Doctoral Thesis Topics 2024/2025

1.
Supervisor: prof. Ing. Pavel Bezoušek, CSc.
Supervisor - specialist: Ing. Jan Pidanič, Ph.D., *Jan.Pidanic@upce.cz*

Detection of weak radar targets on ground clutter background

The thesis subject is research on signal processing methods in radar, enhancing the detection quality of radar targets with low RCS and flat Doppler characteristics on the background of strong, unstable reflections from ground objects. Based on the literature study, the student will analyse the radar reflection characteristics of the selected objects and clutter and develop mathematical models of the reflected signals. The model outputs will be checked on the available data and compared with the results of other authors. Then he will design a signal processing model in Matlab, optimising the probability of detection of the selected objects, using, e.g., pre-detection tracking (TBD), PHD filtering, UKF or sequential Monte Carlo (S-MCM) tracking methods and micro-Doppler object characteristics. The results will be verified using the developed model of the reflected signals and the available real radar data.

2.
Supervisor: doc. Ing. Jan Mareš, Ph.D., *Jan.Mares@upce.cz*
Supervisor - specialist: prof. Ing. Roman Jašek, Ph.D.

Modern machine learning methods in biomedical data analysis

The aim of the dissertation is the design and implementation of a complex system for the analysis of biomedical data. Data for analysis will be provided/measured at the University Hospital of Královské Vinohrady Prague and the Hospital of the Pardubice Region. The system will (i) serve as an auxiliary tool for the specialist (MD) in the objective assessment of the patient's current condition, (ii) enable the analysis of one- and multi-dimensional data (mainly ECG, heart rate, movement data, possibly CT and NMR). The methodology used for the analysis will be based on classical statistical methods (OLR, RF, etc.) and will also use deep learning methods.

3.
Supervisor: doc. Mgr. Jiří Tuček, Ph.D., *Jiri.Tucek@upce.cz*
Supervisor - specialist: Mgr. Jaroslav Marek, Ph.D., doc. Mgr. Pavel Tuček, Ph.D.

Detection and parametrization of nanoparticles

Magnetic nanoparticles based on iron oxides still arouse great interest from the point of view of their basic and applied research. It is known that their physicochemical properties are controlled, among other things, by their size and shape, where quantum and surface phenomena arise. For modeling and predicting the properties of nanoparticle systems, knowledge of the distribution functions of the dimensions, rotations, and frequency distribution of nanoparticles in their ensemble is therefore very useful. These parameters make it possible to assess the appropriateness of the use of such systems and therefore to evaluate their application potential.
The aim of the dissertation thesis will be to create a methodology based on the image analysis of 2D images of microscopic images of nanoparticle systems. Detection will be based on methods for finding object edges. This will be followed by a non-linear regression analysis,

which will enable the detected nanoparticle to be parametrically described by an ellipse. This approximation will make it possible to estimate the distribution functions of nanoparticle dimensions and other characteristics of the entire nanoparticle system. The methodology will be accompanied by a critical mathematical-statistical analysis of the estimated characteristics. The theoretical models proposed and discussed in the work will then be critically evaluated by their application on selected suitable nanoparticle systems, mainly based on iron oxides. The solution to the problem also includes the subsequent computer algorithmization of the evaluation of the size statistical characteristics of nanoparticle sets with a certain degree of autonomy in the processing of their microscopic images.

4.

Supervisor: doc. Mgr. Pavel Tuček, Ph.D., *Pavel.Tucek@upce.cz*
Supervisor - specialist: Mgr. Jaroslav Marek, Ph.D.

Statistical acceptance and its connection to process regulation

Statistical acceptances are used to decide whether the deliveries of certain products from the supplier meet the requirements of the customer, who is interested in the quality of the delivery or the proportion of defective products in the delivery. This can also be freely used in the case where the role of customer and supplier is represented by individual downstream production processes. In each acceptance, acceptance quality control is carried out, which is divided into a hundred percent and selective according to the scope. The work will therefore be devoted to such methods of monitoring the quality of processes and ensuring the required characteristics of product quality and verifying their eligibility. First of all, the student will carry out a thorough research of the current methods used in the field of statistical quality acceptance with an emphasis on the methods of multiple selections. Furthermore, the student will propose new approaches for calculating the price aspects of the acquisition plan. After studying and designing new methods, it is expected that the author will create an application that will enable statistical control of the process, calculation of capability indices, calculation of Hotelling statistics for several characters, and construction of a loss function following the performed statistical acceptance. The student also includes the latest findings from the research conducted in the entire process. In the framework of the created application, the student will mainly evaluate the total cost of quality. Depending on the chosen application, a feedback system will also be designed to transmit detected errors in process parameters that could lead to correction. This procedure is conceptual and a detailed study of individual methods will be needed, including the design of some partial, completely new parts.

5.

Supervisor: doc. Mgr. Pavel Tuček, Ph.D., *Pavel.Tucek@upce.cz*
Supervisor - specialist: Mgr. Jaroslav Marek, Ph.D.

Statistical modeling of natural phenomena: Analysis of landslides

Regression analysis is a statistical method used to analyze the relationship between two or more variables. The main goal of this analysis is to understand how one or more independent variables affect the dependent variable and in what way. Slope slide modeling is a key element in geotechnical engineering to help predict and manage the risks associated with slope (land) slides. Regression analysis is one tool that is often used to create mathematical models that can predict the behavior of a slope and identify factors affecting its stability. Regression analysis focuses on identifying relationships between independent variables (e.g., geological composition, slope, precipitation) and a dependent variable (e.g., slope movement).

Using this analysis, we can reveal which factors have a significant influence on the slope slide and in what way. An important part of the regression analysis is also the determination of the statistical significance of the relationships found and the evaluation of the accuracy of the model. In this way, we can obtain reliable predictions for future landslide events. The student will work with landslide data sets in the village of Halenkovice, where the trainer has access to installed sensors and slope movement sensors. Today, this database has approx. 80 points and a 20-year history. The result of the student's work will be the design of regression models that reliably and rigorously analyze the relationships between individual quantities and parameters. These models will be used to model landslides in the places where the landslides have already been active and this will achieve an understanding of individual dependencies; it will also be possible to target-model the conditions under which landslides occur in locally threatened places and, last but not least, it will be possible to predict the future state of the given locations.

6.
Supervisor: doc. Ing. Dušan Kopecký, Ph.D., *Dusan.Kopecky@upce.cz*
Supervisor - specialist: Ing. Tomáš Zálabský, Ph.D.

Development of methodology and apparatus for measuring the shielding efficiency of flexible shields of electromagnetic interferences

Modern flexible shields of electromagnetic interferences (EMI) based on composites of polymeric materials and conductive fillers suffer from inhomogeneities and defects caused by mechanical fatigue of the material or due to its aging. Current standard methods used to evaluate the shielding efficiency of EMI shields have limited options for locating and evaluating these faults. The aim of this work is therefore to develop a new methodology and equipment for measuring and mapping the shielding efficiency of thin EMI shields based on organic substances. The work will develop a unique device using visualization of the distribution of the electromagnetic field in the near zone, including the methodology of measuring and interpreting the results. The device will also include newly developed software that will allow the visualization of scattering parameters and localization of faults and inhomogeneities. The result of the work will be an advanced method for the study of shielding efficiency, which can be applied in materials research and in the optimization of chemical, mechanical and electrical properties of EMI flexible shields. The work will take place in collaboration with the University of Chemistry and Technology in Prague.

7.
Supervisor: doc. Ing. Tomáš Brandejský, Dr., *Tomas.Brandejsky@upce.cz*

Development of continuous genetic programming algorithms

The goal of this PhD work is to outline and to develop original algorithm of continuous genetic programming for model identification (symbolic regression) of complex systems. The continuous genetic programming eliminates non-linearity (leap changes) in behaviors of developed models in classical algorithms of genetic programming. Thus (theoretically) after finishing of a such algorithm it should be more efficient, than standard algorithms of genetic programming and thus more suitable to modeling of complex systems described by data sets up to category „Big Data“. The goaů of this work is to verify this precondition. For testing of suggested algorithm the design of original implementation with application of parallel programming is expected as well as the verification on set of complex examples with use of computer cluster (supercomputer). On the base of this validation the work will be formulated.