Support Vector Machines Technique in Analysis of Concrete- Critical Review

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ABSTRACT

The state of art of support vector mechanics method (SVM) problems related to civil engineering is presented in this paper till now. Areas of further research are presented and ongoing numerical investigations on SVM techniques are shown.

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Introduction

Building comprises of various structural elements namely slabs, beams, columns and masonry structures. Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure. The amount of concrete used worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminium combined. Concrete's use in the modern world is exceeded only by that of naturally occurring water. Concrete is also the basis of a large commercial industry. Globally, the ready-mix concrete industry, the largest segment of the concrete market, is projected to exceed $100 billion in revenue by 2015. In the United States alone, concrete production is a $30-billion-per-year industry, considering only the value of the ready-mixed concrete sold each year. Given the size of the concrete industry, and the fundamental way concrete is used to shape the infrastructure of the modern world, it is difficult to overstate the role this material plays today.

This paper presents state of art of knowledge on support vector machine method for the modelling and analytical studies on beams and concrete cubes. The discussion includes analytical modelling of concrete cubes and beams.

The development of ANNs followed a heuristic path, with applications and extensive experimentation preceding theory. In contrast, the development of SVMs involved sound theory first, then implementation and experiments. A significant advantage of SVMs is that whilst ANNs can suffer from multiple local minima, the solution to an SVM is global and unique. Two more advantages of SVMs are that that have a simple geometric interpretation and give a sparse solution. Unlike ANNs, the computational complexity of SVMs does not depend on the dimensionality of the input space. ANNs use empirical risk minimization, whilst SVMs use structural risk minimization. The reason that SVMs often outperform ANNs in practice is that they deal with the biggest problem with ANNs, SVMs are less prone to over fitting. "They differ radically from comparable approaches such as neural networks: SVM training always finds a global minimum, and their simple geometric interpretation provides fertile ground for further investigation.

Overview of Svm Technique

Support vector machine constructs a hyper plane or set of hyper planes in a high- or infinite-dimensional space, which can be used for classification, regression, or other tasks. Intuitively, a good separation is achieved by the hyper plane that has the largest distance to the nearest training data point of any class (so-called functional margin), since in general the larger the margin the lower the generalization error of the classifier. Whereas the original problem may be stated in a finite dimensional space, it often happens that the sets to discriminate are not linearly separable in that space. For this reason, it was proposed that the original finite-dimensional space be mapped into a much higher-dimensional space, presumably making the separation easier in that space. To keep the computational load reasonable, the mappings used by SVM schemes are designed to ensure that dot products may be computed easily in terms of the variables in the original space, by defining them in terms of a kernel function $k(x,y)$ selected to suit the problem. The hyper planes in the higher-dimensional space are defined as the set of points whose dot product with a vector in that space is constant. The vectors defining the hyper planes can be chosen to be linear combinations with parameters of images of feature vectors that occur in the data base. With this choice of a hyper plane, the points in the feature space that are mapped into the hyper plane are defined by the relation $\sum_i \alpha_i k(x_i, x) = $ constant. Note that if $k(x,y)$ becomes small as 'y' grows further away from 'x', each term in the sum measures the degree of closeness of the test point 'x' to the corresponding data base point x_i. In this way, the sum of kernels above can be used to measure the relative nearness of each test point to the data points originating in one or the other of the sets to be discriminated. Note the fact that the set of points 'x' mapped into any hyper plane can be quite convoluted as a result, allowing much more complex discrimination between sets which are not convex at all in the original space.

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Applications
• SVMs are helpful in text and hypertext categorization as their application can significantly reduce the need for labelled training instances in both the standard inductive and transductive settings.
• Classification of images can also be performed using SVMs.
• Experimental results show that SVMs achieve significantly higher search accuracy than traditional query refinement schemes after just three to four rounds of relevance feedback.
• SVMs are also useful in medical science to classify proteins with up to 90% of the compounds classified correctly. Hand-written characters can be recognized using SVM.

Analytical research work on support vector machine for civil structures

1) Kasthurirangan Gopalakrishnan,2010-This paper presents an efficient off-line pavement back calculation system based on support vector machines (SVM) and compares its performance with another popular machine learning technique, multi-layer perceptrons (MLP). Both systems are trained and tested using synthetic deflection basins generated using two-dimensional axi-symmetric finite element software covering a wide range of in-service pavement scenarios. The results show that the effectiveness of SVM approach in pavement back analysis is comparable to MLP approach, in general, and better in some specific cases. In this paper they have concluded that, the effectiveness of SVM approach in pavement back analysis is comparable to MLP approach, in predicting Asphalt Concrete (AC) surface layer and nonlinear sub grade layer modulus, and better in predicting unbound nonlinear base layer modulus parameter However, ANN MLP model development require a large number of controlling parameters to optimize and relatively larger training database while SVM require only three controlling parameters with little dependency on the magnitude of training datasets required. These advantages of SVM can make it a promising alternative to MLP considering the availability of limited and non representative data frequently encountered in civil infrastructure real-life decision-making situations.

2) Alireza Farhidzadeh,2014- this article proposes a pattern classifier technique titled support vector machines. Small-scale fracture experiments were carried out to impose controlled cracking modes, record acoustic emission data for each cracking mode, and evaluate the performance of classifiers. The results show that the classification boundaries for AE features and their associate uncertainties could be successfully estimated. The effect of sensor distance as an imperative parameter in variation of classification boundaries could be quantified. Furthermore, the adequacy of other feature sets for classification was also examined. Based on this study they have concluded that, if a cementitious material is tested with acoustic emission monitoring, decision boundaries have to be modified for some different sensor distances. The source of AE has to be localized first and then classified as shear or tensile based on the closest pre-defined boundary. It is found that several pairs of descriptors perform quite well in terms of classification error regardless of the data set. The most indicative are AF–CF, Duration–Ampl, Amp–PF and Amp–CF. The last pairs are also threshold-independent. However, the best (lowest) error rate, is reached by the pair AF–RA for the data of the 2nd sensor alone. Still more experimental work needs to be conducted in order to upgrade the work. First in terms of scale to apply in larger and realistic geometries closer to the dimensions of actual concrete elements. Also the material will be concrete with large aggregates which

are assumed to have even stronger scattering effect on the waves. Additionally, a larger number of sensors should be used in order to check the efficiency of the algorithms for several different distances.

3) Isah A. Lawal1-This work demonstrates the use of abductive machine learning techniques for the prediction of pile bearing capacity. A RMSE value of 59.22kN and 92.5kN and a correlation coefficient of 0.82 and 0.83 were obtained with respect to the pile bearing capacity values predicted in two separate experiments conducted respectively. An improvement of almost 9% in terms of prediction error was recorded. This result indicated that the proposed abductive network approach yields a better performance compared to the other already implemented technique. However, the experiments conducted revealed that for a good prediction, a large number of training set is required to train the model before evaluation. So, to validate the performance of the abductive network approach it is recommended that data set obtained from the fields are use in further studies. This will help realize the full potential of abductive network approach in pile bearing capacity prediction. Meanwhile, the work has outlined the advantages of abductive networks and has placed it in the perspective of geotechnical engineering problem computing point of view. Thus, researchers are encouraged to consider them as valuable alternative modelling tool. Hopefully, future work will consider the possibility of extending the approach to modelling of soil behaviour and site characterization.

4) Yogesh Aggarwal 2007-The paper discusses the results obtained to predict reinforcement in singly reinforced beam using Neural Network (NN), Support Vector Machines (SVM's) and Tree Based Models. Major advantage of SVM's over NN is of minimizing a bound on the generalization error of model rather than minimizing a bound on mean square error over the data set as done in NN. Tree Based approach divides the problem into a small number of sub problems to reach at a conclusion. Number of data was created for different parameters of beam to calculate the reinforcement using limit state method for creation of models and validation. The results from this study suggest a remarkably good performance of tree based and SVM's models. Further, this study found that these two techniques work well and even better than Neural Network methods. A comparison of predicted values with actual values suggests a very good correlation coefficient with all four techniques. in this they concluded that the, Successful analysis and prediction should be always based on the use of various types of models. Different models, although in close accuracy, offer various advantages over each other. In this, the equation was developed as shown below.

Equation developed by SVM is:
(Normalized) steel provided = 0.3443 * (normalized) Breadth + -0.1883 * (normalized) Depth+ 0.1707 * (normalized) Length + 0.0445 * (normalized)Load + 0.745 * (normalized) Moment+ 0.2306 * (normalized) Minimum depth + 0.069 *(normalized) per steel + -0.3066 * (normalized) Min steel -0.0886

►ANN approach gives results with good prediction and has an inbuilt flexibility for choosing any number of independent variables without assuming an explicit equation. But it requires non linear optimization with the possibility of converging only in local minima.
►Prediction of strength by linear regression is found to be adequate and the approach can be easily adopted for ready use because of the explicit nature of the strength equation.
►SVMs has shown a satisfactory performance for the prediction of strength. The time taken to build model by SVMs

is comparatively less than that required by NN. Modal Trees have advantages in both compactness and prediction accuracy, attributable to the ability of modal trees to use the local linearity in the data. It is more understandable and allows one to build a family of models of varying complexity and accuracy.

5) Selcuk Saatci,2007-- This study aims to present and verify a nonlinear finite element analysis procedure employing the Disturbed Stress Field Model, based on a smeared rotating crack approach, as an advanced method of modelling shear behaviour under impact conditions. The proposed methodology has a wide range of applicability, and displays fast solution time while providing extensive and accurate information on structural behaviour. The methodology was tested by analyzing a set of RC beams subjected to impact loads. A high level of accuracy was demonstrated in various comparisons between test and analysis results, including peak and residual displacements, crack profiles, and reinforcement strains.

The conclusion of this paper was that, the proposed NLFEA procedure performed well in predicting displacements, damage levels, and reinforcement strains. The shear-critical failure under dynamic loading of statically flexural-critical specimens was captured well. The proposed procedure was computationally efficient. The time required to complete an analysis was typically significantly shorter than with some other well-known sophisticated finite element programs. Using short time steps for improved accuracy did not have a severe adverse effect on computational times because iterations converged faster with shorter time steps;

6)Satish B Satpal1,2013- In this article, the effectiveness of support vector machine (SVM) is examined for health monitoring of beam-like structures using vibration-induced modal displacement data. The SVM is used to predict the intensity or location of damage in a simulated cantilever beam from displacements of the first mode shape. Twelve levels of damage intensities have been simulated at 12 locations, and six levels of white Gaussian noise have been added, thereby obtaining 1,008 simulations. About 90% of these are used for training the SVM, and the remaining are used for testing. The trained SVM is able to predict damage intensity and location of all the training set data with nearly 100% accuracy. The test set data reveal that SVM is able to predict damage intensity and damage location with errors varying from 0.28% to 4.57% and 0% to 20.3%, respectively, when there is no noise in the data. Addition of noise degrades the performance of SVM, the degradation being significant for intensity prediction and less for damage location prediction. The results demonstrate the use of SVM as a powerful tool for structural health monitoring without using the data of healthy state. This work attempts to evaluate the capability of support vector machines for predicting the intensity or location of damage for health monitoring of a cantilever beam. The 1,008 simulations have been studied using 12 levels of damage intensities, 12 locations, and 7 noise levels (including no noise). The SVM has been trained with vibration-induced displacements collected at 91 points for the first mode shape as input and damage intensity or location as output using only 90% of the simulations, the rest being kept aside for testing. After training, the SVM is able to predict any damage intensity or location of the training set data with almost zero error. The errors in the test set without noise are less than 2.5% for damage intensity prediction and below 6% for damage location prediction in the central section of the beam. Location prediction degrades drastically near the fixed end of the beam for any level of noise and is inaccurate near the free end only for high levels of noise. On the contrary, damage intensity prediction is significantly affected by noise for low damage intensity. High noise causes significant deterioration in performance at damage intensities lower than 25%. The worst level of noise (30 dB) results in 11% to 22% error for damage intensities higher than 25% and a much higher error at lower damage intensities.

7)Kezhen Yan, 2013-This paper aims to show a possible applicability of support vector machine (SVM) to predict the splitting tensile strength of concrete from compressive strength of concrete, a SVM model was built, trained, and tested using the available experimental data gathered from the literature. All of the results predicted by the SVM model are compared with results obtained from experimental data, and we found that the predicted splitting tensile strength of concrete is in good agreement with the experimental data. The splitting tensile strength results predicted by SVM are also compared to those obtained by using empirical results of the building codes and various models. These comparisons show that SVM has strong potential as a feasible tool for predicting splitting tensile strength from compressive strength. The splitting tensile strength of concrete estimations from compression strength has been obtained so far in the literature either through regression or other methods. This present study reports a new and influential approach for predicting the splitting tensile strength using SVM for the first time in the literature. The study conducted in this paper shows function, it is necessary to choose the appropriate kernel for each particular application problem in order to guarantee satisfactory results. The results of radial basis function and polynomial indicate that RBF and polynomial kernel have the ability to predict the splitting tensile strength of concrete from compression strength with an acceptable degree of accuracy. The use of SVM is very advantageous for the prediction of the splitting tensile strength of concrete from compression strength because it can perform nonlinear regression efficiently for high-dimensional data sets. Furthermore, its solution is global. The satisfactory predictions of the splitting tensile strength of concrete by the model indicate that SVM is a useful modelling tool for engineers and research scientists at concrete construction fields.

8)Weihang Zhang1-In this paper long time immersion test of fly ash concrete specimens in sulphuric acid is carried out. On the basis of the experimental datum, a novel prediction model for sulphuric acid corrosion of concrete based on support vector machine (SVM) is proposed. The design steps and learning algorithm are also given. Five main influencing factors including the water and cement ratio, pH value of the soaking solution, cement and fly ash quantity, specimens fluidity are analyzed with the proposed model. By comparison with the measured results, the mean square error (MSE) of predicted result of the model is 0.188. It implies that this new method of computation appears to be a useful tool for sulphuric acid corrosion of fly ash concrete research. This study has investigated the use of SVM for prediction of sulphuric acid corroding concrete. The performance of the proposed method is verified by comparing the predicted results with the experimental results. MSE of the predicted results by SVM method is only 0.188. It implies that SVM can be regarded as a very effective method for prediction of sulphuric acid corroding concrete.

Conclusions:

Considerable progress has been made from last few years in the analytical studies of civil structures using SVM technique and information available is summarized in this paper. Since, various kind structures were analysed using FEM and ANN technique but SVM is proved to be most supervised technique when compared to FEM and ANN.

Based on the work done by Satish B Satpal This work attempts to evaluate the capability of support vector machines for predicting the intensity or location of damage for health monitoring of a cantilever beam. The SVM is able to predict any damage intensity or location of the training set data with almost zero error in comparison with FEM.

Based on the work done by Yogesh Aggarwal SVMs has shown a satisfactory performance for the prediction of strength. The time taken to build model by SVMs is comparatively less than that required by ANN. Thus the research work for civil structures can be analysed using SVM technique which is well supervised and can be encouraged for the accurate analysis.

Further scope for SVM method based on literature review, it was found that SVM technique will give reliable results and further attempt can be made for civil engineering structural design, mainly on mechanical properties of concrete and improvisation on the experimental studies on geo-polymer concrete, steel fibre concrete etc.

A lot of experimental studies has been done on geo-polymer concrete, fibre reinforced concrete etc. Hence, using SVM technique for reliability of results, SVM technique can be used for assessing mechanical properties of concrete.

Further studies on mechanical properties of concrete to relate one another through SVM technique can be done.

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