Carnegie Mellon

CASOS

Ph.D. Program in Computation, Organizations & Society

Unsupervised Plan Detection In Maritime GPS Data

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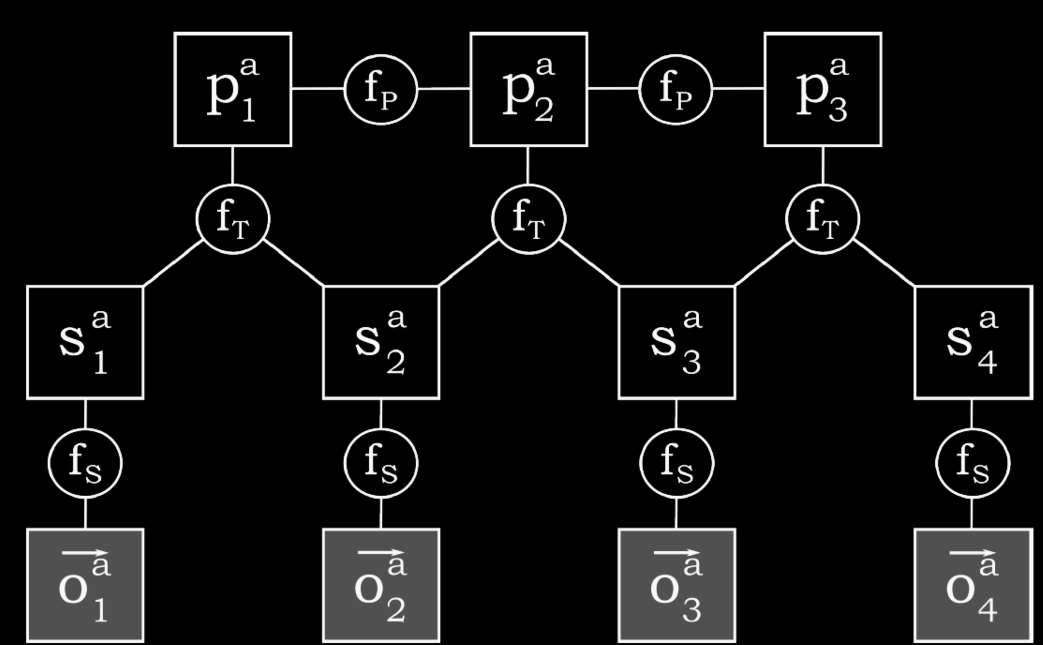
Plan Detection with Factor Graphs

Automating Traffic Monitoring

- Human analysts can look at maps and traces and guess ship destinations, but there are too many to check all!
- We automate plan detection by assuming that ships have hidden plans (destinations) that influence their actions.
- The relationship between observed positions and hidden plans is encoded by a probabilistic factor graph
- The graph compactly represents a joint PDF as the product of the following factors measured on the graph variables:



- *O* variables are GPS locations and speeds at each time step. These observed variables are used to infer the rest.
- *S* variables are hidden state variables represent a meaningful location and speed.
- *P* variables are plan variables representing a destination.
- F_S factors measure compatibility between an observation and a Gaussian centered at the state location.
- F_T factors measure the likelihood of transitioning from one location to another, mediated by the current plan.
- F_P factors represent the chance of transitioning to a new plan (which gives a time scale to the network)

- Once model is trained, future locations can be inferred by adding hidden states and performing Gibbs sampling.

Unsupervised Training

Dealing with Unlabeled Information

- Factor graphs are typically trained by having a set of data for which hidden values are known.
- Since no such training set exists for MMV data, we must do unsupervised learning: we find a set of assignments to hidden variables and values for factor parameters that has ***maximum self-consistency***.

- 2 Variants: Synchronous and Asynchronous EM

Algorithm 1 ASYNCHRONOUS

$\vec{w}^0 \leftarrow$ Draws from prior
$\vec{x}^0 \leftarrow$ Random allocation
$t \leftarrow 1$
loop
  $\vec{w}^t \leftarrow \vec{w}^{t-1}$
  $\vec{x}^t \leftarrow \vec{x}^{t-1}$
  for all $x \in X$ **do**
    $\vec{x}^t \leftarrow (\vec{x}^t \leftarrow x, \operatorname{argmax}_c P_{\vec{w}^t}\left(X = \vec{x}^t \leftarrow (x^t, c)\right))$
    $\vec{w}^t \leftarrow \operatorname{argmax}_{\vec{w}} P_{\vec{w}}(X = \vec{x}^t)$ (local updates)
  end for
  $t \leftarrow t + 1$
end loop

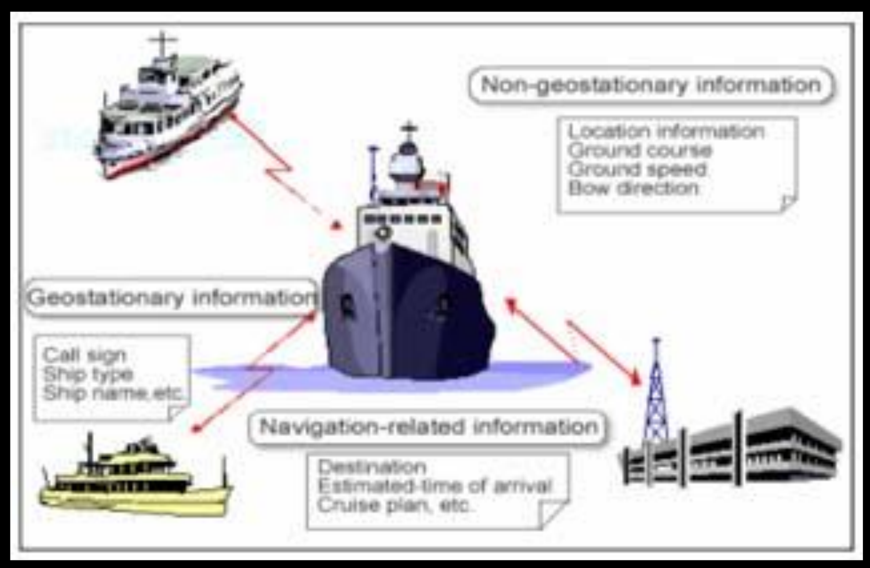
Algorithm 2 SYNCHRONOUS

$\vec{w}^0 \leftarrow$ Draws from prior
$t \leftarrow 0$
loop
  $\vec{x}^t \leftarrow \mathrm{MLE}_{\vec{w}}(\vec{x})$ (calls MLBP)
  $\vec{w}^{t+1} \leftarrow \operatorname{argmax}_{\vec{w}} P_{\vec{w}}(X = \vec{x}^t)$
  $t \leftarrow t + 1$
end loop

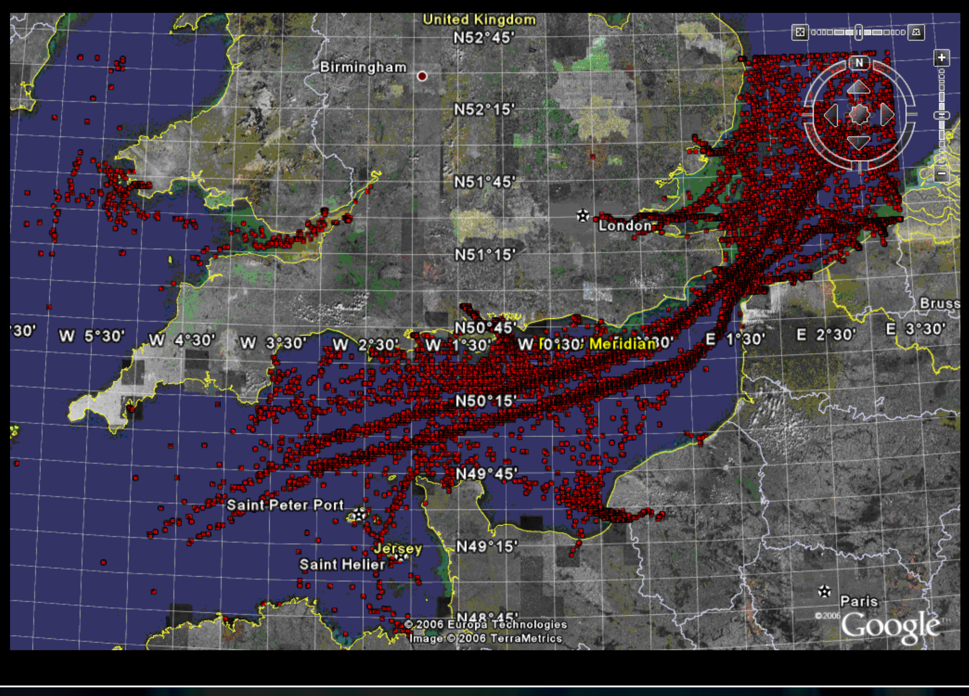
GPS Data on Merchant Marines

Automated Information System (AIS)

- For traffic control and security, large vessels are required internationally to carry an AIS transponder
- AIS transponders can be queried from other ships or ground for GPS location, course, and identity



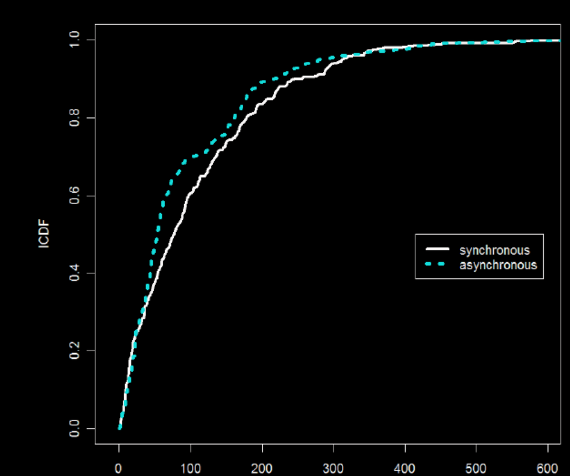
- Sensors queried AIS transponders on vessels traveling through the English Channel over a period of 5 days.
- Over 40000 observations of over 1700 ships were recorded. A small sample is visualized below.

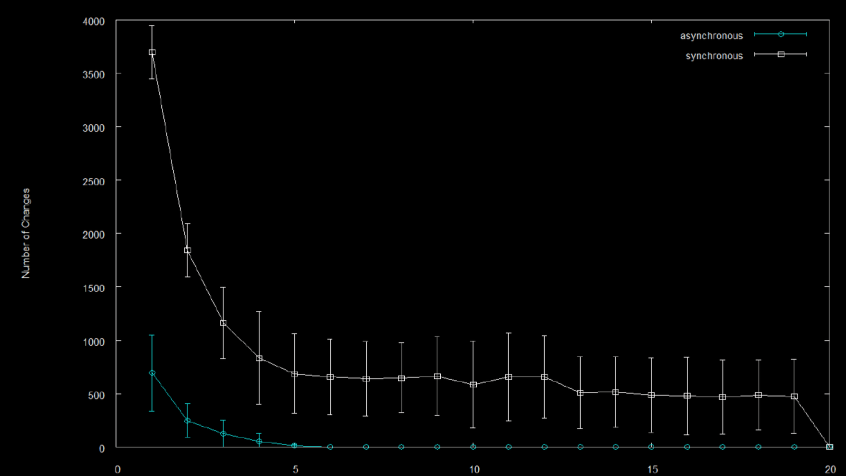


Initial Results

Coarse but Promising Predictions

- Asynchronous updates outperformed Synchronous updates in terms of both convergence rate and prediction accuracy.





- Learned map of likely transitions was compelling but coarse – future work must improve map resolution.

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