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S. Gatsenko [1], Yu. Buchinsky [2]

[1] National Defence University of Ukraine named after Ivan Chernyakhovsky, Kyiv, Ukraine
[2] Military unit A 3438, Odesa, Ukraine

THE ANALYSIS OF EXPERT SYSTEM FOR ADAPTING DECISIONS FOR DETERMINING THE TYPE OF RADIO RESPONSE SOURCES

In this article, the authors of research described the sources of radio radiation and explained the complexity of identifying sources of radioelectronic radiation under a priori uncertainty. Authors of the article state, that the source of radio-electron radiation can be identified by a set of parameters of its signal. It is established that the informational nature of the signal source of radio emission for the devices of radio monitoring depends on how reliable this signal is detected and how accurately (precisely) its parameters are determined, which are useful days of radio monitoring of the message or value. Because signal tracking always takes place against a background of different kinds of interference, the fact of detecting a signal, as well as errors in measuring signal parameters and selecting messages are always random. The problem of determining the type of signal, and therefore the source, which it emits, is partially solved by the preliminary analysis of the ether on the hearing conducted by the operators of radiomonitoring. This makes it possible not to distract from non-informative signals belonging to sources of radio-electronic radiation that are not showing interest to radio monitoring, to shorten the search time for sources of radio-electronic radiation and to minimize the cost of depreciation of equipment. The disadvantage of this method is the necessity to have a sufficient number of trained operators and to constantly increase their training. Was given that the preparation of one operator to a professional level can last 6-12 months, it is very difficult to provide data requirements. Therefore, in the given article it is suggested to analyze the parameters of sources of radio-electronic radiation on a set of parameters of sources signals of radio-electron radiation with the help of expert decision support system concerning determination of sources parameters of radio-electronic radiation. In the article, the authors proposed an expert system for determining the parameters of sources of radio-electronic radiation using a database management system. Unlike machine programs that use procedural analysis, expert systems solve problems in a narrow subject area (specific field of expertise) based on deductive considerations. Such systems are often able to find solutions that are unstructured and poorly defined. They cope with the lack of structuring by involving heuristics, that is, the rules described in accordance with the experience of using the equipment, which may be useful in those situations where the lack of necessary knowledge or time eliminates the possibility of complete analysis.

Keywords: radiomonitoring; expert system; decision support system; distributed computing.

Introduction

Based on the information provided in [1], the basis of the functioning of passive devices of radio monitoring is the detection of signals transmitting messages (for example, the signal of air traffic control) and the recognition of the parameters of high-power signals of stationary, onboard, ship and ground radar stations (RS). Informativity of the signal source of the radio emission (SRE) for the devices of radio monitoring depends on how reliable this signal is detected and how accurately (accurately) are determined its parameters, which are useful days of radio monitoring message or value. Signal tracking always takes place against a background of different kinds of interference, the fact of detecting a signal, as well as errors in measuring signal parameters and selecting messages are always random.

In view of the above, ***the purpose of this article*** is to develop an expert decision support system to determine the type of radio emission sources.

Presentation of the main material

Useful information for radio monitoring is obtained by analyzing electromagnetic fields $u(t,r)$ on the opening of the receiving antenna $r \in L$ during the time $t \in [-T/2; T/2]$ on the background of space-time obstacles $n(t,r)$. Assuming that signal and interference are additive, then:

$$u(t,r,\alpha_i) = s(t,r,\alpha_i) + n(t,r), \qquad (1)$$

where $s(t,r,\alpha_i)$ is the time dependent signal t, spatial r coordinates and parameters α_i; $n(t,r)$ is the set of obstacles depending on time t and spatial r coordinate.

Spatial-temporal obstacles $n(t,r)$ caused by the joint action of the atmosphere and outer space, the adjective noise of the antenna-feeder network, and other noise of the reception apparatus of the radio monitoring device.

Parameters α_i and spatial parameters r bring radio-monitoring useful information for it. Processing of the signal from the receiving antenna of the radiomonitoring station is almost always divided into spatial and temporal. First of all, the processing of the signal in space. This operation is performed by the antenna system - a spatial filter that selects a signal against obstacles in different areas of the space and determines the spatial parameters of the signal (direction to the SRE). The result of spatial processing is, above all, the estimation of the parameters of the spatial position and movement of the source of radiation.

Then the signal processing is carried out by the station receiver of the radiomonitoring in the time domain. As a result of time processing, carrier frequencies, radiation power, qualitative and quantitative characteristics of modulating functions and other parameters of the signals of the SRE of radiomonitoring objects are determined.

Complexity of the field structure (sometimes this structure is called "complex signaling situation") is conditioned by the presence of many emitters of radio signals and sources of indirect and unintentional radiation, by changing the geometric, frequency and time parameters of the emitted signals due to the maneuvering of emitters in the space in which radio monitoring facilities function (in the environment of interests radiomonitoring).

Complex signaling situation is, on the one hand, the subject of analysis for the devices of radio monitoring, its creation involves the emission of radio-electronic devices of radio-monitoring objects. But, on the other hand, the complexity of the signaling situation for the devices of radio monitoring provides the process of detecting and defining the parameters of the signals of radio monitoring objects against the background of non-informative radiation. Many unnecessary radiation is mainly and creates the background noise $n(t,r)$, which complicates the work of the operators of stations of radiomonitoring. In addition, the task of monitoring is to monitor the dynamics of changes in the signal situation, that is, fixing signaling situations, consisting of signals at each time in the interests of radio monitoring.

The problem of determining the type of signal, and therefore the source, which it emits, is partially solved by the preliminary analysis of the ether on the hearing conducted by the operators of radiomonitoring. This allows you not to be distracted by uninformative signals belonging to the SRE, that are not of interest to radio, to reduce the search SRE and minimize the cost of depreciation of equipment.

Disadvantage of this method can be the necessity for a sufficient number of trained operators and a constant increase in their training. Given the fact that the training of one operator to a professional level can last 6-12 months, it is very difficult to meet these requirements.

In the case of a signal from the SRE, which is of interest to radio operator conducts instrumental measurements of radioequipment using radio stations and defines the parameters of the signal, namely: F_H is the bearing frequency of the signal; T_i is the period of pulse following; τ_i is the pulse duration; T_c is the period of following of signal repetition.

With the data value the operator must determine the type of SRE using reference records or memory, which slows down the decision-making process and increases the probability of an error. For an operator who has not acquired the necessary experience in determining the type of RS, this operation is practically impossible or very complicated and takes a long time.

In order to eliminate the above-mentioned, negative factors and bring the speed of information processing by the operators of radiomonitoring to the real-time scale, for the first time an expert decision making support system (DMSS) was developed for determining the type of SRE for signal parameters.

In [2] states, that expert systems represent a class of computer programs, that conduct analysis, perform a classification, give advice and define types. They are focused on solving problems, which usually require expert examination by a specialist. Unlike machine programs that use procedural analysis, expert systems solve problems in a narrow subject area (specific field of expertise) based on deductive considerations. Such systems are often able to find solutions that are unstructured and poorly defined.

They cope with the lack of structuring by involving heuristics, that is, the rules described in accordance with the experience of using the equipment, which may be useful in those situations where the lack of necessary knowledge or time eliminates the possibility of complete analysis.

Selection of software for the implementation of an expert system for determining the type of RS. Software tools for the implementation of the expert system were developed to provide the DMSS type functions for the definition of the SRE type.

One of the effective approaches for creating a "query-response" system is web services. Web service or web office is a programmed system with standardized interfaces identified by a web address.

Web services can interact with each other and with third-party applications with messages based on specific protocols (SOAP, XML-RPC, etc.) and transactions (REST). Web service is unit of modularity when using the service-oriented architecture of the application. The basic principles of organizing systems based on web services are described in [3].

Protocol of interaction between the software and the web service selected SOAP protocol, as it allows you to fully realize all the necessity of this expert system. SOAP (Simple Object Access Protocol) is a protocol for exchanging structured messages in a distributed computing environment.

SOAP can be used with any application layer protocol: SMTP, FTP, HTTP, HTTPS, etc. However, its interaction with each of these protocols has its own peculiarities, which should be defined separately. Often, SOAP is used over HTTP.

It should be noted that this approach allows us to switch to the concept of constructing a distributed computing system and put it on a server that has high computing capabilities and local access to databases, difficult and time-consuming computing tasks.

Description of any web service is contained in the XML document in WSDL (Web Services Description Language). You can get a description of the WSDL using a link that is indicated by an arrow.

Any expert system provides input, accumulation, storage and analysis of expert knowledge. In order to use them, the expert system user must have quick and easy access to this knowledge. Aforementioned factors led to the selection of a database as a data warehouse. Among many database management systems (hereinafter referred to DBMSs), the MySQL database was selected (principles for constructing algorithms using databases described in [6]) to provide software compatibility.

The implementation of the web service was provided using the Delphi 7 programming system. This system supports all the necessary technologies, including SOAP and MySQL.

Architecture of an expert system for determining the type of RS by parameters. General architecture of the expert system for determining the type of radar is shown in Fig. 1. It consists of the following components:

main program - automated control system. It is a key, organizing element in the work of the complex as a whole;

web service - a service that is deployed on the basis of a server personal computer (PC). Performs the functions of receiving the request, access to the database management system and providing a response to the results;

MySQL DMSP - a database that provides the input, accumulation, storage and delivery of information that is necessary to the user.

Work of the expert system in conjunction with the DMSS program consists of several stages, which are indicated by the arrows with the numbers in fig. 1.

After a preliminary analysis of the ether, the operator decides on the instrumental analysis of the detected signal from the SRE.

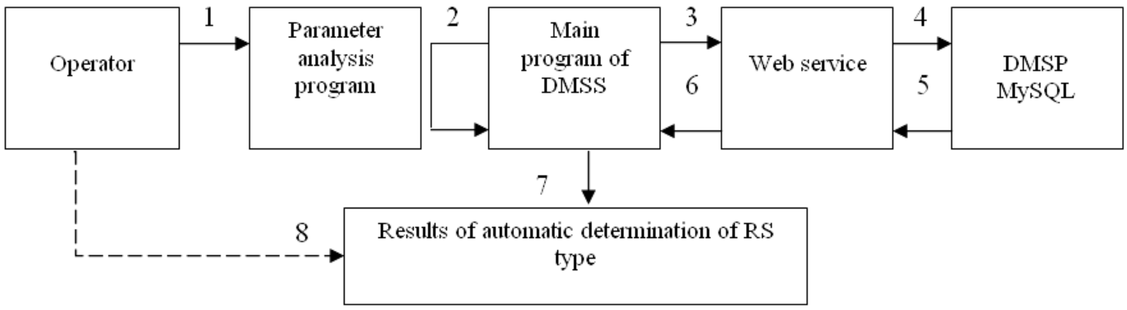

Fig. 1. General architecture expert system determine the type of RS

In the first stage, the operator submits a command to the program for measuring the parameters of the signal to read, calculate and process the signal parameters from the equipment. The result of the staffing, combat program of the station is file with the extension ".dat" (hereinafter - dat file), which contains set of data on measurements for a certain period of time.

At the second stage of the work, the system loads the newly created data file of the main program and deduces from it all the signal parameters, namely: F_H (carrier frequency), T_i (pulse follow-up period) and τ_i (pulse duration). Each of these parameters can have several values, usually from two to five;

In the third stage, the system generates a request for a web service as a function:

$$\text{Param}T_0\ \text{RLC}\left(SF, ST, STau\right), \quad (2)$$

where SF is the a set of specified carrier frequency signals (up to five values) separated by a space character; ST is the set of defined periods of follow-up of pulses in a signal (up to five values) separated by a space mark; $STau$ is the set of specified pulse duration in the signal (up to five values) separated by a space mark.

At the fourth stage, the web service makes a set SQL-request to DMSP MySQL by a certain algorithm.

At the fifth stage, after receiving data from the MySQL database, the web service concludes, which types of RS are suitable for the given parameters.

At the sixth stage, the web service delivers certain types of RS in the order of decreasing the probability of their determination and formulates the response to the automated control system (ACS) "R" in the format:

$$N_1; P_1; N_2; P_2; \ldots N_n; P_n, \quad (3)$$

where N_i is the name of the radar station defined by the web service; P_i is a probabilistic factor, that matters in conditional clauses (the greater the value of the coefficient, the more likely, that the station signal corresponds to the calculated parameters).

At the seventh stage of the expert system, the DMSS program creates an informational, interactive display on the monitor displaying a response from the web service in tabular form.

At the eighth stage of the expert system, the radio monitoring operator must confirm the version of the result of the system, that it considers most probable. This function is necessary because sometimes the probability P of two or more RS is approximately the same. In this case, the operator makes his choice based on other knowledge or a priori information. Confirmation is performed by double-clicking the left mouse button of the "mouse" type on the line with a correctly defined RS. As a result of confirmation, the bearings on the RS are applied to the map, in case, if the RS is determined by the ground, then the information about its work is entered in the table and schedule of the stationary RS. In case of detection of on-board or ship RS, information about it is entered in the monitoring table of the air (marine) situation.

Algorithm of the expert system for determining the type of radar is shown in Fig. 2. This algorithm is an integral part of a web service located on a database server in order to increase the speed of the web service access to the database server, avoiding low-speed data transmission channels.

At the first stage of the algorithm, reception and downloading of parameters measured by the monitoring station and transmitted through SOAP to the web service is carried out.

At the next stage, the tolerances on the carrier frequency F_H are determined by the formulas:

$$F_{H_{max}} = F_H + \left(\frac{F_H}{K_F}\right), \quad (4)$$

$$F_{H_{min}} = F_H - \left(\frac{F_H}{K_F}\right), \quad (5)$$

where K_F is the admission factor taking into account the inaccuracy of frequency determination by the station of radio monitoring. Coefficient K_F determined based on the reasons for the error of determining the carrier frequency of the signal by equipment of the radio monitoring station, namely ± 11 MHz and $K_F = 2000$; $F_{H_{max}}$, $F_{H_{min}}$ is the maximum and minimum carrier frequency, taking into account the coefficient of tolerance.

Next step in the database is to select all possible radio sources that correspond to the range

$$F_{H\min} \le F_H \le F_{H\max},$$

after which their names are entered into an intermediate array of types of SRE. Each coincidence value F_H with reference adds to the total probability of a weighted value $P_{F_1} = 3$.

At the end of the analysis of the coincidence of the measured values with values in the database, taking into account the coefficient of admission K_F the SRE search algorithm is launched for $f_{n\,min}$ and $f_{n\,max}$ table rtr_rls. after which their names are entered into an intermediate array of types of SRE.

In this analysis, all possible radio sources that match the range are selected from the database

$$f_{H\min} \le F_H \le f_{H\max}.$$

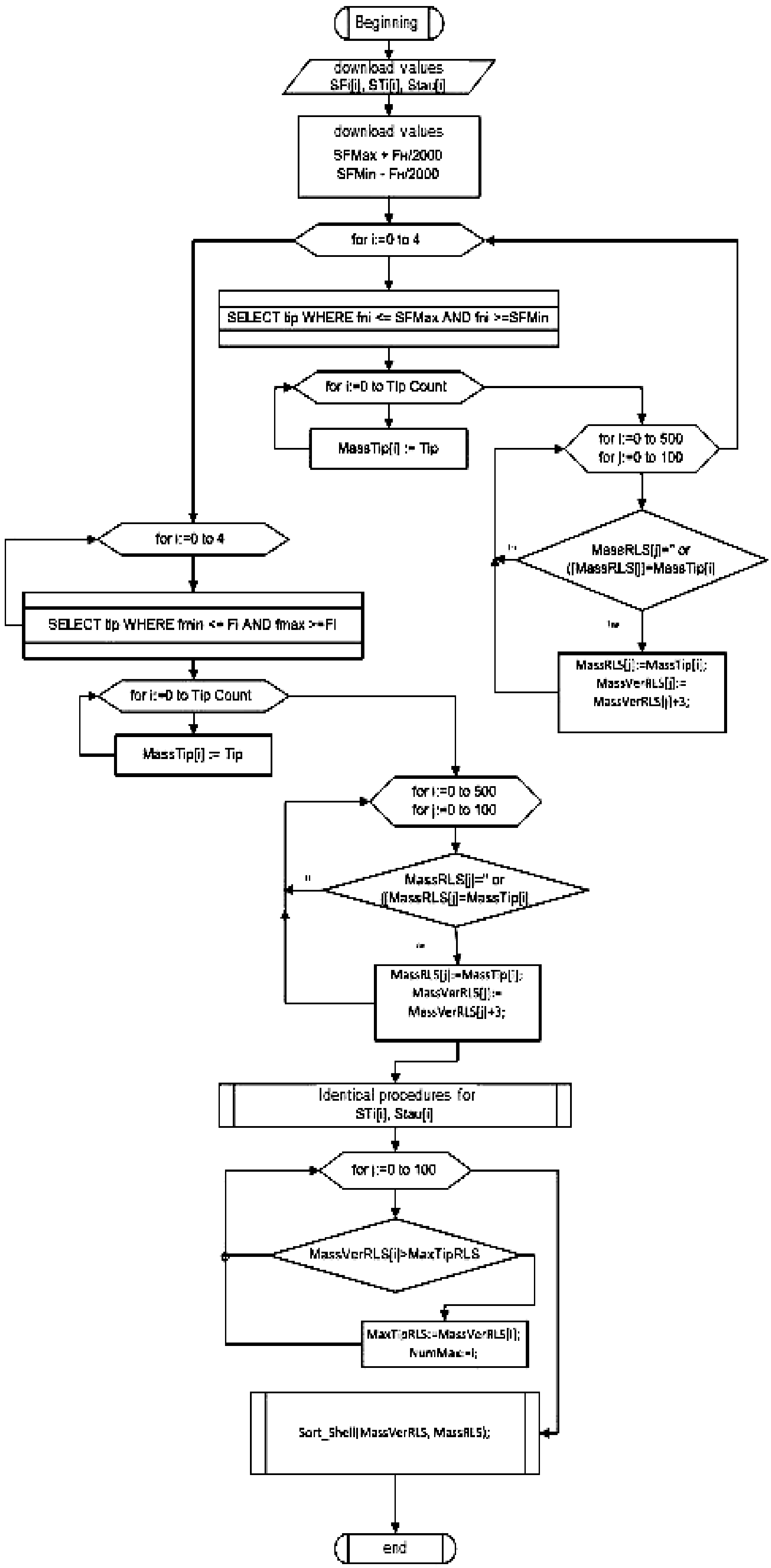

Fig. 2. Partial algorithm of the expert system for determining the type of RS by signal parameters

Since the inclining of the carrier frequency in a certain area of values is less informative than the correspondence with a specific value, then each finding value F_H within

$$f_{H_{\min}} \le F_H \le f_{H_{\max}}$$

adds to the probability value the weight factor

$$P_{F_2} = 1 .$$

Similarly, two blocks are used to search for the matching of measured values by reference to T_i (pulse follow-up period) and τ_i (duration of impulses). At the same time value $T_{i\,max}$ and $T_{i\,min}$ are calculated by the formulas:

$$T_{i\ max} = T_i + \left(T_i / K_T \right), \tag{6}$$

$$T_{i\ min} = T_i - \left(T_i / K_T \right), \tag{7}$$

where K_T is the tolerance factor, which takes into account the inaccuracy of determining the period of follow-up of pulses by the station of radiomonitoring.

Since the avarage square error of measurement T_i (period of pulse following up) no more 0,1 mcs, and the range for defining this parameter is significant 2-79999, coefficient K_T defined

$$K_T = 1000.$$

$T_{i\,max}, T_{i\,min}$ is the maximum and minimum value of the pulse follow-up period, taking into account the admission coefficient.

Value $\tau_{i\ \max}$ and $\tau_{i\ \min}$ are calculated by the formulas:

$$\tau_{i\ \max} = \tau_i + \left(\tau_i / K_\tau \right), \tag{8}$$

$$\tau_{i\ \min} = \tau_i - \left(\tau_i / K_\tau \right), \tag{9}$$

where K_τ is the tolerance factor, which takes into account the inaccuracy of determining the period of follow-up of pulses by the station of radio monitoring.

The device square error of measurement τ_i (duration of impulses) no more, than 0,1 microseconds, coefficient K_τ is defined and makes up $K_\tau = 2000$; $\tau_{i\ \max}$, $\tau_{i\ \min}$ is the maximum and minimum value of pulse duration, taking into account the coefficient of tolerance.

When weighing weight coefficients in cases with T_i and τ_i value of weight coefficients $P_T = 1$ and $P_\tau = 1$.

After creating an array with a list of SRE and their total probabilistic parameters whose parameters are more or less consistent with the reference ones, the algorithm of the expert system works by sorting the array that places the SRE in the order of decreasing their probabilistic values.

Last stage of the web service's work is to formulate a response to the radiomonitoring program and transfer it to the SOAP protocol.

After receiving a response from the web service, the radiomonitoring program displays the values of the SRE type table for confirmation by the operator of the radio monitoring station.

Conclusion from this explosion

In order to solve the scientific problem of automation of the process of detection and recognition of radiation sources, for the first time an expert system was supported for decision-making on determining the type of SRE in terms of its signal parameters in the interests of radio-monitoring. As the system advises the operator of the radio monitoring station on the most likely option, requirements for qualification of operators can be reduced, which significantly reduces the financial and time costs for their training, and the process of work at the station becomes part of training the operator.

Directions of further researches on the improvement of the software algorithm of the expert estimation of the signal, subject to the deep modernization of the equipment, will allow the transition to semi-automatic or fully automatic operation of the radio monitoring station, which will open new possibilities and significantly increase the efficiency of radio monitoring through increased efficiency and reliability of decision-making by operators of radio monitoring stations.

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Аналіз експертної системи підтримки прийняття рішень по визначенню типу джерел радіовипромінювань

С. С. Гаценко, Ю. А. Бучинський

Авторами проаналізовані джерела радіоелектронного випромінювання і описана складність їх ідентифікації при апріорній невизначеності. Заявлено, що джерело радіоелектронного випромінювання може бути ідентифікований набором параметрів його сигналу. Встановлено, що інформаційний характер джерела сигналу радіовипромінювання для пристроїв радіомоніторингу залежить від того, наскільки достовірний цей сигнал і наскільки точно (достовірно) визначені параметри, які його ідентифікують. Оскільки моніторинг сигналів завжди відбувається на тлі різних видів перешкод, факт виявлення сигналу, а також помилки у вимірі параметрів сигналу та вибір повідомлень завжди випадкові. Проблема визначення типу сигналу і, отже, джерела, який він випромінює, частково вирішується попереднім аналізом ефіру на слух, який проводиться операторами радіомоніторингу. Це дозволяє не відволікатися від неінформативних сигналів, що відносяться до джерел радіоелектронного випромінювання, які не виявляють інтересу для радіомоніторингу, скоротити час пошуку джерел радіоелектронного випромінювання і звести до мінімуму вартість амортизації обладнання. Недоліком цього методу є необхідність мати достатню кількість навчених операторів і постійне їх навчання. Визначено, що підготовка одного оператора до професійного рівня може тривати 6-12 місяців. Тому в даній статті пропонується проаналізувати параметри джерел радіоелектронного випромінювання по набору параметрів джерел сигналів радіоелектронного випромінювання за допомогою системи підтримки прийняття рішень по визначенню параметрів джерел радіоелектронного випромінювання. У статті автори запропонували експертну систему для визначення параметрів джерел радіоелектронного випромінювання з використанням системи управління базами даних. На відміну від машинних програм, які використовують процедурний аналіз, експертні системи вирішують проблеми у вузькій предметній області (спеціальна галузь знань) на основі дедуктивних міркувань. Такі системи часто можуть знайти рішення, які неструктурованість і погано визначені. Вони справляються з відсутністю структурування, використовуючи евристику, тобто правила, описані відповідно до досвіду використання обладнання, які можуть бути корисні в тих ситуаціях, коли відсутні необхідні знання або кількість часу виключає можливість повного аналізу.

Ключові слова: радіомоніторинг; експертна система; система підтримки прийняття рішення; розподілені обчислення.

Анализ экспертной системы поддержки принятия решений по определению типа источников радиоизлучений

С. С. Гаценко, Ю. А. Бучинский

Авторами исследованы источники радиоизлучения и описана сложность их идентификации при априорной неопределенности. Заявлено, что источник радиоэлектронного излучения может быть идентифицирован набором параметров его сигнала. Установлено, что информационный характер источника сигнала радиоизлучения для устройств радиомониторинга зависит от того, насколько достоверен этот сигнал и насколько точно (достоверно) определены параметры, которые его идентифицируют. Поскольку мониторинг сигналов всегда происходит на фоне различных видов помех, факт обнаружения сигнала, а также ошибки в измерении параметров сигнала и выбор сообщений всегда случайны. Проблема определения типа сигнала и, следовательно, источника, который он излучает, частично решается предварительным анализом эфира на слух, который проводится операторами радиомониторинга. Это позволяет не отвлекаться от неинформативных сигналов, относящихся к источникам радиоэлектронного излучения, которые не проявляют интереса для радиомониторинга, сократить время поиска источников радиоэлектронного излучения и свести к минимуму стоимость амортизации оборудования. Недостатком этого метода является необходимость иметь достаточное количество обученных операторов и постоянное их обучение. Определено, что подготовка одного оператора до профессионального уровня может длиться 6-12 месяцев. Поэтому в данной статье предлагается проанализировать параметры источников радиоэлектронного излучения по набору параметров источников сигналов радиоэлектронного излучения с помощью системы поддержки принятия решений по определению параметров источников радиоэлектронного излучения. В статье авторы предложили экспертную систему для определения параметров источников радиоэлектронного излучения с использованием системы управления базами данных. В отличие от машинных программ, которые используют процедурный анализ, экспертные системы решают проблемы в узкой предметной области (специальная область знаний) на основе дедуктивных соображений. Такие системы часто могут найти решения, которые неструктурированны и плохо определены. Они справляются с отсутствием структурирования, используя эвристику, то есть правила, описанные в соответствии с опытом использования оборудования, которые могут быть полезны в тех ситуациях, когда отсутствуют необходимые знания или количество времени исключает возможность полного анализа.

Ключевые слова: радиомониторинг; экспертная система; система поддержки принятия решения; распределенные вычисления.