DEFENCE AND SPACE

MULTI-LEVEL INFORMATION FUSION AND ACTIVE PERCEPTION FRAMEWORK

TOWARDS A MILITARY APPLICATION

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NATO SET-262 - 6th November 2018

DGA GREYC AIRBUS

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1) Situation Awareness

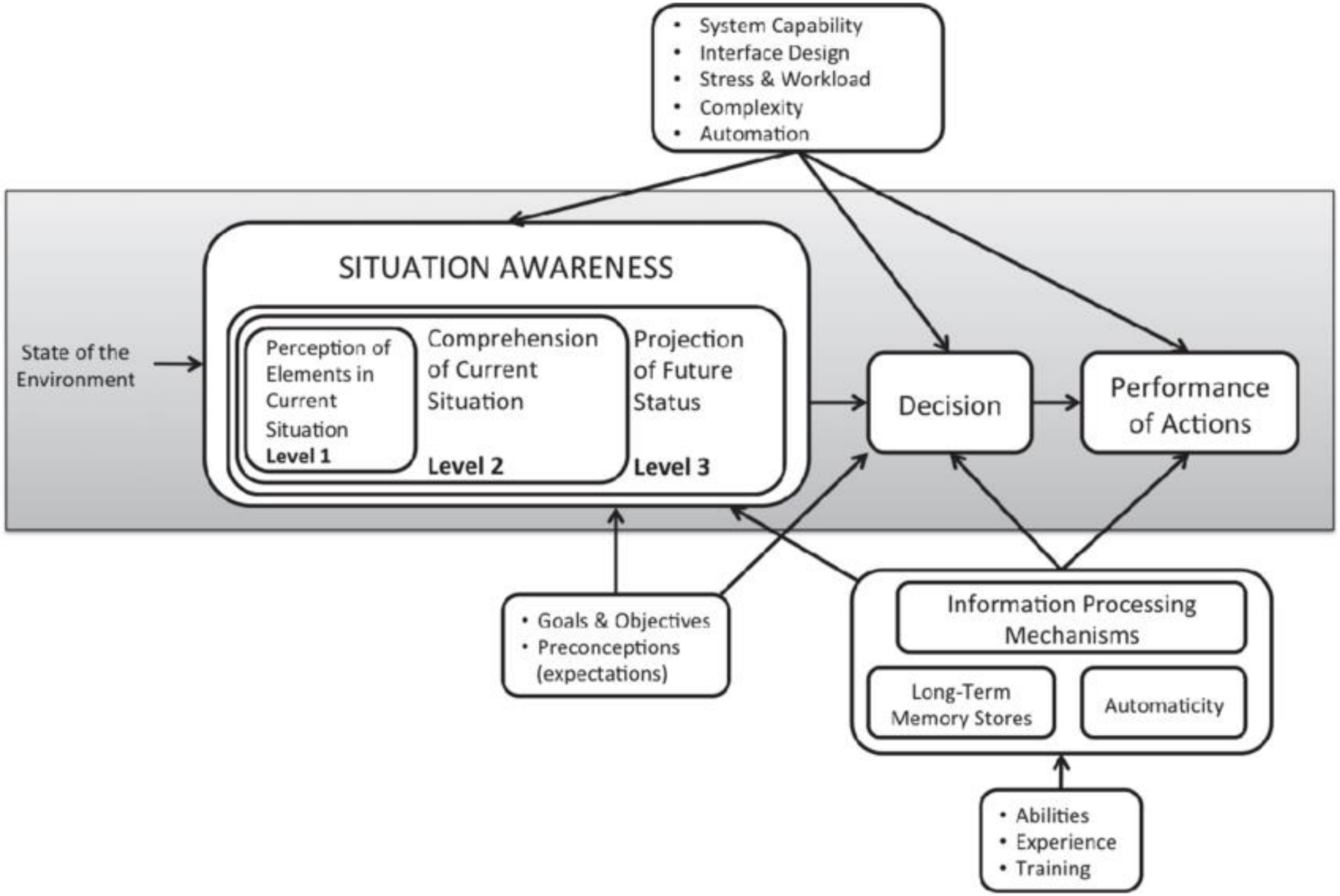
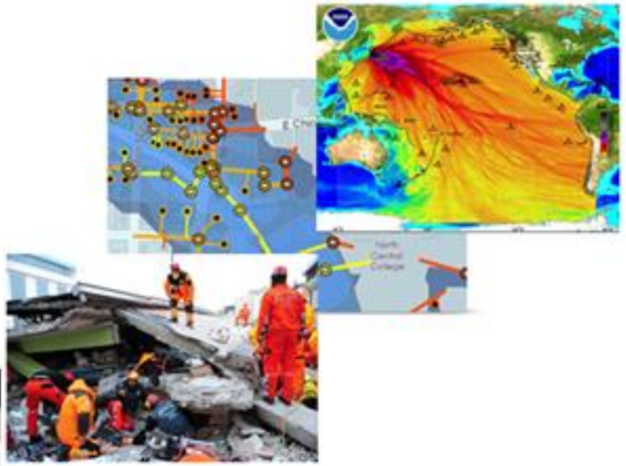


Figure 1 : Endley's model of Situation Awareness

2) Crisis situation



Strong constraints :

- Speed of information aquisition
- Limited ressources

3) Active Perception

Passive perception :

- Get all possible information with all available sensors
- Only based on quantitative cursor to get information

Active perception :

- Need to search for **relevant information**
- Define **dynamically** what to observe
- Find the best sensor to get information on relevant object

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1) Scientific motivation

Question :

In a **dynamic environment**, which variables are the most valuable to observe to **maximize the information gain** ?

Key-feature :

Most Valuable Variable (MVV) : variable that bring more information than the others to reduce ambiguity on the state of the object

2) Why defining these MVV ?

Constraints and state-of-the-art:

- Crisis situation implies two major problematics :
  - Information acquisition speed
  - Limited resources
- In the literature :
  - Mostly passive perception approaches
  - Optimisation of the variables / sensors association problem

Our approach :

- Active Perception framework
- Add an MVV analysis process to bring a qualitative cursor on information

3) Active Perception Framework

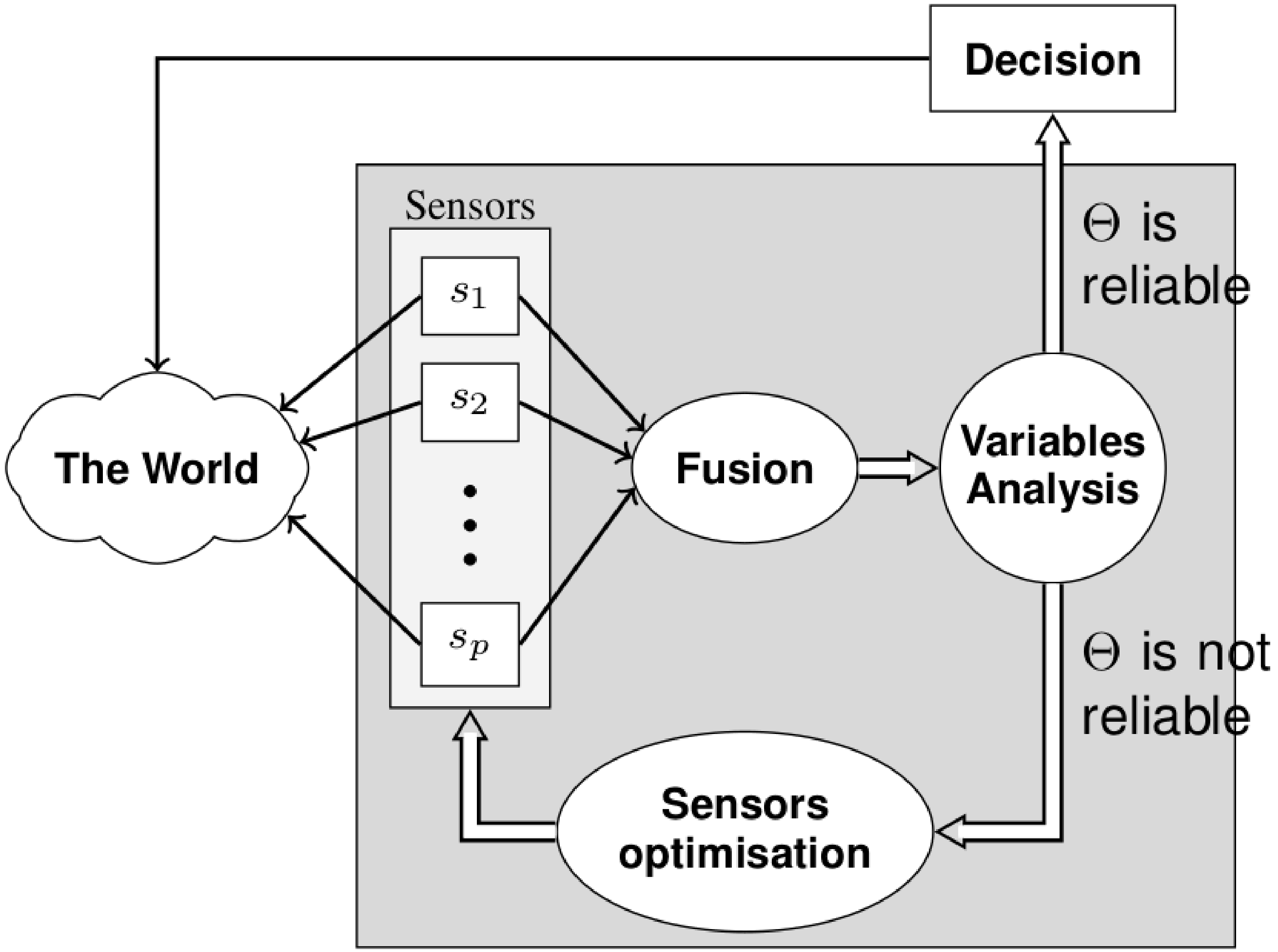

Figure 2 : adapted from the framework in [*Zhang & al*, 2012]

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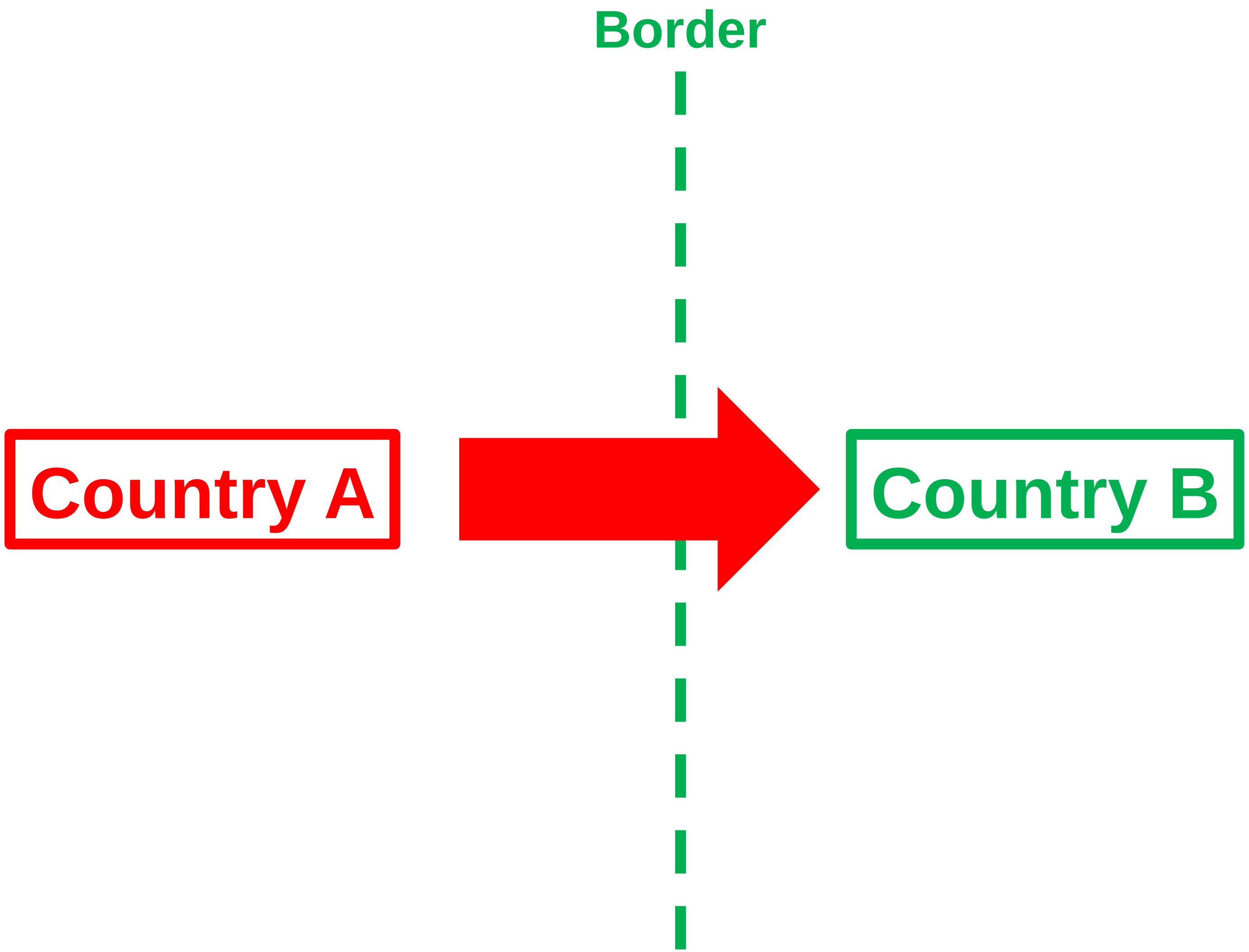
1) Military scenario - Context

Scenario :

- Two bordering countries are in conflict
- The enemy country (**A**) tries to invade the allied country (**B**) with military forces

Objectives :

- Define the strategy of the enemy
  - ➢ By which point will he attack ?
- Represent the threat and localise it
- Understand the phase of the attack



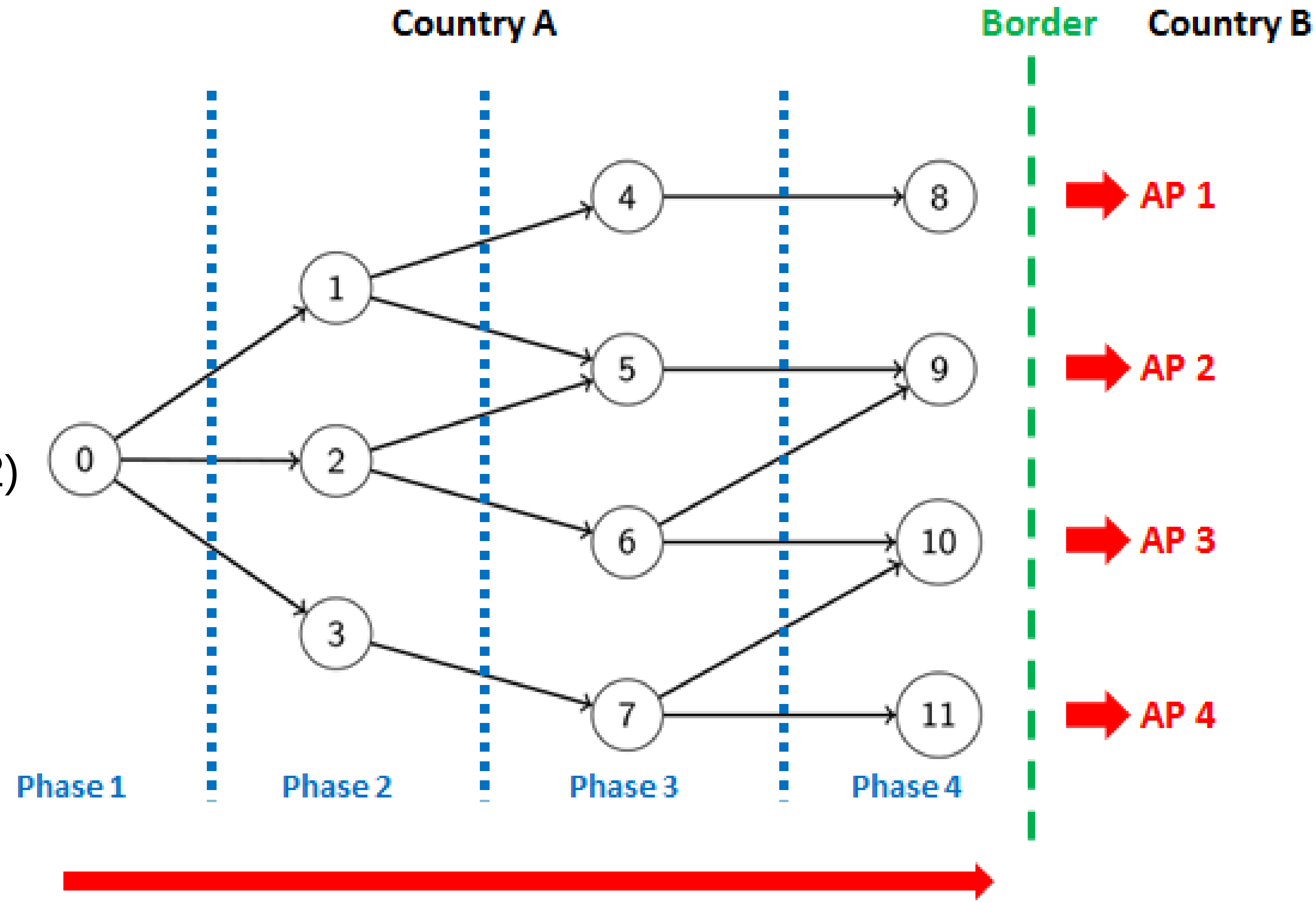
2) HPIZ and Attack Point

High-Priority Information Zones :

- **HPIZ** : zones considered as important to observe to understand enemy's manoeuvres and identify the threat
- HPIZ are given by intelligence services (B2) before the attack

Attack Points :

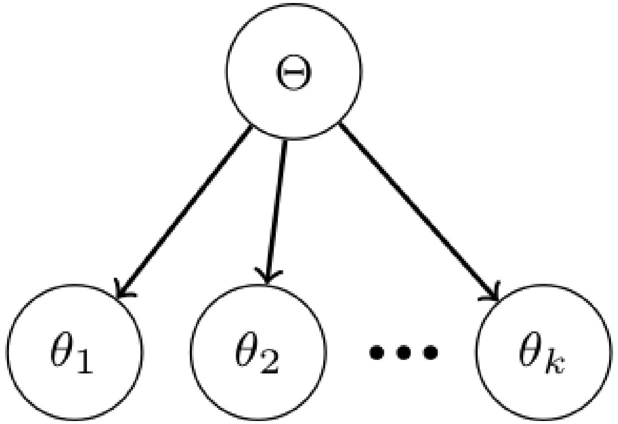
- Points of arrival of enemy's forces that we need to define to prepare the counter-offensive



3) Evironment modelling

Evaluated Situation

Monitored elements

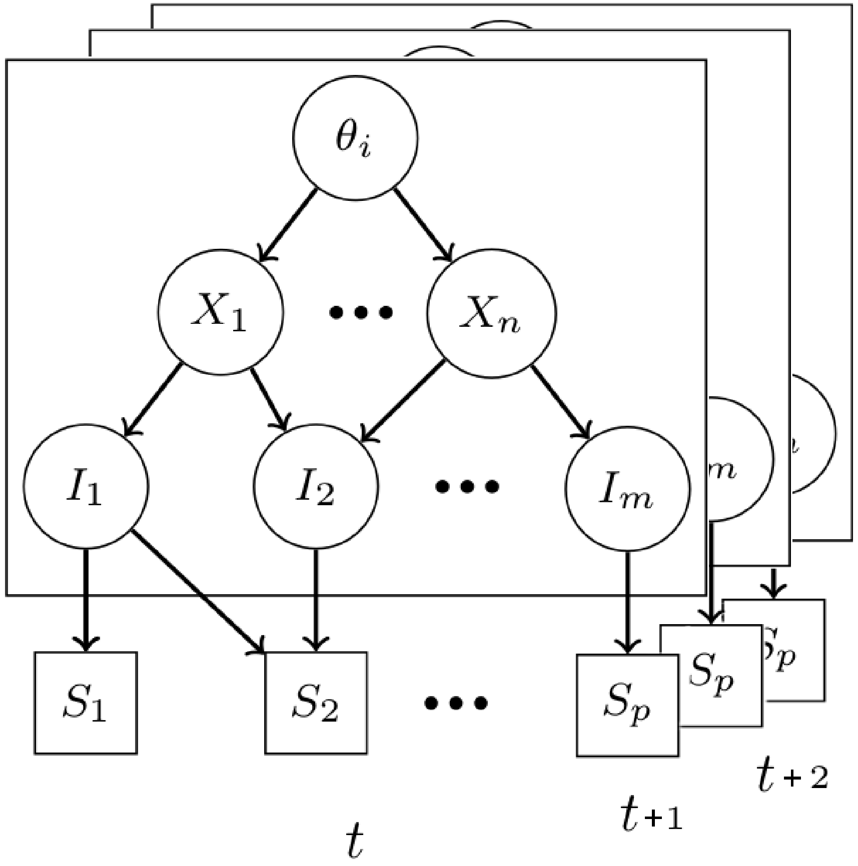


Hypothesis

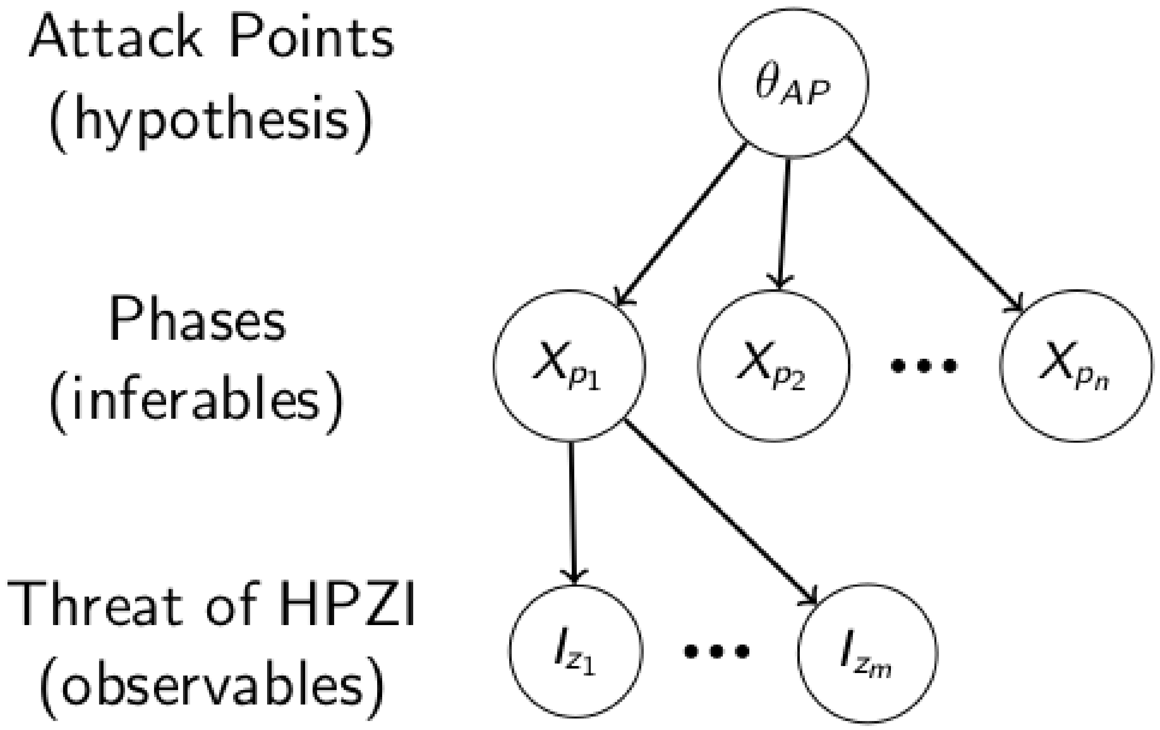
Inferable variables

Observable variables

Sensors



4) Scenario modelling

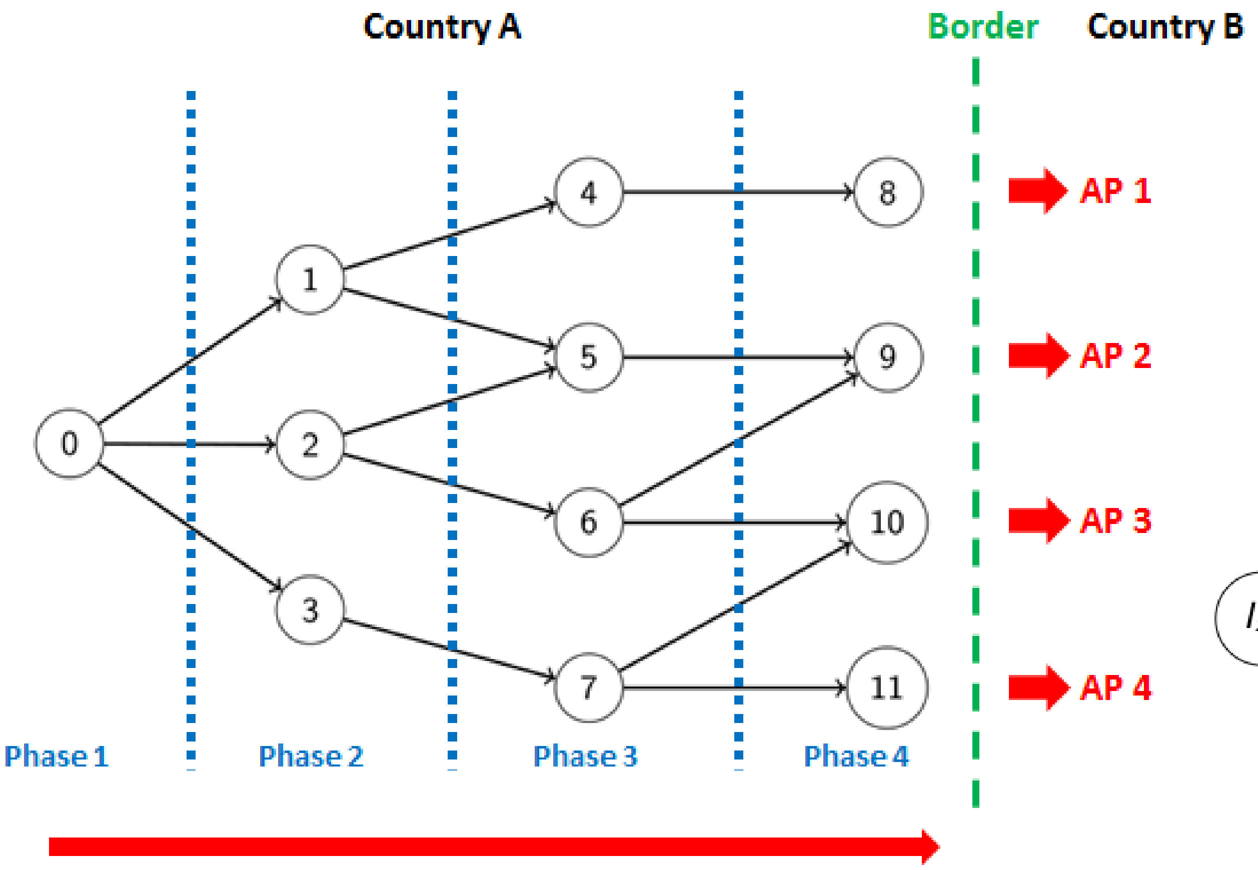


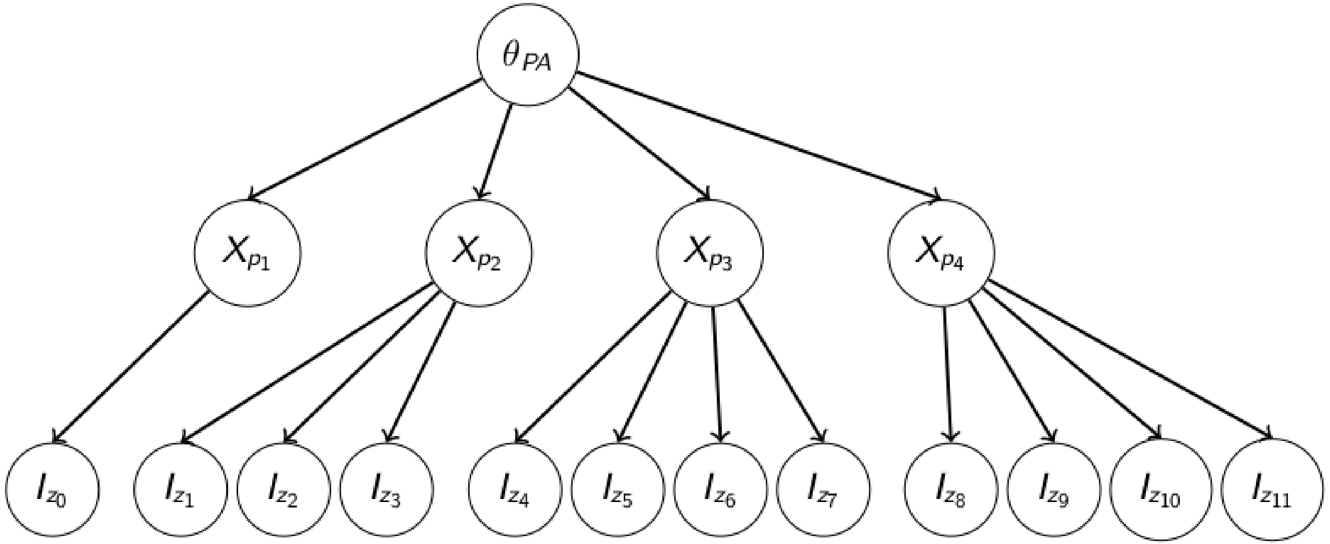
$\begin{bmatrix} 1 \\ \dots \\ n \end{bmatrix}$ → Which Attack Point will the enemy assault ?

$\begin{bmatrix} ZIP_1 \\ \dots \\ ZIP_q \end{bmatrix}$ → By which HPIZ the main threat will go through ?

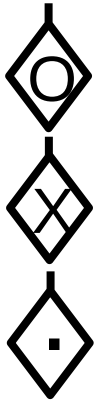
[High Threat, Medium Threat, Low Threat, No Threat] → What is the HPIZ's threat level ?

5) Example of military scenario





6) Threat propagation



Tank : 5

Infantery : 3

Artillery : 1

Threat score by HPIZ :

- Each company has a threat score corresponding to its dangerosity and its role in the assault
- $P\left(X_{p_m} = I_{HPIZ_i}\right) = \dfrac{TA_{HPIZ_i}}{\sum_{HPIZ_j \in \pi(u(HPIZ_i))} TA_{HPIZ_i}}$

$$P(\theta_{AP} = AP_l) = \alpha \prod_{I_{HPIZ_i} \in u(AP_l)} \sum_{I_{HPIZ_j} \in u(I_{HPIZ_i})} P\left(X_{p_m} = I_{HPIZ_i}\right) . P\left(I_{HPIZ_i} \mid I_{HPIZ_j}\right)$$

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1) Reliability score

Shannon entropy :

$$H(X) = -\sum_{t=1}^{n} P(x_i)\, \log\, P(x_i)$$

Reliability score of a variable :

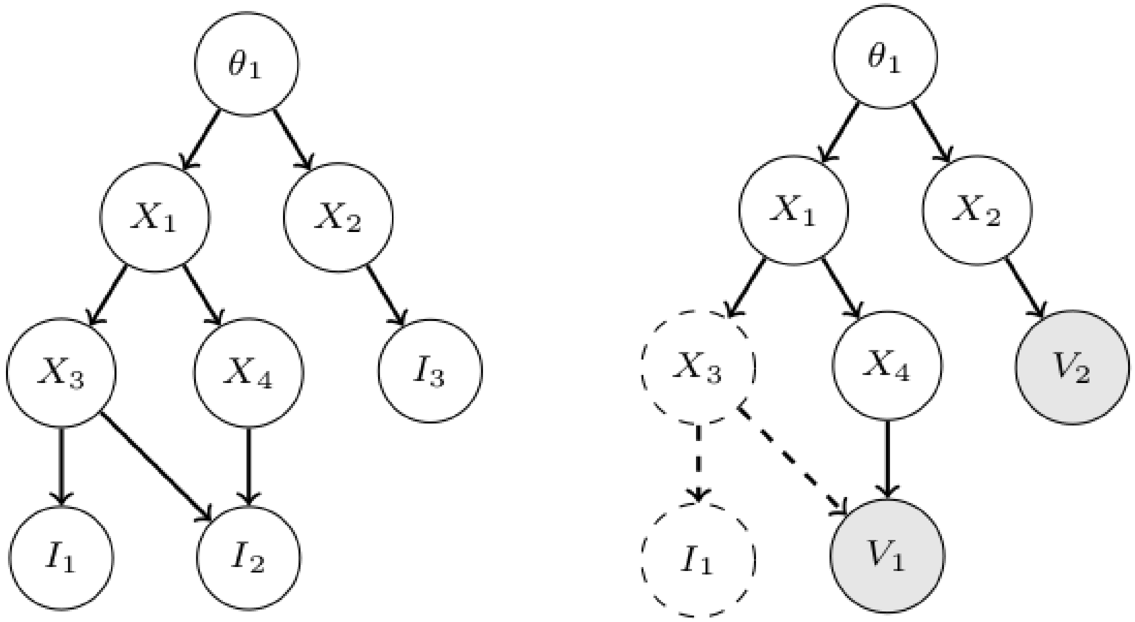
- Reliability threshold : $\Gamma = 0.20$
- Trusted variable : $H(X_i) < \Gamma$

- **Aim** : $\forall\theta \in \Theta, H(\theta) < \Gamma$

2) MVV analysis algorithm

Algorithm 1: MVV analysis algorithm

```
procedure RECURSIVEMVVANALYSIS(node, 𝒱)
    if hasNoChild(c) then
        𝒱 ← 𝒱 + {node}
    else
        if γ(node) < Γ then
            for each child c ∈ childrenOf(node) do
                recursiveMVVAnalysis(c, 𝒱)
            end for
        else
            return
        end if
    end if
    return
end procedure
```



(a) Hypothesis representation (b) Most valuable variables

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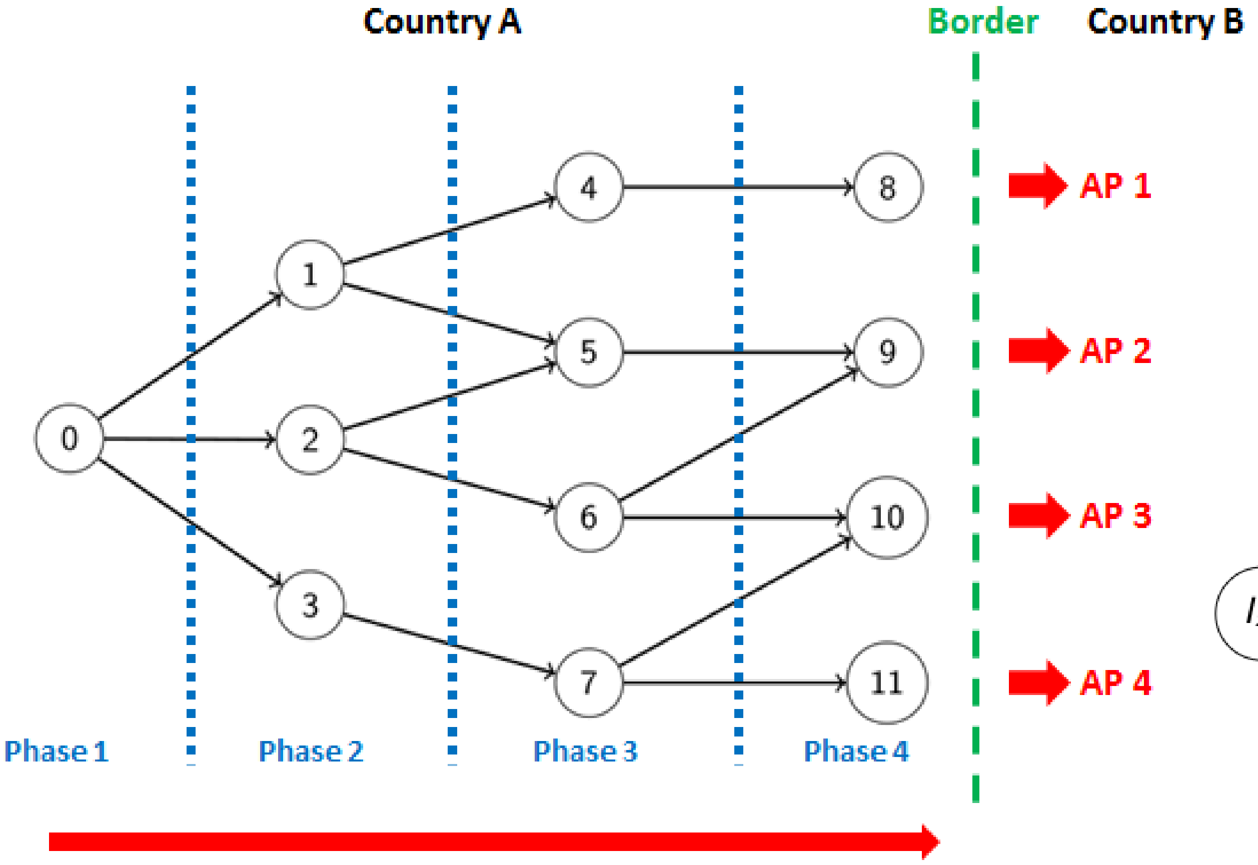
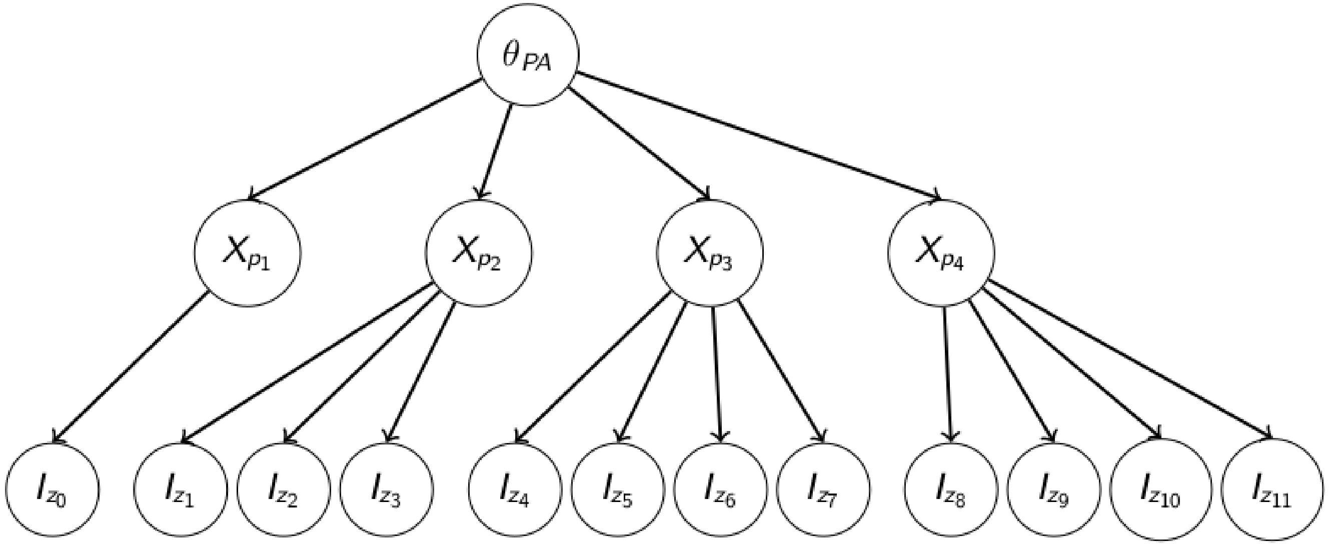
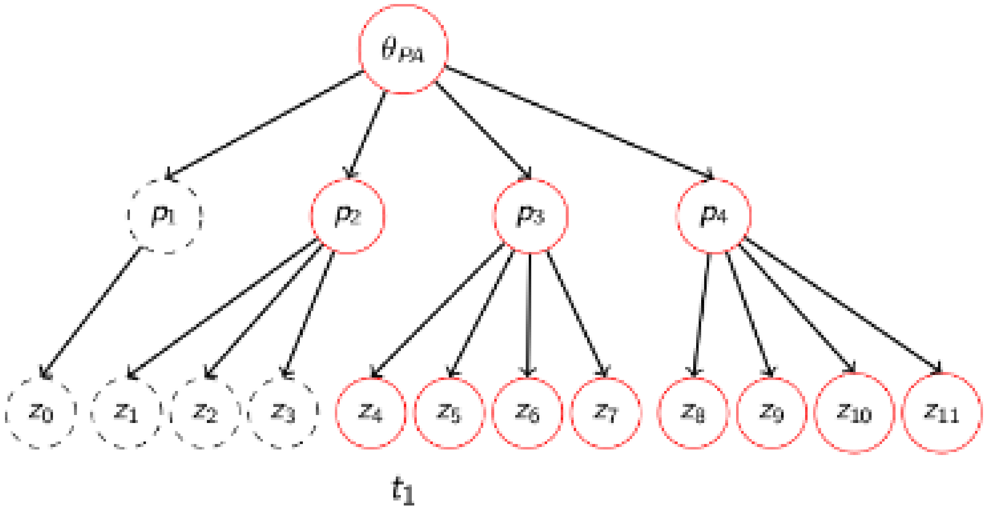
1) Example of military scenario





2) Military scenario example (1)

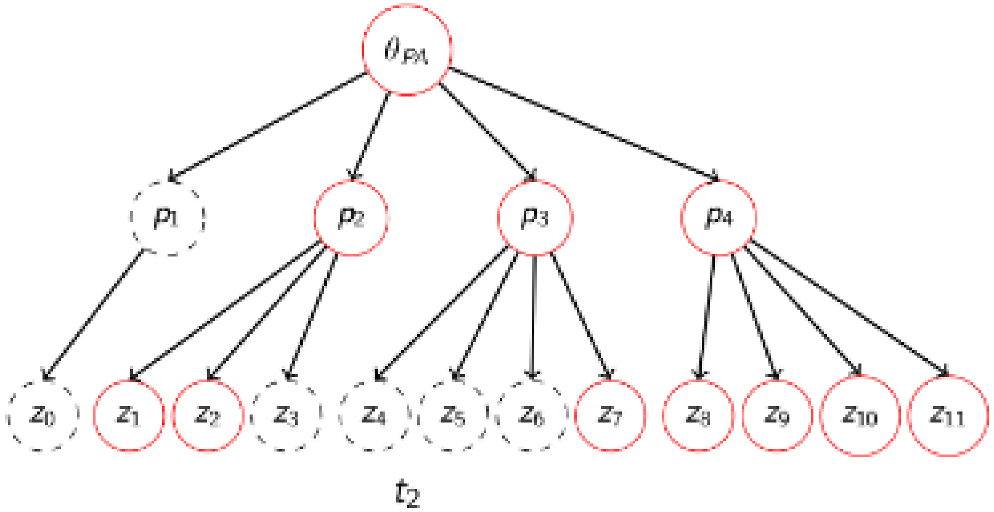


Sensor groups	t_1	t_2	t_3	t_4
Group 1	$HPZI_6$	$HPZI_7$	$HPZI_{10}$	$HPZI_{10}$
Group 2	$HPZI_4$	$HPZI_2$	$HPZI_5$	$HPZI_9$
Group 3	$HPZI_5$	$HPZI_1$	$HPZI_9$	$HPZI_5$

	t_1	t_2	t_3	t_4	t_5
θ_{AP}	0.96	0.66	0.35	0.27	$\emptyset$
θ_{p_1}	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$
θ_{p_2}	0.35	0.47	$\emptyset$	$\emptyset$	$\emptyset$
θ_{p_3}	0.97	0.43	0.41	0.36	0,26
θ_{p_4}	0.96	0.62	0.44	0.22	$\emptyset$

Attack points	t_1	t_2	t_3	t_4
$P(\theta_{AP} = AP_1)$	0.181	0.151	0.088	0.008
$P(\theta_{AP} = AP_2)$	0.366	0.498	0.87	0.945
$P(\theta_{AP} = AP_3)$	0.272	0.294	0.085	0.042
$P(\theta_{AP} = AP_4)$	0.181	0.057	0.013	0,005

2) Military scenario example (2)



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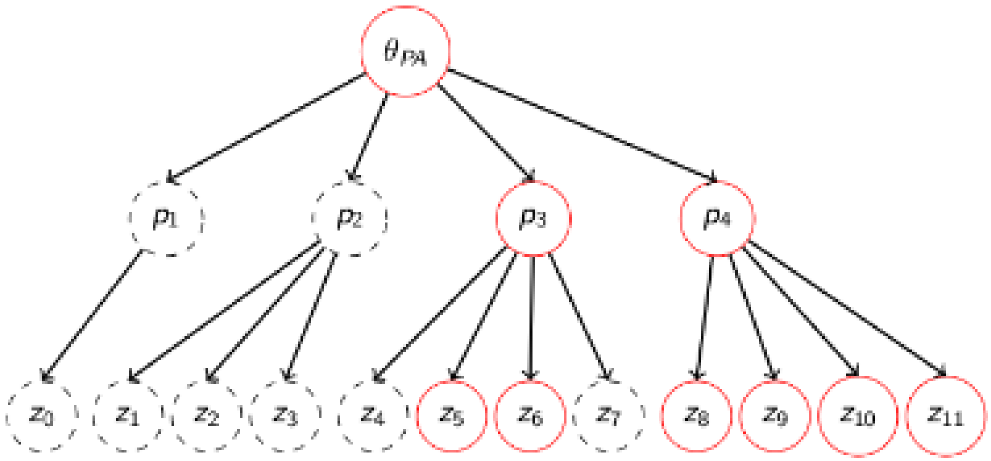
2) Military scenario example (3)



t_3

Sensor groups	t_1	t_2	t_3	t_4
Group 1	$HPZI_6$	$HPZI_7$	$HPZI_{10}$	$HPZI_{10}$
Group 2	$HPZI_4$	$HPZI_2$	$HPZI_5$	$HPZI_9$
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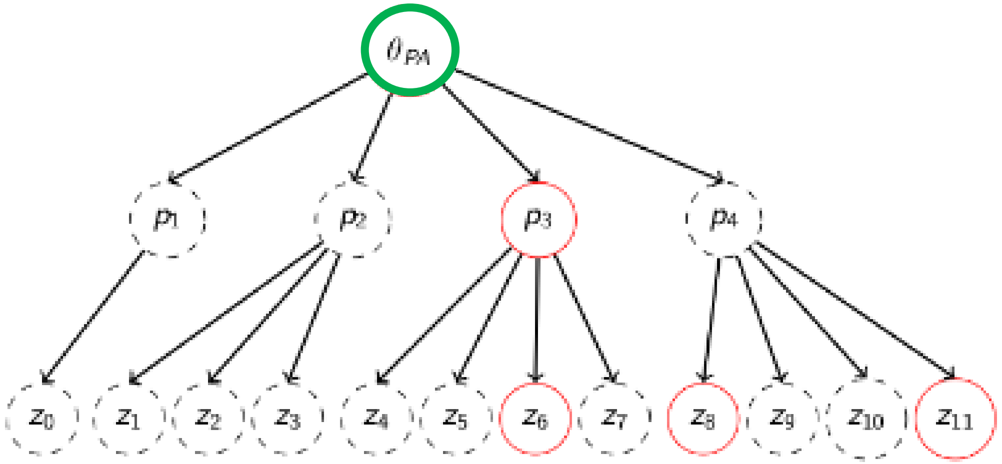
2) Military scenario example (4)



t_5

Sensor groups	t_1	t_2	t_3	t_4
Group 1	$HPZI_6$	$HPZI_7$	$HPZI_{10}$	$HPZI_{10}$
Group 2	$HPZI_4$	$HPZI_2$	$HPZI_5$	$HPZI_9$
Group 3	$HPZI_5$	$HPZI_1$	$HPZI_9$	$HPZI_5$

	t_1	t_2	t_3	t_4	t_5
θ_{AP}	0.96	0.66	0.35	0.27	$\emptyset$
θ_{p_1}	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$
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Conclusion

Contribution :

- Military scenario formalisation
- First heuristic of threat propagation
- Application of MVV analysis to this scenario

Next steps :

- Threat propagation improvement (possibility of turning back, dynamic path, …)
- Sensor management with multi-criteria utility function
  - Time
  - Resources (energy)
  - Sensor dependence
  - …

Some references

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Thank you

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