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STO TECHNICAL REPORT

PUB REF STO-MP-SAS-114-PPK

ANNEX K
Risk Game: Impact of Information Quality on Decision Making

Anne-Laure Jousselme

Risk Game

Impact of information quality on decision making

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NATO STO
Centre for Maritime Research and Experimentation (CMRE)
La Spezia, Italy

NATO SAS114

Copenhagen, 7 December 2016

Outline

CMRE Maritime Security programme overview

The Risk Game design

Preliminary results

Formalisation

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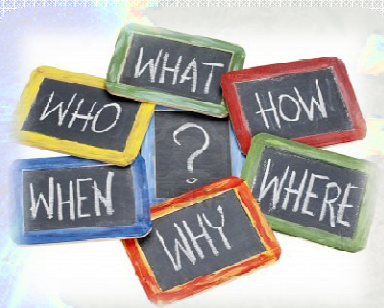
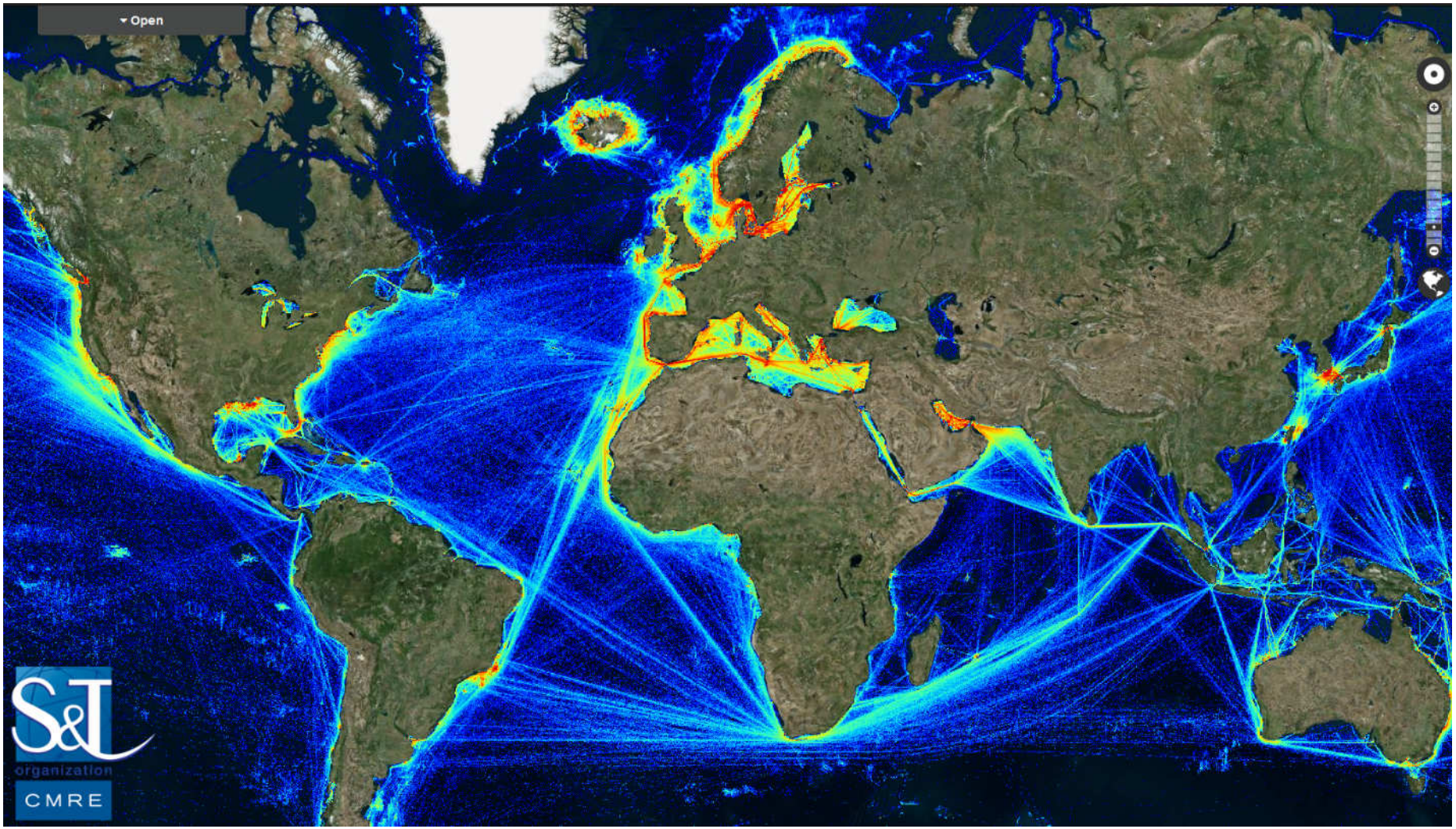
Maritime Security

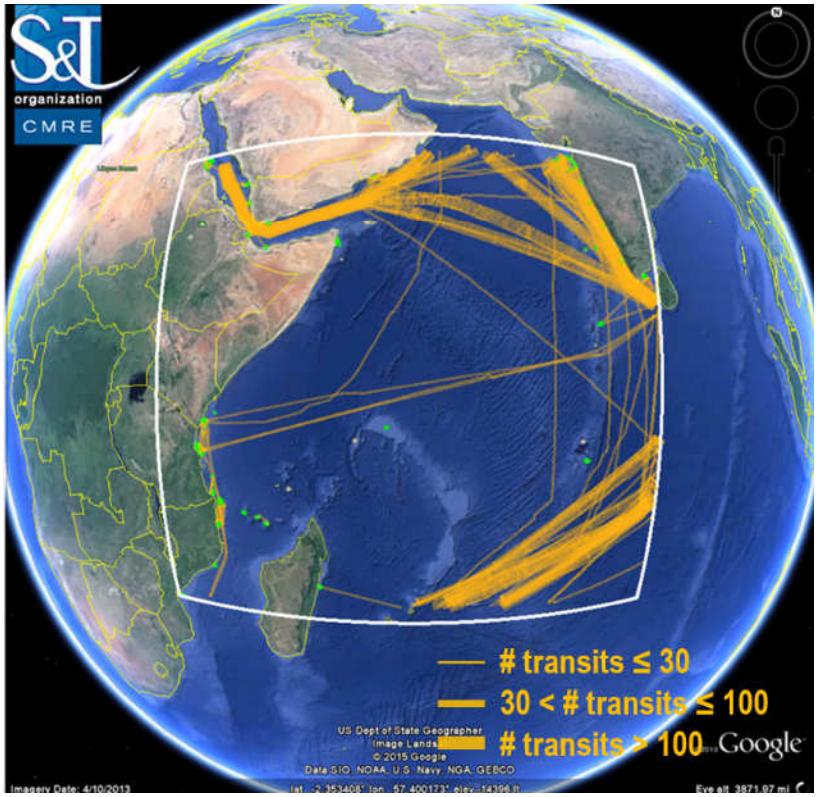


Maritime Traffic Surveillance

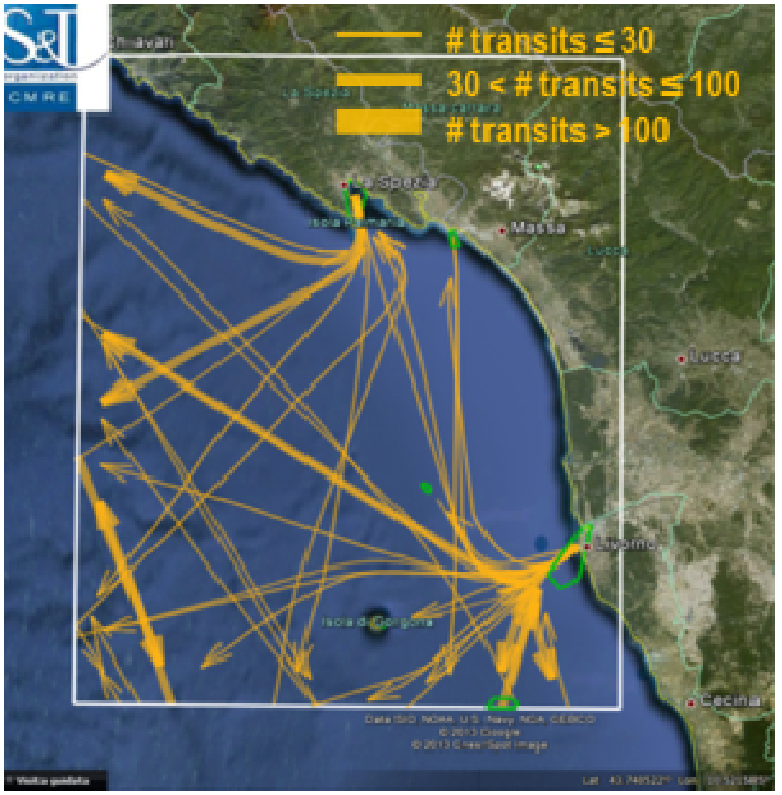


Traffic Route Extraction and Anomaly Detection (TREAD)

Large Scale

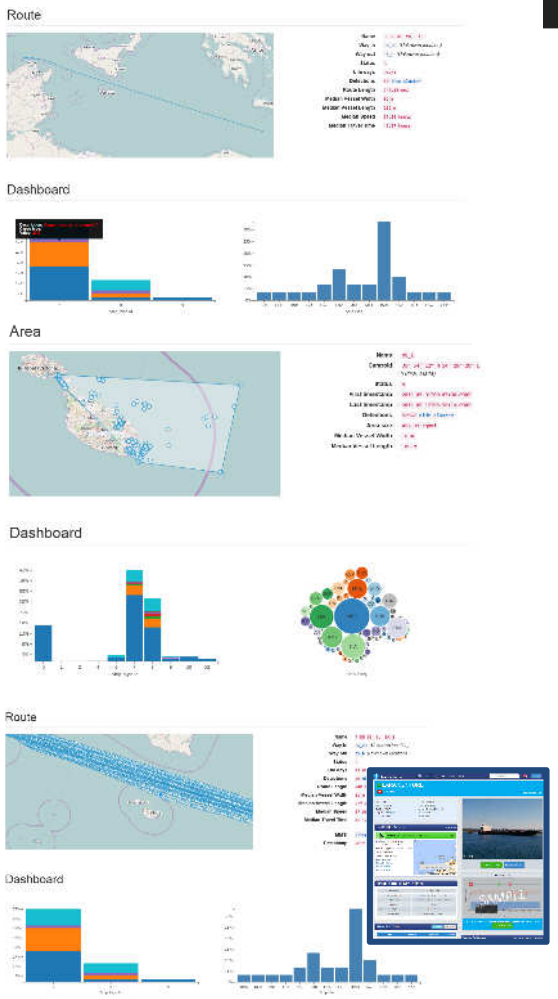


Local Scale



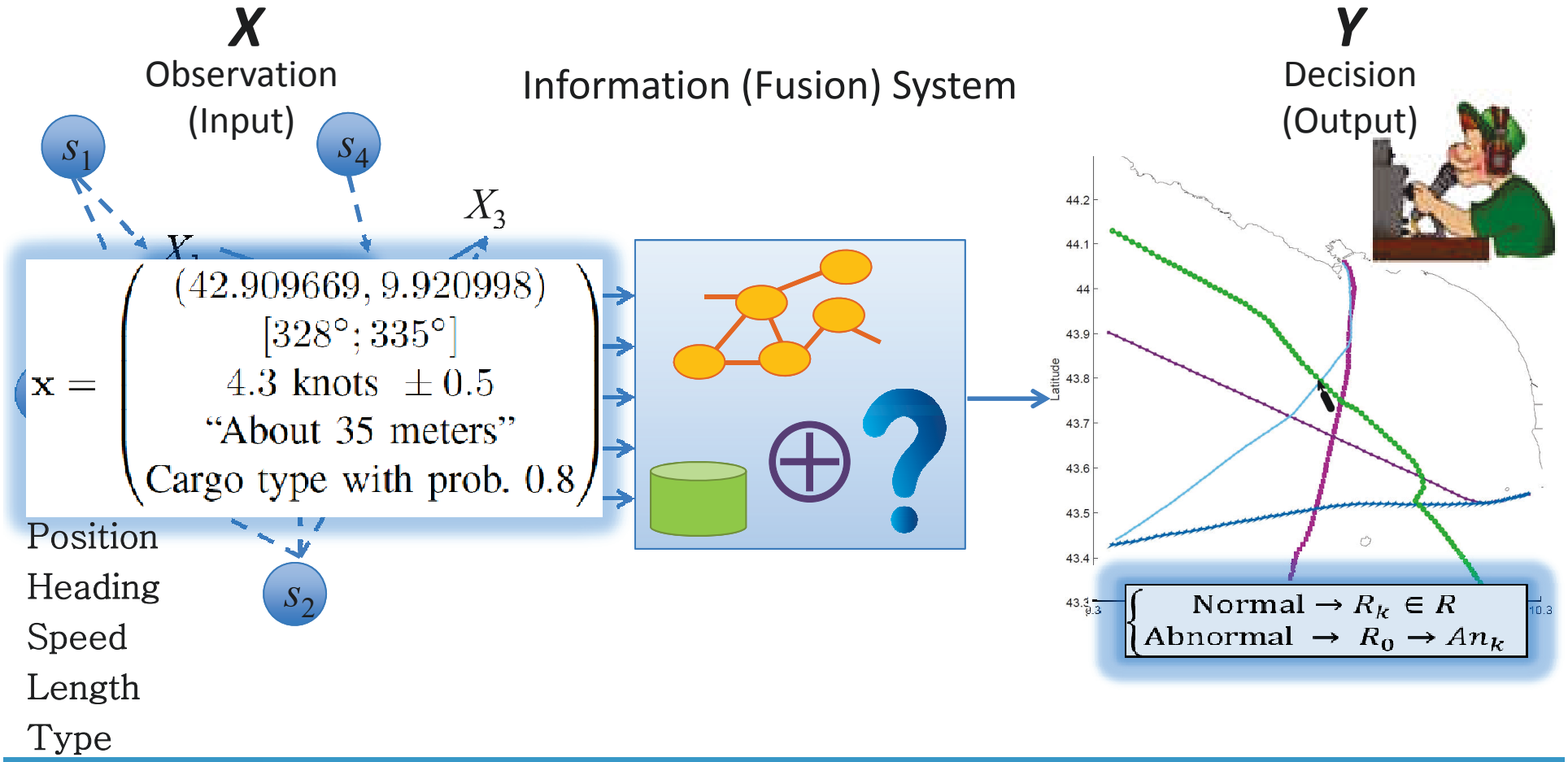
Pallotta G., Vespe M., Bryan K. (2013) "Vessel Pattern Knowledge Discovery from AIS Data: a Framework for Anomaly Detection and Route Prediction". *Entropy, Big Data Issue* 15(6), pp. 2218-2245. ISSN 1099-4300

Traffic Analysis/Summary Route Statistics



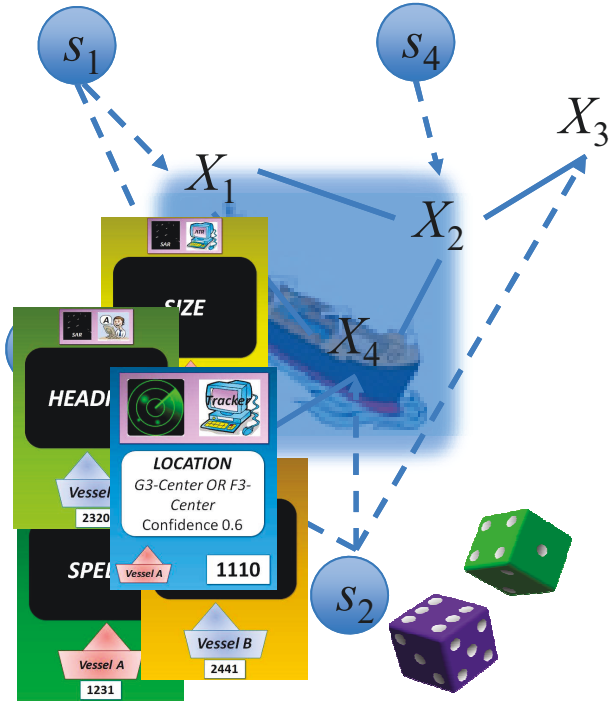
L. Cazzanti, G. Pallotta, "Mining Maritime Vessel Traffic: Promises, Challenges, Techniques," Proc. of the OCEANS'15 MTS/IEEE Conference, 2015

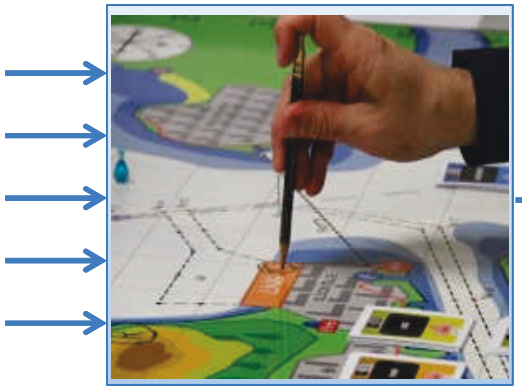
Maritime Anomaly Detection and situation awareness

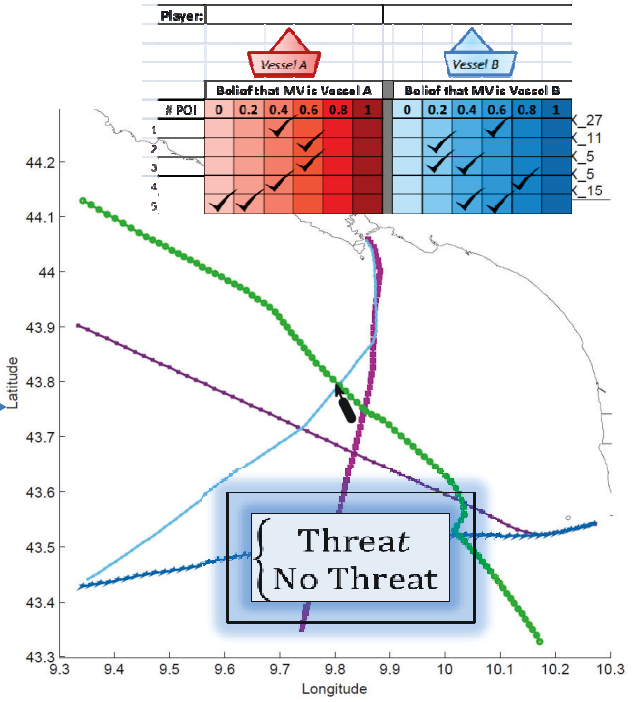


RISK GAME

A methodology to elicit expert knowledge and know-how in making decision based on imperfect information







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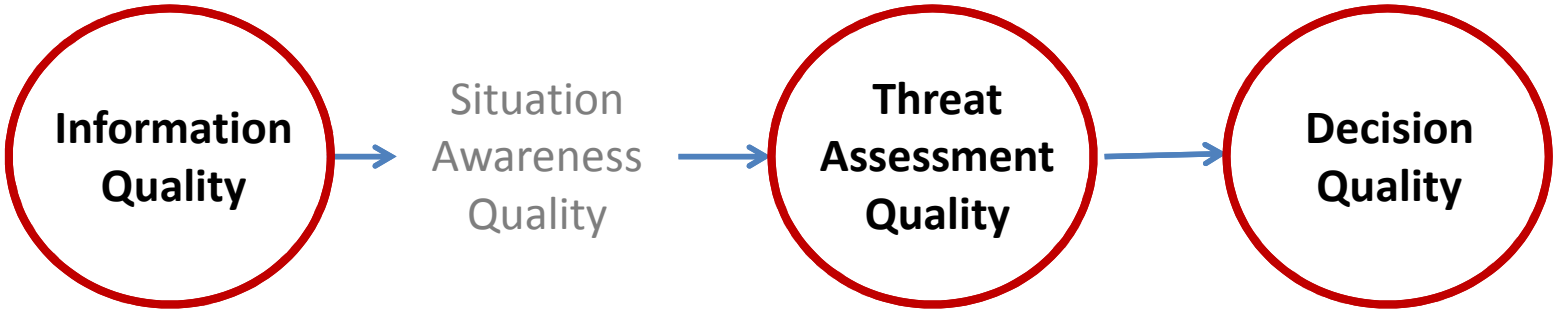
Purpose of the game

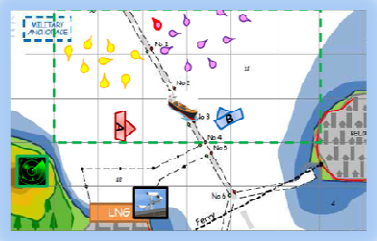
- The Risk Game is a general methodology to elicit knowledge and know-how from Subject Matter Experts especially in their ability to
  - deal with information of different nature (from sensors to human witnesses),
  - consider the information quality (including source quality) and
  - reason about concurrent events.
- It is a technique aimed at capturing data expressing human reasoning features and information needs while performing a specific task of maritime situation assessment.

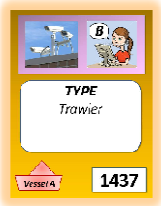


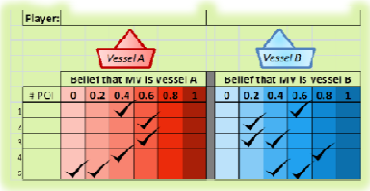
Playing the game

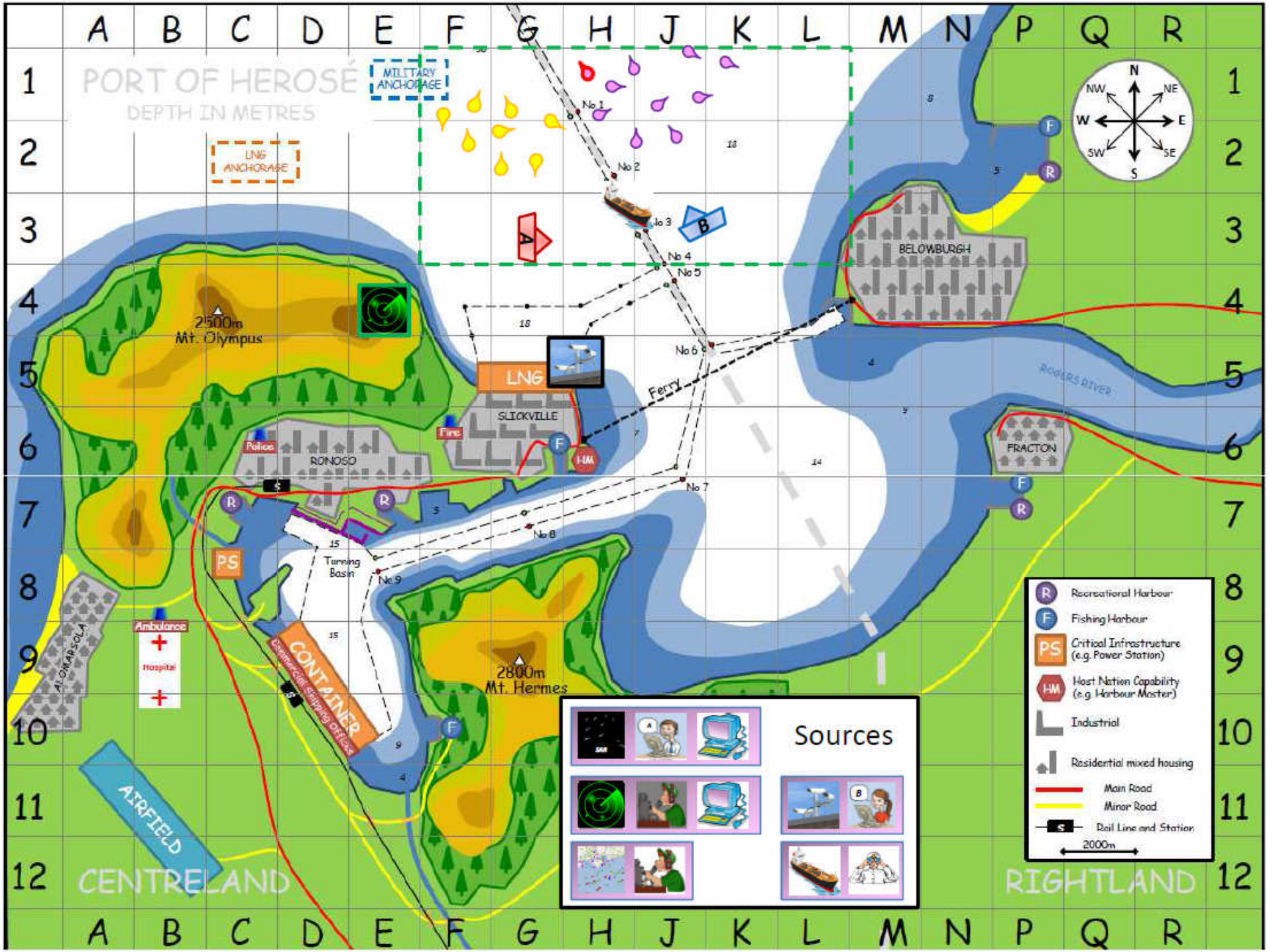
Queries

Scenario → Information → Player → Belief assessment → Decision

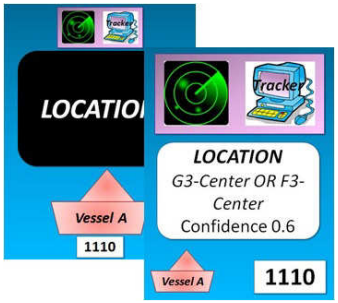




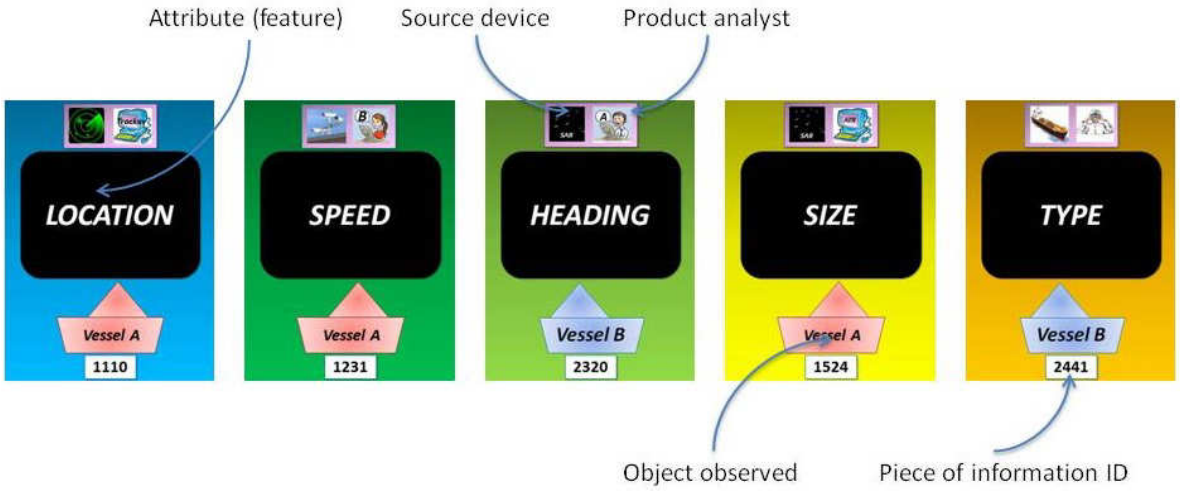



PORT OF HEROSÉ
DEPTH IN METRES
MILITARY ANCHORAGE
LNG ANCHORAGE
No 1
No 2
No 3
No 4
No 5
No 6
No 7
No 8
No 9
A
B
BELOWBURGH
2500m
Mt. Olympus
LNG
SLICKVILLE
Ferry
Fire
Police
RONOSO
FRACTON
ROGERS RIVER
Turning Basin
PS
Ambulance
Hospital
AL OMARSOLA
CONTAINER
Commercial shipping offices
2800m
Mt. Hermes
AIRFIELD
CENTRELAND
RIGHTLAND
N
NW
NE
W
E
SW
SE
S
Sources
Recreational Harbour
Fishing Harbour
Critical Infrastructure (e.g. Power Station)
Host Nation Capability (e.g. Harbour Master)
Industrial
Residential mixed housing
Main Road
Minor Road
Rail Line and Station
2000m

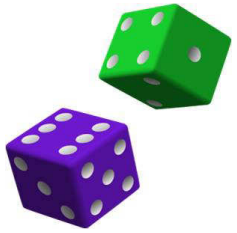
Information cards



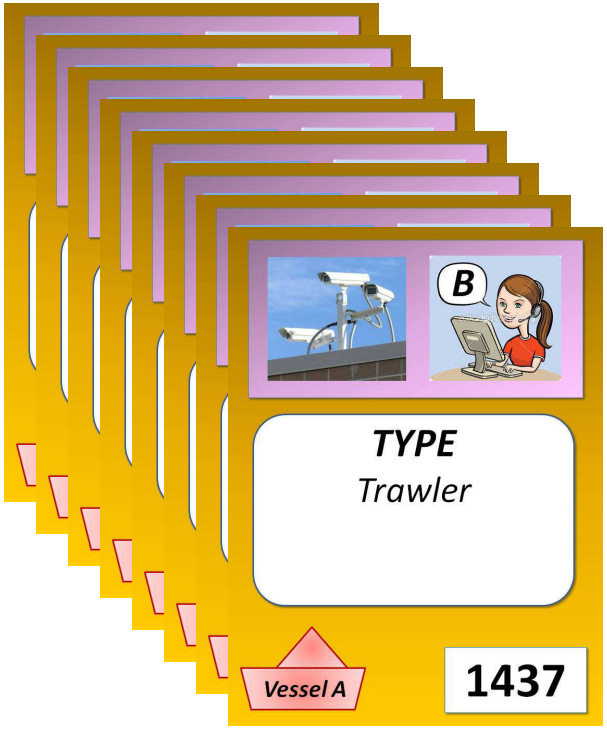
- Information is **abstracted away** by cards
- Only the **back** of the card is fisrt presented to the player

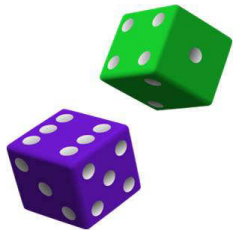


- At each round, the player selects:
  - The **vessel**
  - The **attribute**
  - The **source**
- The **information quality** is determined by a dice roll

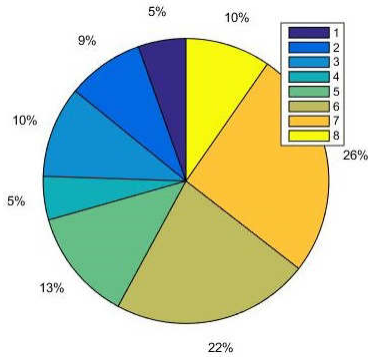


Information quality





- 8 versions of the same information
- Only one is available to the player
- The player rolls the dices to determine the quality obtained, i.e., one of the 8 cards
- The randomization is not uniform and represents roughly the sources limitations



True	Precise	Certain	Randomization	Q. rank
1	1	1	0.11	8
1	1	0	0.22	7
1	0	1	0.22	6
1	0	0	0.11	5
0	1	1	0.06	1
0	1	0	0.11	3
0	0	1	0.11	2
0	0	0	0.06	4

Uncertainty of hard and soft sources

Phrase	
Remote	0
Very unlikely	0.2
Unlikely	0.4
Even chance	0.5
Probably/Likely	**0.6**
Very likely	0.8
Almost certainly	**1**

- We follow the *Standardized lexicon used by the National Intelligence Council (US)*
- **Added an arbitrary numerical scale**
- Only 2 levels of uncertainty are considered:
  - *Hard sources output a probability of either 0.6 or 1*
  - *Soft sources say the event is either probable/likely or almost certain*

Contextual information

CROAKERBOAT

MMSI – 316111000 IMO – 8800468

Location (t0)	H2-right
Speed (t0)	4 knots
Heading (t0)	NW
Size	30m X 6m
Type	Trawler
Flag	RightLand

CONTEXT

Time	Spring 16:45
Traffic	Heavy
Sea state	4
Fog	0

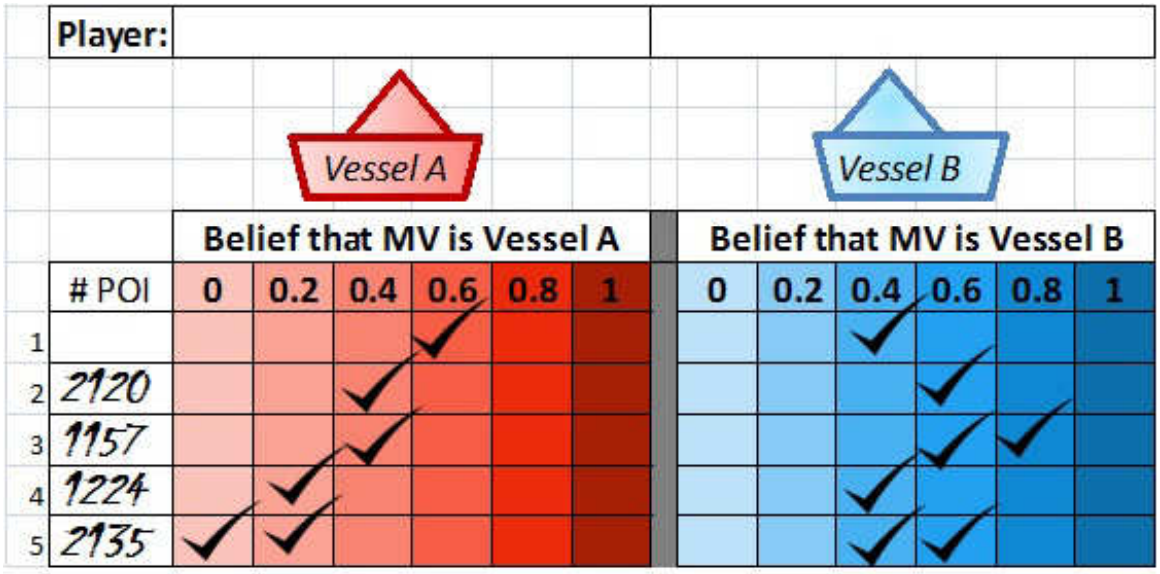
- Information about the lost vessel is provided
- As well as some other contextual information
- Harbor Protection Level is TWO

Harbour Protection Level	Force Protection Level	Security Alert State	ISPS Code
ONE	ONE	DELTA	THREE
TWO	TWO	DELTA	THREE
THREE	THREE	CHARLIE	TWO
FOUR	FOUR	BRAVO	TWO
FIVE	FIVE	ALFA	ONE

- Relationship between FPLs/NATO Security Alert States/ISPS Code

Record of belief state (SAW)

- After querying and discovering a piece of information, the player rates his/her belief state regarding the two events:
  - *The lost vessel is A*
  - *The lost vessel is B*



- The card ID is recorded (unique)
- The two belief values **do not need** to sum up to 1
- Assessing **just one** of the two events is allowed

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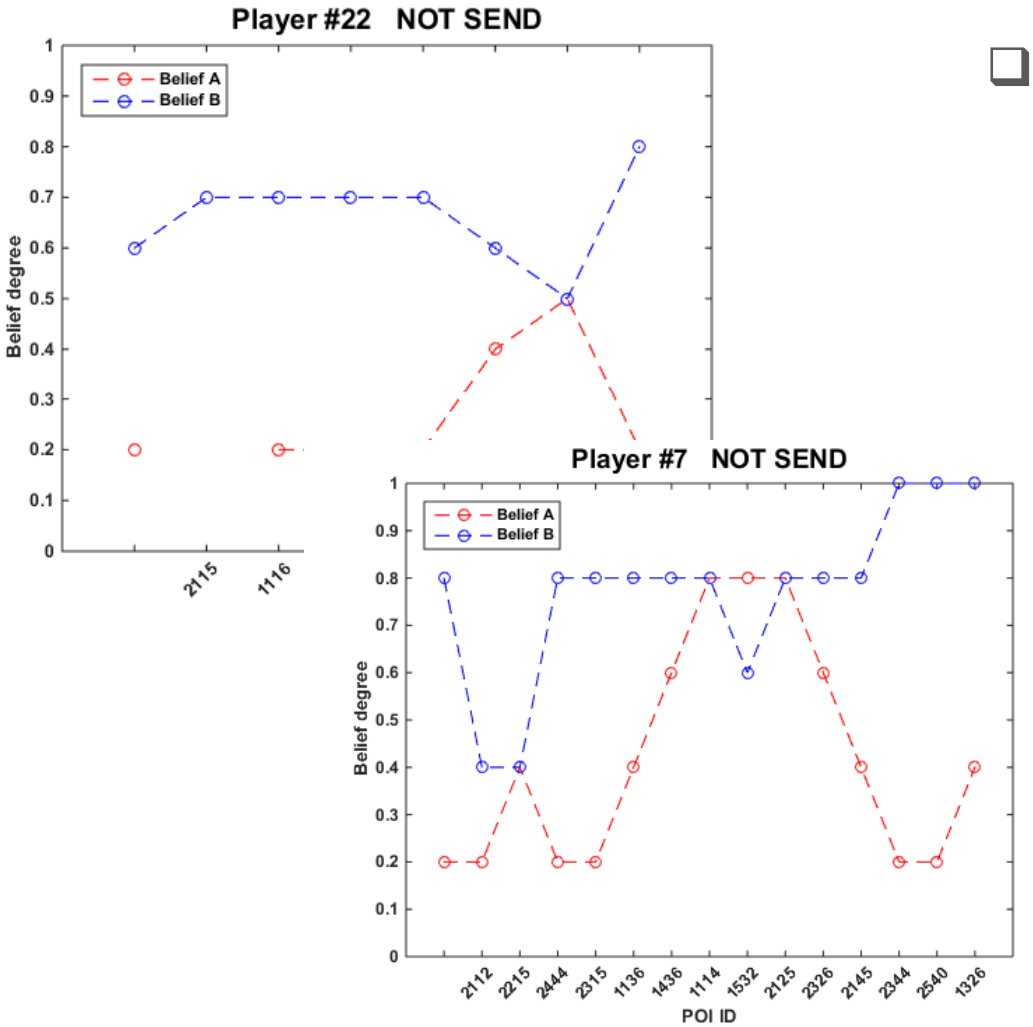
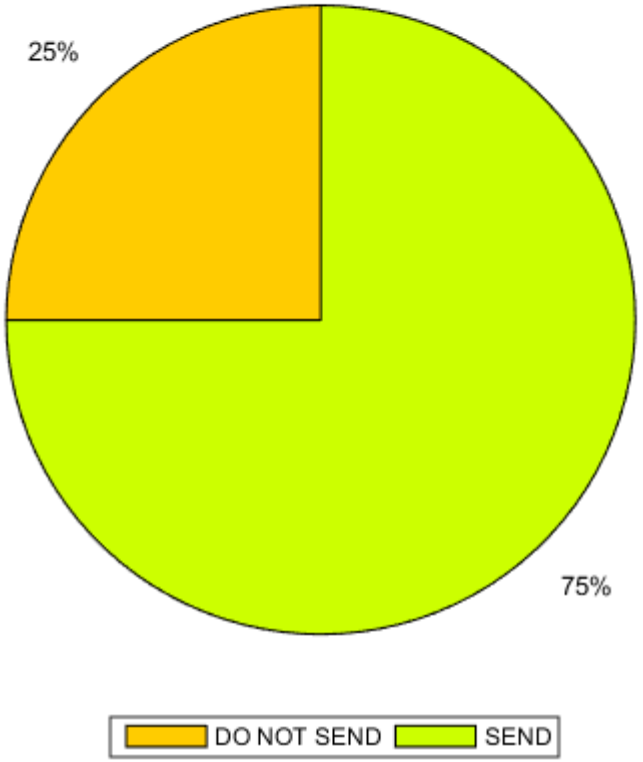
Dataset collected



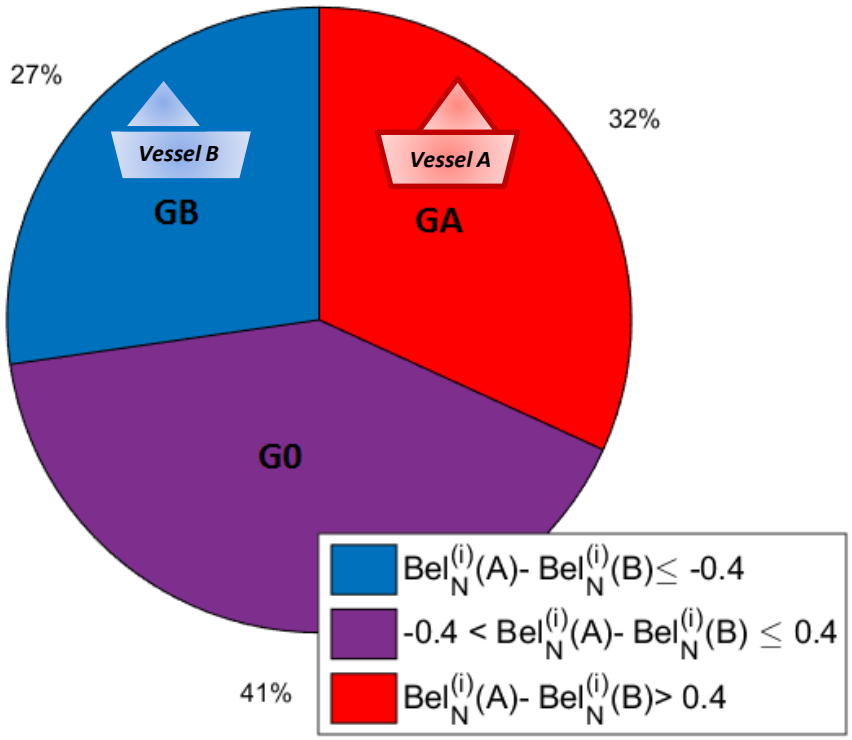
- We collected the data from the set of players about:
  - The evolution of **belief state** regarding the two events
  - The **final decision**
  - The **ID** of the piece of information picked-up (vessel, source and attribute)
  - The **quality** of information obtained
  - Possible **missing** assessments

Final decision

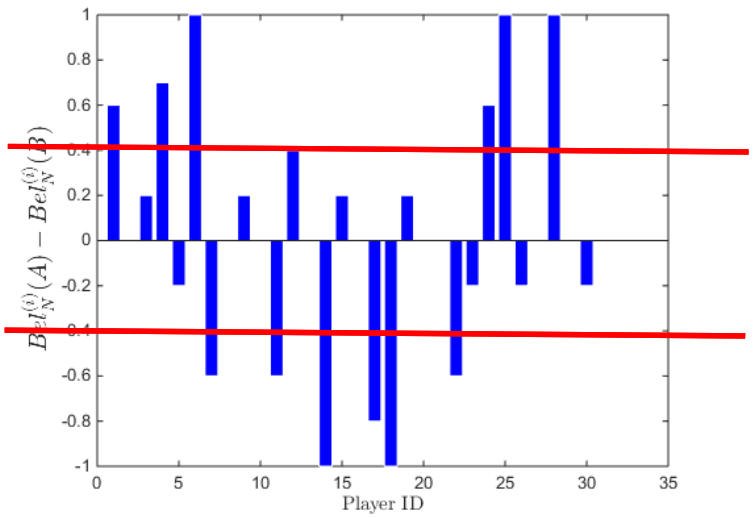


- Most of the players took the decision to send the patrol ("good decision")
- Explained by the asymmetry of the two vessels' risk levels

Final belief

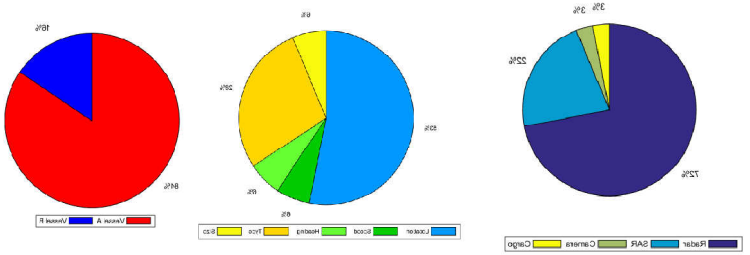


- We build 3 groups of players based on their final belief:
  - GA: Greater belief toward A
  - GB: Greater belief toward B
  - G0: Uncertain

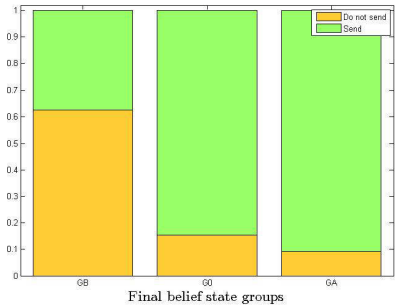


Some preliminary results

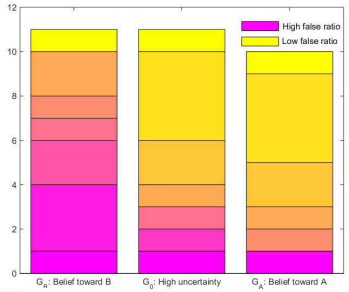
- Information needs (most and first queried attribute, vessel, source)



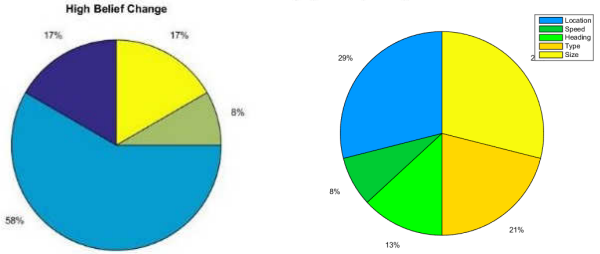
- Final belief vs decision



- Impact of false of false information on final belief



- Impact of information content and attribute on belief change



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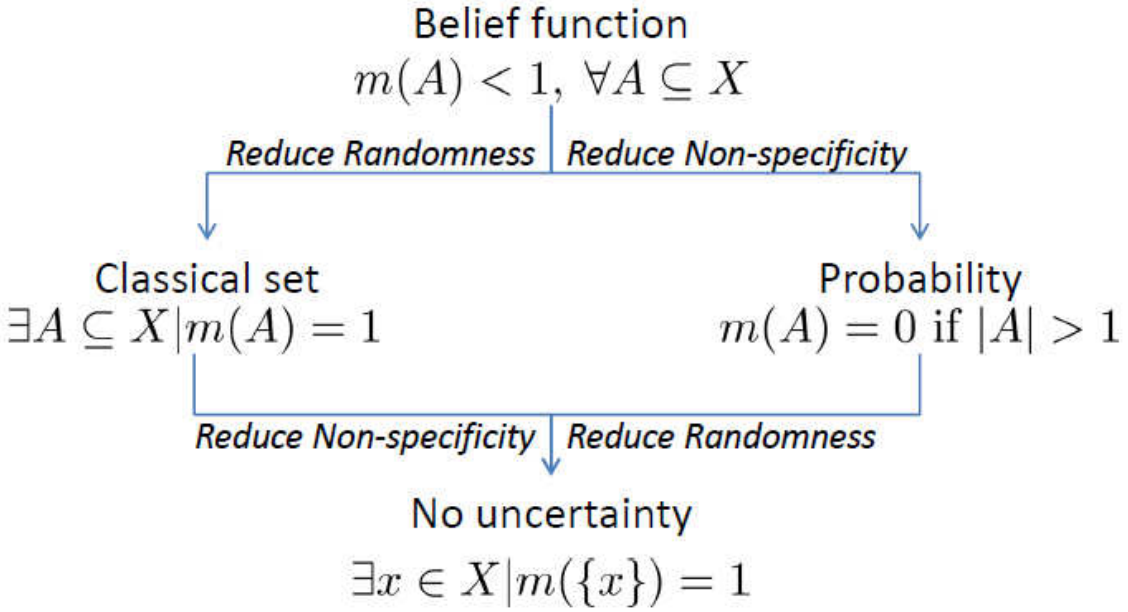
Basics on evidence theory (1)

- Framework for uncertainty representation and processing
- Represents both uncertainty (randomness or epistemic) and imprecision (or non-specificity)
- Expresses for instance: "I'm not certain that x belongs to A"
- Extends both classical sets and probabilities



Basics on evidence theory (2)

- Let $\boldsymbol{x}$ be an ill-known value defined over a frame of discernment $\mathcal{X} = \{x_1, \ldots, x_K\}$
- $\mathcal{X}$ is a set of exhaustive and exclusive hypotheses
- A Basic Belief Assignment (or mass function) $m : 2^{\mathcal{X}} \rightarrow [0, 1]$ such that

$$\sum_{A \subseteq \mathcal{X}} m(A) = 1$$

  - Closed-world hypothesis : $m(\varnothing) = 0$ (Dempster, Shafer)
  - Open-world hypothesis : $m(\varnothing) \neq 0$ (Smets)
- Interpretations: m represents the uncertainty regarding $\boldsymbol{x}$
  - *deterministic value* (Shafer, Smets)
  - *random variable* (Dempster)
- Subsets A of $\mathcal{X}$ such that $m(A) > 0$ are the focal elements of m

Basics on evidence theory (3)

Belief function

$$bel(A) = \sum_{B \subseteq A} m(B)$$

- $bel(A)$ is obtained by summing up all the focal elements that imply A.

Plausibility function

$$pl(A) = \sum_{B \cap A \neq \emptyset} m(B)$$

- $pl(A)$ is obtained by summing up all the focal elements that are consistent with A

In Dempster's view, $bel(A)$ and $pl(A)$ are respectively the lower and upper bound of the unknown probability of A:

$$bel(A) \leq P(A) \leq pl(A)$$

Basics on evidence theory (4)

Conjunctive combination $\textcircled{\cap}$ (unnormalised Dempster's rule)
For two mass functions m_1 and m_2 provided by two independent and reliable sources:

$$m_{1\textcircled{\cap}2}(A) = \sum_{B \cap C = A} m_1(B) m_2(C)$$

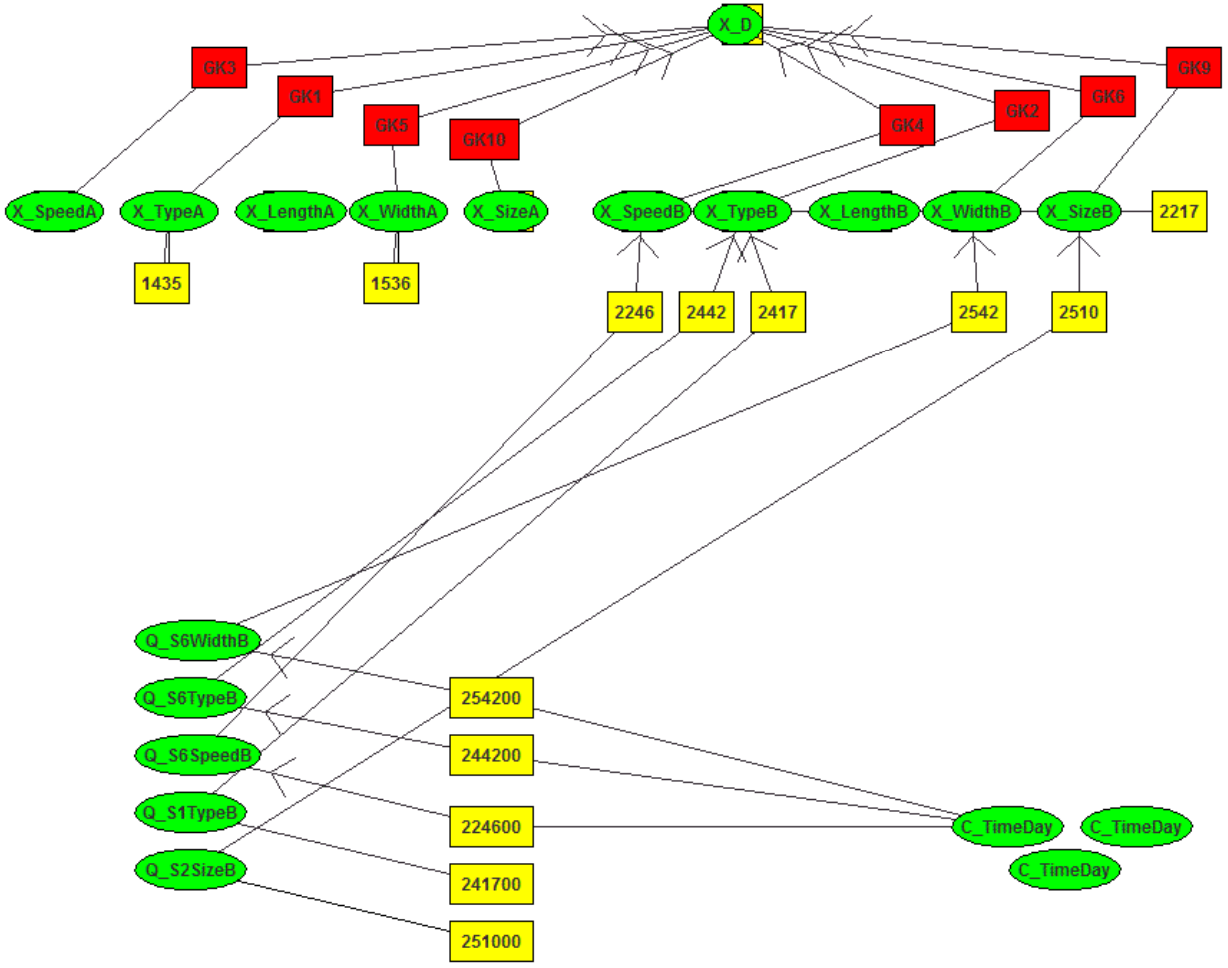
- The mass of the empty set is called the weight of conflict :

$$m_{1\textcircled{\cap}2}(\varnothing) = \sum_{B \cap C = \varnothing} m_1(B) m_2(C)$$

Example:

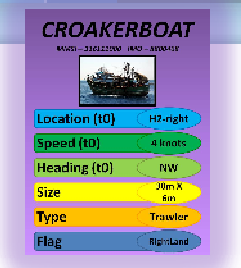
	$(x_1, 0.2)$	$(x_2, 0.2)$	$(\mathcal{X}, 0.6)$
$(x_2, 0.5)$	$(\varnothing, 0.1)$	$(x_2, 0.1)$	$(x_2, 0.3)$
$(\mathcal{X}, 0.5)$	$(x_1, 0.1)$	$(x_2, 0.1)$	$(\mathcal{X}, 0.3)$

Valuation-Based Networks



General graphical approach to reasoning under uncertainty [Shenoy & Shafer]:

- Probabilities
- Belief functions
- Possibilities
- Ranking functions



Two reasoning schemes

- **IF** the information of the observed vessel **does not match** the information about the missing vessel **THEN**

➢ LOG0: the missing vessel is the other one: if NOT FVA then B

*Because we are looking for a fishing vessel (a trawler) with known size (width and length), and because we assume that the missing vessel is either A or B, any information about the observed vessel **not matching** these specifications necessarily identifies the other one.*

- **IF** the information of the observed vessel **does match** the information about the missing vessel **THEN**

➢ LOG1: We have **no clue** about the location of the missing vessel, and this observation **does not bring any information**: if FVA then A U B

Indeed, if the fact that the information matches the specification of the missing vessel does not bring any further information since the observed vessel can simply be any other vessel with the same specifications.

➢ LOG2: Our belief toward the observed vessel increases: if FVA then Bel(A)

A.-L. Jousselme, G. Pallotta, J. Locke, *A Risk Game to study the impact of information quality on human treat assessment and decision making*, CMRE report, CMRE-FR-2015-009, 2015.

A.-L. Jousselme, N. Ben Abdallah, F. Pichon, *A Risk Game formalisation in support to the automation of Maritime Situation Awareness: Analysis of reasoning profiles*, CMRE report, CMRE-FR-2016-011, 2016 (to be published).