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TRANSFERRING HUMAN FACTORS KNOWLEDGE FROM AVIATION TO DEVELOPMENT OF A WARNING SYSTEM FOR LANDSLIDE

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There is a successful history of transferring knowledge from aviation to other domains such as medicine (Thomas & Helmreich, 2002). In this study the ICAO multistage alerting service (2008) served as model for the specification of an early warning system for landslide. The early warning system is designed to monitor mass-movement data provided by GPS sensors, and to generate warnings and alarms to the National Alarm- and Warning Center of Styria, Austria. For the human factors specification of the new system a qualitative analysis was performed. Results are discussed with regard to applicability of human factors guidelines from aviation to development of systems for regional alarming centers which initiate and supervise disaster management activities.

The change in earth climate leads to an increasing number of torrential rain events and the consequence of mass-movement events with different dimensions. As Austria is located within the inner Alpine regions its infrastructure and population are exposed to a certain danger. By now there is no adequate early-warning-system for such mass-movement events available in Austria. As Lettieri, Masella and Radaelli (2009) remarked in a review of international disaster management studies, the use of technologies based on satellites, ground sensors and specific decision support systems have been too less investigated until now. In the Projekt GeoWSN a real-time monitoring system with "Wireless-Sensor-Network" with GPS positioning technique is being investigated.

The multistage alerting service for search and rescue described by ICAO (2008) and implemented by member states was used as model for the specification of three warning stages for landslide. Originally, ICAO defines the uncertainty (INCERFA), alert (ALERFA) and distress (DETRESFA) phases, and specifies activation criteria for each phase and corresponding action plans.

Furthermore, human factors issues for the human machine interface were identified based on aviation human factors design standards published by the Federal Aviation Administration (Ahlstrom & Longo, 2003) and reviews of disaster management literature (Collins & Kapuku, 2008; Lettieri et al., 2009; Simpson, 2008; Uniyal, 2008; Kapucu, Arslan & Demiroz, 2010).

Method

For the human factors specification of the new system a qualitative analysis was performed with participation of thirteen members of the development team, including authorized rescue agents, experts in geology, navigation, informatics, communication technology and psychosocial crisis intervention.

A questionnaire structure was elaborated based on following sources:

- Applicable disaster management regulations and guidelines,
- A review of functionality requirements for technical systems (Bayrak, 2009),

- Organizational issues involved in disaster monitoring and management (Kapucu, Arslan & Demiroz, 2010; Collins & Kapuku, 2008; Jaques, 2010),
- Usability of the system (Chin, Diehl & Norman, 1988),
- Alarm thresholds with respect to the balance between missed and false alarms (Parasuraman, Hancock & Olofinboba, 1997), and procedures for false alarms.

Results

Alerting Phases

The multistage alerting service described by ICAO (2008) was used as model for the specification of three warning stages for landslide. The warning system for landslide should be implemented in alpine areas where there is a risk of creeping slopes over a longer period of time. In this case expert observers cannot be assigned for a long term to monitor the area, and the experience showed that the assignment of non-expert observers often leads to false alarms and waste of valuable time and resources. Thus, the new GPS-based system shall be implemented to provide objective data which are processed by the system according to a set of area-specific thresholds which are set by geology experts.

Similarly to the ICAO (2008) alerting service, in our study three warning phases were defined, including triggers and action plans. Of course, our triggers and action plans were specific for landslide. In the first phase there is monitoring, but unlike in aviation, this phase can last for a long period of time if the acceleration of the mass-movement does not exceed a specified threshold. In the second warning phase the mass-movement reached 90% of the threshold value and expert observers are sent to observe the area. The concerned emergency organizations and population are informed to expect landslide and access in the danger area is restricted. In the third phase of alarming, there is an acute danger of landslide and the population and emergency organizations are alarmed to activate their previously specified action plans.

Interface Design

This section addresses the application of human factors system design standards from aviation published by FAA (Ahlstrom & Longo, 2003) to disaster monitoring and alarming systems.

A closer look at working conditions of the agents in the alarming center showed that, the same as pilots and air traffic controllers, they monitor a large amount of systems in a dynamic, distributed and real-time environment. However, their systems did not reach the level of standardization we face in the aerospace branch. Especially displays for warning systems are provided by a multitude of sources with various design philosophies (Figure 1).

The agents have short response times and are expected within minutes to identify dangers and warnings, and to deploy the respective action plans. It is obvious that the display design for disaster monitoring, same as aircraft cockpit design influences the performance of the operator (Trollip & Jensen, 1991). Thus, we found that early warning, anticipatory cues and multiple coding of display indications, and multimodality of warning and alarms were key human factors requirements.

The use of colors for coding the warning phases was similar to the aviation standard: red for alarm, yellow for caution, green when no danger is detected by the system. The freedom in

Europe with respect to color coding of disaster warning can be seen in some other systems which use purple for the highest alarm phase.

***Figure 1.* “Cockpit” of the authorized agents in the alarming center of Styria.** Various warning systems are displayed on different monitors.

Systemstatus

Knoten	Sensorik	GPS
B	✗	✓
1	✗	✓

***Figure 2.* A model of the graphic interface of the early-warning system for landslide.** The display shows multiple coding of the system status.

Another example illustrated in Figure 2 is the multiple coding of system status indications which use both colors (green and red) and symbols (e.g. x for missing data flags).

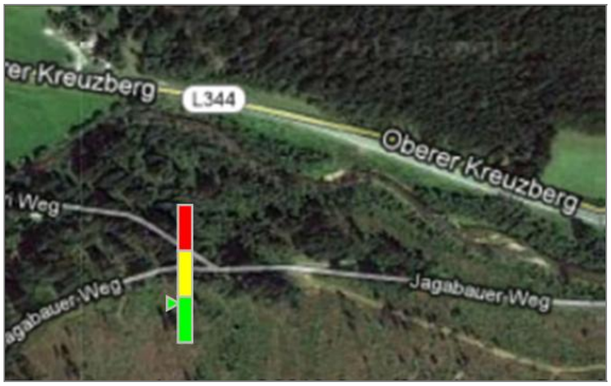

***Figure 3.* A model of the graphic interface of the early-warning system for landslide.** The display shows multiple coding of the warning phase.

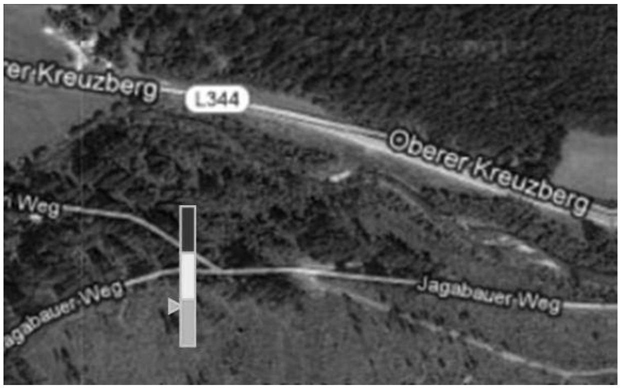

***Figure 4.* The same model of the graphic interface in gray.**

Furthermore, for displaying the warning phase we selected an indication similar to aircraft engine instruments (Figure 3), which indicates the actual warning phase and also allows anticipation. In this case the position of the arrow shows that the system currently does not detect any danger, but the arrow is near the threshold to the second warning phase indicating that a change might occur. Another benefit of this kind of indication is that it intuitively shows the degree of danger from low to high and it can be well interpreted independent of the color (Figure 4).

One reason for multiple coding is that although color coding has the benefit to speed up decoding of an indication (see Ahlstrom & Longo, 2003), there might be operators with color blindness who cannot rely on color codes alone. This issue is not so uncommon even among recreational pilots, but it is seldom considered by designers.

Furthermore, for warning and alarms a multimodal procedure was developed using besides visual display indications also aural cues, triggered by the communication equipment of the agents (e.g. SMS, Alarm-App).

Usability criteria of the human-machine-interface (HMI) of the warning system were specified in terms of functions, terminology and information, display modality, user concept and error tolerance which are not described here more detailed.

However, there were more human factors issues to be considered in developing the human machine interface of the system which required inputs from different experts who participated to the development: system functionality requirements and organizational issues. These are rather typical disaster management issues.

System functionality requirements

This section addresses system functionality requirements or what the agents should expect from the system in terms of accuracy, availability, redundancy, reliability, maintainability (Bayrak, 2009). For example accuracy of sensors was set at the range of 10 cm and data transmission failures of 5%. The capability of the system to identify and display data errors, as well as procedures for designing an error tolerant system, and abnormal procedures for technical failures that cannot be avoided were specified. Availability, derived from the time system is working divided by the time when the system exists between failures was set between 95% and 99%. Redundancy was specified in terms of redundant software and hardware to compensate especially for loss of components. Another critical feature to define was the system reliability, as lifetime of components or time to failure of a unit. Furthermore maintainability of the system was specified as a measure of the time within the system can be repaired after a failure.

Organizational requirements

This section addresses system features necessary for the organizations involved in warning and disaster management. From organizational point of view system performance factors were considered the connectivity to and the availability of a commonly accessible pool of information using a web interface (e.g. chat-room, messaging, photo-sharing). Furthermore, connectivity with another system providing demographical and strategic infrastructure information was considered.

Discussion

Generally results are supportive for the applicability of human factors system design standards from aviation to disaster monitoring and alarming systems. However, this should not be seen as an over-generalization. Disaster management is a growing research field with specific domains, actors and regulations. Besides the scientific approach, other factors and interest areas (e.g. political, economic, social) play a major role on interpretation, prevention and management of disasters.

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