Bayesian Networks for Assessing the Reliability of a Glacier Lake Warning System in Switzerland

Rouven A. Sturny[1,2] and Michael BRÜNDL[1*]
[1] WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland
[2] Silvaplus Sàrl (Martigny, Swizerland)
*Corresponding author. E-mail: bruendl@slf.ch

INTRODUCTION

Together with structural mitigation measures, land-use planning and biological measures (e.g. protection forests), warning and alarm systems have become very important in the management of risks caused by Alpine natural hazards such as snow avalanches, debris flows, rock fall and landslides. Safety in mountain regions can be improved by well-functioning warning and alarm systems. In this paper we present a reliability analysis of a warning system, which is installed for a timely detection of glacier lake outburst floods (GLOF) in the Swiss Alps.

METHOD

The considered glacier lake is situated below Lower Grindelwald Glacier in the Bernese Alps in Switzerland. In the summer months the level of the lake can drain rapidly and can cause floods which are potentially affecting residents and tourists in the valley. To mitigate this risk, a warning system has been installed. We have chosen Bayesian Networks for the assessment of the reliability of this warning system because incomplete knowledge, common cause failures and human factors can be integrated in BN in a straightforward way, which is hardly possible by other methods.
In a first step we developed a schema, which includes all possible kind of failures, before we defined the nodes and child-nodes of the BN representing the components of the system. The relations of the nodes and child-nodes were described with Conditional Probability Tables (CPT) for technical and non-technical components. For each of the components the failure rates were determined or calculated and filled into the CPTs, which allowed us to calculate the reliability for all components (**Fig. 1**). Finally, we conducted a sensitivity analysis to analyze the influence of certain nodes on the alerting units ‘visual acoustic signal’ (VAS) and ‘alerting of the intervention entities’ (AIE).

RESULTS

The two alerting signals have almost the same reliability of 0.94 whereas the alerting of intervention units reaches a reliability of only 0.83. Given that the probability of occurrence of a flood for the summer season 2009 was 0.0055 per day, the probability that an event occurs at the same time as the corresponding warning units fail was calculated as 3.3×10^{-4} and 9.4×10^{-4}. This means the probability for a working VAS is 0.99967 and 0.99906 for the AIE.

CONCLUSIONS

The present study shows how Bayesian Networks (BN) can be used to conduct a quantitative reliability analysis for a warning system protecting several communities from glacier lake outburst floods. Our study revealed two strengths of BN: (1) once the structure of the BN is defined, knowledge on probabilities must only be available for the nodes not having any parent nodes, at least for our example, and (2) the development of failure scenarios can be done in a straightforward way. We can conclude that the investigated warning system is highly reliable in detecting dangerous floods due to numerous redundancies. Future studies should base on solid data regarding the failure rate of components, evaluate longer periods of data measurements, study the role of sensor position, and integrate the role of human factors.

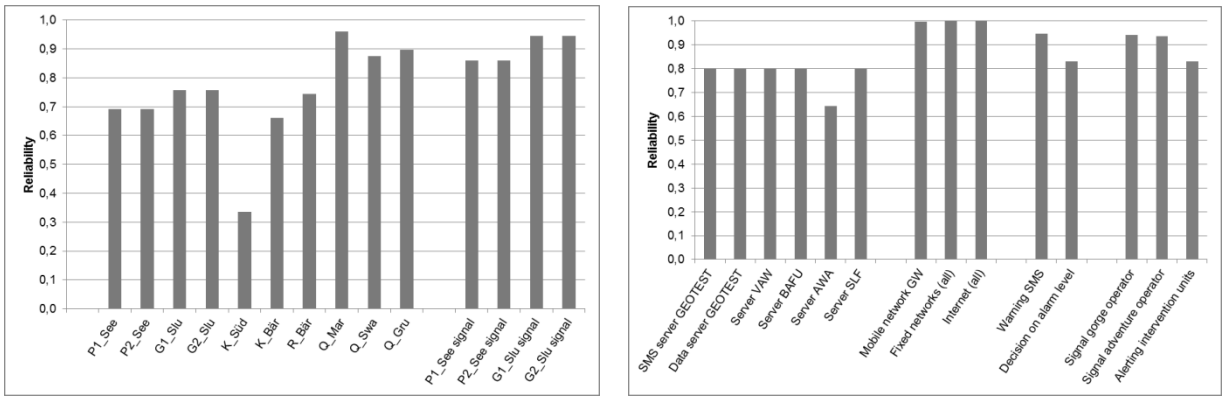

Fig. 1: Reliability values calculated by the BN. The elements on the x-axis of the left figure correspond to the monitoring components, those on the right figure to the data management and warning and alarm components.

Keywords: warning system, reliability, alerting, glacier lake outburst, Bayesian Networks