Acoustic Detection System for Operational Avalanche Forecasting

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ABSTRACT

Applied acoustics has recently come to the fore as a useful tool for improving avalanche forecasting by supplying the means of automatically detecting, in continuous real time, avalanche activity over a mountain range. Such information, which is impossible to provide from manual observations alone, due to weather, lack of visibility at night, masking relief's, etc., is of major importance to forecasting systems - in particular for those using analogy-based reasoning models.

The acoustic system ARFANG consists of four microphones combined in such a way as to constitute an acoustic goniometer: the incident direction of sound waves - azimuth, elevation - are obtained from the calculated time-delays of sound waves between pairs of microphones.

Special microphones called ECHO were built and installed at Anzère ski resort (Switzerland). ECHOs are dedicated to infrasounds and are suitable for high mountain winter topographical and meteorological conditions. The system including automatic signal recognition procedures demonstrated the possibility of using sounds to detect and localize avalanches over areas extending up to several square km.

ARFANG is going to be interfaced to the avalanche forecasting system NXLOG - which uses avalanches observed in the past to produce predictions - with the objective of building an automatic avalanche forecasting tool.

1. OBJECTIVE

Case-based forecasting systems have shown that they can perform excellent avalanche predictions (Bolognesi, 1996). The principle of these systems is: 'same causes produce same effects'. According to this postulate, daily forecasts can be inferred from avalanche activity recorded during the most similar days stored in a data base (fig.1).

It is easy to understand that predictions can only be right if the data are reliable. Input data are to models what fuel is to engines: a critical performance factor. Thus it is meaningful to try to obtain the best input data possible.

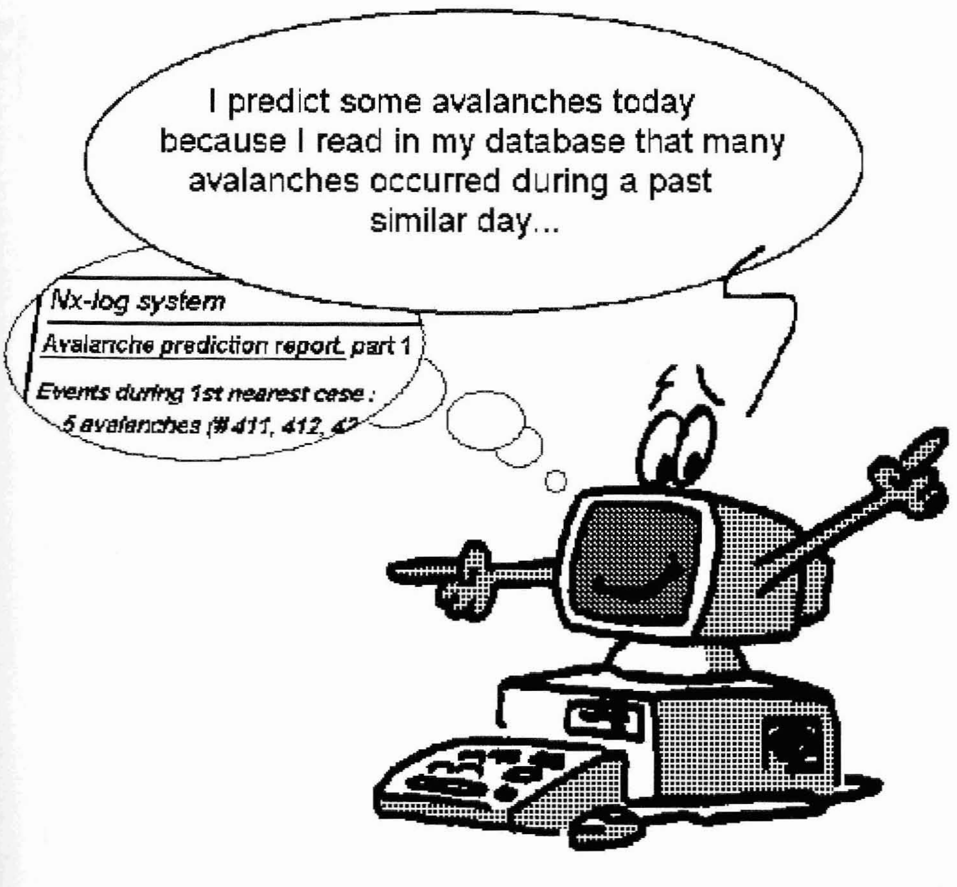

Fig.1: Our electronic friend must be informed about avalanche activity as precisely as possible!

Many sensors have been developed in order to provide frequent and accurate meteorological data. But case-based forecasting systems also need avalanche data, which are often difficult to collect, even with many human observers, because of fog, storms, or night. But what cannot be seen may be heard...

Applied acoustics has recently come up with a new means of automatically detecting avalanches: ARFANG system (cf.§2) is already able to deliver real time information about avalanche activity over mountain ranges.

Our objective is now to connect ARFANG to the forecasting expert system NXLOG (Bolognesi, Buser, Good, 1994) in order to try to create an efficient chain.

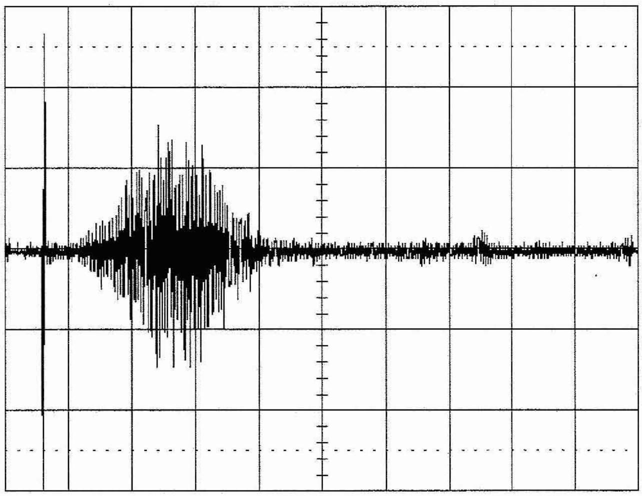

Fig. 2: Sound wave form recorded during an artificial release of avalanche. The signal represents the time evolution (abscissa) of the acoustic pressure in the (low) frequency range 1- 20 Hz (vertical axis).

2. THE ACOUSTIC SYSTEM

During their movement, most avalanches produce infrasounds, i. e. acoustic signals within approx. 1- 20 Hz (Chritin, Rossi, 1995). These inaudible and long-range low-frequency sounds (fig. 2) are suitable for automatic and real-time detection and localisation of the avalanche activity over an extended area of several square km.

The ARFANG experimental system (fig. 3) consists of four special outdoor microphones combined in such a way as to constitute an acoustic goniometer (instrument to measure angles). The four microphones are set up in the form of a cross or star either on masts or under the snow cover in a 20 to 50 square meter area.

The system determines automatically the incident direction - geographical azimuth and elevation - of sound waves from their calculated arrival time delays between pairs of microphones. Dedicated microphones (Rossi, Chritin, 1995), named ECHO and optimised to the mountain winter meteorological and topographical conditions were designed, built and installed.

Apart from avalanches, some other infrasound sources exist - natural (storms, waterfalls, etc.) or man-made (planes, industry, etc.) - all of which can also potentially be piched by the microphones. The question is therefore to recognize avalanche infrasounds from all other infrasounds present in the environment. The method is developed on the principle of the acoustic form analysis (fig. 5) of the incoming acoustic events. This analysis is based on the comparison of the time evolution of intensity values in appropriate frequency bands.
(fig. 6) if both the output values of the intensity analysis and of the goniometer fullfill avalanches criteria characteristics.

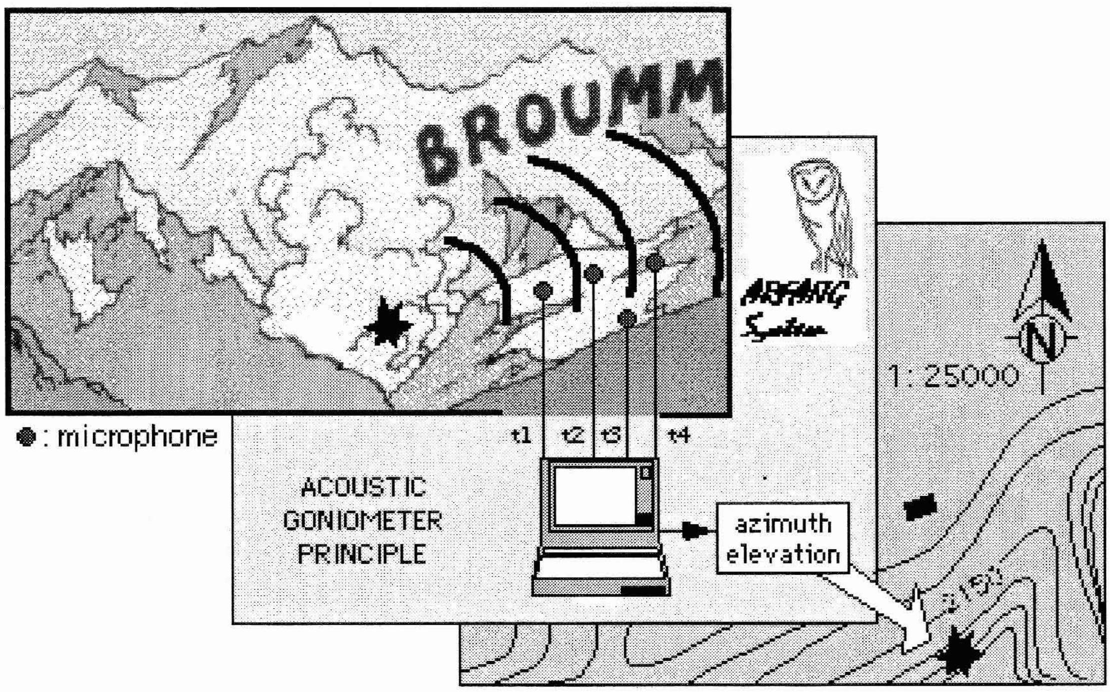

Fig. 3: Principle of avalanche localisation by acoustic goniometry

3. THE AUTOMATIC FORECASTING CHAIN

The acoustic system ARFANG lives in the present: it cannot forecast any avalanche. The best it can do is to detect and record continuously every « acoustic event » that happens in a given area and then transmit it to NXLOG.

In order to perform the daily avalanche prediction, this system first runs its nearest cases selection procedure which uses Euclidian distance calculations to find the most 'similar' past days regarding snow- and weather conditions. Then NXLOG reads the avalanche activitity observed during these 'similar' days in its avalanche data files. Then NXLOG runs its expert system. This procedure applies rules making inferences from avalanche activity observed during nearest cases as well as from present snow- and weather situation and topographical conditions. At the end of this process, NXLOG delivers a probability of accidental avalanche for each slope of the defined area (typically a ski resort).

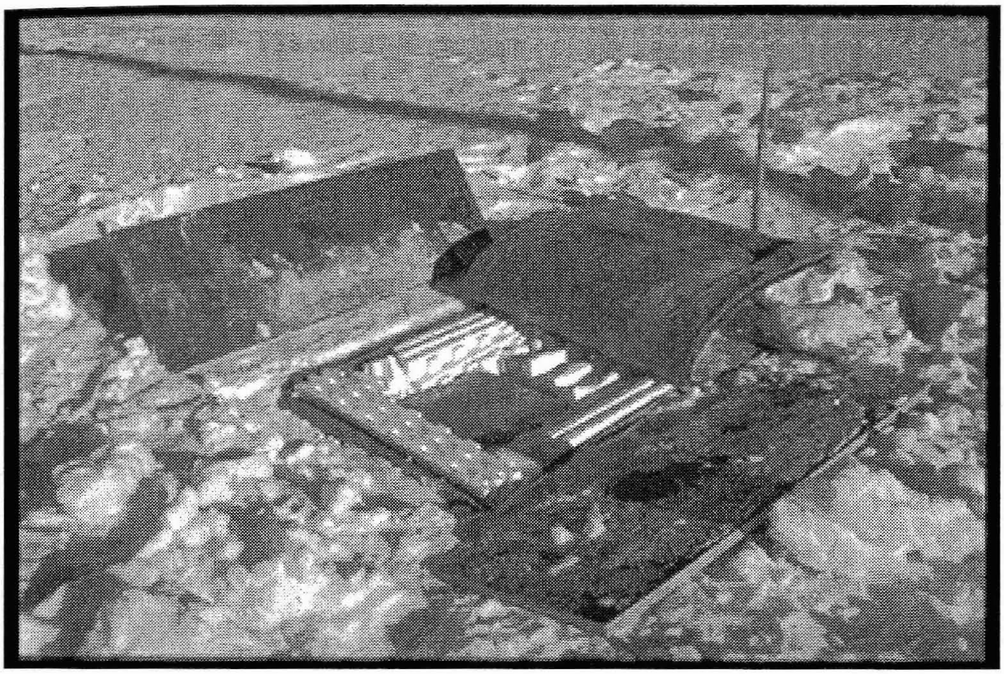

Fig. 4: Special infrasound microphones ECHO, installed under the snow cover.

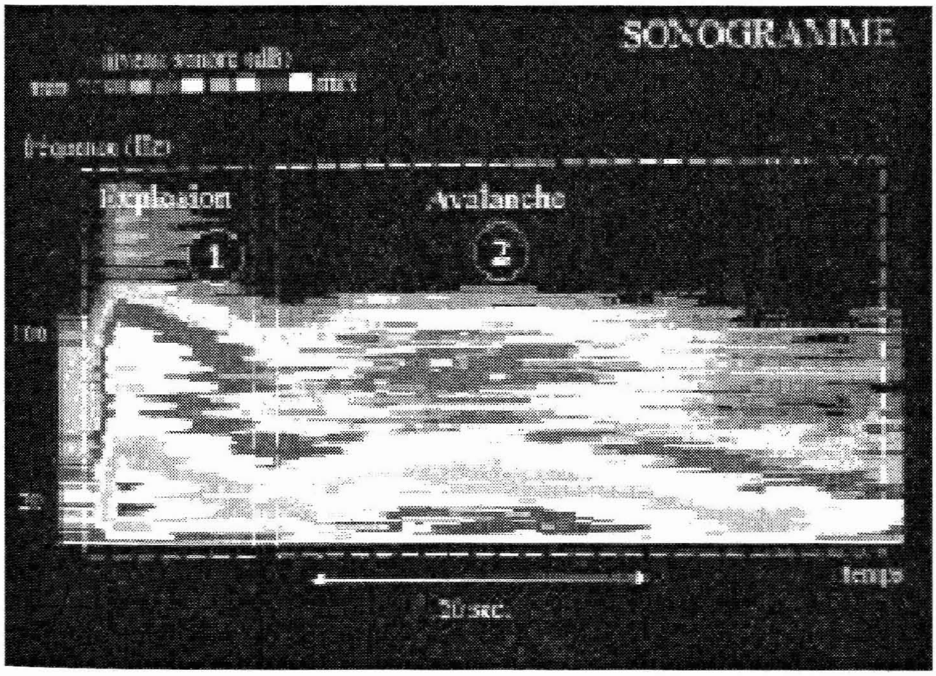

Fig. 5: Spectrographic analysis(1): released explosion, (2): avalanche.

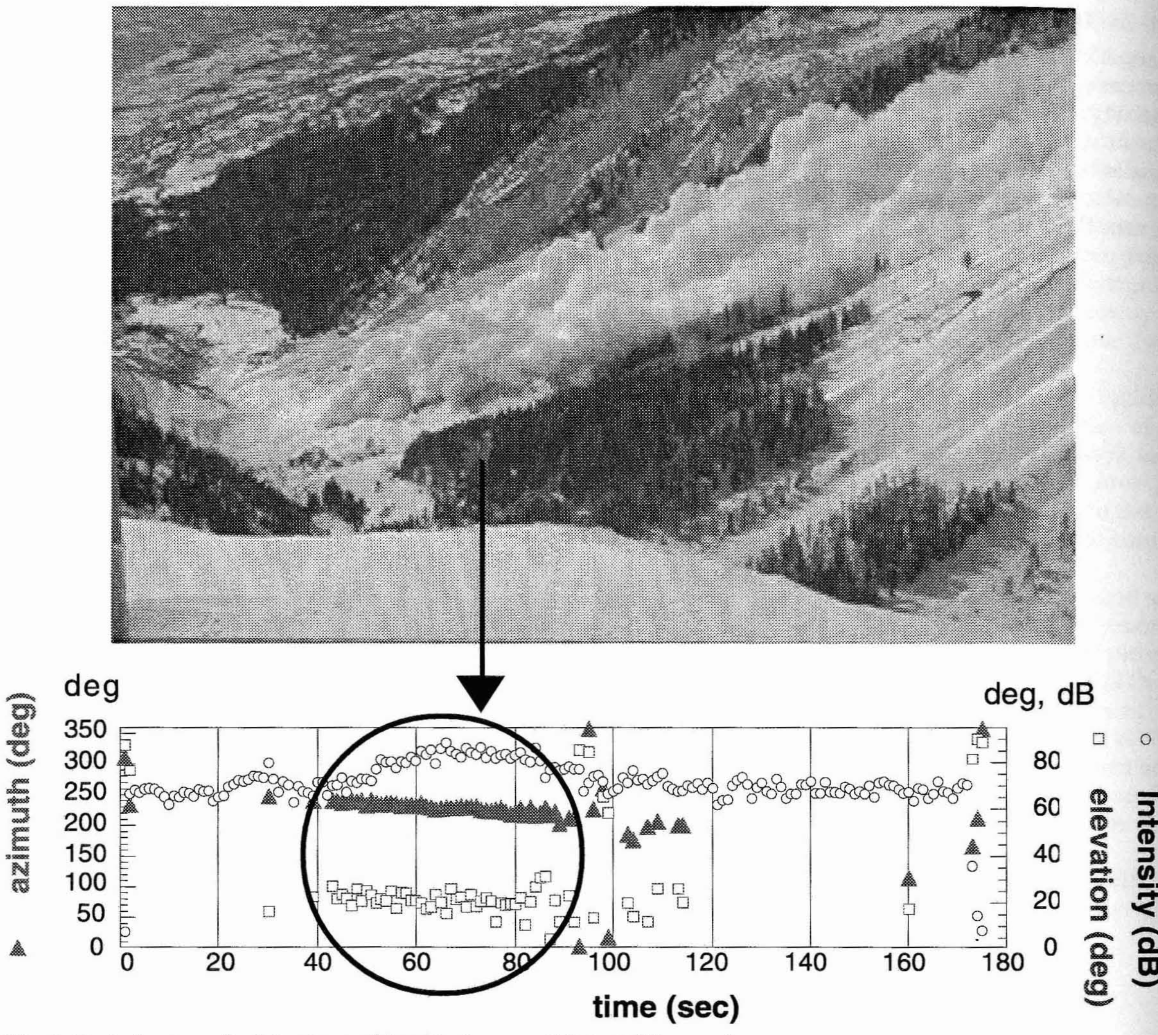

Fig. 6: Typical automatic detection and localisation result (1 to 10 Hz range).

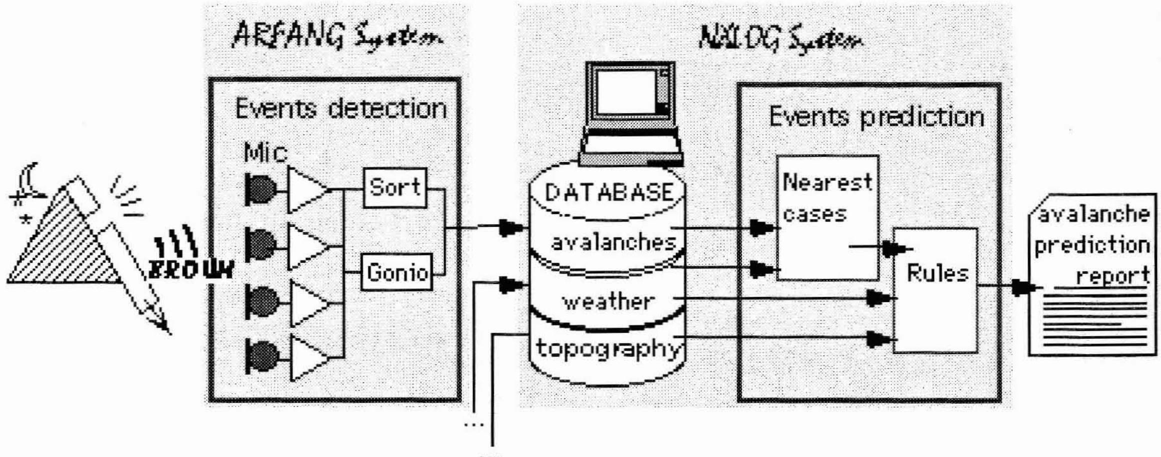

Fig. 7: ARFANG - NXLOG chain

If ARFANG is able to be a better avalanche observer than ski patrol men (who do not work at night and who cannot see anything during foggy days...), then we can expect to improve the NXLOG performance. These two systems should therefore make a very efficient chain.

CONCLUSION

ARFANG demonstrated the feasability of automatically measuring avalanche activity over an extended area by acoustical means. The next step is to use it in the actual situation, connected to the forecasting system NXLOG and to evaluate such a chain.

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