Extending the Range of Temporal Specifications of the Run-Time Event Calculus

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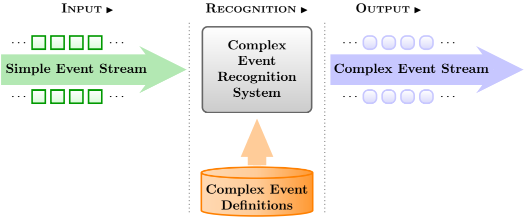
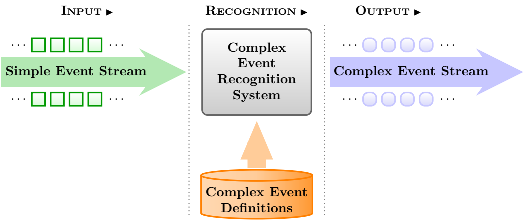
Composite Event Recognition



Composite Event Recognition



https://cer.iit.demokritos.gr (activity recognition)

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.

Kowalski R., Sergot M., 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 (RTEC)

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

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

where

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

Artikis et al., An Event Calculus for Event Recognition. In IEEE Transactions on Knowledge and Data Engineering (TKDE), 27(4), 895–908, 2015.

Activity Recognition

$$
\begin{aligned}
&\textbf{initiatedAt}(\mathit{interaction}(P_1, P_2) = \mathit{greeting},\ T) \leftarrow \\
&\quad \textbf{happensAt}(\mathit{active}(P_1),\ T),\ \textbf{happensAt}(\mathit{active}(P_2),\ T), \\
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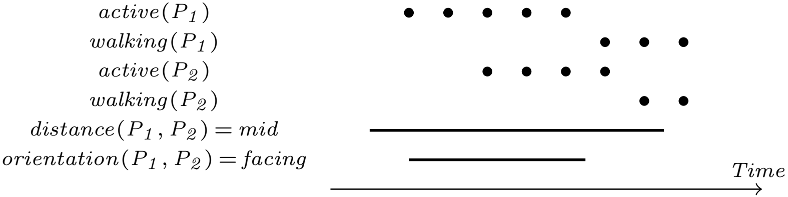

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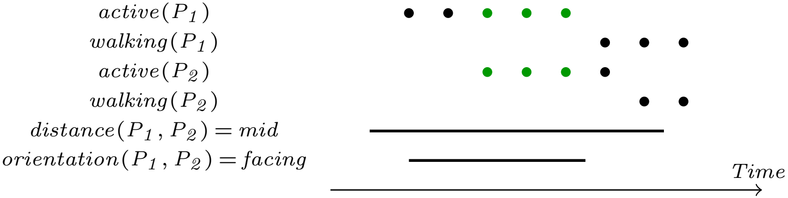

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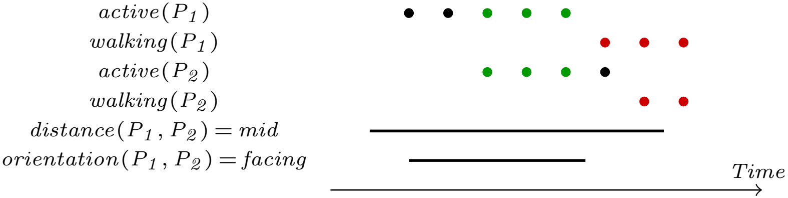

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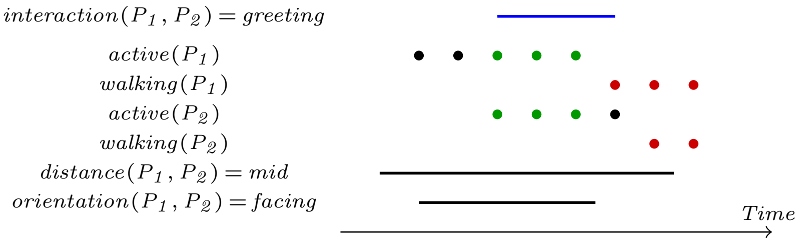
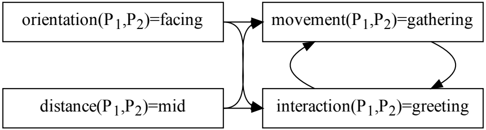


Semantics



Mantenoglou et al., Stream Reasoning with Cycles. In International Conference on Principles of Knowledge Representation and Reasoning (KR), 544–553, 2022.

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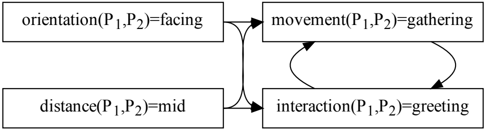

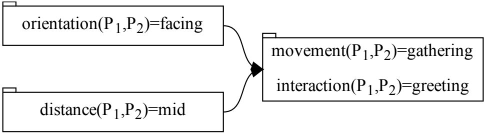

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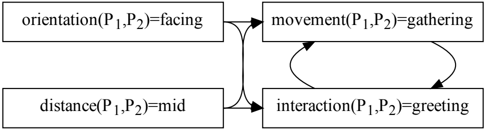

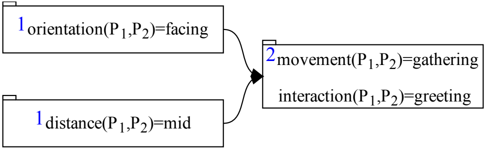

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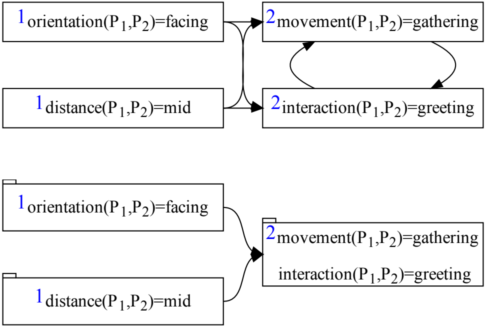

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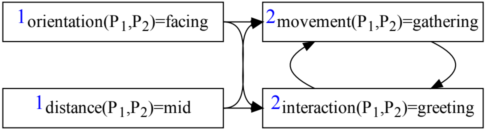

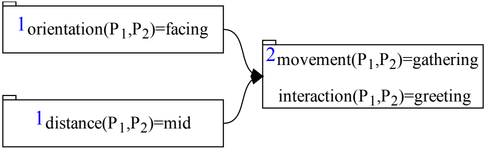

Semantics

An event description of RTEC is a locally stratified logic program.

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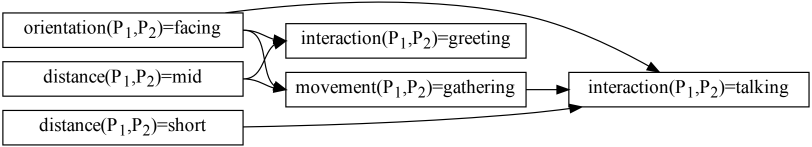
Problem Statement (1)



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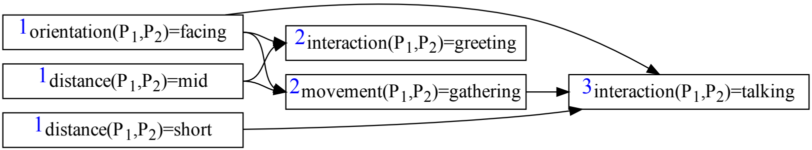

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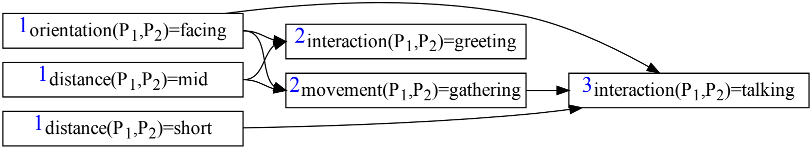

- A fluent may have at most one value at any time; an initiation of $F = V_1$ implies a termination of $F = V_2$, where $V_1 \neq V_2$.

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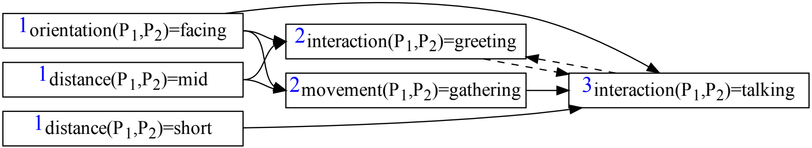

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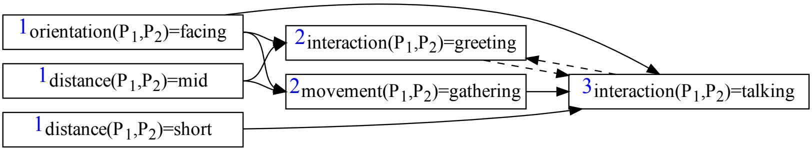

- A fluent may have at most one value at any time; an initiation of $F = V_1$ implies a termination of $F = V_2$, where $V_1 \neq V_2$.
- Implicit dependencies between fluent-value pairs with the same fluent may prohibit bottom-up processing.

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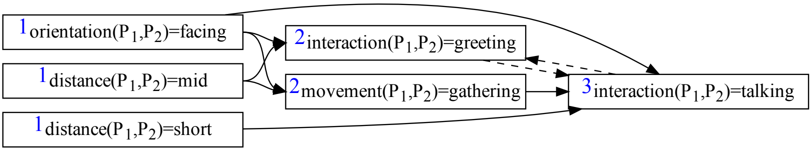
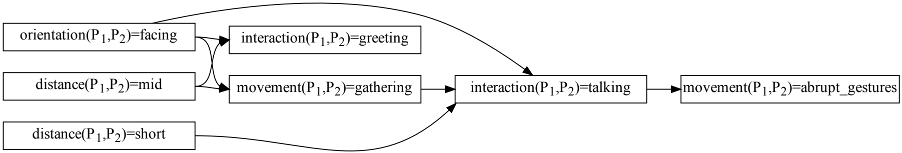


- A fluent may have at most one value at any time; an initiation of $F = V_1$ implies a termination of $F = V_2$, where $V_1 \neq V_2$.
- Implicit dependencies between fluent-value pairs with the same fluent may prohibit bottom-up processing.
- Solution: assign to fluent-value pairs of $interaction(P_1, P_2)$ a higher level than $movement(P_1, P_2) = gathering$.

Problem Statement (2)



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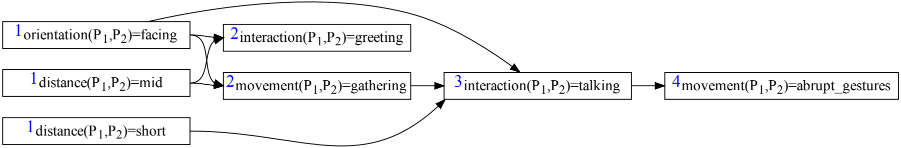

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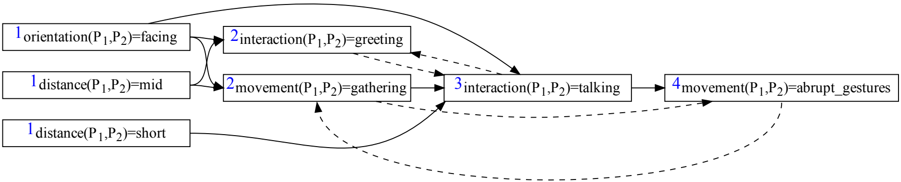

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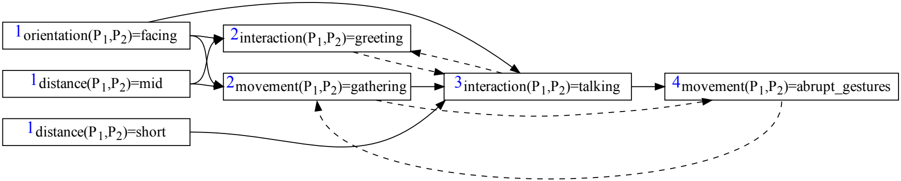
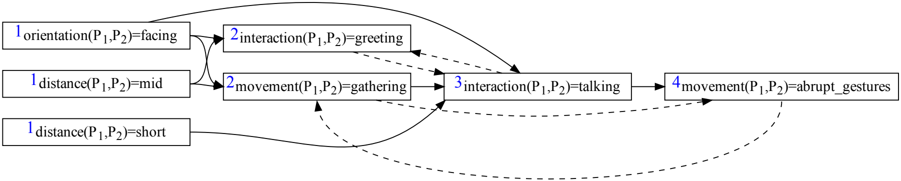


- We can have arbitrary implicit relations.

Problem Statement (2)



- We can have arbitrary implicit relations.
- Solution: assign to fluent-value pairs of $interaction(P_1, P_2)$ and $movement(P_1, P_2)$ the same level.

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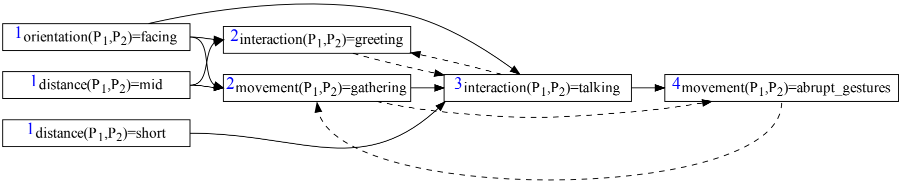
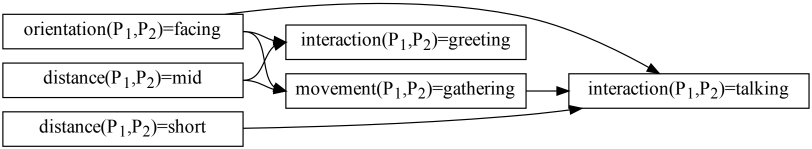


- We can have arbitrary implicit relations.
- Solution: assign to fluent-value pairs of $interaction(P_1, P_2)$ and $movement(P_1, P_2)$ the same level.
- RTEC_{fl}: An extension of RTEC that supports every possible dependency graph.

RTEC$_{fl}$: Fluent Dependency Graph



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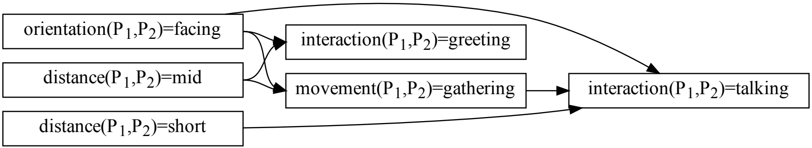

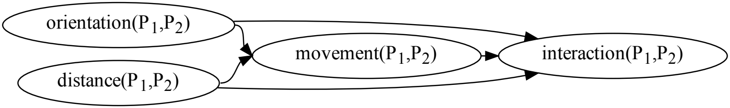

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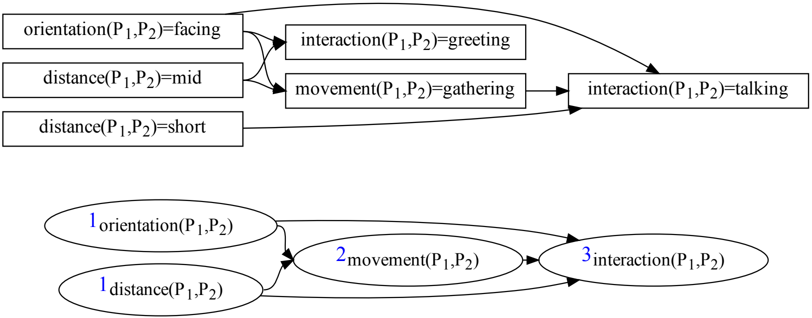

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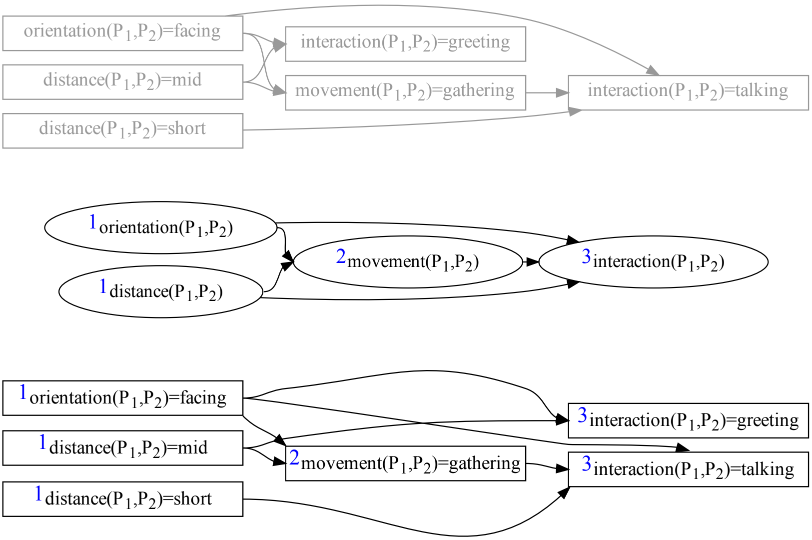

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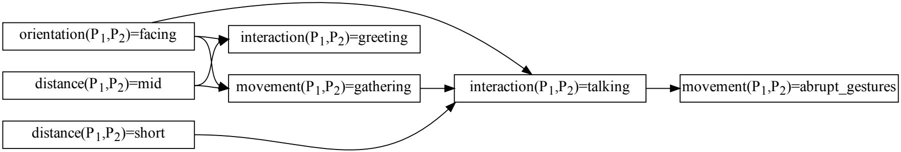

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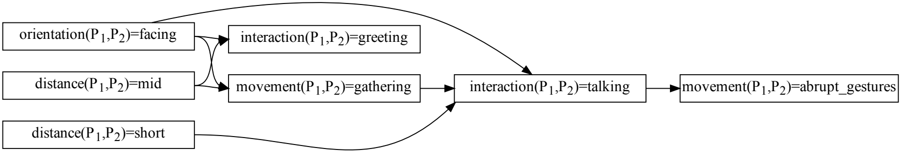
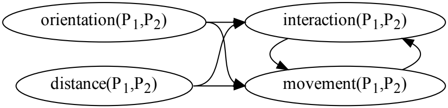
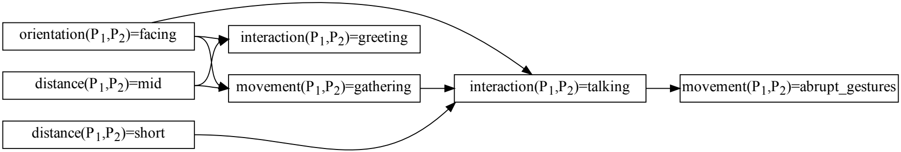
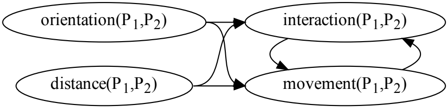
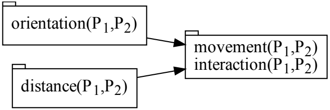




RTEC$_{fl}$: Contracted Dependency Graph







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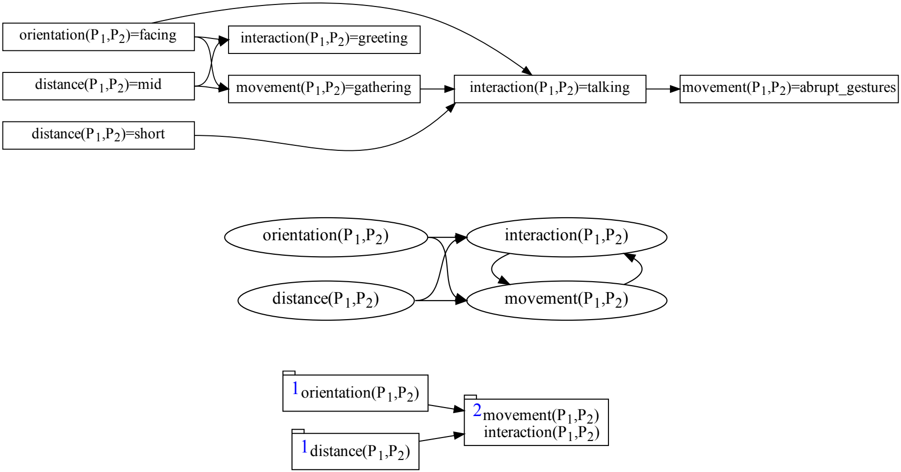

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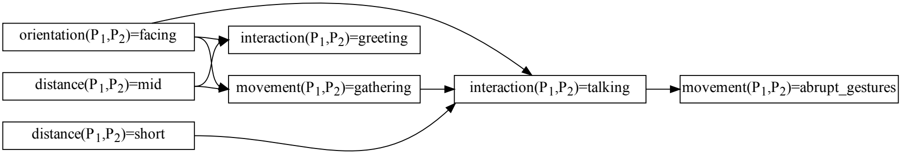

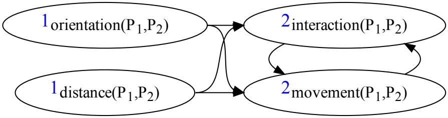

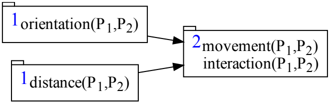

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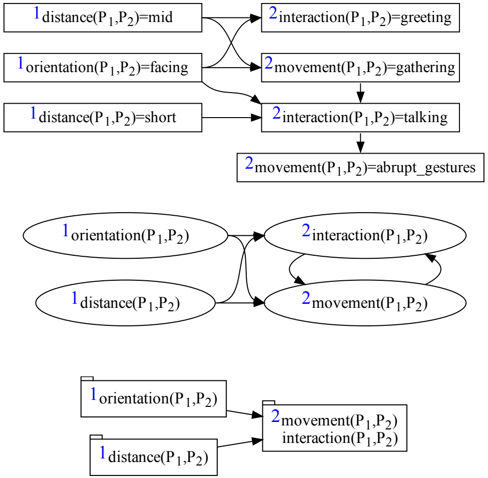
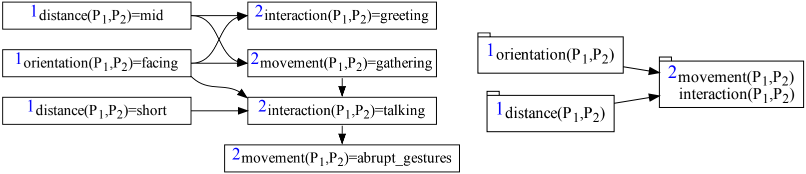


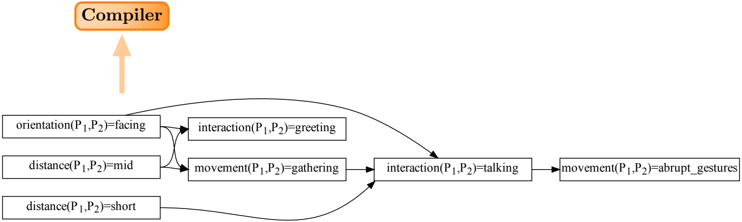
RTEC$_{fl}$: Semantics



Semantics

An event description of RTEC$_{fl}$ is a locally stratified logic program.

RTEC$_{fl}$: Compiler



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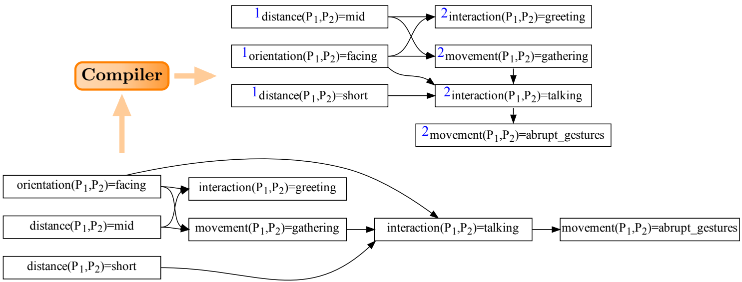

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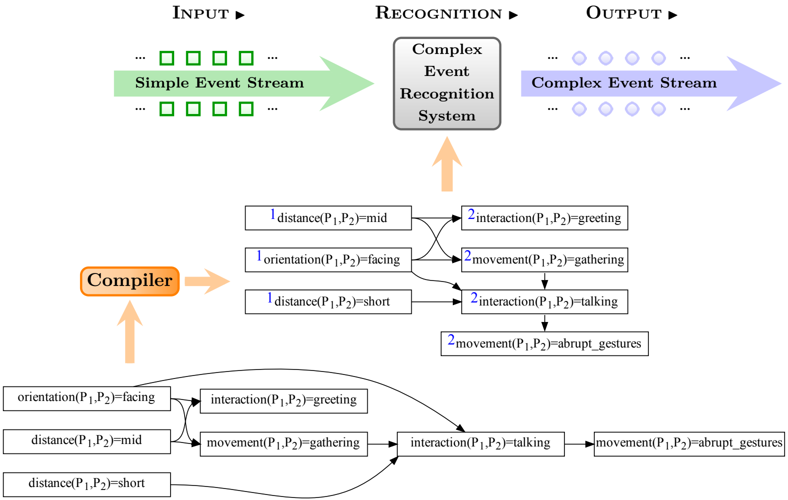

https://github.com/aartikis/RTEC

Summary & Further Work

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Further Work:

- Capture sequencing phenomena.
- Neuro-symbolic framework for composite event recognition.