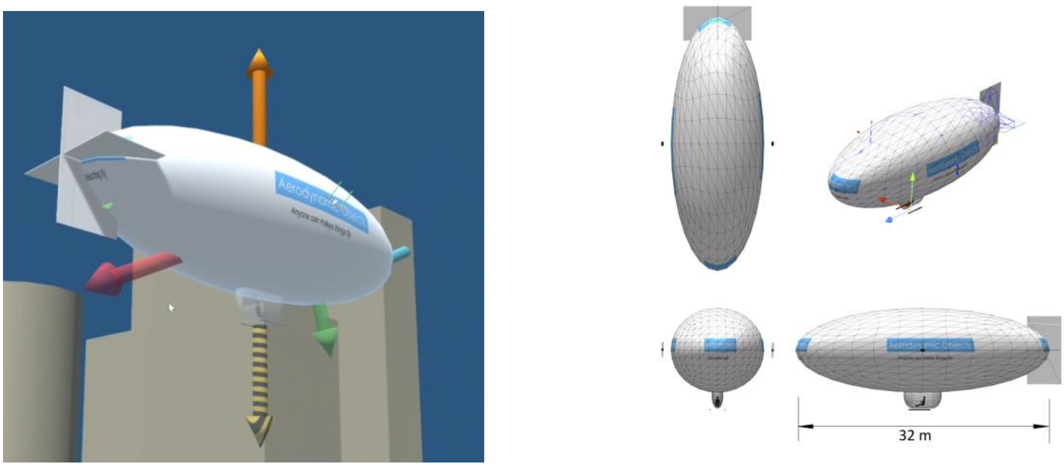
Aerodynamic Objects

Demo Descriptions

Last updated 09/04/2025

The Aerodynamic Objects package comes with a range of demo scenes in Unity that illustrate some of the technical and creative possibilities of the tool. The demo scenes aim to provide best practice for model development using AO and provide a prefab and custom code resource for users to learn from and add to their own projects. Each demo scene has specific version for each of the standard, universal and high-definition render pipelines in Unity.

Airship



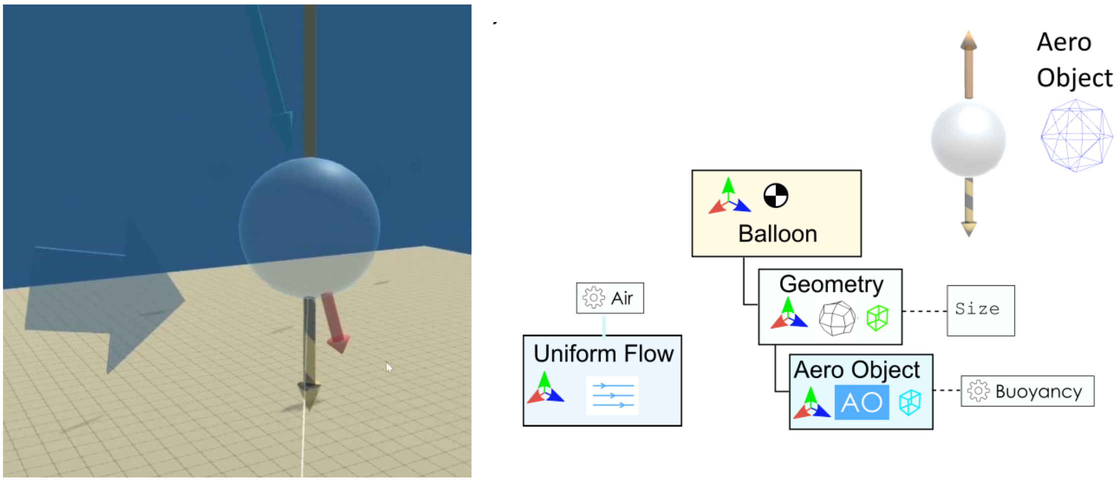
A large airship modelled in Aerodynamics Objects

This airship model is built from an ellipsoid Aerodynamic Object body with lift, drag and buoyancy models. There is a simple cruciform tail that provides directional stability and pitch and yaw control when the airship is moving forwards. There are two bi-directional thrusters that can provide fore and aft thrust or differential thrust to turn. These thrusters can also be tilted to provide vertical thrust to control height. Start up the engines using w then tilt upwards using +. Turn left and right using a and d. The buoyancy force is the orange arrow, and the weight force is the yellow and black arrow.

Key features

- Buoyancy model
- Cruciform tail with aerodynamic control surfaces
- Rotary thrusters for propulsion

Balloon



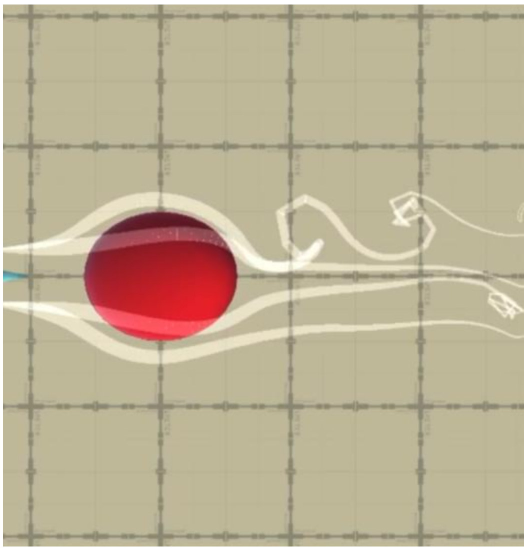
A helium balloon carries a tethered load

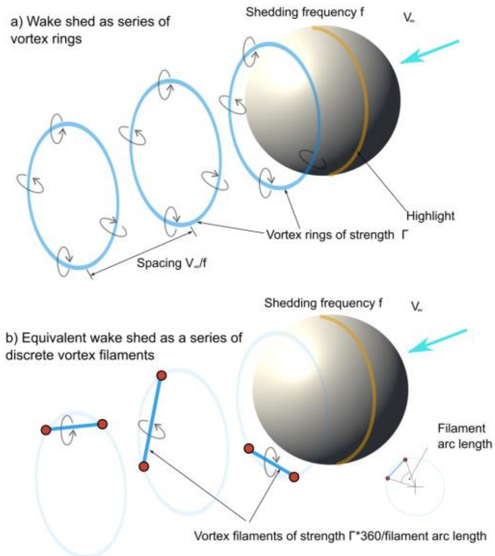
A simple lighter-than-air balloon attached to a ballast weight with a simple string model. The balloon has an aerodynamic model with Buoyancy and Drag components. The environment uses a Uniform Flow component to set the density of the surrounding air and a simple wind model. The balloon has a custom BallloonController script running on it that allows the user to inflate or deflate the balloon and hence change the buoyancy force. The user can also change the wind speed and change the length of the string during run time.

Key Features

- Buoyancy and drag vary dynamically with balloon size at run time
- Wind field generated by Flow Primitive
- Sensors used for measuring forces

Bluff Body Wakes





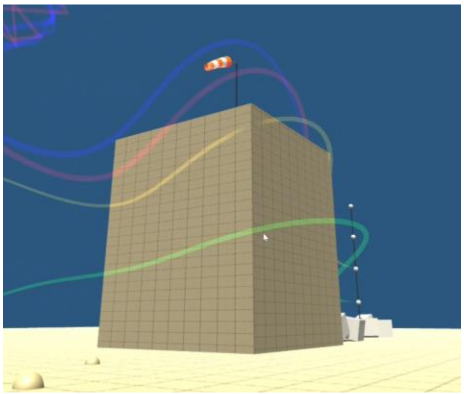
Turbulent wakes produced by flow around a variety of dynamic ellipsoid objects

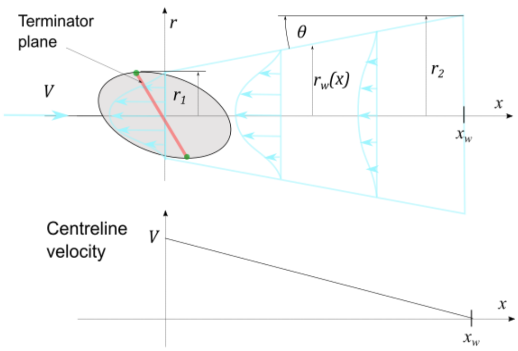
These demos show the use of AO Displacement Fields to create flow around solid bodies and AO Bluff Body Wakes to create regions of retarded, turbulent flow arising from flow separation. Various AO flow visualisation tools are showcased to illustrate different ways flowfields can be visualised.

Key features

- Displacement body
- Bluff body wake
- Flow partitioning
- Visualisation tools

Building Wake





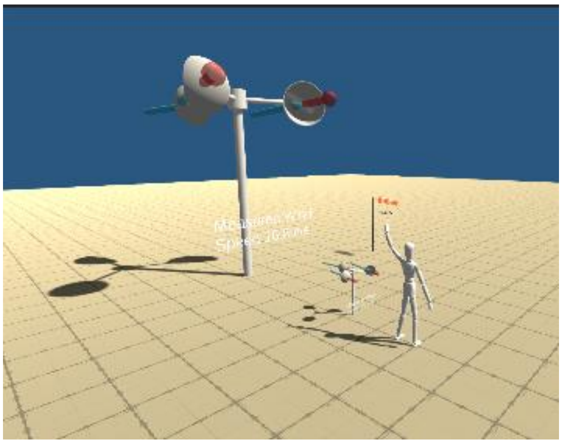
Wind blows around a large building producing a turbulent wake

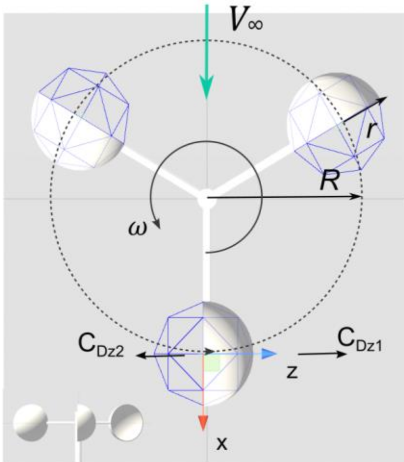
This demo shows the generation of an unsteady flow field behind a large, stationary bluff body represented by a building. The flow speed is 10m/s. A smoke mast, surface particles, particle grid and a windsock is used to visualise the flow.

Key features

- Displacement body used to produce flow around building
- Large scale turbulent eddies produced by a Bluff Body Wake component
- Multiple visualisation tools used in parallel

Cup Anemometer





Wind speed is measured using cup anemometers at different scales

This demo shows the use of AO for modelling cup anemometers. These devices spin in the wind since the cups have more drag when facing into the wind than out of the wind. This is modelled using an AO User Drag component which specifies the cup drag coefficient in forward and reverse directions. There exists a very simple formula that relates the measured wind speed to the angular rate of the anemometer that uses just the forward and reverse cup drag coefficients and the arm radius, see https://web1.eng.famu.fsu.edu/~shih/eml3016/lecture-notes/cup%20anemometer.PDF.

There are three anemometers in the scene with linear scales of 1, 5 and 25. Each has the same anemometer script running on it. Because the aerodynamic behaviour is based on physics, the anemometer behaviour scales correctly with the scaled size of the device.

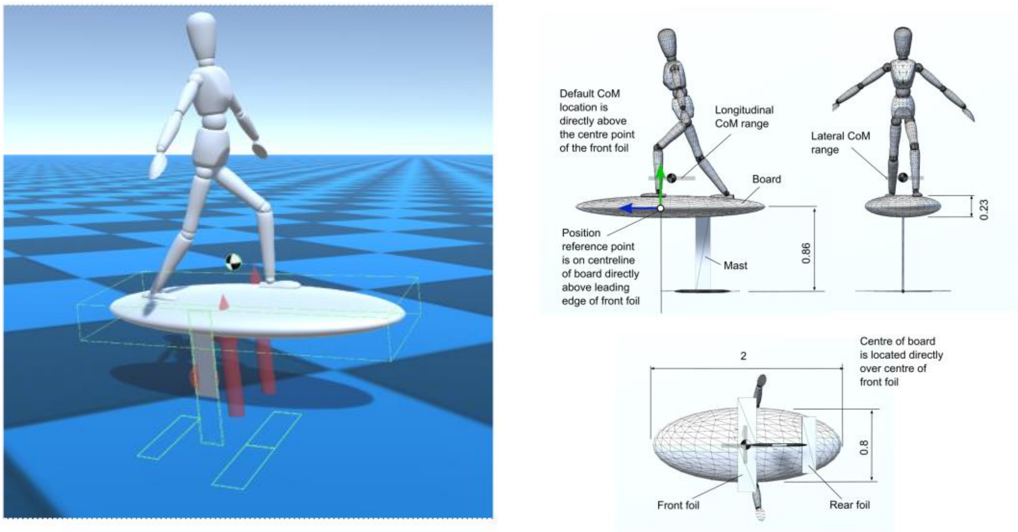
A uniform wind speed of 15m/s is applied globally to the scene. A Fluid Motion Driver component on the Uniform Flow object is used to slowly vary the wind direction (azimuth). Cup anemometers are agnostic to wind direction, so the wind speed measurement stays constant. The wind direction can be seen by the Wind Sock object in the scene.

A close look at the wind and drag arrows on the anemometer cups shows that the local wind direction experienced by the cup is a combination of the cup rotational velocity and the free stream wind velocity. You can also see that when the open face of the cup is facing into the wind, the relative magnitude of drag is increased (drag arrow gets longer).

Key features

- User supplied cup drag model
- Quantitative measurement
- Validation of model implementation against anemometer theory at a range of scales

FoilBoard



Glide above the water surface using a realistic physical model of a FoilBoard

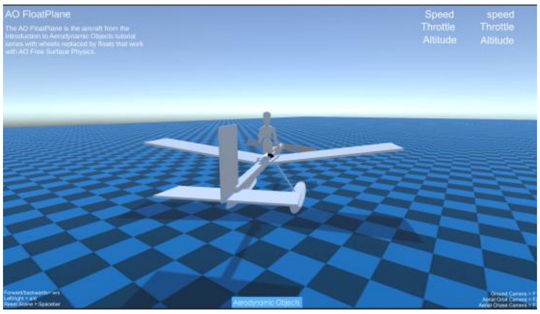
A foil board is essentially a surfboard mounted on top of an underwater model glider. The glider has a main wing and a tail plane (front foil and rear foil). The main wing generates lift to support the weight of the board and rider. The tail plane is used to help set the trim (balance angle of attack) of the main wing. The rider controls the board by weight shift. Lateral shift causes the board to turn, longitudinal shift alters the trim angle of attack and subsequently allows control of ride height. Addition of a small underwater propeller gives self-propulsion.

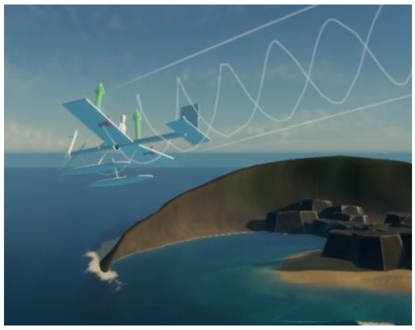
Key features

- User interaction is via weight shift on the board
- PID controllers implemented for speed, height and roll angle
- Aero/hydrodynamic components demonstrate correct physical behaviours across the free surface

For further technical details see the FoilBoard case study document

FloatPlane





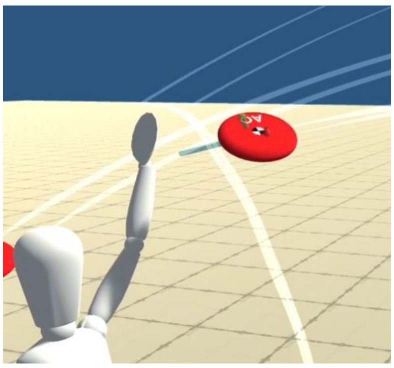
Take-off and land on water using a simple AO tutorial aircraft

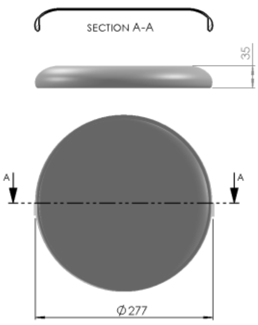
The AO FloatPlane is the aircraft from the Introduction to Aerodynamic Objects tutorial series with wheels replaced by floats that work with AO Free Surface Physics.

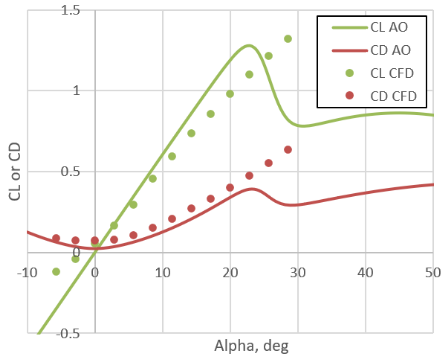
Key features

- Fully functional but easy to fly aircraft with ailerons, elevator, rudder and throttle
- Aircraft supported on water surface using pontoon buoyancy
- Pontoon drag model includes form drag and wave drag to correctly account for shape and size

Frisbee







Spinning frisbee prefabs are launched from a frisbee launcher

This demo illustrates the use of Aerodynamic Objects to model a frisbee. A frisbee is a type of spin-stabilised disc wing. A non spinning disc wing is unstable in pitch and will immediately tumble in flight. Spin makes little difference to the aerodynamics, but it creates a gyroscopic effect whereby pitching moment due to aerodynamic instability causes a slow rate of roll about the flight axis known as precession. The rate of precession depends on the spin rate of the disc and how unstable it is in pitch. All discs are unstable to some extent, but good discs are less unstable.

The frisbee model here uses a single Aerodynamic Object that is attached to the rigid body of the frisbee and hence spins around with it. However, since the disc is axially symmetric, the overall aerodynamic force and moment is only dependent on the orientation and magnitude of the flow velocity relative to the disc normal. The stability of the disc is determined by the location of the aerodynamic centre relative to the disc centre. The aerodynamic centre of a frisbee is much further aft than on conventional wing shapes or flat plates- this is what makes it fly so well.

Frisbees are launched by an automatic launcher. Launch setting can be adjusted in the inspector using the controls on the Frisbee Launcher game object

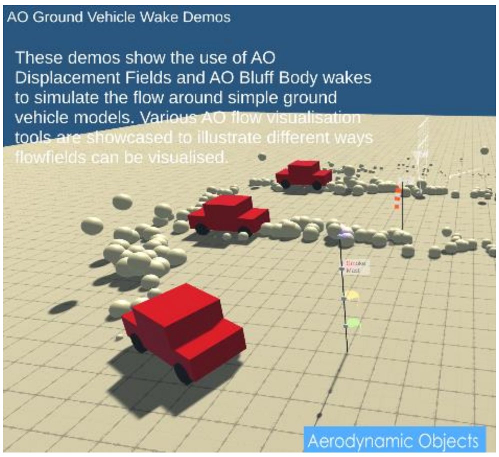
Key features

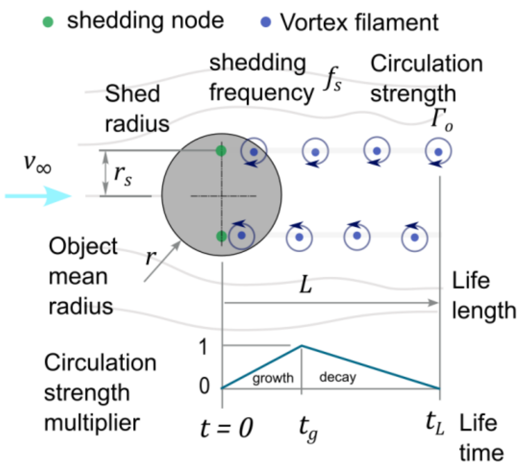
- Aerodynamic model implemented on a rapidly rotating rigid body
- Integration with physics engine gives correct gyroscopic behaviour of frisbee motion
- User supplied aerodynamic centre in lift model

For more info on disc wing aerodynamics see

https://www.dropbox.com/scl/fi/rcaesjwfq3u70til7lk4u/FrisbeeAerodynamics.pdf?rlkey=vfu45dsrlh1ycg9g4iufytbtf&dl=0

Ground Vehicle Wakes





Ground vehicles produce turbulent wakes

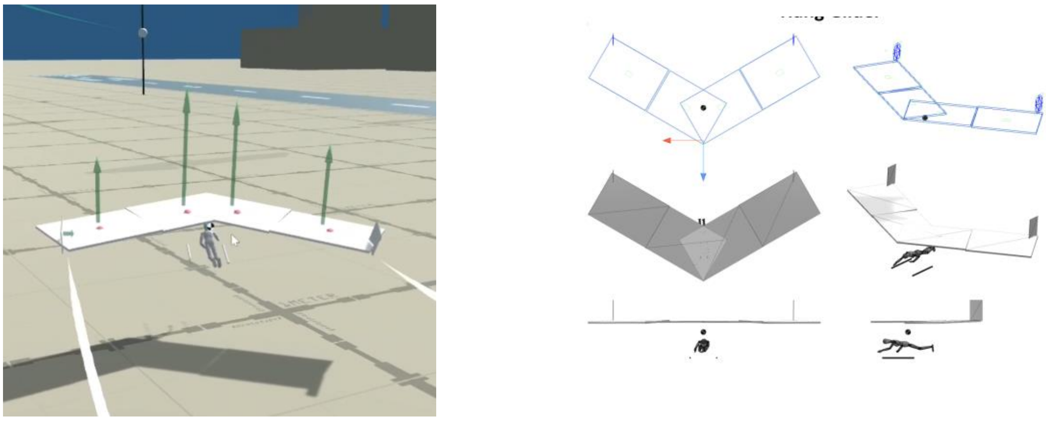
These demos show the use of AO Displacement Fields and AO Bluff Body wakes to simulate the flow around simple ground vehicle models. Various AO flow visualisation tools are showcased to illustrate different ways flowfields can be visualised.

Key features

- Displacement bodies
- Bluff body wakes

- Surface particles driven by motion in the wake

Hanglider

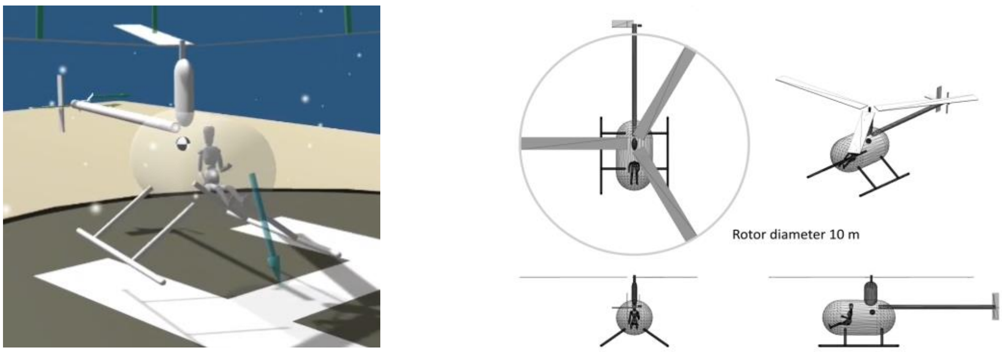


A simple flying wing hanglider soars in ridge lift

Key features

- Aerodynamic balance achieved using wing twist
- Combined pitch and roll control obtained using control mixing on a pair of elevons
- Rising air over a hill modelled using a displacement body

Helicopter



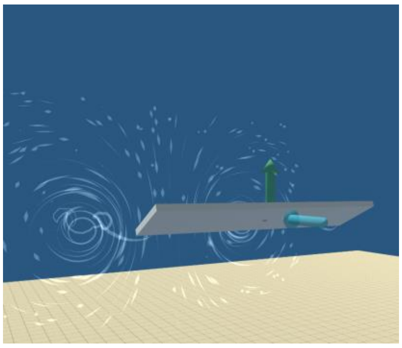
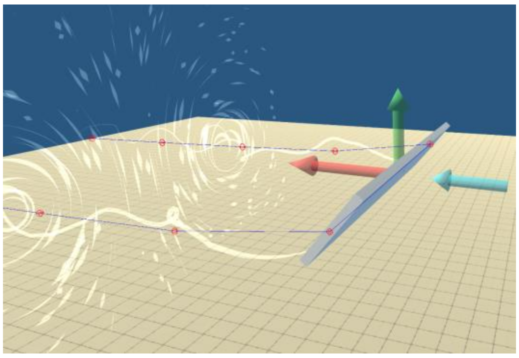
A fully functional helicopter with articulated main rotor

This helicopter is a simple mechanically controlled helicopter with a main rotor and tail rotor. Each rotor blade is made up of one Aerodynamic Object panel. The helicopter is controlled by changing blade pitch angle. Because the main rotor blades are attached using flapping hinges, they move up and down depending on the load on them. This allows the rotor disc to tilt in response to cyclic blade pitch inputs and is used to control vehicle pitch and roll. Yaw comes from controlling the thrust of the tail rotor. It is a challenge to fly using keyboard input, but possible with practice. Start with around 80% throttle and use very small control inputs. To start off with, try to take off, hover just above the landing pad then land again. Then try the same at a different yaw angle (a/d). The Aerial Chase Cam view (F3) makes this easier to start with.

Key features

- Integration of aerodynamics with fully articulated spinning rotor blades
- Use of a vortex ring Flow Primitive to model rotor downwash
- Per-object interaction control to manage interaction of wake with rotor and airframe

Lifting body wakes

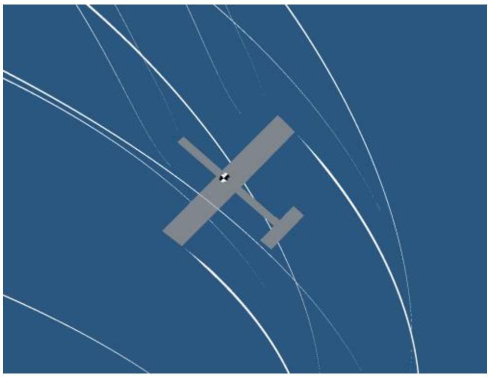
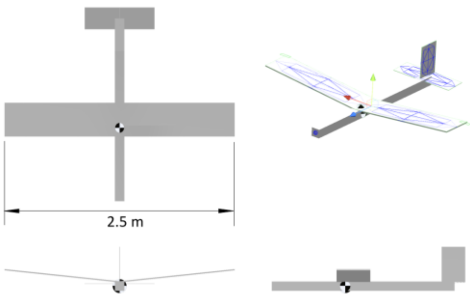



Vortex wakes are produced from translating and rotary wings

Key features

- Lifting body wake component used to produce a wake downstream of a wing
- Wakes respond to dynamic changes in wing lift
- Rotary wake generates representative model of rotor downwash

Model Glider

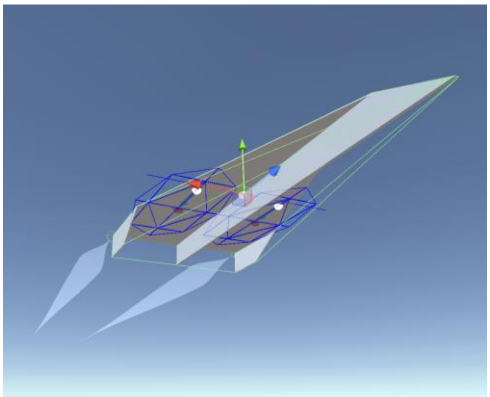
Multiple spawned gliders circle downwards

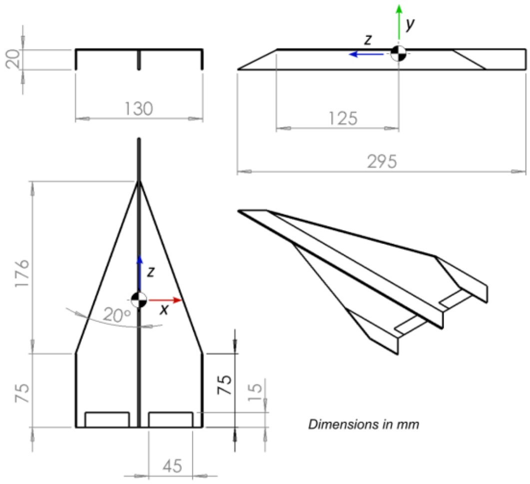
The Model Glider is a simple aircraft modelled with two Aerodynamic Object panels for the wings and one each for the tailplane and fin. There is no engine

Key features

- Simple glider prefab made up from four Aerodynamic Objects
- Longitudinal and lateral trim set by changing tailplane and fin rigging angles
- Gliders interlock to form composite bodies at high spawn rates

Paper Plane





Classic paper planes make an airshow

This demo illustrates a simple paper plane model made in Aerodynamic Objects. The plane is based on a classic design folded from an A4 piece of paper. The planes are spawned at random positions and orientations. They also have their trailing edge control surfaces set with a small variance around the trim point so that all the planes fly slightly differently.

The camera follows one plane at a time to the ground, then chooses another one to follow. The simulation runs at 0.1x slow motion by default.

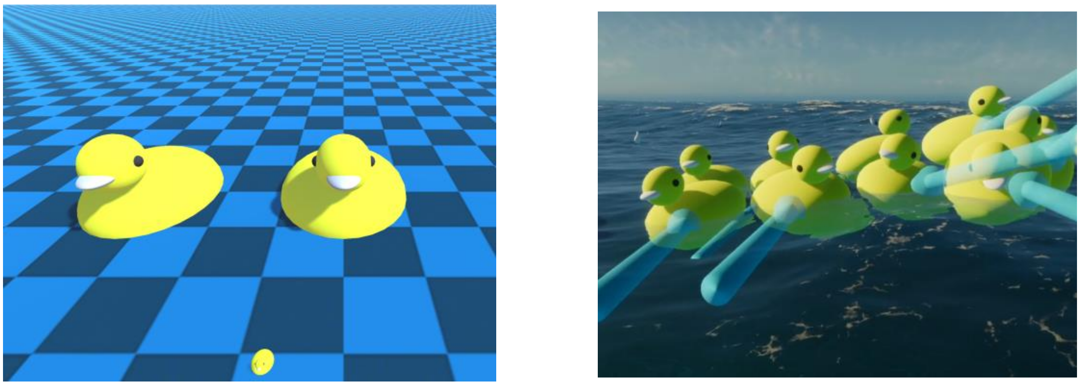
Simulation parameters can be adjusted in the Paper Plane Spawner object.

Key features

- Low aspect ratio delta wing aerodynamic model set up using two Aerodynamic Objects
- Aero model verified against Computational Fluid Dynamics data
- Flight dynamics verified against experimental observation

For further technical details see the PaperPlane case study document

Plastic Ducks



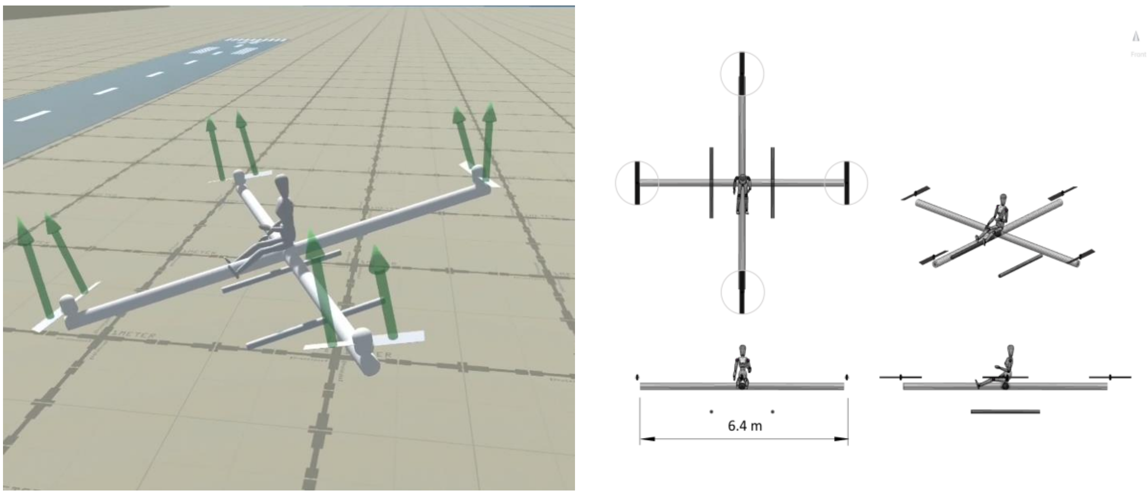
Simple floating objects at various scales interact with water

Plastic ducks are modelling using a single ellipsoid object with buoyancy, form drag, and wave drag. A duck spawner can be used to fill the scene with multiple ducks.

Key features

- AO buoyancy model demonstrated to be stable at a wide range of body sizes and masses
- Wave drag model correctly accounts for variation in 'hull speed' for ducks of different sizes
- Ability to spawn 100s of ducks simultaneously demonstrates performant capability of AO code base

Quadcopter



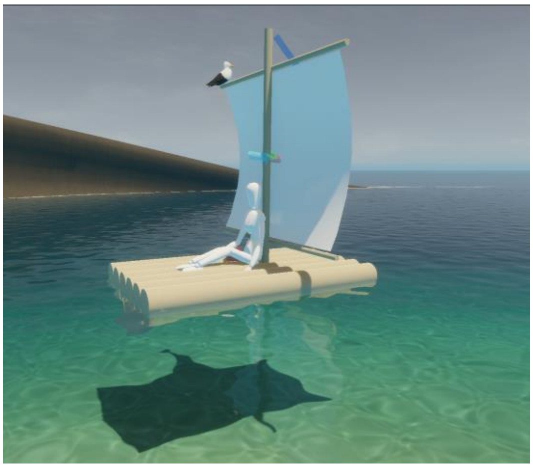
A quadcopter flies using rotors modelled using Aerodynamic Objects

Key features

- Change in rotor speeds used to obtain lift, pitch and roll control

- Simple autopilot manages interface between pilot inputs and rotor speed demands
- Dynamics successfully simplified compared to helicopter by using inertial rotors with kinematic blades

Raft

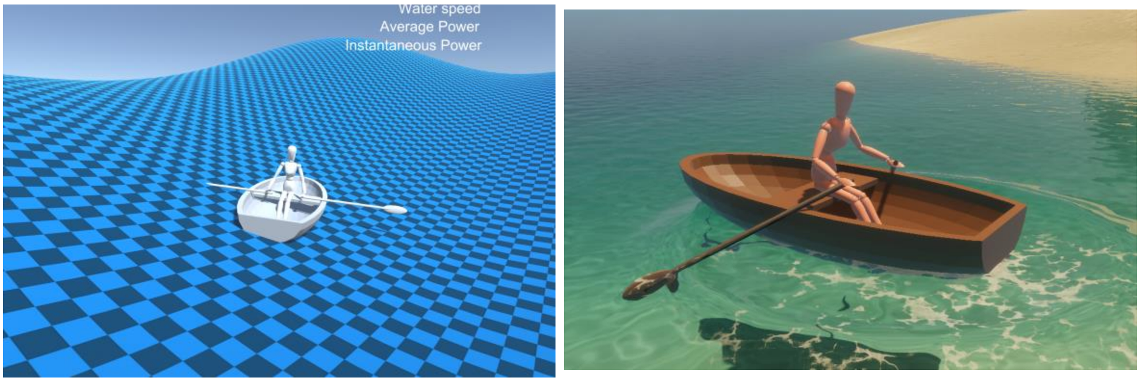


Drift on the open ocean on a simple raft with sail

Key features

- Unity cloth sail that deforms under aerodynamic load
- Mast streamer based on chain on physics objects
- Integrated with Unity 6 water system

Rowing boat



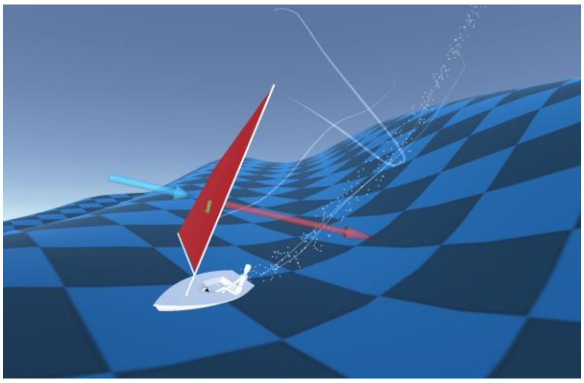
A physics-based rowing boat modelled using Aerodynamic Objects

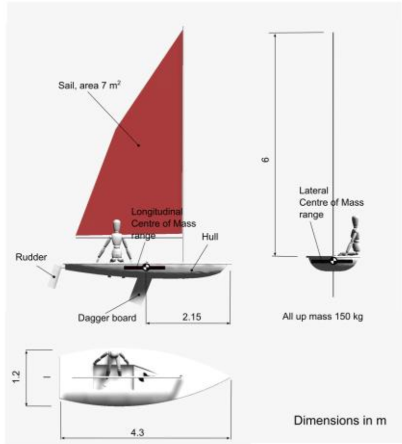
Key features

- Propulsion is via hydrodynamic forces on the oars. Power input is calculated and displayed on screen
- User input changes frequency of rowing motion to control boat speed, differential control of phase controls turning

- Inverse kinematics on mannequin provides visual feedback of rowing effort

Sailboat





A fully controllable sailing dinghy is driven by aerodynamic and hydrodynamic forces

A sailing boat is like an aircraft flying on its side on a water surface. The surfaces generate aerodynamic forces from the relative motion of the air and the lower surfaces generates hydrodynamic force due to the relative motion of the water. Aerodynamics and hydrodynamics are based on the same fluid dynamics principles, but the main difference that water is approximately 1000x as dense as air. This means that hydrodynamic surfaces on boats such as rudders are much smaller than the equivalent aerodynamic surfaces, such as sails.

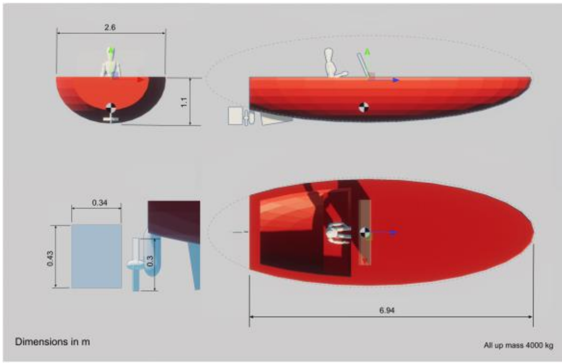
For this case study, we are using Aerodynamic Objects to model the physics of a Laser dinghy class of sail boat. Lasers are relatively small one or two person boats that are widely used for recreational and competitive sailing. The mass of the boat is around 70 kg, and with a single sailor the total mass is around 150 kg. The quoted ideal wind speed range for Lasers is 8 to 12 knots (4 to 6 m/s), depending on sail size choice and crew mass.

Key features

- User control via sail angle, rudder angle, and centre of mass position
- Boat is able to realistically tack into wind and run with the wind
- Model is scalable to different sized sailboats

For further technical details see the Sailboat case study document

Speedboat



A high-performance propeller driven watercraft

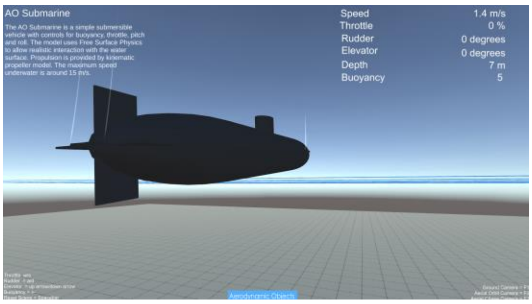
The speedboat aero/hydrodynamics is modelled using Aero Objects for the hull, keel, rudder and two propeller blades. The hull Aero Object includes models for Lift, Drag, Wave Drag, Rotational Damping, Buoyancy and uses Free Surface Physics to manage interaction with the water surface.

The boat has a keel plate that provides additional direction stability and roll damping. The keel plate also has a physical collider that allows the boat to slide over ramps etc without the propeller striking the ground. A rudder is fixed to the propeller mast and a combination of steering and thrust vectoring is obtained by rotation of the mast about its axis.

Key features

- Scalable kinematic propeller model that can be scaled for use on other ships
- Hull model showcases capability of AO Free Surface Physics to usefully model dynamic bodies immersed in two different fluids
- Boat can be used to tow other floating objects using a tow line

Submarine



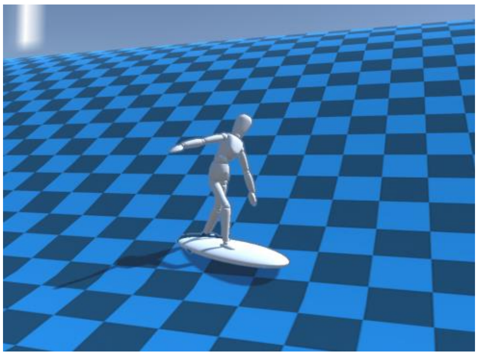
Explore the depths with a 50m long submarine

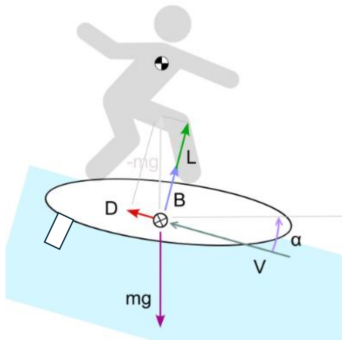
The AO Submarine is a simple submersible vehicle with controls for buoyancy, throttle, pitch and roll. The model uses Free Surface Physics to allow realistic interaction with the water surface. Propulsion is provided by kinematic propeller model. The maximum speed underwater is around 15 m/s.

Key features

- Physics-based propeller model
- Direct buoyancy control
- Realistic behaviour at the surface using AO Free Surface Physics

Surfer





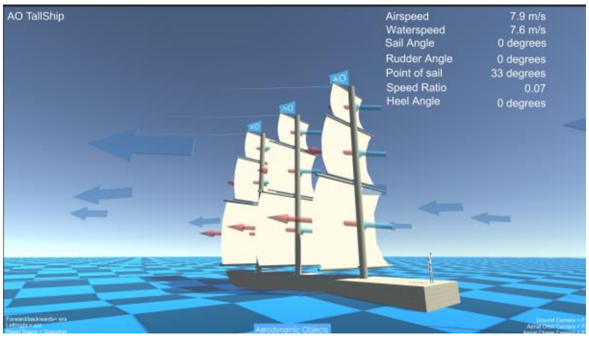
Surf on big waves using a simple hydrodynamic surfboard model

Surfboard angle of attack to the water (alpha) is controlled by shifting the Centre of Mass (CoM) of the surfer forward or back and the centre of volume moves until pitch equilibrium is achieved. The system is stable if the surfboard is longer than it is deep. A circular body like a barrel is neutrally stable. A surfer controls equilibrium forward speed by using weight shift to change angle of attack and hence change drag. As speed increases, the lift will increase. Since the overall hydrodynamic force needs to be the same, the buoyancy force will decrease accordingly as the apparent weight of the board is effectively reduced.

Key features

- Buoyancy model uses surface normal information allowing correct modelling of force equilibrium on wave faces
- Board attitude control via weight shift allowing carving turns and speed control
- Kinematic mannequin control to visually communicate pose mapped to CoM position

Tall Ship



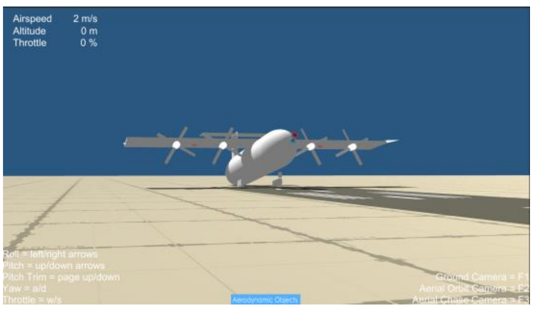
A large sailing ship with 9 sails

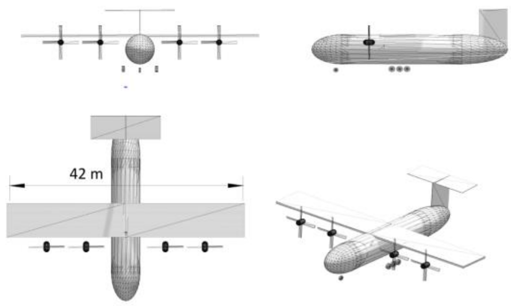
A clipper-like sailing ship with a displacment of 300 tonnes and 30m length. Sail angle of all sails is controlled collectively.

Key features

- Sailing controlled via rudder and sail angle user inputs
- Sails are made using Unity cloth and deform under aerodynamic load
- Fully integrated with Unity's water system in Unity 6.

Transport Aircraft





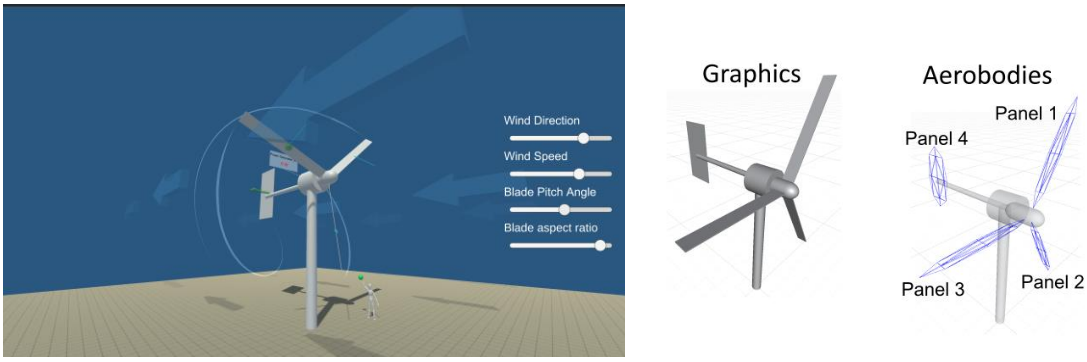
A heavy lift transport aircraft flies using four propeller engines

A four-engined transport aircraft loosely based on an A400M but with lower wing loading so that it flies relatively slowly. Propellers are modelled with Aerodynamic Object panels that spin around a hub to produce thrust. The pitch and diameter of the propeller blades can be varied in the editor to model propellers with different characteristics. Can you take off, complete a circuit and land again?

Key features

- Aerodynamics and flight dynamics successfully scaled to large aircraft
- Articulated control surfaces
- Uses propeller engine prefabs

Wind Turbine



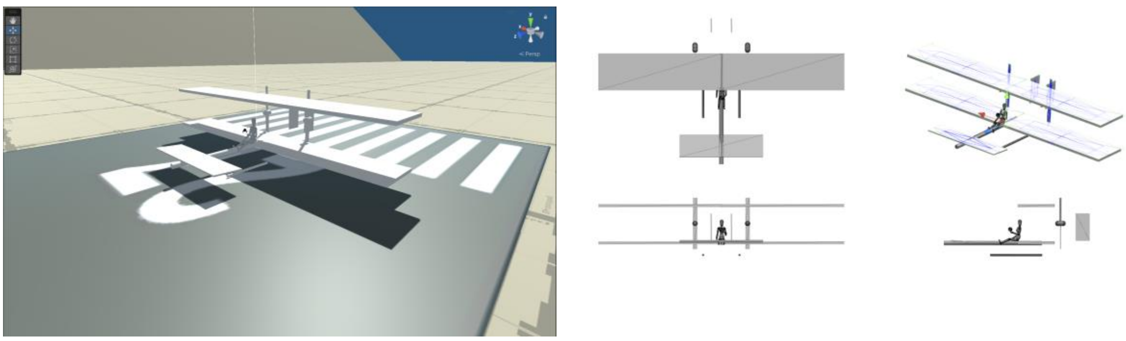
A horizontal axis wind turbine is used to generate power

A simple wind turbine made from three Aerodynamic Object blades and tail fin with Lift and Drag components. The rotor and tail fin assembly is free to rotate around the mast so that it naturally points into the wind. The user can vary the aspect ratio of the blades and blade pitch angle as well as the wind speed and direction. The turbine has a simple generator model that outputs power proportional to aerodynamic torque and rotation rate. The brightness of the light is proportional to the power generated. How much green energy can you make?

Key features

- User control of blade radius, aspect ratio and angle
- Physics-based calculation of torque and power obtained from rotor aerodynamics
- Wind facing behaviour obtained from vertical tail

Wright Flyer



The classic Wright Flyer recreated in Aerodynamic Objects

This aircraft has a layout loosely based on the Wright Flyer. It has a foreplane at the front for longitudinal balance and pitch control and fins at the back for directional stability and yaw control. For this demo, the pitch and yaw inputs physically move the foreplane and rudders rather than changing the camber. The aircraft is relatively easy to fly.

Key features

- Pitch control using a foreplane
- Roll control using camber variation on wings
- Yaw control using twin all moving fins