Stream Reasoning with Deadlines

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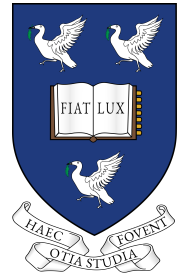
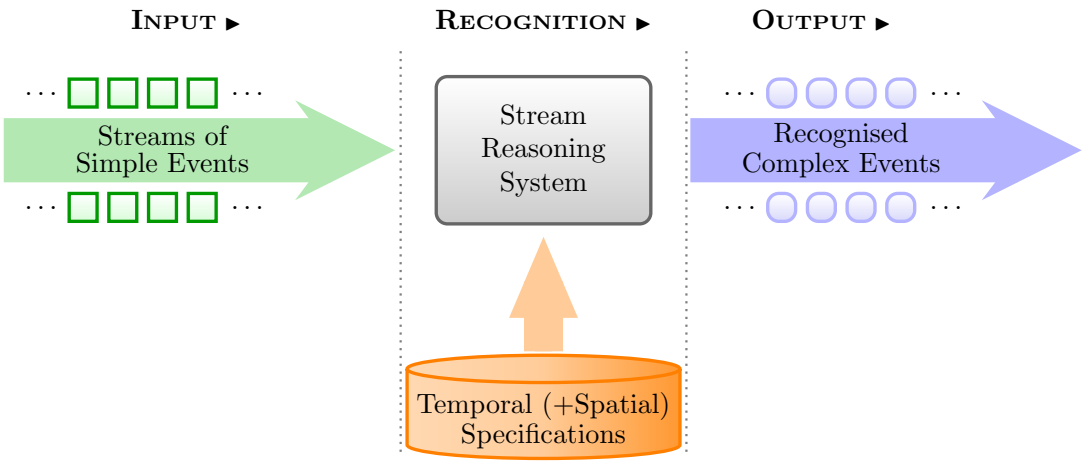


Stream Reasoning



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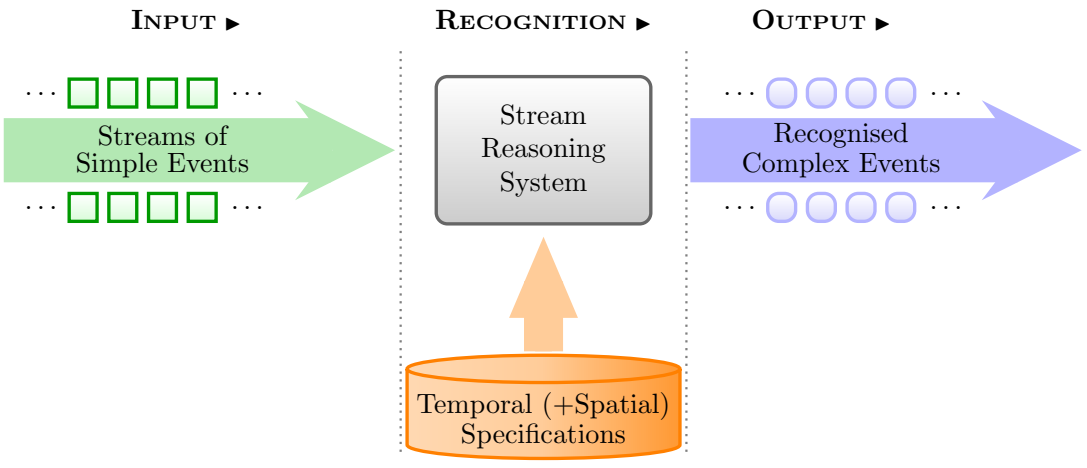

https://cer.iit.demokritos.gr (maritime)

Event Calculus

- A logic programming language for representing and reasoning about events and their effects.
- Key components:
  - event (typically instantaneous).
  - fluent: a property that may have different values at different points in time.

Robert A. Kowalski, Marek J. Sergot: A Logic-based Calculus of Events. New Gener. Comput. 4(1): 67-95 (1986)

Event Calculus

- A logic programming language for representing and reasoning about events and their effects.
- Key components:
  - event (typically instantaneous).
  - fluent: a property that may have different values at different points in time.
- Built-in representation of inertia:
  - $F = V$ holds at a particular time-point if $F = V$ has been *initiated* by an event at some earlier time-point, and not *terminated* by another event in the meantime.

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Run-Time Event Calculus

Predicate	Meaning
happensAt(E, T)	Event E occurs at time T
initiatedAt$(F = V, T)$	At time T a period of time for which $F = V$ is initiated
terminatedAt$(F = V, T)$	At time T a period of time for which $F = V$ is terminated
holdsFor$(F = V, I)$	I is the list of the maximal intervals for which $F = V$ holds continuously
holdsAt$(F = V, T)$	The value of fluent F is V at time T

Artikis A., Sergot M. and Paliouras G., An Event Calculus for Event Recognition. In IEEE Transactions on Knowledge and Data Engineering (TKDE), 27(4), 895–908, 2015.

Fluent-Value Pair Specification

$$\textbf{initiatedAt}(F = V,\ T) \leftarrow \textbf{happensAt}(E_{In_1},\ T), [\text{conditions}]$$
$$\ldots$$
$$\textbf{initiatedAt}(F = V,\ T) \leftarrow \textbf{happensAt}(E_{In_i},\ T), [\text{conditions}]$$

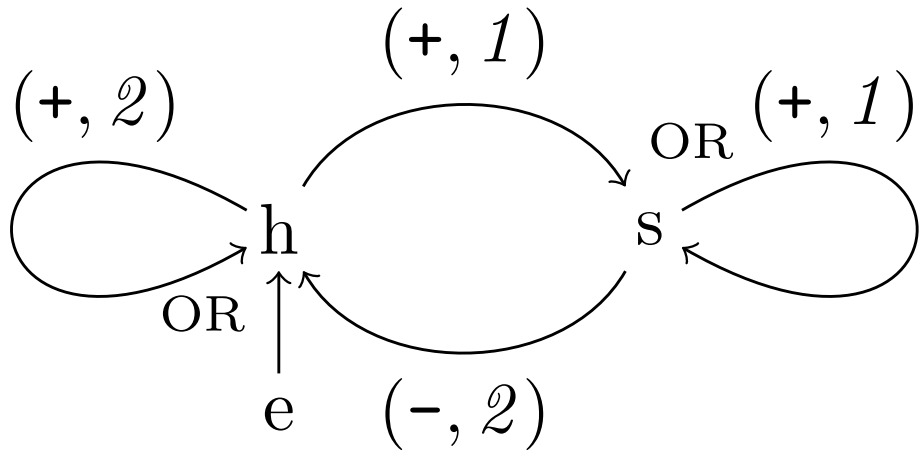
$$\textbf{terminatedAt}(F = V,\ T) \leftarrow \textbf{happensAt}(E_{T_1},\ T), [\text{conditions}]$$
$$\ldots$$
$$\textbf{terminatedAt}(F = V,\ T) \leftarrow \textbf{happensAt}(E_{T_j},\ T), [\text{conditions}]$$

where

$$\text{conditions:} \quad {}^{0-K}\textbf{happensAt}(E_k,\ T),\ {}^{0-M}\textbf{holdsAt}(F_m = V_m,\ T),\ {}^{0-N}\text{atemporal-constraint}_n$$

Motivation: Deadlines

- Biological Feedback Loops: the values of biological variables in a feedback loop change with a time delays.



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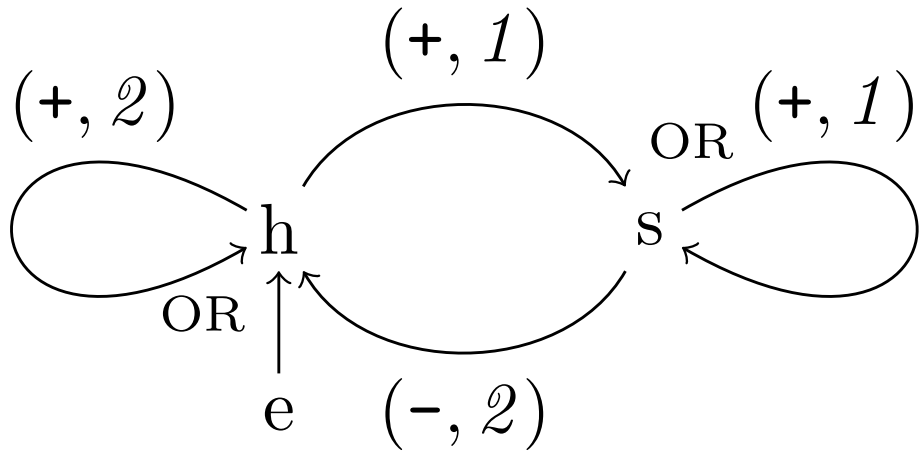

- Maritime Situational Awareness: a fishing activity is terminated at a specified time after multiple changes in heading.

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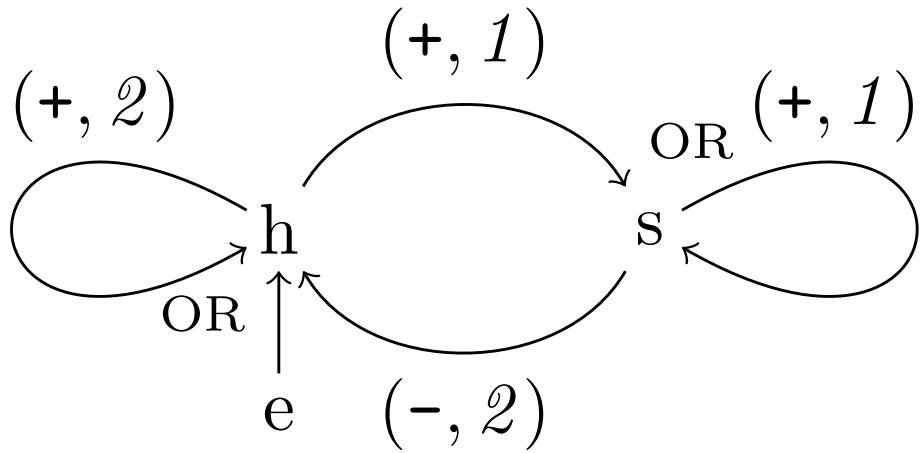

- Maritime Situational Awareness: a fishing activity is terminated at a specified time after multiple changes in heading.
- Multi-Agent Systems: agents may be suspended temporarily. Further violations may extend the period of suspension.

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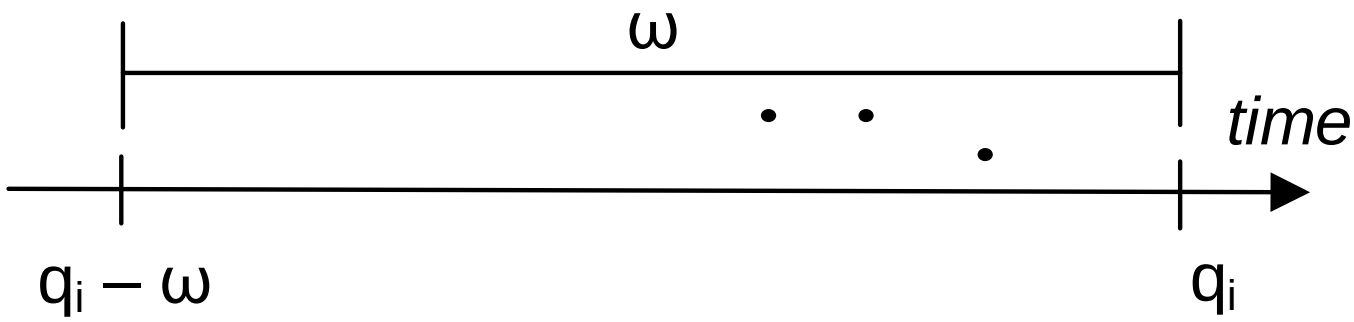
RTEC$^{\rightarrow}$: Deadlines



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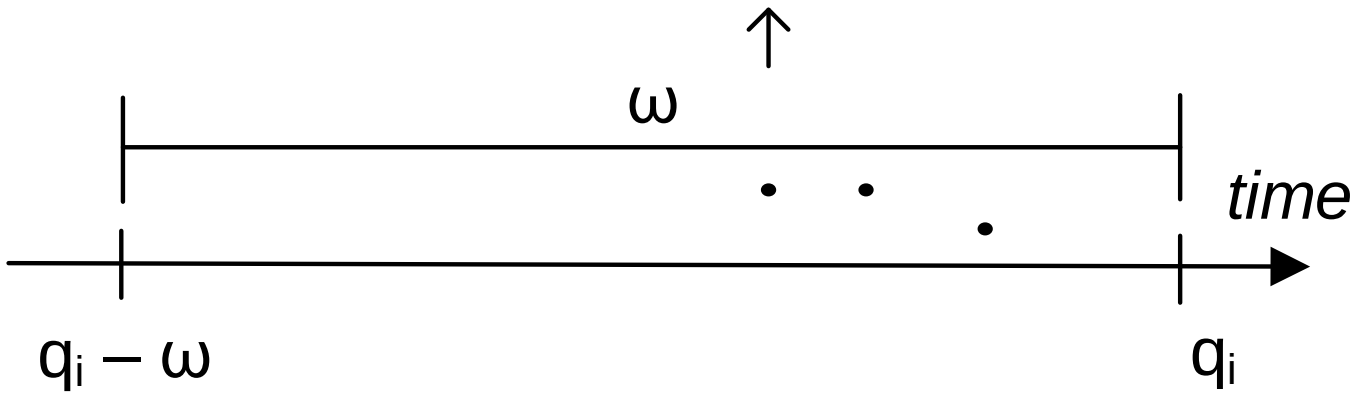

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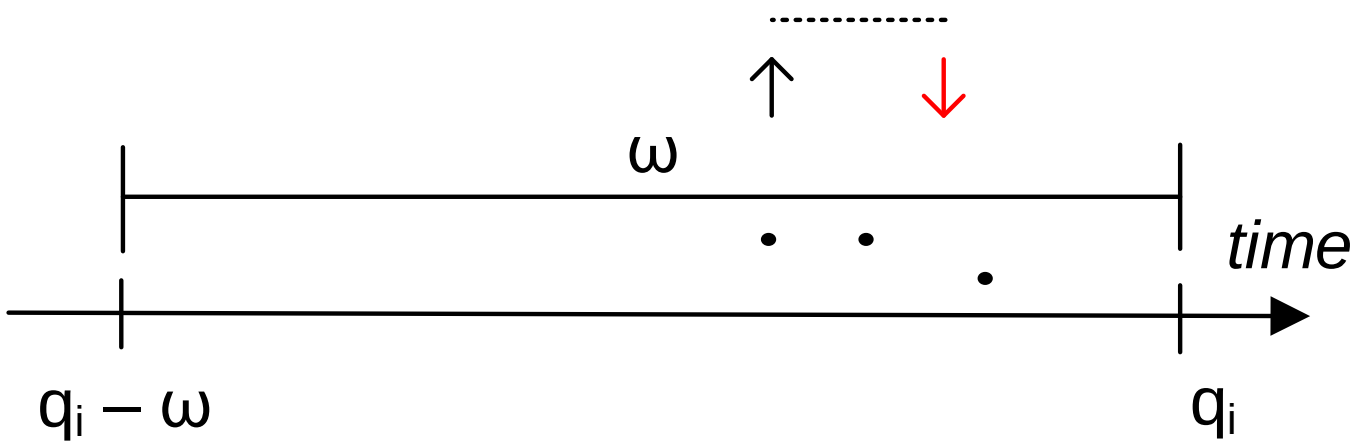

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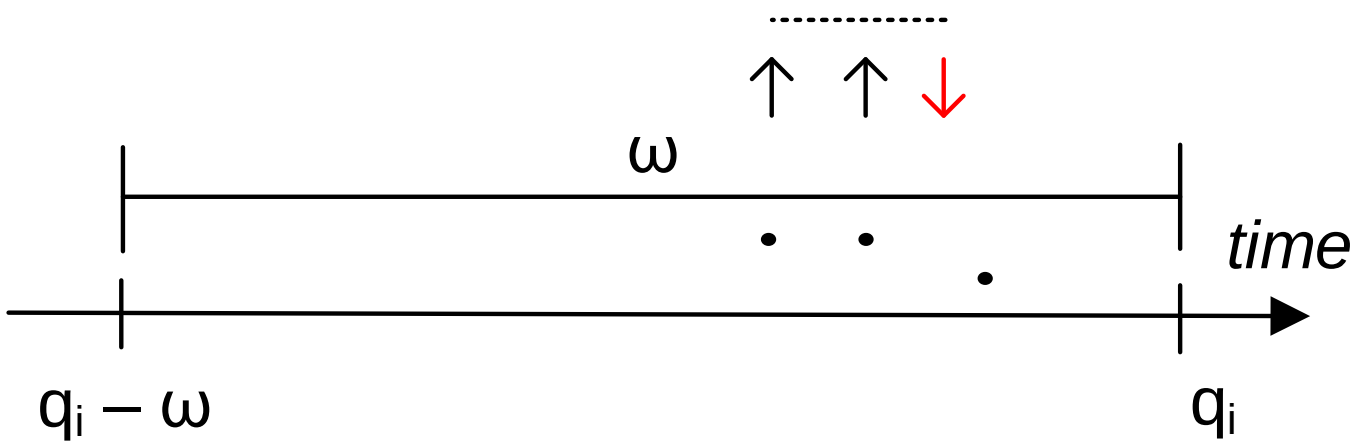

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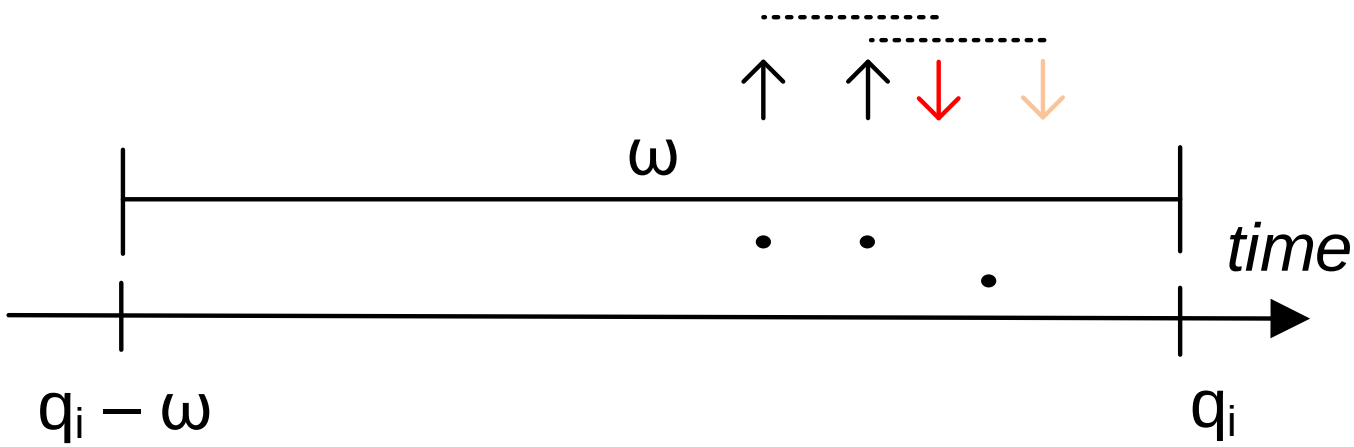

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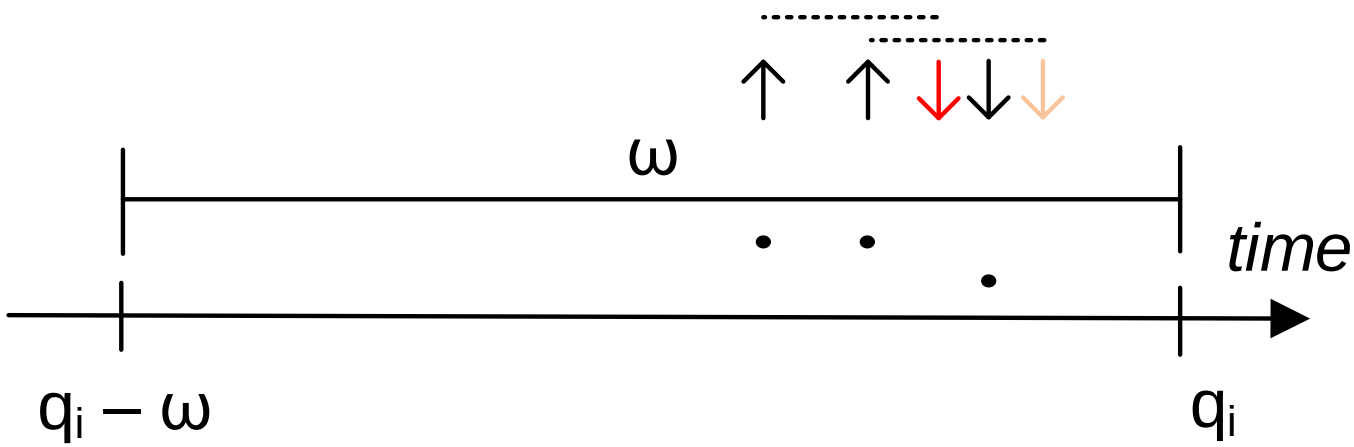

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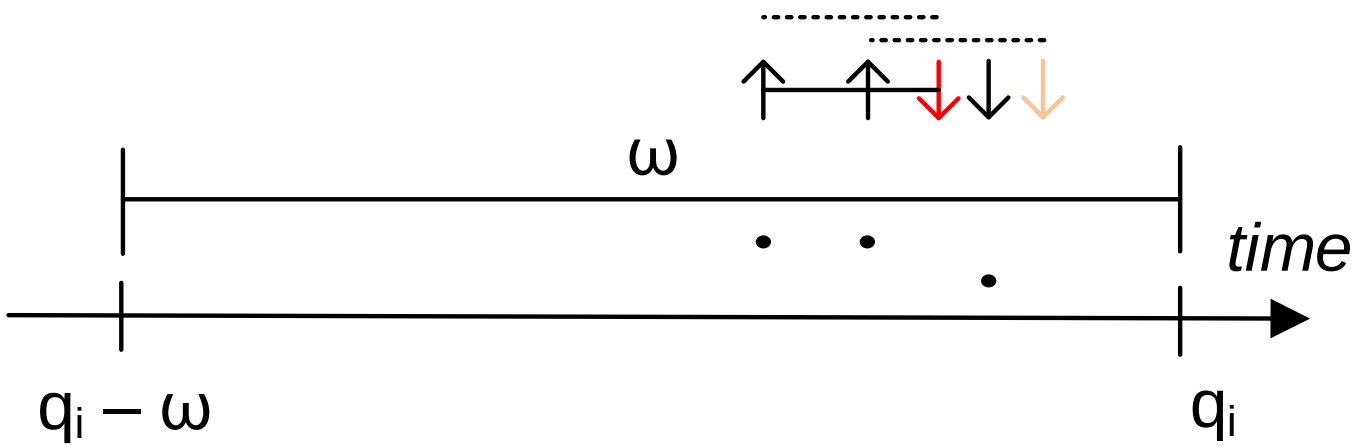

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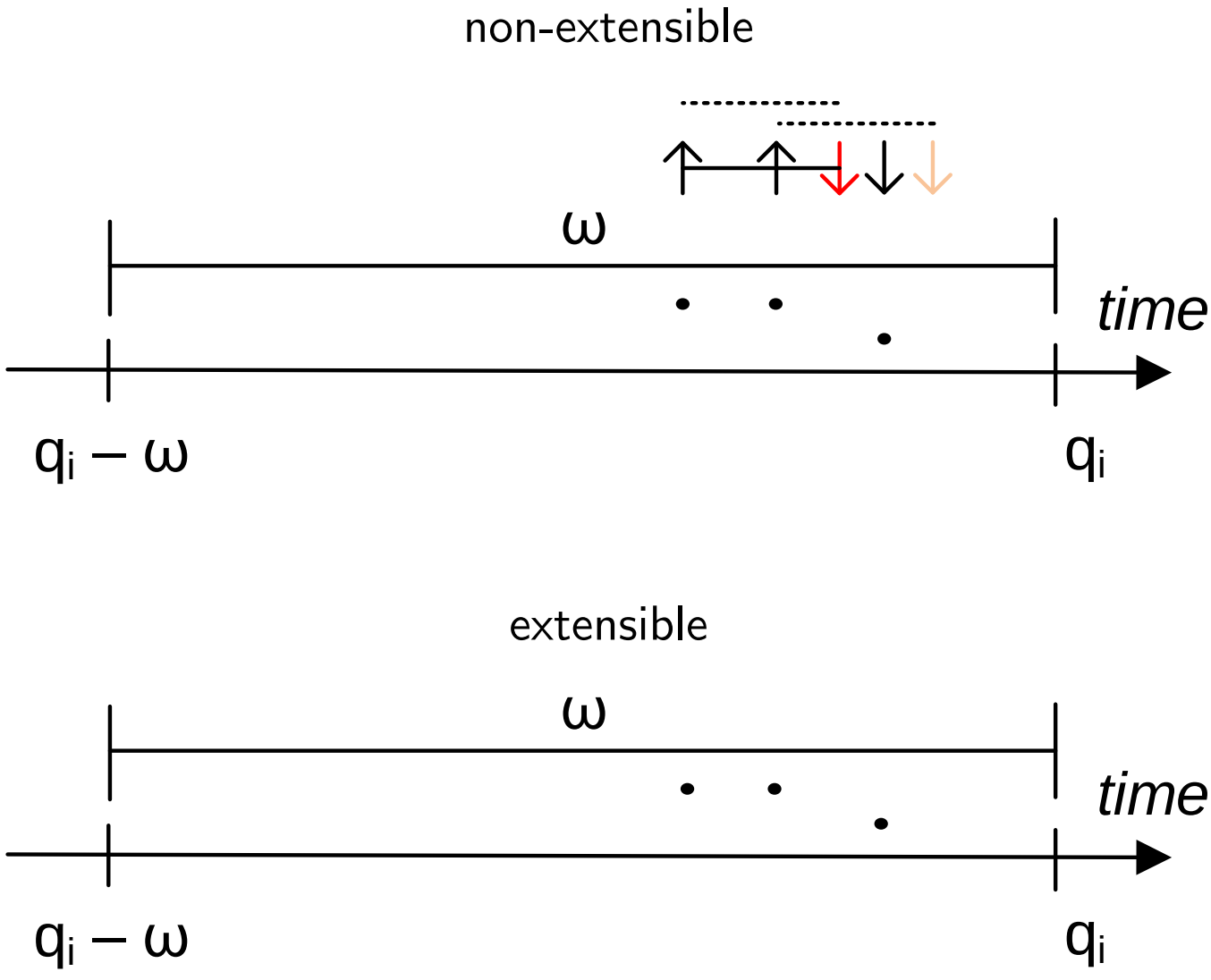

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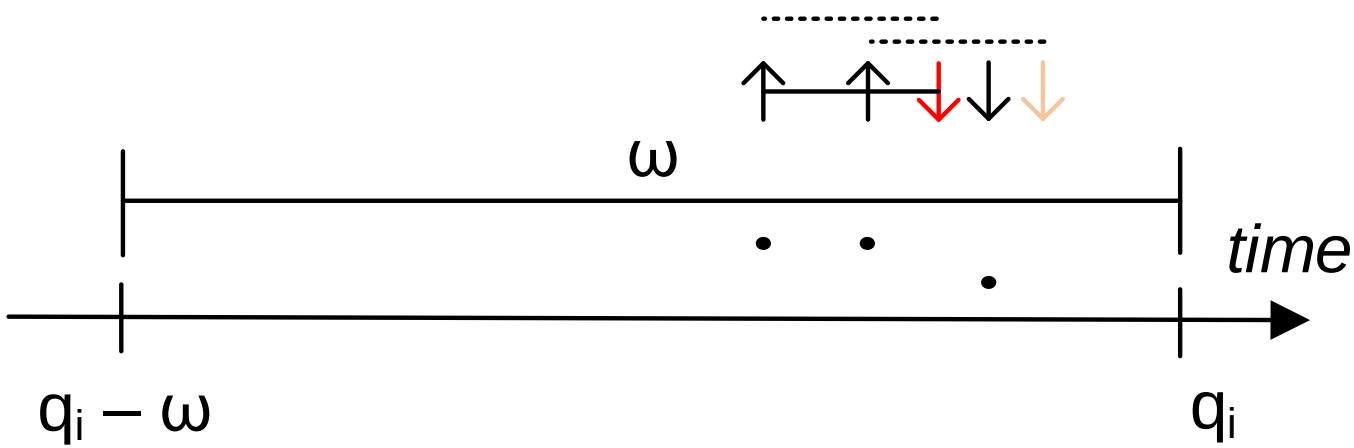

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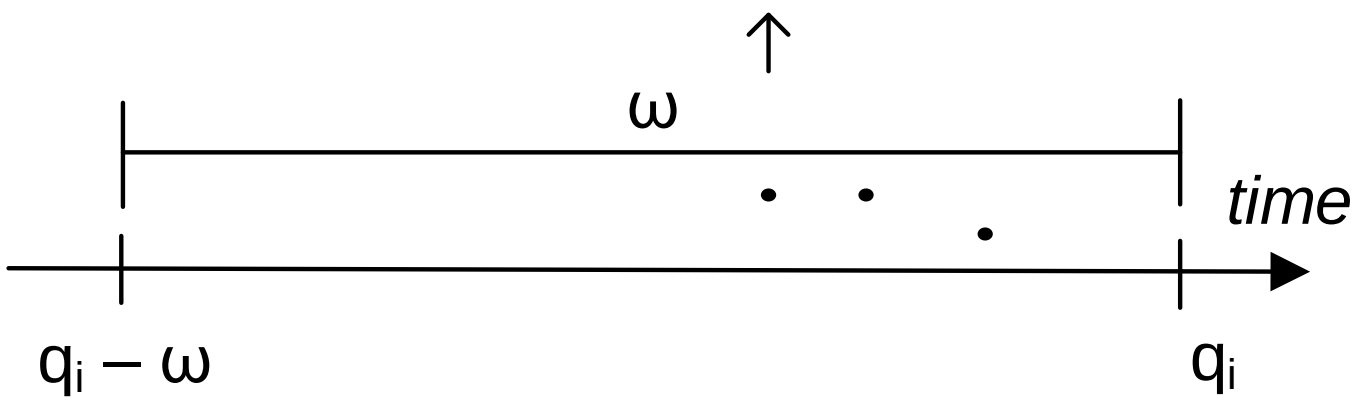

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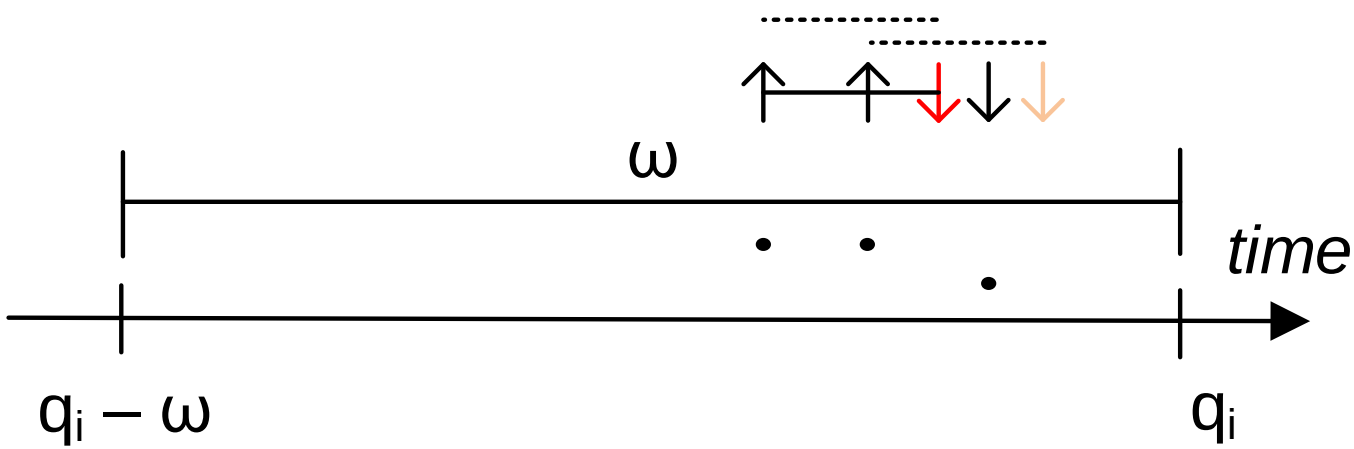

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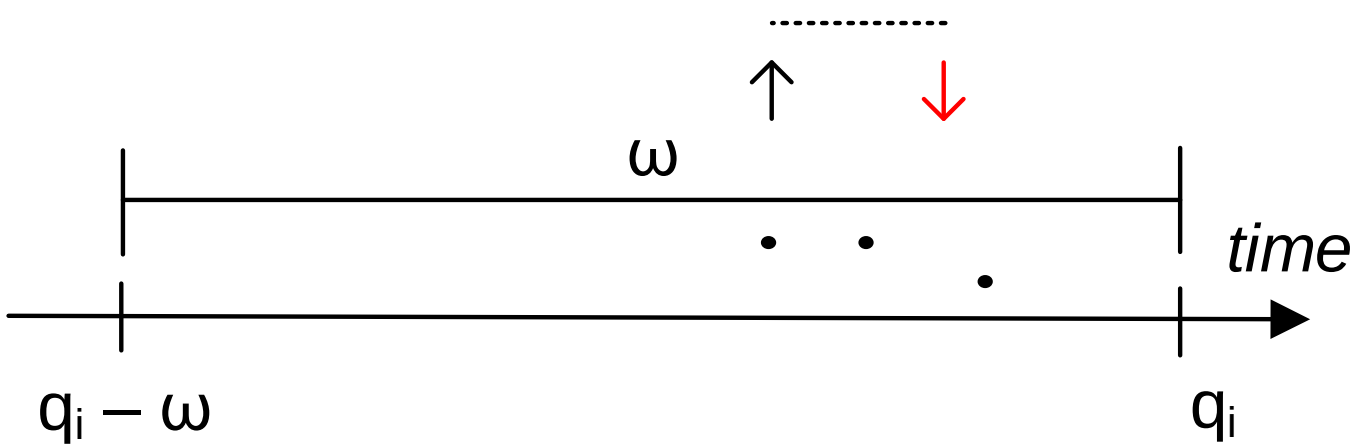

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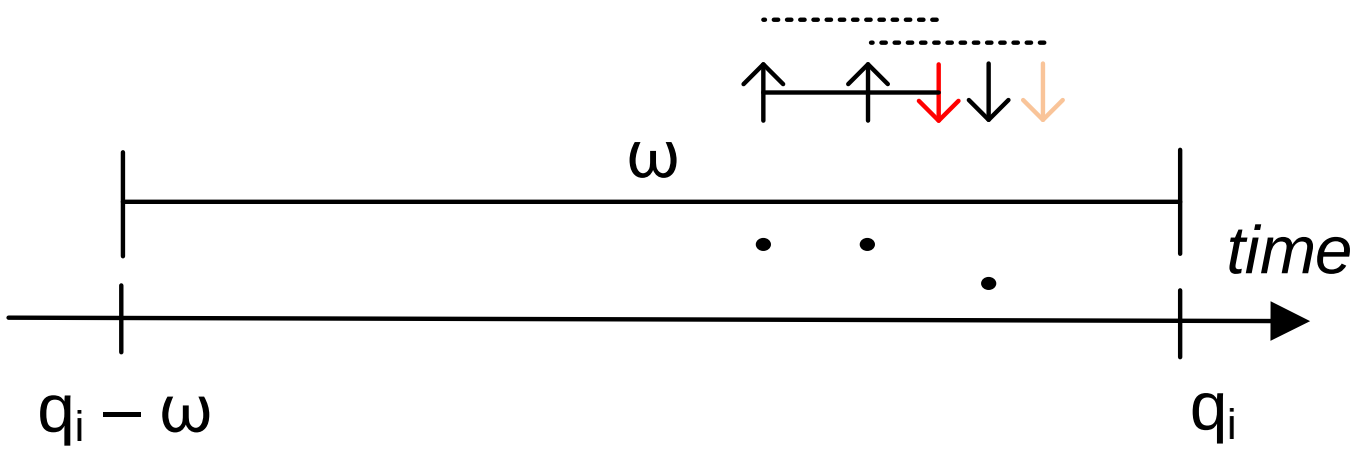

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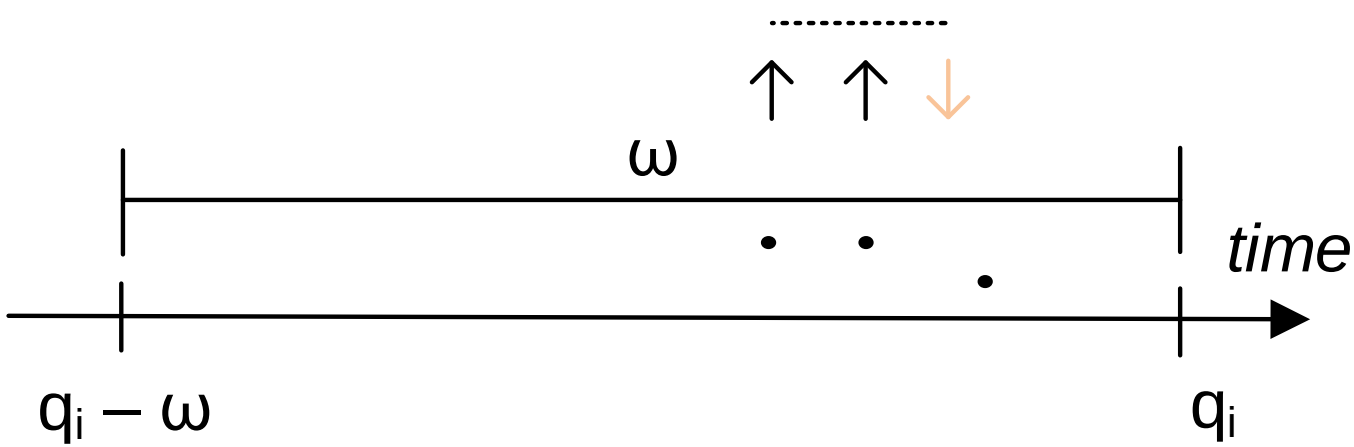

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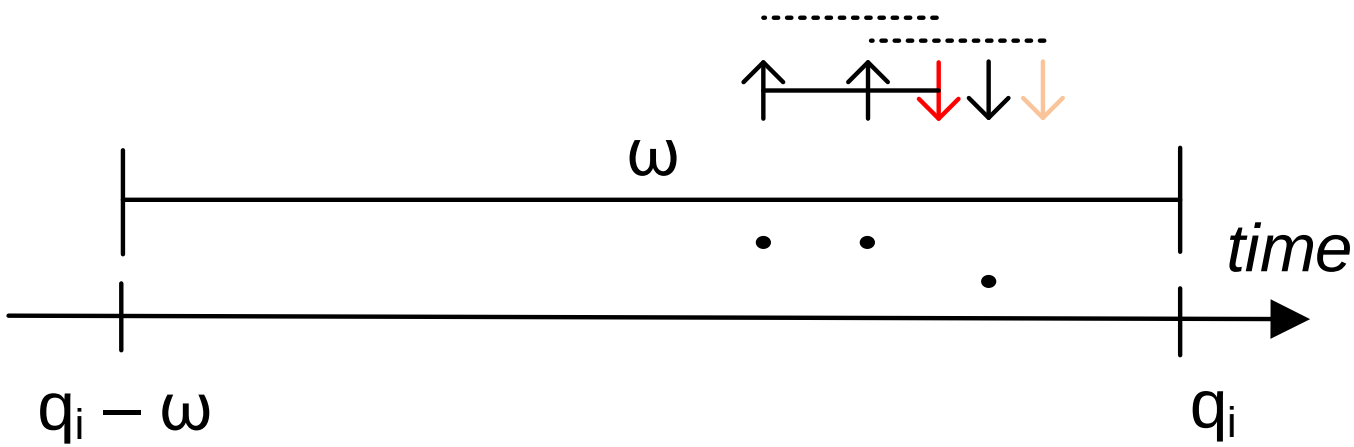

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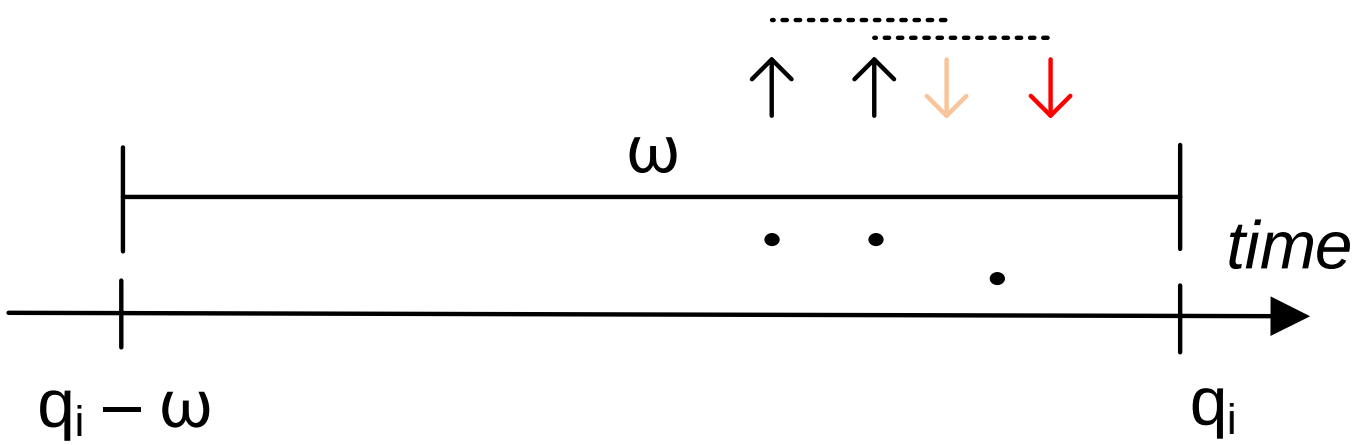

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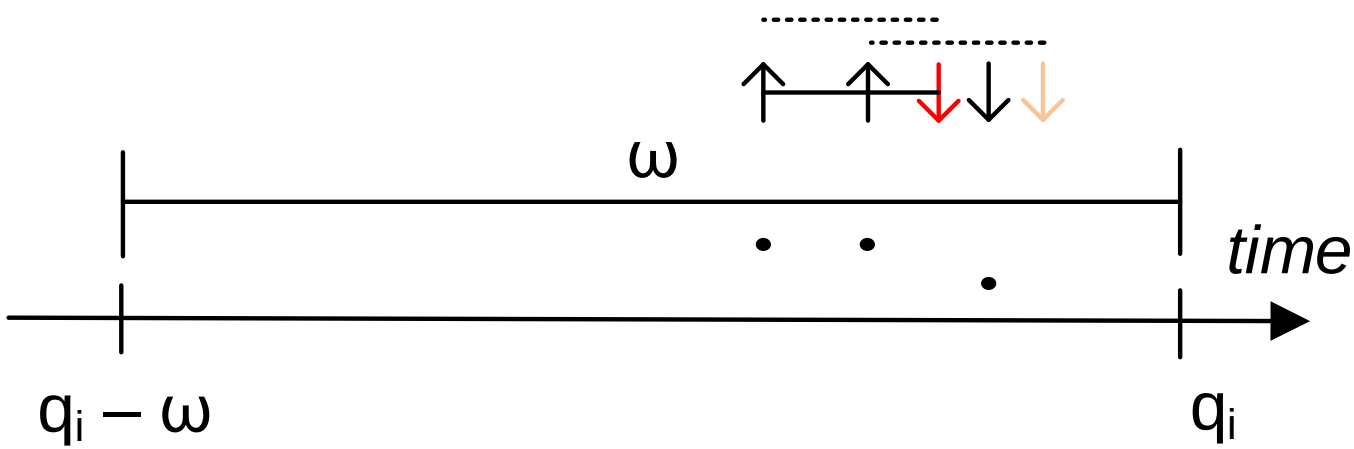

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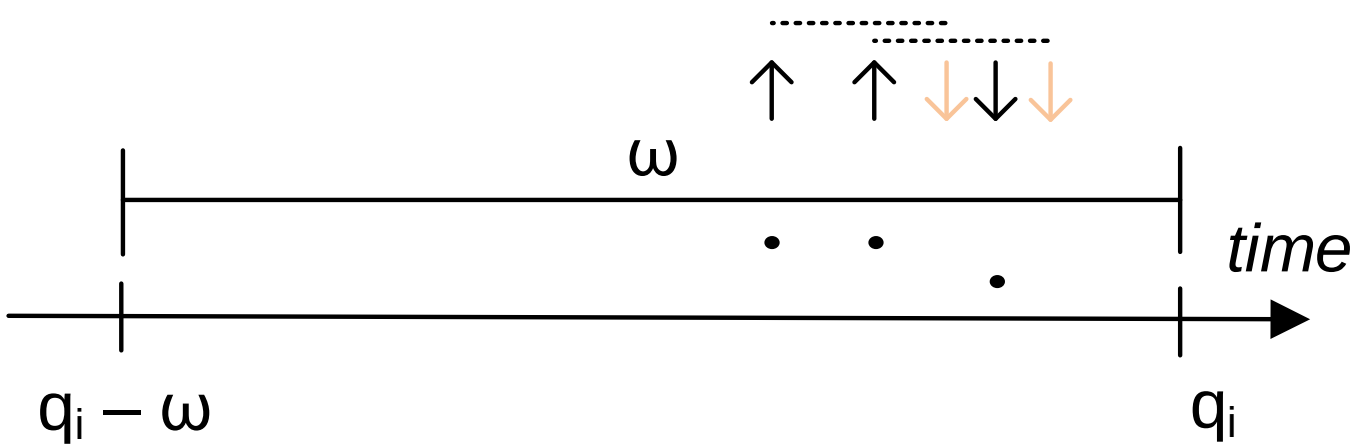

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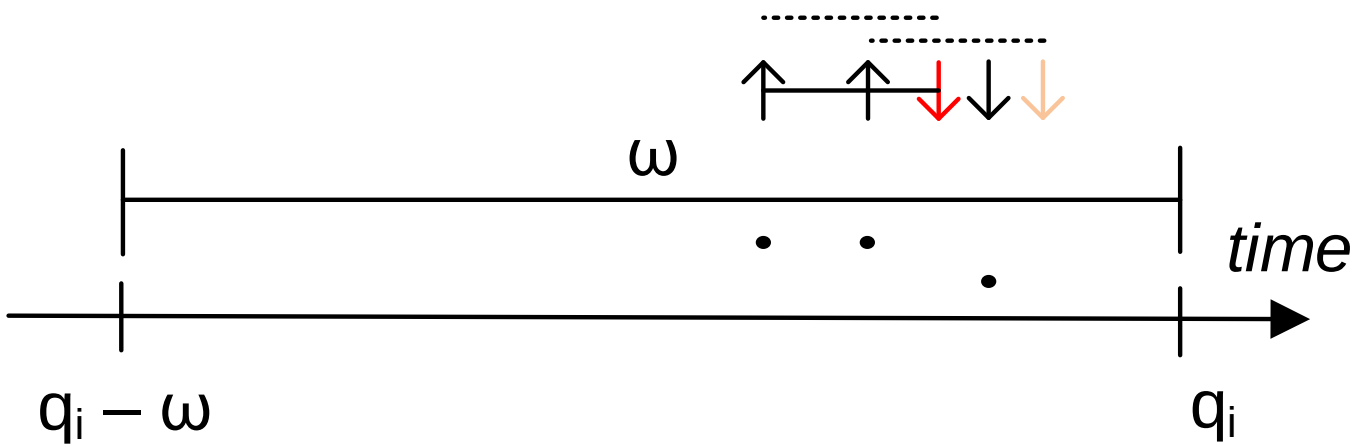

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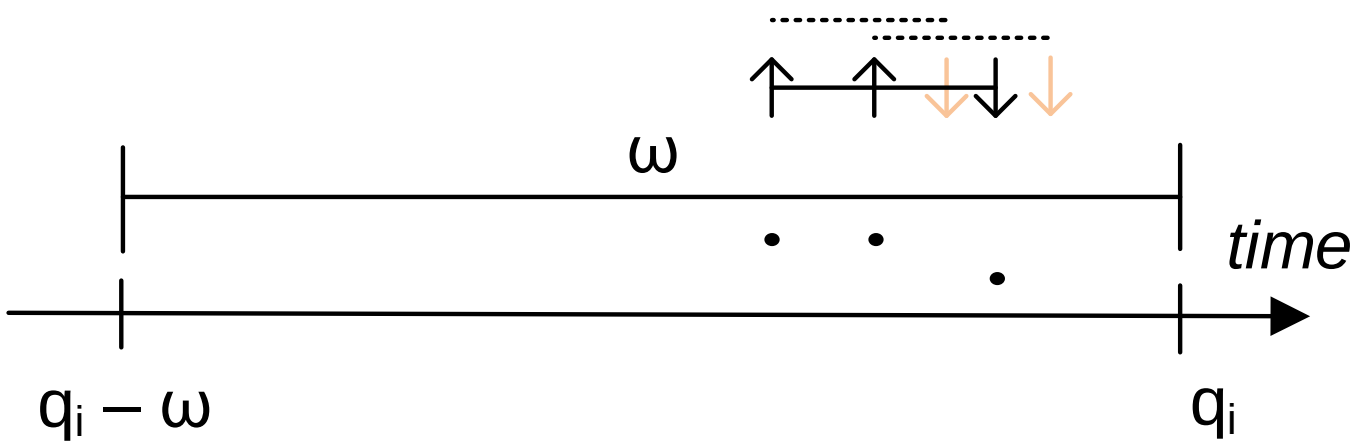
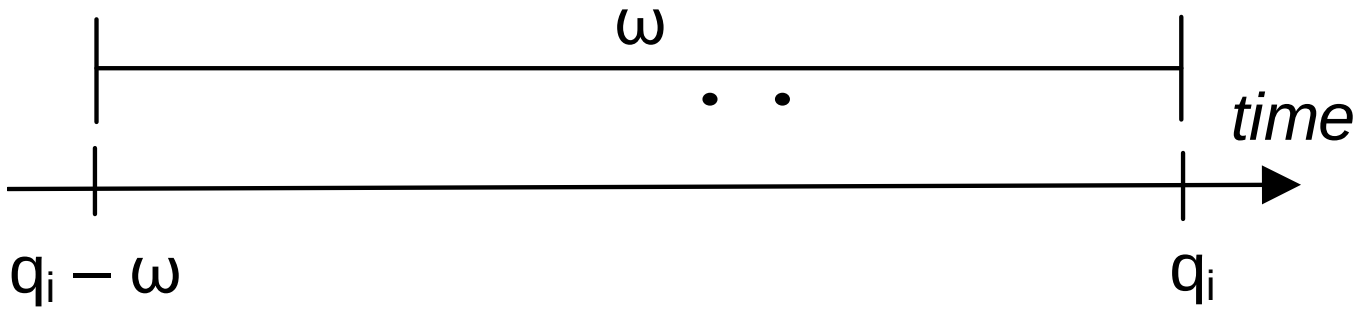


Handling Deadlines: Caching



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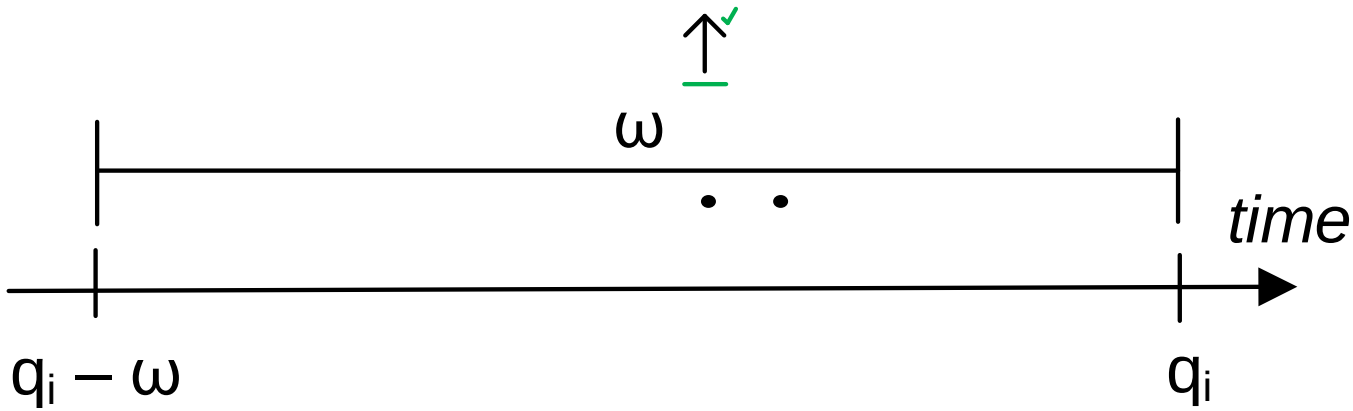

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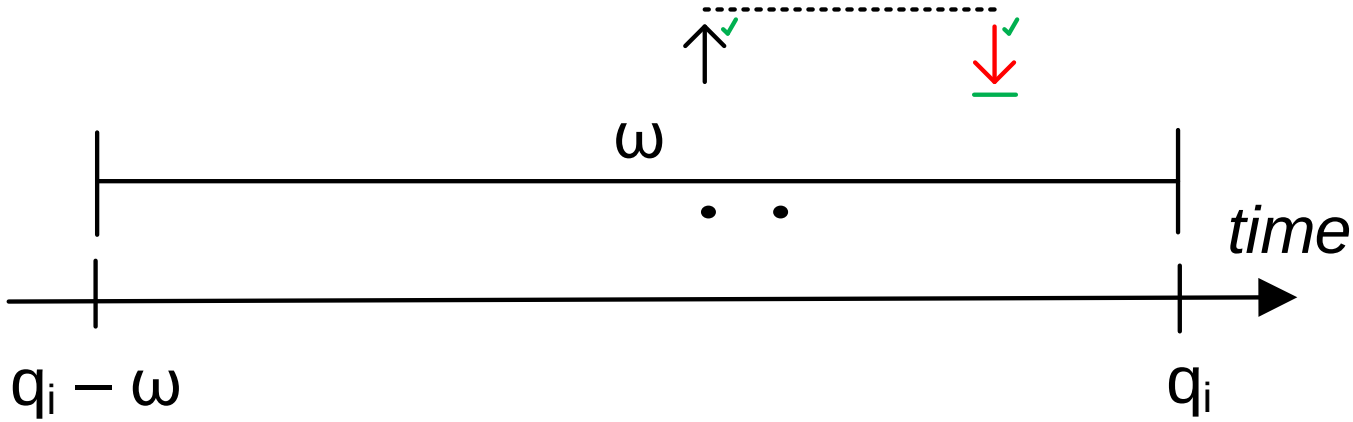

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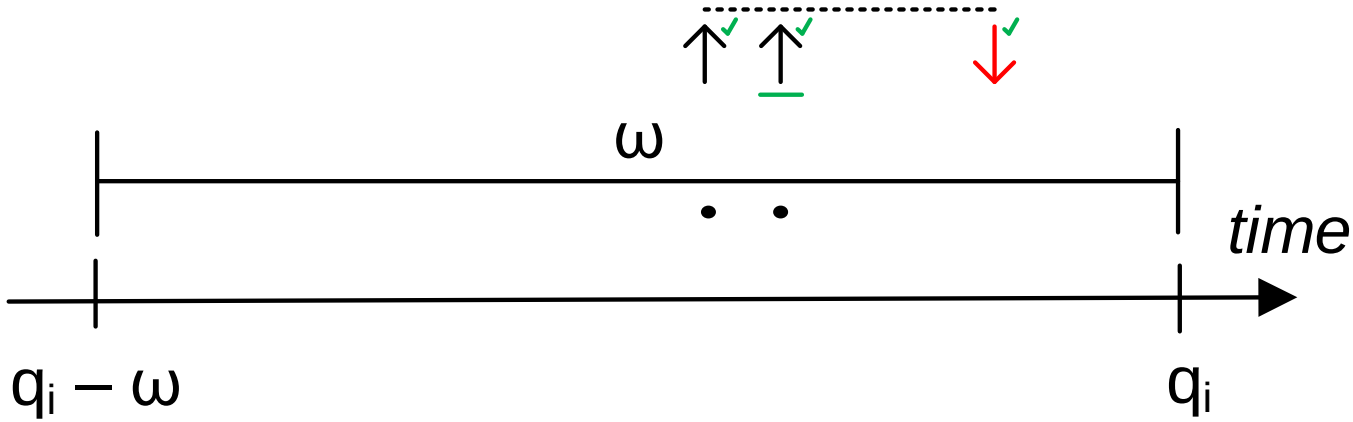

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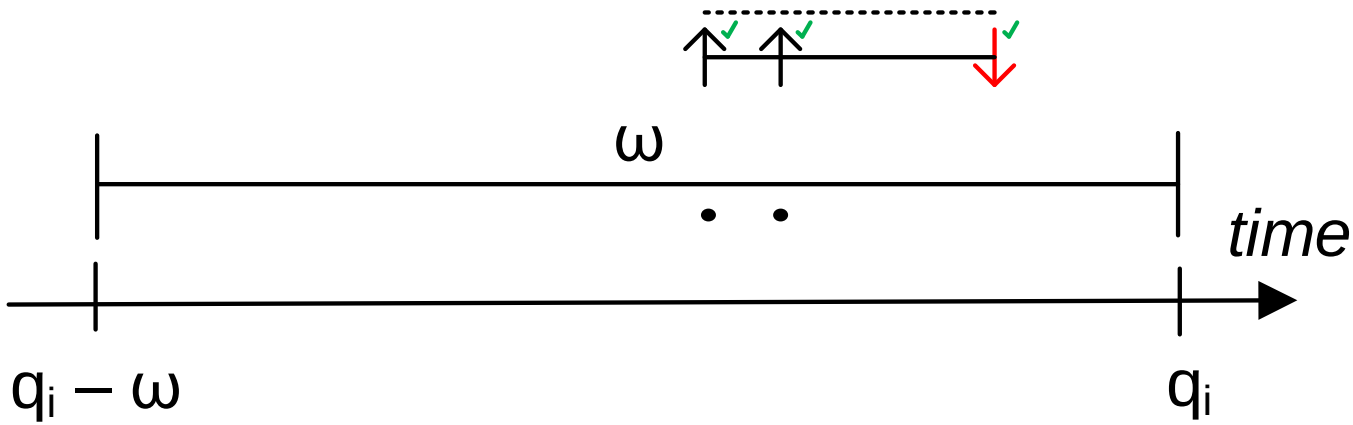

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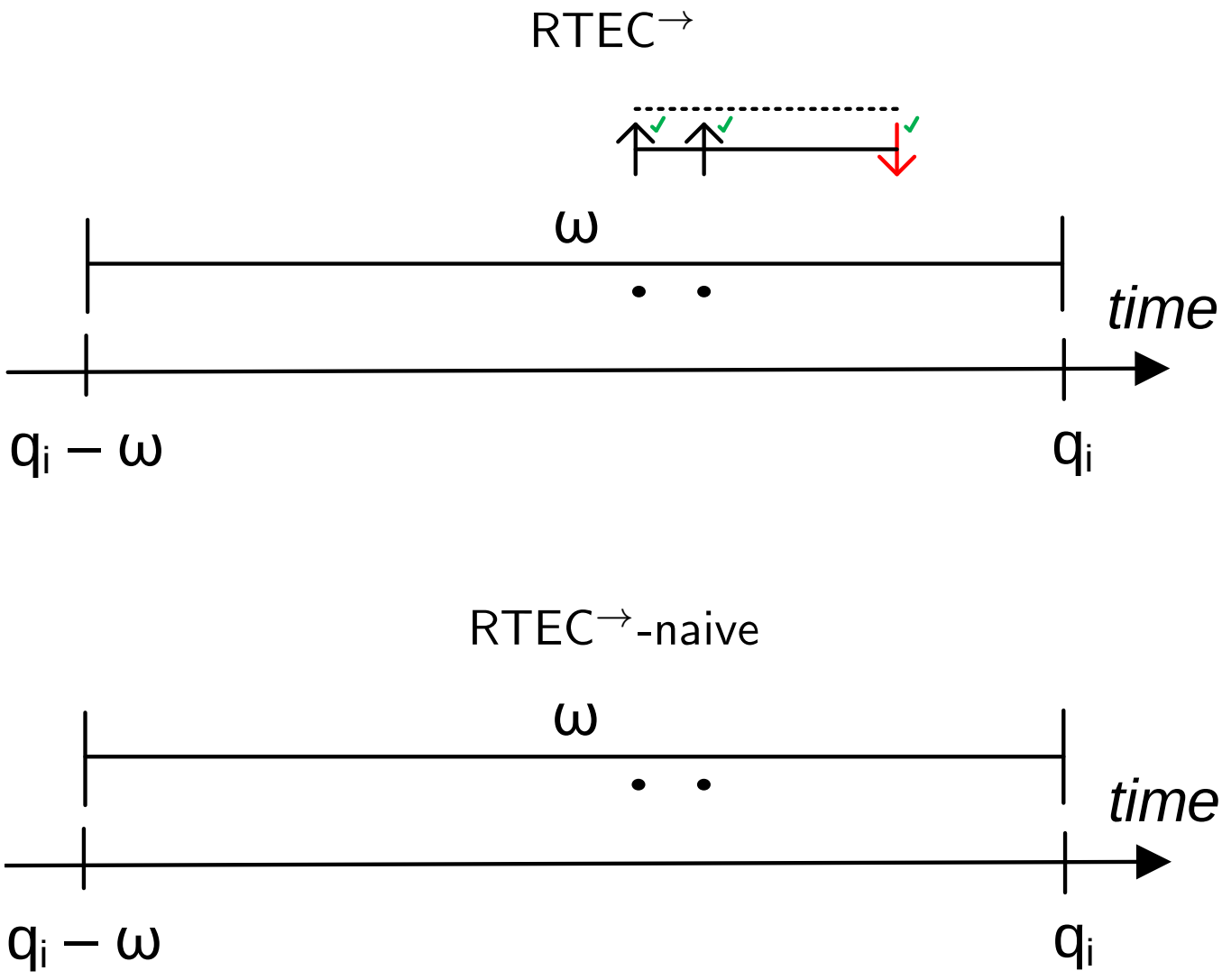

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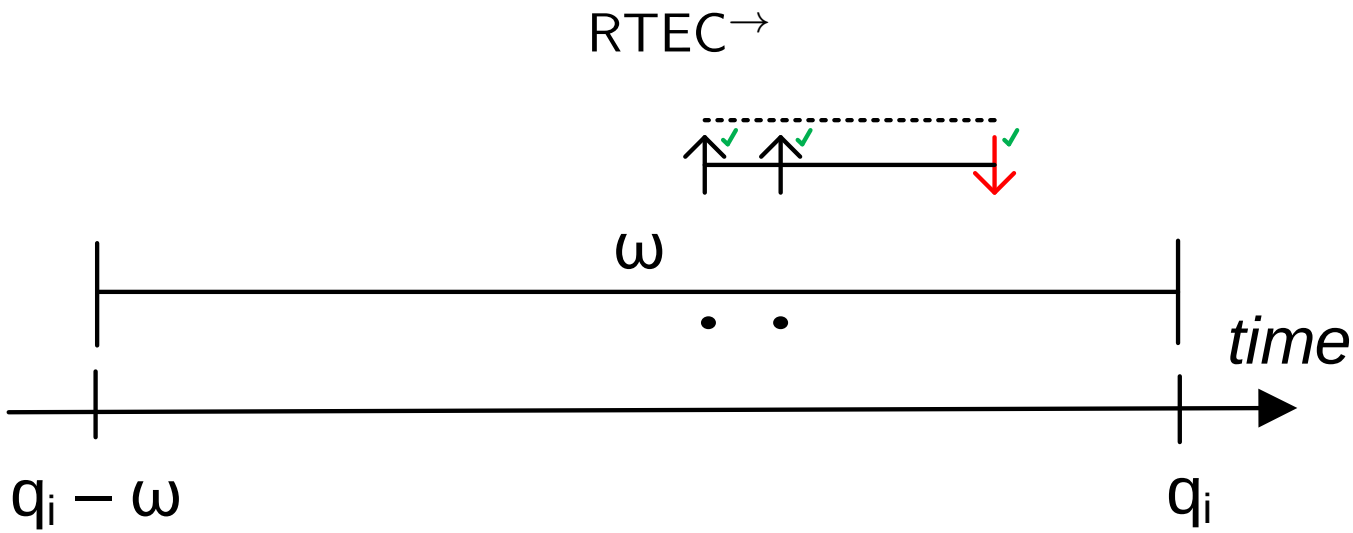

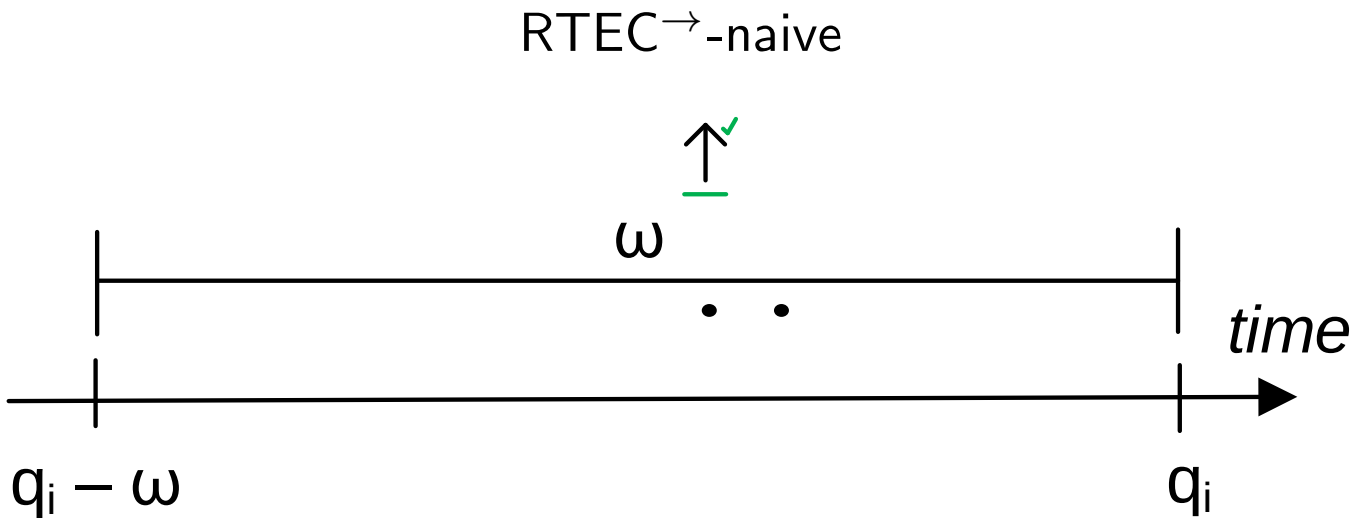

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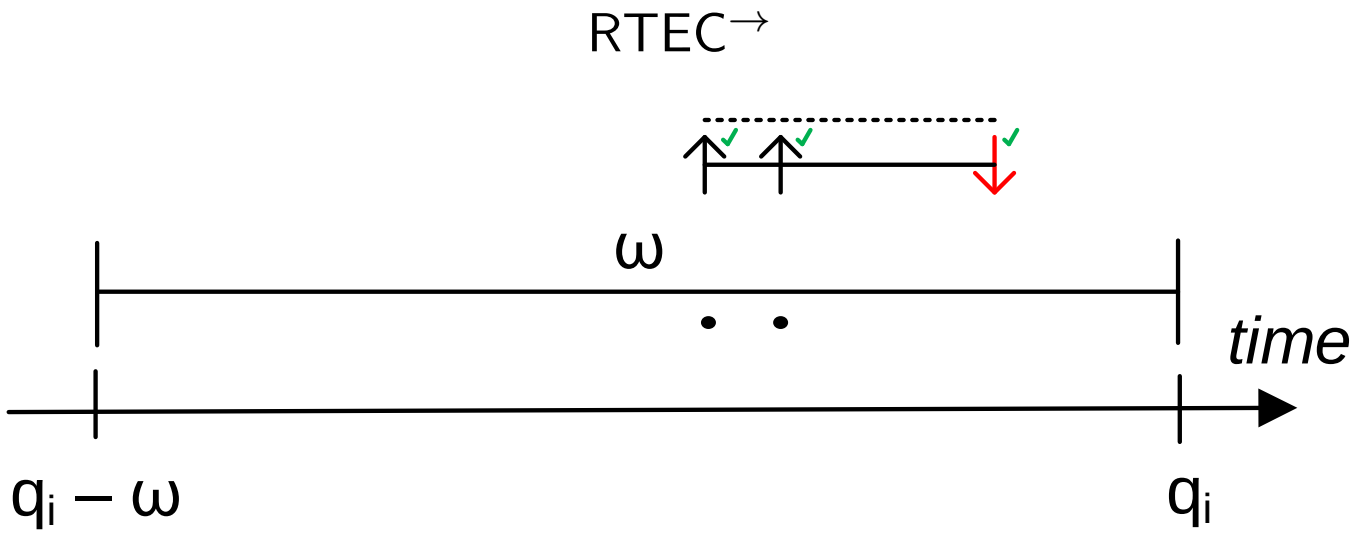

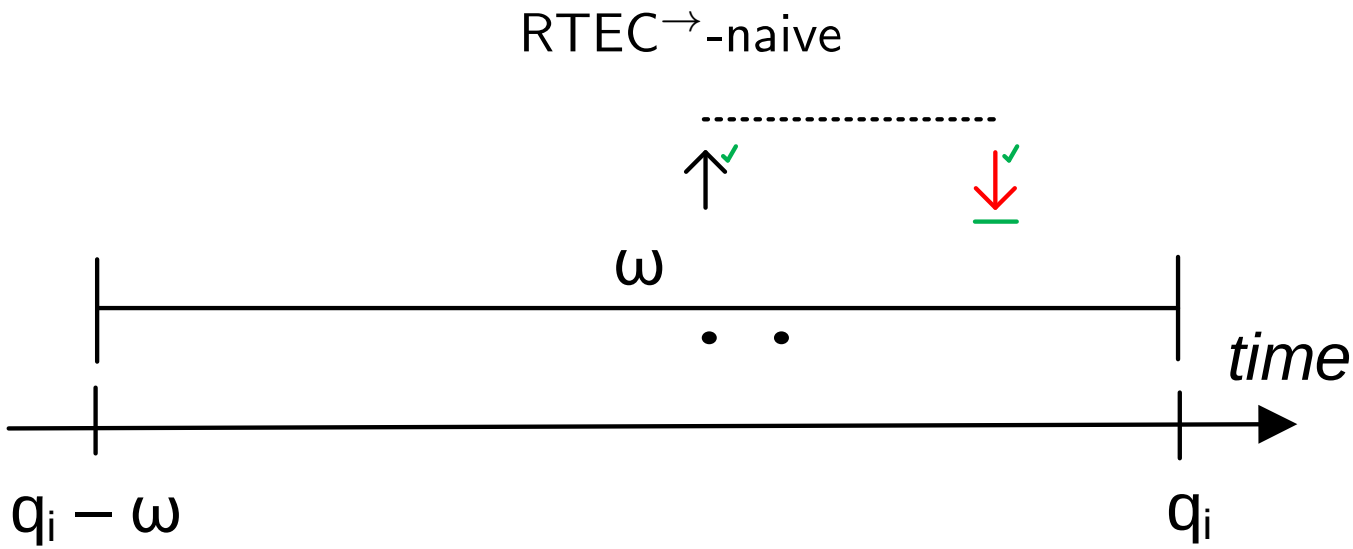

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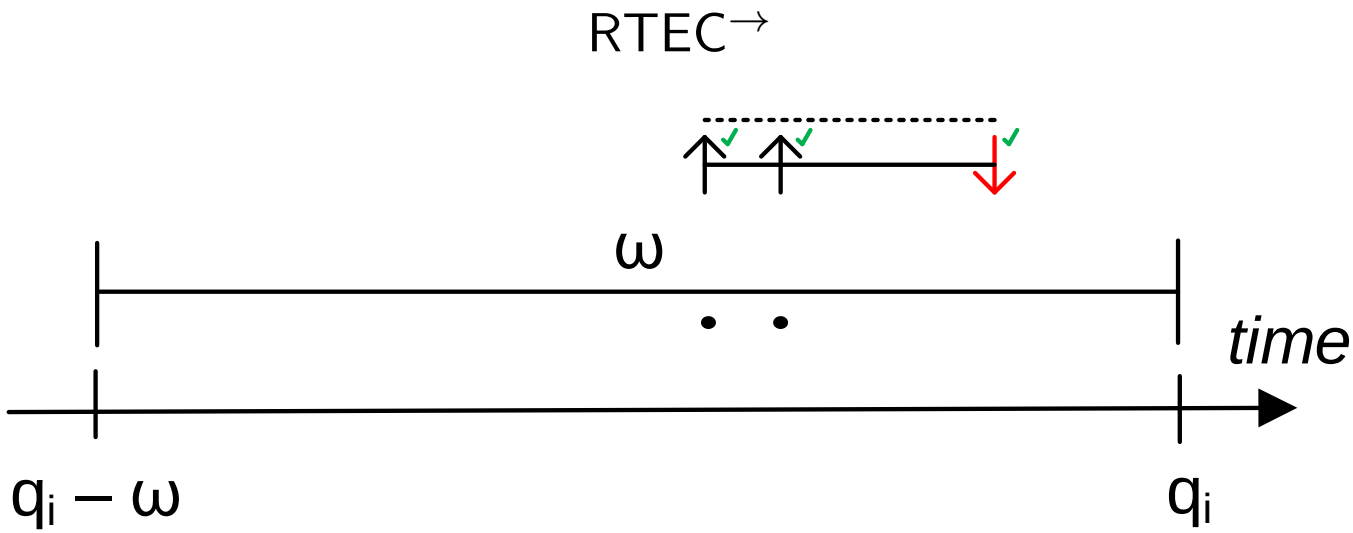

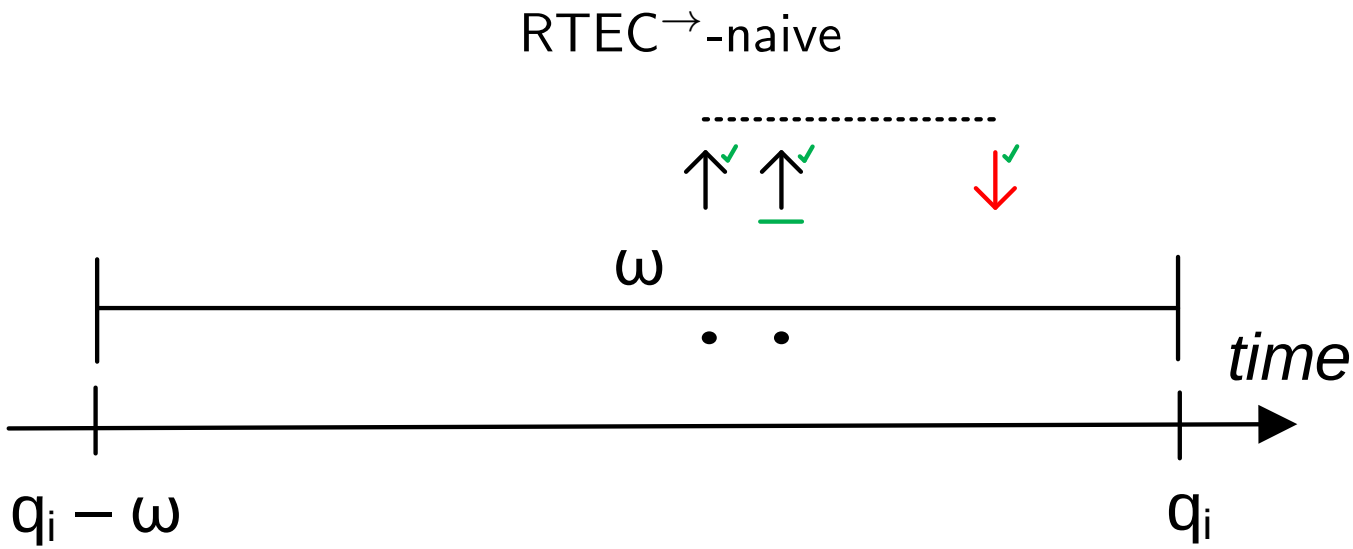

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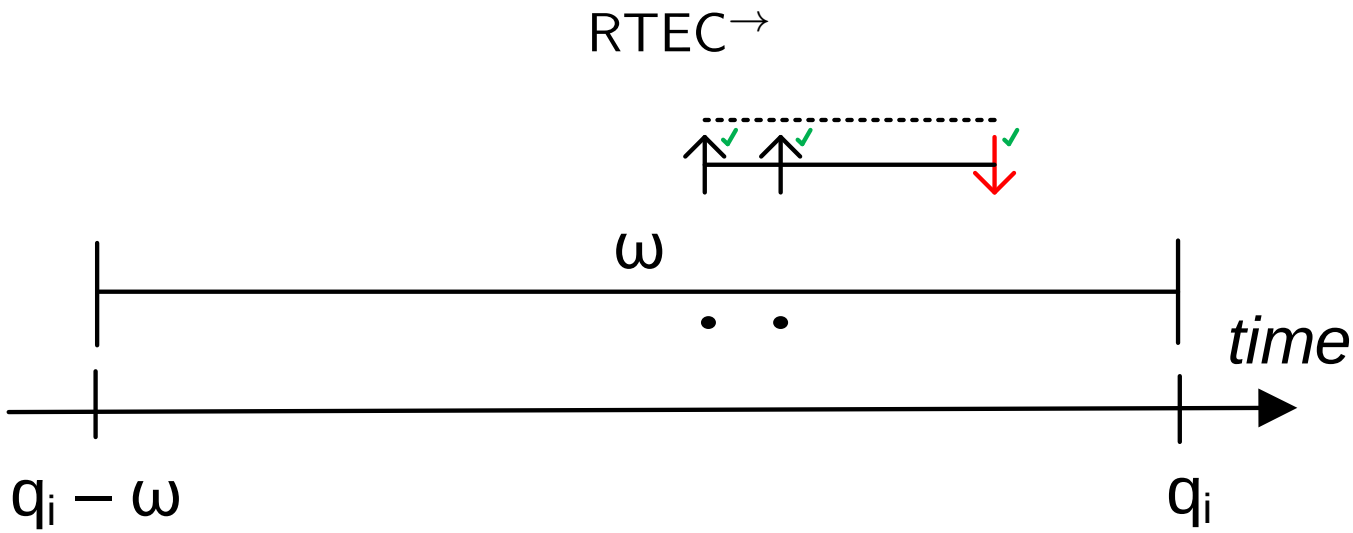

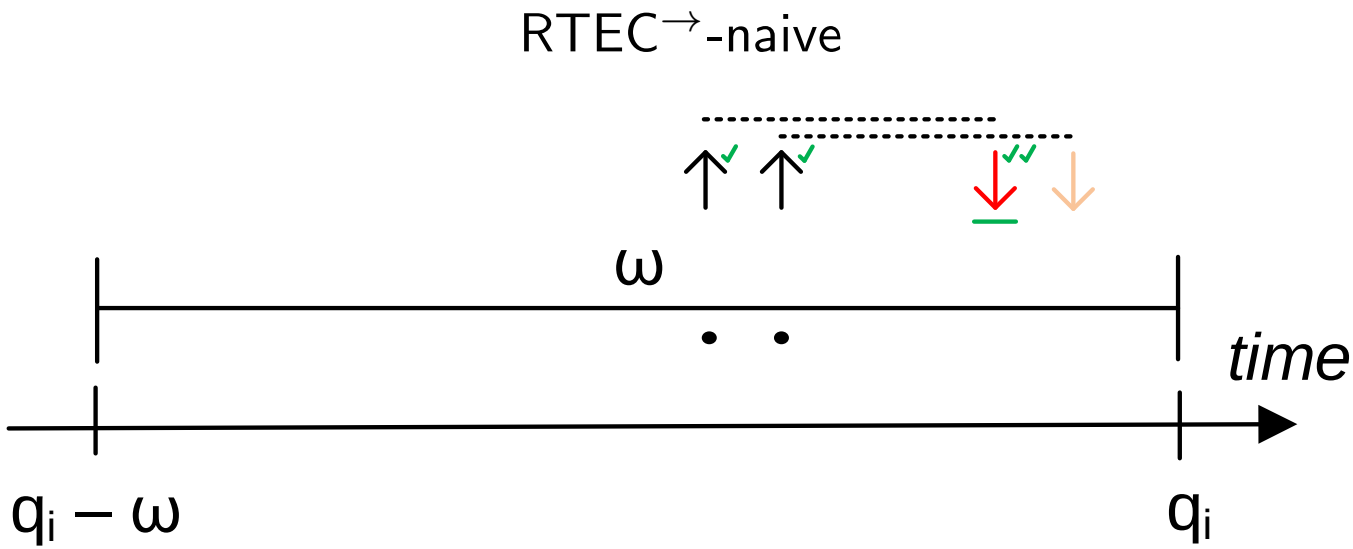

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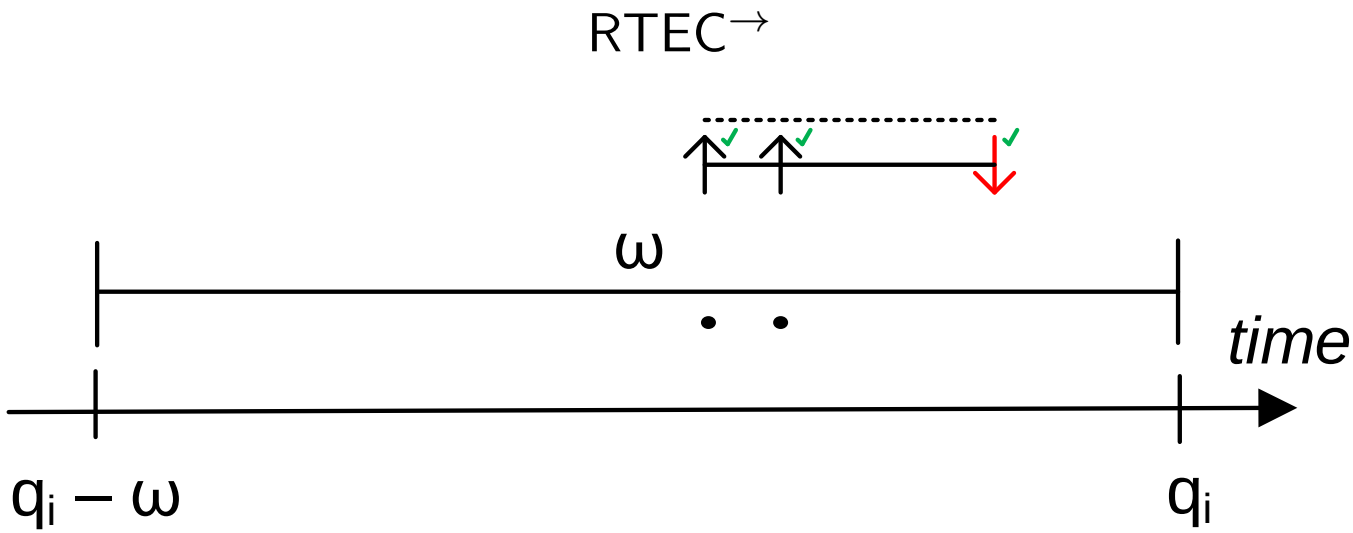
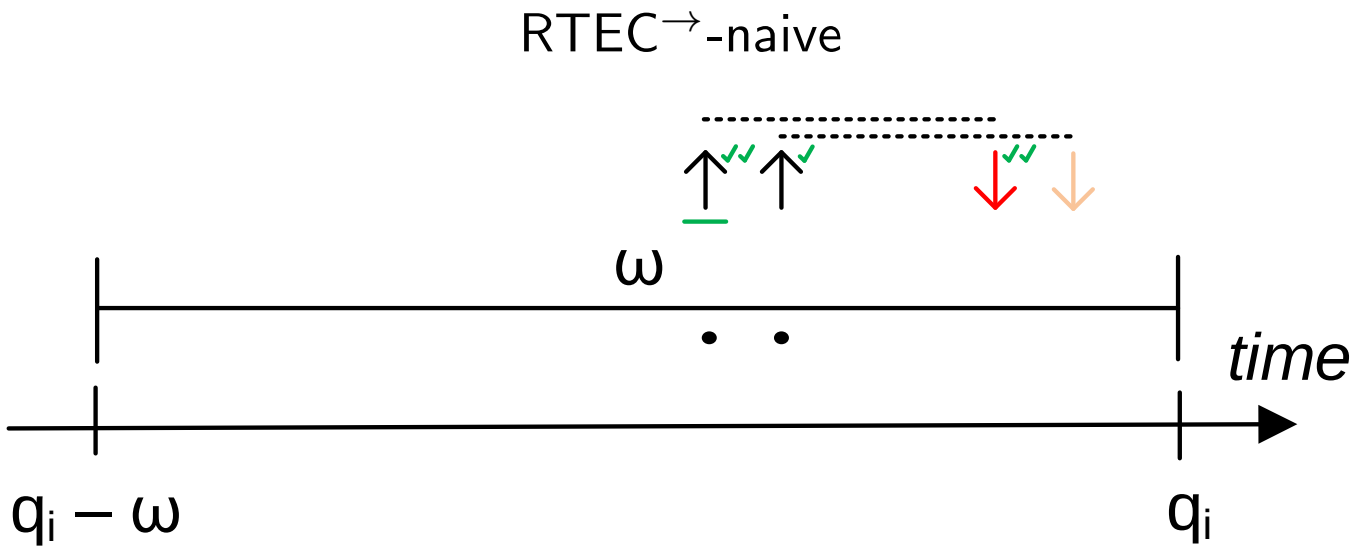
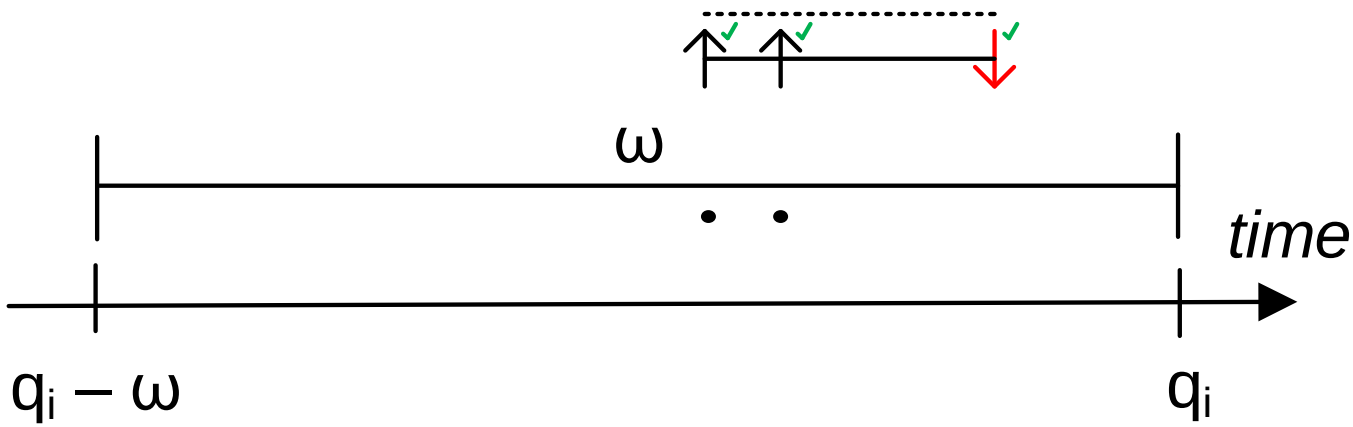


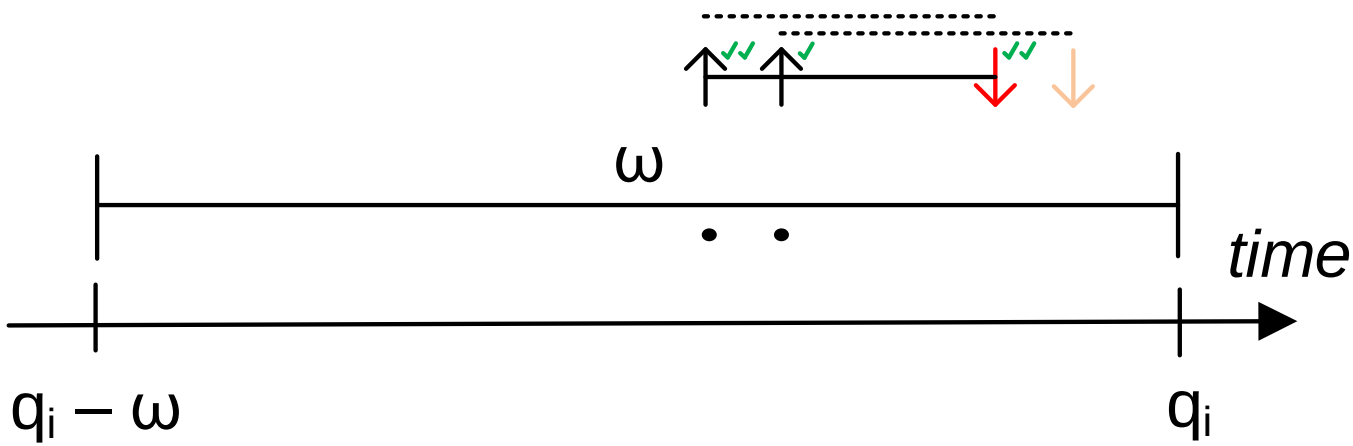


Handling Deadlines: Caching

RTEC$^{\rightarrow}$



RTEC$^{\rightarrow}$-naive



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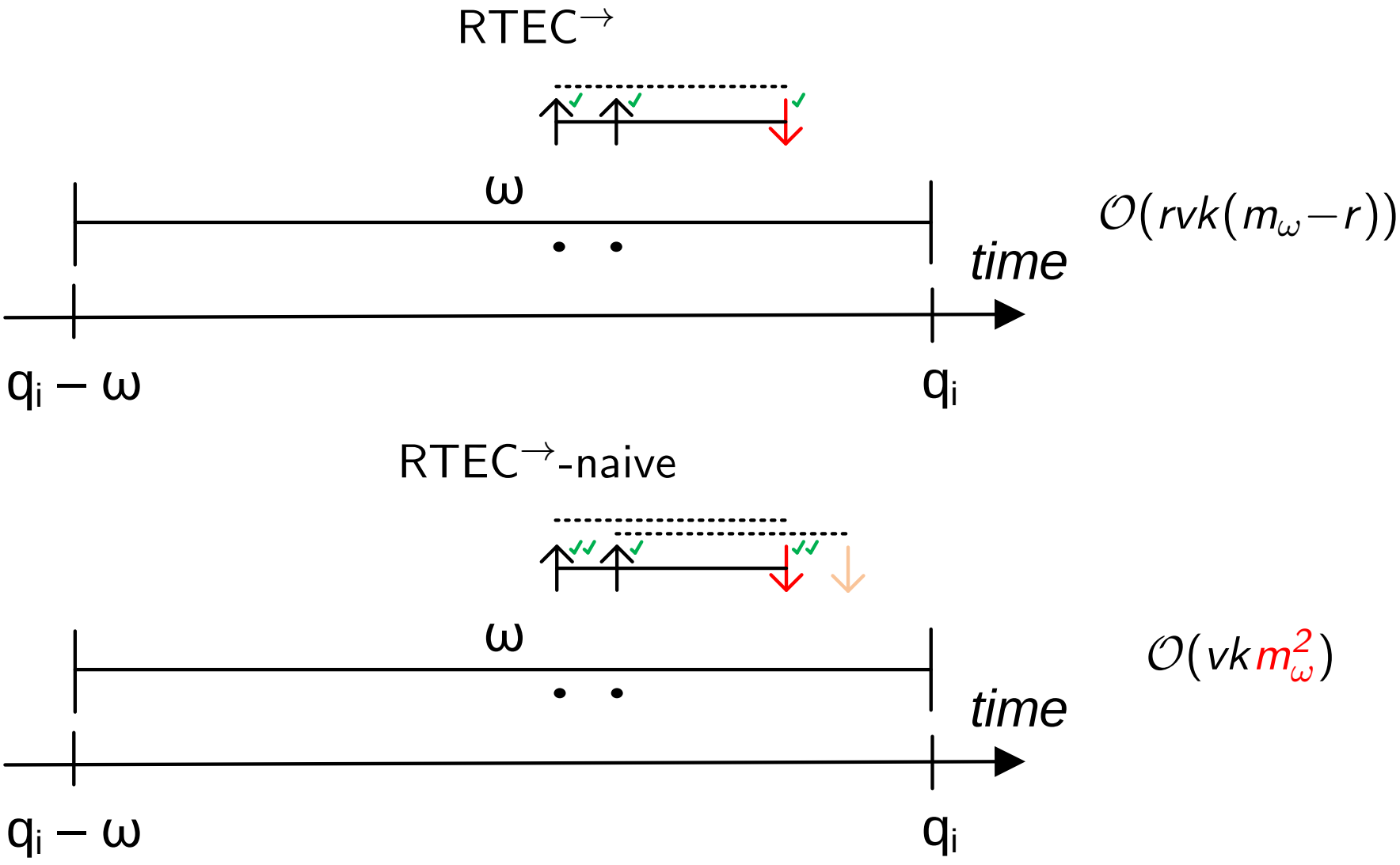

Experimental Setup

Biological Feedback Loops

- Compute, e.g., the concentrations of h-cells and s-cells in immune response.

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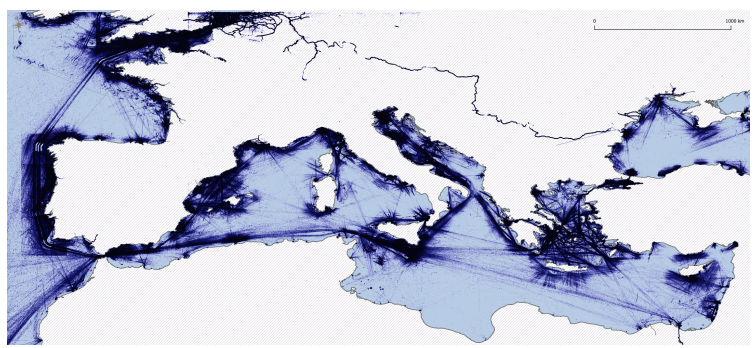
- Recognise dangerous, illegal and suspicious vessel activity.



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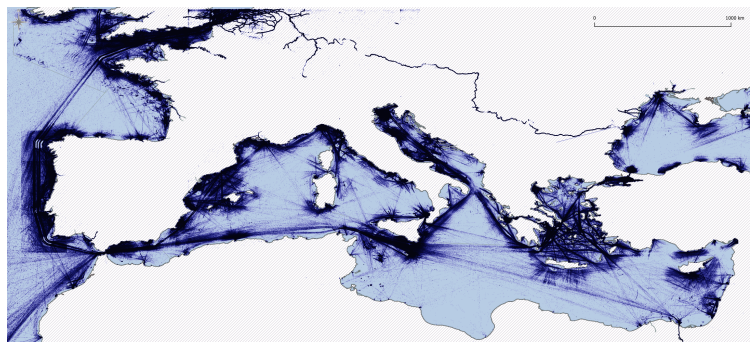
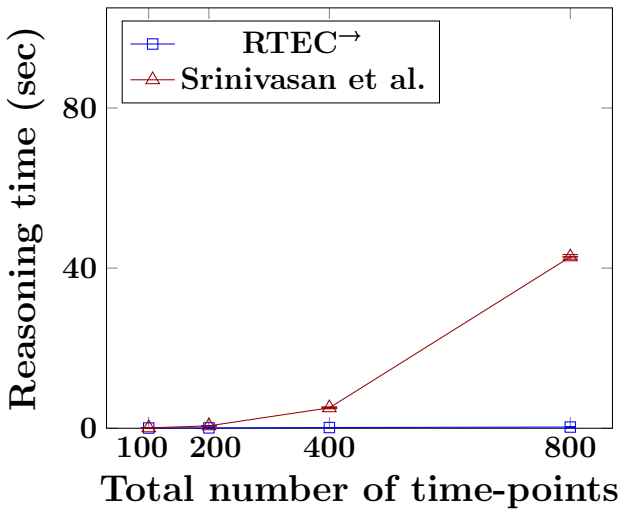


Code, Data & Temporal Specifications

`https://github.com/aartikis/RTEC`

Experimental Results

Immune Response



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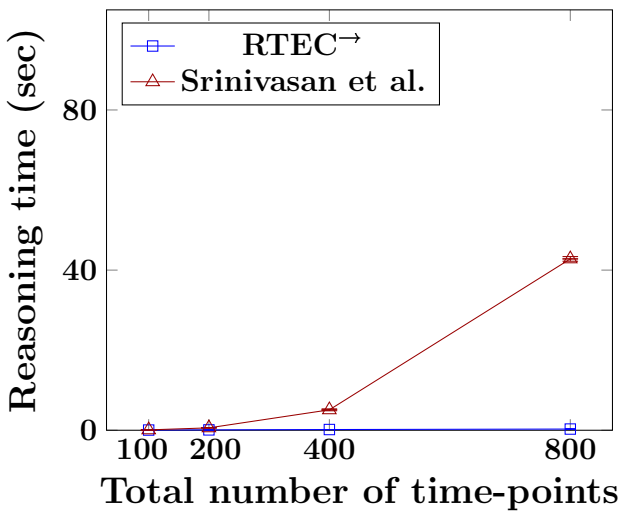
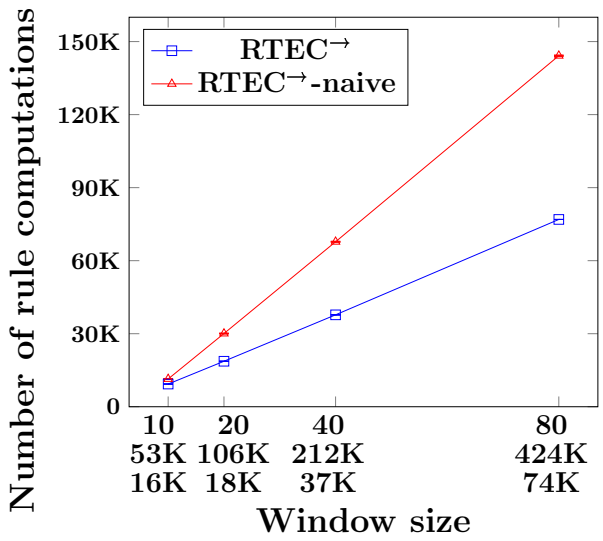
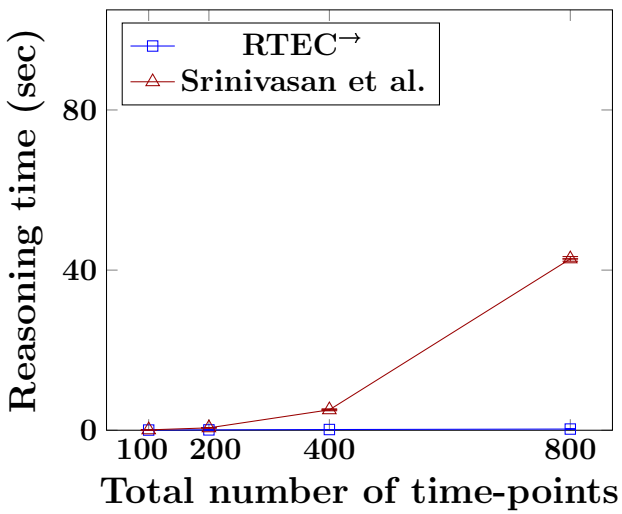


NetBill



Experimental Results

Immune Response



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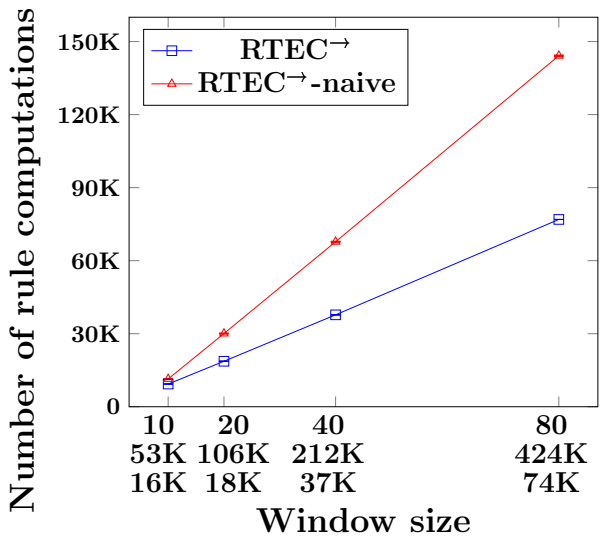
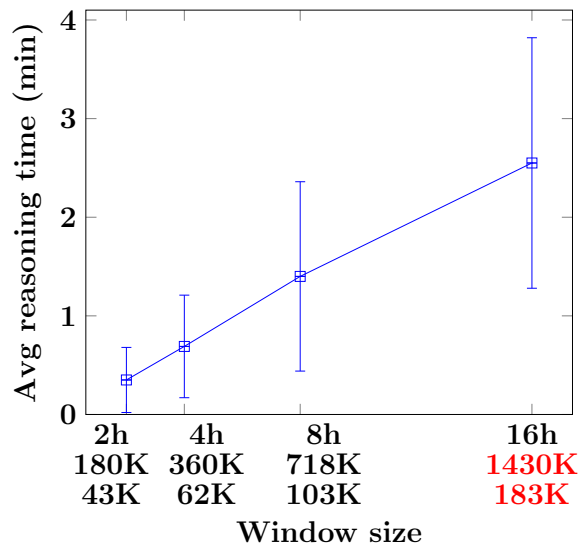


European Seas



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Resources

`https://cer.iit.demokritos.gr/`