IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Risk Analysis Model That Uses Machine Learning to Predict the Likelihood of a Fire Occurring at A Given Property

Lakshmisri Surya

Sr. Data Scientist & Department of Information Technology

USA

Abstract

Combining multiple datasets and applying machine learning algorithms would help city officials and fire services direct their resources more efficiently, avoid disasters, and save lives in the occurrence of a fire incident. Also, it might at most help in making accurate forecasts about where fires are going to occur. Every year, the risk analysis model that implements machine learning responds to emergency calls and helps prevent the occurrence of a fire incident. It is because they can give out smoke alarms, inspect commercial buildings, and educate the community on matters that surround risky behaviors that may trigger fire, among other preemptive actions. Additionally, this success comes along with challenges and associated problems such as limited resources. For this very time, they have only achieved very little in terms of risk analysis mechanisms. Predicting the occurrence of fire in property constitutes a very significant component in management and analysis of fire. This is because it plays a significant role in recovery efforts, mitigation, and resource allocation. It is challenging to accurately predict a fire incident, although it is an essential factor in protecting property and human life. This paper provides the proposed models, which are focused on statistical machine learning and risks optimized by the use of indexing for assessment fire risks. Generally, the models that are currently used in predicting fire does not provide satisfaction and accuracy. The factors that affect the occurrence of fire are the frequency of fire occurrence and diversity, which are very sparse. Therefore, to improve the accuracy of predicting fire occurrence, there must be a risk analysis model that implements smart machine learning technology. This research paper presents an analysis and description of property fire prediction methods based on machine learning. A novel algorithm for property fire risk prediction, which is based on machine learning, is presented. Also, the implementation of the algorithm that uses data from different frameworks is demonstrated in having the ability to predict the fire occurrence accurately.

Key Words

Machine learning, Risk analysis models, Artificial neural network, fire risk prediction, and assessment.

Introduction

For a very long time, fire occurrences have been a devastating effect on both property and human life. Therefore, in combating this, humans have been coming up with different approaches to deal with the fire. The unique approach predicts the probability of fire occurrence (Madaio et al., 2015). Although, it remains a challenging task to predict the occurrence of fire. It is because fire is attached to very many variables that affect its occurrence and the total number of fire incidents in a day is very minimal. This means that the data set for fire occurrence is sparser since most of its data sets' values revolve around zero. Therefore, in combating this issue, evaluating the risks of the fire has been implemented in predicting the occurrence of fire. The model used in this approach implements various machine learning algorithms, which include boosting, super vector machines, and logistic regression. Globally, due to the health and environmental impacts of fires and the fact that fire regimes have been evolving, fire detection has gained increased attention (Castelli et al., 2015). The accuracy of predicting using machine learning models is far much superior as compared to the existing models that are currently used in predicting the occurrence of fire. Additionally, everyone's expectations that the machine learning models will contribute to evaluating the possibility of fire-associated risks in factories and buildings will be evaluated.

Fire detection is a very significant way to reduce the harm that can occur if there is a fire. Modeling the relationships between the fire hazard and control factors is an essential method for estimating fire activity since the factors of specific strain more influence these areas. In various engineering applications, artificial neural networks (ANN) have been commonly embraced as predictive analytics (Watts & Hall, 2016). ANN has progressively been used to assess the frequency of catastrophic fires and to forecast the creation of fires and smoke. Instead of conventional numerical methods involving extensive data storage and long calculation, the intelligent approach is an innovative way to determine a property's fire protection (Sculley et al., 2015). Although fire analysis is typically noise degraded, a few ANN models are specifically created for this task. Data regression is among the methods in the framework for predictive analytics. In the field of function approximation, this is also a significant research subject (Zhang et al., 2016). Various data regression artificial neural network (ANN) methodologies have been introduced, particularly Radial Basis Function (RBF) and Multi-layer Perceptron (MLP).

Literature Review

Risk Analysis Models that Implement Machine Learning to Detect Fire

There has been an increasing tendency to incorporate cognition and automation into various engineering applications with the ever-growing new technologies increase. Despite a variety of measures, and interestingly more of all sub-disciplines of engineering, the community of structured fire safety and fire engineering continues to follow a classical position to solve the fire crisis (Lau et al., 2015). The ability to incorporate machine learning is becoming a unique technology for evaluating efficiency and fire resistance of systems to support rising needs to implement quality-based solutions (Meacham et al., 2016). It is also clear that the validity of using ML to restructure fire prediction assessment since the established ML models have a significant level of perceived notion, i.e., learning from past behaviors and the potential to improve their predictive capacity through autonomous and unattended learning.

ML does not rely on mere mathematical equations or guidelines to start a study compared to conventional strategies. But instead, to comprehend a concept, ML tries to mimic the human-like thought process and is especially appropriate in situations where many inputs are available (Chuvieco et al., 2014). An ML model attempts to capture underlying knowledge through adaptive learning and a comprehensive examination of inputs and selected output using algorithm search allowed by neural networks. When an initial trend is established, this trend will become the first move in recognizing the essence of the experience on hand to explore enhanced patterns with more excellent prediction capabilities. An ML model consists of various hidden and visible layers together with processing units, usually referred to as neurons. These neurons are also organized to form an intelligent structure or network, which establishes a continuous connection amongst layers and functioning neurons, with a similar layout to that of a human brain (Karray et al., 2014). The first layer includes the inputs or predictors in this network and is linked to a range of hidden layers with the potential to establish linear or non-linear models. The hidden layers are also interconnected with the output layer, which is made up of outputs or target variables.

Two commonly known approaches implement ML to detect fires: image-based approach and sensor-based approach. Starting with the image-based approach to detect fire, a convolutional neural network is implemented whereby it is trained to perform the task. The primary process involved is testing the model for validation, training the model, annotating the dataset, and preparing it (Pourtaghi et al., 2016). The model of deep learning is always implemented using drones that are serving the purpose of surveillance to detect the presence of fire. The task involved in this approach is more similar to the approach of the detection model. After the model has successfully learned the features associated with the flames from the annotations and data itself, it can be implemented in fire detection. In this case, the commonly implemented model is MobileNet since it provides the best accuracy with fewer complexities it is computation due to the use of depth-wise convolution (Lecun et al., 2015).

Additionally, this approach can be extended further in detecting how to sever an incident by using the k-nearest neighbor algorithm. The drones detect the flames and send warnings to the relevant authority to take any action necessary for the scenario. Therefore, using this model, deep learning is implemented to mitigate the level of the catastrophe.

In the second approach, which is the sensor-based approach, the sensors present within a property are used in delivering a cumulative prediction about the occurrence of fire. The sensors are implemented to measure the amount of oxygen in the atmosphere, carbon monoxide, hydrogen sulfide, and carbon dioxide (Saoudi et al., 2016). The retrieved data is then combined with variations of the surrounding temperature and the change in the levels of humidity, which are used in detecting fire. Machine learning in this approach is trained from millions of datasets in collaboration with its components to make more accurate predictions. Therefore, when the ML models detect an anomaly, an alarm is raised to warn the relevant authorities.

Additionally, models of classification, which include logistic regression, can also detect the fires (Alkhatib, 2014). This means that an advanced type of application that implements the same concept would be used in predicting the occurrence of the next fire incident. This issue of fire is a time series problem. It can only be resolved effectively using machine learning models, such as long short-term memory (LSTM) and recurrent neural network (RNN). Therefore, this means that machine learning has enormous potential for growth in the sector of fire prediction.

Artificial Neural Network (ANN) as a Method of Fire Prediction in ML

The non-linear model of artificial neural networks that are highly dynamic can estimate and replicate any non-linear function that is non-linear of a dynamic phenomenon, such as the occurrence of fires with large fault tolerances. Additionally, the Artificial neural networks have more outstanding mapping capabilities that are non-linear compared to conventional parametric regression models or multiple regression models and can also benefit from adaptive and self-learning capabilities (Hu et al., 2015). An artificial neural network (ANN) is a concept that applies mathematics that can be easy to implement as modeling of technology that attempts to mimic the human brain's essential attributes in connection to its highly parallel information processing capacity (Karouni et al., 2014). Therefore, model design and tuning and the original learning algorithms themselves are the major components for ANN technologies.

All those other features of an ANN can also have a significant effect on the model's efficiency. The first is the ability of humans to learn through experiences. The second is obtaining the experience gained from fresh and unknown examples via the learning experience (Schmidhuber, 2015). Generally, ANN has been used as an alternative to the conventional frameworks to find tentative but agreed and satisfactory solutions to complex problems out of scope for linear and traditional frameworks in a reasonable timeframe

(Yan et al., 2016). Thus, ANN is principally applied in any problem that may be difficult within the human scope and has a flawed model and rich in fire prediction data. Another thing worth mentioning is that although ANNs are incredibly powerful, they can sometimes be very sophisticated and are called algorithms of the black box, which implies that this is very difficult to comprehend and describe their internal workings of the model.

Statistical Machine Learning as a Model of Predicting Fire

Learning through data is referred to as statistics, while machine learning makes computers intelligent through learning via data. Therefore, in simple words, statistical machine learning is applying statistics in the framework of machine learning. Generally, statistics implements the interference concept with hypothesis testing and estimation (Hantson et al., 2015). Additionally, statistics possess normality when it comes to data assumptions. Thus, statistical machine learning brings about the performance improvement of machine learning through normality assumptions and statistics interference. Also, regression represents statistics, and deep learning is an algorithm that is used in machine learning. When investigating the fire, a fire risk model is constructed using statistical machine learning in collaboration with an optimized risk indexing (Schmidhuber, 2015). Hence, the data related to the risk of fire comprises variables that are explanatory and affects the fire occurrence and response variable, which indicates the frequency of fire occurrence. Since the response variables hold the data for frequency, the method of count data analysis is implemented among statistical machine learning models.

In assessing the fire risk for the factories and buildings, this approach uses the data provided on fire occurrence. The data set contains a massive number of variables that are connected to the occurrence of fire. In keeping the data independent, the data is separated into model verification and model construction. Furthermore, the inspection data is then combined with data of fire incidents, which are then classified into whether the fire occurred or not (Saoudi et al., 2016). Also, in optimizing each component's weight, the deviation concept is applied to the mean value of the likelihood index of a fire occurrence. Thus, using this process, the occurrence of fire can be accurately predicted.

Benefits of using Machine Learning Models in Fire Prediction

With the current applications of ML models such as expert systems and neural networks, the sector of fire management has effectively advanced the prediction mechanisms. This has helped the field congruently progress with the various ML methods adopted in predicting the possibility of fire within a property (Sculley et al., 2015). The models are capable of; fire management, addressing fire effects, predicting fire behavior, establishing risk, susceptibility, and fire occurrence, determining the climate change and fire weather, and fuel the mapping, fire detection, and characterization (Castelli et al., 2015). Therefore, this means that there are more opportunities that are presented for applying ML methods, which include agent-based learning and deep learning in the sector of fire prediction and prevention and areas involving extensive datasets.

However, although machine learning models have the ability of by themselves, fire experts are also necessary to ensure models that are more realistic of the process of fire across all the frameworks. This will help in addressing the complexity of some of the methods of machine learning, which include deep learning requiring a sophisticated and dedicated knowledge so that they can be implemented (Lau et al., 2015). Additionally, ANNs can be configured to offer an unsupervised learning task, which will significantly assist and reduce cumbersome in the sector of fire prediction. It will also assist in detecting fire sooner, just as they ignite. As the fire is still relatively small, it aids in facilitating an effective and quick response and reduces property damage. The automated detection of smoke or fire in optimal or infra-red images will extend the temporal and spatial coverage of detecting fire (Saoudi et al., 2016). It also increases the efficiency of detecting smoky conditions hence removing bias associated with the observation by humans. In this case, the analytical task is the problem of classification, which is suited quite well-using machine learning methods.

How the Research on Fire Prediction using ML Will Help the United States

Researchers introduced the implementing machine learning idea to a hypothetical scenario in which hundreds of fires simultaneously broke out. This sounds crazy, but in recent times, in parts of western United States, the whole condition is now all too frequent as changing climate has resulted in the dry and hot situation on the ground, which can put a nation at elevated danger of fire (Madaio et al., 2015). Speed is one benefit of this new system. With each new dataset, the algorithm learns and efficiently works out all the critical thresholds for detecting massive fires. It is indeed possible for a person to do the same manually or perform simulations around each unique fire. However, the machine learning model's statistical method is relatively faster and more reliable, specifically for concurrently involving different fires. Each local firefighter authority, county, state, and season could significantly benefit from some updated techniques and tools developed using machine learning models. Additionally, to protect crucial infrastructure and property and saving lives potentially, the efforts placed in predicting fire will become more critical in preserving all these elements.

Conclusion

Researchers extend the idea of machine learning in predicting fire to a particular situation in which hundreds of fires rapidly broke out. This sounds far-fetched, however in recent times, in parts of western United States, such a situation is now all too normal as climate change has culminated in dry and hot realities on the ground, which can place an area at significant risk of fire. Additionally, the levels of destruction are often high. Thus, it is of prime significance to predict fires well enough in time to take action immediately. Traditional approaches to fire monitoring, nevertheless, frequently fail to identify a fire in the moment. To minimize this threat, anticipating such an environmental crisis is, therefore, a primary issue. To anticipate and predict forest fires, many innovations and new approaches have been suggested. The trend is towards machine learning integration to enhance the detection and prediction of the incidence of fires. Therefore, machine learning models have the advantage of pooling operations, extracting in-depth features, and sharing considerable information, which allows them to obtain effective results on fire prediction. The machine learning model will also have a crucial practical application value for planning the prevention and management of fire.

References

[1] Alkhatib A (2014). A review on forest fire detection techniques. Int J Distrib Sens N. Hindawi Publishing 2014:1673–1683

[2] Castelli, M., Vanneschi, L., & Popovič, A. (2015). Predicting burned areas of forest fires: an artificial intelligence approach. *Fire ecology*, *11*(1), 106-118.

[3] Chuvieco, E., Aguado, I., Jurdao, S., Pettinari, M. L., Yebra, M., Salas, J., ... & Martínez-Vega, F. J. (2014). Integrating geospatial information into fire risk assessment. *International journal of wildland fire*, *23*(5), 606-619.

[4] Hantson, S., S. Pueyo, & E. Chuvieco. (2015). Global fire size distribution is driven by human impact and climate. *Global Ecology and Biogeography* 24(1): 77–86.

[5] Hu, F., G.S. Xia, J. Hu, & L. Zhang. (2015). Transferring deep convolutional neural networks for the scene classification of high-resolution remote sensing imagery. *Remote Sensing* 7(11): 14680–14707.

[6] Karouni A, Daya B, & Chauvet P (2014). Applying decision tree algorithm and neural networks to predict forest fires in Lebanon. J Theor Appl Inf Technol 63(2):282–291

[7] Karray F, Jmal MW, Abid M, BenSaleh MS, & Obeid AM (2014). A review on wireless sensor node architectures. In: Proceedings of 9th international symposium on reconfigurable and communication-centric systems-on-chip (ReCoSoC). IEEE, pp 1–8

[8] Lau, C. K., Lai, K. K., Lee, Y. P., & Du, J. (2015). Fire risk assessment with scoring system, using the support vector machine approach. *Fire Safety Journal*, *78*, 188-195.

[9] Lecun, Y., Y. Bengio, & G. Hinton. (2015). Deep learning. *Nature* 521(7553): 436–444.

[10] Madaio, M., Haimson, O. L., Zhang, W., Cheng, X., Hinds-Aldrich, M., Dilkina, B., & Chau, D. H. P. (2015). Identifying and prioritizing fire inspections: a case study of predicting fire risk in Atlanta. *Bloomberg Data for Good Exchange, New York, NY, USA*.

[11] Meacham, B. J., Charters, D., Johnson, P., & Salisbury, M. (2016). Building fire risk analysis. In *SFPE Handbook of Fire Protection Engineering* (pp. 2941-2991). Springer, New York, NY.

[12] Pourtaghi ZS, Pourghasemi HR, Aretano R, & Semeraro T (2016). Investigation of general indicators in on forest fire and its susceptibility modeling using different data mining techniques. Ecol Indic 64:72–84

[13] Saoudi M, Bounceur A, Euler R, & Kechadi T (2016). Data mining techniques applied to wireless sensor networks for early forest fire detection. In: International conference on internet of things and cloud computing (ICC). ACM, pp 1–7

[14] Schmidhuber, J. (2015). Deep Learning in neural networks: An overview. *Neural Networks* 61: 85–117.

[15] Sculley, D., Holt, G., Golovin, D., Davydov, E., Phillips, T., Ebner, D., ... & Dennison, D. (2015). Hidden technical debt in machine learning systems. *Advances in neural information processing systems*, *28*, 2503-2511.

[16] Watts, J. M., & Hall, J. R. (2016). Introduction to fire risk analysis. In *SFPE handbook of fire protection engineering* (pp. 2817-2826). Springer, New York, NY.

[17] Yan X, Cheng H, Zhao Y, Yu W, Huang H, & Zheng X (2016). Real-time identification of smoldering and flaming combustion phases in forest using a wireless sensor network-based multi-sensor system and artificial neural network. Sensors (Basel) 16(8):1–10

[18] Zhang Q, Xu J, Xu L, & Guo H (2016) Deep convolutional neural networks for forest fire detection. International Forum on Management, Education and Information Technology Application (IFMEITA), pp 568–575