Partnerships Program

Joint Applied Research Projects (PCCA)

Summary of the Research Report

Work package:	2
Phase title:	*Creation of the structure of the experimental model and implemented CDD methods*
Project title:	*Experimental model for change detection and diagnosis of vibrational processes using advanced measuring and analysis model-based techniques.*
Cod:	PN-II-PT-PCCA-2013-4-0044
Acronym:	VIBROCHANGE
Main authority:	(UEFISCDI) – *Executive Unit for Financing Education Higher, Research and Development and Innovations and Creativity.*
Contractor:	*"Dunărea de Jos" University of Galaţi*
Contract no:	224 / 01.07.2014
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Consortium:

CO - Dunărea de Jos University of Galați, Aiordăchioaie Dorel, Project manager
P1 - INCD în Informatică Bucharest, Popescu Dan Theodor, Team Lider P1
P2 - INCDMTM Bucharest, Cioboată Daniela, Team Lider P2
P3 - TeamNet Engineering SRL Bucharest, Roman Nicu, Team Lider P3

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Phase #2: The summary of the Research Report

1. Introduction

The project considers the *Change Detection and Diagnosis problem* (CDD) in vibrational processes using advanced measuring and analysis techniques model-based. The vibrational processes are characterized by vibrational phenomena, which include mainly, as effect, mechanical vibration signals, resulting in normal or abnormal operating.

It is an important trend concerning the replacement of the systematic procedure of maintenance of machinery and equipment's by conditional maintenance strategies, based on continuously or selective monitoring of the process, with the scope of detection of abnormal behaviour and to avoid catastrophic events of economic or ecological nature. In this context, early time detection of abnormal behaviour of systems seems to be a necessary solution, possible and efficient, in rapport with a right working mode description, without artificial excitation, change of the working regime or breaks.

The general objective of the project is to build an experimental model for CDD with application in vibrational process monitoring, using advanced measuring and analysis techniques model-based. The specific objectives are: (O1) Development, implementation and validation of new methods, techniques and algorithms for CDD; (O2) Optimization of classical algorithms for CDD; (O3) CDD information fusion coming from and in time of process monitoring; (O4) Development of a CDD software library, which will implement both classical (known) methods and optimized and new developed ones during the project running; (O5) Development and testing of an experimental model for CDD, with commercial features, hardware and software, which will use the results obtained during the project, under all aspects: theoretic, algorithmic and methodologic.

The monitoring of the vibrational processes will consider, in project, another two waves, which are naturally generated and accompanying, partial or complete, continuously or discontinuously, the mechanical vibrations: (1) acoustic waves, inside the audio spectrum; (2) ultrasound waves, with frequencies up to 100 kHz. The project looks on information analysis and processing generated by the set of three presented sources, and to information fusion, for the best decision. The approach will allow the improvement of the process monitoring, more efficient and matched to the considered scope, in rapport with non-fusion, and will be a novelty on national level and one of the few approaches in international area.

The project is sustained by the following consortium: "Dunarea de Jos" University of Galati (Coordinator); National Institute of Research and Development in Informatics, Bucharest (Partner 1); National Institute of Research and Development in Mechatronics and Measurement Technique, Bucharest (Partner 2); Teamnet Engineering SRL of Galati (Partner 3).

The project will build two products, both new, original and international competitive, which will provide solutions to CDD problems of vibrational processes. P1: A program library, as Toolbox of Matlab, which will implement the best algorithms for CDD, using both classical and advanced techniques, as those based on multiresolution analysis, information fusion and soft computing. The product will build a reference for CDD problem and will allow the performance evaluation of new algorithms to the old ones. By using real data from vibrational processes, CDD benchmarks will be proposed; P2: an experimental model, having a CDD software application as basis, to be used in monitoring of some pilot processes, in laboratory, and of a complex industrial process. The physical model will be the basis to launch full commercial products for various processes and markets.

The presented results, as well as the support systems resulted (e.g. measuring and testing systems) will raise the procedural algorithmic level for the improvement of industrial process monitoring, enhancing their operational safety.

2. Objectives

The objectives of the 2nd stage in the year 2015 had two basic objectives. The first objective concerns the development of a set of programs dedicated to the issue of CDD, called generic Toolbox Matlab for CDD (VIBROTOOL). Programs implement methods, techniques and algorithms for monitoring vibration processes (machines and industrial machinery), based on the model. These include filtering techniques, verosimilitate techniques, different "models" of distances, multiple changes detection/segmentation, extracting the characteristics in time and frequency domains, demixarea "blind" signals, time-frequency analysis, etc.

The second objective is to establish the basic structure of the module hardware for CDD (VIBROMOD), a software application, as an independent. The structure will be used to choose a hardware solution for individuals and its testing in various industrial scenarios during the Third Phase of the project.

Working under laboratory conditions, it will build an electromechanical system (VIBROGEN) for generating vibration under controlled conditions of electro-mechanical processes studied.

3. The results of the 2nd phase

The results of the research, carried out under Phase II of the project, are presented in the form of a research report which contains 280 pages.

The present document represents a synthesis of original research report. From those presented in the study, which is the subject of stage II of the project, an intermediate stage, it shows the results:

1. We selected major components of rotary machines, which will be subject to detection and diagnosis. These components relate mainly to the bearings and gearboxes of rotating machines, for which the transmission mode of vibration and vibration patterns specific to those two components. For diagnostic purposes were established more specific heuristics diagnostic equipment rotation that will serve as the basis for solving the problem of diagnosis after detection of a change in the operation of the machine.

2. We were selected for specific methods and techniques of modelling and identification in order to CDD, directed principally at "blind" separation of sources of vibration, extracting the characteristics in time and frequency, and the detection of changes in the dynamics of rotating machine, for which they were developed software components, implemented in the Matlab Toolbox for CDD (VIBROTOOL) and subsequently in the hardware module for CDD (VIBROMOD) (some of these).

3. We have established functional requirements of experimental model VIBROCHANGE as functions, parameters and results to be achieved with it. Have been established and the necessary functions of vibration measurements in terms of the choice of translators and their characteristics in order to achieve the objectives of the monitoring.

4. Programmes were developed in the Matlab code that will define the toolbox-CDD (VIBROTOOL). These are organised into two directions: demo programs and subroutines/functions work. Demo programs were tested with synthetic or signals of vibration signal previously recorded: seismic signals, different accelerations, etc., signals what constitutes a reference for the other programs work. Toolboxul Matlab for CDD implements several algorithms for solving the CDD, some of whom originated in developing the project, but also some picked up from various sources, in particular public for "blind" separation of sources and analysis of time-frequency, which together with those who contribute to resolving the problem of the original CDD.

5. It have been written and tested elementary functions, similar to those in Matlab (standard, so without dedicated functions used in the toolbox) for the VIBROMOD module in order to CDD. These functions will be implemented in the end on a platform that is not running the Matlab environment.

6. We elaborated three ways to use the experimental model, which make use of components VIBROSIG, VIBROTOOL and/or VIBROMOD, two off-line and on-line.

7. We established the building blocks that will be included in the experimental model, as follows:
    a. PRO1. Block of computation parameters statistics
    b. PRO2. Block of spectrum Fourier amplitude calculation
    c. PRO3. Filtration block signals
    d. BSS1. Sources separation block
    e. TFR1. Time-frequency distribution calculation block
    f. TFR2. Renyi entropy calculation block
    g. CDS1. Block segmentation and can be interconnected in various ways, thus contributing to solving the problem of CDD in a practical situation.

8. Settled and developed program modules for Matlab Toolbox. It contains the categories of software modules for: primary processing of signals (PRO); detection and segmentation changes (CDS); "blind" separation of sources (BSS); time-frequency analysis (TFR)

9. It was defined and implemented the merger of several categories of algorithms in the original proceedings, used for monitoring rotary machines, procedures which fall within experimental model VIBROCHANGE, which will be completed within the Third Phase of the project (final) and tested on experimental data collected on the pilot and equipment on a process operating under real conditions/industrial operation.

10. It was designed and tested a micro-generator system of mechanical vibration (VIBROGEN), under controlled conditions and work load. It can be used independently or for validating the scope of work of translators, as well as to highlight defects in rotary machine monitoring purposes. Based on the data provided by this micro-system, in the next stage, it will build a more general system testing with transducers of vibration fault of rotary machines adapted.

4. Published papers

1. Theodor D. Popescu and Mihaela Andrei, *Multiple Hypothesis Testing with Application in Vibrating Signals Analysis*, The IEEE International Symposium on Systems Engineering, Rome, Italy, 28-30 september 2015, pp. 71-76.

2. Siviu Epure, Bogdan Dumitrascu and Dorel Aiordachioaie, *VIBROGEN - An experimental system to study vibration waveforms generated by faults under arbitrary load conditions*, The IEEE International Symposium for Design and Technology in Electronic Packaging - SIITME-2015, Brasov, Romania, 22 - 25 october 2015, pp. 239-244.

3. Theodor D. Popescu and Bogdan Dumitrascu, *An Application of Renyi Entropy Segmentation in Fault Detection of Rotating Machinery*, The 16th IEEE International Conference on Research and Education in Mechatronics REM2015, Bochum, Germany, 18-20 november 2015, pp. 288-295.

Galați, 26.11.2015

Project Manager,

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