# Optimisation Methods for Complex Event Recognition

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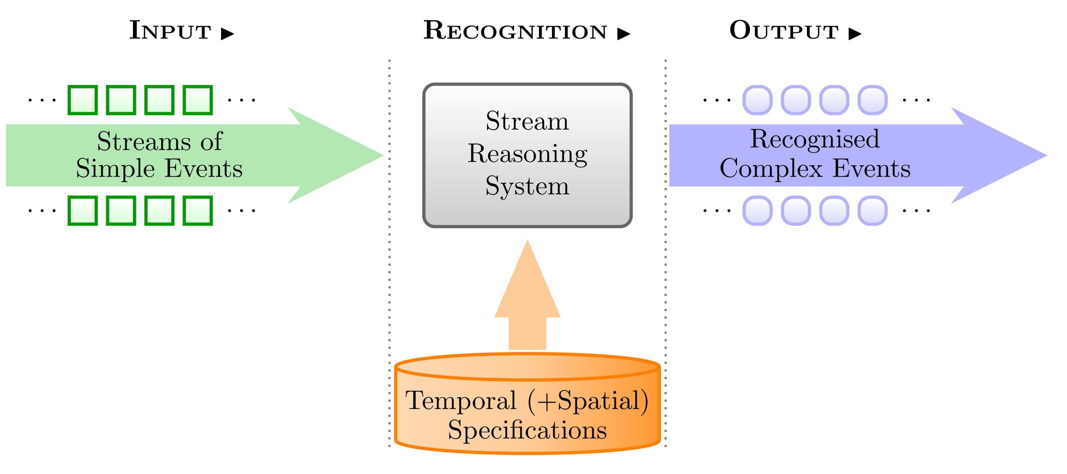
## Problem Statement & Motivation

Real-world **Complex Event Recognition** (CER) applications require **Stream Reasoning** (SR) techniques, which feature:

- **highly-efficient** reasoning over data streams
- high **expressive power** in spatiotemporal specifications
- robustness to **uncertainty**




The lack of a CER system which handles effectively all the above requirements motivates this thesis.

## Goal of the Thesis

The development of a **logic-based Stream Reasoning system** with the following properties:

- high **efficiency** and optimisation techniques
- high **expressive power**
- highly-efficient **probabilistic inference** algorithms
- **neural-symbolic techniques**

## Event Calculus

A **logic-based, temporal formalism** for representing and reasoning about events and their effects.

- built-in representation of the common-sense **law of inertia**
- **succinct and intuitive definitions** of domain specifications
- **logic programming** implementation

## Run-Time Event Calculus

An **Event Calculus** dialect **optimised for Stream Reasoning**.

- **Prolog implementation**
- **formal semantics**
- **windowing**, **caching** and **indexing** techniques
- **efficient** enough for CER applications

## Probabilistic Event Calculus

A **probabilistic** Event Calculus dialect for handling **noise in the input data**.

- built on top of **ProbLog**
- **caching** mechanism to **avoid re-computations**
- **high accuracy** in case of:
  - multiple complex event definitions
  - few probabilistic conjuncts in definitions
- probability fluctuations may deteriorate recognition

## Probabilistic Interval-based Event Calculus

A batch processing algorithm over instantaneous recognition.

- **succinct interval-based recognition**
- **robust to abrupt probability fluctuations**
- **linear-time** batch processing

## Work So Far

We have worked on the following topics:

- Probabilistic Interval-based Event Calculus for **online reasoning**
- Run-Time Event Calculus with **extended expressive power**

## Expressive Power: Cyclic Dependencies & Deadlines

The Run-Time Event Calculus has been extended to express:

- **cyclic dependencies** in temporal specifications
- properties subject to **deadlines**

Efficient reasoning over specifications with cyclic dependencies or properties with deadlines requires:

- modelling specifications as **locally stratified logic programs**
- an **incremental caching** algorithm to **avoid re-computations**

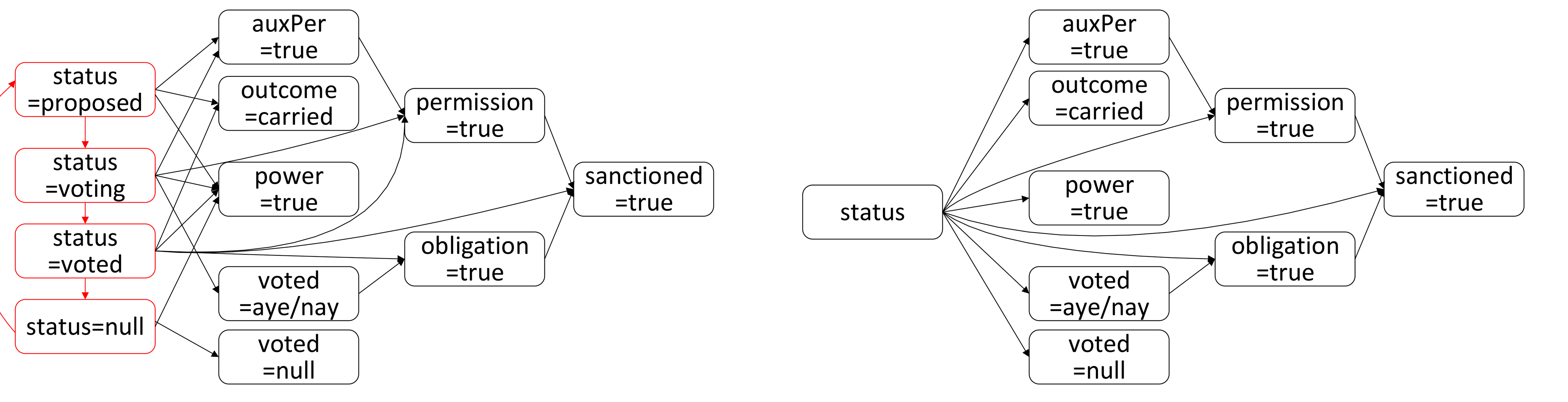



Figure 1. The event description of a simple voting protocol. Full dependency graph (left) and strongly connected component contracted dependency graph (right)

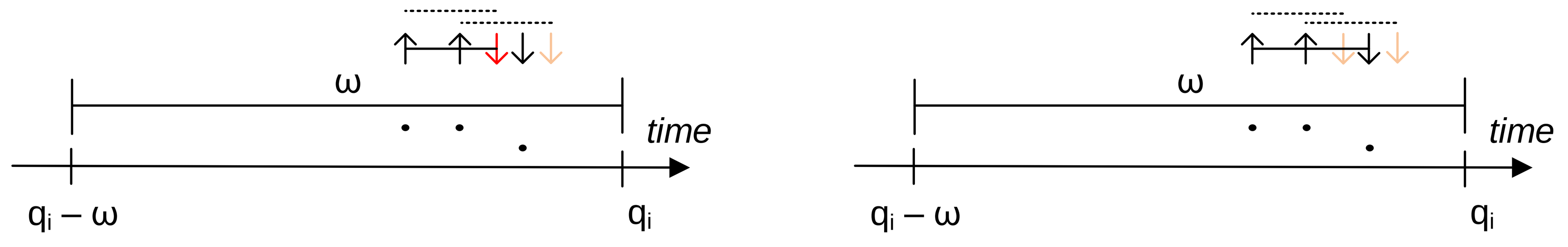



Figure 2. An example of modelling non-extensible (left) and extensible (right) deadlines in the Run-Time Event Calculus

## Online Reasoning under Uncertainty with the Event Calculus

An online version of the Probabilistic Interval-based Event Calculus.

- **online interval computation over temporal windows**
- a **minimal memory** for storing potential starting points of future intervals
- a **bounded memory version** which further decreases memory requirements while maintaining high accuracy

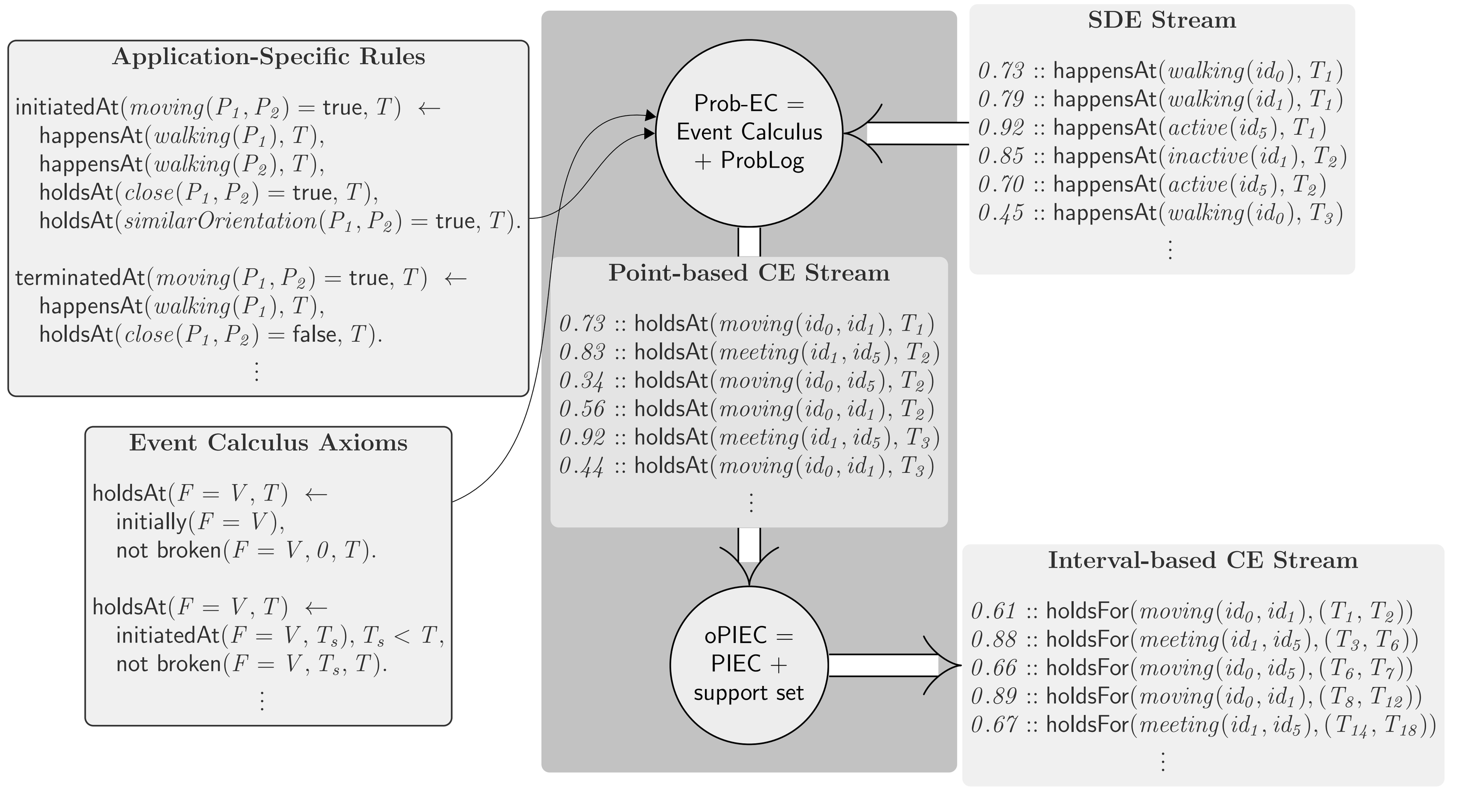



Figure 3. Online Probabilistic Interval-based Event Calculus: Architecture

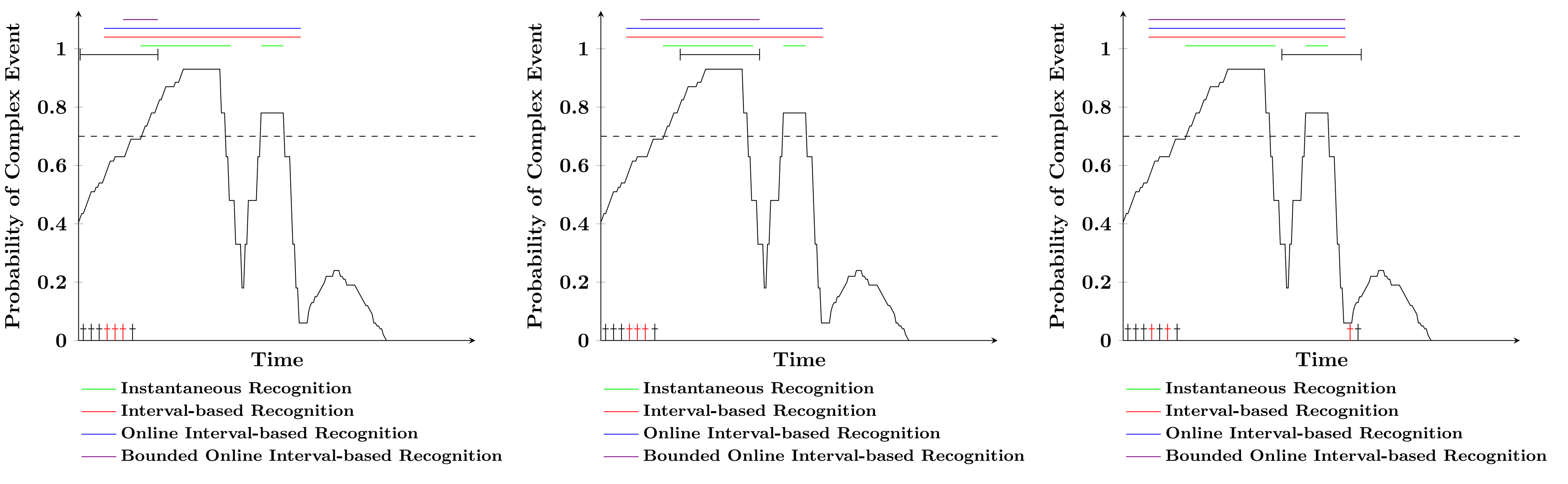



Figure 4. Bounded-memory Online Probabilistic Interval-based Event Calculus in action

## Further Work

In the future, we aim to:

- develop **highly-efficient probabilistic inference algorithms for Event Calculus theories**
- Integrate **probabilistic reasoning in the Run-Time Event Calculus**
- Combine these approaches in **a neuro-symbolic framework**

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