# Scientific Report

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| Period of the fellowship | 03/03/2013 to 04/03/2014 |

# I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my stay in the CRAB Lab of NTNU, I have integrate my research activity to the current thematics explored by the team. My domain of expertise concerns the use of autonomous learning methods to the design of behaviours for swarm of robots (typically more than 100 robots). The CRAB Lab has started an activity around the use of swarms of real robots. During my fellowship, I have work to the application of autonomous learning methods to ensure the robustness of swarms of real robots.

The first avenue takes inspiration from natural swarms such as ants assembling together in order to cross obstacles. Self-assembly mechanisms can enforce the robustness of the swarm by making it able to address a large range of environments, from maze to those requiring common actions. As in natural swarms the assembly of robots is not always necessary. Previous studies have found that the self-assembly of autonomous robots is possible, but none focused on the factor impacting the autonomous learning of self-assembly depending of the specificities of the environment. In order to study the impact of the environment I have investigate the design of neutral environments, which appeared to be not trivial. Moreover, it appears that this type of behaviour is close to the speciation behaviours observed in nature. Therefore, I have also survey the works established in biology on these aspects. The work done on has highlight the similarities between natural swarm and artificial swarm and the importance of the environment. We have therefore make a significant contribution on the best use of self-assembly in swarms of robots.

The second avenue explored concerns the design of a robotic platform for swarm robotic. Previous platforms were either inexpensive but with few functionalities (just pushing objects and moving in the environment), or full of functionalities but expensive (typically around 100 euros). The approach taken by the CRAB Lab to address this trade-off is to design a cheap base with the basic functionalities, and the possibility to extend it. By this mean, the platform can be customized to the specific research agenda of each researcher for a low cost. For example, I am now extending it to test the self-assembly of a large number of real robots. To do so, I have learn the process relative to 3D modelisation and fast prototyping. On this platform I have also work at the realisation of software libraries. In order to promote this platform I have lead the redaction of an article (this was a new challenge for me), and present it at one conference and one workshop. I am also establishing cooperation with researchers in France and U.S.A. to use the platform on different research agendas.

As part of my involvement in the CRAB Lab I have also co-supervise all master students with an activity related to swarm robotics (7 during my stay). This has allowed me to improve my leadership abilities and learn more about the differences between countries on this matter . Norwegian students proved to be autonomous in the conduct of their work and relied on me mainly for methodological aspects. By this mean I have been able to explore a larger area of the swarm robotic field. Based on their autonomy, Norwegian students proved to be very good at proposing new problems and original approaches to solve them.

# II – PUBLICATION(S) DURING YOUR FELLOWSHIP

During my fellowship I have publish two articles and one is under review.

The first article published is titled "Evolution of Altruism and Spatial Dispersion: an Artificial Evolutionary Ecology Approach" and has been published at the European Conference on Artificial Life (ECAL) conference. It presents the latest results we have obtained on the evolution of altruistic behaviours in swarm of robots. More specifically it focusses on the impact of altruism on the dispersion strategy of the robots. I have present it in September 2013.

The second article published is titled "The ChIRP Robot: a Versatile Swarm Robot Platform" and has been published at the 2nd Conference on Robot Intelligence Technology and Applications (RITA). Its aim is to present the possibilities offered by the ChIRP robot, and has been presented by Christian Berg Skjetne in December 2013.

The article under review is titled "The affect of niches on the evolution of self-assembly in evolutionary robotics" and has been sent to the Genetic and Evolutionary Computation COnference (GECCO) of 2014. It aims at presenting the work done on the evolution of self-assembly for swarm of robots. Two contributions are presented:
- the first shows the design of a neutral environment to compare different behaviours
- the second shows the impact of the structure of the environment on the evolution of self-assembly

# III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

I have assist to 2 conferences, one workshop and present two seminars during my ERCIM stay.

**GECCO** : The Gecco conference is a major conference in the field of evolutionary computation and is composed of a large number of tracks. Researchers in Evolutionary Robotics are coming to the Alife/Evolutionary Roboics track. I have attend the presentations of this track as well as some of the presentations relative to Generative and Developmental Systems. Coming to the conference allowed me to keep the contact with the community by assisting to presentations and discussing with other researchers. I have notably present the ChIRP robots to multiple of my colleagues present at the conference.

**ECAL** : The Ecal conference is a conference a conference at the cross road between evolutionary algorithms and artificial life. This conference is one of the main target of my publications. The communities of ECAL and GECCO are naturally overlapping. It was therefore also the occasion to continue discussions started at GECCO, and start a collaboration with U.S.A.

**ECAL workshop** : The workshop was focussed on hardware in link of artificial life. I took that occasion to present the ChIRP robot. This presentation was the first public presentation of the ChIRP.

**IRI Barcelona** : As part of my first REP to the Institut de Robòtica i Informàtica Industrial (IRI) of Universitat Politecnica de Catalunya (UPC) of Barcelona I have give a seminar on swarm robotic. This seminar has present general aspects on swarm robotics to then focus on the work I am doing in the autonomous learning of behaviours. I have also present the ChIRP robot and highlight possible cooperation avenues with the CRAB Lab.

**LORIA Nancy France** : As part of my second REP to the laboratoire Lorrain de Recherche en Informatique et ses Applications (LORIA) of Nancy I have give a similar seminar. Since the team was already familiar with the swarm robotics approaches, the seminar was focused on the latest results I obtained. Also, as the team is already familiar with the design of swarm of robots this part was reduced in compare to the first seminar.

# IV – RESEARCH EXCHANGE PROGRAMME (REP)

**First REP**

I have done my first REP from the 10/02/2014 to the 21/02/2014 in the IRI at Barcelona. This laboratory is focused on the use and design of single robots i.e. of robots performing a task autonomously without the need of cooperation. I have visit the team of Juan Andrade Cetto which is focused on the problem of Simultaneous Localization And Mapping (SLAM). This problem can be summarized as follow: a robot is placed in a previously unknown environment and has to establish autonomously the cartography of the environment thanks to its own sensor. The main difficulty comes from the noise present both on the movements of the robot and its sensors. As a consequence a large number of observations have to be combined in an optimal way in order to produce the most accurate map possible.

During my stay I have establish a new cooperation revolving around the use of SLAM algorithms so as to solve search and rescue missions by swarm of robots. In these scenarios swarm of robots are deployed in an environment and have to find and rescue a target. Previous work have focus on the ability to find the target, and stopped as soon as it was done. An objective of the collaboration is to achieve a scenario where a robot find the target and then attract the other robots to this target. This would combine the work done on the SLAM algorithms to explore optimally the environment and give the coordinate of the target and the works done on autonomous learning to optimize the usage of these informations.

**Second REP**

I have done my second REP from the 24/02/2014 to the 28/02/2014 in the Loria laboratory. I have been welcomed by the team of François Charpillet which is focusing on the study of biologically inspired solution for artificial systems. The robotic field is one of the targets pursued by this field. Within this context the behaviours of robots can be optimized by multiple methods ranging from hand crafted behaviours to evolutionary robotics. My discussions with researchers of the team were naturally revolving around the study of multi-agent systems and swarm robotics. I have also had the pleasure to realize that this team was interested in the multiple topics similar to mine such as the realization of tasks by a swarm of robots, the use of SLAM algorithms in groups of robots, and the design of simple rules resulting in the emergence of complex phenomenons.