Interdisciplinary Project : Apple Reconstruction

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1 Introduction

This project was born from the idea of Frederic Christien to use a destructive method to reconstruct material structure as explain in an article from Asad Ullah [1].

It was a 3 month project and our approach was to try a similar technique on a macroscopic object to give to the research a functional Matlab algorithm. In a such short amount of time we tried our work on an apple and a dry sausage.

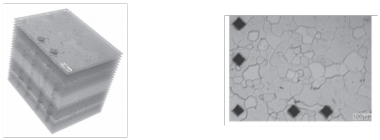

Figure 1: Method explanation

2 Method overview

2.1 Article method

To sum up the method described by Asad Ullah in his article[1], the idea is to take pictures of a metal micro-structure with landmarks while you destroy it. First you create a frame by drilling several holes in your micro-structure. And then you take a picture of the micro-structure in (0,x,y) plan. To obtain those pictures you have to destroy the structure along z axis. At the end you have a stack of pictures that allows you to reconstruct the structure. You will find an example of the micro-structure and of the stack in Figure 1 at 1

2.2 Mathematical model

To model the external structure of a macroscopic object we defined it as a series of plans with a series of origin to locate each plan compared to the other plans a series of orientation vectors (one for each plan) to get the orientation of each plan and a series of external shapes to describe the shape of the macroscopic object.

Mathematically, the external shape is an ensemble of points $(x_{i,j}) \in \mathbb{R}^2$ were j is the index of the plan, the origins are also an ensemble of points $O_j = (O_{1,j}, O_{2,j}) \in \mathbb{R}^2$ were j is the index of the plan and the orientation vectors are an ensemble of vectors $v_j = (v_{1,j}, v_{2,j})^T \in \mathbb{R}^2$.

To obtain the aligned external structure we apply a transformation of the space Φ. Let's define $\Phi : (x_{i,j}) \rightarrow (rot_{-\theta_j}(x_{i,j}))$ with $\theta_j = tan^{-1}\left(\frac{v_{2,j} - O_{2,j}}{v_{1,j} - O_{1,j}}\right)$

2.3 Matlab implementation

We first tried to develop the algorithm Python 2.7 and a 3D library but the render did not look interactive enough for our M. Christien. To tackle that issue we used matlab.

To align the different plans we did not use any implemented functions but to detect the external structure we used shearcolor function.

3 Experiments

3.1 Apple experiment

To get the origins and the orientation vectors we used blue and red food coloring. To cut the apple with a constant step we used a kitchen slicer. And to get the pictures we used a scanner.

After the experiment we post processed the images with an image editing software (Paint). That allowed to have a series of pictures similar to the one you can observe in 2 at page 2.

3.2 Dry sausage experiment

We used a similar method to obtain the shape of a dry sausage. But some adjustment had to be done. In fact it could appear more simple to apply our method on a dry sausage rather than on an apple because its external structure seems easier to model but the internal structure made it harder to do.

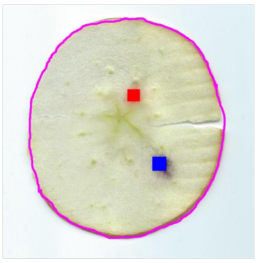

Figure 2: Apple slice

For instance, we could not use the kitchen slicer because the flesh of the dry sausage was to soft. To tackle that issue we used a slicing machine adapted to dry sausages. It was also impossible to use food coloring to get the origins and the orientation vectors. You will find some dry sausage slices in figure 3 at page 2.

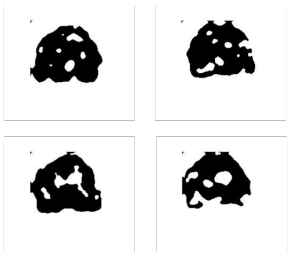

Figure 3: Dry sausage slices

4 Results

4.1 Experiment results

The experiment worked well enough on the apple but some problems occurred. Some slice were destroy by the slicer before scanning so we had to extrapolate the shape manually generating errors. The image editing software smoothed the hue value of our annotations that made our Matlab algorithm less efficient. Beside those technical issues, we manged to create a 3D structure of an apple as you can find in figure 4 at page 3.

The aim of the dry sausage experiment was to create an external and internal structure. But it was the piece of fat was to thin to be seen on two slices. Furthermore as we explained before, we could use food coloring to get the origins and the orientations vectors. All those issues made the annotation and the creation of a 3D model impossible.

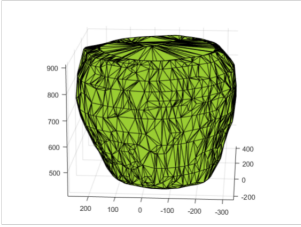

Figure 4: Apple reconstruction

4.2 To go further

First, an automation of the annotation is needed to make our work functional. A detection of different inner structures had to be added to our work to be relevant for a material structure investigation. A way to take picture of the object with a good resolution would improve our results.

5 Conclusion

This project gave us the opportunity to work in collaboration with a researcher. After 3 month we gave a functional algorithm and hints on how M. Christien could duplicate the technics described by Asad Ullah in his article[1]

References

[1] Ullah, A., Liu, G., Wang, H., Khan, M., Khan, D.F. and Luan, J., 2013. Optimal approach of three-dimensional microstructure reconstructions and visualizations. Materials Express, 3(2), pp.109-118.