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Faculty of Administrative
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AUTOMATED SYSTEM FOR CONCRETE DAMAGE CLASSIFICATION IDENTIFICATION USING VARIOUS CLASSIFICATION TECHNIQUES IN MACHINE LEARNING

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ABSTRACT
Reinforced concrete is the most widely used material for Malaysian building construction. However, the significant disadvantage of this material is it is prone to the material damage, which causes a decrease in the durability of the concrete and causes structural damage. To determine the suitable repair technique on this material, proper identification procedure on damage classification must be executed. Currently, manual inspection performed by a qualified inspector is the primary inspection method to determine the concrete damage. The manual inspection is a process that is subjective and scarcely effective since it depends heavily on the personal experience and expertise of the inspector to interpret the damage classification. Besides its subjective nature, manual inspection is also to be a time-consuming approach, dangerous, inconsistent, costly, and a laborious task. The demand of experienced inspectors also presents a challenge for the pressing lack of highly skilled and experienced construction inspectors. To overcome the issues, datasets of reinforced concrete damage images are intelligently trained and classified by selected Machine Learning algorithms such as Naïve- Bayesian, Discriminant Analysis, K-Nearest Neighbor, and Support Vector Machine. This invention can recognize a certain damage while the classification of defects is classified according to the features extracted from the images by using GLCM algorithm. The performance of these algorithms is evaluated by dividing the dataset into two sections: testing and training. Cost and time usage can be minimized by using this invention which can help the engineers or construction inspectors. This invention is a significant tool that can predict types of reinforced concrete damage accurately.

Keywords: Concrete Defect, Naïve-Bayesian, Discriminant Analysis, K-Nearest Neighbor, Support Vector Machine

INTRODUCTION

In the last three decades, Malaysia has witnessed immense growth in many sectors of the economy, not least in the construction industry. Malaysia's construction sector advanced 58.6 percent in the third quarter of 2020 which the civil engineering sub-sector remained dominant as the main contributor to the value of construction work done with 45.8 per cent share (Kei, 2016). As the growth of the construction industry, the demand for the structural defect inspectors of civil structures is increasing too. It is challenging to manage the number of demands by using the current approach, which is a visual inspection by trained inspectors combined with decision-making criteria. According to the Federal Highway Administration (FHWA) reports there are few limitations that might affect the efficiency and decision-making of visual inspection in terms of timing, interpretability and accessibility. There are thousands requests for inspection annually in Malaysia itself with 11,000 requests in 2018 according to the Department of Occupational Safety and Health (FMT Reporters, 2019). Steel corrosion, cracks, and spalling are structural defects that often occur in the construction world (Bakri & Mydin, 2014) . The concrete defects need to be secured to maintain the building's structure and to stop any more failures. The key to ensuring the 'health' of a building's construction is frequent inspection.

The automated system for structure inspection is much needed to carter this problem. In this research, supervised learning algorithms applied for defect classification are the Naïve-Bayesian, Discriminant Analysis, K-Nearest Neighbors (KNN), and Support Vector Machine (SVM) algorithm. This method uses machine learning algorithms to classify a particular type of defect. The detection defects identify or recognize a defect, while the classification of defects classified according to the features extracted from the area of defects. Machine learning is a subfield of Artificial Intelligence (AI) that is useful for classifying, predicting, and clustering data sets, depending on the application (Sitara, 2018). The researcher selected this classifier due to a straightforward method. It required less data and was reported to be highly efficient and effective in solving classification problems. Cost and time usage can be minimized over this method which can help improve the study. Furthermore, it can predict types of concrete defects accurately.

In this research, 200 images of concrete defects images are used to develop a supervised learning model to assess whether the model correctly classifies the concrete image as having "crack," "corrosion," "spalling," or "non-damage." The primary aim of this study is to examine and evaluate a concrete damage detection system based on picture classification with the use of Machine Learning Algorithms. The objectives of this study are:

i) To employ adequate methods for data features extraction using GLCM that leads the classification identification using classification technique in machine learning
ii) To implement Naïve-Bayesian, Discriminant Analysis, K-Nearest Neighbors, and Support Vector Machine (SVM) algorithms to classify the data.
iii) To evaluate the results of classifiers and determine the best among them based on their accuracy and precision.

MATERIALS AND METHOD

This part summarized the method used in this study:

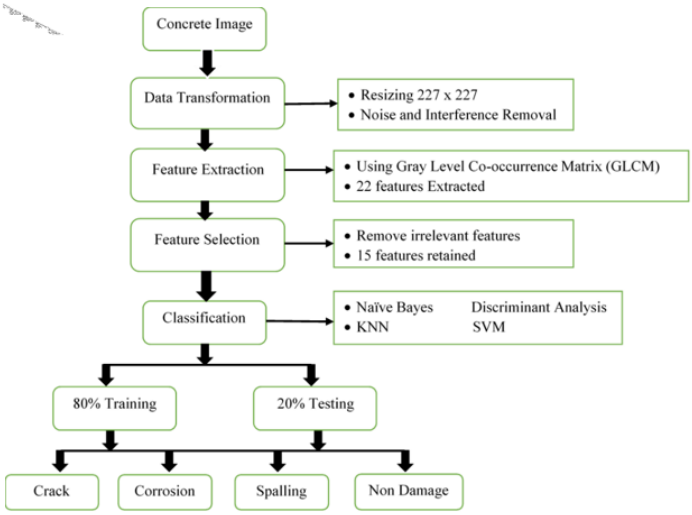

Figure 1: Flowchart of This Research

Features Extraction using Gray Level Co-Occurrence Matrix (GLCM)

Feature Extraction is a process for indexing and retrieving images to capture visual content (Mohanaiah et al., 2013). In this process was the extraction of features obtained after the MATLAB program had been run. Gray Level Co-Occurrence Matrix (GLCM) has proved to be a popular statistical method of extracting features from images (Mohanaiah et al., 2013). It is considered a process for converting the specified data into a suitable classifier format and determining the normalized images for classification identification. Finally, the images are to be displayed in the relevant recognition features to classify the object by the classifier.

Features Selection

One of the most important principles in machine learning is feature selection, which has a significant effect on the model's efficiency (Raheel Shaikh, 2018). Feature selection is the method of reducing the number of input variables to minimize the computational cost of modelling while also improving the model's output in some cases (Brownlee, n.d.). In other words, it is a method used to classify and exclude unneeded, insignificant and redundant attributes from data that do not even contribute to the accuracy of a predictive model or can reduce the model's accuracy (Brownlee, n.d.).

TYPE	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
CRACK	29.3380	0.0781	0.8807	0.8807	23.8386	-3.4983	0.0758	0.5997	0.9253	0.962
CORROSION	20.7320	0.5103	0.8782	0.8782	212.6452	-1.9687	0.4057	0.1020	2.6829	0.812
NON-DAMAGE	43.4108	0.0544	0.7471	0.7471	1.1464	-0.1631	0.0543	0.7307	0.5583	0.972
SPALLING	26.4068	0.2569	0.8787	0.8787	107.6682	-6.8399	0.2327	0.2112	2.0378	0.887
VARIANCE	93.0302	0.0444	0.0044	0.0044	9190.7506	8.0165	0.0266	0.0911	0.9646	0.005

F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22
0.9623	0.7258	29.2101	10.7190	99.1784	0.8685	0.0781	0.2604	-0.617	0.721	0.9914	0.9988
0.8075	0.1980	20.8502	8.5370	49.3721	2.2988	0.5103	0.7622	-0.450	0.874	0.9564	0.9928
0.9729	0.8262	43.2331	13.0969	160.5881	0.5208	0.0544	0.1958	-0.514	0.528	0.9940	0.9997
0.8861	0.3452	26.3844	9.9149	72.9486	1.8427	0.2569	0.5506	-0.529	0.858	0.9744	0.9961
0.0059	0.0901	90.8347	3.6566	2295.4453	0.6860	0.0444	0.0693	0.004	0.025	0.0001	0.0000

Figure 2: Feature Extraction and Selection

Classification model

i) Naïve-Bayesian

Naive Bayesian classifier is an algorithm for classification that is based on Bayes Rule. It will forecast class membership probabilities. For example, it determines the possibility of a given sample belonging to a particular class. The Bayesian classifier is based on Bayes' theorem and the posterior hypothesis. Besides that, Naive Bayesian classifiers provide a vital concept that an attribute value is independent of all attribute values. This naive theory is called "conditional class independence," which is structured to minimize the computation involved and is defined as "naive" because of this (Shahi et al., 2015).

ii) Discriminant Analysis

Discriminant Analysis is a loose derivation from the term discrimination where it is a widely used concept for classifying levels of an outcome. In other words, it is helpful in evaluating whether a set of variables are successful in predicting category membership (Pranov Mishra, n.d.).

iii) K-Nearest Neighbor (KNN)

K-Nearest Neighbor (KNN) is one of the simplest Machine Learning algorithms. It is based on the approach of Supervised Learning. KNN algorithm assumes the similarity between the new case/data and available cases and puts the new matter into the most similar category to the general categories. KNN is a non-parametric, lazy learning algorithm (Garcia et al., 2010). Its objective is to use a database in which data points are classified into several classes to predict a new classification of the sample points.

iv) Support Vector Machine (SVM)

A Support Vector Machine (SVM) is a formally defined hyperplane-separating discriminative classifier. In other words, the algorithm outputs an optimal hyperplane that categorizes new instances, given labelled training data (supervised learning). This hyperplane is a line dividing a plane into two sections in two-dimensional space, where each class is located on either side. Support Vector Machine represents the training data as space points divided into categories by a simple gap as large as possible (Chen, 2009).

RESULT AND DISCUSSION

The performance of all the classifiers are evaluated and shown in the figure 2 and table below. The training data is used to train the data and minimize the probability of misclassification and produce the best classification model. The accuracy and precision of the training and testing data are evaluated to determine the best classifier among Naïve Bayes, Discriminant Analysis, K-Nearest Neighbor and Support Vector Machine.

Table 1: Training and Testing Accuracy for Each Classifier

Classifier	Training	Testing
Naïve	90%	79%
Discriminant	89.4%	85%
KNN	88.88%	83.33%
SVM	92.50%	87.50%

Table 2: Performance of Each Classifier on Testing Dataset

	Crack		Corrosion		Spalling		Non-Damage	
	Precision	Recall	Precision	Recall	Precision	Recall	Precision	Recall
Naïve	100.00%	91%	100%	93%	93%	100%	90%	100%
Discriminant	100.00%	93%	100%	93%	93%	100%	93%	100%
KNN	100.00%	91%	100%	93%	93%	100%	90%	100%
SVM	100.00%	93%	100%	95%	95%	100%	95%	100%

Figure 3: Overall Performance for Each Classifier for Testing Data

It is observed that the performance in terms of accuracy for each classifier for training dataset is high. There is a slight decrease of the accuracy of the testing datasets but this is maybe due to the small size of data testing. The accuracy of the testing can be improved by increasing the amount of data. The preliminary findings demonstrate that the proposed approaches are effective for detecting concrete damage in reasonable conditions. This allows for a more exact detection of concrete damage in a more effective and timely manner.

This technology could be used in the construction industry to improve the capacity to detect defects in massive solid constructions. As a result, the model developed may be employed by the structural health monitoring system (SHM) to classify concrete photos according to their classifications automatically. Support Vector Machine has the highest accuracy of 87.5 percent.

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