ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium
for Informatics and Mathematics

Scientific Report

First name / Family name	Konstantin Amelin
Nationality	Russia
Name of the *Host Organisation*	Norwegian University of Science Technology (NTNU)
First Name / family name of the *Scientific Coordinator*	Kristin Y. Pettersen
Period of the fellowship	01/05/2015 to 30/04/2016

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The research activity during the ERCIM fellowship period was the following:

- The adaptive coding procedure for parameter identification and data exchange between the mobile robots (quadrocopters are used for practical testing) moving in the formation was studied experimentally and numerically. Parameter identification was studied experimentally by two methods: by continuous-time identification algorithm and by LSE.
- Stability and tracking accuracy of the group of mobile robots, moving in formation were studied taking into account dynamics of the single agent in the formation, structure of information flow graph and the data rate limitations between the agents in the formation.
- The way to adjust step-size of local voting protocol using stochastic approximation type algorithm was prepared. The network model was assumed to have switched topology, noise in measurements. The control strategy (a modification of a local voting protocol) for load balancing of network system and algorithm for choosing its step-size is developed.
- The method of maintain integrity data in decentralized group of mobile robots was developed. The technology of communication, hardware and software feasibility of using this method were showed. The implementation of a decentralized algorithm for the checksum data with using the local voting protocol is proposed, in order to preserve data integrity when there is a lack of communication with the members, or some of the mobile robots fail.
- The procedures for constructing a confidence set for the unknown parameters of a linear scalar SISO plant was described. The main theoretical result is that these procedures operate without any significant assumptions about the external noise.

This is very important from the practical point of view since it is difficult to obtain a-priori knowledge about the noise characteristics in a wide range of applications.

- Decentralized algorithm based on local voting protocol to collective choice of motion direction in autonomous group of surface mobile robots was prepared.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Published Papers:

1. Konstantin Amelin, Stanislav Tomashevich, Boris Andrievsky, Recursive Identification of Motion Model Parameters for Ultralight UAV // 1st IFAC Conference on Modelling, Identification and Control of Nonlinear Systems, June 24-26, 2015, Saint Petersburg, Russia

In the paper the possibility of using parameter estimations is examined. Identification algorithm is used to get quadcopter model parameters. It is shown that this method is applicable for this type of UAVs. Experiments with different configurations were conducted and described. The results obtained show the efficiency of the applied identification procedure. Comparison with the results of the non-recursive least-squares identification scheme is presented.

2. Boris Andrievsky, Stanislav Tomashevich, Alexander L. Fradkov, Konstantin Amelin, Quadrocopters Formation Control Over the Limited-band Communication Network // In. Proc. of 1st IFAC Workshop on Advanced Control and Navigation for Autonomous Aerospace Vehicles (ACNAAV'15), University of Seville, Spain, 10 – 12 June 2015

In the paper, stability and tracking accuracy of the group of quadrocopters, flying in the formation are studied taking into account jointly dynamics of the single agent in the formation, structure of information flow graph and the data rate limitations between the agents in formation. Stability of the formation in the absence of data quantization is studied both for continuous-time and discrete-time system cases. The results of the numerical study of the formation performance for the case of binary adaptive quantization of data transmission between the agents are presented. The results obtained confirm the theoretical statements, following from the data rate theorem and give the quantitative information about the system performance in the case of data rate limitations and the adaptive binary coding/decoding procedure.

Accepted Papers:

3. Konstantin Amelin, Kirill Tyshev, Vasiliy Kaliteevskiy, Communication and Maintaining of data integrity method for decentralized network of autonomous group of mobile robots // In. Proc. of 3rd International conference on Control, Decision and Information Technologies, April 6-8, 2016, Malta, P. -----

In this work the method of communication and maintenance of integrity of data in the decentralized network of autonomous mobile robots is suggested. The software and hardware feasibility of such method is proposed. For collective storage and maintain data integrity in decentralized group of mobile robots, the algorithm of checksum calculations is proposed. The local voting protocol is used for load balancing of mobile robots. For the programming implementation of the data communication, multi-agent technology is used.

4. Konstantin Amelin, Natalia Amelina, Yury Ivanskiy and Yuming Jiang, Choice of Step-Size for Consensus Protocol in Changing Conditions via Stochastic

Approximation Type Algorithm // In. Proc. of 3rd International conference on Control, Decision and Information Technologies, April 6-8, 2016, Malta, P.---

In the paper a multi-agent network system of different computing nodes is considered. A problem of load balancing in the network is addressed. The problem is formulated as consensus achievement problem and solved via local voting protocol. Agents exchange information about their states in presence of noise in communication channels. At certain moment network system topology changes and new step size of control protocol is chosen to meet new conditions. Step size adjustment is done by stochastic approximation type algorithm. Analytically obtained optimal step size values are given. Simulation example demonstrating step size adjustment is provided.

5. Konstantin Amelin, Kirill Tyshev, Boris Andrievsky, The method of saving data integrity for decentralized network of group of UAV with using local voting protocol // In. Proc. of 12th IFAC International Workshop on Adaptation and Learning in Control and Signal Processing, June 29 - July 1, 2016 Eindhoven, The Netherlands, P. ----------

In the paper, the method of saving data integrity of data, based on the randomized algorithm, for the decentralized group of UAVs is suggested. The hardware of UAV to work in the group was proposed. Multi-agent approach for organization of group communication is used. The local voting protocol is used for load balancing of mobile robots. The theoretical results are applied for real group of UAVs.

6. Alexander L. Fradkov, Stanislav Tomashevich, Boris Andrievsky, Konstantin Amelin, Ilya N. Kaliteevskiy Adaptive Coding For Data Exchange Between Quadrotors In The Formation // In. Proc. of 12th IFAC International Workshop on Adaptation and Learning in Control and Signal Processing, June 29 - July 1, 2016 Eindhoven, The Netherlands, P. ----------

In the paper, the procedure of adaptive coding for data transmission between quadrotors, moving in formation, is presented and numerically studied. Quadrotor parameters identification is fulfilled based on processing the experimental data. The results are compared with the theoretical statements. Efficacy of the adaptive coding procedure is shown.

7. Granichin O., Amelin K. "Randomized Control Strategies under Arbitrary External Noise", The IEEE Transactions on Automatic Control Submission, Volume 61 (2016), Issue 4 (April).

This paper deals with the identification problem for a linear dynamic plant described by an autoregressive moving averaging model with additive external noise (exogenous disturbance). We use an approach which is based on randomization of control and allows to make minimal assumptions about the noise: randomized test perturbations in control and the external noise must be stochastically independent. In particular, any unknown but bounded deterministic real sequence is an example of such a noise. In the case of a finite set of observations, we propose two procedures for computing data-based confidence regions for unknown parameters of the plant. They could be used in adaptive control schemes. The first procedure is of the stochastic approximation type, while the second one is developed in the general framework of “counting of leave-out sign-dominant correlation regions” (LSCR), which returns confidence regions that are guaranteed to contain the true parameters with a prescribed probability. If the number of observations increases infinitely, we propose the combined procedure for computing confidence

regions which shrink to the true parameters asymptotically. The theoretical results are illustrated via a simulation example with a nonminimum-phase second-order plant.

Paper Under Review:

8. Konstantin Amelin, Natalia Amelina, Oleg Granichin, and Tatjana Khantuleva, Adaptation of Airplane's "Feathers" in a Turbulence Flow // In: Proc. of the 55st IEEE Conference on Decision and Control, Las Vegas, USA, December 12-14, 2016

The problem of the control of multi-agent robotic systems is considered. It was stated that the use of traditional mathematical models to describe the motion is often leads to a very complex problems involving a state space with extremely high dimension with a large number of transducers/sensors and actuators. However, multi-agent technology can effectively solve many of the problems arising in this context by replacing the general model of interactions in a complex system with a plurality of local models and their aggregation (clustering). In this paper our previous results for the case of time-varying structure of wind disturbances are extended. We applied the results of synchronization and consensus in network control for the flight control when a vast array of sensors and actuators ("feathers") is distributed over the surface of the airplane. The possibilities of using a Local Voting Protocol for the adaptations of airplane's "feathers" in a turbulence flow are studied.

Paper in progress:

9. Claudio Paliotta, Konstantin Amelin, Kristin Y. Pettersen, Multi-agent control algorithm for collective choice movement direction of decentralized group of mobile robots.

In this work the consensus achievement problem in the decentralized group of mobile robots to collective select direction motion toward the source signal is considered.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. 1st IFAC Conference on Modelling, Identification and Control of Nonlinear Systems, June 24-26, 2015, Saint Petersburg, Russia
2. 1st IFAC Workshop on Advanced Control and Navigation for Autonomous Aerospace Vehicles ACNAAV'15
3. 3rd International conference on Control, Decision and Information Technologies, April 6-8, 2016, Malta
4. 12th IFAC International Workshop on Adaptation and Learning in Control and Signal Processing, June 29 - July 1, 2016 Eindhoven
5. 55st IEEE Conference on Decision and Control, Las Vegas, USA, December 12-14, 2016

IV – RESEARCH EXCHANGE PROGRAMME (REP)

the Spanish Research Consortium for Informatics and Mathematics (SpaRCIM), Artificial Intelligence Research Institute (IIIA), Spain, Prof. Dr. Ramon Lopez de Mantaras, 9 - 26 September, 2015.