A Review of Literature for Using Artificial Neural Networks for Solving the Maximum Independent Set Problem

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Literature Review

Introduction

Artificial neural networks have been one of the hottest topics in the field of AI in recent years. This literature review focuses on some of the most recent applications of ANNs in various industries including medicine, biometrics, and combinatorial optimization problems. Each study covered in this review was published within the last five years to ensure an accurate representation of the state of neural networks. While some of the topics covered in the literature may be nuanced, such as classifying medical data, they represent the continual need to improve on industry capabilities.

Modern Applications of Artificial Neural Networks

In the last few years, artificial neural networks (ANN) have been one of the leaders of the AI industry. With their robust capabilities, researchers are constantly identifying new applications and formulating them into ANN solvable problems. A common trend seen in the literature is the application of ANNs in the fields of medicine. One recent study was done on classifying brain tumors as benign or malignant using MRI images. In this study Kumar et al. (2023) proposed a novel solution that combined a convolutional neural network with transfer learning. They showed that their approach showed significant improvements compared to multiple existing networks with the same function. Their method displayed accuracy levels of over 99% and represents only one of the many novel approaches to medicinal improvement. Another study that I found to be interesting was done to identify bowel sounds using a long short-term memory (LSTM) neural network. The goal of this study was to automate the detection of bowel sounds and aid in identifying links to other diseases (Narożniak, 2023). The proposed algorithm achieved a 97% accuracy rate and was able to insert computational abilities to an area previously unexplored.

There are also plenty of technical applications of artificial neural networks currently being researched as well. One common trend is using ANNs in smart vehicles. Bolimera et al. (2023) attempted to solve some of the issues with lane analysis systems by applying convolutional neural networks and projection mapping. By using the CNN to identify lanes, they then map an optimal curve over the points identified on the lane that can be used to aid lane assist and self driving systems. In a separate field, Król (2023) published a thesis that used a Siamese neural network to implement a biometric signature verification system. The study proved fruitful as it produced an error rate of just 9.98% when identifying skilled forgeries. Due to the robustness of ANNs, there are new studies being published everyday on their applications that would be too much to cover in a single literature review.

Neural Networks and Combinatorial Optimization Problems

As with most sub-domains of computational intelligence, it is not uncommon to see researchers constantly applying new models to combinatorial optimization problems. Yang and Gu (2023) describe their attempt at finding optimal solutions for the traveling salesman problem by simplifying the model of a transformer neural network. By simplifying their model, they were able to achieve reduced memory usage at the cost of prediction accuracy. The novelty in their study is combining the simplified transformer with heuristic search methods to improve the accuracy of the model while retaining the reduced memory usage.

Some researchers have formulated their real world problems into combinatorial optimization problems and applied neural networks to them. The challenge of optimally designing electric vehicle fast charging stations was recently tackled using neural networks. Lin et al. (2023) used a surrogate based model to simulate the behavior of a charging system given an input set of design parameters such as number of charging poles, converter modules, and switching contactors. Using the output data from the simulation, a neural network was trained to map the design parameters to performance indicators to be optimized (Lin et al., 2023).

Neural Networks and the Maximum Independent Set Problem

Gasse et al. (2019) took a rather unique approach to applying neural networks to combinatorial optimization problems. Rather than trying to optimize a single problem, they proposed a new graph convolutional neural network model to learn branch-and-bound variable selection policies. In doing so, they essentially trained a model to find the optimal way of solving various optimization problems. They found that in solving the maximum independent set problem, their GCN method produced high levels of accuracy but performed noticeably slower on more difficult instances.

In another approach Li et al. proposed a solution to NP-hard problems based on a convolutional neural network that predicts how likely each vertex in a graph is to be part of the optimal solution (2018). They found that this naive approach proved ineffective for larger problem instances. This was because as the problem size increased, there could be multiple unique solutions that satisfied the optimal condition. Each node in the graph could be in some of these solutions, so a single probability per node became an issue. Their solution was to extend their model to generate multiple probability maps per run that each tracked a uniquely diverse solution. Being able to explore multiple solutions at one greatly increased the effectiveness of the model for larger solutions (Li et al., 2018).

One last unique approach proposed by Schuetz et al. (2022) considered a new approach to applying GCNs to solving NP-hard combinatorial optimization problems. The idea is to implement a standard GCN that is applicable to COPs in the form of quadratic unconstrained binary optimization problems (QUBO). The proposed architecture is based on quantum physics as the loss function is derived from creating problem specific Hamiltonians. They then applied a relaxation strategy to the Hamiltonian that provided them a general loss function that could be used to evaluate loss for problem specific QUBO matrices. With this architecture, a single model can be designed and tailored to the problem, for example MISP, and solved by passing in the corresponding QUBO matrix along with the generated graph G. The appeal of this study is that rather than building on existing heuristics and algorithm combinations, it combines industry forefront topics from AI and Physics to open up a new realm for exploration.

Conclusion

The studies reviewed in this paper demonstrate the continued efforts by researchers to apply ANNs to real world problems. What is now a common trend of using machine learning and AI in the field of medicine was shown to not be going anywhere along with autonomous vehicle development. When compared to other computational methods, these studies have shown that neural networks combined with heuristic methods are capable of producing promising results when solving NP-hard optimization problems. Finding efficient solutions to the maximum independent set problem still poses a challenge to researchers however, applications of neural networks may open new avenues for exploration.

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