

Concordia University
Department of Computer Science and Software Engineering

SOEN341 --- Software Process
Fall 2006 --- Section H

Term Project --- Naval Battle Simulation System

1. Introduction

The project consists in the design and implementation of a Naval Battle Simulation System. Elements of the system include the Simulation Controller, the different classes of Ships, the Aircraft Carrier and its Aircrafts, the Submarine and, finally, all the Weapons, including missiles that are used by the Ships and Aircrafts to defend themselves or attack others. Many of these elements are to be coupled with other elements, yet all elements are expected to be independent and designed in a modular manner. For example, the aircraft carrier is responsible for giving a mission statement and permission to take-off to an Aircraft on its deck, and the Aircraft Carrier and Aircraft are to be designed and implemented as to entirely distinct objects; also, some ships, aircrafts, and missiles are using a radar that should be instances of the same radar class.

2. Disclaimer

Note that I agree that this is a rather violent subject because of its direct relation with warfare. However, this is one of the few good examples of a large and complex system where communication, cooperation, distributed computation and real-time aspects can be taken into consideration. Yet, its comprehension and coding is quite simple and thus adapted to an academic context such as this course. I sincerely hope anyone will not be offended by the subject.

3. Architectural Restrictions

As you will see by reading the following description, many requirements are redundant. You should take care that this redundancy is not reflected in the design and implementation. Emphasis should be put on adopting a proper system architectural design, and for it to be implemented to make the system easier to maintain and expand. System architecture issues include:

- Minimization of redundancy in requirements and specifications.
- Factorization of features common to all vehicles by forming a set of "Vehicles Features". Same for communication and detection elements, as well as for the various weapons.

- Optimization of system's architecture to achieve better maintainability and expandability through the design and implementation of inheritance relationships based on the above feature factorizations.
- Minimization and clarification of interfaces between simulation elements in order to maximize their reusability, testability through loose coupling.

By achieving a good architecture design for you system, you will be able to design reusable parts that can be later used and expanded to provide more system features. For example:

- A correctly designed "ship" class can be later on expanded to develop all specific kinds of ships, same for aircrafts.
- A correctly designed radar can later on be expanded to implement a sonar. By extension, same for all communication/detection elements.

Note that it is not expected that you emphasize on graphical rendering of the simulation. It is however expected that the simulation be followed and controlled easily. I suggest that you rely on the model-view-controller architectural design, in which the inspectors/controllers (see below) act as view/control elements of the MVC model, respectively.

4. Description of Main Simulation Elements/Issues

4.1. Simulation Controller

The Simulation Controller is the heart of the simulation. All Ships, Aircrafts and Ammunitions must give their position periodically to the Simulation Controller so that it knows exactly where are all the objects on the map at any time. For any object, the only way to know the position of another object is done by interrogating the Simulation Controller. Only radars and sonars can interact with the Simulation Controller to get the position of other objects within their range. The Simulation Controller also provides a user interface to view the objects navigating on the map. The Simulation Controller is also responsible for the generation of threats to simulate attacks on the fleet.

The Simulation Controller subsystem is very different from all the other parts of the system. It is responsible for showing the positions and actions of all the ships and aircrafts (optionally on a map) in real time and provide a user interface to control the simulation. All the objects communicate their position to the Controller, so it is coupled to all objects in the simulation.

Main functionalities

- Provide objects location information to radars and sonars.
- Simulate communications media (air or water) for the transmission of radio waves.
- Generate ships (friends or enemies)
- Provide a user interface
- Provide a view of the virtual world where the simulation takes place
- Provide a clock for the whole simulation and ensure that all simulated elements receive an equal share of time.

Software interfaces

- Communication/detection (provide ships location, act as communication media)
- All Ships, Aircrafts and Weapons (gather location information, synchronization)
- Simulator User (Graphical user interface)

4.2. Communication/Detection

The Communication/detection part is responsible for the design and implementation of all devices using radio waves for communication (radio devices used to communicate information between ships and aircrafts), and detection (radars and sonars used to detect enemies). This portion of the system is somewhat small but is of crucial importance for the development of all other parts, e.g. ships, aircrafts, missiles use radars/sonars/radios.

Enemies can only be detected using a radar (for aircrafts and ships) or sonar (for submarines). Radars and sonars are on board ships and aircrafts. If an enemy is not detected using a radar or sonar, it is virtually non-existent in the simulation, as far as other ships and aircrafts are concerned. Note that this does not mean that “unseen” enemies cannot attack you. It just means that other objects are not aware of their existence. So we need to simulate radars and sonars to detect enemies. Allies also have to communicate with one another to share some information about the location of enemies. Aircraft carriers also need to communicate their orders to Aircrafts. So we need to simulate these communication devices.

The simulation should not allow for two ships or aircraft to directly communicate with one another. All communication should happen through an intermediate media (air or water). Same for detection using radar/sonar, which should be done through an intermediate media (air or water).

Radar

A radar is a wave emitter/receiver that emits radio waves into a media (air), and then waits for some of these waves to bounce on objects and come back to it, thus detecting these objects.

Main attributes

- Range: 300 km
- Objects detected

Functionalities

- Turn on/off
- Emit waves
- Receive waves

Software interfaces

- Battleship
- Cruiser
- Aircraft
- Sea-sea missile

- Air-air missile
- Air-sea missile
- Sea-air missile
- Simulation Controller

Sonar

A radar is a wave emitter/receiver that emits radio waves into a media (water), and then waits for some of these waves to bounce on objects and come back to it, thus detecting these objects.

Main attributes

- Range: 50 km
- Objects detected

Functionalities

- Turn on/off
- Emit waves
- Receive waves

Software interfaces

- Submarine
- Destroyer
- Torpedo
- Simulation Controller

Radio Emitter/Receiver

A radio emitter/receiver can be used to send and receive messages through a communication media (air). It is assumed that all receivers within the range receive the message sent by an emitter.

Main attributes

- Range: 1000 km
- Message log/queue

Functionalities

- Turn on/off
- Emit waves
- Receive waves

Software interfaces

- All ships and aircrafts
- Simulation Controller

Passive Detector

A very simple detector that detects variations of the earth's magnetic field induced by the presence of large metallic objects such as a Ship. Its range is very limited, but it does not emit any waves, so it is undetectable. In our simulation, it is mainly to be used as detonator into a magnetic-field induced mine.

Main attributes

- Range: 1 km
- Objects detected: Ships

Functionalities

- Turn on/off
- Receive waves

Software interfaces

- All Ships (to signify a hit)
- Simulation Controller

Probe

A very simple device that is the combination of an underwater detector (sonar or passive detector) and a radio. It detects ships, and sends a radio message to its launcher Aircraft when it detects them.

Main attributes

- Range: as Sonar or Passive Detector
- Detected: Ships / Submarine

Functionalities

- Turn on/off
- Send/receive waves
- Send message using radio

Software interfaces

- Simulation Controller (radio / detector)

4.3. Vehicles

Aircraft Carrier

The Aircraft Carrier gives long-range capacities to the fleet by launching Aircrafts to locate and destroy enemy Ships and Aircrafts. The Aircraft Carrier itself is "blind". It can only "see" enemies by the information it gets from its patrolling aircrafts (and by communication with its allied ships). Much of the job done by the Aircraft Carrier itself is communication with its

Aircrafts to gather threat information and react to it as fast as possible to eliminate threats while they are as far as possible from the fleet.

Main attributes

- Resistance: 300 hit points
- Maximum speed: 70 km/h
- Number of Aircrafts carried: 30

Weapons

- No weapon

Main functionalities

- Direct all its Aircrafts' missions (complex)
- Communicate enemies' position with allies
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Aircraft (assign missions, communicate) (via radio)
- Other ships (exchange information about enemies) (via radio)
- Communication/detection (exchange information via radio with aircrafts and ships) (radio)

Suggested sub-objects

- Navigation Officer
- Air Traffic Control Officer
- Communications Officer
- Aircrafts (really a sub-object?)
- Radio

Aircraft

The Aircraft is used by the Aircraft Carrier to provide a long-range radar visibility by patrolling and to intercept far enemy Aircrafts and Ships. It communicates to the Aircraft Carrier the position of any enemy Aircraft or Ship it encounters during a patrol.

Main attributes

- Resistance: 2 hit points
- Maximum speed: 2250 km/h
- Radar radius (sea/air): 150 km
- Maximum range: 3000 km (depends on speed and altitude)

Weapons

- Air-Sea Missile
- Air-Air Missile

Main functionalities

- Use radar to locate enemy aircrafts and ships
- Use radio to communicate with allies
- Fire weapons
- Use radio to receive orders from Aircraft Carrier
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Aircraft Carrier (mission statements, exchange information about enemy ships and aircrafts)
- Weapons
- Communication/detection

Suggested sub-objects

- Radar
- Weapon Launcher
- Radio

Destroyer

The Destroyer locates underwater threats with its sonar and attempts to intercept them with its torpedoes. It cooperates with Submarines teammates by sending them the coordinates of all detected enemy submarines.

Main attributes

- Resistance: 150 hit points
- Max. Speed: 60 km/h
- Sonar radius: 50 km

Weapons

- Torpedo
- Sea-Sub Missile

Main functionalities

- Use sonar to locate enemy submarines
- Fire weapons (see list)
- Use radio to communicate with allies
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Submarine (exchange information about underwater threats)
- Weapons
- Communication/detection

Suggested sub-objects

- Navigation Officer
- Sonar Officer
- Sonar
- Communications Officer
- Radio
- Weapons Officer
- Weapon Launcher

Cruiser

The Cruiser locates airborne threats with its radar and (1) gives the information about far threats to the Aircraft Carrier and (2) attempts to intercept close airborne threats with its missiles. It also receives information from the Aircraft Carrier about far enemy aircrafts detected by friend Aircrafts.

Main attributes

- Resistance: 200 hit points
- Maximum speed: 65 km/h
- Radar radius: 200 km

Weapons

- Sea-Air Missile

Main functionalities

- Use radar to locate enemy aircrafts
- Fire weapons (see list)
- Use radio to communicate with allies
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Communication/detection
- Weapons

Suggested sub-objects

- Captain
- Navigation Officer
- Radar Officer
- Radar
- Communications Officer
- Weapons Officer
- Weapon Launcher
- Radio

Battleship

With its radar, the Battleship scans the surrounding water surface for enemy ships. It also receives information from the Aircraft Carrier and Submarine about far seaborne threats. The Battleship then will attempt to eliminate the nearest threats using its Sea-Sea Missiles and Cannons.

Main Attributes

- Resistance: 300 hit points
- Maximum speed: 70 km/h
- Radar radius: 75 km

Weapons

- Sea-Sea Missile
- Heavy Cannon

Main functionalities

- Use radar to locate enemy ships
- Fire weapons (see list)
- Use radio to communicate with allies
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Communication/detection
- Weapons

Suggested sub-objects

- Navigation Officer
- Radar Officer
- Radar (sea)
- Communications Officer
- Weapons Officer
- Weapon Launcher
- Radio

Submarine

The Submarine cruises underwater and attempts to destroy enemy ships and submarines using its sonar and torpedoes. The submarine has a unique advantage: it is invisible to all Ships and Aircrafts, except to Destroyers and other Submarines, which can detect them underwater with their sonar.

Main attributes

- Resistance: 125 hit points
- Maximum speed: 60 km/h

- Sonar radius: 50 km

Weapons

- Torpedo
- Sub-Sea Missile

Main functionalities

- Use sonar to locate enemy ships
- Fire weapons (see list)
- Use radio to communicate with allies
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Communication/detection
- Weapons

Suggested sub-objects

- Navigation Officer
- Sonar Officer
- Sonar
- Communications Officer
- Weapons Officer
- Weapon Launcher
- Radio

Sea Patrol Aircraft

An Aircraft based on a Naval Base instead of being based on an Aircraft Carrier. It is actually much bigger than the fighter Aircrafts on board of the Aircraft Carriers. It can stay in the air much longer and thus it can patrol a much wider area. It can also lay probes (see below) to detect submarines, and use Sea-Sub Missile/Torpedo.

Main attributes

- Resistance: 5 hit points
- Maximum speed: 850 km/h
- Radar radius (sea/air): 200 km
- Range: 5000 km

Main functionalities

- Use radar to locate enemy aircrafts and ships
- Use radio to communicate
- Fire weapons
- Receive orders from Naval Base
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Naval Base (mission statements, exchange information about enemy ships and aircrafts)
- Weapons
- Communication/Detection

Suggested sub-objects

- Radar
- Weapon Launcher
- Radio

Weapons

- Sea-Sub Missile/Torpedo

Patrol Ship

A very simple and small Ship used to patrol around Naval Bases for protection. It is armed with Sea-Sea Missiles.

Main attributes

- Resistance: 50 hit points
- Max. Speed: 70 km/h
- Radar radius: 25 km

Main functionalities

- Steer
- Accelerate/decelerate
- Use radar to locate enemy ship
- Fire weapon
- Use radio to communicate with allies
- Assess attack/defense situation

Software interfaces

- Simulation Controller
- Weapons
- Communication/Detection

Suggested sub-objects

- Captain
- Radar
- Radio
- Weapon Launcher

Weapons

- Sea-Sea Missile

4.4. Weapons

The Weapons are coupled to all elements that use or are subject to attack by weapons. This part consists in the design of all the different Weapons (missiles and cannon shells) used in the simulation, hence its importance. However, the design of each type of Ammunition is easy and there are lots of common characteristics between the different Weapons. Modular design and the use of inheritance will enable you to easily develop a greater number of different weapons.

The Weapons are used by Ships, Aircrafts and Submarines to eliminate threats. They have limited functionalities, but there are different kinds of weapons, such as the various missiles, torpedoes and cannon shells. One of the most important aspects of the design of Weapons is the design of the software interface with the weapon launchers. Most Weapons are auto-aiming, relying on their own Radar or Sonar to aim to their assigned target. Some others (e.g. cannon shells) follow a ballistic trajectory and are unguided after they are shot. All Weapons have a Controller object that is responsible for:

- Transmitting the object's position to the Simulation Controller from time to time;
- Tell the Charge to detonate if the target is hit;
- Tell the target that it has been hit;
- Control aiming by acting on the Rudder following the information given by the Radar.

The latter applies only to auto-aiming Weapons. In the following attribute definitions, "Latency time" refers to the time it takes to fire a first shot on a given target. It includes time spent on aiming and sending target information to the Weapon (in the case of missiles and torpedoes). Further shots on the same target should not take latency time into account, unless the target has moved significantly (which is often the case when using anti-air missiles).

Sea-Sub Missile/Torpedo

This missile transports a torpedo to a certain position and launches it when it touches the water at the end of its course. That is why it does not have any precision or firepower attribute.

Main attributes

- Range: 11 km
- Maximum speed: 1000 km/h
- Precision: N/A
- Launcher's latency time: 20 sec.
- Firepower: N/A
- Launcher's rate of fire: 3/min.
- Aiming: ballistic

Software interfaces

- Destroyer
- Target Submarine (to signify a hit)

- Simulation Controller

Main functionalities

- Fire
- Ballistic trajectory control
- Launch torpedo

Suggested sub-objects

- Controller
- Torpedo

Sea-Air Missile

Main attributes

- Range: 148 km
- Maximum speed: 3125 km/h
- Precision: 75%
- Launcher's latency time: 5 sec.
- Firepower: 2
- Launcher's rate of fire: 10/min
- Aiming: radar

Software interfaces

- Cruiser
- Target Aircraft (to signify a hit)
- Simulation Controller
- Communication/detection

Main functionalities

- Fire
- Use radar to acquire target
- Detonate

Suggested sub-objects

- Radar
- Charge

Heavy Cannon Shell

Main attributes

- Range: 38 km
- Maximum speed: 2745 km/h
- Precision: 60%
- Canon's latency time: 20 sec.
- Firepower: 25
- Canon's rate of fire: 15/min (3 tubes)

- Aiming: ballistic

Software interfaces

- Battleship
- Target Ship (to signify a hit)
- Simulation Controller

Main functionalities

- Fire
- Ballistic trajectory control
- Detonate

Suggested sub-objects

- Controller
- Charge

Sea-Sea Missile

Main attributes

- Range: 120 km
- Maximum speed: 1060 km/h
- Precision: 75%
- Launcher's latency time: 30 sec.
- Firepower: 50
- Launcher's rate of fire: 2/min
- Aiming: radar

Software interfaces

- Battleship
- Target Ship (to signify a hit)
- Simulation Controller
- Communication/detection

Main functionalities

- Fire
- Use radar to acquire target
- Detonate

Suggested sub-objects

- Controller
- Radar
- Charge

Torpedo

Main attributes

- Range: 38 km
- Maximum speed: 120 km/h
- Precision: 75%
- Launcher's latency time: 30 sec.
- Firepower: 125
- Launcher's rate of fire: 2/min.
- Aiming: sonar

Software interfaces

- Submarine, Destroyer
- Target Ship (to signify a hit)
- Simulation Controller
- Communication/detection

Main functionalities

- Fire
- Use sonar to acquire target
- Detonate

Suggested sub-objects

- Controller
- Rudder
- Sonar
- Charge

Sub-Sea Torpedo/Missile

This torpedo transports a Sea-Sea Missile to a certain position and launches it when it goes out of the water at the end of its course. That is why it does not have any precision or firepower attributes.

Main attributes

- Range: 38 km
- Maximum speed: 120 km/h
- Precision: N/A
- Launcher's latency time: 30 sec.
- Firepower: N/A
- Launcher's rate of fire: 2/min.
- Aiming: "ballistic" (underwater)

Software interfaces

- Submarine
- Target Ship (to signify a hit)

- Simulation Controller

Main functionalities

- Fire
- Ballistic trajectory control
- Launch sea-sea missile

Suggested sub-objects

- Controller
- Sea-sea missile

Air-Sea Missile

Main attributes

- Range: 140 km
- Maximum speed: 1060 km/h
- Precision: 75%
- Launcher's latency time: 10 sec.
- Firepower: 50
- Launcher's rate of fire: 6/min
- Aiming: radar

Software interface

- Aircraft
- Target Ship (to signify a hit)
- Simulation Controller
- Communication/detection

Main functionalities

- Fire
- Use radar to acquire target
- Detonate

Suggested sub-objects

- Radar
- Charge

Air-Air Missile

Main attributes

- Range: 48 km
- Maximum speed: 4400 km/h
- Precision: 80%
- Launcher's latency time: 5 sec.
- Firepower: 5
- Launcher's rate of fire: 10/min

- Aiming: radar

Software interfaces

- Aircraft
- Target Aircraft (to signify a hit)
- Simulation Controller
- Communication/detection

Main functionalities

- Fire
- Use radar to acquire target
- Detonate

Suggested sub-objects

- Radar
- Charge

4.5. Supplies, Refueling & Bases

All vehicles (Ships and Aircrafts) can be designed to have unlimited fuel and unlimited ammunitions (Cannon Shells, Missiles). However, it is felt in order to provide more lively simulation that the vehicles must implement the following features:

- All vehicles must have limited fuel and ammunition supplies.
- All vehicles must have a mechanism to refuel and rearm.
- Naval Bases must be implemented to allow ships to refuel and rearm.
- Naval Bases should be displayed on the map as an island.
- Naval Bases can be attacked by any Weapon that can harm a Ship.
- Naval Bases should have a productivity rate to produce: Ships, Fuel and Weapons.

4.6. Inspectors/Controllers

The system should enable the user to interact or even inspect the state of the system or the Ships and Aircrafts involved in the simulation. This feature aims at the implementation of a generic inspection and control facility for the simulation and all objects involved in it.

- Simulation controller:
 - Control panel to allow the set up of the initial situation of the simulation.
 - Clickable list of vehicles that exist in the simulation, even including vehicles that were destroyed. Clicking on an item on the list will open a window to inspect the status of the object, and control it as specified below.
 - Inspector to see the communication and detection requests made by radios, radars and sonars to the Simulation Controller.
- Vehicles:
 - Inspector/controller for each kind of vehicle. Each inspector should have the same look and feel.

- Display the speed, direction, fuel level, side, and number of each type of weapon on board, mission statement and name of base Aircraft Carrier for Aircrafts, etc.
- Textual display and logging of actions taken by the vehicle.
- It should be possible to change the speed, direction, number of weapons, fuel level, side, or mission statement, etc.
- Communication/Detection:
 - The Radio (Communication Subsystem) on board Vehicles should have an inspector/controller available, enabling the textual display and logging of exchanged messages. The controller should allow to change the range of the radio, and allow the user to have the radio send messages he inputs. It must also be possible to turn the radio on/off.
 - A similar inspector/controller must exist for radars and sonars.

4.7. Strategic Coordination

In a simplistic simulation, the vehicles are all acting in isolation. They can collaborate by exchanging enemy ship positions to their allies, but they do not coordinate their actions to maximize their efficiency as a group. This important feature aims at the definition and implementation of algorithms to maximize the efficiency of the whole fleet:

- Ships and Aircrafts must collaborate to maximize their efficiency in attack or defense. For example, if a group of ships is encircling a group of enemy ships, they should collaborate to eliminate their enemies using a minimal number of weapons, and destroy all enemies in the shortest time interval, to minimize casualties on their own side.
- There must not be a central node for information gathering and decision-making. Algorithms must be based on negotiation. For example, it would not be acceptable to have the Aircraft Carrier decide of the actions of all the fleet. All ships must make their own decisions based on negotiation with others.
- All message and information passing for negotiation must be done via the radio.

5. Conclusion

This project is presented in order for you to realize that it is of prime importance that you assess its difficulties versus your team's capacities from the start. For instance, I don't expect that you will successfully implement a fully functional simulation system with full graphic rendering and embedded artificial intelligence. As part of deliverable 1, you will be asked to establish a project scope. It is strongly advised that your team starts right now to assess what are realistic goals to be met on this project versus your team mates' capacities.