Optimizing Naval Search Operations

This project aims to develop a simulation model to optimize naval search operations, enhancing detection capabilities while minimizing search time. The key focus areas include probability calculations, wind condition adjustments, and scenario-based analysis to improve overall search effectiveness.

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IE 630 Course Project

Objectives and Scope

Objectives

Devise an efficient simulation model to support naval search operations, optimize detection probability, and reduce search time.

Scope

The model will consider factors like wind conditions, search patterns, and sensor capabilities to enhance search accuracy and effectiveness.

Methodology

Utilize probabilistic calculations, scenario comparisons, and simulation optimization to identify the most effective search strategies.

Data Collection and Assumptions

1

Weather Data

Wind speed and direction data for the search area.

2

Probability Models

Develop probabilistic models to estimate the likelihood of detection based on environmental factors and search parameters.

3

Initially Assumed

Assume the probability for missing values in separate grids and obtain speed and direction through user input.

Model Logic and Methodology

1

Matrix Initialization

Initialize matrices: Start with search area and matrix for probability values. Assign initial values to represent search conditions and probabilities. This sets the groundwork for subsequent calculations and updates in the search model.

2

Probability Calculations

Update the matrix with probabilities of finding the target. Consider variables like wind speed and direction. Use these calculations to refine search strategies and maximize detection likelihood.

3

Search Optimization

This iterative process aims to maximize detection while minimizing search time for naval operations.

Base Case Analysis

1

Scenario Setup

Average wind conditions : Wind speed of 10, 20 and 30 knots and various direction of 45, -45, 135, -135 and 90 degrees.

Initial search area size : (n x n) square matrix.

Environmental conditions : Moderate sea state and clear weather conditions.

2

Simulation Run

Implement the chosen search pattern and update probability matrices based on wind conditions and search efforts.

3

Insights

Wind speed and direction significantly impact search patterns and detection probability. Strong winds may alter search trajectories and affect sensor accuracy, requiring adaptive search strategies.

Scenario Comparisons

Varying Wind Conditions

Evaluate the impact of different wind speeds and directions on search effectiveness, considering their impact on detection probability and search time.

Alternate Search Patterns

Explore the use of different search patterns, such as parallel or expanding square, and analyze their performance under various environmental conditions.

Sensor Enhancements

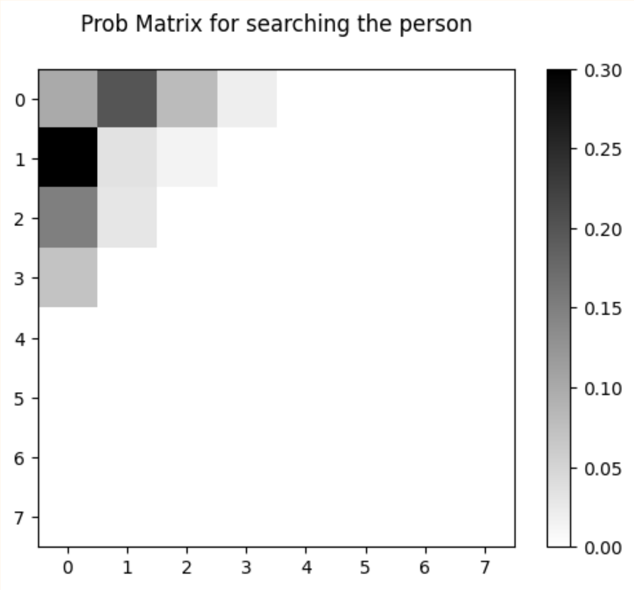
Assess the potential benefits of incorporating advanced sensor technologies, such as high-resolution radar or thermal imaging, to improve detection capabilities.

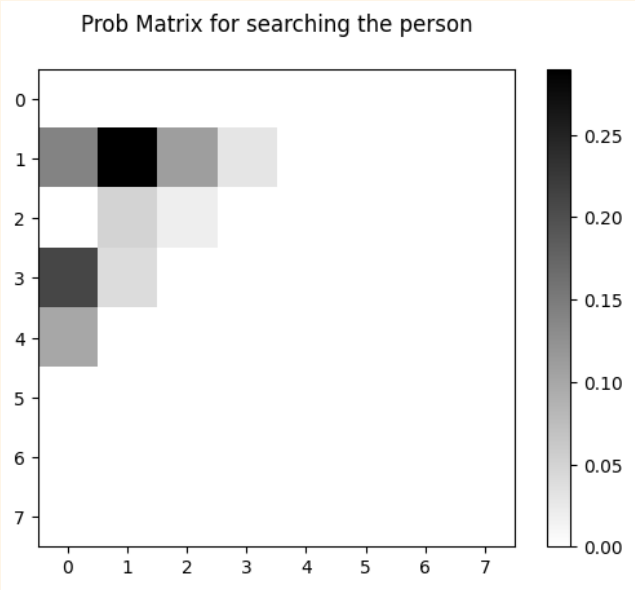
We manually calculated 50 iterations for different wind conditions. Our algorithm improves search efficiency by calculating average iterations for specific grids using matrix-based methods.

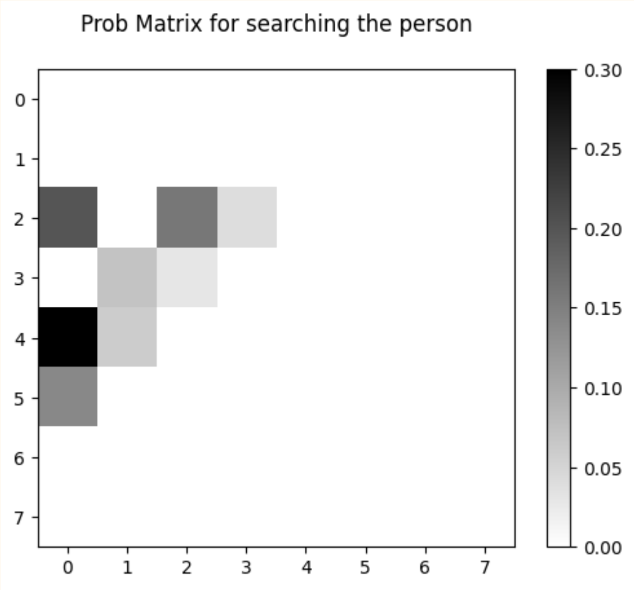
No. of Avg. Iterations : Speed (in Knots) and Direction (Degree)

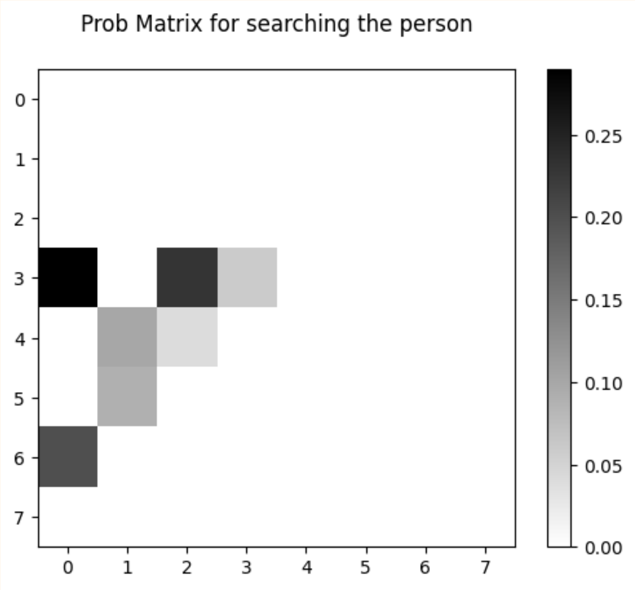
	(10 , 45)	(10 , 135)	(20 ,-45)	(20 , -135)	(30 , 90)
Our Algorithm	5	4.8	3.1	3.2	1.9
Grid Algorithm	10	10	10	10	10

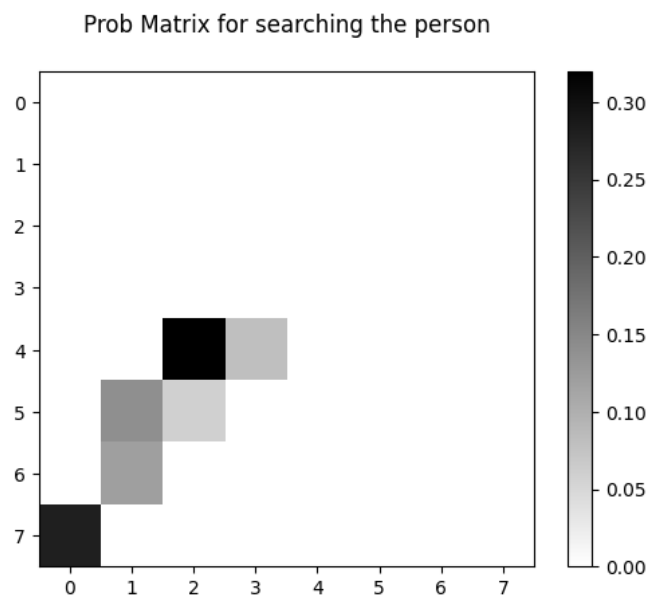
Simulation Result

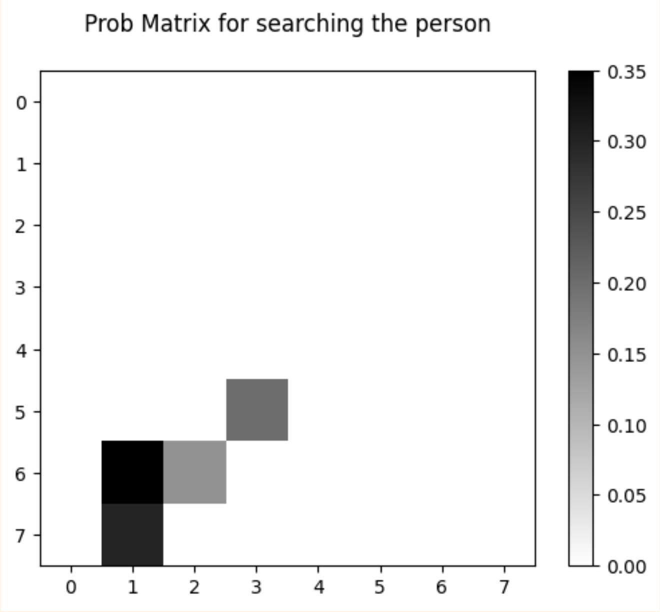


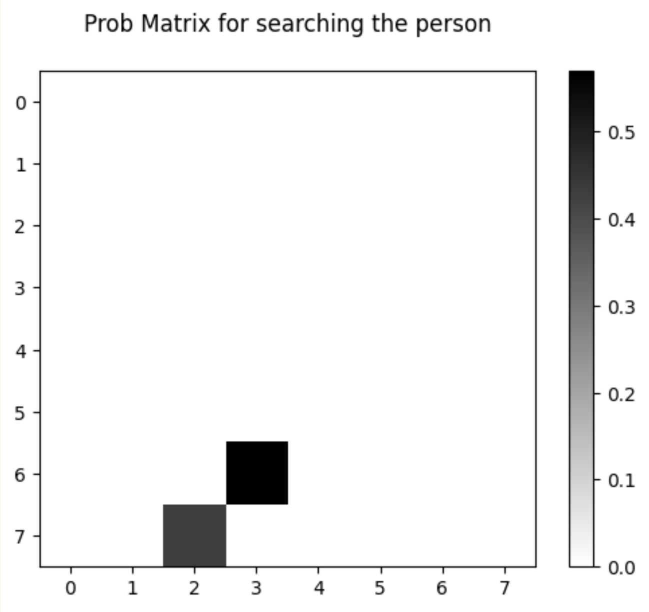












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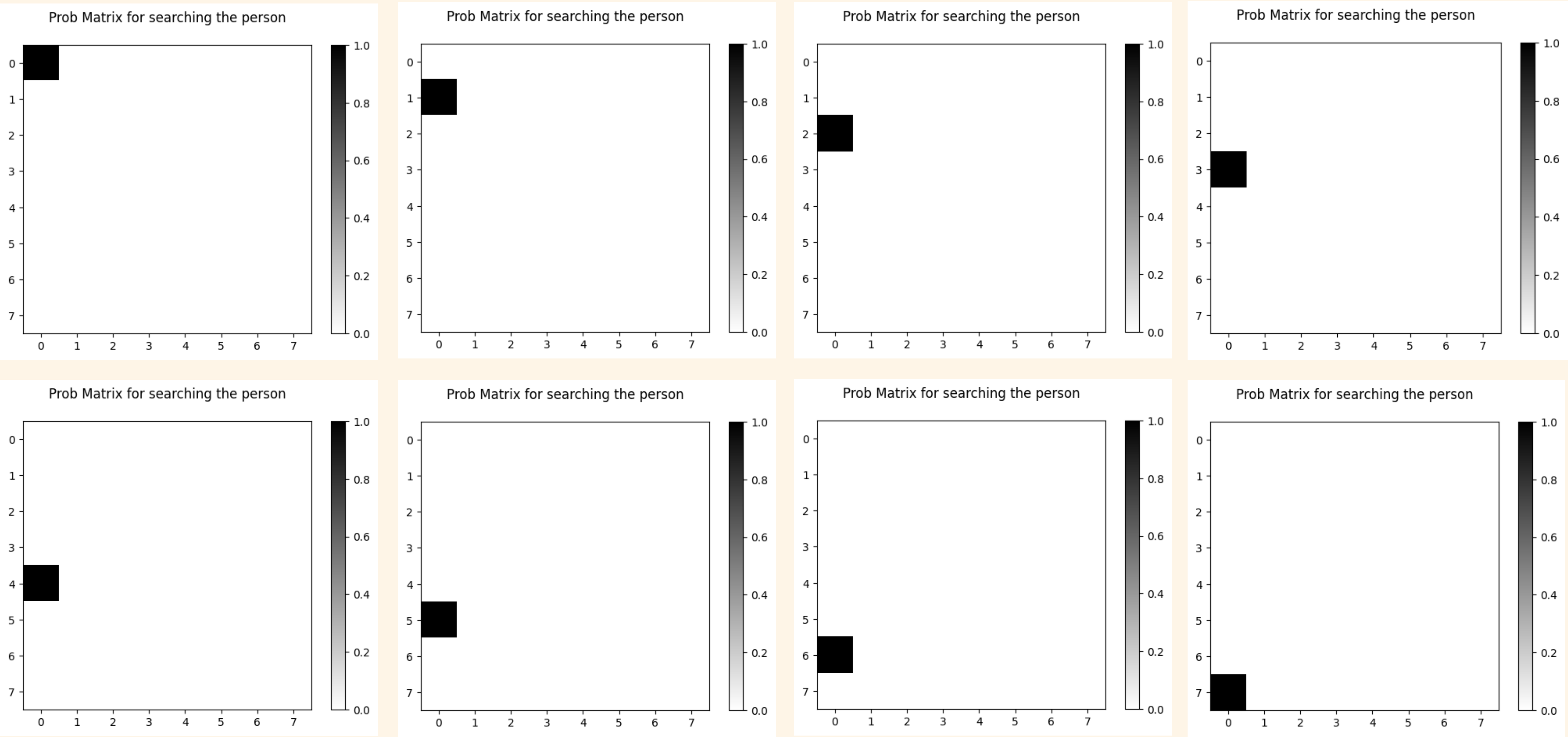

Simulation Result

For 8x8 Matrix: (Speed , Direction) = (10 , 45)

Our Algorithm (Iterations)	Grid Method
4	1
2	2
5	3
5	4
1	9
7	10
8	11
4	17
8	18
6	25
AVG = 5	AVG = 10

For 8x8 Matrix: (Speed , Direction) = (10 ,135)

Our Algorithm (Iterations)	Grid Method
2	1
4	2
5	3
3	4
1	9
7	10
8	11
4	27
8	18
6	25
AVG = 4.8	AVG = 10

For 8x8 Matrix: (Speed , Direction) = (20 , -45)

Our Algorithm (Iterations)	Grid Method
3	1
1	2
4	3
3	4
1	9
2	10
5	11
4	17
5	18
3	25
AVG = 3.1	AVG = 10

For 8x8 Matrix: (Speed , Direction) = (20 , -135)

Our Algorithm (Iterations)	Grid Method
4	1
2	2
5	3
3	4
1	9
3	10
5	11
2	17
5	18
2	25
AVG = 3.2	AVG = 10

For 8x8 Matrix: (Speed , Direction) = (30 , 90)

Our Algorithm (Iterations)	Grid Method
2	1
1	2
3	3
2	4
1	9
1	10
3	11
2	17
3	18
1	25
AVG = 1.9	AVG = 10

Conclusion and Recommendations

Conclusion

The developed simulation model provides a valuable tool for naval commanders to plan and execute highly effective search operations, optimizing the use of limited resources and improving overall search effectiveness.

Our Algorithm takes atleast 50 % less searches than the uniform search to capture the target.

Our Algorithm demonstrates effectiveness in adapting to varying wind conditions and directions, resulting in optimal search iterations compared to the static grid-based approach.

The adaptability is crucial for enhancing naval search operations' efficiency and maximizing the probability of detecting missing items while minimizing search time.