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Avalanche Prediction from Meteorological Data of Mountains through AI Techniques

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***Abstract*---Avalanches, tends to cause, amongst the most critical problems to the people and the infrastructure, in the mountain area of India. The processes that leads to avalanche releases are predetermined however the place and time of avalanche releases are notoriously challenging to prognosticate. Statistical approaches provides a substitute for deterministic predictions, by means of data released from meteorological departments, for predicting the likelihood of avalanche release that is natural. We took help from classification trees for predicting times or days with as well as without the avalanche in various part of Indian mountains area, which was grounded on parameters from meteorological data. A data-archive of nearly 10 years with avalanche surveillance was temporally and conceptually linked with wind's grids, temperatures and precipitation data. Grids were utilised owing to the fact that they dispensed additional temporally reliable datasets than were offered by measurements of local weather stations through Artificial intelligence technology.**

***Keywords*--- Artificial intelligence, Avalanches, Meteorological data, prediction, mountains**

I. INTRODUCTION

Avalanche (correspondingly known as snow slide) is basically a consequence that befalls once a cohesive snow Slab be positioned onto fragile layers of snow fracture as well as it glides downhill slope that is steeper. Triggering of the avalanches basically starts from the zones of mechanical failures in snow packs (slab avalanches) once the pressure of snow surpasses its strength however occasionally it only happens to be a gradual widening (snow avalanches that is loose). Once it has initiated, the avalanche generally accelerates promptly besides growing in volume and mass by means of entraining further snow in it. If, avalanches travel sufficiently wilder, a range of snow might combine together with air creating a dust of snow avalanche, which basically is a kind of current of gravity. [1] Avalanches generally covers three major topographies that is the zone from where it has started, the track of avalanche, and the zone of runout. Lunching of avalanches takes from the starting zone that is frequently the one of the utmost unstable portion of the slope, generally happens to be on height on mountains. As soon as the avalanches begins to slide down, it vigorously endures down the track of avalanche, downhill is the natural path which is followed by it. Later to an avalanche, huge clearances or else misplaced tree's chutes provides the evidences of the trajectory of avalanche. Finally, the avalanche approaches to stop in the runout zone, which is present at the bottommost of the slope, where the piling up of debris along with snow takes place [2]. Rocks slides or else debris of rocks also behave in a comparable manner as the snow behaves, and so it is also denoted as avalanche. Gravity may only be responsible for the burden on the snowpack, which in case of non-fulfilment might either cause weakening of the snow packs or else increase burden because of precipitation. Initiation of avalanches caused by this very method, are called spontaneous avalanches. Avalanches might as well be generated by various other charging circumstances including biological or human linked events. Activities of the seismic waves might as well generate the failures in the snow packs as well as avalanches [1].

Track of avalanche is the trails followed by an avalanche going downhills. Huge upright swath of trees misplaced from slopes or the clearings that are chute-like are seldom considered as the sign that a huge avalanche has frequently crossed over that place, making their peculiar paths. There might also be presence of big pile-ups of debris and snow found in the vicinity of bottom of slope, indicative of avalanche run through. The zone of runout is the one wherever the debris and snow have conclusively stopped. Correspondingly, this as well is considered the site of the zone of deposition, where there is the highest heaps of debris and snow. Various elements might influence the probability of avalanches, involving temperature, weather and steepness of slope, alignment of slope (whether the slope is north facing or south facing), terrain, direction of wind, usual conditions of snowpack

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Vol 8, Issue 4, April 2021

and vegetation there. Various blending of such factors or elements can generate extreme, moderate or low avalanche situations. Several such situations, namely snowpack and temperature, might alter on an hourly or daily basis [3].

TYPES OF AVALANCHE: - There are main four avalanche to make it understand better:

1. **Loose snow avalanche: -** Usually found on steep slope and observed after a snowfall that has freshly appeared. Subsequently, as the snow do not have much time to colonize completely or it has been loosened by the sun's rays; snowpack is not so compact. These have a sole point of beginning or origin, widening itself as they move downhill.
2. **Slop avalanches**: - Snow Avalanches that are loose could in turn trigger Slab Avalanches that are basically categorized by the collapse of a huge ice block down the slope. Flimsy slabs instigates comparatively smaller extent of damages, whereas the heavy slabs of snow are accountable for various accidents.
3. **Powder snow avalanche**: - It is a mixture of the various other varieties of avalanches, Snow as well as Slabs that are loose. Half of the lower part of this avalanche comprises the slab or else an impenetrable snow concentration, air and ice; over this is a snow dust cloud and this snowball can generally form into a huge avalanche when it proceeds downwards along the slope. The speed of this avalanche can reach up to 190 mph and can go as far as it can.
4. **Wet snow avalanche**: - such avalanches are moderately life-threatening because they can travel gradually by reason of friction in it, which alongside gathers remains from the pathway very effortlessly. This avalanche incorporates snow and water at the commencement, on the contrary, the interpretation of this avalanche have presented us speed can be picked up by it with effortlessness [4].

ARTIFICIAL INTELLEGENCE: - Intelligent resolutions, bottomed on artificial intelligence (AI) technology, to resolve the complex empirical problems in numerous areas are seemingly incrementally prevalent these days. Systems that are AI-based are being made as well as implemented throughout the world in innumerable applications, chiefly due to its symbolic interpretation, elasticity as well as capabilities of explanation [5]. The AI technologies researcher and their present usage in the fields of short term electric load forecasting (STELF). The description of AI in the STELF is delineated, which leads to the analysis of numerous tactics or methods in addition to the present directions of research. Electrical load forecasting has an essential part in order to accomplish next generation concept of power systems namely the efficient energy management, smart grid as well as planning of enhanced power systems. Resulting in a higher estimation or prediction precision, which is needed for several horizons of time that are linked with dispatching, regulations, unit commitment of power grid as well as scheduling of it. AI based technologies are being made as well as deployed throughout the world for the variety of usages due to its excellent capabilities to deal with the complicated output and input relationships. Here in this paper, we provide, the systematic and comprehensive review of literature of this Artificial Intelligence based short term load forecasting techniques. The chief purpose of this report is to identify and analyse the Artificial Intelligence (AI) based load forecast models performances as well as research gaps. Accurateness of ANN centred forecast models is discovered, that it is reliant on number of specifications namely architecture of forecast models, activation functions, combination of inputs as well as training algorithms of network along with various supplementary external variable that affect the inputs of the forecast models [6].

Avalanches of snow are counted amongst the highly devastating natural hazards that is life threatening for humans, built structures, landscapes as well as ecosystems in the regions comprising mountain. Intricacy of modelling of snow avalanches have been reviewed in various reports however its modelling has not been documented well. Modelling of snow avalanches, in this analysis report, was accomplished utilising three of the chief data classifications; incorporating site of occurrence of avalanche, factors relating to meteorological conditions as well as characteristics of terrain. Two of the learning models based on machine learning; that is, multivariate discriminant analysis (MDA) and support vector machine (SVM), were made use of. A ratio consisting of 70 to 30 of data was used for validating and calibrating these models along with the sensitivity analysis that suggested that the geomorphologic site of occurrence, slope of area, topographic wetness and precipitation index were amongst the highly effectual variables when considering the modelling. A map of snow avalanche signified that the terrible hazards that are caused by snow avalanche zones were mostly effectual close to the streams as well as

were coordinated along the hillsides in the vicinity of pathways of water. Verdicts of report could be beneficial for the planning of land usage, to regulate the pathways of snow avalanche, as well as to avoid the apparent hazards that are encouraged by it. It could also prove to be a helpful reference for forthcoming studies on the snow avalanche hazards' modelling. [7]

WHAT IS METEROLOGICAL DATA - An event of avalanche was sufficiently noteworthy to be documented, avalanche might have possibly frightened the roads. Since 1975, Variables of the meteorological data for the days when avalanche was witnessed as well as data relating to meteorology has been manually collected as well as collected utilising the automated or computerised stations in those areas. Though, the data gathered was highly varied because of the following, 1) sundry spectators for the measurements that were manually done; 2) numerous sensors throughout the surveillance period for the measurements that were automated; 3) unreliable or changeable degrees of quality of data. To evade such glitches, we chose to utilise various source of meteorological data. Utilising the above described three data sets also approved us to examine the parameters of meteorological data that was accountable for the release of avalanche on the nationalised scales. Evaluating the parameters of meteorological data from days of avalanche with the considerations on days that were without avalanche, we chose certain number of days that were without avalanche in the subsequent ways: Firstly, no numeral of days without avalanche had to be equivalent to the numeral of days with avalanche which gives a stable model of it. Furthermore, an attempt was made to retain the numeral of preferred days without avalanche on any of the particular month equals to the numeral of days of avalanche in the similar month. Such above said things was not constantly achievable as some of the months had avalanche beyond half of the days of existence, assigning lesser than a half of days for the non-avalanche times. Owing to such cases that are fewer in number, we selected the closest day whichever the preceding or the following months. For choosing the days without avalanches, we ignored the kind of avalanche being witnessed. By way of explanation, the days consisting of witnessed avalanches of whichever types were certainly not chosen as days without avalanche. Conclusively, days of non- avalanches were under no circumstance chosen twice, which means that all the days without avalanches were kept to be exclusive. For every single day without avalanches, the similar parameters for meteorological data as was formed for the days with avalanche were made from the grids of meteorological data (Tables 1 and 2). Additionally being specific temporally, the datasets that were without avalanches was also specific to locations of occurrence as the spatially distributed grids bring about meteorological parameter. We selected the locations of non-avalanches days on the coordinate of the meteorological stations available in the superior parts of Grasdalen. The site was not at all in the middle of the detected paths of avalanche, however it was selected to allow comparisons with the meteorological station's data (outcomes not presented here) [8].

II. REVIEW OF LITERATURE

The western United States' snow avalanche atmosphere has for long time been supposed to comprise of the three chief climatic zones relating to diverse features of avalanche: continental, intermountain as well as coastal. The zone that is coastal side of the Pacific mountains range is categorized by ample snowfalls, greater densities of snow densities as well as elevated temperatures. The zone continental to the Colorado Rockies is categorised with decreased temperatures, lower densities of snow, reduced snowfalls, snow temperatures gradient being higher and a further constantly unbalanced snowpack as a consequence of depth hoar. Utah, Idaho and Montana which is the intermountain zone is present amid the former two zones. Quantitative assessment of the snow avalanche's climatic conditions of the area was performed being deployed on the data of Avalanche's Networks that is present West-wide, from the year 1969 to the year 1995. A bipartite classification of the climate of avalanche which is situated on a familiar threshold as well as varieties of snow packs and variables of climate such things exemplifies a wide range of climatology of the main three zones, certain spatially assorted arrangements as well as alterations with elevations. Prevalent spatial swings or shifts towards further coastal acclimatization took place for the duration of the year 1985/86 as well as the year 1991/92 and shift towards more continental acclimatization took place in the course of the year 1976/77 as well as the year 1987/88. Height irregularities at 500 mb explains most of such shifts or swings, however, regular plot of climatic conditions along with variables of avalanches throughout the seasonal extremities for the regions in the northern Utah, further illustrates the significance of apprehending snowpack as well as variations in weather conditions that happens on a timescales of daily to weekly. Data received from various sites of central Rocky Mountains specifies certain associations of the teleconnection patterns of Pacific–North America as well as the Pacific decadal oscillations, elucidating the significance of long-term records of application in an assessment of avalanche vulnerability [9].

An inventory map of snow avalanches was engendered from imagery in Google Earth, various survey of fields and regional documentations. Out of 101 locations of avalanches, 71 (i.e., 70%) of them were utilised for models training and 30 (i.e., 30%) of them were consumed to authenticate the subsequent model. Fourteen of the snow avalanches acclimatising components were utilised in the role of self- determining variables in the process of anticipating modelling. Initially, the weights of PD and Bel methods were employed to every class of factor. Then it was united with the two LR and MLP learning model the for snow avalanches susceptibility mapping (SASM). There outcomes were supported utilising sensitivity, positive prognostic values, predictive negative values of it, accuracy, specificity, values relating to area-under-the-curve (AUC), root-mean-square errors. Therefore, the AUCs relating to hybrid models, i.e., PD-LR is 0.941, Bel-LR is 0.936, Bel-MLP is 0.931 and PD-MLP is 0.924. Bottomed on the results of validation, the hybrid model of PD-LR attained the desirable accuracy amongst all other models of it. This approach of hybrid modelling may offer us with the precise as well as consistent estimations of snow avalanche-prone regions for the supervision and to make various decisions regarding it [10].

In the year 2019- hazard predictions of Snow avalanches utilising machine-based learning techniques by researchers from Natural Resources Faculty of University of Tehran , Oxford Brookes University , Obuda University, Budapest, Hungary, Ho Chi Minh City, Thang University, Viet Namby utilising Two of the machine-based learnieng model, viz., multivariate discriminants analysis (MDA) and support vectors machine (SVM) [11].

2009 – Early-Warning Systems and Disasters Monitoring For Snow Avalanches across Highway of Tianshan by [12]

2018 – Modeling, Mapping As well as Snow Avalanche Simulations In Valley of Alaknanda, Central Himalayas: Assessment of Hazards by [13] from Geosciences as well as Study Groups of Disaster Management, Indian Institute of Remote Sensing, ISRO, Dehradun, India.

2016 - Parameters for Avalanches for employing Sensor Node in the Snow compelled Regions by [14] from Teerthankar Mahaveer Univesity, Moradabad, , Panipat Institute of Engineerinf' & Technology, Panipat.

2020 - HIM‐STRAT: a network‐based neural model for simulations of snow covers and predictions of hazards from avalanche throughout North‐Western Himalayas by [15].

Models based on Artificial neural network (ANN) have been evolved for the snowpack parameter simulations of— hardness of RAM, temperature, shear strength, densities, wideness as well as settlements of layers of snowpack utilising physically detected data of weather. The snowpack parameter that is simulated have been utilised for the evolvement of ANN for the purpose of prediction of avalanche [16].

Snow avalanches are counted amongst the deadliest natural threats comprising of chief environmental as well as socioeconomic damages in the freezing mountain areas. The demolishing accumulations and propagations of debris of snow avalanches along with a large amount of destructions of rocks of surface as well as particles of vegetation frightens human existence, networks of transportation, ecosystems, built environments, along with water sources [17].

The troops of Indian army are positioned in higher altitudes of snow bound areas of Western Himalayan regions, linger under serious risk of snow avalanche, which is also called as ‘white death’, throughout the winter season. Snow & Avalanche Study Establishment (SASE) is dedicated to guarantee the safe movement of Indian army troops in those regions that has been tirelessly employed towards the mitigation of this danger through both active and passive methods. Whereas, the active method of installation of control structures offers permanent solutions, it is very difficult to implement and often economically unviable. [18]

2019 - Data efficient Random Forest model for avalanche forecasting by [19] Snow and Avalanche Study Establishment.

2009 - Snow Avalanche Climatology of Indian Western Himalaya By [20] from Defence Research and Development Organisation.

III. RESEARCH OBJECTIVES

Objective of the project is to develop an avalanche prediction model which can be used in high altitude areas to save men and material from avalanche calamity.

- Build a user friendly application for desktop and mobile phone.
- Understanding domain requirements of real time snow parameters and
- addressing with automated process by integrating other sensor data.
- Analysis of sector specific data with many parameters received from SASE DRDO.

IV. METERIALS AND METHODOLOGY

Modeling of Snow avalanche here in this project was basically performed operating two chief groups of the data,

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Vol 8, Issue 4, April 2021

meteorological factors and terrain characteristics. Such data of weather are gathered from the internet. Artificial Neural Network is used in this project for the forecasting of avalanches. Hazards from avalanches could be moderated by warning people in that area. In the present situations, avalanche's threat is estimated by the professionals of this field, and these professionals act in accordance to their wisdom as well as experiences. Professionals utilize facts and evidences from the present and past snow appearances, weather situations of present as well as past, terrains, history of avalanche along with it, occasionally, the use of snow profile information is been done by them. Particular as well as generalized models accepted for forecasting of avalanche has not yet been made.

In many areas, current system equipped with artificial intelligence are being made and utilised. Systems comprising of artificial intelligence can gradually substitute the systems that professionals use and can assist them with their jobs. For the predictions of dangers from avalanches, artificial neural networks can be utilized which will use data from weather conditions as well as other information measured. ANN are basically the investigative systems, which imitates the decision making processes that is biologically controlled by human brains. Forecasting of hazards from avalanches are some of the specific tasks that these networks accomplish [21].

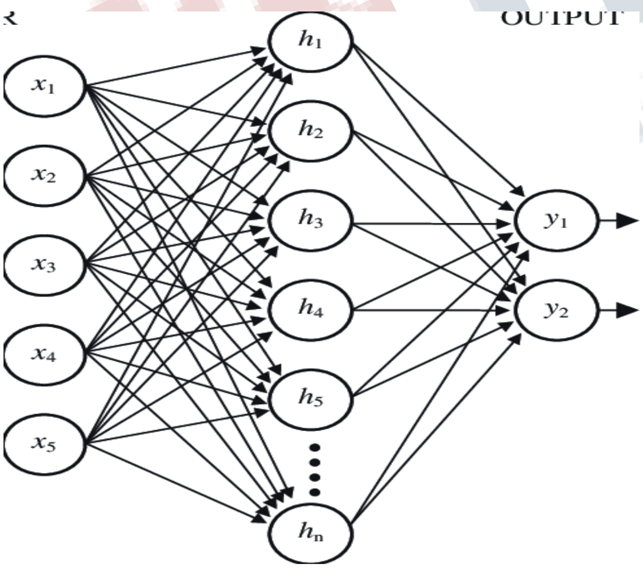


FIGURE 1 Example of Neural Network

The basic knowledge of networks was determined grounded on the experiences, which probably in present illustration consists of weather details from past as well as conditions of snow along with ascertained dangers from avalanche in the dataset. Entire data is allocated into two major set of groups: data of training along with data of tests. It is essential to instill neural networks beyond single winter since individual winter has unusual weather conditions as well as conditions of snow. When additional data from additional winter seasons are utilised, we could obtain an enhanced neural network outputs.

Normalization of all the inputs to neural networks are basically in between the range from 0 and 1. Outputs gathered from neural networks is danger of avalanche, in relations to classes.

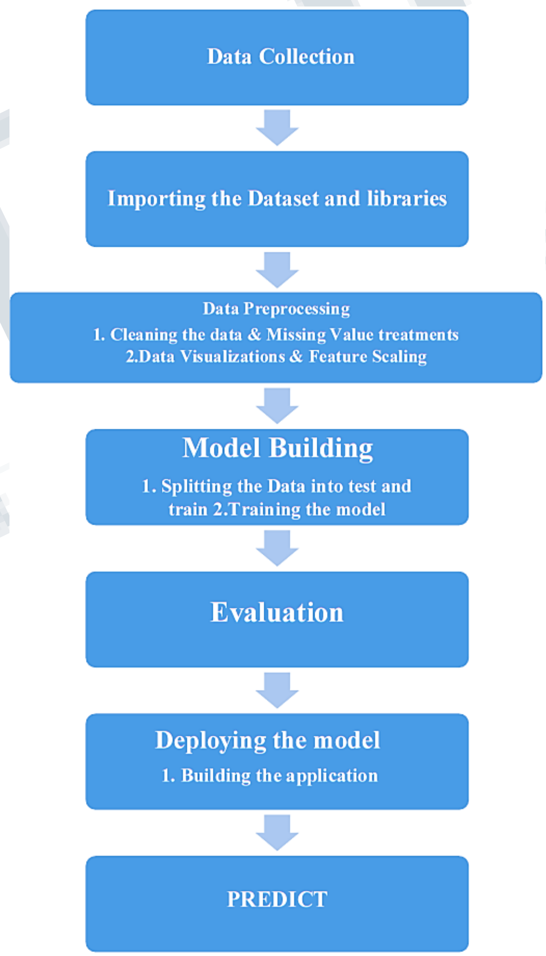


FIGURE 1 FLOWCHART OF APPLICATION

Decision Tree Alogorithm

One of the powerful resolutions to classifications problem is contemplated to be Alogo-tree besides it is used in a lot of applications in the real world. In the current

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 8, Issue 4, April 2021

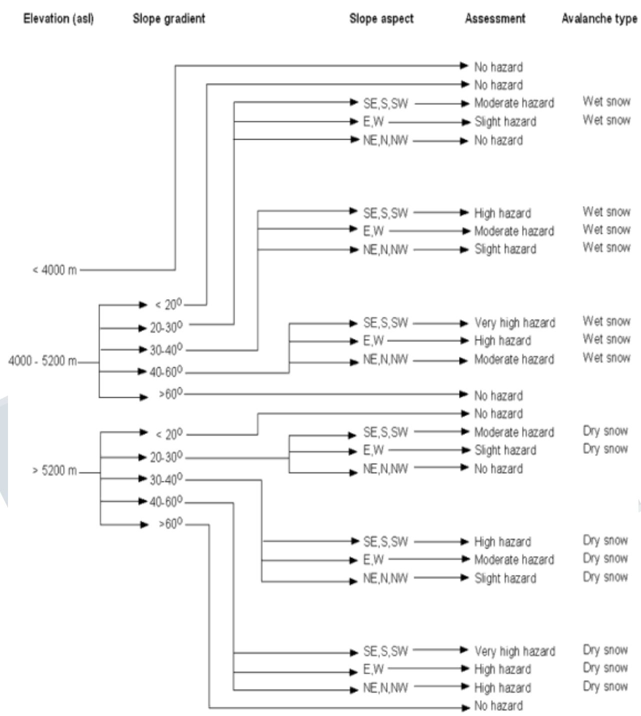
scenario, various data mining methods are utilised for forecasting of weather, along with several levels of accurateness. Using the above said literatures, we got to know that, there are certain jobs that are accomplished contemplating the Neural Networks, Rule-based Methods, Naïve Bayes, Memory based reasoning, Support Vector Machines, Bayesian Belief Networks. However, neither of one-self have tried identifying for Decision trees utilising Sets of data. Hence, in this report an effort is tried for the prediction of forthcoming forecast of weather. Decision trees is basically a decision supporter device that utilises a model that is tree-like for decision as well as their likely significances involving resources cost, chance events outcomes, along with its effectiveness in the area. This is considered to be one of the ways to present an algorithm that solely comprises of control statements that are conditional. Alogo-trees are generally utilised in research operations, particularly in the analysis of decisions, assist in identifying an approach which is more probable in reaching an objective, further it is a famous tool amongst machine learnings. Decision tree occurs to be flowchart-kind of a figure, in which, each and every internal nodes signifies a 'test' on an attribute (for instance, when coin flips whether it comes up to be a head or a tail), each and every branches signifies the results of test as well as each and every leaf nodes denotes a label of class (decisions are received after one has computed every attribute). The classification rules are represented by the route from roots to leaves.

For the analysis of decisions, decision trees as well as the jointly associated guided diagrams are made in use just like an analytical and a visual decisions supporting tools, in which the anticipated values (or utilities expected) of contending substitutes are estimated.

Three kinds of nodes are consisted by a decision tree, they are as follows:

Decision node – generally typified as squares
Chance nodes – generally typified as circles
End node – generally typified as triangles

Decision making trees are basically utilised in the research operations as well as management operations. In operation, if, the decision has to be made online having no recalls also it is in the state of partial knowledge available, at that time, decision trees shall be made parallel using probability models which will act as a worthiest alternative model or else algorithm models for online selections. One more utilisation of the decision tree is, can be made as illustrative mean aimed at estimating probabilities that are condition related. Decision trees, utilities function, influence diagram as well as various other conclusive investigative methods or tools are educated in the business schools, public health sectors, and health economics to undergraduate scholars. They also are samples of research operations otherwise management sciences approaches.



Note: N = north, NE = northeast, E = east, SE = southeast, S = south, SW = southwest, W = west, NW = northwest

FIGURE 2 Example of decision tree for avalanche prediction

A. Tool and Framework Chosen for Solution

Table 1 Tools and framework chosen for solution

Description	Consideration	Final	Reason
Framework	Tensorflow sklearn	Tensorflow	• Google Colab implementation • Faster
Model	Logistic Regression Decision Tree Classifier ANN	ANN	• Due to its High Accuracy and Speed
Data Set for Training in Phase 1	www.kaggle.com Dataset 1 Dataset 2	Dataset 1	• More features and better correlation
Deployment Environment	Google Colab GPU		
Application Framework	Python	Python	The application will need to be real-time in future. The framework will be integrated.

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V. RESULT AND DISCUSSION

Model Training details of Phase 1

- Dataset – www.kaggle.com datasets
- Data points – 204/ 4216
- Classes – 3
- Model – Logistic regression, decision tree classifier, ANN
- No of batch – 25 and Epochs – 10000
- Classification Accuracy – 92%
- Time taken for prediction – few Milliseconds

Demonstrative figures of Model Results

With new Model built the following results can be seen

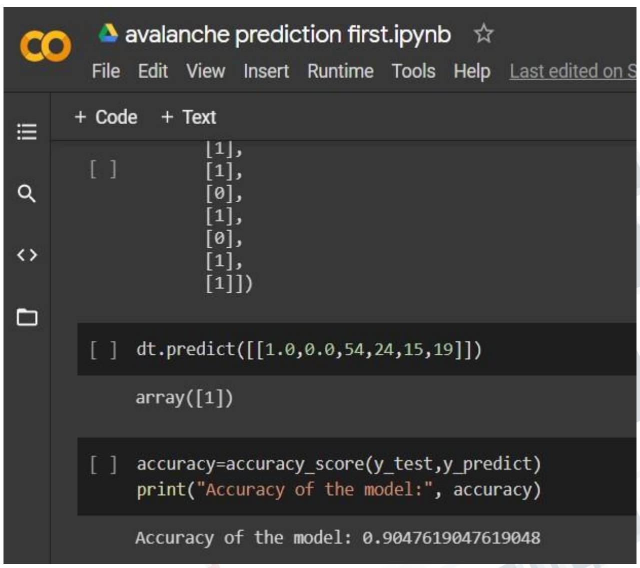
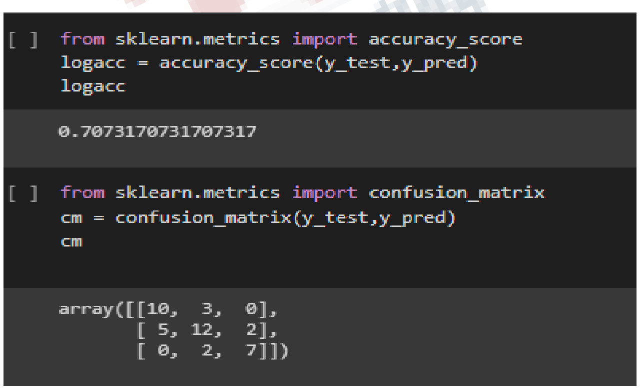
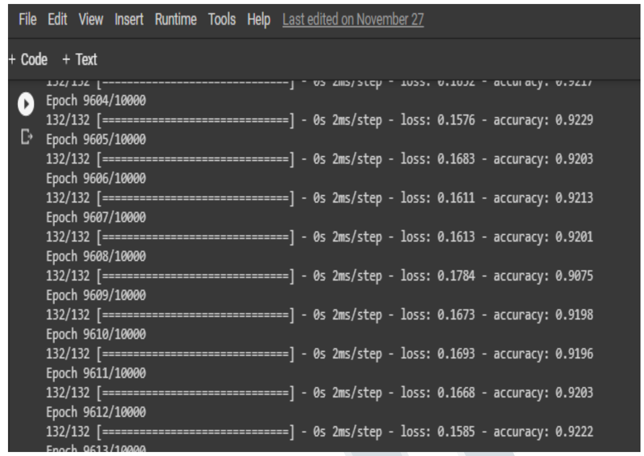


FIGURE 3 Results with Model (Decision Tree Classifier)





VI. CONCLUSION

Machine learnings could be utilised to resolve numerous chores by scrutinising pattern of data presented. Classification occurs to be a machine's learning job where the training of the algorithms is done along with datasets of examples of input-output. Classification tasks that are further complicated, namely recognition of object, learning deeply has given out promising outcomes. In the recognition of object, deep CNNs have basically set off as a state of the art of the method.

Coaching a Neural Network for the purpose of completion of tasks could probably be slow and time-wasting. Conducive to coach NN, a huge quantity of data is necessitated, failing to which, the performance of training of NN could be enhanced, accompanied by transfer learnings where pre-trained models are utilised to enhance the functioning of new models. Training functioning of NN is further influenced using several hyper variables. Regulating the hyper parameters in contemplation to outreach the excellent training performances might be harder. Nevertheless, this procedure could be made automatic making the use of approaches that are practical as random and grid hyper parameter research method.

Current report represented hazards from snow avalanches utilizing three of the machine learning techniques. Outcomes from such model signified the excellent performances in the modeling of snow avalanches.

The results are very encouraging. Initially, the modest amount of avalanche occurrence data and its subjectivity seemed to perhaps thwart efforts to apply machine learning to avalanche forecasting in the area. Despite the modest amount of data, the models perform very well.

The sorting out performances of the model was

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 8, Issue 4, April 2021

basically estimated by calculating their accurateness as well as their usual accuracy of class. The Logistic Regression Model performed poorly. Decision Tree Classifier architecture evidenced to enhance the performance of classification. They attained the finest accuracy which was 90%. Further, NN architecture ascertained to enhance the performance of classification. They attained the finest accuracy of 92%. Computational performances was assessed by evaluation of time which was needed for the classifications along with model utilising a GPU as well as a CPU. Classifications were far quicker using GPU, as was anticipated. Time needed for the classifications using GPU was covered within millisecond. For applications in real-time, the time needed to Classify is not a factor that is limiting. Performance needs to be improved for real time along with accuracy of classification. The new SASE DRDO data set needs to be collected for Kargil Sector and model needs to be evaluated.

Set up on the classifications trees meant to split days of avalanche as well as days without avalanche utilising parameters from meteorological studies that is originated from temperatures, precipitation along with grids of wind, we got the below stated interpretations: One of the most essential parameters was precipitation for avalanche release in the study 794 area, mainly if given as five, one or three-day sum. Precipitation was followed in importance by wind speed and temperature parameters. - Based on a set of simple meteorological parameters it can reasonably well be predicted whether a day will have avalanches or not. - Predicted climate change with an increased number of days with high precipitation will lead to an increase in avalanche days.

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