Partnerships Program

Joint Applied Research Projects (PCCA)

Summary of the Research Report

Work package:	III
Phase title:	*Construction of the experimental model and finishing of the CDD toolbox*
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
Phase deadline:	15.12.2016

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

Galați-2016

Phase #3: 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.

2. Objectives

Figure 1 presents the links among the main modules of the experimental model VIBROCHANGE. It is about VIBROTOOL (Toolbox for CDD under Matlab) and VIBROMOD (hardware module for CDD, which implements some algorithms of VIBROTOOL). For testing in laboratory conditions a test module called VIBROGEN was built, which will generate vibrations waves under controlled conditions.

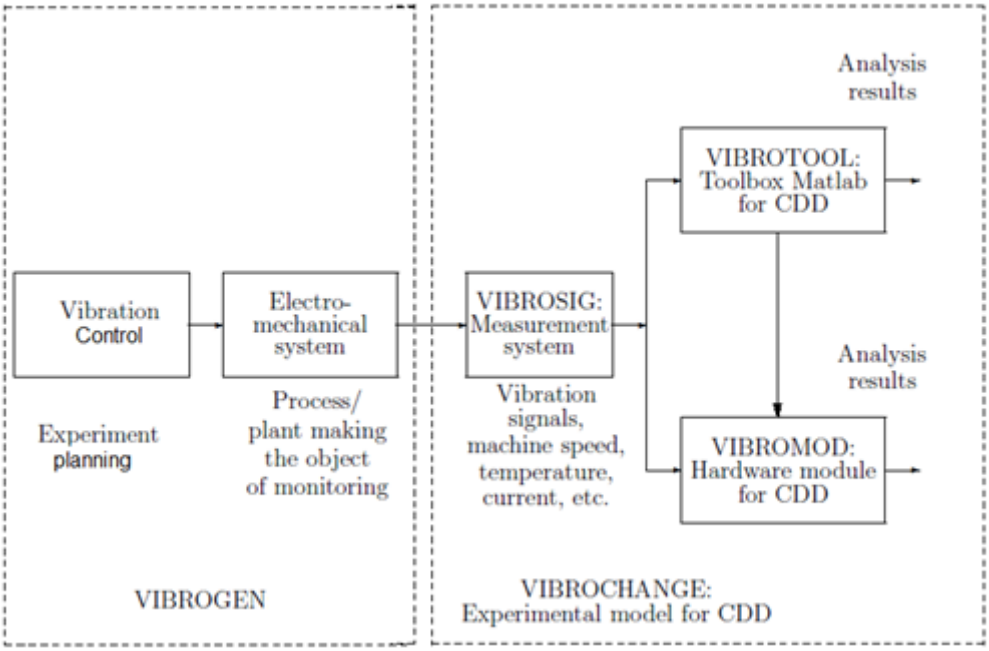

Figure 1: The main processing blocks involved in the VIBROCHANGE project

The 3rd phase had three specific objectives. The first objective is referring to new components of the Matlab's toolbox for CDD, called VIBROTOOL. These components have advanced methods for CDD based on signal processing approach.

The second objective is to have the testing system called VIBROGEN, for testing in the laboratory conditions of various mechanical elements as gearboxes and bearings.

The third objective is referring to the construction of the VIBROMOD module, both hardware and software, as possible solution of low frequency vibration monitoring in industrial equipment.

3. The main results of the phase

The results of the research, carried out under Phase III of the project, are presented in the form of a Research Report, which contains 306 pages.

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

1. The Matlab toolbox for CDD problems is almost finished. For details please see [1] and [6].
   The library has now the following types of programs:
   a. Primary signal processing (PRO);

b. Change detection and segmentation (CDS);
c. Blind source separation (BSS)
d. Time-frequency analysis (TFR)
e. Sparse computing for CDD
f. Feature extraction based on statistical and informational signal processing approaches.

2. The CDD algorithms have been validated by Monte Carlo simulation approach.

3. The testing system called VIBROGEN is finished. The system is computer controlled, by imposing the speed regimes of an electrical machine and by connecting and controlling a mechanical load. A general picture is presented in Fig. 2.

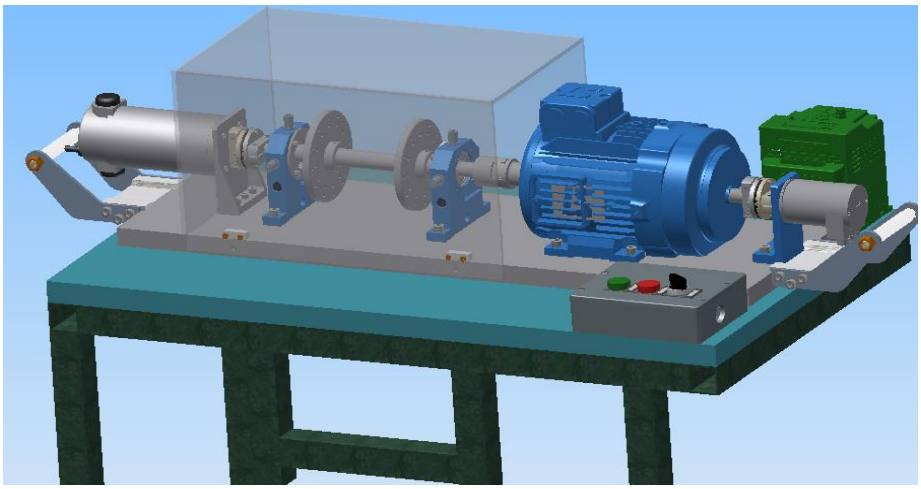

Figure 2: The VIBROGEN system

4. The module VIBROMOD is almost finished. Figure 3 presents the physical interconnection among the main modules: VIBROGEN and VIBROMOD. There are specialized electronic modules for data acquisition, speed measurements, control unit (PLC) (for level #1 of the processing) and communication. On upper level, i.e. #2 and #3, are using computers running advanced signal processing algorithm developed in Java. Details are in [3] and [7].

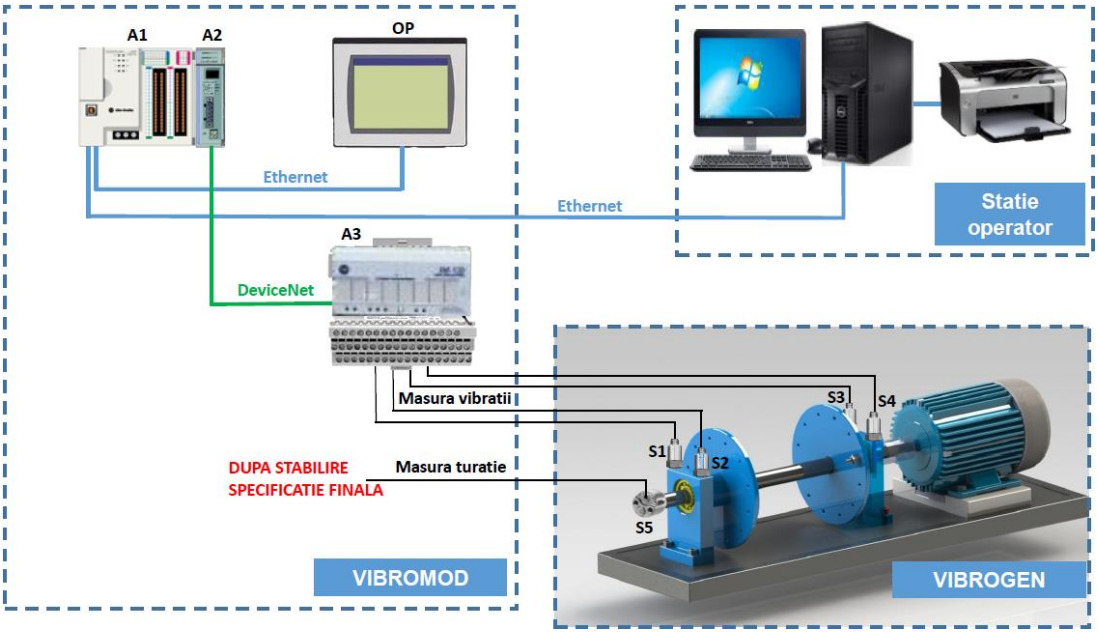

Figure 3: The structure of the VIBROCHANGE experimental model

5. A feature extraction system from time-frequency images was developed. The structure of the system is presented in Fig. 4. The system makes also the detection and masking of the interference terms, which are discovered by cross-correlations. An example is presented in Fig. 5, where the interference components of a signal with three components are detected and partially removed. For details please see [5].

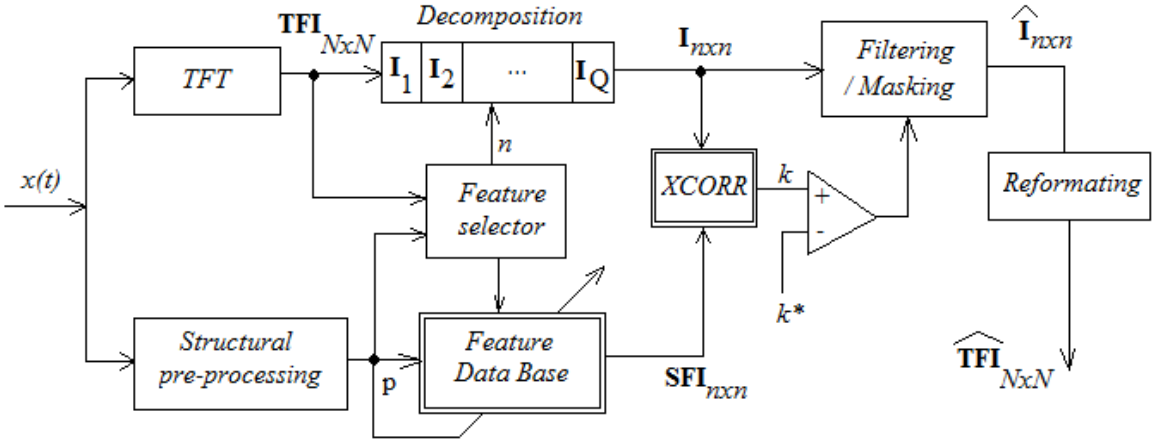

Figure 4: The structure of the system for feature extraction

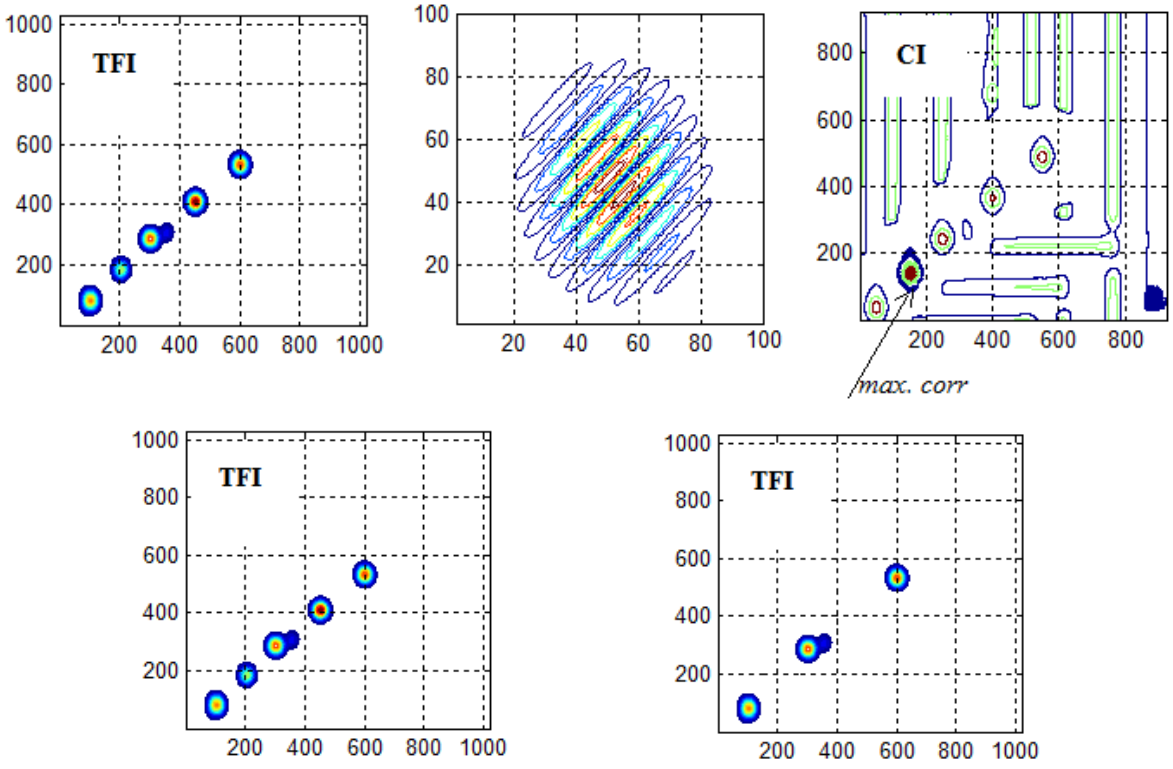

Figure 5: Detection and filtering of the interference terms

6. Advanced signal processing methods for CDD, members of VIBROTOOL Matlab toolbox, was implemented in Java. Fig. 6 presents two examples: envelope detection and instantaneous frequency estimation by using Hilbert transform. Details are in [6].

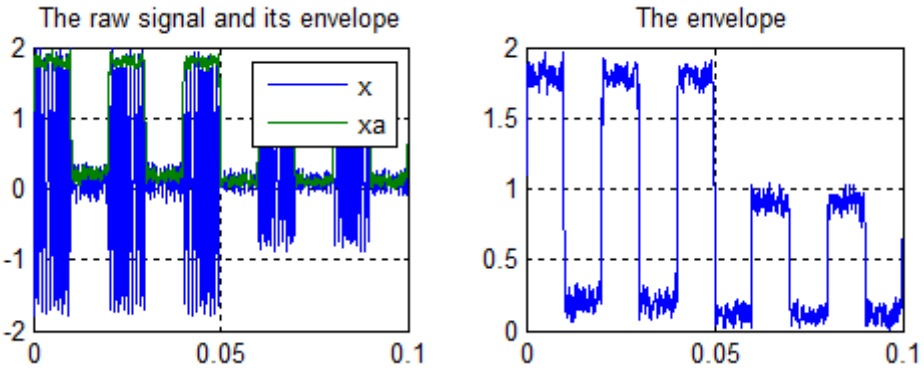

Figure 6.a: Envelope detection

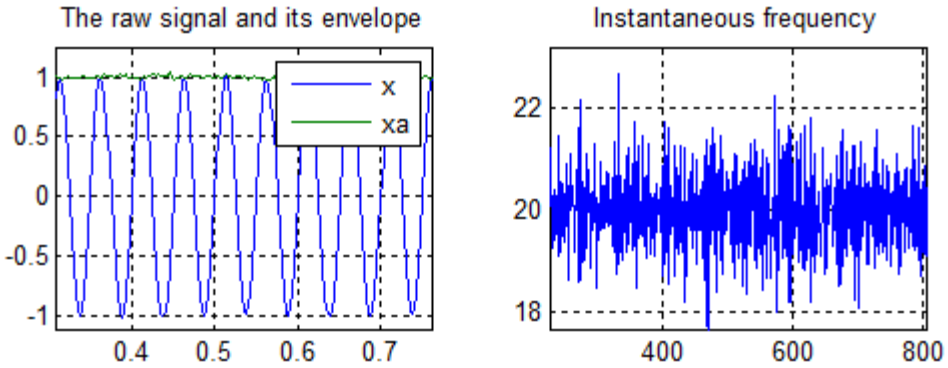

Figure 6.b: Frequency estimation;
f_real = 20 Hz; f_estimated = 19.9842 Hz; Noise power = 0.01 W.

The next phase of the project, phase no. 4, with deadline 30.09.2017, is to make experiments with real equipment in order to evaluate the experimental model VIBROCHANGE.

4. Published papers

[1]. Bogdan Dumitrascu, Dorel Aiordachioaie, and Theodor D. Popescu, *VIBROTOOL – A Matlab Toolbox for Change Detection and Diagnosis in Vibration Engineering*, The 13th IEEE International Conference on Development and Application Systems, (DAS-2016) Suceava, Romania, May 19-21, 2016, pp. 6-9.

[2]. Dorel Aiordachioaie and Bogdan Dumitrascu, *On the Change Detection Methods with Sensitivity at Variance of The Processed Signal*, The IEEE 39th International Conference on Telecommunications and Signal Processing (TSP-2016)**,** in Vienna, Austria, June 27-29, 2016, pp. 417-420, 2016.

[3]. Dorel Aiordachioaie, Theodor D. Popescu, *VIBROMOD – An Experimental Model For Change Detection and Diagnosis Problems*, Workshop on New Perspectives in Measurements, Tools and Techniques for system's reliability, maintainability and safety, (IMEKO-2016), Milano, Italia, 2016.

[4]. Anisia Culea –Florescu, Dorel Aiordachioaie, *Some Results on Change Detection Based on Advanced Signal Processing Paradigm*, The IEEE International Conference – 8th Edition Electronics, Computers and Artificial Intelligence, (ECAI-2016), 30 June-02 July, 2016, Bucharest, România**,** pp. 1-6.

[5]. Dorel Aiordachioaie, *On Time-Frequency Image Processing for Change Detection Purposes*, 7th International Workshop on Soft Computing Applications, 24-26 August 2016 Arad, Romania (SOFA-2016), paper 18**.**

[6]. Dorel Aiordachioaie, and Theodor D. Popescu, *VIBROTOOL - Software Tool for Change Detection and Diagnosis in Vibration Signals*, IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS-2016), 16-19 October 2016, Fairmont Bab Al Bahr Hotel, Abu Dhabi, United Arab Emirates (UAE), pp. 640-643, 2016.

[7]. Iulian Nacu, Laurentiu Luca, Nicu Roman, and Dorel Aiordachioaie, *On VIBROMOD – An Electronic Equipment for Data Vibration Measurement and Analysis*, The 22nd IEEE International Symposium for Design and Technology in Electronic Packaging (SIITME-2016), Oradea, 20-23 October, 2016.

[8]. Theodor D. Popescu and Dorel Aiordachioaie, *Robust change detection in signals using energy concentration and regression models*, 13th IEEE International Conference on Signal Processing (ICSP-2016), 6-10 November 2016, Chengdu, China, pp. 1707-1713.

Galați, 26.11.2016

The VIBROGEN Project Manager,

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