# Context-enhanced Information Fusion: Applications

ADVANCED ALGORITHMS FOR EFFECTIVELY FUSING HARD AND SOFT INFORMATION

NATO STO IST-155 Lecture Series

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# Outline

- Lecture II: Applications
  - Context for target tracking
    - Constraining estimates
  - Context for situation assessment
    - Refining inference
  - Is context always a good thing? An intelligence case
    - De-contextualization

Part I

# CONTEXT-ENHANCED TARGET TRACKING

[1][2]

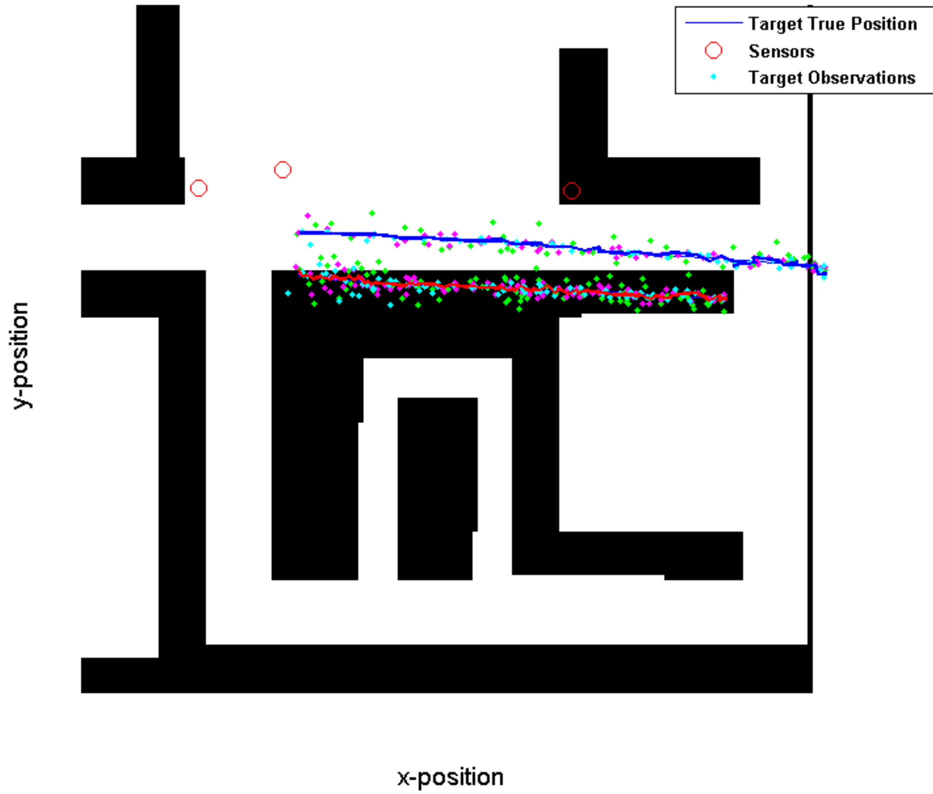
# Formulation

- In real-world monitoring applications it often happens that a sensor provides a sequence of unreliable observations due to partial occlusion of the target, unfavorable weather conditions, sun blinding, persistent reflections, etc.


- Checking the measurements against a map of the monitored area is a form of contextual knowledge inclusion that could, as in the latter example, provide an insight on the reliability of the sensor in a specific situation.

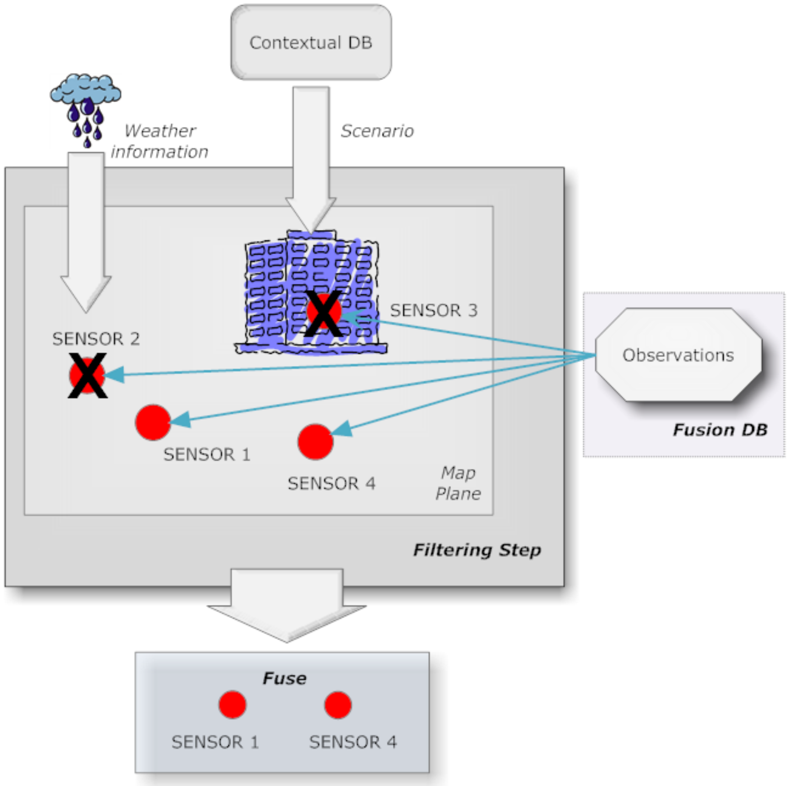
# Experiment – extreme case

- False track
- It can be discarded considering the scenario planimetry
- Prevent its creation



# Contextual effects on measurements

- Observations can be severely disrupted by contextual factors (occlusions, unfavourable weather conditions, reflections, etc.)
- The pre-filtering step exploits contextual information as a means to filter erroneous observations
- Task dedicated to optimization via contextual knowledge



# Context exploitation strategies

- **Pruning**: discard the sensors that give measurements not compatible with contextual information (utility in {0,1})

- **Discounting**: measurements are weighted a reliability factor given by context analysis (utility in [0,1])

# Bayesian Estimation

$$\boldsymbol{x}_{k+1} = \boldsymbol{f}_k(\boldsymbol{x}_k) + \boldsymbol{v}_k \qquad \boldsymbol{p}\,(\boldsymbol{x}_{k+1}|\boldsymbol{x}_k)$$

$$\boldsymbol{y}_k = \boldsymbol{h}_k(\boldsymbol{x}_k) + \boldsymbol{w}_k \qquad \boldsymbol{p}\,(\boldsymbol{y}_k|\boldsymbol{x}_k)$$

$$\boldsymbol{c}_k = \boldsymbol{h}_{ck}(\boldsymbol{x}_k) \qquad \boldsymbol{p}\,(\boldsymbol{c}_k|\boldsymbol{x}_k)$$

Solving estimation problem as a Bayesian recursion

Prediction step

$$\boldsymbol{p}\,(\boldsymbol{x}_k|\boldsymbol{y}_{1:k}) \longrightarrow \boldsymbol{p}\,(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k})$$

↓

Chapman-Kolmogorov equation

$$\boldsymbol{p}\,(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k}) = \int \boldsymbol{p}\,(\boldsymbol{x}_{k+1}|\boldsymbol{x}_k)\boldsymbol{p}\,(\boldsymbol{x}_k|\boldsymbol{y}_{1:k})dx_k$$

Measurement Update

$$\boldsymbol{p}\,(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k}) \longrightarrow \boldsymbol{p}\,(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k+1})$$

↓

Bayes rule

$$\boldsymbol{p}\,(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k+1}) = \frac{\boldsymbol{p}(\boldsymbol{y}_{1:k}|\boldsymbol{x}_k)\,\boldsymbol{p}(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k})}{\boldsymbol{p}(\boldsymbol{y}_{k+1}|\boldsymbol{y}_{1:k})}$$

# Context as a Constraining Factor

Context defined as non-linear inequality

$$\boldsymbol{a}_k \leq \boldsymbol{c}_k\left(\boldsymbol{x}_k\right) \leq \boldsymbol{b}_k$$

$$\boldsymbol{C}^{\boldsymbol{k}} = \{\boldsymbol{c}_0, \boldsymbol{c}_1, \dots, \boldsymbol{c}_k\}$$

Bayesian recursion including context

Prediction Update

$$\boldsymbol{p}\left(\boldsymbol{x}_k | \boldsymbol{y}_{1:k}, \boldsymbol{c}_{1:k}\right) \longrightarrow \boldsymbol{p}\left(\boldsymbol{x}_{k+1} | \boldsymbol{y}_{1:k}, \boldsymbol{c}_{1:k}\right)$$

Measurement Update

$$\boldsymbol{p}\left(\boldsymbol{x}_{k+1} | \boldsymbol{y}_{1:k}, \boldsymbol{c}_{1:k}\right) \longrightarrow \boldsymbol{p}\left(\boldsymbol{x}_{k+1} | \boldsymbol{y}_{1:k+1}, \boldsymbol{c}_{1:k+1}\right)$$

[1]

# Context in Estimation Process

**Context inclusion in the prediction update**

Prediction step:

$$\boldsymbol{p}\left(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k+1}\right)=\int \boldsymbol{p}\left(\boldsymbol{x}_{k+1}|\boldsymbol{x}_{k},\boldsymbol{c}_{1:k+1}\right)\boldsymbol{p}\left(\boldsymbol{x}_{k}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k}\right)dx_k$$

Update step:

$$\boldsymbol{p}\left(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k+1},\boldsymbol{c}_{1:k+1}\right)=\frac{\boldsymbol{p}(\boldsymbol{y}_{1:k+1}|\boldsymbol{x}_{k+1})\,\boldsymbol{p}(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k+1})}{\boldsymbol{p}(\boldsymbol{y}_{k+1}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k+1})}$$

**Context inclusion in the measurement update**

Prediction step:

$$\boldsymbol{p}\left(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k}\right)=\int \boldsymbol{p}\left(\boldsymbol{x}_{k+1}|\boldsymbol{x}_{k},\boldsymbol{c}_{1:k}\right)\boldsymbol{p}\left(\boldsymbol{x}_{k}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k}\right)dx_k$$

Update step:

$$\boldsymbol{p}\left(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k+1},\boldsymbol{c}_{1:k+1}\right)=\frac{\boldsymbol{p}(\boldsymbol{y}_{1:k+1}|\boldsymbol{x}_{k+1})\boldsymbol{p}(\boldsymbol{c}_{1:k+1}|\boldsymbol{x}_{k+1})\boldsymbol{p}(\boldsymbol{x}_{k+1}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k})}{\boldsymbol{p}(\boldsymbol{y}_{k+1}|\boldsymbol{y}_{1:k},\boldsymbol{c}_{1:k})\boldsymbol{p}(\boldsymbol{c}_{1:k+1}|\boldsymbol{c}_{1:k})}$$

[1]

# Design Decision

Context inclusion in the prediction update

$$\boldsymbol{p}(\boldsymbol{x}_{k+1}|\boldsymbol{x}_k, \boldsymbol{c}_{1:k}) \propto (1-\boldsymbol{\alpha})\boldsymbol{p}(\boldsymbol{x}_{k+1}|\boldsymbol{x}_k), \quad if\ \ \boldsymbol{x}_k \in \boldsymbol{c}_{1:k};$$

$$\boldsymbol{p}(\boldsymbol{x}_{k+1}|\boldsymbol{x}_k, \boldsymbol{c}_{1:k}) \propto \boldsymbol{\alpha}\boldsymbol{p}(\boldsymbol{x}_{k+1}|\boldsymbol{x}_k), \quad otherwise.$$

Context inclusion in the measurement update

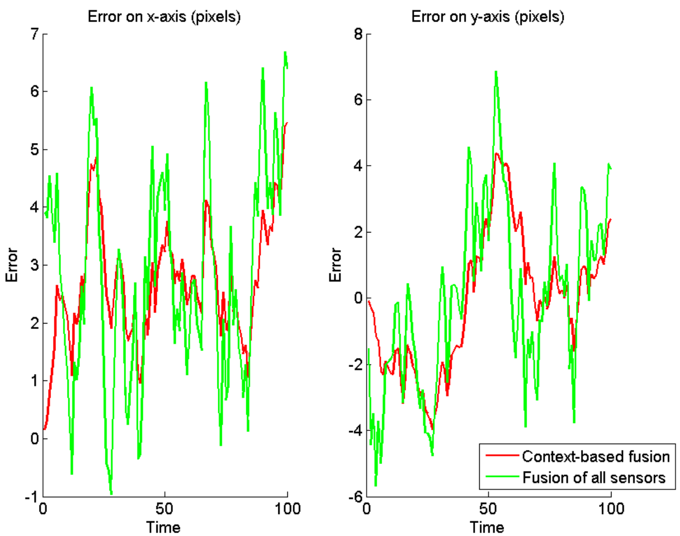
$$\boldsymbol{p}(\boldsymbol{c}_{1:k}|\boldsymbol{x}_k) = 1-\boldsymbol{\alpha}, if\ \ \boldsymbol{x}_k \in \boldsymbol{c}_{1:k};$$

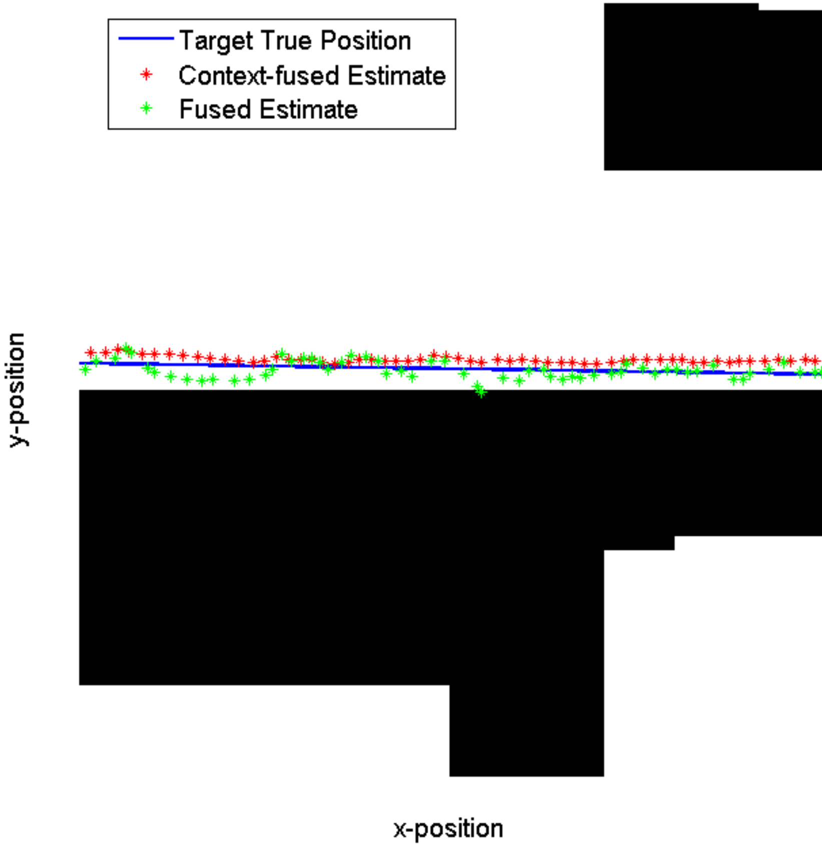
$$\boldsymbol{p}(\boldsymbol{c}_{1:k}|\boldsymbol{x}_k) = \boldsymbol{\alpha}, \qquad otherwise.$$

[1]

# Urban scenario example

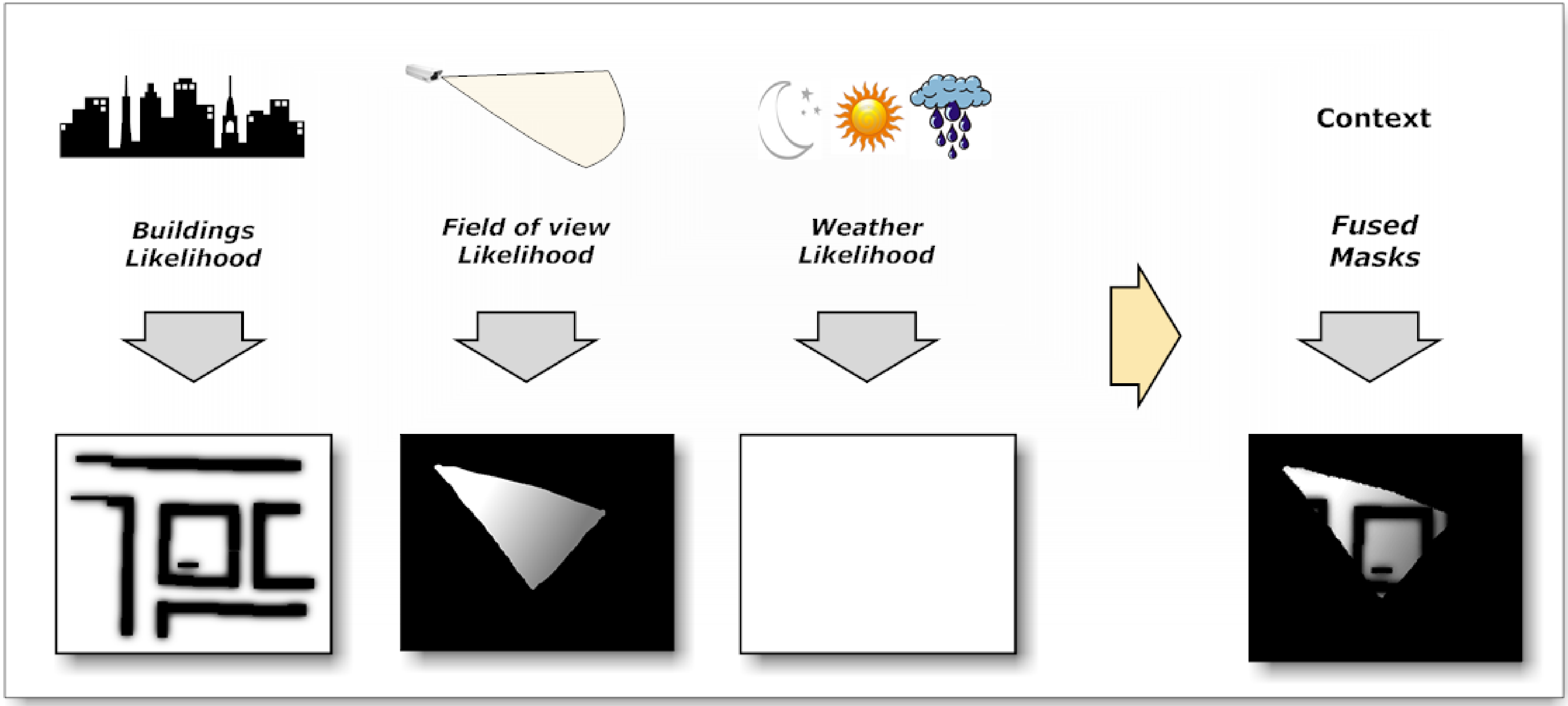
- Error and uncertainty reductions consistently observed
- Discounting strategies might be preferable



# Fusion of context likelihoods

- Different masks can be generated to encode specific detection capabilities of a sensor regarding to specific contextual aspect [2]



# I part - Conclusions

- Context can be couched in a Bayesian framework for estimation processes (e.g. target tracking)
- Heterogeneous information from different sources can be exploited to condition the estimation
- Succesful attempts in various domains can be found in the literature
- Dynamic context exploitation the main future challenge

Part II

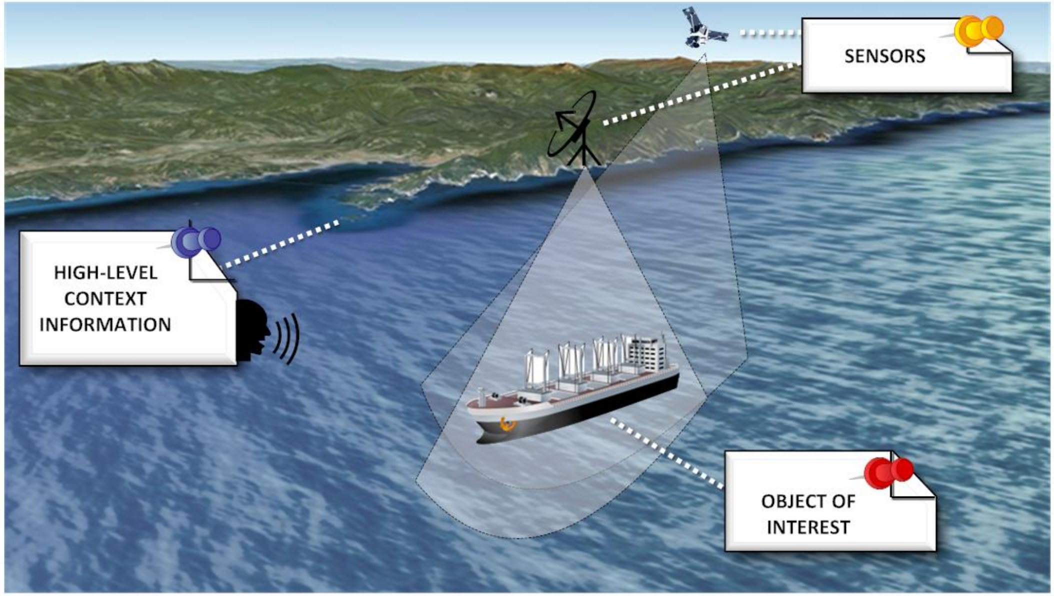
# CONTEXT FOR SITUATION ASSESSMENT

[3]

# Anomalies

Events and anomalies are important building blocks for developing a situational picture

Exceptional input/condition to which the system is generally called to respond




- In a Situation Assessment system a knowledge base is consulted to infer possible conclusions from the anomalous condition

# Situation assessment

- The incorporation of abductive/inductive and deductive **reasoning** is a vital element in an automated fusion and situational awareness system.
- The main goal of a reasoning engine or probabilistic inference system is to **associate a posterior probability to a set of queries** given observed evidence.
- Dealing with **uncertainty** is one of the most desirable characteristics for a fusion system, as uncertain data affects decisions and the quality of the estimates.

# Common issues in SA systems

- Accuracy / reduced false alarm rate generally the primary objectives
- Adapatability
  - To changes in the domain
  - To domain change
  - Context exploitation
- Scalability
- Encoding expert knowledge into chosen formalism
  - KB mantainance?
  - How to handle Hard+Soft data

# Common issues in SA systems (2)

Discussed here:

- Encoding expert knowledge into chosen formalism
- Adapatability
- Scalability

**Uncertainty management**

- Uncertainty in detections and knowledge
- Accuracy / False alarm rate

**Expressiveness / ease of representation**

# First Order Logic

- FOL formulas provide a compact way of expressing knowledge
- However, in most real world scenarios, **logic formulas are *typically* but not *always* true**
- For instance:
  - A world (truth value of ground atoms) failing to satisfy even a single formula would not be considered possible
  - There could be no possible world satisfying all formulas

# (Un)-satisfiability of the KB

| Eng | First- gic |
|---|---|
| Friends o iends are frie | x, y) ∧ Fr(y, z) ⇒ Fr(x, z) |
| Friendless people smoke. | Fr(x, y)) ⇒ Sm(x)) |
| Smoking causes cancer. | Ca(x) |
| If two people are friend | x∀ y ⇔ (Sm(x) ⇔ Sm(y)) |
| both smoke or neither does. | |

Flipping a truth value of a predicate (sensor noise?) could make the entire KB unsatisfiable for that configuration

↓

no reasoning could be performed, the configuration is not valid

# Combining logic with probability

- First-order logic (FOL) is a powerful language to represent **complex relational information**

- **Probability** is the standard way to represent uncertainty in knowledge

Combining the two would allow to model complex probabilistic relationships in the domain of interest

# Markov Logic Networks

- **Markov Networks**
  - Efficiently handling uncertainty
  - Tolerant against imperfection and contradictory knowledge
  - Allow inference over undirected graphs of random variables
- **First-Order Logic**
  - Compact representation and incorporation of wide variety of knowledge (e.g. a priori , contextual, etc.)

→ Combination of Markov Networks and First-Order Logic to use the advantages of both

# Markov Logic Networks

- A Markov Logic Network (MLN) L is a set of pairs ($F_i$,$w_i$ ) where:
  - $F_i$ is a first-order logic formula
  - $w_i$ is a real number (the weight of the formula)

- The set of all $F_i$ constitutes the Knowledge base

- The weight $w_i$ associated to each $F_i$ reflects how strongly the constraint imposed by the formula is to be respected

# Markov Logic Networks (2)

Applied to a finite set of constants C it defines a Markov network $M_{L,C}$ :

- $M_{L,C}$ has one binary node for each possible grounding of each atom in L. The value of the node is 1 if the ground atom is true, 0 otherwise.

- There is an edge between two nodes iff the corresponding ground atoms appear together in at least one grounding of a formula in L.

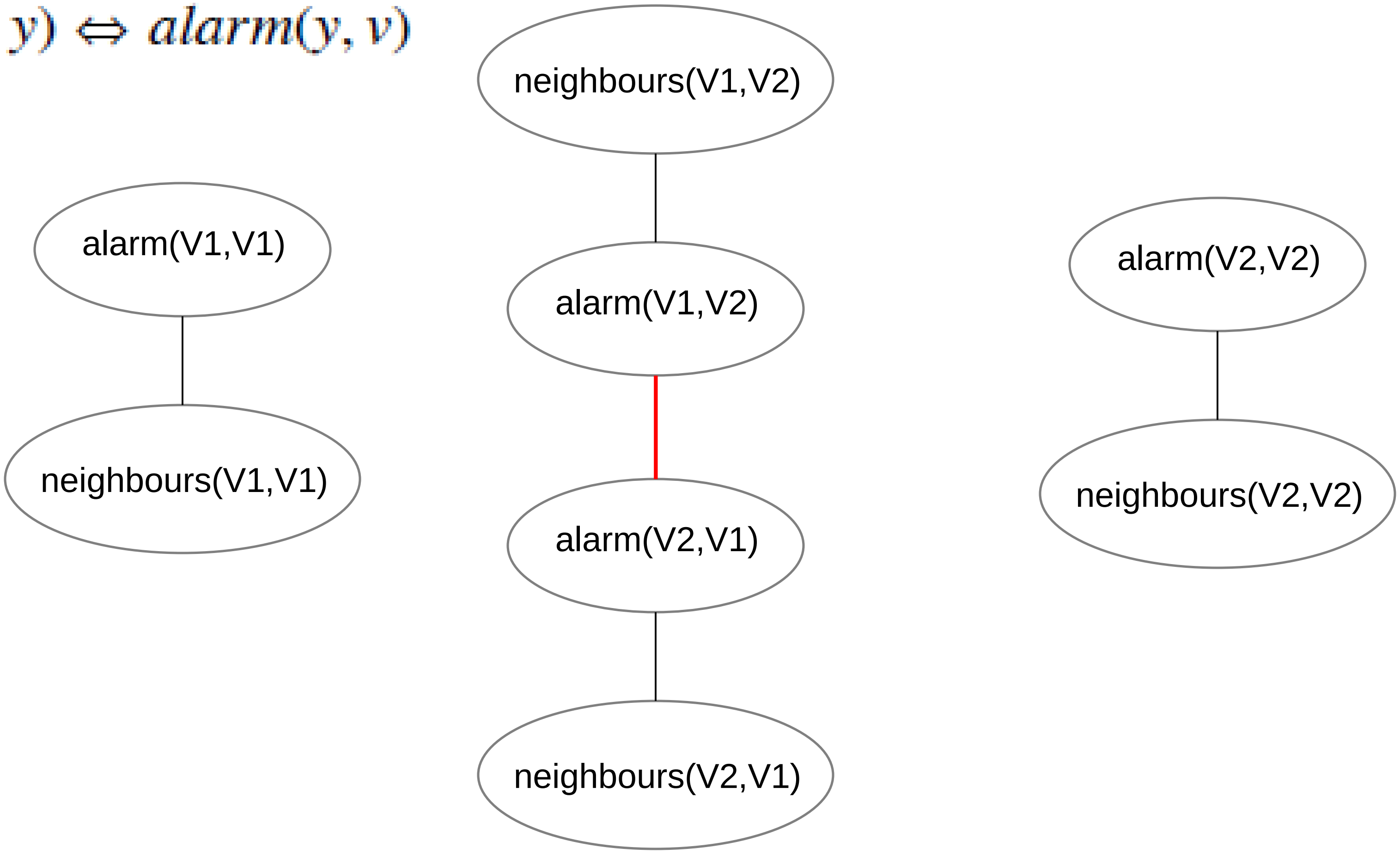
# Markov Logic Networks (3)

A MLN is a template for Markov Networks:

– Single atoms in the template will generate nodes in the network
– Formulas in the template will be generate cliques in the network

# Ground network example

$$neighbours(v, y) \Rightarrow alarm(v, y)$$
$$alarm(v, y) \Leftrightarrow alarm(y, v)$$



# Markov Logic Networks (4)

- A ground MLN specifies a **joint probability distribution over possible worlds** (i.e. truth value assignments to all ground atoms)

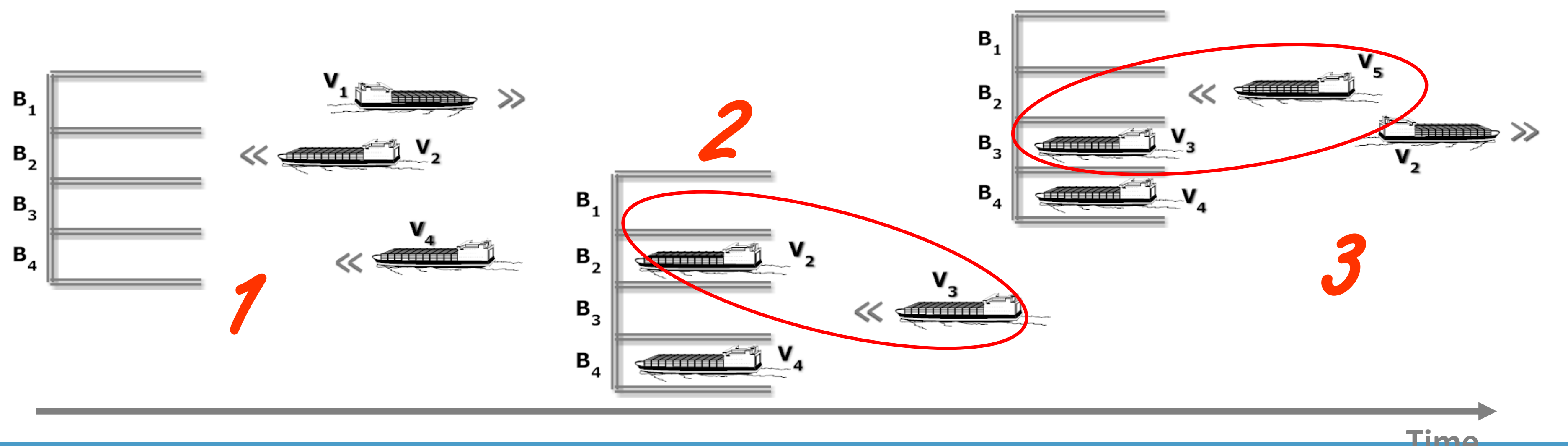
- The probability of a possible world x is:

$$p(X = x) = \frac{1}{Z} \exp\left( \sum_{i=1}^{|L|} w_i n_i(x) \right)$$

where $n_i(x)$ is the number of true groundings of $F_i$ in the world $x$

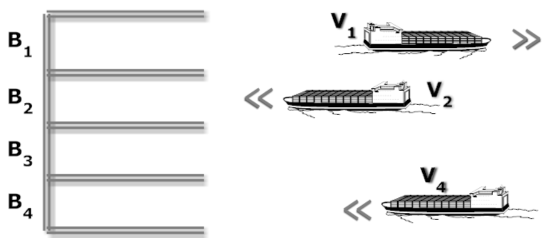
# Example scenario

- Five cargo ships *V1,...,V5* head toward a harbour *H*, carrying hazmat *M1,...,M4*
- Some materials (M2,M3) if combined together can be dangerous (e.g. bleach and ammonia)
- (V2,V3) and (V3,V5) are our *suspicious* couples



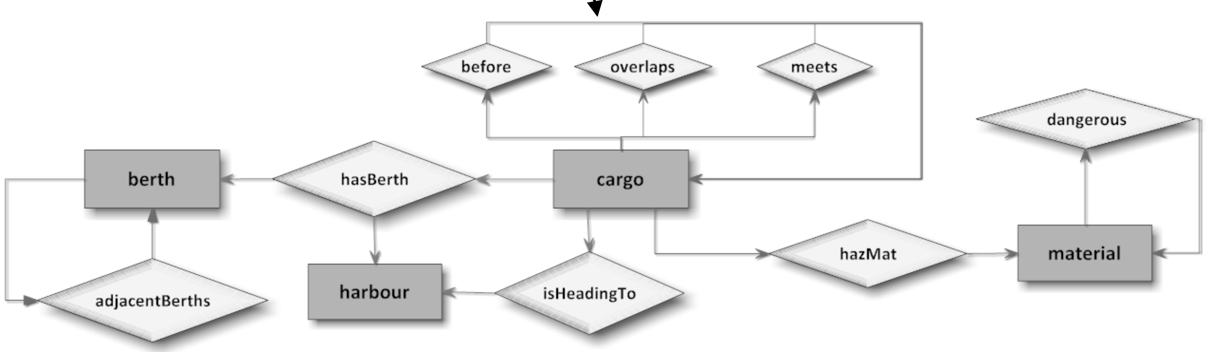
# Construction of the network

## *Description of the problem*




Situation

Abstraction




Entities and relationships

# Construction of the network

*Description of the problem*

↓

*Translation in FOL*

- ✓ FOL → propositions (terms, logical connectives) + predicates and quantifiers
- ✓ For each entity and relation, we define a predicate, which can be true or false
- ✓ Temporal predicates (Allen's logic - concurrency)
- ✓ Spatial predicates (proximity)

**cargo(v)**
**material(m)**
**hazMat(v,m)**
**neighbours(v,y)**
**...**

$$cargo(v) \wedge cargo(y) \wedge hazMat(v,m1) \wedge hazMat(y,m2) \wedge neighbours(v,y) \wedge dangerous(m1,m2) \wedge concurrent(v,y) \Rightarrow alarm(v,y)$$

# Construction of the network

*Translation in FOL*

↓

*Construction of Markov Logic Network*

| Formula |
| --- |
| $neighbours(v, y) \Rightarrow alarm(v, y)$ |

→

| Formula | weight |
| --- | --- |
| $neighbours(v, y) \Rightarrow alarm(v, y)$ | 3.5 |

# Construction of the network

*Construction of MLN*

↓

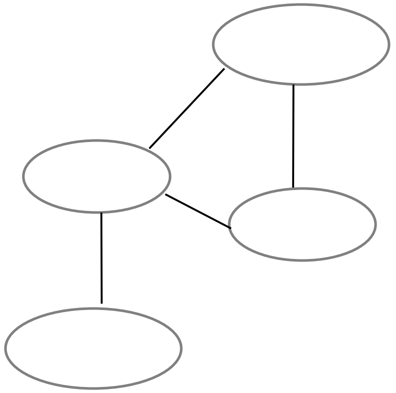
*Markov Network for a set of constants (given by observations)*

cargo(v)
neighbours(v,y)
...

→

cargo(**V1**)
cargo(**V2**)
neighbours(**V1,V2**)
...

→



...

# Construction of the network

*MN for a set of constants*

↓

*Compute formulas probability*

| | | | | |
|---|---|---|---|---|
| Cargo(V2)<br>Material(M2)<br>isHazmat(M2)<br>... | + | Cargo(V3)<br>Material(M3)<br>isHazmat(M3)<br>... | ⇒ | **Alarm(V1,V3)?** |

# What the experts know:

| # | Rule | Weight |
|---|---|---|
| 1 | $overlaps(v,y) \Leftrightarrow overlaps(y,v)$ | $\omega$ |
| 2 | $meets(v,y) \Leftrightarrow meets(y,v)$ | $\omega$ |
| 3 | $neighbours(v,y) \Leftrightarrow neighbours(y,v)$ | $\omega$ |
| 4 | $concurrent(v,y) \Leftrightarrow concurrent(y,v)$ | $\omega$ |
| 5 | $dangerous(m1,m2) \Leftrightarrow dangerous(m2,m1)$ | $\omega$ |
| 6 | $alarm(v,y) \Leftrightarrow alarm(y,v)$ | $\omega$ |
| 7 | $meets(v,y) \lor overlaps(v,y) \Leftrightarrow concurrent(v,y)$ | $\omega$ |
| 8 | $\neg meets(v,y) \land \neg overlaps(v,y) \Leftrightarrow \neg concurrent(v,y)$ | $4/5\ \omega$ |
| 9 | $before(v,y) \Rightarrow \neg concurrent(v,y)$ | $\omega$ |
| 10 | $\neg concurrent(v,y) \Rightarrow \neg alarm(v,y)$ | $\omega$ |
| 11 | $cargo(v) \land isHeadingTo(v,h) \land harbour(h) \Leftrightarrow hasBerth(v,x,h) \land berth(x)$ | $\omega$ |
| 12 | $cargo(v) \land cargo(y) \land hasBerth(v,x,h) \land hasBerth(y,z,h) \land adjBerth(x,z) \Leftrightarrow neighbours(v,y)$ | $\omega$ |
| 13 | $\neg neighbours(v,y) \Rightarrow \neg alarm(v,y)$ | $4/5\ \omega$ |
| 14 | $cargo(v) \land cargo(y) \land hazMat(v,m1) \land hazMat(y,m2) \land \neg dangerous(m1,m2) \Rightarrow \neg alarm(v,y)$ | $3/5\ \omega$ |
| 15 | $cargo(v) \land cargo(y) \land hazMat(v,m1) \land hazMat(y,m2) \land neighbours(v,y) \land dangerous(m1,m2) \land concurrent(v,y) \Rightarrow alarm(v,y)$ | $\omega$ |

Symmetry

Time rules = concurrency

Spatial rules = adjacency

Definition of suspicious or anomalous condition

*“Two cargos share adjacent berths in a harbour”*

*“Two cargos are in the same harbour at the same time”*

***Alarm**: “two cargos share adjacent berths in a harbour and are moored at the same time, and they carry hazmat that are dangerous when combined together”.*

# Context: what do we know about…?

… the harbour
… the materials

*The adjacent berths are*
*Harbour has berths*
*Some materials are dangerous when mixed*

$dangerous(M_1, M_2)$

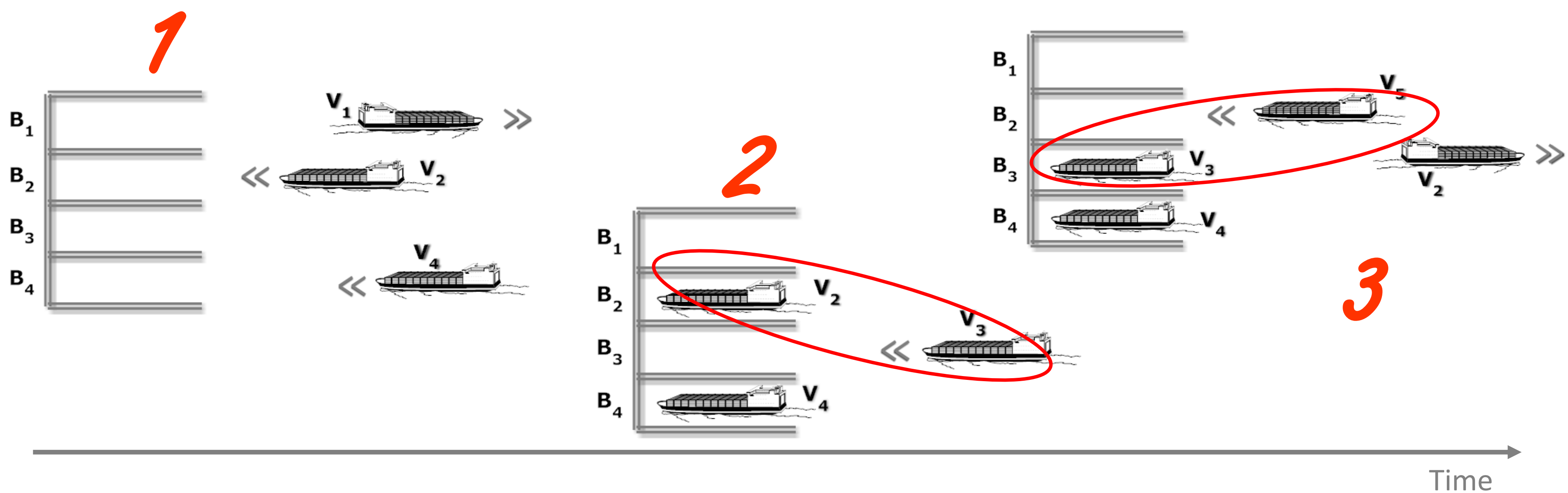
$dangerous(M_2, M_3)$

$dangerous(M_2, M_4)$

$\neg dangerous(M_1, M_4)$

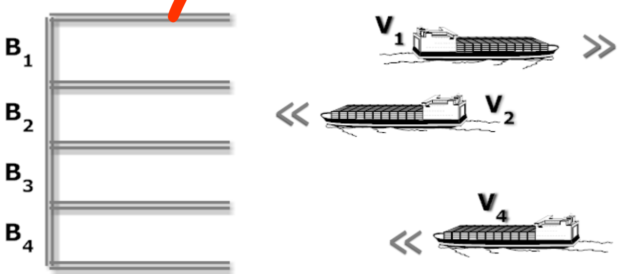
$\neg dangerous(M_3, M_4)$

$\neg adjBerth(B_2, B_4)$



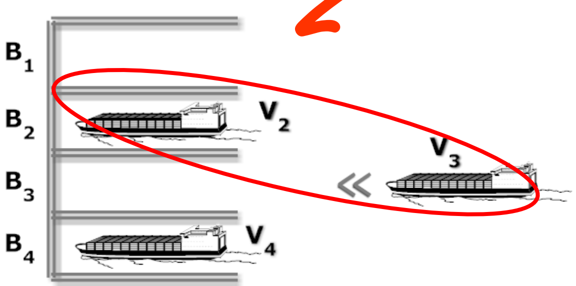
# Observations: what do we see?

1




*Some cargos carry hazmat*

2




*Paying more attention:*

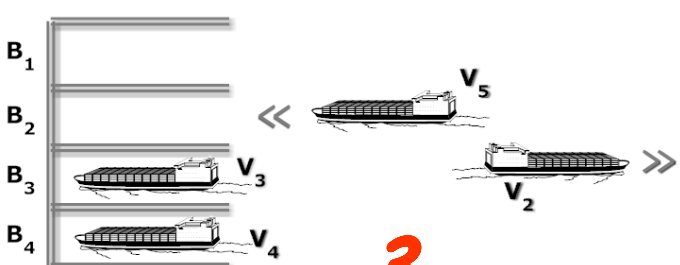
*Some of them are adjacent and concurrent and carry hazmat*

*The cargos have assigned berths*

From context...

$dangerous(M_1, M_2)$
$dangerous(M_2, M_3)$
$dangerous(M_2, M_4)$
$\neg dangerous(M_1, M_4)$
$\neg dangerous(M_3, M_4)$

Th ... ning




3

Time

$cargo(V_1)$
$cargo(V_2)$
$cargo(V_3)$
$cargo(V_4)$
$cargo(V_5)$
$hazMat(V_1, M_1)$
$hazMat(V_2, M_2)$
$hazMat(V_3, M_3)$
$hazMat(V_4, M_4)$
$hazMat(V_5, M_2)$
$isHeadingTo(V_1, H_1)$
$isHeadingTo(V_2, H_1)$
$isHeadingTo(V_3, H_1)$
$isHeadingTo(V_4, H_1)$
$isHeadingTo(V_5, H_1)$
$hasBerth(V_1, B_1, H_1)$
$hasBerth(V_2, B_2, H_1)$
$hasBerth(V_3, B_3, H_1)$
$hasBerth(V_4, B_4, H_1)$
$hasBerth(V_5, B_2, H_1)$
$before(V_1, V_2)$
$before(V_1, V_5)$
$overlaps(V_2, V_3)$
$overlaps(V_2, V_4)$
$overlaps(V_4, V_3)$
$overlaps(V_3, V_5)$
$overlaps(V_4, V_5)$

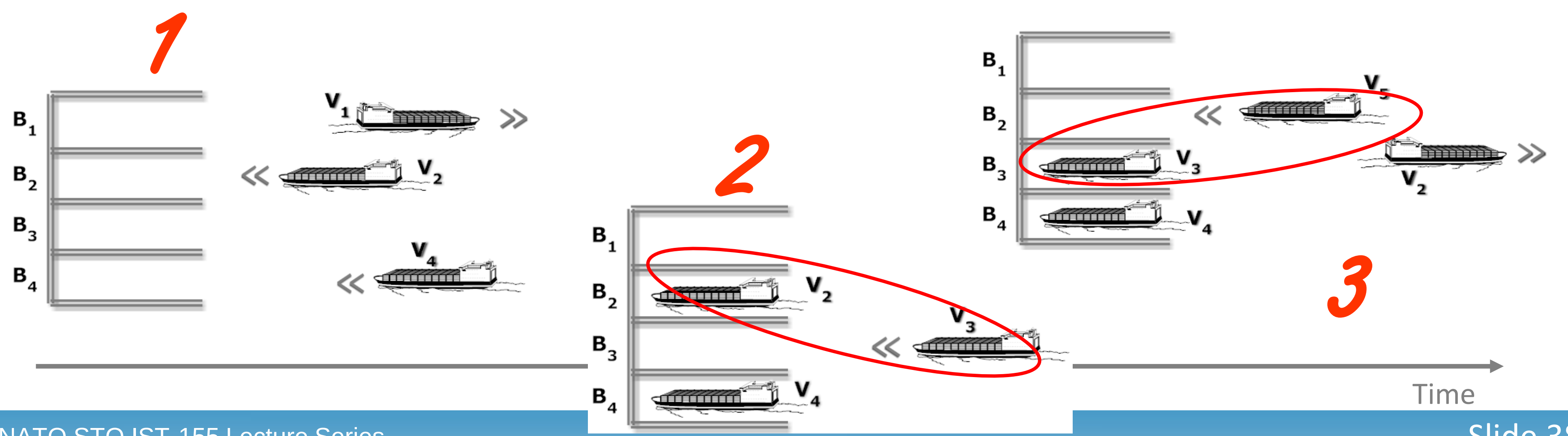
# Alarm flags

| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ |
|---|---|---|---|---|---|
| $V_1$ | | 0.01 | 0.23 | 0.17 | 0.01 |
| $V_2$ | 0.01 | | 0.33 | 0.37 | 0 |
| $V_3$ | 0.23 | 0.33 | | 0.34 | 0.32 |
| $V_4$ | 0.17 | 0.37 | 0.34 | | 0.32 |
| $V_5$ | 0.01 | 0 | 0.32 | 0.32 | |

| $V_3$ |
|---|
| N |
| Y |
| |
| N |
| Y |

| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ |
|---|---|---|---|---|---|
| $V_1$ | | 0.05 | 0 | 0 | 0.01 |
| $V_2$ | 0.05 | | 0.95 | 0.18 | 0.01 |
| $V_3$ | 0 | 0.95 | | 0.02 | 0.89 |
| $V_4$ | 0 | 0.18 | 0.02 | | 0.51 |
| $V_5$ | 0.01 | 0.01 | 0.89 | 0.51 | |

*Without contextual information* | *With contextual information*



# Reasoning about events with MLNs

- A few interesting possibilities for SA:
  - Comple events as conjunction of simple events
  - Completion of complex events evaluation
  - Observation uncertainty
  - Abduction

# Conjunction of simple events

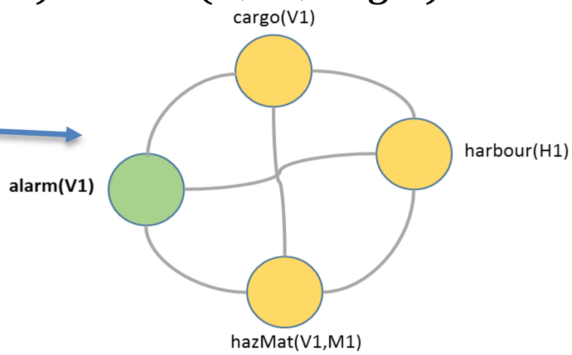
- **Complex events**
  - Might be not directly observable
  - Deducible from conjunction of simple events (sufficient preconditions)

$$evt_1 \wedge evt_2 \wedge \cdots \wedge evt_k \rightarrow \text{cpxEvt}$$

Example:

$$cargo(v) \wedge hazMat(v,m) \wedge harbour(h) \wedge isHeadingTo(v,h) \wedge risk(h,m,High)$$

Markov Network




Ground atoms: *cargo(V1), hazMat(V1,M1), harbour(H1)*

Query atom: *alarm(V1)*

# Completion of complex events

- Good to know that something (bad) is about to happen

↓

- Detection of complex event before its completion
- In classic FOL the complex event would be just *false*

Example:

$$cargo(v) \wedge hazMat(v,m) \wedge harbour(h) \wedge isHeadingTo(v,h) \wedge risk(h,m,High)$$

| Weight | 1 event | 2 events | 3 events | 4 events | 5 events |
|---|---|---|---|---|---|
| **3.0** | 0.5000 | 0.5000 | 0.5430 | 0.5941 | 0.9526 |

# Observation uncertainty

- MLNs support rule uncertainty
- Observations/evidence uncertainty natural requirement for SA systems
  - Sensors and sources produce uncertain estimates/statements
- Uncertain evidence supported by recent reasoners

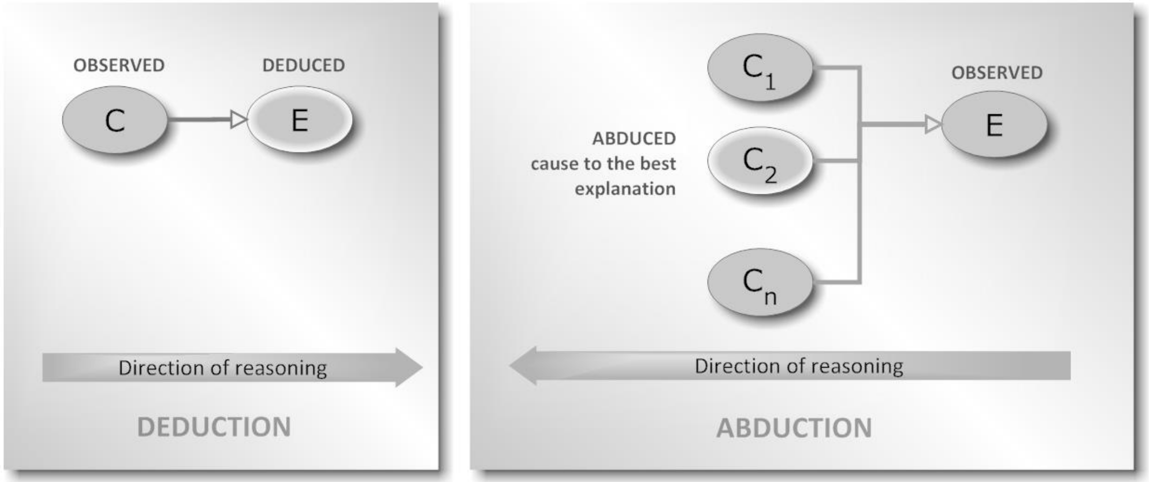
Example:

1.0 1.0 1.0 1.0

$$cargo(V1) \wedge hazMat(\mathrm{V1}, \mathrm{M1}) \wedge harbour(H1) \wedge isHeadingTo(\mathrm{V1}, H1)$$

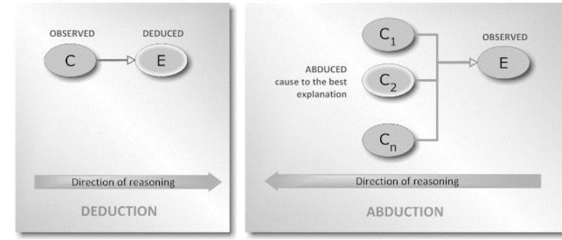
0.1 0.66

# Abduction




- Deductive reasoning:
  - Allows to derive new knowledge when antecedent is True
- Abductive reasoning:
  - Looks for causes that can explain observed events or effects

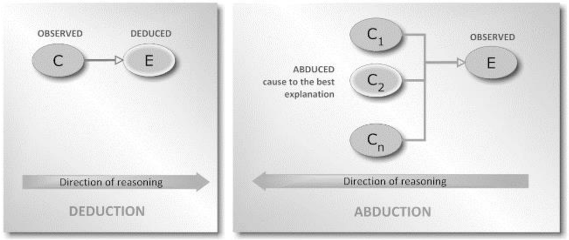
# Abduction (2)




- Issues:
  - No support from formal logical mechanism (deduction has *modusponens*)
  - Multiple causes are possible
  - Truth value of antecedent is unknown !!

- However:
  - Some support is provided for MLNs
  - Context can be key element to establish most probable causes

# Abduction (3)




Example:

$$2.0\ storm(area) \wedge isIn(v, area) \rightarrow deviatesFromRoute(v)$$
$$3.0\ ice(area) \wedge isIn(v, area) \rightarrow deviatesFromRoute(v)$$
$$3.0\ hijacked(v) \rightarrow deviatesFromRoute(v)$$

- KB needs to be augmented with the following rule (+ mutual exclusion constraints)

$$\omega\ \ deviatesFromRoute(v) \rightarrow$$
$$\big(\exists\ area\ storm(area) \wedge isIn(v, area)\big) \vee \big(\exists\ area\ ice(area) \wedge isIn(v, area)\big)$$
$$\vee\ hijacked(v)$$

- E.g. Contex can provide info on the risk level of the area

# Discussion

- Establish separation between “always valid” a priori knowledge and what is contextual to the domain
  - Modular development of knowledge repositories
- Context heterogeneity and fusion levels
  - Hard/Soft fusion
- Middleware needed for context-exploitation

# Conclusions

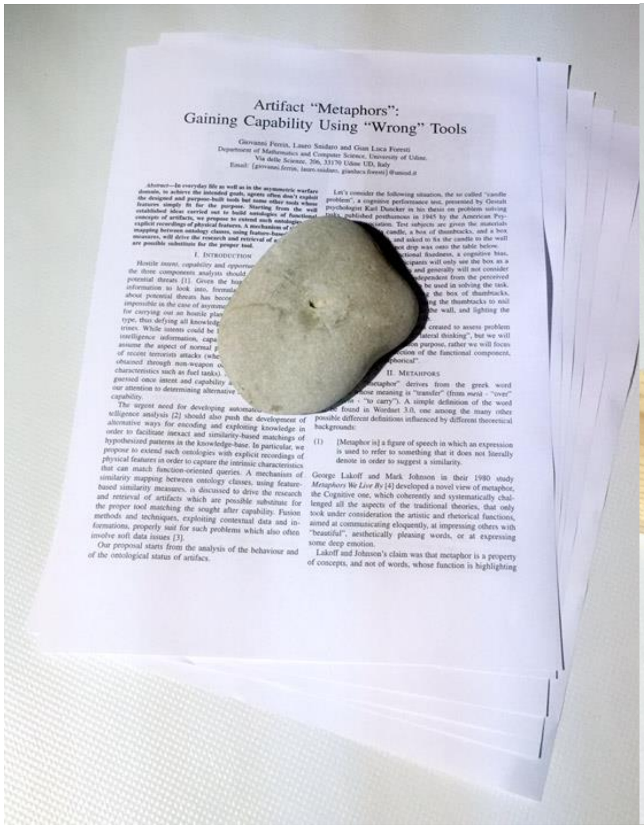
- Markov Logic Networks as an efficient tool that leverages both the expressive power of first order logic and the probabilistic uncertainty management of Markov Networks.
- Can couch both rule uncertainty and observations uncertainty.
- The knowledge base is grounded with observed (incomplete) empirical evidence, and reasoning is performed online exploiting high-level contextual and a priori information.
- Applied to Situation Assessment in maritime domain.

Part III

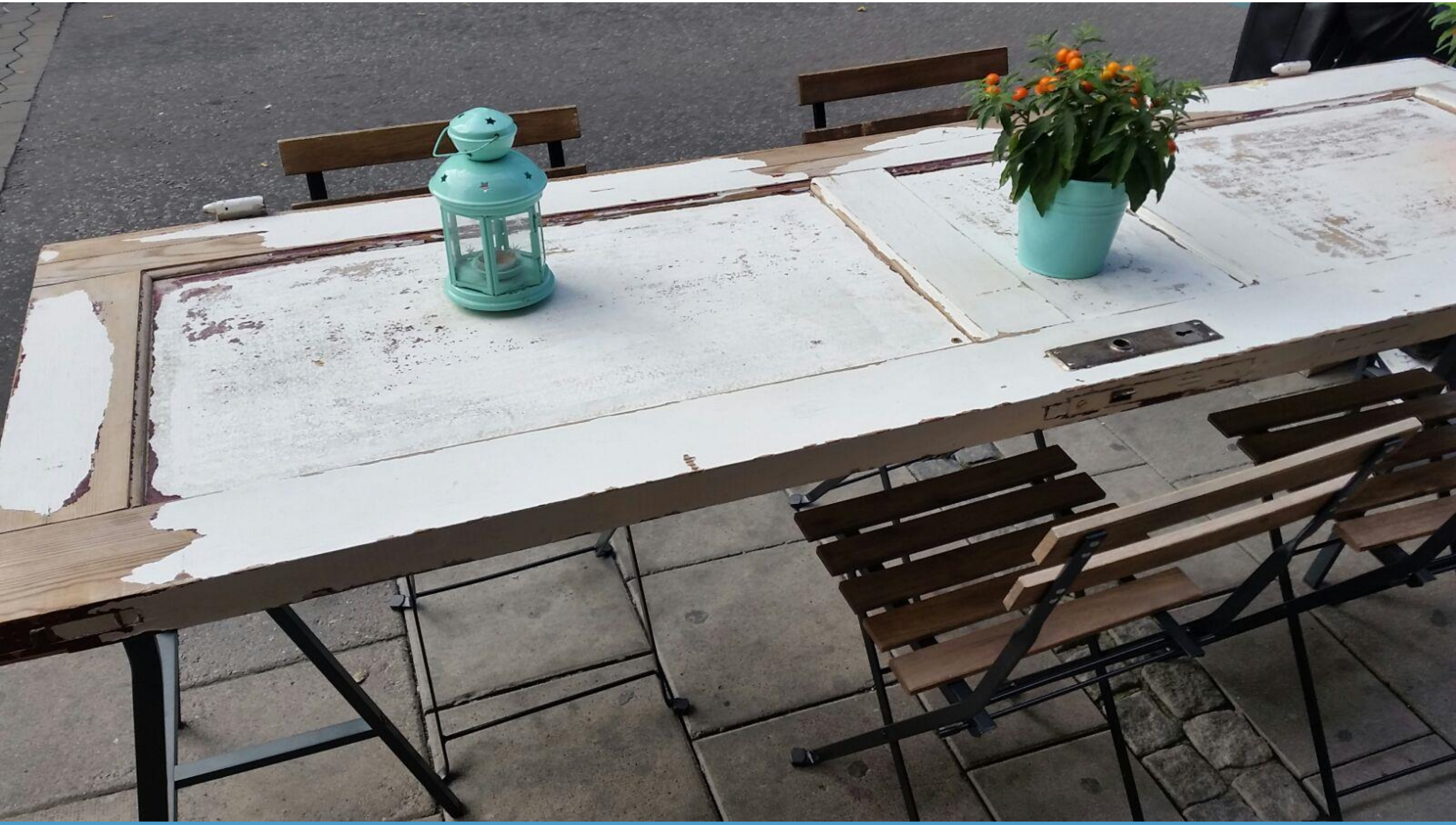
# IS CONTEXT ALWAYS A GOOD THING? AN INTELLIGENCE CASE

[4]

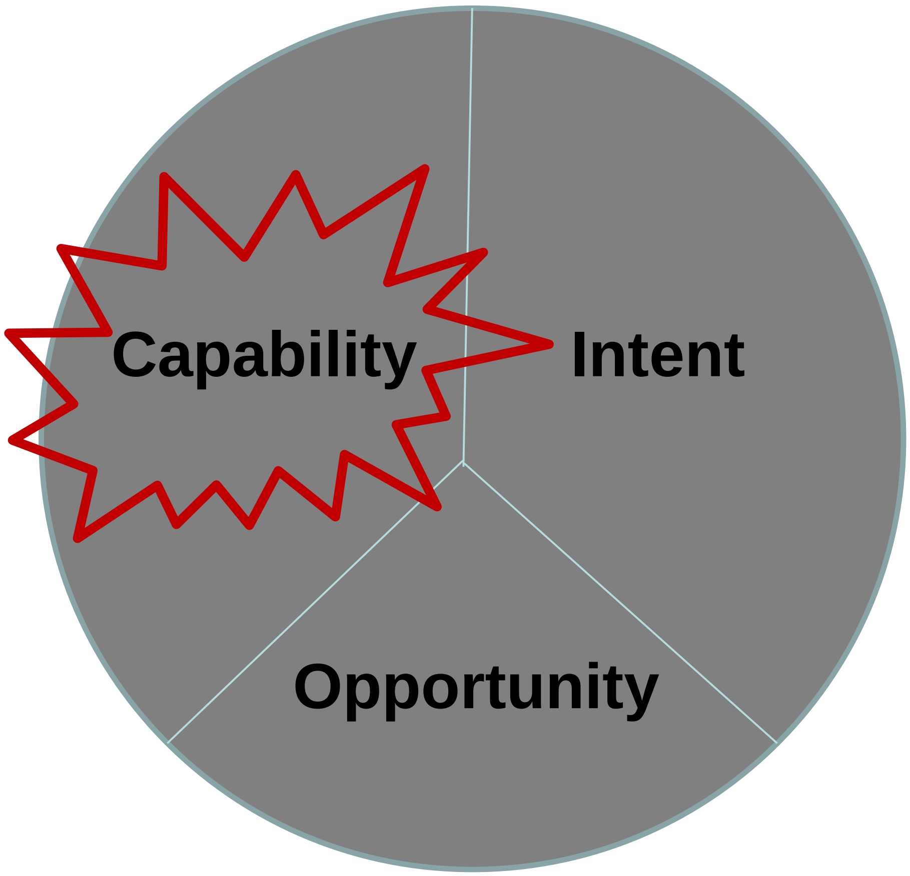
# Improper uses ?




# Improper use?



# Threat assessment



# Metaphor definition(s)

- A figure of speech in which an expression is used to refer to something that it does not literally denote in order to suggest a similarity. (*Wordnet 3.0*)

- Metaphor [is a] figure of speech that implies comparison between two unlike entities, as distinguished from simile, an explicit comparison signalled by the words “**like**” or “**as**”. (*Encyclopaedia Britannica*)

# Metaphor – Traditional views

- metaphor is a **property of words**; it is a linguistic phenomenon;
- metaphor is used for some **artistic and rhetorical purpose**;
- metaphor is based on a **resemblance** between the two entities that are compared and identified;
- metaphor is a conscious and deliberate use of words, and **you must have a special talent** to be able to do it and do it well;
- it is also commonly held that metaphor is a figure of speech that **we can do without**; we use it for **special effects**, and it is not an inevitable part of everyday human communication.

# Metaphor – Cognitive view

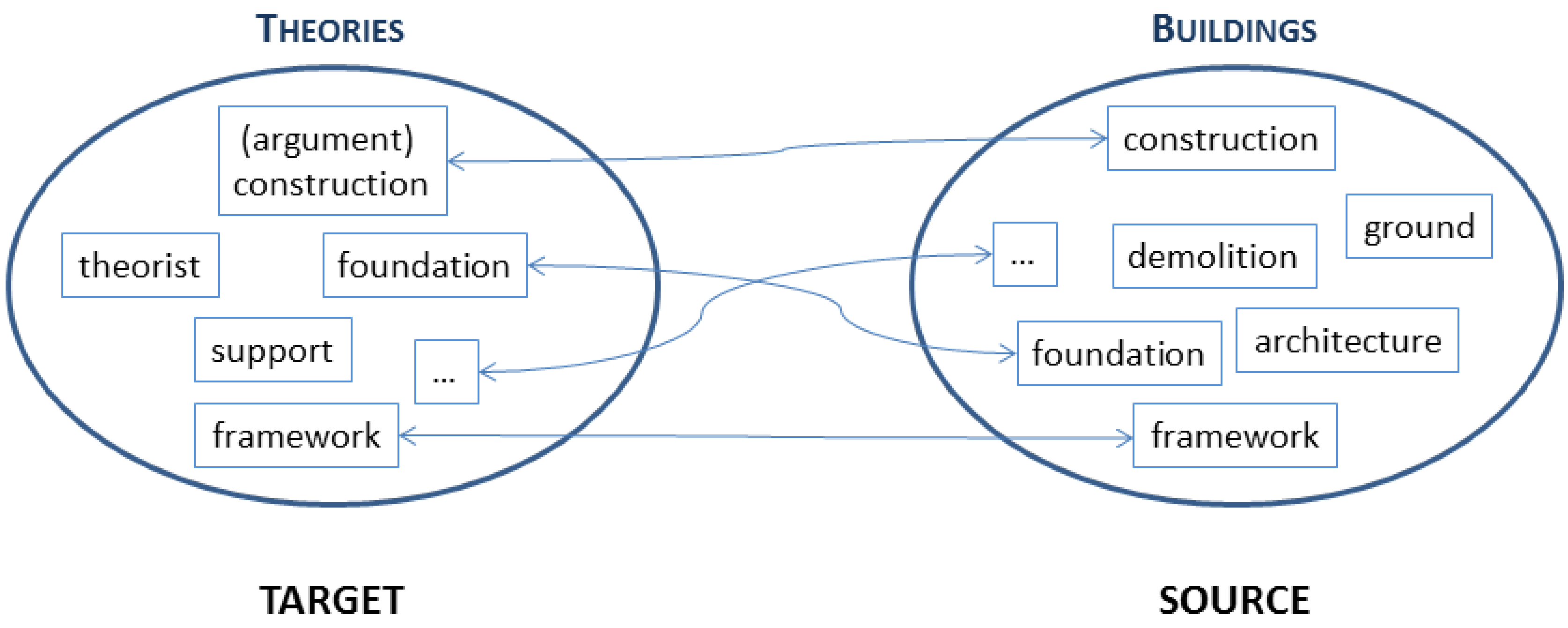
- metaphor is a **property of concepts**, and not of words;
- the function of metaphor is to **better understand certain concepts**, and not just some artistic or esthetic purpose;
- metaphor is **often not based on similarity**;
- metaphor is **used** effortlessly **in everyday life** by ordinary people, not just by special talented people;
- metaphor, far from being a superfluous though pleasing linguistic ornament, is an **inevitable process of human thought and reasoning.**

*Metaphors We Live By,* Lakoff & Johnson, 1980

# Theoretical commonality

- Metaphor theories, despite their deep differences from a theoretical point of view, basically make a large use of concepts such "**structure**" and "**pattern**" and stress the point according to which metaphor is abundant in common language as much as in common communication in a wide sense.

# Structure mapping in Metaphor



# Artifacts

- Dictionaries usually define an "**artifact**" as a simple object made by human art and workmanship, an artificial product (distinguished from a natural object)
- The art of making something involves, and sometimes implies, intentional agency; thus an artifact may be defined as

  *"an object that has been **intentionally** produced for some **purpose**"*

# Artifact Ontological Status

- Currently researchers from three different domains are currently working on a common perspective about artifact ontology
  1. applied ontology
  2. engineering design
  3. philosophy of technology

# Artifact Ontological Status

- Three different definitions of "artifact"
  - **D1**. (Ontological Artifact - A*pplied ontology*)
    A technical artifact *A* is a physical object which an **agent** (or group of agents) creates by two, possibly concurrent, **intentional acts**:
    the **selection** of a material entity (as the only constituent of *A*) and the **attribution** to *A* **of a technical quality or capacity**

# Artifact Ontological Status

– **D2**. (Engineering Artifact)
  A technical artifact *A* is a physical object created by a **production process**. The process is **intentionally performed** by one or more **agents** with the goal of producing the object
  *A* which is **expected to realize intended behavior** in some given generic technical situation.

# Artifact Ontological Status

– **D3**. (Technological Artifact)
A technical artifact $\mathcal{A}$ is a physical object created by the carrying out by an **agent** (or by agents) of a **make plan** for an object with a physical description D.

# Artifacts and Functions

- Artifacts can be characterized in terms of functions and goals
- Being *𝓕* the function or purpose which an artifact has been created for, its properties as an *𝓕*-object can be divided into two classes
  - a) properties **relevant** to the functioning of the object as an *𝓕*-object
  - b) properties irrelevant to the purpose *𝓕*

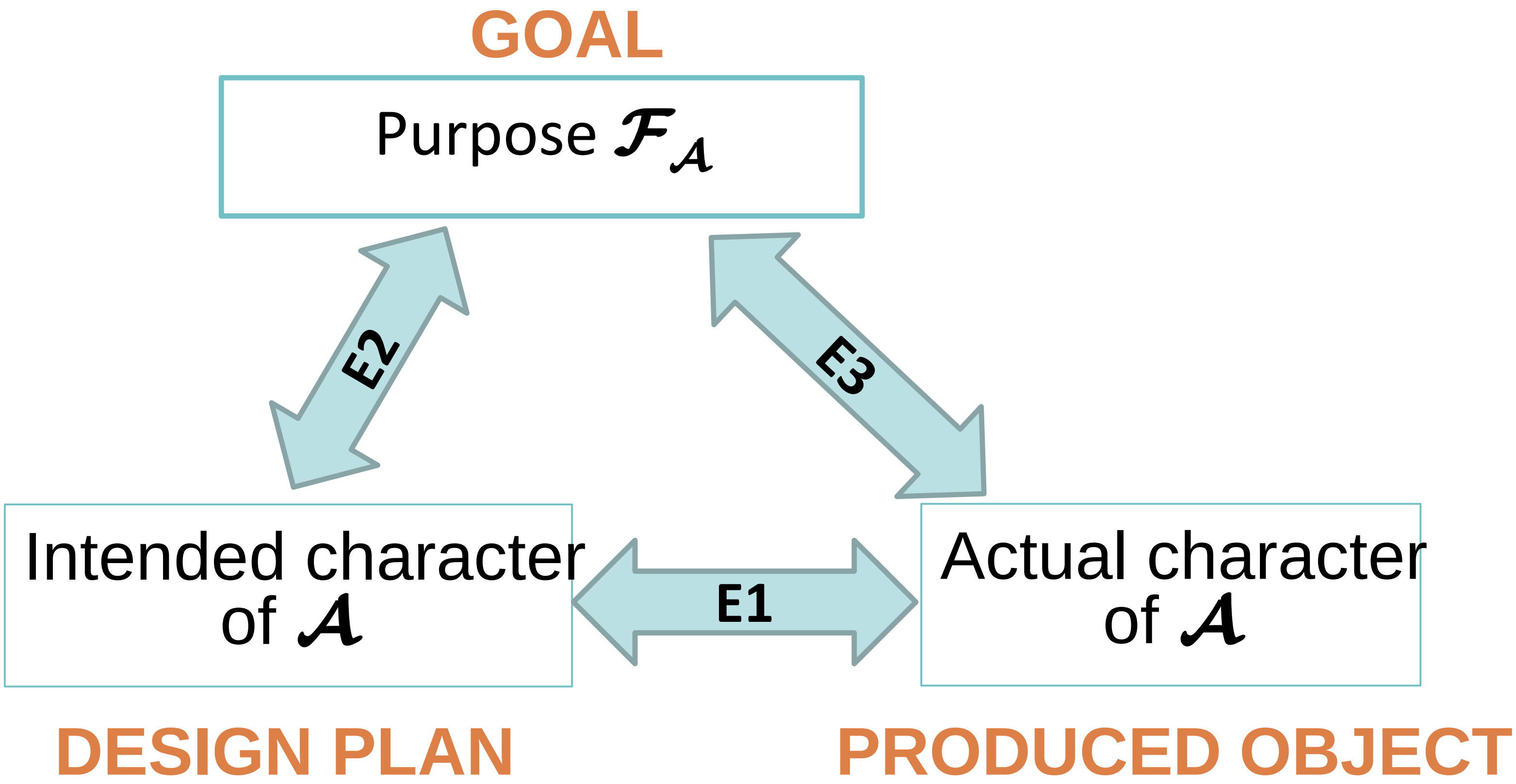
# Artifacts and Functions

- an artifact includes all the properties regarded as significant for the purpose $\mathcal{F}$ within the productive intention of its author(s)
- the properties are not to be considered a simple collection of predicates, but **relationally structured**
- in many cases an object is expected to serve different purposes with different degrees of success

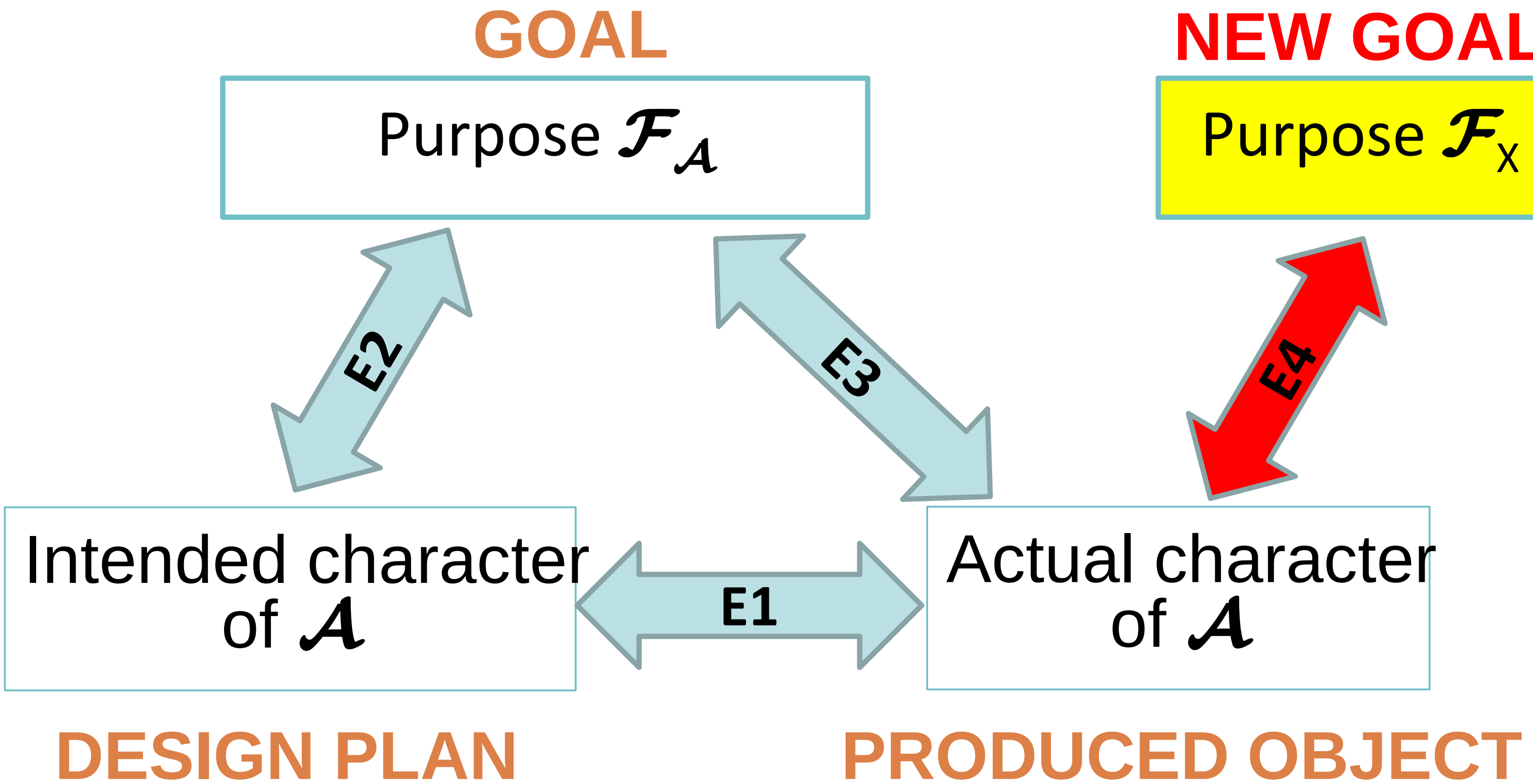
# Artifacts and Functions

- Evaluation of an artifact
  - **E1** - degree of fit or agreement between the intended character and the actual character of an artifact $\mathcal{A}$
  - **E2** - degree of fit between the intended character of an artifact $\mathcal{A}$ and the purpose $\mathcal{F}$, that is, the appropriateness of the artifact's "project" for the purpose $\mathcal{F}$
  - **E3** - degree of fit between the actual character of an artifact $\mathcal{A}$ and the purpose $\mathcal{F}$, that is, the suitability of the artifact $\mathcal{A}$ for $\mathcal{F}$

# Artifacts and Functions



# Artifacts and Functions



# Artifacts and Functions

- Evaluation of a “metaphorical” artifact
  - **E4** - degree of fit between the character of an $\mathcal{F}_{\mathcal{A}}$–artifact and the purpose $\mathcal{F}$x , that is, the suitability of the artifact for an $\mathcal{F}$x different from the one it has been designed for

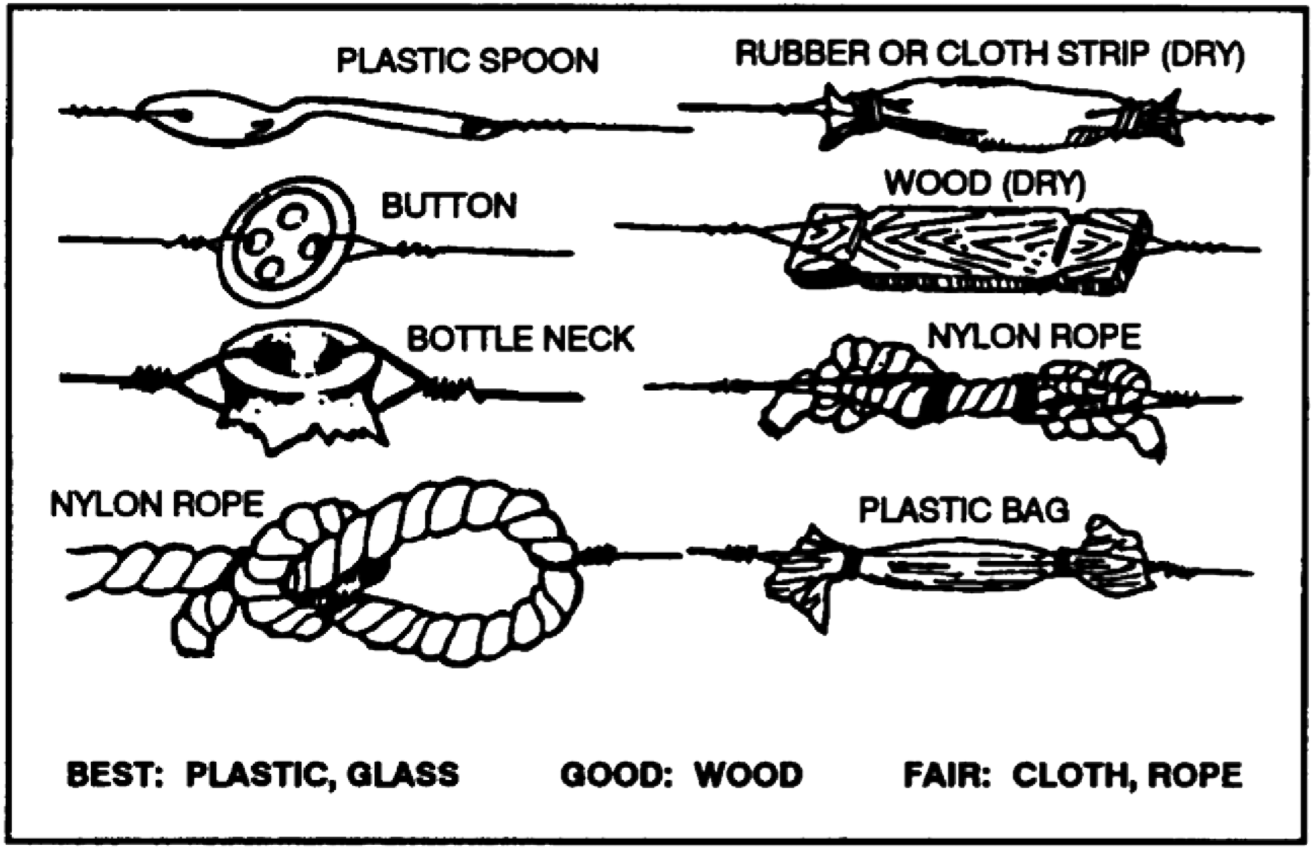
# Artifacts and Functions

- The **capability** of a tool $\mathcal{A}$ to fit the function (purpose, or intent) $\mathcal{F}$ can be expressed with the following vector of weighted ($W_n$) $\mathcal{F}$-significant properties $P_n(\mathcal{F})$.

- $C_{\mathcal{A}}(\mathcal{F}) = [\, P_1(\mathcal{F}) * W_1 , \ldots , P_n(\mathcal{F}) * W_n \,]$

which allows to accomplish evaluation **E4** using a proper metric

# An Example




*FM 23-10 Sniper Training*, US Department of the Army, August 1994

# Evaluation E4 for the Example

- $\mathcal{F}$ = electrical insulation
- $\mathcal{F}$-properties:
  - – Resistivity
    - Hygroscopy
  - – Mechanical (tensile) strength
  - – Physical dimensions

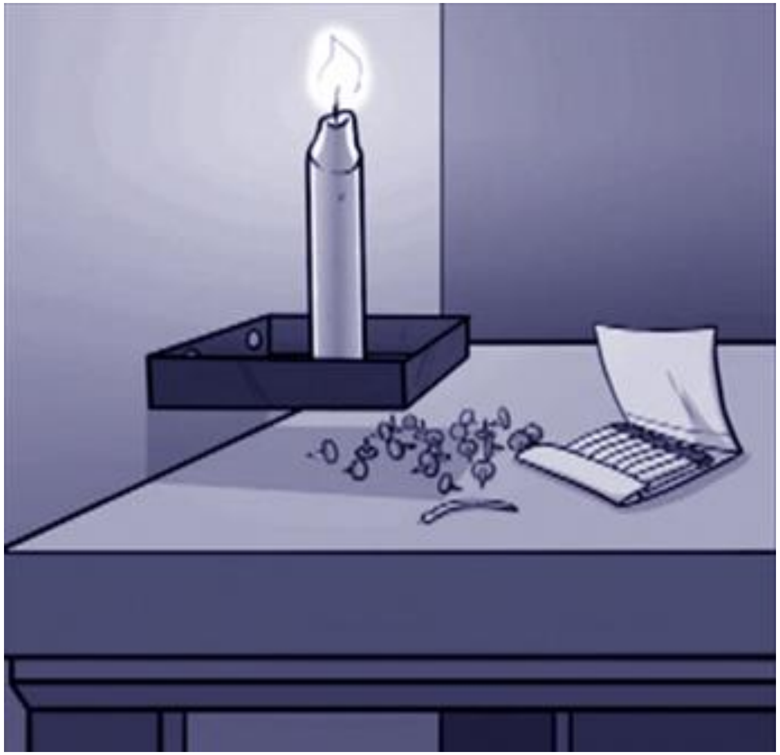
# Artifacts and Context

- Dunker's candle problem

Fix the candle to the wall so that, once lit, it will not drip wax onto the table below.
Given material:
a candle,
a box of thumbtacks,
a box of matches
on a table.

# Artifacts and Context

- Dunker's candle problem

# Artifacts and Context

- **Context** is fundamental in achieving tasks by providing expectations, constraints and additional information for inference about the items of interest

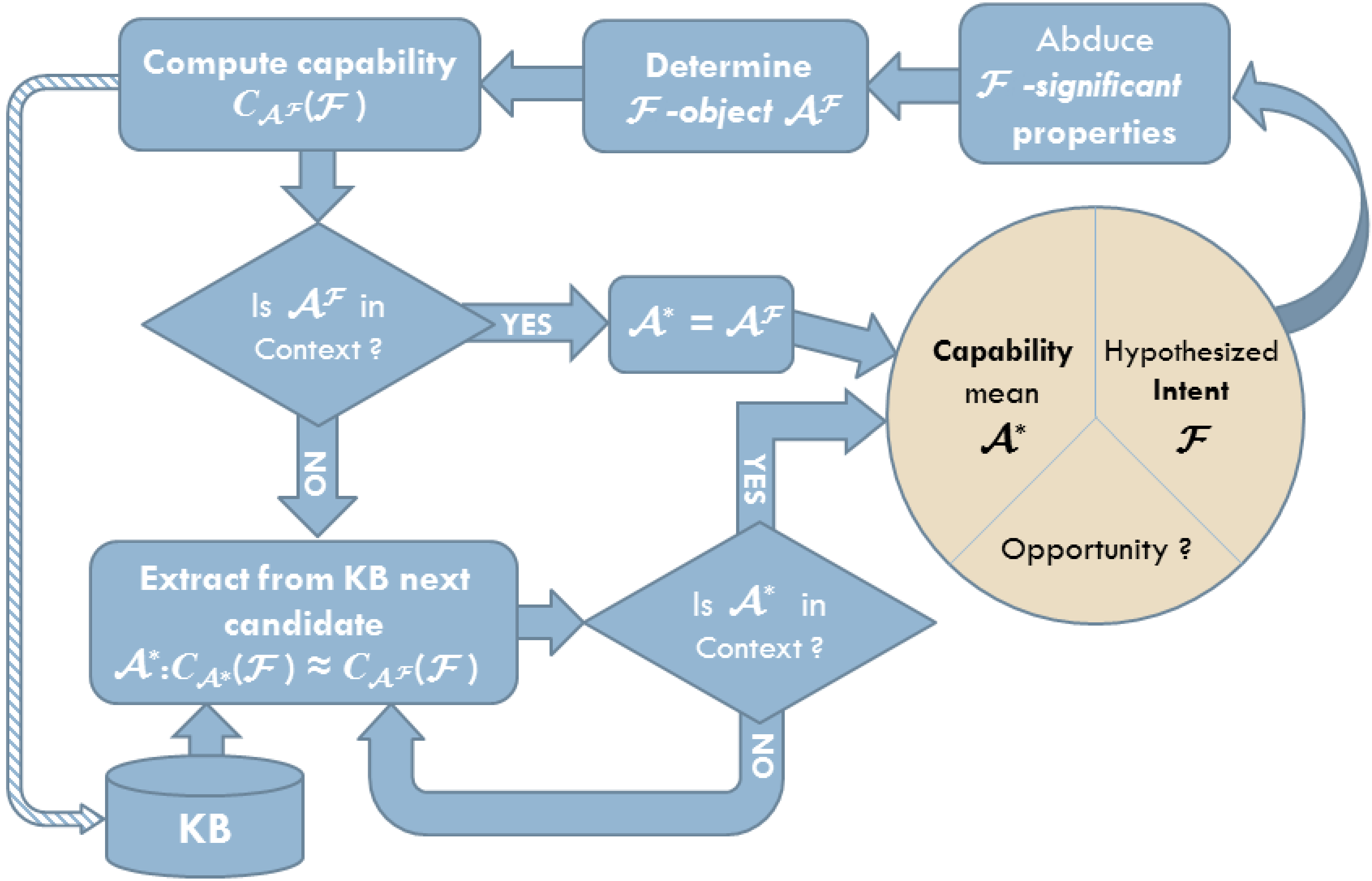
**BUT**

- in the domain of artifact "metaphors", which involves problem-solving issues, context consolidates **functional fixedness obstructing a possible solution** (remember the box of thumbtacks).

# Artifacts and Context

- **De-contextualization** of objects is the first step of a process of "creative" production of **substitute tools**
- Sometimes the process is deliberately accomplished to perform malicious actions, the most macroscopic among the accomplished ones being the metaphorical substitution
  "JET AIRPLANES are WEAPONS"
  in the 9/11 Twin Towers attack

# Capability evaluation



# III-part Conclusions and Future Work

- Artifacts/Tools can be used to achieve goals different from the ones they have been designed and built for
  - Artifact/Tool character (intended function) depends on structured sets of properties
- Functional ontologies can be exploited, enriched with the cited properties, to represent Artifacts/Tools
  - A mechanism of mapping between Capability vectors can drive the retrieval of «metaphorical» Artifact/Tools substitutes
- Context plays a fundamental role but also a mechanism of de-contextualization is necessary to avoid functional fixedness

**Lauro Snidaro, Jesús García, James Llinas, Erik Blasch** **2016**

Springer

| | |
|---|---|
| **FOUNDATIONS** | |
| 1 | Context and fusion: definitions, terminology |
| **CONCEPTS of CONTEXT FOR FUSION** | |
| 2 | Formalization of "context" for information fusion |
| 3 | Context as an uncertain source |
| 4 | Contextual tracking approaches in information fusion |
| 5 | Context Assumptions for Threat Assessment Systems |
| 6 | Context aware knowledge fusion for decision support |
| **SYSTEMS PHILOSOPHY of CONTEXTUAL FUSION** | |
| 7 | System-Level Use of Contextual Information |
| 8 | Architectural Aspects for Context Exploitation in Information Fusion |
| 9 | Middleware for exchange and validation of context data and information |
| 10 | Modeling User Behaviors to enable Context-Aware Proactive Decision Support |
| **MATHEMATICAL CHARACTERIZATION OF CONTEXT** | |
| 11 | Supervising the fusion process by context analysis for target tracking |
| 12 | Context Exploitation for Target Tracking |
| 13 | Contextual Tracking in Surface Applications: Algorithms and Design Examples |
| 14 | Context Relevance for Text Analysis and Enhancement for Soft Information Fusion |
| 15 | Algorithms for Context Learning and Information Representation for Multi-Sensor Teams |
| **CONTEXT IN HARD/SOFT FUSION** | |
| 16 | Context for dynamic and multi-level fusion |
| 17 | Multi-level Fusion of Hard and Soft Information for Intelligence |
| 18 | Context-based Fusion of Physical and Human Data for Level 5 Information Fusion |
| 19 | Context Understanding from Query-Based Streaming Video |
| **APPLICATIONS OF CONTEXT APPROACHES TO FUSION** | |
| 20 | The Role of Context in Multiple Sensor Systems for Public Security |
| 21 | Entity Association using Context for Wide-Area Motion Imagery Target Tracking |
| 22 | Ground target tracking applications. Design examples for military and civil domains |
| 23 | Context-based Situation Recognition in Computer Vision Systems |
| 24 | Data Fusion Enhanced with Context Information for Road Safety Application |
| 25 | Context in Robotics and Information Fusion |

Upcoming book on Context-enhanced Information Fusion

# Thank you!!

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[2] L. Vaci and L. Snidaro, «Encoding context likelihood functions as classifiers in particle filters for target tracking», in Proceedings of the IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems, 2016

[3] L. Snidaro, I. Visentini, and K. Bryan, “Fusing uncertain knowledge and evidence for maritime situational awareness via Markov Logic Networks”, Information Fusion, Vol 21 (January 2015), 159-172

[4] G. Ferrin, L. Snidaro, and G.L. Foresti, “Artifact Metaphors: Gaining Capability Using "Wrong" Tools”, Proceedings of the 17th International Conference on Information Fusion, July 6-9, 2015, Washington, D.C., USA, pp. 1176-1181.