ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

Scientific Report

First name / Family name	Henri Der Sarkissian
Nationality	French
Name of the *Host Organisation*	CWI
First Name / family name of the *Scientific Coordinator*	Joost Batenburg
Period of the fellowship	01/02/2017 to 31/01/2018

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my fellowship, I mainly worked on the segmentation problems in X-ray computed tomography (CT) and links with discrete tomography. The project was designed within a collaboration between the Computational Imaging group of CWI and the Marine biodiversity group in Naturalis Leiden. This group needs to analyze large datasets of seashells and assess their shapes with non-destructive CT imaging.
In this context, I worked both on the physical characterization of the CT scanner (mainly the source spectrum) and the segmentation of the data, transforming a greyscale 3D image into a single binary volume.

The following elements have been (co-)developed:
- Python scripts for processing the imaging data, from the CT projections to the thickness evaluation.
- An automatic segmentation method using prior tomographic information. In absence of a reference for accurate segmentation such as in phantom studies, it is very hard to assess the correctness of the segmentation and the manual selection of parameters can lead to deviations between the actual object and its binary representation. Inspired by previous works about discrete tomography and variational frameworks, we designed a fast algorithm to segment discrete images (representing only few different materials) steered by the information provided by the tomographic projections. The main idea behind it is that reconstructed CT images exhibit unwanted structures and bias (such as streak artefacts for instance) which actually arise by the structure of the inverse problem. Using this prior knowledge allows us to improve the segmentation fidelity. This work has been

submitted for publication.
- Implementation of computational calibration methods for the source spectrum estimation of a micro CT device using an aluminium phantom. The goal of the source spectrum estimation is to accurately correct for beam-hardening artefacts that arise from the polychromatic X-ray source and which differs from one device to another in order to minimize its effect.
- Implementation of X-ray projection simulation tools using the ASTRA toolbox. The simulation includes polychromatic beam source, detector spatial response (PSF), attenuation properties of materials and phase-contrast effects.

Within this project, I also explored the effect of segmentation and the use of a task-based thresholding scheme based on the inclusion of a test artefact of known geometry in each batch of CT scan. Especially in this project, the same object ("reference shell") was scanned along with each batch of 5 samples. The goal is to calibrate the surface extraction procedure of the scanned shells, from the deviations measured on the reference object. This work is still ongoing.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

[1] H. Der Sarkissian, N.R. Vigano, K.J. Batenburg. *A data consistent variational segmentation approach for real-time tomography*. Submitted to *Fundamenta Informatica* in October 2017.
Abstract: Computed Tomography (CT) is a X-ray imaging technique that allows to reconstruct volumetric information of the analysed objects from their projections. The most popular reconstruction technique is the Filtered Back Projection (FBP). It has the advantage of being the fastest technique available, but also the disadvantage to require quite many projections to retrieve good quality reconstructions. In this article we propose a segmentation method for tomographic volumes composed of few materials. Our method combines existing high-quality variational segmentation frameworks with the data consistency approach used in tomography and discrete tomography. We show that our algorithm performs well under high noise level and with moderately low number of projections, and that the data consistency significantly improves the segmentation, at the cost of only one FBP reconstruction and forward projection.

III – ATTENDED SEMINARS, WORKSHOPS, CONFERENCES

- **NICAS (Netherlands Institute for Conservation Art and Science) matching days**, 4 April 2017, Amsterdam
Attendant
This interdisciplinary workshop intended to bring together data and imaging scientists with art and conservation scientists in order to develop further collaborations and explore research opportunities.

- **Focused Workshop on Real-Time Tomography**, 10-17 April 2017, Amsterdam
Attendant
This workshop was organized within the COST EXTREMA action and had an international audience. The focus was on the data processing methods in different X-ray tomographic setup (lab source, synchrotron, etc.) and their integration into a full task-oriented imaging pipeline.

- **Mini VOXEL workshop on Processing and Analysis of Light-field Data**, 16-17 October 2017, Amsterdam
Speaker: "Regularized data-aware segmentation"
This workshop was organized within the H2020 VOXEL project and had a European audience. Its focus was light field image processing and more generally application of computational imaging methods to light-field problems.

- **EMAT/CWI get together day**, 10-17 April 2017, Amsterdam
Attendant and speaker: "Regularized data-aware segmentation"
This one day workshop aimed at getting to know each other between the EMAT lab in Antwerp and the CI team in Amsterdam, presentation of projects and prospective future works.

- **Invited seminar in CNR - ISTI**, 11th January 2018, Pisa
Speaker: "Tomographic imaging in CWI: Algorithms and applications"
Abstract: Tomography is a widely used imaging tool to explore the 3D inner structure of object without having to cut it open using penetrating beams. In this talk, I will present the different aspects of tomographic imaging handled and developed at the Computational Imaging group in CWI, Amsterdam. The broad application range include cultural heritage imaging, food industry, biology and nano-technologies. Some of these applications require specific treatment because of the imaging conditions (few projections, noise, setup geometry, etc.) and most of them need segmentation of the 3D images to extract the features of interest. In this context, some algorithmic tools developed within the group, with a focus on discrete tomography, will be presented.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

REP Institute: CNR ISTI – Signal and Images Laboratory, Istituto di Scienza e Tecnologie dell'Informazione "Alessandro Faedo", Pisa, Italy

Local scientific contact: Prof. Emanuele Salerno

Description: I visited the Signal and Images lab of CNR ISTI from January 08th to January 12th 2018. During my stay, I gave a talk at the lab seminar called "*Tomographic imaging in CWI: Algorithms and applications*" where I presented my work and some activities of the Computational Imaging group.
I also have been introduced to the lab activities and especially the applications in cultural heritage: blind deconvolution, restoration, multispectral imaging. I also visited other connected research groups: the Visual Computing Group within the institute, with a strong skills in computer graphics for cultural heritage; and the Applied Laser Spectroscopy Lab (CNR-ICCOM), with expertise and imaging facilities in spectral imaging. Interesting collaboration opportunities were discussed.