exploitation, process, locomotive, recognition electromechanics, safety, computer, resources, heteronomous classification

Maciej CYGAN[1]

POSTULATE OF INCOMPLETE DATA IN EXPLOITATION RECOGNITION OF ELECTROMECHANICAL TRACTION PROCESSES OF ELECTRIC LOCOMOTIVE FROM THE POINT OF VIEW OF MOTION DISTURBANCES

Computer system for acquiring of knowledge on electromechanical traction processes from the point of view of motion disturbances performs processing of exploitation measurement data of electric locomotives, estimates driving characteristics and classifies the processes.

Due to multiplicity of transportation processes to be realized exploitation recognition decisions concerning each traction process under monitoring do not have to be made on the base of complete knowledge acquired on each monitored process. It is especially important due to the time consumption and necessity to get mass calculations performed by recognition computer system.

In the paper a concept of recognition of electromechanical traction process on the base of incomplete data with use of non-symbolic methods is presented.

POSTULAT NIEPEŁNYCH DANYCH W EKSPLOATACYJNYM ROZPOZNANIU ELEKTROMECHANICZNYCH PROCESÓW TRAKCYJNYCH LOKOMOTYWY ELEKTRYCZNEJ ZE WZGLĘDU NA ZABURZENIA RUCHU

Komputerowy system pozyskiwania wiedzy o elektromechanicznych procesach trakcyjnych, ze względu na zaburzenia ruchu, przetwarza eksploatacyjne dane pomiarowe lokomotywy elektrycznej, estymuje charakterystyki napędowe, dokonuje klasyfikacji procesów.

Decyzje rozpoznania eksploatacyjnego, dotyczące każdego monitorowanego procesu trakcyjnego, z uwagi na wielość realizowanych procesów transportowych, nie muszą być dokonywane w oparciu o pełną wiedzę pozyskiwaną o każdym monitorowanym procesie; jest to szczególnie istotne z uwagi na czas i konieczność masowych obliczeń wykonywanych przez komputerowy system rozpoznania.

W opracowaniu przedstawiona została koncepcja systemu rozpoznania elektromechanicznego procesu trakcyjnego w oparciu o niepełne dane, z pomocą metod niesymbolicznych.

[1] Warsaw University of Technology, Faculty of Transport, POLAND;
Warsaw 00 662, 75 Koszykowa St. Phone: 022 234 7938, E-mail: mcygan@it.pw.edu.pl

1. INTRODUCTION

Recognition of electromechanical traction processes from the point of view of motion disturbances, also in function of electric locomotive exploitation time, is a question connected with safety of traction transportation process realization. Expression of the safety question in process categories becomes important when existence of computer exploitation supervision system is anticipated.

As in safety no absolute criteria are possible, multiplicity of criteria variously directed and thus extended system of process tests must be taken into consideration.

The expression in the process categories means both the operations connected with acquiring of data for supervision system in form of measurement process characteristics of the object under investigation and the operations connected with generation of property characteristics of the investigated process. Thus a need to rationalize resources of supervision computer system occurs especially in case when an electric locomotive driving system consists of some equivalent subsystems.

2. PARADIGM OF ELECTROMECHANICAL TRACTION PROCESS RECOGNITION FROM THE POINT OF VIEW OF MOTION DISTURBANCES

In the case under discussion recognition of the electromechanical traction process is directed on disturbances of electric locomotive driving axles.
The basic stages presented below intended to recognize the process of individual driving system are important also for multidimensional process of electric locomotive.

2.1 Acquiring of knowledge on electromechanical traction process with use of symbolic methods

Essential part of procedures for recognition of electromechanical traction process of electric locomotive from the point of view of motion disturbances concerns recognition of expert-system input vector pattern with use of symbolic methods based on cause-effect relationships of time-space character and on syntactic processing of symbols.

a. Expert selection of process variables
Dynamic process traction characteristics that changes in continuous manner makes - after measurement and numerical digitization - a sequence of statistically dependent samples of input signals for t_i moments. The digitization is made in parallel in relation to all characteristics of the process variable set:

instantaneous traction voltage	$u(t)$		$u(t_i)$
instantaneous traction current	$i(t)$	$\Rightarrow$	$i(t_i)$
instantaneous power	$p(t)$		$p(t_i)$
angular velocity of driving axles	$\dot{\vartheta}(t)$		$\dot{\vartheta}(t_i)$

Fig. 1. Samples of input signals for t_i moment

b. Index functionals of estimation
After linearization and compression of the mathematical model equation system a packed linearized equation is obtained in the following form:

$$\dddot{\vartheta}_k^{\,*} + c^*_{eq}(t_i)\cdot\ddot{\vartheta}_k^{\,*} + \aleph^*_{eq}(t_i)\cdot\dot{\vartheta}_k^{\,*} = F_{eq}(u^*,i^*;t_i) \qquad (1)$$

Interpretation of the packed linearized equation (1) follows just from its form.

Electrodynamic functionals $c^*_{eq}(t)$ and $\aleph^*_{eq}(t)$ mean substitute electromechanical dumping and substitute electromechanical rigidity, respectively, and they become process estimation index functionals point based for t_i.

c. Prerprocessing

Preprocessing determines - by approximation of nominal values and input signal disturbances - sets of subsequent values of input vector.

d. Electromechanical functional of input signal processing

An algorithm completes the input vector with subsequent point based - for t_i - positions which are the values of input variable electromechanical functional $F(u^*,i^*;t)$ and its component functions $f_n(u^*,i^*;t)$. The form of input pattern at this stage looks as follows:

$$\left\|\begin{array}{c|c|c|c|c} u\ (t_i) & u^o(t_i) & u^*(t_i) & f_1\ (u,i;t_i) & \\ i\ (t_i) & i^o(t_i) & i^*(t_i) & f_2\ (u,i;t_i) & F(u^*,i^*;t_i) \\ p\ (t_i) & p^o(t_i) & p^*(t_i) & f_3\ (u,i;t_i) & \\ \dot{\vartheta}\ (t_i) & \dot{\vartheta}^o(t_i) & \dot{\vartheta}^*(t_i) & f_4\ (u,i;t_i) & \end{array}\right\|$$

Fig. 2. Developed form of the input vector of the electromechanical traction process estimation system from the point of view of motion disturbances.

e. Together with the components of the motion disturbance functional $F(u^*,i^*;t)$:

$$F(u^*,i^*;t) = f_1(u^*,i^*;t) + f_2(u^*,i^*;t) + f_3(u^*,i^*;t) + f_4(u^*,i^*;t) \qquad (2)$$

index values $c^*_{eq}(t)$ and $\aleph^*_{eq}(t)$ generated as a result of numeric processing of input information signals determine basic characteristics of the process properties.

f. On the base of qualitative meaning of index values $c^*_{eq}(t)$ and $\aleph^*_{eq}(t)$ a set of attachment classes of recognition system reference vector is determined.

$$\lambda_A:\ c^*_{eq}(t_i) > 0 \ \ i \ \ \aleph^*_{eq}(t_i) > 0; \qquad \lambda_C:\ c^*_{eq}(t_i) > 0 \ \ i \ \ \aleph^*_{eq}(t_i) < 0 \qquad (3)$$

$$\lambda_B:\ c^*_{eq}(t_i) < 0 \ \ i \ \ \aleph^*_{eq}(t_i) > 0; \qquad \lambda_D:\ c^*_{eq}(t_i) < 0 \ \ i \ \ \aleph^*_{eq}(t_i) < 0$$

Simultaneous identification of $c^*_{eq}(t)$ and $\aleph^*_{eq}(t)$ together with estimation of their value determine the operation range of the process classes recognized.

2.2 Acquiring of knowledge on electromechanical traction process with use of non-symbolic methods

Non-supervised classification determines basic set of classes and at the same time it shows to which class an input signal sample is attached. The conditions (3) have first of all

qualitative meaning irrespective of traction structure of connections in which subsystems of electric locomotive driving system occur.

At the stage of the supervised classification the codebook vector space of expert processor associative memory completes the property characteristics determined by the following functionals:

- of substitute electrodynamic damping:

$$\zeta(t_i) = f(c_{eq}^{*2}(t_i), \aleph_{eq}^{*}(t_i));$$

- of electrodynamic time measure of 'time constant' type:

$$\tau(t_i) = f(c_{eq}^{*'}(t_i)).$$

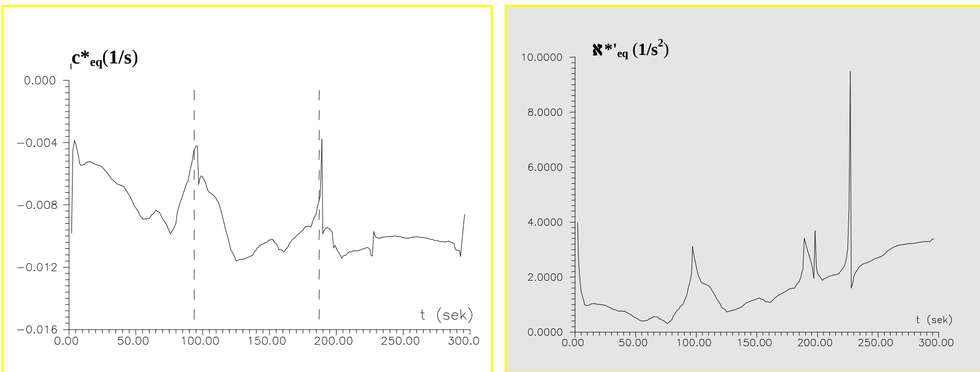

Fig. 3. Example of property characteristics of start-up process $c_{eq}^{*}(t)$ *and* $\aleph_{eq}^{*}(t)$

Identification of characteristics

$$\{ c_{eq}^{*}(t_i), \ \aleph_{eq}^{*}(t_i), \zeta(t_i), \ \tau(t_i) \}$$

determines process record collected for t_i moments as well as lays out supervised classification ranges.

If classification of each subsequent process under investigation is based on property characteristics of a given process that are generated by expert computer system, such current classification connected with the given process is called *autonomous classification*. Creation of knowledge on subsequent processes in case of autonomous classification means that each time full resource of procedures connected with data processing, with generating of process property characteristics and with classification is used.

Referring to observation and qualitative interpretation following from classification is a base for use of non-symbolic methods for acquiring of knowledge on the traction process

under investigation, Fig. 4.

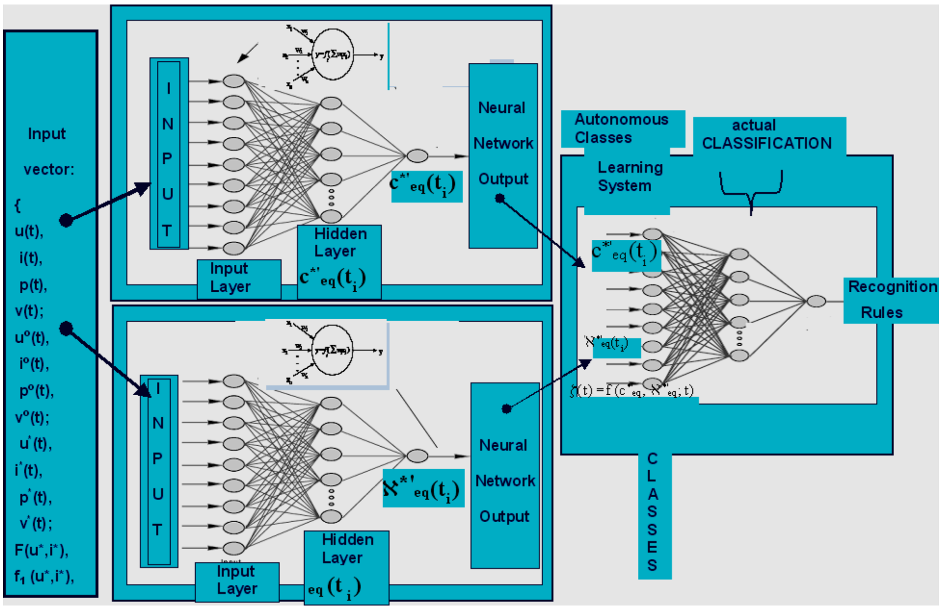

Fig. 4. Individual drive - autonomous classification

3. RESOURCES OF COMPUTER SYSTEM FOR RECOGNITION OF ELECTROMECHANICAL TRACTION PROCESSES FROM THE POINT OF VIEW OF MOTION DISTURBANCES

Basic resources of the process recognition system follow from needs connected with processing of information that concerns creation of: input vector pattern value, process property characteristics as well as structure and value of associative memory reference vector.

a. Input vector: collection of process measurement data in form of simultaneous exploitation characteristics; parallel preprocessing of measurement signals in order to determine nominal characteristics and motion disturbance characteristics; determination of characteristics of motion disturbance forcing functional and its components.

b. Property characteristics: point based - for t_i - synthesis of index recognition functionals; generation of parallel characteristics (properties) of process recognition; point based qualitative interpretation of property characteristics.

c. Codebook vector of recognition processor associative memory: non-supervised classification, supervised classification; determination of dominant values in classes; ordering of codebook vector qualitative structure in accordance to classes.

d. Recognition of multidimensional process. Electric-locomotive electromechanical traction system consisting of some driving subsystems realizes traction process which is a multidimensional process. As it is known, driving subsystems are able to realize traction process in variable connection structure, Fig. 5.

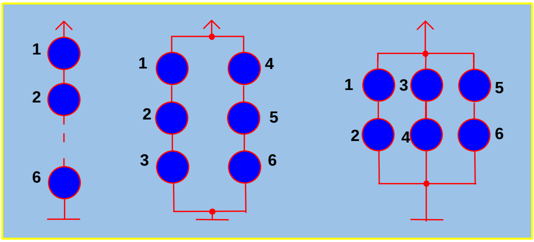

Fig. 5. Changes in connections of engine groups in multidimensional traction process

In order to apply recognition to multidimensional process, at lest for exploitation safety, it would be necessary to make simultaneous monitoring and comparative investigations of component processes of all traction subsystems taking also the changes in their connection structure into consideration. Such attitude anticipates considerable increase of resources and development of the structure of parallel recognition computer system, Fig. 6.

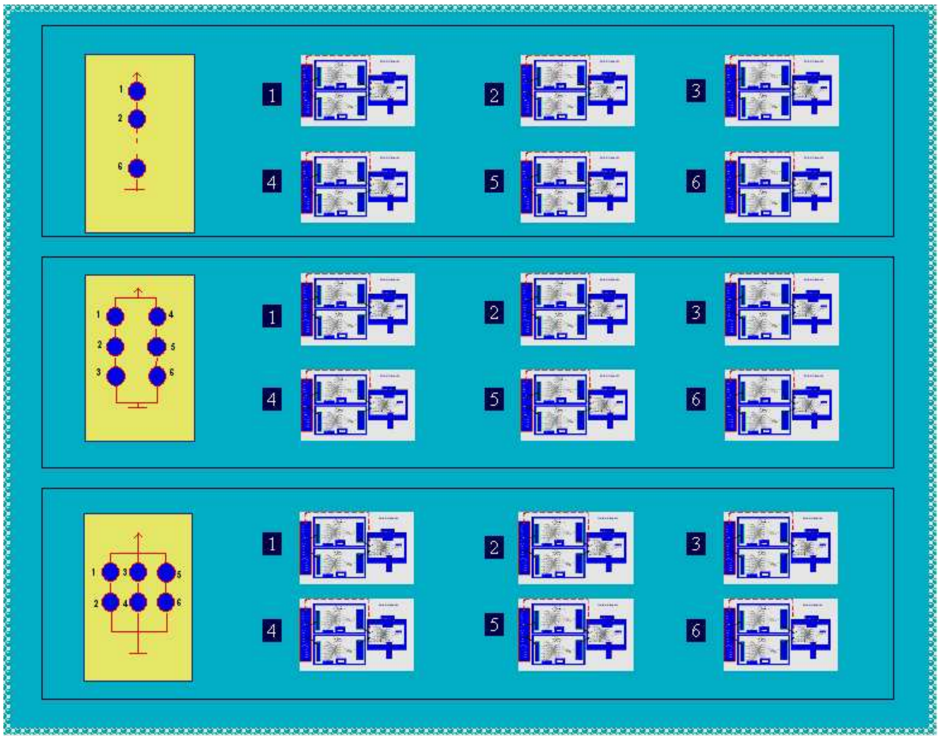

Fig. 6. Multidimensional process - autonomous classification

In connection with that some doubts may occur as to costs of the system and its reliability first of all due to simultaneous measurement monitoring of all subsystems,

parallel processing of all exploitation characteristics including individual autonomous classification of each process.

4. HETERONOMOUS CLASSIFICATION - POSTULATE OF INCOMPLETE DATA

If investigation of each subsequent process is based on a system of non-self classes existing in knowledge base as already determined for a previously investigated process, such classification would be called *heteronomous classification*.
Application of the heteronomous classification means that we use periodical - determined for some time of exploitation - standard of codebook vector of processor associative memory.

As traction subsystems of locomotives are similar their similar process may be classified and recognized in accordance with accepted codebook vector standard. It means that we do not have to make each time the most time-consuming procedures (item 2b) connected with synthesis of index values and generation of property characteristics.
Accepting the common standard we assume that it is reliable for all subsystems. If

locomotive drive subsystems are similar and realize similar processes it is not necessary for each of them to have its own individual recognition computer system with own measurement equipment.

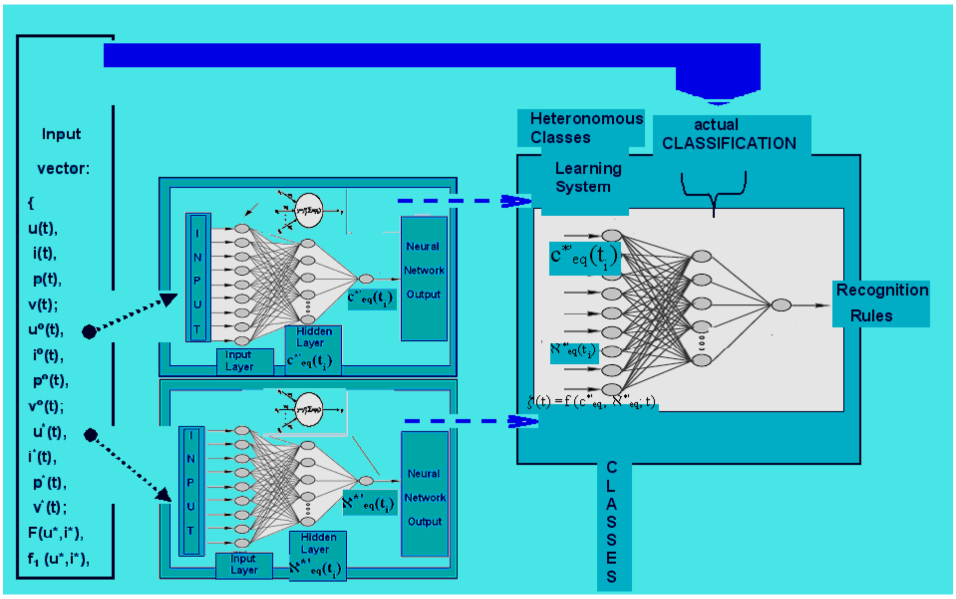

Fig. 7. Individual drive - heteronomous classification

So, the postulate of incomplete data means that classification of a process is made directly on the base of measurement data and characteristics of preprocessing with use of reference vector already existing in knowledge base. The recognition system created this way becomes an operational system with sequence limitations in access to limited resources.

5. CONCLUSIONS

In point of fact the classification defines a process under investigation with use of properly recognized, point based - for t_i moment - sequences of hypotheses $H(t_i)$. Reliability of the hypotheses - according to qualitative interpretation - is based on record $E(t_i)$ collected in form of process property characteristics.

Reliance degree RD (H, E) attributed to a recognized hypothesis H depends also on classification applied - autonomous or heteronomous one. It means that reliance degree of even properly recognized hypothesis may depend also on creation of reference vector of processor associative memory.

As to the question of safety we assume that there are no absolute criteria. Proper process recognition, especially in those questions, should be determined by the record collected and reliable recognition of hypotheses.

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