FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

UNIVERSITY OF Southampton
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Simulation of Tactical Yacht Racing: A Human-Psychological-Physical AI-System in a Dynamically Changing Yacht Racing Environment

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Introduction

- A large impact on the performance of the yacht is how the crew, especially the helmsman anticipates/responds to these changing environmental conditions
- Decision making depend on expertise, personality and attitude
- To predict the performance of a yacht the yacht and the crew have to be simulated as a whole system
- Steady state performance of a sailing yacht and manoeuvring performance can be modelled with good accuracy
- A yacht race is influenced by non-deterministic variables such as weather conditions and sea state
- To win a race strategic and tactical decisions are important as sailing yachts are or are almost identical

Aims of Research

A1 How does realism of a fleet race sailing simulator influence sailor performance?

A2 Part of on-going research that focuses on the development of training tools for sailing that capture human psychological responses which includes to examine and simulate the decision making process of experts in such a dynamic and uncertain sailing environment

A3 Simulation of the motion of the sailing yacht, especially the interaction between the yachts during overtaking manoeuvres ('blanketing effect', 'covering', etc.)

Robo-Race

MATLAB®-Simulink® code which is able to simulate solo and real time fleet races of multiple yachts with one controlled by a real sailor.

Fig. 1: Two yachts on the racecourse

Automatic crew which consists of :

Helmsman
- Modelled by proportional-integral-derivative (PID) controller
- Outputs the rudder angle and rudder rate
- Steers to a reference apparent wind angle or towards the next mark

Sail tailor
- Outputs are the sheeting angle and its derivative
- A PID controller minimises the error between the reference sheeting angle and its actual value
- A 2nd controller depowers the sail to limit the actual heeling

Navigator
- Checks the position of the yacht on the racecourse
- Issues strategical decisions
- Detects changes in wind conditions
- Controls manoeuvres and the following speed recovery

A1 Display Environments

Basic Setup

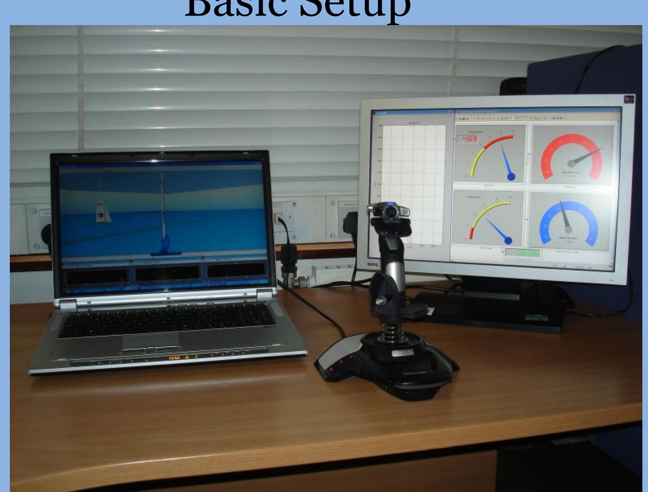
Fig. 2: Basic Display Environment

- Two flat screens (15.4" and 20")
- Joystick
- PID-controller

Advanced Setup

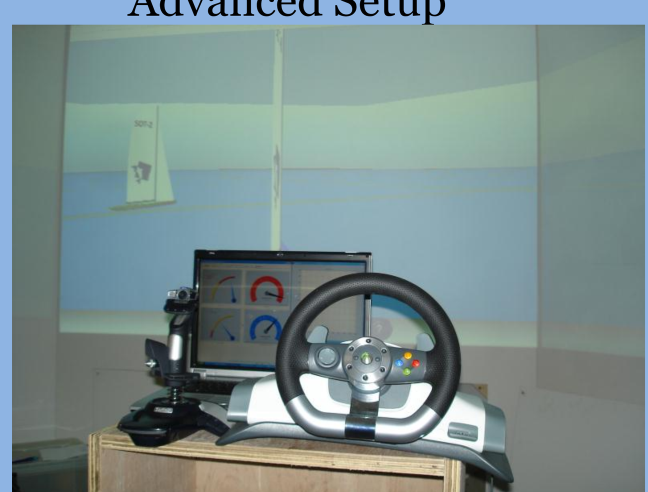
Fig. 3: Advanced Display Environment

- Three Overhead-Wall-Projectors
- One flat screen (15.4")
- Steering Wheel and Joystick

A1 Task, Run Setup, Sailors and Session Procedure

- 1 real sailor races against 2 computer controlled *Robot*-American Cup Class-yachts
- 7 races with different setups: starting positions, yacht performances, opponents' skills and onboard instrument support
- Upwind race: ¾ of a nautical mile with rounding of mark to finish
- Performance variables: race time and race position when finishing
- Stochastic wind of variable speed and angle with oscillatory pattern (~5m/s ± 20°)
- 8 sailors are classified into groups (sailing skills, background and utilisation of computer games, input devices) of expertise (novice, experienced, and expert)
- Session procedure: presentation to ensure identical pre-knowledge, trial, questionnaire part one, 7 races, questionnaire part two and final discussion

A1 Upwind Race Tracks and Results

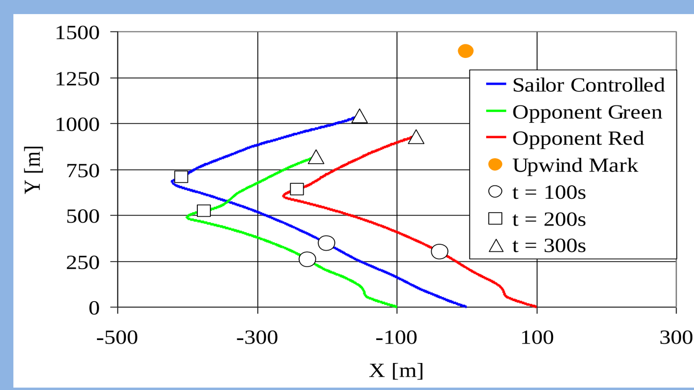

Figure 4: Example of race tracks from sailor #4, race #7 using ADE/Steering Wheel, as the two computer controlled yachts respond to the wind shifts the pattern of wind variation can be seen in their course variation

Sailor #	Level of Sailing Skills	Level of CG and ID	Performance Improvement [%]	Position in Race #1 / Race Time [s]	Position in Race #7 / Race Time [s]	Comparison to Joystick Race #1	Comparison to Joystick Race #7
4	Experienced	Expert	8.4	1 / 443.2	1 / 408.8	8.3	5.4
5	Expert	Experienced	6.3	1 / 429.7	1 / 404.3	14.8	51.1
6	Novice	Expert	-4.5	1 / 408.6	1 / 427.8	-	-
7	Experienced	Novice	16.8	3 / 516.5	1 / 442.1	-	-
8	Expert	Expert	20.7	3 / 520.7	1 / 431.2	-	-

Basic display environment (BDE):
- No clear picture of performance improvement can be drawn
- Sailors struggled with joystick/PID-controller setup (wrong input)
- Delivers necessary environmental information to the sailor

Advanced display environment (ADE):
- Clear performance improvement for almost every sailor
- Problem-free handling of the steering wheel device (positive feedback)
- More involved, active, concentrated and vital user behaviour

A1 Conclusions (BDE and ADE investigations)

- The sailor's performance can be improved by enhancing the realism of the simulation
- ADE with direct rudder angle control supports the user's natural sailing behaviour
- BDE with PID-controller is neither practical nor effective
- ADE/steering wheel setup is an effective training tool for sailing
- Further work is necessary to enhance the simulator's realism

A2 New Make Model (NWM) for Modelling Covering/Blanketing

- The upwind yacht's wake is represented as single heeled horseshoe vortex and image system
- Changes in vortex strength are convected into the wake as a pair of vortex line elements
- These move in accordance with the self-induced velocity, local wind, velocity induced by the opponent
- A viscous wake model is implemented to account for the yacht's viscous effect

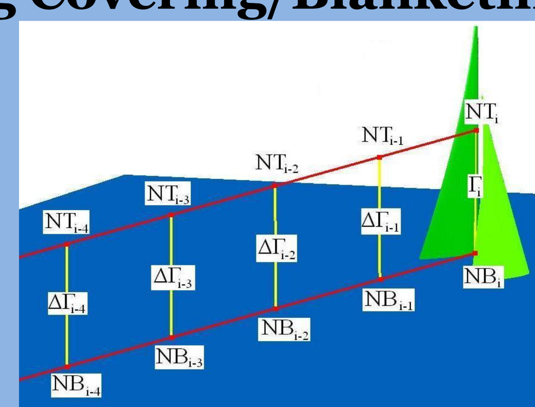
Fig. 5: Vortex System

A2 Test Cases – NWM vs. previous implemented wake model

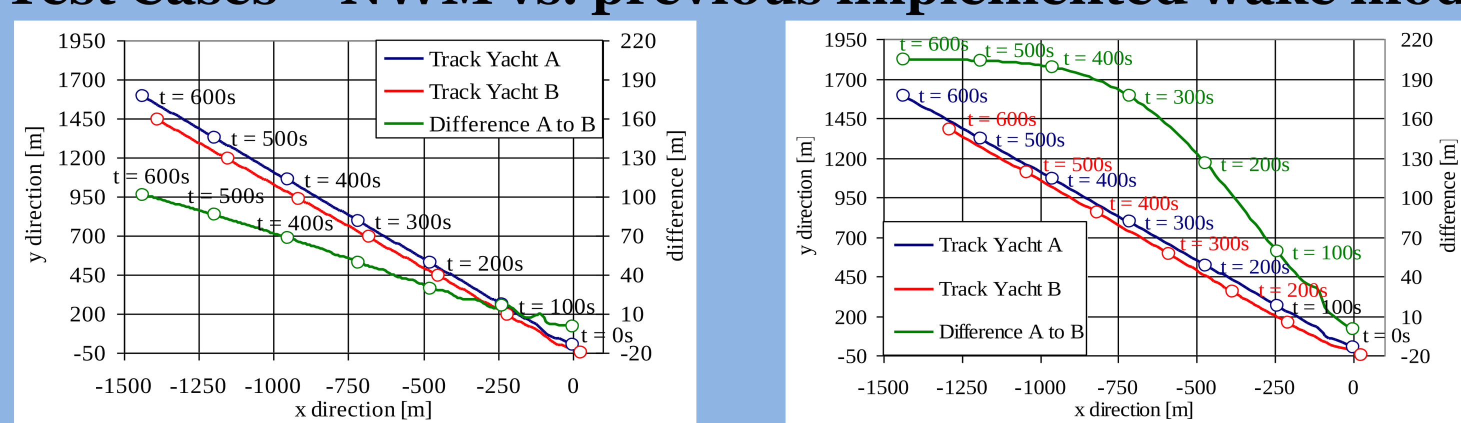

Fig. 6: Upwind race using the NWM (left) and the previous implemented wake model (right) where the following yacht, Yacht B, sails in the wake of the leading yacht, Yacht A. Tracks show that Yacht B bears away (left) and that the distance between the yachts increases gradually compared to the almost parallel tracks (right).

A2 Conclusions (NWM investigations)

- The NWM outperforms the empirical wake model as it captures the main features of the flow to a sufficient level of fidelity
- The NWM is capable of describing the phenomena of blanketing/covering within a yacht fleet simulation environment with multiple yachts
- The NWM enhances the reality of *Robo-Race* which in turn supports the sailor in his/her natural sailing behaviour
- Detailed CFD analysis of the yacht's wake gave important insight of the vortex core development and showed good agreement for single and multiple yacht setups

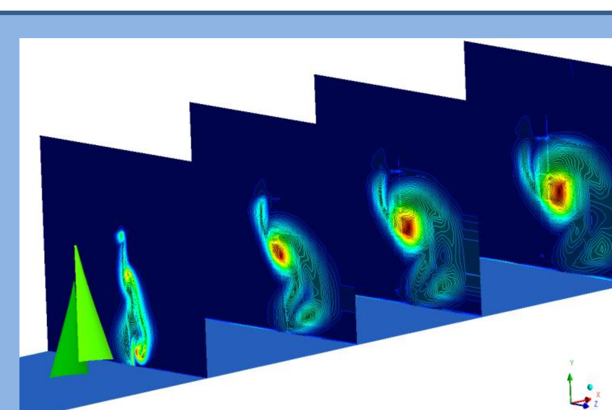
Fig. 7: Vortex core development

Future Work

- A3 Development of a model describing the human behaviour and decision making process of sailors within a multiple yacht race environment

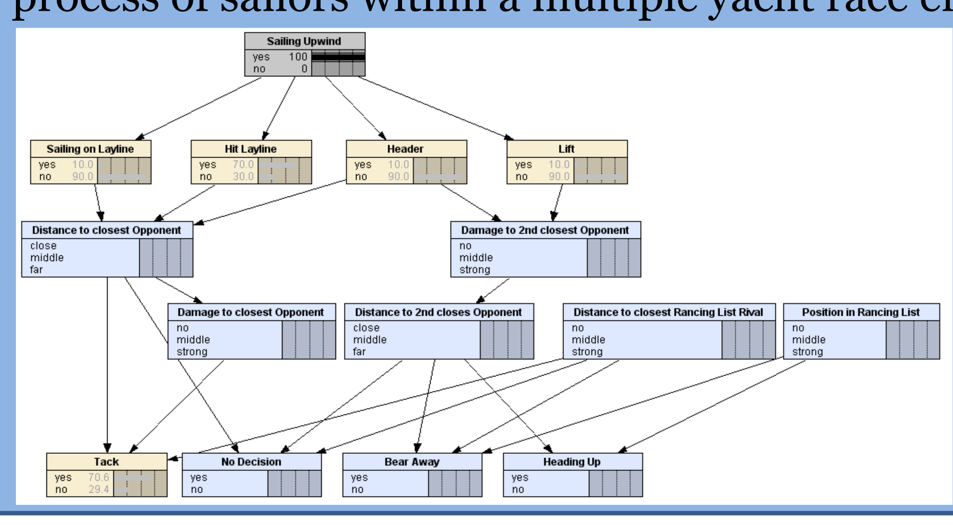
Fig. 8: Schematic layout of a Bayesian Believe Network used for a series of tactical yacht fleet races.