ERCIM "ALAIN BENSOUSSAN" FELLOWSHIP PROGRAMME

Scientific Report

First name / Family name	N Varatharajan
Nationality	Indian
Name of the *Host Organisation*	Norwegian University of Science and Technology (NTNU)
First Name/family name of the *Scientific Coordinator*	Prof. Webjørn Rekdalsbakken
Period of the fellowship	01/10/2018 to 30/09/2019

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

Our project at NTNU, Aalesund concerns the construction of anatomically and physiologically realistic virtual 3D models of human joints based on MRI imaging. We will build realistic 3D organ models by using accurate segmentation of high-resolution 2D images that have the potential of very closely imitate the anatomy of human joints. In parallel to the 3D modelling this project also includes the building of a lab for experimental surgery. In this lab, we use a robot with a 6D force sensor attached at the tool point to test the functionality of body joints before and after surgery. While performing a test pattern on the joint, the robot will collect real-time data of force, speed and position, before and after the surgical intervention. These data will be analysed to resolve the result of the surgery. We will also use the collected data to help decide the physiological characteristics of the different tissues of the joint, using methods from AI and machine learning. These results will be included in the 3D models to parameterize the physiological characteristics of the different tissues of the joint. The goal is to establish **digital twins** of human joints.

We considered the Knee joint in our project which is one of the complex joints in the human body consists of the femur, tibia, fibula and patella bones. The knee joint posses ligaments and cartilages. Ligaments are fibrous connective tissue which connects bones to other bones, and

provides stability and strength to the joint. The following ligaments connect bones in the knee joint: Anterior cruciate ligament (Lateral condyle of the femur - intercondyle of the tibia), posterior cruciate ligament (anteromedial femoral condyle - posterolateral tibia), lateral collateral ligament (Lateral epicondyle of the femur - fibula), medial collateral ligament(medial epicondyle of the femur - medial condyle of the tibia) and patellar ligament (patella - the tibia). Cartilage is the soft tissue which is transferring loads from one skeletal element to the other and covers the contact portions of patella, tibia and femur, and of providing frictionless sliding of bones on each other in the joint. The mechanical properties of Cartilage are anisotropy, spatial inhomogeneity, tension-compression nonlinearity, etc. Osteoarthritis (OA) is a common disease that damages cartilage for the aged people, affecting 10% of men and 18% of women over 60 years of age. The damage in cartilage causes pain, swelling, and loss of motion of the joint, etc.

Image segmentation is the first step in processing images for visualization and one of the sub-goals in the above main goal. Image segmentation of a digital image is to divide pixels/voxels into different regions which are belonging to the same attributes. Segmentation can be done by either manually or using computer-based techniques. Manual segmentation of MR images is a time-consuming process and labour cost involved for every single scan which is having hundreds of images. In past decades, variety of algorithms have been introduced to perform fully automatic or semi-automatic segmentations for computer-based techniques.

Magnetic Resonance Imaging (MRI or nuclear MRI) technique is a noninvasive digital imaging technique, and widely used to study and treat Osteoarthritis. MRI technique acts as a superior imaging technique than X-rays, computed tomography (CT), positron emission tomography (PET), ultrasound, arthrography, computed tomography arthrography, digital tomo-synthesis, etc. MR imaging procedure has more advantages including good contrast and without ionizing radiation. It can detect bone marrow lesions, joint fluid changes, ligaments and meniscal damage, osteophyte formation, cartilage morphology, as well as macromolecular changes which often precede morphological changes.

We use MR images of the Knee joint for segmentation of different labels/tissues using deep learning techniques.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. Ibrahim A. Hameed, Eirik Gromholt Homlong**, N Varatharajan,** Webjørn Rekdalsbakken, Kjell-inga Gjesdal, Robin Trulssen Bye, "Segmentation of Knee Joint Anatomy Using Deep Learning Techniques", ***(under preparation***).

2. **N Varatharajan**, Martin Petterson, Ibrahim A. Hameed, Webjørn Rekdalsbakken, Kjell-inga Gjesdal, Robin Trulssen Bye, "Estimation of effectiveness of different sequences of MR Images for automatic segmentation of Knee joint using deep learning", ***(under preparation***).

III – ATTENDED SEMINARS, WORKSHOPS, CONFERENCES

I attended the following summer school/workshop:

Summer School: Imaging and machine learning
Venue **:** Institute Henri Poincare, 11 rue Pierre et Marie Curie,75231 Paris Cedex 05Paris, France.
Date **:** 1 April 2019 to 5 April 2019

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I visited the following lab:

Location: Centrum Wiskunde & Informatica (CWI), Science Park 123, 1098 XG Amsterdam, The Netherlands.
Scientific Coordinator: Prof. Dr. K.J. Batenburg, Computational Imaging Department
Duration: 8 April 2019 to 12 April 2019

Prof. Dr K.J. Batenburg's computational imaging lab is mainly focusing on the generation of 3D imaging. The technique is based on an interdisciplinary approach which is combining mathematics, computer science and physics. Their solution approach to the computational imaging problems can be used to various fields of science, medicine, industry, and etc. We (My scientific coordinator and me) had a very good interaction and discussion for my focused problems with Prof. Dr K.J. Batenburg and his team members. Prof. Dr K.J. Batenburg showed a very good interest for further visits and collaborative research work with NTNU, Alesund, Norway.