Defining lines of maximum probability for the design of patrol vessel itineraries

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Fernando Bação
Victor Lobo
bacao@isegi.unl.pt; www.isegi.unl.pt

Outline

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4. Some results
5. Conclusions and future work

Introduction

• A large number of tasks performed by the Portuguese navy are related with non-military missions such as:
  • enforcing the protection of the Portuguese Exclusive Economic zone from illegal fishing activities;
  • monitoring environmental risks;
  • search and rescue missions (SAR).

The Problem

• Defining patrol itinerary:
  • Important problem in the planning stage of these missions.
  • Presently, largely based on the previous empirical experience of the officer in charge.
  • There are no guidelines or objective criteria to support the patrolling itinerary design.

The Problem

• Find a method for defining the best patrol itinerary
  • There are data available from previous missions.

The Problem

• It can be considered that the best route is the one that roughly goes through all the points where occurrences of the same kind were reported in the recent past.
  • Using this criterion the problem can be thought of as being an instance of the Traveling Salesman Problem (TSP), more rigorously a special case of the TSP.
The SOM and variants

The Problem

- There are important differences between this and the TSP:
  - while in TSP the problem is essentially an operational one;
  - here the focus is on producing the path that, based on the observed occurrences, "best predicts future occurrences".

Objective

- Our main assumption:
  The best predictor for future occurrences is given by the set of points that represent the position of the historically reported occurrences.

Objective

- We seek to establish a strategy which enables a more consistent approach to the design of patrol itineraries
- Establishing a more objective and optimal procedure.
- Propose a method to define the routes of "maximum probability"

Related work

- Complexity analysis and possible solutions can be based on the TSP.
- The TSP is a well known problem that has been thoroughly studied in operations research (OR).

"If a salesperson has to visit n cities and if he desires to minimize the distance, which is the best path?"

Related work

- The only way to find the optimal solution consists on calculating (at least implicitly) all the possible paths.
- The number of possible paths for n cities is given by n!

<table>
<thead>
<tr>
<th>Nº Cities</th>
<th>Possible Paths</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>10</td>
<td>3628800</td>
</tr>
<tr>
<td>50</td>
<td>3.04141E+64</td>
</tr>
<tr>
<td>70</td>
<td>1.1979E+100</td>
</tr>
<tr>
<td>90</td>
<td>1.4857E+138</td>
</tr>
</tbody>
</table>

Our Proposal

- For our purpose the relative density of the points of previously reported occurrences is much more relevant than the actual exact position of each of the reported occurrences.
- Given the preemptive nature of these missions the objective is to use the historical data to loosely orientate the path.
- The fundamental idea is that areas of high density of reported occurrences constitute a good predictor of future occurrences. For this reason the areas of high density should be patrolled.
Our Proposal

• To accomplish these objectives we need a tool that is able to fit a line based on the density of previous occurrences.

• Taking advantage of some of the work developed in the adaptation of the SOM to the TSP we propose the use of a 1-dimensional SOM for the calculation of the best patrol itinerary.

The SOM and variants

The Self-Organizing Map

• Unsupervised neural network, used for data visualization, reduction and clustering
• It maps data onto a 1 or 2 dimensional grid

Color Demo
Demo 1
Demo 2

Experimental Setting

• The database file was composed of x,y geographic coordinates and had the following format:

<table>
<thead>
<tr>
<th>Latitude (y)</th>
<th>Longitude (x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>y1</td>
<td>x1</td>
</tr>
<tr>
<td>y2</td>
<td>x2</td>
</tr>
<tr>
<td>y3</td>
<td>x3</td>
</tr>
</tbody>
</table>

• The software used was Matlab and “SOM Toolbox for Matlab”.
• We test both open and closed paths as sometimes is not necessary to start and end the patrol in the same port.
• The tests were performed with SOMs with different numbers of neurons.

Results

• In the first set of tests we used closed paths.
• We ran experiments with different numbers of SOM units (from twice as many as data patterns down to 1/4),
• In each case, we ran 50 independent tests, which due to the non-deterministic nature of SOM lead to slightly different results.

<table>
<thead>
<tr>
<th>Number of SOM units</th>
<th>Average length</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>24.50</td>
<td>3.24</td>
</tr>
<tr>
<td>50</td>
<td>20.00</td>
<td>2.34</td>
</tr>
<tr>
<td>25</td>
<td>14.00</td>
<td>1.86</td>
</tr>
<tr>
<td>10</td>
<td>10.00</td>
<td>2.46</td>
</tr>
</tbody>
</table>
Results

- We repeated all previous tests using open paths.
- In this case, it is assumed that the patrol vessels may start and end their cruises in different ports, which would be those closest to the beginning and end of the itineraries obtained.
- One again we ran 50 experiments for each number of possible SOM units.

<table>
<thead>
<tr>
<th>Number of units</th>
<th>Average length</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>30.00</td>
<td>0.047</td>
</tr>
<tr>
<td>20</td>
<td>40.00</td>
<td>0.051</td>
</tr>
<tr>
<td>30</td>
<td>50.00</td>
<td>0.053</td>
</tr>
</tbody>
</table>

- Distance decreases as the number of units decreases.
- The std is much lower in this case, indicating an "easier" optimization problem.

Conclusions

- We conclude that SOMs can be used as a flexible and quick way to solve the best patrol itinerary problem.
- The processing time is rather small (around 8 seconds on a standard PC) which allows real time redefinition of the path as new information is acquired.
- The use of points related with past occurrences gives the opportunity to design an itinerary which constitutes an informed "best guess" on where the presence of the patrol vessel is bound to discourage illegal fishing activities and be available for SAR missions.

Conclusions

- We do not, at present, show any comparisons with other methods, since no other systematic methods are used to perform this task.
- There are four main aspects that must be improved:
  - the use of true geographic distances,
  - forcing initial/final home ports,
  - taking into account natural barriers, and
  - using SOM unit density to define speed.

Thank you