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On Applying Artificial Intelligence Techniques to Building Sea-Going Ships

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Abstract

Sea-going ships are autonomous complex objects that are intensively automatized due to safety and economic factors. The issue is complicated enough to entail a need for powerful methods such as Artificial Intelligence techniques.This report gives a brief description of several problems of ship-building for which Artificial Intelligence techniques seem to be particularly suitable. They include: inventing so called diagnostic models on the basis of experimental data, power systems protective relying, unmanned power plant control system and merchant fleet management. The concept of the sea-going robot-ship is also discussed, and some general remarks on the Artificial Intelligence approach to problem solving and conclusions containing agenda for research are added.

1. Introduction

Ships are made to transport cargo across the sea, catch fish, carry weapons and for other particular ends. All these ends require ships to carry various gear necessary to fulfil the duties they perform. Today's ships are equipped with quantities of such gear. Power of their electric plants is measured in tens of megavoltamperes (MVA) as is the power of relatively large factories. There are three main specific features of these "movable factories":

- hostile environment,
- safety constraint,
- unmanned service.

Changeable (abruptly and within a very wide range) temperature, sea water, moist and salty air, vibration etc. - all these disadvantages cause everything to corrode, wear away, deteriorate and go wrong very quickly on a sea-going ship. However the consequences of damage at sea can be much more serious than the consequences of the same damage in an onshore installation. They can mean immense loss, including loss of human life and destruction of large areas of the environment.

Hence everything on a sea-going ship must be as safe as possible.Thus it is necessary that almost every device on the ship must be under constant supervision of a highly experienced crew.

On the other hand, people are not always reliable. In many situations it is just the so-called *human factor* that is the cause of particular damage. In addition the cost of qualified human labour at sea is high due to low attractiveness of the life on shipboard. Hence, there have been efforts made to develop automatic systems to replace this labour with so-called *unmanned service* (unmanned power plant at the beginning).

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Therefore it is not the purpose of the automatic control system in a ship power plant to perform only routine operations of various installations but also to check the condition of all gear in the power plant. The system has to recognize in what particular condition is each object under consideration and to predict its future condition for a given period of time. Then it should take a proper decision, whether to start appropriate emergency procedure (e.g., to inform the crew of malfunction) or not. Now there appears the need of yet more sophisticated control that lies in supporting (or even carrying on automatically) the optimum strategy of exploitation of the plant.

And, last but not least, ships are going across the sea.The need here is navigation, i.e., planning a route to get to a desirable location, designating the position of the ship on the sea, detecting navigation obstacles and avoiding them. Everything this is performed by the human crew but with the increasing help of some auxiliary equipment: radiolocation, sonic finders, satellite navigation systems, automatic steering equipment, etc. And it seems it would be useful that these arrangements be united together into one integrated system that can substitute for the deck officer (or support him at least).

In the recent years there has appeared a new trend in Automatic Control Systems: intelligent controls and intelligent machines that are following expert systems which already have been applied in a variety of fields. They hold out new hope for achieving an effective control over complicated systems and processes. The concept of intelligent controls is not quite new. Its inventing goes back to 1971. (see: *Saridis & Valavanis*). Since then there has been much activity in the field. However it is still rather in its initial stage (see: *Aström*) and only a few of practical working solutions have been reported.

Sea-going ships and their environment (shipyards and merchant marine fleets) seem to be the good ground for implementing and developing this new techniques. As it was outlined above there is an urgent need for the new solutions in this field. On the other hand, shipping is a very profitable business. It happens that modern ships give even better opportunity to gain greater profits. So always there is a call for new techniques in the ship-building industry. Now the answer to that call should be Artificial Intelligence. In the following sections some of the problems of ship-building for which Artificial Intelligence techniques seem to be particularly suitable are discussed. However the scope of interest of the report is primarily limited to cargo vessels.

2. Inventing diagnostic models on basis of experimental data

The issue is a system that can detect, isolate and identify malfunctions of a given complex object and generally determine distinguishable (from viewpoint of the applied criteria) states of it on the basis of values of accessible, measurable quantities relevant to the given object.

It seems to be obvious that a condition *sine qua non* of every successful control over any object is to have some formal description of it. In our case it is desirable that this description contain some projection of distinguishable states of the object. No matter if such a model is used *explicite* during the proceeding (as for instance in *model-based failure detection and isolation method* - see: *Gertler*) or merely helps the designer to invent a suitable algorithm for operation of a diagnostic system. Initially it even may not be entirely known and only then somehow developed by the diagnostic system itself (e.g. *via empirical machine learning*).

The model under consideration is called *a diagnostic model*. A diagnostic model of a given complex object is a mathematical object that relates the input variables: so called *diagnostic symptoms*, i.e., accessible, measurable parameters of the object (whose domains are sets that are discrete or continuous, unordered or ordered in various ways), to the output *state variable*, with a domain (nominal or ordered) consisting of elements that represent distinguishable (from the given view-point) states of the object. The model also contains some *intermediate* variables: so called *object descriptors*, i.e., parameters that describe the object (or one of its coherent parts) as a compact whole. All variables are time dependant.

A diagnostic model can be formally represented as an ordered quintuple:

$$DM = < T , X , E , \rho_e , \rho_d >$$

where:

T - *time base* (a parameter that allows to project physical time, with its domain; it can be represented as a linear space over an ordered pair);

X - *diagnostic symptoms* (see above);

Y - *object descriptors* (see above);

ρ_e - *estimative relation*, i.e., relation between diagnostic symptoms and object descriptors;

ρ_d - *diagnostic relation*, i.e., relation between object descriptors and state variable.

There are two ways of inventing diagnostic models:
- to deduce them from knowledge of the object under consideration;
- to induce them from experimental data.

The first method is widely in use. It's greatest disadvantage is that it demands throughout knowledge of the object under consideration. As this knowledge differs from object to object the method cannot be generalized. In addition, it does not guarantee correct solutions particularly if the object is remarkably complex.

The second method refers to the case of an experienced motorman who can detect and distinguish "by ear" various moods of operation of his machine. He does not know why there are particular sound effects, but it does not matter. His "diagnostic model" can be even more convenient, more useful than most of those invented by researchers by the way of deduction. However it is usually better if he has some background knowledge on his machine. It is helpful for him in becoming the motor-expert and it positively quickens the process. In the Artificial Intelligence domain, the method he is using is called *learning from examples* (see: *Michalski, Carbonell & Mitchell*).

Such a model, if suitably formalized, can be used to develop algorithms for diagnostic systems. The model does not project the structure of the object under consideration. In the Zigler's (see: *Zigler*) scale of model validation it is merely *predictive valid*. But it does not matter in this case.

To invent the diagnostic model of some complex object (e.g. ship's main engine) in the way of learning from examples, the object has to be subjected to the throughout test of work in altering circumstances while there are introduced artificial failures to its component parts. During the test all parameters of the object that are accessible for measurement have to be monitored. Further processing of obtained data consists in:

- selecting the optimum number and choice of parameters that are necessary to enable detecting and determining distinguishable states of the object on the basis of knowing values of these parameters;
- finding out the best rules of this detection and determination.

The criterion of optimization is imposed by both safety and economic factors. They should be met simultaneously.

Let the object under consideration be the ship's main engine. There should be monitored up to some forty parameters of it (such as pressure, temperatures, voltages, tensions, etc.), and several tens of artificial failures (such as less or more worn out or even broken details) should be introduced. The values of monitoring parameters should be registered during performance of the engine in a variety of circumstances (varying load, speed, ambient temperature, etc.). As a result a set of data composed of hundreds of thousands related values should be expected. It would be impossible to handle efficiently these data, to draw any reasonable conclusions from this set using traditional methods. It seems that just here is the place for suitably arranged machine learning from examples - one of the powerful techniques of Artificial Intelligence. With reference directly to the case of an experienced motor-man, noise and vibration can be applied as diagnostic symptoms. The method is developed and seems to be promising (see: *Bartel & Monostor*).

Nevertheless, the actual problem is not merely inventing diagnostic models. In fact the issue is to invent algorithms for diagnostic systems. Researchers involved in solving the question have developed the method that calls for models sketched out above. The structure of these models was designed to meet requirements of relevant topics. Their main feature is the *object descriptors* that allow objects to be represented as some compact, coherent wholes. However this approach is not at all mandatory. It seems to be advantageous, but if it turned out that there were a better approach it should be also accepted without hesitation.

The basis of Ryszard S. Michalski's approach to the theory of machine learning is the AQ algorithm (see: *Michalski*). The algorithm and involved topics including variable-valued logic system originate from the switching theory which is a part of the theory of automata. Their language of formalisation is the Boolean algebra. As a matter of fact diagnostic models could be considered as *a generalization of discrete automata* employing the variable-valued logic system as the language of formalisation. Working out the concept could result in new more general theory.

3. Power systems protective relaying

In truth the application of Artificial Intelligence methods suggested below is merely a particular case of using them to develop diagnostic systems that was outlined in section 2. It is due to the very fact that the main issue of power system protective relying is just accurate detection and identification of abnormal conditions to be found in the system.

Every protective gear or system has to perform three basic functions:

- incessantly carrying out diagnosis of the protected object, i.e. identifying distinguishable (from the view-point of relying) states of the object;
- taking decision if the object is in normal or in abnormal condition; and if it is an abnormal condition, what emergency procedure should be started;
- executing chosen emergency procedure.

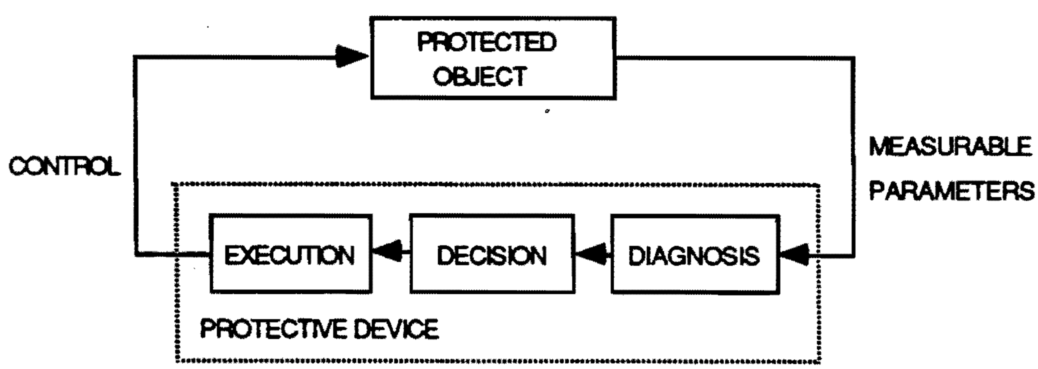

Fig. 1.

In more sophisticated protective schemas these three basic functions of the protective device are usually performed by different separate gear, but the principle refers even to the simplest fuse made of a piece of wire. Just this piece of wire "measures" the values of current as a *diagnostic symptom* and checks if the protected object is in the normal state or in the state of overload or short-circuit. On the basis of values of current and their variability in time, the values of *object descriptors*: temperature and electrodynamic forces are ("physically") "calculated". Their domains consist of two values: {*admissible, excessive*}. If the value of one of object's descriptors is *excessive* the fuse "comes to a decision" to restrain energy flow and "execute that decision" by melting or blowing itself out.

The protective relying has been employed since the very beginning of practical utilization of electricity. It has been constantly changing and advancing, however its basic principles remain the same. And still any general method of theoretical analysis of involved problems has not been developed. Even in the newest books they write on "the art of relying" (see: *Ghomen*) - just "art" not "science". And this is very meaningful.

Such a method would be desirable to enable the formal comparison of various protective algorithms or devices - the first step to their optimization. It would be the key to employing known formal methods to solving problems of protective relying. Recently there have appeared attempts to introduce to the matter methods of *the decision theory*. However they meet an obstacle: lack of appropriate means for formal representation of relevant problems. There are in use various techniques: analytic differential equations, Boolean logic equations, matrices of some distinctive values of parameters so called *signatures*, etc. All these non-coherent, partial models are united together with verbal descriptions hardly (if at all) transformable into any computer language. This refers particularly to considering systems as wholes.

The issue is the lack of appropriate mathematical language of formalisation. It seems that such a language can be adopted from some particular solution of machine learning. I mean the variable-valued logic system of Ryszard S. Michalski (see: *Michalski*). It appears to be a very advantageous approach. The existing versions of variable-valued logic (VL_1, VL_2, VL_{21}, APC) were not designed to meet requirements of the power protective systems analysis. But the general definition of the variable-valued logic system gives the hope and opportunity to apply it also to more general applications than has yet been done.

Of course models of power systems and their component devices can be invented with the Artificial Intelligence method of learning from examples. It seems that it is rather unlikely to find really novel solutions with reference to power systems component gear (generators, transformers, motors, breakers, etc). But it is different if it is to refer to power systems as wholes. It is still rather uninvestigated land and it looks as if these new powerful methods advise researcher to be ready for the unexpected.

4. Unmanned power plant system

The unmanned power plant system seems to be the most interesting field for today's potential employment of methods of Artificial Intelligence in ship-building. It appears partially in the application of knowledge acquisition and handling methods for diagnostic purpose sketched in section 2. of this report, but is much more general and far-reaching.

The basic features of unmanned power plant control are:

- routine attendance of main engine and auxiliary gear: control and monitoring, performing commands from the bridge;
- short-period power plant operation securing safety in case of emergency;
- long-period power plant maintenance securing safety and best economic profits.

Vessels with limited periods of unmanned operation have been built for years. Nonetheless, today's ship power plant control systems do not by far carry out the above mentioned capacity in full. The development of new solutions is carried out. It aims at decreasing the participation of men in maintenance of power plant, that can be obtained only by improving quality of automatic control.

Problems involved here are very complex. In addition ship power plants operate in a changeable, dangerous environment, in circumstances that cannot be foreseen and even cannot be precisely estimated. It is unthinkable to elaborate procedures for all possible emergencies. So the unmanned power plant control system cannot act in conventional ways using ready-made algorithms. It seems that the only reasonable solution is to apply here the methods of Artificial Intelligence. The scheme should be designed as an intelligent computer system provided with some knowledge-base, with module for knowledge-acquisition (perhaps on the way of learning from examples during service apart from initial learning by rode) and with an inference engine to work out the best counteractions against various troubles. The fourth essential component of the arrangement is the user interface. But unlike that in "standard" knowledge-base arrangement there is yet another even more expanded special interface to connect the computer to the system of sensors and executive devices. It is the so-called *intelligent control system.*

The block diagram (fig. 2.) shows the idea of intelligent unmanned ship plant control system. There are three main subsystems:

- process control subsystem that is responsible for the quality of parameters of the process output (e.g. voltage stabilisation);
- safety control subsystem that takes upon itself the duty to assure tolerable conditions of performance for the process and the process control subsystem (protective relying does this in electric plants);
- maintenance control subsystem that controls both previous ones and the process through the agency of them (e.g., a scheme for fitting the number of running generators to the load level).

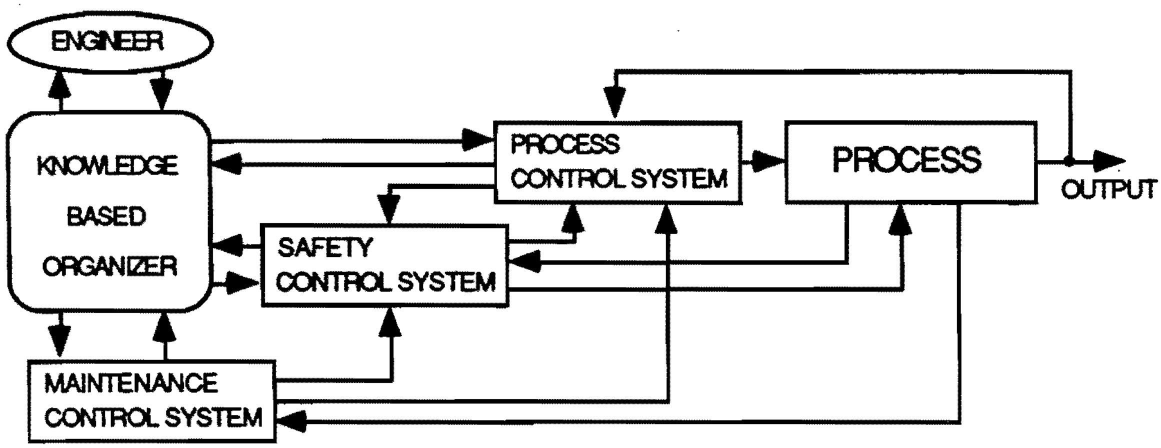

Fig. 2.

So the structure of the system is composed of four levels hierarchically ordered according to the principle of performing more and more general tasks (and perhaps according to the principle of being more and more intelligent).

Unmanned power plant control systems of today's vessels are arranged in similar structure, though, of course, they do not contain knowledge-based units.

The less immediate employment of Artificial Intelligence is the appropriate expert system supporting process of developing schemas for the unmanned power plant control.

5. Ship as an autonomous robot

As stated above (in section 1.) the sea-going ship is an autonomous object that sails across the sea and performs some operations. Particularly, the cargo vessels are shifting goods, avoiding obstacles, across some distance, perhaps along the best (usually the shortest) way. Exactly just the same things autonomous intelligent robots are to do (and a few others).

There are two conclusions that can be drawn from this coincidence:

- experiences in inventing intelligent robots can be used for problems relevant to building and exploitation of sea-going ships (and vice versa, of course);
- the future of sea-going ships as robot sea-going ships.

The first conclusion seems to be very self-evident. The method of employing experiences of one domain to solving problems in other domain is widely in use in science and technology. However here it is rather difficult to make use of this opportunity. Yes, the main point of the issue is still the same: navigation in a changeable environment. But differences between ships and robots are very considerable. Each of the two has different size, different drive, different sensors and other installations. Ships, apart from human eyes, have gyro-compasses, logs, radars, radiogoniometric receivers, sonic finders, receivers of satellite navigation systems, etc. These sensors combined with maps and pilotage books allow ships to be led safely through night and fogs. Robots use rather TV cameras as their sensors and do not enjoy the use of maps.

Nevertheless if the matter is the modern, highly automated vessel, things turn out to be similar: there is some place to be achieved, there are obstacles and disturbances, there are signals from sensors, and the problem is to compute the most accurate control signals for effectors.

The other concept is the cargo ship as an autonomous robot. Such a robot-ship would sail automatically from one place (perhaps some port) to another, across the sea, without any interference from people except for commands from its shipowner. It would look after its gear itself. It would repair minor damages and call for help if it would be impossible. The kernel of such a scheme should be some artificial intelligent device. It would be equipped with some knowledge-base, using learning by rode (asking people for information) and from examples (drawing conclusions from various occurrences during service). That knowledge base would concern geography of sea-routes, oceanography, meteorology and relevant topics as well as maintenance of ship gear and cargo technology. Of course the robot-ship would perform all functions of the unmanned power plant system (that were sketched out in section 4.) but even widened to meet attendance of all ship systems. So it would plan and accomplish tactics and strategy for its most economic and safety exploitation (under the circumstances of shipowner's commands).

Although the concept is rather a point of the future, some of its features are introduced to practice now. A few were sketched in above sections. The others concern mainly automation of navigation. There is no doubt that the robot-ship will not appear at once (if at all) in finished form. It will be rather a long process of improving more and more automated models.

6. Merchant marine fleet management

Now - in the way to more and more general issues - it is the time for the most general point: the shipyard and the merchant marine fleet.

For the most part the topics that were outlined in previous sections concern the process of shipbuilding, too. This industry ever has been very modern (as it has manufactured present-time products) so employing latest solutions - knowledge-base systems for instance - seems to be the question of the day here. It flows from economic reasons: shipping ever has been very profitable so there is something like the shipowners' race to anticipate the charters' requirements by having the right ship at the right place at the right time. And "the right ship" means just the modern ship. It profits.

Shipowners are doing their best to make the most of their vessels.But vessels do carry cargo. It comes from various, sometimes rather small traders in harbours all over the world. It is carried to various, sometimes very distinct places all over the world. The cruises of the ships should be therefore very carefully planned in such a way to make them be possibly the most fully loaded and carry cargo through possibly the shortest route. Ships should go with economic speed: gain due to being earlier in the port of destination must be greater then extra expenses for more fuel. Plans should take into account that sometimes earlier arrival means exclusively extra costs if (for instance) discharging cannot take place. And there are many similar problems. This by itself makes merchant marine fleet management a very difficult puzzle that has to be settled currently and on time. In addition, everything goes on under the pressure of keen competition, sometimes - as a matter of fact - limited by multilateral agreements (the conference system) that however brings new complications. One more factor that makes it yet harder finding satisfactory solutions is environment: the sea with its changeability and jeopardy of the *elements*.

The problem outlined here seems to be purposely cut for expert system engineers: a pot of money that can be gained on making in time accurate expert decisions. But this goes by far beyond the scope of this report.

7. General remarks: Artificial Intelligence approach to problem solving

The most impressive far-reaching aim of Artificial Intelligence investigations is to remove or at least to curtail considerably the domain of human intellectual activity and substitute it with the operation of intelligent machines. And - as it comes from the label itself - even their more modest ends still concern neither more nor less but just the intellectual grasp. Inventing machines that perform in the way that is recognized as intelligent demands the answer to the most fundamental questions of knowledge acquisition, inference, learning, reasoning, concept formation, creating hypotheses. To this end researchers study human brains and investigate the way people think. They have the use of the knowledge of psychologists. On the other hand they develop some general theory of problems solving:

- methods of precise formal representation of problems, of real objects and real relations;
- methods of handling these formal representations.

But this is just the charge every researcher is carrying on in his domain of science. As yet people still do things that maybe in the future intelligent machines will effect for them (perhaps even more successfully). So it is useful the methods invented by Artificial Intelligence researchers be employed in other domains. The point is that they approach the most fundamental problems of human cognition from another, more general side then researchers of various particular domains do. Thus they are not involved in stereotypes (as those last-mentioned) that can interfere with finding novel solutions.

Any intellectual process essentially means rational manipulation of mental symbols. So thinking is impossible beyond language and it is the language that limits thought. If there were no appropriate language notion a given thing could not be thought about at all. So quality of all descriptions to a decisive extent depends up on the quality of so called *language competence* (see: *Smith & Wilson*) i.e., on that if the applied language contains all notions necessary to project reality under consideration and satisfactory methods to handle these notions. Up to now perhaps nobody has investigated language competence of formal languages used in particular domains of science and technology. It seems there is no doubt that some of them are unsatisfactory and thus impeding development of the field.

And the Artificial Intelligence researchers do propose here new solutions. Let an example be the variable-valued logic system proposed by Ryszard S. Michalski. This is a generalisation of known multiple-valued logic systems. It provides new mathematical language that allows achievement of *"more orthogonal" projection of reality into the space of statements* (see: *Michalski*). It seems to be a very promising concept that can be adopted to many domains. Some proposals of employing it were shown above. They can be however yet more far-reaching.

Among other particular features of the "orthogonality" of descriptions using variable-valued logic as a language of formalisation, there is a rather novel approach to the concept of truth. It is clearly considered as *a property of relationship between statements and reality* (see: *Michalski*). And the concept itself belongs to the system not to any metasystem (metalanguage) as in the classic approach. This could have immense theoretical meaning changing some well-known theorems. In addition the domain of truth is not a two-valued set *{false,true}* but it can be any non-empty linearly ordered set. All this has profound philosophical and logical meaning to that extent that perhaps here are constructing elements for the novel mathematical definition of truth substituting (or rather widening) the up-to-date one of Tarski that refers merely to the classical philosophical definition (and sense) of truth.

But these far-reaching implications of variable-valued logic system as the language of description of reality have not been investigated yet. The founder of the concept has been involved more in practical then exactly theoretical problems and has been developing mostly those first. However, it seems there are so many essential discoveries at the practical level in the field now, that the time for their generalisation has already come.

8. Conclusions: Agenda for Research

A research project aiming at development of a knowledge-based control system for sea-going ship power plants is proposed to be carried on at the Merchant Marine Academy in Gdynia, Poland. The project consists of three parts:

- subproject 1.: inventing diagnostic models of ship power plant gear and systems;
- subproject 2.: developing an expert system for ship power plant control and maintenance;
- subproject 3.: developing an intelligent control system for ship power plants.

These three partial projects found a "slightly ordered" set: the proper solution of some problems in one field is necessary for solving problems in another field. However, the relations are so tangled here that the research should be carried on simultaneously in all three subprojects.

As a model of the ship power plant the training arrangement existing at the Merchant Marine Academy should be taken. It consists of the gear originated from a ship.

First of all a knowledge-based system - perhaps supported by a version of the Ryszard S. Michalski's algorithm AQ - should be developed. This will give opportunity to carry on investigations aimed at designing an expert system for ship power plant control and maintenance, and at inventing diagnostic models on the way of machine learning from examples. Taking into account current possibilities, the system should be based on the PC industry compatible hardware. It supports satisfactory technical opportunities, assures low price of the arrangement and, last but not least, is relatively easily available in Poland.

The next step should be:

- in the subproject 1.: developing a computer system for learning from examples and then carrying on practical experiments with ship power plant gear at the test station;
- in the subproject 2.: inventing the remaining units of the expert system; it should be completed in the way aiming at future application to the intelligent control system;
- in the subproject 3.: research aiming at designing the scheme of sensors and effectors for the intelligent control at the ship power plant.

Provided the specified above research goals are secured the next step can be taken. It should be a final development of a model of a knowledge-based control system for sea-going ship power plant. However the research in the remaining two subprojects, aiming at improving the quality of the obtained solutions, should be continued. The other problems that were outlined in this report could be the object of another project.

The co-operation and support from the Center for Artificial Intelligence would be desirable.

References

Åström, K. J., *Toward Intelligent Control, IEEE Control Systems Magazine*, vol. 9, no. 2, pp. 60 - 64, 1989.

Bartel, L. and Monostor, I., *Vibration Monitoring: A Pattern Recognition Approach, in: Intelligent Autonomous Systems*, Ed.: Hertzerburger, L.O. and Groen, F.C.A., Notrth-Holland, 1987.

Bernard, J. A., *Use of a Rule-Based Systems for Process Control. IEEE Control Systems Magazine*, vol. 8, no, 6, pp. 3 - 13, 1988.

Baskin, A. B. and Michalski, R. S., *An Integrated Approach to the Construction of Knowledge-Based Systems: Experience with ADVISE and Related Programs, in: Topics in Expert Systems Design*, Ed.: Guida G. and Tasso, C., North-Holland, 1989.

Gertler, J., *A Survey of Model Based Failure Detection and Isolation in Complex Plants, IEEE Control Systems Magazine*, vol. 8, no. 6. pp. 3 - 11, 1988.

Ghomen, T., *Modern Power Systems Analysis*, Wiley and Sons, 1988.

Michalski, R. S., Carbonell, I. and Mitchell, T., Ed., *Machine Learning: An Artificial Intelligence Approach*, TIOGA Publ. Co., 1983.

Michalski, S. R., Variable-Valued Logic and Its Application to Pattern Recognition and Machine Learning, in: Computer Science and Multiple-Valued Logic. Theory and Applications. Ed.: Rine, D. C., North-Holland, pp. 506 - 534, 1975.

Saridis, G.N. and Valavanis, K.P., *Analytical Design of Intelligent Machines, Automatica*, vol. 24, no. 2, pp. 123 - 133, 1988.

Smith, N. and Wilson, D., Modern Linguistics. The Result of Chomski's Revolution. Indiana University Press. 1980.

Tai-Hang, L., *Intelligence Control of Big Complicated Systems, in: Intelligent Autonomous Systems*, Ed.: Hertzerburger, L.O. and Groen, F.C.A., Notrth-Holland, 1987.

Zeigler, B.P., *Theory of Modelling and Simulation*, Wiley and Sons, 1976.

The enclosed list of references is incomplete. It contains merely publications on Artificial Intelligence and Intelligent Control.

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