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Internship report

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Internship provider:

Murphy Surveys Ltd.

Head Office Kilcullen

Kilcullen, Co. Kildare

Ireland

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Introduction

About Murphy Surveys

Murphy Surveys Ltd. (established in 1983) is a nationwide and international operating consultant surveying company that offers a wide variety of surveying services, such as “classic” surveying but also the most up to date surveying systems. Just to name a few of them this services include Land and Engineering Surveying, Measured Build Surveys, GPS and Laser Scanning, BIM, topographic surveys, setting out, monitoring, utility surveys & GPR, Hydrographical and Ground Penetrating Radar.

The company has several offices in Ireland and the UK. The Irish Head Office, running by the brothers Niall and Ray Murphy, where I have worked during my internship, is based in Kilcullen, Co. Kildare. A village approximately 50 kilometres away from the city centre of the Irish capital, Dublin (Irish: *Baile Átha Cliath*).

Murphy Surveys was established more than 30 years ago in Ireland and currently has three offices in Ireland and another five offices in the UK (UK Head Office based in London, England) and the company is still expanding. So far the company developed to one of the leading surveying companies in Ireland and the UK.

At present Murphy Surveys has a staff of over 120 people in Ireland and over 60 people in the UK. The laser scanning department at the Head Office currently has around 11 to 13 employees. Ricardo Oliviera, my supervisor during the period of the internship is the head of the scanning department. The equipment of the department is absolutely up to date and among others contains a Leica P20 and a Z+F Imager 5010C laser scanner as well as a quite handy Faro laser scanner. Beside the laser scanner equipment the use of a GPS receiver and the more classic total station is also a part of the daily field work.

In the advertisement Murphy Surveys describes itself as one of the most dynamic, experienced, professional, innovative and technically proficient surveying companies in Ireland and the UK today.

My time with Murphy Surveys

During my time at Murphy Surveys I was involved in several projects in which I mainly assisted experienced surveyors. On site I worked almost daily with the Z+F laser scanner and a Leica TS15 total station, but I operated and used a Leica P20 laser scanner, a Leica GS15 GPS set and digital levels as well.

While in the Office, I was introduced to the software that is used daily within the company, e.g. Z+F Laser Control, Leica Cyclone, Leica Cyclone Topo II, AutoCAD and Leica Cloudworx. I had the opportunity to create registrations of the scans and extract features from the point cloud data I gathered during the scanning projects on site, namely 2D elevations, floor plans and sections, as well



as 3D topographical information.

Furthermore I also assisted in several topographical and measured building surveys (MBS) round the entire country, using a Leica TS15 total station and a Leica GS15 GPS set.

During the period of the internship I was working from Monday to Friday with a daily working time from 8am to 5:30pm including a lunch break. When I worked on site the working time was a bit more adjustable, depending on the project we worked in.

On site I was involved in several really interesting and exciting scanning projects that gave me a great impression of a surveyors role. The work on site took about two-third of the time of my internship. The other third I stayed in the office and usually I worked with the data I gathered on site.

Just to give a quick introduction to my work on site I will name two projects in the following breaks I was involved for several weeks. A more detailed description about my daily field and office work can be found in the main part of this report.

My first big project in which I was involved as an assistant surveyor for more than three weeks was the complete high quality acquisition of the OPW Head Quarter (Office of public works, Ireland) building in Trim, Co. Meath. A really fancy and architectural well designed office building, focussing on an economizing consumption, with a great view on the historical city centre and especially the ancient Trim castle.

My second big project took place on the area of the St. James's Hospital in the city centre of Dublin. We had the job to measure and scan several buildings to draw plans of the current condition of the buildings. This is necessary because of the planned reconstruction of this area. The city council is planning a new Children's Hospital and therefore a few existing buildings will be demolished in the near future. For the planning permissions plans of the dwindling buildings are necessary!

At the beginning of the main part of this internship report I will describe the process of a demanding scanning project both the field work and the processing work in the office with the help of the two projects mentioned above.

The scanning survey of sections of the M7 and M9 motorways was another project that took part during my time with Murphy Surveys. In the second part of the main body of this report I will describe what products and results I created from the scan data with software that is daily used within the company.

Main part

In this part of my internship report I want to describe my daily work at Murphy Surveys and beyond that I want to point out some special projects I worked in.

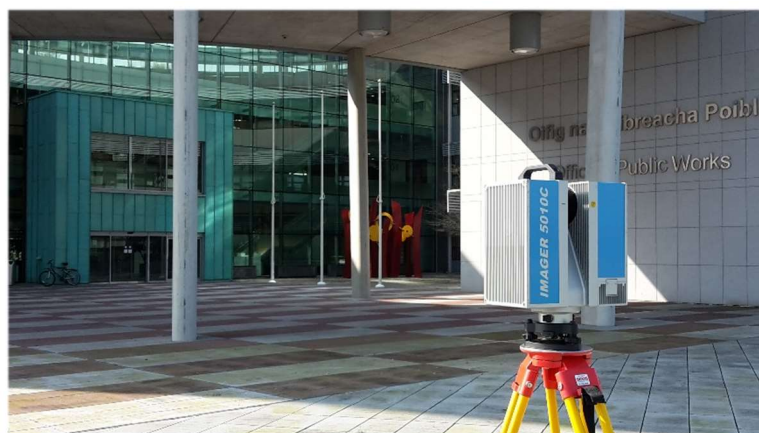
I will describe the approach to the surveying and scanning projects, the surveying equipment we used on site and the software we used in the office. Furthermore I will underline some characteristic features of the projects and problems we had to solve during the projects.

1st project - OPW Head Quarter in Trim, Co. Meath

This project was my first project with Murphy Surveys and it started directly from the first day of my internship. The pure work on site took us full 14 days. Due to smaller breaks, because of necessary work in the office, I worked in Trim the first four weeks of my internship.



OPW Head Quarter in Trim, Co. Meath



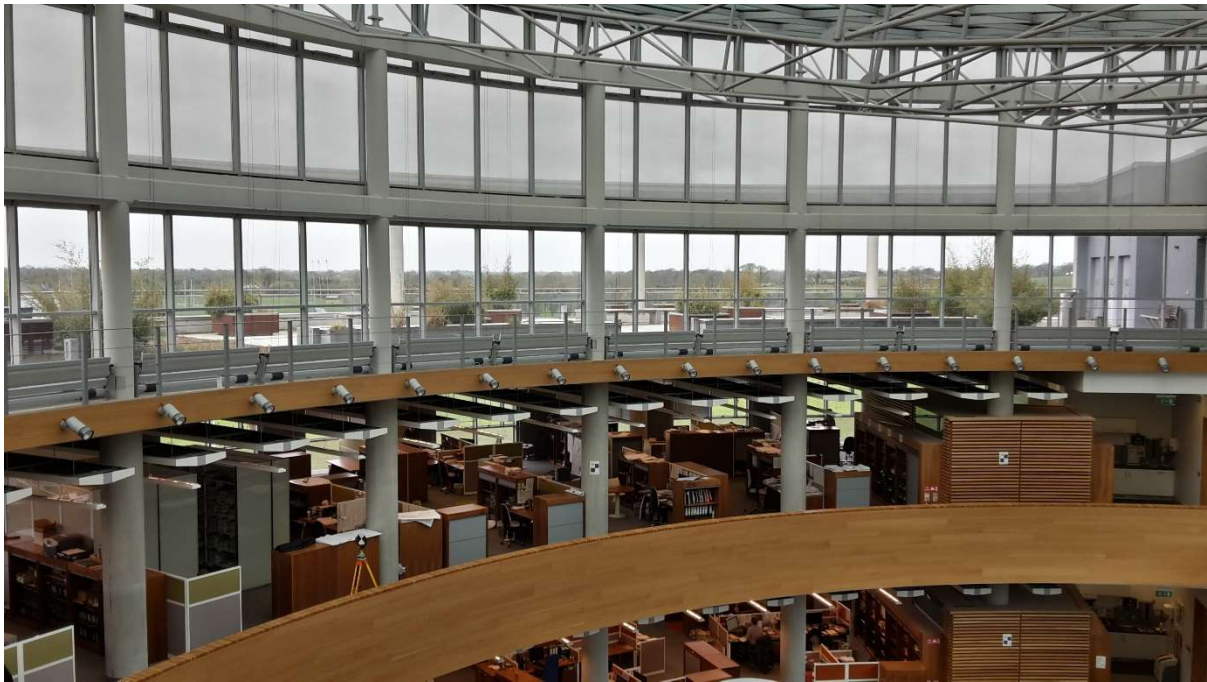
Laser scanner Z+F Imager 5010C



Facade of the OPW Head Quarter with black and white tilt-and-turn targets in front of it



Tripods with tilt-and-turn targets centred and levelled above a control point



View from the third floor to show the different targets (tilt-and-turn and paper targets) to combine the single scans with Leica Cyclone later on



Scan of the terrace located on the third and thus the highest floor of the building

We have scanned the entire building from the outside (elevations) and the inside (four floors plus basement) with a Z+F Imager 5010C laser scanner.

The client, namely the OPW (*Office of Public Works*), required current 2D floor plans and elevations of the whole building. In addition to it they asked for a BIM (*Building information modelling*), a generated digital representation of the entire building. To keep it plain, a 3D model with AutoCAD. Because of this requirements and the difficult geometry of the building Murphy Surveys decided to gather the necessary data of the entire building with a laser scanner. We used the laser scanner mentioned above especially because of the opportunity to create coloured 3D point clouds.

After each single 360° scan, the laser scanner takes several photos of the surrounding area. Later on in the office the surveyor can use the software Z+F Laser Control to create a 360° panorama photo for each single scan. In a next step the software assigns a RGB colour value from the created panorama photo to each point of the scanned point cloud. As a result the user receives a coloured scan.

For the conjunction of the single scans we used circular tilt-and-turn targets, colloquially called as “lollipops”, mounted on adjustable and adaptable tripods or just simple (magnetic) stands. Complementary to this we used printed and numbered paper targets. Numbered targets aren’t really necessary but they help the user and the software to register the scans afterwards. Usually at Murphy Surveys the work on site and the processing of the data in the office will be done by two different people. Therefore numbered targets can be quite helpful for the assignment of the scans. For the software numbered targets are helpful during the process of the registration, because the software can calculate with more constraints which leads to faster and sometimes even better results!

In some other scanning projects we even used spherical targets in addition to the other targets. They look like unstructured white volleyballs and have a magnetic stand.

The tilt-and-turn and the paper targets that we used for this project are also called “Black and White”-targets because of its chequered patterns. All targets mentioned above can be found and registered automatically with a software during the registration of the scans by using Leica Cyclone or Z+F Laser Control.

To see photos of the different kinds of targets that can be used with the laser scanner have a look in the “supplementary photo” part of this report below!

Around the building we constructed a geodetical network of several control points. These points were measured twice with GPS and got coordinates in the Irish reference system. On the one hand this was necessary as a control of the single scans with the laser scanner and on the other hand for a global reference for the locally measured coordinates. As another control we did a traverse around the building with a total station, measuring every control point in a constraint centring. As a next step we completed a traverse through the building and coordinated control points on the ground and the first floor. Later during the project we coordinated control points on the second and the third floor with a total station, but this time not in a controlled traverse.

The Z+F Imager 5010C laser scanner which we used for this project works with a horizontal field of view of complete 360° and a vertical field of view of 320°. The range of this scanner is perfect for

scans in smaller and bigger rooms and open areas in buildings, like lobbies. But it works quite dependable and adequate outdoors as well, what's really important for scanning the quite high elevations of this building.

For the scans we levelled the laser scanner on a casual tripod and especially inside the building, we used "spider legs" under the tripod because of the slightly slippery ground.

Usually we did a full panorama scan of the surroundings from one setup. Before every scan the user respectively the surveyor has to check the scan settings of the scanner, because you can choose between different levels of resolution and quality. Have a look at the spreadsheet:

Deflection unit		Scan duration			
		less quality ⁶	normal quality ⁶	high quality ⁶	premium quality ⁶
Angle resolution	pixel/360° horizontal & vertical				
"preview" ⁴	1,250	---	0:26 min	---	---
"low"	2,500	0:26 min	0:52 min	1:44 min	---
"middle"	5,000	0:52 min	1:44 min	3:22 min	6:44 min
"high"	10,000	1:44 min	3:22 min	6:44 min	13:28 min
"super high"	20,000	3:28 min	6:44 min	13:28 min	26:56 min
"ultra high" ⁵	40,000	---	13:28 min	26:56 min	53:20 min
"extremely high" ⁵	100,000	---	81:00 min	162:00 min	---

Extract from the brochure of the Z+F Imager 5010C

(the time information are almost similar to the laser scanner Leica P20)

In most cases we chose the normal quality setting combined with a middle resolution in smaller rooms with an average size and the high resolution in bigger and wide open rooms and areas. Depending on the geometry and size of a room we even chose the high quality combined with a high resolution to get a more proper point cloud.

In cases where the objects and features of interest were quite far away from the scanning setup or we had a setup in a really wide open area, we mostly decided to choose the super high resolution combined with a high quality.

Because of the manner of functioning of a laser scanner gathering a room, most times more than one setup was necessary to really gather the entire room with every corner and important geometry and detail.

If the user changes the resolution of a scan in fact this changes the density of the measured point cloud and the distance between two points of the measured point cloud.

After a scan is completed the scanner automatically creates the HDR (*High Dynamic Range*) pictures of the surroundings. Like I already wrote, this step was necessary because we wanted to create a coloured point cloud later on. The HDR pictures offer the great advantage to create more balanced photos, what is especially important in areas with a lot of shadows or sun exposure. It is an innovative and helpful development but doesn't always creates the perfect photos that the advertisement promises. The best quality pictures can be done on a cloudy day, because no intense reflecting surface will disturb the appearance of the taken photo.

This step took another five minutes after each completed scan, which leads to a full working time of approximately 12 minutes for one scan in high quality and resolution plus HDR pictures of the surroundings.

To give an example and to have a better idea of the amount of data that will be created during one scan I will mention some basic details:

For a scan in the lobby of the building, so a quite wide and open area, we chose a scan in high resolution. As a result the scanner creates a scan file with a size of around 330MB that contains 42.585.959 points what corresponds to a resolution of 4451 x 10.013 measured points in the point cloud.

On a usual day we could scan from approximately 20 to 60 setups depending on the chosen quality and resolution, whether we took HDR pictures or not and of course the extraneous influences. The scanner we used has an on-board internal hard disk drive (*HDD*) with about 60GB of free space and offers the opportunity to export the scan files and data to an external USB-stick what is quite handy and sometimes even necessary because of the amount of data produced on one single day of a project.

Just to keep it descriptive I will make a small calculation. If we do 20 scans in high quality on one day this leads to an amount of data of 20 x 330MB. This means we produce about 6,4GB data on one day!

For the complete scan of the OPW Head Quarter office around 480 scans were necessary! This means around 60 scans for the basement and 100 to 110 setups per floor for the other four floors (ground floor, 1st floor, 2nd floor and 3rd floor). For the single scans we chose different resolutions, but like you can imagine as a result we got a huge amount of data!

Processing in the office

When the work on site has been finished the gathered data can be processed in the office.

During this part of the project the main focus is on the registration of the scans. A **unified and tidied point cloud** of the complete measured object will be the result of the registration.

However before the registration can be started a few preliminary works are necessary. In this case we used the registration-software Z+F LaserControl for the first steps (filtering the scans and subsequently create coloured scans).

The process of filtering is divided into different steps. I mainly used the default settings of the registration-software.

- filtering the scans (preprocessing filters):
 - Intensity
 - Invalid
 - Mixed pixel
 - Range
 - Single pixel
 - Thin

Filtering the scans doesn't mean that single points or pixels will be deleted. In reality the software just creates a mask to mask out the pertaining points of the scan.

To understand what effect the filtering has I will describe the most significant filters:

The mixed pixel filter is the most important filter, because this filter masks out pixels which are on edges and therefore are not valid. The intensity filter masks out pixels below minimum and above maximum the selected intensity. The range filter masks out pixels which are not in the selected range and the thin filter is a very simple filter to get equal density, but the filter algorithm works just in a single line.

After the filtering is finished, we can start to colourise the scans. This means to map colours onto the scans, respectively to assign a fixed RGB-value gained from the HDR photos to every 3D coordinated point in every single scan. For this work different steps are necessary:

- Generate coloured scans:
 - HDR generation
 - Balancing images
 - Export balanced images
 - Colour map scan
 - Enhance image

In most cases and projects we don't work with colourised scans. We just use the intensity that the laser scanner measures automatically during every scan for every single point of a scan. The simple reason why we created colourised scans in this project was because the client asked for it.

Annotation: At Murphy Surveys usually the whole process of registration including the filtering of every single scan will be done with the software Cyclone of the company Leica. This software can process scans produced by the Leica P20 laser scanner as well as scans done by the Z+F Imager 5010C or other laser scanners.

The main reason we used Z+F LaserControl at the beginning of the registration process in this project was the feature of colourising the scans what is not possible with Leica Cyclone. After filtering and colourising the scans we exported the scan files to Cyclone and finished the registration with this software.

After this steps have been finished the actual **registration** can begin. During my time at Murphy Surveys this work has been done with the software Leica Cyclone always.

The process of registration consists of different steps which I will explain in the following paragraphs. Nevertheless I will give a short summary at the beginning before I start to describe the single steps more detailed.

- Process of registration with Leica Cyclone:
 - Register all visible targets in each single scan
 - Constraints for conjunction of scans / try to connect the scans (Auto-Add Constraints)
 - Register scans
 - Create ModelSpace for the whole project (check point cloud manually for bigger mistakes e.g. crossing walls or points of the same surface appear in different levels)

- Cloud Registration process (every scan checks the conjunction to the other scans (creating more constraints))
- Untidied point cloud
- Tidied point cloud (manually deleted some points (e.g. scan through windows))
- Unifying the point cloud (*result*: tidied and unified point cloud)

From this point of the main part I will exemplify the process of registration with the help of my 2nd project. This is a possible approach because the procedure of the field work as well as the work in the office was almost identical and definitely comparable.

2nd project - St James's Hospital in Dublin

On the area of the St James's Hospital, located in the city centre of Dublin, Murphy Surveys had many assignments during the period of my internship because of a recently planned New Children's Hospital. Therefore I assisted in many surveying projects located on this area, mostly scanning projects. There was a big range of different buildings. For example a teaching hospital that was part of the venerable Trinity College Dublin, a very old stone wall building that houses a canteen, old and historical office- and administration buildings of the St. James's Hospital and private clinics.

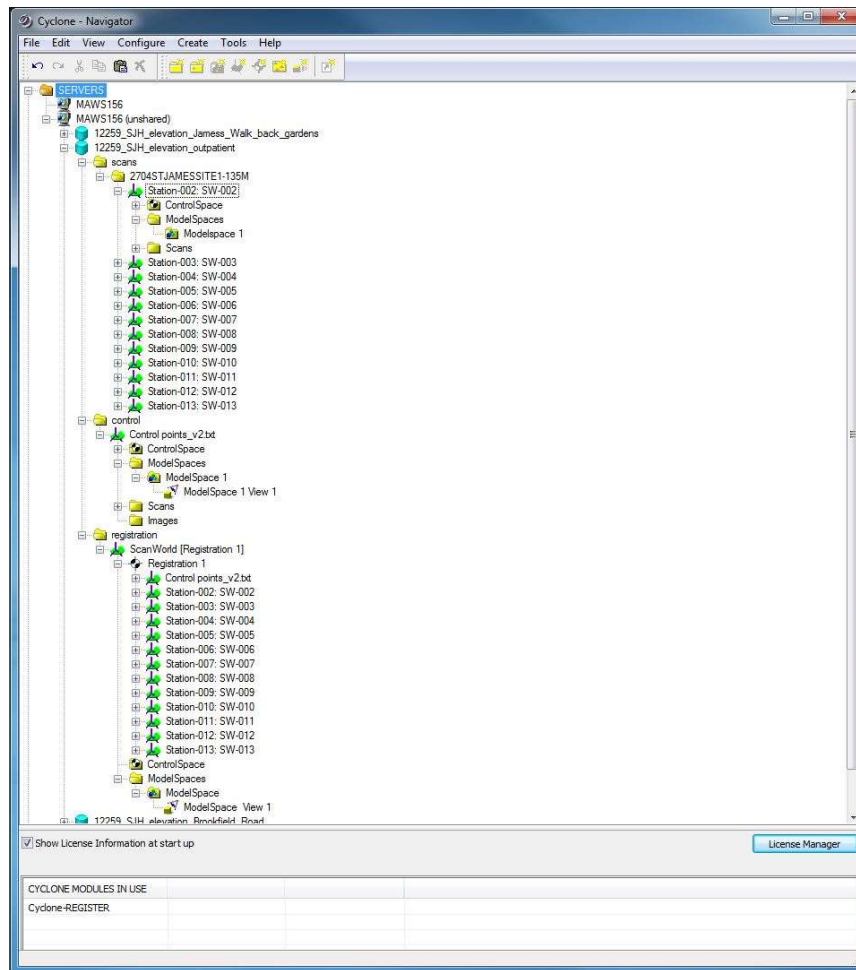
As results of the single scanning projects on this area 2D plans, ground plans, elevations and / or sections through the buildings, based on the information gained from the 3 dimensional point clouds or MBS (*Measured Building Survey* created with a classic total station connected to a laptop and a MBS software) were asked by the client. But the reason the plans are needed were different. One time it was because of a planned expansion of a building and the subterranean connection of two buildings through a tunnel. Another time it was because of a planned demolition of an old, but historical building and the construction of a new building on the same spot.

The following screenshots that support the description of my work were made during the processing of this projects in the office with the software Leica Cyclone.

I will now continue to explain the process of registration in a more detailed way:

Cyclone is a database organised and constructed software. Because of this architecture the user has two options to start a project. An already existing project can be simply added or the single scans have to be imported to the database as a common Cyclone-project.

After the import of the scans the “project tree” of Cyclone looks like this:



Registration of scans with Cyclone:

The first step of every registration of a batch of scans is to register all targets respectively “pick” all targets that appear in the scans. There are really good and mostly reliable operators and algorithms implemented in the software to automatically locate the centre of the targets. In some cases the software can even automatically detect the targets in the scanned point cloud. In other cases this has to be done manually by the user who operates the software.

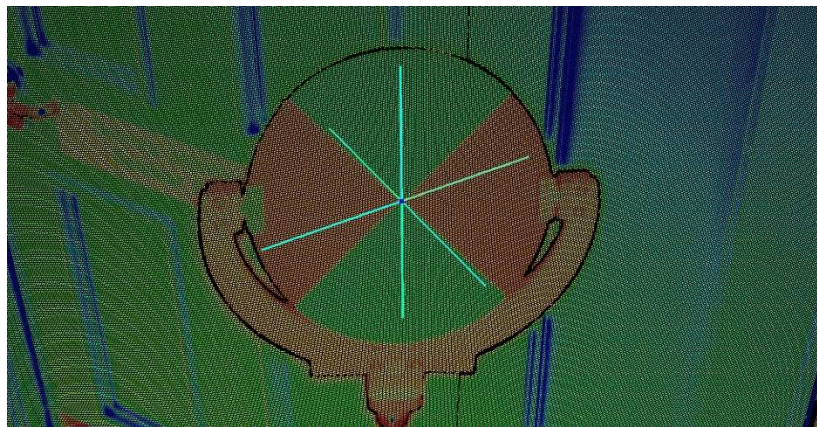
After the centre of the target is located, the user can add a number (known as *Target ID*) for the point and if necessary the height of the target. The height is always necessary if the target is centred and levelled on a tripod above a coordinated control point that is used for the registration. The control points are either coordinated in the Irish reference system by a GPS system or a total station for example with the help of a traverse. Control points serve as connection points to the global reference system as well.

If the target cannot be centred automatically the user can try to pick the centre manually, but the user should consider that the result of this operation will not be as good as an automatically computed centre! The reason for this circumstance is the fact that the centre of a target in most cases is not a measured point and therefore will be computed between the existing and measured

pixels of the point cloud.

When every target is registered, the user can continue with the registration of the scans.

In this project as well as in every other bigger project I worked at during my time with Murphy Surveys we worked with control points that were coordinated in the global Irish reference system. Therefore we had to import a text-file (a simple .txt file in an ASCII-format) that contains all the coordinates (X-, Y- and Z-values) of the used control points. In addition to a simple control this coordinates have another task during the registration process. Every registration with Cyclone needs a **home scan** (equal to a reference scan) and usually the control points assume this task. This means that every following scan is checking the connection to the home scan and tries to refer to it.



Automatically located centre of a tilt-and-turn target

Ann.: The colour representation of the point cloud results from measured intensity of each point

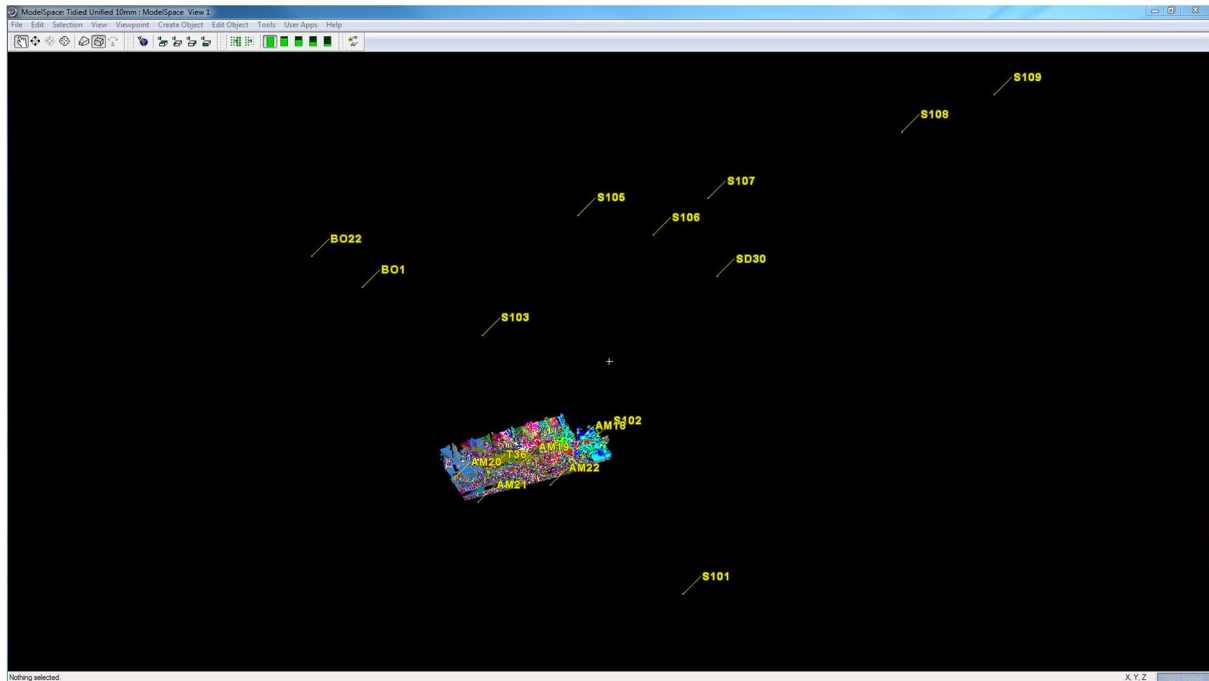
As the next step of the registration Cyclone is looking for constraints to combine the scans. This procedure is called “**Auto-Add Constraints**” and works with the geometry of the registered targets. To find a solution respectively a conjunction between two scans Cyclone needs at least three common points / targets in every scan! In exceptional cases this step even works with two common targets presupposed both targets are numbered, because now we have enough constraints to combine two scans. But in practice we work with unnumbered targets and with at least three common points and furthermore to obtain better results even with more than three common points.

In cases when not enough common targets are available and finding constraints between two scans is impossible for the software, it can be helpful to find natural common points in both scans like corners of door- or window frames (and it can be even a good idea to give those freely selected points the same number in both scans). In Cyclone this points are called “vertex”. In most cases the software will find a solution now, but with a high probability the quality of the conjunction will not be as good as with automatically centred targets. But it can be a quite practicable and handy compromise.

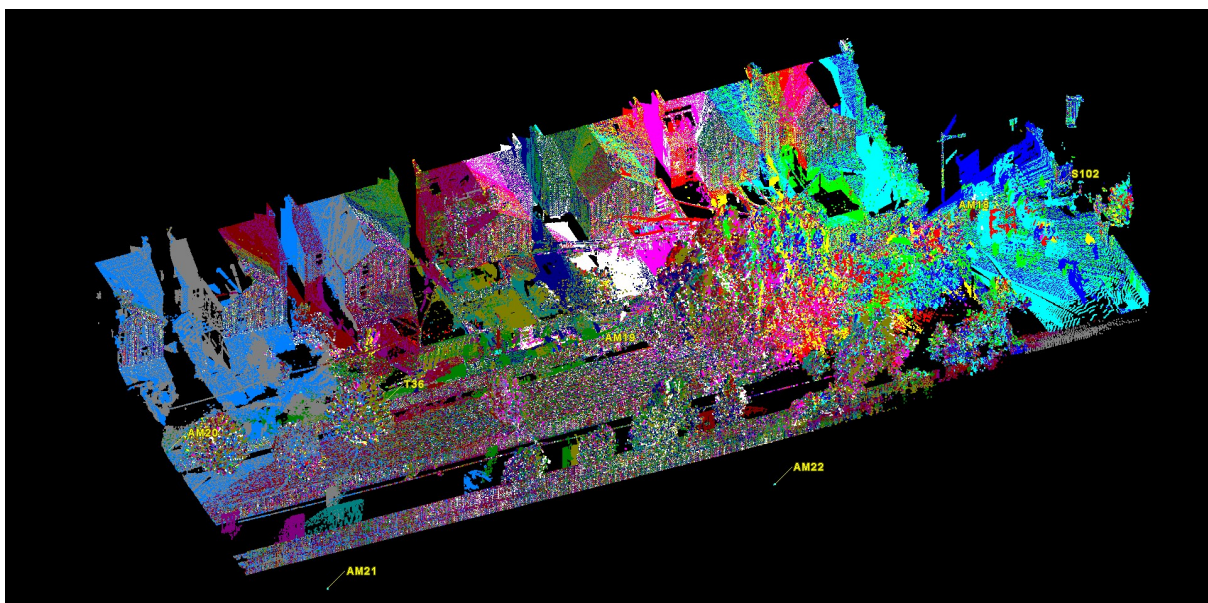
The targets (“Lollipop” and paper targets) and the natural items (like corners) are called **tie-points**.

After the software found all necessary constraints and the calculated errors are tolerable the user can finally register all the scans. As a result of this step a ModelSpace for the entire project that contains all the combined scans can be created with Cyclone. For this moment the user has to do an

extensive visual check of the created point cloud. This means that the user has to check the point cloud manually for bigger mistakes and discrepancies between the single pixels of the cloud and the geometries. To present an example, points of the same surface should not appear in different levels and the point cloud should not contain crossing walls or other geometrical mistakes. **Cut planes** through the point cloud and **limit boxes** can be a really helpful tool to complete these checks!



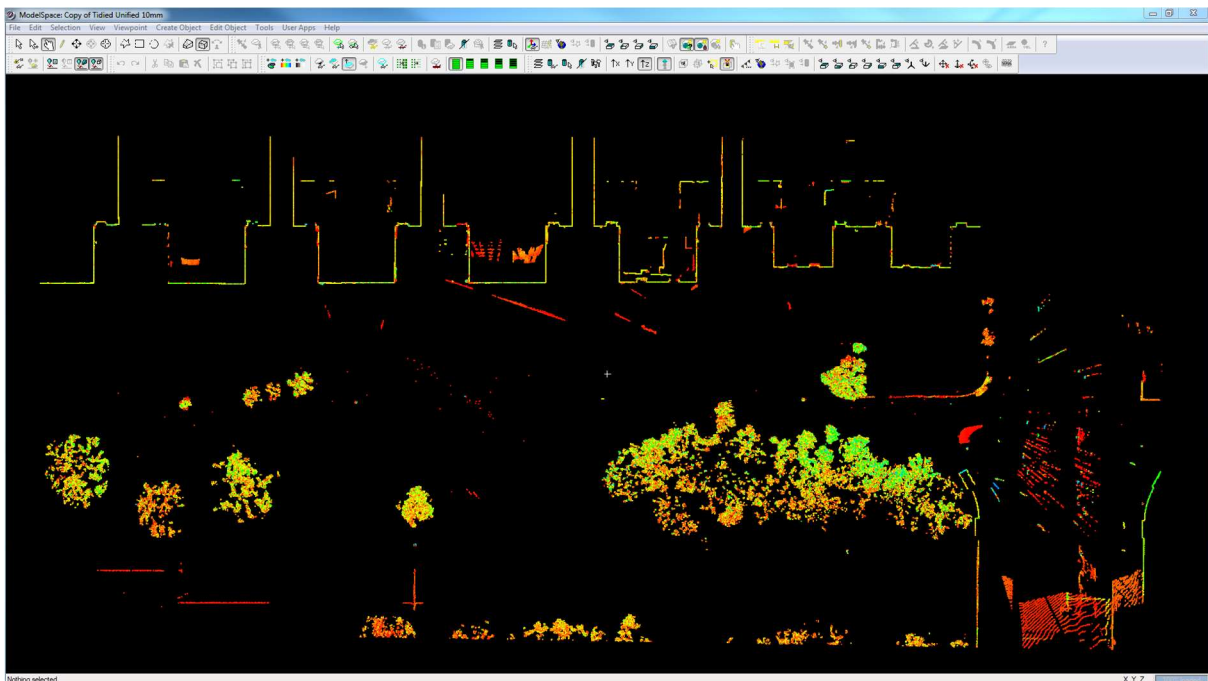
The points with the yellow numbers represent the control points (tie-points) and are part of the **home scan**



Scans combined in one common ScanWorld (incorporated points of the single scans appear in different colours)



Vertical cut plane to check the quality and credibility of the point cloud



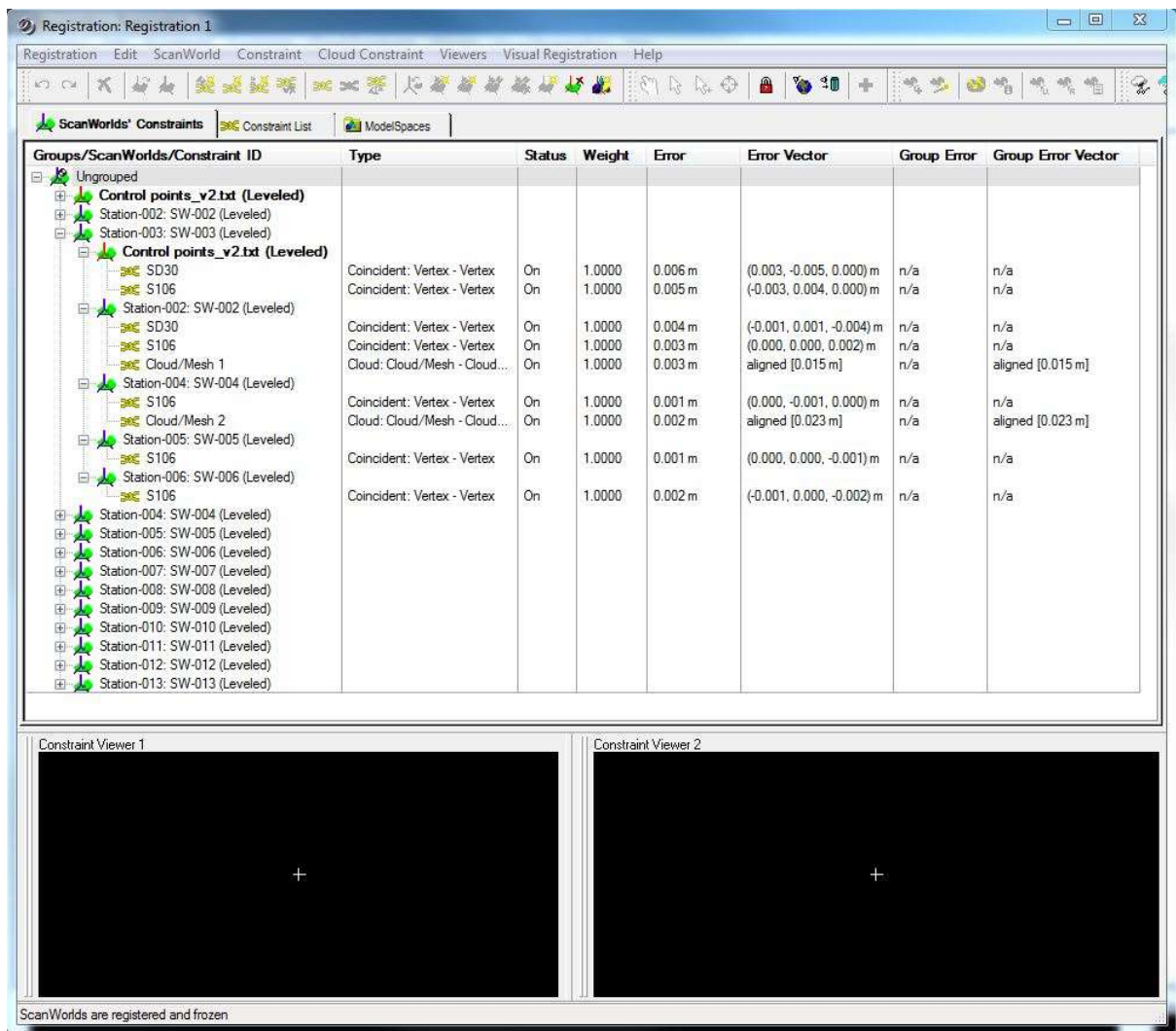
Horizontal cut plane to check the quality and credibility of the point cloud

When the ScanWorld is checked sufficient and appears as far as possible in the correct and required way, the user can start the next operation. With selecting the method “Auto-Add Cloud Constraints” Cyclone tries to mesh all available scans to find more connections between all the scans and finally to create new constraints between them. This is mainly based on the geometry of the scans and is called the *Cloud Registration Progress*.

After the Auto-Add Cloud Constraint operation is done the user has to check the results and errors! In the current project the values seem to be really satisfying. Therefore the user can create another ScanWorld including all the scans combined together at this moment of the process. Once again the user should visually check (same approach like I explained above) the recently created ScanWorld. When the ScanWorld appears in an impeccable and flawless condition at this point of the process the registration is almost finished!

Constraint ID	ScanWorld	ScanWorld	Type	Status	Weight	Error	Error Vector	Group Error	Group Error Vector	Group
395 S106	Control points_v23xt (Leveled)	Station-004: SW-004 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.004 m	(-0.003, 0.003, 0.000) m	n/a	n/a	Ungrouped
395 S106	Control points_v23xt (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.004 m	(-0.003, 0.003, -0.001) m	n/a	n/a	Ungrouped
395 S107	Control points_v23xt (Leveled)	Station-004: SW-004 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(-0.001, -0.001, 0.000) m	n/a	n/a	Ungrouped
395 S107	Control points_v23xt (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(-0.001, -0.003, 0.000) m	n/a	n/a	Ungrouped
395 S108	Control points_v23xt (Leveled)	Station-013: SW-013 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.009 m	(0.007, 0.004, 0.003) m	n/a	n/a	Ungrouped
395 S107	Control points_v23xt (Leveled)	Station-007: SW-007 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(0.000, -0.003, -0.001) m	n/a	n/a	Ungrouped
395 S107	Control points_v23xt (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.004 m	(0.000, -0.004, 0.000) m	n/a	n/a	Ungrouped
395 S106	Control points_v23xt (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.006 m	(-0.004, 0.004, -0.002) m	n/a	n/a	Ungrouped
395 S107	Control points_v23xt (Leveled)	Station-008: SW-008 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.004 m	(-0.001, -0.003, -0.001) m	n/a	n/a	Ungrouped
395 S106	Station-002: SW-002 (Leveled)	Station-003: SW-003 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(0.000, 0.000, 0.002) m	n/a	n/a	Ungrouped
395 S106	Station-002: SW-002 (Leveled)	Station-004: SW-004 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(0.000, -0.001, 0.003) m	n/a	n/a	Ungrouped
395 S030	Station-002: SW-002 (Leveled)	Station-003: SW-003 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.003 m	aligned [0.015 m]	n/a	aligned [0.015 m]	Ungrouped
395 S030	Station-002: SW-002 (Leveled)	Station-003: SW-003 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.004 m	(-0.001, 0.001, -0.004) m	n/a	n/a	Ungrouped
395 S106	Station-002: SW-002 (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, 0.000, 0.001) m	n/a	n/a	Ungrouped
395 S106	Station-002: SW-002 (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(0.001, -0.001, 0.001) m	n/a	n/a	Ungrouped
395 S106	Station-003: SW-003 (Leveled)	Station-004: SW-004 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, -0.001, 0.000) m	n/a	n/a	Ungrouped
395 S106	Station-003: SW-003 (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, 0.000, -0.001) m	n/a	n/a	Ungrouped
395 S106	Station-003: SW-003 (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(-0.001, 0.000, -0.002) m	n/a	n/a	Ungrouped
395 Cloud/Mesh 2	Station-003: SW-003 (Leveled)	Station-004: SW-004 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.002 m	aligned [0.023 m]	n/a	aligned [0.023 m]	Ungrouped
395 unlabeled	Station-004: SW-004 (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, 0.001, 0.001) m	n/a	n/a	Ungrouped
395 unlabeled	Station-004: SW-004 (Leveled)	Station-007: SW-007 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(-0.002, 0.002, 0.000) m	n/a	n/a	Ungrouped
395 unlabeled	Station-004: SW-004 (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(0.000, -0.001, -0.002) m	n/a	n/a	Ungrouped
395 S107	Station-004: SW-004 (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(0.001, -0.003, -0.001) m	n/a	n/a	Ungrouped
395 S107	Station-004: SW-004 (Leveled)	Station-007: SW-007 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(-0.001, -0.002, -0.001) m	n/a	n/a	Ungrouped
395 unlabeled	Station-004: SW-004 (Leveled)	Station-007: SW-007 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.005 m	(-0.001, -0.001, 0.005) m	n/a	n/a	Ungrouped
395 S106	Station-004: SW-004 (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(-0.001, 0.002, -0.002) m	n/a	n/a	Ungrouped
395 S107	Station-004: SW-004 (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, -0.001, 0.000) m	n/a	n/a	Ungrouped
395 Cloud/Mesh 4	Station-004: SW-004 (Leveled)	Station-006: SW-006 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.003 m	aligned [0.024 m]	n/a	aligned [0.024 m]	Ungrouped
395 Cloud/Mesh 5	Station-004: SW-004 (Leveled)	Station-007: SW-007 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.002 m	aligned [0.027 m]	n/a	aligned [0.027 m]	Ungrouped
395 Cloud/Mesh 6	Station-004: SW-004 (Leveled)	Station-008: SW-008 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.004 m	aligned [0.023 m]	n/a	aligned [0.023 m]	Ungrouped
395 unlabeled	Station-004: SW-004 (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(0.001, 0.001, 0.001) m	n/a	n/a	Ungrouped
395 unlabeled	Station-004: SW-004 (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(-0.001, 0.001, 0.000) m	n/a	n/a	Ungrouped
395 S107	Station-004: SW-004 (Leveled)	Station-009: SW-009 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(-0.002, -0.001, -0.002) m	n/a	n/a	Ungrouped
395 S107	Station-004: SW-004 (Leveled)	Station-008: SW-008 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(0.000, -0.002, -0.002) m	n/a	n/a	Ungrouped
395 unlabeled	Station-004: SW-004 (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(0.001, 0.001, 0.002) m	n/a	n/a	Ungrouped
395 S106	Station-004: SW-004 (Leveled)	Station-005: SW-005 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(0.000, 0.001, -0.001) m	n/a	n/a	Ungrouped
395 Cloud/Mesh 3	Station-004: SW-004 (Leveled)	Station-005: SW-005 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.001 m	aligned [0.020 m]	n/a	aligned [0.020 m]	Ungrouped
395 S107	Station-005: SW-005 (Leveled)	Station-007: SW-007 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.002 m	(0.002, -0.001, -0.001) m	n/a	n/a	Ungrouped
395 Cloud/Mesh 10	Station-005: SW-005 (Leveled)	Station-009: SW-009 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.003 m	aligned [0.030 m]	n/a	aligned [0.030 m]	Ungrouped
395 S107	Station-005: SW-005 (Leveled)	Station-008: SW-008 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, -0.001, -0.001) m	n/a	n/a	Ungrouped
395 S107	Station-005: SW-005 (Leveled)	Station-009: SW-009 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.003 m	(-0.001, 0.000, -0.002) m	n/a	n/a	Ungrouped
395 Cloud/Mesh 9	Station-005: SW-005 (Leveled)	Station-008: SW-008 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.004 m	aligned [0.022 m]	n/a	aligned [0.022 m]	Ungrouped
395 Cloud/Mesh 8	Station-005: SW-005 (Leveled)	Station-007: SW-007 (Leveled)	Cloud: Cloud/Mesh - Cloud/Mesh	On	1.0000	0.002 m	aligned [0.021 m]	n/a	aligned [0.021 m]	Ungrouped
395 unlabeled	Station-005: SW-005 (Leveled)	Station-006: SW-006 (Leveled)	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.001, 0.000, 0.000) m	n/a	n/a	Ungrouped

This register shows the constraint list with a special focus on the “Error”-column. This column is very helpful to estimate the reached quality of the registration and of course the quality of the accomplished scans on site.



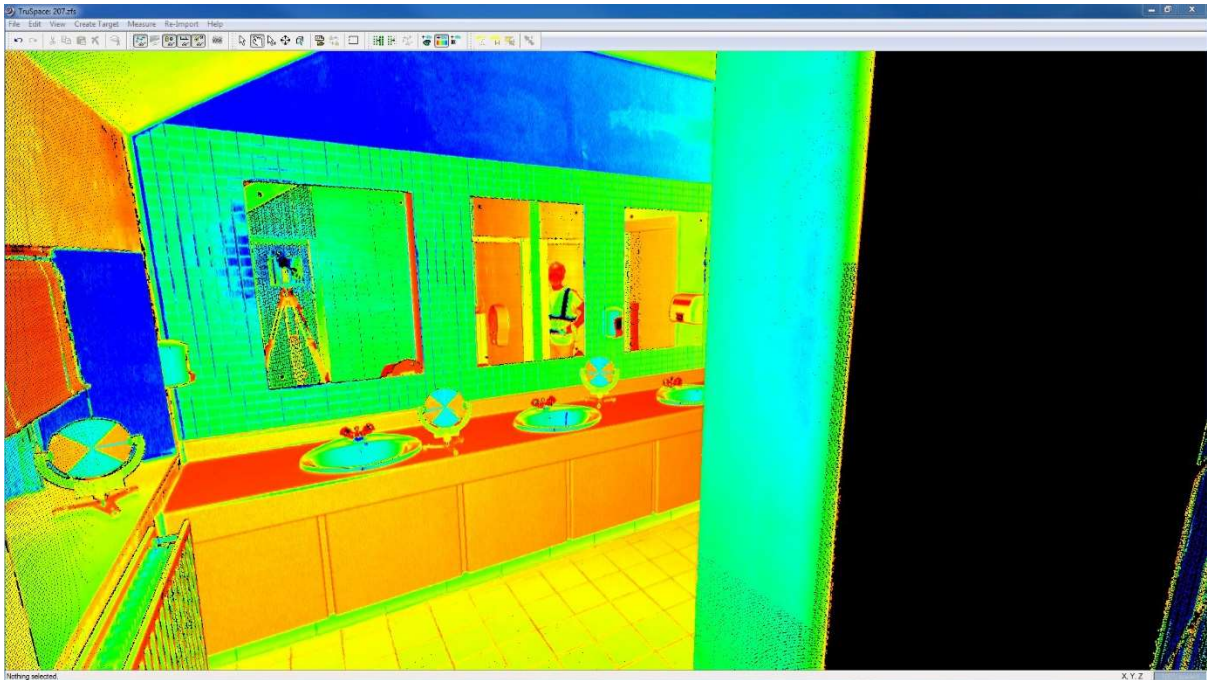
This window lists the correlation of the scans in a quite nearly arranged way

The ScanWorld that is created so far is also called an **untied point cloud**. For the last step of the registration it is advisable to tidy this point cloud first.

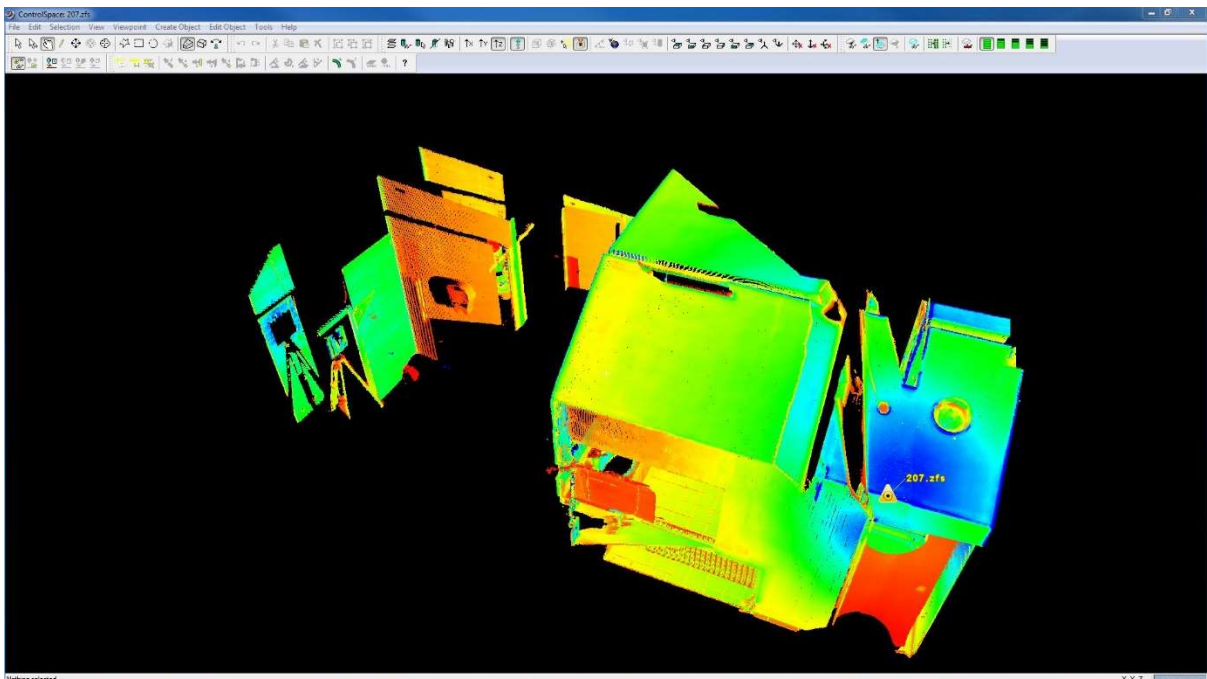
Especially scans in outdoor areas often contain more pixel information than the user really needs of this particular area.

There is also a problem with windows and mirrors in buildings. When a laser beam hits the surface of a window, some points will be on the surface of the window, but others will pass the window and therefore pixels appear somewhere in the surroundings. Probably the laser scanner scanned the leaves of the tree in front of the window or the facade of the neighbouring building, but this data is not of particular importance for the present project.

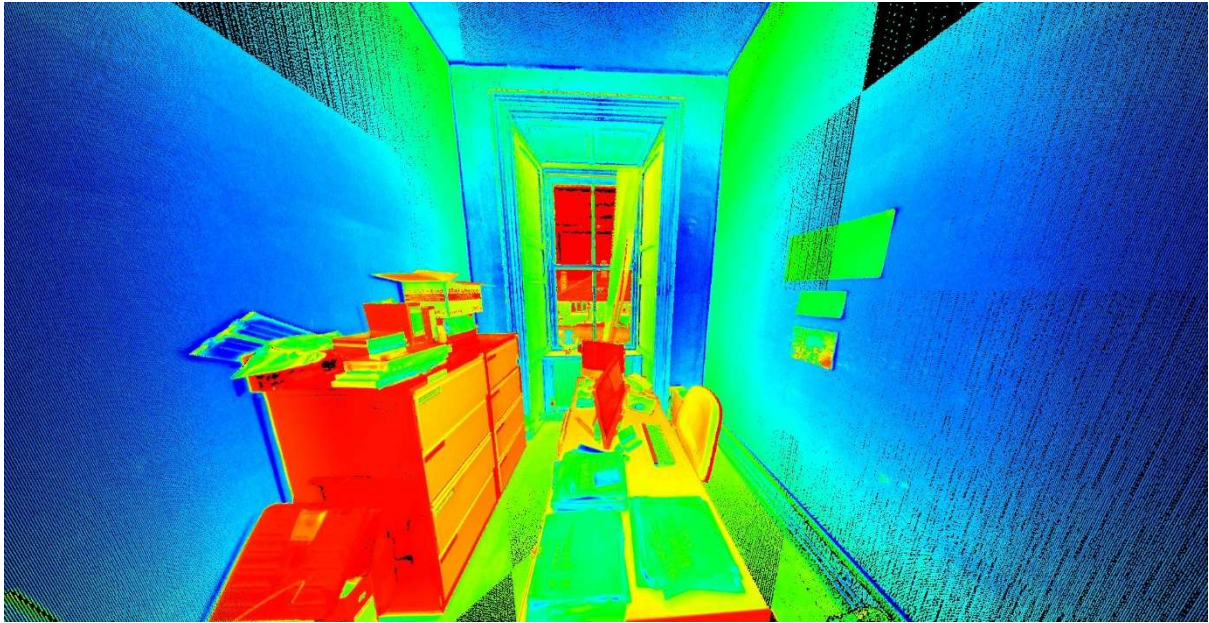
The results of a scan in a room with mirrors (especially in bathrooms, restrooms and toilets) is quite surprising! This effect can be best shown with the help of screenshots of a point cloud. You will find a screenshot of this effect below.



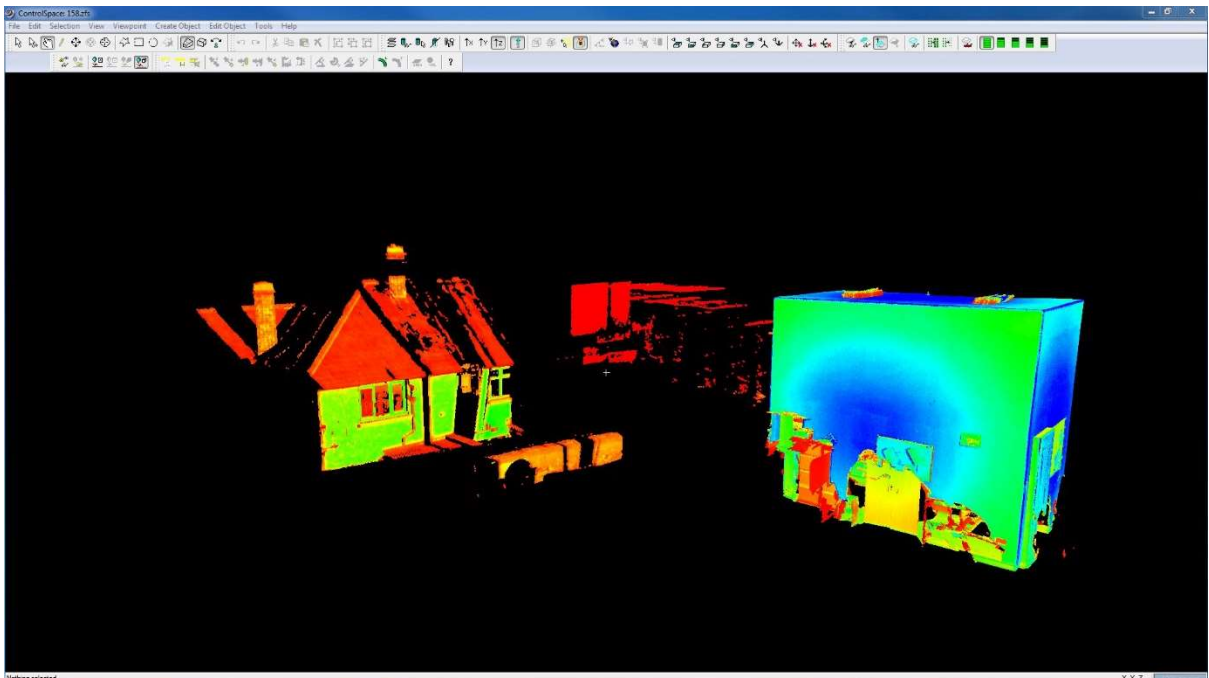
Scan of a public toilet with mirrors above sinks with a view from the current scan position



Resulting scan observed from a higher position with a good view on the caused effect from the mirror



Scan in a room with a window



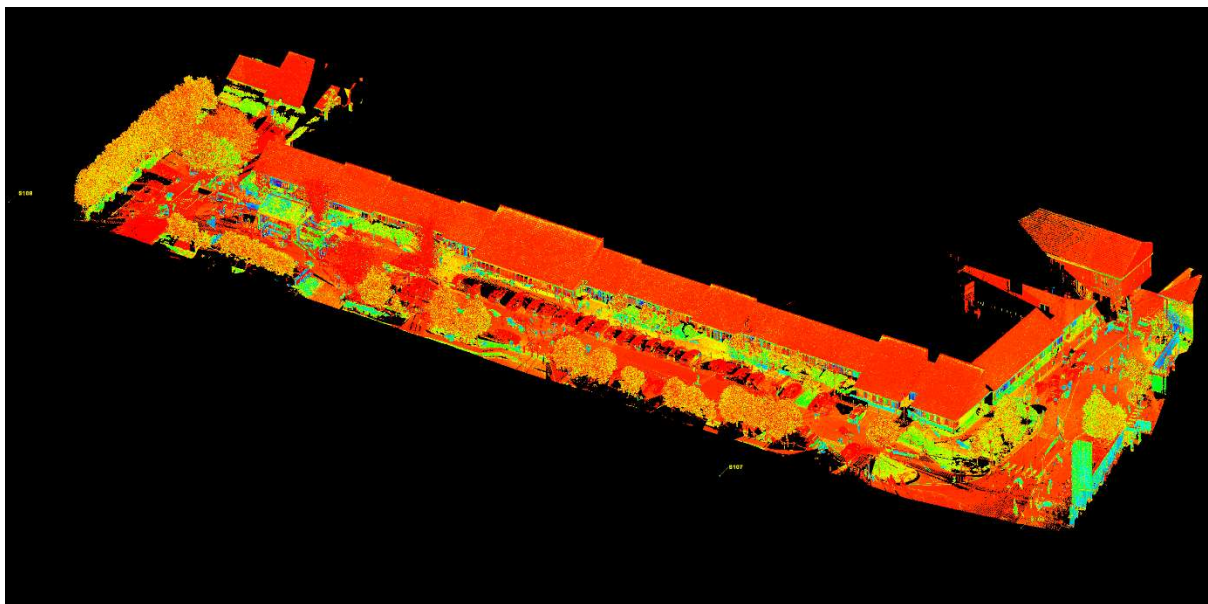
In this case only the geometry of the room is of interest, therefore all pixels outside the room can be deleted

After all points that are not helpful for the project have been manually deleted we can call the ScanWorld a cleaned or **tidied point cloud**.

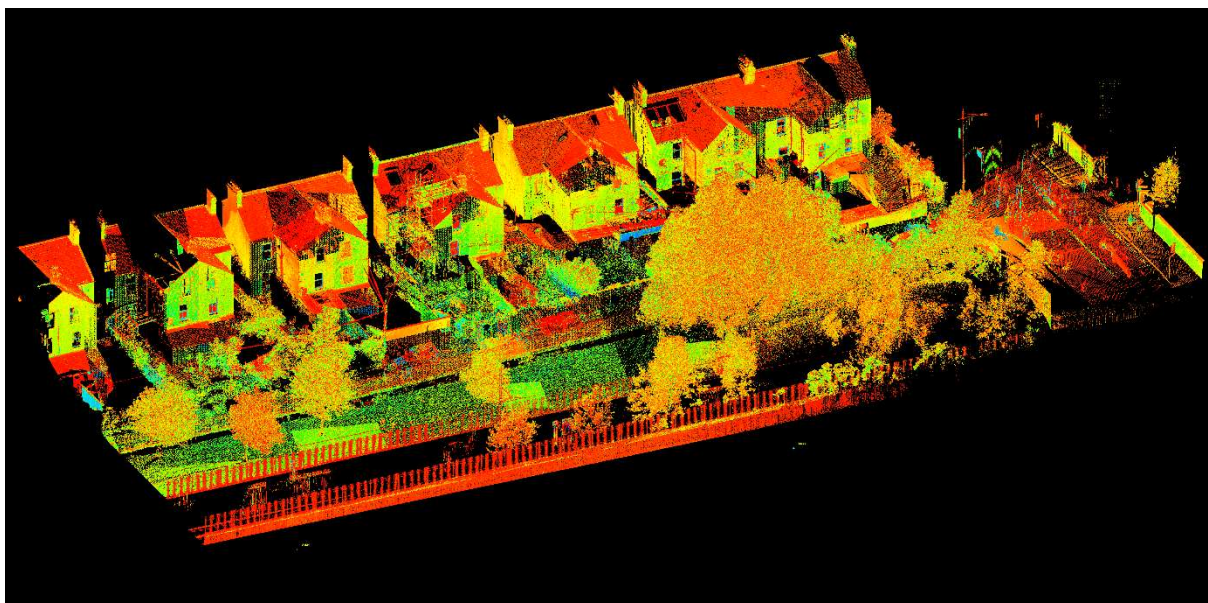
As the last step of the registration the user can create a **unified point cloud**.

Unifying the existing point cloud has several advantages. To list a few of them, it makes modelling about 20% faster and reduces the size of the point cloud what leads to a better and improved performance while working with the point cloud. Furthermore this enables region growing of a surface and enables the use of versions of Leica CloudWorx older than version 4.2.

Examples for a tidied and unified point cloud / Cyclone ScanWorld:



Front of a Hospital building on the area of the St. James's Hospital



Row of houses in the neighbourhood of the St. James's Hospital

Annotation: *Beside the scanning projects I was involved in a few different topographical surveys on the area of the St. James's Hospital in Dublin as well as across the Irish countryside. Because the main focus of my work was definitely on the scanning department I only give a short impression of the typical work process during this kind of surveying work at this point of the report.*

Topographic survey

- Create a geodetic mesh of several control points around the working area of the surveying project and coordinate the control points twice with GPS (approx. 30 minutes difference between both GPS measurements). One measurement lasts at least for a period of three minutes.
- To check the height of the control points a controlled levelling of the points is necessary. This means the surveyor has to do the levelling back and forth! Afterwards one control point get assigned a fixed height and the heights of the other control points are related to this height from now on.
- With the help of a controlled traverse the surveyor can check the quality of the 2D-position of the control points.
- Surveying the topography
 - Usually with a total station and a circular all around prism
 - For isolated sections and areas an integrated GPS and total station survey can be done to gain higher quality coordinates and more reliable measurements (with a GPS base station centred on a tripod above a known and coordinated control point)
 - Using the Leica SmartWorx Controller to save the results of the topographic survey and working with strings and points that are known within the company workflow
- Finally check and prove the steady position of the total station on the current setup (measurement to one of the control points and have a look at the differences)
- Use the data gained on site to draw topographical maps of the specific area (usually with AutoCAD)

Impressions of the topographic surveys



Topographic and boundary survey of an old carpentry

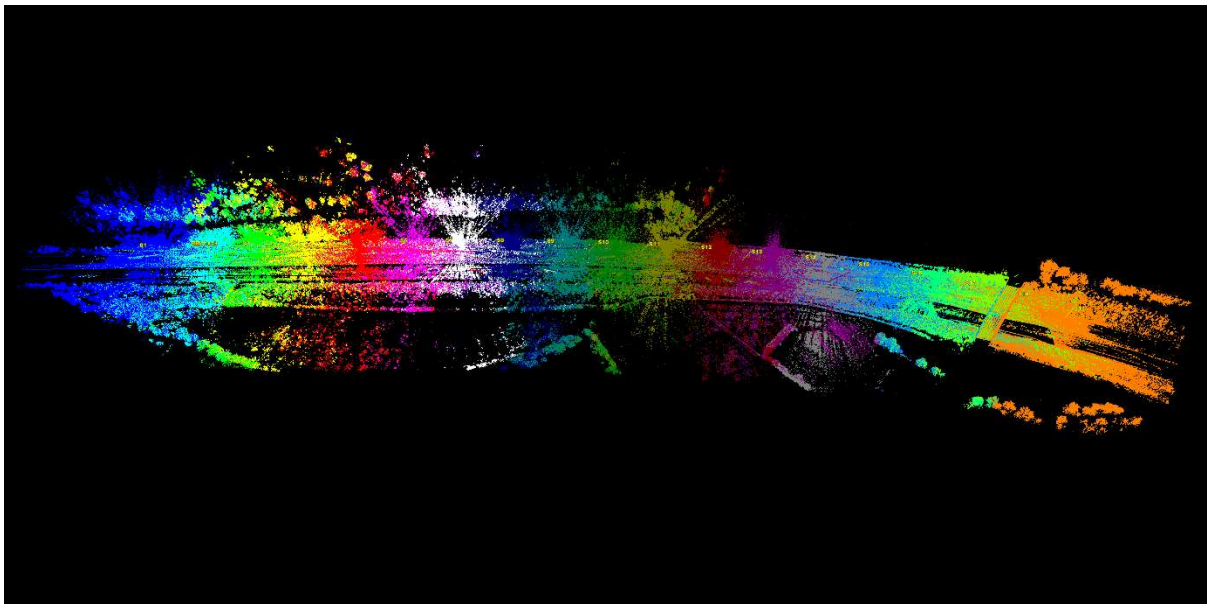


Topographic survey of a bridge and its surroundings in Cloondara, Co. Longford

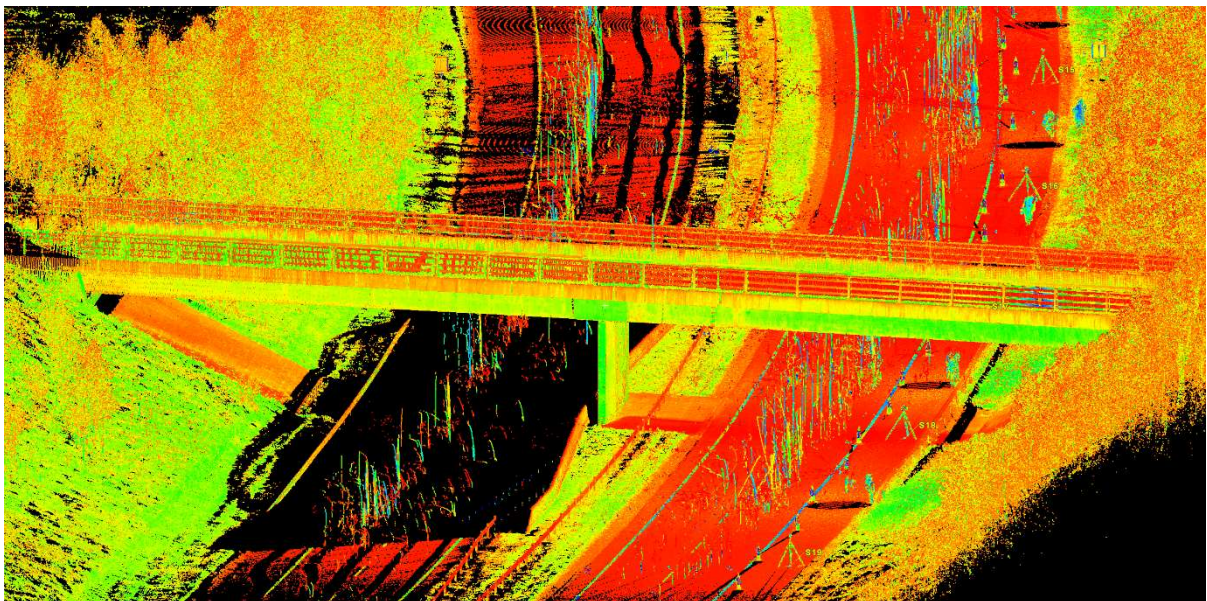
M7 and M9 motorway project

As part of my office work during my time with Murphy Surveys I registered and processed scanned sections of the Irish M7 and M9 motorway. I did the registration with the same approach I explained in this report further above. Again a unified point cloud is the result of every registration. After successfully finishing the registration of the motorways I used the unified point clouds to extract features and geometrical information or to draw plans based on the pixels of the point cloud.

In this part of my report I will introduce specific examples for what a surveyor can do with a unified point cloud of a motorway.

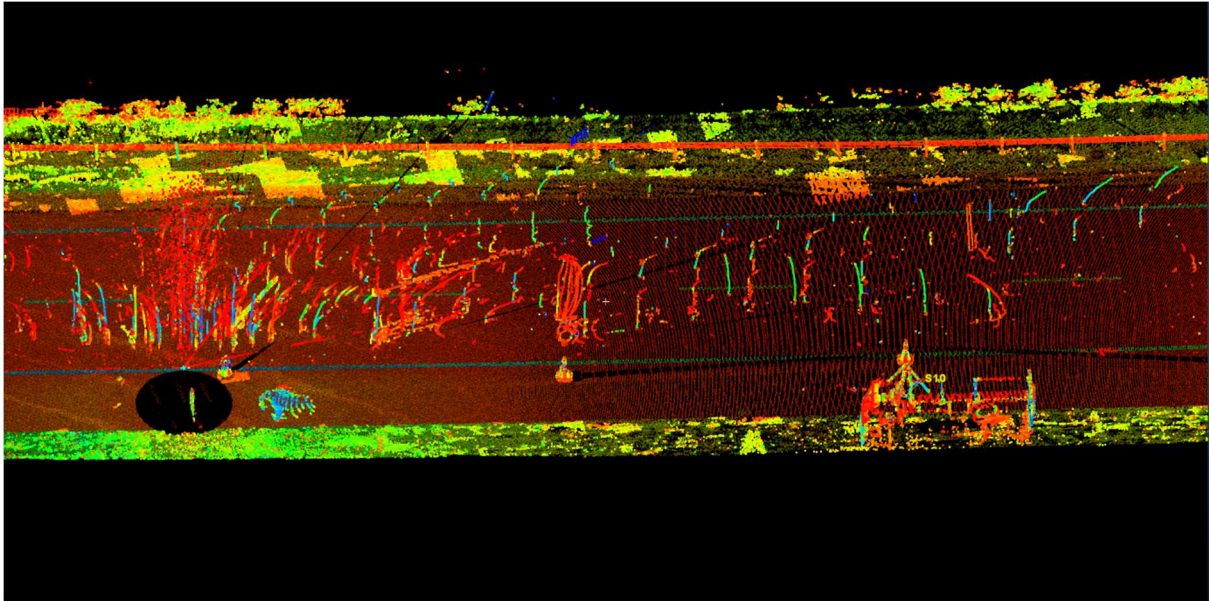


*Section of the M7 motorway after the **Cloud to Cloud** registration with Leica Cyclone*

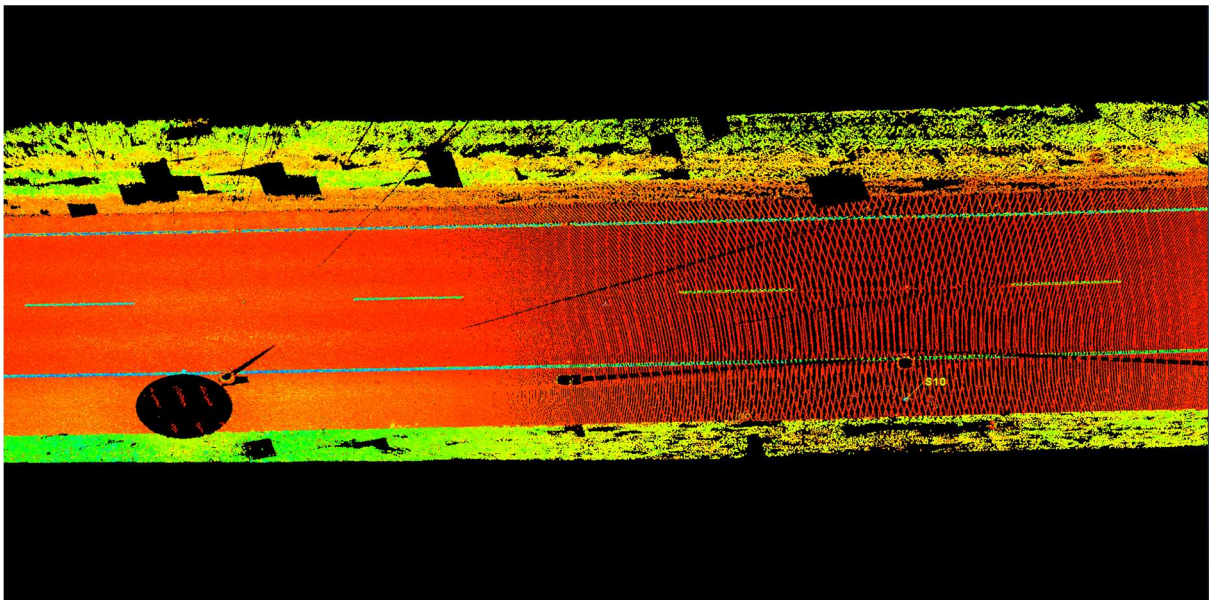


Untidied but unified point cloud with a lot of noise (e.g. vehicles that pass by)

In one project I produced topographical drawings of parts of a motorway based on the points of the point cloud with the software Cyclone Topo II of the company Leica. In another step I created a smooth surface of the motorway without all the noise (e.g. passing vehicles) that appears on the scans. This smooth surface was the basis of a regular grid of heights. To create the smooth surface and the grid I used the software Leica Cyclone.



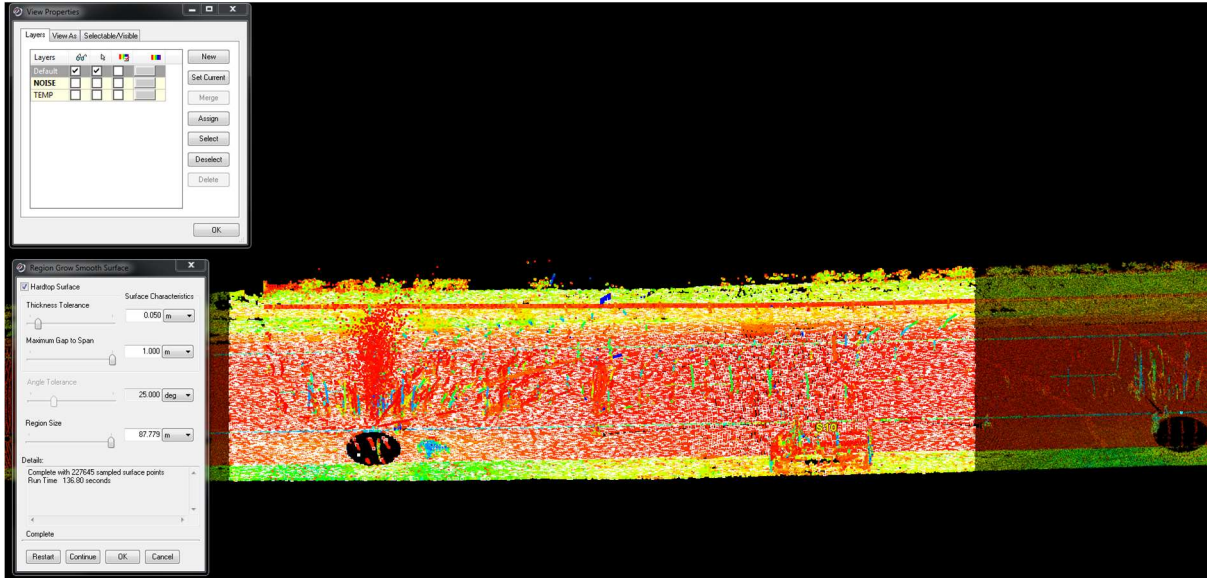
Raw point cloud, including the noise



*Point cloud after using the **smooth surface** function*

Using the **Region Grow Smooth Surface** function offered by the software Leica Cyclone is a quite handy tool to delete the noise above the surface of a motorway. Afterwards the points which build the surface of the motorway can be used to create a regular grid of the motorway. This grid contains heights of the surface what is a perfect information to e.g. analyse the condition of the tarmac.

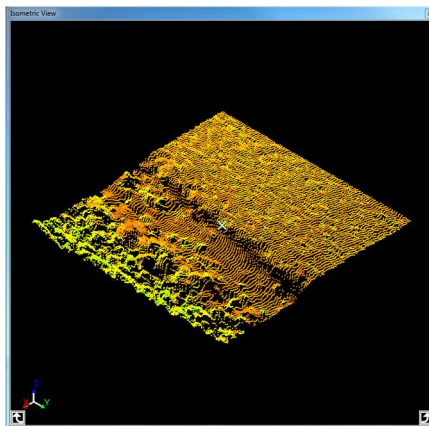
To create a smooth surface the user has to define a specific part of the point cloud, for example simply with the rectangular selection. Then it is necessary to pick at least three points of the currently selected surface of the motorway. Then subsequently the software Cyclone creates a balanced level of the surface of the motorway. As a last step the software deletes all points that are outside the balanced level with a predefined tolerance.



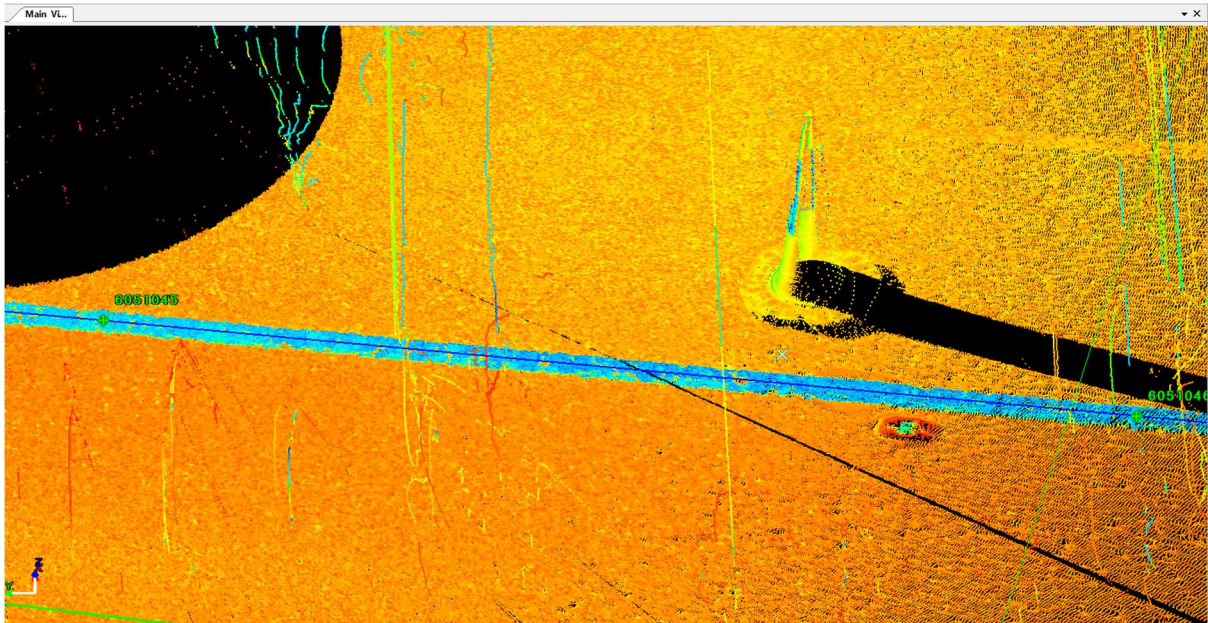
Selected part of the motorway and adjustable settings of the smooth surface function

The software Leica Topo II can be used to export topographical features from a point cloud or to draw topographical lines or objects based on the information provided by the point cloud. In this application case the user can directly pick points in the point cloud and the software creates the preselected lines or objects. As a result this data can be used to create topographical plans. This software works a bit like completing a topographical survey in a point cloud instead of really doing it with a total station on site.

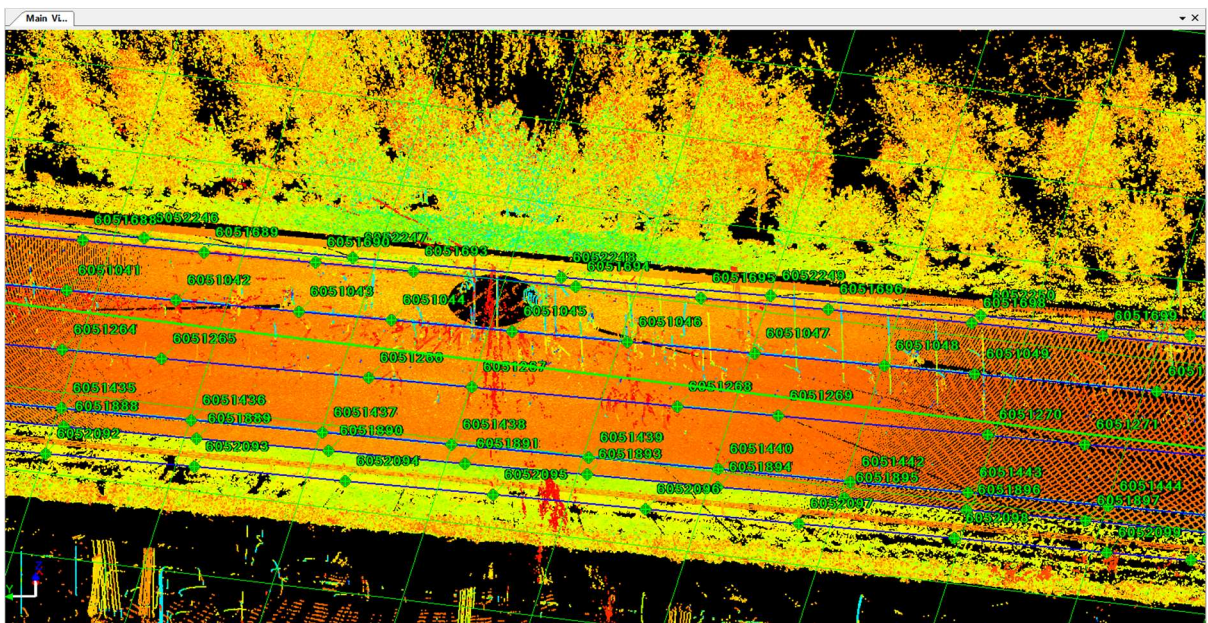
The rendering of the point cloud is quite detailed. Therefore in most cases a clear assessment of the point cloud is possible.



The screenshot shows the edge of the surface of a motorway, the transition from tarmac to the roadside



Drawing of the white solid line that borders the traffic lane of the motorway with Cyclone Topo II



*Drawn topographical lines with Cyclone Topo II and every picked point will be saved with its 3 dimensional coordinates including its height
(the user can export these lines and for example import it into AutoCAD to create an accurate topographical map of the motorway)*

Finally I have to say that Cyclone Topo II is a software for gathering new topographical information, lines or objects from scanned point clouds which can be exported to draw plans with AutoCAD for example.

Concluding part

The 12 weeks in Ireland at Murphy Surveys were a really awesome and unforgettable time! I had the opportunity to gain a lot of new experiences in different fields of surveying. The work in the laser scanning department, a field of surveying that will get even more significant in the near future and that creates a wide range of possible new applications was really satisfying and gainful.

Murphy Surveys gave me the opportunity to get a closer and quite detailed look at the daily work of a surveyor both on site and in the office. Now I have a better idea of a surveying engineer's role in an engineering office of the free economy.

Murphy Surveys is a client oriented company and it is really interesting to deal with the different requests, concepts and ideas of them. Furthermore the interdisciplinary work with architects, civil engineers, CAD specialists, geophysicist and construction managers, just to list a few, is a real challenge but absolutely valuable for the own always ongoing learning process.

I really enjoyed the international atmosphere at this company and I appreciate the work in such an international team where Irish and foreigners of many different countries across Europe and even the world are working together "hand in hand".

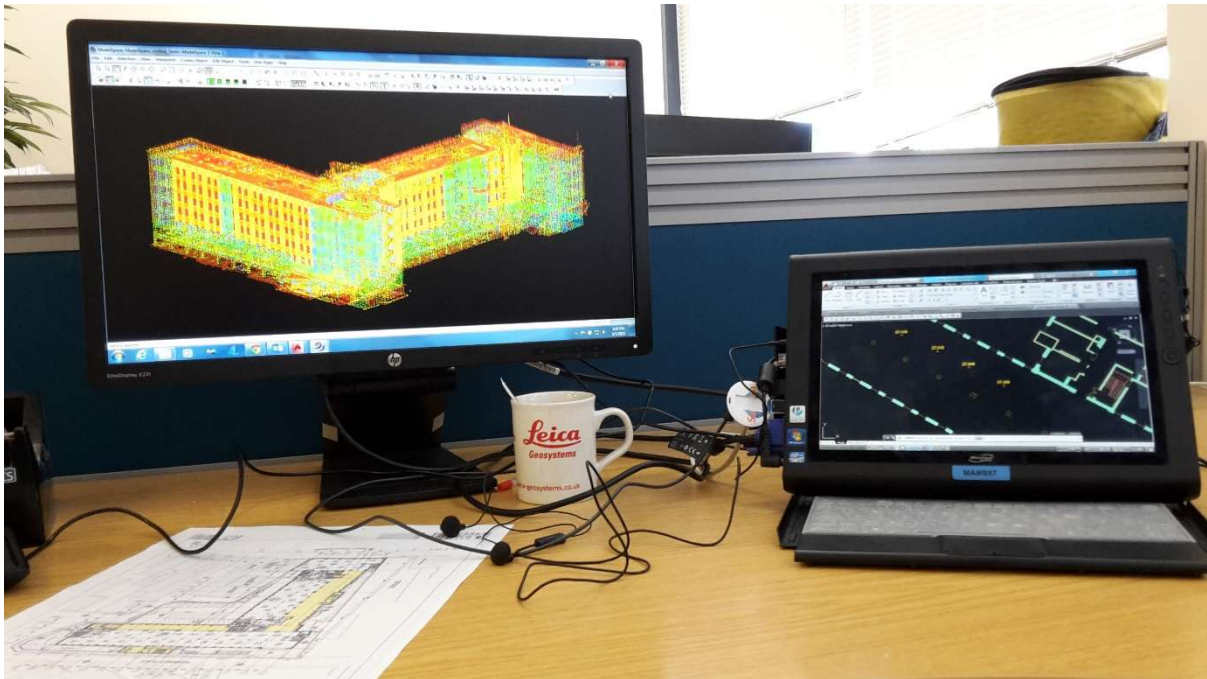
It only took me a surprising short time to settle in the work at the company and the everyday life in Ireland.

As another big advantage of this work abroad I could further improve my language skills, especially during the contact with my colleagues. And beside the technical skills I have learned during my time at Murphy Surveys, there are all the small things in everyday life I have learned and experienced that developed me in a really positive and pleasant way and that I will definitely never forget.

I can absolutely recommend such a step to every other student who dares to complete an internship abroad!

Supplementary photos and drawings

Work in the office



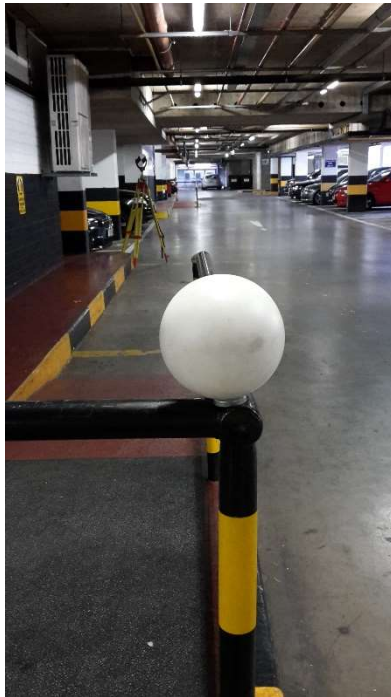
Typical workspace in the office (extracting features of a 3D unified point cloud to a 2D floorplan)

Maintenance vehicle



Typical work vehicle used for the field work (usually two surveyors are working together on site)

Different kind of targets for laser scanning projects



Spherical target with a magnetic stand



Black and white tilt-and-turn targets mounted on adjustable and adaptable tripods



Black and white tilt-and-turn targets mounted on simple stands (alternatively with a magnetic stand)



Numbered, simply printed paper targets



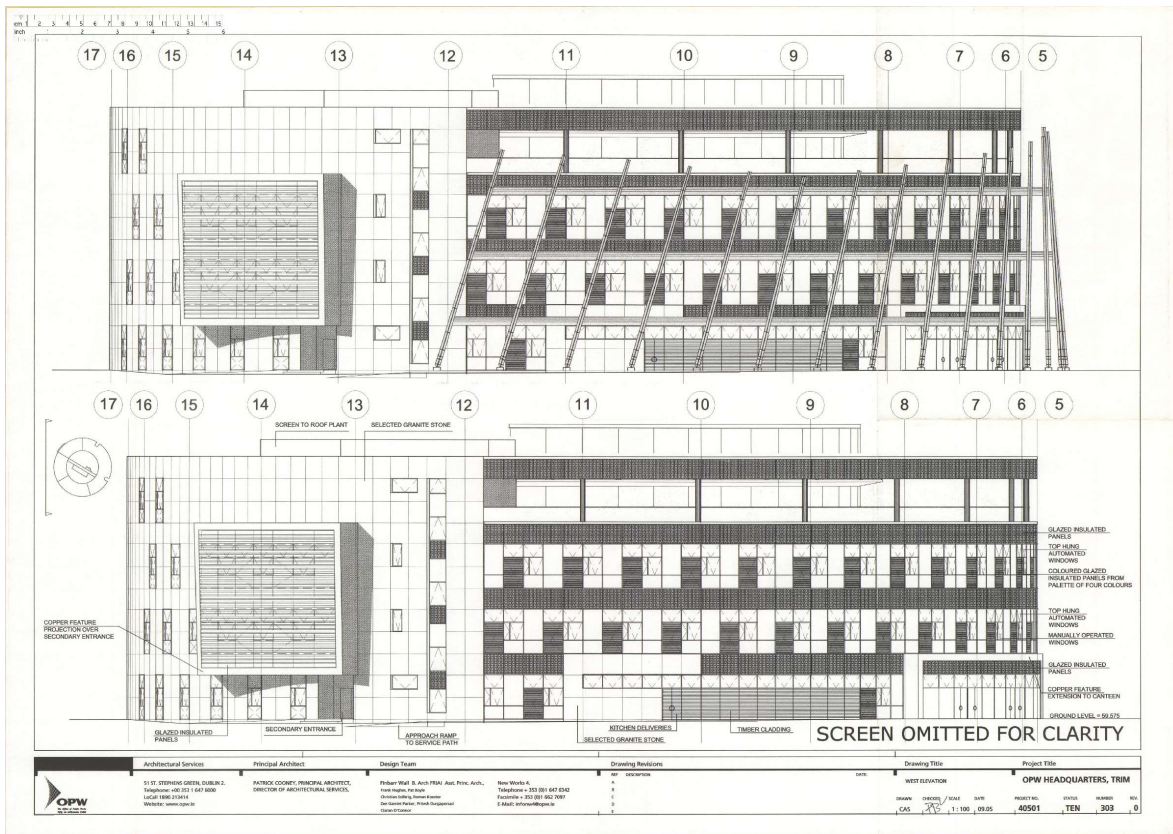
Combined usage of the different targets viewed from one setup

Rolling wheeled tripod

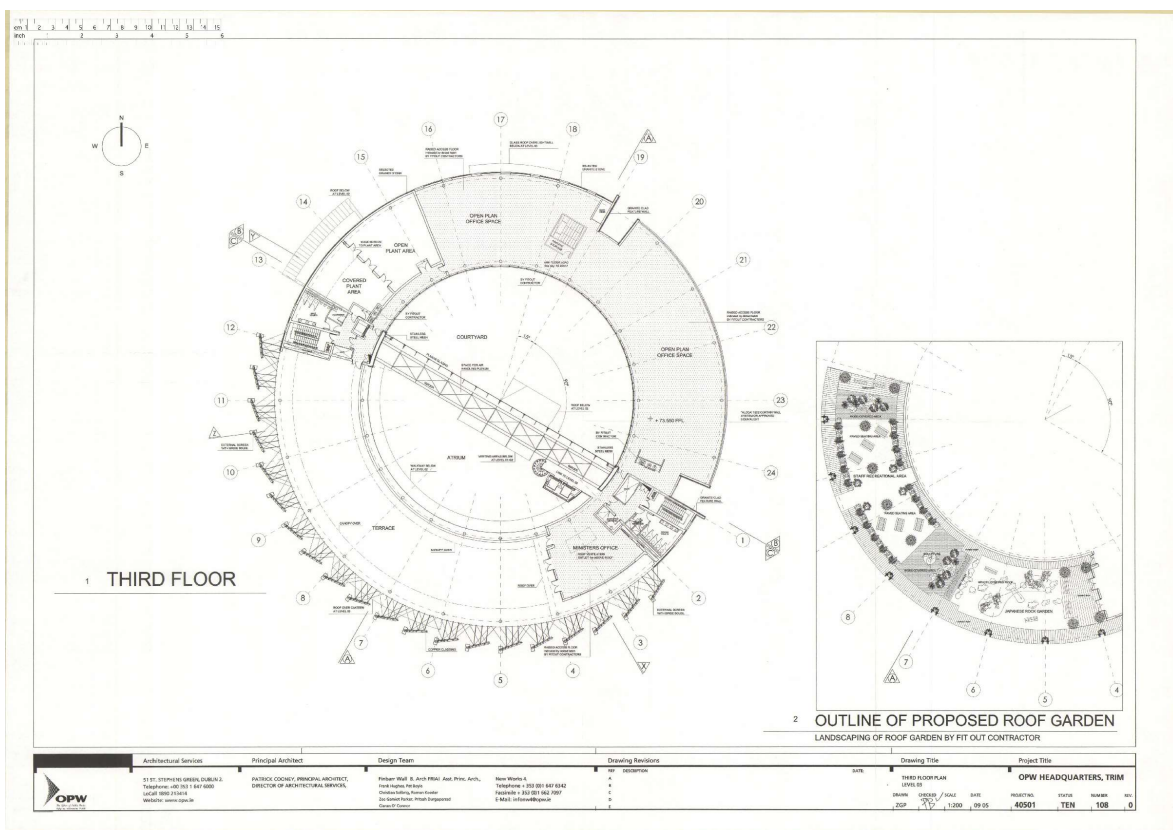


*Rolling legs for casual tripods (great solution for flat surfaces – in this case for a parking level)
much quicker change of the setup position!*

Example for a typical elevation



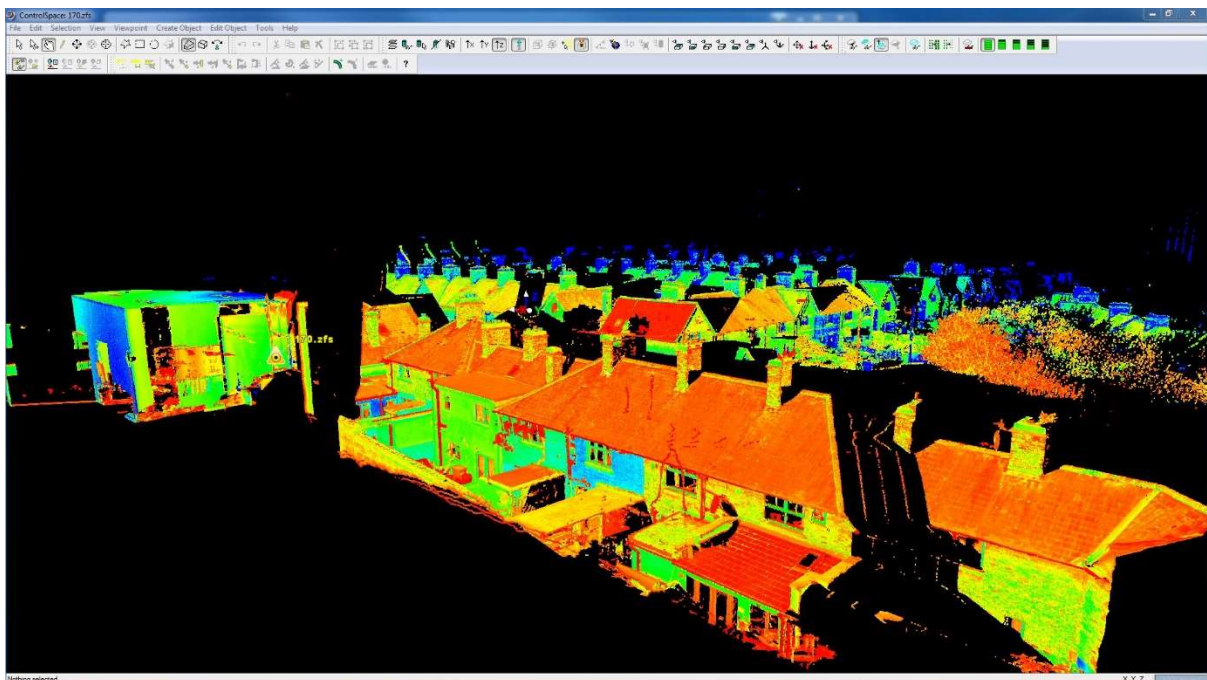
Example for a typical floor plan



Special experiences during my work with Murphy Surveys



Setup on a windowboard to be able to scan the backyards of the buildings above...



...and displaying the scanned 3D-points with Leica Cyclone

Working on the area of the St. James's Hospital in Dublin:



Scans of laboratory spaces at the St. James's Hospital in Dublin





*During our work on site we were not always alone and unimpeded
(photo taken in the academic teaching hospital of the Trinity College Dublin)*



Digital levelling through a building under construction to complete a scanning project

List of documents and homepages I used for this report

- <http://www.leica-geosystems.com>
Leica Cyclone Help Manual
- <http://www.zf-laser.com>
Z+F Imager 5010C Case Study HDR
Z+F Imager 5010C 3D laser scanner Brochure
Z+F Laser Control Manual
- <http://www.murphysurveys.com/>

Annotation:

All photos published in this report were made during the period of the internship by myself, namely Florian Rogosch.

The screenshots resulted during my work in the office.