OPEN ACCESS

International Journal of Engineering Innovations in Advanced Technology

ISSN: 2582-1431 (Online), Volume-4 Issue-4, December 2022

A Survey On Avalanche Forecasting Using Machine Learning

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***Abstract*—Avalanche forecasting is an iterative process, where forecasters use weather data and snow observations in addition to previous assessments to conclude what forecast to publish. This project investigates how the forecasting process could be automated, using three seasons worth of data from 23 of Norway's avalanche forecasting regions. Three scenarios were considered, using different amounts of input parameters based on what data would be available to the model in each respective scenario. For each scenario a machine learning model was trained, and a separate naïve model was constructed. The machine learning model could only beat the naïve model in the simplest scenario, using only weather data. In the other scenarios it was found that the data representation was lacking; highly intermittent snow observation data was structured as time series when a more pre-processed representation may have been more fruitful.**

***Key words* — avalanche forecasting, intermittent, machine learning**

I. Introduction

Machine learning is a type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed. Machine learning focuses on the development of Computer Programs that can change when exposed to new data. Machine learning involves computer to get trained using a given data set, and use this training to predict the properties of a given new data. Basics of Machine Learning, and implementation of a simple machine learning algorithm using python. Python community has developed many modules to help programmers implement machine learning. In this paper We have built a web application which predicts the range of avalanche. It is done by building a machine learning model using the best algorithm and integrating it into the flask application.

An avalanche (also called a snow slide) is an event that occurs when a cohesive slab of snow lying upon a weaker layer of snow fractures and slides down a steep slope. Avalanches are typically triggered in a starting zone from a mechanical failure in the snowpack (slab avalanche) when the forces of the snow exceed its strength but sometimes only with gradual widening (loose snow avalanche). After initiation, avalanches usually accelerate rapidly and grow in mass and volume as they entrain more snow. If the avalanche moves fast enough, some of the snow may mix with the air forming a powder snow avalanche, which is a type of gravity current. Slides of rocks or debris, behaving in a similar way to snow, are also referred to as avalanches. The load on the snowpack may be only due to gravity, in which case failure may result either from weakening in the snowpack or increased load due to precipitation. Avalanches initiated by this process are known as spontaneous avalanches. Avalanches can also be triggered by other loading conditions such as human or biologically related activities. Seismic activity may also trigger the failure in the snowpack and avalanches. Although primarily composed of flowing snow and air, large avalanches have the capability to entrain ice, rocks, trees, and other surficial material. However, they are distinct from slush flows which have higher water content and more laminar flow, mudslides which have greater fluidity, rock slides which are often ice free, and serac collapses during an icefall. Avalanches are not rare or random events and are endemic to any mountain range that accumulates a standing snowpack. Avalanches are most common during winter or spring but glacier movements may cause ice and snow avalanches at any time of year. In mountainous terrain avalanches are among the most serious objective natural hazards to life and property, with their destructive capability resulting from their potential to carry enormous masses of snow at high speeds.

Manuscript received November 17, 2022; Revised December 12, 2022; Accepted December 14, 2022

II. LITERATURE REVIEW

The snow cover model SNOWPACK includes a detailed model of snow microstructure and metamorphism. In SNOWPACK, the complex texture of snow is described using the four primary microstructure parameters: grain size, bond size, dendricity and sphericity. For each parameter, rate equations are developed that predict the development in time as a function of the environmental conditions. The rate equations are based on theoretical considerations such as mixture theory and on empirical relations. With a classification scheme, the conventional snow grain types are predicted on the basis of those parameters. The approach to link the bulk constitutive properties, viscosity and thermal conductivity to microstructure parameters is novel to the field of snow cover modelling. Expanding on existing knowledge on microstructure-based viscosity and thermal conductivity, a complete description of those quantities applicable to the seasonal snow cover is presented. This includes the strong coupling between physical processes in snow: The bond size, which changes not only through metamorphic processes but also through the process of pressure sintering (included in our viscosity formulation), is at the same time the single most important parameter for snow viscosity and thermal conductivity.

[2] The application of nearest-neighbour algorithms to the task of regional avalanche forecasting in Switzerland is presented in this paper. The database used for the development of the model consists of snow and weather data from 60 manual weather stations and conventionally estimated avalanche-hazard levels. All these data are collected by the Swiss Federal Institute for Snow and Avalanche Research on a daily basis during winter. Data between 1987 and 1996 (10 winters) are used for our study. For the manual weather stations, a nearest-neighbour model has been developed: NXD-VG calculates the 10 nearest-neighbour days by using a Euclidean weighted distance metric. A regional avalanche-hazard map is calculated by interpolating the results of NXD-VG between the stations. The avalanche forecasters can access the results of the model calculation directly because they are integrated into a program for bulletin construction. The model was validated using three complementary approaches. First, the database is cross-validated for all the winters available to estimate an unbiased prediction error of the models for two selected stations. Second, selected situations of the database are recalculated. Third, the model output is compared daily to the official forecasts published during winter 1999/2000.

[3] True Skill Statistic (TSS) and the Heidke Skill Score (S), as used in the context of the contingency, table approach to forecast verification, are compared. It is shown that the TSS approaches the Probability of Detection (POD) whenever the forecasting is dominated by correct forecasts of non-occurrence, i.e., forecasting rare events like severe local storms. This means that the TSS is vulnerable to “hedging” in rare event forecasting. The S-statistic is shown to be superior to the TSS in this situation, accounting for correct forecasts of null events in a controlled fashion. It turns out that the TSS and S values are related in a subtle way, becoming identical when the expected values (due to chance in a k × k contingency table) remain unchanged when comparing the actual forecast table to that of a hypothetical perfect set of forecasts. Examples of the behaviour of the TSS and S values in different situations are provided which support the recommendation that S be used in preference to TSS for rare event forecasting. A geometrical interpretation is also given for certain aspects of the 2 × 2 contingency table and this is generalized to the k × l case. Using this geometrical interpretation, it is shown to be possible to apply dichotomous verification techniques in polychotomous situations, thus allowing a direct comparison between dichotomous and polychotomous forecasting. The so-called True Skill Statistic (TSS) and the Heidke Skill Score (S), as used in the context of the contingency, table approach to forecast verification, are compared. It is shown that the TSS approaches the Probability of Detection (POD) whenever the forecasting is dominated by correct forecasts of non-occurrence, i.e., forecasting rare events like severe local storms. This means that the TSS is vulnerable to “hedging” in rare event forecasting. The S-statistic is shown to be superior to the TSS in this situation, accounting for correct forecasts of null events in a controlled fashion. It turns out that the TSS and S values are related in a subtle way, becoming identical when the expected values (due to chance in a k × k contingency table) remain unchanged when comparing the actual forecast table to that of a hypothetical perfect set of forecasts. Examples of the behaviour of the TSS and S values in different situations are provided which support the recommendation that S be used in preference to TSS for rare event forecasting. A geometrical interpretation is also given for certain aspects of the 2 × 2 contingency table and this is generalized to the k × l case. Using this geometrical interpretation, it is shown to be possible to apply dichotomous verification techniques in polychotomous situations, thus allowing a direct comparison between dichotomous and polychotomous forecasting.

[4] Storm cycle factors affect slab avalanche response primarily in terms of loading in

starting zones. Wind velocity and supply of transportable snow, relative to terrain, control redistribution and thus potential loading of avalanche slopes. Snow metamorphism in near-surface layers may affect the degree of involvement of old snow in slab avalanches and the rate of bonding between the slab and old snow surface. Early season snow conditions and general loading rate during the season may also affect avalanche response. We evaluated empirical factors that combine wind velocity with new snow amount, describe the potential for near-surface grain growth and provide indices of between-storm snow condition. The importance of different factors was rated in terms of explaining deviance in avalanche activity indices. Avalanche activity indices included maximum size, number of releases and sum of sizes of released avalanches. Ranking and scores for the different factors resulted from classification and regression tree analyses carried out on avalanche observations from Alta, Utah and Mammoth Mountain, Califomia. Time lagged conventional factors describing snowfall and derived wind-drift parameters ranked highest in all tests. Snow drift factors segregated into prominent wind directions showed moderate importance. Among the non-storm factors, the starting snow depth of a particular year ranked highest showing the importance of interannual variability. This was followed by the accumulated vapor pressure difference, which we formulated to describe the potential for near-surface grain growth. The average snow depth increases and other factors followed in importance.

[5] DNA micro-arrays now permit scientists to screen thousands of genes simultaneously and determine whether those genes are active, hyperactive or silent in normal or cancerous tissue. Because these new micro-array devices generate bewildering amounts of raw data, new analytical methods must be developed to sort out whether cancer tissues have distinctive signatures of gene expression over normal tissues or other types of cancer tissues. In this paper, we address the problem of selection of a small subset of genes from broad patterns of gene expression data, recorded on DNA micro-arrays. Using available training examples from cancer and normal patients, we build a classifier suitable for genetic diagnosis, as well as drug discovery. Previous attempts to address this problem select genes with correlation techniques. We propose a new method of gene selection utilizing Support Vector Machine methods based on Recursive Feature Elimination (RFE). We demonstrate experimentally that the genes selected by our techniques yield better classification performance and are biologically relevant to cancer. In contrast with the baseline method, our method eliminates gene redundancy automatically and yields better and more compact gene subsets. In patients with leukemia our method discovered 2 genes that yield zero leave-one-out error, while 64 genes are necessary for the baseline method to get the best result (one leave-one-out error). In the colon cancer database, using only 4 genes our method is 98% accurate, while the baseline method is only 86% accurate.

[6] This paper examines the positive and negative aspects of a range of interpretations of nearest- neighbours' models. Measures-oriented and distribution-oriented verification methods are applied to categorial, probabilistic and descriptive interpretations of nearest neighbours used operationally in avalanche forecasting in Scotland and Switzerland. The dependence of skill and accuracy measures on base rate is illustrated. The purpose of the forecast and the definition of events are important variables in determining the quality of the forecast. A discussion of the application of different interpretations in operational avalanche forecasting is presented.
Nearest-neighbours (NN) avalanche forecasting compares data describing past avalanche and non-avalanche days with current or forecast data. In NN a distance between days in the dataset and the forecast day is defined to identify previous days which are most "similar" to the forecast day (the nearest neighbours). The nature of events on the nearest ne LaChapelle, E.R. 1980. The fundamental processes in conventional avalanche forecasting.

[7] Conventional avalanche forecasting is practiced as a mix of deterministic treatment for snow and weather parameters and inductive logic to reach actual forecast decisions. Inductive logic of the scientific method dominates, making frequent use of iteration and redundancy to minimize decision uncertainties. The mental processes involved are holistic rather than analytical. Elementary information theory can be used rationally to sort data categories for minimum entropy and optimize inductive reasoning. Recognizing these principles affords a chance to improve the practice and teaching of conventional forecasting techniques. Snow avalanche forecasting is defined here to include estimates of both current and future snow stability. The discussion is confined to the conventional, widely-practiced methods of avalanche forecasting based on a mix of meteorology, snow physics, and empirical experience. Purely statistical methods are omitted.

[8] Many ski areas, backcountry avalanche centers, highway departments, and helicopter ski operations record and archive daily weather and avalanche data. This paper presents a probabilistic method that allows avalanche forecasters to better utilize

historical data by incorporating a Geographic Information System (GIS) with a modified meteorological nearest neighbour's approach. This nearest neighbour approach utilizes evolving concepts related to visualizing geographic information stored in large databases. The resulting interactive database tool, Geographic Weather and Avalanche Explorer, allows the investigation of the relationships between specific weather parameters and the spatial pattern of avalanche activity. We present an example of this method using over 10,000 individual avalanche events from the past 23 years to analyse the effect of new snowfall, wind speed, and wind direction on the spatial patterns of avalanche activity. Patterns exist at the slide path scale, and for groups of adjacent slide paths, but not for either the entire region as a whole or when slide paths are grouped by aspect. Since wind instrumentation is typically located to measure an approximation of the free air winds, specific topography around a given path, and not simply aspect, is more important when relating wind direction to avalanche activity.

[9] Abstract Different statistical methods have been tested to answer the challenging problem of forecasting avalanche activity. For each approach, the theoretical background is briefly described, and the main advantages and drawbacks are discussed. The first method consists of a simple discriminant analysis applied to a sample of avalanche days against a sample of non- avalanche days. The second approach tries to take into account different types of avalanche phenomena associated with different types of snow and weather situations. It requires the development of an avalanche typology compatible with the available variables, and leads to a two-stage decision model. A given day is first allocated to a weather type, within which the proper model avalanche-non-avalanche is then processed. A third method, a local non- parametric one, consists of drawing, for the day under study and in an appropriate predictor space, its nearest neighbours from the sample file in order to get an estimate of the probability of avalanche occurrence. For each approach, the explanatory variables may be processed directly as quantitative continuous data or as qualitative categorized data. This removes the problems associated with the very asymmetric distribution of half of them, at the cost of a moderate loss of information. As a rule, the methods were calibrated and then applied to the winters 1972–73 and 1973–74 used as a test sample, thus allowing comparison of their respective potentials in operational forecast.

[10] Avalanche forecasting for a given region is still a difficult task involving great responsibility. Any tools assisting the expert in the decision-making process are welcome. However, an efficient and successful tool should meet the needs of the forecaster. With this in mind, two models, were developed using a commercially available software: CYBERTEK- COGENSYSTM, a judgment processor for inductive decision-making–a principally data- based expert system. Using weather, snow and snow-cover data as input parameters, the models evaluate for a region the degree of avalanche hazard, the aspect and altitude of the most dangerous slopes. The output result is based on the snow-cover stability. The new models were developed and have been tested in the Davos region (Swiss Alps) for several years. To rate the models, their output is compared to the a posteriori verified hazard. the first model is purely data-based. Compared to other statistical models, the differences are: more input information about the snow cover from snow profiles and Rutschblock tests, the specific method to search for similar situations, the concise output result and the knowledge base that includes the verified degree of avalanche hazard. The performance is about 60%. The second, more-refined model, is both data- and rule-based. It tries to model the decision-making process of a pragmatic expert and has a performance of about 70%, which is comparable to the accuracy of the public warning.

[11] A dataset of daily avalanche activity observed consistently for 14 years in the surroundings of Zuoz in the Engadine valley (eastern Swiss Alps) is analysed. All medium-sized and larger avalanches had been mapped by the local snow and avalanche observer. They were digitized into a geographic information system (GIS) and linked to the daily snow and avalanche observations. Thus, the avalanche activity and its spatial distribution could be analysed and visualized. A classification for avalanche size and avalanche activity is proposed. In 52% of the potential starting zones an avalanche is released at least once in 14 years. The avalanche area decreases strongly with the frequency of avalanche occurrence. Preliminary analysis of the relation of daily avalanche activity to weather, snow and snow cover revealed a wide variety of contributory factors. Even for large amounts of new snow, snow-cover conditions prior to snowfall or temperature evolution might decide the extent of the avalanche activity. For six examples, the avalanche hazard (five-degree European scale) is visualized by means of avalanche activity The GIS approach will be followed to build a tool for local avalanche forecasting in Zuoz.

III. PROBLEM IDENTIFICATION

The word Avalanche refers to snow and ice. It means a mass of snow, ice, rocks, slush falling

rapidly down a mountain. Snow avalanches are the most destructive natural hazards threatening human life, ecosystems, built structures in mountainous regions. Each year avalanche kills more than 150 people worldwide. If the person buried under an avalanche more than 15 minutes then there is no chance of survive. So, the life of the people in that region is difficult to live.
Although primarily composed of flowing snow and air, large avalanches have the capability to entrain ice, rocks, trees, and other surficial material. However, they are distinct from slush flows which have higher water content and more laminar flow, mudslides which have greater fluidity, rock slides which are often ice free, and serac collapses during an icefall. Avalanches are not rare or random events and are endemic to any mountain range that accumulates a standing snowpack.

Avalanches are most common during winter or spring but glacier movements may cause ice and snow avalanches at any time of year. In mountainous terrain avalanches are among the most serious objective natural hazards to life and property, with their destructive capability resulting from their potential to carry enormous masses of snow at high speed. In these four types of avalanches

1. Wet Avalanches
2. Dry Avalanches
3. Dry Slab Avalanches
4. Loose Snow Avalanches

A. *Wet Avalanches*

Wet avalanches are triggered by warm air temperatures, sun or rain, causing water to percolate through the snowpack and decreasing its strength. Most avalanche professionals make a hard separation between wet snow avalanches and dry snow avalanches, because they are so different. Much of their mechanics are different, they move differently, and it's only natural for us to think of them as two altogether separate beasts. But really there's a continuum between wet and dry avalanches.

Like dry snow avalanches, wet avalanches can occur as both sluffs and slabs. Wet avalanches usually occur when warm air temperatures, sun or rain cause water to percolate through the snowpack and decrease the strength of the snow, or in some cases, change the mechanical properties of the snow. Once initiated, wet snow tends to travel more slowly than dry snow-like a thousand concrete-carrying trucks dumping their loads at once, rather than the hovercraft-like movement of a dry avalanche.

B. *Dry Avalanches*

Dry avalanches, though beautiful, are extremely violent and seize up like concrete the instant they come to a halt. Dry avalanches are the stunningly beautiful ones that roar down the mountain, light and fluffy, like clouds of powder, but beneath the misty powder cloud is a rushing mass of snow-the "core" of the avalanche-that is a fluidized mix of air (70 percent) and ice particles (30 percent).

Like dry snow avalanches, wet avalanches can occur as both sluffs and slabs. Wet avalanches usually occur when warm air temperatures, sun or rain cause water to percolate through the snowpack and decrease the strength of the snow, or in some cases, change the mechanical properties of the snow. Once initiated, wet snow tends to travel more slowly than dry snow-like a thousand concrete-carrying trucks dumping their loads at once, rather than the hovercraft-like movement of a dry avalanche.

C. *Dry Slab Avalanches:*

Nearly all avalanche deaths in North America are caused by slab avalanches, caused when a cohesive plate of snow suddenly slides away. A "slab" is a cohesive plate of snow that slides as a unit on the snow underneath. A slab doesn't have to be hard it just has to be relatively stronger than the snow underneath. A typical slab is about half the size of a football field, about one to two feet (30-60 cm) deep, and usually reaches speeds of 20 mph (32 km/h) within the first three seconds, quickly accelerating to around 80 mph (128 km/h) after the first, say, six seconds. The bonds holding a slab in place fracture at about 220 mph (352 km/h) and the slab appears to shatter.

Dry slab avalanches can lie teetering on the verge of catastrophe, sometimes for days or even months. The weak layers beneath the slabs are extremely sensitive and the rapid addition of the weight of just one person can easily initiate a fracture on a slope that would not have avalanched otherwise. A slope can sometimes be a giant booby trap-seemingly waiting for just the right person to come along. The crack often forms well above the victim, leaving little room for escape.

D. Loose Snow Avalanches:

Loose snow sliding down a mountain is called a loose snow avalanche. Small loose snow avalanches are called "sluffs." Few people are killed by loose snow avalanches because they tend to be smaller, and they tend to fracture beneath you as you cross a slope, rather than above you, as slab avalanches often do. Most of the people killed in loose snow avalanches are climbers, or extreme skiers and boarders in very steep terrain.

E. Drawbacks

• Death of People and Animals
• Property Damage
• Transportation Disruptions

- Communication and Utility Disruptions
- Crop Failure

Death of People and Animals: Asphyxiation is the most common cause of death by an avalanche. People and animals buried deep in the snow suffocate to death due to a lack of oxygen. The force of an avalanche can also break and crush bones easily. People can also freeze to death when buried under several feet of snow. If found within 15 minutes of being buried under an avalanche, there is a high chance for the victim to survive. However, the survival probability decreases with time. Some of the world's deadliest avalanches have caused the deaths of hundreds of thousands of people. Property Damage: A powerful avalanche can completely destroy buildings and other constructions that come in its way. Houses, shacks, cabins, and even the ski resorts can be ruined during this disaster.

Transportation Disruptions: Avalanches can completely disconnect mountain settlements higher up from the rest of the world. The railroads and roads might have to close down due to the damage caused by the avalanche to the transport infrastructure. Roads might be covered in thick snow from the avalanche that makes the movement of vehicles impossible for days before the snow is cleared off. Cars and trains traveling in the area during the avalanche can also be wiped off or buried under the snow. Communication and Utility Disruptions: Avalanches can wreak havoc in the lives of the people living in and around the disaster area. Power lines can be broken so that people go without electricity for several days. Telephone and cable lines can also be disrupted leaving people with no way to communicate with others or seek help. Such issues can also delay rescue missions. Oil, gas, and water pipes may burst, leak, or be crushed leading to a lack of supply of these vital requirements.

Crop Failure: If the snow from an avalanche accumulates on farmland located at the lower altitudes, it can completely destroy the crop causing a crop failure and heavy economic losses for the farm.

REFERENCES

[1] Brabec, B. and Meister, R. 2001. A nearest-neighbour model for regional avalanche forecasting. Ann. Glaciol., 32, 130–134.1

[2] Doswell, C., Davies, J. and Keller, D.L. 1990. On summary measures of skill in rare event forecasting based on contingency tables. Weather Forecast., 5, 576– 595.2.0.CO;2>.

[3] Davis, R.E., Elder, K., Howlett, D. and Bouzaglou, E. 1999. Relating storm and weather factors to dry slab avalanche activity at Alta, Utah, and Mammoth Mountain, California, using classification and regression trees. Cold Reg. Sci. Technol., 30(1–3), 79–90.

[4] Guyon, I., Weston, J., Barnhill, S. and Vapnik, V. 2002. Gene selection for cancer classification using support vector machines. Mach. Learn., 46(1–3), 389–422.

[5] Heierli, J., Purves, R.S., Felber, A. and Kowalski, J. 2004. Verification of nearest- neighbours' interpretations in avalanche forecasting. Ann. Glaciol., 38, 84–88.

[6] LaChapelle, E.R. 1980. The fundamental processes in conventional avalanche forecasting. J. Glaciol., 26(94), 75–84.

[7] McCollister, C., Birkeland, K.W., Hansen, K., Aspinall, R. and Comey, R. 2003. Exploring multi-scale spatial patterns in historical avalanche data, Jackson Hole Ski Area, Wyoming. Cold Reg. Sci. Technol., 37(3), 299–313.

[8] Obled, C. and Good, W. 1980. Recent developments of avalanche forecasting by discriminant analysis techniques: a methodological review and some applications to the Parsenn area (Davos, Switzerland). J. Glaciol., 25(92), 315–346.

[9] Schweizer, J. and Föhn, P.M.B. 1996. Avalanche forecasting – an expert system approach. J. Glaciol., 42(141), 318–332.

[10] Stoffel, A., Meister, R., Schweizer, J., 1998. Spatial characteristics of avalanche activity in an alpine valley—a GIS approach. Annals of Glaciology 26, 329 – 336.