

CHIME: A CFD-HEKF Framework for Hydrodynamic Modelling and Manoeuvring Analysis of Axisymmetric AUVs

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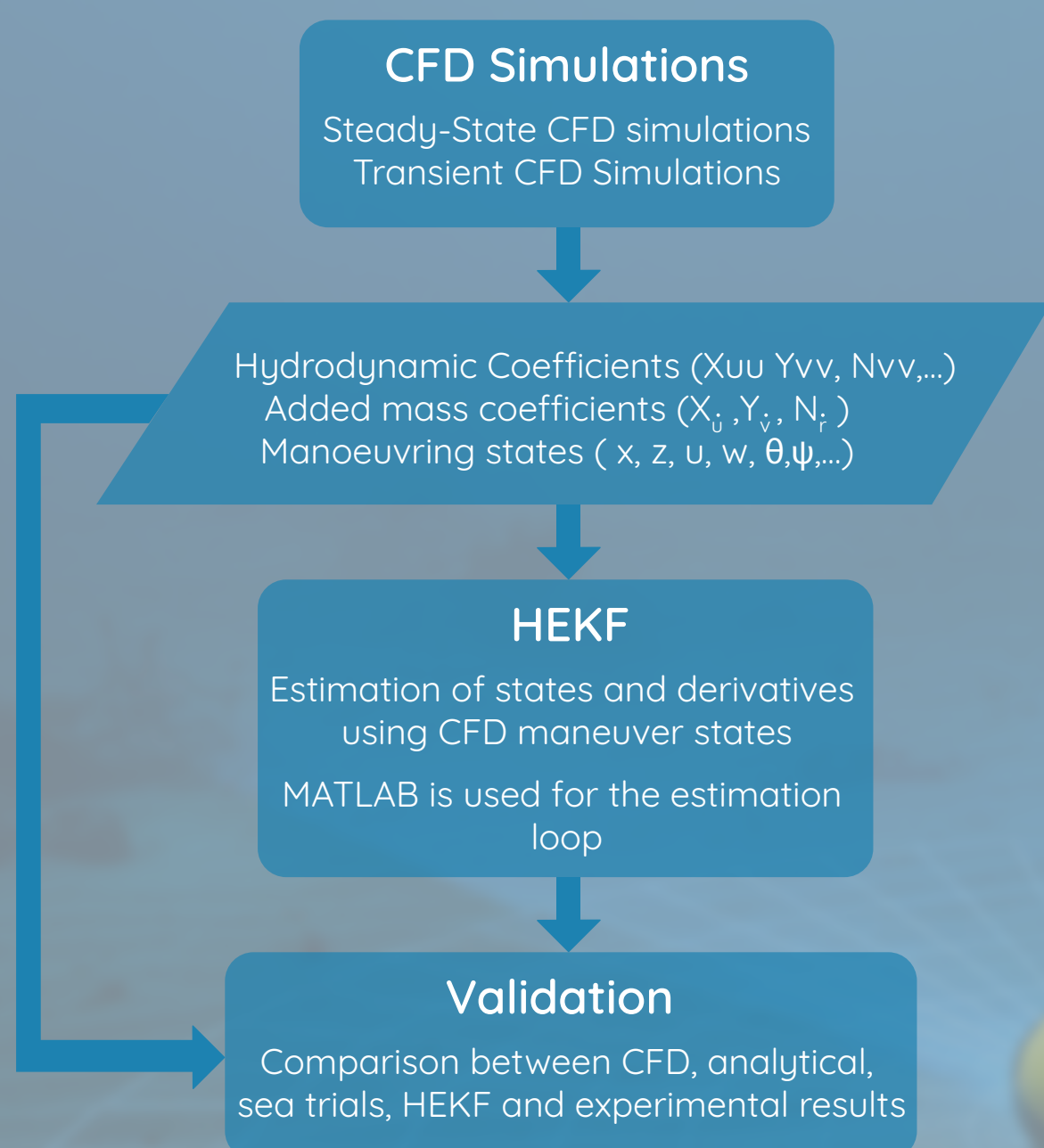
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Introduction / Motivation

- Accurate hydrodynamic modelling is vital for AUV manoeuvrability and control.
- Traditional analytical and experimental methods are costly and assumption-dependent.
- CFD offers high-fidelity flow predictions, while HEKF refines unmeasured coefficients.
- The proposed CHIME framework combines both to deliver a simulation-only, high-accuracy alternative to experimental testing.

Methodology

The CHIME framework combines CFD simulations and a non-linear Hybrid Extended Kalman Filter to estimate all hydrodynamic, damping, and added-mass coefficients from manoeuvre data alone.



Conclusions

- CHIME enables full AUV hydrodynamic modelling using simulations only.
- Achieves 1–3 % agreement with sea-trial manoeuvre results and Eliminates the need for experimental testing..

Reference

- M. Ibrahim, R. Mendes and J. B. De Sousa, "Enhancing AUV Dynamic Models with CFD-Derived Hydrodynamic Coefficients," 2024 IEEE/OES Autonomous Underwater Vehicles Symposium (AUV), Boston, MA, USA, 2024, pp. 1-6, doi: 10.1109/AUV61864.2024.11030781

Results

Hydrodynamic Coefficients

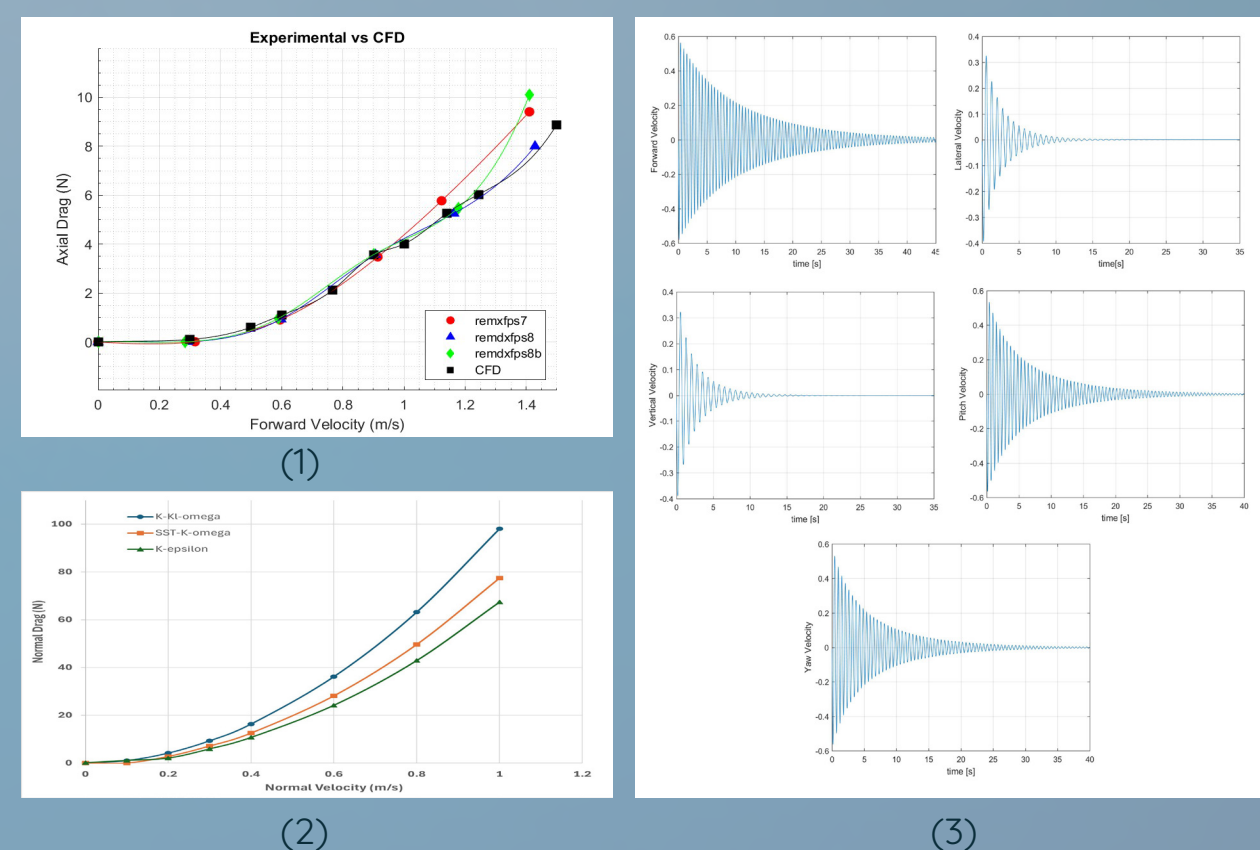


Figure (1): Axial Drag Vs. Forward Velocity, Figure (2): Normal Drag Vs. Normal Velocity, Figure (3): Velocity Oscillations

CFD Maneuvres states

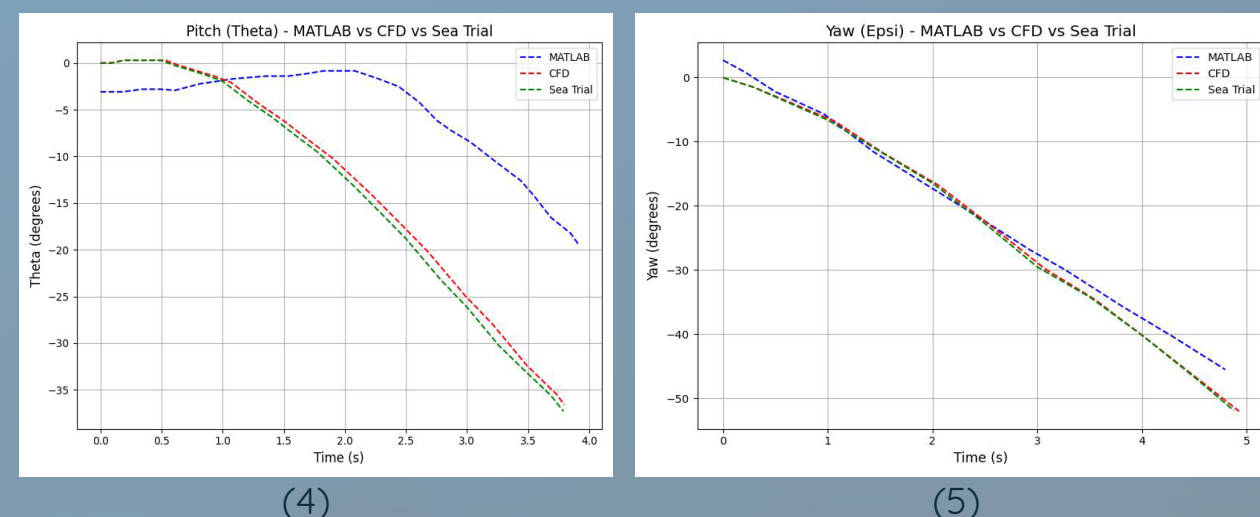


Figure (4): Diving Pitch Angle, Figure (5): Turning Yaw Angle

HEKF Estimated State

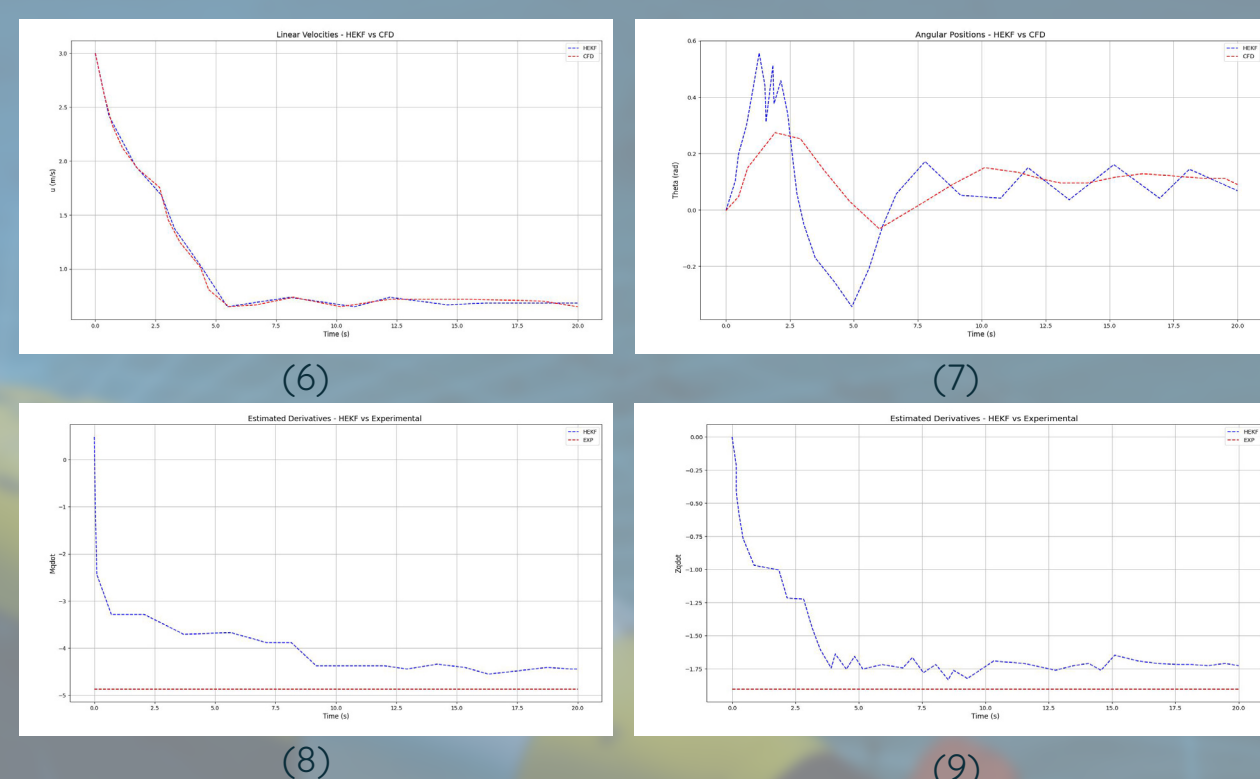


Figure (6): Axial Speed Estimate, Figure (7): Pitch Angle Estimate, Figure(8): Estimated $\dot{Mq}$, Figure(9): Estimated $\dot{Zq}$

- CFD-derived coefficients (drag, lift, fin) matched experiments within 2 % error; added-mass terms improved significantly over analytical models.
- Manoeuvre simulations (turning, diving) agreed with sea-trial data within 1–3 % error.
- HEKF estimates aligned within 3 % of CFD and within 10 % of experimental results.