Advanced signal processing techniques for cyclostationary modelling in Gaussian and non-Gaussian noisy environment -detection of cyclic sources, estimation, optimisation of algorithms and validation in the context of fault identification

Nowadays, it is possible to record data describing various processes, phenomena or behavioral mechanisms. Many of these are cyclical in nature (rotation of the earth, movement of sea waves, breathing, heartbeat, etc.). These phenomena, once recorded into a time series (signal), can be described by mathematical models called cyclostationary, which, in the cases discussed, seem the most natural. Despite intensive research in the analysis of such models by several leading research centers for different areas (telecommunications, bio-signals, mechanical engineering, econometrics, etc.), further research in the development of cyclostationary methods is necessary especially for a special class of cyclostationary signals with impulsive (non-Gaussian) perturbations, which may have many causes depending on the area of application.

Within the framework of the project, knowledge of the sources of cyclostationary processes and of the disturbances occurring in the analyzed signals will be completed and systematized. Physical models (with justification) and mathematical models of cyclostationary signals and their disturbances will be proposed. Methods and computer programs (algorithms) for the description of data with cyclostationary behavior and for their preprocessing will be developed. The preprocessing of the studied signals includes the decomposition of signals composed of multiple cyclostationary sources and different types of interference, the segmentation of inhomogeneous signals and the classification of segments. Depending on the nature and level of interferences, different methods will be proposed to analyze the considered models. In general, different representations of cyclostationary signals will be proposed. The classical dependence measures presented in robust versions and alternative dependence measures (alternative to the classical measures) will be used to build such representations. The concept of the classical representation of a cyclostationary signals in the form of a frequency-frequency map will be generalized to other representations. The sensitivity of the methods to the presence of disturbances of different levels and nature will be analyzed and the computational complexity of the proposed methods will be investigated.

The algorithms developed are universal. In this project, the area of mechanical engineering related to fault detection using vibration and vibroacoustic signals will be used to illustrate both the challenges and the proposed solutions. The availability of sensory technologies, data analysis methods and, finally, the increase in reliability requirements for machine systems have led to a dynamic development of machine diagnostic methods. For rotating machinery, the key components are gears and rolling bearings. Due to the naturally occurring cyclic behavior in rotating machines, the most intuitive methods for data analysis are cyclostationary techniques. In this project, the effectiveness of the methods will be evaluated by means of developed criteria in the context of the detection and analysis of cyclostationary signals for the detection of local faults in gears and rolling element bearings.

The new representations will be evaluated using developed criteria for signals collected on laboratory and for a number of signals recorded under industrial conditions.

The methods developed can be used not only for the detection of cyclostationary sources, but can also be an intermediate element for subsequent data processing steps. One of the key steps in diagnostics is signal pre-filtering to improve the signal-to-noise ratio (SNR). The methods developed will enable the identification of the frequency band containing diagnostically useful information. The new methods will also be validated in this context.