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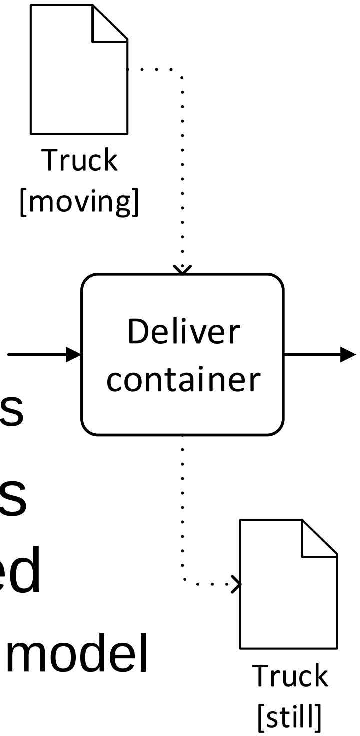
ARTIFACT-DRIVEN MONITORING FOR HUMAN-CENTRIC BUSINESS PROCESSES WITH SMART DEVICES: ASSESSMENT AND IMPROVEMENT

Context and problem statement

- Most business processes involve non-automated activities
  - I.e.: freight transportation, supply chain, etc…
- Human operators are required to execute these activities
- Traditional BPMSs rely on explicit notifications to detect when these activities are performed
  - They present to the operator a list of activities assigned to him
  - The operator has to indicate which activities are started and when they are finished
- Sending notifications is time consuming and prone to mistakes
  - The operator has to interrupt his work to interact with the BPMS
  - The operator may forget to send notifications
  - The operator may erroneously or intentionally send notifications on activities not being performed

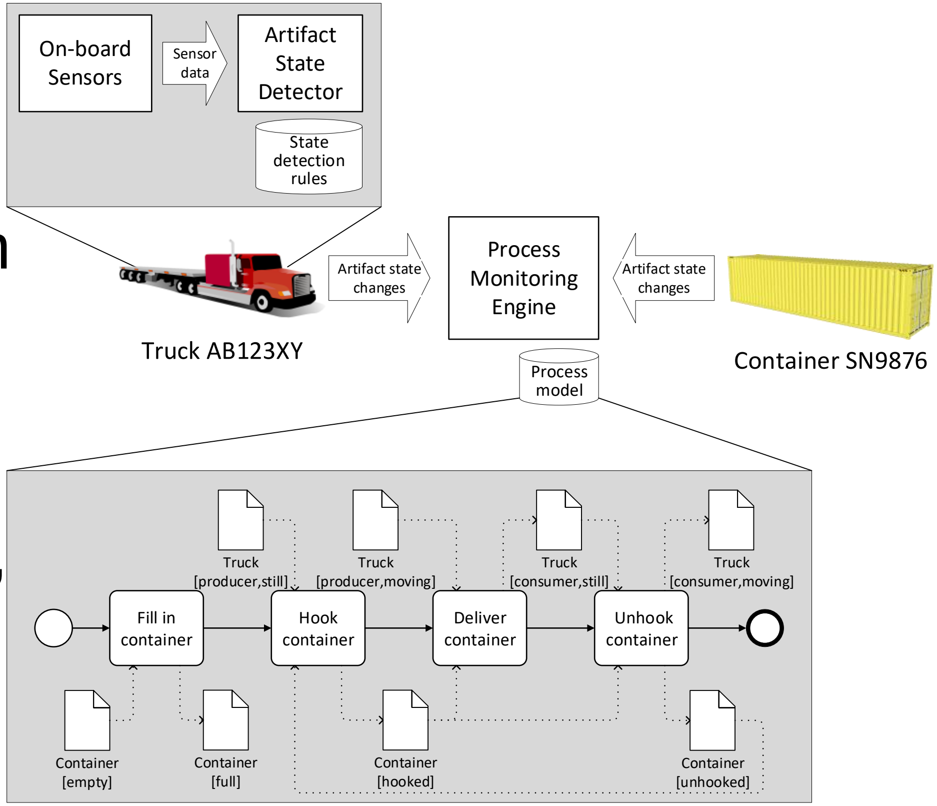
Artifact-driven process monitoring

- Instead of relying on notifications sent by operators, we rely on the physical artifacts participating to the process
- Artifacts represent the objects that interact with activities when the process is executed
  - Activities require some artifacts to have a specific state (i.e., certain characteristics) to be executed
  - Activities may alter the state of one or more artifacts
- Based on the state of the physical objects, it is possible to know when activities are performed
  - Artifacts and states are represented in the process model with data objects
  - An activity can only start when the artifacts assume the indicated state
  - An activity terminates when artifacts change their state



Exploiting the IoT to monitor processes

- Correctly determining the state of an artifact is paramount for the monitoring to be accurate
- The Internet of Things can equip physical objects with sensors, computing devices and communication interfaces, making them **smart**
- Smart objects can then autonomously infer their own state and forward it to the monitoring platform

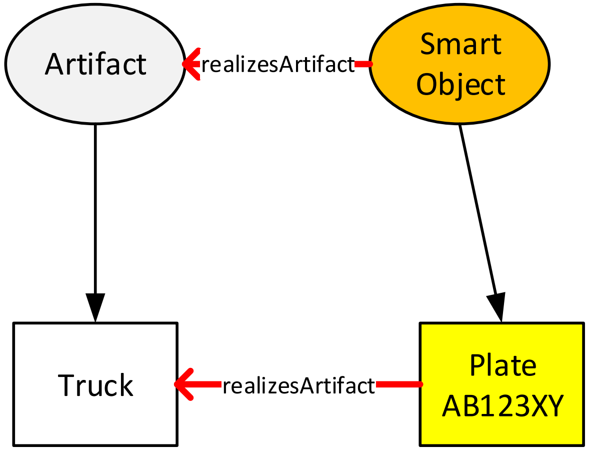


Process monitorability

- The **monitorability** of a process indicates how many activities in a process can be monitored by smart objects
- The monitorability depends on the capabilities of the smart objects embodying the artifacts:
  - Smart objects may lack sensors to determine one state
  - Smart objects may lack rules to derive one state from sensor data
  - If one state cannot be determined, activities that require or produce that state cannot be monitored
- We propose an ontology-based approach to:
  - Formalize the capabilities of smart objects
  - Estimate the monitorability
  - Provide suggestions to improve the monitorability

Smart object ontology

- Ontology derived from FIESTA-IoT that captures the capabilities of the smart object



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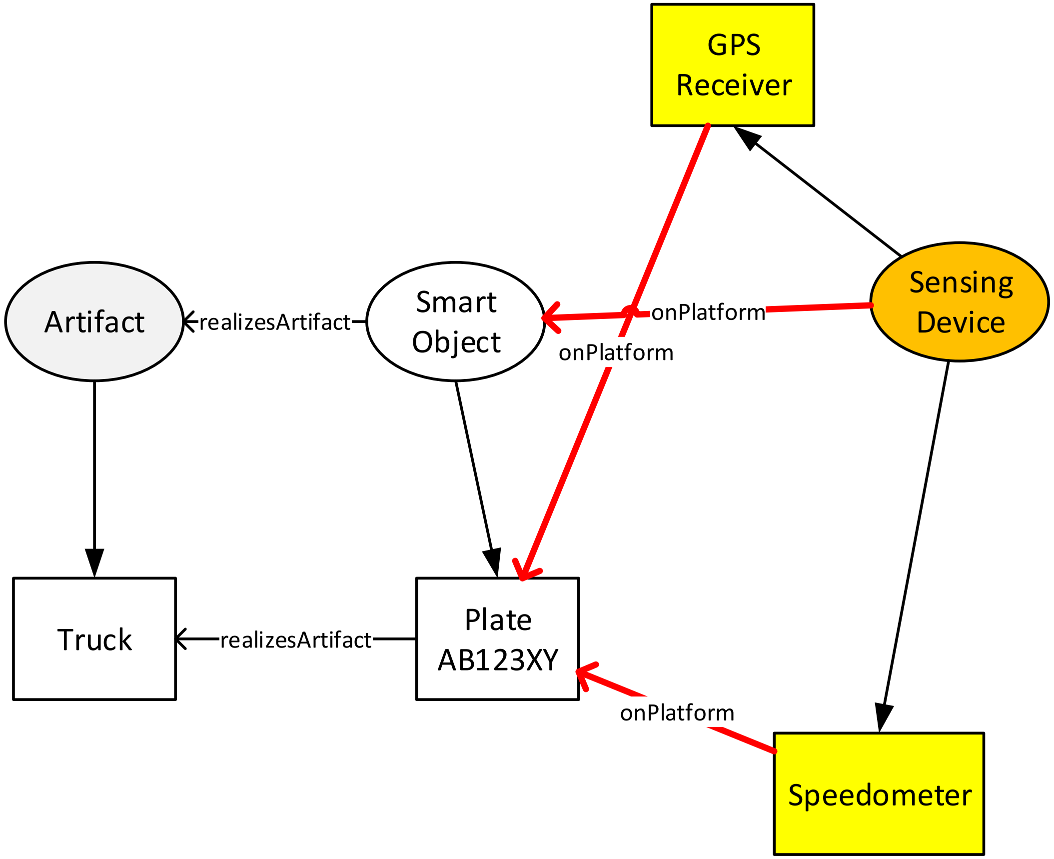

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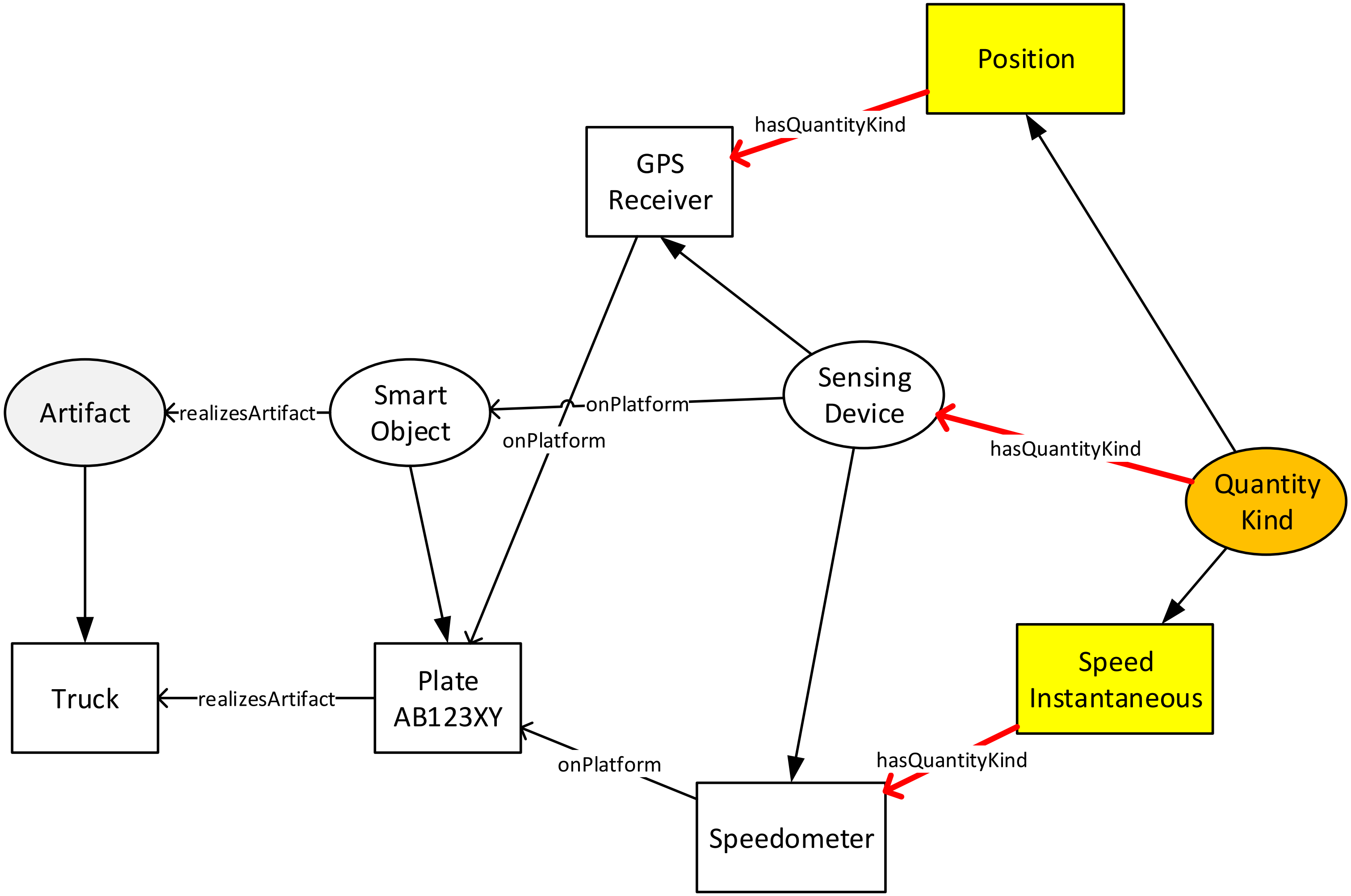

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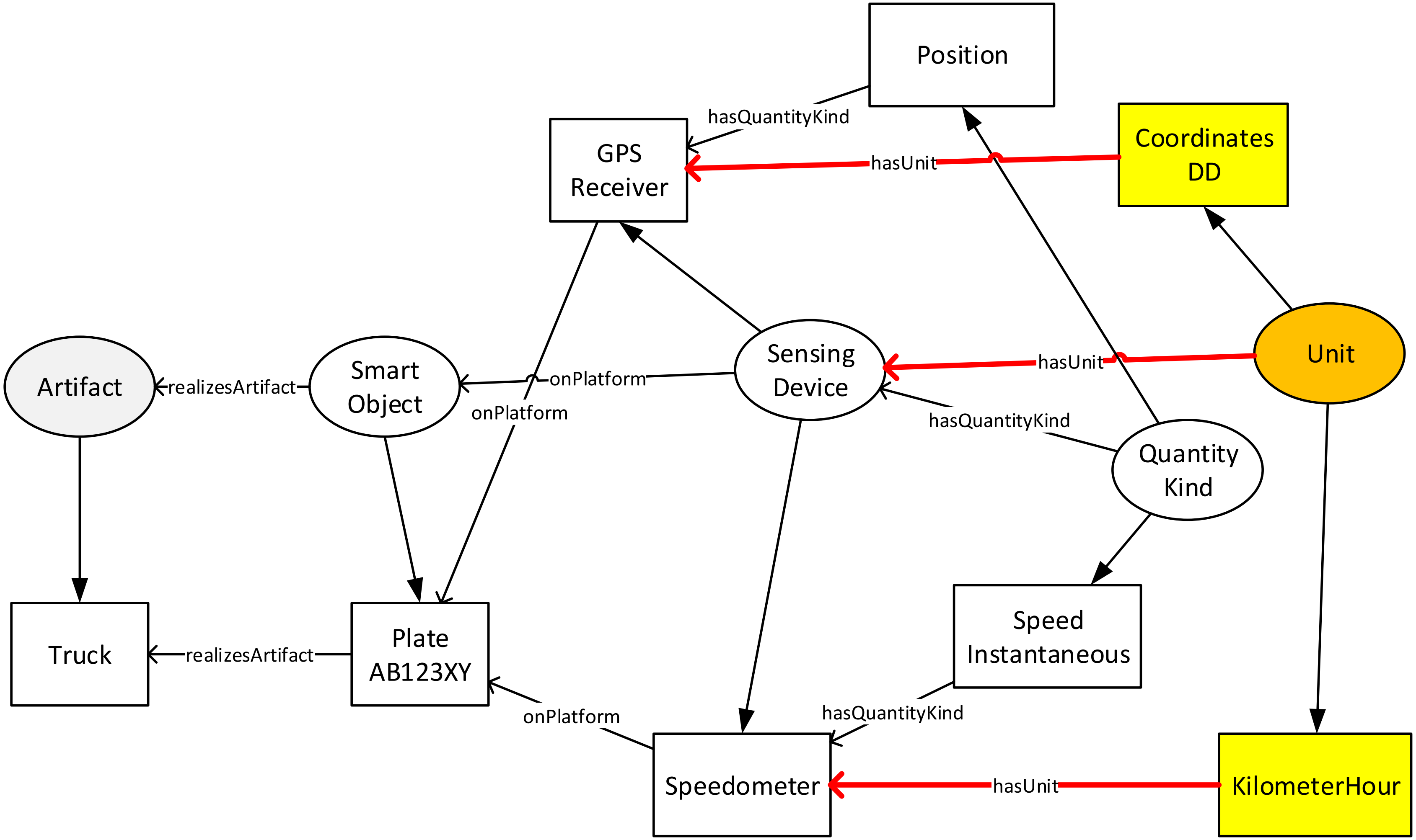
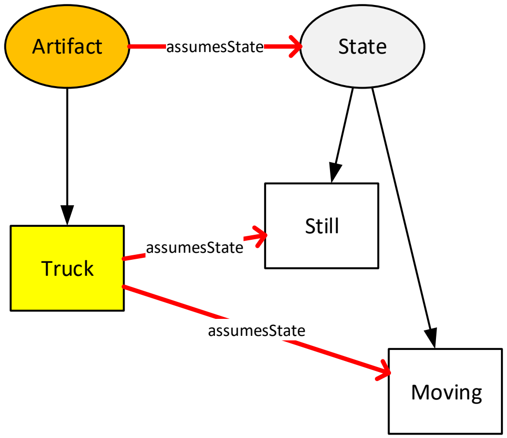


State detection rules ontology

- Ontology derived from Physics Domain ontology (Hachem et al. – MDS 2011) that formalizes how sensor data is used to infer a state



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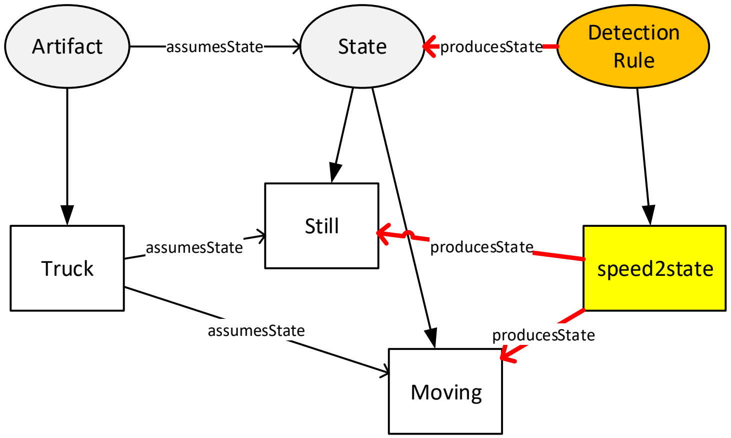

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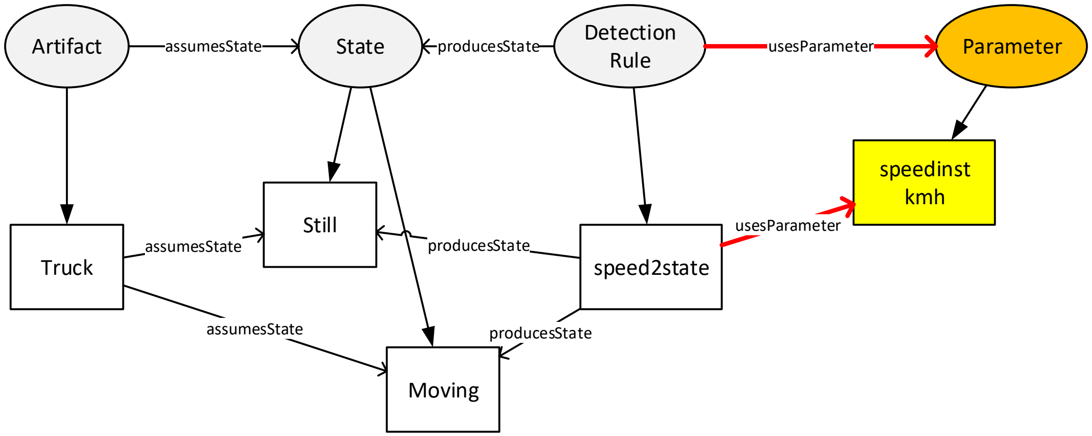

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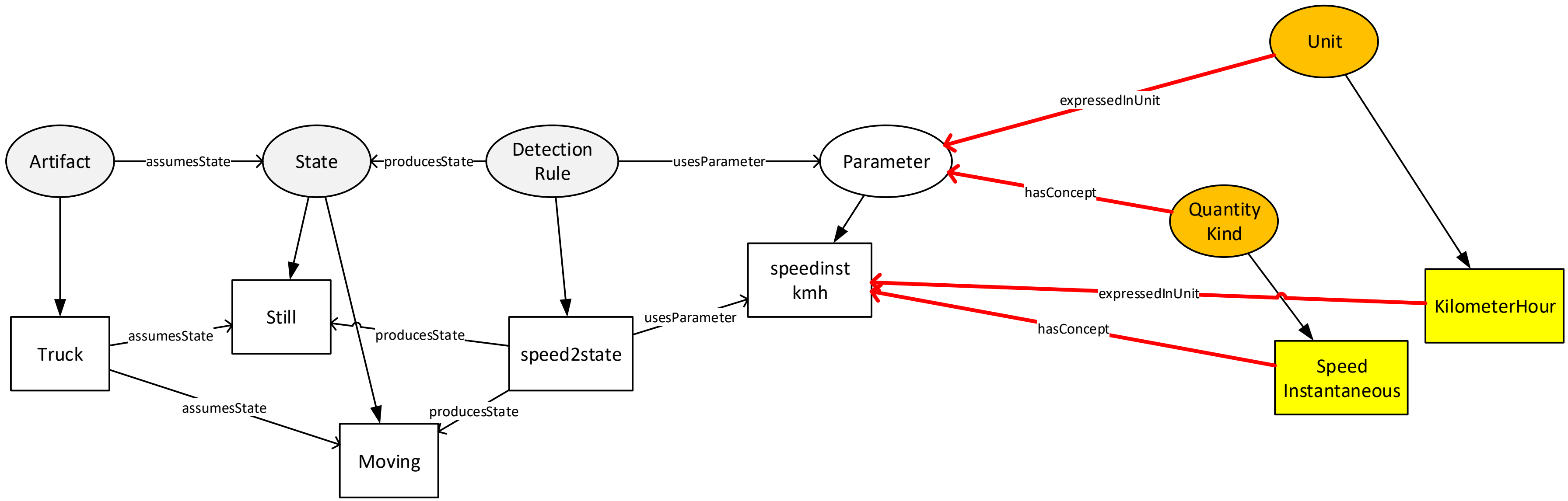

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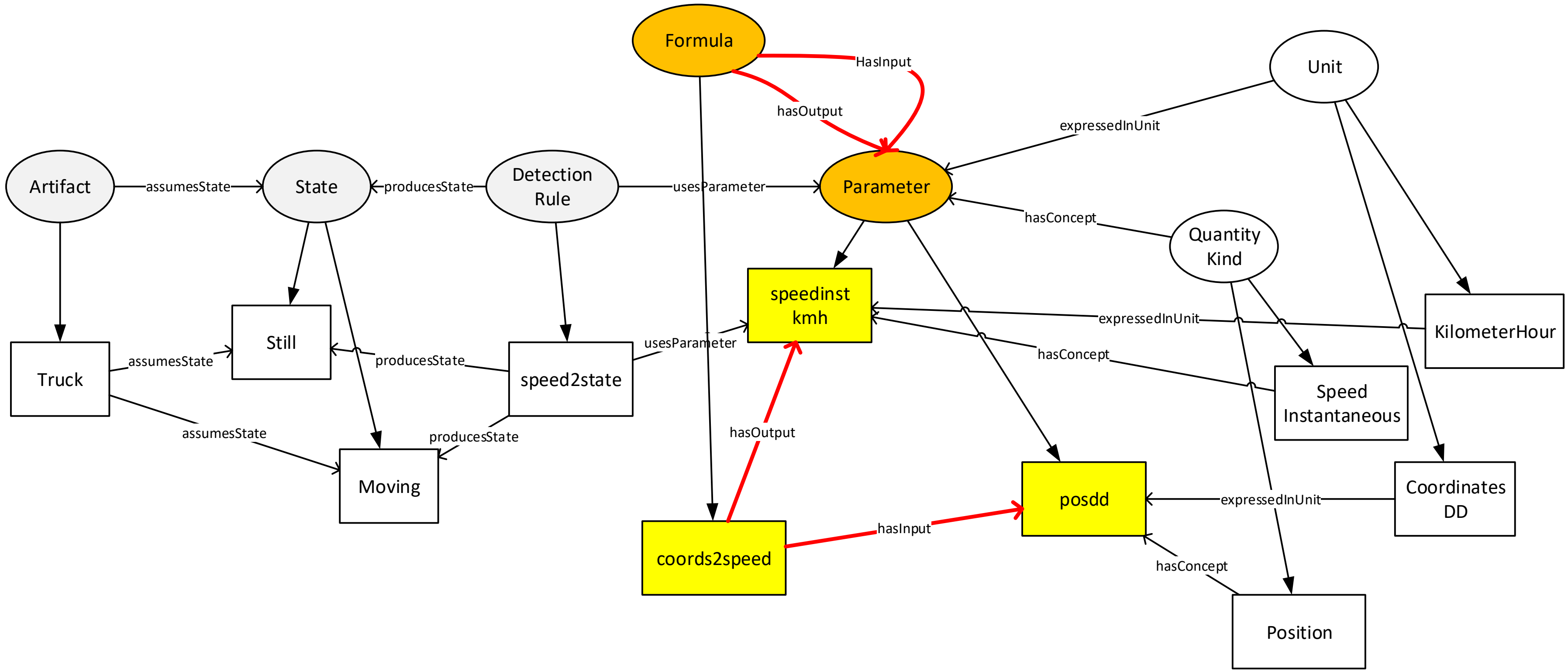


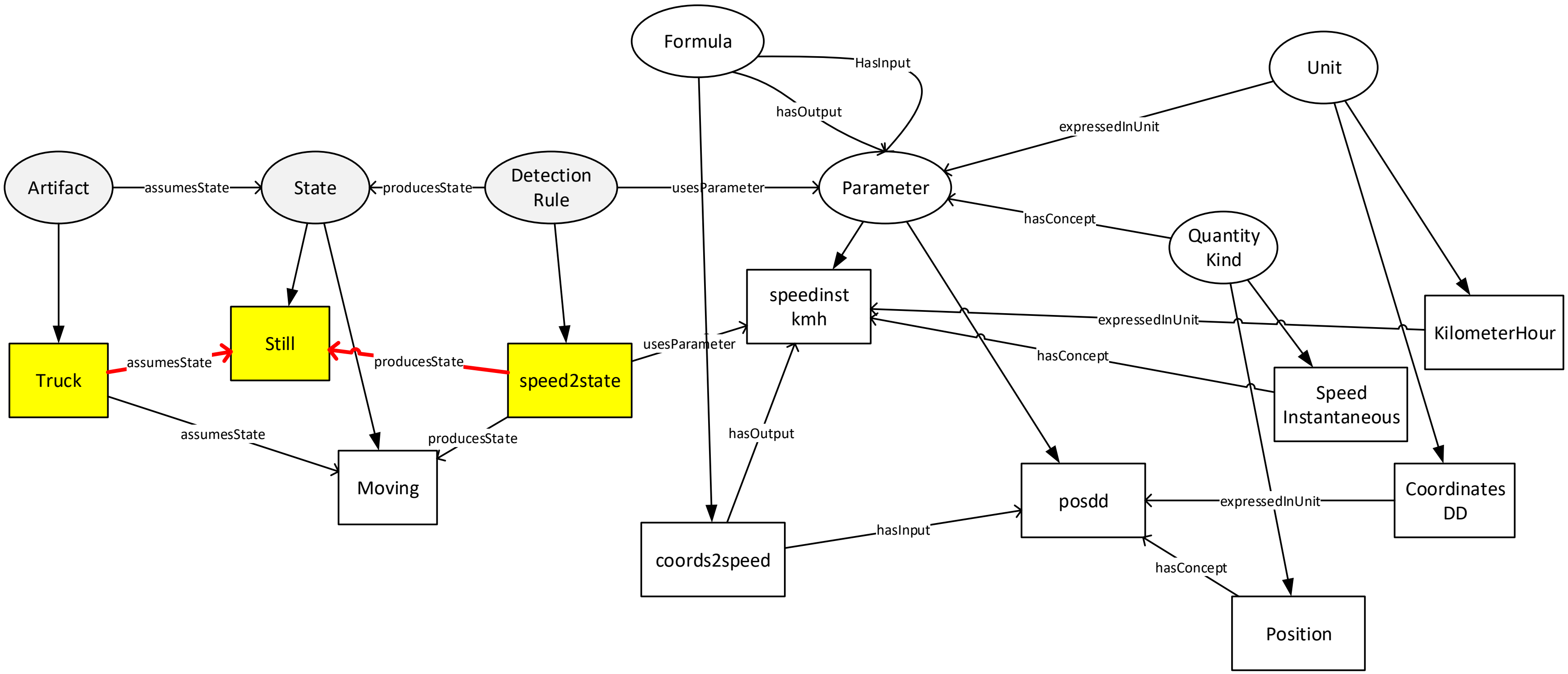
Process monitorability assessment

- For each couple **<artifact, state>** in the process model, we need to determine how many smart objects $\overline{SSO}$ can infer that state based on their capabilities
- To do so, for each smart object SSO that embodies **artifact**, the ontologies are queried to determine:
  - If a detection rule to infer **state** exists
  - Which parameters are required by that rule
  - If the sensors on the smart object provide the required parameters
- Then, the monitorability of **<artifact, state>** is computed as:

$$Mon^{ARS}(\langle artifact, state\rangle, I) \rightarrow [0,1] = \left|\overline{SSO}\right| \ / \ |SSO|$$

Process monitorability assessment

- Determine if truck **AB123XY** can infer **<truck, still>**:
  - ☑ If a detection rule to infer **still** exists
  - ☐ Which parameters are required by that rule
  - ☐ If the sensors on **AB123XY** provide the required parameters



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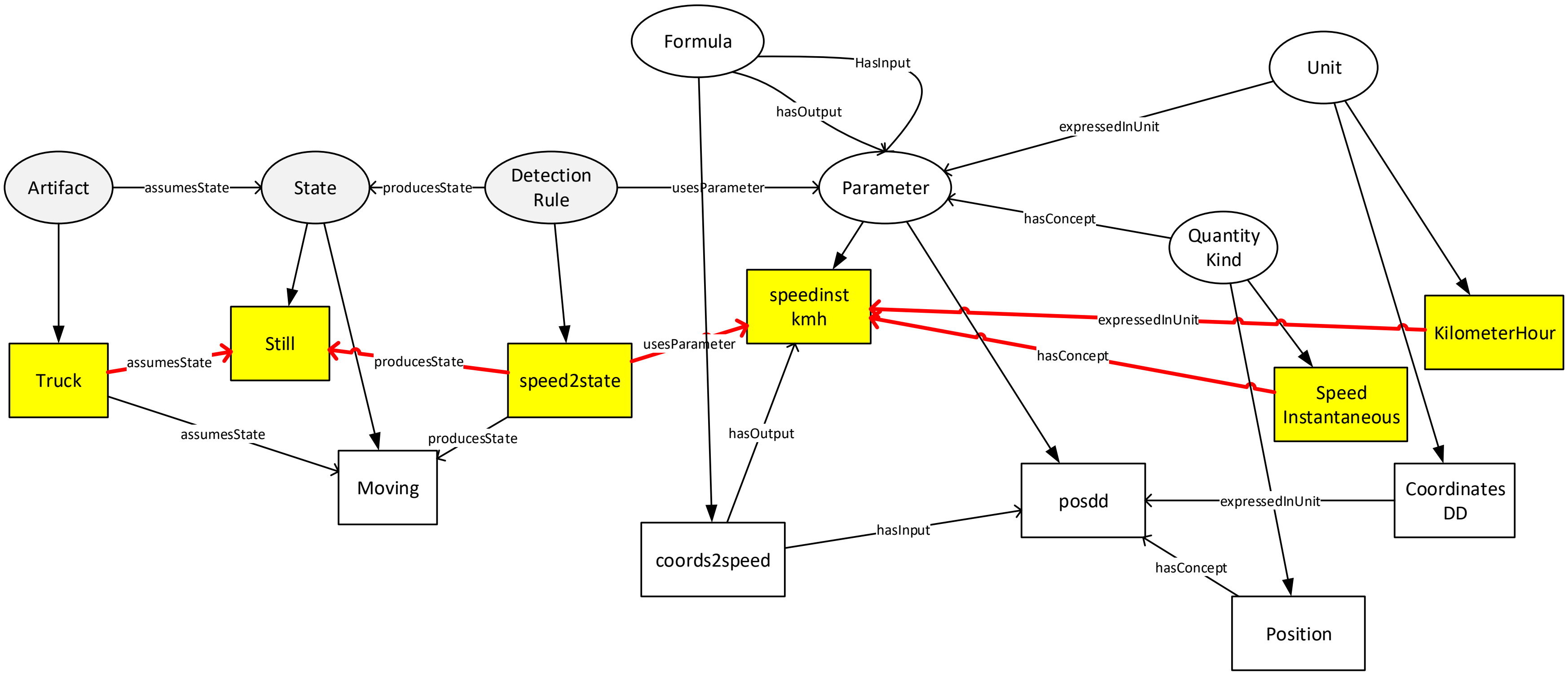

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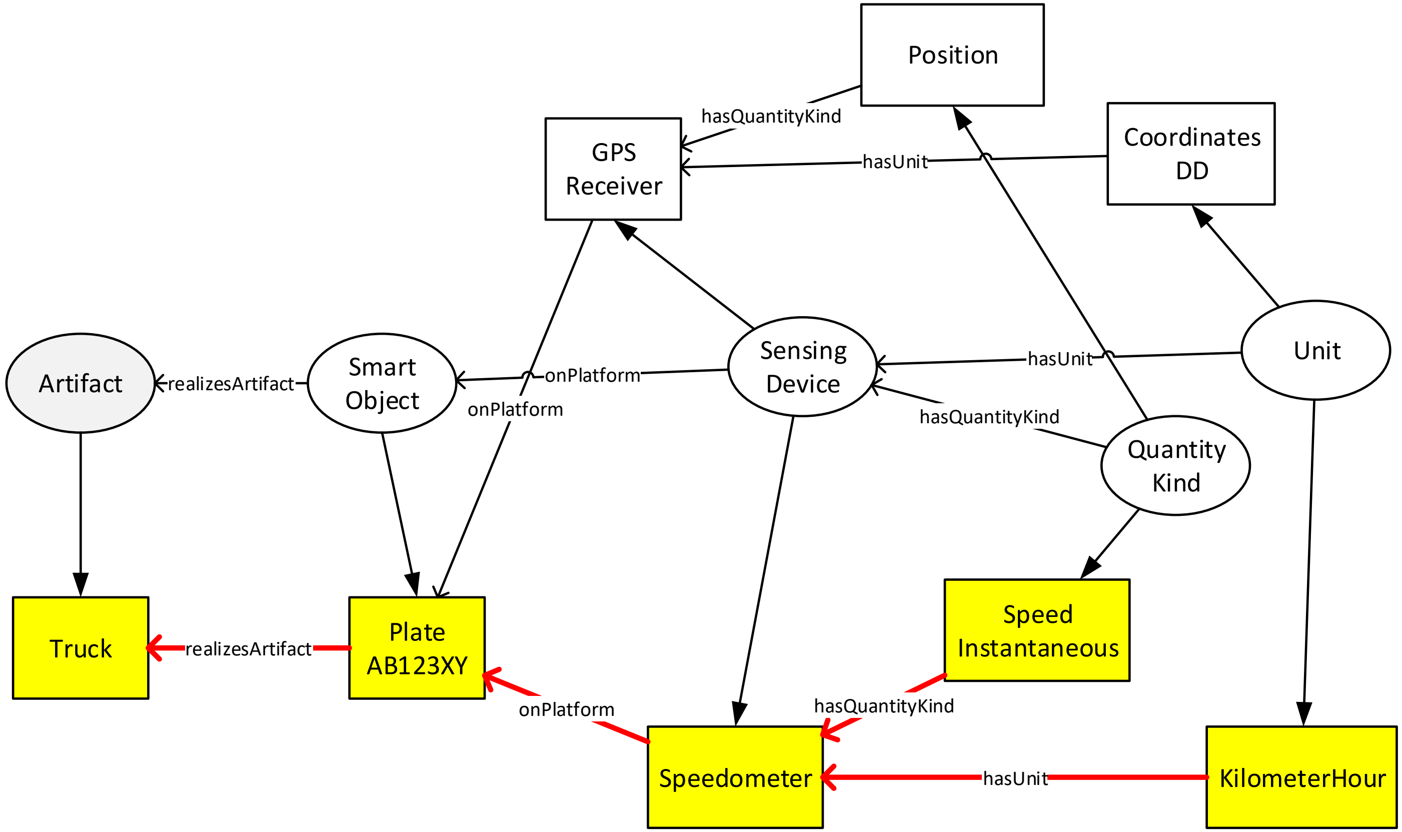


Process monitorability assessment

- Once Mon^{ARS} has been determined for every couple <artifact, state>, the monitorability of the activation and the termination of an activity is determined as:

$$Mon^{C}(A_i.C_i^{start}, I) \rightarrow [0,1] = \prod^{ARS_{i,j} \in A_i.C_i^{start}} Mon^{ARS}(ARS_{i,j}, I) \quad (1)$$

$$Mon^{C}(A_i.C_i^{stop}, I) \rightarrow [0,1] = \prod^{ARS_{i,k} \in A_i.C_i^{stop}} Mon^{ARS}(ARS_{i,k}, I) \quad (2)$$

- Then, the monitorability of an activity is:

$$Mon^{A}(A_i, I) \rightarrow [0,1] = \frac{1}{2} \cdot \Big(Mon^{C}(A_i.C_i^{start}, I) + Mon^{C}(A_i.C_i^{stop}, I) \Big)$$

- Finally, the monitorability of the process is:

$$Mon^{P}(P, I) \rightarrow [0,1] = \frac{\sum^{A_i \in P} Mon^{A}(A_i, I)}{|A_i \in P|}$$

Process monitorability improvement

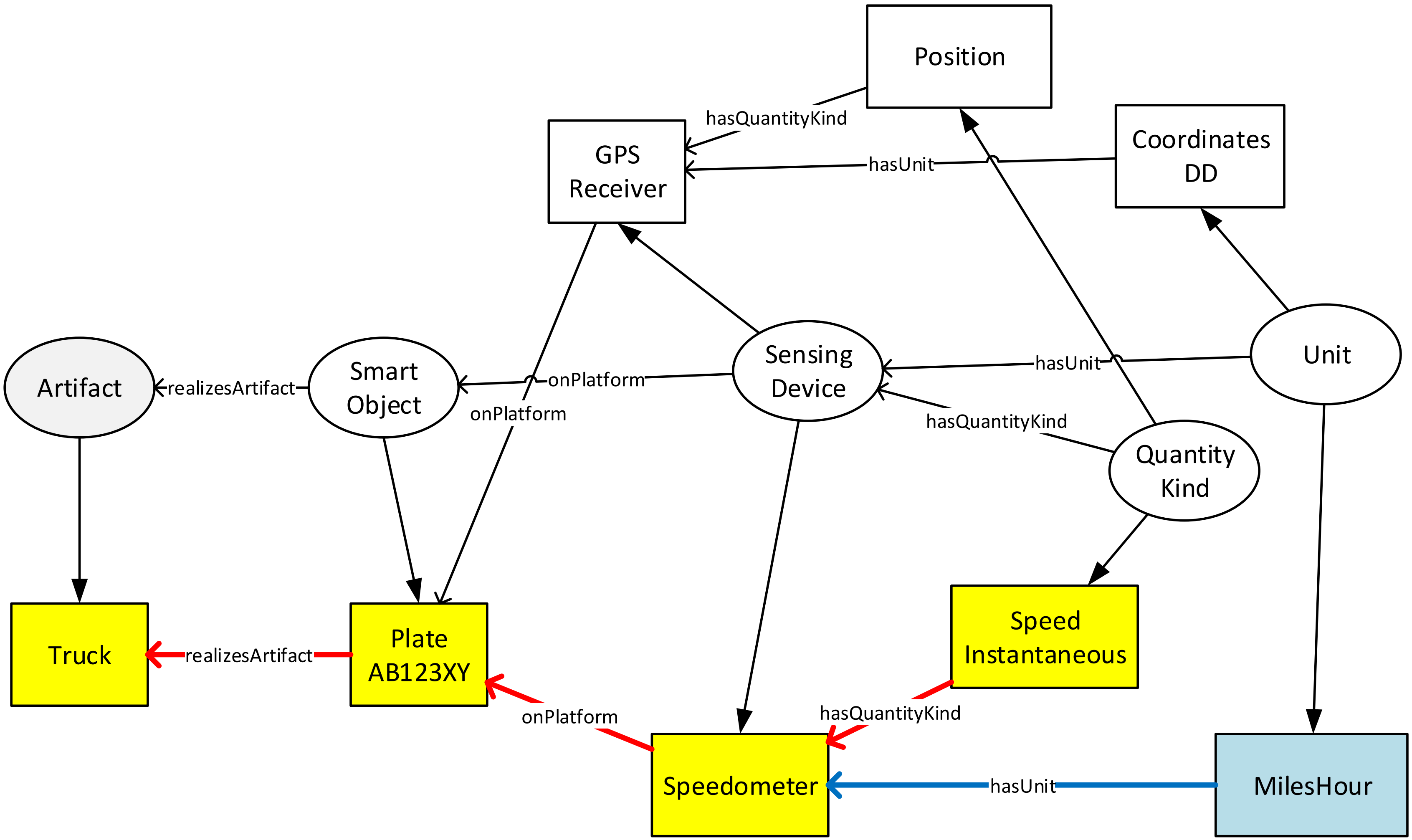
- To improve monitorability, three types of actions are possible:
  - Alter the process model to rely on different artifacts or states to determine when activities are executed
  - Improve the state detection rules
  - Modify the smart objects introducing new sensors
- When altering the process model, for each couple **<artifact, state>** that cannot be monitored, the ontologies can suggest:
  - Another state **state’** for **artifact** such that:
    $Mon^{ARS}(\langle artifact, state' \rangle, I) > 0$
  - Another artifact **artifact** such that
    $Mon^{ARS}(\langle artifact', state \rangle, I) > 0$

Process monitorability improvement

- To improve the state detection rules, the ontologies can detect smart objects that:
  - Cannot detect a state just because their sensors use a data format different from the one required by the detection rule
  - Cannot detect a state, but provide sensor data that can be used to indirectly derive that state
- By introducing a new detection rule similar to the existing one except for the input parameters, these smart objects can detect that state.
  - This positively affects the monitorability of the process
- For smart objects that cannot provide sensor data to detect that state, either directly or indirectly, the ontologies can suggest which sensors should be introduced

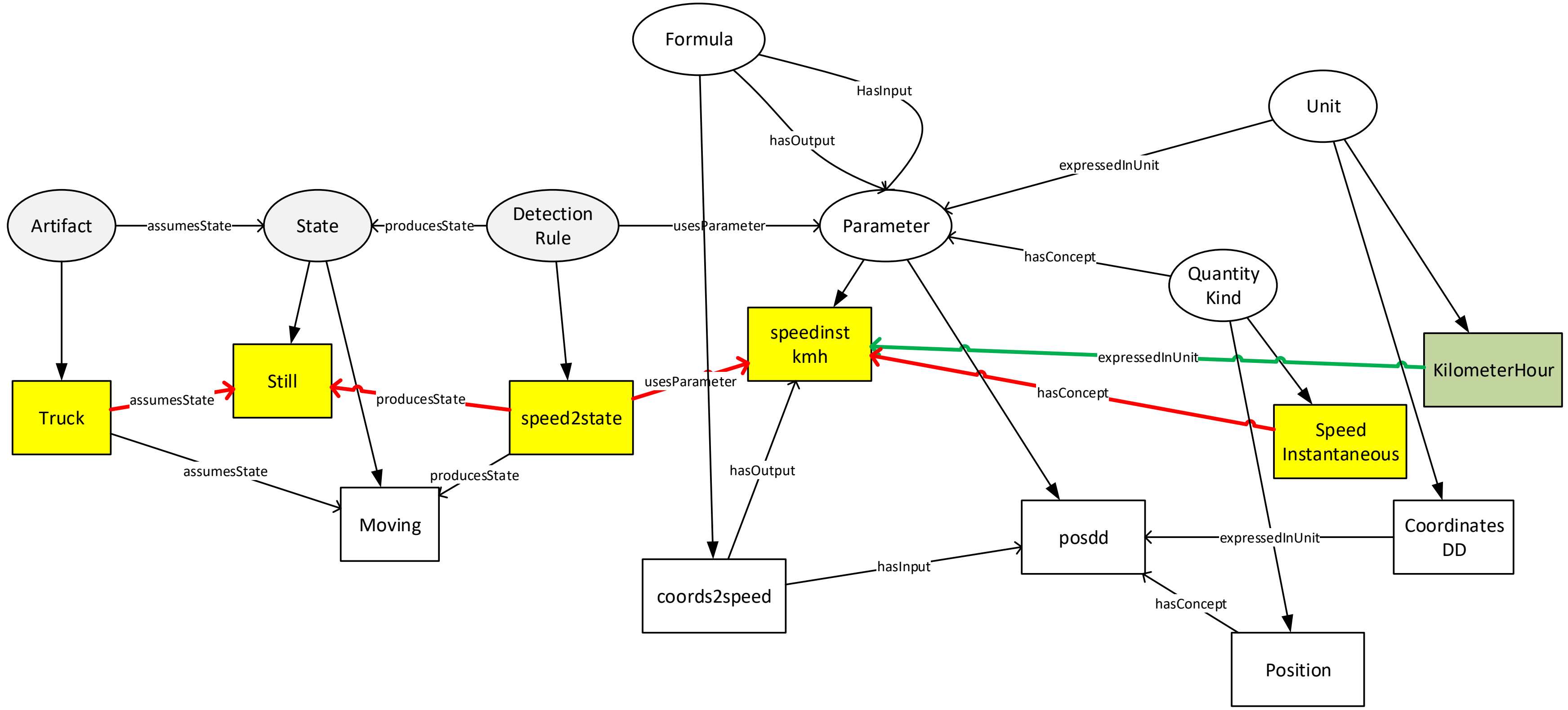
Process monitorability improvement

- Truck CD456WX provides the speed in miles per hour



Process monitorability improvement

- Truck CD456WX provides the speed in miles per hour
- To detect <truck, still>, rule speed2state requires the speed to be expressed in kilometers per hour
- Truck CD456WX cannot use speed2state, so it cannot detect <truck, still>

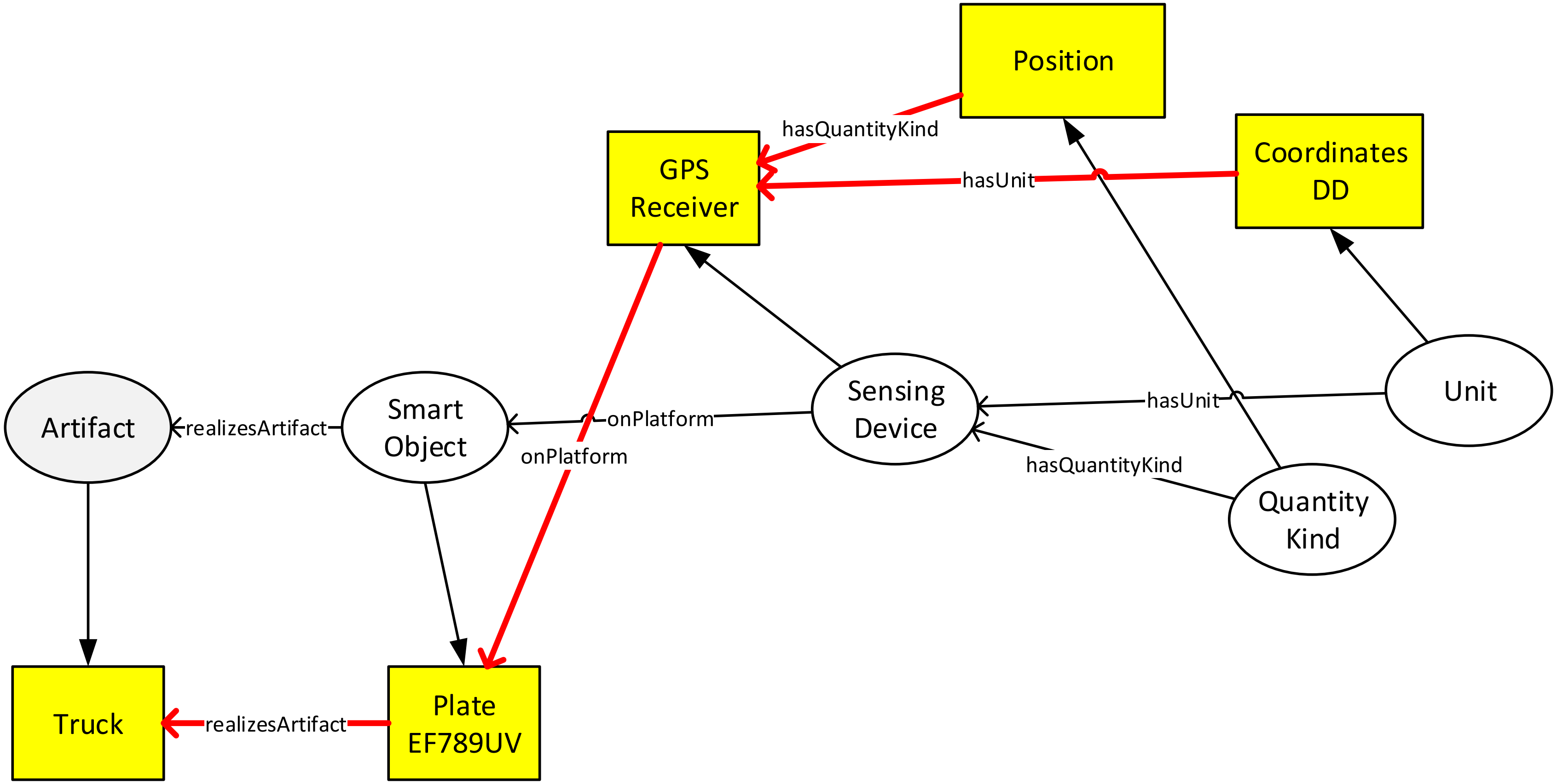


Process monitorability improvement

- Truck CD456WX provides the speed in miles per hour
- To detect <truck, still>, rule speed2state requires the speed to be expressed in kilometers per hour
- Truck CD456WX cannot use speed2state, so it cannot detect <truck, still>
- A new rule speed2state’ can be derived from speed2state by converting the speed from miles per hour to kilometers per hour
- With speed2state’, Truck CD456WX can now detect <truck, still>

Process monitorability improvement

- Truck EF789UV provides its own position in decimal degrees coordinates



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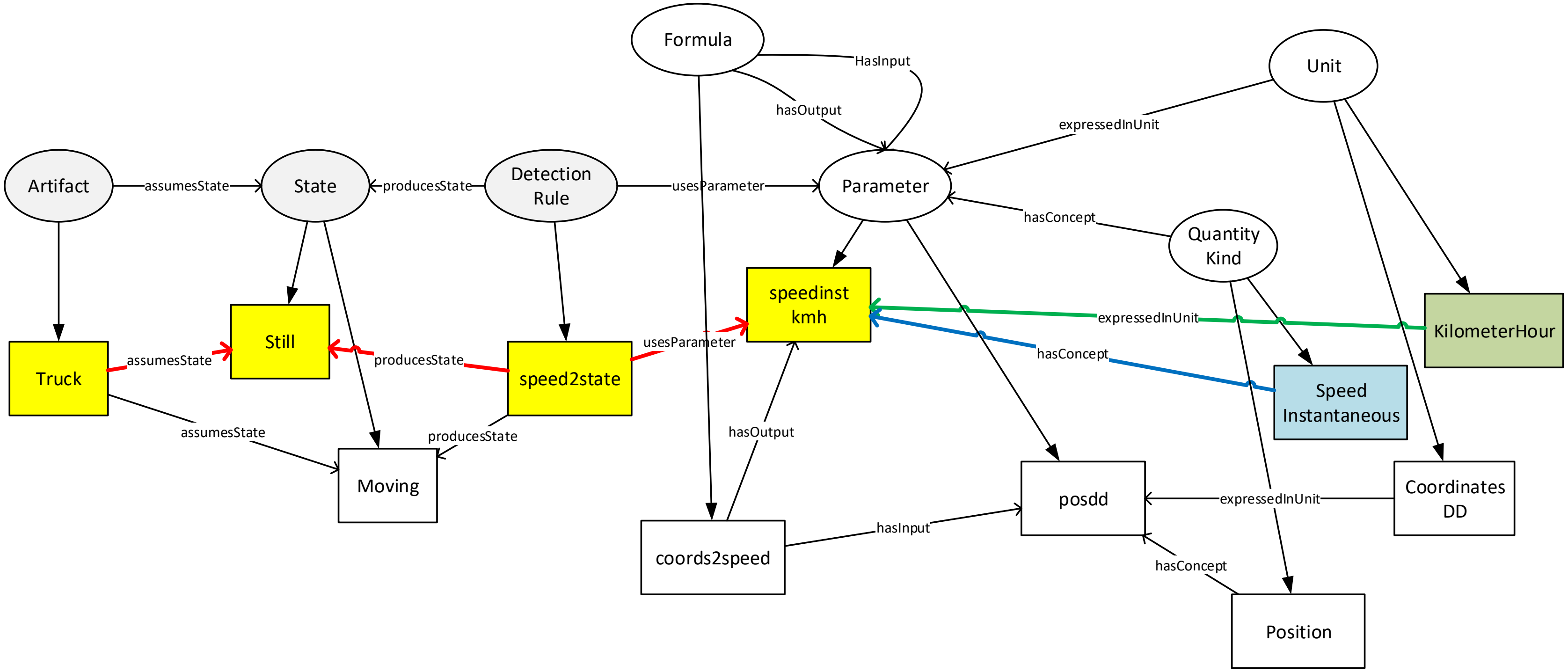
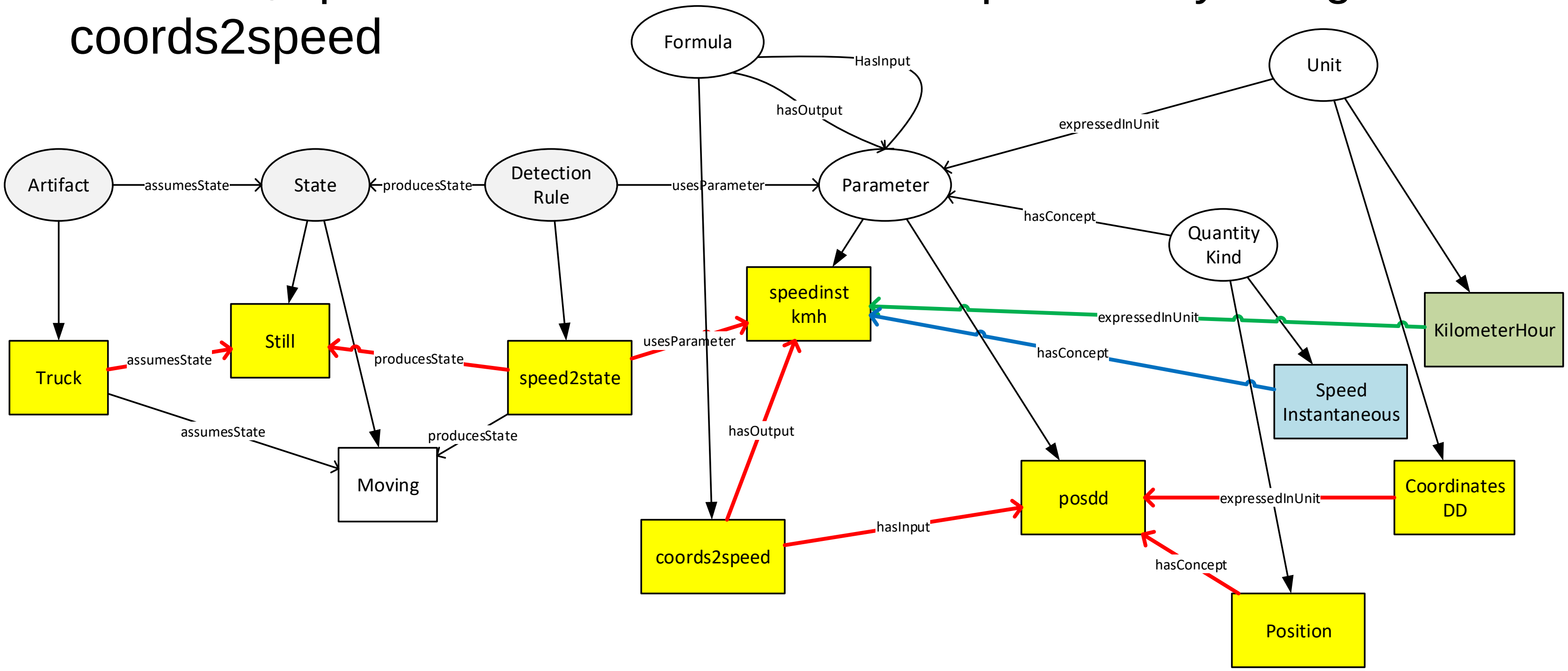


Process monitorability improvement

- Truck EF789UV provides its own position in decimal degrees coordinates
- To detect <truck, still>, rule speed2state requires the speed
- Truck EF789UV cannot use speed2state, so it cannot detect <truck, still>
- However, speed can be derived from the position by using formula coords2speed



Process monitorability improvement

- Truck EF789UV provides its own position in decimal degrees coordinates
- To detect <truck, still>, rule speed2state requires the speed
- Truck EF789UV cannot use speed2state, so it cannot detect <truck, still>
- However, speed can be derived from the position by using formula coords2speed
- A new rule coords2state can be derived by combining speed2state with coords2speed
- With coords2state, Truck CD456WX can now detect <truck, still>

Conclusion

- Artifact-driven process monitoring relies on the state of the artifacts participating to a process to determine when activities are performed
- The monitorability of a process depends on the capabilities of the smart objects embodying the artifacts
- Capabilities can be formalized with ontologies
- Ontologies can be queried to:
  - Automatically determine the monitorability of a process based on a process model
  - Suggest modifications in the process model, smart objects and detection rules to improve monitorability
- Future work on automatically configuring smart objects
  - i.e. deploying on smart objects only detection rules that are needed to monitor a process

Thanks for your attention

Any question?

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TRASPORTI ITALIA 2020

UNIONE EUROPEA
Fondo europeo di sviluppo regionale

PON Ricerca e Competitività 2007-2013

Ministero dell'Istruzione, dell'Università e della Ricerca