



MIU

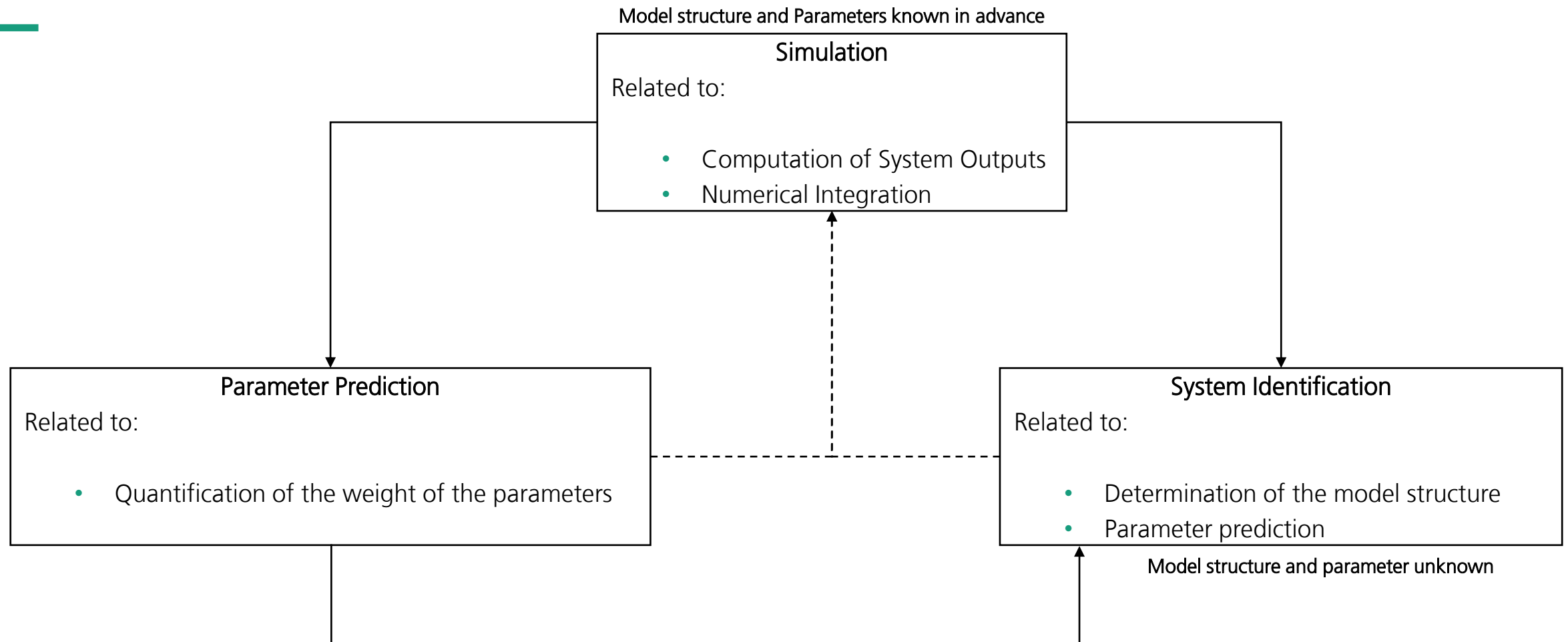
Maritime
Innovation
Update



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Improvement in System Identification for Surface
and Underwater Vehicles Based on AI Algorithms

System Identification for Surface and Underwater Vehicles



Model structure and Parameters known in advance

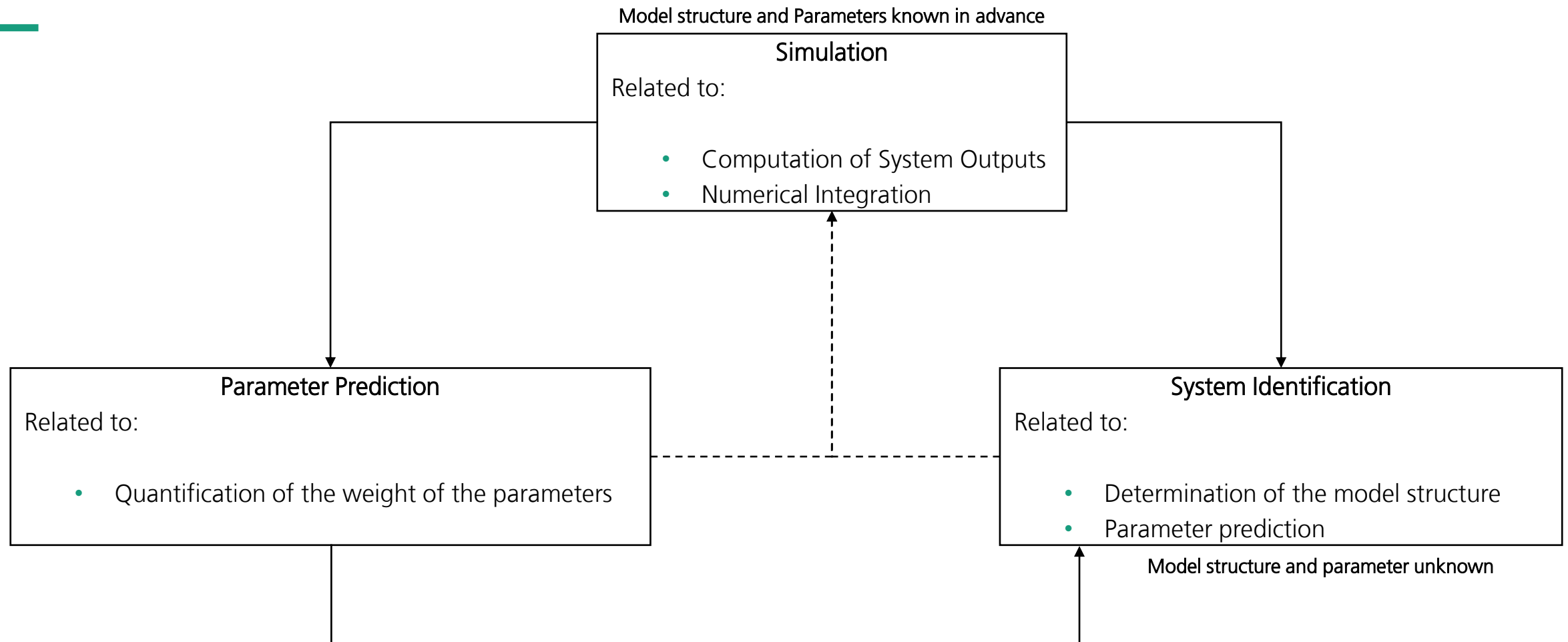
Different Mathematical Models based on the Taylor-series approximation methods, most of them based on Abkowitz Model.

$$\begin{aligned}
 m (\dot{u} - v r - r^2 x_G) &= X \\
 m (\dot{v} + u r + \dot{r} x_G) &= Y \\
 I_{zz} \dot{r} + m(ur + \dot{v})x_G &= N
 \end{aligned}$$

$$\begin{aligned}
 F &= F(u, v, r, \dot{u}, \dot{v}, \dot{r}; \delta) \\
 &= F_0 u^2 \\
 &+ F_u u \Delta u \quad + F_{uu} \Delta u^2 \quad + F_{uuu} \Delta u^3 / u \\
 &+ F_{\dot{u}} \dot{u} \quad + F_{\dot{u}\dot{u}} \dot{u}^2 / u^2 \quad + F_{\dot{u}\dot{u}\dot{u}} \dot{u}^3 / u^4 \quad + \\
 &+ F_v uv \quad + F_{vv} v^2 \quad + F_{vvv} v^3 / u \quad + \\
 &+ F_v |v| v |v| \\
 &+ F_{\dot{v}} \dot{v} \quad + F_{\dot{v}\dot{v}} \dot{v}^2 / u^2 \quad + F_{\dot{v}\dot{v}\dot{v}} \dot{v}^3 / u^4 \quad + \\
 &+ F_r ur \quad + F_{rr} r^2 \quad + F_{rrr} r^3 / u \quad + \\
 &+ F_{r|r|} r |r|
 \end{aligned}$$

$$\begin{aligned}
 F &= F(u, v, r, \dot{u}, \dot{v}, \dot{r}; \delta) \\
 &= F_0 u^2 \\
 &+ F_u u \Delta u \quad + F_{uu} \Delta u^2 \quad + F_{uuu} \Delta u^3 / u \\
 &+ F_{\dot{u}} \dot{u} \quad + F_{\dot{u}\dot{u}} \dot{u}^2 / u^2 \quad + F_{\dot{u}\dot{u}\dot{u}} \dot{u}^3 / u^4 \quad + F_{\dot{u}\dot{u}} \dot{u} \Delta u / u \quad + F_{\dot{u}\dot{u}\dot{u}} \dot{u} \Delta u^2 / u^2 \\
 &+ F_v uv \quad + F_{vv} v^2 \quad + F_{vvv} v^3 / u \quad + F_{vvvv} v^4 / u^2 \quad + F_{vvvvv} v^5 / u^3 \\
 &+ F_v |v| v |v| \\
 &+ F_{\dot{v}} \dot{v} \quad + F_{\dot{v}\dot{v}} \dot{v}^2 / u^2 \quad + F_{\dot{v}\dot{v}\dot{v}} \dot{v}^3 / u^4 \quad + F_{\dot{v}\dot{v}} \dot{v} \Delta u / u \quad + F_{\dot{v}\dot{v}\dot{v}} \dot{v} \Delta u^2 / u^2 \\
 &+ F_r ur \quad + F_{rr} r^2 \quad + F_{rrr} r^3 / u \quad + F_{rrrr} r^4 / u^2 \quad + F_{rrrrr} r^5 / u^3 \\
 &+ F_{r|r|} r |r| \\
 &+ F_{\dot{r}} \dot{r} \quad + F_{\dot{r}\dot{r}} \dot{r}^2 / u^2 \quad + F_{\dot{r}\dot{r}\dot{r}} \dot{r}^3 / u^4 \quad + F_{\dot{r}\dot{r}} \dot{r} \Delta u / u \quad + F_{\dot{r}\dot{r}\dot{r}} \dot{r} \Delta u^2 / u^2 \\
 &+ F_{\delta} u^2 \delta \quad + F_{\delta\delta} u^2 \delta^2 \quad + F_{\delta\delta\delta} u^2 \delta^3 \quad + F_{\delta\delta\delta\delta} u^2 \delta^4 \quad + F_{\delta\delta\delta\delta\delta} u^2 \delta^5 \\
 &+ F_{\delta|\delta|} u^2 \delta |\delta| \\
 &+ F_{vu} v \Delta u \quad + F_{vu} v \Delta u^2 / u \quad + F_{vuu} v^2 \Delta u / u \quad + F_{vvuu} v^3 \Delta u / u^2 \quad + F_v |v| u v |v| \Delta u / u \\
 &+ F_{ru} r \Delta u \quad + F_{ruu} r \Delta u^2 / u \quad + F_{rru} r^2 \Delta u / u \quad + F_{rrru} r^3 \Delta u / u^2 \quad + F_r |r| u r |r| \Delta u / u \\
 &+ F_{\delta u} u \delta \Delta u \quad + F_{\delta uu} \delta \Delta u^2 \quad + F_{\delta\delta u} u \delta^2 \Delta u \quad + F_{\delta\delta\delta u} u \delta^3 \Delta u \quad + F_{\delta|\delta|} u \delta |\delta| \Delta u \\
 &+ F_{vr} vr \quad + F_{vrr} vr^2 / u \quad + F_{vrrr} vr^3 / u^2 \quad + F_{vvrr} v^2 r / u \quad + F_{vvrrr} v^2 r^2 / u^2 \\
 &+ F_{vvrr} v^3 r / u^2 \quad + F_v |r| v |r| \quad + F |v| r |v| r \\
 &+ F_{v\delta} v \delta \quad + F_{v\delta\delta} v \delta^2 \quad + F_{vv\delta} v^2 \delta \quad + F |v| \delta u |v| \delta \quad + F_v |v| \delta |u v| \delta \\
 &+ F_{r\delta} r \delta \quad + F_{r\delta\delta} r \delta^2 \quad + F_{rr\delta} r^2 \delta \quad + F |r| \delta u |r| \delta \quad + F_r |r| \delta |u r| \delta \\
 &+ F_{vr\delta} vr \delta / u \quad + F_{v\delta u} v \delta \Delta u \quad + F_{r\delta u} r \delta \Delta u \quad + F_{vr\delta} vr \delta
 \end{aligned} \tag{2}$$

System Identification for Surface and Underwater Vehicles



Parameters Estimation

According to International Towing Tank Conference ITTC

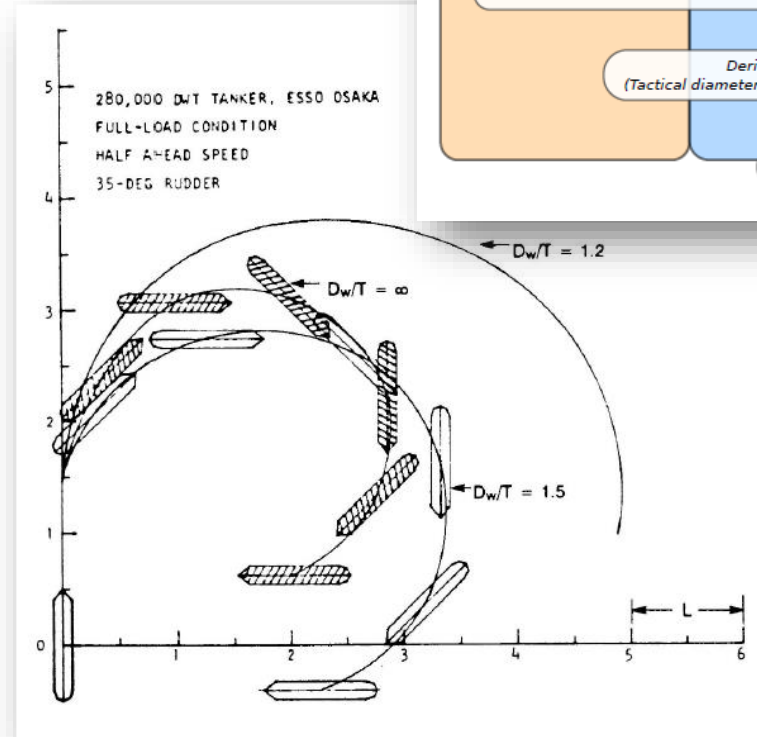
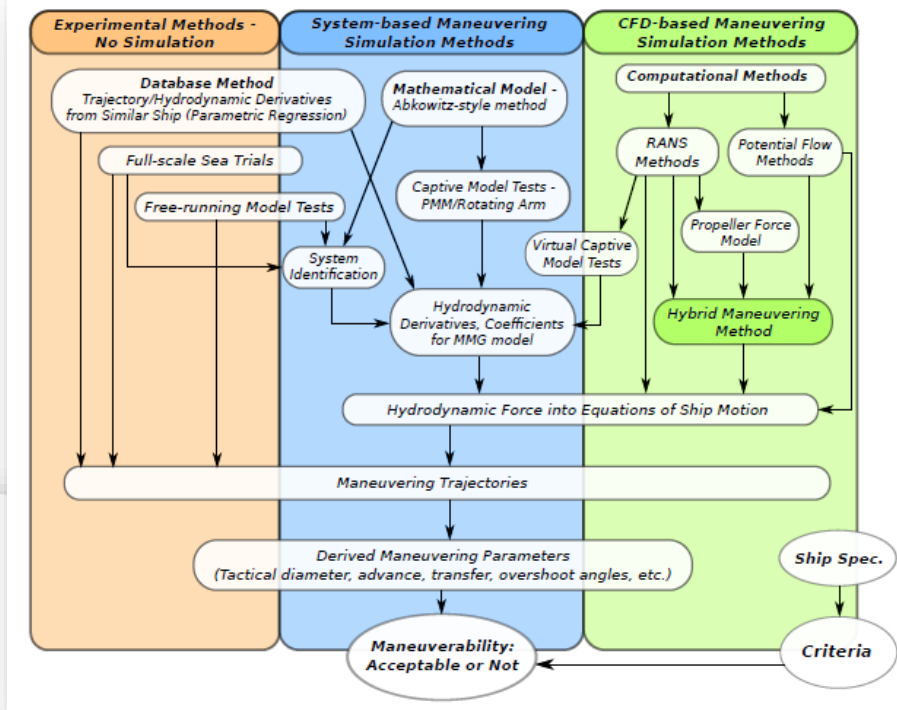
The hydrodynamic coefficients can be predicted in different ways. Unfortunately, some of them are very expensive and non-real time. Which produce that systems have an only two sets of the parameters for Deep and Shallow Water conditions.

Ship type: Tanker Vessel Eso Osaka

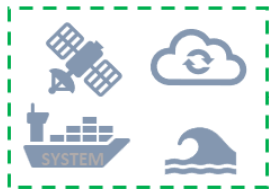
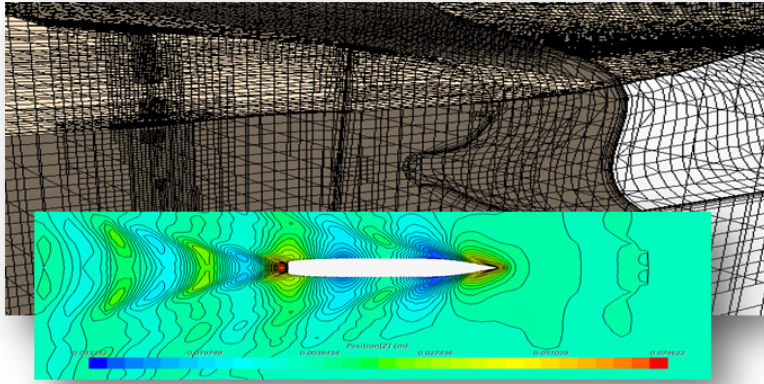
Load Condition: Full Load - 280000 DWT

Speed = 10 kn

Rudder Angle = 35 degrees starboard side.



Machine Learning implementation on System Identification



TRAINING DATA

LABELLED

PARTIAL

PARTIAL SUPERVISED

MODEL or MODIFY

GENERATIVE MODELS (GAN)

REINFORCEMENT LEARNING

CLASSIFICATION

REGRESSION

No

UNSUPERVISED

DISCRETE or CONTINUOUS

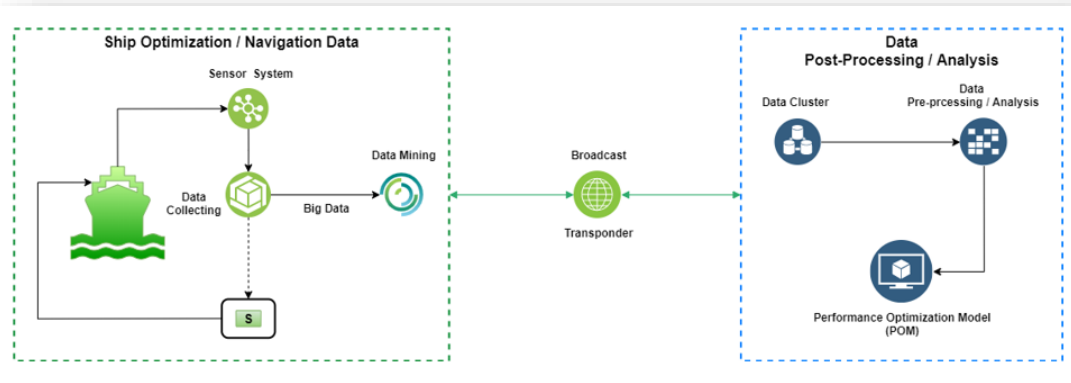
CLUSTERING

EMBEDDING

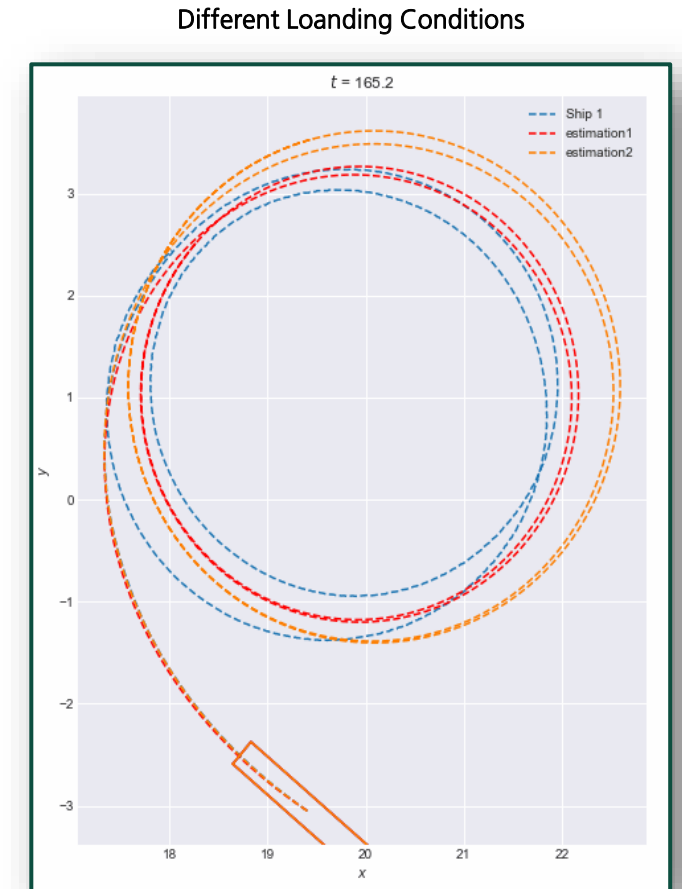
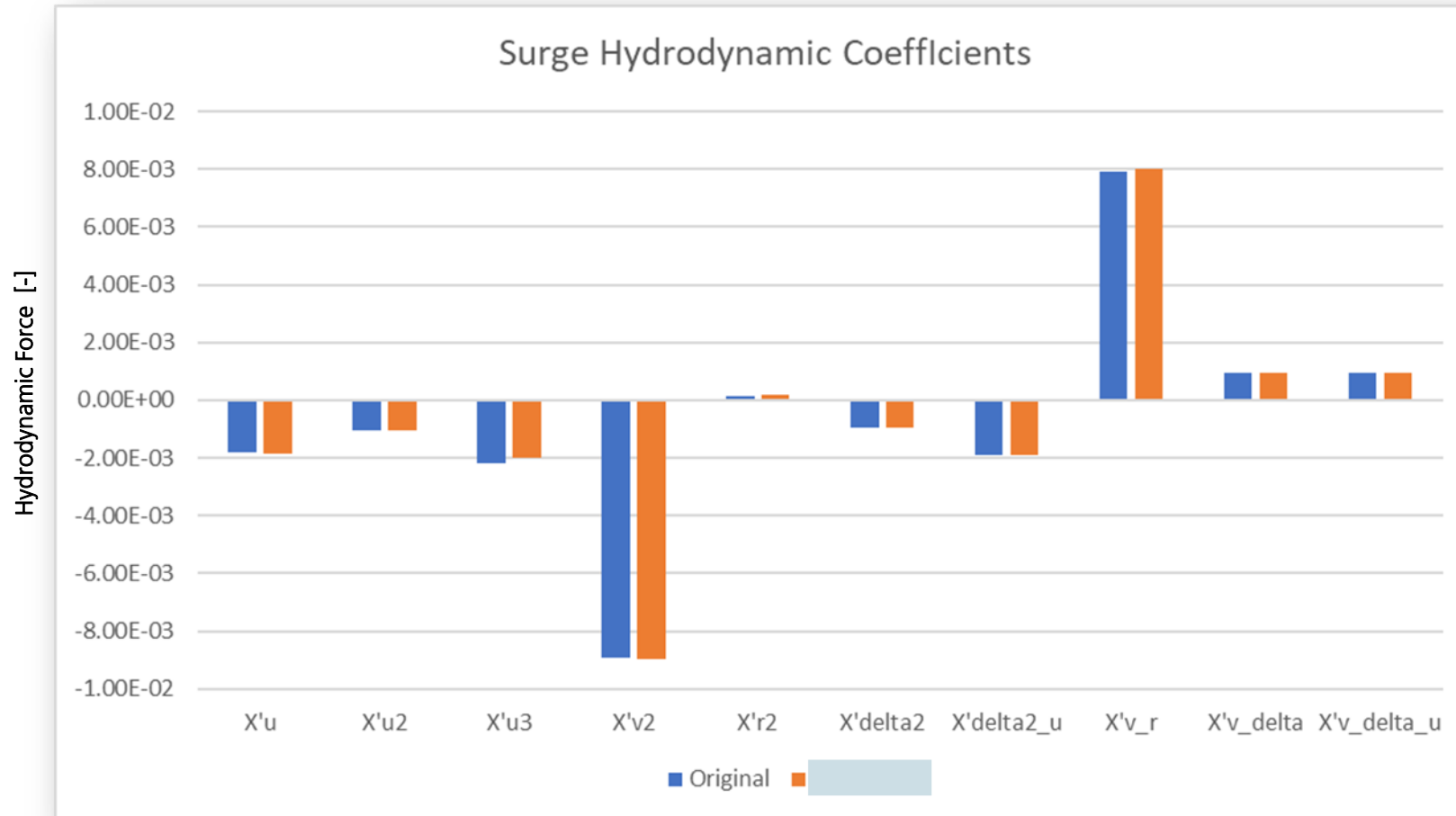
YES

SUPERVISED

MODEL or MODIFY



Machine Learning implementation on System Identification





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