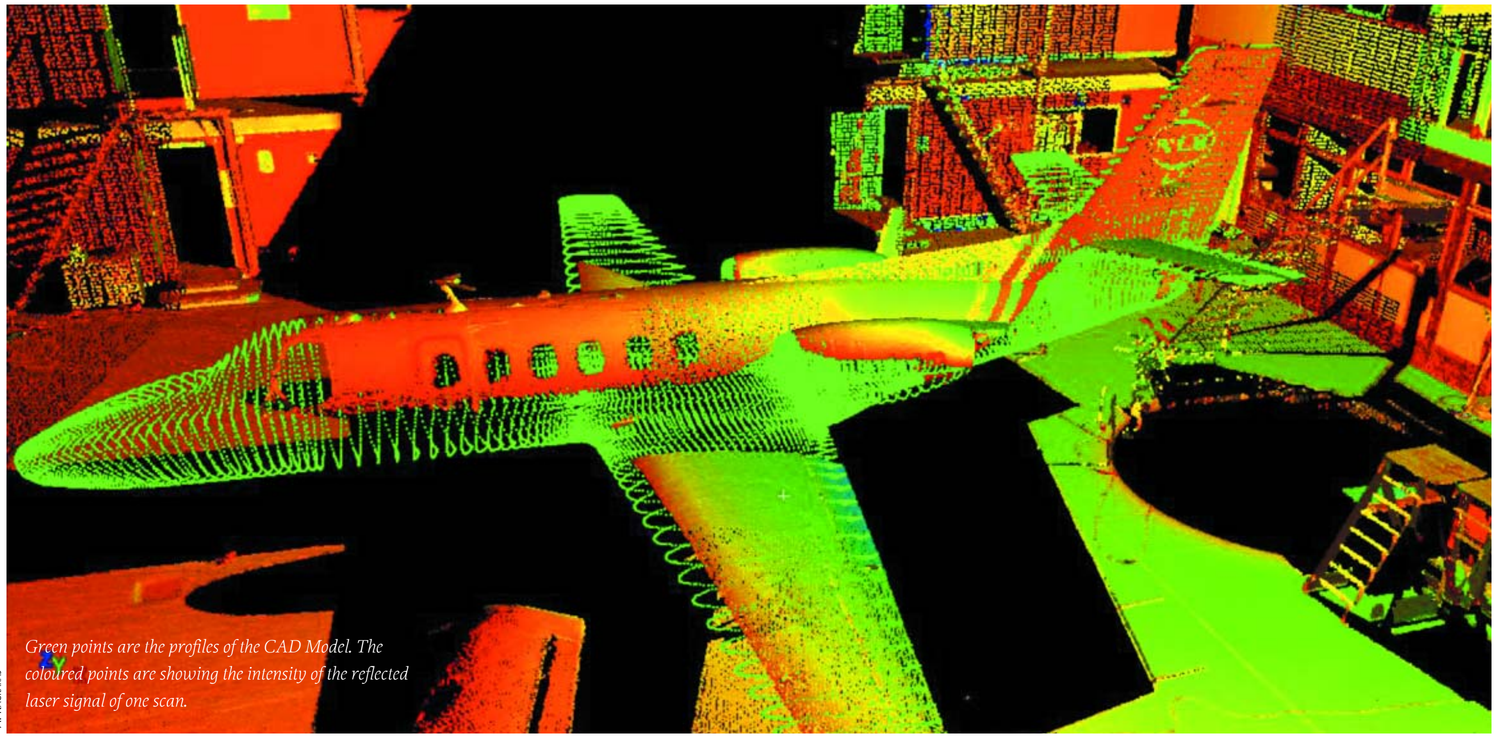


Green points are the profiles of the CAD Model. The coloured points are showing the intensity of the reflected laser signal of one scan.

A. Kagkaras

3D MODEL GENERATION WITH LASER SCANNERS

Approaches towards the improvement of CFD input data and other applications

The creation of models for Computational Flow Dynamics (CFD) studies is becoming a more important research field. Currently the Computer Aided Design (CAD) models are employed in these simulations, but it is hard to improve these algorithms for the simulation process. Therefore the other way is to make better models with the goal of getting better simulation results. On the other hand a CAD model of the constructor doesn't take the current state of the airplane into account. Just think of a ten year old airplane – it's obvious that it is not fresh out of the factory.

by: A. Bucksch, Researcher at Optical and Laser Remote Sensing
A. Kagkaras, Graduate student at Optical and Laser Remote Sensing

Currently Laser Detection and Ranging (LADAR) is a rapidly developing application for measuring the shape of objects. In principle nothing more is done than sending out a laser beam, and measure the reflection that is coming back from the object. This can be done in two different ways. One way is to send out a laser pulse and measure the time until a reflected signal is received. And the other way is to use a continuous beam and measure the difference in the phase of the reflected beam when it reaches the sensor in the scanner. The second one is the fastest one and can easily capture 120.000 points in (x,y,z)-coordinates [2]. At the moment there are three companies that sell these phase-based scanners. These companies are Zoller+Froehlich (Imager5003), Leica (HDS4500) and Faro (LS880). The HDS4500 of Leica and the Imager5003 of Zoller+Froehlich (Z+F) are identical models. The inventor of this Laser Scanner is the company Z+F from Wangen in Germany.

One of the newest applications is to measure aeroplanes and generate a CFD-Model out of the gathered points. This collection of points is often named a point cloud.

But CFD studies are already being done for a while. Why do it with a laser scanner?

This is easy to answer. It's just for the simple reason of generating a better model of an aeroplane, which can be put into the simulation software. Currently the (simplified) CAD Models are used for the computation of airflow around the plane. But it is easy to guess, that the resulting airplane from the factory will have a few differences from the model produced by the manufacturing process. And over the years and after many flights we found out that there are deformations of a few centimetres on the wings and on the body. Furthermore there are a few bumps and dents in the wings, which are about one centimeter deep based on the reference of the CAD Model. Therefore the following steps are taken:

- Scanning
- Registration (Combining several point clouds)
- Modelling (Generating surfaces out of points)
- CFD-Simulation
- Comparison with old results, from the CAD Model

How does the model generation work?

Obviously an aeroplane and a laser scanner are needed to go on. Fortunately, the Aerospace Engineering Faculty has a Cessna Citation that is used for teaching and scientific purposes and the Optical and Remote Sensing Group was provided with a Z+F Imager5003 laser scanner. Now everything is ready for the most essential part of the project, the measurement phase.

This step has to be designed in advance so that an optimal set-up can be used. The best possible measurement set-up should, ideally, provide a complete coverage of the object in question with the least amount of scan positions. Other aspects should be thought out beforehand as well. Targets need to be placed in specific positions, which can later be used for the processing of the obtained point clouds. Finally, because laser scanning can pose health risks, people on the site should be informed about the measurement procedure so that the necessary precautions can be taken.

In our project twelve scanning positions have been used. Still, due to time constraints with the Cessna and the laser scanner we were prevented from having a complete coverage of the plane. However, we managed to acquire the impressive amount of 180 million points from these scans!

Next step is to combine the different point clouds from the different scans into one final and cohesive result. This procedure is called registration and is based on the fact that the laser scans should overlap in some degree between them. The overlapping parts of the scans are fitted together with the help of the Iterative Closest Point (ICP) algorithm [1], which finds the optimal connection of the various point clouds via an iterative process. This algorithm tries to solve the problem of registration in a least squares sense. Thus, constraints are being created between the pairs of overlapping point clouds, which in the end are used for a global computation, which provides the final outcome.

But how did this work in our case? The registration process gave 31 constraints which in the end resulted in a cohesive point cloud of the aeroplane, consisting of 13.6 million points. That is pretty impressive when you think that the original model used for the CFD studies consisted only of 50000 points.

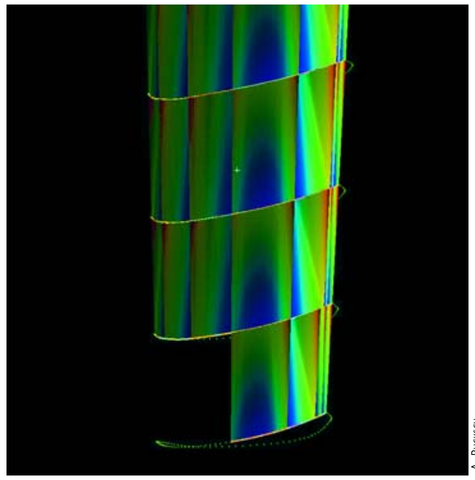
This is still far from a finished result. The only thing we have managed to obtain until now is a huge amount of points that resemble the actual Cessna. If we want to use it for any further work, we need to model it. What modelling requires is the determination of the optimal mathematical surfaces that fit the point cloud 'better'. This basically means that the selected surface should represent the smallest possible deviations from its corresponding points.

Of course there is no specific surface that can magically fit the whole plane. An aeroplane is a complex object that consists of many smaller parts. This fact has an impact when it comes to modelling as well, because it forces us to 'cut down' the object into more elementary components, which are more suitable for surface fitting. To create the most faithful model to reality as possible though, would obviously mean that this segmentation could go on forever. Certainly, the level of detail provided by the laser scans gives us a lot of choice when it comes to modelling. But how far should we go with this?

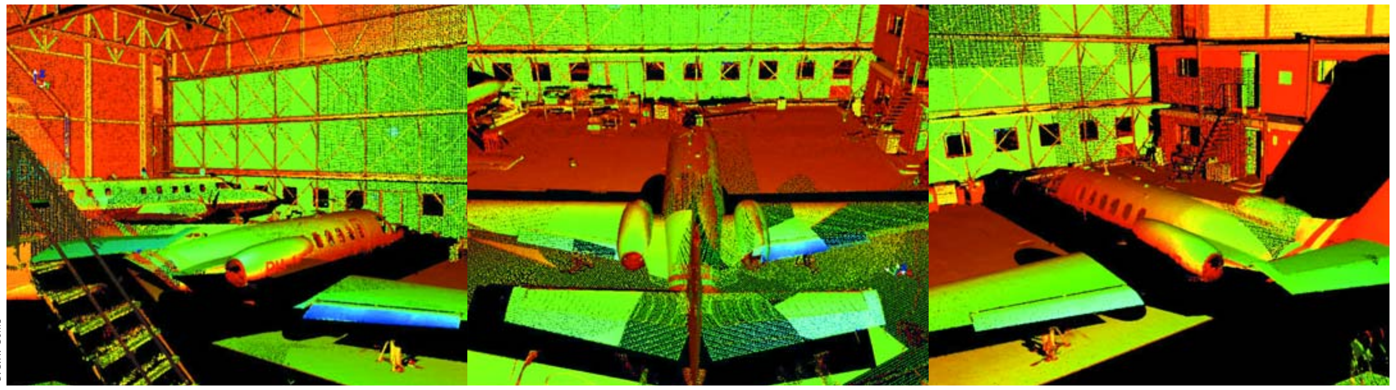
The answer is never simple, because it all depends on the application. What is of most interest for our assignment? Since our project has to do with CFD modelling, we decided to focus our attention to the main part of the aeroplane that is studied in this field, namely the wing. Furthermore, for a bet- »

(left) The Cessna plane of the Aerospace Faculty in the hangar at Schiphol. (right) Patches over the profiles of the left wing. (bottom) Scan of the left side (before registration), the tail wing (registered) and the right side (before registration) of the TU Cessna.

L. De Jong



A. Bucksch



B.G.H. Gorte

ter modelling of the wing, we also have to divide it into smaller parts. But with which criteria can this division be decided? Mainly by examining the point cloud in advance and evaluating which surfaces can provide the best description of our object.

In our case the wing is divided into three main parts: the front, the middle and the tail. Also, top and bottom sections had to be distinguished for the middle and the tail parts. In each part different surfaces seem to fit better. For the front and the middle part we decided to choose quadratic surfaces like cylinders or ellipsoids. These are suitable approximations of the given parts. Finally, for the tail parts planar surfaces are sufficient.

So the final purpose of this project is to see if the result of CFD studies can be positively influenced by using laser scanners and the models generated from these point clouds. This means that we have to position the two models into the same coordinate system and compare their differences. For our project this was done by creating additional constraints between the original CAD model and the laser scanned one, thus making a smaller registration of sorts. Obviously the original design model is too perfect and does not take into account the years of flying and modifications performed on the plane. The laser scanned model gives us the opportunity to model details and deformations which can effectively influence the quality of the CFD studies' results.

Sounds easy, but why is it still complicated to do?

A lot of factors make this task more complicated than it seems to be at a first glance. First of all we don't know much about the behaviour of LASER on different materials. At present we don't have parameters to correct the influence of reflectivity and colour in laser data. All we know is that we have different kinds of behaviours in range, colour and reflectivity [3]. That's the reason why this is currently investigated in another project. Luckily planes are almost entirely of the same material and colour, so that we don't have to take into account these errors too much. But the modelling part is still time consuming. Most of the things are done by hand, because surface reconstruction is still an unsolved topic for those conditions. The huge amount of data is too much for most of the known algorithms. Another reason is that the known algorithms have certain drawbacks. These drawbacks can be found in the ability to model holes or in the use of basic bodies like spheres or cylinders to represent parts of the point cloud. Another drawback can be the assumption of a water-tight model [4].

In practice it can be time consuming to go out for scanning, but not because of technical matters. Moreover it is a problem of people being afraid of the LASER. LASER is still something dangerous in the minds of most people. That's what they learnt from Star Wars and Star Trek. Therefore the scanning of the Cessna took us almost 10 hours, because we were only able to do measurements in the working breaks.

Why don't we measure more?

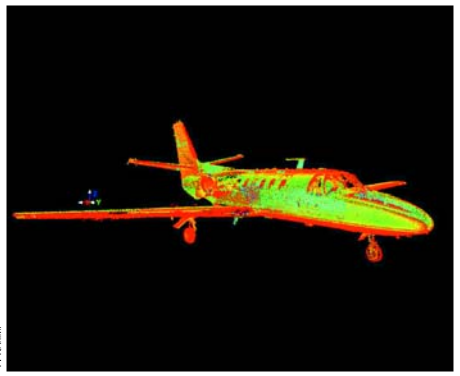
There are a lot more applications, like extracting the topology of trees or reconstructing ancient buildings like the church or the market place of Delft.

In fact, measuring an aeroplane is a thrilling and challenging application. But for measuring more complex objects like gothic buildings or trees, we have to invest in a lot more fundamental research. This research is placed around the topics feature extraction, segmentation and topology description of such point clouds. These topics are still addressed by our research.

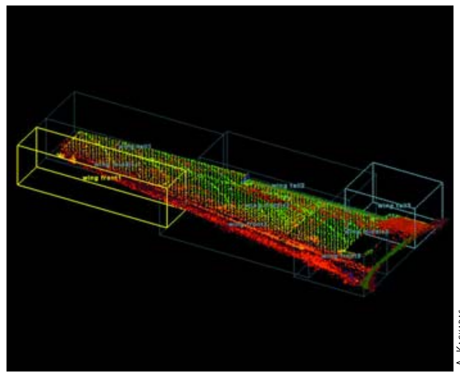
Thanks to Z+F and Leica for making this project possible. Z+F were lending us the Imager5003 and Leica (Netherlands) was giving us the opportunity to investigate their Software Cyclone.

(top) The scanner measuring one part of the tail wing. (left) The fully registered Cessna from twelve scans. The surrounding is removed in Cyclone. (right) Division of right wing in smaller parts for modelling.

S. Sablerolle



F. Karimi



A. Kagkaras

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