Scientific Report

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Period of the fellowship	01/11/2012 to 31/10/2013

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

The research activity during the fellowship period, in line with the ABCDE Research Training Program, was the following:

- The approximate consensus problem statement of multi-agent stochastic system with nonlinear dynamics, noise, delays and switched topology was introduced.
- The conditions for achieving asymptotic and e-consensus consensus are obtained and the estimation of time to e-consensus is presented.
- Analytic conditions for approximate consensus in stochastic network with noise and switched topology are proposed for two cases: for case without delays in measurements and for case with delays in measurements.
- It was proposed to study the initial stochastic system with the corresponding average discrete or continuous systems and the estimates of the closeness of trajectories were obtained.
- Load balancing problem in decentralized stochastic network was reformulated as a consensus problem in network and conditions for eps-optimal load of the nodes are established.
- The analytical research for two cases: for case without delays in measurements and for case with delays in measurements is made and the simulation results are presented.
- The consensus approach was applied to prolong the network lifetime in underwater sensor network and differentiated consensus problem was posed.
- The consensus protocol (similar to local voting protocol) was used for the scheduling problem in wireless networks and corresponding analytical conditions were obtained.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Published Papers:

1. N. Amelina Local voting protocol for decentralized load balancing of network with switched topology and noise in the measurements // Vestnik St. Petersburg University. Mathematics, 2013, vol. 46, no. 3, pp. 118–125.

The applicability of local voting protocol for the nonstationary problem of load balancing in a decentralized network with switched topology and measurement noise is investigated. The obtained theoretical results are illustrated by simulation models. The system is considered with and without the redistribution of tasks. It is shown that an adaptive multiagent strategy with the redistribution of tasks among the neighbors is better for handling the distribution of tasks than a strategy in which tasks are sent to random nodes and are not redistributed after arrival.

2. K. Amelin, N. Amelina, O. Granichin, O. Granichina, B. Andrievsky Randomized Algorithm for UAVs Group Flight Optimization // Proc. of 11th IFAC International Workshop on Adaptation and Learning in Control and Signal Processing, July 3-5, 2013, Caen, France, pp. 205-208.

The problem of small UAVs flight optimization is considered. To solve this problem thermal updrafts are used. For the precise detection of the thermal updrafts center the simultaneous perturbation stochastic approximation (SPSA) type algorithm is proposed.
If UAVs use thermal updrafts so they can save the energy during the flight. Therefore the flight time will be vary for different UAVs. In order to optimize the area monitoring, the consensus approach has been proposed.

3. N. Amelina, A. Fradkov Consensus Problem in Stochastic Network Systems with Switched Topology, Noise and Delay // Proc. of The Twelfth International Conference on Networks (ICN 2013), January 27 - February 1, 2013 - Seville, Spain, pp. 118-124.

This paper deals with the problem of achieving consensus in decentralized stochastic network with switched topology and noise and delays in measurements. To solve the consensus problem of the group of interacting agents it was supposed to use the stochastic approximation type algorithm with the step-size non-decreasing to zero. Simulation results show the quality of the algorithm.

4. K. Amelin, N. Amelina, O. Granichin, O. Granichina Combined Procedure with Randomized Controls for the Parameters' Confidence Region of Linear Plant under External Arbitrary Noise// Proc. of 51st IEEE Conference on Decision and Control, December 10-13, 2012, Maui, Hawaii, USA, pp. 2134-2139.

The new algorithm is proposed for the estimating of linear plant's unknown parameters in the case of observations with arbitrary external noises. It is based on adding of randomized inputs (test perturbations) through the feedback channel. The assumptions about the noise are reduced to a minimum: it can virtually

be arbitrary but independently of it the user must be able to add test perturbations. We combine the previous result about asymptotic properties of randomized control strategy with the new one which is followed by a nonasymptotic approach of LSCR (Leave-out Sign-dominant Correlation Regions) method. The new algorithm gives confidence regions for series of finite sets of observations. These regions shrink to the true values of an unknown parameters when number of observations tents to infinity while the algorithm complexity does not increases.

5. N.O. Amelina, A.L. Fradkov Approximate Consensus in a Stochastic Dynamical Network with Incomplete Information and Delayed Measurements // Automation and Remote Control, 2012, Vol. 73, No. 11, pp. 1765–1783.

Consideration was given to the problem of achieving an approximate consensus in the decentralized stochastic dynamic network under incomplete information about the current states of the nodes, measurement delay, and variable structure of links. Solution was based on the protocol of local voting with nonvanishing steps. The results obtained were applied to the analysis of the dynamics of the system of balancing the computer network loading.

6. N. Amelina Consensus in Stochastic Systems with Uncertainties in Measurements // Proc. of The Int. Student Conf. "Science and Progress". Saint-Petersburg, Russia, November 12-16, 2012, p. 48.

Distributed coordination in networks of dynamic agents has attracted an interest numerous researchers in recent years. In previous works the stochastic approximation algorithm for solving consensus problem was proposed and justified for the group of cooperating agents that communicate with imperfect information in discrete time, under condition of switching topology and delay. Analyzing of discrete stochastic systems may be complicated in practical applications.

Accepted Papers:

7. N. Amelina, O. Granichin Local Voting Protocol in Decentralized Load Balancing Problem with Switched Topology, Noise, and Delays // Proc. of 52st IEEE Conference on Decision and Control, December 10-13, 2013, Firenze, Italy.

In this paper the applicability of the local voting protocol with nonvanishing step-size for decentralized stochastic network load balancing is studied under nonstationary problem formulation. The network system was considered to have a switched topology, and the control strategy uses noisy and delayed measurements. Conditions for achieving a suboptimal level of loading agents are established, and an estimate of the appropriate level of suboptimality is given depending on the step-size of the control algorithm, the structure of the averaged network and the statistical properties of noise and delays in measurements.Obtained theoretical results are illustrated by simulations of simultaneously processing of 10^6 tasks by 1024 agents with 2048 links. It is examined that the performance of the adaptive multi-agent strategy with redistribution of tasks among "connected" neighbors is significantly better than the performance of the strategy without redistribution.

8. N. Amelina, Y. Jiang Consensus in Computer and Communication Systems in a Stochastic Environment // Accepted to ERCIM NEWS 2013

During the process of resource allocation in a computer system, it is vital that consensus is attained, ie: every node in the system must reach the same state with respect to certain chosen measures, such as having the same amount of steady-state remaining workload. Despite its importance, consensus is rarely considered in studies that model and evaluate resource allocation problems in computer and communication systems. Our research focuses on resource allocation from a consensus angle: we investigate the consensus properties of a distributed control strategy and apply this control strategy to various computer and communication systems.

Papers Under Review:

9. N. Amelina Consensus in Stochastic Systems with Uncertainties in Measurements with Simulation in JADE // In Book of Proceedings of The Int. Student Conf. "Science and Progress", 2013

We study distributed coordination in networks of dynamic agents and analyze it by method of continuous models.

10. Dimitrios J. Vergados, Natalia Amelina, Yuming Jiang, "New Insights on the Effect of Scheduling in Stochastic Wireless Multihop Networks", Submitted to INFOCOM 2013

One of the challenges in wireless multihop networks is the problem of scheduling transmissions in an efficient and fair manner. The performance of a scheduling algorithm is closely related to its ability to

adapt to the changing traffic conditions. Although theoretical results have been obtained regarding the capacity of wireless multihop networks, analytic results on the interaction of load balancing and scheduling algorithms have yet to be derived. In this paper we consider a stochastic wireless multihop network of nonlinear nodes with switching topology, noisy and delayed measurements. The problem of wireless scheduling was modeled as a load balancing problem and the consensus protocol was suggested to solve it. Conditions for an approximate consensus that gives an almost optimal behavior of the system were provided. Through analysis and simulation, we evaluate the performance of various scheduling algorithms. We show that load balancing improves the delay and fairness of the system.

11. Ameen Chilwan, Natalia Amelina, Zhifei Mao, Yuming Jiang, Dimitrios J. Vergados, "Consensus Based Approach for Improving the Network Lifetime in Stochastic Underwater Sensor Networks", Submitted to INFOCOM 2013

Among the main objectives of wireless sensor network design is to prolong the network lifetime. In underwater sensor networks, this problem is even more critical due to the difficulty in battery replacement and/or recharging. In this paper, we study the problem of extending the network lifetime for stochastic underwater sensor networks. We consider a clustered network, where sensors are divided into two groups: the clusterheads ("super nodes") that send the information to sink, and the ordinary sensors that collect information about the environment. The sensors are considered to have nonlinear dynamics with switching topology, and noisy and delayed measurements. Two consensus based protocols are introduced for determining the workload distribution throughout the network. To analyze the original stochastic system, an averaged deterministic model is introduced. In addition simulations are performed to cater the stochastic behaviour which show that the proposed protocols increase the network lifetime without compromising energy efficiency.

12. Natalia Amelina, Alexander Fradkov, Yuming Jiang, Dimitrios J. Vergados, "Approximate Consensus in Stochastic Networks with Application to Load Balancing", Submitted to IEEE Transactions on Information Theory

This paper is devoted to the approximate consensus problem for stochastic networks of nonlinear agents with switching topology, noisy and delayed information about agent states. A local voting protocol with nonvanishing step size is examined. To analyze dynamics of the closed loop system, the so-called method of averaged models is used. The analysis is applied to the load balancing problem in stochastic dynamic networks with incomplete information about the current states of agents and with changing set of communication links. The conditions to achieve the optimal level of load balancing are obtained. The performance of the system is evaluated both analytically and by simulation.

13. K. Amelin, N. Amelina, O. Granichin Task Distribution Algorithm for the Cooperating Group of Light Autonomous Unmanned Aerial Vehicles // Submitted to 2nd RED-UAS 2013 IFAC Workshop on Research, Education and Development of Unmanned Aerial Systems, November 20-22, 2013, Compiegne, France

In this paper the possibility of applying a consensus approach to organize a distribution of tasks in an autonomous group of small Unmanned Aerial Vehicles (UAVs) is studied. The use of several small UAVs with autonomous distribution of tasks gives a significant advantage over the use of a single UAV. The well-known consensus protocol --- local voting protocol is suggested to solve this problem. To provide a communication in network the multi-agent technologies are used.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. The Int. Student Conf. "Science and Progress". Saint-Petersburg, Russia, November 12-16, 2012
2. 51st IEEE Conference on Decision and Control, December 10-13, 2012, Maui, Hawaii, USA
3. The Twelfth International Conference on Networks (ICN 2013), January 27 - February 1, 2013 - Seville, Spain
4. 11th IFAC International Workshop on Adaptation and Learning in Control and Signal Processing, July 3-5, 2013, Caen, France

IV – RESEARCH EXCHANGE PROGRAMME (REP)

1. UMA, Spain, NEO (Networking and Emerging Optimization) group, Prof. Enrique Alba, 3-11 February, 2013
2. CWI, Netherlands, Stochastic Group, Bert Zwart, 14-28 April, 2013