Method overview

A lot of work is done researching and discussions between all group members and trying different data and methods to better understand the problems behind scanning with a laser and 3D reconstruction.

For the 3D reconstruction to work the power crust algorithm requires a dense point cloud uniformly sampled from the object. We understood this problem while trying to reconstruct different simulated data. This helped us to understand more why the 3d reconstruction needs the scanning protocol and what are the requirements of the protocol.

IT is impossible to determine the scanning points of a curved object so that the samples of the surface are uniformly distributed. The breast has different curvatures and different size and shapes. To solve that the approach is to assume a cylindrical boundary of the object and perform a scan from different heights Z and azimuth angle $\phi$ at a fixed radial distance $\ro$.

The result of the scan after some linear calculation is a point cloud non uniformly distributed around the object. To create a uniformly distributed sampling the points need to be resampled. This is done by fitting mathematical functions to the points and resampling from the functions at a defined interval.

Using this method, we can control the density of the point cloud by defining the resampling interval and produce a uniformly sampled point cloud that is sufficient for Power Crust.

A new problem is found and that is how to fit mathematical functions in 3 dimensions. In 2D the problem is a little easier but in 3D it is difficult as everything become more complex.

The goal of the interpolation is to find the functions that represent the relations between (x, y, z ) for the point cloud generated by the initial scanning protocol.

The method taken is to create multiple 1-dimensional functions that represents the relation between the different variables.

First the relation between Z and X, then the relation between Z and Y. and lastly the relation between (X, Y).

More specifically We need to find 3 functions F, G and P so that for a given point cloud (X\_i , y\_i , Z\_i ). F(Z\_i )= X\_i , G(Z\_i ) = Y\_i and finaly a parameter form of P(t) = ( X\_i, Y\_i).

After finding the functions to resample from the cloud points, we generate an equidistant array of heights Z for a desired $ \delta Z $. We use F(Z\_i) and G(Z\_i) to get X\_j and Y\_j. Then we fit a function P(t) to X\_j and Y\_j in each height level Z\_i. Then we generate an equidistant array of t\_i defined by a desired \delta t that is approximately equal to \delta Z to resample the functions p\_i(t) at each height z\_i. This create the coordinate (x\_i and Y\_i ) at each Z\_i and results in a uniformly sampled object that we can control its density by choosing a desired \delta t and \delta z.

Data characteristic

Before going through what type of functions fits the data best, it is good to mention the noise in the data. It was not surprising that the data is noisy, that was expected but we didn’t know what type of noise we would expect. As this depends on the setup and laser. Getting some real data gave us a better picture on the type of noise.

First, we had some outliners and that is points that are far outside the breast contour that does not have any explanation on why they would appear as there is no object at those locations. All group members software and hardware have worked together to investigate in those problems by trying different setups and configuration and giving different ideas of the possible source of the noise. We find out that the outliners were because of reflection of the environments specially when the sensor does not find the object the sensitivity of the camera goes higher. This noise was removed by building a case around the setup. Which gave us a better quality of the data.

Second there was an offset in the data that appears that the data point sampled are not symmetrical compared to the STL file, we think that this problem is due to a calibration offset in Yumi or the end effector size due to 3d Printing. We will sample 3 repeatable scans and see if the offset is not changing. If it is not this is easily solvable by compensating for It in the code. If it is changing a further investigation should be done.

Third There is some small noise in the data and the points appears that they are not exactly on the surface, 2 values at the same height may sometimes have the same values of x or y.

Finaly there is high amount of noise is present from the samples around the nipple region and this is due to the curvature of the surface as the laser is far from normal to the surface in this region.

The last 2 type of noise are discussed in the following section and approached by the typ of functions used and another suggest approach.

Function fitting:

There are different types of functions and different type of fitting algorithm with different complexity.

The method taken in this part is not the most complex or advanced method and that’s because of the time limitation of the project and the knowledge of the authors.

This part of the project includes the most potential for improvement as the goal has been to deliver a complete system that we can evaluate. That will give the opportunity to improving in future work as there will be a system to compare to.

Starting by the functions that fit the relation between Z and X and the relation between Z and Y.

This function represents the contour of the breast at different azimuth angles. Even with a variation of the breast sizes and shapes the contour of the breast can be represented as a spline which is a combination of polynomial. The problem is the noise of the data that is mentioned in the section above, a small variation in the noise leads to a less smooth spline if the spline has to fil all points. The easiest approach is to choose a smaller number of points to create the spline which have been implemented.

Another approach will be to use different optimization technique as minimizing the mean square error or a regression model. There exists also different algorithm that optimize the number and order of the polynomial to fit the data.

The second function is the functions that represents the relation between X and Y at different heights, those functions are more challenging as we need a parametric function to fit a circular nonsymmetrical data. Researching the topic gave us that it is best to be fitted by a period trigonometric polynomial. The problem would be to find a solution that minimize the mean squared error between the trigonometric function and the measured values. The paper refers to the conjugate gradient decent method to solve that problem which is done by first reformulating the equations as a Toeplitz system of equations.

None of the group members have the knowledge of those algorithm and it requires time to implement those method, we decided to use a simpler method and focus on the complete system instead. Those method will be discussed in the future work of the report instead.

We implemented instead a simple mean square error minimization of an eclipse function as it is simpler to solve an eclipse equation. The breast shape is not symmetrical, and an eclipse would not fit all type of breasts, but it would be a good start to compare to in improvement.

Another method is to use also a spline to fit the circular data, depending on the time left after setting together the system we would probably use the spline method and compare it to the eclipse method, but it is not a priority as the priority remain to deliver a complete system.

Another approach:

Another approach is also formulated and may be implemented depending on the time left.

The second approach is to perform an initial scan the same as in the current method and use the splines to find the normal direction to the initial scanned surface. We than use this information to create a new scanning protocol that will place the laser sensor normal to the surface at desired scanning points which will results in more accurate sampling and less noisy data.

This second approach does not feel that it needs a lot of working hours, but we still want to priorities the delivery of a complete system.

The plan of the upcoming period is trying to implement the second approach on Monday 28 while waiting for the new breast to be printed. The first approach is already implemented and will be assembled together and evaluated between 29 November and 2 December. If the system works and we are able to get the results from the first approach by the 2 of December. We will use 5 and 6 of December to put together the second approach. Otherwise, we use those days to debug the first approach. We will be working on the presentation between 7 and 9 of December. Structuring and commenting our code between 13 and 16 of December so that we can deliver the software on the 16 of December. The remaining time of the project is used to write the final report that will be delivered on the 13 of January.

From another side sampling real data gave us a better understanding of the noise and challenges that the scanning protocol have.

The scanning protocol need to result in a uniformly distributed low noise point cloud. It is impossible to directly

From another side