Computer Assistance in Avalanche Forecasting

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Extended Abstract

In this paper, I discuss two computerized modules for avalanche forecasting, including results of field testing and experiences with the products.

Avalanche forecasting consists of prediction of current and future snow stability. Current research at the University of British Columbia is aimed at changing forecasting from an intuitive art to a science. The approach is by developing numerical and expert system modules by using all the data available to a forecaster (numerical and non-numerical). The strategy can presently be defined in three parts:

I. An explanation of data classes available and their relation to the scale, character and formulation of the forecasting problem. For a detailed description of data classes in avalanche forecasting based on relevance, ease of interpretation and character (numerical or non-numerical) the reader can refer to Chapters 6 and 7 of McClung and Schaerer (1993). Therefore, I will not discuss this part further in this paper.

II. A description of the numerical portion of the system. This part uses discriminant analysis (both parametric and non-parametric) and Bayesian statistics to give estimates of the probability of avalanching based on calculations in 6 or 7 dimensional (depending on whether dry or wet avalanches are expected) discriminant space.

III. A description of the non-numerical portion of the system. This part consists of an expert system to interpret data from snow profiles with respect to snow stability. The expert system is entirely rule-based in contrast to the numerical algorithm in part II. The data analyzed are nearly independent of the data in part II. The data consist of the information contained in a standard snow profile including comments. See McClung and Schaerer (1993) for more a description of snow profiles and the information used.

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II. NUMERICAL PORTION OF THE SYSTEM

The data used in the analysis are numerical in character: snow, weather and avalanche occurrence information collected at regular intervals. An historical data base (about 10 years of records) is analyzed and compared numerically with the parameters measured at the time the forecast is sought. In addition, the forecaster's degree of belief about the probability of avalanching is converted into a probability to be combined in a dynamic (real time) sense to yield a 'posterior' probability which is used to issue warnings. Two years of rigorous, operational field testing with the system (1992-1994) show that the predictive capability of the system is very consistent: overall accuracy is about 80% (80% 1992-93 and 78% 1993-94). Accuracy (using posterior probability) during avalanche time periods is about 70% and during non-avalanche periods it exceeds 80% We believe that 20% error approaches the residual uncertainty in the avalanche forecasting problem. This error estimate is similar to that for weather forecasting. The consistency in our results has been confirmed in testing of over 500 time periods during two winters.

In addition, to giving a warning, experience has shown that the non-parametric discriminant analysis gives the forecaster highly relevant information about the snow, weather and avalanche activity for similar situations in the past (Nearest Neighbour calculations). Our system produces calculations of the 30 closest points (Nearest Neighbours) in discriminant space (6 or 7 dimensional for Kootenay Pass, B.C.) and we compare these closest situations in the past to the present situation defined by the input data vector. The calculations are made with the Mahalanobis Distance metric. This choice of metric eliminates the need for use of arbitrary weighting factors and it enables correlations among the variables to be retained. The analysis includes graphical display of the avalanche activity for the 30 Nearest Neighbours. This includes information about the avalanches in the past including: avalanche activity [sum of the sizes on the Canadian size scale, McClung and Schaerer, 1993], a moisture index [average moisture content of observed avalanches : dry, moist or wet], and information about whether the observed avalanches were natural or artificially triggered. We also have graphical display to compare the predictor variables for the present situation with any one of the Nearest Neighbours. For the latter graph, we used standardized variables so that all variables range over the same scale. Our experience shows that both the text output of Nearest Neighbours and the probability calculations and the graphical output are very useful to the operational forecaster. The details of the numerical system are provided by McClung and Tweedy (1994).

III. NON-NUMERICAL PORTION OF THE SYSTEM

Avalanche forecasters also use non-numerical information to forecast avalanches. In order to approach the accuracy achieved by forecasters through experience (traditional method without the use of computer analysis) we believe we must use the same 'data' sources they use. To encompass a large part of this information, we have developed a rule-based expert system (called Snow Profile Assistant) to interpret snow-pack structure with respect to stability. Since snow-pack structure is not considered in the numerical system described in Part II, the data analyzed in the expert system are nearly independent of those in Part II.

In contrast to the use of expert knowledge in a dynamic, Bayesian sense (Part II), one could describe the use of expert knowledge in this portion as static: rules are essentially fixed from one forecast to another. This portion of our system consists of non-numerical algorithms developed from rules gained from interviewing expert forecasters. The software was developed initially from influence diagrams constructed for slab and loose snow avalanche formation (both wet and dry). The influence diagrams and rule base were constructed by interviewing avalanche forecasters (as well as myself) in order to capture their reasoning with respect to snow profile interpretation. In addition, the rules were screened by me to make sure that the rule-base agrees with the physical processes with respect to our current understanding.

The input requirement for the system includes all the data from a standard snow profile including comments. Once these data are entered, the system operates by analyzing each snow-pack layer by itself and in combination with adjacent layers. For each layer, a cumulative relative certainty factor (a number between 0 and 1) is calculated (Pearl, 1988) as evidence about instability is accumulated. When the certainty factor exceeds a set threshold, information in either graphical or text form may be output to highlight the type of instability predicted (slab or loose snow) and the associated reasoning. Graphical screen output highlights any layer which exceeds the certainty factor threshold and text output is given for the layers with the three highest certainty factors which exceed the threshold. The reader is referred to a forthcoming paper (McClung, et.al. ,1995) for a complete description of the Snow Profile Assistant Program. The system was field tested in four field areas during the winter of 1993-94. This resulted in refinement of the rules to give a product which can be used operationally for assistance to forecasters.

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