IT SUPPORTING DELIVERY OF INPUT PARAMETERS FOR THE CORRELATION LAYER OF THE MULTI-LAYERED EMERGENCY WARNING SYSTEMS MODEL

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În acest articol este propusă introducerea nivelului de corelare în structura sistemelor de avertizare pentru situații de urgență. Pentru a putea reprezenta date de intrare de calitate ale unui proces de corelare, mesajele de avertizare trebuie să conțină informație precisă. Sunt propuse îmbunătățiri ale cerințelor asupra datelor conținute în mesajul de avertizare, față de standardele existente în prezent. Sunt avute în vedere întrebările fundamentale: ce, când şi unde. Este detaliată propunerea asupra celei de-a treia, dimensiunea spațială.

In this paper we propose the insertion of the correlation layer within the structure of the emergency warning systems. In order to represent quality input data for a correlation process, the alerting messages have to contain accurate information. We propose some improvements for the requirements on data contained by the alerting message, over the standards that currently exist. Three fundamental questions are taken into consideration: what, when and where. The proposal on the third one is detailed here, namely the spatial dimension.

Keywords: correlation, alerting, warning, GIS

1. Introduction. The classic model of the emergency warning systems

In literature, there are descriptions of the emergency warning systems, many of them addressing systems dedicated to certain types of disasters and some of them willing to be all-hazard warning systems. Therefore, among the large variety of disaster types, leading to a wide variety of warning systems, we can differentiate: warning systems for earthquakes [1][2][3][4], warning systems for floods [5][6][7][8][9], warning systems for landslides [10][11][12][13], warning systems for production plants [14], warning systems for chemical and biological attacks [15] [16], warning systems for fire disasters [17][18], warning systems for potential tsunamis in Romania [19]. All-hazard warning systems frequently take the ambiguous form of nation-wide programs as: IPAWS Program in U.S. (Integrated Public Alert and Warning System) that joins a number of projects to create communications pathways providing public alert and warning functions [20]; NAPHM in Taiwan (National Science and Technology Program for Hazards

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Mitigation) aimed at organize the research and development efforts in the related government ministries in a more systematic way, to integrate the research results and to transform them into useful applications in disaster reduction, including the warning systems [21]; HazInfo project in Sri Lanka (Last-Mile Hazard Warning System) that was developed as a standards-based (CAP – Common Alerting Protocol) community information system, all-hazards, all-media alert and notification system [22].

Starting from the examples of the implemented systems at present, one can observe that these are generally organized on three main layers:

1) monitoring layer;
2) interpretation layer;
3) alerting layer.

Table 1

Logical layers of the classical warning systems

Alerting	*Examples* Radio/TV Broadcast, Internet, SMS, Reverse 112, sirens etc.
Interpretation	*Examples* Mathematical models, Differential analysis of images, Deformation blocks analysis etc.
Monitoring	*Examples* Weather radar, Satellite Images, Aerial Images, Rainfall monitoring, Seismic monitoring, Process sensors, bio-sensors etc.

From the three layers identified above, a critical one is the Interpretation layer, because we base on it the decision to launch an alert to the public and the precise determination of its recipients. Although advanced interpretation technologies and methods exist, the complexity of the problem may highly increase and practical solutions are often impossible. On the other hand, input data for the interpretation layer has to be as accurate as possible. From the difficulties a warning system may face we can enumerate the following: excessive alerting, misdirected alerting, false alarms, system scalability.

The contributions of this paper are the analysis of a wide spectrum of warning systems for emergencies, the identification of a general multi-layered model of these systems, the proposal to add a new layer to this model, the deduction of necessary support functions, the implementation of one of this functions, namely the rigorous geospatial alert definition function.

Further more, this paper is organized as follows: in section 2 we present the proposal to add a new layer to the model of emergency warning systems, in section 3 a few standards for alerting are mentioned and the three fundamentals elements that an alerting message must contain are established; in subsection 3.1 the taxonomy element is introduced and its issues are briefly considered;

similarly, in subsection 3.2 time element is introduced; in subsection 3.3 the location element is introduced and a method of representation is proposed; in subsection 3.4 the proposed structure is described; in section 4 we demonstrate that the proposal is a practical and easy to implement one; in section 5 we sketch the directions to follow.

2. Proposal to insert a new layer – alert correlation layer

One of the main problems of the current warning systems is that data interpretation is done locally. Also, problems of consistency, redundancy etc. may arise at the moment of independent generation, by each of the systems, of alerts. Because we think warning systems as distributed systems, it naturally appears the idea of the necessity for correlating alerts coming from different sources.

I therefore identify as necessary to introduce a fourth level, namely the correlation layer, through which the various systems communicate and harmonize the operating mechanisms. Issues that can not be evaluated based on computational models will therefore be supplied by introducing the communicational layer.

Table 2

Proposal to insert the correlation layer into the model of the alerting systems

Alerting	As above
Decisional correlation	*Examples* Data from flood warning systems and data from earthquake warning systems represent significant information for the landslide warning systems; data from earthquake warning systems represent significant information for the warning systems for production plants etc. etc.
Interpretation	As above
Instrumental correlation	*Examples* Similarity analysis, manifestation patterns, favorable conditions, consequences, causality etc.
Monitoring	As above

The functions of the logical layer *correlation* can show their utility in two points: the decision to formulate an alert about an individual phenomenon may be strengthened if we have a broader perspective on other phenomena that have, had or may occur within the environment; we called this stage *instrumental correlation*; in a later stage, which we called *decisional correlation,* having available a broader set of alerts, we can derive at a higher level new forms, causality relations, incompatibility, dependence etc.

It is though necessary to firstly create the prerequisites and the framework in which above mentioned analyses to work; the warning message or alert is the carrier of all the parameters that describe the reported event. Warning messages, as they are standardized at the moment, do not transport and do not contain the information accordingly to the strong requirements that a correlation level would have.

Precisely these problems are the ones that we try to highlight here and to provide them with a solution by the introduction, into the alerting systems theory, of certain elements to support the specific functions.

3. What, when, where? Three fundamental questions about alerts, for which it have to be found an answer, in the presence and with the help of IT systems

We advanced in a previous article the idea of using IP networks and the Internet in general as a medium for transmitting alerts [23]. It appeared, in an early stage, the need to discriminate between the traffic represented by emergency messages and the other types of traffic, in order to grant the first one a higher level of priority over the rest of the traffic, for this purpose applying a mark on the IP packets from the structure of emergency messages. Alert messages may originate from different sources and may differ both in the form of representation and as the nomenclature. Since alert messaged may be encoded in various formats, each alert should be translated into a standard format that is recognized by the correlation process. This translation is called *normalization* and requires that the syntax and semantics of sensor alert to be recognized.

The need for interoperability in the alerting field is affirmed by the elaboration of a series of open standards like EDXL, CAP, TSO, some already adopted as OASIS standards. The alerting message has to be complete, self-describing and interoperable. In the next sections we will try to sketch or to provide a more complete answer than the one given by the mentioned standards, for three apparently simple but essential questions, regarding the content of the alert message and the possibility to process it in an alert correlation system: what event is alerted, the moment of time it occurs, the place where it happens.

3.1. The need for a taxonomy of events

The alert correlation process receives input data that differ both in substance and in the way content is represented. It is therefore necessary to transform these messages, outside of the correlation process or in one of its early stages, into a well-defined standard format that is understood by the following stages of processing.

Regarding the standardization in the space of names of the alerts, the agencies involved in the emergency management can agree on a common framework of alerting by which an inventory is made and all types of possible events that must be alerted, along with their characteristics, are specified. Information technology tools can support this task both at the conceptual level, for example by ontological representations, and at the implementation level, by dedicated software to store and publish these representations.

In the example below, a simple representation for the class of resources of type *flood alert* is imagined, using the RDF (Resource Description Framework) Schema formalism:

```
<?xml version="1.0"?>
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xml:base="http://www.emergency.dom/alerts#">
<rdfs:Class rdf:ID="alert" />
<rdfs:Class rdf:ID="flood_alert">
  <rdfs:subClassOf rdf:resource="#alert"/>
</rdfs:Class>
</rdf:RDF>
```

3.2. The time problem in the alert correlation process. Method of ordering at the message level

For a correlation system, it is very important that the temporal information bounded to the reported event it is known. From the correlation system point of view, the temporal sequence of activities that lead to the creation of an alert is as follows: an event is detected to start, an alert is created, the alert is transmitted to the correlation system. Subsequently or during the process, the end of event is detected. There were already highlighted four temporal elements: the moment the event is detected, the moment the alert is created, the moment the alert is sent and the moment the event ends.

Because the system where messages are exchanged is a distributed one, where messages originate from various sources, a new problem that arises it to correctly establish the temporal precedence of events. It is possible for a sensor X to associate an event A a timestamp later than the one that a sensor Y associates to another event B, however the event A to occur before event B (perhaps simply because the clock of X is later than the clock of Y). Among the obvious solutions to this problem one can state synchronization with precise time servers and the use of the time moment immediately before the emission of alert as reference time, by the correlator. We shall not forget though that in discussion here are emergencies, when problems like delay, delay variation or network congestion must be paid attention. It can happen for some messages to arrive late, others to arrive out-of-order and others to not arrive at all, which would cause real problems for the correlation phase.

A solution to determine the correct order of messages is the use of logical timestamps, solution introduced by Leslie Lamport since 1978 [24]. In the cited article the problem of temporal sequence of events is examined and an algorithm is described which can be used to correctly establish the temporal order in which events occur.

A distributed system is comprised of a collection of distinct processes which are spatially separated and which communicate one with another by exchanging messages. In a distributed system it is sometimes impossible to tell which of two events happened first.

Thus the relation "happened before" is only a partial ordering of events in the system. Lamport uses the concept of logical clock as a simple number associated with an event, where the number is interpreted as the moment at which the event occurred. More specifically, for every process *Pi,* a clock *Ci* is defined, as a function that associates a number *Ci(a)* to every event *a* of that process. If an event *a* occurs before another event *b*, then it must happen at an earlier *time* then *b.* This condition is called *The clock condition* and formally is written as follows: if *a* occurs before *b*, than: $Ci(a) < Ci(b)$. For the system of clocks to meet the condition, the processes must obey the following three implementation rules: (1) Every process *Pi* increments its *Ci* between any two successive events; (2.a) If an event *a* is the sending of a message *m* by process *Pi*, then the message *m* contains the timestamp $Tm = Ci(a)$. (2.b) After receiving a message *m*, the process *Pi* sets *Ci* as the maximum of current value and *Tm* incremented by one unit.

The idea we propose here is that alert systems should implement the above described algorithm. For this purpose, the alert message has to transport the logical timestamp. If the layer from the TCP/IP stack, suitable to be used to mark messages for prioritization in IP networks, was the IP Layer, now the layer that seems to be appropriate is the Application Layer. Thus, the XML message structure will be added the <LOGICAL_TIMESTAMP> item.

```
<LOGICAL_TIMESTAMP>31283913</LOGICAL_TIMESTAMP>
```

3.3. The place problem

A special component of an alert message is the geographical area where the content of the alert is bounded. Standards mentioned above include in the message structure elements of geographical separation, though not always sufficient for the precise specification of the shape of each region. For example, CAP standard contains the element *area*, which can describe from geographical points, given by WGS84 latitude and longitude coordinates, shapes of type point, polygon or circle, and specify a geographical code (for example the address) and the minimum and maximum altitude of the region where the alert is valid. EDXL standard encloses the element *targetArea*, which permits to similarly describe shapes of type point, polygon or circle, a country by specifying the county code ISO 3166-1 or an administrative subdivision by specifying ISO 3166-2 code.

Using only this elements it's hardly possible to completely describe any geographical area. There are more precise ways to represent areas on the surface of the Earth, provided by Geographic Information Systems. Therefore we propose the introduction into the structure of alerting messages of certain elements to completely specify the geometry of the geographical shape which the alert is about. Specifically, those require:

a) Specification of reference system – Spatial Reference System Identifier SRID (for example SRID 4326, for WGS84 latitude/longitude coordinate system);

b) Specification of the envelope of the shape, a rectangle specified by the coordinates of the lower left corner and the ones of the upper right corner, where the shape falls and which bounds the shape;

c) Specification of the geometric shape of the region referred by the alert. This can be specified in an open format like WKTGeometry (Well-known Text Representation for Geometry), humanly readable, or its binary equivalent WKBGeometry (Well-Known Binary Representation for Geometry).

WKT for Geometries is a textual language for representing vector geographical objects. With its support one can represent points, lines, polygons, triangulated irregular network (TIN) and polyhedrons. An object can contain several different geometries of the same type in the so-called multi-geometries and geometries of different type can be grouped into collections of geometrical objects. Coordinates of the geometries may be interpreted as 2D (x, y), 2D m (x, y, m), 3D (x, y, z) or 3D m (x, y, z, m) shapes, where x and y are horizontal coordinates, z the vertical coordinate and m is a measure used to store routing data in a linear reference system.

Its binary equivalent, WKB, provides a portable representation of a geometric shape at machine level, as a continuous string of bytes. It is obtained by the serialization of a geometric object as a sequence of numeric types from the set {Unsigned Integer, Double} and then serialization of each numeric type as sequence of bytes using one of the two standard and well defined representations for numeric types (NDR - Network Data Representation, XDR - eXtended Data Representation) [25]. The binary coding that is used is specified by an byte which precedes that bytes serialized. The only difference between the two representations is the byte order, in NDR coding the most significant byte is the last (Little Endian) and in XDR coding the most significant byte is the first (Big Endian).

The two formats are specified using the BNF notation (Backus-Naur Form) for context-free languages in standard OGC 06-103r4 [26]. In this document, one can also find WKT examples for various geometrical shapes.

The next figure exemplifies the Well Known Binary Codification, in NDR variant (B=1), for polygons (T=3) with two linear rings (NR=2), each of them being determined by three points (NP=3) [27].

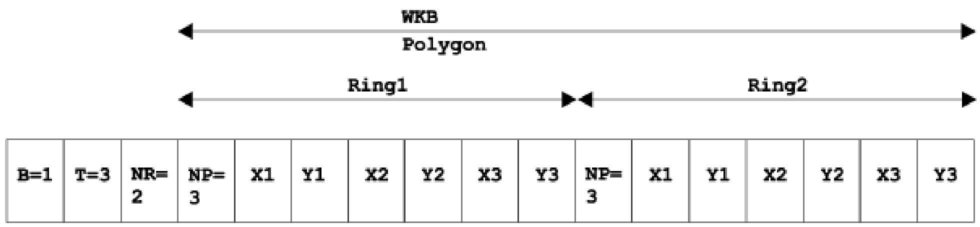

Fig. 1. Example of WKB codification

We propose the creation of the element *geo_spec* (Geographical Specification) within the structure of the alert messages, as a container for geographical information. Bellow is presented the geographical component of a sample alert message, as it would look like for a triangular (fourth point is the same as the first, closed polygon) region from the city Ploiesti, Romania:

```
<?xml version = "1.0" encoding = "UTF-8"?>
<alert xmlns = "urn:oasis:names:tc:emergency:cap:1.1">
...
<geo_spec>
<srid>31700<srid>
<minx>579499.188955933</minx>
<miny>384047.558379211</miny>
<maxx>579827.854100149</maxx>
<maxy>384529.091032352</maxy>
<wktg>polygon ((579499.188955933 384383.866898865,579827.854100149
384529.091032352,579766.707096573
384047.558379211,579499.188955933 384383.866898865))</wktg>
<wkbg>010300000001000000040000001d5be6056af21410856b477ff7517415f
9d4cb5e7b12141bb95375d44781741e08f086a6db1214188c2c73bbe70174101d5
be6056af21410856b477ff751741</wkbg>
</geo_spec>
...
</alert>
```

Interpretation of *wktg* and *wkbg* elements from above is according to the open standards.

3.4. The DOM for the geographical component of alert message

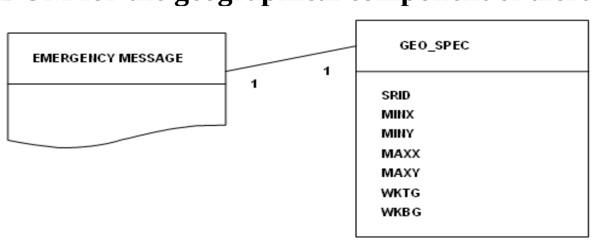

Fig. 2. DOM model of emergency messages

SRID is an integer number, *minx, miny, maxx, maxy* are decimal values and *wkbg* and *wkbt* are stored as strings.

4. Practical validation of the proposal on the spatial dimension of the message

Obviously the values listed above are difficult to manually specify and manage. For easy inclusion in the alert message structure of the shape of the area covered by the alert, we must base on the tools provided by geographic information systems.

Further on, we are going to validate the practical character of the proposal on the GIS component of the alert message, by implementing it in a software application of type emergency alerting dispatch center. Marking an area in an emergency situation has to be done considering both the place where the event occurs and the place that is affected by that event (not always identical). Without restricting the generality degree of the proposal to include a precise geographical area in the alert message structure, we can assume, in the context of the application, that the warning is done considering the place where the event occurs.

A possible use case scenario of the application is the following: a gas station from Ploiesti, located on Soseaua Vestului street, telephonically alerts 112 that a failure happened in one of the gas pumps, which led to a massive fuel leak, resulting in high fire risk. At this time an alert should be placed, either by the 112 operator, or by another specialized agency, with the help of an alert dispatching application and recorded in a database used by the National Information System for Emergency Alerting. Further away, the alert begins a suitable management process, that includes the correlation phase and can complete with its exposure on the Internet as Web service and alerting, by any other available means, the persons in danger.

The emergency alert dispatcher application is built on a 3-tier architecture using open technologies. For map generation the server used is Mapserver [28], and for alert storage a relational database engine is employed, namely Postgres [29], which was added the Postgis [30] extension to enable spatial functionalities. Auxiliary maps and functions are accessed via web services freely available on Internet (OpenStreetMaps, Google Maps, Bing Maps, Yahoo Maps). The web server used is Apache and the server programming language is PHP, with Mapscript extension. On the client side GeoMoose application is used [31], which includes functions from the OpenLayers [32] javascript library.

Romania is in the process of creating its own spatial data infrastructure, by implementing the European Directive INSPIRE (Infrastructure for Spatial Information in Europe) [33]. In place of or in conjunction with the maps and map tools mentioned above, but by similar methods, could therefore be used, in a possible national implementation, data much more current and accurate, available through this infrastructure.

Back to the alerting scenario from above, we assume that the information about the massive fuel petrol leak at gas station was confirmed. The dispatcher will search the gas station in question on the map. In this example the search is based on postal address, using Google's geocode service. In a real implementation it is necessary to use a dedicated service, but on the same principles.

With the help of the service, the gas station was located on the map. At this point other layers and information from the neighborhood of the gas station can be visualized, information that helps creating the so-called common operational picture, and the operator can proceed to mark the danger zone. In this case, the marking is done by drawing on the map the shape of the zone, simultaneously with the completion of certain other data fields representing information associated with alert (name, type etc.).

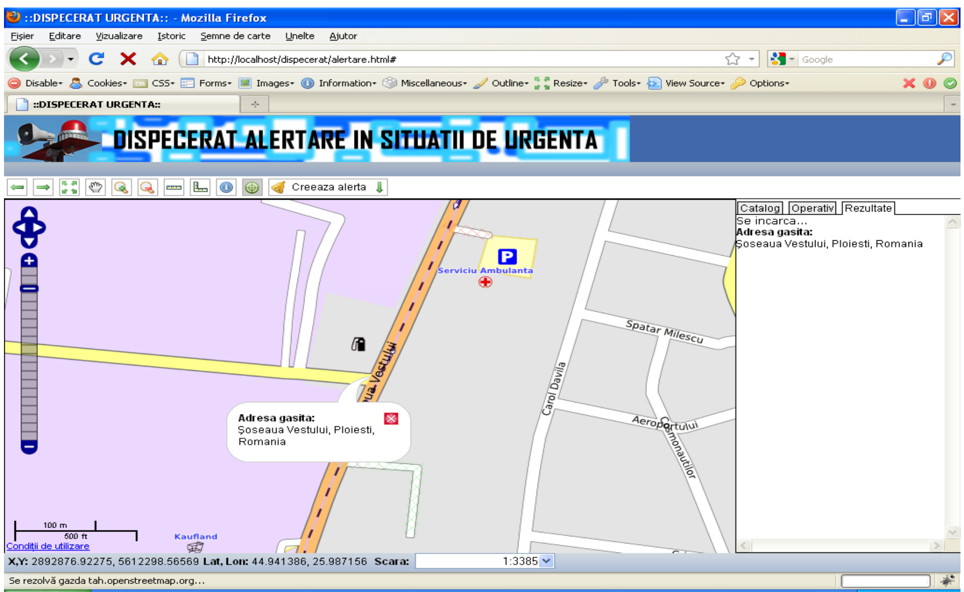

Fig. 3. Localization of the searched address, where the event occurs, on the map

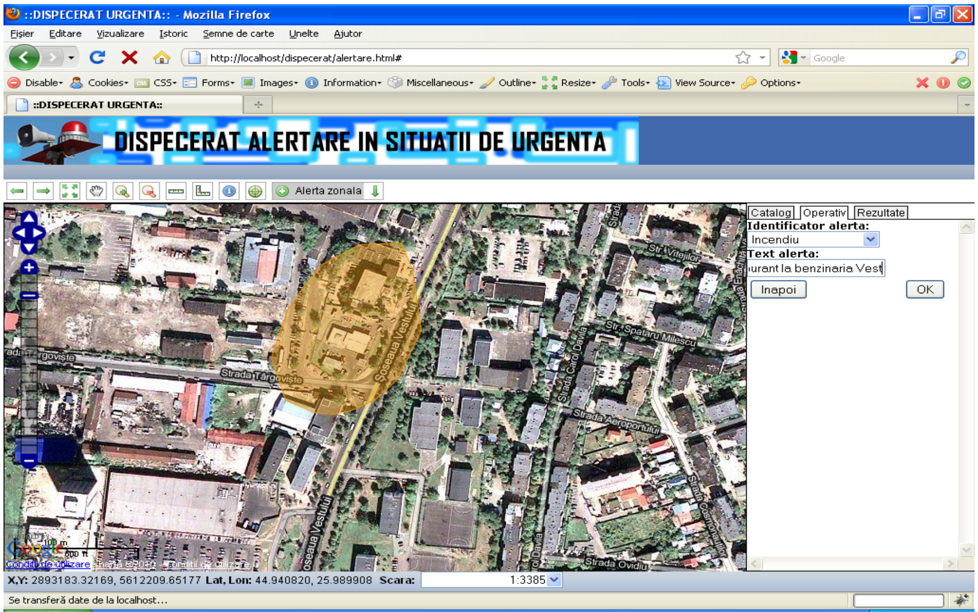

Fig. 4. Drawing of the alert of type polygon on the map, with the tool provided by the application

Now this alert is rigorously spatially defined and stored in a database with GIS capabilities.

Geographical component of the alert message that can be generated based on this record is as follows:

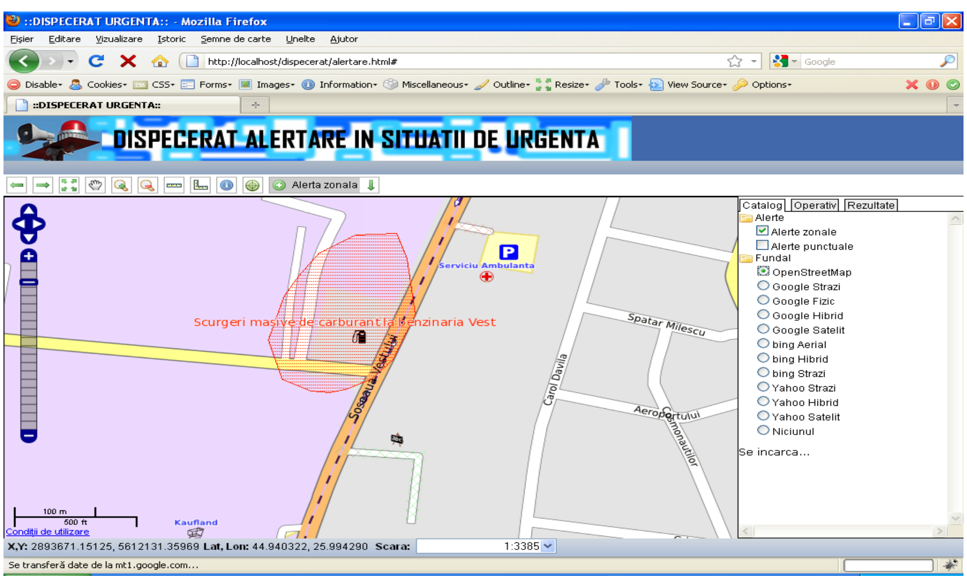

Fig. 5. Displaying on the newly created alert on the map

Both WKTG and the Envelope can be deduced from WKTB, however it may prove useful to have coordinates in clear text, thus being able to locate them on a paper map when missing a computer with GIS capabilities. In the above example, the coordinates are represented in Web Mercator reference system, the one used by Google Maps (EPSG 900913), but they can be reprojected in the national system Stereo 70 (EPSG 31700).

5. Conclusion and further work

In this paper we proposed the idea of introducing the correlation layer into the structure of early warning systems for emergencies. There is no question about the fact that the processes taking place within those systems must be conducted in the presence, and more, efficiently making use, of computer tools. We proposed to complete the model of alerting messages with elements addressing the typological delimitation of alert, the temporal delimitation and the spatial delimitation. We detailed the proposal on the spatial delimitation and we implemented it in an application for emergency alerting, using tools from the area of geographic information systems.

Further on, the problems to be solved are the need for an ontology of alerting messages and the aspect of events' temporal delimitation, possibly using logical timestamps. All these ideas, along with others that we previously introduced, like the marking of IP packets from the emergency messages structure, for prioritization (emergency signaling through Internet infrastructure), could then be used in elaborating a complex system for emergency alerting.

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