Advancing Maritime Design: HPC-Enhanced Hull Optimization in Wave Dynamics

Slovenian National Competence Centre operates within Slovenian National Supercomputer Network – SLING who promotes the use of high-performance computers capabilities for research in science, industry, academia and the provision of public services. The most important task is raising the level of knowledge of users and general awareness of the benefits of using high-performance computers.

Organisations involved:

In silico specializes in numerical simulations of Computational Fluid Dynamics (CFD) for various engineering fields. The company's flagship service, Cloud Towing Tank (CTT), brings advanced CFD expertise to marine engineering. CTT offers comprehensive simulations, including ship resistance, self-propulsion, manoeuvring, seakeeping, and propeller-hull interaction, addressing a wide spectrum of maritime challenges.

Arctur is a privately owned company specialising in advanced and innovative IT solutions, with a strong focus on R&D. For over 25 years, Arctur has been providing exceptional Cloud and HPC services on its cutting-edge infrastructure with a team of experienced engineers.

Technical/scientific Challenge:

Optimizing a container ship's hull for both calm water and added resistance in waves is a complex technical challenge. In calm water, the focus is on reducing resistance to enhance fuel efficiency and speed. This often involves streamlining the hull shape to minimize resistance. However, in wave conditions, additional factors like wave-induced motions, wave reflection and refraction come into play. This demands an iterative approach by employing CFD simulations and HPC resources to balance streamlined shapes for calm water efficiency hull geometry features that reduce added wave resistance.

Solution:

To enhance the hull's performance, a two-stage optimization workflow was applied. Initially, the hull's global geometry parameters were optimized. Subsequently, a localized fine-tuning of the ship's bow was conducted. Furthermore, the employed approach preserved the required displacement of the vessel across all modifications. Testing encompassed three calm water speeds and one in regular wave conditions, analysing 27 variations per stage—totalling 216 CFD simulations. Performance was

assessed through a consolidated propulsion power metric. The obtained data was then analysed through a surrogate model, which provided valuable insights into the influence of the selected variables on the vessel's performance, ensuring a robust and informed optimization process.

Business impact:

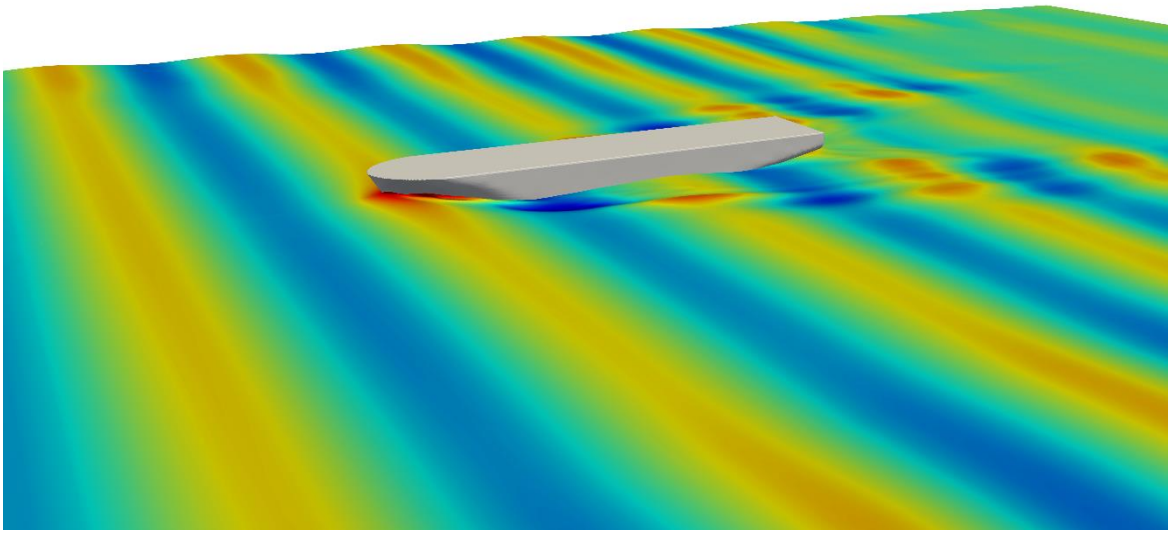
HPC significantly enhances our operational agility by enabling parallel simulations at a larger scale. The ability to run numerous computations simultaneously reduces the time required for complex analyses, allowing for rapid iteration. This rapid turnaround is crucial for staying ahead in a fast-paced market and meeting client expectations for swift project completions.

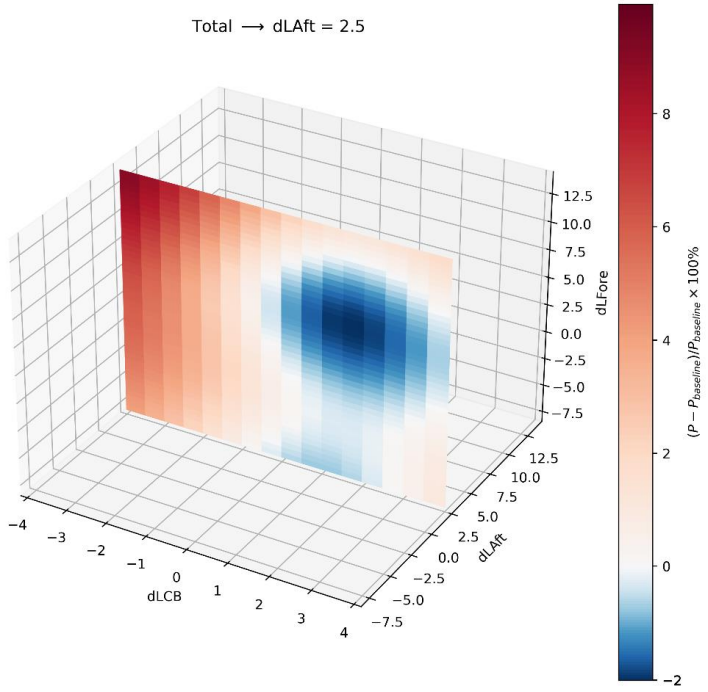
The elastic nature of HPC resources aligns perfectly with our project-driven workflow. By leveraging HPC services, we can scale our computing power to meet peak demands without the hefty investment in physical infrastructure. This flexibility ensures we can manage large-scale calculations during high-demand periods efficiently, maintaining smooth and uninterrupted project progression.

This scalability of HPC resources not only optimizes our operational costs but also empowers us to take on larger, more ambitious projects. It alleviates the stress of resource management, allowing us to focus on innovation and quality of service. Consequently, our business is more adaptable, responsive, and capable of seizing opportunities in a dynamic industry landscape.

Benefits:

- Drastically cuts simulation time
- Lowers operational costs
- Enhances design precision
- Boosts response to peak demands





Images 1-2: The plot illustrates relative changes in weighted power, as predicted by the surrogate model. Colour gradients on the slice plane clarify variations within the design space for easier analysis.

Napredno oblikovanje na področju plovil: Optimizacija trupa s pomočjo HPC v dinamiki valovanja

Slovenski nacionalni kompetenčni center deluje v okviru Slovenskega nacionalnega superračunalniškega omrežja (SLING), ki spodbuja koriščenje superračunalniških (HPC) zmogljivosti za potrebe znanstvenih in industrijskih raziskav, na akademskem področju ter pri zagotavljanju javnih storitev. Želi dvigniti nivo znanja v Sloveniji ter povečati ozaveščenost o vseh prednostih, ki jih prinaša ta tehnologija.

Vključene organizacije

I**n silico** je podjetje specializirano za numerične simulacije računalniške dinamike tekočin (CFD) za različna področja inženiringa. Vodilna storitev podjetja Cloud Towing Tank (CTT) v pomorski inženiring prinaša napredno CFD ekspertizo. CTT ponuja celovite simulacije odpornosti ladje, lastnega pogona, manevriranja, plovnih značilnosti ladje ter medsebojne interakcije med propelerjem in trupom, s čimer naslavlja širok spekter izzivov v pomorstvu.

ARCTUR

Arctur je podjetje v zasebni lasti, specializirano za napredne in inovativne IT rešitve, z močnim poudarkom na raziskavah in razvoju. Arctur, s svojo ekipo izkušenih inženirjev, že več kot 25 let zagotavlja vrhunske storitve v oblaku ter storitve HPC na lastni infrastrukturi.

Tehnični/znanstveni izziv

Optimizacija trupa kontejnerske ladje za plovbo v mirnih vodah in v primeru dodatnega upora zaradi valovanja predstavlja kompleksen tehnični izziv. V mirnih vodah je poudarek na zmanjšanju upora za izboljšanje učinkovitosti porabe goriva in hitrosti, kar pogosto pomeni optimizacijo trupa. V primeru valov pa je potrebno upoštevati še druge dejavnike, kot so gibanje, ki ga povzročajo valovi, odboj in lom valov. To zahteva interaktivni pristop z uporabo CFD simulacij in HPC sistemov, da se na ta način doseže uravnoteženo obliko trupa za večjo učinkovitost v mirnih vodah in geometrijske značilnosti, ki zmanjšujejo dodatni upor valov.

Rešitev:

Za izboljšanje zmogljivosti trupa je bila uporabljena optimizacija v dveh fazah. Najprej je bila izvedena optimizacija splošnih geometrijskih parametrov trupa, nato še lokalizirana fino nastavitev ladijskega premca. Uporabljeni pristop je tako ohranil zahtevani izpodriv plovila pri vseh modifikacijah. Testiranje je vključevalo tri hitrosti v mirni vodi in eno pod pogojem običajnih valov, pri čemer je bilo analiziranih 27 variacij na stopnjo – skupaj 216 CFD simulacij. Zmogljivost je bila ocenjena z združeno metriko pogonske moči. Pridobljeni podatki so bili nato analizirani z nadomestnim modelom, kar je ponudilo dragocen vpogled na vplive izbranih spremenljivk na zmogljivost plovila, s čimer je bil zagotovljen robusten in informiran proces optimizacije.

Poslovni doprinos

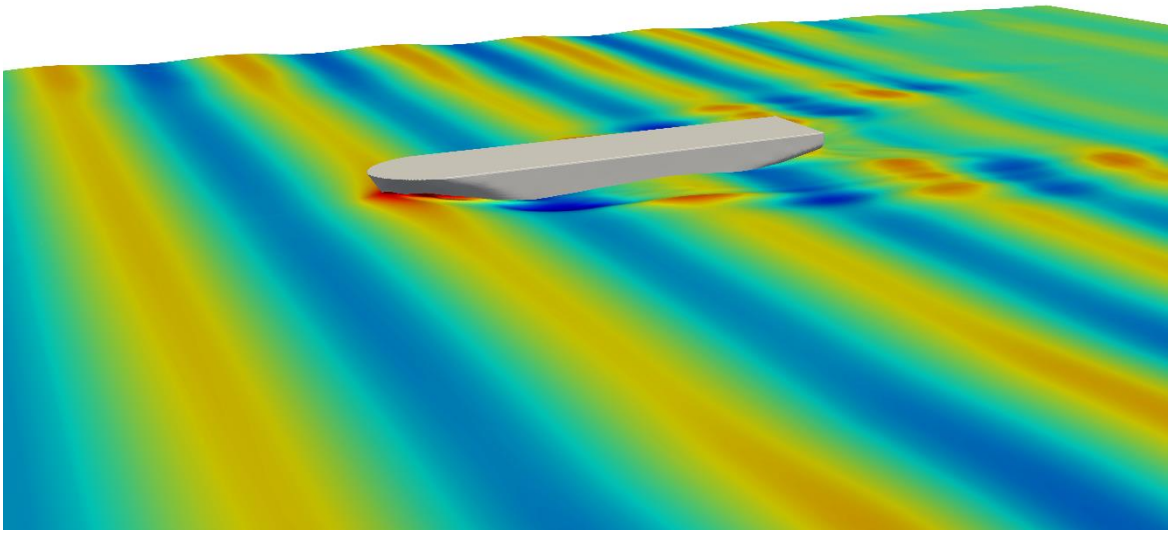
HPC močno izboljšuje našo operativno agilnost, saj omogoča izvedbo vzporednih simulacij v večjem obsegu. Zmožnost istočasnega izvajanja številnih izračunov skrajša čas, potreben za kompleksne analize, kar omogoča hitro iteracijo. Ta hitra obravnava je ključna za ohranjanje prednosti na hitro razvijajočem se trgu in izpolnjevanje pričakovanj strank glede hitrega zaključka projektov.

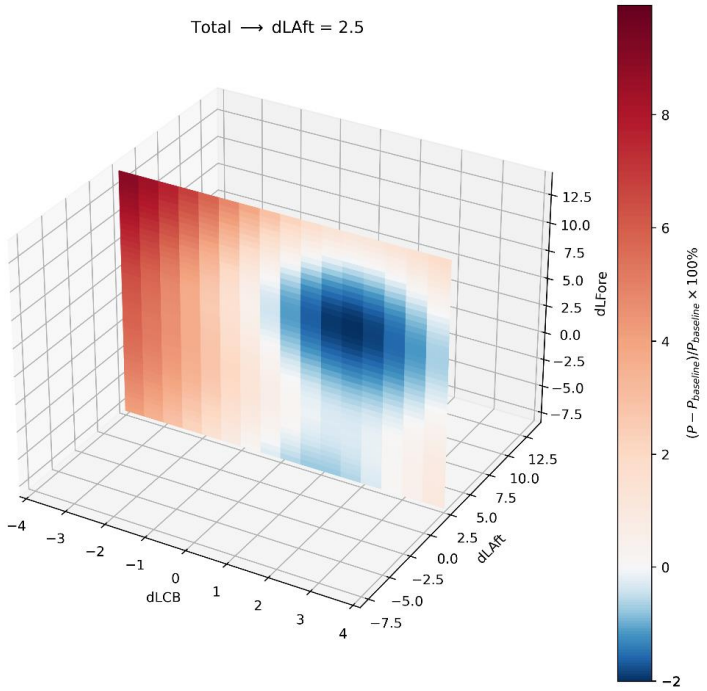
Elastičnost HPC zmogljivosti se popolnoma sklada s potekom našega projektnega dela. Z izkoriščanjem HPC zmogljivosti lahko povečamo svojo računalniško moč, da zadostimo največjim zahtevam brez večjih naložb v fizično infrastrukturo. Ta prilagodljivost zagotavlja, da lahko učinkovito upravljamo obsežne izračune v obdobjih večjega povpraševanja ter pri tem ohranjamo nemoten in neprekinjen napredek na projektu.

Razširljivost HPC zmogljivosti ne samo optimizira naše operativne stroške, ampak nam tudi omogoča, da prevzamemo večje in bolj ambiciozne projekte. Zmanjšuje stres pri upravljanju virov in nam omogoča, da se osredotočimo na inovacije in kakovost storitev. Posledično je naše podjetje bolj prilagodljivo, odzivno in sposobno izkoristiti priložnosti v dinamičnem industrijskem okolju.

Prednosti

- Znatno zmanjša čas simulacije
- Zmanjša operativne stroške
- Izboljša natančnost dizajna
- Poveča odziv v času večjih povpraševanj





Sliki 1-2:

Graf ponazarja relativne spremembe utežne moči, kot jih predvideva nadomestni model. Barvni prelivi na rezalni ravnini pojasnjujejo variacije v prostoru oblikovanja za lažjo analizo.

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