Using Environmental Contexts to Model Restrictions on Sensor Capabilities

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Short Resume

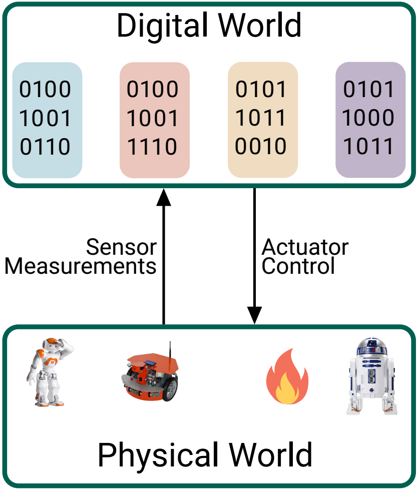
- Since March 2020 research assistant at the Operating Systems Group of the TUC
- 2016–2020 tutor for research and teaching
- 2013–2020 student of Applied Informatics and Automotive Software Engineering

Research Focus

Programming models for heterogeneous CPS to enable I/O virtualization

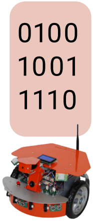
CPS

- Connect logical and physical world
- Multitude of heterogeneous sensors and actuators
- Observing through sensors
- Influencing through actuators



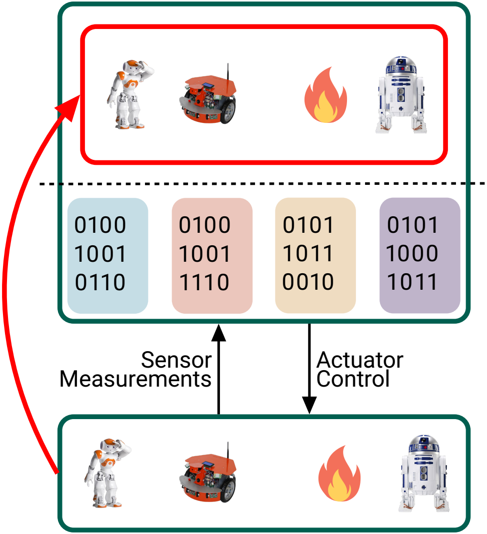
Challenges

- Distributed, heterogeneous, mobile, unreliable devices
- Different sensors/actuators may join/leave the system
- Currently: devices programmed individually
- Prone to error and complex
- We need **abstractions**!



Abstractions

- Systemic view, devices programmed as a whole
- Changing devices due to motion/failure
- Distribution, location, motion transparency on application level
- Require sensor and actuator virtualization

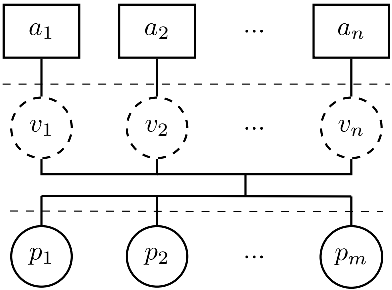


Virtualization

Definition

Virtualization is the utilization of a logical resource that is mapped onto possibly multiple physical resources at access/on demand.

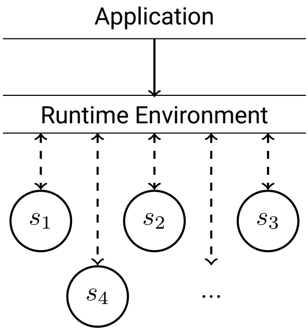
- Virtual resources v_i managed by runtime environment
- Transparent **exchange** of physical resources p_j
- Transparent **sharing** of physical resources for applications a_k



$\Rightarrow$ **Detachment of applications and physical resources**

Sensor Virtualization

- Focus on transparent exchange of physical sensors
- Programmer not directly involved in managing sensors
- Changing sets of devices due to unreliability or mobility transparently handled
- Developer specifies **what** should be measured
- RTE infers **how** it is measured



Programming Model: Physical Object Specifications

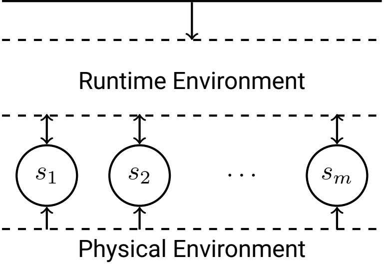
- Vector of object properties

$$\vec{z} = \begin{bmatrix} (\tau_1, r_1) \\ \dots \\ (\tau_n, r_n) \end{bmatrix}$$

- τ_j is type of property (i.e., domain of possible values)
- r_j is rule on values of type τ_j (i.e., does value fit object's property?)

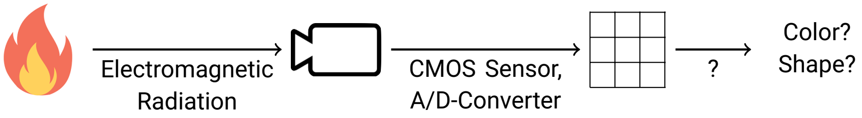
Which sensors should be utilized?

```
Fire {
  Color: =red;
  Temp: >300;
}
```



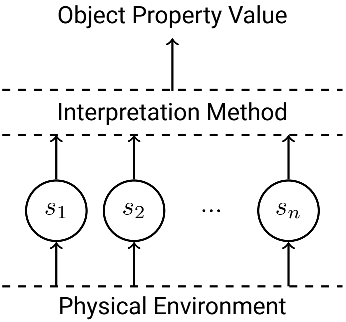
Sensor Model

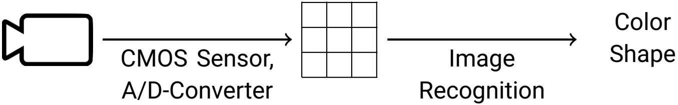
- Sensors measure physical quantity
- Transform measurement into digital signal via measurement process
- Grouped into classes based on measurand and measurement process
- Output may **not** directly map to object property types



Interpretation Methods

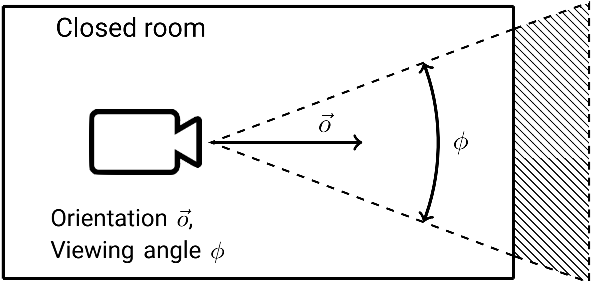
- Transform digital output of sensors into value of physical property type
- RTE chooses methods based on this type
- Each method requires output of sensors of certain classes
- These outputs have to be related





Spatial Sensor Capabilities

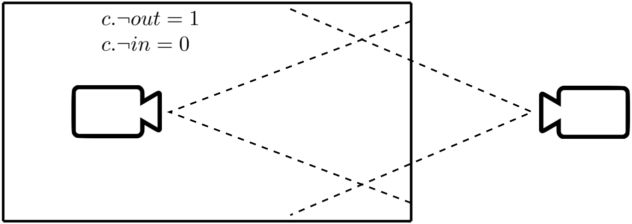
- Sensor measurements are valid for region of space
- Depends on their location, surroundings and sensor-specific parameters



How to describe the influence of surroundings on sensors?

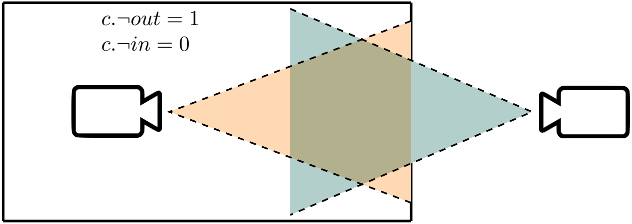
Environmental Context Model

- Restrict regions for which sensor measurements are valid
- Context c is defined by:
  - Region of space (set of locations): $c.X$
  - Influenced physical quantity (e.g., electromagnetic radiation): $c.q$
  - Inward- and/or outward-blocking (e.g., tinted windows): $c.\neg out$, $c.\neg in$



Influence of Contexts on Sensors

- Measurable region intersects with context's region
- Similar physical quantity observed/influenced

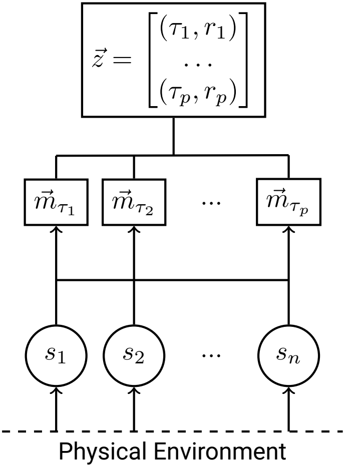


Choice of Sensors

Only the measurements of sensors with intersecting observed regions can be chosen as inputs for an interpretation method.

Recap Sensor and Context Models

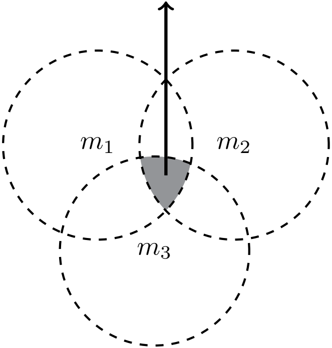
- Programmer provides object property description $\vec{z}$
- RTE deduces possible interpretation methods $\vec{m}_{\tau_i}$ for each object property z_i of type τ_i
- Choice of sensors based on required classes and whether measurement regions overlap



Physical Object Identification

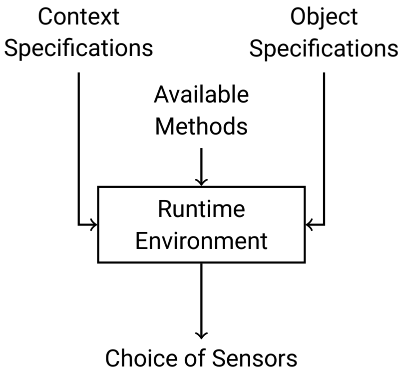
- Result of interpretation method is also valid for region of space
- Intersection of observed regions of input sensor measurements
- For checking whether all properties are present, regions of chosen interpretation methods have to overlap
- Object is present at locations where all rules are satisfied

$$\begin{bmatrix} r_1(m_1) \\ r_2(m_2) \\ r_3(m_3) \end{bmatrix} = \begin{bmatrix} ? \\ ? \\ ? \end{bmatrix}$$



Conclusion

- Presented sensor and environmental context models
- Allow to describe restriction of sensor capabilities based on environmental contexts
- Enables RTE to continuously choose sufficient sets of sensors to observe physical object
- Sensor virtualization introduced



Future Work

- Metrics for optimal choice of sensors for measuring object properties
- Efficient data structures for model implementation
- Similar models for actuators to enable actuator virtualization

Thank you!