

**Fulbright Program in Ukraine**

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INDUSTRIAL APPLIED MATHEMATICS

Common project between Ivan Franko National University of Lviv (IFNU), Karpenko Physico-Mechanical Institute of the National Academy of Sciences of Ukraine (PMI),
and the Fulbright Program in Ukraine

Introduction

The project is aimed to establish a new educational Master program, Mathematical and Computer Modeling, at the IFNU; to initiate the PhD program in applied mathematics; to consolidate efforts of researchers in both IFNU and PMI to cope with pivotal problems of applied mathematics in industry; and to establish relationships with U.S. institutions of higher education and researchers in the field of applied mathematics in industry. Boosted by American scientists, the project provides a unique opportunity for students to master novel mathematical tools and to implement them as part of an international research team. To fill gaps in Ukrainian teaching practices of applied mathematics, the project will introduce such theories as inverse problems, parallelization, and multi-scale- and domain decomposition based on numerical analysis. Because it is directly involved in practical experiments, PMI will assume the role of a mediator, formulating the research problems and implementing their solutions in Ukrainian industry. This synergetic approach between IFNU and PMI will form a new generation of highly-qualified professionals and scientists with internationally-recognized, high-level expertise, and potentially can be employed in many Ukrainian institutions, ranging from small IT companies to R&D departments of industrial giants.

The term of the proposed project is five years.

Preliminary and project argumentation

In a time of rapid progress of technologies and wide-spread use of high-performance computers, Lviv, as a cultural capital of Ukraine, has the status of a powerful scientific center and aspires to be named the ‘Ukrainian Silicon Valley’. However, the local labor market feels a shortage of experts in step with up-to-date information technologies; Ukrainian industries are major players on the market looking for such specialists. The role Department of Applied Mathematics of Ivan Franko National University is an important source of such potential experts in the region. It is one of the oldest scientific and educational institutions in East Europe and a cradle of many scientific schools. It is worth mentioning that founder of modern functional analysis, Stefan Banach, is one of many famous scientists who worked in the University.

The Karpenko Physico-Mechanical Institute is the biggest research institution in western Ukraine and provides research support to such Ukrainian industries as aerospace, metallurgy, power generation, natural resources development, etc. Dealing mainly with analysis of stress resistance, corrosion protection, and lifetime prediction of various engineering objects, the goal of the research program in the institute is shifting to replace costly experiments by numerical simulations. As one of the steps towards this goal, a powerful computing cluster has recently been established in the Institute. Another problem that becomes crucial is creation of diagnostic methods of complex structures that are based on nondestructive evaluation. As inverse problem theory is at the core of the processing of measured data, the intersecting interests of both IFNU and PMI are obvious.

However, under the inherited Soviet-era style of education, applied mathematics is seen to serve as an instrument for fundamental sciences; the need to solve computational problems for industries is not considered at an adequate level. This is becoming an acute problem in Ukraine at the present time. Moreover, the rapid rise of the variety and performance capabilities of computational facilities forms a great demand for experts with different knowledge and experience than is presently available in Ukraine. For this reason the project focuses on the industrial aspects of applied mathematics, as is practiced in many western research universities. In this context, the University of Maryland serves as an excellent example of the combination research and education, where there is offered a Master of Science program in applied mathematics with an ‘industrial track’ in addition to a ‘traditional track’.

Last year a legitimate initiative to create a new Masters program in Mathematical and Computer Modeling (specialization # 8.04030103) was launched as an effort to change the situation mentioned above. Its implementation requires modernizing teaching strategy, developing new curricula, and providing appropriate computational facilities for students. One of the top problems is the development of standards for the program which would be used in Ukrainian universities.

We consider the invitation of foreign experts who can join the process of developing this new program as highly desirable and even indispensable.

Having become a signatory to the Bologna Process in 1995, Ukraine has undertaken the modernization of its old system of education to the three-cycle model being implemented by all countries that have joined to the Bologna Process. It encompasses three major educational degree levels: Bachelor, Master, and Ph.D. degrees. Both the Bachelors and Masters degrees have been successfully adopted in Ukraine; the replacement of the degree of Candidate Nauk (Candidate of Sciences) by the Ph.D. has not yet been implemented, though a proposal has recently been put forward by the Ministry of Education, Science, Youth and Sports. IFNU and the National University of Kyiv-Mohyla Academy have independently begun to implement Ph.D. programs (primarily in several humanities fields) and are clearly exceptions in Ukraine. We would very much like to take advantage of the experience of U.S. institutions of higher education and U.S. professors in the preparation of graduate students toward obtaining the Ph.D. degree in applied mathematics, and in assisting our institution in developing appropriate and up-to-date curricula that would serve as good examples for the modernization of the Ukrainian Candidate of Science degree to the Ph.D. degree.

The Ivan Franko National University of Lviv and the Karpenko Physico-Mechanical Institute are able and ready to provide a motivating and productive atmosphere for foreign scholars to teach, consult, conduct research, and to introduce American culture to Ukrainians students and scholars, and to introduce these foreign scholars (and hopefully students) to Ukrainian culture and the higher education system..

Goal

The goal of this project is threefold:

1. To establish at IFNU a new educational program for the preparation of a Master of Science degree in Mathematical and computer modeling (specialization #8.04030103);
 - extend opportunities for students to gain new knowledge in modern approaches in applied mathematics;
 - provide the mathematics content needed for a student to pursue a career in professional areas requiring advanced mathematics;
 - prepare students for advanced graduate study in mathematics.
2. To develop recommendations to launch the Ph.D. program in applied mathematics
In the near future along with improvement of the current preparation of Candidate of Science students ;
 - elaborate requirements for the Ph.D. degree in applied mathematics;

- develop the structure of the educational components for the Ph.D. program in applied mathematics;
 - align the current Candidate of Science degree program with the requirements of the future Ph.D. program in applied mathematics.
3. To formulate mathematical problems and develop solutions which employ direct and inverse strategies of interpretation of phenomena that occur or are used in industry;
- conduct research to develop understanding of the physical problem;
 - restate the physical problems in terms of multiscale/nonlinear mathematical models;
 - create and implement the numerical models/solutions using high-performance parallel computing facilities.

Project description

Realization of the project includes the following stages:

- 1) Licensing of the department for new Master program;
- 2) Preparation of standard for the new Master program;
- 3) Development of curricula for the new Master program;
- 4) Definition of new courses, selection of course books, preparation of syllabi and typical assignments;
- 5) Conducting research and supervising the research of Masters students;
- 6) Development of recommendations for launching the PhD in applied mathematics.

At the first stage the head of departments in the IFNU and other faculties have to prepare needed materials for licensing of a department to prepare masters in the new program before American scholars' visits. Other stages do not actually require aligning in time, but, to provide flexibility, correspond to the fulfillment of specific activities according to the competence and preference of American scholars.

It is planned that a student who has at least the Bachelor diploma in Applied Mathematics can achieve a Master degree in Mathematical and Computer Modeling during 3 trimesters. The last trimester would be completely devoted to preparation of the Masters thesis. American professors will be invited to deliver one or two courses of lectures and to become co-supervisors of Master theses. American scholars also will provide consultations and be involved in the development of organizational/methodological aspects of education in both Master and Ph.D/ programs according to the goals of the project. These foreigners can also be involved in research activity with faculty of the Department of Applied Mathematics or with researchers in the Karpenko Physico-Mechanical

Institute. American scholars will be expected to deliver lectures and participate in scientific seminars during their stay in Ukraine.

Ukrainian teachers will attend the lectures and seminars in order to prepare new courses for students who will pursue study in the new Masters of Science in Mathematical and Computer Modeling program. It is worth mentioning that Prof. Yarema Savula, Dean of the Faculty, is a member of the Special Council of the State Accreditation Commission of Ukraine that makes it highly likely that the developed draft of the new Masters program would be considered as a basis for an all-Ukrainian standard in the program.

The list of new courses that could be prepared is given in the proposed order of delivery to students:

- Introduction to non-linear functional analysis;
- Numerical methods in mathematical modeling;
- Inverse problems in industry, medicine and geosciences;
- Mathematical modeling in science and industry;
- Applied optimization;
- Ill-posed problems and regularization methods;
- Inverse scattering and spectral problems;
- Inverse boundary problems;
- Numerical approaches in inverse problem solutions;
- Parallel computing in mathematical simulation;
- Finite element and boundary element models;
- Multi-scale and domain decomposition strategy in parallelization.

The tentative list of courses is proposed based on analysis of modern approaches in applied mathematics, industrial applications of the approaches and possible generalization, aimed at providing flexibility for the student in terms of future employment. The courses are completely different from those which are taught to Master students in the current applied mathematics program (specialization # 8.04030101).

Some of these courses can be electives; the faculty of the Department of Applied Mathematics and research staff at PMI will join American scientists in course preparation and lecturing.

Anticipated outcomes of the project

- developed curricula for the new Master program;
- developed series of new courses;
- developed draft of standard in the Masters program;
- obtained license for the new Masters program;

- developed curriculum for Ph.D. in applied mathematics;
- Ukrainian teacher/scientists become well aware of the peculiarities of American teaching/research methodology;
- international collaboration and possible common grant applications;
- supervised completion of several Masters and Candidate of Science theses;
- published papers in co-authorship with American scientists;
- developed solution for numerical simulation of metal deformation and cracks;
- developed solution for inverse problem for recovering parameters of internal structure and identification of damages;
- created basis for further close collaboration between IFNU and PMI, which includes:
 - a) employment of graduate students and preparation of Ph.D. candidates during post-graduate studies in PMI;
 - b) common research projects;
 - c) establishing an educational center on the basis of PMI;
 - d) searching for industrial partners and common grant applications.