ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium
for Informatics and Mathematics

Scientific Report

First name / Family name	Rashid Khan
Nationality	Pakistani
Name of the *Host Organisation*	NTNU
First Name / family name of the *Scientific Coordinator*	Prof. Anne Kværnø
Period of the fellowship	01/04/2016 to 31/03/2017

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The internet of things has started to form; currently involving “things” which are bound to a fixed geometry. However, the emergence of mass-produced inexpensive devices for sensoring and processing information, and using the results of this for electronic control, have increased the possibilities to manipulate and move larger material objects (larger than electrons) in a similar manner. I.e., the possibility to create an internet of moving things.

For inexpensive production and reliable, maintenance free, operations over long periods of time, such systems should contain a minimum of components, in particular components which wear out before the lifetime of the entire system — like wheels and rotating motors with mechanical bearings. By magnetic levitation of objects the need for wheels and ordinary mechanical bearings may be eliminated, after which propulsion may be achieved by controlled electromagnetic induction. Various versions of such technologies have f.i. been implemented in Maglev trains (after they have reached a sufficiently high speed). However, the development of the latter technologies seems to be slow (in comparison to computational units and sensors), perhaps due to the extremely high cost per unit. In this project we want to start in the opposite end of transportation, based on components which can move by making low-speed “jumps” between closely located discrete equilibrium positions (thereby reducing stability requirements).

We developed the main programs in the Python programming language, using object oriented methods. For numerical efficiency we mostly relied on code from the *Numpy* and *Scipy* packages. Two important parts of the system are class Container, with objects from class PermanentMagnet as properties (in addition to several more), and class Backbone, with objects from class PermanentMagnet and class ElectroMagnet as properties (in addition to several more). These classes contain methods to compute electromagnetic fields, forces and torques etc. One object from class Backbone, plus one or more objects from class Container are properties (in addition to several more) of class Layer, where a method for computing the overall dynamics — including back-reactions from the various components — are located.
I contributed to the following tasks for the project:

1. Review of standardization activities in the area of Electromagnetism
2. Literature review for projects on levitation and maglev
3. Literature review for levitation techniques and Python programming
4. Coding with Python programming language

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. **Rashid Khan, Anne Kværnø, Kåre Olaussen**, *Simulating the dynamics of passive magnetic structures in electromagnetic fields (in progress/preparation)*

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. Attended the Conference at Norwegian University of Science and Technology, ***Maths Meet Industry - What you can do with a PhD ? 22-23 September 2016 Trondheim Norway***

IV – RESEARCH EXCHANGE PROGRAMME (REP)

N/A