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Statistical procedures for determining of parameters for the evaluation of the condition and safety in logistic of military vehicles

Statystyczne procedury wyznaczania parametrów oceny stanu i bezpieczeństwa w logistyce pojazdów wojskowych

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Abstract. The use of technical condition assessment methods in the process of vehicle operation, which are the basis for automating the process of recognizing their current condition and safety, is synonymous with modernity. The purpose of this study is to present fragments of numerical procedures used for programmed studies of changes in the state, reliability, and safety of technical objects in use. The presented methodology, supported by elements of achievements in application of statistical methods, is the basis for a comprehensive assessment of supervised facilities, which are so important for innovative strategies for the operation of technical facilities. However, this requires optimization of the set of diagnostic parameters, development and optimization of condition control tests and optimization of genesis and prognosis methods. The solution to these tasks depends on many factors related to the degree of complexity of the objects, the quality of the operation process and the course of their aging and wear processes. The analysis and synthesis of the obtained research results should allow for the development of dedicated procedures

and inference rules for the tested objects (vehicles) in the field of data acquisition and processing for the observation matrix, which is presented in the form of ready-made algorithms in this work. These are important procedures constituting the basis for more and more often built control and diagnostic systems introduced to facilities already at the stage of construction and production in modern technical facilities. Such systems are the basis for monitoring state changes, security threats, reliability, and supervision in the rational operation of technical facilities. .
Keywords: logistic, safety, algorithms, modeling, inference

Abstrakt. Stosowanie w procesie eksploatacji pojazdów metod oceny stanu technicznego, które są podstawą automatyzacji procesu rozpoznawania ich aktualnego stanu i bezpieczeństwa, jest synonimem nowoczesności. Celem tego opracowania jest przedstawienie fragmentów procedur numerycznych stosowanych do programowanych badań zmian stanu, niezawodności i bezpieczeństwa użytkowanych obiektów technicznych. Przedstawiona metodologia wsparta elementami dokonań z obszaru zastosowań metod statystycznych to podstawy całościowej oceny nadzorowanych obiektów, jakże ważnych dla innowacyjnych strategii eksploatacji obiektów technicznych. Wymaga to jednak optymalizacji zestawu parametrów diagnostycznych, opracowania i optymalizacji testów kontrolnych stanu oraz optymalizacji metod genezy i prognozowania. Rozwiązanie tych zadań zależy od wielu czynników związanych ze stopniem skomplikowania obiektów, jakością procesu eksploatacji oraz przebiegiem procesów ich starzenia i zużycia. Analiza i synteza uzyskanych wyników badań powinna pozwolić na opracowanie dedykowanych procedur i reguł wnioskowania dla badanych obiektów (pojazdów) w zakresie pozyskiwania i przetwarzania danych do macierzy obserwacji, która jest przedstawiona w postaci gotowych algorytmów w tym pracowaniu. To ważne procedury stanowiące podstawę dla coraz częściej budowanych systemów sterująco – diagnostycznych wprowadzanych do obiektów już na etapie konstruowania i wytwarzania w nowoczesnych obiektach technicznych. Systemy takie są podstawą monitorowania zmian stanu, zagrożenia bezpieczeństwa, niezawodności i nadzoru w racjonalnej eksploatacji obiektów technicznych.
Słowa kluczowe: logistyka, bezpieczeństwo, algorytmy, modelowanie, wnioskowanie

Introduction

In the process of technology development and production, an important issue is to ensure products of appropriate "quality" and efficiency. The properties of the facility, influencing the quality and efficiency, cause more and more technical problems for specialists in various fields of technology, as well as for economists interested in them in terms of the needs of the economy. These problems often constitute the basic issue on the safety, state and rational management of fixed assets in an enterprise, especially in the field of management (Żółtowski, 1997).

Treating the use of vehicles as the main stage of verification of their suitability and meeting of social expectations, more and more often at this stage, intensive tests of their correct operation are carried out in properly formalized operation structures (Będkowski, Dąbrowski, 2000; Cempel, 2000; Śniedziewski, 2021).

The possibilities of achievements in all areas of the theory of operation allow for modern solutions in the field of planning and optimization of the procedures for designing, constructing, manufacturing and operating vehicles, according to the main criterion of their quality and efficiency of use. This facilitates the planning and implementation of a modern method of managing fixed assets (Birger, 1978, p. 32; Cempel, 1998, pp. 224-253; Żółtowski, 1995).

The interdisciplinary connection of vehicle operation problems clearly indicates the dominant role of technical diagnostics among them, treated as a tool for examining the condition of vehicles and shaping their quality and ways of using them in IT management system (Bajkowski, Grzesikiewicz, Jusis, 2000; Bruel, 1993; Giergiel, 2000).

In the multi-stage process of vehicle existence (valuation, construction, production, operation), the operation phase is the final verification of the product (product) performance, including the "quality" of all previous stages (Cempel, Natke, 1996; Żółtowski, 1995; Żółtowski, 1997).

Nowadays, the term "operation" is understood as a set of purposeful organizational, technical and economic activities of people with technical devices and the mutual relations between them from the moment of taking over the device for use in accordance with its intended use, until its disposal after liquidation (Augustyn, 2022; Śniedziewski, 2021).

Generally, therefore, the problem of exploitation, which has recently found its place in the logistic system, has a multi-layer (hierarchical) structure, for the analysis of which methods developed by the general theory of systems are necessary. In the vehicle operation system, the use subsystem and the maintenance subsystem inseparably connected with it are always treated as the main one (Bendat, Piersol, 199; Cempel, Natke, 1996; Natke, Cempel, 1997).

Only fit vehicles are in the subsystem of use, and they can be used intensively (as intended) or in waiting, when there is a standstill for demand for use. Each malfunction causes the vehicles to go to the maintenance subsystem, where the serviceability is restored and where the recommended maintenance is performed (Giergiel, Uhl, 2000; Śniedziewski, 2021; Żółtowski, Cempel, 2004).

The current technical condition of the vehicle, represented by the values of the measured symptoms of the condition, is the basis for the operational decision. Correct implementation of such a strategy requires effective methods and means of technical diagnostics and trained technical personnel. It also requires overcoming the mistrust of decision makers as to the effectiveness of this type of exploitation.

The economic effects of this method of exploitation are disproportionately higher than in other strategies, which determines the success and great interest in this solution (Banek, Batko, 1997; Broch, 1980; Winiwarter, Cempel, 1996).

The field of knowledge, safety, technical diagnostics, already formed within the field of exploitation sciences - deals with the assessment of the technical condition by examining the properties of working processes and accompanying vehicle operation.

The essence of technical diagnostics consists in determining the condition of the vehicle (assembly, subassembly, element) indirectly, without dismantling, based on the measurement of generated diagnostic signals (symptoms) and comparing them with nominal values.

The value of the diagnostic signal must be related to the known relationship with the diagnosed feature of the object's condition, characterizing its technical condition (Birger, 1978, p. 32; Grifin, 1990; Żółtowski, 1997).

The created dedicated system of statistical research of results includes many different procedures and software implementation for the needs of:

- acquisition of dynamic processes (e.g., vibration),
- processing of measured signals,
- research on the interdependence of recorded signals,
- testing the sensitivity of symptoms,
- cause and effect inference,
- visualization of the results of the analysis.

The main components of this system (specific for the field) are:

- LMS Test Xpress software to carry out measurements,
- results visualization and data transfer programs (import unv, Excel),
- SYMPTOMS PROGRAM for determining estimators of measured signals,
- software for measuring the sensitivity of measures: OPTIMUM (qualitative research) and SVD (quantitative research),
- software for studying dependence (correlation) and regression (bonding models),
- system of building inference models (Excel, MATLAB, BEDIND),
- research IT system - integration of statistical methods.

Diagnostic data obtained most often from on-board control and diagnostic systems of vehicles after initial processing constitute indications for the development of cause-and-effect models and are the basis for decisions made (Batko, Gołaś, 1998; Giergiel, Uhl, 2000; Śniedziewski, 2021).

Methods and algorithms based on acute and fuzzy algebra, classic methods of condition assessment, as well as adaptive and neuro-fuzzy algorithms constitute the basis for obtaining information that ultimately describes the technical readiness of vehicles (Banek, Batko, 1997; EASA 2022; Żółtowski, 1995).

This work shows the basic algorithms in the process of acquiring and processing diagnostic information in a multi-symptom approach, enabling multi-damage recognition of the condition of vehicles.

Computational algorithms

In this paper a set of computer algorithms was developed, was called Technical Systems State Analysis (TESSA) and contain computational tools to make a technical state analysis. TESSA is integrated for eight modules and each module is an analysis procedure.

In the Fig. 1 is showed the main module of TESSA and administrate the modules (Awrejcewicz, 1996; Banek, Batko, 1997; Żółtowski, 1997a). The modules are the following:

- import *.UNV format,
- to build symptoms matrix,
- SVD procedure,
- OPTIMUM procedure,
- Input/Output relationship function,
- optimization,
- Neuronal Network,
- MAC procedure.

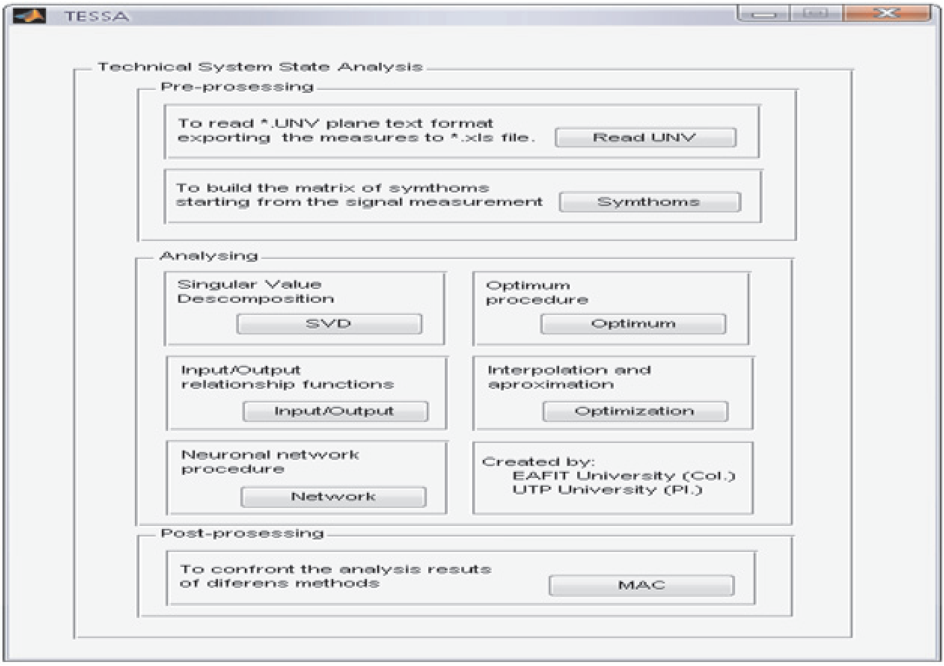


Fig. 1. Technical Systems State Analysis (TSA)
Source: Own elaboration

Import *.UNV format

The import *.UNV format module read, draws and exports to .xls format the universal files obtain of DIFA system. The module can read one, two or even more channel saved in the universal format. The universal format has a defined and rigid syntax. The structure of the universal format must have the proper to correctly read the file (Cempel, 1998; Żóltowski, Cempel, 2004.

When the universal file is read correctly, the data and the quantity of samples is display in the module, besides the values of each channel is shown. In the plot is displayed the number of channels, the position, and the data of the acquisition (see Fig. 2).

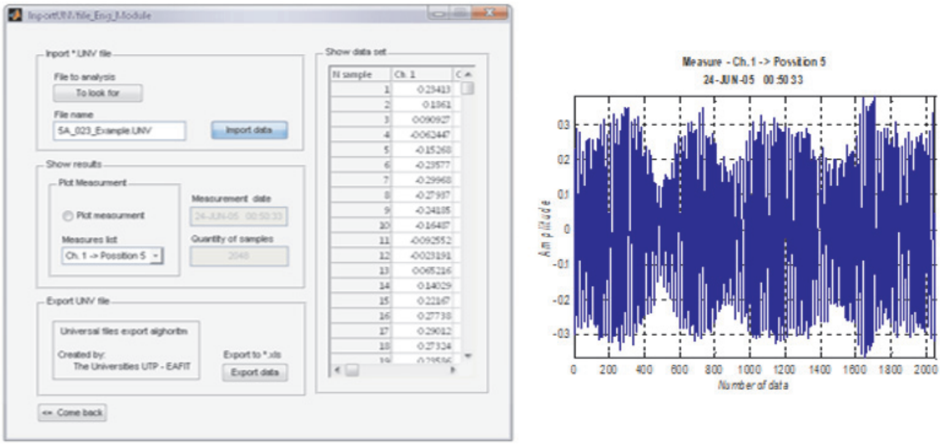


Fig. 2. Import *UNV format module
Source: Own elaboration

To build symptom matrix

This module read an .xls file which must have a defined and fixed structure. The module can calculate the symptoms present and construct a symptom matrix (Awrejcewicz, 1996). The matrix is showed automatically in the module (see Fig. 3).

There are symptoms calculated from related signals and high order analysis (FFT, FRF, TF, etc.) which must be setting the frequency domain to get the index symptom, this is making through a graphical interface of easy and intuitive operation (see Fig. 4).

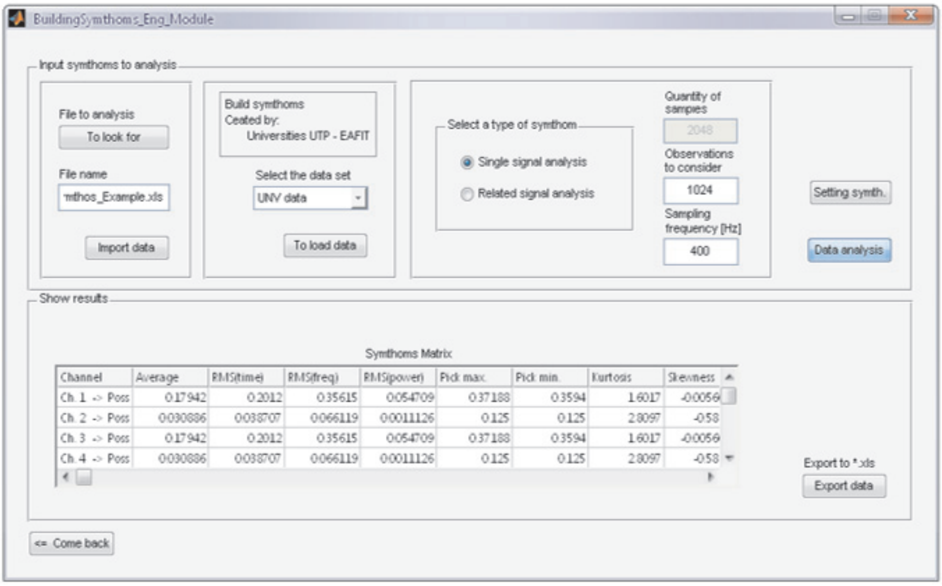


Fig. 3. To build symptoms module
Source: Own elaboration

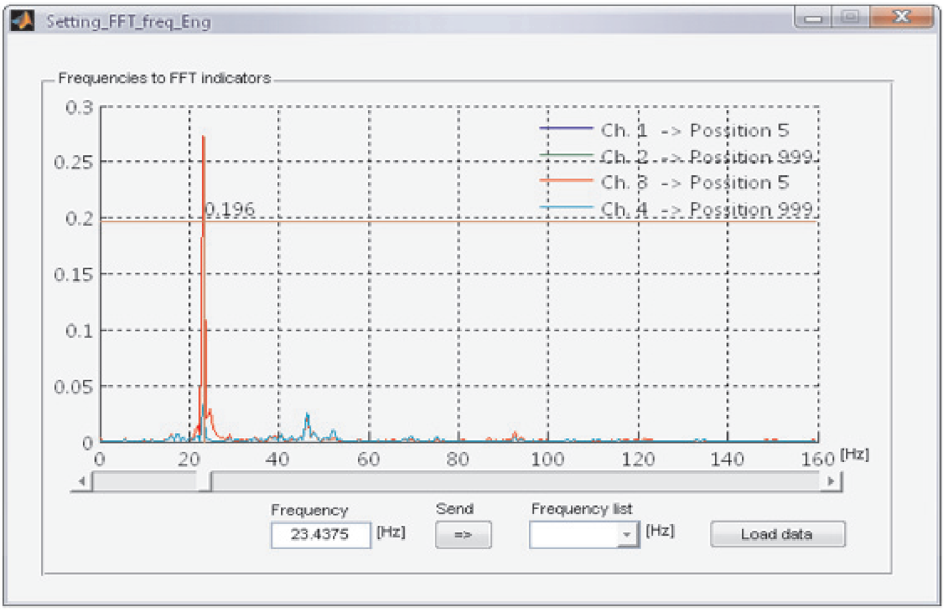


Fig. 4. Setting symptom parameters of high order
Source: Own elaboration

OPTIMUM procedure

The OPTIMUM module (Żółtowski 1995; Żółtowski 1997a; Żółtowski 1997b) is shown in the Fig. 5. The module can be calculating the best parameters for diagnostic to different ways:

- correlation coefficient,
- sensibility of symptoms,
- determination of Euclid's distance.

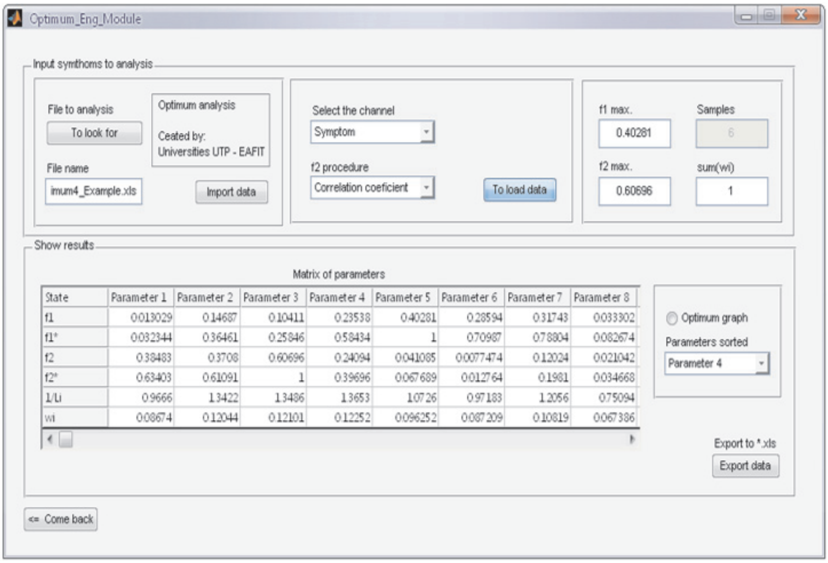
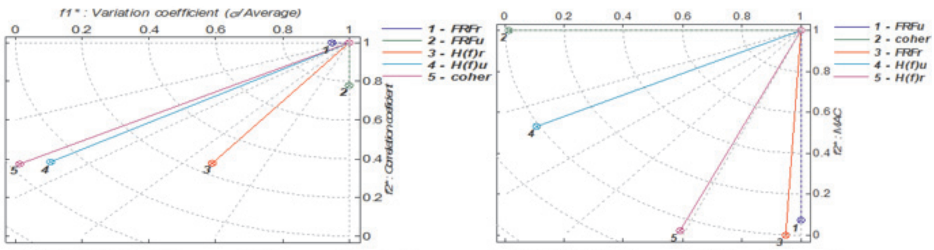


Fig. 5. OPTIMUM module
Source: Own elaboration

The results are display as diagrams (see Fig. 6).



a. OPTIMUM whit correlation coefficient b. OPTIMUM sensibility of symptoms

Fig. 6. OPTIMUM diagrams
Source: Own elaboration

SVD procedure

The SVD Module is a computational tool to make a multidimensional analysis through the linear algebra field (Cempel, 1998; Cempel, Natke, 1996b; Żółtowski, 1995). The module enables sort upwardly the observations relative to a selected symptom (see Fig. 7), this action makes vary the dimensional space due the set of symptoms is centered and normalized by the new initials' values if each symptom (see Fig. 8).

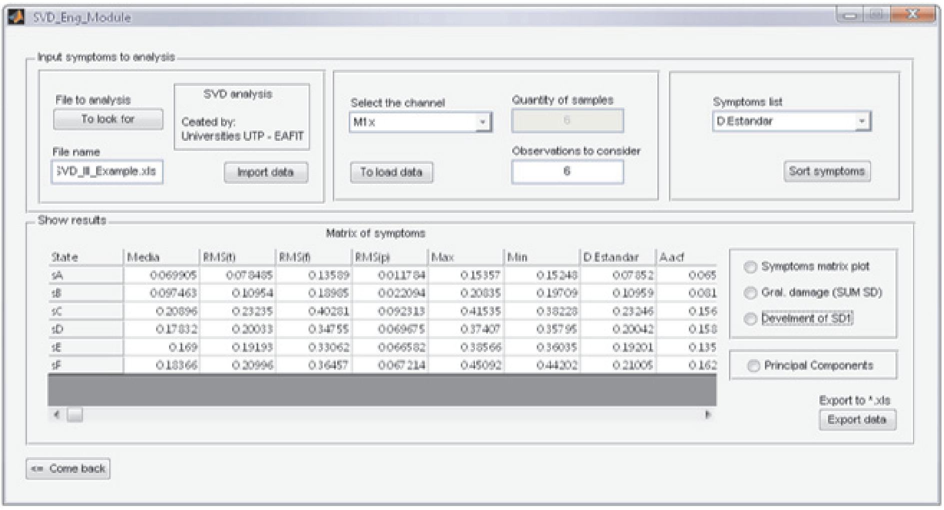


Fig. 7. SVD Module
Source: Own elaboration

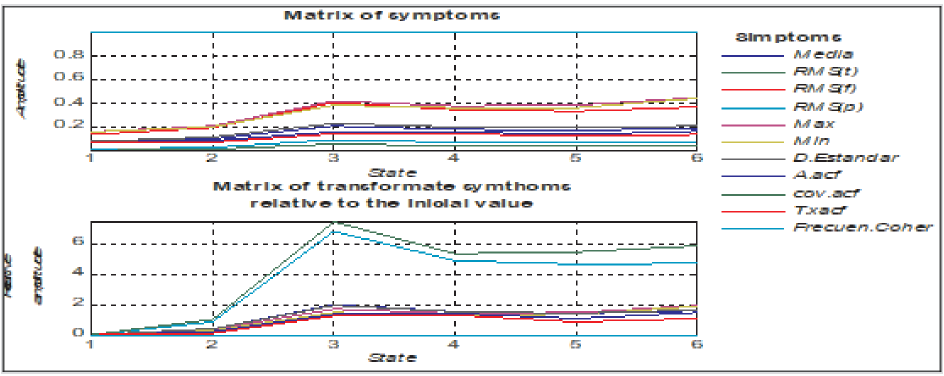


Fig. 8. Original symptom matrix and transformed symptom matrix
Source: Own elaboration

The SVD Module calculates the general damage and the development of SD1 (see Fig. 9), besides represents un three dimensions the three most characteristic symptoms and their relationship (Fig. 10).

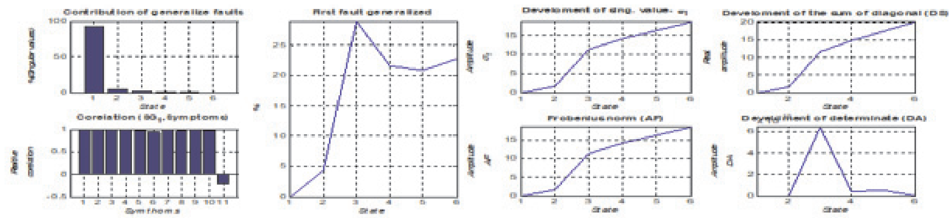


Fig. 9. Analysis of damage
Source: Own elaboration

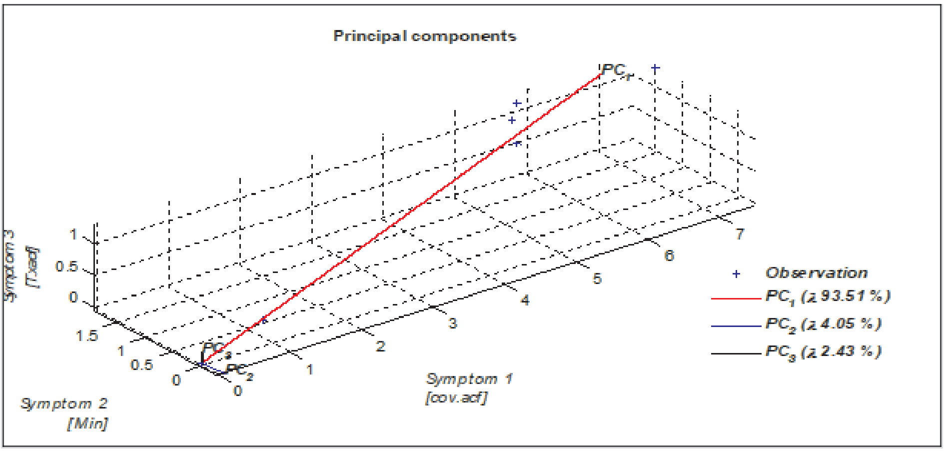


Fig. 10. Principal Components representation
Source: Own elaboration

Input/Output relationship functions

This module computes the functions of high order between two signals (Bishop, Johnson, 1990; Śniedziewski, 2021). The calculated function is FFT, FRF, TF, Coherence Cross-correlation (see Fig. 11) and makes the analysis in the frequency domain. Each function can be setting to find the area under the curve, it means, to do a numerical integration in a defined limit (see Fig. 12).

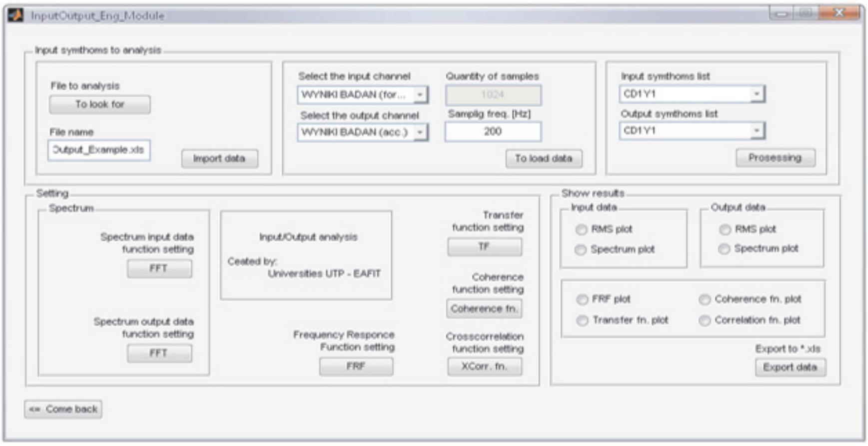


Fig. 11. Input/Output Module
Source: Own elaboration

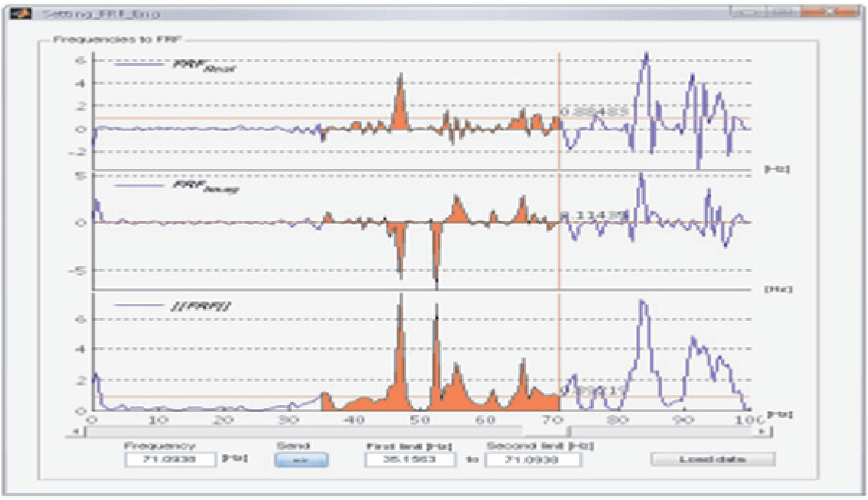


Fig. 12. Setting the limits of area function
Source: Own elaboration

Optimization

The optimization module (see Fig. 13) has two parts:

- interpolation,
- approximation.

The interpolation can be Piecewise cubic Spline or Lagrange polynomial, in each case founds the maximums and minimums absolute and locals (see Fig. 14).

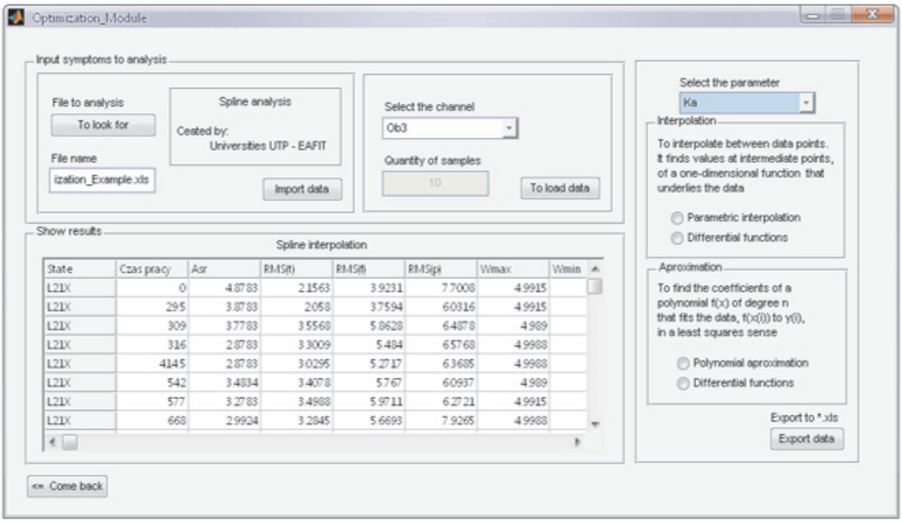


Fig. 13. Optimization module
Source: Own elaboration

A numerical calculus of the differential function is made, and then a numerical procedure is realized to find the roots of the differential function (Banek, 1997; Bendat, Piersol, 1996; EASA, 2022) .

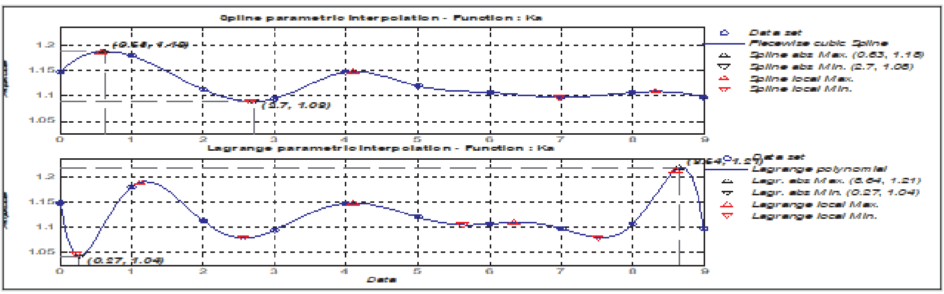


Fig. 14. Interpolation Spline and Lagrange
Source: Own elaboration

The approximation procedure is a non-liner least squares method, it is in 2, 3, 4 and 5 or order. Each approximation has its SSE value and analytical equation (see Fig. 15).

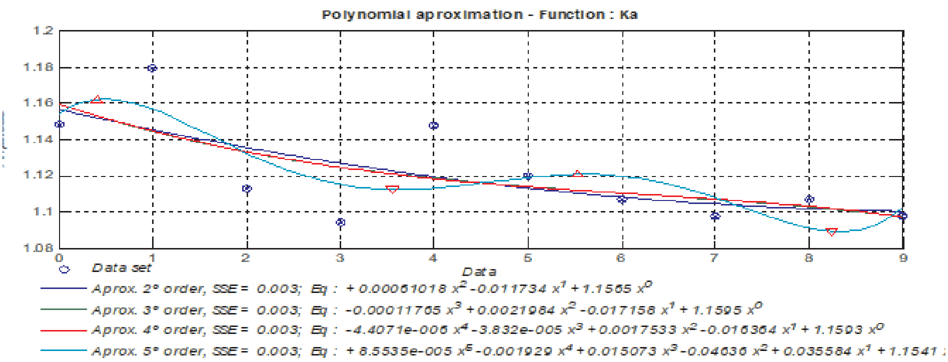


Fig. 15. Approximation 2, 3, 4, 5 and order

Source: Own elaboration

Neural Network

Neural Network has two parts. The first part is the neuron training, whole the Neural Network learns about the function's relationship. The second one part is the simulation at the Neural Network with another data set (see Fig. 16).

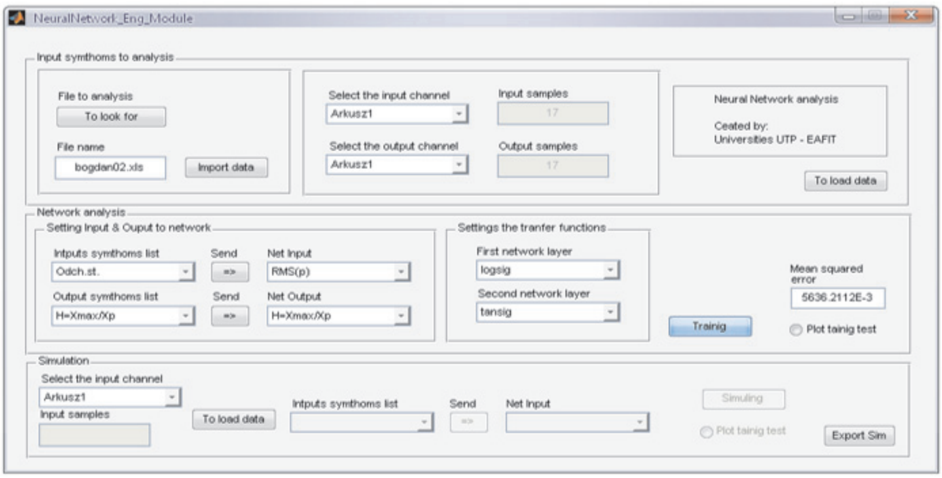


Fig. 16. Neural Network module

Source: Own elaboration

The training process is shown in the Fig.17.

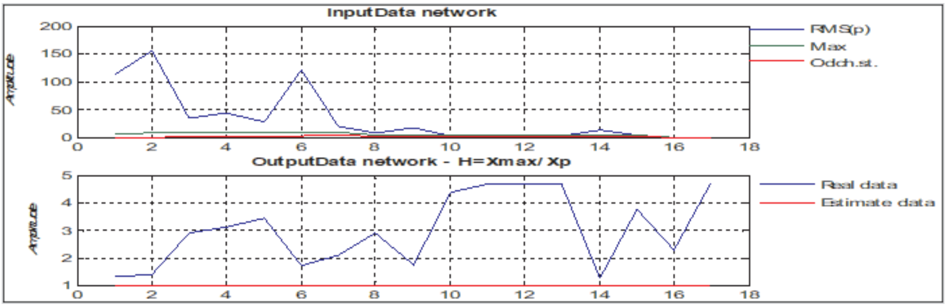


Fig. 17. Training test of Neural Network
Source: Own elaboration

MAC procedure

MAC is a versatile module. It is very useful to calculate and analysis the correlation into two vectors of matrices (see Fig. 18).

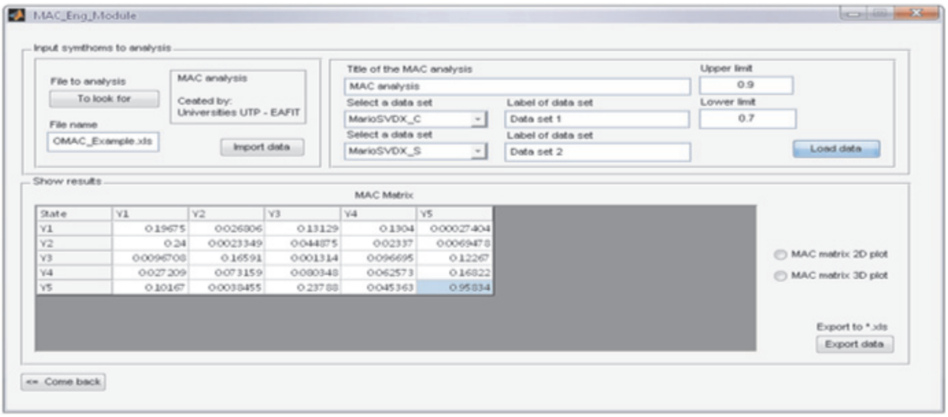


Fig. 18. MAC module
Source: Own elaboration

The results obtained in MAC module can be plot as illustrative diagrams (see Fig. 19).

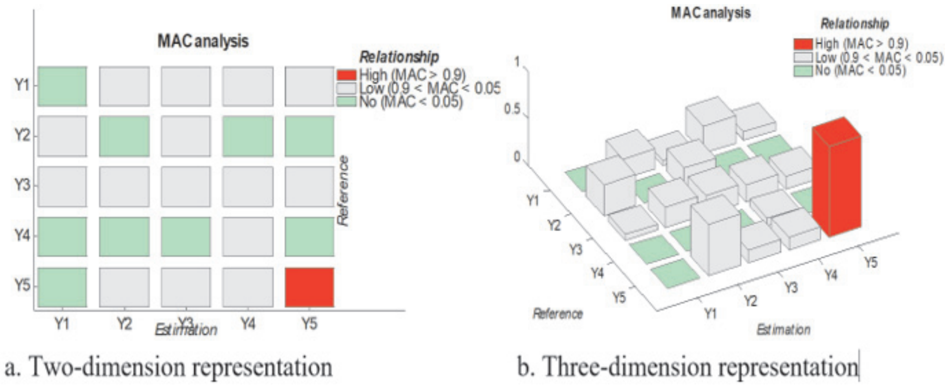


Fig. 19. MAC diagram
Source: Own elaboration

Conclusions

Operation of vehicles deals with the problems of the process of the existence of objects, from concept and design, through construction, production, and use, to liquidation and disposal after use. These problems coexist with the issues of technical suitability, reliability and safety, ecology, occupational health and social and living conditions.

Systemic treatment of the presented issues requires extensive use of research methods, especially in the field of information processes necessary to make effective operational decisions. Computer-assisted vehicle operation is already a reality, more and more often supporting their rational use supported by procedures for selecting measures for assessing the condition, safety, and environmental protection.

The intensification of problems with operation and the related needs for access and selection of process parameters for changing the technical condition, reliability, and operational readiness result from the verification nature of this stage of the life of vehicles.

The presented information procedures in obtaining and processing available measures of the state and safety of use are the basic procedures for their practical application in the built control and diagnostic systems of modern vehicles.

The technical diagnostics, which are outstanding at this stage, relates to the issues of the selection of measures of the quality of use and diagnostic service with the use of IT systems. They are the basis for the proposed quality assessment procedures for many requirements included in the control systems, most often already integrated with vehicles earlier, already at the stage of assessment, construction, and production.

The proposed procedures of this study are original algorithms important in the acquisition and processing of measurement data from research, often obtained with excess, built based on available statistical methods.

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