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ORIGINAL PAPER

Informational decision support for risk reduction related to hailstorm in Oltenia region: Romania

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Abstract This paper deals with the design of a system for decisional support dedicated to an anti-hail system. It is proposed a specific system for Romania anti-hail network, which completes the existing systems with specific information in order to identify the best solutions for both coordination and launch. The main topics refer to the system structure, information handled in the system and reconstruction of a signal based on Bayes criterion. The system comprises two main components: a subsystem of launch decision and a subsystem for assisting the launch decision. In order to achieve this system, the following important issues are considered: the use of communication via GPRS, monitoring the parameters throughout all operating period, log-values, status and alarms, operator actions logs, friendly graphical interface and the generation of tabular and graphical reports for any period. The system enables an increased efficiency by shortening the time for action, a good organization and a high degree of security.

Keywords Hail · Risk · Decisional system · Hail suppression · Monitoring system · Geographic information system (GIS)

1 Introduction

We are seeing a sharp change in climatic factors, often with violent manifestations. In these circumstances, it appears necessary to monitor the climate action and the implementation of means of intervention to reduce economic losses caused by such events. The

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achievement of an anti-hail system (AS) is an important component of a complex monitoring and operating structure.

The main methods of combating hail are related to the seeding clouds with rockets, artillery and aircraft, the use of canon shock wave, ground particle generators and anti-hail nets.

At the international level, there are research programs (Abshaev 2003; Kamalov 2011; Potapov et al. 2007; Krakovskaia et al. 1994; Krauss and English 1986; Zoran et al. 2007, WMO scientific and technical programmes 2011) contained in the "Register of National Weather Modification Projects," which cover almost the entire world (e.g., U.S., Russia, Europe, China, Brazil, Morocco, Greece, Saudi Arabia, Nigeria, Israel). Some of these are as follows: The Meteorological Program for Agriculture (AGMP) of the World Meteorological Organization having as a role the support of agricultural production and related activities in order to develop viable systems which lead not only to the increasing of agricultural product quality, to the reducing of losses and risks, to the conservation of natural resources but also to the reducing of pollution with chemical agents that contribute to environmental degradation; TasHydro project in Australia realized cloud seeding operations over an area covering approximately 1,000 km^2 in the Snowy Mountains. An annual monitoring and reporting of the effects of clouds seeding is realized. In France took place three projects for changing the extreme weather events. These were performed by private companies which had as main role the reduction in hail fall effects on the cultivated area. In the first project, NaCl was used and which was introduced to the basis of clouds with airborne pyrotechnic generators. The second and the third project explored the behavior of the clouds at the AgI scattering action with air missiles or with ground-based generators (Kamalov 2011).

Seeding clouds have numerous problems (Abshaev et al. 2011; Bolgov et al. 2009; Dessens 1986; Mladjen et al. 2003; Shu et al. 2001; Zhekamukov and Abshaev 2009a, b Zoran et al. 2007), no matter the method of seeding (Armayan et al. 2011; Babic and Kostic 2003; Kamalov 2011), so that an intervention at the right moment and in the optimal area will increase the efficiency of combating hail. Nowadays, there are developing several information systems for finding optimal solutions to these problems. It is noticed the computer system HASIS 3D (Three-dimensional Hail Suppression Information System) developed by the Faculty of Electronic Engineering from Niš-Serbia.

A national anti-hail system was established in Romania in 1999 and, recently, was established a National Authority (Romanian Law no. 173/2008, Decision nr.604 of July 28, 1999) against hail fall and for the stimulation of the rainfall. During the mentioned period, were developed a lot of research activities, supported by government bodies or by businesses, and presently, there are concerns for the extension of these activities through doctoral researches, through international, cross-border or regional partnerships researches. It can be said that the management of hail fall and the rainfall stimulation has become, in our country, a current preoccupation with conceptual, descriptive, and predictive valences, specific in scientific areas.

Presently, in Romania, an anti-hail system is functioning, and it is desired to implement a large-scale National Anti-hail System. This system is designed, developed, and operated by a consortium setup of the National Administration of Meteorology, "Electromechanics Ploieşti" and a new institution created to conduct the extension of the anti-hail system, namely "The stimulation rain and anti-hail System Administration." Since 2005, an anti-hail unit is working in Prahova and Buzău counties and recently in Vrancea and Iaşi. For Oltenia Region, have been established the following areas to be protected: Drăgăşani area, Craiova area (Segarcea—Dăbuleni), and Băileşti—Vânju Mare area (Project "*Joint risk monitoring during emergencies in* the Danube border area" part of the Cross-Border

Cooperation Program Romania–Bulgaria—Report “Study on the location of local units,” 2012). The anti-hail system uses rockets with 82.5 mm caliber and an orientable launcher. The information about the appearance of hail cloud and its dimensions is provided by the meteorological stations from SIMIN-Integrated Meteorological Information System. To lead a well-founded and timely decision, any decision process must to acquire, to process, and to interpret a growing volume of information, in a very short time. For instance, to obtain a short time period between the last update of the cloud front (which can provide information about the hail formation) and the moment shooting order, it is necessary to integrate various input variables so that the operator to have as much information to be merged into one “screen.” Therefore, it is necessary to achieve an integrated monitoring system for the launch units of the anti-hail system.

In this paper, an informational decision support for an anti-hail system is presented. The system will be deployed in the Oltenia region, situated in the south-east of Romania, within the project “Joint Risk Monitoring during Emergencies in the Danube Area Border,” Cross-Border Cooperation Program Romania–Bulgaria, 2007–2013, MIS-ETC Code 166. The paper is organized as follows. Section 2 presents the structure of the anti-hail supporting system. In Sect. 3, the dataflow of information through the system is fully discussed. Section 4 deals with an analytical approach concerns the decisional signal through the system, more precisely, a Bayes-based criterion is used in order to test the validity of the decision. Finally, some conclusions are collected in Sect. 5.

2 System structure

The anti-hail decisional supporting system is an assembly of software, hardware components, procedures, strategies, activities, and people organized to process data related to combating hail, to fulfill the task of reducing/eliminating the damage caused by hail and the achievement of measurable performance criteria (Şulea et al. 2010).

Figure 1 presents a generic structure of the decisional supporting system architecture for anti-hail units. The main components of a launching unit, necessary for the decisional supporting system, as is shown in Fig. 2, are represented by a general packet radio services (GPRS) communication module, the monitoring system, the launching ramps, and an optional computer running specific applications (Manolea et al. 2011).

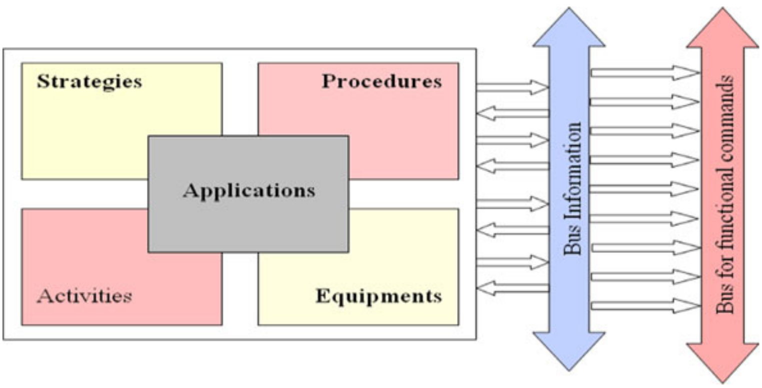

Fig. 1 The anti-hail supporting system architecture

The GPRS communication module is a terminal identified by an IP address, always connected and available, and the GSM network is transformed into a transmission network and packet switched technology like TCP/IP.

The main components of the decisional supporting system are as follows (see Fig. 3):

- the subsystem of launch decision
- the subsystem for assisting the launch decision

Monitoring systems for decision support are useful when decision criteria are numerous, conflicting data, when the search is difficult, takes time and satisfactory solution must be given rapidly, which is the case of decision to launch the rockets in the anti-hail systems (Papadopoulou et al. 2011; Zerger and Wealands 2004).

The subsystem of launch decision addresses exclusively to the central control unit. The subsystem is a multifunctional geographic information system (GIS) which can help the staff of the central control unit upon the decisions which must be taken in extreme situations. The current Romanian weather monitoring system allows an update to about each 7–9 min, and the information of clouds progress comes at the central control unit in about every 15 min.

Taking into account that the time between the last update of the clouds and the time for ordering the shooting must be as short as possible, it is necessary to integrate various input variables so that the operator should have as much information as merged into a "screen." The main layers of information, the input variables, are related to the evolution of clouds, topography and cultivated areas, launch units and organizational elements.

The cloud evolution of the protected region (i.e., Oltenia region) is very important because the intervention will take place only if the weather radar indicates the presence of hail or its risk (Fig. 4 shows an example of clouds evolution).

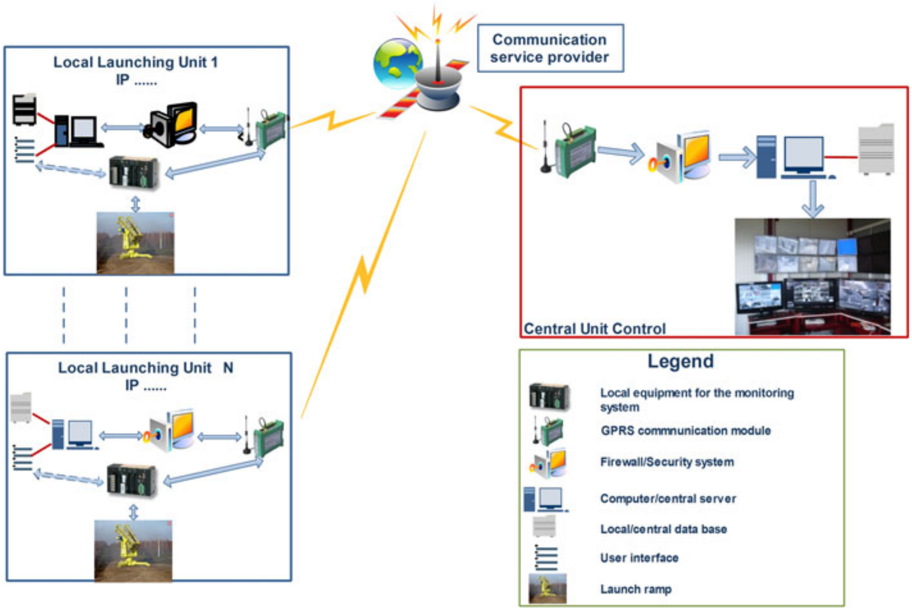

Fig. 2 The monitoring system architecture for anti-hail units

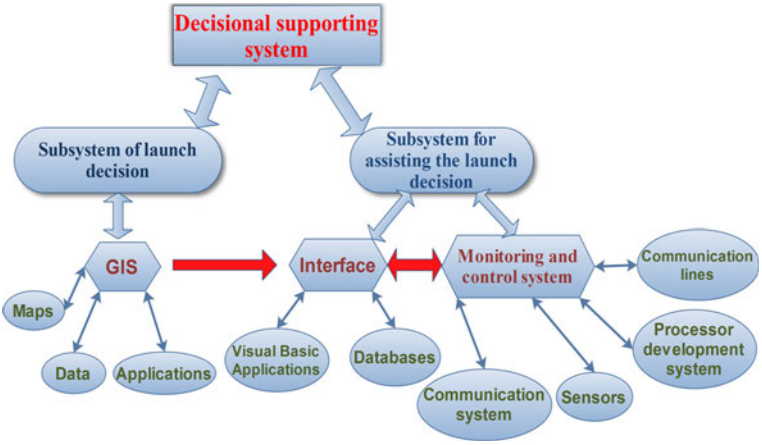

Fig. 3 The main components of the decisional supporting system

In Fig. 5, are symbolically presented the cultivated areas to be protected, represented by polygons of different colors: green, blue, yellow, orange, red symbolizing the type of each crop (fruit trees, vines, wheat, maize, etc.); the coordinates of the launch unit and the central unit are represented by specific symbols.

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. GIS technology can be integrated into any enterprise information system framework. Geographic information systems applications are becoming wide-spread. GIS is an integral part of modelling risk, risk management, monitoring system,

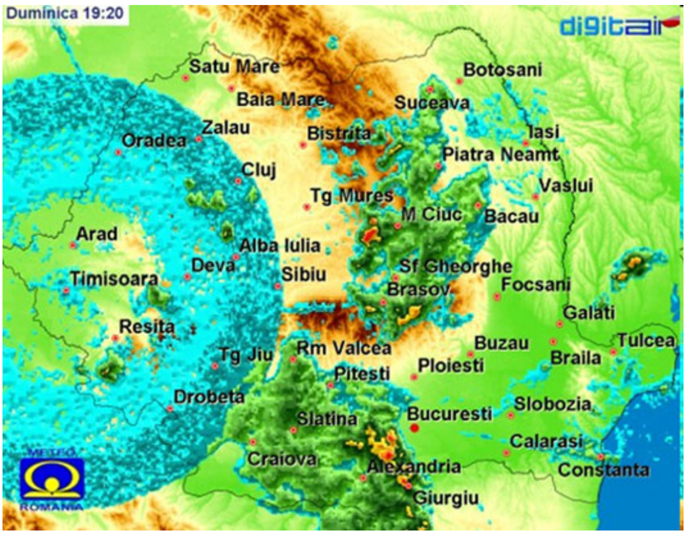

Fig. 4 Example of clouds evolution in Romania

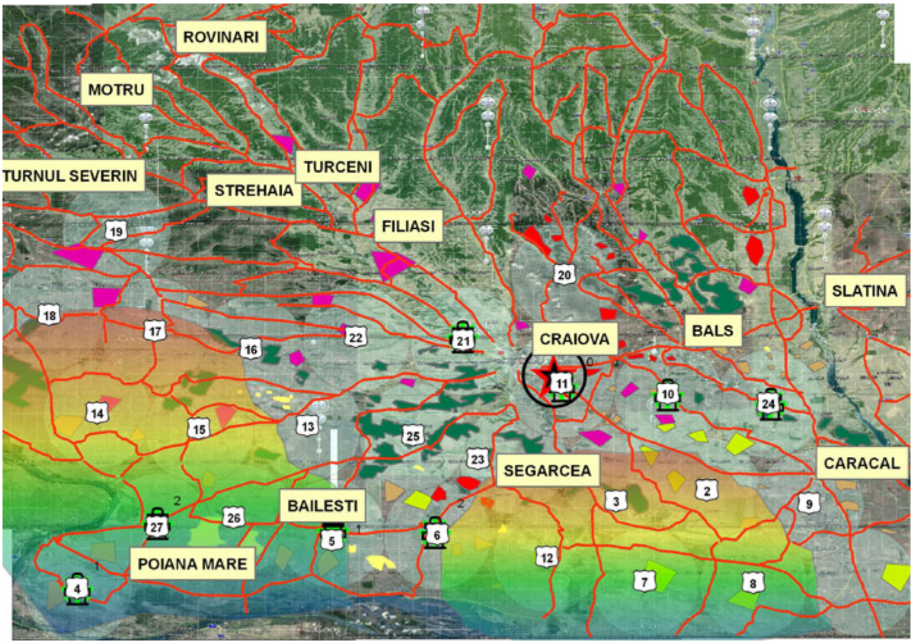

Fig. 5 GIS representation for Oltenia Region—Romania

decisional supporting system (DSS), etc. (Carrara et al. 1999; Lazzari and Salvaneschi 1999; Zerger and Wealands 2004).

The range of launch ramps is also important, and it is highlighted by area which is covered by a central control unit. The access roads and their types (agricultural, county, national, European) are highlighted for prompt intervention in case of failure.

The starting point in developing the GIS was GoogleEarth 5.2.1, which provides us the images that define the area of Oltenia. The georeferencing of images was performed with Quantum GIS. The user provides as input the image points whose coordinates are known, and the program applies an algorithm based on the number of points entered (which must always be at least three). The image is corrected and can be saved separately with georeference information (which is saved in a separate file with the same name but different extension, for example, JGW, TFW, EWW, GeoTIFF files).

The layers and the shapes were created in ArcCatalog. The following shape files were created: Central Control Unit Oltenia, Bârca Local Unit (LU), Poiana Mare Local Unit, Craiova Local Unit, road access, Oltenia Coverage Central Control Unit, Cloud Front, area fruit trees, vines, canola, corn, wheat, forest area, rays local action units, Oltenia raster. Raster Oltenia contains georeferenced images, which once loaded will create Oltenia region. There have been created dot shape type files: Bârca LU, Poiana Mare LU, Craiova LU, Oltenia Central Unit, etc. georeferenced with the same system as in the case of the images. The symbols used to represent are as follows: local unit and central control unit . Area covered by a local unit is a circle with a diameter of 16 km. To cover a large part of Oltenia, a total of 28 launching units are needed. The exact position of the launch units will be based on a study made by specialists.

Cloud front is an essential element in the activity of combating hail; therefore, it is the starting point for the launch parameters calculation. This layer of information will be provided by National Meteorological Agency (NMA) taking into account its format and can automatically update every maximum 10 min.

Based on information provided by the Ministry of Agriculture will be created proper layers to be protected: fruit trees, vines, rape, maize, wheat, forest area, etc. The map was made with ARCGIS 9—registered mark.

The decided local unit is accessed through an application that connects to the subsystem of launch decision. Once taken the launch decision, it must be implemented in shortest time possible, by using interfaces, communications system, monitoring systems, and systems for assisting the launch decision. In the diagram of the decision process, the decision is the central element. To make the right decision, we need a system to help us to take a decision and another system to help us (assist) to implement decision in conditions of maximum efficiency.

The subsystem for assisting the launch decision aims reducing intervention time, better organization, a high degree of security, greater efficiency, reduced operating and maintenance costs and improved performance.

As it is shown in Figs. 6 and 7, the main components of the monitoring system placed in the local launch unit are as follows: GPRS modem, optional computer, a master that can communicate up to 4 slaves, sensors, positioning system, selector of rockets. The components from the central control unit are as follows: GPRS modem and data server.

Figure 6 shows the hardware structure of the monitoring system placed in the local launch unit. The 12 inputs–outputs represent the inputs of the slave module but also the outputs used to enable missiles to be launched. The inputs provide information related to

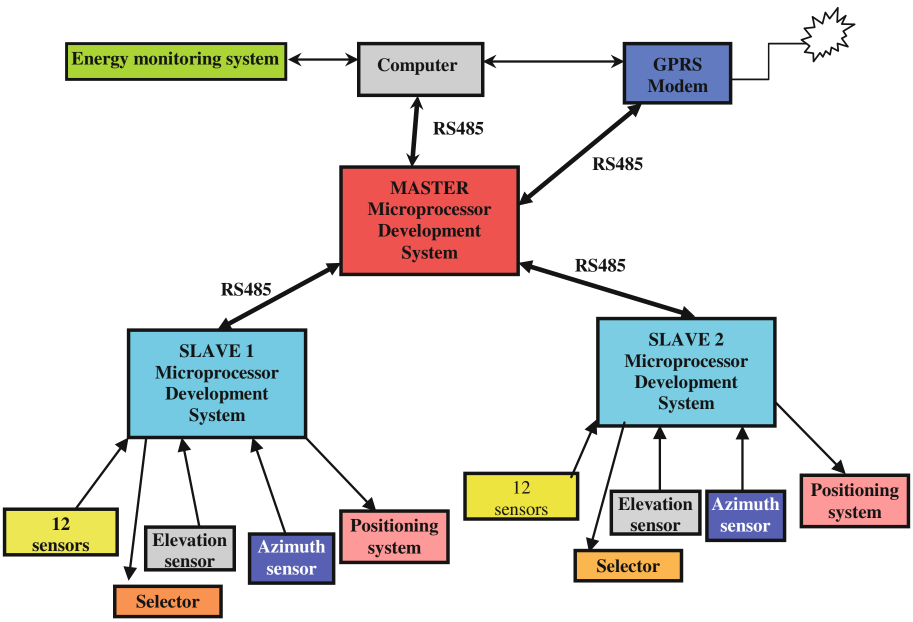

Fig. 6 Monitoring system components from the local launch unit

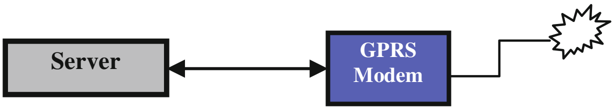

Fig. 7 Monitoring system components from the central control unit

rockets, information about the type of rocket, number, and the lot of the launched rocket. The main input variables for the subsystem for assisting the launch decision are as follows:

- the ramp launch number—for a secured identification by the operator;
- the battery voltage—availability of the energy supply system; due to prioritization system, it will always be ensured the minimum energy for positioning ramp and release heat;
- confirmation of hail clouds presence—an element of safety before launch;
- confirmation of free air space—a safety element before launching.

At the central unit, the following factors are ensured:

- centralization of data, storing them in databases or logs of values;
- friendly graphical interface that allows quick viewing of the status of items represented by standard symbols or suggestive drawn so that it can be easily identified by any operator and colored according to the state (normal or alarm);
- determining the state of alarm and reporting their location (symbols, colors, flashing), the bubble element associated;
- opening/closing inside ramp—an element of security and protection of launch ramp;
- positioning elements: azimuth and the elevation;
- number and position of the rocket on the ramp—thus ensuring control over the activity of launching and loading ramp;
- the choice to missile for launching.

The main output data will be represented by positioning the ramp, by firing order, and by the daily–monthly shooting report.

The interface of the subsystem for assisting the launch decision, given in Fig. 8, was made with the help of Visual Basic.

The connection is initiated from the central control unit, and the transmission is automatic at the rate determined or when one of the parameters changes, as follows: the number of the launch installation, the type of the launch installation, the azimuth, the elevation of the two groups, the presence of the rockets on the installation, the time of data acquisition for each part of the launch installations.

3 Information handled in the system

The main information handled in the local launching unit is linked to the launch pad, and it is presented in Fig. 9. The information transmitted between local launch unit and central control unit is presented in Fig. 10. The minimum information submitted by the central control unit to the local unit Fig. 11 refers to “pre-alarm-input,” “alarm input,” coordinates of shooting, the type of fire.

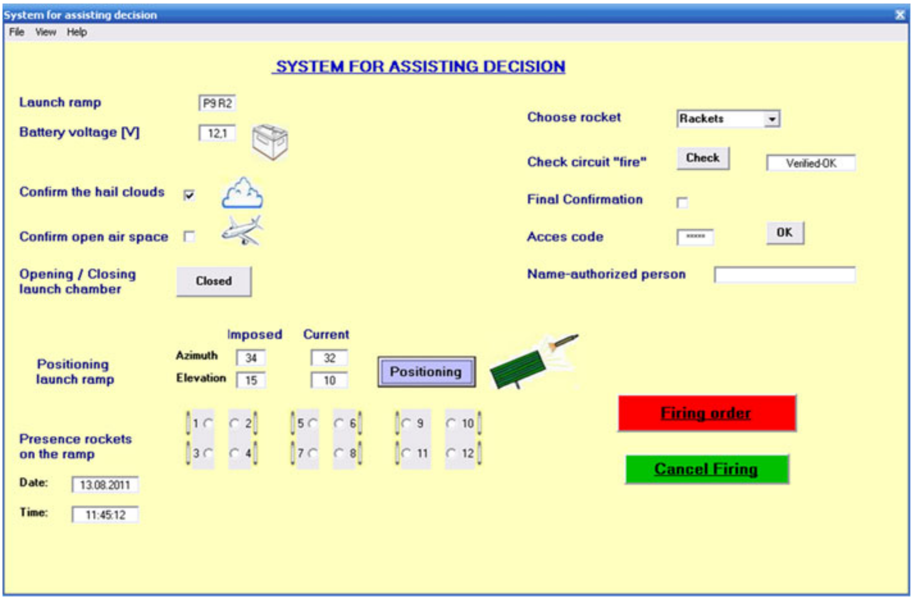

Fig. 8 Decision support subsystem interface

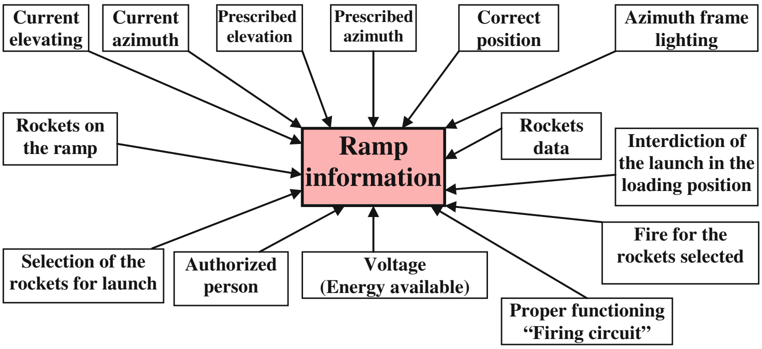

Fig. 9 Information about the launching ramp

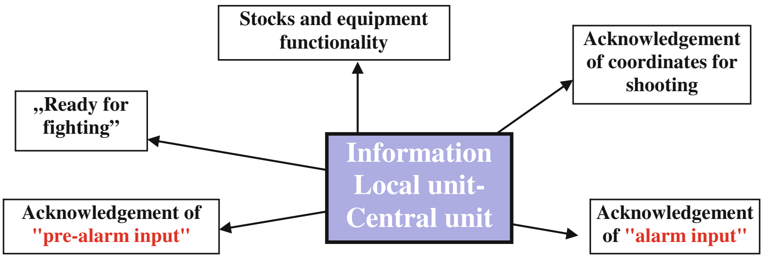

Fig. 10 Information transmitted between the local launch unit and central control unit

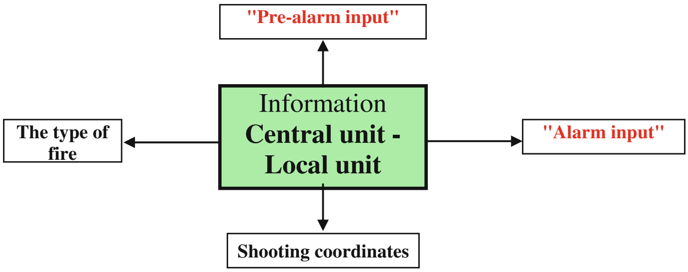

Fig. 11 Information handled between central control unit and local launch unit

The main information which circulates between the central unit and other entities is related to airspace, and it is presented in Fig. 12. The most important information (Fig. 13) for launching decision is related to hail occurrence probability, hail cell coordinates, cloud coordinates, cloud speed, wind speed, isotherms, forecasts, free air space, the coordinates of the active launching units, administrative territorial elements (crops, roads, localities).

The efficiency of the proposed architecture and of the decision mechanism should be checked by using some modelling and simulation procedures. In order to address this issue, several models of the subsystems of the informational decisional system were implemented to simulate the behavior of the proposed architecture. These models were designed for the following operations and components: normal operation, "pre-alarm-input" operation, "alarm input" operation, and several parts of the local launch units monitoring systems.

The models were built and checked through simulation by using Petri nets and the Visual Object Net++ package. These models help to the implementation of the monitoring system, which is a major component of the decisional supporting system presented in Fig. 3.

As exemplification of the designed models, the Petri nets model of the "pre-alarm-input" operation in a local unit is presented in Fig. 14, and the Petri nets model of the "pre-alarm-input" operation in the central unit is depicted in Fig. 15. The simulations performed with these models showed that the workflows are suitable, and the proposed solution is efficient.

The main output of the DSS is the decision. It can be cases when the decision is not correct implemented or get altered in the execution area. In this situation, it is necessary the restoration of the decision often transposed into a signal. Based on this theory, the next section will deal with decision signal reconstruction.

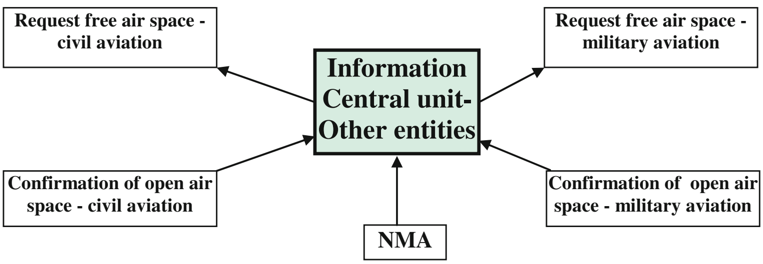

Fig. 12 Information handled between central control unit and other entities

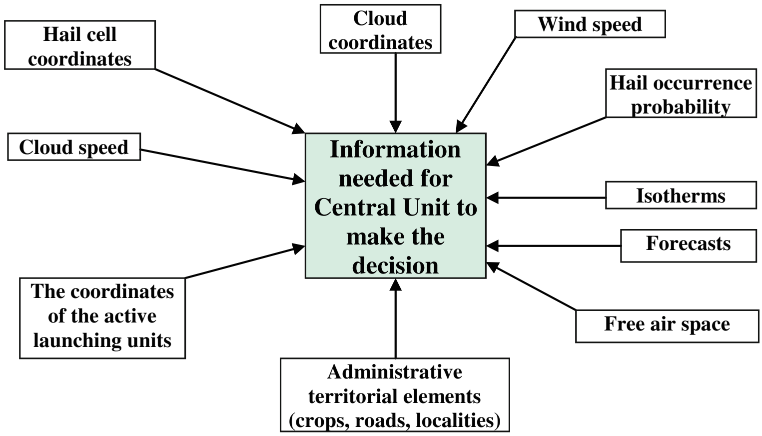

Fig. 13 Information needed in central unit for decision making

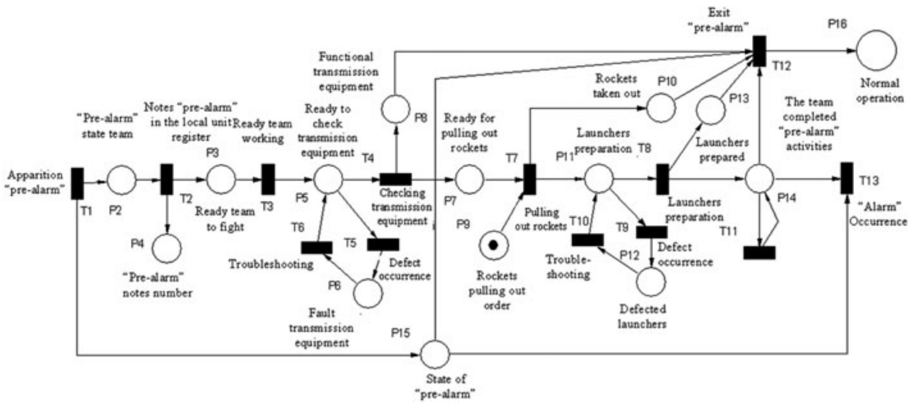

Fig. 14 The Petri nets model of the "pre-alarm-input" in a local unit

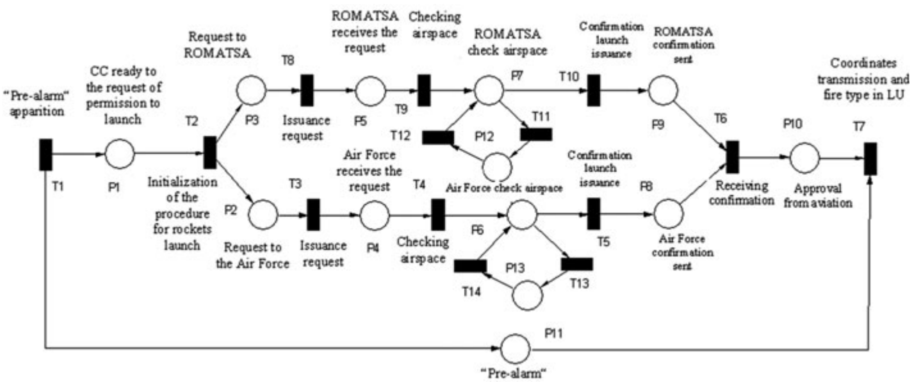

Fig. 15 The Petri nets model of the "pre-alarm-input" operation in the central unit

Concerning the experimental testing of the proposed system, until now a test check of the monitoring system as a part of the informational decisional system (Fig. 3) was achieved. The experimental tests were obtained by using a test bench with the structure presented in Fig. 16. A lot of tests were performed, such as communication between master and slave modules, which are parts of the monitoring subsystem (control of the communication line, slave module response, master module response, no response from the slave modules called and resetting network, etc.), communication between master module and GPRS modem. The tests have proved the proper functioning of the tested subsystems.

4 Reconstruction of a signal based on Bayes criterion: case study

An important issue of the presented decisional support system is the flow of decisional signals through the entire structure. Next, we will develop an analytical approach concerning the decisional signal through the system, by using a Bayes-based criterion.

We neglect the delay time t_d due to the propagation on line (Iancu 2004), and we suppose that received signal will have the form

$$k(t) = s(t) + n(t) \tag{1}$$

$$s(t) = \begin{cases} s_1 \cdot 1[t-(j-1)\cdot T_b], & \text{if } b_j = 0 \\ s_2 \cdot 1[t-(j-1)\cdot T_b], & \text{if } b_j = 1 \end{cases}, \quad \text{for} \quad (j-1)\cdot T_b \leq t < j \cdot T_b \tag{2}$$

where T_b is the sampling period, b_j is the sequence of binary data, s_1 and s_2 are signals, n is the noise.

In a time period T_b, N observations are made, whose result is the vector k.

$$k = [k_1, k_2, \ldots, k_n] \tag{3}$$

This vector is placed in a space of observations, divided into two regions by the Σ surface (Fig. 17). If the peak of the vector is placed in Δ_1 will be decided that the emitter transmitted the signal $s_1(t)$, and if the peak of the vector is placed in Δ_2 will be decided that the emitter transmitted the signal s_2(t). It is important to delimit, as exact as possible, the separation surface Σ between the two domains because it is the decision threshold.

The conditional probability densities are $p(k/s_1)$ and $p(k/s_2)$. Differential volume around vector k is defined by the relationship

$$dk_1 dk_2 \ldots dk_n = dV \tag{4}$$

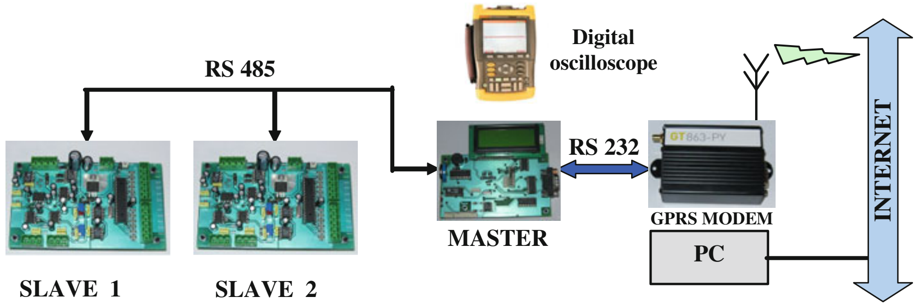

Fig. 16 Structure of the test bench

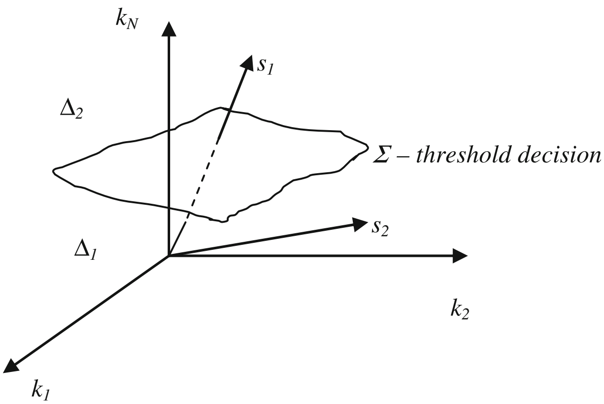

Fig. 17 The representation of K vector, the signal, and the decision threshold

The probabilities P_1 and P_2 with which are emitted the signals $s_1(t)$ and $s_2(t)$ are supposed to be known. Thus, we have one of the following possible variants that have defined the following risks:

r_{11}—good position and the right decision to shoot;
r_{12}—wrong position and the right decision not to shoot;
r_{21}—good position and the wrong decision not to shoot;
r_{22}—wrong position and wrong decision to shoot.

In Table 1, the signal decision correspondence is presented.

Space observations should be divided so that r_{ij} to be minimum. Obviously, the risk is minimal for r_{11}. Effectiveness of anti-hail activities is reduced in a higher proportion of an erroneous decision and a wrong position. The medium risk R is defined by the relation

$$R = r_{11}P(D_1 \cap s_1) + r_{22}P(D_2 \cap s_2) + r_{21}P(D_2 \cap s_1) + r_{12}(D_1 \cap s_2) \tag{5}$$

$$P(D_i \cap s_j) = P_j P(D_i \cap s_j),\ \ i,j = 1 \text{ or } 2 \tag{6}$$

$P(D_i/s_j),\ \ i,j = 1 \text{ or } 2$ can be written:

$$P(D_1/s_1) = \int_{\Delta_1} p(k/s_1)dV \tag{7}$$

$$P(D_2/s_2) = \int_{\Delta_2} p(k/s_2)dV \tag{8}$$

$$P(D_2/s_1) = \int_{\Delta_2} p(k/s_1)dV \tag{9}$$

$$P(D_1/s_2) = \int_{\Delta_1} p(k/s_2)dV \tag{10}$$

Table 1 Signal decision correspondence

	Good position (s_1)	Wrong position (s_2)
Right decision D_1	r_{11}	r_{12}
Wrong decision D_2	r_{21}	r_{22}

It results that

$$\int_{\Delta_1} p(k/s_1)dV + \int_{\Delta_2} p(k/s_1)dV = 1 \tag{11}$$

$$\int_{\Delta_1} p(k/s_2)dV + \int_{\Delta_2} p(k/s_2)dV = 1 \tag{12}$$

Medium risk R becomes

$$R = r_{11}P_1 + r_{22}P_2 + (r_{21} - r_{11})P_1 + \int_{\Delta_1} [(r_{12} - r_{22})P_2 p(k/s_2) - (r_{21} - r_{11})P_1 p(k/s_1)]dV \tag{13}$$

The minimum risk is achieved when

$$(r_{11} - r_{22})P_2 p(k/s_2) - (r_{21} - r_{11})P_1 p(k/s_1) = 0 \tag{14}$$

Taking into account that risk and implicit the cost of a wrong decision is higher than the price of a correct decision, and if the next inequality holds

$$\frac{p(k/s_2)}{p(k/s_1)} < \frac{P_1(r_{21} - r_{11})}{P_2(r_{12} - r_{22})}, \tag{15}$$

then we can say that we have the decision D_1.

But if the next inequality is fulfilled

$$\frac{p(k/s_2)}{p(k/s_1)} > \frac{P_1(r_{21} - r_{11})}{P_2(r_{12} - r_{22})}, \tag{16}$$

then we could say that we have the decision D_2.

As an example, we will consider that the risk values are

$$r_{21} = r_{12} = 1, \quad r_{11} = r_{22} = 0 \tag{17}$$

So we have fulfilled the inequalities

$$\frac{p(k/s_2)}{p(k/s_1)} < \frac{P_1}{P_2} \quad \text{if the transmitted signal is} \quad s_1(t) \tag{18}$$

$$\frac{p(k/s_2)}{p(k/s_1)} > \frac{P_1}{P_2} \quad \text{if the transmitted signal is} \quad s_2(t) \tag{19}$$

The probability densities $p(k/s_1)$ and $p(k/s_1)$ can be estimated with the help of an experimental transmission.

Assuming that the noise affecting the transmission through a channel can be described by a random signal with normal distribution (Gaussian type), then the probability density is

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \cdot e^{\frac{1}{2}\left(\frac{x-x_0}{\sigma}\right)^2} \tag{20}$$

where σ^2 is the variation and x_0 is average value of random variation.

When using a Rayleigh type distribution (the case of waves reflected from the ionosphere), the probability density is

$$p(x) = \frac{x}{\sigma^2} \cdot e^{-\frac{x^2}{2\sigma^2}} \qquad (21)$$

The ratio $\frac{p(k/s_2)}{p(k/s_1)}$ is called the verisimilitude ratio or confidence ratio; the report of the emission probabilities $\frac{P_1}{P_2}$ is called decision threshold. In the case of long transmission data, $P_1 = P_{2,}$ and decision threshold has the value 1.

By using this kind of Bayes-based criterion, a reconstruction of the decision can be obtained; this decision will be used by the system when an erroneous signal was received. Finally, this information will be used in order to update the database of the monitoring system.

5 Conclusions

The systems of risks management have begun to have an increasingly importance, mainly due to the devastation caused by climate change. Thus, the anti-hail systems have known a great evolution in the last twentieth century.

The anti-hail systems with increased efficiency are based on the principle of seeding clouds both in the air and in the land. The informational decision supporting system for the Romania anti-hail network comprises two main components: the subsystem of launch decision and the subsystem for assisting the launch decision.

The system presented in this paper monitors the parameters throughout the all period of operating, log-values, status and alarms, operator actions journals, friendly graphical interface, and the generation of tabular and graphical reports for any period. Moreover, by using a Bayes-based criterion, the restoration of a human decision that is basically a signal was approached, taking into account that in critical circumstances, a restoration of a decision is needed.

Through this system, we have an increasing efficiency by reducing the intervention time, a better organization, reducing operating and maintenance costs, increase degree of security.

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