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MONITORING PORT REGULATIONS AND TRAFFIC VIOLATIONS ON THE SZCZECIN-SWINOUJSCIE FAIRWAY

ABSTRACT In this paper a method of utilising expert system technology for monitoring violations of chosen port regulations on the Szczecin-Swinoujście fairway is presented. The new algorithm developed by authors has been implemented into the program NEXPERT OBJECT. Information contained in this article may be useful while dealing with problems of decision support in VTS systems.

INTRODUCTION

It goes without saying that VTS systems used in restricted areas are of great advantage. However, it seems purposeful to support decision-makers operating a VTS system by means of a computer advisory system that contains knowledge inaccessible in a typical VTS system. The knowledge may be particularly the one obtained from experts – pilots and captains entitled to handle ships on the fairway. The knowledge would be especially helpful in solving untypical situations (collisions on the fairway, handling of dangerous goods etc.).

The article discusses the problem of creating a knowledge base for use by an advisory expert system supporting the operation of Harbour Master's Offices supervising the traffic between Szczecin and Świnoujście.

The knowledge base would contain knowledge of rules thanks to which it is possible to evaluate situations on the fairway in view of chosen port regulations [Instruction, 1993]. The knowledge base as an element of the expert system may be in the future linked with the functioning VTS so that a situation in the fairway would be assessed in real time. The operator would be adequately alerted if port regulations were violated.

A VTS SYSTEM SUPPORTED BY AN EXPERT SYSTEM

Port regulations constitute a legal act, which regulates, *inter alia*, principles for vessel behaviour in the area. Due to detailed character of these principles (they vary for various parts of the fairway and ship type) where regulations have been changing in time, it is not possible to create algorithmised procedures integrated with the VTS system.

A prototype of the knowledge base was made for use by an expert system, which, when linked with VTS data may substantially enhance its performance. The expert system supporting the VTS system, as regards the compliance with port regulations, should enable evaluating a situation in the case of violating the regulations concerning the manoeuvres of:

- passing;
- overtaking;
- exceeding maximum fairway speed.

In the event when one ship overtakes another in an area where this manoeuvre is prohibited, VTS systems produce alert signals warning that regulations have been infringed. The above-mentioned manoeuvres may, however, be also prohibited for certain types of ship in the other fairway segments. Such situations cannot by detected by a typical VTS system. a similar problem applies to permit ship speeds, ship encounter forecasting and crossing the fairway boundary.

Modern VTS systems have a feature of entering the lower and upper vessel speed limit values for a selected area. However, port regulations allow different speed limits in a given area depending on vessel size (length and draft).

One of the functions that a VTS system could maintain is ship encounter prediction, consequently the areas of passing or overtaking can also be predicted. This task is executed in the VTS system by determining current momentary parameters of targets' motion. However, there exist areas in which ships have to alter their speed. Therefore, position prediction will not be accurate. In an expert system the problem may be algorithm-based with consideration given to two aspects. One is related to the calculating of encounter positions of two targets far away from each other. The other case refers to the prediction of the place of passing or overtaking manoeuvres of ships close to each other as in such events advice is difficult due to a limited time and area of manoeuvring. The manner of determining the place where two distant ships will meet would consist in approximate calculations. The calculations should be based on maximum permissible ship motion parameters in specific fairway segments.

When a possible violation is detected by the system, it should inform the operator about the fact and recommend alterations in the movement of ships concerned. The determination of the encounter position for ships close to each other should be based on current vessel movement parameters. An advisory function of the program in such situations should account for both movement parameters and the most dangerous place for passing or overtaking manoeuvres.

In the algorithm of monitoring port traffic violations it is assumed that data on the current traffic situation on the fairway are available. In particular, at any given time **t** the following data would be utilised:

- number of vessels on the fairway (n), and for each vessel on the fairway:
- name,
- length,
- draft,
- actual speed of vessel,
- place at which the vessel is located,
- traffic direction: Świnoujście-Szczecin or Szczecin-Świnoujście.

If we assume that:
A: $\{a_i\}$, i=1,n – set of vessels on fairway Świnoujście-bound
B: $\{b_j\}$, j=1,m – set of vessels on fairway Szczecin-bound,
M: $\{m_k\}$, k=1,p – set of fairway segments,
GM: $\{gm_l\}$, l=1,lm – set of vessel groups divided by allowed passing criterion,
GW: $\{gw_l\}$, l=1,lw – set of vessel groups divided by allowed overtaking criterion,
GP: $\{gp_l\}$, l=1,lp – set of vessel groups divided by permissible fairway speeds,
TM: $\{gm_i,gm_j,m_k\}$, i=1,lm, j=1,lm, k=1,p – table with elements **T** or **N**. The value **T** means that vessel from group $\mathbf{gm_i}$ may pass a ship from group $\mathbf{gm_j}$ within segment $\mathbf{m_k}$,
TW: $\{gw_i,gw_j,m_k\}$, i=1,lw, j=1,lw, k=1,p – table with elements **T** or **N**. The value **T** means that the vessel from group $\mathbf{gw_i}$ may overtake a vessel from group $\mathbf{gw_j}$ within the segment $\mathbf{m_k}$,
TP: $\{gp_i,m_k\}$, i=1,lp, k=1,p – table of permissible speeds for ships from group gp_i within the segment $\mathbf{m_k}$,
then the algorithm of monitoring violations of port regulations in the time t_0 may be formulated as follows:
$\forall a_i, i=1,n, \forall b_j, j=1,m,$: if $m_{a_j} = m_{b_j}$ $\wedge$ TM[gm_{a_i}, gm_{b_j}, m_k] = **N** then two ships {a_i, b_j} violate at time t_0 the regulations concerning ship passing,
$\forall a_i, i=1,n, \forall a_j, j=1,m, j \neq i,$: if $m_{a_j} = m_{a_j}$ $\wedge$ TW[gm_{a_i}, gm_{a_j}, m_k] = **N** then two ships {a_i, b_j} violate in time t_0 regulations concerning overtaking.
$\forall a_i, i=1,n$: if v_{a_i} >TP[gp_{a_i}, m_k] then vessel a_i violates in time t_0 regulations concerning permissible vessel speed,
$\forall b_j, j=1,m$: if v_{b_j} >TP[gp_{b_j}, m_k] then vessel b_j violates in time t_0 regulations concerning permissible vessel speed.
Subsequent steps of the algorithm for time t_0 are presented in Fig.. 1.

Fig_1. Algorithm of monitoring violations of port regulations in a given time interval.

PROGRAM NEXPERT OBJECT

The application NEXPERT OBJECT belongs to the so-called shells, i.e. systems with an empty knowledge base. Basic elements of the system are objects, classes and methods.

OBJECT – is an elementary unit of information in the system. It may present any notion of a given knowledge base. The object may be an element of a larger set (class, subclass) and it may have certain properties attributed to it. a given ship is an example of an object.

CLASS – enables classification of objects with the same properties, behaviour etc. One object may belong to a few classes.

SUBCLASS – an element of a class. The notion is used to narrow down class properties (e.g. the class *vessels* may have the subclass *container ships*).

PROPERTY – is used for describing objects and classes. Properties may be assigned with one of the six basic types:

- boolean – TRUE, FALSE or NOTKNOWN,
- integer,
- float – decimal number with a 16-digit accuracy,
- string – any sequence of characters
- date,
- time,

METHODS – serve for determining operations on properties, individual objects or groups of objects.

The system Nexpert Obiect has its own integrated program (software) environment. There is a special editor used for creating objects, classes and properties. Other available editors are as follows:

- Rule Editor – for creating rules,
- Context Editor – for creating contexts,
- Meta-Slot Editor – for assigning methods to objects,
- Method Editor – for creating methods.

In order to create a knowledge base one may use editors for creating objects, classes, properties and rules. The program offers a possibility of automatic creation of objects, classes and properties while they are being written into the rule editor.
A general form of a rule may be shown as follows:

IF LHS **THEN** the *hypothesis* RHS

where: LHS (Left Hand Side) – in the general case it is a (arbitrary) number of conjunctions of logical expressions,
Hypothesis – a variable which may assume only logical values,
RHS (Right Hand Side) – in general it takes the following form:
THEN $action_1$ **ELSE** $action_2$

$Action_1$ is executed when LHS assumes logical values True, $action_2$ is executed in the contrary case.

The right-hand key of the mouse can be used to activate relevant submenu in particular parts of the window.

Fig. 2. Rule editor with the available submenus.

The knowledge base

The program NEXPERT OBJECT was used for creating a prototype of the knowledge base containing rules for assessing whether port regulations are complied with or not on the Szczecin-Swinoujście fairway. The rules have been limited to three manoeuvres: passing, overtaking and maintaining maximum speeds.

The values of movement restrictions resulting from the port regulations are shown in the tables below. Vessels were divided into three different kinds of groups by their draft and length. Each classification qualifies a vessel to its adequate group: passing (Table 1), overtaking (Table 2) and speed groups (Table 3).

Table 1. Vessels divided into groups for the passing manoeuvre.

GROUP	DRAFT [m]	LENGTH [m]
group 1	0 – 5.50	0 – 60
group 2	5.50 – 6.10	0 – 60
group 3	6.10 – 7.32	0 – 60
group 4	7.32 – 9.15	0 – 60
group 5	0 – 5.50	60 – 80
group 6	5.50 – 6.10	60 – 80
group 7	6.10 – 7.32	60 – 80
group 8	7.32 – 9.15	60 – 80
group 9	0 – 6.10	80 – 120
group 10	6.10 – 7.32	80 – 120
group 11	7.32 – 9.15	80 – 120
group 12	0 – 7.32	120 – 160
group 13	7.32 – 9.15	120 – 160
group 14	9.15 – 9.45	120 – 160
group 15	0 – 8.99	160 – 210

Table 2. Vessels divided into groups for the overtaking manoeuvre.

GROUP	DRAFT [m]	LENGTH [m]
overtaking group 1	to 5.50	to 210
overtaking group 2	5.50 – 9.15	to 210

Table 3. Division of vessels into speed groups.

GROUP	DRAFT [m]	LENGTH [m]
speed group 1	to 6.10	to 70
speed group 2	to 6.10	70 – 240
speed group 3	6.10 – 7.93	to 70
speed group 4	6.10 – 7.93	70 – 176
speed group 5	6.10 – 7.93	176 – 240
speed group 6	7.93 – 12.8	to 70
speed group 7	7.93 – 12.8	70 – 176
speed group 8	7.93 – 12.8	176 – 210

There are certain segments of the Szczecin-Swinoujście fairway where particular groups of vessels, according to the port regulations, may perform given manoeuvres and proceed at a permitted maximum speed. The division of the entire fairway into segments is presented in Table 4.

Tables 5 and 6 present permitted manoeuvres for particular vessel groups at subsequent fairway segments. Each segment has been assigned a maximum value of speed at which vessels belonging to one of the speed groups (Table 3) may proceed. The speeds are set out in Table 7.

Table 4. Division of Świnoujście – Szczecin fairway into segments [UM]

SEGMENT no	SEGMENT BOUNDARIES	DISTANCE FROM FAIRWAY BEGINNING	SEGMENT LENGTH
SEGMENT 1	Beginning of fairway	0 km	2.2 km
SEGMENT 2	Abeam Basen Stoczniowy	2.2 km	1.4 km
SEGMENT 3	Abeam northern point of Kosa Peninsula	3.6 km	1.7 km
SEGMENT 4	Abeam northern point of Mielin Island	5.3 km	5.2 km
SEGMENT 5	Karsibór Bend	10.5 km	6.2 km
SEGMENT 6	Heads of Kanał Piastowski	16.7 km	18.3 km
SEGMENT 7	Abeam northern point of Chełminek Island	35 km	2 km
SEGMENT 8	Two buoys no 13-14	37 km	6.1 km
SEGMENT 9	Abeam Mańków Dolna buoy	43.1 km	2.2 km
SEGMENT 10	Abeam Krępa Dolna buoy	45.3 km	3.1 km
SEGMENT 11	Abeam Raduń Górna buoy	48.4 km	5.7 km
SEGMENT 12	Abeam Ina-S buoy	54.1 km	9.5 km
SEGMENT 13	Abeam Orli Przesmyk	63.6 km	4.1 km
	End of the fairway (Basen Górniczy)	67,7 km	

Table 5. Possible passing manoeuvres involving vessels from various groups in the particular fairway segments.

SEG-MENT	⇩GROUP and GROUP⇨	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	1, 2, 5, 6, 9	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
2	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		
3	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
	15	✔	✔			✔	✔			✔						
4	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
	15	✔	✔			✔	✔			✔						
5	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
6	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
7	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
	15	✔	✔			✔	✔			✔						
8	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
	15	✔	✔			✔	✔			✔						
9	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
10	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
11	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
12	1, 2, 3, 4, 5, 7, 9, 10, 12	✔	✔	✔	✔	✔		✔		✔	✔		✔			
	15	✔	✔			✔	✔			✔						
13	1, 5	✔	✔	✔	✔	✔		✔		✔	✔		✔			

Table 6. Possible overtaking manoeuvre involving various group vessels in particular fairway segments.

SEGMENT	⇩GROUP and GROUP⇨	overtaking group 1	overtaking group 2
1	Prohibited overtaking in this segment of fairway		
2	Prohibited overtaking in this segment of fairway		
3	Prohibited overtaking in this segment of fairway		
4	Prohibited overtaking in this segment of fairway		
5	overtaking group 1	✔	✔
6	overtaking group 1	✔	✔
7	Prohibited overtaking in this segment of fairway		
8	Prohibited overtaking in this segment of fairway		
9	overtaking group 1	✔	✔
10	overtaking group 1	✔	✔
11	overtaking group 1	✔	✔
12	Prohibited overtaking in this segment of fairway		
13	Prohibited overtaking in this segment of fairway		

The prototype of an expert system was based on the foregoing guidelines. According to the general algorithm (Fig. 1) it was assumed that the data on a vessel position and current speed are obtained from the VTS system in real time. Precise monitoring of a maximum vessel speed in a given fairway segment and of compliance with the rules of passing and overtaking on the fairway is done on the basis of a particular algorithm presented in Fig. 3. Each pair of vessels (vessel a and vessel B) on the fairway is being analysed.

In order to simulate a real situation, vessel parameter data were interactively entered after the expert system had been started. When the interference is concluded, the created model of the advisory system displays information on the fairway traffic situation. Apart from communicating that the port regulations have been violated, the program informs the user on safe vessel movement, which does not break any of the three, rules being monitored.

Table 7. Maximum vessel speeds depending on speed group and fairway segment.

SEGMENT No	SPEED GROUP	MAXIMUM SPEED [knots]
1, 2, 3	1, 2	7
	3, 4, 5, 6, 7, 8	6
4, 5	1, 2, 3, 4, 5, 6, 7, 8	7
6	1, 2, 3, 4	12
	5, 6, 7, 8	10
7	1, 3	12
	6	10
	2, 4, 5, 7, 8	8
8, 9	1, 2, 3, 4	12
	5, 6, 7, 8	10
10	1, 3	12
	6	10
	2, 4, 5, 7, 8	8
11	1, 2, 3, 4	12
	5, 6, 7, 8	10
12, 13	1, 2	8
	3, 4, 5, 6, 7, 8	6

Fig 3. Particular algorithm of simulated system operation

VERIFICATION OF THE EXPERT SYSTEM

The system VTS – ES (expert system) was simulated for verification.

An external computer program generated data on vessels on the fairway. The program, activated in the background, modifies the content of a text file with the following structure:

no_1 $name_1$ l_1 dft_1 v_1 km_1 rel_1

no_2 $name_2$ l_2 dft_2 v_2 km_2 rel_2

...

no_n $name_n$ l_n dft_n v_n km_n rel_n

For the purpose of verification of the correctness of the expert system inference, data in the text file were being modified in time so that conditions could arise for port regulations violations in respect to permissible speeds, overtaking and passing on the fairway.

The analysis of generated situations leads to a conclusion that the system correctly verifies traffic situations: does not respond if the regulations are complied with, registers violations of fairway speed limits and signals passing and overtaking violations.

SUMMARY

The developed prototype of a rule-based knowledge base for monitoring the compliance with port regulations on the Świnoujście-Szczecin fairway shows that VTS functions can be extended with an advisory system facilitating the supervision and management of the traffic.

It is assumed that in the developed algorithm the expert system will use data registered in the VTS system in real time. One advantage of the system is that the rules can be easily modified and new ones can be entered. This may be necessary for such reasons as alterations in port regulations. The expert system should be enriched with the knowledge of experts – pilots and captains. Such knowledge cannot be described by any mathematical formulae, except knowledge base rules.

In the future it will be possible to expand the knowledge base with knowledge broader than that concerning port regulations. Factors affecting the fairway traffic should be incorporated, such as:

- hydro-meteorological conditions,
- fairway marking,
- cargo carried onboard (dangerous goods in particular),
- procedures to be followed in emergency situations, etc.

It should be emphasised that the expert system would only provide advice to the man – the officer in charge of fairway traffic. Nevertheless, additional information obtained from the expert system should contribute towards the safety of the entire system of traffic organization.

LITERATURE

1. Port Regulations – Instruction N^o 10 of the Szczecin Maritime Office Director, Szczecin, 1993 (in Polish).
2. NEXPERT OBJECT documentation – Neuron Data, USA, 1994.
3. Chromiec J., Strzemieczna E.: *Artificial intelligence. Methods of designing and analysis of expert systems.* Akademicka Oficyna Wydawnicza PLJ, Warszawa 1994 (in Polish).
4. Mulawka J.J.: *Expert systems.* Wydawnictwo Naukowo-Techniczne, Warszawa 1996 (in Polish).
5. Grabowski M., The Piloting Expert System: Transition from Off-Line Prototype to On-Line Decision Support. Navigation: Journal of the Institute of Navigation. Vol. 37, No. 1, 1990

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