Summer Internship Project
Report

[TODO] Topic

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Abstract

Contents

Chapter 1

Objective

This internship had several personal objectives:

- Discover the world of research in the field of computer vision in a scientific way.
- Put into practice my knowledges acquired during my bachelor and my first year of master.
- Develop my english skills in order to be able to communicate with the world of research.

The technical objective of the internship was to contribute to an interdisciplinary research project bridging plant biology, 3D imaging, and computer science. My main contribution was to modelize the propagation of CO_2 in leaves cells using a diffusion equation.

Chapter 2

Introduction

2.1 PRIP Laboratory

2.1.1 Presentation

The Pattern Recognition and Image Processing Laboratory (PRIP) is a research group of the Vienna University of Technology (TU Wien) and is part of the Computer Science department. The TU Wien is Austria's largest research and educational institution in the field of technology and natural sciences. The Computer Science department is one of Europe's leading research and innovation institutions. PRIP Laboratory is focused on advanced image representations and methods that allow the structure of the image to become an essential part of recognition systems. Among the people working in the PRIP Laboratory are:

- Prof. Walter G. Kropatsch, Head of the Group.
- Dr. Jiří Hladůvka, My tutor.
- Majid Banaeyan, PhD student.
- Darshan Batavia, PhD student.

2.1.2 *Water's gateway to heaven* project

Water's gateway to heaven is an interdisciplinary research project funded through the Life Sciences programme on Multimodal Imaging of the Vienna Science and Technology Fund (WWTF) [3]. The project is a collaboration between three viennese universities:

- Plant ecophysiologists and anatomists at the University of Natural Resources and Life Sciences [5].
- Plant cell biologists at the University of Vienna [6].
- Computer scientists expert in pattern recognition and image analysis at the Vienna University of Technology (TU Wien) [7].

The project focusses on the stomata, tiny pores on the surface of plant leaves. Stomata open and close to provide CO_2 for photosynthesis and to limit water loss. This project uses novel temporal $3D$ imaging to provide a better description of stomatal movements in order to get a mechanistic understanding of how transient this movement. The goal is to answer long-standing questions about stomatal movements and to generate basic knowledge on how to improve stomatal responses under dynamic environments in order to increase net productivity and water-use efficiency [9].

2.2 Technical overview

The images use for this project are $3D$ images of leaves coming from high-resolution X-ray micro-tomography (micro-CT) and fluorescence microscopy. The size of the images is $2000 \times 2000 \times 2000$ pixels. In order to track the change of the individual cells over time, hierarchies of abstract topological cell complexes are used, which will reduce the image data to a neighboring structure of the plant cells without losing the relation to the original data. This makes it possible to verify hypotheses at any time that arise during the course of the biological analysis but may not have been known at the time the hierarchy was built. Furthermore, this structure of the plant cells is to be used to simulate dynamic processes [8].

2.2.1 Combinatorial maps

Chapter 3

Work Done

3.1 First work

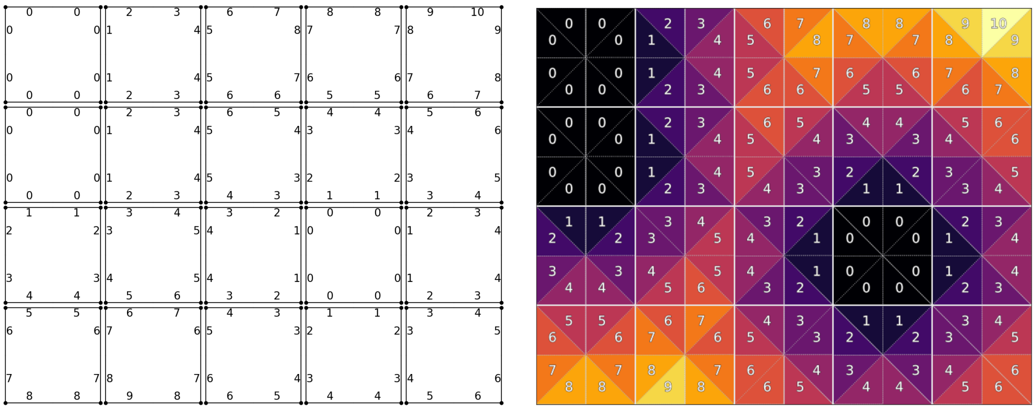
During the first month, my work was mainly focused on being familiar with the project and the data, in order to find the best way to contribute to the project.

3.1.1 Python library

Carmine Carratù, the previous ERASMUS student, has been working on algorithms for the computation of distance transform into $G-maps$. My goal was to understand the code and know how to use it to create figures for future publications. The code was not documented so in reading the code I started to comment it and create documentation. I also bring some optimizations to the code. Some functions was not very helpful for the purpose of the project and the code was in several files, whereas we wanted to keep the code as simple as possible in one notebook. So I created this notebook to combine all the usefful and documented functions in one place.

New representation on a $G-map$

The representation of the distance transform was changed to be more intuitive. On the figure (3.1a) the distance transform is represented as a $G-map$ with the distance values on the dart. It's hard to see the variation of the distance values. The new representation is shown in the figure (3.1b). This representation uses triangles for each dart showing the distance values. In addition, we use the *inferno* color map that is perceptually uniform with monotonically increasing luminance [2].



(a) Old representation (b) New representation

Figure 3.1: Different representations of the distance transform on a $G-map$

New representation on a leaf image

On the leaf image, the representation was changed too. Before the distance transform was print with a black and grey color map as shown in the figure (3.2a). The new representation, shown in the figure (3.2b) uses the *inferno* color map and an overlay can be seen to show the other parts of the leaf image.

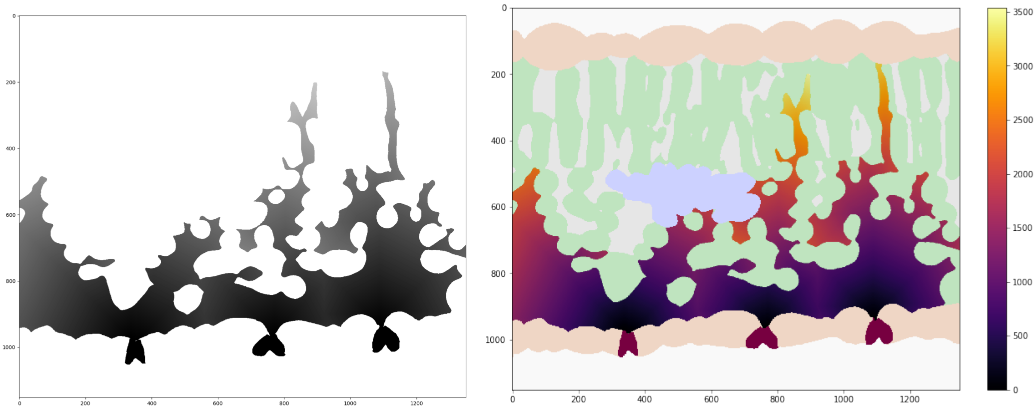
Wave propagation animation

The distance transform algorithm uses a wave propagation method to propagate the distance values. I used *Click* [1] Python package to create a command line program that can be used to animate the propagation of the distance transform.

3.1.2 Diffusion equation

In order to achieve the main goal of the Watergate project it's important to study the gas exchange process that occurs in plant leaves. The distance transform is used to compute the geodesic distance from stomata to mesophyll cells where the photosynthesis is performed. The gas exchange rate depends on this distance over which the diffusion occurs [4]. To study gas exchanges inside leaves, we have chosen the diffusion equation, described in 2D by this Partial Differential Equation (PDE):

$$\frac{\partial u}{\partial t} = \alpha \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) \tag{3.1}$$



(a) Old representation (b) New representation

Figure 3.2: Different representations of the distance transform on a leaf

where $u(x, y, t)$ is the concentration at position x, y in time t and α is the diffusion coefficient.

With a finite-difference method, we can convert the PDE (3.1) into an explicit equation described as follows:

$$u(x, y, t+1) = u(x, y, t) + \alpha\big(u(x+1, y, t) + u(x-1, y, t) + u(x, y+1, t) + u(x, y-1, t) - 4u(x, y, t)\big) \quad (3.2)$$

where $\Gamma(x)$ is the set of neighbors of pixel x.

Chapter 4

Future Work

4.1

4.1.1

Chapter 5

Conclusion

Acknowledgment

References

[1] Click Python Package website. https://click.palletsprojects.com/.

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[6] University of Vienna website. https://www.univie.ac.at/en/.

[7] Vienna University of Technology website. https://www.tuwien.at/.

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[9] Water's gateway to heaven website. https://waters-gateway.boku.ac.at/.