Scientific Report

First name / Family name	Fei GAO
Nationality	China
Name of the *Host Organisation*	Norwegian University of Science and Technology, Norway
First Name / family name of the *Scientific Coordinator*	Ilangko Balasingham
Period of the fellowship	01/11/2011 to 31/10/2012

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my ERCIM period, I was with the Signal Processing group, Department of Electronics and Telecommunications, Norwegian University of Science and Technology (NTNU) on Nano communications networks.
Radio frequency (RF) technology for in-body communication, localization and tracking of micro devices and implants has been studied in several papers including channel models, RF communication systems, and electromagnetic wireless nano sensor networks. Further investigations are needed to understand such results can be applied for brain networks.
Therefore, in addition to the physical experiments, a simplified theoretical model/phantom of the brain is needed to study the effect of electromagnetic exposure and the Alzheimer's disease (AD) on neurons, glia cells and networks of neurons from a theoretical perspective.
Then our purpose is come into being, that is "Mathematical analysis on bio-inspired communication network theory" in brain networks and relative Nano communication inside the brain nerves' networks.
The scientific research had two parts mathematically.
Firstly, it is on understanding the concept of nano communications and specifically on brain networks, where we focused on neuron transmission and connectivity using distances and cluster coefficients defined as adjacency matrix. On the statistical shortest path for information transmission in nano neuron communication networks, I used improved artificial intelligent discrete algorithms, ant colony optimizations, to resolve the problems.
The second part is about the abstract dynamic nonlinear and chaos systems applied for nano communications. That is for the mathematical differential equations describing the models of brain networks. In this part, I used some improved swarm intelligent methods and evolutionary algorithms to solve the characters of the systems, such as the unknown systematic parameters, time delays, unstable periodic orbits with high orders, unknown structure of the differential equations etc. The methods we used are artificial bee swarm optimization with its improved version, differential evolution algorithm and particle swarm optimization.
Furthermore, I generalized the above two parts into high mathematic levels. That is, I'm doing some fractional order dynamical systems in these areas.
I have attended seminars and have given talks about my research work at the Signal Processing Group.
During the my ERCIM.period, I have three SCI index journal paper published and one paper accepted in international conference.
In addition, I visit two REP institutes in INRIA France and Luxembourg. I met 2 professors and some researchers who have similar academic interests. And I have given speeches on fractional order systems when I did REPs.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

[1] Gao F, Fei FX, Xu Q, Deng YF, Qi YB, Balasingham I (2012)
A novel artificial bee colony algorithm with space contraction for unknown parameters identification and time-delays of chaotic systems

Appl. Math. Comput., 219 (2), 552-568

Abstract
This paper is concerned with the uncertain parameters and time-delay of nonlinear chaotic systems, which is of vital significance in chaos control and synchronization. In this article, a novel artificial bee colony algorithm (ABC), with space contraction and optimization technique based on the foraging behavior of honeybees, is newly proposed to solve the estimation problem via a nonnegative multi-modal nonlinear optimization, which finds a best combination of parameters such that an objective function is minimized. The illustrative examples, in Lorénz, Chen, Lü chaos systems and Mackey–Glass time-delay chaos system, are given though ABC and ABC with space contraction self-adaptively (ABCSC) respectively. Simulation are done and comparisons to some existing results by a recent version of ABC, HTCMIABC demonstrate that ABCSC is superior to ABC and HTCMIABC for unknown parameters and time-delays of the chaotic systems accurately and effectively. And it is a promising tool for chaotic system identification as well as other numerical optimization problems in mathematics.

[2] Gao F, Fei FX, Deng YF, Qi YB, Balasingham I (2012)
A novel non-Lyapunov approach through artificial bee colony algorithm for detecting unstable periodic orbits with high orders
Expert Syst. Appl., 39 (16), 12389-12397

Abstract
In this paper, a novel non-Lyapunov way is proposed to detect the unstable periodic orbits (UPOs) with high orders by a new artificial bee colony algorithm (ABC). And UPOs with high orders of nonlinear systems, are one of the most challenging problems of nonlinear science in both numerical computations and experimental measures. The proposed method maintains an effective searching mechanism with fine equilibrium between exploitation and exploration. To improve the performance for the optimums of the multi-model functions and to avoid the coincidences among the UPOs with different orders, we add the techniques as function stretching, deflecting and repulsion to ABC. The problems of detecting the UPOs are converted into a non-negative functions' minimization through a proper translation, which finds a UPO such that the objective function is minimized. Experiments to different high orders UPOs of 5 wellknown and widely used nonlinear maps indicate that the proposed algorithm is robust, by comparison of results through the ABC and quantum-behaved particle swarm optimization (QPSO), respectively. And it is effective even in cases where the Newton-family algorithms may not be applicable. Density of the orbits are discussed. Simulation results show that ABC is superior to QPSO, and it is a successful method in detecting the UPOs, with the advantages of fast convergence, high precision and robustness.

[3] Gao F, Qi YB, Balasingham I, Yin Q, Gao HR (2012)
A Novel non-Lyapunov way for detecting uncertain parameters of chaos system with random noises
Expert Syst. Appl., 39 (2), 1779-1783

Abstract
The paper is concerned with the uncertain parameters and time-delays of chaos system

with random noises. A scheme based on differential evolution algorithm (DE) is newly introduced to solve the problem via a nonnegative multi-modal nonlinear optimization, which finds a best combination of parameters and time-delays such that an objective function is minimized. The illustrative examples, in both systems free of time-delays and time-delays systems with random noises, are given to demonstrate the validity of the proposed method.

[4] Fei Gao, Feng-Xia Fei, and Ilangko Balasingham.
An Ant Colony Biological Inspired Way For Statistical Shortest Paths In Complex Brain Networks. In the Proc. of 7th IEEE/ACM Body Area Networks Conference (Bodynets), Oslo, Norway, Sept. 2012

Abstract
What is the mechanism of information transferring, when some of the brain nerves' links do not work? Brain is the most complex, ingenious processing system in world. The complex brain networks is an inter-discipline of complex networks and neuroscience. In this paper, an ant colony optimizations are introduced to solve the crux, shortest path for information transferring mechanism. Some reviews are presented on progress of complex brain networks and computational neuroscience firstly. The deep research on brain complex networks will have a profound effects on artificial intelligence methods which models the mechanisms. Then simulations are done to finding shortest path in probabilities for theoretical nerve networks through ant colony optimization methods. The results show the proposed way is a successful method in detecting the statistical shortest path in brain networks when nerves' link broken, with the advantages of fast convergence and robustness.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1) ABCDE Seminar, Berlin, German, 9 Nov. 2011
2) 7th IEEE/ACM Body Area Networks Conference (Bodynets), Oslo, Norway, Sept24-26. 2012

IV – RESEARCH EXCHANGE PROGRAMME (REP)

1) My first visit was hosted by Professor Pierre Del Moral.
   INRIA Bordeaux-Sud Ouest, Bordeaux, France
   10SEP-23SEP, 2012
2) My second visit was hosted by Professor Pascal Bouvry.
   Computer Science and Communications (CSC) research unit of the Faculty of Sciences, Technology and Communications of Luxembourg University, Luxembourg.
   30SEP-13OCT, 2012