: Comparison of spatial interpolation algorithms

Appendix 7: Economic model suggestion

This appendix was first meant to be a part of the report itself, but due to time limitations and the amount of work needed to do this economic model justice in regards to explaining it properly with all the economic principles it involves, that was not possible. Instead this appendix will give an overview of the model and I will explain how it could be used in a DMP setting.

Techno-business assessment

The Techno-business assessment (TBA) model is a model suggested by Josip Zoric and Darijus Strasunskas. Josip works at Telenor R&I and Darijus at the Norwegian University of Science and Technology Trondheim, Norway.

Their model is a techno-business assessment approach which is convenient for service platform analysis. It combines the following methodologies for qualitative analysis: modeling, scenarios, mapping and projection techniques, and service and enabler portfolio theory. Scenario based analysis is carried out in four analytical domains: user, business, system and technical. After qualitative analysis it engages in quantitative analysis, based on value flow modeling and valuation.

The model is meant to supplement existing business analyses with a new methodology to value service platforms not just the services. Furthermore the methodology should be apt to provide early business estimates, in parallel with demo / prototype development. [1]

Framework

The framework to techno-business assessment is based on the following aspects [1]:

- Models – to simplify the service platform complexity
- Model-based scenarios – to analyze goals, roles, responsibilities and contributions of various actors and entities
- Mappings – to increase the level of model details when necessary
- Projections – to quantify models and scenarios (e.g. project financial or resource usage)

- Business valuation – to produce scenario-specified value flows (e.g. cash flows)

Four domain models are used in the TBA framework [1]:

1. User model describes services from the end-user perspective
2. Business models conveys a conceptual framework for the business logic
3. System models provides complete details of the services from a system point-of-view
4. Technical model exhibits technology and implementation specifics

Scenarios play an important role in the TBA approach. They are used as analytical tools common for all four domain models, and can be used for “mapping and projecting” models. Scenarios are also convenient for handling complexity of interactions between actors, enablers, services and other service platform entities.

Modeling and simulation

Modeling and simulation of service usage contains the following phases [1]:

- Scenario modeling and mapping
- Simulation of usage of services, enabler and other service platform entities
- Simulation of service provision, resulting in the value (cash) flow profiles
- Value (cash) flow –based analysis and valuation

Modeling representative usage patterns is done by describing scenario stories for all relevant classes of users and then mapping them to message sequence charts (MSCs).

Mapping scenario interaction to services is done by mapping possible alternative solutions that can provide the same service. E.g. it is possible to send an instant message by various solutions depending on the service context (SMS, MMS or e-mail).

Mapping services to enablers is done by using enabler level MSCs that show the different enablers (entities that are needed to realize a service) that are needed for a service.

Mapping enabler-level MSCs to service platform capabilities and resources is then done to find the various possible implementations of a service. These mappings give the possibility to specify interaction sets in such a way that they can be analyzed: qualitatively (including structural, model-based analyses), and quantitatively – with help of various projections (financial, resource) the impact (cost, revenue, resource usage) can be measured.

Mapping enablers to actors is done because each service interaction requires that the set of enablers is performed by various actors. Execution of an enabler requires resources from an actor that assumes this role. Each role can be performed by a set of actors. [1]

These analyses and mappings can then help us answer questions like [1]:

- How will the new functionality contribute to a particular user groups and scenarios?
- How important and sensitive is it for services, and can they be replaced with less advanced cheaper solutions?
- What are estimates of service usage and revenue (as well as their sensitivity) per user group, service and enabler?
- What are financial projections and the value of the whole service platform solution (for the estimated period of 10 years)?

Why this model?

Because this model is highly customizable when it comes to scenarios it can be applied over a wide range of different sectors. By using scenarios this model can be used to:

- Help companies like Microsoft to evaluate as an example if they should continue to develop Windows XP and let users have improved versions of it, or if they should develop and release a new operating system (as they did with Windows Vista) or if they should continue developing XP until they have a new “much better” operating system they can release (e.g. Windows 7).

- It can be used for hardware manufacturers to assess the value of releasing a new hardware solution which is slightly better than what currently exists or if they should wait with releasing something which is a much better solution than what currently exists.

The possibilities are many because of the models four domain perspectives (user, business, system, technical) which all are based on scenarios that can be adapted to fit the need of particular situations.

TBA for DMP

Techno-business assessment can be used on a system like DMP by building different usage scenarios. They could include:

- Different user groups
 - Premium users, pay the most but get the highest guarantee of minimum quality
 - Normal users, pay less but receives a lower minimum quality
 - Free users, do not pay, but receives the lowest guarantee when it comes to minimum quality
- Business perspective could look at different strategies, should we concentrate on selling to few users but at high cost or many users with lower cost? What would give the highest revenue?
- The system and technical parts would give MSCs that describes all enablers that were needed to realize the DMP system and help identify the best / cheapest / most reliable way to realizing the service.

As we can see there are good possibilities to use TBA for DMP, and further researching the TBA model and how to use it in a DMP setting should be done.

References:

- [1] Zoric, J., Strasunskas, D., “*Techno-business assessment of services and service platforms: Quantitative, scenario-based analysis*” 2008. Telenor R&I, Norwegian University of Science and Technology Trondheim, Norway. Retrieved June 10, 2009 from: <http://folk.ntnu.no/dstrasun/articles/ZoricStrasunskas08.pdf>

Appendix 8: Completed forms and questionnaires

This appendix contains the signed “Informasjon og samtykkeserklæring” form found in Appendix 1 and the questionnaires that have been completed for each participant (the questionnaire can be found in Appendix 2).

Appendix 1: Informasjon og samtykkeserklæring

Time-variable scene quality – perception tests

Jeg skriver en masteroppgave om hvordan vi oppfatter tidsvariabel kvalitet av objekter i en scene. Gjennom dette skjemaet vil du hjelpe meg å samle informasjon om hvordan variasjon av kvalitet over korte tidsintervaller blir oppfattet.

Oppgaven gjennomføres på instituttet for telematikk ved NTNU i samarbeid med professor Leif Arne Rønningen.

Prosjektet er basert på frivillig deltagelse, og du kan når som helst underveis trekke deg og be om at data samlet om deg blir slettet uten noen begrunnelse. Du er ikke pliktig til å gjennomføre forsøket, og en eventuell avbryting vil ikke få noen konsekvenser. Dataene som blir samlet inn vil bli behandlet konfidensielt, og kun undertegnede vil ha tilgang til dem. Eventuelle resultater fra undersøkelsen vil bli behandlet anonymt

Undersøkelsen gjennomføres på Carusolaben ved instituttet for telematikk på Gløshaugen og vil ta ca. en halv time. Før selve forsøkene begynner skal du, i tillegg til å svare på noen enkle spørsmål, få se noen videoklipp for å gjøre deg vant til testmiljøet. Under forsøkene vil du få se en rekke videoklipp i varierende kvalitet, som du skal vurdere i forhold til et originalt videoklipp. En mer utfyllende muntlig forklaring får du før forsøket begynner.

Forskningen utføres i henhold til retningslinjer for action research som betyr at jeg vil være den som fyller ut spørreskjemaet, og jeg vil være med å diskutere dine synspunkter slik at jeg bedre kan forstå hva du synes. Jeg vil være tilgjengelig for spørsmål og kommentarer både før, under, og etter gjennomføringen av forsøkene så hvis det er noe du lurer på underveis er det bare å spørre.

Håvard Berge

SAMTYKKEERKLÆRING

Prosjekt tittel: Time-variable scene quality – perception tests

Jeg har lest informasjonen og er villig til å delta i prosjektet.

Trondheim

Sted

18/5-2009

Dato

Harald

Underskrift

Appendix 1: Informasjon og samtykkeserklæring

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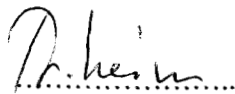
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Håvard Berge

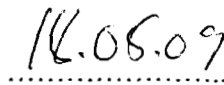
SAMTYKKEERKLÆRING

Prosjekt tittel: Time-variable scene quality – perception tests

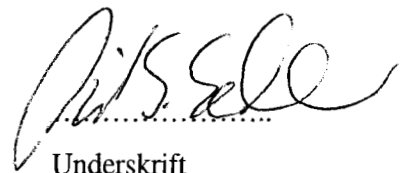
Jeg har lest informasjonen og er villig til å delta i prosjektet.



Sted



Dato



Underskrift

Appendix 1: Informasjon og samtykkeserklæring

Time-variable scene quality – perception tests

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Håvard Berge

SAMTYKKEERKLÆRING

Prosjekt tittel: Time-variable scene quality – perception tests

Jeg har lest informasjonen og er villig til å delta i prosjektet.

TROVDHEIM

Sted

19/5-09

Dato



Underskrift

Appendix 1: Informasjon og samtykkeserklæring

Time-variable scene quality – perception tests

Jeg skriver en masteroppgave om hvordan vi oppfatter tidsvariabel kvalitet av objekter i en scene. Gjennom dette skjemaet vil du hjelpe meg å samle informasjon om hvordan variasjon av kvalitet over korte tidsintervaller blir oppfattet.

Oppgaven gjennomføres på instituttet for telematikk ved NTNU i samarbeid med professor Leif Arne Rønningen.

Prosjektet er basert på frivillig deltagelse, og du kan når som helst underveis trekke deg og be om at data samlet om deg blir slettet uten noen begrunnelse. Du er ikke pliktig til å gjennomføre forsøket, og en eventuell avbryting vil ikke få noen konsekvenser. Dataene som blir samlet inn vil bli behandlet konfidensielt, og kun undertegnede vil ha tilgang til dem. Eventuelle resultater fra undersøkelsen vil bli behandlet anonymt

Undersøkelsen gjennomføres på Carusolaben ved instituttet for telematikk på Gløshaugen og vil ta ca. en halv time. Før selve forsøkene begynner skal du, i tillegg til å svare på noen enkle spørsmål, få se noen videoklipp for å gjøre deg vant til testmiljøet. Under forsøkene vil du få se en rekke videoklipp i varierende kvalitet, som du skal vurdere i forhold til et originalt videoklipp. En mer utfyllende muntlig forklaring får du før forsøket begynner.

Forskningen utføres i henhold til retningslinjer for action research som betyr at jeg vil være den som fyller ut spørreskjemaet, og jeg vil være med å diskutere dine synspunkter slik at jeg bedre kan forstå hva du synes. Jeg vil være tilgjengelig for spørsmål og kommentarer både før, under, og etter gjennomføringen av forsøkene så hvis det er noe du lurer på underveis er det bare å spørre.

Håvard Berge

SAMTYKKEERKLÆRING

Prosjekt tittel: Time-variable scene quality – perception tests

Jeg har lest informasjonen og er villig til å delta i prosjektet.

Trondheim

Sted

27.05.09

Dato

Stein Ør Eriksen

Underskrift

Appendix 1: Informasjon og samtykkeserklæring

Time-variable scene quality – perception tests

Jeg skriver en masteroppgave om hvordan vi oppfatter tidsvariabel kvalitet av objekter i en scene. Gjennom dette skjemaet vil du hjelpe meg å samle informasjon om hvordan variasjon av kvalitet over korte tidsintervaller blir oppfattet.

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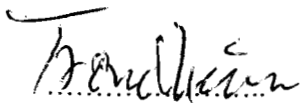
Forskningen utføres i henhold til retningslinjer for action research som betyr at jeg vil være den som fyller ut spørreskjemaet, og jeg vil være med å diskutere dine synspunkter slik at jeg bedre kan forstå hva du synes. Jeg vil være tilgjengelig for spørsmål og kommentarer både før, under, og etter gjennomføringen av forsøkene så hvis det er noe du lurer på underveis er det bare å spørre.

Håvard Berge

SAMTYKKEERKLÆRING

Prosjekt tittel: Time-variable scene quality – perception tests

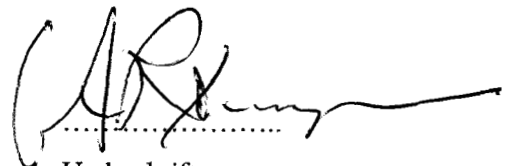
Jeg har lest informasjonen og er villig til å delta i prosjektet.



Sted



Dato



Underskrift

Appendix 2: Questionnaire

Questionnaire

This questionnaire is divided into four parts. The first part should be completed before the experiments are carried out. Part 2 should be completed after the acclimation clips have been shown. Part 3 should be completed when the experiment video clips is shown. The fourth part can be completed after the experiment is completed. During the entire process I will be available for questions if something should be unclear.

Part 1 (complete prior to the experiment)

Age: 62

Gender: Male Female

Occupation: professor

Do you use? Glasses/contact lenses Neither

Are you colorblind? Yes No

Computer habits

Approximately how many hours do you spend in front of a computer every week?

< 5 5 - 10 10 - 15 15 - 20 20 - 25 25 <

What is the size of the monitor you use the most when using a computer (in inches)?

< 15 15 17 19 20 21 22 24 30 30 < Don't know

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

TV habits

Approximately how many hours do you watch TV or movies every week?

< 5 5 - 10 10 - 15 15 - 20 20 - 25 25 <

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

How far away from the TV are you usually sitting (in meters)?

<1 1-2 2-3 3-4 4-5 5-6 6 < 42"

Have you ever watched "High Definition" video material or broadcasts in HDTV format?

(If you do not know cross no)

Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games using specialized glasses?

(If you do not know cross no)

Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games without using specialized glasses?

(If you do not know cross no)

Yes No

Part 2

After looking at the 1920x1080p video clip at 59.94 fps, evaluate the following clips using the video just shown as reference.

The scale given is 1 – 10 where 10 describes a video clip that has the same quality as the reference clip and 1 is a clip where the viewing experience is so severely degraded that it is unwatchable.

If you at any time during the testing process want to watch the reference clip again you can just ask. I will via discussion help evaluate the different video clips so that I better gain an understanding of your views. I will also at times during this test ask you to look for specifics in the video shown. This could e.g. be that I want you to focus on the background and evaluate that compared to the background on the reference clip. By doing this, learning will be a part of the experiment because I direct you to look for specific qualities in the video clip.

7

Clip 1

Video clip 1 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Comments: *again baseline / hopping*
diff before even test 1.

Clip 3

Video clip 3 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Comments: _____

Part 3

This part of the experiment will evaluate the quality of video clips with approximately the same bitrate against each other. The clips will have varying frame patterns and different spatial resolution of their low quality frames.

The different combinations used for video clips are chosen by using the table of different bitrates presented in chapter 2.2.1. The video clips chosen have a bitrate between 705Mbps and 810Mbps and we will try to find out if increased bitrate always increase the quality of the video clip, or if there are intelligent ways of combining frames that increases the quality, as the viewer experiences it, even when using a lower bitrate. All clips will be shown at 59.94 fps.

The scale in this experiment is -3 to 3 where 0 indicates same as the reference, a negative value indicates that the video clip is worse than the reference and a positive value indicates that it is better than the reference.

The reference video clip for this part is shown with a 1 – 2 frame drop pattern which showed to be the best combination during the first experiment with a quality drop of 55.56% which gives the low resolution frames for this video clip a resolution of 720p (1280x720).

Clip 1

Video clip 1 is shown with 75% reduction in spatial resolution 25% of the time using a cyclic 1 – 1 – 1 – 2 frame pattern (Three original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown with 71.56% reduction in spatial resolution 33.33% of the time using a cyclic 1 – 1 – 2 frame pattern (Two original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown with 43.75% reduction in spatial resolution 66.67% of the time using a cyclic 1 – 2 – 2 frame pattern (One original quality frame will be followed by two frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown with 30.56% reduction in spatial resolution 75% of the time using a cyclic 1 – 2 – 2 – 2 frame pattern (One original quality frame will be followed by three frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Appendix 2: Questionnaire

Questionnaire

This questionnaire is divided into four parts. The first part should be completed before the experiments are carried out. Part 2 should be completed after the acclimation clips have been shown. Part 3 should be completed when the experiment video clips is shown. The fourth part can be completed after the experiment is completed. During the entire process I will be available for questions if something should be unclear.

Part 1 (complete prior to the experiment)

Age: 28

Gender: Male Female

Occupation: STUDENT

Do you use? Glasses/contact lenses Neither

Are you colorblind? Yes No

Computer habits

Approximately how many hours do you spend in front of a computer every week?

<5 5-10 10-15 15-20 20-25 25 <

What is the size of the monitor you use the most when using a computer (in inches)?

<15 15 17 19 20 21 22 24 30 30 < Don't know

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

TV habits

Approximately how many hours do you watch TV or movies every week?

<5 5-10 10-15 15-20 20-25 25 <

Screen format:

(If you use both types approximately the same check both boxes)

- Normal (4:3) Widescreen Don't know

How far away from the TV are you usually sitting (in meters)?

- <1 1-2 2-3 3-4 4-5 5-6 6<

37"

Have you ever watched "High Definition" video material or broadcasts in HDTV format?

(If you do not know cross no)

- Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games using specialized glasses?

(If you do not know cross no)

- Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games without using specialized glasses?

(If you do not know cross no)

- Yes No

Part 2

After looking at the 1920x1080p video clip at 59.94 fps, evaluate the following clips using the video just shown as reference.

The scale given is 1 – 10 where 10 describes a video clip that has the same quality as the reference clip and 1 is a clip where the viewing experience is so severely degraded that it is unwatchable.

If you at any time during the testing process want to watch the reference clip again you can just ask. I will via discussion help evaluate the different video clips so that I better gain an understanding of your views. I will also at times during this test ask you to look for specifics in the video shown. This could e.g. be that I want you to focus on the background and evaluate that compared to the background on the reference clip. By doing this, learning will be a part of the experiment because I direct you to look for specific qualities in the video clip.

2

Clip 1

Video clip 1 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: *sup. støy bil det vinter*
st. obj: mye støy vinter, ser piksler
D. obj: var frame rate, ikke lett å se piksler

Clip 2

Video clip 2 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: *over: dataløsning som reduserer inntrykket*
Back: mindre "vinsting"
st. obj: mye vinter, piksler
D. obj: litt mindre støy

Clip 3

Video clip 3 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: Start with summer scene 60fps 4:2:2

Adaptation are missing

Clip 4

Video clip 4 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: Rate: var., rather low sample

St. Obj: more pixels, with missing, more noise, more motion

Dyn Obj: ca. same, some background

Part 3

This part of the experiment will evaluate the quality of video clips with approximately the same bitrate against each other. The clips will have varying frame patterns and different spatial resolution of their low quality frames.

The different combinations used for video clips are chosen by using the table of different bitrates presented in chapter 2.2.1. The video clips chosen have a bitrate between 705Mbps and 810Mbps and we will try to find out if increased bitrate always increase the quality of the video clip, or if there are intelligent ways of combining frames that increases the quality, as the viewer experiences it, even when using a lower bitrate. All clips will be shown at 59.94 fps.

The scale in this experiment is -3 to 3 where 0 indicates same as the reference, a negative value indicates that the video clip is worse than the reference and a positive value indicates that it is better than the reference.

The reference video clip for this part is shown with a 1 - 2 frame drop pattern which showed to be the best combination during the first experiment with a quality drop of 55.56% which gives the low resolution frames for this video clip a resolution of 720p (1280x720).

Clip 1

Video clip 1 is shown with 75% reduction in spatial resolution 25% of the time using a cyclic 1 - 1 - 2 frame pattern (Three original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: *over step done pikasler*
back: over step
step: over skjelving

Clip 2

Video clip 2 is shown with 71.56% reduction in spatial resolution 33.33% of the time using a cyclic 1 - 1 - 2 frame pattern (Two original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: *litt verd. p. 7*
Bakgrunn: *stort sett samme*
st. obj. *varer litt, spesielt bakgrunn med tekst / sang etc.*
d. obj. *ekskl. tekst*

Clip 3

Video clip 3 is shown with 43.75% reduction in spatial resolution 66.67% of the time using a cyclic 1 - 2 - 2 frame pattern (One original quality frame will be followed by two frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: *gen. litt forskj. siden statisk obj er en bit uskyldig til av bildet*
Bak: *stør stikke, litt bedre*
st: *mer kognitive*
d:

Clip 4

Video clip 4 is shown with 30.56% reduction in spatial resolution 75% of the time using a cyclic 1-2-2-2 frame pattern (One original quality frame will be followed by three frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Appendix 2: Questionnaire

Questionnaire

This questionnaire is divided into four parts. The first part should be completed before the experiments are carried out. Part 2 should be completed after the acclimation clips have been shown. Part 3 should be completed when the experiment video clips is shown. The fourth part can be completed after the experiment is completed. During the entire process I will be available for questions if something should be unclear.

Part 1 (complete prior to the experiment)

Age: 29

Gender: Male Female

Occupation: Research and Edu. advisor

Do you use? Glasses/contact lenses Neither

Are you colorblind? Yes No

Computer habits

Approximately how many hours do you spend in front of a computer every week?

< 5 5 - 10 10 - 15 15 - 20 20 - 25 25 <

What is the size of the monitor you use the most when using a computer (in inches)?

< 15 15 17 19 20 21 22 24 30 30 < Don't know

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

TV habits

Approximately how many hours do you watch TV or movies every week?

< 5 5 - 10 10 - 15 15 - 20 20 - 25 25 <

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

How far away from the TV are you usually sitting (in meters)?

< 1 1 - 2 2 - 3 3 - 4 4 - 5 5 - 6 6 < 32"

Have you ever watched "High Definition" video material or broadcasts in HDTV format?

(If you do not know cross no)

Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games using specialized glasses?

(If you do not know cross no)

Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games without using specialized glasses?

(If you do not know cross no)

Yes No

Part 2

After looking at the 1920x1080p video clip at 59.94 fps, evaluate the following clips using the video just shown as reference.

The scale given is 1 – 10 where 10 describes a video clip that has the same quality as the reference clip and 1 is a clip where the viewing experience is so severely degraded that it is unwatchable.

If you at any time during the testing process want to watch the reference clip again you can just ask. I will via discussion help evaluate the different video clips so that I better gain an understanding of your views. I will also at times during this test ask you to look for specifics in the video shown. This could e.g. be that I want you to focus on the background and evaluate that compared to the background on the reference clip. By doing this, learning will be a part of the experiment because I direct you to look for specific qualities in the video clip.

3

Clip 1

Video clip 1 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 1 – 2 – 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 1 – 2 – 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Comments: _____

Part 3

This part of the experiment will evaluate the quality of video clips with approximately the same bitrate against each other. The clips will have varying frame patterns and different spatial resolution of their low quality frames.

The different combinations used for video clips are chosen by using the table of different bitrates presented in chapter 2.2.1. The video clips chosen have a bitrate between 705Mbps and 810Mbps and we will try to find out if increased bitrate always increase the quality of the video clip, or if there are intelligent ways of combining frames that increases the quality, as the viewer experiences it, even when using a lower bitrate. All clips will be shown at 59.94 fps.

The scale in this experiment is -3 to 3 where 0 indicates same as the reference, a negative value indicates that the video clip is worse than the reference and a positive value indicates that it is better than the reference.

The reference video clip for this part is shown with a 1 – 2 frame drop pattern which showed to be the best combination during the first experiment with a quality drop of 55.56% which gives the low resolution frames for this video clip a resolution of 720p (1280x720).

Clip 1

Video clip 1 is shown with 75% reduction in spatial resolution 25% of the time using a cyclic 1 – 1 – 1 – 2 frame pattern (Three original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown with 71.56% reduction in spatial resolution 33.33% of the time using a cyclic 1 – 1 – 2 frame pattern (Two original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown with 43.75% reduction in spatial resolution 66.67% of the time using a cyclic 1 – 2 – 2 frame pattern (One original quality frame will be followed by two frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown with 30.56% reduction in spatial resolution 75% of the time using a cyclic 1 – 2 – 2 – 2 frame pattern (One original quality frame will be followed by three frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Appendix 2: Questionnaire

Questionnaire

This questionnaire is divided into four parts. The first part should be completed before the experiments are carried out. Part 2 should be completed after the acclimation clips have been shown. Part 3 should be completed when the experiment video clips is shown. The fourth part can be completed after the experiment is completed. During the entire process I will be available for questions if something should be unclear.



Part 1 (complete prior to the experiment)

Age: 26

Gender: Male Female

Occupation: student

Do you use? Glasses/contact lenses ^{lenses} Neither

Are you colorblind? Yes No

Computer habits

Approximately how many hours do you spend in front of a computer every week?

< 5 5 - 10 10 - 15 15 - 20 20 - 25 25 <

What is the size of the monitor you use the most when using a computer (in inches)?

< 15 15 17 19 20 21 22 24 30 30 < Don't know

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

TV habits

Approximately how many hours do you watch TV or movies every week?

< 5 5 - 10 10 - 15 15 - 20 20 - 25 25 <

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

How far away from the TV are you usually sitting (in meters)?

< 1 1 - 2 2 - 3 3 - 4 4 - 5 5 - 6 6 < 32"

Have you ever watched "High Definition" video material or broadcasts in HDTV format?

(If you do not know cross no)

Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games using specialized glasses?

(If you do not know cross no)

Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games without using specialized glasses?

(If you do not know cross no)

Yes No

Part 2

After looking at the 1920x1080p video clip at 59.94 fps, evaluate the following clips using the video just shown as reference.

The scale given is 1 – 10 where 10 describes a video clip that has the same quality as the reference clip and 1 is a clip where the viewing experience is so severely degraded that it is unwatchable.

If you at any time during the testing process want to watch the reference clip again you can just ask. I will via discussion help evaluate the different video clips so that I better gain an understanding of your views. I will also at times during this test ask you to look for specifics in the video shown. This could e.g. be that I want you to focus on the background and evaluate that compared to the background on the reference clip. By doing this, learning will be a part of the experiment because I direct you to look for specific qualities in the video clip.

4

Clip 1

Video clip 1 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____
_____ *rusting - static* _____

Clip 2

Video clip 2 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Comments: _____

Part 3

This part of the experiment will evaluate the quality of video clips with approximately the same bitrate against each other. The clips will have varying frame patterns and different spatial resolution of their low quality frames.

The different combinations used for video clips are chosen by using the table of different bitrates presented in chapter 2.2.1. The video clips chosen have a bitrate between 705Mbps and 810Mbps and we will try to find out if increased bitrate always increase the quality of the video clip, or if there are intelligent ways of combining frames that increases the quality, as the viewer experiences it, even when using a lower bitrate. All clips will be shown at 59.94 fps.

The scale in this experiment is -3 to 3 where 0 indicates same as the reference, a negative value indicates that the video clip is worse than the reference and a positive value indicates that it is better than the reference.

The reference video clip for this part is shown with a 1 – 2 frame drop pattern which showed to be the best combination during the first experiment with a quality drop of 55.56% which gives the low resolution frames for this video clip a resolution of 720p (1280x720).

Clip 1

Video clip 1 is shown with 75% reduction in spatial resolution 25% of the time using a cyclic 1 – 1 – 1 – 2 frame pattern (Three original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown with 71.56% reduction in spatial resolution 33.33% of the time using a cyclic 1 – 1 – 2 frame pattern (Two original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown with 43.75% reduction in spatial resolution 66.67% of the time using a cyclic 1 – 2 – 2 frame pattern (One original quality frame will be followed by two frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown with 30.56% reduction in spatial resolution 75% of the time using a cyclic 1 - 2 - 2 - 2 frame pattern (One original quality frame will be followed by three frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____



Appendix 2: Questionnaire

Questionnaire

This questionnaire is divided into four parts. The first part should be completed before the experiments are carried out. Part 2 should be completed after the acclimation clips have been shown. Part 3 should be completed when the experiment video clips is shown. The fourth part can be completed after the experiment is completed. During the entire process I will be available for questions if something should be unclear.

Part 1 (complete prior to the experiment)

Age: 30

Gender: Male Female

Occupation: IT

Do you use? Glasses/contact lenses Neither

Are you colorblind? Yes No

Computer habits

Approximately how many hours do you spend in front of a computer every week?

<5 5-10 10-15 15-20 20-25 25 <

What is the size of the monitor you use the most when using a computer (in inches)?

<15 15 17 19 20 21 22 24 30 30 < Don't know

Screen format:

(If you use both types approximately the same check both boxes)

Normal (4:3) Widescreen Don't know

TV habits

Approximately how many hours do you watch TV or movies every week?

<5 5-10 10-15 15-20 20-25 25 <

Screen format:

(If you use both types approximately the same check both boxes)

- Normal (4:3) Widescreen Don't know

How far away from the TV are you usually sitting (in meters)?

- <1 1-2 2-3 3-4 4-5 5-6 6 < 46"

Have you ever watched "High Definition" video material or broadcasts in HDTV format?

(If you do not know cross no)

- Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games using specialized glasses?

(If you do not know cross no)

- Yes No

Have you ever watched stereoscopic (three-dimensional) images/video/games without using specialized glasses?

(If you do not know cross no)

- Yes No

Part 2

After looking at the 1920x1080p video clip at 59.94 fps, evaluate the following clips using the video just shown as reference.

The scale given is 1 – 10 where 10 describes a video clip that has the same quality as the reference clip and 1 is a clip where the viewing experience is so severely degraded that it is unwatchable.

If you at any time during the testing process want to watch the reference clip again you can just ask. I will via discussion help evaluate the different video clips so that I better gain an understanding of your views. I will also at times during this test ask you to look for specifics in the video shown. This could e.g. be that I want you to focus on the background and evaluate that compared to the background on the reference clip. By doing this, learning will be a part of the experiment because I direct you to look for specific qualities in the video clip.

5

Clip 1

Video clip 1 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: gen: ikke bra
bak: steg man ikke så ofte
st: det mest pålekkende
d: for så spes

Clip 2

Video clip 2 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 - 1 - 2 - 2 frame pattern (Two original quality frames will be followed by two frames of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: Bedre generelt
Bak: litt mindre hopping
st: peker mer mindre hopping
d: ganske bra, jevn bevegelse

Clip 3

Video clip 3 is shown at 29.97 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: ganska bra
bak: lite hoppning
st: mindre hoppning
dt: så fps

Clip 4

Video clip 4 is shown at 59.94 fps with 75% reduction in spatial resolution 50% of the time using a cyclic 1 – 2 frame pattern (One original quality frame will be followed by one frame of lower quality and this will be repeated over and over)

	1	2	3	4	5	6	7	8	9	10
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Comments: Bra, så bra
Bak: väster lika bra, som originalen
st: ganska bra en del pikseler, mycket mindre hoppning
dt: väster, lika bra, varken så bra
teket.

Part 3

This part of the experiment will evaluate the quality of video clips with approximately the same bitrate against each other. The clips will have varying frame patterns and different spatial resolution of their low quality frames.

The different combinations used for video clips are chosen by using the table of different bitrates presented in chapter 2.2.1. The video clips chosen have a bitrate between 705Mbps and 810Mbps and we will try to find out if increased bitrate always increase the quality of the video clip, or if there are intelligent ways of combining frames that increases the quality, as the viewer experiences it, even when using a lower bitrate. All clips will be shown at 59.94 fps.

The scale in this experiment is -3 to 3 where 0 indicates same as the reference, a negative value indicates that the video clip is worse than the reference and a positive value indicates that it is better than the reference.

The reference video clip for this part is shown with a 1 – 2 frame drop pattern which showed to be the best combination during the first experiment with a quality drop of 55.56% which gives the low resolution frames for this video clip a resolution of 720p (1280x720).

Clip 1

Video clip 1 is shown with 75% reduction in spatial resolution 25% of the time using a cyclic 1 – 1 – 1 – 2 frame pattern (Three original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 2

Video clip 2 is shown with 71.56% reduction in spatial resolution 33.33% of the time using a cyclic 1 – 1 – 2 frame pattern (Two original quality frames will be followed by one frame of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 3

Video clip 3 is shown with 43.75% reduction in spatial resolution 66.67% of the time using a cyclic 1 – 2 – 2 frame pattern (One original quality frame will be followed by two frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

Clip 4

Video clip 4 is shown with 30.56% reduction in spatial resolution 75% of the time using a cyclic 1-2-2-2 frame pattern (One original quality frame will be followed by three frames of lower quality and this will be repeated over and over)

	-3	-2	-1	0	1	2	3
General impression:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Background:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Static objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dynamic objects:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments: _____

