SEASAFE – SHIP COLLISION AVOIDANCE SIMULATOR

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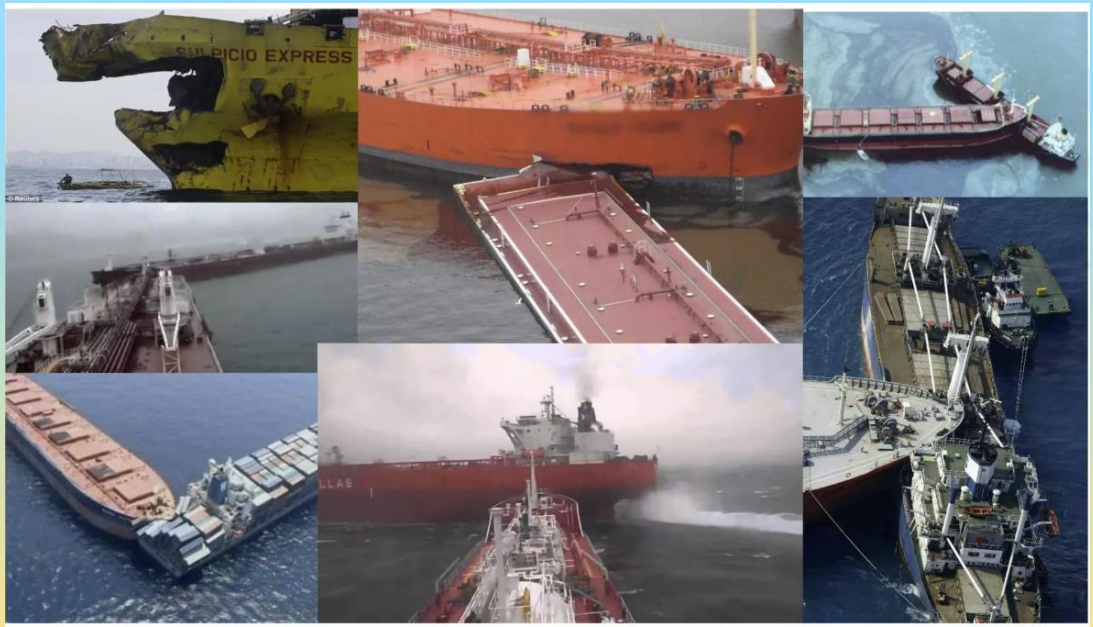
INTRODUCTION

- Shipping industry accounts for over 80% of global trade volume. As the volume of maritime traffic increases, the potential for accidents rises.

- Our goal – create collision avoidance algorithm for vessels.



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PROBLEM DEFINITION

- In an open sea environment with only **autonomous** vessels, each starting simultaneously from source points toward their destinations, the goal is to ensure that all ships reach their destinations safely.

- Compliance with current maritime navigation rules.

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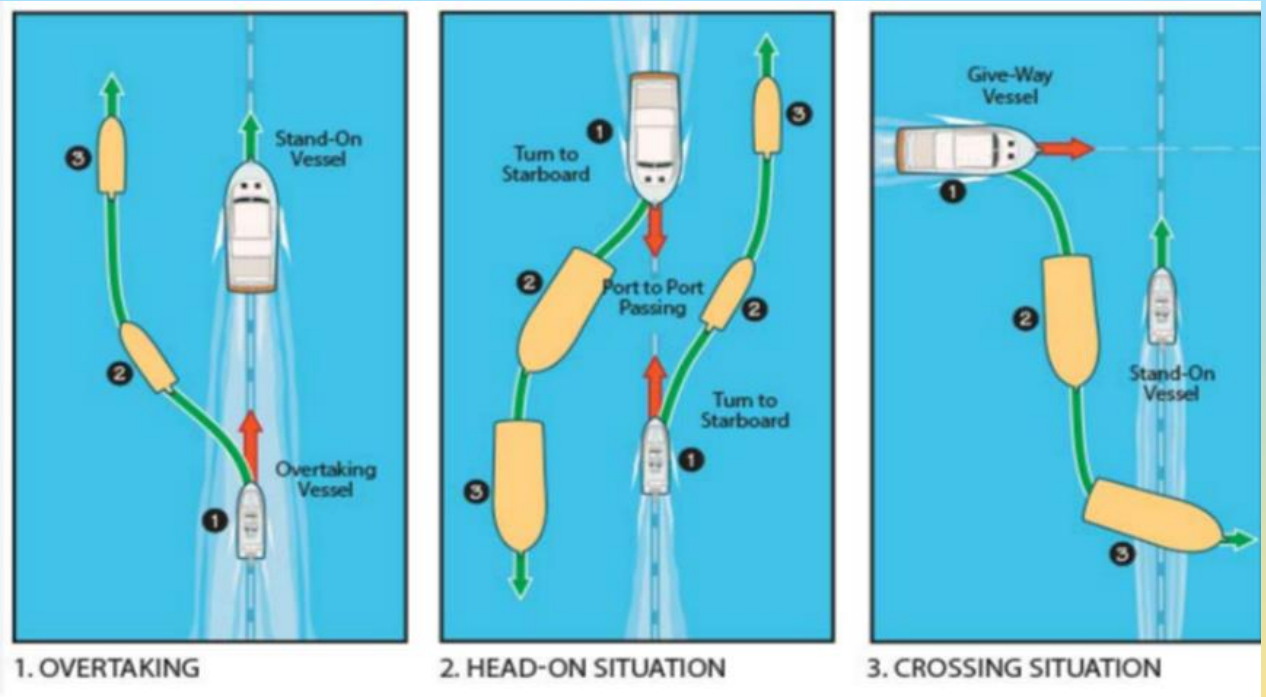
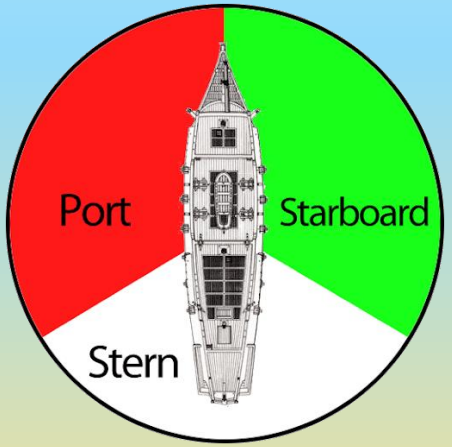
COLREG

- IMO(International Maritime Organization) established COLRG – Convention on the International Regulations for Preventing Collisions at Sea.
- COLREG sets out the rules that all vessels must follow to prevent collision. Just as there are rules to be followed by car drivers, there are rules to be followed by vessels.





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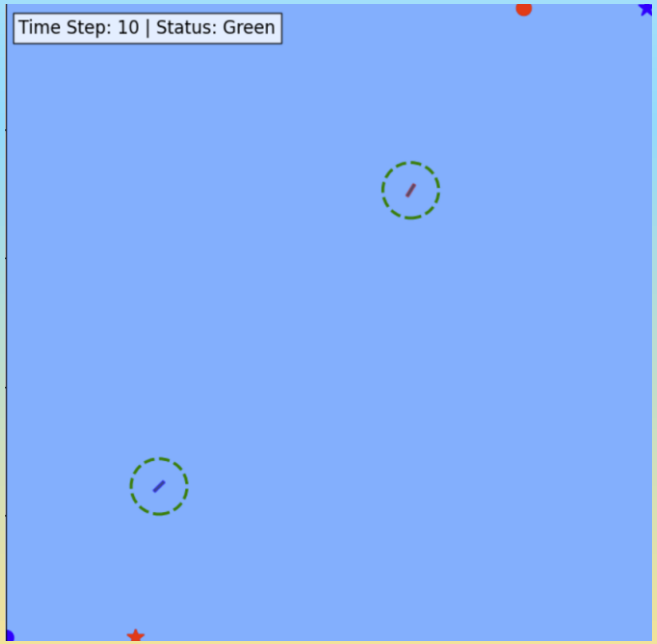
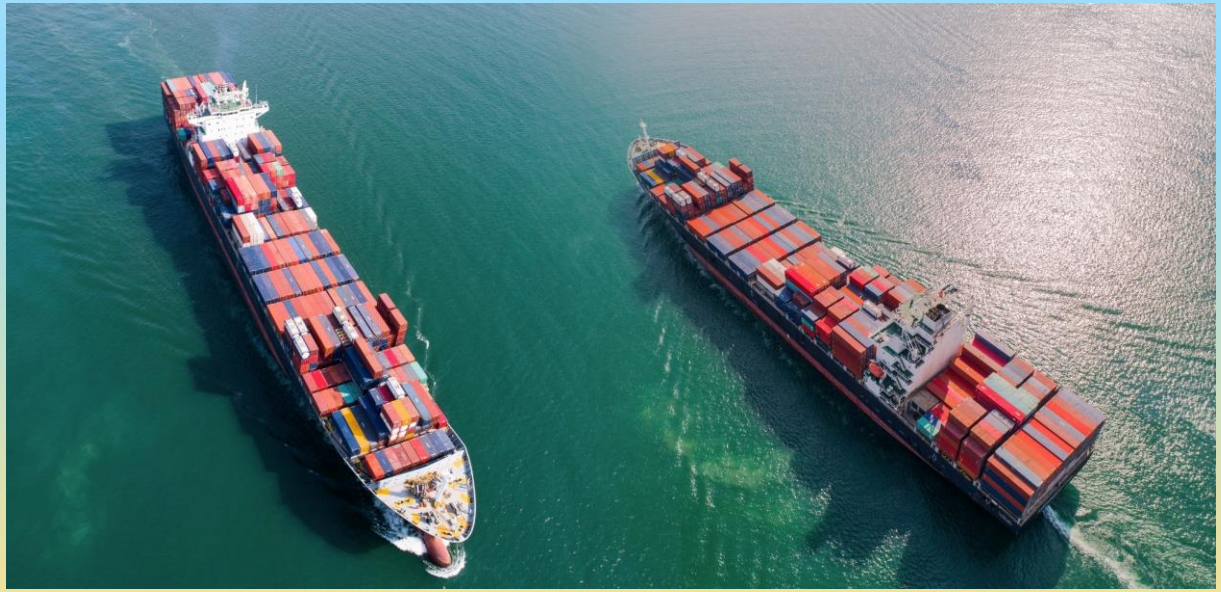
GOALS

- Theoretical goal - Develop an algorithm for collision avoidance that complies to COLREG.
- Practical goal - develop a simulator that runs our algorithm.





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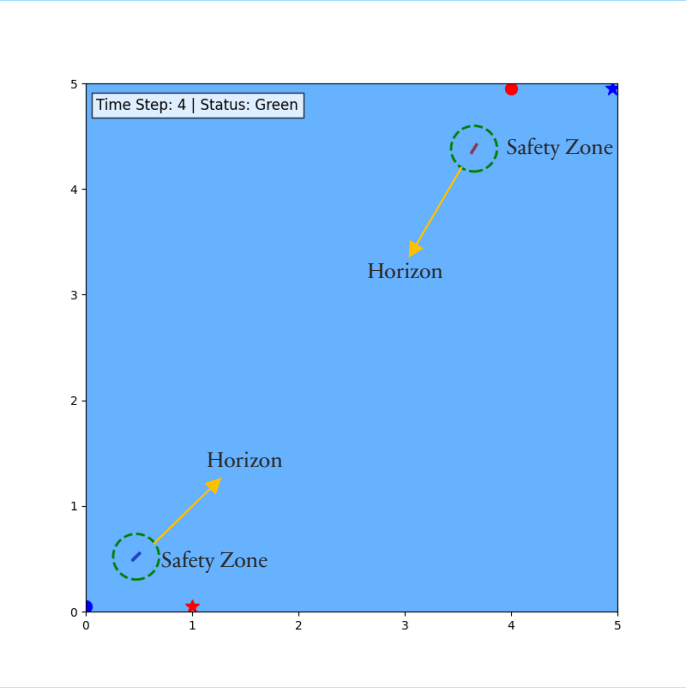
ENVIRONMENT

- Safety zone: a circular area around the ships with configurable radius e.g., 50m.
- Horizon - the lookahead distance considered by the vessels when searching for potential collision and for collision avoidance maneuvering.
- Time step - An interval in the simulation during which the system updates the state of all ships.



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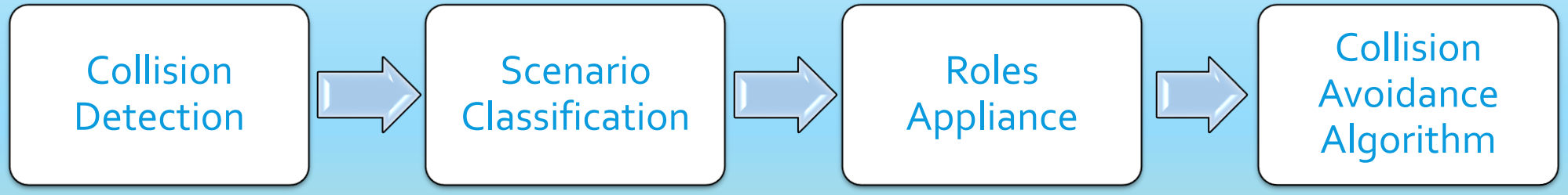
FLOW



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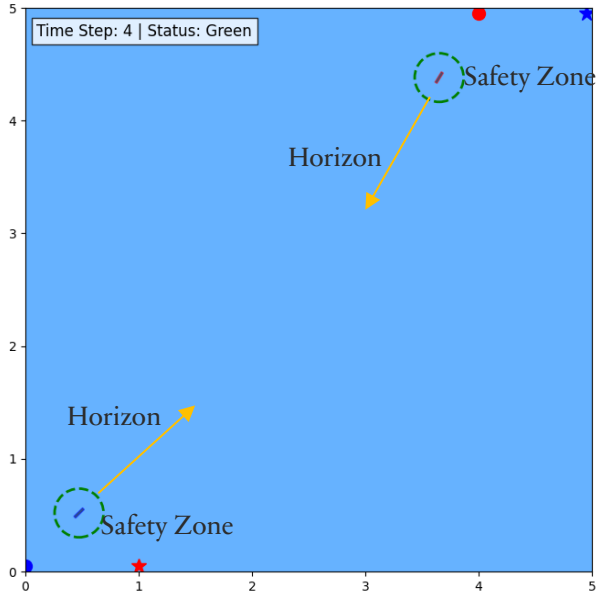
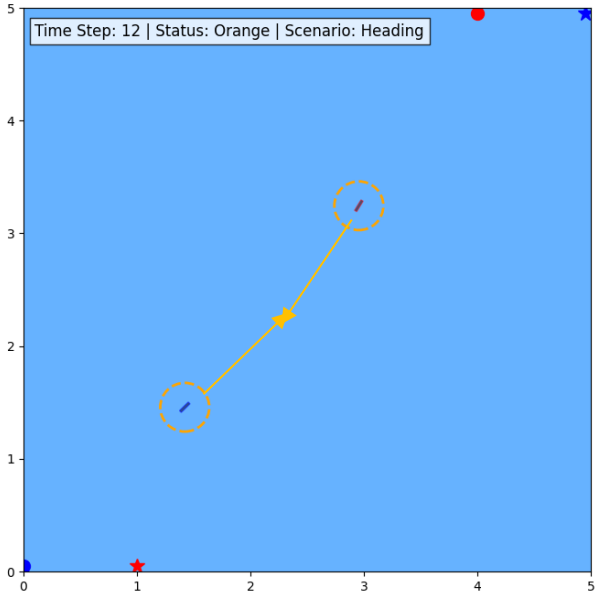
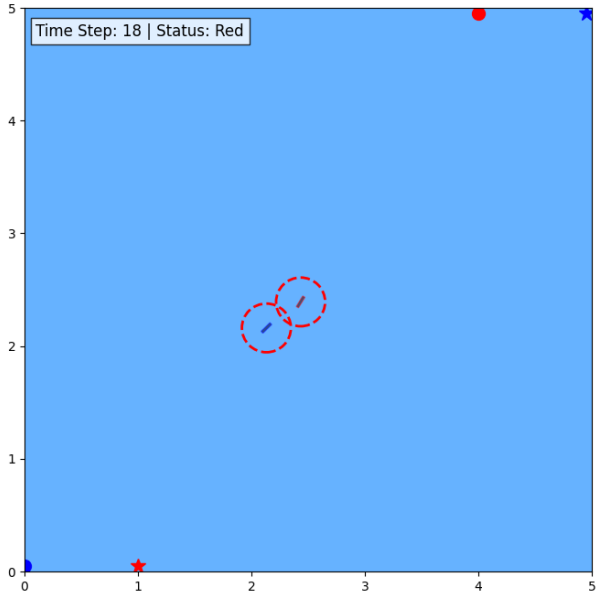
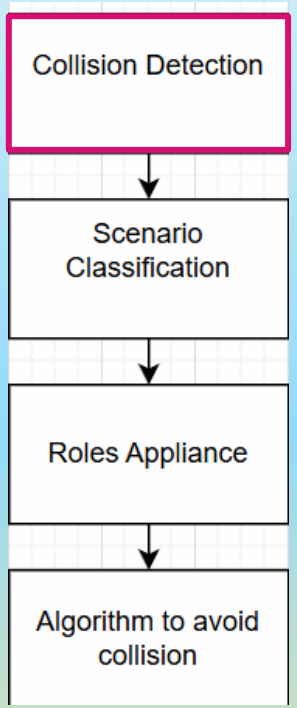
COLLISION DETECTION

- Collision – a case where two or more ships enter each other's Safety zone.
- At each time step, the algorithm search until the horizon for collision.









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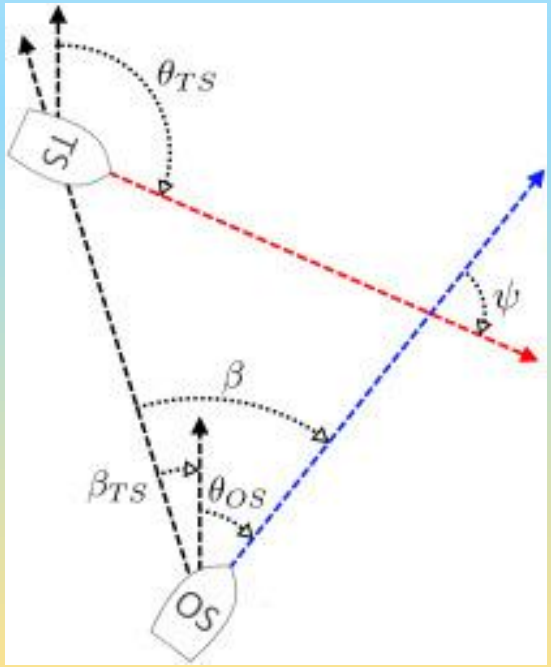
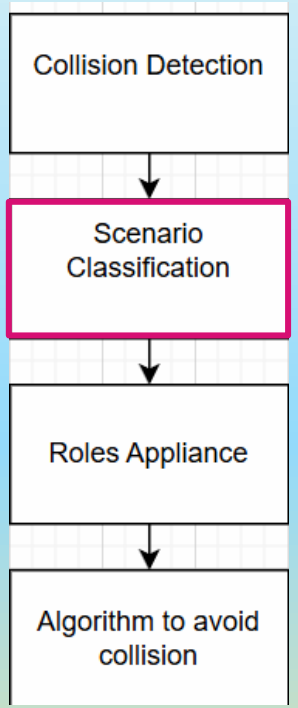
CLASSIFICATION

- We use TAG-CSC(Temporal and Geometric COLREG Scenario classification) system, it's a system to classify COLREG scenarios based on relative bearings of the ships.



Scenario set	β_G boundaries (°)	ψ_G boundaries (°)
G_{HO}	[−45, 45)	[135, 180)
	[−45, 45)	[−180, −135)
G_{CGW}	[45, 180)	[−180, −64)
	[67.5, 112.5)	[−64, 0)
	[−30, 45)	[−135, −64)
G_{CSO}	[−180, −45)	[66, 180)
	[−112.5, −67.5)	[0, 66)
	[−45, 30)	[66, 135)
G_{OGW}	[−67.5, 67.5)	[−65, 66)
G_{OSO}	[−180, −112.5)	[−65, 66)
	[112.5, 180)	[−65, 66)



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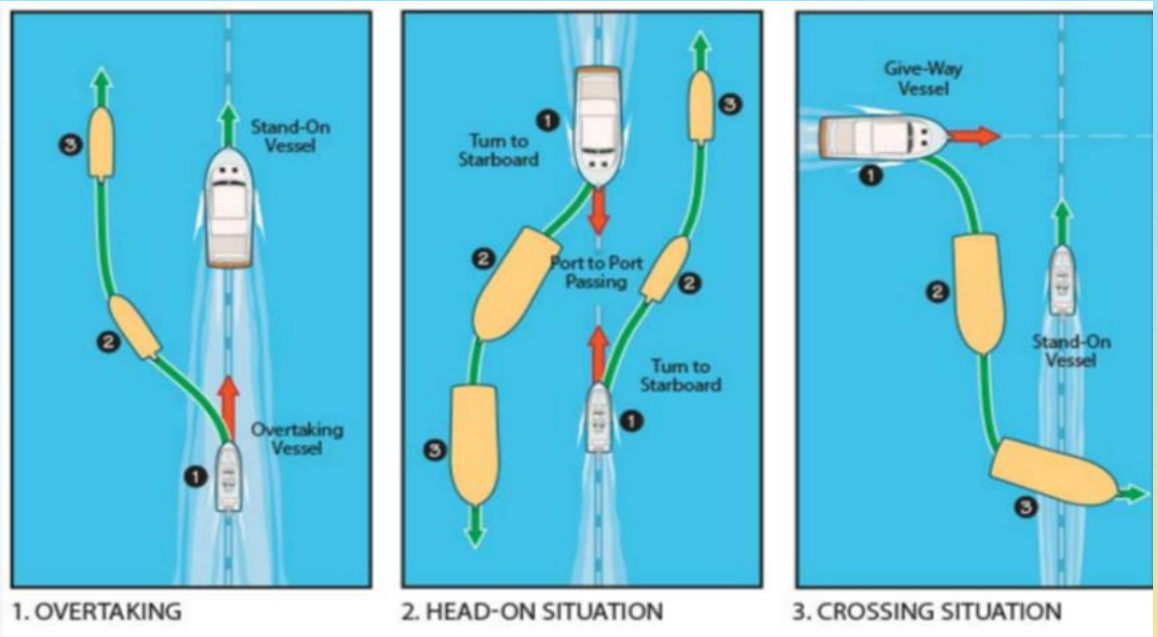
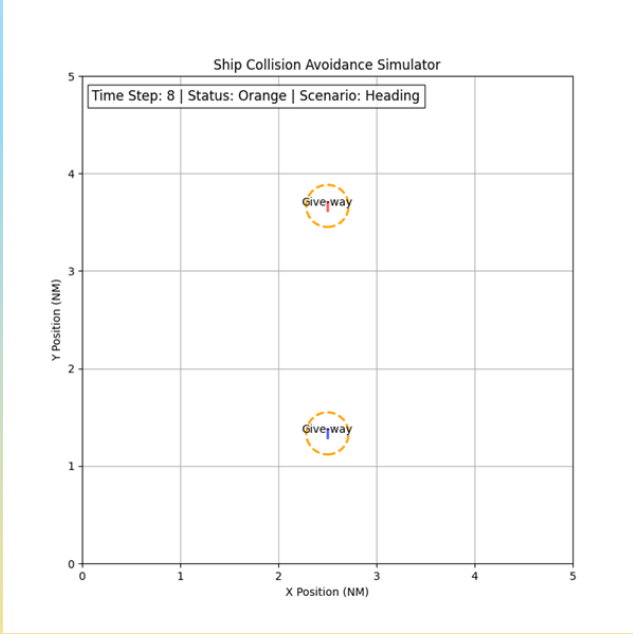
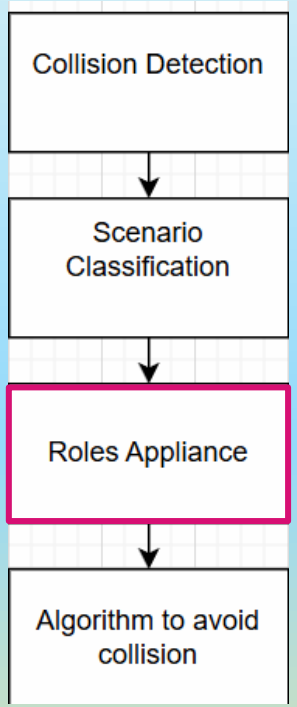
ROLES

- After classifying the collision, we will apply roles for each vessel based on TAG-CSC system we expanded on earlier.







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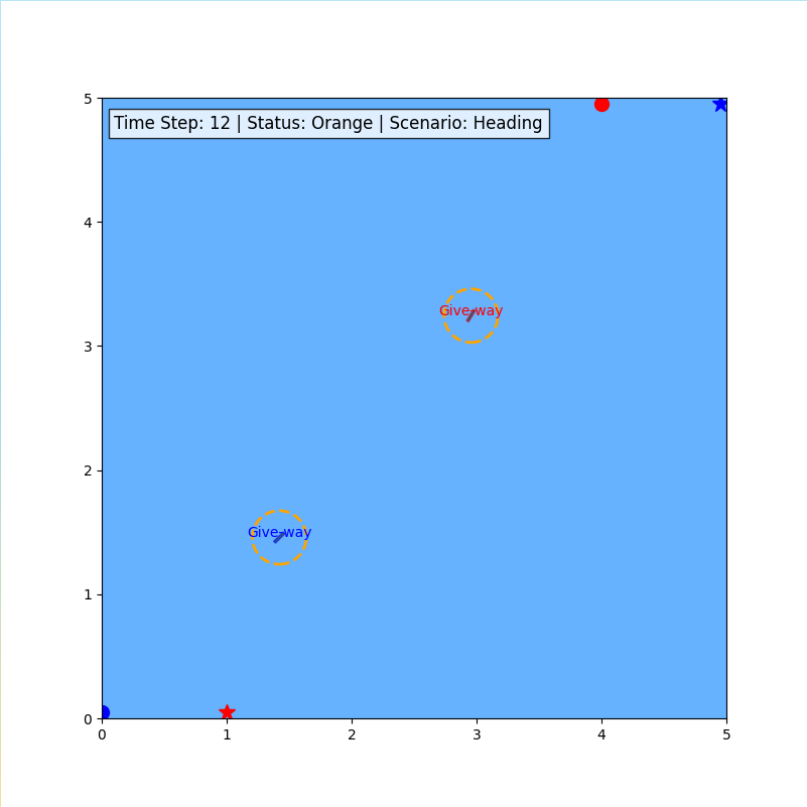
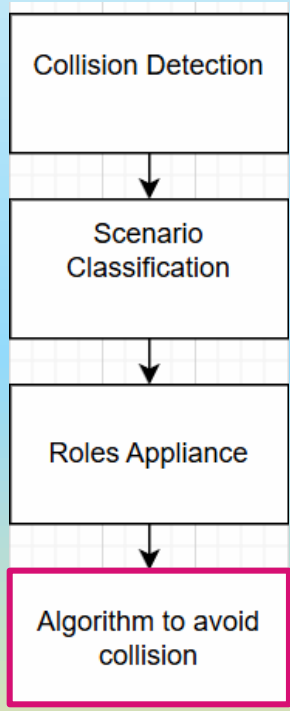
ALGORITHM

- After detecting collision, classifying scenario and applying roles, the algorithm should kick in and handle the collision avoidance.





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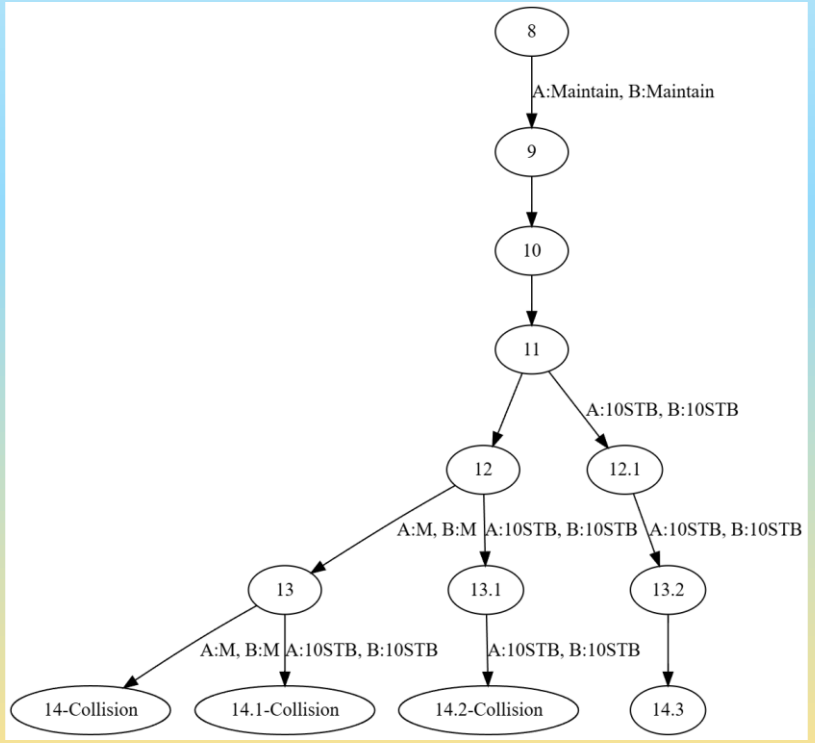
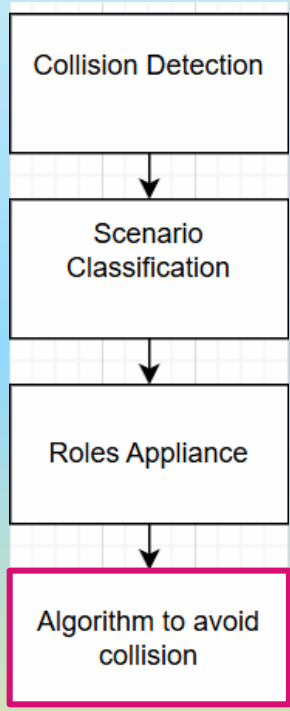
TREE SEARCH

- Tree search is an algorithmic method used to explore possible states or decisions systematically.
- Represents the problem as a tree where nodes signify states and edges denote actions or decisions.





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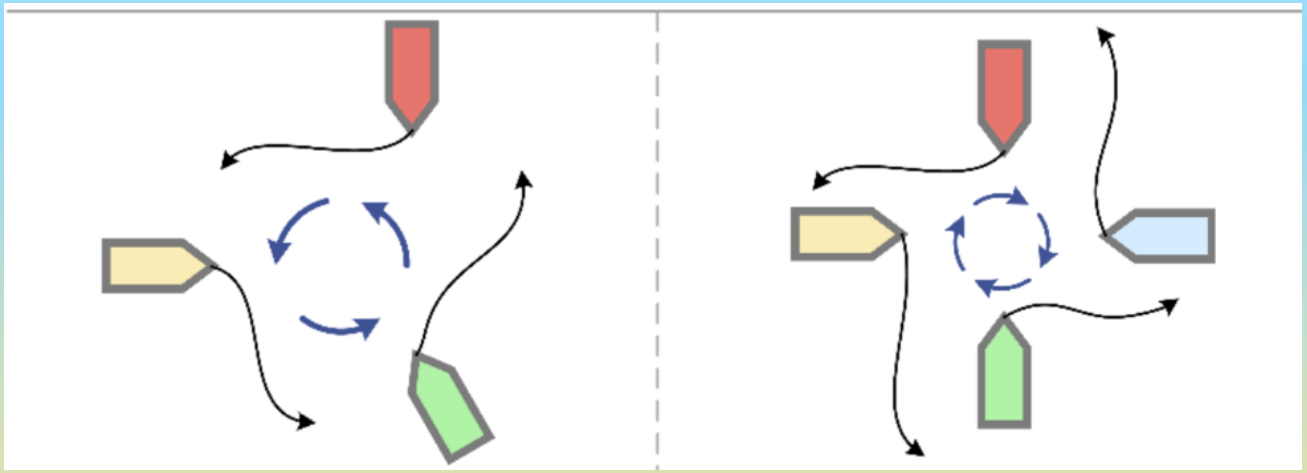
MULTI-VESSEL SCENARIOS

- Multi-vessel scenarios are defined in a general manner in COLREG (Rule 8).
- Haven't reached that yet, that's an object for the next phase of the project.



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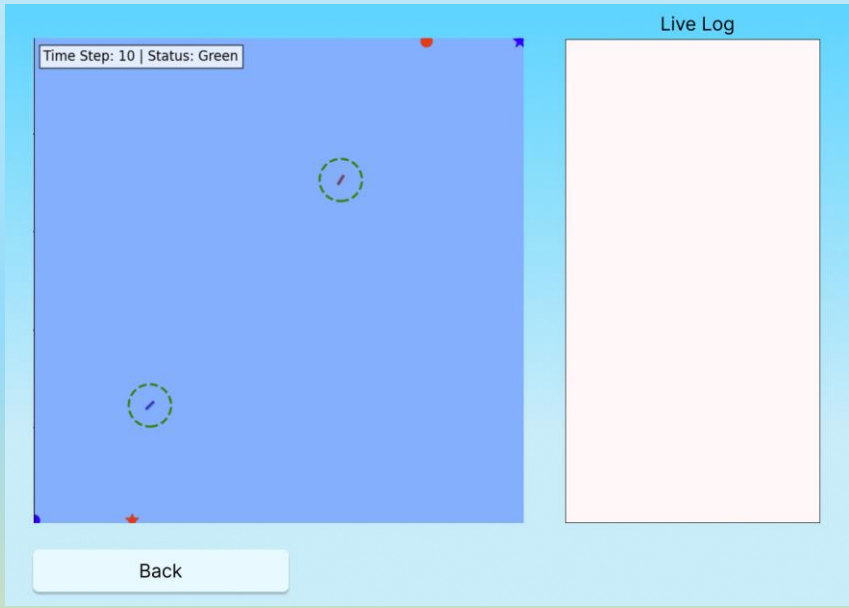

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SOFTWARE ARCHITECTURE

- Modular Design:
    - Separation of Concerns: Simulation Engine and Collision Avoidance Algorithm are independent modules.
- Algorithm Integration:
    - Clear and Simple API
    - Generic Interface:
        - API is not tied to a specific algorithm implementation.
        - Allows for easy substitution or updates to the algorithm.

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TOOLS

In order to develop the simulator, we will use some well known technologies:

- Python with PyGame
- NumPy, Matplotlib and Networkx
- Git for version control
- PyTest for testing

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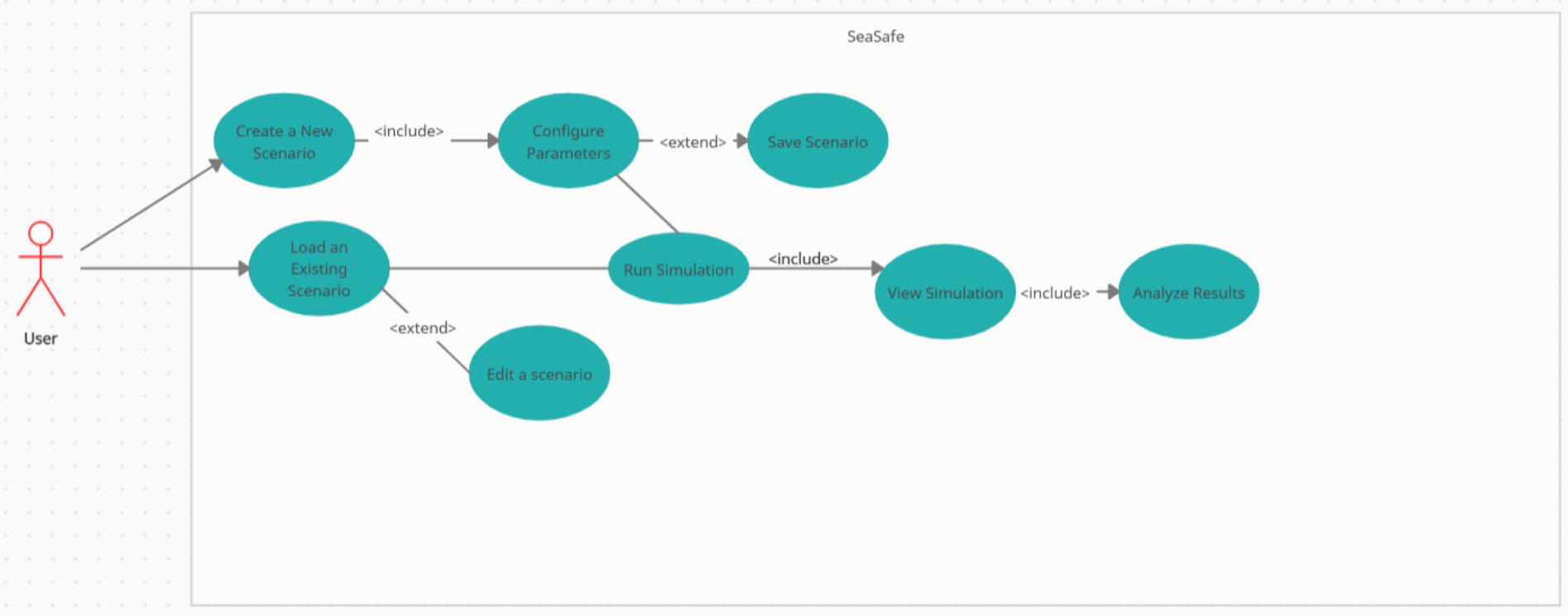
UML – USE CASE



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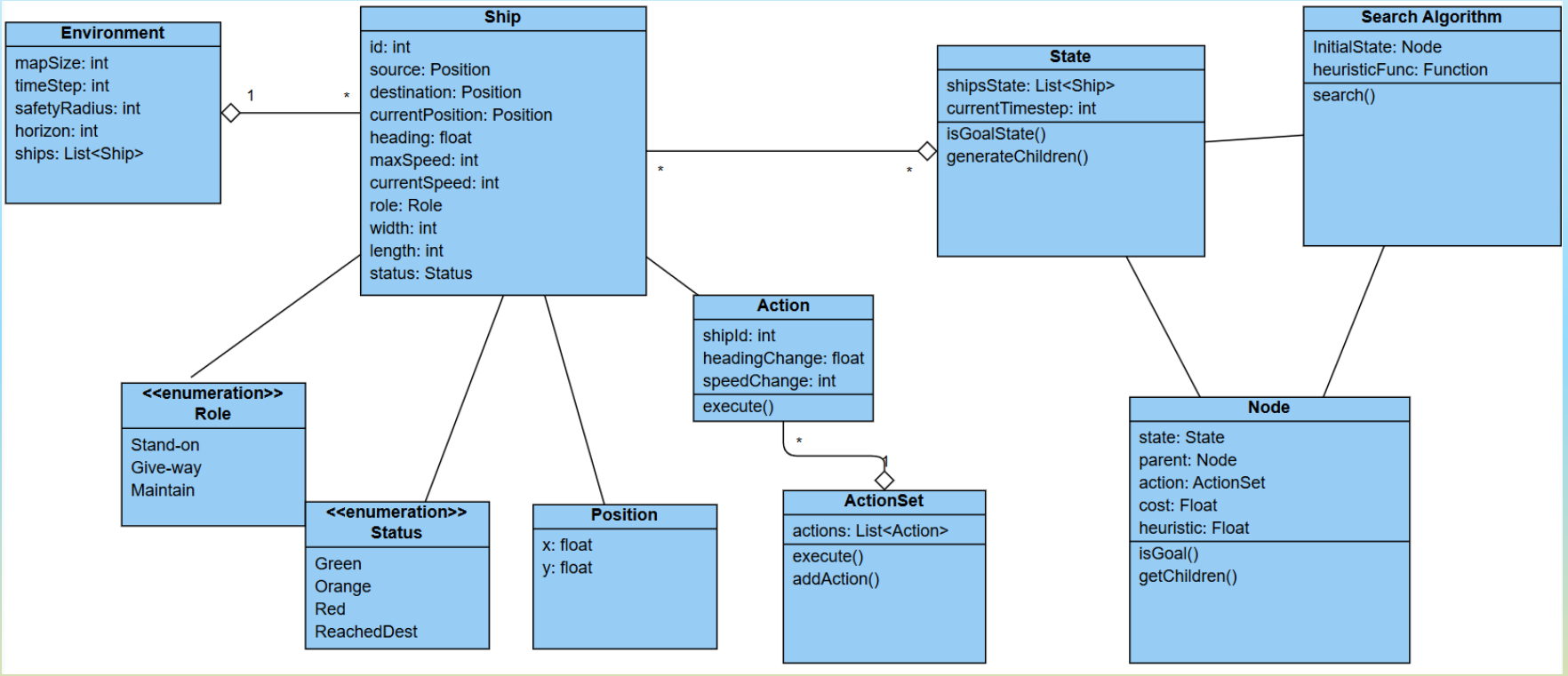
UML – CLASS DIAGRAM



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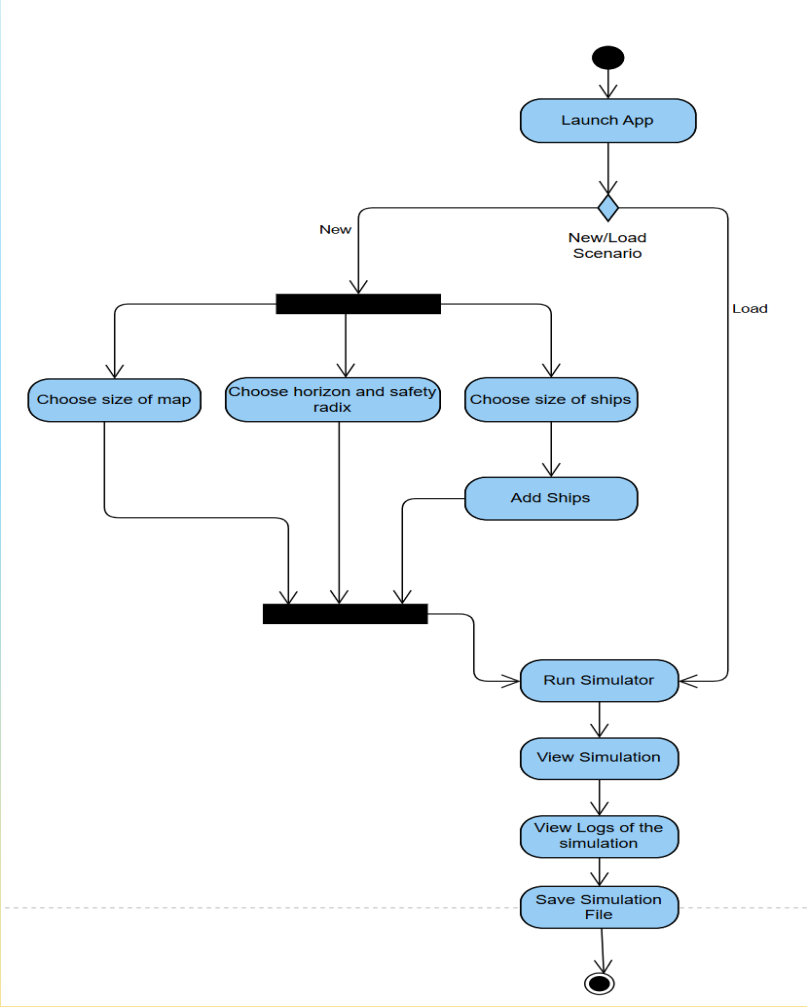
UML – ACTIVITY DIAGRAM



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TESTING PLAN

- Unit testing
- Integration testing
- Simulation testing

- Example of test cases:

6	Filling non-coordinate value for ship source point	Error message: "Please enter a valid coordinate for source point."
7	Filling non-coordinate value for ship destination point	Error message: "Please enter a valid coordinate for destination point."
8	Press "Run Simulator" before inputting source points	Error message: "Please enter ship source points."
9	Press "Run Simulator" before inputting destination points	Error message: "Please enter ship destination points."

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EXPECTED RESULTS

1.A COLREG-compliant collision avoidance algorithm capable of handling complex, multi-vessel scenarios.
2.A simulation system for testing and visualizing the algorithm's performance under various conditions.

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THANK YOU FOR LISTENING

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