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Embedding a geographic information system in a decision support system for landslide hazard monitoring

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SUMMARY

In this paper we present an application that exploits a geographic information system as a front-end of a complex information system supporting the management of landslide hazard in Valtellina, an alpine valley in Northern Italy.

A decision support system (EYDENET, operational since October 1996), incorporating a geographic information system and a data interpreter based on artificial intelligence techniques, processes the readings of the 250 most significant instruments of a monitoring net of about 1000 sensors installed on different landslides in several alpine valleys.

Data gathered by extensometers, clinometers and pluviometers, to check both movements of rocks and climatic conditions which could affect them, are processed by EYDENET, that provides on-line interpretation of data, helps the users analyse them, and generates natural language explanations and alarm messages for the people responsible for the environmental management and the civil protection.

KEY WORDS: Landslides; safety management; major hazard early alarm/prediction systems; automatic monitoring; Geographic Information Systems (GIS); Decision Support Systems (DSS); Artificial Intelligence (AI)

SUBJECT: Hazard phenomena: L. Landslides;
Preparedness and Countermeasures: 3. Data analysis and risk assessment; 4.2.3. Warning systems

SHORT TITLE: Embedding a GIS in a DSS to monitor landslides

THE CONTEXT: LANDSLIDE HAZARD MANAGEMENT

In the summer of 1987 a ruinous flood affected large areas of the Valtellina (Northern Italy) and caused many landslides.

Debris flows dammed the Adda river in the evening of July 18, forming a small lake that reached a maximum elevation of 1062.5 m.a.s.l., approximately 10 m above the Adda riverbed, and an extension up to 266,000 m^2.

On July 19 the Adda river overflowed and partially cut the dam, reducing the extension of the lake to 124,000 m^2.

On July 28 a large mass of rock, estimated to be 34 millions m^3, suddenly moved down towards the Adda valley, destroyed the village of Morignone, fell into the small lake and generated a large wave that moved upstream and destroyed the villages of Poz, S. Antonio Morignone and Tirindrè, which had been evacuated some days before. Then the wave reached the village of Aquilone, approximately 2,300 m upstream from the unstable area, that had not yet been entirely evacuated, and as a result 27 people were killed (fore more details on the Valtellina landslides see Azzoni et al., 1992).

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THE MONITORING SYSTEM

To provide for the requirements stated above, ISMES developed an information system (INDACO) that comprises a real time automatic *monitoring* system, a *telemetry* system and a *data base* with processing functions[1].

[…]

ADVANCED SOFTWARE TECHNIQUES FOR SAFETY MANAGEMENT

In the last decade ISMES has been charged with developing several software systems to deal with different problems in the field of safety management, such as seismic vulnerability assessment of buildings, dam safety, monitoring of seismic and volcanic regions.

In this field artificial intelligence (AI) concepts and technologies can assist engineers by providing additional components to be integrated into existing information systems, which may perform *intelligent* processing of data related to safety management.

Therefore, for its safety management software systems ISMES used AI technologies, that provided powerful tools for the design of intelligent modules: causal networks of processes, qualitative modelling, model-based reasoning, hierarchical object-oriented representations were largely used.

[…]

[1] INDACO, a PC-based system, was originally developed for dam monitoring, and has been installed at about 40 sites in Italy and abroad for monitoring large dams and monuments.

A DECISION SUPPORT SYSTEM FOR INTERPRETING LANDSLIDE MONITORING DATA

EYDENET is a decision support system for the interpretation of data gathered by the hydrogeological monitoring system of the Valtellina (Figure 1).

EYDENET operates in real time and is linked to the automatic monitoring system; it processes the measurements of the main instruments of the monitoring network (about 250 sensors), providing a global interpretation and explanation of the state of the areas which are monitored and evaluating this state against a desired state.

[…]

To clarify the interpretation process, imagine that after the numerical processing, the following rules are applied:

```
IF   status WAS alarm
     AND rate of change 1 WAS second level
     AND rate of change 2 WAS first level
THEN status IS prealarm2
     AND index IS medium anomaly

IF   status WAS normal-to-prealarm2
     AND rate of change 1 WAS first level
THEN status IS prealarm1
     AND index IS low anomaly

IF   status WAS normal-to-prealarm2
     AND rate of change 1 WAS second level
     AND rate of change 2 WAS first level
THEN status IS prealarm2
     AND index IS medium anomaly
```

where *status* and *index* are the aforesaid parameters, *rate of change 1* is the variation of the measure over the 24 hours and *rate of change 2* is the variation of the measure over the 4 hours, both codified by checking them against a set of thresholds which define a quantity space (normal, first level, second level, etc.).

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As soon as the indexes for the instruments of an area have been set, other rules are applied to set the index of the area itself; they are used both to define the global state of the area and to filter false alarms, that is anomalies arising from a single instrument, but not supported by the behaviour of correlated instruments which should provide sufficient evidence for an abnormal situation. Although the interpretation process is rather more complex, for the sake of simplicity a rule can be rearranged like this:

```
IF    index of extensometer 303 IS medium anomaly
      AND
      index of extensometer 304 IS normal
      AND
      index of extensometer 305 IS normal
THEN
      index of area IS normal
```

The rule processor is also able to identify physical processes currently going on, such as rock falls, and assign to them an *activation index*, that is taken into account to define the global index of a zone. Moreover, whenever a process is active, EYDENET identifies the geographical zones that could be affected by this process (e.g., the sites that could be reached by a slide).

[…]

THE TECHNOLOGY

EYDENET was developed on a personal computer (Pentium) with MS-Windows 3.X using Visual Basic (main process, communication, numerical processing, interface), Prolog2 (evaluation and explanation), MapInfo (GIS) and Access (database). Visual Basic uses Prolog as a DLL (Dynamic Link Library), while shares data with MapInfo via OLE (Object Linking and Embedding).

EYDENET has been operational since October 1996 at the *Monitoring Centre for the Control of Valtellina*, set up by the Regione Lombardia at Mossini, near Sondrio; it is operated by a senior geologist and a team of engineers of the Regione Lombardia.

EYDENET is installed on a personal computer connected to a net of PCs, which form the distributed automatic acquisition system; it gets from them the data to be processed via a data server. The system is also connected to external acoustic devices (through serial port), to warn the people of the monitoring centre of alarm situations.

FUTURE DEVELOPMENTS

[…]

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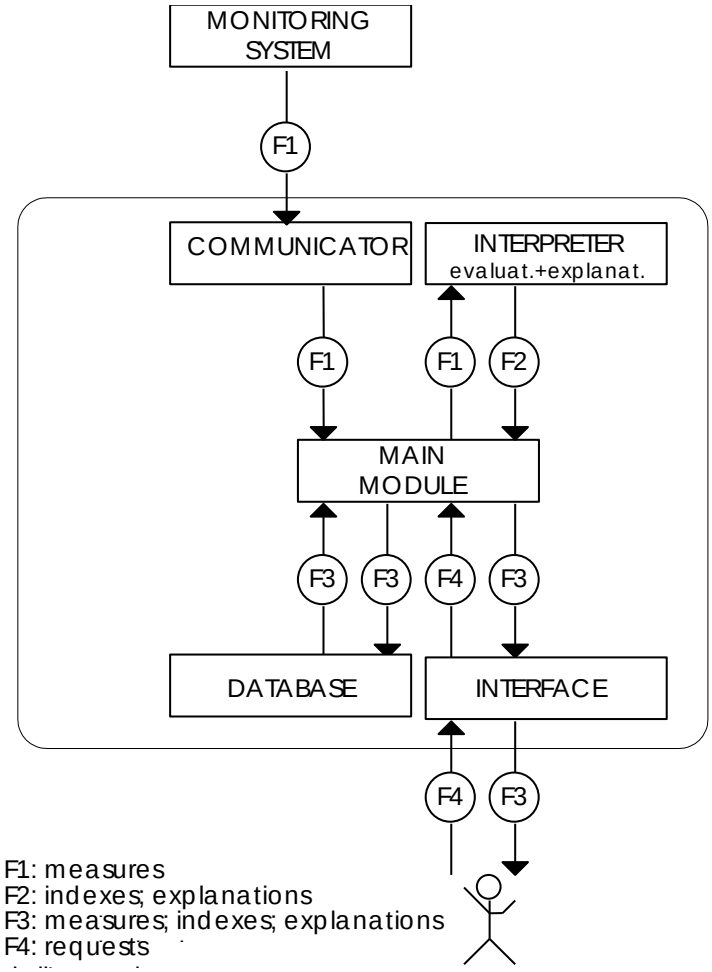

Figure 1 - The architecture of Eydenet

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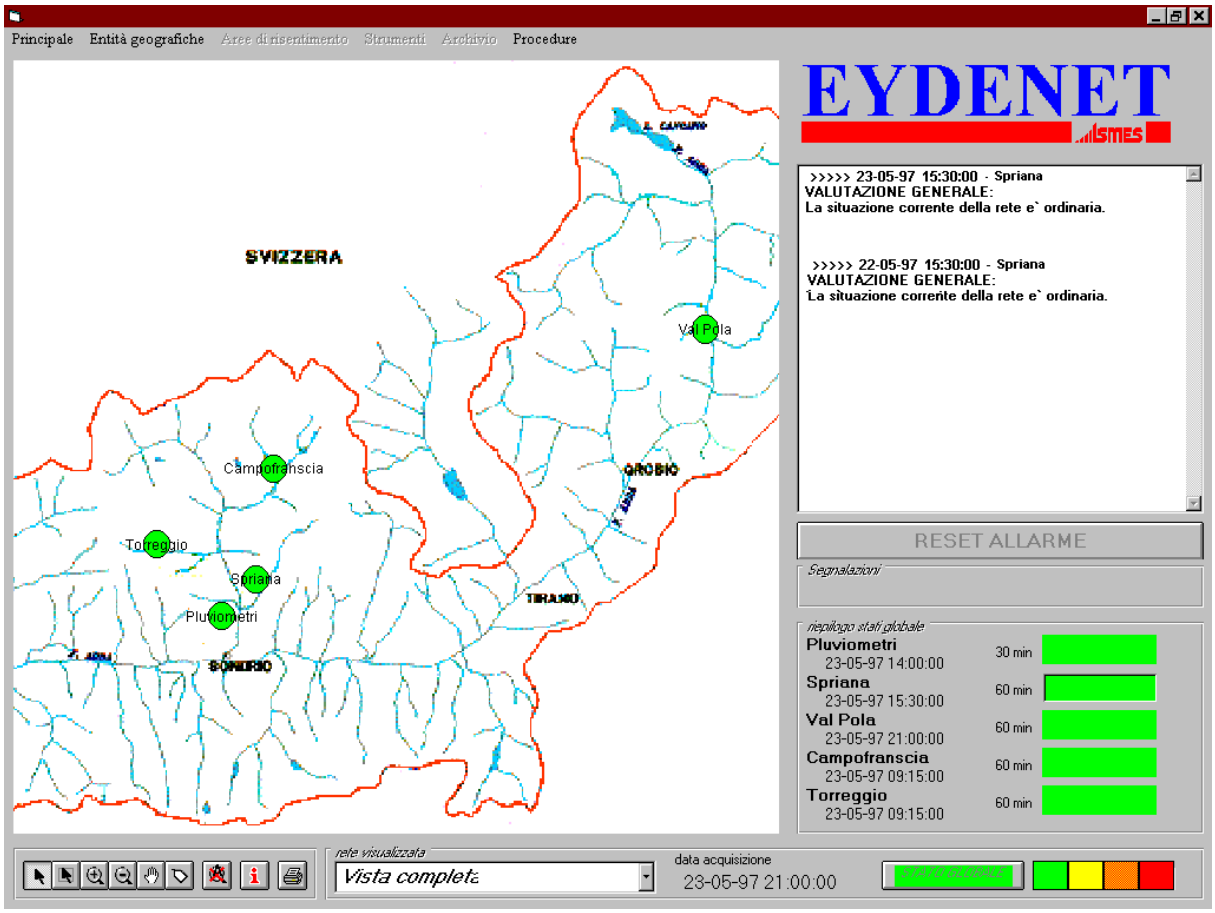

Figure 2 - Eydenet: the window-based interface

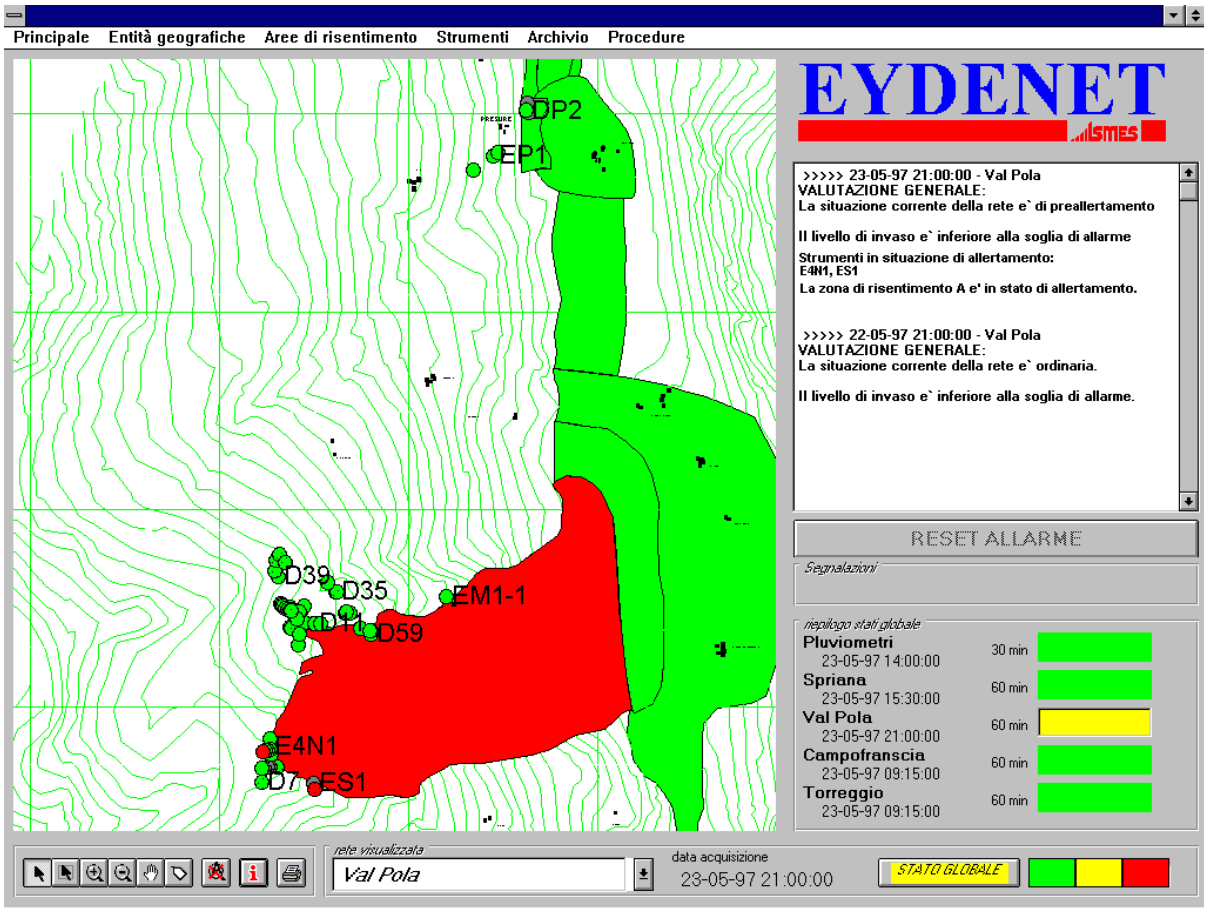

Figure 3 - Hazard level of zones

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