



Towards Characterizing Distributed Complex Situation Assessment as Workflows in Loosely Coupled Systems

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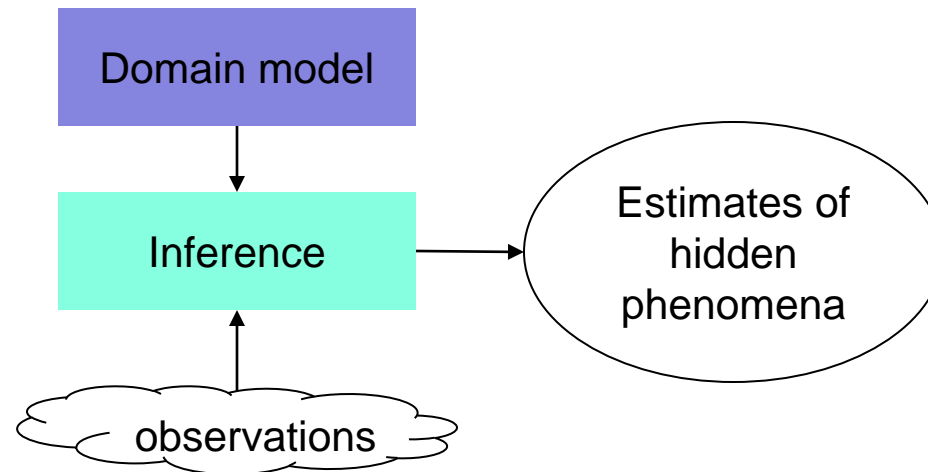
THALES



- **Context: Situation Assessment**
- **Domain characterization**
- **Workflows supporting consistent assessment**
- **Conclusions**



- Reasoning about phenomena in partially observable domains
 - Observable and “hidden” phenomena.
 - Infer hidden phenomena.
- Domain models describe relations between different phenomena
 - Mental models used by experts
 - AI-based approaches: rule-based, Bayesian networks, Neural nets, etc.



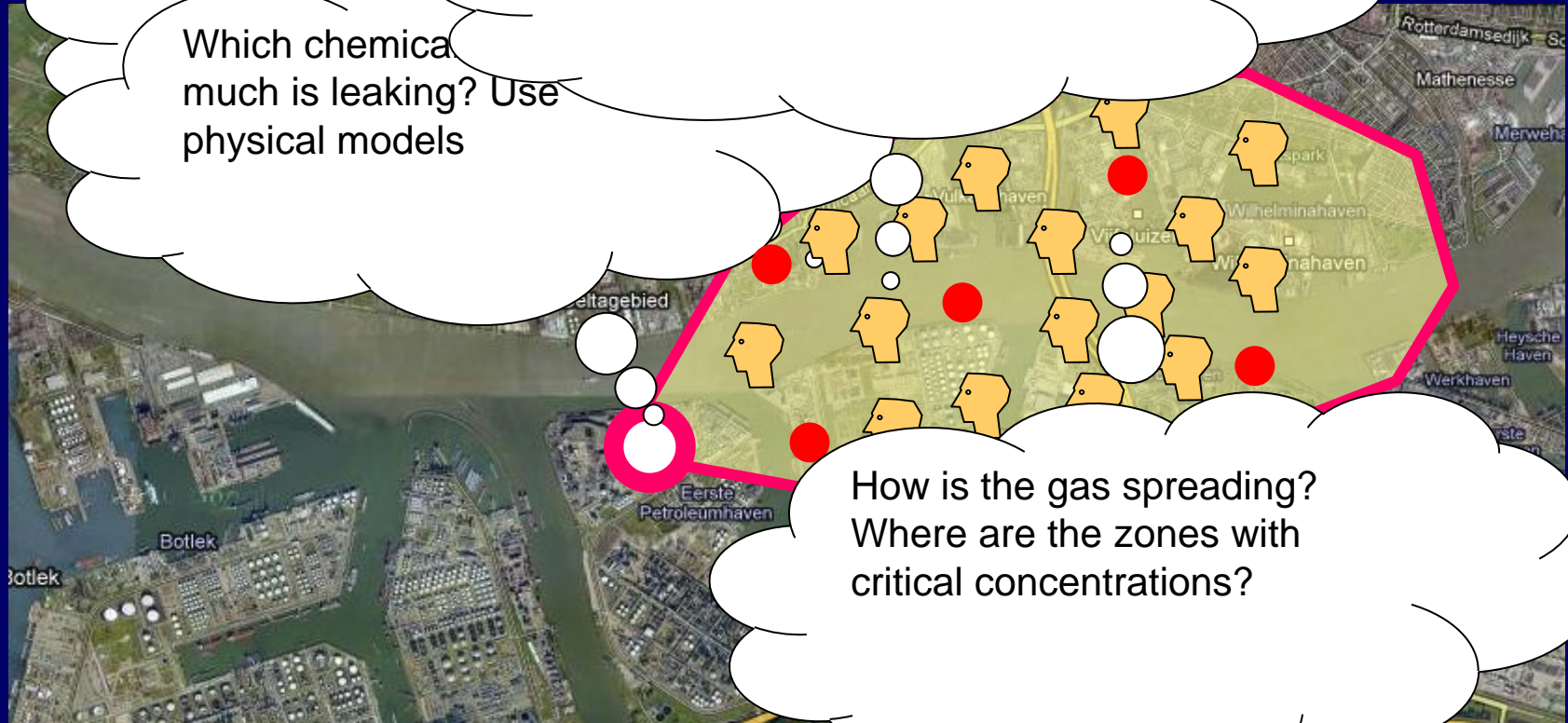
Situation Assessment: Example

Detect the gas/leak
source: co

Which chemical
much is leaking? Use
physical models

How are the residents and the
environment affected?

How is the gas spreading?
Where are the zones with
critical concentrations?

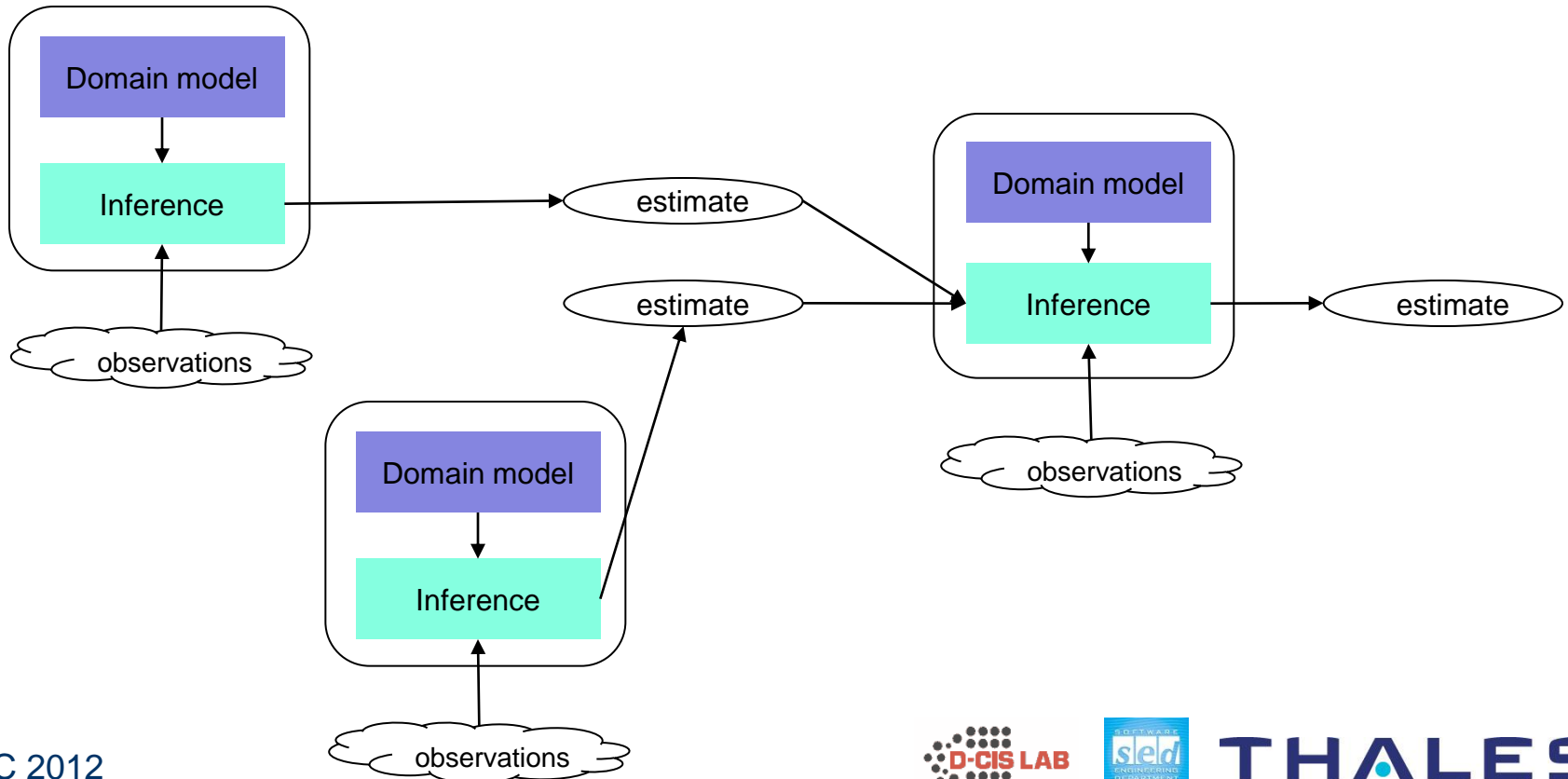




- Collect and process large amounts of information
 - Spatially and temporally distributed observations (sensors, intelligence).
 - Substantial domain knowledge (understand correlations between the data).

- Centralized solutions are often not practical/tractable
 - Communication and processing bottlenecks.
 - Complex processing mechanisms .
 - Privacy/sensitivity issues.

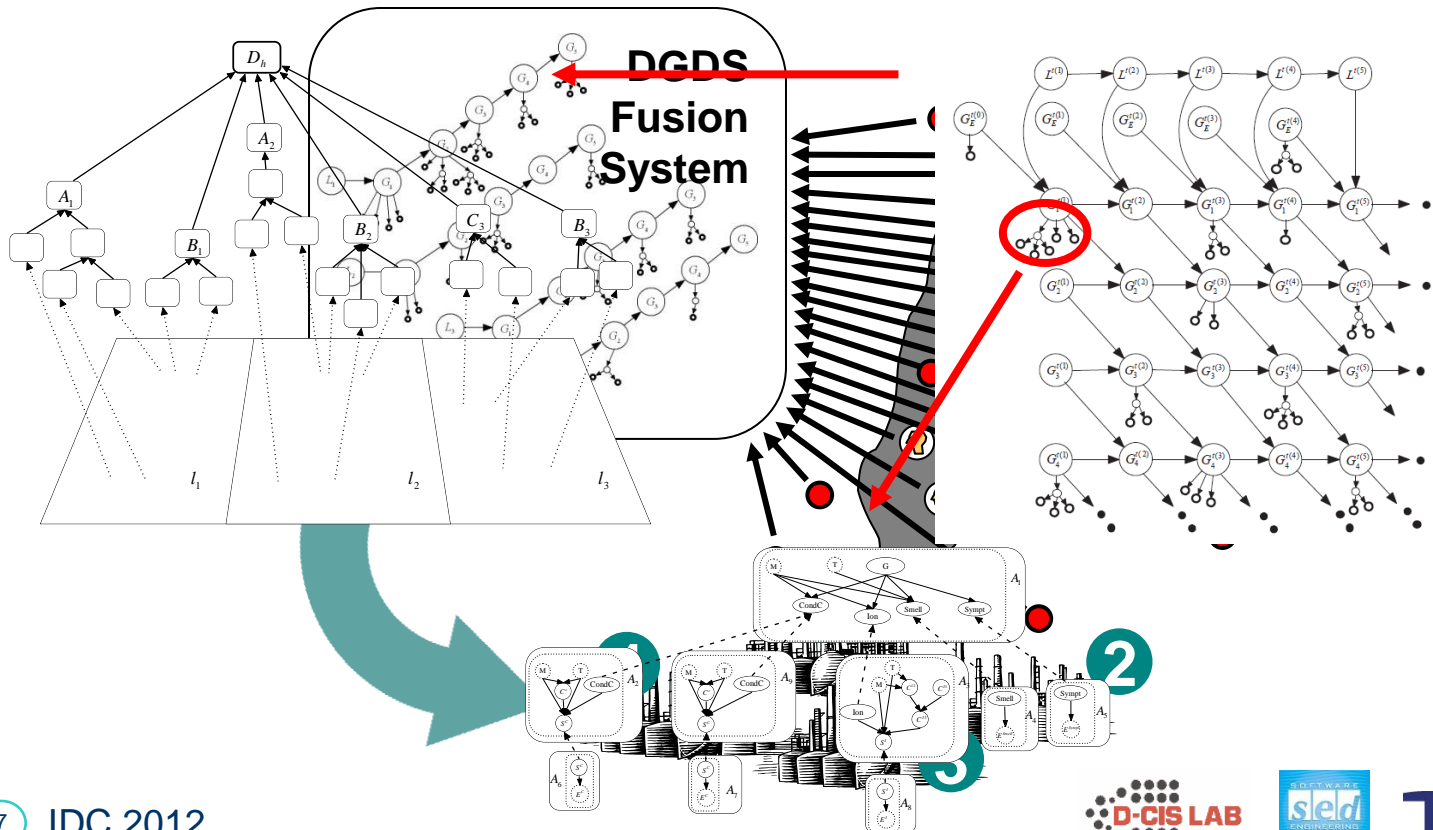
- Distribute info acquisition and assessment via loosely-coupled processes.
 - Each process supports reasoning about certain aspects of the domain.
 - The assessment is based on workflows where messages carry partial analysis results.



Distributed Solutions: Example

■ Gas detection and leak localization

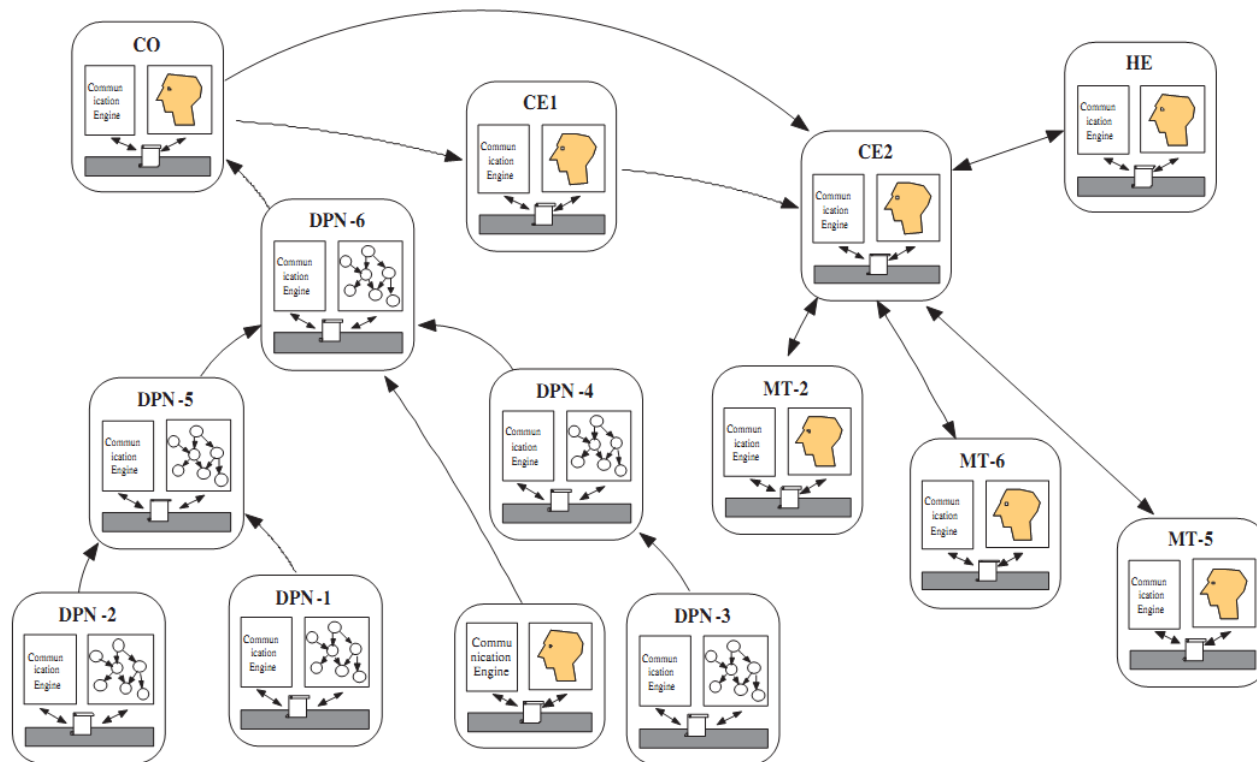
- Fuse sensor data and human observations (very noisy data)
- Use modular Bayesian networks (de Oude & Pavlin 2007, Pavlin et al., 2010)
- Fusion agents, a rigorous implementation of fusion services and their composition (plug&play).



Distributed Solutions: Example

■ Agent-based collaborative situation assessment in crisis management

- Many different types of experts collaboratively assess the situation.
- Agents support service discovery, negotiation and communication (Pavlin et al., 2010, Badica et al., 2010, Penders et al., 2011).



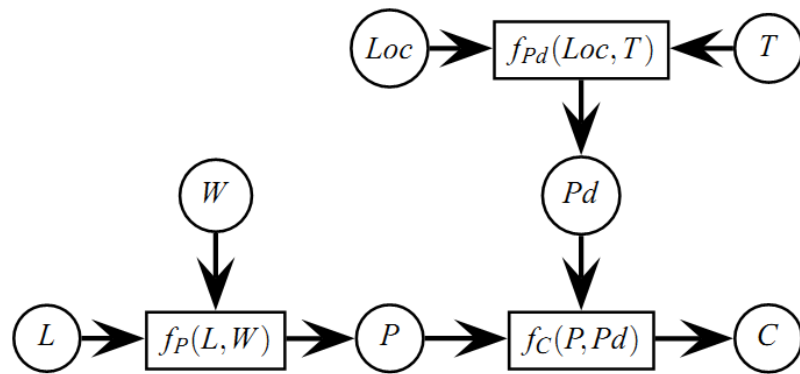


- Workflows are critical for the correct assessment
 - The right experts/processes have to get the right information.

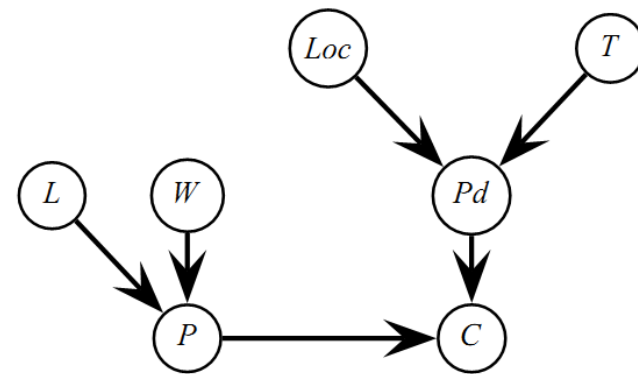
- When do workflows support correct assessment?
 - The workflow structure must reflect the dependencies in the domain.
 - Workflows must be based on rigorous models (termination, avoid deadlocks, etc.).

- Does a solution based on loosely coupled modules exist?
 - This depends on the domain → characterize domains.

- Phenomena of interest are often outcomes of causal processes.
- A combination of dependent causal processes → Domain Structure

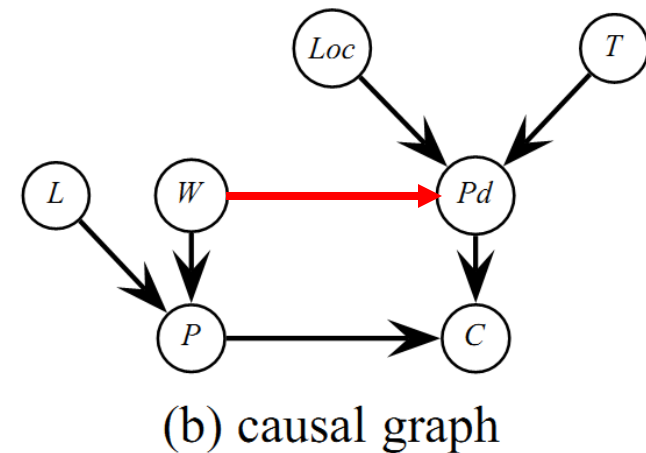
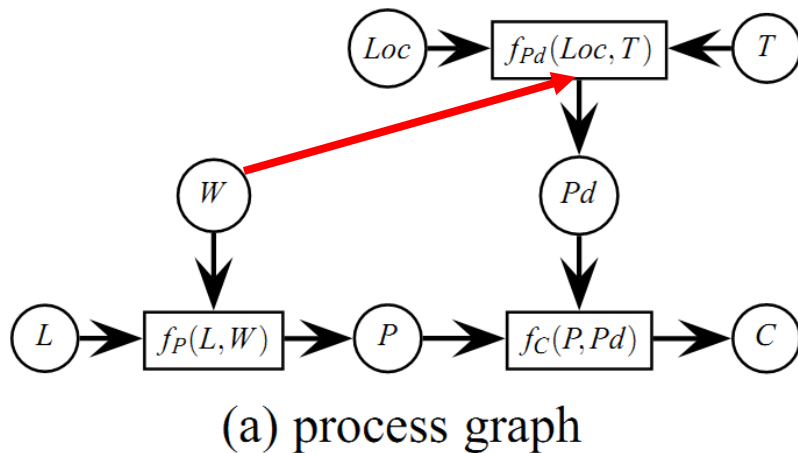


(a) process graph

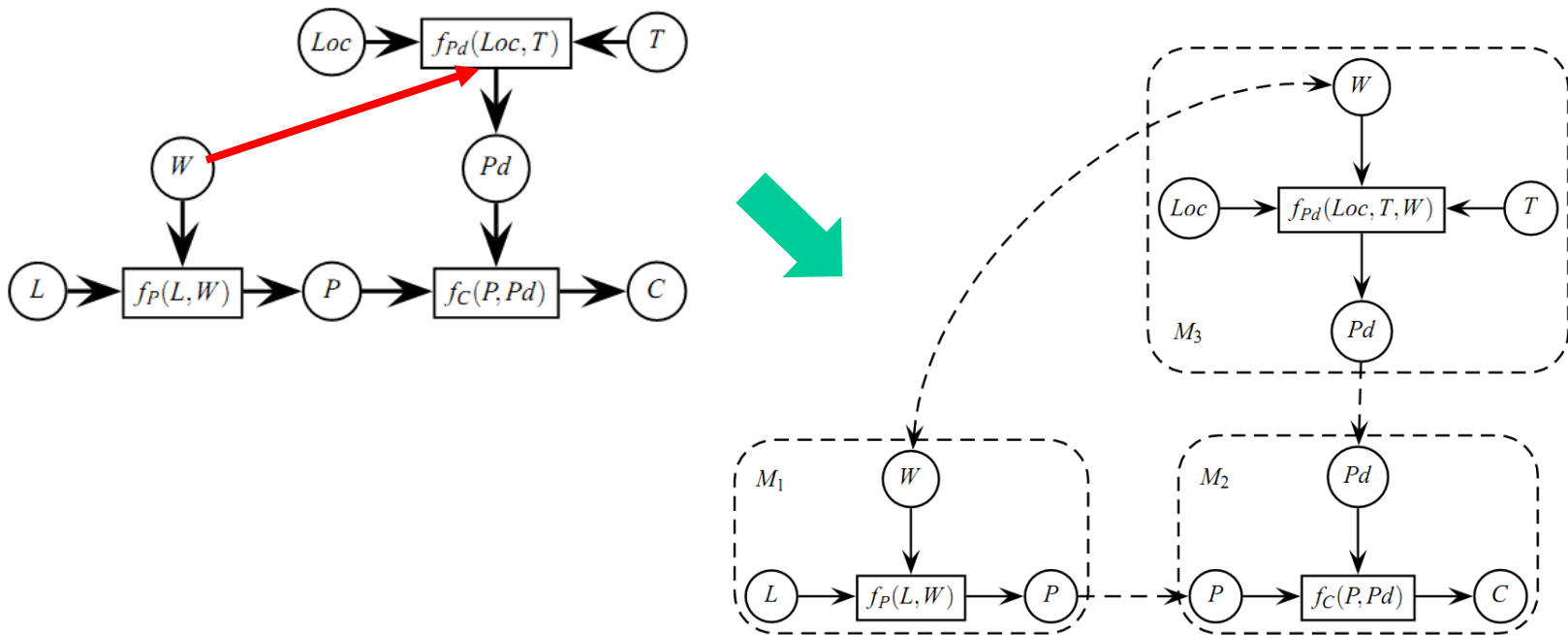


(b) causal graph

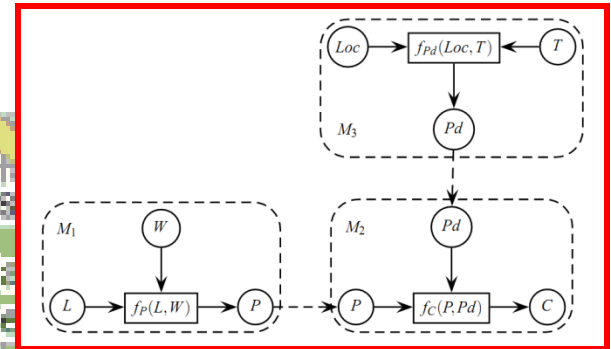
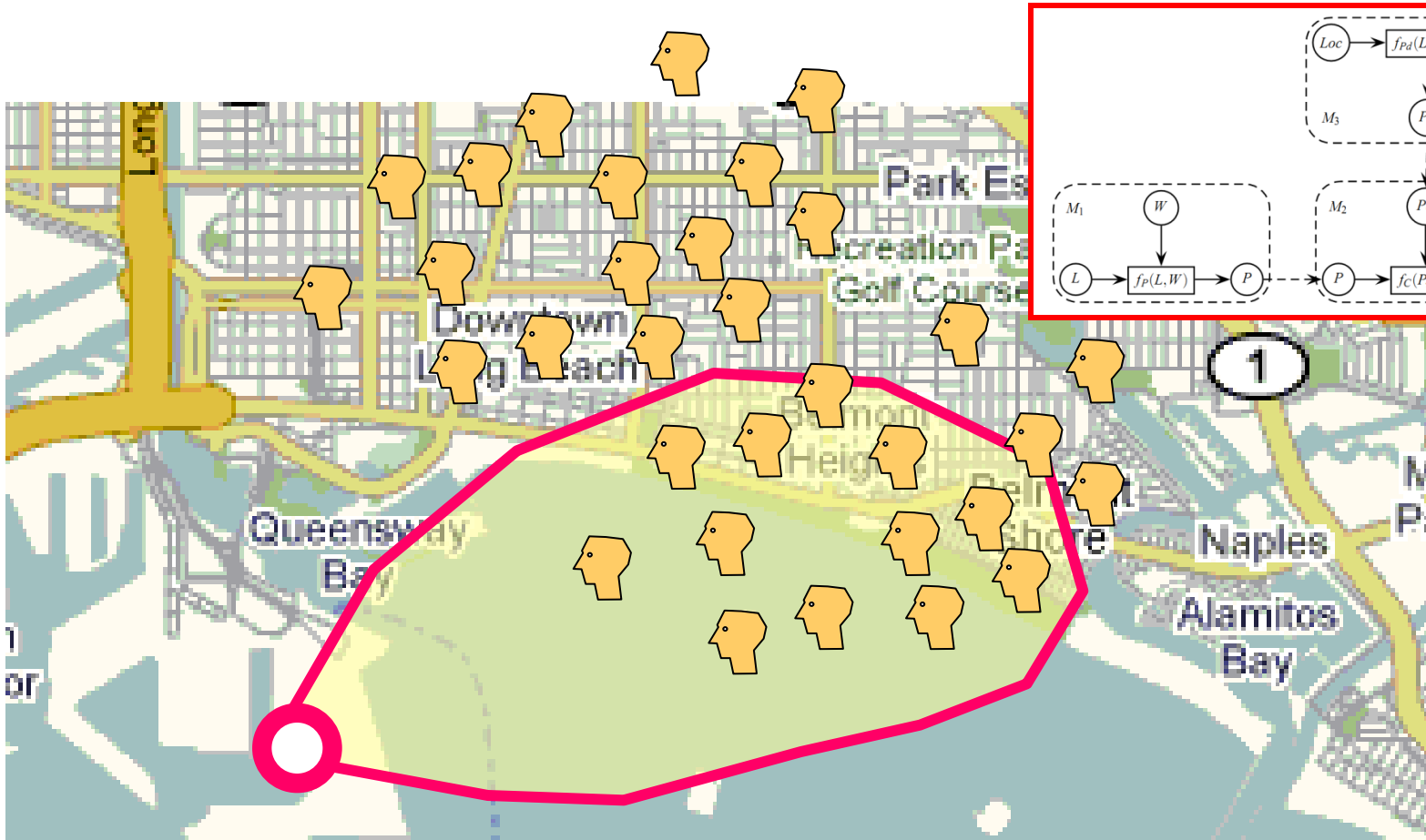
- Locality of causal relations is the key for correct process distribution:
 - If we know direct causes of an effect then the indirect causes are irrelevant.
 - D-separation in Bayesian Networks (Pearl 1988).
- Greater in degree results in greater cardinality of functions.
- Loops increase the inference complexity.



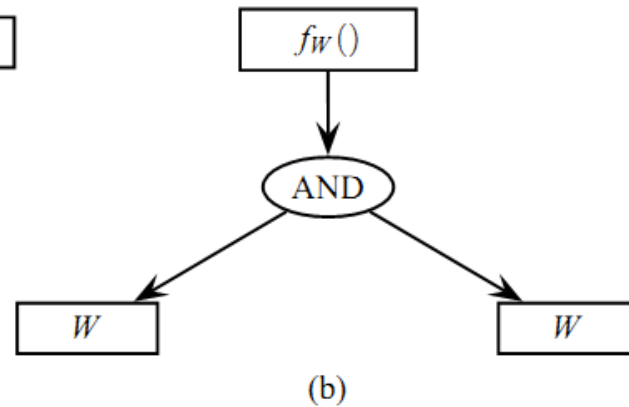
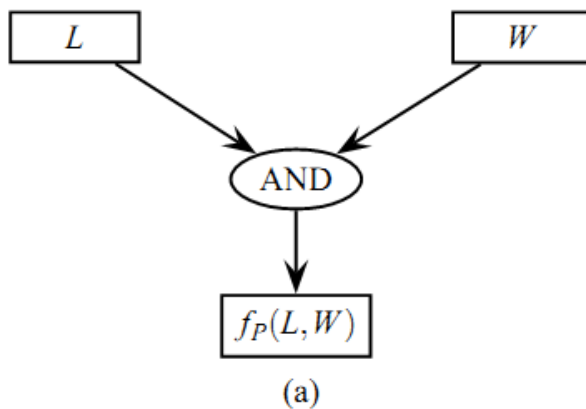
- Each module provides a specific transformation between different types of information.
- Necessary condition for correct assessment: A system of modules captures all dependencies between the phenomena in the Domain Structure.



Inconsistent Inference: Example

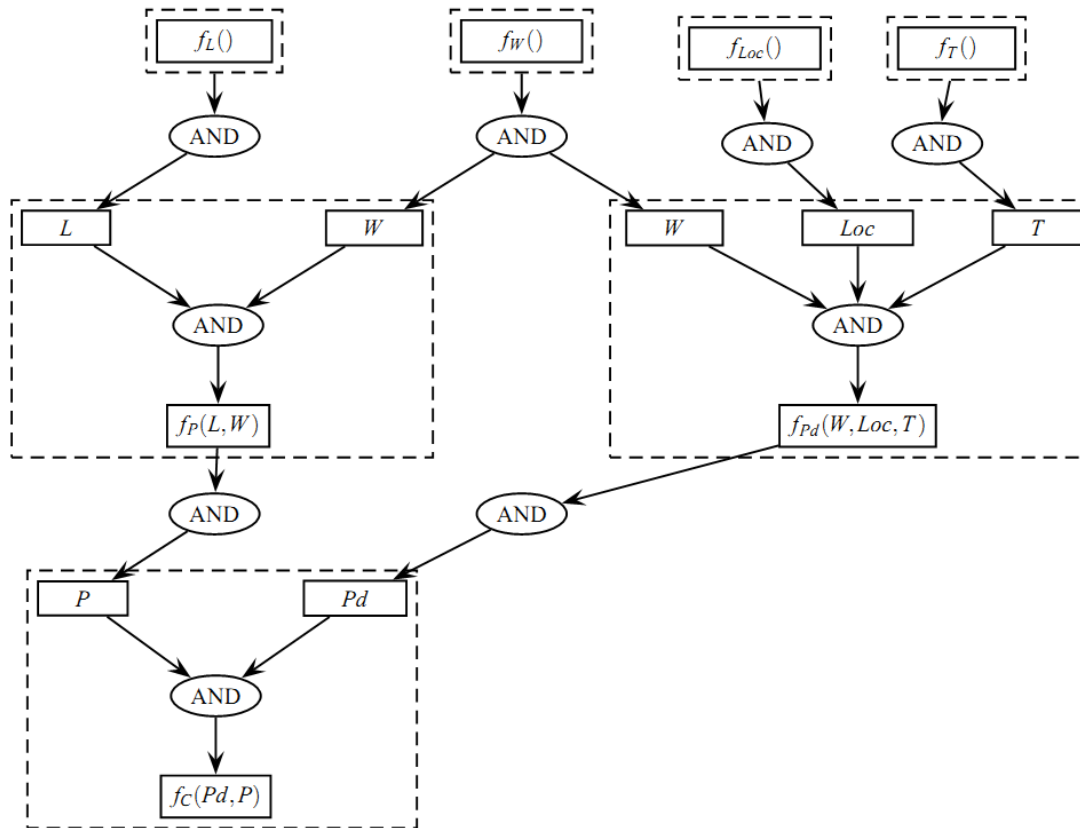


- Standard Workflow Model (SWM): a structured set of coordinated tasks and info exchanges.
- Workflows are formed dynamically, using service discovery based on Domain structures.
- Basic workflow constructs: a combination of activities and control flow constructs.
 - Capture computation done by the modules.
 - Based on the Domain structure.



Dynamic Workflow Composition

- Compose workflow constructs into ad-hoc workflows which support correct assessment and are sound from the control point of view.





- Characterize workflows supporting consistent situation assessment.
- Domain Structure, a combination of causal processes.
 - Graphical representation → explicit representation of the locality of the causal dependencies
 - Guidance for the definition of sound workflows and systematic complexity analysis.
- **Workflows must capture the dependencies in the Domain Structure.**
- Formalization of workflows supports analysis of their properties.
- Future work:
 - In depth analysis of the role of the workflows in more complex/generic reasoning problems.
 - Investigate the mapping between SWM and Petri-nets and the application of workflow analysis tools.



Thank you!

- Distribute assessment task throughout a system of modules
 - Each module provides a specific transformation between the information.
 - Data driven approach: the overall assessment is reduced to the communication of specific estimates and observations.
 - Consumers and suppliers communicate in a peer-to-peer fashion.

