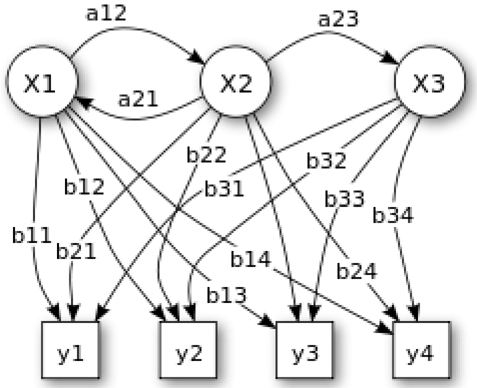
Markov Models

Applied to Anomaly Detection

By Saab Group



The paper

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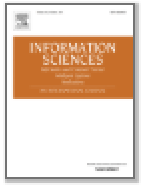

Anomaly detection based on a dynamic Markov model

Huorong Ren [a, b], Zhixing Ye [a, b], Zhiwu Li [c, a]

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What is a Markov Model?

- In probability theory, a Markov model is a stochastic model **used to model randomly changing systems**.

- It is assumed that **future states depend only on the current state**, not on the events that occurred before it (that is, it assumes the Markov property).

What is a Markov Model?

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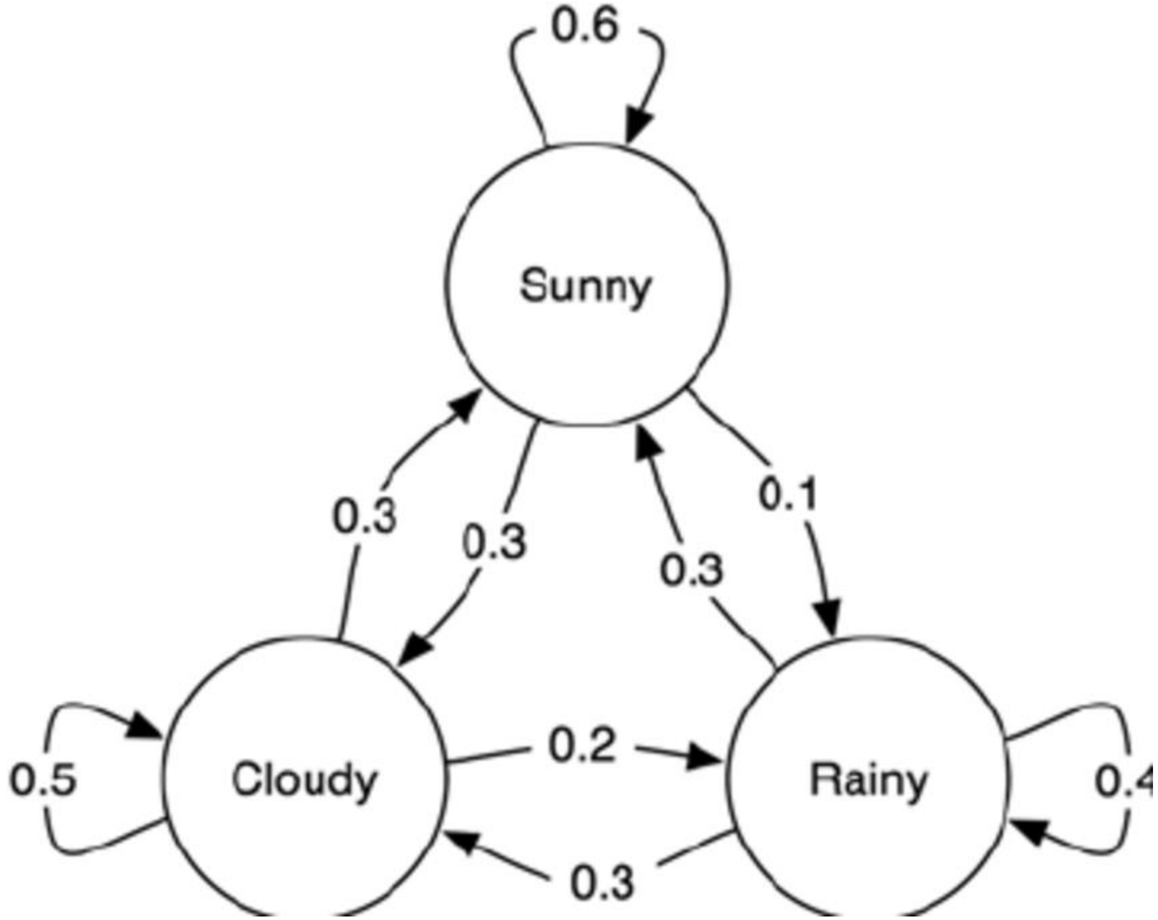
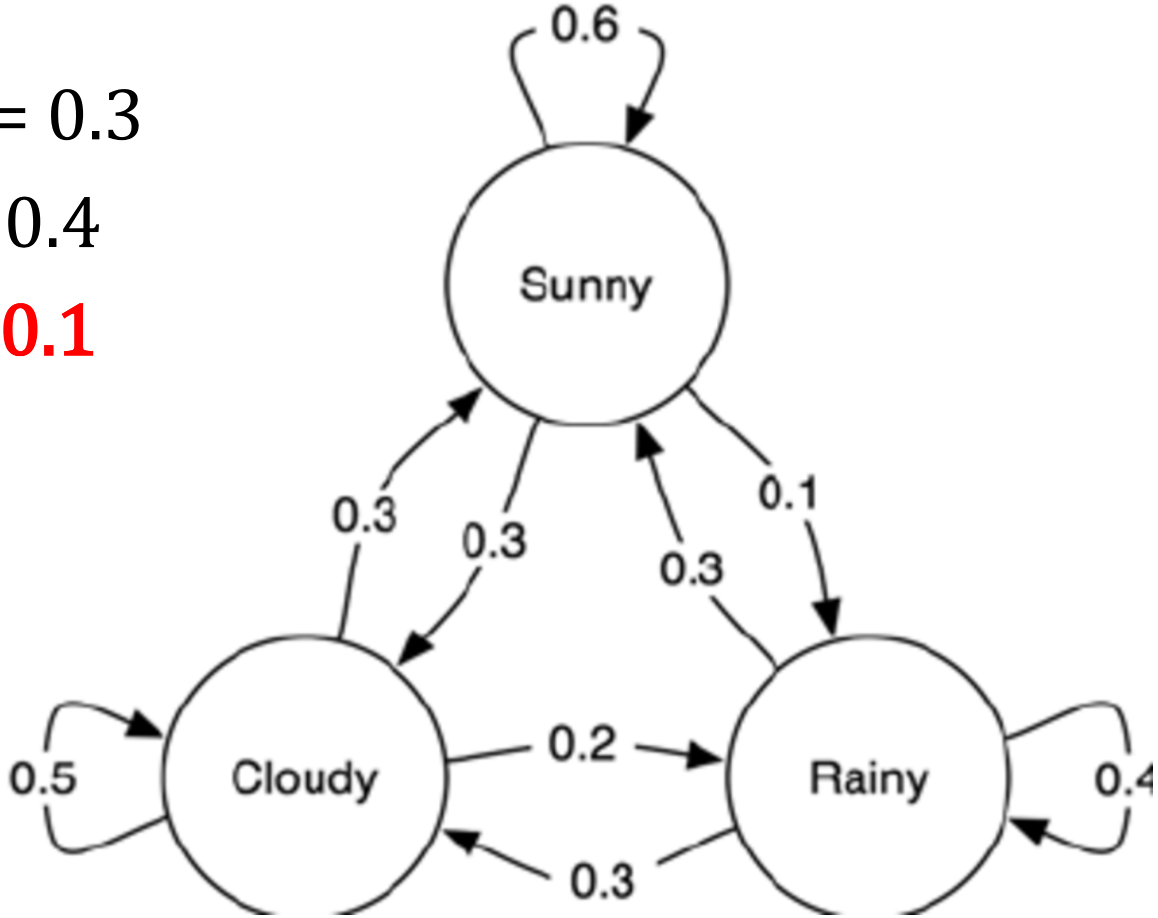


Why is this helpful in anomaly detection?

- P(sunny|cloudy) = 0.3
- P(rainy | rainy) = 0.4
- P(rainy|sunny) = **0.1**



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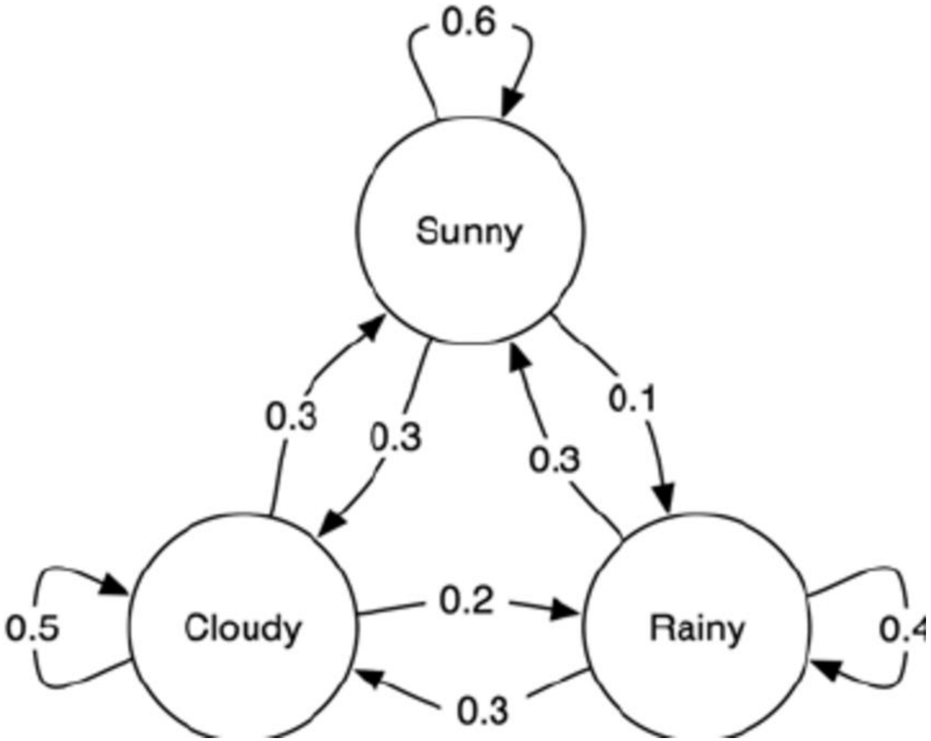
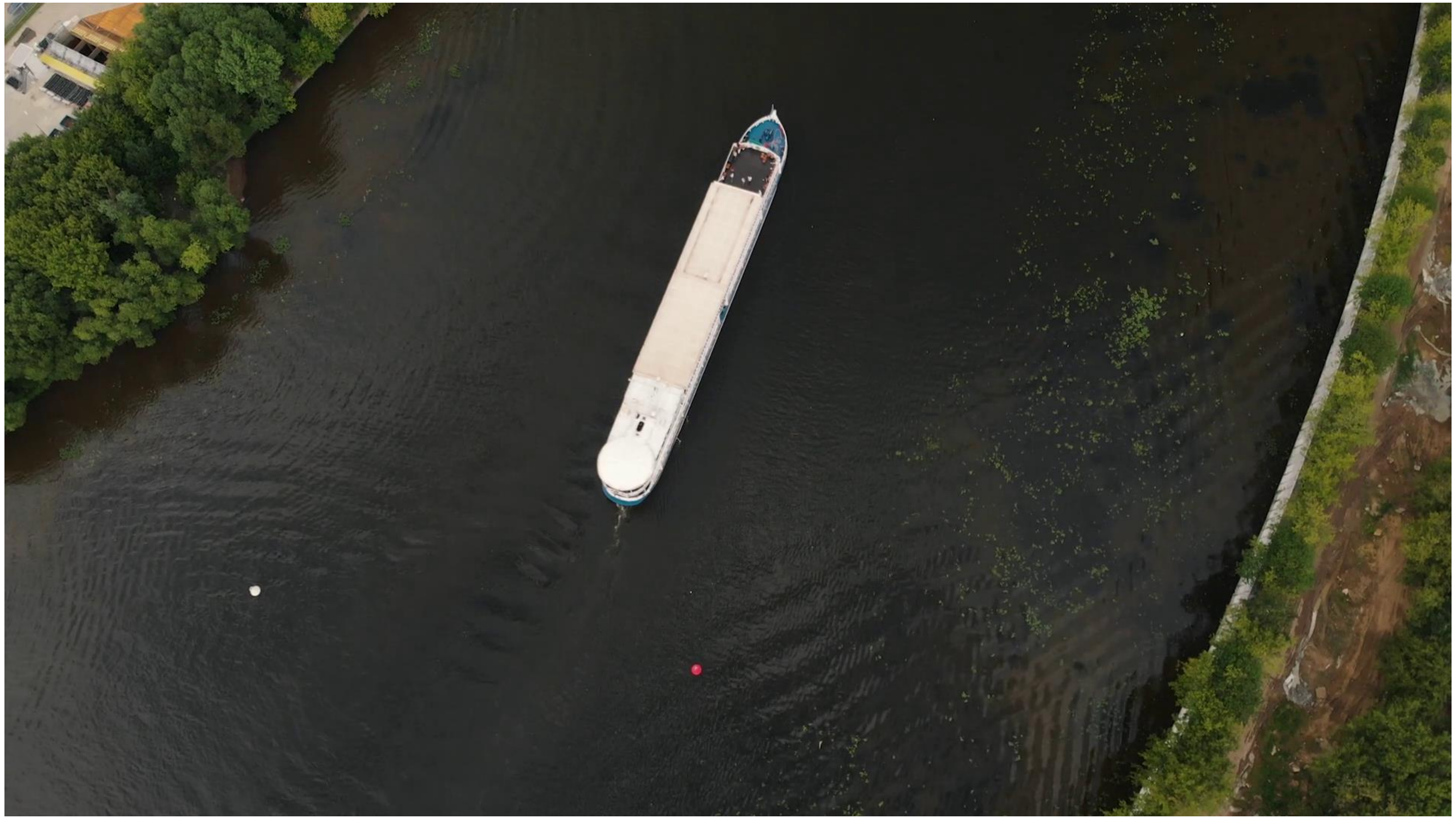
ANOMALY
DETECTED



Why can this be applied to our Project?



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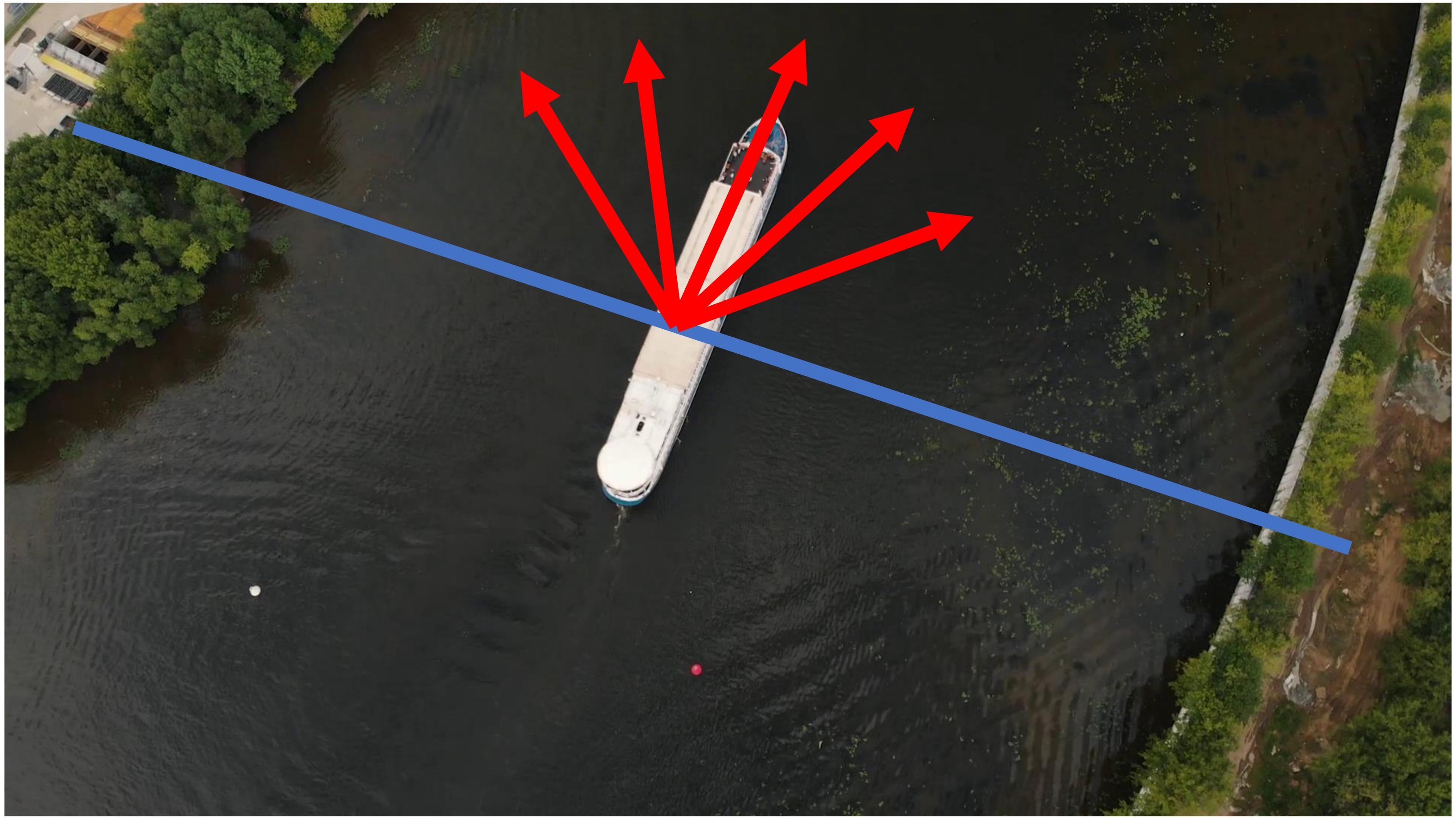

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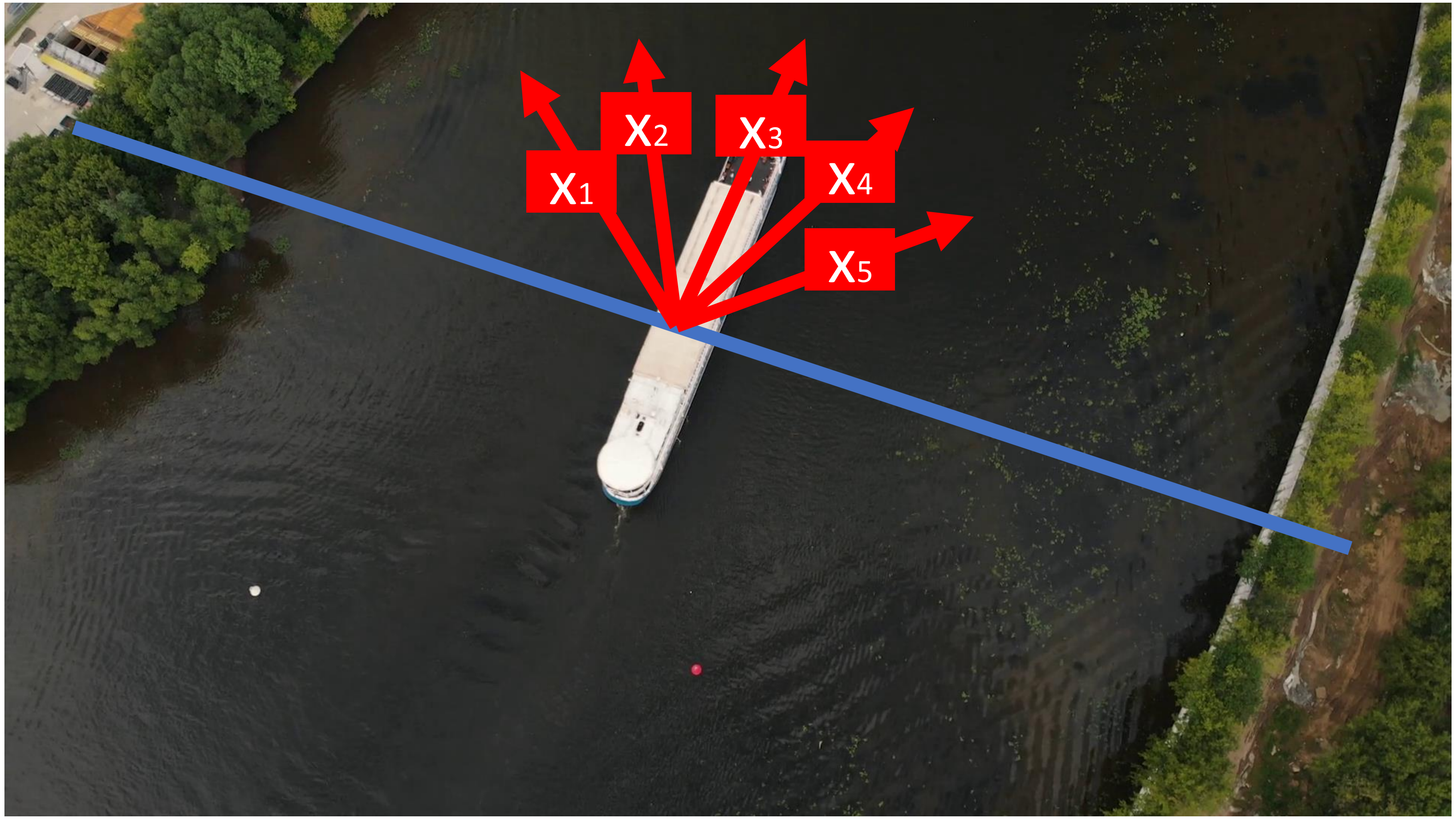
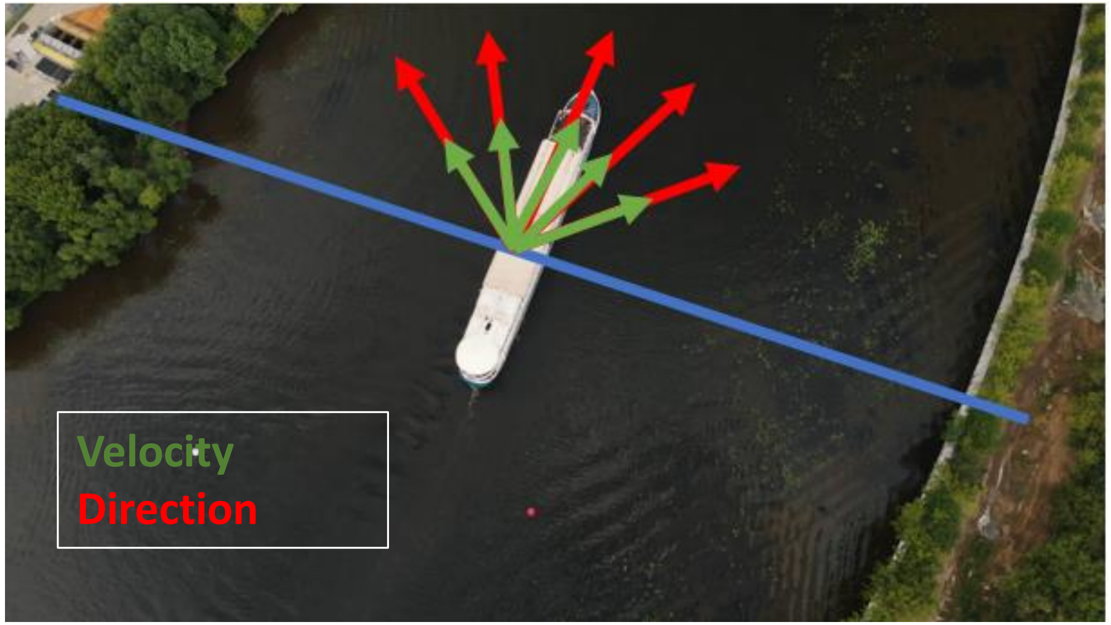
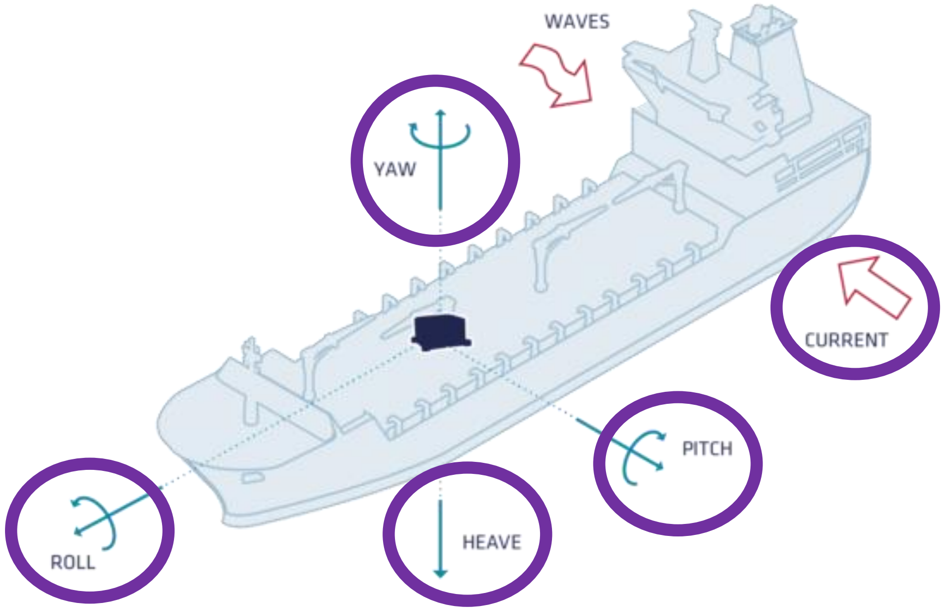


Transitions

And… if we have other interesting features?





Since all measurements are bounded

- We can partitionate them and classify them
- E.g:

So what's the average speed of a sailboat? **Most sailboats cruise at a speed of 4-6 knots (4.5-7 mph), with a top speed of 7 knots (8 mph or 13 km/h). Larger racing yachts can easily reach speeds up to 15 knots (17 mph or 28 km/h), with an average cruising speed between 6-8 knots (7-9 mph). Cruising speeds of over 8 knots are uncommon.**

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0 km/h

30 km/h

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0 km/h

30 km/h

slow

normal

fast

Since all measurements are bounded

- We can partitionate them and classify them.

- Now each classification is a substate of the measurement, so that for speed we have both slow, normal and fast sub-states.

- Position could be partitioned into **suspicious** and **non-suspicious** according to the history of anomalies detected in a certain port.

- The direction can also be partitioned(we Will see it in the following slides).

Since all measurements are bounded

- So if we use in out model 3 states representing the speed, 2 states representing the position and 5 states representing the direction, there Will be:

$$\binom{10}{3} = 120\ states$$

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- **This might be too much (or not)**

?

More Data

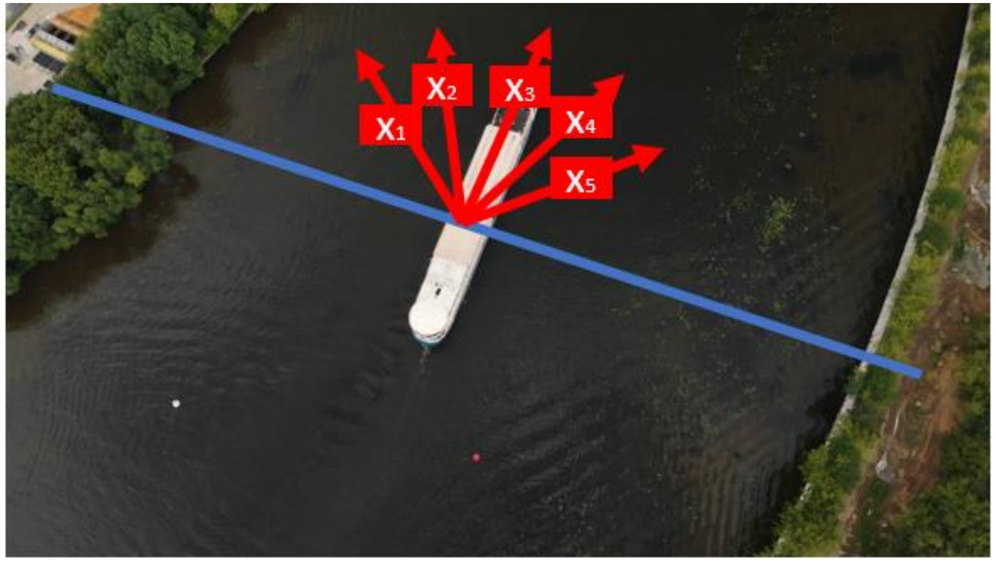
=

More information
per state

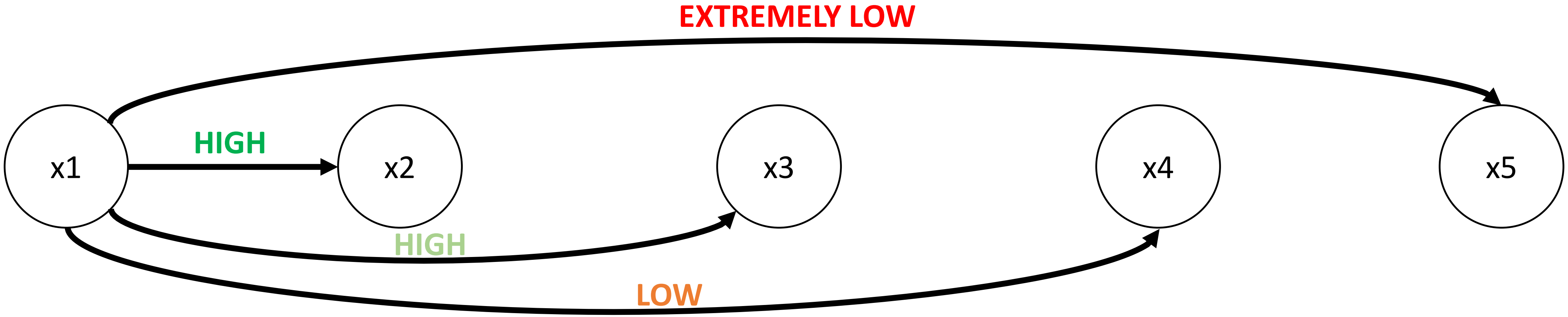
An example focusing only in direction

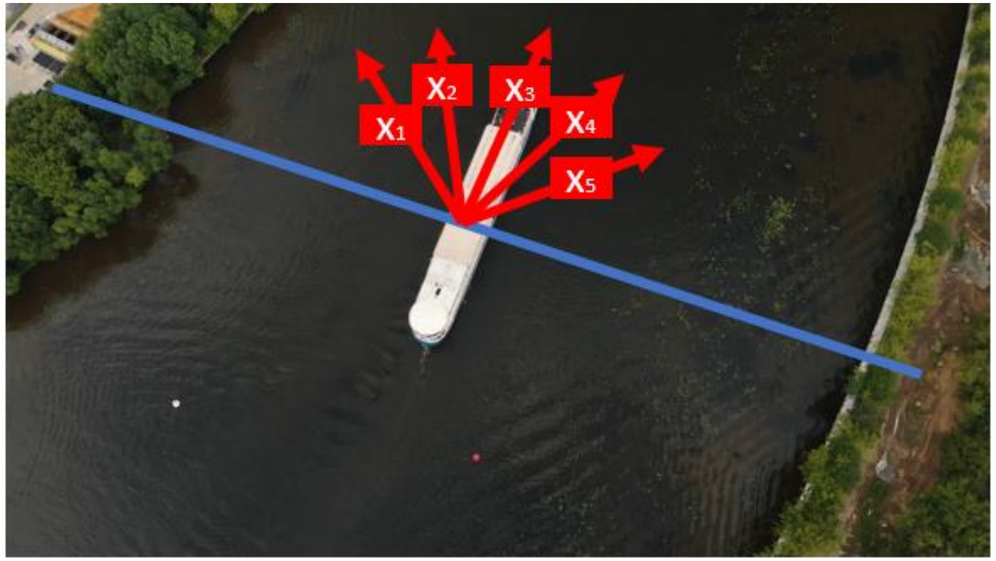
- We can extract much more features (depends on the data)

x1 x2 x3 x4 x5



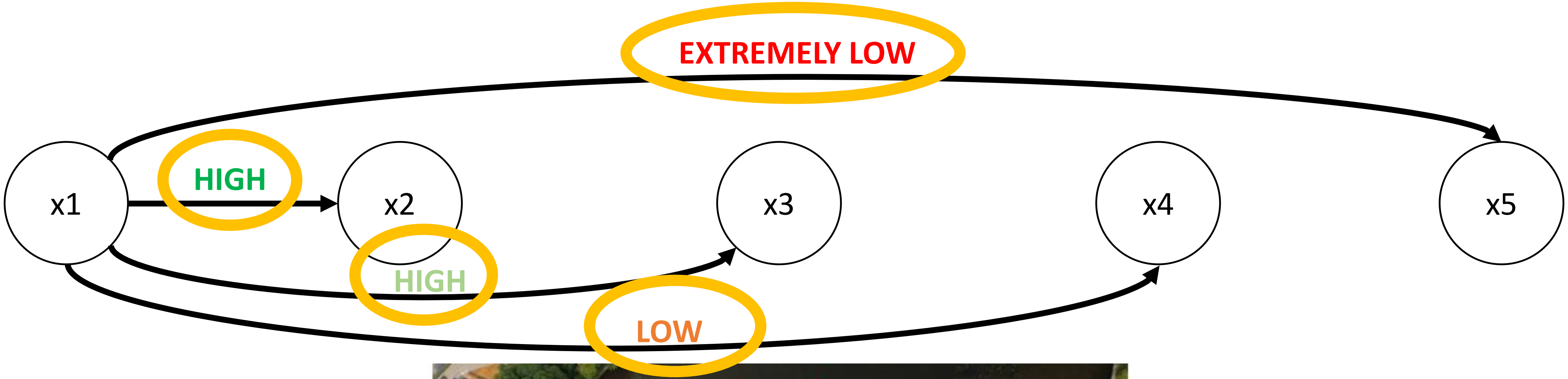
Basic Model

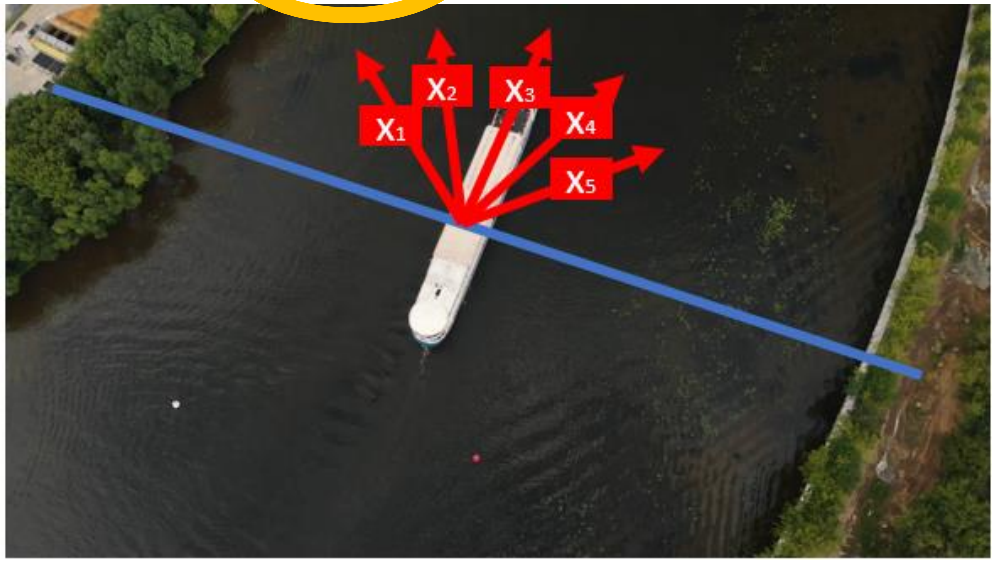




Basic Model

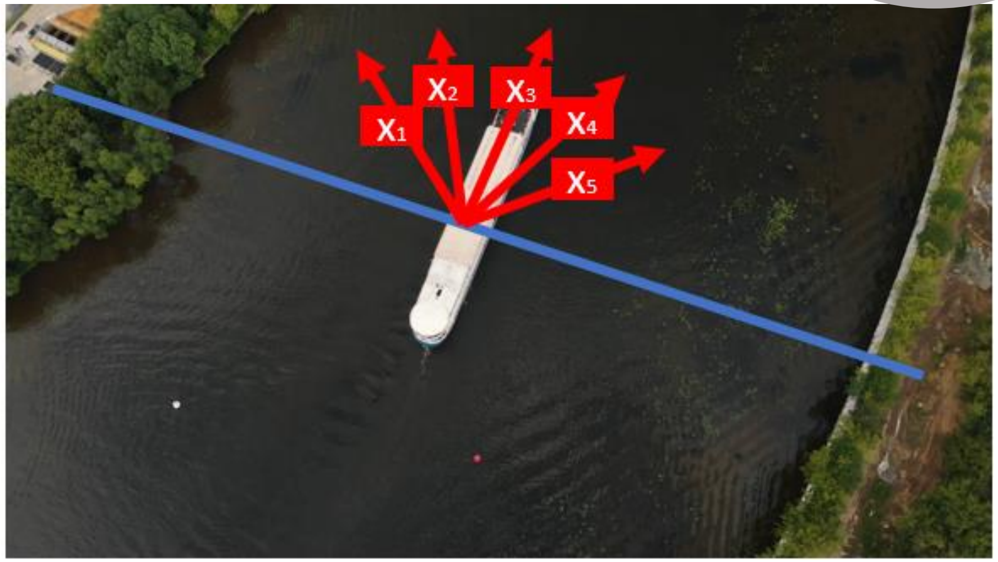
What could we extract from the





Basic Model

Finally...



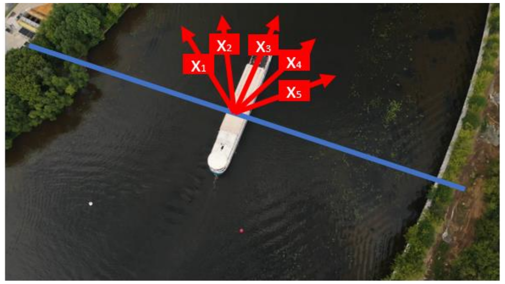
If there is a transition from x1 to x5:

WE ARE JUST IN FRONT OF AN

Implementation

Finally...

Once defined the states, we can compute probabilities of transition between one state to another and represent them on a matrix



Transition Probability Matrix

$$\begin{array}{cc} & \begin{array}{cccc} 1 & 2 & \cdots & n \end{array} \\ \begin{array}{c} 1 \\ 2 \\ 3 \\ \vdots \\ m \end{array} & \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ a_{31} & a_{32} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \end{array}$$

a_{ij} = Probability of transition from i to j

Idea:

- Get the probability values from a training set
- Evaluate the model with the test set
  - Whenever a transition happen, check the probability of that to have ocurred and if it is under a tested threshold → ANOMALY

Also Interesting

- **Problem**
  - Speed and size of the ships should get evaluated in conjunction.
    - Higher speeds are supossed to be adopted by smaller ships
    - High speeds are not anomalous for big ships
- **Markov Models allow us to evaluate speed and length together**
  - Given a range of posible values for speed and length, we can partitionate both so that given a **transition pair**

(speed1, length)→ (speed1, length)

Initially: (100km/h, 500m) → → (type 7, type 5) → STATE 4

Finally: (20 km/h, 500m) → → (type 4, type 5) → STATE 7

SO

STATE 4 to STATE 7

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