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LAURENT BABOUT, DOMINIK SANKOWSKI
Faculty of Electrical, Electronic, Computer and Control Engineering
Technical University of Lodz

DENIDIA PROJECT: A MARIE CURIE ACTION TO INCREASE EXCELLENCE IN HARDWARE AND SOFTWARE DEVELOPMENT RELATED TO TOMOGRAPHY APPLICATIONS

Recenzent: **prof. Andrzej Pląskowski**

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This paper summarizes the 4-year FP6 Marie Curie Transfer of Knowledge project, in terms of recruitment/secondment strategy, scientific organization and achievements related to tomography. Emphasis is placed on the interaction between different research areas that has been thought in order to increase the level of expertise of the Computer Engineering Department in the field of tomography, both concerning hardware and software applications.

1. INTRODUCTION

Tomography techniques have become very popular in the past 10 years, even if they have emerged more than 30 years ago. A rapid survey[1] shows that more than 19000 articles have been published in the past 10 years that deal directly or indirectly with tomography techniques or data in scientific fields such as physics,

[1] Results from www.scopus.com. Last consultation: 20.08.2010.

engineering, earth science, computer science, chemical engineering and materials science, but excluding life and health sciences. The large number of publications is mainly related to the large number of techniques that fall into the tomography group since it is possible to obtain non destructively 2D/3D sectional images from various technical approaches, regrouped in 2 main families: soft field and hard field tomography. Electrical tomography is part of the former group while X-ray and gamma-ray tomography techniques are part of the latter.

It is during that last decade that the Computer Engineering Department (CED) has started its activities in the domain of tomography, but mainly related to computer science solutions (i.e. image reconstruction, data analysis) applied to electrical capacitance tomography measurements [1-5]. The aim of CED was to expand its knowledge to a wider range of tomography techniques and applications, especially linked to hard-field tomography techniques, but also to widen it expertise in electrical capacitance tomography through new hardware (i.e. acquisition unit and sensor design) and software design. Another aspect was to get a higher expertise in computer vision and graphics by tackling real application problems deduced from 3D images, mainly obtained from X-ray tomography measurements.

This knowledge expansion was made possible thanks to a 4-year European project, started in October 2006, under the FP6 Marie Curie Transfer of Knowledge-Development scheme called DENIDIA. This acronym is deduced from the project title "**D**evelopment of **E**xcellence in **N**on **I**nvasive **D**iagnostic system for **I**ndustrial and scientific **A**pplications". Transfer of knowledge was made through recruitment of experienced researchers (ER) and secondment of research staff to selected top-class partners from France, UK, Norway and Malaysia. The aim of this paper is to give more insights about the strategy that has been followed during this project, the action plan and a brief overview of the results that have been obtained.

2. PROJECT STRUCTURE AND MANAGEMENT

The project originally planned to recruit top-class researchers and second research staff to partners for a total of 132 research-month. Besides difficulties met in the recruitment process, we finally reached 90% of our goal since a total of 120 research-month was achieved. The detailed recruitment organization is shown in the Gantt chart presented in Fig. 1. One can see that no recruitment nor secondment was realized during the first year, as it was originally planned, due to difficulties in finding and candidates. Everything that was planned during this first project year was postponed to the 3 remaining years. During the project, we have recruited 7 researchers, among which 2 classified as more experienced (MER) due to their experience in research that exceeds 10 years. Recruitment periods spanned between 4 to 24 months. Three of them were Third Country Nationals (i.e. dr Y.B. He and dr Z. Liu from the China, dr A. Kornev from Ukraine) while the remaining researchers were EU Citizens (i.e. dr K. Brandisky from Bulgaria, dr D. Styra from Lithuania and dr K. Tan from UK) or from Associate Countries (i.e. Prof. E. Hammer from Norway). In terms of secondment, we have selected top-class partners for the different training periods. These included French laboratories such as the MATEIS laboratory (INSA-University of Lyon represented by Prof. E. Maire) specialized in X-ray tomography for materials science applications and the A2SI laboratory (ESIEE-University of Paris-Est represented by Prof. M. Couprie) specialized in image processing and discrete mathematics. Two partners from UK were also selected: the Henry Moseley X-Ray Imaging Facility (UoM- University of Manchester represented by Prof. P.J. Withers) specialized in X-ray tomography and the Department of Electronic and Electrical Engineering (UoBa-University of Bath represented by dr M. Soleimani) specialized in image reconstruction and inverse problems. Knowledge about gamma-ray tomography was achieved through the partnership with the Department of Physics of the University of Bergen (UiB represented by Prof. G.A. Johansen). Finally, a partner from Third Country, the Malaysian Nuclear Agency (MNA, represented by Dr. J. Abdullah) was selected for its expertise in gamma-ray tomography, but also in neutron-based technology.

Recruitment and secondment were organized around three main research actions:

- Action 1: 3D ECT-sensor design and measurements
- Action 2: Spatial resolution improvement of ECT-new concepts and design
- Action 3: computer vision and graphics: 3D visualisation, 3D processing, 3D data analysis

The tasks carried out by the different researchers were related to the 3 main actions as shown in Fig. 2. One can see that Action 1 did actually not focus only on 3D ECT and sensor design, but also on development of new ECT acquisition unit, as it will be explained later on in this paper. One can also see that some tasks are common to 2 different actions which shows how the 3 actions were not treated separately, but as a whole as much as possible.

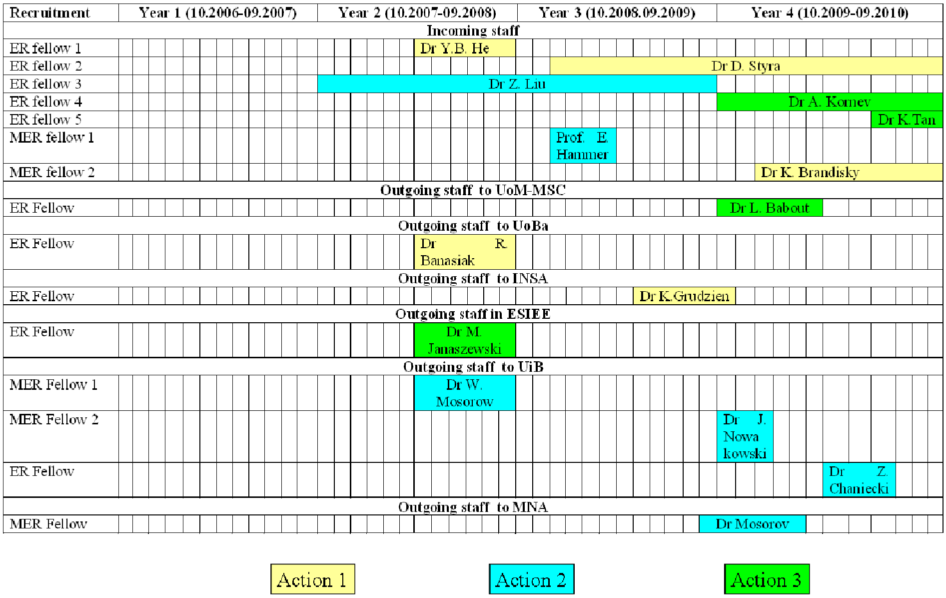

Fig. 1. Gantt chart of the recruitment and secondment process during DENIDIA project

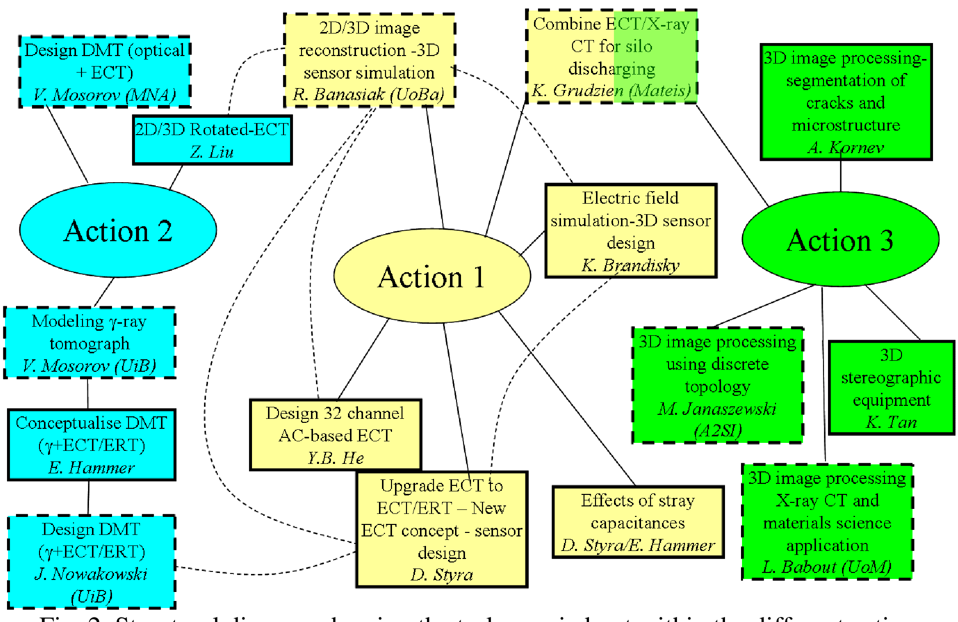

Fig. 2. Structural diagram showing the tasks carried out within the different actions

3. RESULT OVERVIEW

As mentioned earlier, Fig. 2 presents the different tasks realized during the DENIDIA project. The topics have covered the full range of research activities that can deal with tomography, such has acquisition unit development, sensor design, electric field simulation, image reconstruction, data fusion from different tomography modalities, 3D image processing and analysis. The tasks with the most valuable achievements - in the present case, the number of publication is chosen as a the main criterion- are mentioned below. This does not mean that tasks which had led to less publication are less important since they may have occurred more recently. However some of them are described in details in the same issue of this paper [6-8].

A major achievement has been the design by dr Y.B. He, initially to cope with 3D capacitance measurements [9]. Later on, this system has been updated and modified by dr D. Styra (16/16 channel AC-based ECT/ERT called DECaRT) to allow parallel measurements of resistance and capacitance in the case of conductive/non-conductive mixture such as the one characterizing oil/salt water/gaz flow in pipeline. This has been a crucial update to carry out measurements using the multi modality sensor developed in collaboration with the UiB which combines electrical measurements with gamma-ray signal to quantify components in stratified multiphase flow in pipeline based on the methods presented in [10]. At the same time, dr D. Styra has developed a new concept of miniaturized ECT system that can be directly mounted on sensor, with a new method to compensate stray capacitance for non-stray immune system [11]. DECaRT has also the great advantage, since it is home-made, to allow integration of the stepper motor control inside the main software to synchronize capacitance measurements with rotation of the rotatable sensor developed by dr Z. Liu [12, 13]. The results obtained using such sensor in terms of shape accuracy and object fraction have been very promising for static objects while some limitations linked to the acquisition speed and low signal-to-noise ratio (SNR) have been found during dynamic test that corresponds to horizontal slug regime during solids pneumatic [14]. In the latter case, different image reconstruction strategies have been tested, even the ones developed by Banasiak during his training period at UoBa. [15]. It is worth mentioning that that collaboration has been particularly fruitful in terms of publications with 5 papers published during 2009-2010 related to 3D/4D ECT [15-19]. These non linear approaches, despite a relative long computation time, have shown very promising results, both in 2D and in 3D to reconstruct accurately sample shapes.

Compared to action 1 and action 2 that have been relatively close in terms of research subjects dealing essentially with ECT-based research, action 3 has been a relative separate action. One can notice in Fig. 2 that still a link with action 1 exists with the comparison between X-ray tomography data and ECT measurements on silo discharging [20, 21]. However, most of the tasks have concerned the development of image processing algorithms, as well as data analysis, related to materials science application based on X-ray tomography measurements. This work has been done in collaboration with UoM and ESIEE in the case of investigation of stainless steel response to stress corrosion cracking. More specifically, the work has focused on the development of so-called hole filling algorithm by dr M. Janaszewski during his training period at ESIEE to identify bridge ligaments that occur along the crack path [22, 23]. It has been also shown by dr L. Babout during his training period at UoM that this algorithm can have potential interest to be used in other materials science applications [24]. Another aspect of the work has concerned the development of an algorithm to separate crack object to air object that surrounds the material since cracks generally appear at the surface of sample. This has been done during collaboration between dr A. Kornev and dr H. Talbot from ESIEE [25]. Another aspect of the action concerns the development of a 3D stereographic system to help interpretation of images. More details are given in [6]. This system, preferentially developed for X-ray tomography images, can be also of great interest to visualize results from other modalities such as 3D ECT.

4. CONCLUSIONS

With 7 recruited fellows and 8 training periods in 6 different top-class partner institutions for a total of 120 research-months, the DENIDIA project has successfully achieved its original goal of increasing excellence in tomography research by covering a large spectrum of applications such as hardware design and development, image reconstruction, image processing and analysis. The success of the project can also be measured with the set of new collaborations that have been established during the past 4 years, but also the number of publications. Indeed, 9 papers have been published so far in international journals with more to come, more than 10 in national, more than 15 in conference proceedings and 1 patent application has been filled. This project has also given new ideas for future EU grant applications.

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PROJEKT DENIDIA: PROGRAM MARIE CURIE W CELU UZYSKANIE DOSKONAŁOŚCI W ZASTOSOWANIACH NAUKOWYCH I PRZEMYSŁOWYCH PRZY WYKORZYSTANIU TOMOGRAFII PROCESOWEJ DLA BEZINWAZYJNYCH SYSTEMÓW DIAGNOSTYCZNYCH

Streszczenie

W artykule przedstawiono podsumowanie Transferu Wiedzy dokonanego w ramach projektu Marie Curie ToK 6PR trwającego 4 lata. W okresie tym rekrutacja badaczy przyjeżdżających oraz oddelegowanie naukowców Katedry Informatyki Stosowanej do Zagranicznych Instytucji Partnerskich pozwoliło zwiększyć potencjał naukowy pracowników Katedry w zakresie tomografii procesowej. Nacisk na interdyscyplinarność badań naukowych prowadzonych w Katedrze, podniósł poziom wiedzy pracowników w Katedrze Informatyki Stosowanej w dziedzinie tomografii dotyczącej zarówno sprzętu, jak i oprogramowania.