UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Department of Computer Science

DALHOUSIE UNIVERSITY
FACULTY OF COMPUTER SCIENCE

Artificial Intelligence applied to Marine Renewables

Jaume Manero

June 20, 2022

MASTER IN RENEWABLE ENERGY IN THE MARINE ENVIRONMENT
REM PLUS

Co-funded by the Erasmus+ Programme of the European Union

Bio

Jaume Manero

Consultant

- I help companies in their path to digital excellence

Student

- I have a PhD in Artificial Intelligence (2020), but the fast pace of change in this area makes me study every day

Researcher

- I research at the HPAI (High Performance Artificial Intelligence Group at the Barcelona Super Computing Centre) and at the Mylab IoT group at Dalhousie University in Canada

Professor

- I teach AI, Deep Learning and Machine Learning at IE University and Dalhousie University

…… and I love swimming in the sea while watching the amazing underwater sea life in Menorca

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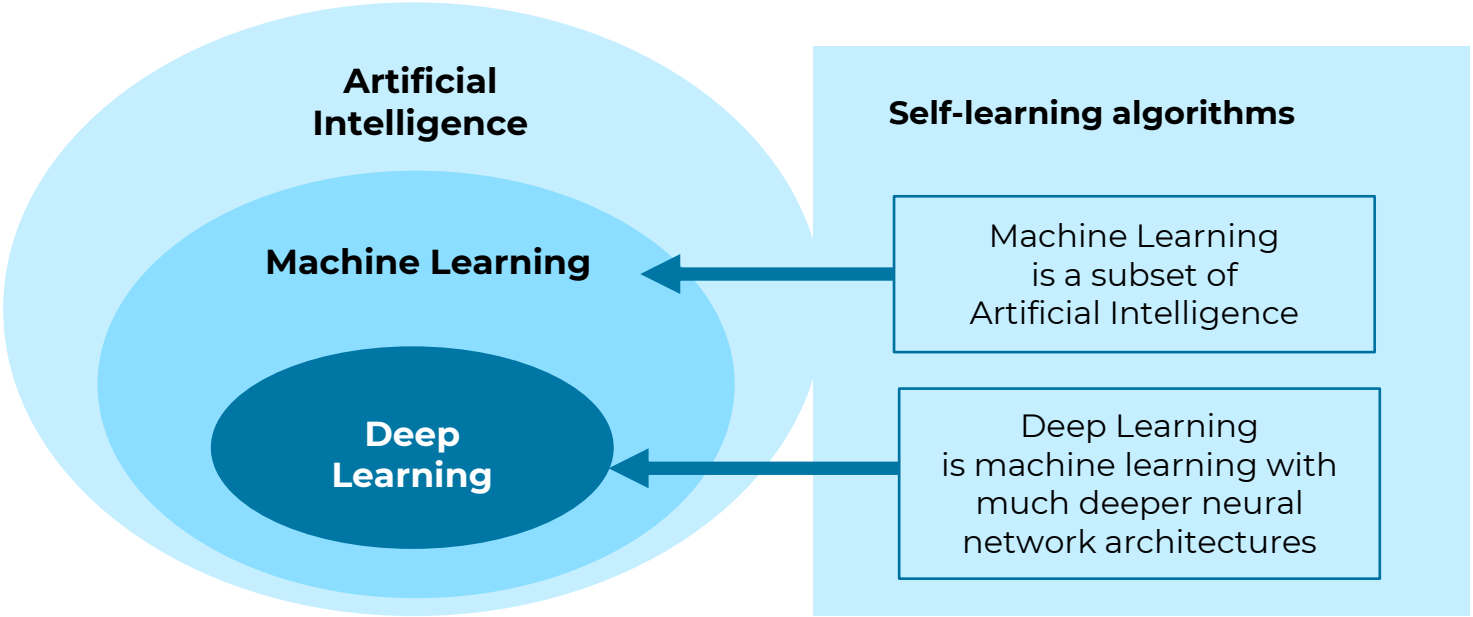
Content

Artificial Intelligence and Machine Learning



Is Deep Learning Artificial Intelligence?

Many recent accomplishments in Deep Learning

Google engineer says Lamda AI system may have its own feelings

By Chris Vallance
Technology reporter

15 hours ago

BBC NEWS

Meet DALL-E, the A.I. That Draws Anything at Your Command

New technology that blends language and images could serve graphic artists — and speed disinformation campaigns.

The New York Times

Tech

‘The Game is Over’: Google’s DeepMind says it is on verge of achieving human-level AI

The INDEPENDENT

New Gato AI is ‘generalist agent’ that can carry out a huge range of complex tasks, from stacking blocks to writing poetry

Anthony Cuthbertson • Monday 23 May 2022 07:35 • Comments

InfoQ

Meta Open-Sources 175 Billion Parameter AI Language Model OPT

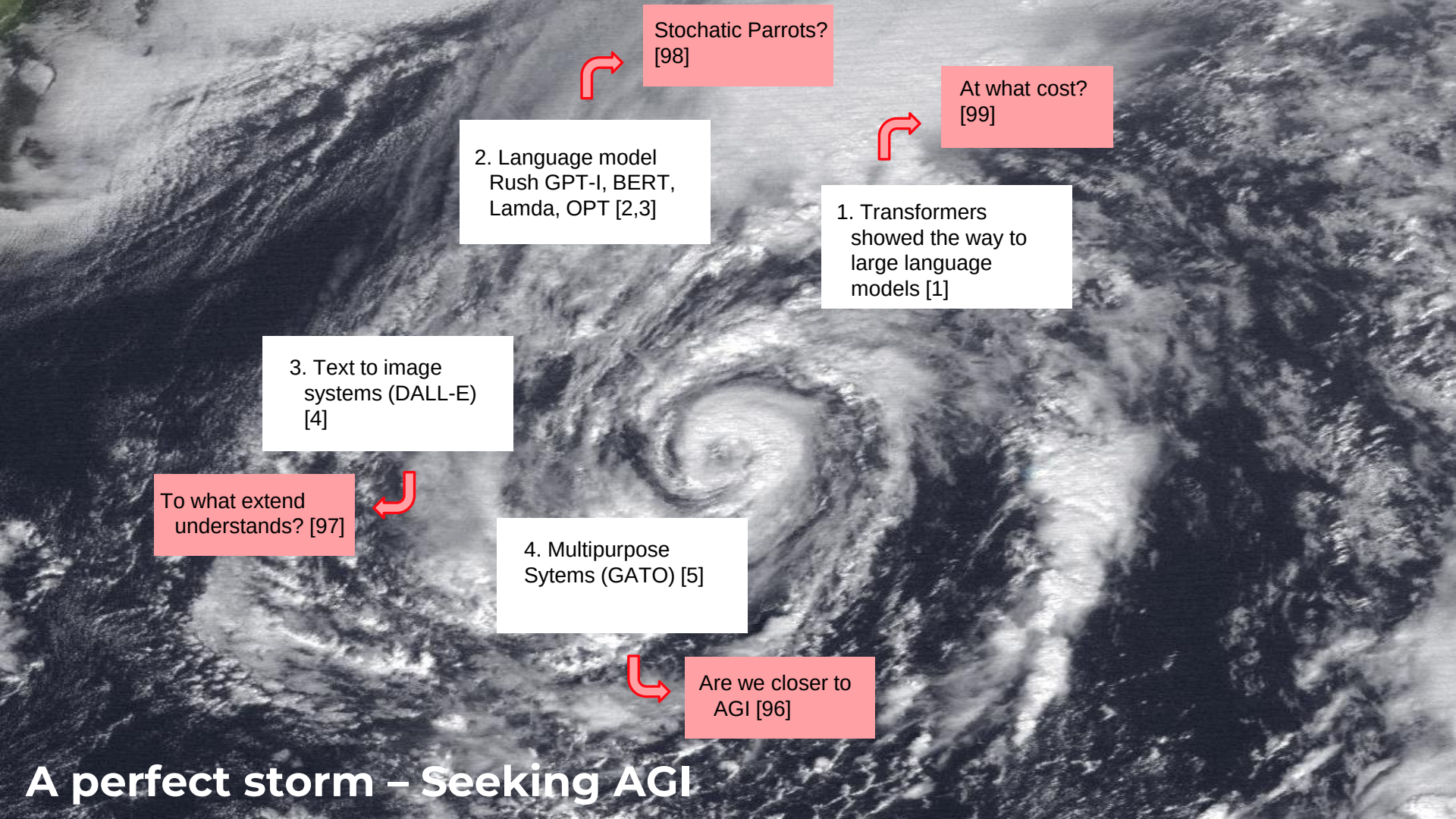
LIKE DISCUSS

JUN 07, 2022 • 3 MIN READ

by

Meta AI Research released Open Pre-trained Transformer (OPT-175B), a 175B parameter AI language model. The model was trained on a dataset containing 180B tokens and exhibits performance comparable with GPT-3, while only requiring 1/7th GPT-3's

EDUCATIONAL CON



A perfect storm – Seeking AGI

[1] Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., … Polosukhin, I. (2017). *Attention Is All You Need*. doi:10.48550/ARXIV.1706.03762

[2] Floridi, L., Chiriatti, M. GPT-3: Its Nature, Scope, Limits, and Consequences. *Minds & Machines* **30,** 681–694 (2020). https://doi.org/10.1007/s11023-020-09548-1

[3] Devlin, J., Chang, M.-W., Lee, K., & Toutanova, K. (2018). *BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding*. doi:10.48550/ARXIV.1810.04805

[4] Shoeybi, M., Patwary, M., Puri, R., LeGresley, P., Casper, J., & Catanzaro, B. (2019). *Megatron-LM: Training Multi-Billion Parameter Language Models Using Model Parallelism*. doi:10.48550/ARXIV.1909.08053

[5] Ramesh, A., Pavlov, M., Goh, G., Gray, S., Voss, C., Radford, A., … Sutskever, I. (2021). *Zero-Shot Text-to-Image Generation*. doi:10.48550/ARXIV.2102.12092

[6] Reed, S., Zolna, K., Parisotto, E., Colmenarejo, S. G., Novikov, A., Barth-Maron, G., … de Freitas, N. (2022). *A Generalist Agent*. doi:10.48550/ARXIV.2205.06175

[99] Sharir, O., Peleg, B., & Shoham, Y. (2020). *The Cost of Training NLP Models: A Concise Overview*. doi:10.48550/ARXIV.2004.08900

[98] Bender, E. M., Gebru, T., McMillan-Major, A., & Shmitchell, S. (2021). On the Dangers of Stochastic Parrots: Can Language Models Be Too Big? 🦜. *Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency*, 610–623. Virtual Event, Canada. doi:10.1145/3442188.3445922

[97] Gary Marcus. *Artificial General Intelligence Is Not as Imminent as You Might Think*. Scientific American June 2022

[96] Gary Marcus. *A very preliminary analysis of DALL-E 2* - arXiv

Let’s leave the AGI fight for now. DL works……

MIT Technology Review

Featured Topics Newsletters Events Podcasts

ARTIFICIAL INTELLIGENCE

AI for protein folding

DeepMind has opened new paths for drug discovery and design by solving a 50-year-old problem in biology.

By Will Douglas Heaven February 23, 2022

SUSTAINABILITY

Google and France’s Engie Team Up to Accelerate Wind Power

Google is selling the service through its cloud division, which is trying to lure clients with tools for managing energy usage and reducing emissions. Early tests on Google’s data centers improved the value of wind energy by 20 percent.

Bloomberg News | Jun 02, 2022

San Francisco Chronicle

BAY AREA

Cruise gets state permit to offer paid driverless taxi rides in San Francisco

Andres Picon

June 2, 2022 | Updated: June 3, 2022 6:27 p.m.

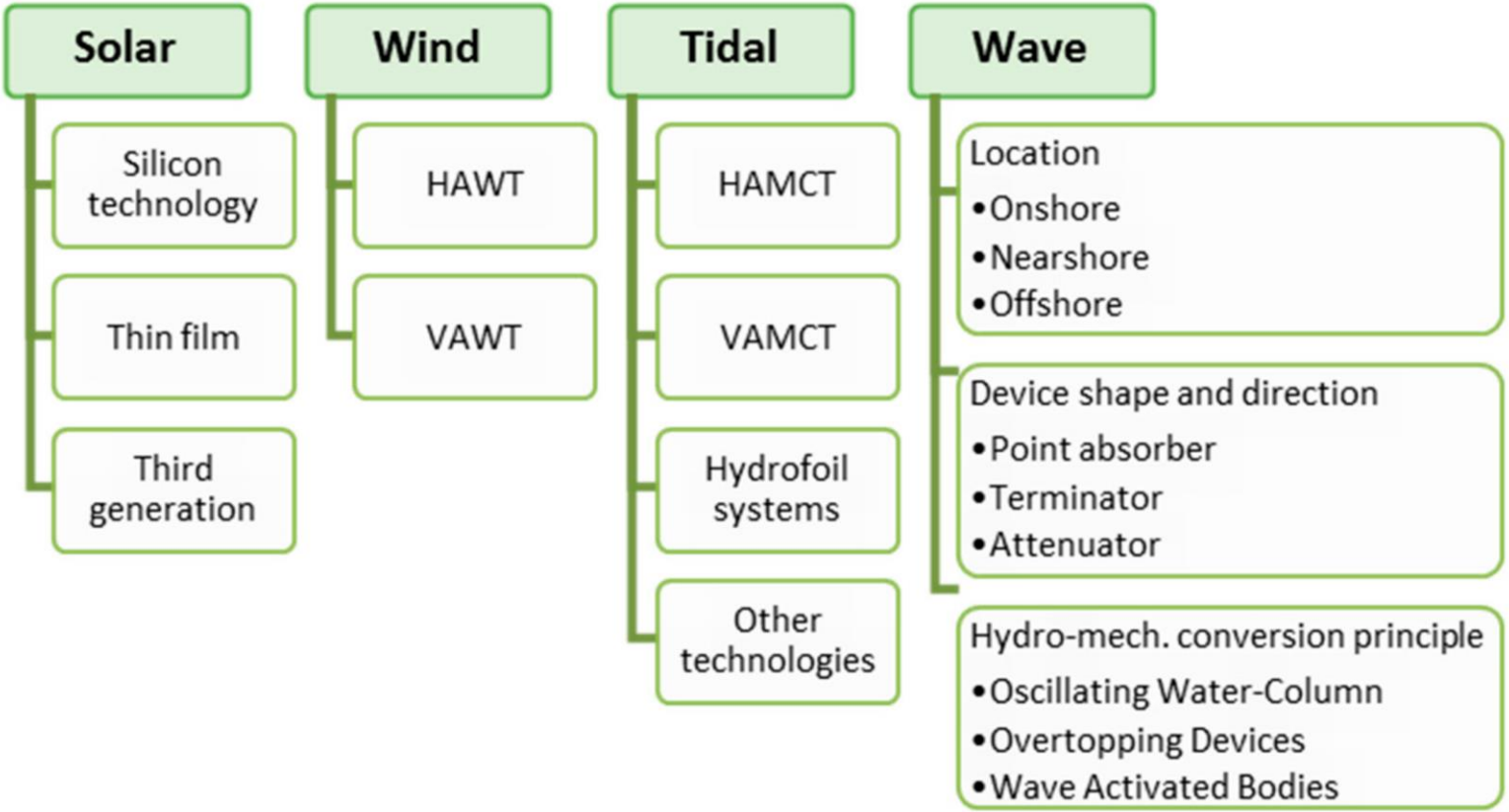
Content

What makes Marine Renewables different?

- **Fluid, Fluid-air, Fluid-Fluid interactions**
- **Harsh environment**
- **Project and pilot costs**

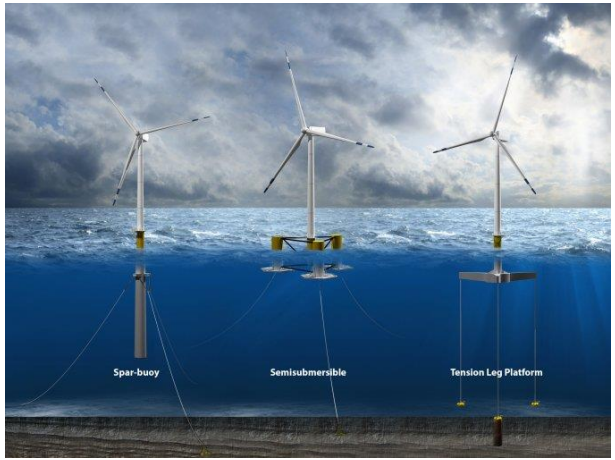
- **68% of the earth’s surface**
- **Enormous potential**

A Taxonomy of marine renewables

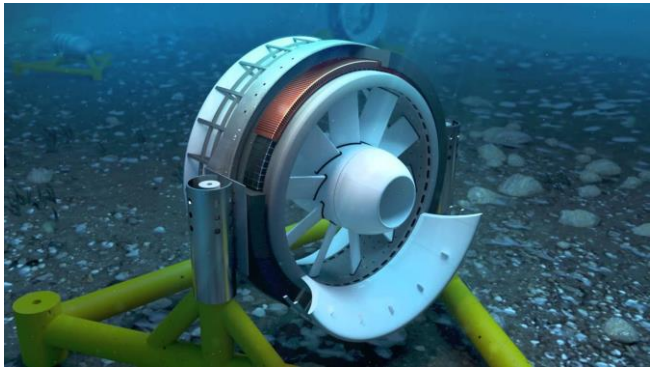


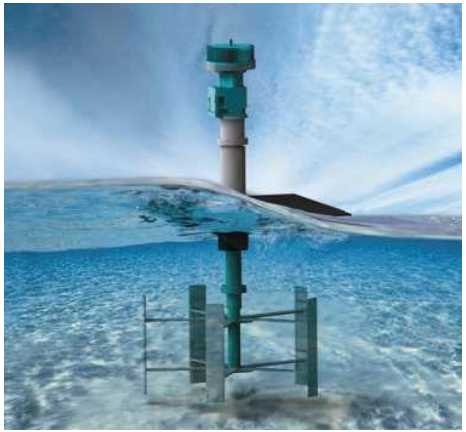
Roy A, Auger F, Dupriez-Robin F, Bourguet S, Tran QT. Electrical Power Supply of Remote Maritime Areas: A Review of Hybrid Systems Based on Marine Renewable Energies. *Energies.* 2018; 11(7):1904. https://doi.org/10.3390/en11071904

HAWT: Horizontal Axis Wind Turbine
VAWT: Vertical Axis Wind Turbine



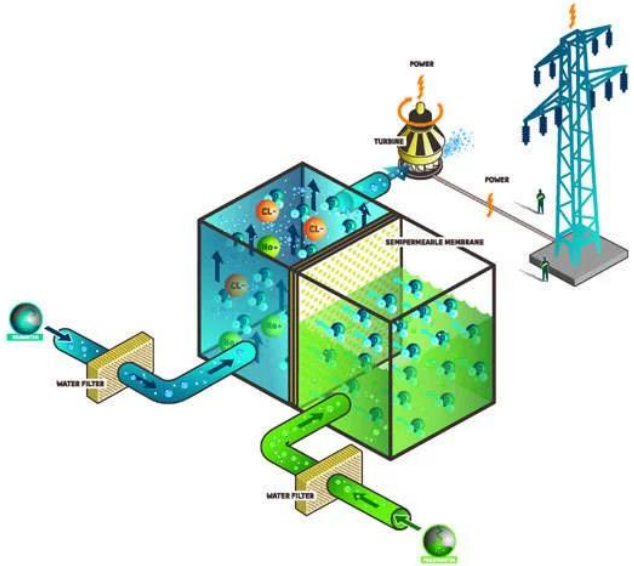
HAMCT: Horizontal Axis Marine Current Turbine
VAMCT: Vertical Axis Marine Current Turbine





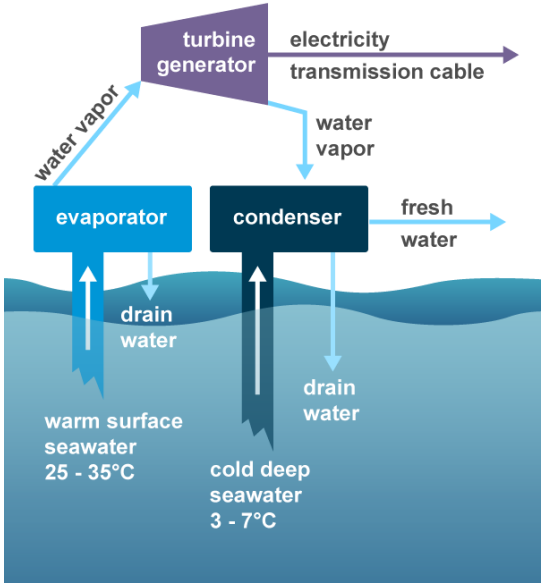
And some exploratory sources ahead

Osmotic Power



Rolf Jarle Aaberg (2003). Osmotic power: A new and powerful renewable energy source?. *Refocus, 4(6), 48-50. https://doi.org/10.1016/S1471-0846(04)00045-9*

Ocean Thermal Energy Conversion



Herrera, J.; Sierra, S.; Ibeas, A. Ocean Thermal Energy Conversion and Other Uses of Deep Sea Water: A Review. *J. Mar. Sci. Eng.* **2021**, *9*, 356. https://doi.org/10.3390/jmse9040356

How it is a Renewables project life-cycle?

Where can we apply AI in Marine Renewables?

Everywhere

Areas were Deep Learning and Machine Learning can work

By applying ML to complex or remote images
Like satellite image interpretation, LIDAR, SONAR or remote sensing data

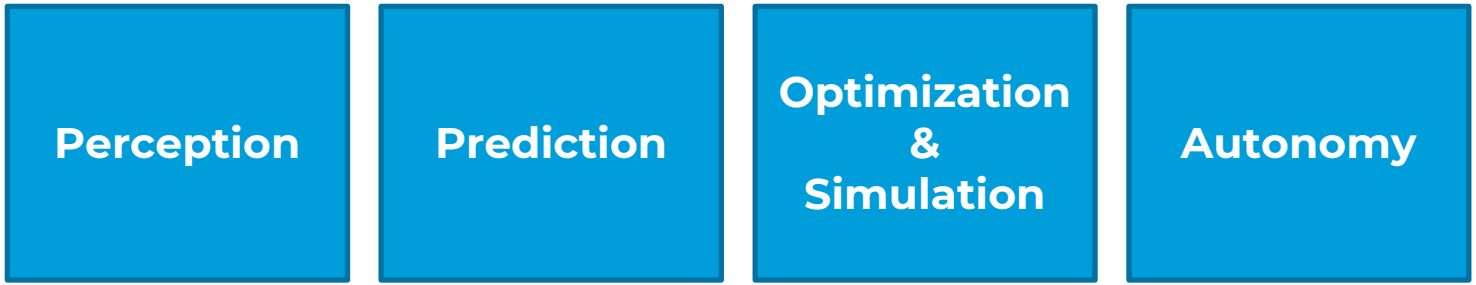
By future values from the past. Using supervised approaches to weather, sea level, current, tidal prediction

By using DL algorithms to optimize engineering, design challenges that allow developing better and more efficient generation approaches

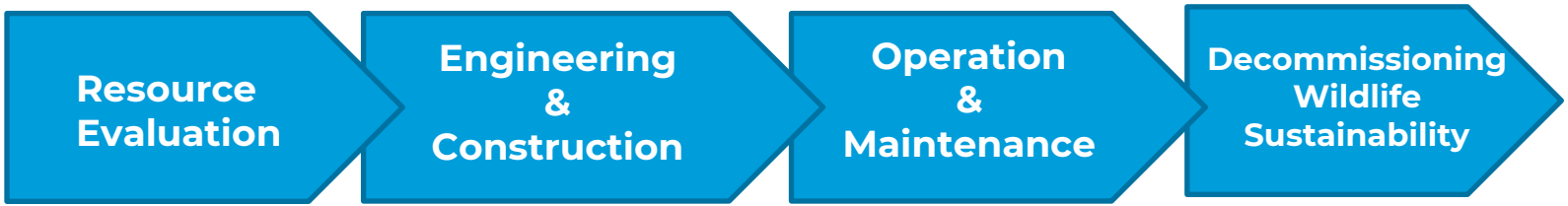
By using reinforcement learning algorithms, to build algorithms that control autonomous machines that work in harsh environments or control complex operations

Use cases galore

- To apply deep learning approaches in an industry we must identify and test as many approaches as possible
- The introduction of Deep Learning in Marine Renewables is at its early stages, but it will be accelerated by transposing use cases from other ‘sister’ industries
- The specific conditions of Marine Renewables open the door to new and unexpected applications in many areas



Let’s describe some interesting use cases



- Wind Resource prediction
- Tidal modelling
- Wave modelling
- Climate Change Modelling
- Demand/Market prediction

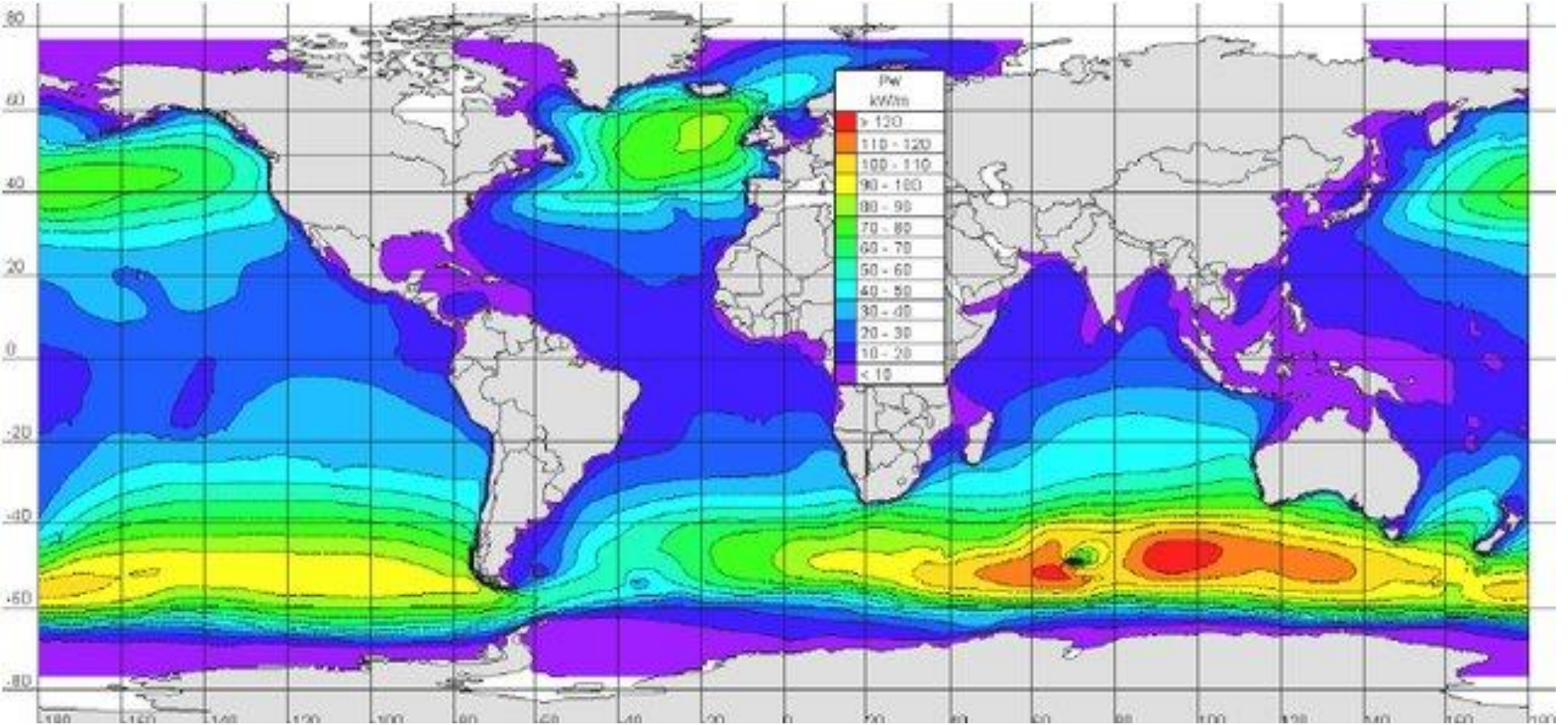
- Wake effects
- Tidal management
- Wave modelling
- Climate Change Modelling

- Wind Resource prediction
- Tidal prediction
- Wave/Wind prediction
- Weather prediction
- Short term Demand/Market

- Protecting ecosystems
- Modelling decommissioning
- Measuring impact on Nature

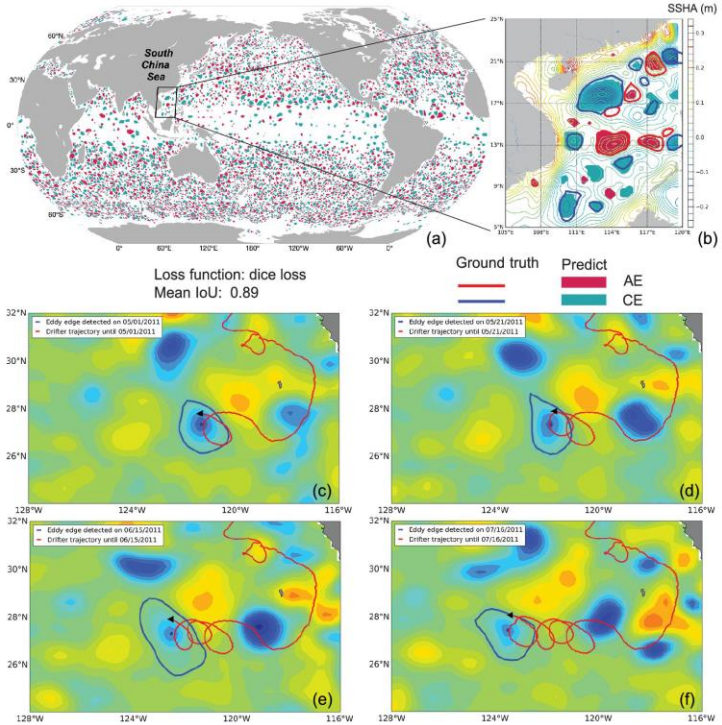
Content

Sea Resource Evaluation



Analysis of Ocean Energy resources

Using Satellite images



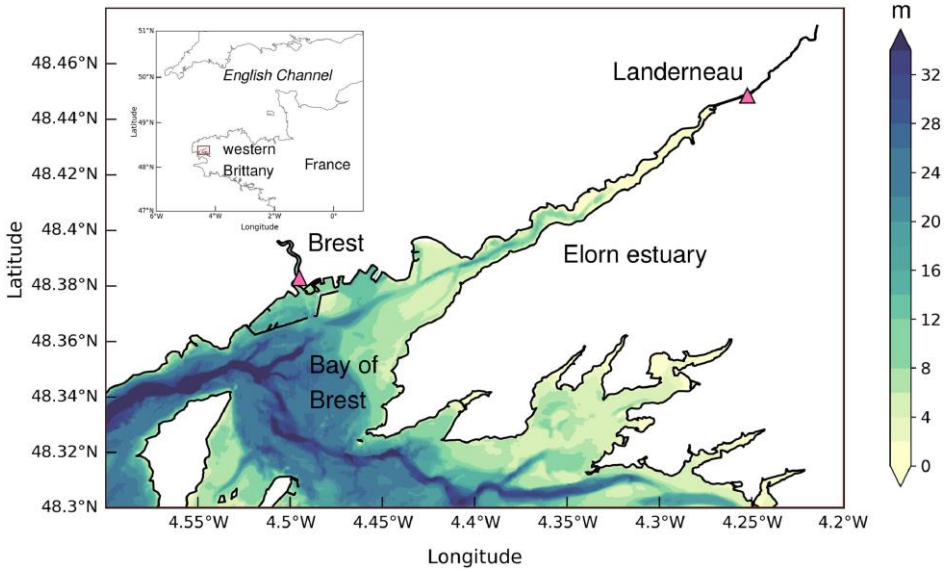
(a) Mesoscale eddies detected by the AI-based method in the global ocean on 1 January 2019. (b) Mesoscale ...

- Ocean has many remote areas that are difficult to map and study
- Waves and tidal currents require complex fluid modelling
- With the widespread availability of satellite images, we can use self-learning algorithms to identify patterns
- In this example deep learning is used to identify circular sea water currents (eddys)

Xiaofeng Li, Bin Liu, Gang Zheng, Yibin Ren, Shuangshang Zhang, Yingjie Liu, Le Gao, Yuhai Liu, Bin Zhang, Fan Wang, Deep-learning-based information mining from ocean remote-sensing imagery, National Science Review, Volume 7, Issue 10, October 2020, Pages 1584–1605, https://doi.org/10.1093/nsr/nwaa047

Analysis of Ocean Energy resources

Predicting sea level in tidal estuary



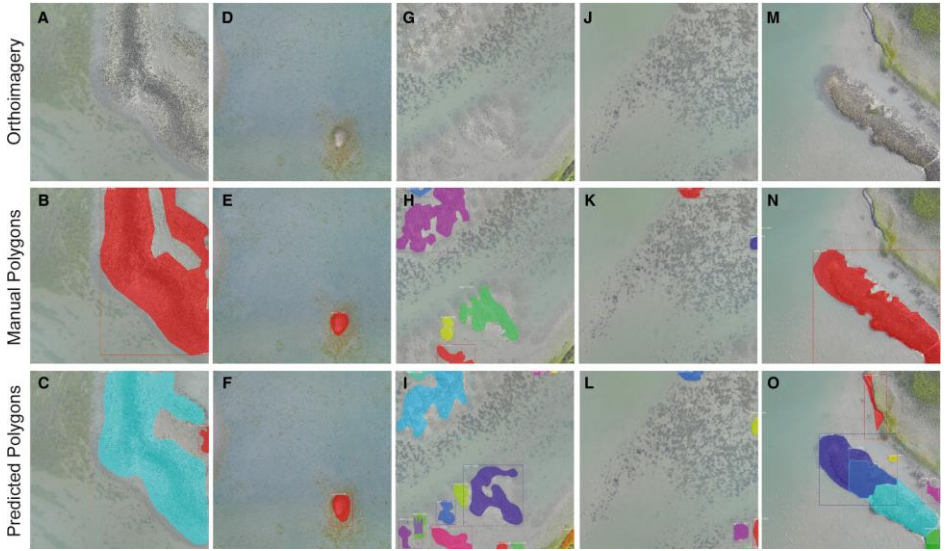
- Instead of using numerical simulations (high computational cost) they use ML models to predict sea levels in the Elorn estuary (Britanny France)
- The ML models used 4 variables: French Tidal coefficient, atmospheric pressure, wind velocity and river discharge.
- This simple model improved prediction of inundation events.

Guillou, N., & Chapalain, G. (2021). Machine learning methods applied to sea level predictions in the upper part of a tidal estuary. Oceanologia, 63(4), 531–544. doi:10.1016/j.oceano.2021.07.003

Ocean Energy resource preservation

Processing aerial images with DL

- Coastal ecosystems are difficult to monitor due to lack of data in complex spatial habitat patterns
- Aerial images are processed with OysterNet a Deep Learning architecture based on Convolutional Networks.
- OysterNet enables assessments of oysters heights and densities, and in the future more coastal habitat types.



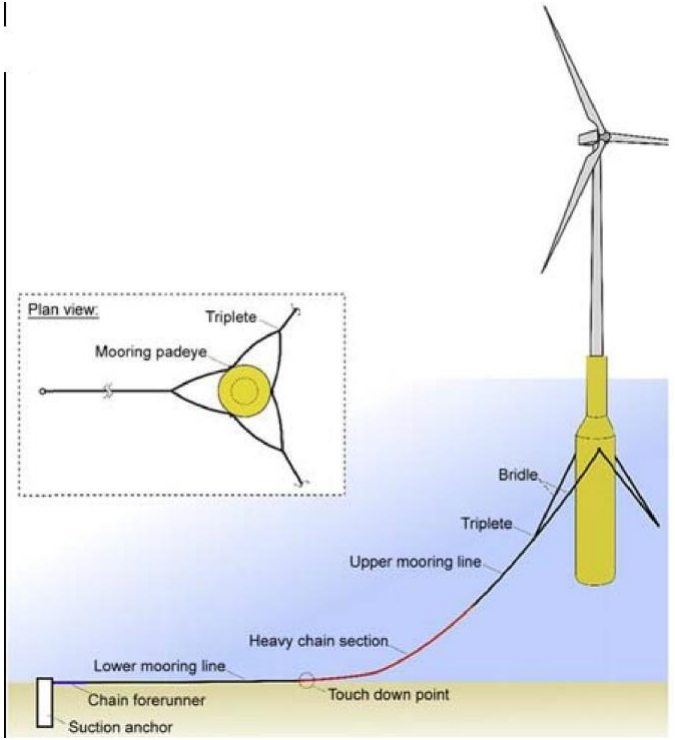
Ridge, J.T., Gray, P.C., Windle, A.E. and Johnston, D.W. (2020), Deep learning for coastal resource conservation: automating detection of shellfish reefs. Remote Sens. Ecol., 6: 431-440. https://doi.org/10.1002/rse2.134

Engineering and Construction

Engineering the generation sites

Modelling Viscous Hydrodynamics

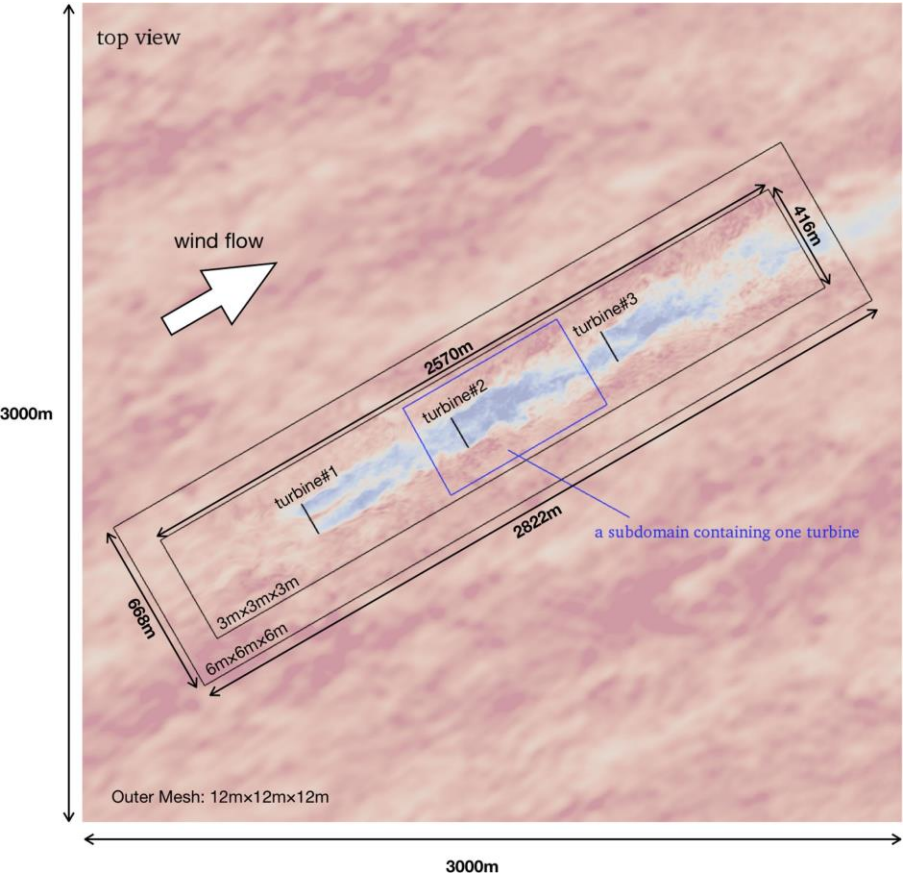
- Ocean engineering is challenging due to the stochastic nature of ocean waves, viscous effects of the flow, non-linear resonance, etc.
- This works uses Machine Learning to model nonlinear viscous hydrodynamic loads floating offshore wind turbines (and some others)
- ML and DL models show their capabilities for modelling complex engineering problems



Ma, Yu. Machine learning in ocean applications : wave prediction for advanced controls of renewable energy and modeling nonlinear viscous hydrodynamics. PhD Theses MIT. 2020 Boston

Wake effect in offshore wind

Modelling wake in offshore parks



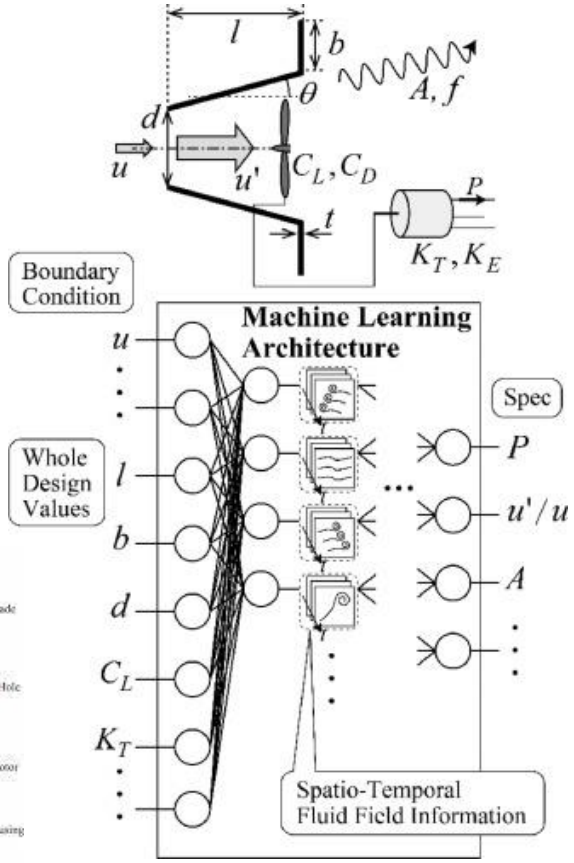
- Wake effects are important to design wind parks
- Traditional numerical models require tens of thousands of CPU hours on a high-performance computing cluster
- The model predicts the wake interactions in 9 turbines in seconds in a Desktop computer
- This method is proposed for dynamic wind farm modelling and is based on recurring LSTM networks

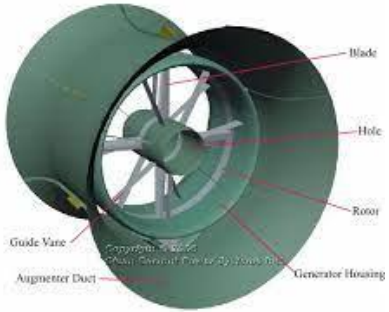
Zhang, J., & Zhao, X. (2020). A novel dynamic wind farm wake model based on deep learning. *Applied Energy*, *277*, 115552. doi:10.1016/j.apenergy.2020.115552

Designing Tidal generators with DL

Forecasting design values of a tidal generator

- This design has been made for Tsugaru strait in Japan
- To design the optimal geometry of the diffusers of the generators a deep learning model is defined
- The deep neural network forecasts design values from a given fluid field with satisfactory results and optimal use of resources



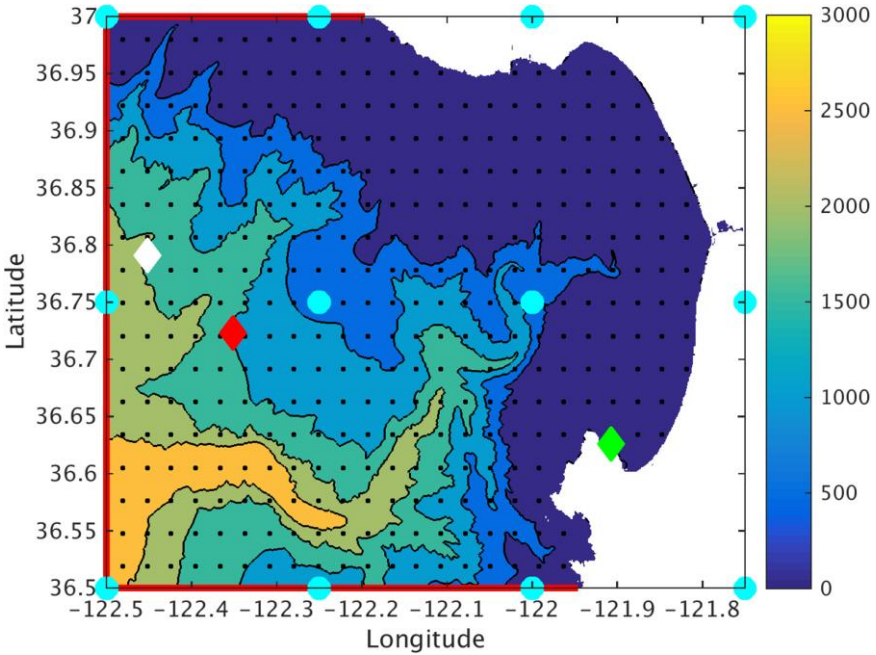


Fujiwara, R., Fukuhara, R., Ebiko, T., & Miyatake, M. (2022). Forecasting design values of tidal/ocean power generator in the strait with unidirectional flow by deep learning. *Intelligent Systems with Applications*, *14*, 200067. doi:10.1016/j.iswa.2022.200067

Operation and Maintenance

Forecasting waves

Deep Learning models acting as surrogates of SWAN model



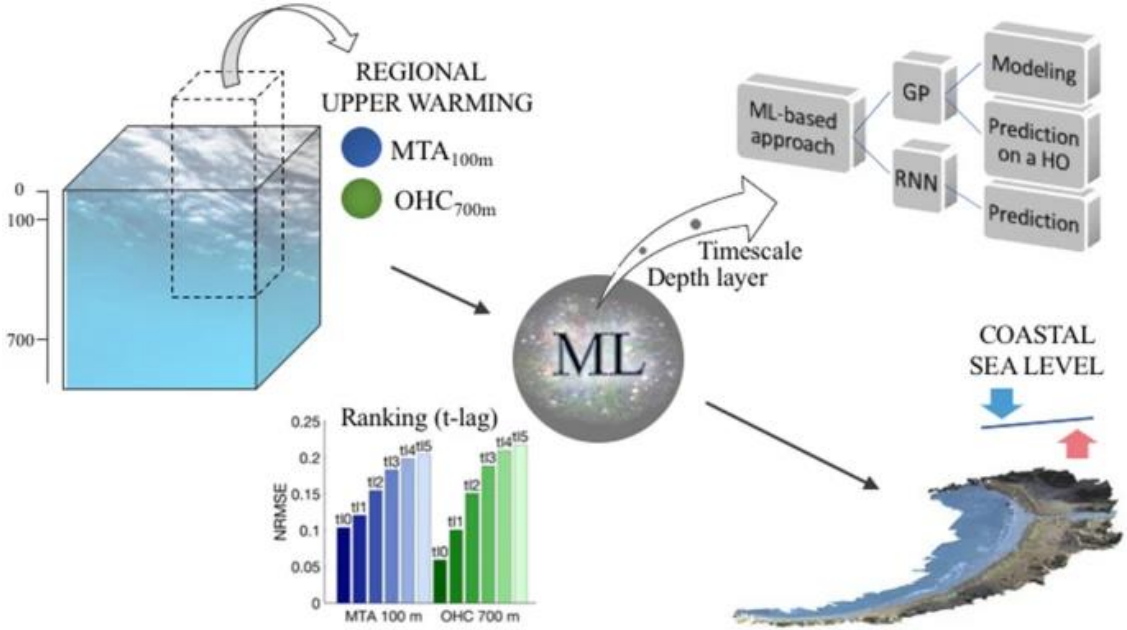
- Tested in Monterrey Bay
- Prediction of wave heights and wave conditions
- The Model identified wave heights with an error of 9cm and over 90% of the characteristic periods
- It shows the possibilities of ML models to model complex physical models and obtain accurate predictions

James, S. C., Zhang, Y., & O'Donncha, F. (2018). A machine learning framework to forecast wave conditions. *Coastal Engineering*, *137*, 1–10. doi:10.1016/j.coastaleng.2018.03.004

Climate Change

Predicting sea level changes

- Ocean basins are changing due to climate change
- By using a machine learning approach on sea temperature variations, we obtain estimates that anticipate changes in a 1-3 years timescale
- Modelling sea level with ML becomes a key forecasting tool



Nieves, V., Radin, C. & Camps-Valls, G. Predicting regional coastal sea level changes with machine learning. *Sci Rep* **11,** 7650 (2021). https://doi.org/10.1038/s41598-021-87460-z

Tidal and Sea Level prediction

Predicting sea level changes

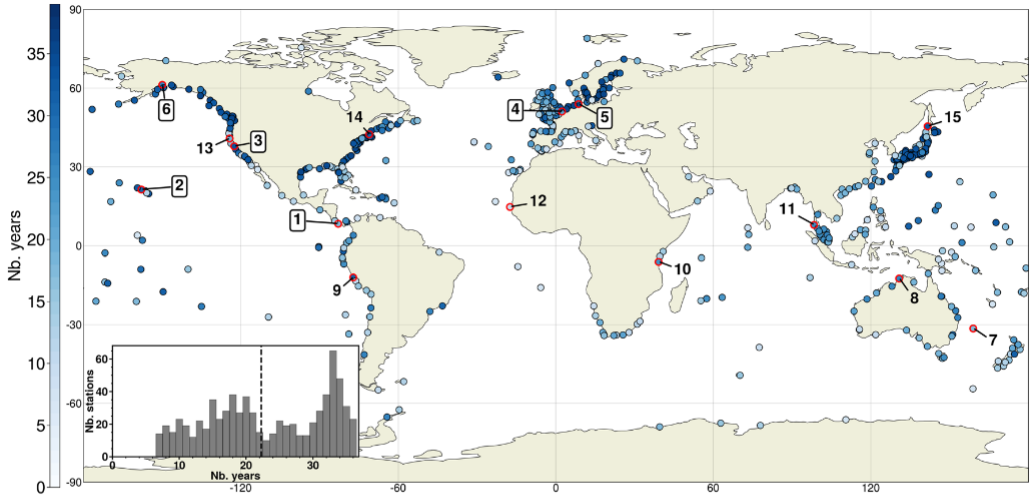


Figure 1. Tide stations considered in this study. Inset figure presents the histogram of the length of the data records with the median value shown by a dashed line. The set of 15 stations selected for further analysis is circled in red: 1-Puerto Armuelles (Panama), 2-Honolulu (Hawaii), 3-San Francisco (USA), 4-Dunkerque (France), 5-Cuxhaven (Germany), 6-Anchorage (USA), 7- Lord Howe (Australia), 8- Darwin (Australia), 9-Callao (Peru), 10-Zanzibar (Tanzania), 11- Ko Taphao (Thailand), 12- Dakar (Senegal), 13- Humboldt Bay (USA), 14- Boston (USA), 15- Wakkanai (Japan). Results for the boxed numbers (1–6) are shown in the main study and the rest (7–15) in supplementary.

- 4 DL methods to predict surge of local sea-level based on local atmospheric conditions.
- The models are based on ANN, CNN and RNN(LSTM) approaches.
- LSTM shows better results
- The results are promising in mid-latitudes

Tiggeloven, T., Couasnon, A., van Straaten, C. *et al.* Exploring deep learning capabilities for surge predictions in coastal areas. *Sci Rep* **11,** 17224 (2021). https://doi.org/10.1038/s41598-021-96674-0

Decommissioning , Wildlife and Sustainability

Fish identification for tidal-energy projects

Listening underwater to understand fish stocks

- Understanding fish patterns is critical in ocean energy projects
- There is a strong resistance from fishermen to any development that may impact their fisheries
- Understanding the impact of new infrastructures in actual fish stocks is key

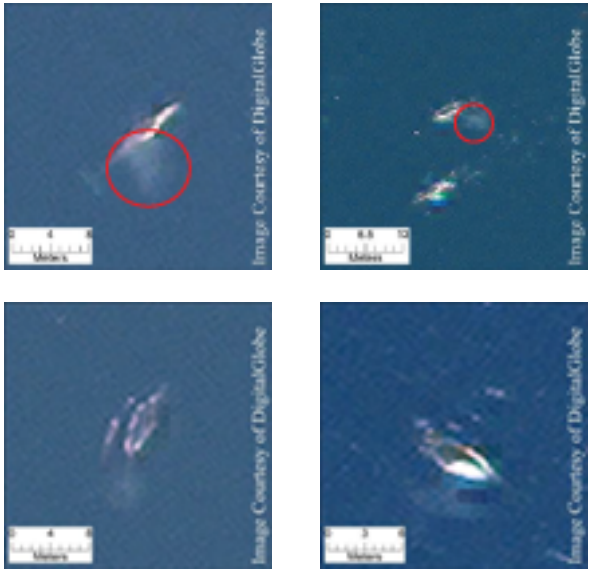
Staines, G., Zydlewski, G. B., Viehman, H. A., & Kocik, R. (2020). Applying Two Active Acoustic Technologies to Document Presence of Large Marine Animal Targets at a Marine Renewable Energy Site. *Journal of Marine Science and Engineering*, *8*(9). doi:10.3390/jmse8090704

Kandimalla, V., Richard, M., Smith, F., Quirion, J., Torgo, L., & Whidden, C. (2022). Automated Detection, Classification and Counting of Fish in Fish Passages With Deep Learning. *Frontiers in Marine Science*, *8*. doi:10.3389/fmars.2021.823173

Where are the whales?

Identifying whales from satellite images using Machine Learning

- Using Satellite imagery, we can access remote areas not accessible using traditional methods
- In this research the author found 4 different types of whales
- Classification based on Machine Learning approaches
- There is a public dataset available from this work that can be used for further research



Cubaynes, H. C., & Fretwell, P. T. (2022). Whales from space dataset, an annotated satellite image dataset of whales for training machine learning models. *Scientific Data*, *9*(1), 245. doi:10.1038/s41597-022-01377-4

Cubaynes, H. C., Fretwell, P. T., Bamford, C., Gerrish, L., & Jackson, J. A. (2019). Whales from space: Four mysticete species described using new VHR satellite imagery. *Marine Mammal Science*, *35*(2), 466–491. doi:10.1111/mms.12544

Content

Conclusions

Where can DL be applied?

Perception

- Satellite
- LIDAR / SONAR
- Remote sensing
- Images/Videos

Prediction

- Resource prediction
- Current modelling
- Climate Change impacts
- Market prediction
- Production prediction
- Meteo prediction
- Predictive maintenance
- Fish / mammal stocks

Optimization & Simulation

- Modelling engineering
- Modelling park layout
- Fluid dynamics
- Corrosion wear & Tear

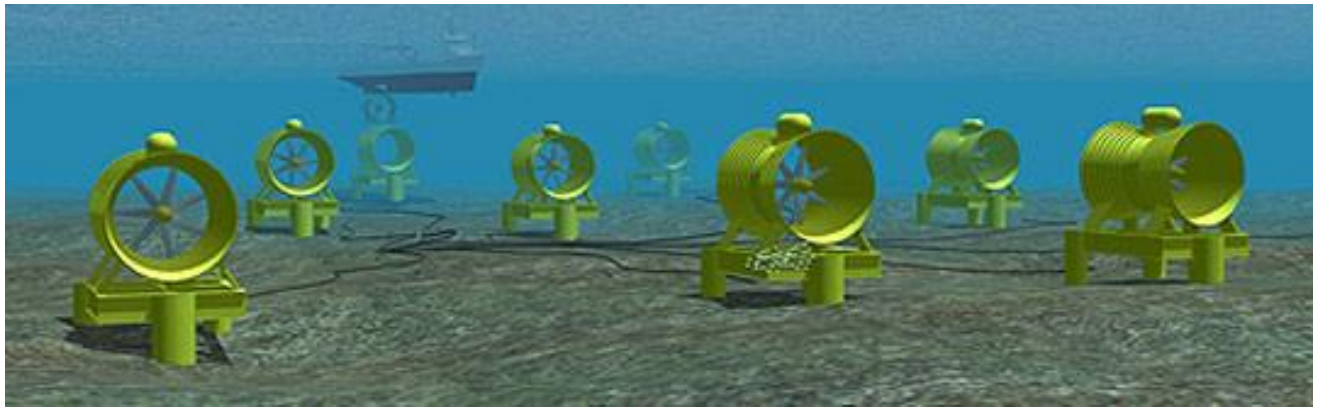
Autonomy

- Robotics
- Self-adapting generation
- Autonomous control

Conclusions

A look into the future

- Research shows many nascent applications of deep learning in this field
- The research shown in this conference is recent and with high potential.
- There are use cases everywhere. The limit is our imagination



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