Article

Title

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Abstract: The proposed work aims to provide a path planning solution that use data about sea and weather conditions to find the optimal path the links 2 positions.

Keywords: path planning; sea-state

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1. Introduction

In recent years, robotics has been optimizing the monitoring and exploration of maritime and coastal scenarios through the use of multiple and sophisticated autonomous systems. This category includes the Autonomous Underwater Vehicles (AUV), underwater robots capable of completing missions autonomously, and the Autonomous Surface Vehicles (ASV), vehicles that rotate on the surface of the water without a crew. The application fields are various: geological prospecting, oceanographic monitoring, military sector, etc. Maritime navigation is an essential aspect of the shipping industry. Path planning in a maritime scenario is the process of determining the optimal route a vessel can take from the point of departure to the destination.

The goal of this paper is to propose a new path planning method that uses a probability map to influence the final path according to the sea-weather conditions. The algorithm has bees tested on a real scenario, where the path planning has been performed in a maritime environment in the "Gulf of Naples" (Italy) according to the "**Progetto ARES**. Our contribution to the project is the development part of a DSS (Decision Support System) that helps the operator during a mission by providing a path planning solution that takes into account the sea-weather conditions. The focus will be on discussing the various challenges that arise in this area and the proposed solutions to overcome them. The method will be compared to some state-of-the-art techniques too.

1.1. State-of-the-art

TODO

1.2. Our contribution

TODO

2. Method

The Sum Product Algorithm (SPA) is a well-known technique in the field of probabilistic graphical models, used to efficiently calculate the marginal probabilities of variables in a factor graph. In recent years, researchers have applied the SPA to the problem of path planning in robotics and autonomous vehicles. The SPA can be used to compute the probability of a robot successfully reaching a destination, given the current state of the environment, such as the presence of obstacles or the position of other objects. This approach allows for more efficient and accurate path planning, as it takes into account the uncertainty inherent in real-world environments. By leveraging the power of probabilistic inference techniques like the SPA, researchers are making significant strides towards creating more robust and effective path planning systems for a wide range of applications. The probabilistic frame espoused in this work is grounded on Factor Graphs(FG) that represent a unified way of rephrasing di rected and undirected probabilistic graphical models in an easy- to- manipulate forward and backward communication propagation(signal inflow). Our work on FG in reduced normal form(FGrn) has further simplified the FG frame reducing the network to interconnections of single-input single-output(SISO) blocks and diverters. Probabability consistence can be fluently propagated for conclusion and literacy. Seminal work on FG can be set up in and; some details on the optimized executions of FGrn can be set up in.

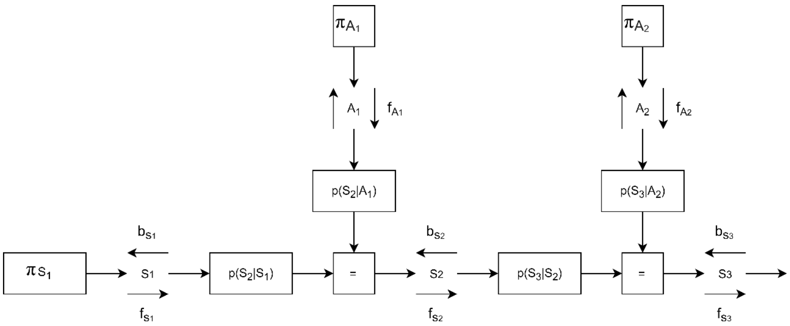

Figure 1. Factor graph in normal reduced form

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$$\begin{array}{l}
f_{(S_tA_t)^1}(s_ta_t) = \sum_{s_{t-1}a_{t-1}} p(s_ta_t|s_{t-1}a_{t-1}) f_{(S_{t-1}A_{t-1})^3}(s_{t-1}a_{t-1});\\
b_{(S_{t-1}A_{t-1})^3}(s_{t-1}a_{t-1}) \propto \sum_{s_ta_t} p(s_ta_t|s_{t-1}a_{t-1}) b_{(S_tA_t)^1}(s_ta_t);\\
f_{(S_tA_t)^2}(s_ta_t) = c_t(s_ta_t);\\
b_{(S_tA_t)^2}(s_ta_t) \propto b_{(S_tA_t)^3}(s_ta_t) f_{(S_tA_t)^1}(s_ta_t);\\
b_{(S_tA_t)^1}(s_ta_t) \propto f_{(S_tA_t)^2}(s_ta_t) b_{(S_tA_t)^3}(s_ta_t);\\
f_{(S_tA_t)^3}(s_ta_t) \propto f_{(S_tA_t)^1}(s_ta_t) f_{(S_tA_t)^2}(s_ta_t).
\end{array} \tag{1}$$

where the simbol $\propto$ means "proportional to" because only some messages are normalized. The posterior distributions of all variables are obtained via the product rule between the forward and backward messages:

$$p_{(S_tA_t)^i}(s_ta_t) \propto b_{(S_tA_t)^i}(s_ta_t) f_{(S_tA_t)^i}(s_ta_t), \quad t = 1, ..., T; \;\; i = 1, 2, 3. \tag{2}$$

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In our work, we consider a discrete environment of size $N \times M$ and the considered agent can move in eight directions: up, down, left, right, and the four diagonal directions. Using a discrete representation of the environment, each cell of the grid, that rapresent the possible states of the agent, can be associated with a variable $r_{i,j}$ (Reward), where i and j are the row and column indices of the cell, respectively. The value of $r_{i,j}$ is 1 if the cell is occupied and 0 if the cell is completly free of obstacles or a value between 0 and 1 whereever there is an higher or lower preference to move in that cell. The agent can move from one cell to another only if the destination cell is free.

The reward function $r_{i,j}$ is a function of the current state of the environment, and it is assumed to be known to the agent. This function has been obtained by modeling the input dataset and it will be discussed in the next section.

2.1. Input data

The developed module takes as input several sets of data divided into:

- Data for the construction of the parameterized map: wave motion
- Mission data: mission objectives, NG Worker start and goal positions, drone release positions(Intermediate positions), mission duration, etc.;

All the weather data are provided by the PARTHENOPE[2]. The data are provided in the form of a netCDF file, which is a self-describing file format that allows the storage of multidimensional arrays of scientific data and they are used to store both the map and the reward function. As input data for the construction of the reward function, the following parameters are considered:

- Significant height of wind and swell waves(see figure 2a).
- Peak direction(see figure 2b).
- Costal map(see figure 3a).

The signficant height of the waves information has been used to get the informations about the Sea State.The term Sea State describes the general condition of the surface of the open sea. This is comprised of two core measurements, the wave height which is dependent on the local surface wind strength and thus termed the 'wind sea' and the swell which i s a slow and regular movement of the sea in rolling waves that do not break and are in the process of dissipating as they travel from their relatively distant origin.
The sea state is described by the following chart:

Code	**Heigt [m]**	**Description**
0	no wave	Calm (Glassy)
1	0 - 0.10	Calm (Rippled)
2	0.10 - 0.50	Smooth (Wavelets)
3	0.50 - 1.25	Slight
4	1.25 - 2.50	Moderate
5	2.50 - 4.00	Rough
6	4.00 - 6.00	Very Rough
7	6.00 - 9.00	High
8	9.00 - 14.00	Very High
9	14.00+	Phenomenal

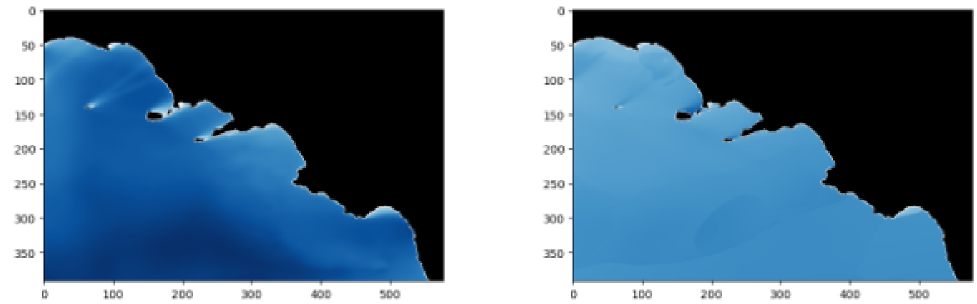
Those informations are trasformed in a probabilistic fashion using values from 0 to 1, where 0 means sea state 0 and 1 sea state greater or equale to 4.
Sea state greater then 4 are considered as the same because the considered agent (NG Worker) is not able to operate in those conditions.
SPIEGARE DELLA SCELTA DI INCLUDERE VALORI FINO A SS 4 The costal map is a binary map where 1 represents the presence of a coast and 0 the absence of a coast. This map has been processed applying a Gaussian filter to the original map to create a smooth transition between the coast and the sea to create different zones to avoiding collisions of the results path with the coast as shown in figure 3b.

The reward function is obtained by combining the three parameters in a weighted sum and then normalizing the result in the range [0,1].

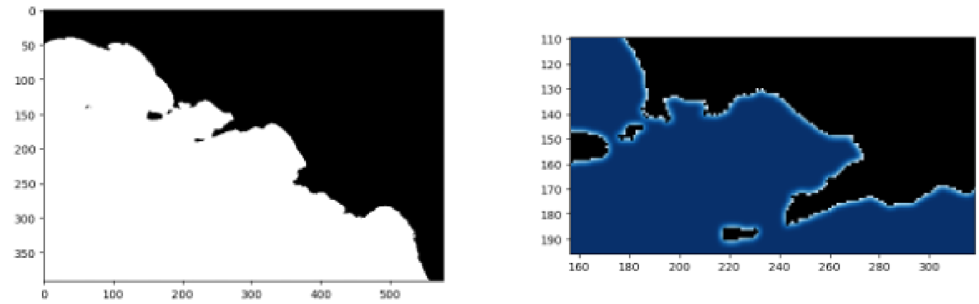
TODO

2.2. Algorithm

TODO



(a) Wave height **(b)** Peak direction



(a) Costal map **(b)** Costal map smoothed

2.3. Communication

The communication between all the components of the DSS can comunicate through a MQTT broker. MQTT or Message Queue Telemetry Transport is a featherlight and effective message protocol developed for the Internet of effects(IoT). It allows bias to change data in a publish- subscribe model, where data is published by a sender and entered by one or further subscribers. The protocol is grounded on a customer- garçon armature where guests can publish or subscribe to motifs on a garçon(also known as a broker). MQTT is ideal for IoT bias because it consumes minimum bandwidth and has low above, making it able for low- authority and resource- constrained bias. Its simplicity, scalability, and trustability have made it popular with inventors and has come a standard-issue protocol in the IoT assiduity. An MQTT broker is a intermediary mecca that acts as a communication broker between MQTT guests. It's responsible for entering, storing, and ranking dispatches between guests. When an MQTT customer publishes a communication to a special content, the broker receives the communication and forwards it to all acceded guests that are interested in that content. also, when an MQTT customer subscribes to a content, the broker stores the subscription and forwards any dispatches published on that content to the acceded customer.

On the other phase, an MQTT customer is a device or operation that communicates with an MQTT broker. It can be either a publisher, subscriber, or both. When a customer publishes a communication to a special content, it sends the communication to the broker, which also on it to all acceded guests. When a customer subscribes to a content, it sends a subscription request to the broker, which stores the subscription and forwards any dispatches published on that content to the acceded customer.

In summary, the MQTT broker acts as an conciliator between MQTT guests, entering and ranking dispatches, while the MQTT guests are the bias or operations that give with the broker, publishing and assenting to dispatches. Together, the MQTT broker and guests form a publish- subscribe network, allowing effective and dependable message in IoT surroundings.

TODO

3. Results

TODO

4. Conclusions

TODO

5. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

5.1. Subsection

5.1.1. Subsubsection

Bulleted lists look like this:

- First bullet;
- Second bullet;
- Third bullet.

Numbered lists can be added as follows:

1. First item;
2. Second item;
3. Third item.

The text continues here.

5.2. Figures, Tables and Schemes

All figures and tables should be cited in the main text as Figure 4, Table 1, etc.

Figure 4. This is a figure. Schemes follow the same formatting. If there are multiple panels, they should be listed as: (**a**) Description of what is contained in the first panel. (**b**) Description of what is contained in the second panel. Figures should be placed in the main text near to the first time they are cited. A caption on a single line should be centered.

Table 1. This is a table caption. Tables should be placed in the main text near to the first time they are cited.

Title 1	**Title 2**	**Title 3**
Entry 1	Data	Data
Entry 2	Data	Data [1]

[1] Tables may have a footer.

The text continues here (Figure 5 and Table 2).

Figure 5. This is a wide figure.

Table 2. This is a wide table.

Title 1	**Title 2**	**Title 3**	**Title 4**
Entry 1 *	Data	Data	Data
	Data	Data	Data
	Data	Data	Data
Entry 2	Data	Data	Data
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	Data	Data	Data
Entry 3	Data	Data	Data
	Data	Data	Data
	Data	Data	Data
Entry 4	Data	Data	Data
	Data	Data	Data
	Data	Data	Data

* Tables may have a footer.

Text.
Text.

5.3. Formatting of Mathematical Components

This is the example 1 of equation:

$$a = 1, \tag{3}$$

the text following an equation need not be a new paragraph. Please punctuate equations as regular text.

This is the example 2 of equation:

$$a = b + c + d + e + f + g + h + i + j + k + l + m + n + o + p + q + r + s + t + u + v + w + x + y + z \tag{4}$$

6. Discussion

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

7. Conclusions

This section is not mandatory, but can be added to the manuscript if the discussion is unusually long or complex.

8. Patents

This section is not mandatory, but may be added if there are patents resulting from the work reported in this manuscript.

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Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

9.

All appendix sections must be cited in the main text. In the appendices, Figures, Tables, etc. should be labeled, starting with "A"—e.g., Figure A1, Figure A2, etc.

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3. Author 1, A.; Author 2, B. *Book Title*, 3rd ed.; Publisher: Publisher Location, Country, 2008; pp. 154–196.
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