Towards a Robot Perception Specification Language

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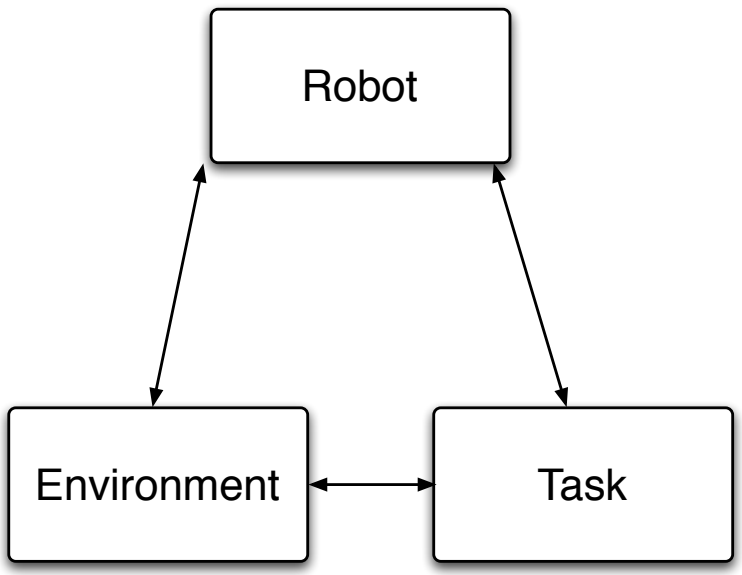
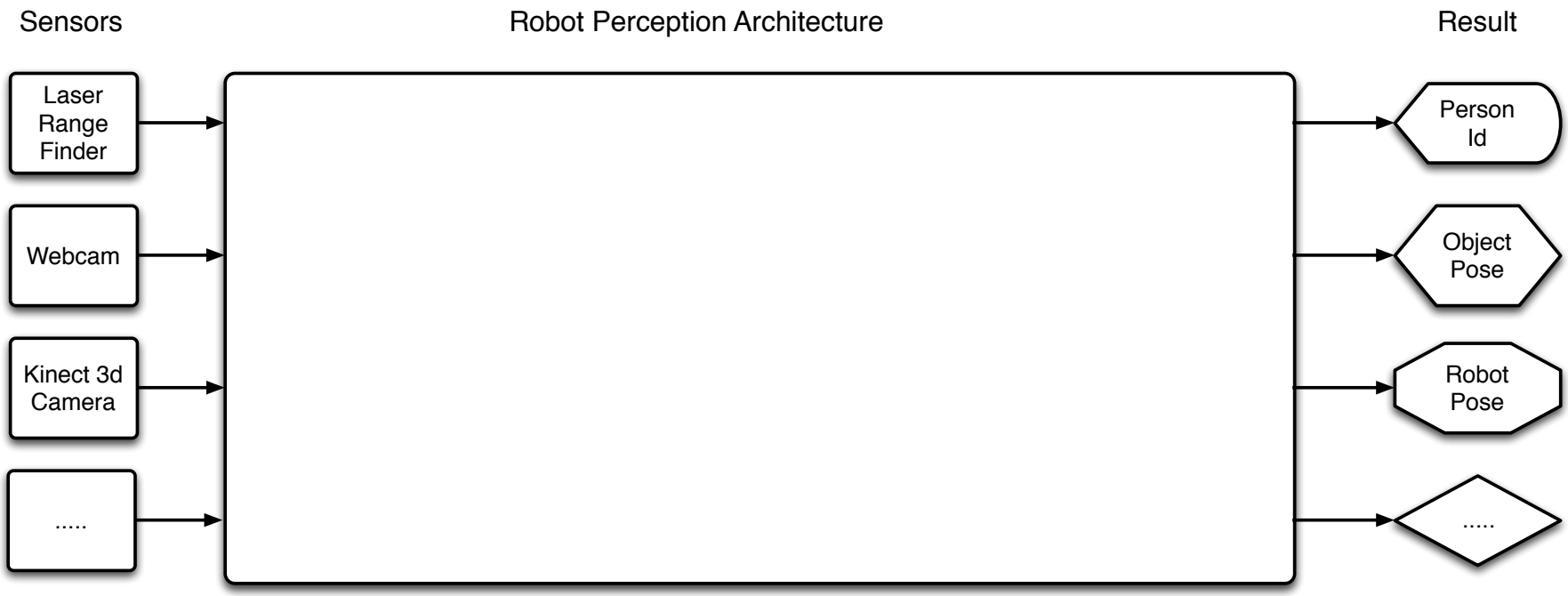
General Purpose Service Robots



In order to successfully achieve its **task** every robot need to perceive its environment.

Robot Perception Architectures (RPAs)



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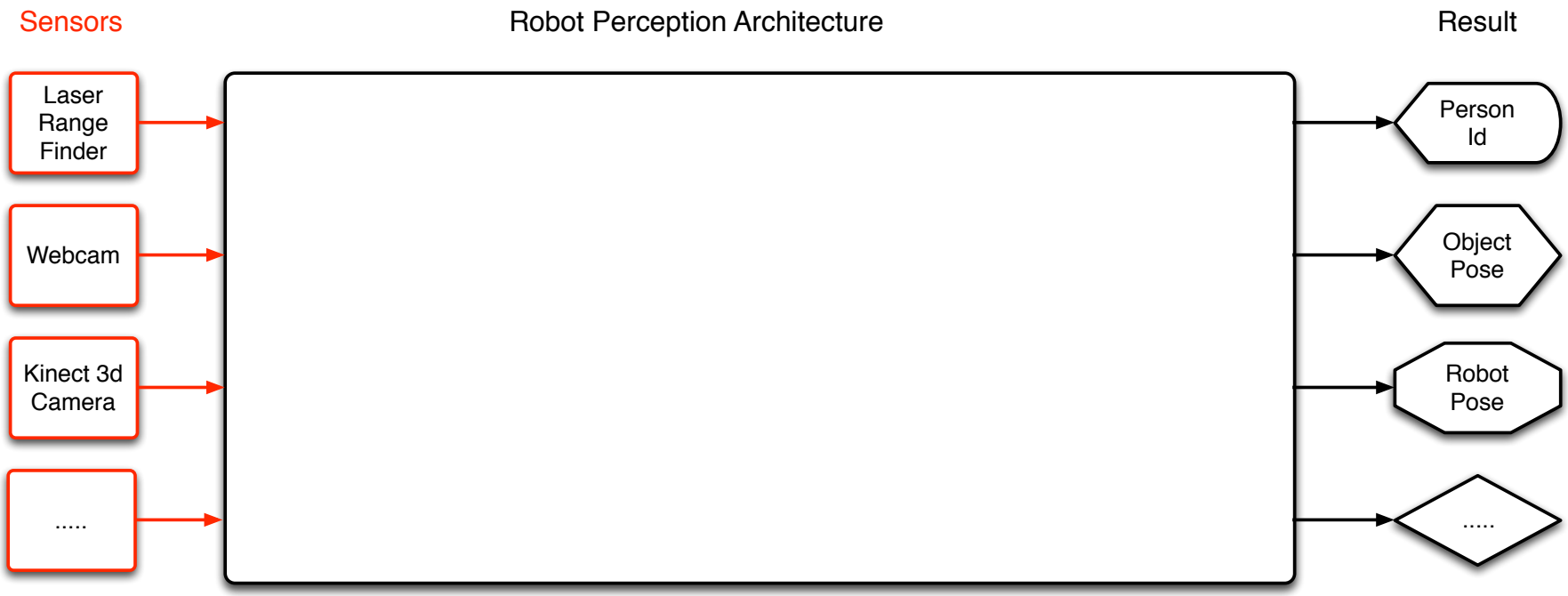

- **Sensors:** several different modalities.

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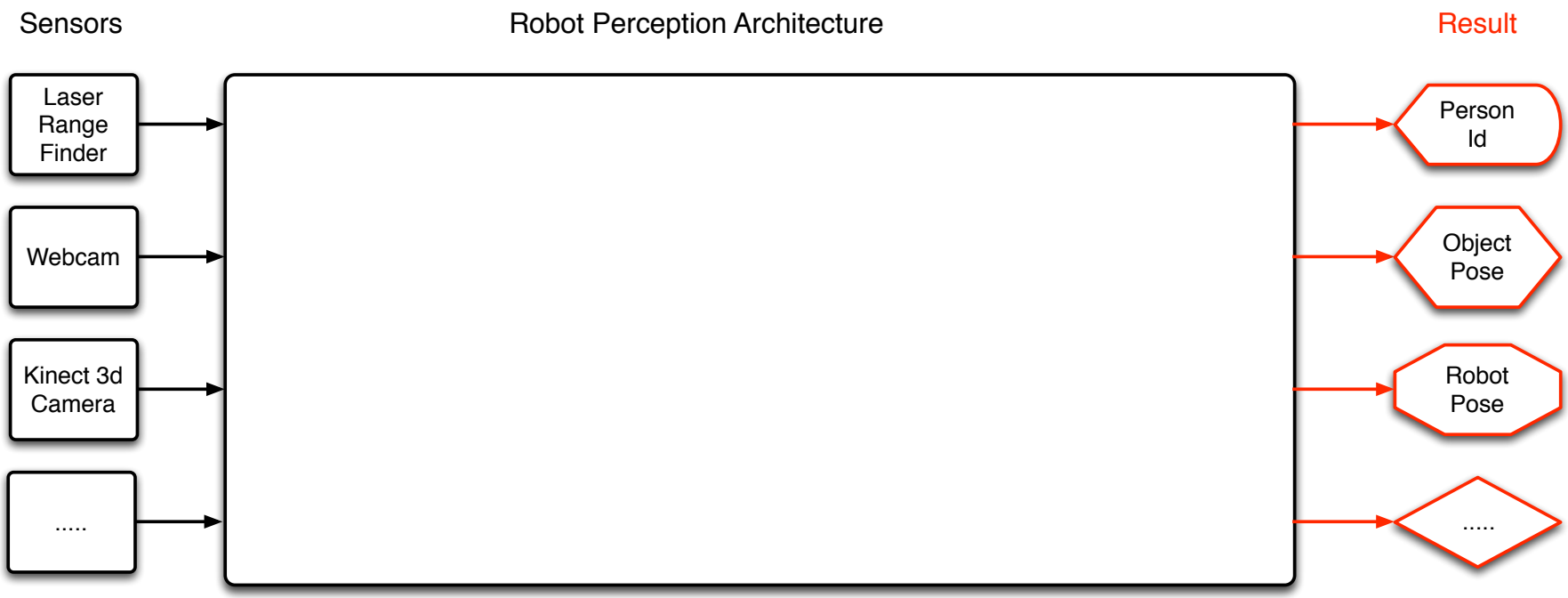

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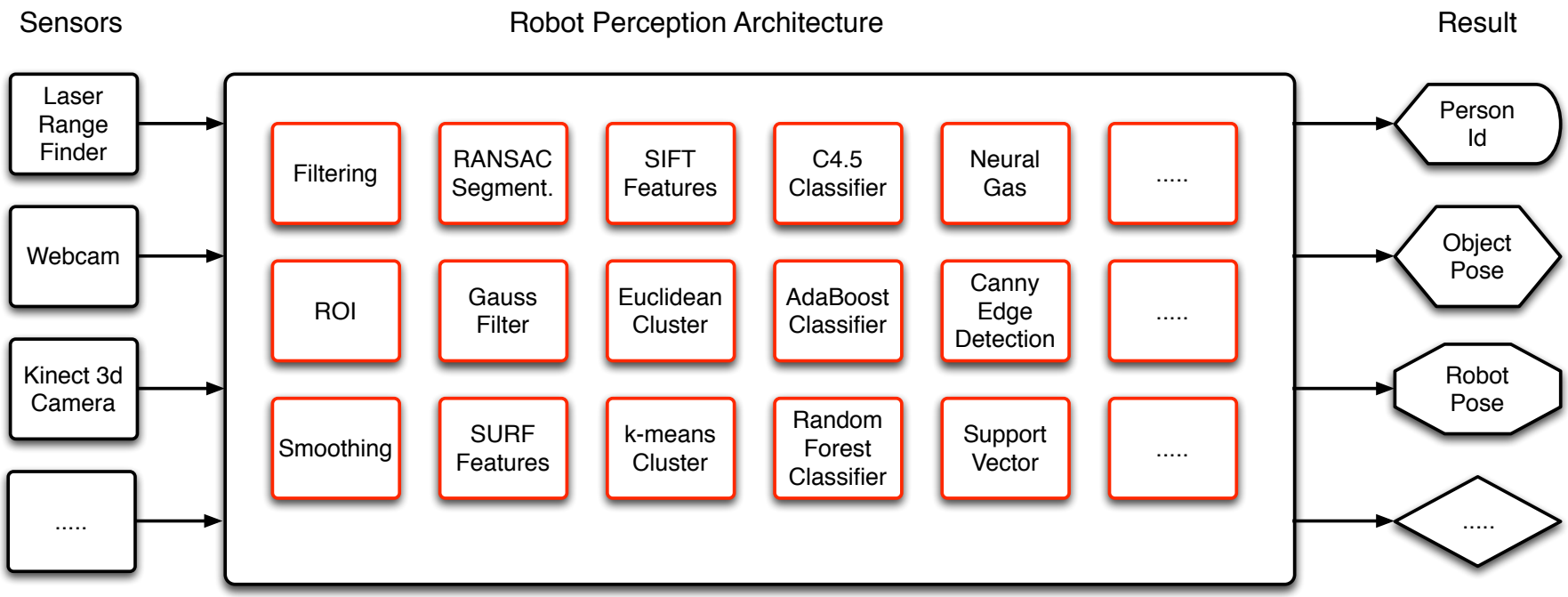
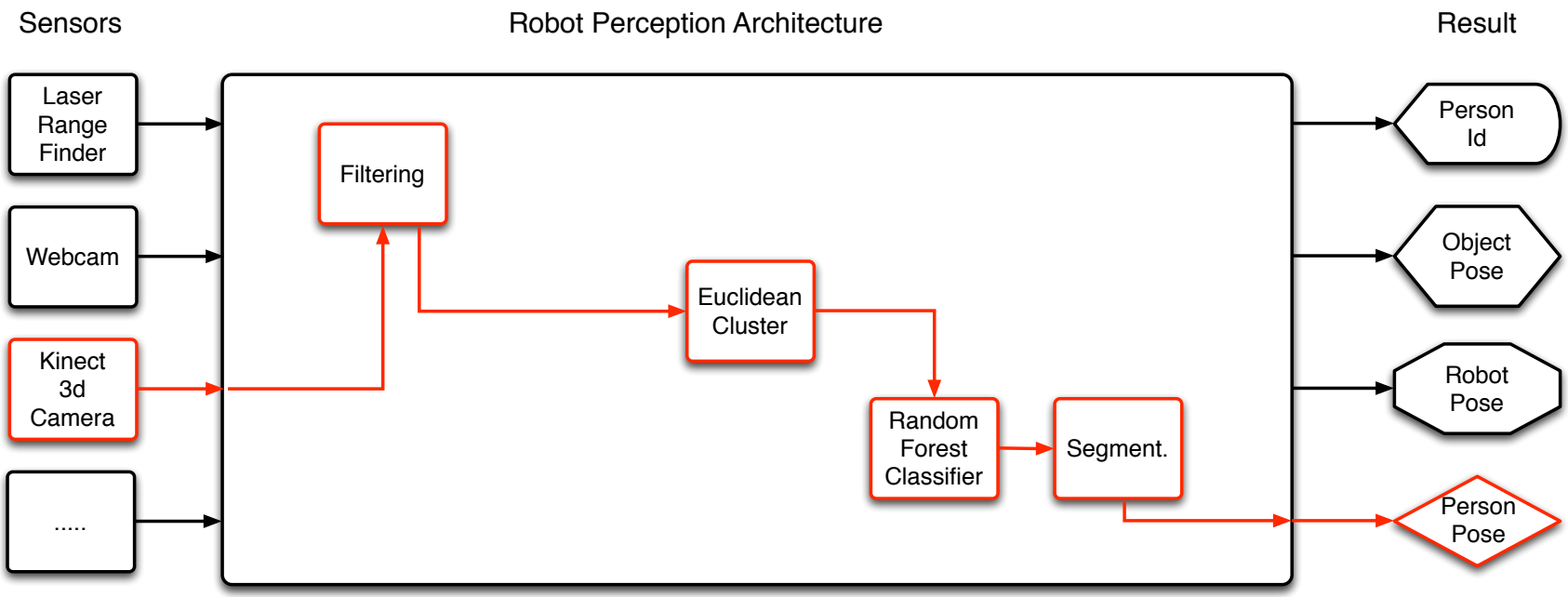
- **Results:** dependent on the task. Very high diversity.

Robot Perception Architectures (RPAs)



- **Sensors:** several different modalities.
- **Results:** are dependent on the task. Very high diversity.
- **RPAs:** composition of components providing different functionalites found in libraries such as OpenCV and PCL.

Example: RPA for People Detection



Frederik Hegger, Nico Hochgeschwender, Paul G. Ploeger, Gerhard Kraetzschmar. **People Detection in 3D using Local Surface Normals**. In Proceedings of the RoboCup Symposium 2012.

Design Time Challenges

Implicit Design Decisions by Domain Experts

Concerning the robot, the task, and the environment. Some exemplary design decisions include:

1. The **sensor configuration** of a particular robot.
2. The general **composition** of an RPA (e.g., selection, configuration and organization of components).
3. The **configuration** of a specific **composition** of an RPA for solving a task-relevant perception problem.

Run Time Challenges

Design Time vs. Run Time

A **systematic** reaction to changing conditions concerning **robot** capabilities, **task** requirements, and **environment** features is very challenging. It is not possible

1. To adapt parameters of computational components (e.g., the σ value of a Gaussian filter) during run time,
2. To execute complete processing chains in a **demand-driven** manner, and
3. To modify and reconfigure robot perception processing chains during run time.

Objective and Approach

Enabling the design and development of task-oriented RPAs...

Approach: Explicit Representations

We will adopt model-based techniques to develop representations (models) for

1. Sensors and their properties (✓)
2. Components and their integrated algorithms (✓)
3. Task-relevant information

Approach: (Re-) Configuration Methods

We need to develop schemes working on the representations (models) to enable dynamic and flexible control and data flow within RPAs.

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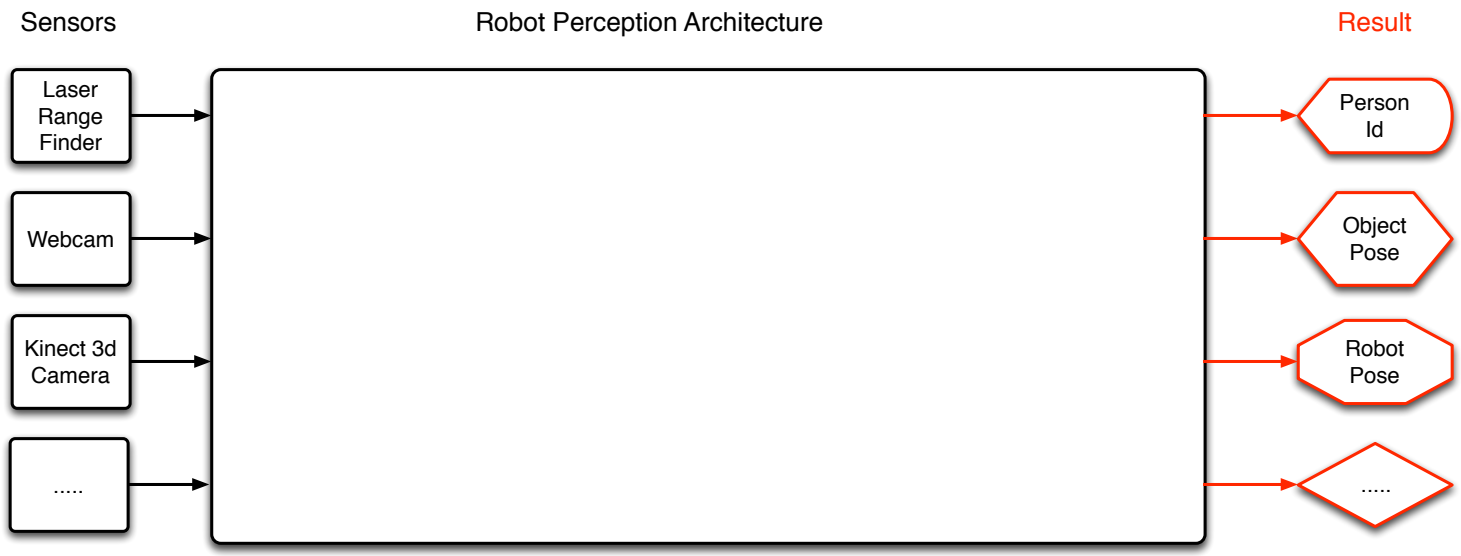
Robot Perception Specification Language (RPSL)



Domain Analysis (Assessment of Existing Applications)

- Levels of abstraction (from raw sensor data to symbols).
- Views on the output and "backtracking" requirements.
- ...

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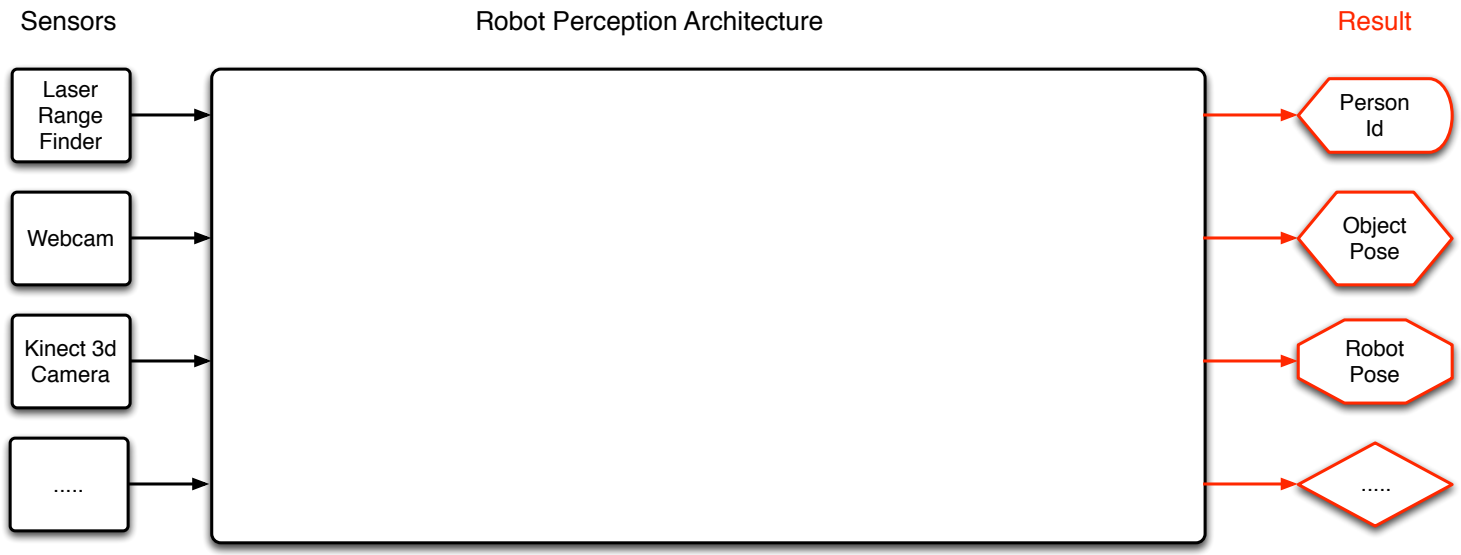

Requirements

RPSL is aimed to be a specification language and should be independent of

- the type of sensor data processed by the RPA, and
- the type of functional components which are assembled to make up an RPA.

Robot Perception Specification Language (RPSL)

Domains

RPSL is composed of the following sub-domains each represented in ECore (plus constraints).

1. Object domain
2. Spatial domain
3. Timing domain
4. Dependency domain
5. And more?
6. Composition domain

Implementation

- Current version of RPSL realized as an external DSL with Eclipse/Xtext and Eclipse OCL.

RPSL: Object Domain

Conceptual Spaces (CS)

CS [9] as a uniform data model in RPSL.

- A **CS** consists of several quality dimensions.
- A **Concept** in a CS is a convex region in that space.
- A **Point** in a CS represents concrete instances of a concept.

Example: Concept Definition

```
myConcepts: Namespace {
  myBox: Concept {
    use_domain Size
    use_domain RGB
     p: Polytope {
       // ...
       Point(RGB.Red, 0)
       Point(RGB.Green, 0)
       Point(RGB.Blue, 100)
       Point(RGB.Blue, 140)
     }
  }
}
```

RPSL: Object Domain

Example: Prototype Definition

```
use Namespace myConcepts
darkBlueBox: Prototype {
    use_concept myConcepts.myBox
    v: Values {
    // ...
    Point(myBox.RGB.Blue, 139)
   }
}
```

RPSL: Spatial Domain

- "Only" object information is not sufficient.
- Spatial surrounding is important as well (e.g., for manipulation)
- Examples are (assuming an egocentric view) statement such as "right of" and "next to".
- We investigate currently which spatial model we will include in RPSL such as RCC-5, RCC-8 and CYS_t.

RPSL: Timing Domain

- Notion of a deadline to encode a particular point in time by which the specified information needs to be available.
- Future Work: Policies to cope with missed deadlines etc.

Example: Timing Specification

```
spec: Specification {
    d: Data {
        get Quantity from myBox
        where myBox.Size.Width >= 20mm
            and myBox.Size.Length > 100mm
        ensure Deadline(100ms)
    }
}
```

RPSL: Dependency Domain

- We need to model dependencies among specifications (some information is required before/after some other).
- We model these dependencies with a Directed Acyclic Graph (DAG).

RPSL: Dependency Domain

Example: Dependency

```
a: Specification {
    d: Data {
        get Quantity ...
}

b: Specification {
    d: Data {
        get Pose ...
}

c: Specification {
dg: DependencyGraph {
    a before b
    ...
}
```

RPSL: Composition Domain

- Composition of the previous domains (whereas some are optional).

Example: Composition with Similarity Measure

```
spec: Specification {
    d: Data {
        get Pose from darkBlueBox
        where Similarity(EuclideanDistance) == 0
    }
}
```

Conclusion and Future Work

- RPSL is not (yet) finished, but it supported already the assessment of RPAs.
- In it's current version RPSL is limited to "simple" scenes (e.g., no active perception) due to missing concepts.
- We are currently applying RPSL to model existing RPAs.

Thanks and Acknowledgement

Thank You! Questions?

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