The Rise and Applications of Machine Learning on Wave Prediction

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Introduction

Machine learning is a rapidly growing field in computer science that has the potential to revolutionize many areas of science and technology. One area where machine learning has shown great promise is in the prediction of ocean wave data. The ability to accurately predict the behavior of ocean waves is important for a variety of applications, including optimizing ship routes, coastal engineering, renewable energy resourcing, and natural disaster prevention. In this technical report, I will explore the rise of machine learning in the prediction of ocean wave data and discuss some of the key applications of this technology.

Need For Wave Data

Historical Need

The need for, and lack of, accurate wave prediction data has been an ongoing issue for a long time now. Ancient civilizations relied on the observation of nature to predict maritime conditions. Even with the advent of modern meteorological and tidal forecasting, there has been no accurate prediction of ocean wave data. This missing predictive information on waves is essential for so many industries and applications. As Pokhrel describes in their report on their transformer-based regression scheme to predict wave height, "While ocean waves are used to study the analogies in various media, nowcasting and forecasting of waves are also crucial for myriad other reasons, including optimizing ship routes for efficient shipping, avoiding disasters, aiding the aquaculture industry, safely conducting military and amphibious operations by the Navy and Marine Corps teams, etc. The other importance of wave prediction lies in the efficient renewable energy generated from renewable energy sources like solar, wind, tidal, wave, etc." (Pokhrel) Data established by machine learning on wave prediction therefore could help a variety of different industries and organizations , leading to greater efficiency without wasting time and resources on disruptions from unknown wave levels.

Current Need

Many companies are in need of predictive wave data, as it will provide accurate information for many maritime applications. Whether it is determining cost-effective shipping routes, or providing optimal sites for wind energy resourcing, machine learning will provide essential information for both safety and efficiency. Providing this data in places where it is not currently being gathered, and predicting future wave conditions, will save companies money for their long term investments. However, that is not even the most pressing reason this machine learning may be used for.

Natural Disasters Causing Demand

In cases of natural disaster involving the ocean, such as tsunamis, knowing how waves will act is very important for the safety of those on the coast. As

Mase describes, “Accurate real-time wave prediction is an invaluable resource for coastal disaster mitigation, especially when determining the activation of disaster evacuation plans and inundation countermeasures.” (Mase) Without this data, lives could be lost through improper planning of evacuations and in setting up protections in places that do not need it, when those resources could be used elsewhere. Furthermore, “In a warning context, being able to provide localized tsunami forecasts at strategic locations would therefore help mitigate the damage. Despite the recent advancements in computing powers and the development of highly efficient tsunami codes, capturing this local variability can oftentimes be infeasible in a warning setting. Traditional high-resolution simulations which can capture these localized effects are often too costly to run ‘on-the-fly.’” (Giles) Older methods of prediction are far too costly to implement regularly, meaning that there is a dire need for something such as machine learning to calculate this data and distribute it to the proper management who can use it to protect people and objects that would be put in danger in the time of accidents.

Previous Attempts

As stated, there have been many attempts in the past to gain this type of wave data to help with the situations described. However, all of them had costs and problems that were too large to overlook, and thus could not be implemented fully. For example, “A variety of prediction methods have been developed. For computational models, wave parameters are simulated and predicted by solving equations based on theoretical models, such as the wave model (WAM) proposed by Group (1988). This method could make good prediction for waves in deep-sea areas, but it has certain limitations of application for nearshore areas with complex terrain.” (Liu) As described by Liu, previous investigations into this topic of predicting wave data has not been very successful. Technology was older and not as sophisticated as it is today, making less reliable and more expensive to do these tasks. However, even today, many of the numerical models being used are not efficient at what they do. “Real-time wave prediction is used to determine the feasibility of marine construction work, but the numerical models currently in use have the disadvantage of being computationally expensive.” (Ozaki) Thus, with the further investigations into machine learning these problems have been slowly going away.

Current Applications

In Guiles report on automated approaches for capturing localized tsunami response, it describes the creation of a machine learning model using Multi-Layer Perceptron (MLP) and its uses in prediction of tsunami activity. The MLP performs very well compared to their other numerical model using Green’s Law, and this was done without refining the parameters of the machine learning and just with running it as they describe, “Off the shelf.” This study reveals the usefulness of machine learning in the context of tsunami activity, and mentions they will be investigating building custom models to predict this wave data as they see a bright future for this area of research. Furthermore, another key application of machine learning in this field is the Transformer-based framework created by Pokhrel to predict wave data from buoys. This implementation was completed and vastly outperformed the previous numerical models they had made, giving much more accurate data at a faster rate. This further gives me indications that machine learning will be the go-to way to predict these sets of data in the future.

Future of Wave Prediction

The final study I would like to discuss on the topic is one that was focused on developing a machine learning model to predict wave data at arbitrary locations. This team headed by Ozaki, was tasked with using knowledge of machine learning models for wave data prediction, and try to expand it. The expansion they focused on was trying to predict data at random locations, instead of nearby to where the model was fed data. This would give far more of a reach to the models we currently have today and expand this type of research even further. In the end, their model worked and was “more accurate than numerical models” (Ozaki), confirming its usefulness. However, it was not the most accurate, and more work has to be done in this field of expanding the machine learning to arbitrary locations. This is a very big step into the future of

machine learning, and it is exciting to see what they will come up with next.

Conclusion

The rise of machine learning in the prediction of ocean wave data has the potential to greatly improve our understanding of the ocean and its behavior. From shipping and natural disaster prevention to coastal engineering, accurate prediction of ocean waves is essential for a variety of applications. While machine learning has shown great promise in this area, there is still much work to be done to fully realize its potential. Further research and development in this field will be crucial for improving the accuracy and reliability of machine learning models for ocean wave prediction. Ultimately, the use of machine learning in this area has the potential to greatly benefit society by improving our ability to predict and respond to the impacts of ocean waves on human activities. The senior design project I am currently working on, in conjunction with the Denmark based company Ørsted, specifically addresses this issue. I am applying machine learning to wave prediction, in an effort to provide valuable wave data predictions for the purpose of building offshore wind turbines.

References

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