PART 1 - GENERAL INFORMATION

**Project Title:** Formation Flight of a Swarm of Flying Eyebots  
**Start date:** 08 September 2010  
**Duration:** 3 months

PART 2 - EXCHANGE PARTICIPANT(S) DETAILS

VISITING SCIENTIST  
Mr. Rohin Kumar  
Dept. of Aerospace Engg.  
Indian Institute of Technology, Kanpur  
Kanpur – 208016, INDIA  
Email: rohin@iitk.ac.in

HOSTING SCIENTIST  
Prof. Dario Floreano  
EPFL STI IMT LIS, ELE 138, Station 11  
Ecole Polytechnique Federale de Lausanne  
CH-1015, Lausanne, SWITZERLAND  
Email: dario.floreano@epfl.ch
Part 3 - Scientific & Technical Information

3.1 Purpose of visit

The Swarmanoid project, a European research project, has as its main scientific objective the design, implementation and control of a novel, distributed robotic system. The Laboratory of Intelligent Systems, EPFL, one of the project partners, is responsible for developing the autonomous flying robots called eye-bots. Eye-bots, which are based on a quadrotor configuration, either fly or attach to the ceiling. They are specialised in sensing and analysing the environment from a high position to provide an overview to the ground robots.

The objective of the proposed project was to demonstrate 3D formation flying of the eyebots in an indoor, non-GPS environment. An algorithm for demonstrating formation flying of a group of 5 to 6 eyebots using the range and bearing system available on each eyebot was to be developed. The algorithm was to be first tested in a customised simulator and on achieving successful results, migrated to the flying eye-bots.

3.2 Short description of work carried out during the visit

LIS, EPFL has an inhouse simulator ARGoS custom-made for the Swarmanoid project. ARGoS has been written in C++ and uses the Open Dynamics Engine library for simulating rigid body dynamics. It includes simulation of various sensors and actuators. On examination of ARGoS, it was found that while it had a mature ground robots model, it lacked a comprehensive flight model for quadrotors. It was decided that a reasonably accurate flight dynamic model of a quadrotor would benefit the formation flight algorithm more.

*Flowchart for the algorithm to obtain forces and moments on the eye-bot*
The final mandate was to model a group of eyebots flying around a reference eyebots attached to the ceiling and using the range and bearing sensors. As a first step, the problem of modeling one eyebot flying around the reference eyebot in a circle in 2D was taken up. The complete equations of motion for a quadrotor in 3D general maneuver was derived taking into account the aerodynamics, equilibrium relations, kinematic relations and the navigation relations. The quadrotor blades were considered rigid and blade dynamics was neglected. The four rotor rotational velocities were considered as the unknowns. The equations of motion derived were in the form of a set of nonlinear algebraic equations and to solve them an open-source mathematics library in C called GSL was used. The purpose of the code developed was to obtain the forces and moments on the quadrotor. Once these are obtained, they can be fed to ARGoS which has the capability of predicting the motion of the vehicle from the forces and moments. A controller can then be implemented to obtain the desired motion of the eyebots. This can be further developed to achieve formation flight. The flowchart of the code for obtaining forces and moments on the eyebot is shown in figure above.

3.3 Outcomes

A reasonably comprehensive flight dynamics model of a quadrotor has been created in C++. It needs to be debugged and thoroughly tested so that it can be used for simulation studies of quadrotors in future. However, the goal of formation flight simulation couldn’t be achieved within the timeframe given.

3.4 Future collaboration with host institution

The just concluded project was an exploratory one. No future joint engagements have been planned yet.

3.5 Various comments

The ISJRP gives a wonderful platform for researchers to be exposed to the state-of-the-art facilities and research being done in Switzerland. I thank the administrators for their effort in ensuring a smooth process.

However, I feel, alternatives to the work-visa requirement should be explored, at least for short duration visits. The work-visa procedure takes a lot of time and has disrupted my schedule. Application process for a normal student visa takes much less time. The search for housing also led to some loss of time in my case which has, in turn, affected the project deliverables. If possible, a few rooms in the University student accommodation could be reserved for visitors from this programme.

3.6 Projected publications/articles resulting or to result from the exchange

A report documenting the state of the art in the field of formation flight has been submitted. No publication has resulted yet because this research is still at a nascent stage and also because of the short duration. However, ample scope exists for publication in future as the field is relatively new.