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Fire risk assessment with scoring system, using the support vector machine approach

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ABSTRACT

An accurate and comprehensive fire risk assessment is very important in a civilized society which provides the stakeholders with the likelihood of fire outbreaks, a rough estimation of people at risk and property losses. Hence, the government can better allocate resources for fire protection strategies. Much research has been carried out on assessment of residential fire risk objectively and quantitatively. These works can be complemented so that the assessment task can be more comprehensive and systematic. This paper proposes a fire risk scorecard based on a scoring system used in banking and insurance industry. Different fire risk factors are weighed by Analytic Hierarchy Process (AHP). Then, industrial and non-industrial buildings are treated as borrowers, the fire risk of each building is assessed and its risk level is identified. Finally, real data are applied to test the fire risk scorecard. The results of the scorecard and support vector machine (SVM) model are then proved to be effective.

1. Introduction

According to the news release from The Ministry of Public Security of the People's Republic of China [1] and China Encyclopedia Online [2], China has about two hundred thousand fire accidents annually from 2006 to 2010, which caused around two thousand deaths and one thousand people injured every year. In 2010, the department recorded property loss of more than one and a half billion Yuan due to fire outbreaks. An increasing trend of fire accidents in densely built-up areas over several years was recorded. In a small geographical area like Hong Kong, the fire department receives more than 35,000 fire calls per year and about one fifth of them are actual fire accidents, 70% of which are in densely built-up areas and the rest from more dispersed risk/isolated regions,as indicated in the report of Hong Kong fire department (2013) [3]. These fire incidents put several thousand people at risk and cause injuries or death to a few hundred people each year. In Taiwan, around 12,000 fire incidents occur every year and thousands of lives are harmed. To prevent life loss and fire incidents from happening, fire departments in every country have spent much more effort than we expect, such as handling fire protection and the misuse of fire hotlines. On the other hand, due to high casualties and high probability of fire accidents in densely built-up areas, fire departments are more prepared for fire in densely populated areas than rural areas. However, fire departments seldom use systematic and data-oriented methods to understand their current situations like the areas they should spend more resources on, which causes inefficient resource allocation and performance inconsistency. Although different risk assessment models have been developed and used, a comprehensive method is needed so that more factors can be taken into account and fire department can identify which buildings are more in need of inspection or precaution and are in a position to better allocate of their resources.

Credit risk assessment used in banking industry can be a very good reference for fire risk assessment. In a bank, different customers are examined as to whether they are likely to default on their debts. One of the methods to assess the probability of default by a customer is credit scorecard. In the scorecard, a wide range of factors are considered and an objective rating is given. The nature of credit risk assessment is very similar to that of fire risk assessment. With suitable modification of the scorecard, the idea of credit scoring system can be applied to fire risk assessment also.

2. Works on fire risk assessment

Fong and Wong (1998) [4] developed many approaches to assess fire risk of a building ranging from statistical methods and risk evaluation to fire risk ranking and fire situation simulation.

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When assessing the fire risk of a certain area and building, different components should be taken into account such as sources of ignition and the number of escape routes and extinguishers in the building. A large number of models have been built for evaluation with consideration of different variables.

The evacuation duration model is a very good model to assess the expected time for people in a building on fire to evacuate, which is a very good factor to assess fire risk. Fire detection model is to find out the trigger time of the heat or smoke detector while the fire growth model assesses the rate of fire growth. Benichour, Kashef, Torvi, Hadjisophocleous and Reid (2002) [5] developed a model considering various factors such as evacuation time and the speed of spread of fire to assess the risk of a model for industrial buildings.

Other kinds of fire risk models have been considered. One of them is life at risk models. According to Lin (2004) [6], life at risk is a very important indicator of a risky building as what we should want to minimize is casualty and property loss. The former is paramount and the latter should be our second goal.

Different factors affect the fire risk or safety of buildings. Those factors should not be assumed to be equally important. Therefore, fire safety assessment gives us a preliminary introduction to the weighting method of factors, according to Lo (1999) [7] and Lin (2004) [6].

Practically, many fire departments use another approach to evaluate the risk of individual buildings. Normally, fire departments in each country have their own checklists to assess fire risk, like the one stated in the fire risk assessment of Safelincs solutions 2014 [8]. The criteria are set or considered by the local expertize and officials which suits their own environments.

Though many methods have been developed for fire risk assessment on different areas such as the spread rate of fire in a certain area, some factors are still missing to calculate the total risk of residential and non-residential buildings. For example, we have to take human factors into account while we shouldn't ignore the regular checks of fire equipment. Fire risk assessments used in fire departments are usually more comprehensive. However, assessments usually refer to insufficiency of the quality of fire protection system rather than pointing out the potential fire risk of a building. Fire inspectors seldom compare and prioritize the importance of different measures so that it is hard for them to assess which factors contribute most to the fire risk. Obviously, some useful information has been neglected which can be used for understanding building risk with respect to fire.

Weighting of fire risk factors needs careful consideration so that factors contributing more can be identified and most to the total fire risk of a building can be estimated. On the other hand, judging fire protection based on theoretical assumptions may not be appropriate, especially when different kinds of sources of references are considered together. Therefore, a pragmatic approach should be considered in this situation.

This research adapts the credit scoring concept to the fire assessment context. Credit scoring is applicable in current situation because it is usually a good–bad classification of the cases. For example, in the consumer banking setting, the bank likes to segregate customers into high and low risk customers before credit is granted. In credit scoring studies, SVM has widely been used and its efficiency and performance have been well justified. SVM is a suitable approach as it performs better not only in the training data set but also generalization while neural networks might easily over generalize. Also, as stated by Bellotti and Crook (2009) [9], SVM is much more efficient compared with methods like logistic regression and discriminate analysis. Huang, Chen and Wang (2007) [10] revealed that SVM does not require determination of probabilities before the analysis and thus makes the method more preferable.

Wang, Lai and Niu developed a green credit scoring (2011) [11] for evaluating the risk of the company. This is a systematic method that considers different factors and comes up with an index. In the paper, green credit scoring system was developed which comprises energy and new environment factors. Then a SVM risk assessment model was introduced and different indexes were input as variables. In the end, the data from the world data set were used to justify the green credit scoring system and the SVM risk assessment model. The results showed the high effectiveness of green credit scoring and SVM risk assessment model. We can employ this technique with some further improvement for weighting of factors to assess the risk of the outbreak of fire accidents for an individual building. Areas like forest and parks are not the main focus of our scoring system because they have different risk dimensions to consider.

3. Fire risk scoring system

3.1. Base set up of the scoring system

In this paper, the objective is to identify the risk level of buildings and the scope of the research includes residential and industrial buildings. Rural areas like mountains, recreation facilities and landfills are not included in our project because they may lead to completely different assessment criteria and involve relatively low property loss and casualties.

In this research opinion is obtained from fire protection experts to make the analysis objective and the factor weighting is determined with the use of Analytic Hierarchy Process (AHP). Then, the weighting of the AHP is used to build the scorecard based on Wang, Lai and Niu (2011) [11]. SVM is used to verify the model. Firstly, the classification accuracy for each level is investigated to see whether the scorecard is valid. Compared to Neural Networks, SVM can avoid over generalization and improve the performance in training data set. Many credit risk scoring methods can be verified by SVM such as the one in Lai, Yu, Zhou and Wang, (2008) [12]. SVM can be used as a tool to verify fire risk assessment tasks.

To identify the risk factors in a building, the common fire precautions adopted in fire departments are used. Different models and guidelines can be added into the assessment to identify the risk factors in a building. As factors are hard to be accurately compared, AHP is an intermediate tool to perform pairwise comparison of different factors. AHP first considers sub-indexes in each category, then it compares the importance of each category. The whole process is done by the fire department and fire risk professionals. In each sub-index, there are two methods to come up with the total score: checklists and experts' scoring. We leave the decision to fire risk professionals as the principles of the scoring are the same. In our paper, we decide to mostly use checklists to demonstrate our results as it is used in most fire departments. Fire risk assessment in telecommunications central offices by Parks (1998) [13] could be taken as a reference.

After we have the total score of a certain building, we verify whether the total score is proportional to the fire risk by historic data, to show the scores are related to the frequency or the probability of the outbreak of fire. However, it is not done with the severity of the fire and causalities. The whole model is an indication of the likelihood of a fire outbreak. Prevention of fire outbreak is the same as saving lives and reducing loss.

After we have assessed sufficient number of buildings, a SVM model can be created to verify the effectiveness of the model. The factors used in the scorecard are used as input variables and binary predicted variables are then generated. Lastly, the validity of the scorecard can be proven with real data using SVM approach.