LOCAL AVALANCHE FORECASTING IN SWITZERLAND : STRATEGY AND TOOLS. A new approach...

Robert Bolognesi, Othmar Buser, Walter Good [1]

ABSTRACT

Local avalanche forecasters have to take daily decisions like "I keep this road open", "No access to this valley today", or "The ski runs must be closed now". Such decisions are very difficult to take because of their human and economic impacts ! Since the 80's, the Swiss Federal Institute for Snow- and Avalanche Research is working on this subject, and has now developed a specific strategy and some tools to help practitioners. The main aspects of this strategy are : research, information, instruction, technical assistance, and coordination. Its strength comes from a constant communication between researchers who design instruments, sensors and software, and practitioners who test them and participate in the developments by giving their own ideas and a regular feedback. At the present time, a new diagnosis support system called NXLOG 2.0 is born from this cooperation. It is the result of merging two existant and proven systems: NXD which uses data analysis procedure (nearest neighbours method) and AVALOG which exploits artificial intelligence techniques. NXLOG 2.0 includes machine learning functions in order to improve its reliability as long as its database expands. It has been implemented on PC, and will run and be tested from the beginning of winter 1994-95 in about 20 European ski resorts (in France, Italy, Scotland, Spain, and Switzerland). In the near future, the system may be used by an increasing number of partners.

INTRODUCTION

What is local avalanche forecasting ? First of all, in order to speak about the same subject, this question must be answered and a strict definition must be given. We propose this one : *local avalanche forecasting consists in assessing the avalanche hazard for <u>each slope</u> of a restricted mountain area.*

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1. Swiss Federal Institute for Snow- and Avalanche Research, Davos, Switzerland.

Figure 1 illustrates what we mean : all winter long, the mayor of this village (Celliers, France) has to decide whether the road must be closed or not. So, he has to estimate the stability of the snowpack at the triggering point. Of course, no error is allowed in the sense that the road is open when an avalanche occurs. However, at the same time, he is under strong pressure to keep the road open because of its social and economic functions.
This is a typical field of application of local avalanche forecasting.

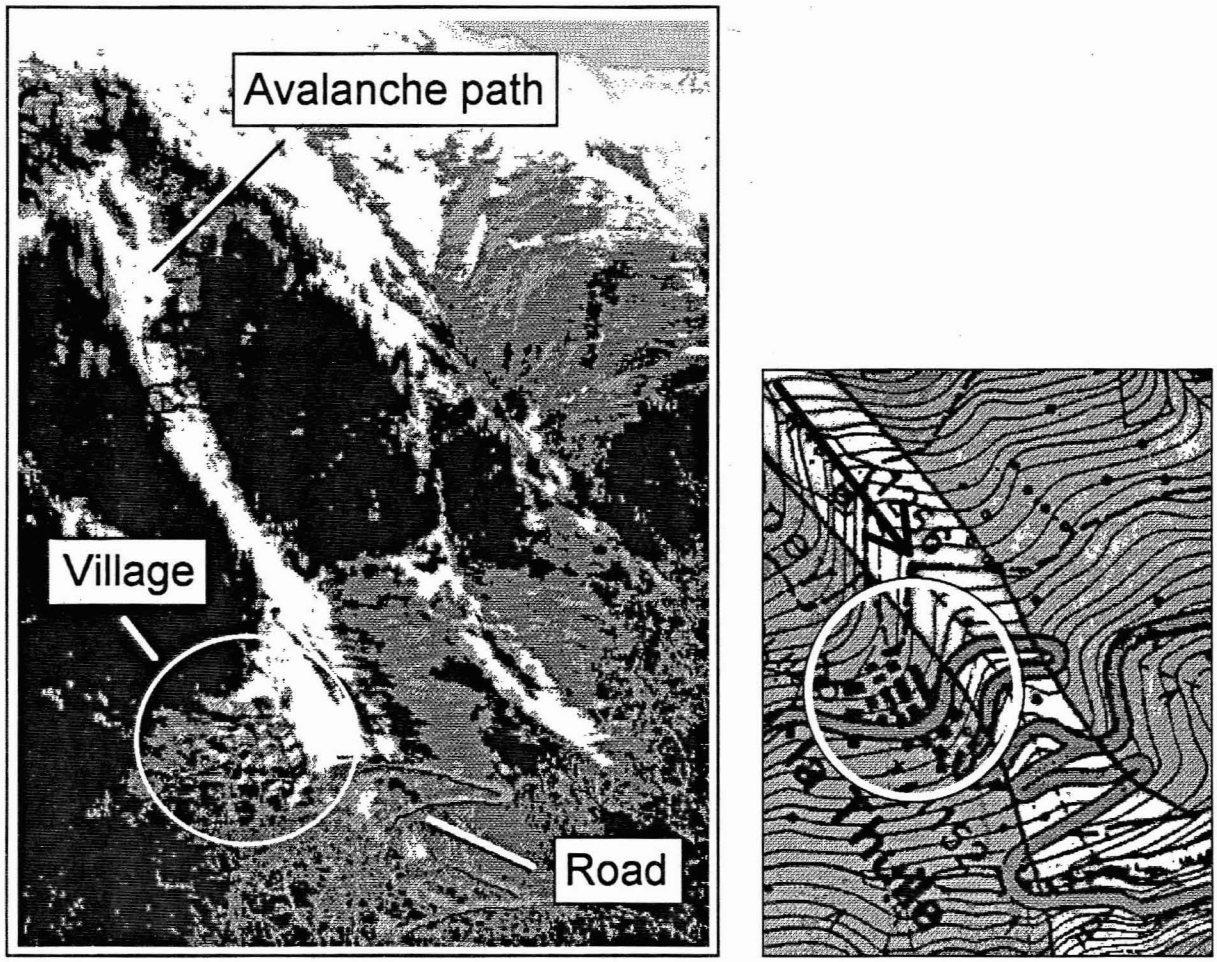


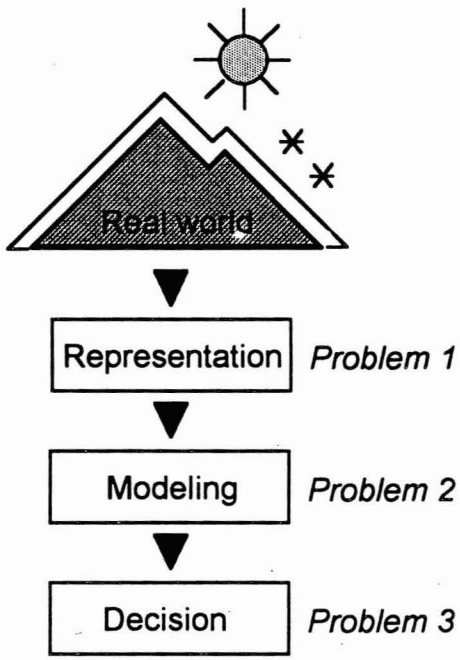
Figure 1 - Local avalanche forecasting may be a daily problem...

To secure a road, a ski resort or a mountain lumber-yard, the problem is the same ; the diagnosis is so difficult and the responsibility so important that forecasters often need tools to be efficient. The Swiss Federal Institute for Snow- and Avalanche Research has designed such a tool, with the cooperation of many practitioners from France, Italy, Scotland, Spain, and Switzerland, who give ideas and feedback. This paper presents this collaboration and the first results.

1. STRATEGY

The goal is to design the "good" tools for operational forecasting, that is to say tools which are helpful and reliable. But many different problems have to be solved ! For the road safety services, we should forecast natural ruptures and runout distances ; ski resorts are more interested in the prediction of avalanches triggered by skiers. In any case, people often wish support when they must take a decision.

In general terms, we can represent the problem of local avalanche forecasting as a sequence of basic problems :



We cannot expect to solve any of these problems if the previous one has no reliable solution. So we have decided to concentrate our attention on the problems of representation and modeling (once more !) in the hope of improving the reliability of the present solutions. The problem of the decision will subsequently be considered.

According to the idea that not only scientists may be experts but also practitioners, we have established contacts between the institute and the safety services of some ski resorts (Courchevel, Méribel, Alpe d'Huez, Crans-Montana, Baqueira, Passo Tonale, etc.). Thus we got an European network consisting of about 50 people working together towards the same goal. Each year, at the beginning of the winter season, the safety services of the network receive the products from SFISAR in order to use them in actual situations. At the end of the winter season, we organize a workshop to get feedback, ideas and wishes. Then, we know what aspects have to be improved before the next winter...

NXLOG 2.0, a new diagnosis support system, is the result of this cooperation. Because we wanted it to be used broadly, it has been designed to run on a PC. It is described in the next section.

2. TOOLS

NXLOG 2.0 contains a data manager and a diagnosis model.
It needs as input a description of the situation, and gives as output the probability of an accidental avalanche for each gully of the chosen area.

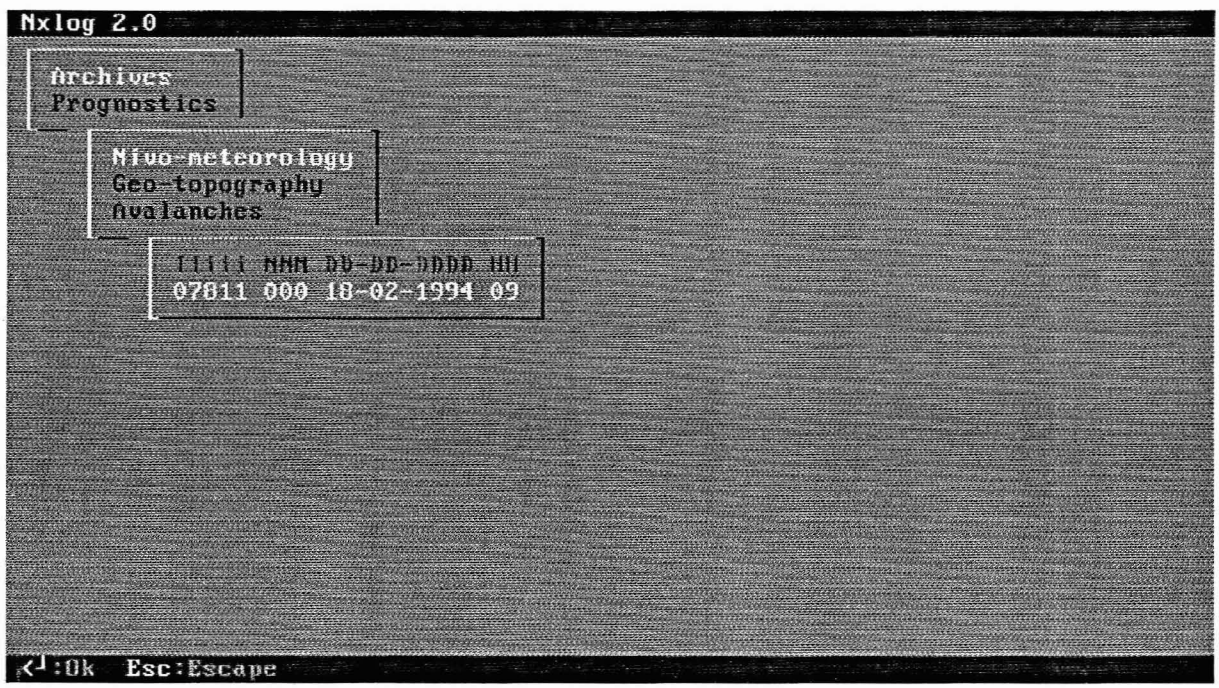


Figure 2 - Main menu of NXLOG 2.0.
Iiiii is the number of the sector (07811=Alpe d'Huez - Le Plat des Marmottes), NNN is the number of the place (000=measurement point), DD-DD-DDDD is the date, and HH is the time

Input

Every forecaster (man or machine) needs a representation of the real world. We must bow to the fact that this picture of reality will be very poor (because partial and punctual). Therefore, the challenge is to draw an usable representation, for lack of an accurate one. Local avalanche forecasting requires different types of informations : it seems essential to have at one's disposal descriptions of weather, snowpack, slopes and past avalanches.
So, the data manager of NXLOG 2.0 allows storing each of these types of information.

* weather and snowpack data (measured twice a day) are :
    Sector number
    Site number

Date
Time
Cloudiness (eights)
Windspeed (knots)
Wind direction (deg)
Air temperature (1/10 °C)
Relative humidity (%)
Precipitation rain (mm)
Precipitation snow (cm)
Snowdrift (g)
Direction of snowdrift (deg)
Total snowdepth (cm)
Penetration depth of penetrometer (cm)
Snow temperature of surface layer (1/10 °C)
Density of surface layer (kg/m3)
Thickness of surface layer (cm)

The model takes into account snowdrift. As a matter of fact, in high altitude, the most numerous avalanches are slab avalanches, and so, it seems important to quantify snowdrift. As no instrument was commercially available, we have devised the "driftometer".

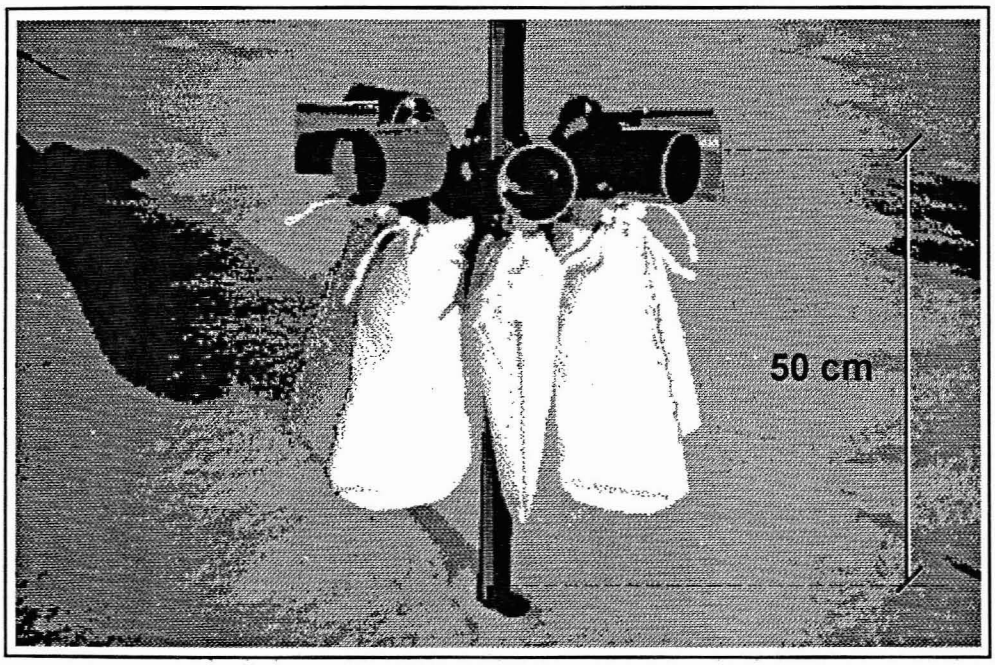


Figure 3 - The "driftometer", used to get a daily numerical index of snowdrift.
In 1993, the prototype was constructed and tested in a wind-tunnel with the cooperation of CEMAGREF (Division Nivologie).

* avalanche data are :

Sector number
Site number
Date
Time
Detonation energy (equivalence kg TNT)
Applied charge (man equivalence)
Length of avalanche (m)
Depth of fracture line (cm)
Length of fracture line (m)

*geographical and topographical data are :

Sector
Site number
Date
Time
Latitude
Longitude
Altitude a.s.l. of starting zone (m)
Exposure of starting zone (deg)
Inclination of the starting zone (deg)
Width of starting zone (m)
Roughness of soil in starting zone (cm)

Process

Two systems are merged into NXLOG 2.0 : NXD (Buser, 1983), using data analysis (nearest neighbours method), and AVALOG (Bolognesi, 1993), using symbolic calculation (artificial intelligence techniques). Let us remind that these approaches have already been used (Guyomarc'h *et al*, 1994, Giraud *et al*, 1994, MacClung, 1994, Schweizer *et al*, 1994). But, as far as we know, this is the first attempt to merge them.

The principle of the process is to use the observations of local events of the past as well as theoretical and practical rules. Figure 3 gives an overview of the process.
How does it work ?

The user enters the date and the time of the day to be analysed.

First step : the *INITIALISATION PROCEDURE* reads the corresponding data in the database : the INITIAL FACTS, which describe the weather, the snowpack, and the avalanche paths.

Second step : the *DATA ANALYSIS PROCEDURE* gives the nearest cases recorded in the database, and the avalanches observed during these days. Here is an important innovation regarding the nearest neighbours method : the weighting coefficients used in the distance calculation are determined by rules according to the context.

Third step : the *INFERENCE ENGINE* produces deductions (INFERED FACTS) from the INITIAL FACTS, the NEAREST CASES FACTS, and the RULES until it finds the probability of avalanches. The validity of each rule is translated into a coefficient and establishes the value of truth regarding the infered fact. This enables the propagation of uncertainty from initial facts to diagnosis.

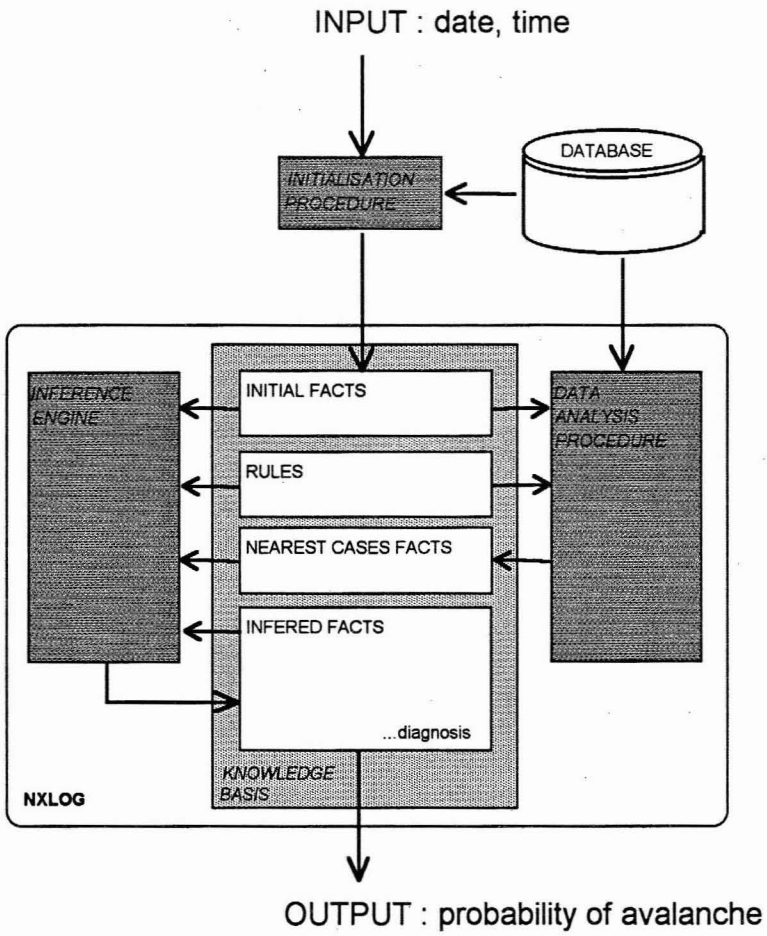


Figure 3 - Overview of the process of NXLOG 2.0

Output

The output of NXLOG 2.0 is the probability of an accidental avalanche for each triggering point of the supervised area (figure 4). The system also gives the user some intermediate results like the events observed for the 3 nearest cases (figure 5).

```
Nxlog 2.0  Prognostics

 IIIII NNN DD-DD-DDDD HH ProbAv

07811 411 09-04-1994 09 0.77 !!
07811 412 09-04-1994 09 0.77 !!
07811 413 09-04-1994 09 0.75 !
07811 414 09-04-1994 09 0.73 !
07811 421 09-04-1994 09 0.85 !!
07811 422 09-04-1994 09 0.01
07811 431 09-04-1994 09 0.85 !!
07811 432 09-04-1994 09 0.75 !
07811 433 09-04-1994 09 0.79 !!
07811 434 09-04-1994 09 0.75 !
07811 435 09-04-1994 09 0.82 !!
07811 436 09-04-1994 09 0.70 !
07811 437 09-04-1994 09 0.69 !
07811 441 09-04-1994 09 0.75 !
07811 442 09-04-1994 09 0.69 !
07811 443 09-04-1994 09 0.75 !
07811 444 09-04-1994 09 0.80 !!
07811 445 09-04-1994 09 0.69 !

F3:Print  Esc:Escape
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Figure 4 - Output of NXLOG 2.0.

Iliii is the number of the sector (07811=Alpe d'Huez - Le Plat des Marmottes), NNN is the number of the gully (411=gully of the Canyon), DD-DD-DDDD is the date, HH is the time and ProbAv is the probability of an accidental avalanche.

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Nxlog 2.0  Prognostics

 IIIII NNN DD-DD-DDDD HH ProbAv

Appendix ...

ANALOGOUS CASES

* Nivo-meteorology
k ddd NNN DD-DD-DDDD HH N DDv FFv ±TTa Ua HHp HHn DDt FFt HHs Ps ±TTs MVs Rs
    0 000 09-04-1994 09 9 270 008 -060 85 000 020 270 /// 155 38 -058 110 00
1   2 000 05-04-1994 09 6 360 002 -120 56 000 021 360 /// 130 38 -072 140 00
2   2 000 07-01-1991 09 9 360 005 -016 // 000 021 /// 000 153 40 -017 160 00
3   8 000 26-12-1990 09 4 360 015 -084 // 000 011 045 /// 084 35 -057 080 00

* Avalanches
k NNN DD-DD-DDDD HH EE CC LLLa HHc LLLc
1 411 05-04-1994 // // 00 //// /// ////
1 412 05-04-1994 // 00 01 //// /// ////
1 413 05-04-1994 // 00 01 //// /// ////
1 421 05-04-1994 // 00 01 //// /// ////
1 431 05-04-1994 // // 00 //// /// ////

F3:Print  Esc:Escape
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Figure 5 - Output of NXLOG 2.0 : appendix.

The system displays the 3 nearest cases. ddd is a variant of Euclidian distance, other fields are described at paragraph "input". It also gives the events observed during these past days : here, we can see that avalanches had been released in gullies 411, 412, 413, etc. for the nearest situation.

Are these predictions reliable ? We do not know at the present time. We can just remind that NXD and AVALOG gave about 80% of right diagnosis and that we expect NXLOG 2.0 to have better performance. Whatever that may be, systematic tests, scheduled for winter 1994-95, will soon bring this essential answer.

CONCLUSION

The next step in the development of NXLOG will be to optimize machine learning procedures which give the system a capability of improving its performance by itself. This is the goal of a new research project which is now beginning with the cooperation of the Artificial Intelligence Laboratory of the Swiss Federal Institute of Technology at Lausanne, and many safety services of ski resorts.

The objective of these current works is to assist persons who must take "yes or no" decisions for local prevention. At the same time, other researches are done to estimate the overall avalanche hazard for a whole region. These different approaches are complementary, and we can easily imagine that they will join in the future. This may also be an evolution for NXLOG...

ACKNOWLEDGEMENTS

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