ONLINE DECISION SUPPORT TOOL FOR AVALANCHE RISK MANAGEMENT

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ABSTRACT: The Avalanche Warning Center Tyrol (Innsbruck, Austria) together with the Department of Geography and Regional Research at the University of Vienna have developed a complex and very powerful database driven online decision support system for visualization and analysis of current avalanche relevant factors in the Tyrolean Alps. In order to understand the avalanche situation it is important to have spatial coverage of meteorological and snow pack factors as well as information covering the avalanche danger scale and topographic situation. All information can be interactively made accessible to the user and includes for example current snow depth, amount of snow accumulation within the last 24 hours, temperature, wind speed and direction as well as the regional distribution of the avalanche danger scale including height and temporal dependencies. Spatial depiction of this information can help comprehend the situation. The faster this information is made accessible the more useful it can be. One very efficient way of making use of spatial information is by incorporating GIS functionality (Geographic Information System) and cartographic expertise. This contribution will give an overview of the application as well as planned extensions and furthermore focus in the following areas:

- Environmental database decision support system – technical specifications, database design, online Internet access
- Cartographic expertise – conceptual structure, design aspects, restrictions, spatial depiction

Keywords: avalanche risk management, online information system, decision support system

1. INTRODUCTION

One of the main duties of all Avalanche Warning Center's today hasn't changed since their foundation – prevention of avalanche fatalities by informing the public about the current snow and avalanche situation in different specific regions. The big difference to former times is however the utilization of new possibilities and techniques of data-collection, spatial depiction and information transfer.

The Avalanche Warning Center Tyrol has developed to a high tech institution with comparatively high-quality standards. Due to sufficient financial support by the local government there is not only an exhaustive network of observers but also one of the highest densities of high-alpine automatic weather stations in the world (see figure 1).

Since the first construction of such weather stations a lot of experience has been achieved. Surprisingly enough their reliability in severe conditions is amazing, however their limits become also visible under such circumstances. In order to receive reliable data, which is one of the bases for our work and the herein described developments, a comprehensive analysis of every potential location has to be undertaken before building them. The succeeding correction of data even with special software is much too time consuming and imprecise.

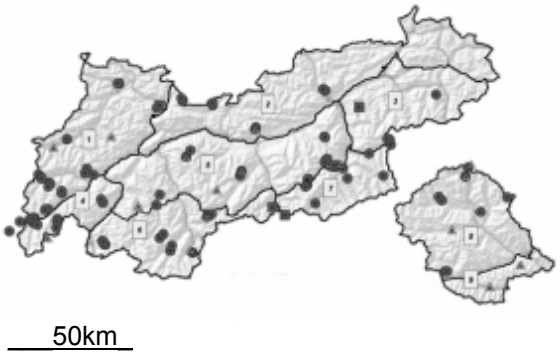

Figure 1: The dots represent the dense network of high alpine weather stations, the triangles the network of the official observers in Tyrol (12.647 km^2), Austria

Three years ago the Avalanche Warning Center Tyrol started a very fruitful collaboration with the Department of Geography and Regional

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Research at the University of Vienna. At the beginning we had to concentrate on verifying and formatting the available meteorological data. The next step was the automatic transfer of confirmed data by the Avalanche Warning Center to the Department of Geography and Regional Research. The Department itself developed an online decision support tool where different types of maps are made accessible during the winter season for any given time period. Our aim is a faster and easier perception of important snow- and avalanche-relevant data. The results should assist the forecaster's work as well as support the user's needs and hopefully help reduce avalanche accidents.

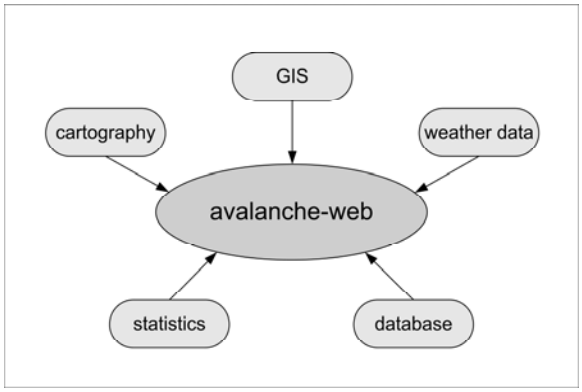

Figure 2: General overview of the modules incorporated in the installed avalanche-web online decision support tool at the Department of Geography and Regional Research

2. DATA and SPATIAL VISUALIZATION

The amount of data for evaluating avalanche danger has increased incredibly during the last decade not only for the avalanche forecaster but also for the people in the backcountry. Due to this fact it was a logical consequence that avalanche forecasters sought after new ways of optimized forms of spatial representation of all significant available data.

It has to be taken into account that there are different demands and tasks for different users. The avalanche forecaster for example needs primarily very detailed information. Well summarized information is very important and helps the forecaster gain a good overview about regional processes. Whereas the general user of the Avalanche Warning Center's products can primarily be satisfied by easily understandable and well prepared information such as maps.

In the end there are two groups of data; "basic" data which can easily be provided by the team of the Avalanche Warning Centers. Basic data can be for example ASCII-files, documents, tables or graphics in different resolutions and complexity from sources, like automatic weather stations, observers, local weather services and forecaster's surveys.

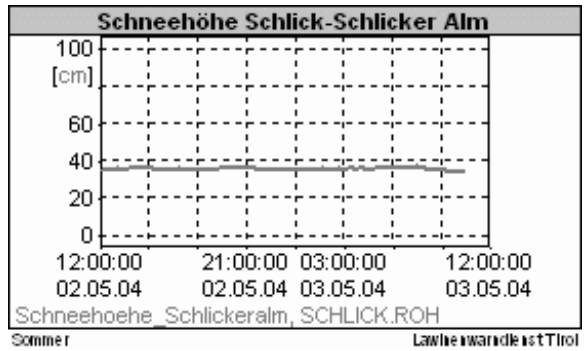

Figure 3: "Basic" information – graphical depiction of a weather station's total snow-height

On the other hand there is "derived" data, which is mainly created in collaboration with other experts, such as cartographers - for example maps or illustrations.

Currently the Avalanche Warning Center offers 6 different types of maps on www.lawine.at/tirol or www.avalanche.at/tirol;

- 4 maps representing a time dependent snow distribution (current situation and past 24h, 48h, 72h difference)
- A temporal animated distribution of the avalanche danger scale for 9 different regions
- Distribution of slope-angles for Tyrol in individually selectable scales

2.1 Maps representing the snow distribution in Tyrol

In order to automatically produce high quality spatial depiction of avalanche relevant features such as the temporal maps on snow height in Tyrol it is important to have access to high quality data. These maps are computed by utilizing up to 40 different simultaneous measurements of snow heights all across Tyrol. At the beginning of the winter season 2004/2005 it will be furthermore possible to additionally import data from newly setup automated weather stations as well as manually captured snow data from observers around Tyrol. This will

be one further step in achieving a high quality end product. In case of incorrect data weather stations can easily be removed out of the automatically generated input process. During the winter season there are 4 maps which are created 3 times daily depicting the total snow height and the total snow height's differences during the last 24, 48 and 72 hours. All maps are available in two different sizes on the Internet.

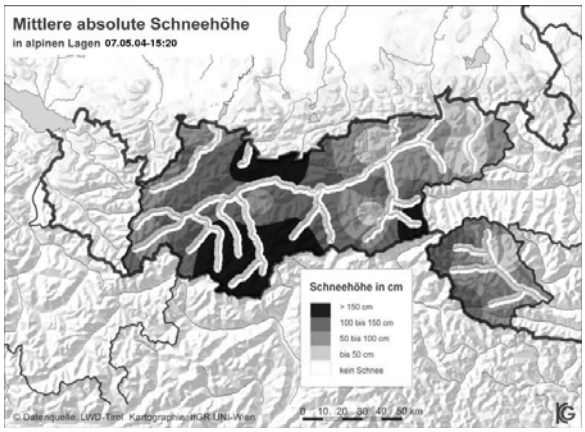

Figure 4: Distribution of the total snow height in Tyrol

2.2 Maps representing the regional avalanche danger scales in Tyrol

The quality of avalanche bulletins has increased parallel to the increasing amount of data. 10 years ago for example Tyrol was not even divided into different regions. There was only one danger degree for the whole area with few regional specifications which had been written down in the bulletin.

Nowadays Tyrol is divided into 9 regions where each region has similar weather, snow pack and avalanche conditions. Up to now we used a simplified illustration of danger scales.

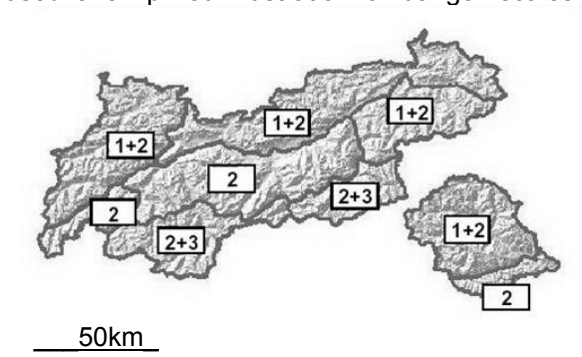

Figure 5: Simplified illustration of the regional avalanche danger scales in Tyrol

The disadvantage of this illustration (figure 5) is the fact that "x+y" can have different meanings. On the one hand it could have characterized a time-dependency (lower degree in the morning, higher one in the afternoon or opposite). On the other hand it could have referred to a height-dependency (lower degree in deeper areas, higher one in higher areas or opposite).

During the last winter season intensive testing of different spatial and numeric depiction methods was undertaken. The goal was on the one side to create a high quality input data structure which could automatically address all situations mentioned above. On the other side this structure had to be convenient for spatial depiction. The result was an XML-file which is now always being automatically generated during the configuration of the current avalanche bulletin. This file is then transferred to the Department of Geography where different types of maps are produced in batch mode within a few minutes. The user is then able to view them on the Internet.

The big challenge was how to represent a temporal feature such as time dependency unmistakably and plausible on the web. The problem was solved by generating two maps, one representing the earlier, the other representing the later situation. Both maps are then combined and animated using simple browser independent web-utilities showing a clear and readable dynamic map.

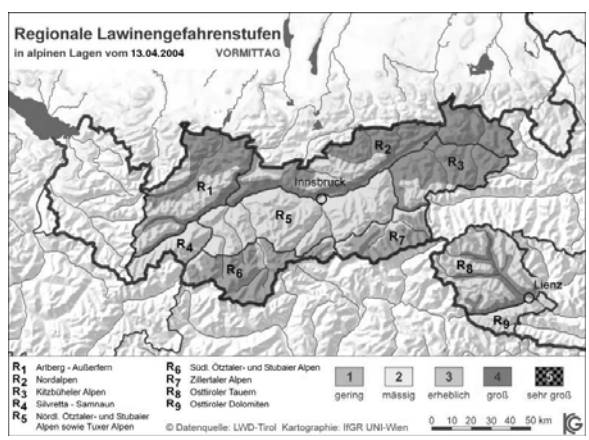

Figure 6: Example of a regional avalanche danger scale in Tyrol; colored, height- and time-dependent examples can be viewed at www.lawine.at/tirol or www.avalanche.at/tirol

Height dependency was the second feature that was additionally introduced in the spatial depiction. This feature was incorporated by utilizing adaptive GIS functionalities using a scale dependent DEM (digital elevation model) combined with the new XML-file structure.

2.3 Maps representing slope-angles in Tyrol

Rule-based decision support tools are currently a hot topic in Europe as well as in the US and Canada. By checking and combining a few major avalanche relevant factors, such as the actual avalanche danger degree of a specific region and the distribution of slope angles within this area the user can statistically reduce the risk of being involved in an avalanche casualty. This development is one of the reasons why people emphasize nowadays more on a good trip planning with nicely prepared and accessible data than they did in former times. TIRIS, a governmental institution in Tyrol offers an online application that depicts slope angles in a resolution of 50 m based on the official topographic base map of Austria scale 1:50.000 for the entire region of Tyrol. Slope angles between 30°-35° are marked yellow, between 35°-40° orange and above 40° red. Scales are individually adaptable up to 1:20.000 and it is possible to navigate either graphically as well as alphanumerically by using place names. This enormous amount of data is managed by a database driven map-server, where the requested maps are calculated and presented on the fly.

3. DISTRIBUTION OF DATA

The Avalanche Warning Center of Tyrol uses and offers all available media for data distribution and collection: phone, fax, teletext, e-mail, SMS, MMS, pocket computers like MDAs or PDAs and Internet.

Statistics show that new technologies have become extremely important. Our access rates on the Internet for example doubled each year during the last winters.

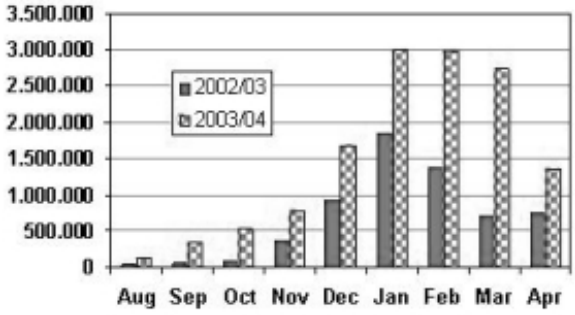

Figure 7: Access rates on Internet www.lawine.at/tirol, winter 2002/03 and 2003/04

That is also the reason why we emphasize our efforts in a perfect provision of data to those highly requested media. Our philosophy is that people who are going in the backcountry have to have access to all information which is needed for a comprehensive trip planning.

Figure 8: The avalanche report, graphs, maps etc. are also accessible via MDAs and PDAs.

3.1 Interactive maps, interactive tools

Last winter season the Department of Geography and Regional Research was able to present another forward-looking application. Instead of having different links to all the needed information an interactive application was created from where information can be accessed in a clear and structured way. Every user can independently put their maps and information together in order to help the decision support process best. In future this application can easily be expanded by incorporating other interactive tools. Such a tool is for example an application called WISKI-Web. Via direct access to our database everyone can individually assemble graphics of all the data from our weather stations

and observers. For a better insight we again refer to our webpage.

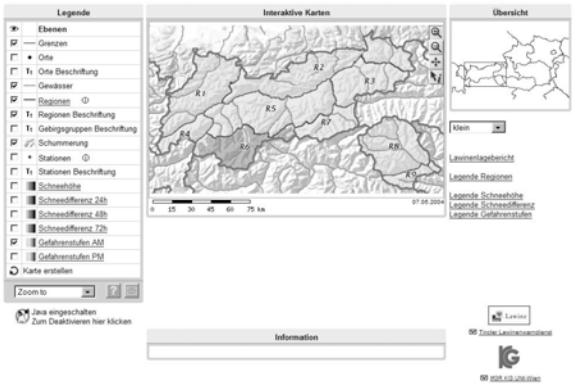

Figure 9: Example of the interactive online application - can be viewed at www.lawine.at/tirol or www.avalanche.at/tirol

4. TECHNICAL SPECIFICATIONS

The advantages of cartographic representations on the Internet can be seen in up-to-dateness, interactivity, spatial communication as well as efficient and cost-effective dissemination. In order to benefit from such an interactive communication platform for environmental strategic decision-support it is important to make use of automated cartographic procedures. This is possible by utilizing standardized cartographic methods with combined access to permanently available thematic geodata that allow the production of spatial output.

The following premises were taken into consideration for a web based avalanche prediction tool:

- An Internet interface as a portal for data retrieval and data visualization
- A structured and consistent database for storing thematic data
- Cartographic expertise for geospatial representation
- Basic statistics for surface interpolation
- Automatic weather data retrieval from external localities

Time plays an important role if up-to-date information must be transported to the user. If design and layout take up too much time cartographic output becomes worthless. In order to accelerate the procedure and keep the output time lag low operation of cartographic realization in batch mode can be utilized. With the help of such automated time-dependent systems short-updating cycles and high efficiency can be achieved.

In order to utilize a fully automated cartographic visualization workflow specific system components are needed. These components consist of a user interface for the World Wide Web, a system interpreter that controls the time-dependent procedural workflow of the system, graphic tools that enable a profound cartographic representation, thematic and geometric data that is either accessed internally or externally and stored in a database management system as well as a GIS that controls the interpolated surface creation.

Before a model of the system can be utilized it is important to address the main functionality of all applications within the system. The updating of the cartographic representations and the allocation for the Web are focal points of the system. These procedures are divided in time-dependent and user-controlled processes. A system-defined process that transfers thematic geo-located weather data to the internal system database controls the time-dependent process. After successful transfer of data the automatic cartographic procedure is initialized. Thereafter the user can retrieve this spatial information independently at any arbitrary time.

The overall system can be subdivided into six modules (see figure 10). These modules summarize the production workflow of the system and produce the spatial output. They are all - except for the cartographic template - initialized each time a request is started by the system interpreter. The workflow of the six system modules is defined as follows:

I Data transfer and data repository: Utilizing via ftp the weather data that can be located on one or more external servers is transferred to the system. Before the data is stored in the database, data plausibility is checked. During the plausibility check the individual values of the different weather stations are inspected. If ambiguous values or defective stations are detected they are not included in the data repository.

II Data extraction and data retrieval: Due to the variety of different maps that can be produced with the available data, precise data extraction and retrieval has to be undertaken. The obtained data is checked and then formatted for further processing with a GIS.

III GIS Modeling: The GIS imports the extracted sample data, transforms the coordinates to the desired projection and calculates a continuous value surface. The interpolated surface is then classified and colored according to predefined cartographic specifications. The result is exported as a geo-referenced image.

IV Image concatenation: The geo-referenced image is combined with the cartographic template by utilizing raster based graphic tools. These tools include image merging, layer cropping and text integration. The result is a cartographic depiction including primary and secondary map elements (such as scale bar, text, legend etc).

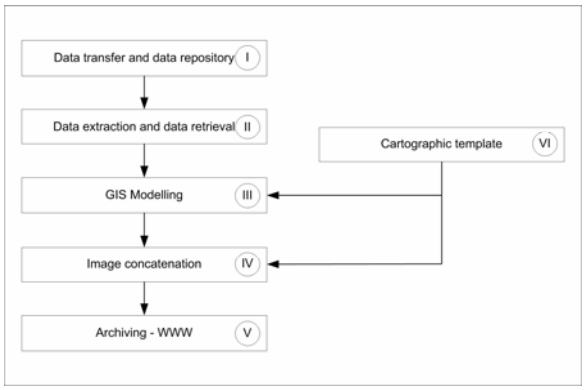

Figure 10: System modules of the avalanche decision support tool

V Archiving - WWW: The produced cartographic representations are saved as compressed images in an archive and posses a unique identifier that consists of a combination of the map type, date and time. The user can hence clearly identify each produced map within the system.

VI Cartographic template: The basic cartographic map elements and principles such as a base map, general layout and an appropriate legend are prepared externally and must be imported during initialization into the system as a static template that is used in combination with the GIS and image concatenation modules. It is important to mention that all spatial information within the system must be graphically adjusted and geo-referenced to this cartographic template.

5. SUMMARY

We are aware that our technical oriented developments in using modern media with well designed maps and illustrations can tempt people in carelessly reading the very important textual part of the avalanche bulletin. But still we are convinced that we can bear this disadvantage. It is comparatively small to the advantage that more and more people will be encouraged to deal with snow and avalanche topics by getting this easily understandable information. In this sense we hope that this contribution can prevent some more avalanche accidents with these efforts...