Gjøvik University College

Bachelor Project 2010

Research of Short Range Scanner's Accuracy in Different Conditions

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1.Introduction

1.1.Background

This Bachelor thesis is the final project of 4 years Bachelor in Geodesy. It is called 'Research of Short Range Scanner's Accuracy in Different Conditions'.

Laser scanning is a process of surveying which is becoming more and more popular each year. This method is used by surveyors, geodesists, civil engineers, architects, archaeologists and others. Using scanned data we can make topographic, detail, cadastral and other engineering plans and models. It is still quite new way of measuring, so there is no so much information about it, like about older ones. For this reason more researches should be done.

In scanning, like in all surveying processes, the accuracy has a very important role. For engineer who uses laser scanner it is necessary to know how instrument reacts to specific environment and which settings are better in particular situations. In this project I used laser scanner and did several different experiments to find out how different conditions can influence the accuracy.

1.2.Task

The task of this project was to make as many scans as necessary to find out if accuracy of measurements varies due to different colours of scanned surfaces and due to different resolutions.

1.3.Aim of the Project

The aim of this project is to learn laser scanning technology and to find out how accuracy differs due to different conditions.

2.Theoretical Part

2.1.Laser Scanning

Laser scanning is a method of measuring which is becoming more and more popular in recent years. There are two types of laser scanning: airborne and terrestrial. In this project I was working with terrestrial laser scanner.

The purpose of laser scanning is to find out 3D coordinates of the object. Scanner does that by measuring distance to the object. Usually in construction of scanners' there is used pulse laser distance meter. In the measuring process pulses go through mirrors scheme, where laser beam breaks. The most common is a scheme of two rotary mirrors: one mirror controls movements of vertical beam and other one – of horizontal beam. Laser scanner works very fast – thousands of measurements per one second. Result of this process is thousands of points with known 3D coordinates. Sets of these points are called point clouds. Amount of points in point cloud varies from hundred thousands and can reach even few millions. [1][2]

After scanning point clouds are connected together in software. To do that, before scanning we need to place some targets in scanned area, which are used in connection process. When this is done, software allows make models. [1]

2.2.Equipment and Software

The main instrument in my project was short range laser scanner *Leica HDS4500* (Figure 1). [3]

Figure 1. *Leica HDS4500*

This scanner works phase – based technology principle (Figure 2). Phase difference is measured between the reflected beam and the transmitted amplitude modulated continuous wave laser beam. The target distance is proportional to the phase difference and the wave length of the amplitude modulated signal. The amplitude of the reflected beam provides the reflected power as well. [4]

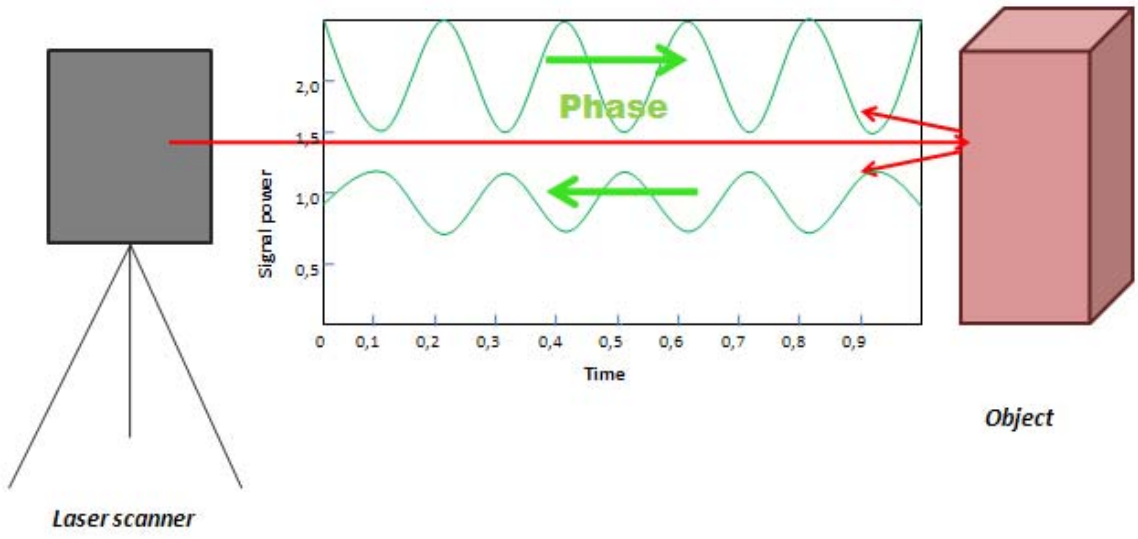

Figure 2. *Principle of phase – based technology*

Leica HDS4500 gives the most optimal effect when scanning is done from 1m distance to 25m. Information about instrument's parameters is given in Appendix 1. [3]

Software *Cyclone 7.0* ™ is used for controlling scanner and processing data. Laser scanner by itself has only turn on/off and turn laser on/off functions. All set up before scanning is done in *Cyclone* ™. Afterwards processing data, registration, modelling, etc. is done in *Cyclone* ™ as well, in *ModelSpace* viewer. Specifications of software *Cyclone 7.0* ™ is given in Appendix 2. [3]

3.Practical Implementation

3.1.Learning System and Software

Before starting implementation of my task, I had to learn how laser scanner *Leica HDS4500* and software *Cyclone* ™ works. In the beginning I read theory that I would understand main principles of scanning system. After that, I started to explore laser scanner and software. The main and most useful material was HIG students' report. I was following their instructions and doing similar tasks.

I started practical work by placing 14 *Leica HDS* targets (Figure 3) on the walls in room B213. I put one target near the floor, next one near the ceiling and so on.

***Figure 3**. Leica HDS Black and White target*

Then I made scans from 4 different stations. I scanned with low resolution and then acquired targets. Scanning with highest resolution takes much more time, so I did not choose this resolution. To acquire target, you need to pick middle point of it (Figure 4) and then choose command *Acquire Targets* (Figure 5).

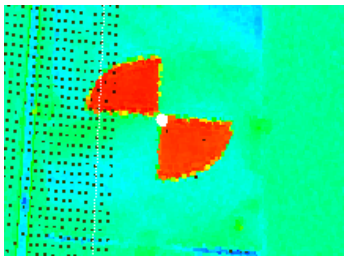

***Figure 4.** Picked middle point*

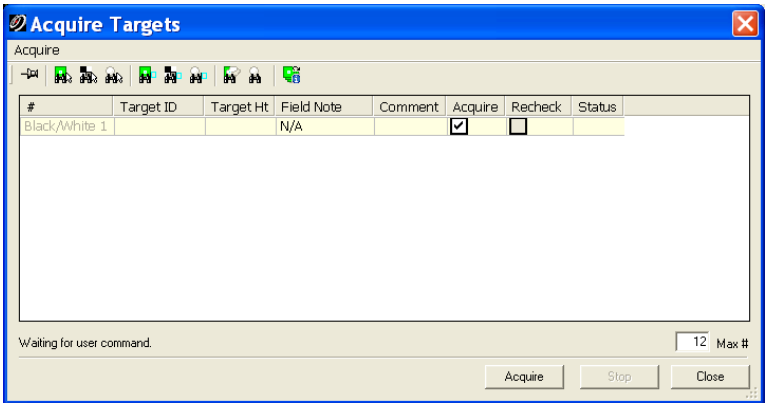

***Figure 5.** Acquire targets table*

Next step before modelling is registration of scans from different stations. In *Cyclone Navigator* we have to choose *Registration*. Here we add scans, which have to have at least three common targets. If registration is done successfully, we have view, which is given in Figure 6.

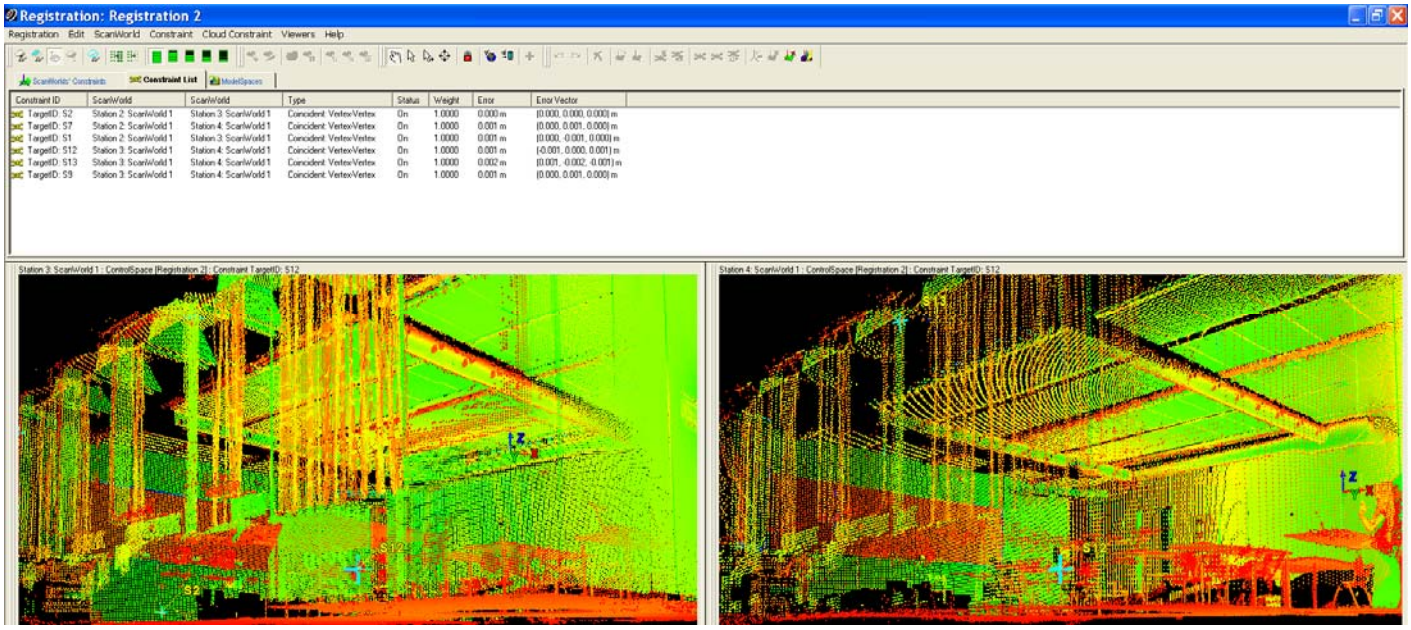

Figure 6. *Registration*

Registration also gives errors of targets, because all of them have to be scanned at least from two different stations.

Now in *ModelSpace* we can make 3D models. Example of 3D model of B213 is given in Figure 7. More pictures are given in Appendix 3.

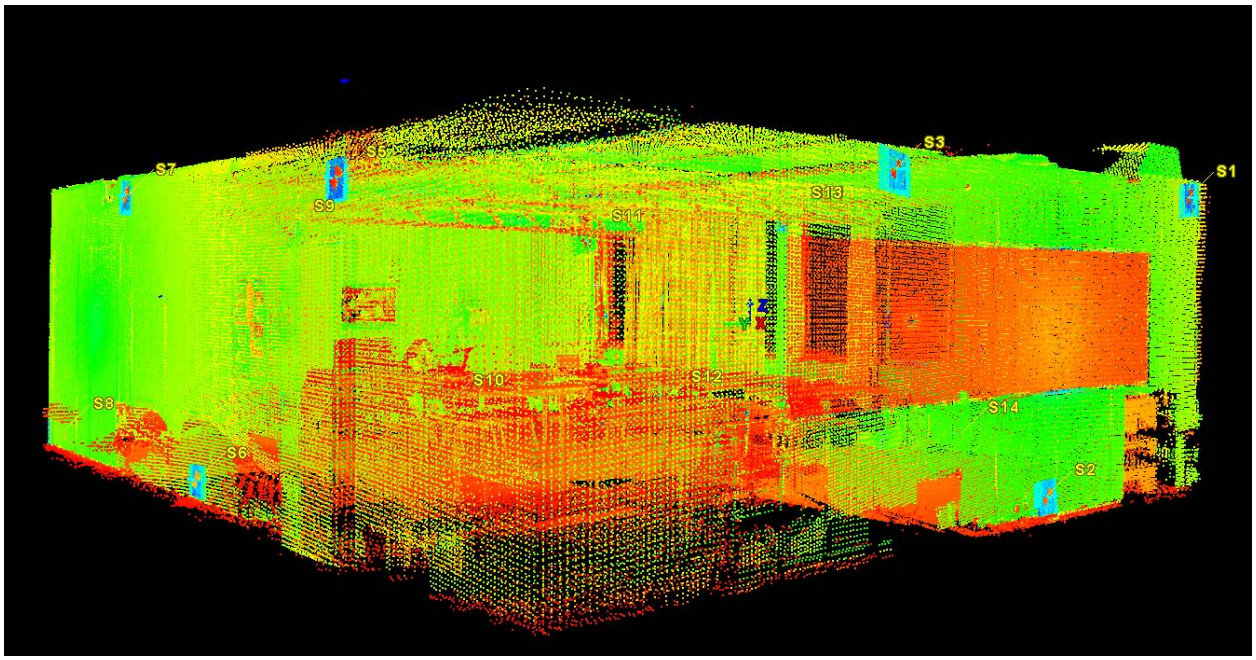

Figure 7. *3D model of B213*

This is a very simple model of the room. Normally scanned data should be cleaned (removed all unnecessary things, like people, chairs, computers, etc.). Also in *Cyclone ModelSpace* it is possible to change colours. Scanned data consists mostly of green and red colours, but we can add real objects' colours.

I did not do full 3D model, because of the lack of time. My task was to find out how accuracy varies due to different conditions, and to learn how to make real and full models would take too much time.

3.2.Experiment with Different Colours

One of my experiments in this project was to scan wall with different colours posters placed on it and to find out how accuracy differs due to colour of scanned surface.

I started this task by choosing colours and making posters. I decided to explore all rainbow colours and black and white in addition to them. I made posters and placed them on the wall. That this experiment would be as accurate as possible, I placed only one poster on the wall at one time and later I placed others on the same place (Figure 8).

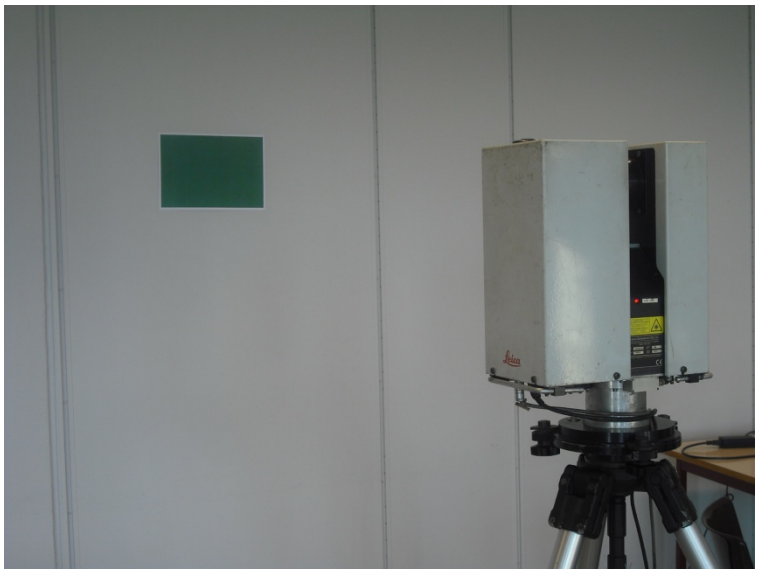

Figure 8. Preparing for scanning

When I started to scan, first I made low resolution preview off all the room (Figure 9). After this was done, I could easily find there exactly is the poster. The field of view in Cyclone is divided into small windows 10^0x10^0. I chose to scan with the highest resolution only two windows where the poster was (Figure 10).

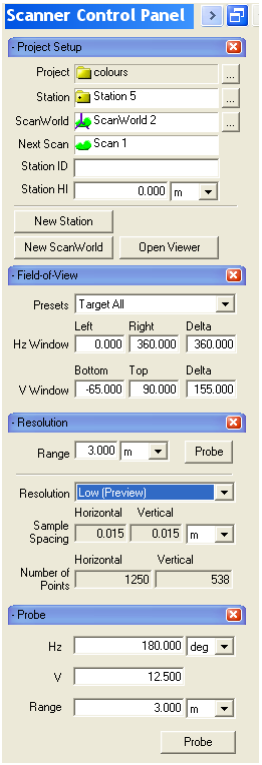

***Figure 9**. Preview settings*

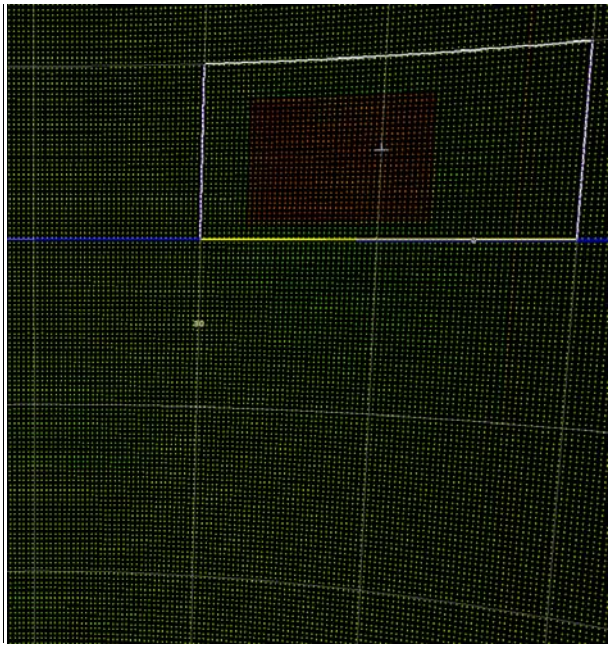

***Figure 10**. Customised scan in Cyclone*

All data I saved in *ModelSpace* (Figure 11).

After scanning white, red, orange and yellow posters, I realised that scanner almost doesn't recognise these colours on white wall. For solving this problem I made a bigger black poster, placed it on the wall and then placed colourful poster on the black one (Figure 12). Like that difference between colours was visible on the scan (Figure 13).

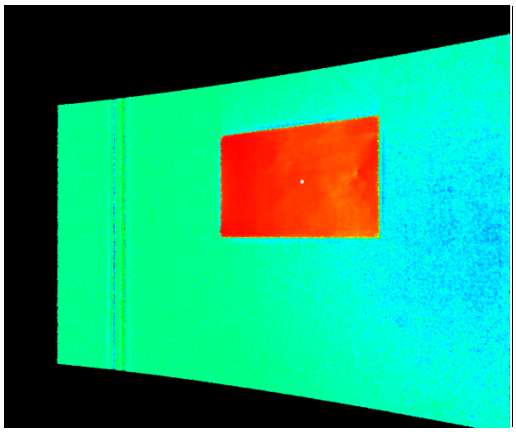

Figure 11. *View of scanned poster in ModelSpace*

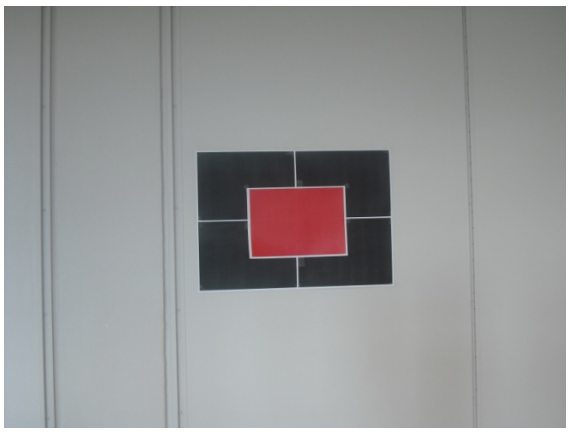

Figure 12*. Red poster placed on the black one*

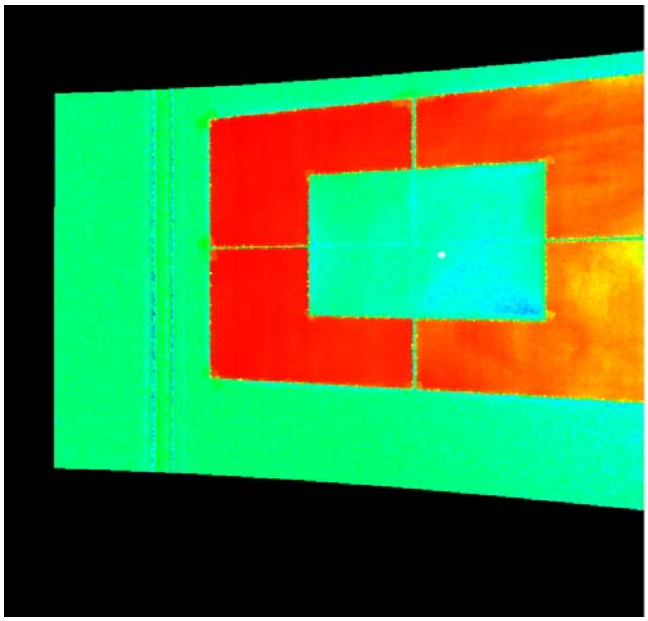

Figure 13. *Scan of orange poster placed on the black one*

When all scans were done, I thought that different colours of background might have influence on number of points. In this case my test how scanner reacts to different colours would be not accurate. So I decided to use *Cyclone ModelSpace* command *Fence*  . This command allows cut a part of scan. I cut only part of the poster in all scans (Figure 14).

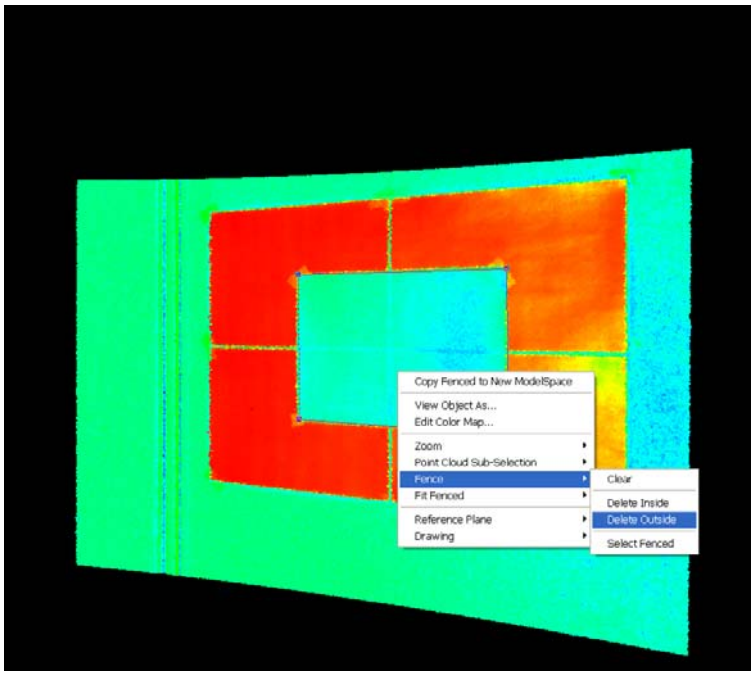

***Figure 14**. Cutting a figure of a poster*

After cutting I checked information about the object (Figure 15).

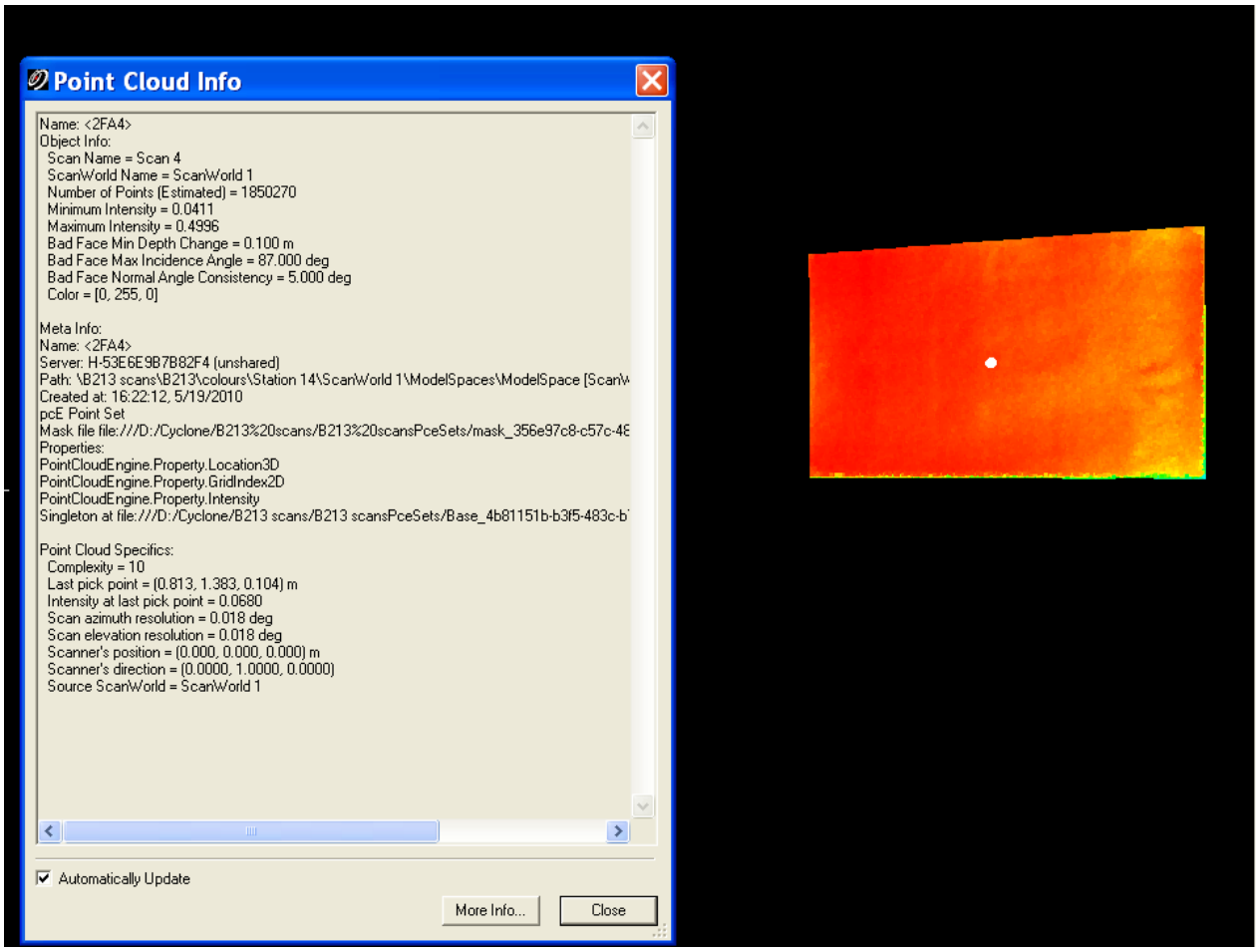

***Figure 15**. Information about light blue poster's point cloud*

I collected number of points data from all 9 scans and put them in ascending order (Table 1).

Colour	Number of points
White	1754451
Orange	1758549
Yellow	1759767
Red	1763283
Black	1831928
Blue	1848000
Green	1849574
Light blue	1850270
Violet	1857256

***Table 1**. Number of points in different colours point clouds*

Graphically these point differences are shown in Figure 16.

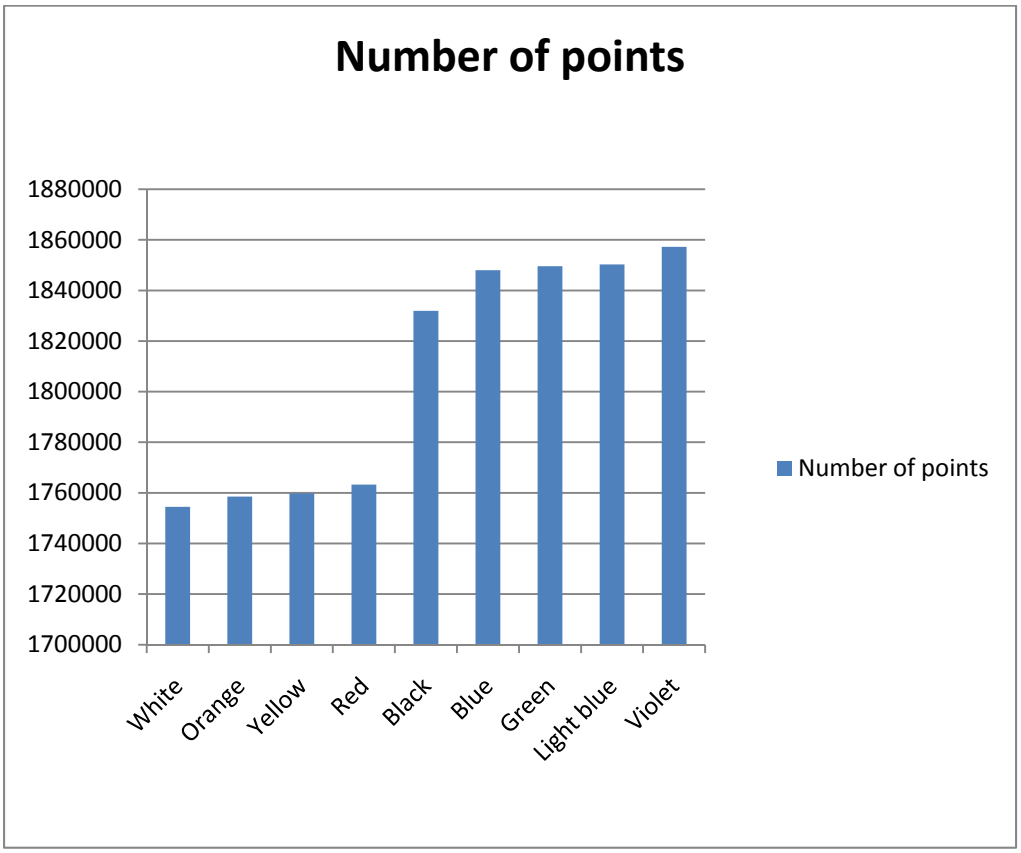

***Figure 16**. Number of points depending on colour*

As we can see from the table and the chart, scanner works better with darker colours. Black, blue, light blue, green and violet colours have about 1oo thousand more points in a point cloud to compare with white, orange, yellow and red.

3.3.Experiment with different resolutions

There are four different resolutions in *Cyclone* ™ for scanning. Surveyor can choose Low, Medium, High and Highest resolution. Low resolution is used for preview. This scan is done very fast, but not accurate. Point clouds consist from much less points (about 500 000-800 000) than higher resolution point clouds.

For 3D modelling in *Cyclone* ™ we have to have targets which we use for connecting several scans together. For registration targets have to be scanned very accurate. To do that we use a command in *Cyclone* ™ called *Acquire targets*.

3.3.1.Experiment measuring coordinates

I scanned with low resolution to get a scan off all the room and then I picked a part with a target which I wanted to scan. For my experiment I used one target and I scanned it with medium, high and highest resolutions and from different distances. I picked a target in room B213 and scanned it approximately from 2, 4, 6 and 8 meters distances. Example of information which I got after acquiring scanned target is shown in Figure 17.

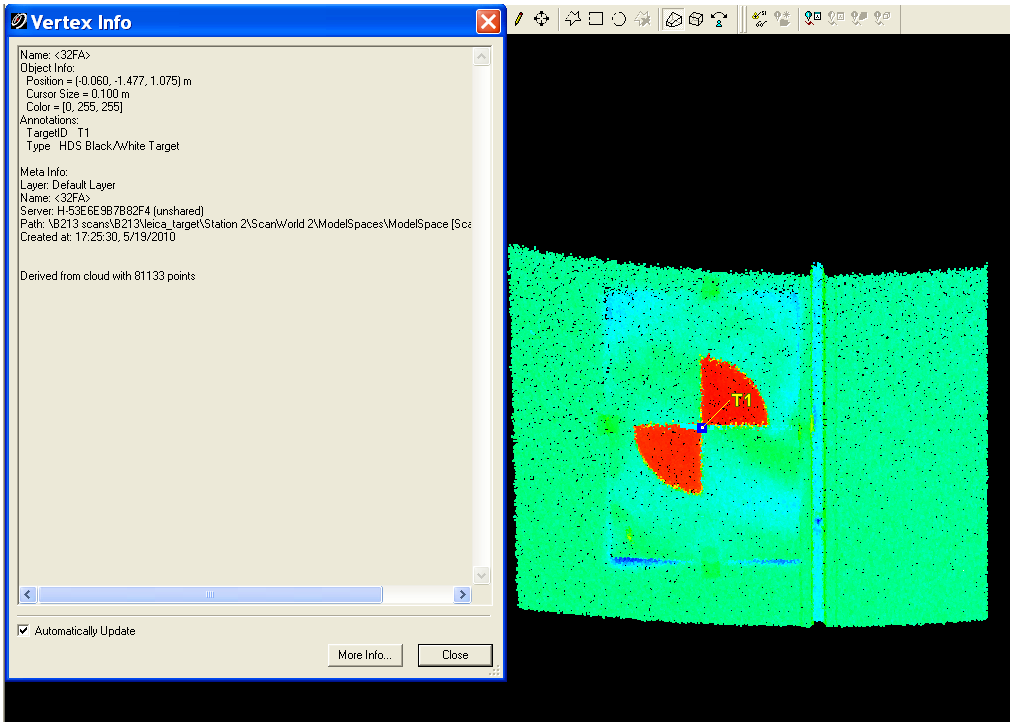

Figure 17. *Target's information (scanned with high resolution)*

After scanning from 4 stations, I had 12 different scans. I picked information about coordinates and put it in tables, that it would be easier to compare. In the example (Table 2) I show results of Station 4. All 4 stations' tables are given in Appendix 4.

Station 4 (8.347m distance)

Resolution	***X***	***Y***	***Z***
Medium	-0.527	-8.330	1.056
High	-0.528	-8.331	1.061
Highest	-0.528	-8.331	1.063
Average	***-0.528***	***-8.331***	***1.060***

Table 2. *Coordinates of target scanned from Station 4*

Data shows that coordinates stay almost the same, doesn't matter with which resolution scanning was done. On the other hand, when distance is becoming bigger, differences are increasing as well, even though they are really small. So I decided to continue experiment with longer distances. There was no possibility to scan from bigger distances in room B213, so I pursued experiment in the basement. I placed new target on the wall and scanned from approximately 5, 10, 15, 20, 25 and 30m distances. Results of coordinates measured from Station 10 are shown in Table 3. All results are given in Appendix 5.

Station 10 (28.652m)

Resolution	***X***	***Y***	***Z***
Medium	12.540	-25.760	0.473
High	12.541	-25.761	0.491
Highest	12.541	-25.763	0.473
Average	***12.541***	***-25.761***	***0.479***

Table 3. *Coordinates of target scanned from Station 10*

After analyzing results I came to conclusion that coordinates' differences are increasing when distances are becoming bigger. I could compare only coordinates which I got after three resolutions scanning, because *Leica HDS4500* uses own coordinate system. This scanner calculates coordinates from different point than it calculates horizontal distance. I found out that because I saw that Y coordinate is not the same as horizontal distance. I couldn't find any information in *Leica Geosystems* website about this, but it might be that when instrument measures coordinates, it calculates distance from the centre of laser (and possibly from the centre of laser scanner), but it measures horizontal distance from the edge of scanner.

After comparing coordinates of three different resolutions scans, I could see that high and highest resolutions scans are more similar to each other than medium resolution scan. Even though I did not compare them with more accurate measured coordinates (for example with total station), it is clear that high and highest resolution measures coordinates better than medium does, because before acquiring targets it is easier to pick middle point, there is more precise view of a target and point clouds consists of more points.

Bigger differences (1-2cm) appear when it is scanned from 25 and more meters distances. When a distance is smaller, differences reach only few millimetres. After this experiment it comes that it is not necessary to scan with highest resolution if it is done from not very big distance, because the results of coordinates are the same, like scanned with medium resolution. Medium resolution scanning takes much less time than highest does, so this is very practical for saving time issues. Although, if scanning is done from bigger than 20-25m distance and measurements of coordinates are required to be as precise as possible, it is better to use highest resolution.

3.3.2.Experiment measuring horizontal distances

As *Leica HDS4500* measures coordinates and distance from different point, I decided to check how much influence resolution has for horizontal distance's accuracy. I used the same scans like in the experiment before, just collected different data (horizontal distances) from *Output* table (Figure 18).

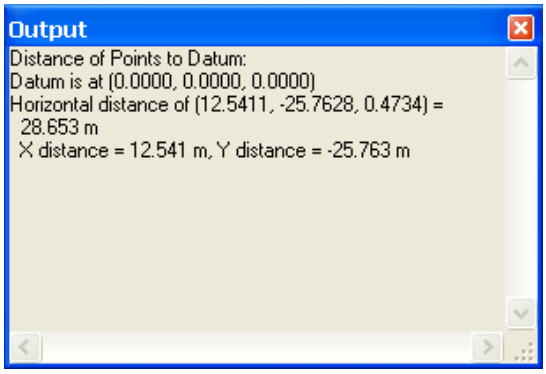

Figure 18. *Point distance table*

The biggest difference in this experiment was 3mm, when scanning was done from almost 30m distance, so if we need to find horizontal distance from scanning, it is better to use medium resolution and save time. Tables with horizontal distances are given in Appendix 6.

3.4. Difficulties

While working on this project, I met several difficulties. The most usual one was connection problems between laser scanner and laptop. Connection cable of scanner is not USB. It is a small plug, which hardly keeps the cable stable (Figure 19, Figure 20).

Figure 19. *Laser Scanner's plug*

Figure 20*. Laptop's plug in*

In the beginning we thought that laptop causes this problem. When we changed computer, this problem didn't disappear, although I met it more rarely.

When I was trying to connect instrument to computer, very often it gave me tables, which are shown in Figure 21 and Figure 22.

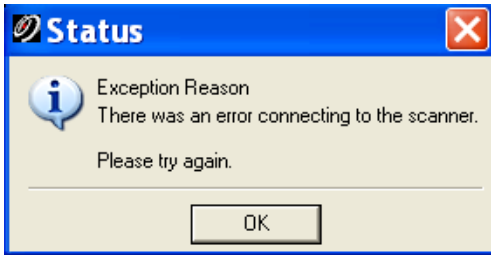

Figure 21. *Exception reason 1*

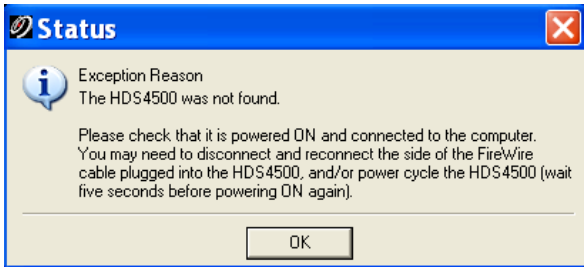

Figure 22*. Exception reason 2*

To solve this problem I had to reconnect cable again, turn off and then again on laser scanner, restart Cyclone ™ or even restart computer. Usually after several times doing that, scanner could be connected.

Another difficulty was too slowly working PC. The problem is that scans are very big and they take a lot of space on computers hard disk. The only one computer at HIG with Cyclone ™ software has too little memory and makes scanning slower and sometimes not reliable. Several times the program was not responding and I lost unsaved data. Then I started to delete older data, which I didn't need any more. After that I didn't loose data any more, but scanning was still quite slow. I think this computer should be changed to newer and more powerful one. Like this surveyor could save time and nerves.

Lack of teaching material was another difficulty. In *Leica Geosystems* website I did not find any manual for *Cyclone* ™. I used HIG students report about using scanner and software. It was very useful in the beginning when I was learning all the system, but later, when I came to specific tasks, I could not find all information in it. At school there was training manual from *Leica* seminar, but it was not very good and consistent. Information about 3D modelling was given in Module 3, but training for scanning only in Module 6! This was really confusing. Both of my used teaching materials were very useful, but took a lot of time, because I had to search information in both of them.

As I already mentioned before in chapter **3.2. Experiment with Colours,** I had a problem with bright posters on white wall. Scanner did not see big difference between poster and wall (Figure 23).

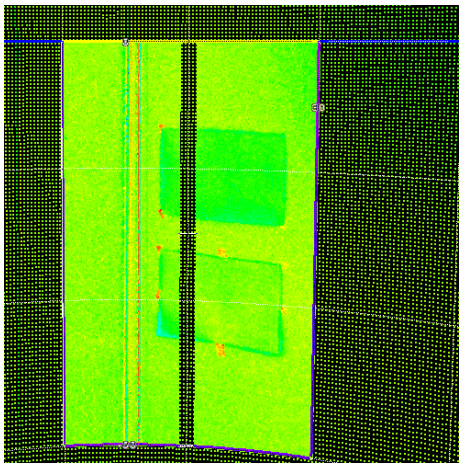

Figure 23. *Hardly visible posters*

I solved this problem by placing bigger black poster on the wall and using it as background for bright posters. I had visible difference as a result (Figure 24).

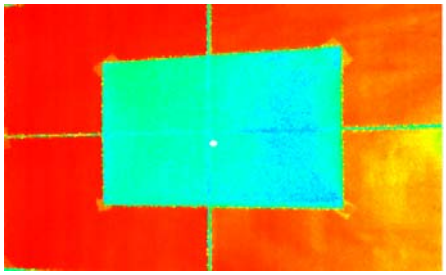

Figure 24. *Visible yellow poster on black background*

4.Conclusion

While doing this project I learned a lot about laser scanning. First of all I got theoretical knowledge about scanning processes, application fields, scanner's working principles and software. Also I gained skills in practical working with *Leica HDS4500* laser scanner and software *Cyclone 7.0* ™.

The most important task of my Bachelor thesis was to test accuracy of laser scanner in specific conditions and settings. I found out that this instrument works more precise when it scans darker colours, like green, blue, violet and black, rather than lighter, like white, yellow, orange and red. Point clouds of darker colours consist of more points, so the scan is clearer. This is useful if surveyor needs to make 3D model, which has to be very accurate and bright, of some object.

Another thing what I explored is that for measuring coordinates and horizontal distances it is not necessary to scan with high or highest resolution, because there are no differences or they are very small to compare with medium resolution scans. This is also very useful to know, because it saves a lot of time and efforts. In my opinion, if surveyor needs to find only this data from scanning and does not need to make an accurate model, it is better to use medium or high resolution rather than highest.

As laser scanning technology is quite new, there is a need to make much more researches about it. Might be, that scanner makes different number of points in point clouds when scans different surfaces. Points' number could also differ when scanning is done in different lighting and vary proportionally to light intensity. These are ideas, which would be useful and interesting to test. Hopefully, these tests will be done and we will be given answers. This could make scanning even more precise and make process easier and quicker.

5.References

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6.Appendixes