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An Uncertain Vessel Movement Model
for maritime safety and security systems

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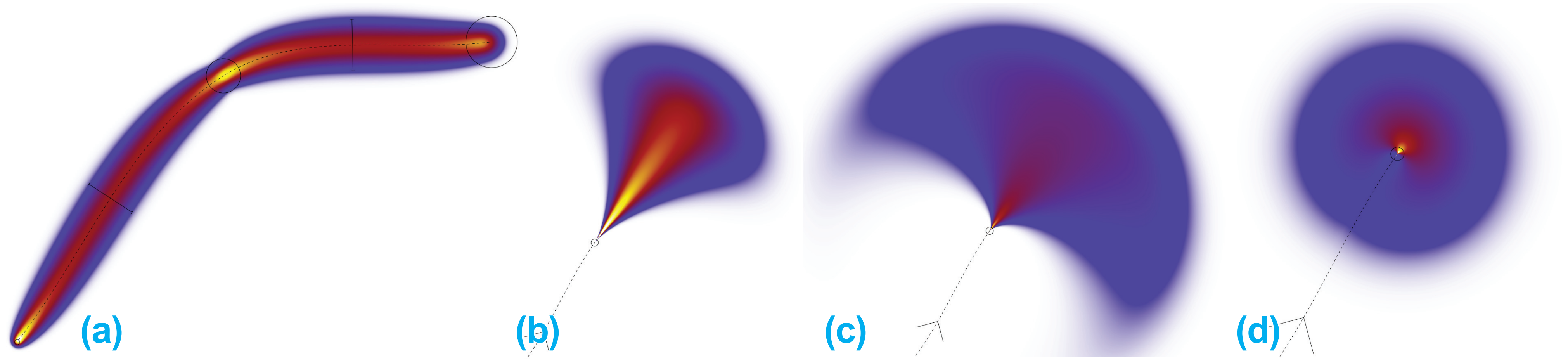
In the maritime safety and security domain, operators have to make decisions based on the available data which may affect lives. To enhance the decision making process, we propose to properly convey the uncertainty present within maritime data such that it plays a role in the decision making process and may improve decision making on the whole.

Visualization

To visualize the probability distributions of the vessels, we use a color map. The mean vessel trajectory is displayed as a dashed line, while the variance of the individual points $\sigma_{\mathbf{p}}$ is shown using a solid circle and the variance of the vessels is shown per line segment by a solid line perpendicular to the line segment and proportional to the movement variance σ_m. A contour can be rendered at a certain probability threshold to denote areas of interest.



Model

We use the Brownian Bridge Movement Model (a) to model a probability distribution between two potentially uncertain points $\mathbf{p}_0$ and $\mathbf{p}_1$:

$$bb(\mathbf{q}) = \frac{1}{T}\int_0^T \mathcal{N}_2(\mathbf{p}, \mu(t), \sigma^2(t)I)\, dt$$

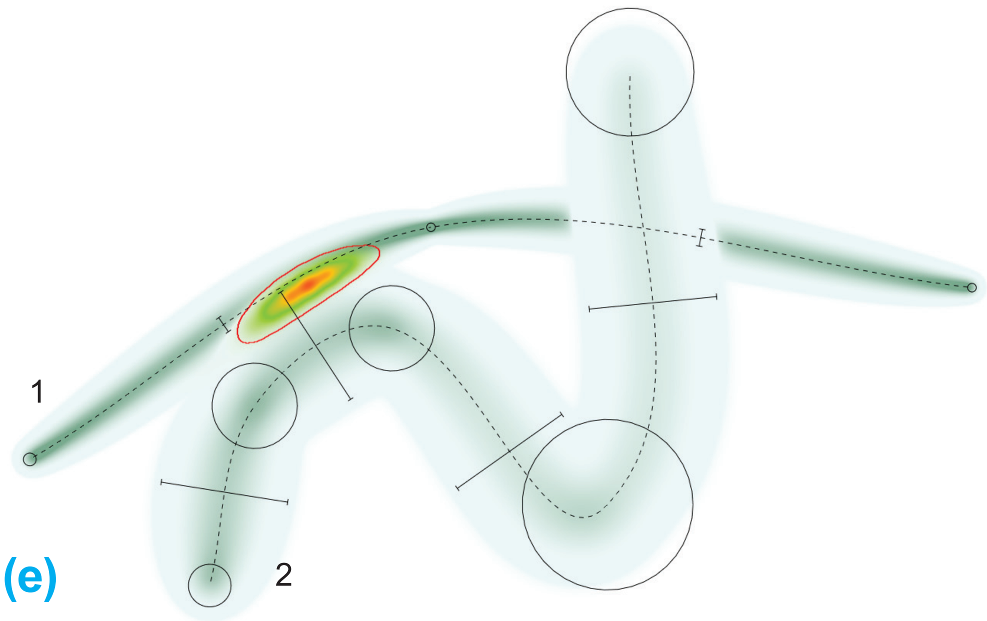
Where $\mathbf{q}$ is some point in space and T is the total time of the movement from $\mathbf{p}_0$ to $\mathbf{p}_1$. The mean follows a spline from $\mathbf{p}_0$ to $\mathbf{p}_1$ at the average velocity, while the variance is based on the movability σ_m of a vessel and the uncertainty in each point $\sigma_{\mathbf{p}_0}$ and $\sigma_{\mathbf{p}_1}$.

To extrapolate the possible future movements of a vessel, given some initial location $\mathbf{p}$, velocity and movability parameters, we use a similar brownian motion-based model in which we model the turning speed and acceleration of the vessel. In Figure (b) we show a vessel with high velocity and acceleration and a low turning speed; In Figure (c) we show a vessel with high velocity, acceleration and turning speed; and in Figure (d) we show a vessel with low velocity and acceleration adn a high turning speed.

We can also show a probability distribution for potential interaction between two vessels, see Figure (e). Interaction is defined by the chance that two vessels are in the same area at the same point in time.

Future work

We would like to extend this work by improving on the probabilistic model, e.g., by allowing interaction between more than two vessels or constraining the movement space with obstacles, improve the visualization of the distribution maps and add some visual cue to visualize the timeliness of the sample points.



The interaction between a large, route-bound vessel (1) recorded with high certainty and a smaller, more manoeuvrable vessel (2), recorded with high uncertainty. The potential area of interaction is highlighted with a red contour.

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