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Web application with data centric approach to ship powering prediction using deep learning

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ABSTRACT

This work describes an AI-based web application to predict passenger ship powering requirements. The data centric approach is developed based on the actual passenger ship design data as a design tool to assist naval architects to quickly estimate the ship brake power. It emphasised on the preliminary design stage to minimise design tasks and laborious calculations. Based on the study, it is observed that the model shows good agreement to the existing empirical method results with 10% mean absolute errors. Significantly, this presents the approach ability to facilitate faster and effective preliminary design, and scalability for large and complex systems.

Code metadata

Current code version	V1
Permanent link to code/repository used for this code version	https://github.com/SoftwareImpacts/SIMPAC-2021-198
Permanent link to reproducible capsule	
Legal code licence	GNU General Public Licence (GPLv3)
Code versioning system used	git
Software code languages, tools and services used	python, html & css
Compilation requirements, operating environments, and dependencies	Python 3.6.15 & docker 20.10.10
If available, link to developer documentation/manual	https://github.com/jtkhair/aiship_webapp/blob/master/README.md
Support email for questions	jauhari.tahir@gmail.com, jauhari@graduate.utm.my

1. Introduction

Ship design is a complex process involving magnitudes of design parameters and components with many considerations. Conventionally, the ship design development is performed sequentially in iterations. It involves detailed and laborious calculations, causing long development lead time.

In practice, naval architects rely on the parametric design approach as the starting point to estimate the design parameters, evaluating them one at a time. As the design progresses, this approach causes both technical and organisational issues due to conflicting design parameters and objectives. Particularly, the processes are affected by the design uncertainties as well as the non-linear design problems in addition to the parameters inter-dependencies.

Existing effort in overcoming these matters includes integrating the parametric design, computer aided design and engineering tools with design optimisation approach [1–3]. It emphasised on the search for optimal design parameters by integrating design, simulation, and analysis tools. However, the heuristic approach is very costly in terms of computing power, software licensing, development lead time and crucially the skills needed to use the applications. The effects are particularly significant in the preliminary design stage. In complement to the integrated approach, the concept deployments as web applications are also observed as the means to disseminate some of the associated costs [4,5].

Recently, artificial intelligence (AI) applications have gained considerable attention in facilitating effective design processes [6,7]. In the ship design domain, the work observed includes predicting the principal design parameters [8], hull form and structural design parameters [9], ship operational parameters [10] and performance [11]. Fundamentally, the AI concept is adopted to reduce the computational

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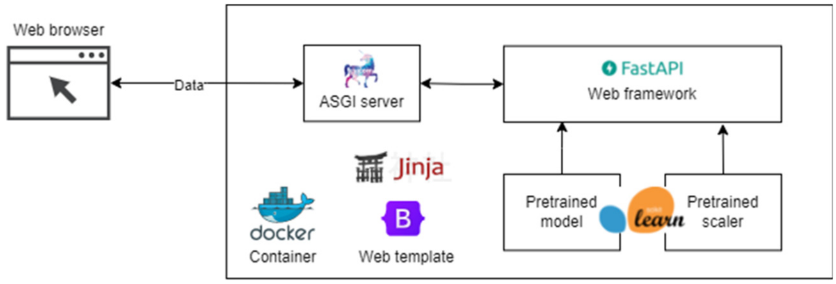

Fig. 1. Web application architecture.

cost and lead time through the data centric approach. This is achieved by leveraging the validated or actual data rather than augmenting new data through laborious design and analysis processes. Hence, introducing this concept as web applications are deemed substantial for usability and effectiveness.

Based on these advancements, an AI-based web application is developed and applied as a part of the "UTM AI_Ship" framework. It is introduced for determining the ship powering requirements in the preliminary design stage. Particularly, this work is devised based on the fully connected feedforward artificial neural network (ANN) model known as the multilayer perceptron (MLP). It is developed using the actual passenger ship principal design parameters published in the "significant ships" and "significant small ships" from 1992–2016 by the Royal Institute of Naval Architecture (RINA) [12].

In this work, the web application is described in Section 2 with an illustrative example of a case study in Section 3. Then, the impact of the application for future development is discussed in Section 4 and the work is concluded in Section 5.

2. Software description

This 2-layer web application consists of the user interface (UI) and the backend that serves the pre-trained ANN model, as depicted in Fig. 1. The Jinja and bootstrap are used for the web template, and UI development while the FastAPI is employed to develop the application programming interface (API). This includes the API to execute the read input data, data pre-processing, inferencing, post-processing, and visualisation.

The overall development is aimed at producing a fast and responsive application while at the same time to promptly provide near optimal design parameters predictions. It starts with developing and tuning the ANN model in python using the scikit-learn machine learning (ML) library. Here, the data is first transformed by scaling the features in 0 to 1 range. The fitted scaler model is saved and then serialised as the pretrained scaler. Subsequently, the ANN is configured, trained, tested, tuned, validated, and serialised as the pretrained model.

Based on the architecture, the FastAPI is implemented to develop responses to the APIs call initiated by the client e.g., web application UI. It takes the data submitted by the users in the UI and processes them at the backend. It then returns the prediction, and visualisation data back to the client. While the Starlette and Uvicorn function to facilitate in building the asyncio service and ASGI server implementation. Finally, the application is containerised for portability using Docker.

In serving the model, the neural network optimisation is performed by varying the hidden layer, number of neurons, hyperparameters variables and values to achieve highest training and testing accuracies with the shortest training time [12]. At the same time, the proposed model is optimised specifically to tackle the nonlinear nature of the observed passenger ship design problems. In this work, the model is trained with 80% of the total dataset and the validation is performed with augmented data based on Bailey's hull series empirical model [13].

3. Illustrative examples

This example describes the locally deployed web application deployment using the container technology as presented in Fig. 2. The UI highlights the data input panel, chart to visualise the predicted P for Vs and Fn, and table to tabulate the resulting output.

The user starts with submitting a set of ship principal parameters in *.csv based on the predetermined schema; (1) waterline length (LWL), (2) breadth at the waterline (B), (3) draught (T), (4) length–breadth ratio (L/B), (5) breadth–draught ratio (B/T). (6) displacement (Δ), (7) block coefficient (CB), (8) speed (Vs) and (9) Froude number (Fn). This will execute the APIs call to the powering prediction process, inferencing the brake power (P) and visualising the output data for the range of Vs and Fn submitted. Currently, the powering requirement prediction process is applicable for monohull type passenger ship design with data range as presented in Table 1.

4. Impact

The web application development is devised based on the established "UTM AI_ship" ship preliminary design methodology and framework [12]. This deterministic and data centric approaches allow for rapid design changes and evaluation without the need for many design iterations. Currently, the optimised model training takes 13.6 s with 85% test score and the inferencing takes 1.9 millisecond to complete. In overall, the powering prediction takes about less than 1 s using the locally deployed web application.

Substantially, the accuracy achieved with the developed ANN model only requires 9 input features rather than 18 and 42 as required by Bailey's [13] Fung's [14] methods respectively. The optimised ANN model shows a mean average error (MAE) of 10% for the case study as observed in Table 2. Consequently, the prediction visualised as in Fig. 3 shows a good agreement to the result derived using the data augmented based on the Bailey's model especially for the Fn range 0.20–0.35. This refers to the general operating condition for displacement hull type passenger ships as observed in the dataset.

In principle, this approach is intended at enabling concurrent and effective design for the large and complex design development hence for scalability. This can be further studied through the AI application in graph theory that represents the overall design processes [12]. As a result, the AI application is viewed to have great potential as the key component in the large and complex system design development process due to the speed and accuracy.

5. Conclusions

This work presented an AI-based web application with the data centric approach to the passenger ship design process. It is developed as a design tool to assist naval architects to instantly estimate and visualise ship brake power in the preliminary design stage. Importantly, the proposed ANN model served by the application shows considerable impact in comparison to the existing methods in terms of complexities,

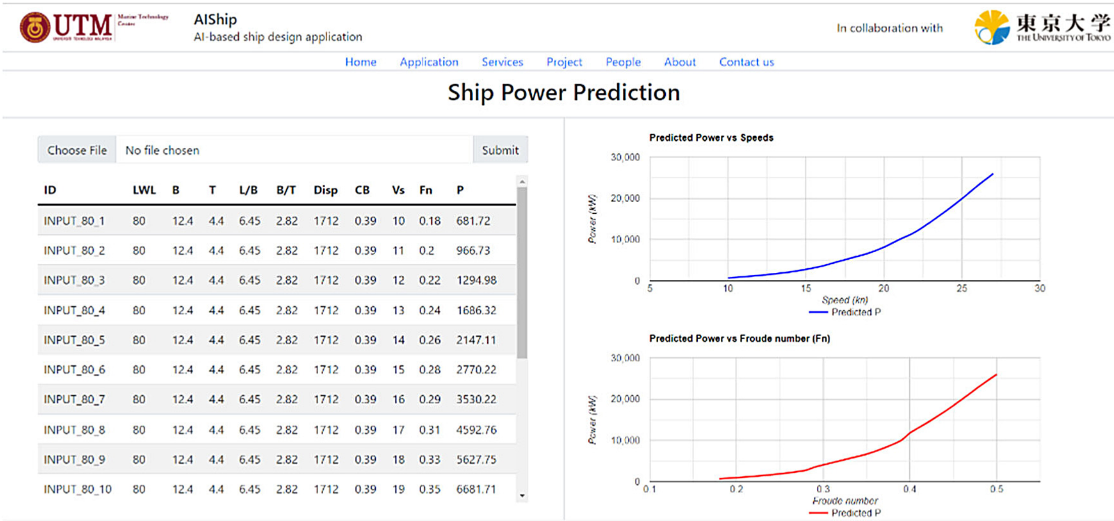

Fig. 2. Web application.

Table 1
Dataset design parameters range.

L (m)	B (m)	T (m)	L/B	B/T	Δ (t)	CB	Vs (kn)	Fn	P (kW)
80–240	14–32	3–8	3.5–9.0	3.0–5.5	2000–32,0000	0.35–0.70	10–30	0.15–0.50	600–70,000

Table 2
Case study for 90 m passenger ship.

LWL (m)	B (m)	T (m)	L/B	B/T	Δ	CB	Vs (kn)	Fn
90	14.4	4.96	6.25	2.9	2088	0.397	10–27	0.17–0.47

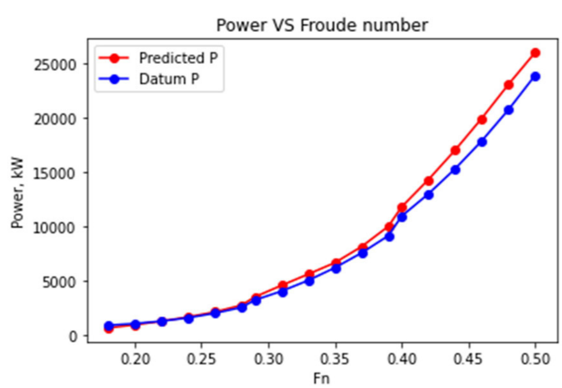

Fig. 3. Predicted and estimated (datum) power comparison for the case study.

costs, and effectiveness. Therefore, the findings show great potential for further development and implementation.

This application version is presently limited to one set of pretrained scaler and ANN models. Thus, it is only tested for the monohull type passenger ship design problem. By including additional models and design options, this will make the application relevant as a general AI and web-based ship design platform. Additionally, this version is developed as a 2-layer application where the data resulting from the inference is not being stored. Therefore, integrating databases to the application is advantageous especially for reporting and in facilitating ANN model improvement.

Other future works proposed include the extension in the form of modules for the other design parameters development such as the stability, manoeuvring and seakeeping performances prediction. They can later be assembled into building the overall web-based ship design platform. In significance, the data centric approach and graph theory are viewed prospective at preserving and reusing design knowledge and data for effective ship design and redesign purposes. Hence, this would enable the application to be generalised and further improved by including different ship types and design characteristics.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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