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RESEARCH ARTICLE

Microsituations as part of the formalization of avalanche climate to avalanche-riskiness and avalanche-safety classes in the emergency situations separation

***M. Ayaz Ahmad[1], Oleksandr Kuzomin[2], Vyacheslav Lyashenko[3] and N. Ameer Ahamad[4]**

1. Physics Department, Faculty of Science, P.O. Box 741, University of Tabuk-71491, Saudi Arabia.

2. Department of Informatics, Kharkov National University of RadioElectronics, Ukraine.

3. Laboratory “Transfer of Information Technologies in the risk reduction systems”, Kharkov National University of RadioElectronics, Ukraine.

4. Physics Department, Faculty of Science, P.O. Box 741, University of Tabuk-71491, Saudi Arabia.

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Corresponding Author

M. Ayaz Ahmad

Abstract

Need to ensure the safety of human life is inextricably linked to the various emergencies studies and experimental analysis. One of the most emergencies manifestations is avalanching. In this case, analysis and forecasting of avalanches is still quite challenging. This is due to the fact that the solution of such problems is largely determined by adequate and interconnected representation of existing diversity of avalanches parameters occurrence. To solve this problem, we consider the concept of microsituations, which is used for a formalized description of emergency avalanche climate, dividing it into avalanche-riskiness and avalanche-safety classes. As a result of such a description was developed a method for the distribution of avalanche climate emergencies to avalanche-riskiness and avalanche safety classes, was proposed the considered method implementation scheme for selection of avalanche-riskiness and avalanche-safety classes from the analyzed set of emergencies.

INTRODUCTION

Avalanches, like the earthquakes, floods, volcanic eruptions, referred to natural phenomena that may cause loss of human life and considerable damage. Despite the fact that the avalanche areas occupy only 6% of the land and the study of such phenomenon is important for the timely avalanche events implementation. As a rule, the above measures include (Cheng et al., 2007; Butler et al., 2008; Uttl et al., 2009) the identification of the avalanche areas and determination of the parameters of phenomenon that precede the formation of avalanches, organization of the time forecasting avalanches service, construction of protective structures, warning avalanches descent.

The practical implementation of activities listed above is carried out relying on the results obtained by using the Geographic Information System (GIS) technologies. The GIS technology can not only simulate the processes and phenomena that determine the conditions of avalanches, identify areas of accumulation, snow drift and dynamics, but also make the predictions on the basis of the constructed models. Moreover, this prediction helps to reduce risks in case of avalanche situations, which causes the consideration of the possibility of using a variety of approaches for such modeling.

Thus, the process of modeling can be considered an important key role in the prediction of the avalanche situations. However, as pointed out in studies of various authors (Purves et al., 2003; Hirashima et al., 2008;

Schweizer et al., 2008; Schweizer et al., 2009) modeling and forecasting process of the avalanche situations is still quite complicated procedure.

The complexity of constructing models for avalanche situations prediction is primarily determined by different parameters which present in the environment of avalanche situations occurrence of the complexity (Schweizer et al., 2008; Eckert et al., 2010). And the need to identify sustainable relationships between the individual parameters of the avalanche situations occurrence environment (McClung, 2002) is the unique characteristics of the environment situations occurrence in each case (Roeger et al., 2003; Hirashima et al., 2008).

Further, other workers in the same field of research (Eckert et al., 2008; Schweizer et al., 2009) described the individual stages of the emergence avalanche situations environment in the form of a coherent events chain.

Finally, it determines the main purpose of this study, which is to consider the appropriateness of the microsituations concept in summarizing the methodology of avalanche situations analysis and forecasting.

Material and Methods

(I) Modeling Avalanche as the Identification Problem

Recently, known and widely used different types of models and numerous modeling techniques in scientific research and engineering practice are important tools. The model of the original object is a representation of an object in a different from of its real existence. If we take as base the level of abstraction, we can define the following types of models for the analysis of emergency situations, which are used to describe the avalanches phenomenon and also already studied by various authors (Lehning et al., 2002; Sovilla, et al. 2006; Kuzemin et al., 2007).

(i) Physical (full-scale) - reproduce the process under study while maintaining its physical nature, they are tools for physical modeling.
(ii) Analog - replacing one object to another with similar properties.
(iii) Math's - abstract models that exist in the form of special mathematical concepts and have meaning only for their interpreting human or machine.

The process of avalanches formation is unique, that consisting of a large number of interrelated parameters, which makes it difficult to research on the real object. Thus, first of all, the construction of avalanche process can be accomplished using a mathematical modeling. At the same time simulation of avalanches formation can be attributed to problems of identification (Kuzemin et al., 2008).

We are describing the identification problem such as followings. For this task, first we use the results of observations of the input and output variables to construct optimal model (in some sense) of identified object interaction (avalanche situation) with the studied parameters.

This interaction occurs through the channels of observation input $\overline{X} = \{X_1,\ldots,X_n\}$ – environment of avalanche situation occurrence and exit $\overline{Y} = \{Y_1,\ldots,Y_n\}$ at discrete times $t_1,\ldots,t_n$.

These observations are related by unknown object operator A_t : $Y_i = A_t(X_i), \quad i = \overline{1, n}$.

The environment impacts on the object via channel $\overline{X}$, and via channel $\overline{Y}$ the object impacts on the environment. Then the identification problem is reduced to operator model determination A_t^*, precisely, obtaining an estimate A_t by observations X_i and Y_i in a discrete moment of time t_i.

Thus, the problem of identification can be decomposed into the following subtasks:
(i) Selection of the input variables (arguments or factors);
(ii) The selection of the output variables (optimization parameters);
(iii) The choice of the model structure;
(iv) Analysis of algorithms using a model for finding extreme of the output values.

(II) Microsituations as Formalization Part of Avalanche-Safety and Avalanche-Riskiness Situations

Each situation " C " represented as a set of " n " microsituations C_i : and $C = \{c_i\}, i = \overline{1,n}, c_i = \langle e_i, R_e \rangle$, where, the important part of the situation can be determined by a pair of $c_i = \langle e_i, R_e \rangle$, and it is called a microsituation of concept " e ".

The concept " e " is called a central concept of microsituation $\langle e_i, R_e \rangle$, and R_e is the multiplicity a context of the central concept " e ".

Also, the central concept of " e " is a central semantic unit, around which is based on the given microsituation.

The multiplicity $R_e = \{r_i\}, i = \overline{1,m}$ consists of the " m " concepts expressing the ratio of the central concept " e " with the other secondary concepts engaged in this microsituation.

We assume a certain dependence of the central concept from the secondary as the attitude, required for microsituation reflection of avalanche situation state. As for the secondary for such microsituation can be a concept central for the other microsituation.

The microsituations used to describe the avalanche-riskiness and the avalanche-safety situations correspond to the followings:
(i) The avalanche climate index or subject of analysis - avalanche situation change,
(ii) The action - as a result of changes in the weather or control action for the prevention an avalanche, elimination the effects of an avalanche,
(ii) The object - of analysis and forecasting, which operates a researcher in the modeling of avalanche climate.

According to the European avalanche danger scale (McClung, 2000) we can give an example of one microsituation and that are: (i) avalanche climate index or subject of analysis - the snow cover stability (e.g., snow cover is well fixed on the slopes and stable - minor avalanche danger).

(ii) The change in the avalanche situation or action - the probability of avalanches collapse is average (for example, the collapse is only possible at a very significant additional burden on certain very steep slopes, only snow shifts can occur spontaneously).

(iii) The avalanche, as an object of analysis and forecast - a small degree of avalanche danger (for example, minor avalanche danger).

Result and Discussion

(I) Avalanche-Riskiness and Avalanche-Safety Situations as Variety of Different Microsituations

Representation of the diversity avalanches occurrence parameters helps to improve the reliability of the analysis and forecasting in a view of microsituations plurality. Each such microsituation corresponds to a particular combination of avalanche occurrence environment settings. At the same time, such representation allows to divide the entire set of factors that influence on the avalanches occurrence into two situations subclasses.

One subclass characterizes the microsituations multiplicity reflecting the emergence of the avalanche and the other subclass is typical for avalanche safety situation in general. Then the risk management of avalanches emergency situations can be represented as a generalized description of the system using a set of different microsituations.

On the basis of this interpretation, summarize logical rules of analyzed data set for subsequent division of avalanche-riskiness and avalanche-safety situations into classes can be represented as follows (Kuzemin et al., 2011):

$$\text{"avalanche - dangerous"} = \left(\{F_L^L(X)\}/\{F_N^L(X)\}\right) \cup \left(\{F_L^L(X)\}/\{F_N^N(X)\}\right) \cup \left(\{F_N^N(X)\}/\{F_L^L(X)\} \cup\right) \cup$$
$$\cup \left(\{F_L^N(X)\}/\{F_N^L(X)\}\right) \cup \left(\{F_N^L(X)\}/\{F_L^N(X)\}\right) \cup \left(\{F_L^N(X)\}/\{F_N^N(X)\}\right),$$

$$\text{"non avalanche - dangerous"} = \left(\{F_N^L(X)\}/\{F_L^L(X)\}\right) \cup \left(\{F_L^L(X)\} \cap \{F_N^N(X)\}\right) \cup \left(\{F_L^N(X)\} \cap \{F_N^L(X)\}\right) \cup \left(\{F_N^N(X)\}/\{F_L^L(X)\}\right)$$

where $F_L^L(X)$, $F_L^N(X)$, $F_N^L(X)$, $F_N^N(X)$ – probability function of microsituations assignment to avalanche-riskiness (avalanche-safety) class respectively, on the set of avalanche danger parameters medium occurrence X. The results, assigning probabilities of investigated data to classes, obtained using such evaluation functions, that describe either avalanche-riskiness or avalanche-safety situations, allow to allocate, first of all, two types of situations on the whole set of avalanche climate occurrence of analyzed data.

Accordingly, it is a situation of avalanches occurrence (Ω_L) and avalanches-safety situation (Ω_N).These situations are described by the set of the most important statistical characteristics X_1, X_2, X_3, X_4, X_5, where X_1 – air temperature X_2 – air humidity, X_3 – wind speed, X_4 – amount of precipitation, X_5 – the angle of the mountain slope.

In turn, each of the considered situations represents a specific set of microsituations $\Omega = \{\omega_i\}$, $i = \overline{i, n}$, every one of them corresponds to a particular group of considered types of avalanche occurrence environment data and reflects, on the one hand, reliable probability of avalanche situation, and, on the other - is characterized by not-avalanche situation probability occurrence.

In other words, avalanche-riskiness situations Ω_L is homogeneous, with respect to the data types, association of different microsituations $\Omega_L = \bigcup_i \Omega_{L_i}$, and avalanche-safety situations Ω_N represent $\Omega_N = \bigcup_i \Omega_{N_i}$.

Each microsituation reflects, to a certain extent, the likelihood of any avalanche-riskiness or avalanche-safety situation as a whole in terms of a certain data type (group) at different values which characterize the situation under consideration. Thus, the overall results of the evaluation study data probability assignment to classes that describe or avalanche-riskiness or avalanche-safety situations can be considered as the basis for the transition to the formation of the corresponding systems microsituations.

(II) Distribution of Avalanche Climate Emergency Situations to Avalanche-Riskiness and Avalanche-Safety Classes

Based on the above mentioned emergency distributing method of avalanche climate, avalanche-riskiness and avalanche-safety classes can be represented as follows:

- The statistical avalanche climate characteristics for finding the most essential avalanche climate parameters are analyzed. And the parameters system which corresponds to the avalanche appearance is determined.
- Avalanche climate parameters classes, concerning occurrence and absence of avalanches, are formed.
- Generalized classes that characterize the appearance of avalanches for different groups of avalanche climate parameters.
- Measurements of closeness between the individual parameters classes that correspond to the avalanche-safety and avalanche-riskiness situations occurrence are determined.

Thus, at considered method initial stage a pre-processing of data is fulfilled. The avalanche climate statistical characteristics are analyzed. As a result of this analysis is formed a set of parameters values, which are determining the avalanches possibility: $Z \to \{X_1,..X_n\}$,

where Z – is general description of the avalanches occurrence, $X_1,\ldots,X_n$ – the most significant parameters multitude, by which are determined the avalanches occurrence conditions from multitude of factors-parameters of avalanches occurrence environment $\{X_k\}$, $n \le k$.

For the most important parameters that determine the avalanches occurrence environment, in particular for Itagar Chichkanskiy district of Kyrgyz Republic, we have the followings:

X_1 – air temperature,

X_2 – air humidity,

X_3 – wind speed,

X_4 – amount of precipitation,

X_5 – the angle of the mountain slope, where we can expect a possible avalanche.

In the second step of the method, for selected sets of the most important parameters, that determine the occurrence of descent environment, using methods of statistical analysis, we determine their relationships with the avalanches occurrence characteristic and form possible environmental conditions groups classes of occurrence and absence of avalanches, which reflect varying degrees of avalanche descent probability:

$$\{X_1,\ldots,X_n\} \Rightarrow \begin{cases} \beta_1^L,\ldots,\beta_n^L & \text{avalanche - dangerous situations,} \\ \beta_1^N,\ldots,\beta_n^N & \text{avalanche - safe microsituations,} \end{cases}$$

where $\beta_1^L,\ldots,\beta_n^L$ – number of interrelated set of values of most essential parameters, where there are conditions of avalanches;

$\beta_1^N,\ldots,\beta_n^N$ – number of interrelated set of values of most essential parameters, where there are no conditions for avalanches.

The next step of this method is avalanches occurrence classes generalization for different groups of avalanches occurrence individual characteristics.

In addition, each of the classes according to the individual groups characteristics of different situations occurrence environment is defined by certain probability interval $(\delta_i^d \div \nu_i^d)$, where d - is a class of avalanches, i is a separate group of characteristics of different environmental situations occurrence for inclusion in avalanche-safety or avalanche-riskiness class.

This is the step of verifying avalanches occurrence classes for possibility to account the changes in environment characteristics dynamics of different situations occurrence. The basis of this stage is correcting evaluation of misclassification cases of avalanche-safety and avalanche-riskiness classes, as well as testing of relevant data by considering new characteristics of the avalanche occurrence environment. Therefore takes place a formal correction of the most significant factors multitude values range, that were determined for avalanches occurrence environment:

$$\left.\begin{matrix} \beta_1^L,\ldots,\beta_n^L \\ \beta_1^N,\ldots,\beta_n^N \end{matrix}\right\} \Rightarrow \begin{cases} \lambda_1^L,\ldots,\lambda_n^L & \text{avalanche - dangerous situations,} \\ \lambda_1^N,\ldots,\lambda_n^N & \text{avalanche - safe microsituations,} \end{cases}$$

where $\lambda_1^L,\ldots,\lambda_n^N$ – adjusted number of the interrelationships sets of the most significant factors with the characteristic of avalanches appearance or absence. The final step of considered method is to determine the measure of proximity (ρ) between different classes of occurrence of avalanche-safety and avalanche-riskiness situations. As a proximity measure can be selected discriminant function values for certain avalanche climate parameters classes groups concerning occurrence of avalanche safety and avalanche-riskiness situations. The general scheme of refined method of avalanche-riskiness and avalanche-safety classes situations allocation shown in Figure 1.

Conclusions

Thus, the work provides a general ideology for the analysis emergency avalanche climate based on a consideration of the microsituations concept. Presented ideology allows not only formalize the procedure of analyzing various avalanche climate emergencies, but also generalize conducting of such analysis based on a variety of environmental factors of avalanches occurrence. Generalizations of various environmental factors of avalanches occurrence is based on the microsituation concept, which allows formalizing and describing emergency avalanche climate through standardized parameters.

During solving the problem of avalanche climate emergency situations, based on a consideration of the microsituations concept, we proposed the description of avalanche-riskiness and avalanche-safety classes.

The concept of microsituation and its formalized definition is put in the basis of avalanche climate emergencies distribution to avalanche-safety and avalanche-riskiness classes.

On the basis of the formation of avalanche-riskiness and avalanche-safety classes we proposed a scheme to clarify the implementation method of allocation avalanche climate emergencies classes. The considered classes of avalanche climate emergencies division were reflected in the survey of mountain ranges of Itagar Chichkanskyi district of Kyrgyz Republic, which confirms the proposed application feasibility and legitimacy in practice.

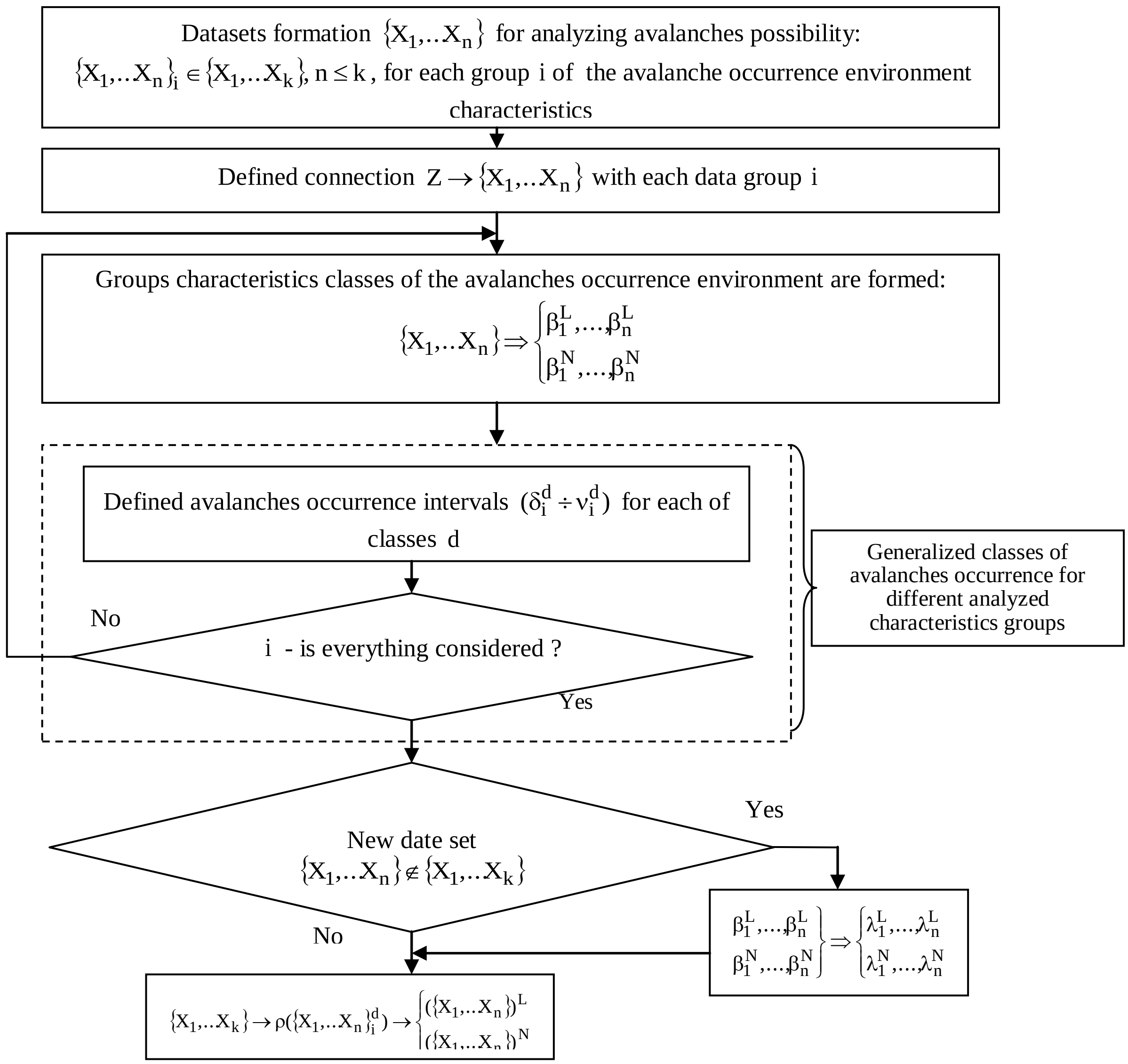

Fig. 1. The implementation scheme of improved allocation method of avalanche-riskiness and avalanche safety situations classes.

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