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TRƯỜNG ĐẠI HỌC DUY TÂN
DUYTAN UNIVERSITY

A review of metaheuristic optimized machine learning regression with applications in construction engineering

Khảo sát các mô hình học máy được tối ưu hóa bởi các thuật toán tìm kiếm với ứng dụng cho phân tích hồi quy trong ngành xây dựng

Hoang Nhat Duc[a,b*], Nguyen Quoc Lam[a,b], Tran Van Duc[b,c]
Hoàng Nhật Đức[a,b*], Nguyễn Quốc Lâm[a,b], Trần Văn Đức[b,c]

[a]*Institute of Research and Development, Duy Tan University, Da Nang, 550000, Vietnam*
[a]*Viện Nghiên cứu và Phát triển Công nghệ Cao, Đại học Duy Tân, Đà Nẵng, Việt Nam*
[b]*Faculty of Civil Engineering, Duy Tan University, Da Nang, 550000, Vietnam*
[b]*Khoa Xây dựng, Trường Đại học Duy Tân, Đà Nẵng, Việt Nam*
[c]*International School, Duy Tan University, Da Nang, 550000, Vietnam*
[c]*Viện Đào tạo Quốc tế, Trường Đại học Duy Tân, Đà Nẵng, Việt Nam*

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Abstract

Regression analysis is an essential task in construction engineering. This article aims at reviewing state-of-the-art research works involving the use of metaheuristic optimized machine learning regression models. Recent research articles published in the time period of 2019-2021 are surveyed. Research areas of construction material, construction management, structural engineering, geotechnical engineering, hydraulic engineering, and structural health monitoring are taken into account. It is expected that the present review would enhance interest among the new users in the application of metaheuristic optimized machine learning regression approaches.

Keywords: Machine learning; regression analysis; metaheuristics; hybrid intelligence; construction engineering.

Tóm tắt

Phân tích hồi quy là một nhiệm vụ quan trọng trong kỹ thuật xây dựng. Bài báo này khảo sát các công trình nghiên cứu liên quan đến việc sử dụng các mô hình hồi quy dựa trên máy học được tối ưu hóa bởi thuật toán tìm kiếm hiện đại. Các bài báo nghiên cứu gần đây được xuất bản trong khoảng thời gian 2019-2021 được khảo sát. Các lĩnh vực nghiên cứu về vật liệu xây dựng, quản lý xây dựng, kỹ thuật kết cấu, địa kỹ thuật, kỹ thuật thủy lực và giám sát sức khỏe kết cấu được xem xét. Bài khảo sát của chúng tôi có mục đích nâng cao sự quan tâm của những nhà nghiên cứu mới đối với việc áp dụng các phương pháp hồi quy máy học được tối ưu hóa bởi các thuật toán siêu tìm kiếm.

Từ khóa: Máy học; Phân tích hồi quy; thuật toán tìm kiếm; trí tuệ lai ghép; kỹ thuật xây dựng.

1. Introduction

Regression analysis is employed for identifying the mathematical relationship between a set of predictors and a variable of interest. This mathematical relationship is then highly useful for various modeling tasks in construction engineering [1]. Recent works involving machine learning (ML) applications

Corresponding Author: Hoang Nhat Duc, Institute of Research and Development, Duy Tan University, Da Nang, 550000, Vietnam; Faculty of Civil Engineering, Duy Tan University, Da Nang, 550000, Vietnam
Email: hoangnhatduc@duytan.edu.vn

have generated data-driven methods that are shown to be more capable than traditional statistical approaches [2-5]. Accordingly, machine learning methods such as artificial neural network (ANN), support vector machine (SVM), least squares SVM (LSSVM), extreme gradient boosting machine (XGBoost), adaptive neural fuzzy inference system (ANFIS), multivariate adaptive regression splines (MARS), etc. have been extensively employed for regression analysis in construction engineering [6].

The effective applications of ML methods highly depend on the setting of their hyper-parameters. This task is generally known as model selection. The problem of ML model selection is not trivial because each ML method may require its own appropriate setting of multiple hyper-parameters. Moreover, these hyper-parameters are often real-valued. This fact makes an exhaustive search for the best combination of hyper-parameters infeasible. Conventional grid search method [7] can be employed for parameter setting. However, this method also suffers from the difficulty of grid size selection and the found solution can be far from optimality. Therefore, researchers have resorted to metaheuristic algorithms such as particle swarm optimization (PSO), genetic algorithm (GA), etc. to optimize the ML models.

2. Application areas

In this section, we survey the applications of MO optimized ML models in research areas of construction material, construction management, structural engineering, geotechnical engineering, hydraulic engineering, and structural health monitoring. Our review focuses on research works published in the time period of 2019-2021. Google scholar is the main search engine used to find studies within our scope. Accordingly, 47 papers have been found by the employed search engine. The number of papers within the areas of construction material, construction management, structural engineering, geotechnical engineering, hydraulic engineering, and structural health monitoring is found to be 9, 4, 10, 14, 6, and 3 (refer to **Fig. 1**).

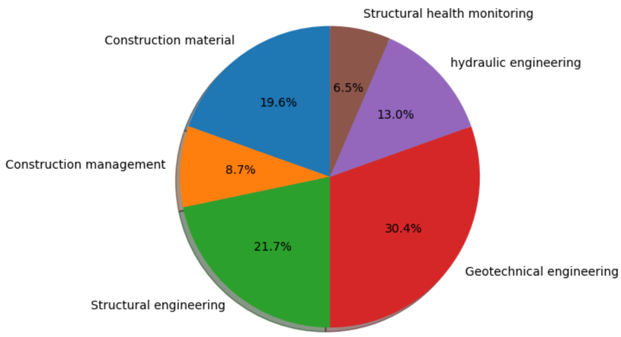

Fig. 2.1. Percentages of application areas

2.1. Construction material

The application area of construction material accounts for 19.6% of the reviewed papers. Herein, Chou and Nguyen [8] employs forensic-based investigation optimization algorithm, the radial basis function neural network, and the LSSVM to estimate the mechanical strength of reinforced concrete materials. A LSSVM integrated with particle swarm optimization is proposed in [9] to predict interface yield stress and plastic viscosity of fresh concrete. Golafshani, Behnood and Arashpour [10] predicts the compressive strength of normal and high-performance concretes using ANN and ANFIS optimized by grey wolf optimizer. Duan, Asteris, Nguyen, Bui and Moayedi [11] relies on a meta-heuristic search of sociopolitical algorithm to optimize an XGBoost model used for predicting the compressive strength of recycled aggregate concrete.

A study in [12] resorts to MARS optimized by water cycle algorithm as a means to estimate the compressive strength of foamed cellular lightweight concrete. Sadowski, Nikoo, Shariq, Joker and Czarnecki [13] develops a firefly algorithm optimized ANN to predict the creep strain of green concrete containing ground granulated blast furnace slag. A model consisting of a differential evolution variant optimized SVM has been put forward to estimate the plastic viscosity of fresh concrete [14]. Salp swarm algorithm coupled with SVM is utilized to estimate the strength of fiber-reinforced cemented paste [15]. Huang, Duan, Zhang, Liu, Zhang and Lei [16] proposes an integration of beetle antennae search algorithm and random forest model to predict permeability of pervious concrete.

2.2. Construction management

A symbiotic organisms search-optimized LSSVM with dynamic feature selection has been proposed in [17] to predict construction productivity. Symbiotic organisms search (SOS) has also been used in [18] to optimize a deep learning model used for forecasting construction cash flow. Gaussian process inference optimized by PSO has been proposed by Cheng, Wu and Huang [19] as a decision support system in construction project management. Chen, Zhang, Zhao and Yang [20] puts forward a model for investment probabilistic interval estimation for construction project; the authors rely on of SVM and gray wolf optimization.

2.3. Structural engineering

Structural engineering is the second largest group which occupies 21.7% of the articles. Parsa and Naderpour [21] employs SVM optimized by teaching–learning-based optimization, PSO, and Harris hawks optimization algorithms to predict the shear strength of reinforced concrete walls. Nguyen, Nguyen, Cao, Hoang and Tran [22] predicts long-term deflections of reinforced-concrete members using a novel integration of PSO and XGBoost. Ngo, Le and Pham [23] combines SVM and grey wolf optimization to model the ultimate bearing capacity in concrete-filled steel tube columns.

A model in [24] employs LSSVM and coupled simulated annealing to model behavior of reinforced concrete columns subjected to earthquake loads. Ben Seghier, Ouaer, Ghriga, Menad and Thai [25] proposes a hybrid soft computational method for modeling the maximum ultimate bond strength between the corroded steel reinforcement and surrounding concrete. A differential flower pollination optimized LSSVM model has been put forward in [26] for estimate the ultimate bond strength of corroded reinforcement and surrounding concrete. Hasanzade-Inallu, Zarfam and Nikoo [27] employs a modified imperialist competitive algorithm-based ANN to determine the shear strength of concrete beams reinforced with fiber-reinforced polymers.

Prayogo, Cheng, Wu and Tran [28] combines different machine learning models via adaptive ensemble weighting and SOS for prediction of shear capacity of reinforced-concrete deep beams. The research work reported in [29] develops three hybrid machine learning algorithms based on ANFIS optimized by simulated annealing, cultural algorithm, and shuffled frog leaping algorithm to predict the critical buckling load of I-shaped cellular steel beams with circular openings. A hybrid intelligent system relying on Bayesian additive regression tree optimized by GA, artificial bee colony, and PSO has been reported in [30] to predict the ultimate axial capacity of axially loaded circular concrete-filled steel tube columns.

2.4. Geotechnical engineering

This research area contributes the highest proportion of reviewed articles with 30.4%. Tunneling boring machine advance rate has been predicted with the uses of metaheuristic algorithms optimized machine learning models. The SVM optimized by grey wolf optimization whale optimization algorithm and moth flame optimization is used in [31] Meanwhile, grey wolf optimization, PSO, social spider optimization, sine cosine algorithm, multi verse optimization and moth flame optimization are employed to optimize XGBoost in [32].

Chou, Truong, Le and Thu Ha Truong [33] proposed a bio-inspired optimization of weighted-feature machine learning for strength property prediction of fiber-reinforced soil; weighted-feature LSSVM optimized by jellyfish search algorithm is employed. Kardani, Zhou, Nazem and Shen [34] estimate the bearing capacity of piles in cohesionless soil based on decision tree, k-nearest neighbor, ANN, random forest, SVM and extremely gradient boosting optimized by PSO. Gholami, Seyedali and Ansari [35] estimates shear wave velocity from post-stack seismic data through committee machine with cuckoo search optimized intelligence models; neural network, support vector regression, and fuzzy inference system are employed. Chou, Truong and Che [36] proposes an optimized multi-output machine learning system for assessing natural hazards related to geotechnical engineering.

Back-propagation neural network, extreme learning machine, SVM, random forest and evolutionary polynomial regression in predicting soil compressibility is proposed in [37] and [38]; genetic algorithm and bee colony are the employed metaheuristic approaches. Tien Bui, Hoang and Nhu [39] and Moayedi, Gör, Khari, Foong, Bahiraei and Bui [40] proposes data-driven models for predicting the soil shear strength. LSSVM and the Cuckoo Search Optimization are used by the former. Elephant herding optimization, shuffled frog leaping algorithm, salp swarm algorithm, and wind-driven optimization are employed in the later to optimize a neural network.

Effective prediction of the peak shear strength of a rock slope is predicted with radial basis function neural network optimized by gray wolf optimization and ant colony optimization algorithms in [41]. Ant lion optimization and spotted hyena optimizer are used to train ANN based bearing capacity prediction; shallow circular footing is the research subject [42]. A study in [43] employs dragonfly algorithm and Harris hawks optimization to predict the bearing capacity of footings over two-layer foundation soils. Pham, Tran and Vu [44] develops a deep neural network architecture trained by particle swarm optimization to enhance the performance in determining the friction angle of soil.

2.5. Hydraulic engineering

Yaseen, Faris and Al-Ansari [45] relies on salp swarm algorithm and extreme learning machine to forecast monthly river flow time series. Scour depth around bridge piers has been modeling with ANFIS coupled with particle swarm optimization and genetic algorithm [46]. A study reported in [47] employs support vector regression and PSO for modeling scouring depth of submerged weir; an integration of extreme gradient boosting machine and genetic algorithm has been put forward in [48] for dealing with the same task. PSO optimized equation-based regression models [49] have been used to predict the scour depth around a bridge pier. In addition, wavelet kernel extreme learning machine and meta-heuristic method of particle swarm optimization has been proposed to predict bed load in gravel-bed rivers [50].

2.6. Structural health monitoring

This application area accounts for only 6.5% of the reviewed papers. Within this group, adaptive time-dependent evolutionary LSSVM model optimized by SOS has been used to predict dam body displacements in [51]. A SOS-optimized least squares support vector regression has been proposed in [52] to estimate the load on ground anchor. Cheng, Prayogo and Wu [53] also combines these two methods for estimating the permanent deformation in asphalt pavements.

3. Conclusion

This article has reviewed research works involving the use of metaheuristic optimized machine learning regression models. Construction material, construction management, structural engineering, geotechnical engineering, hydraulic engineering, and structural health monitoring are the research areas of interest. With a focus on articles published in the time period of 2019-2021, it has been shown that ANN, SVM, LSSVM, and XGBoost are the dominant ML approaches. Meanwhile, conventional PSO and GA are still widely employed for optimize ML regression models. Recently proposed metaheuristic algorithms such as SOS, Harris hawks optimization, gray wolf optimization, etc. have gained an increasing attention from researchers. The present survey work is expected to generate interest among the new researchers in using metaheuristic optimized machine learning regression models and their applications in construction engineering.

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