3D Virtual Prototyping of Home Service Robots Using ASADAL/OBJ

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Agenda

- Introduction
- ASADAL/OBJ Framework
- Prototyping HSR with ASADAL/OBJ
- Conclusion

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- ***Typical development*** of a robot consists of two often sequential, and distinct processes

  - Developing hardware components first, then software applications
  - The lack of available physical HW leads to lengthening the application development time

- ***Virtual prototyping*** of hardware using a software simulator allows much of the application development without hardware
  - Development time can be significantly reduced
  - Hardware design flaws can be detected w/o HW manufacturing
  - Testing applications can be more productive in a virtual environment

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Difficulty of Virtual Prototyping

- The main difficulty of virtual prototyping lies in the ***management of complexity*** for managing interrelated three facets concurrently
  - Form (3D shape and physical properties of virtual objects)
  - Behavior (control execution of objects)
  - Function (data computation of objects)
- Another difficulty of virtual prototyping lies in the ***management of iterative revision*** for developing both target system and its environment incrementally

To solve these difficulties, we developed ASADAL/OBJ framework

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Focus of This Work

- SW development methodology
  - More robot components are built based on SW
  - Component integration should be carefully designed
- Discrete controller synthesis
  - Component interactions become more complex
  - Safety/correctness of robot behaviors is critical
- Topics not covered by this work
  - Dynamic controller
  - Physics engine

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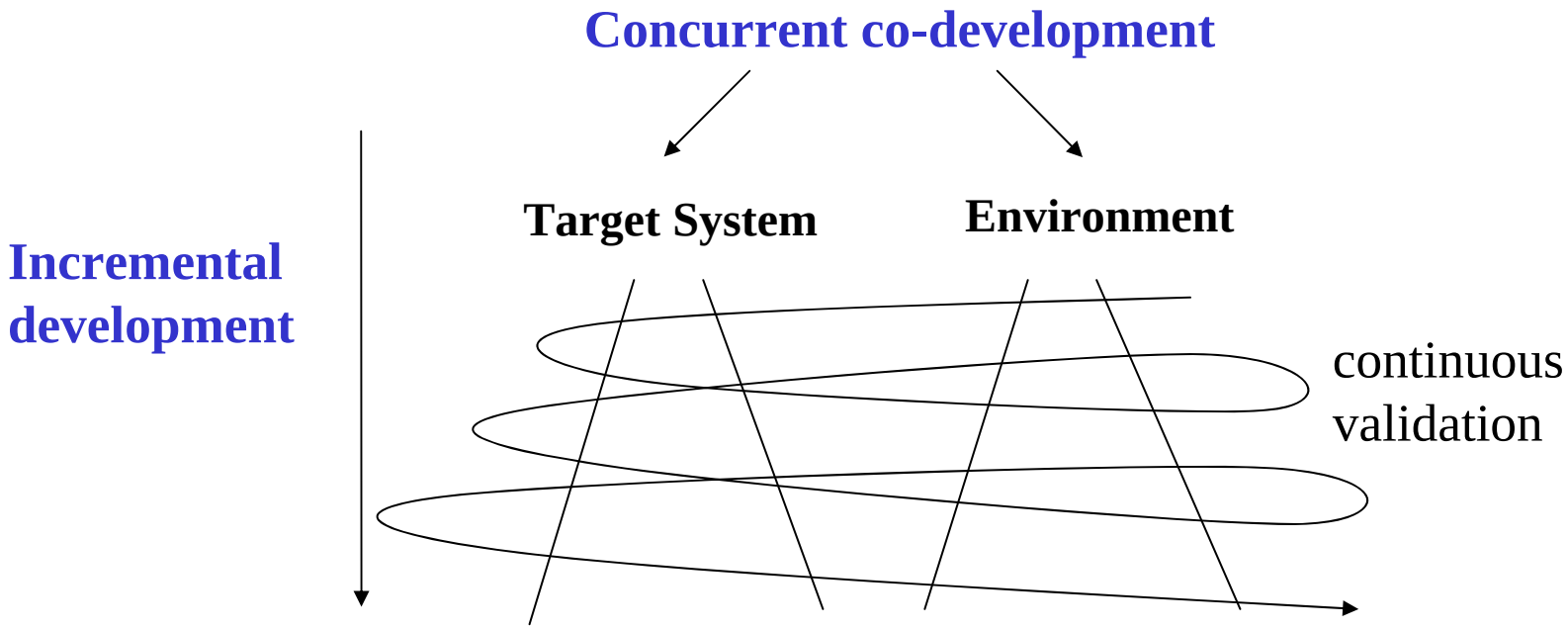
ASADAL/OBJ Framework

- ASADAL/OBJ is a ***3D virtual prototyping toolset*** for real-time specification, validation, and verification
- The main modeling philosophy of ASADAL/OBJ is based on that of ***incremental co-development*** of a target system and its environment.



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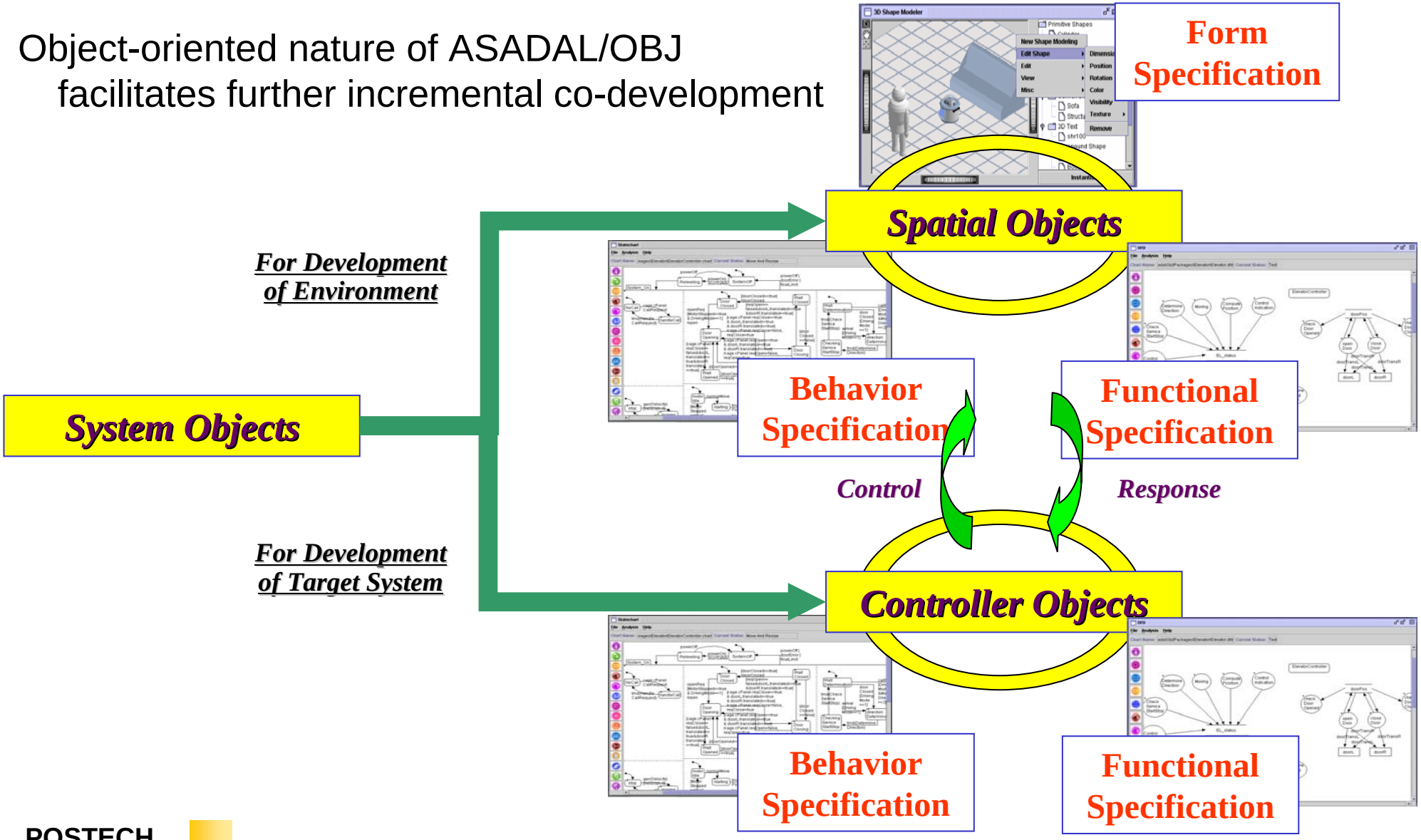
Object-oriented nature of ASADAL/OBJ facilitates further incremental co-development



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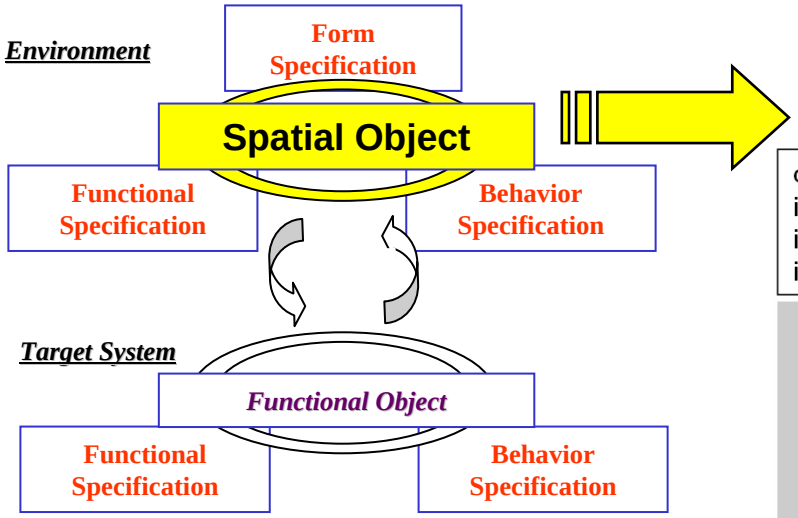
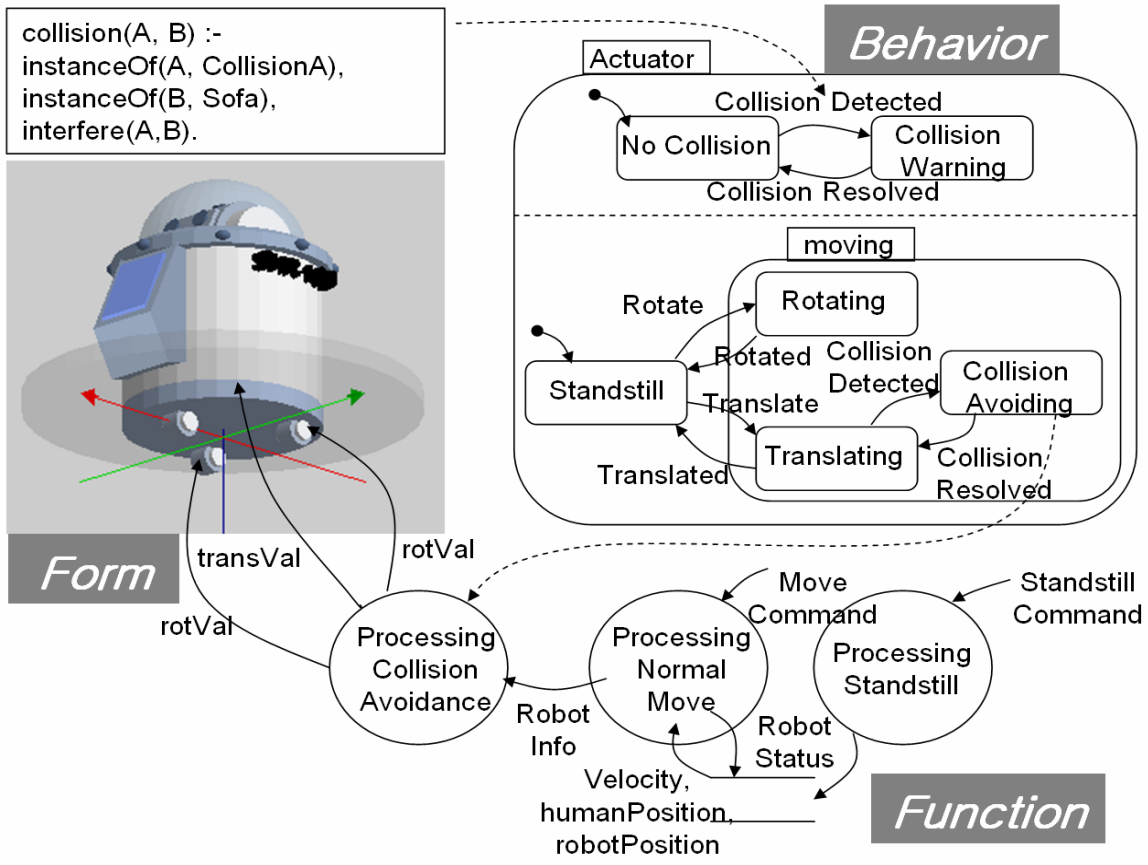
Combination of Specifications



- Spatial Object Modeling
  - Form + Behavior + Function



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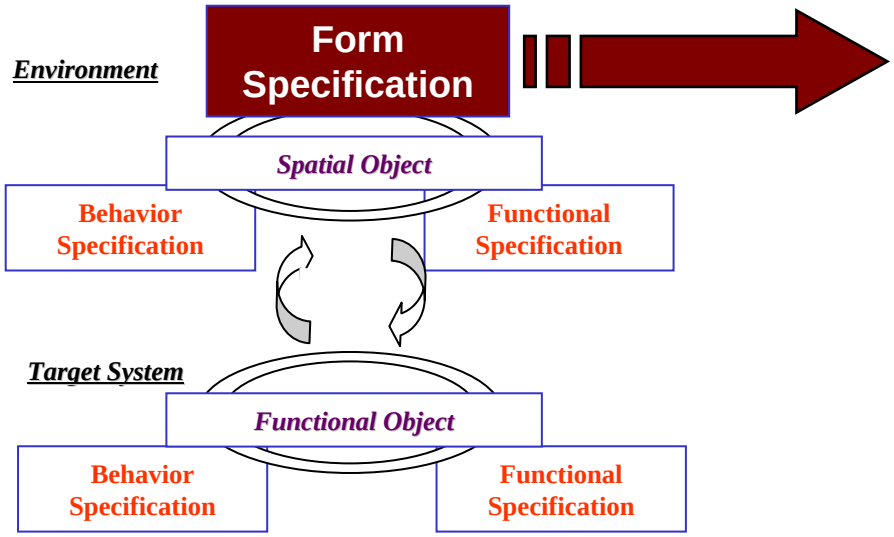
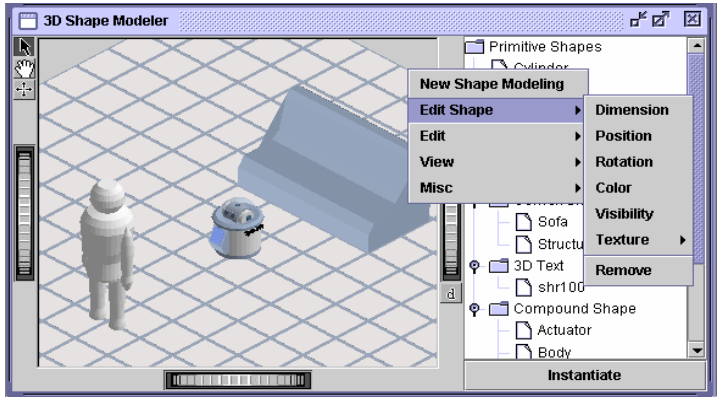
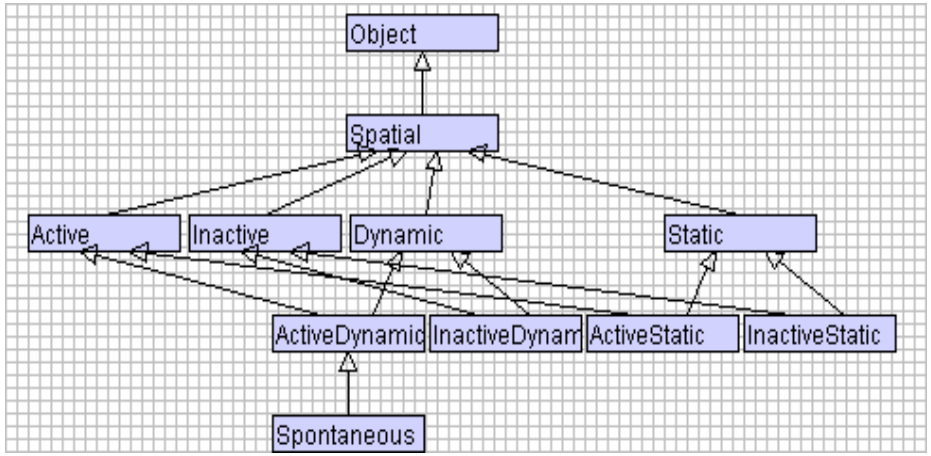
Form Specification



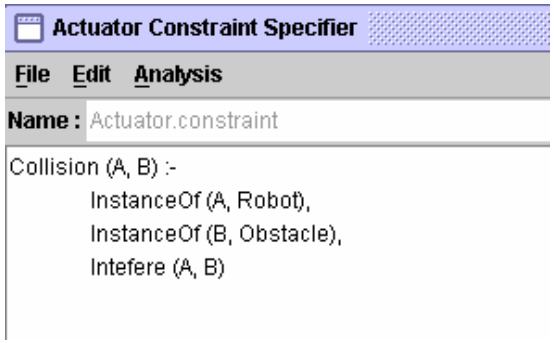
- Spatial configuration
  - Shape, color, position, orientation, etc



- Movement configuration
  - Active, inactive, dynamic, static



- Spatial relation
  - Interfere, contact, above, below



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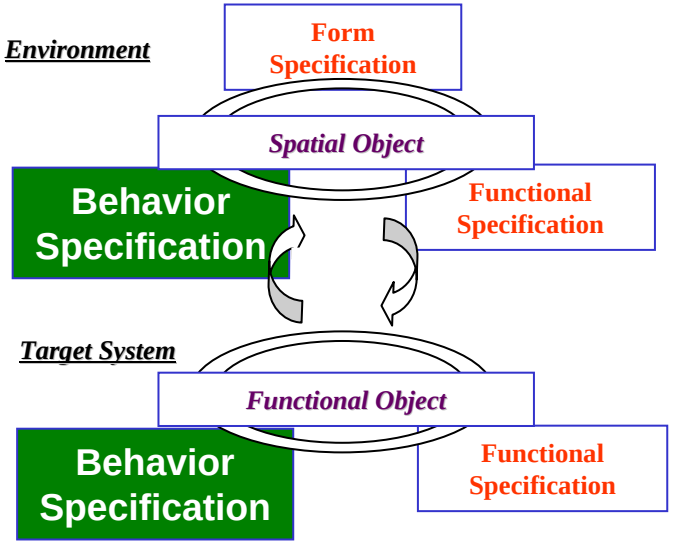
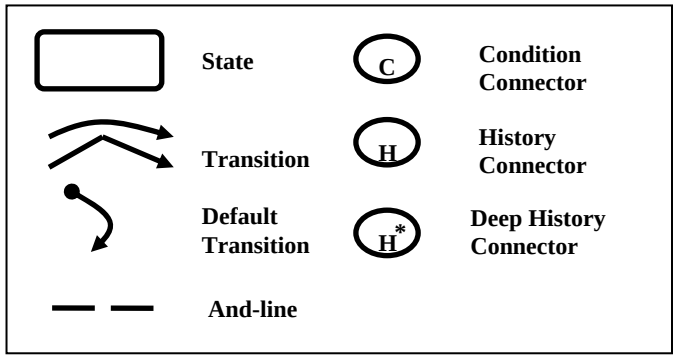
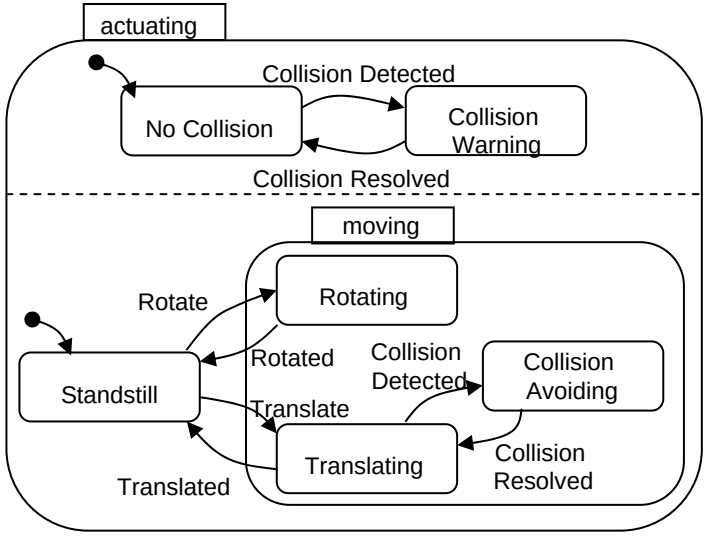
Behavior Specification

- Statechart
  - Dynamic temporal action and reaction







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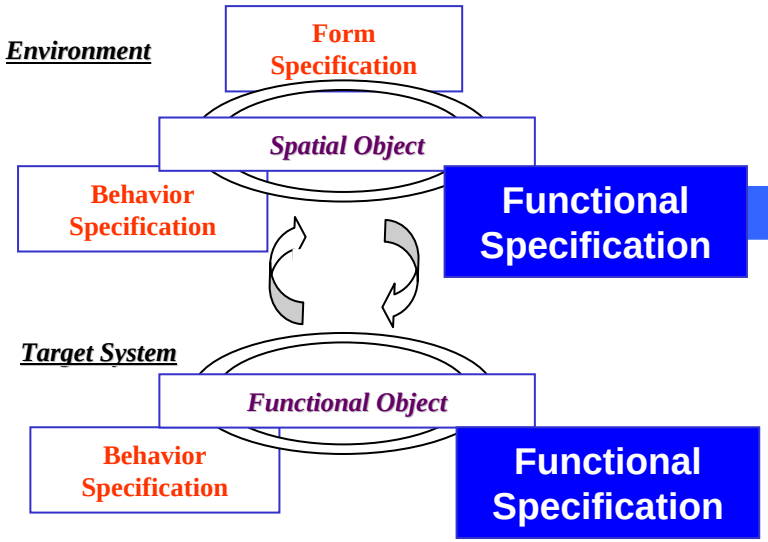
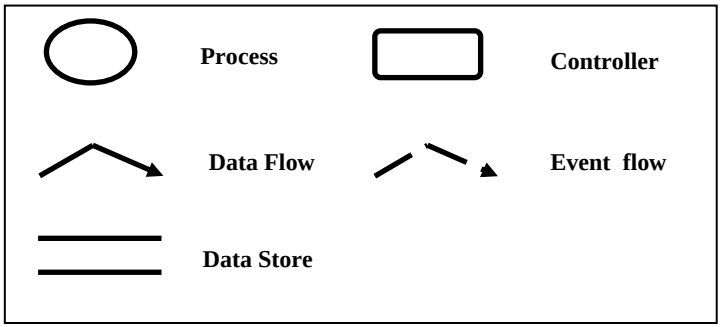
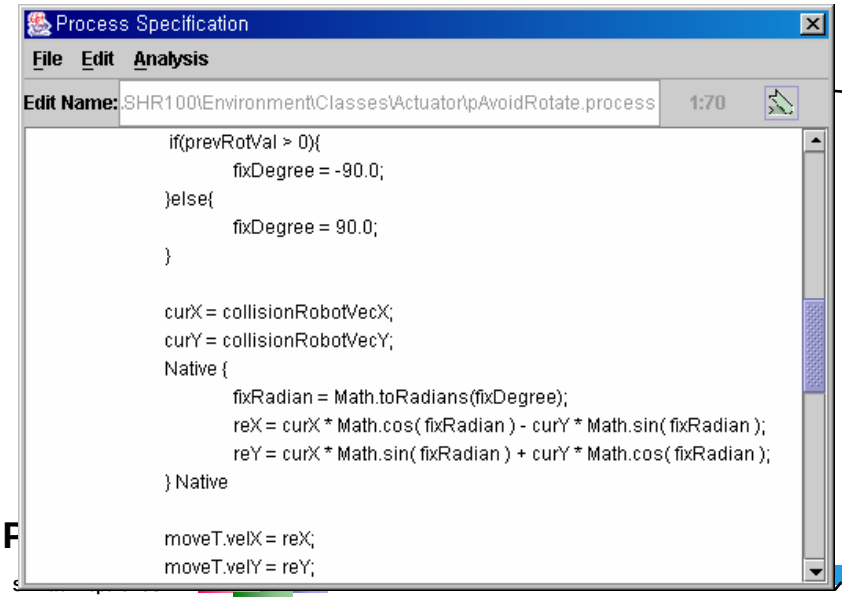
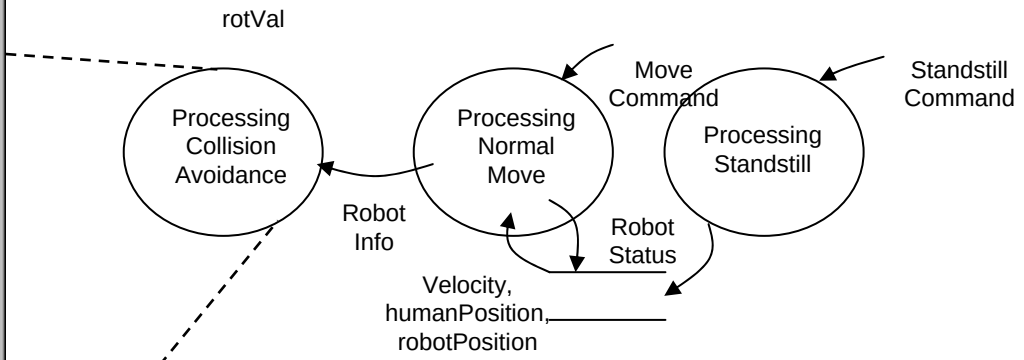
Function Specification



- DFD (Date Flow Diagram)
  - Computation to transform inputs to outputs

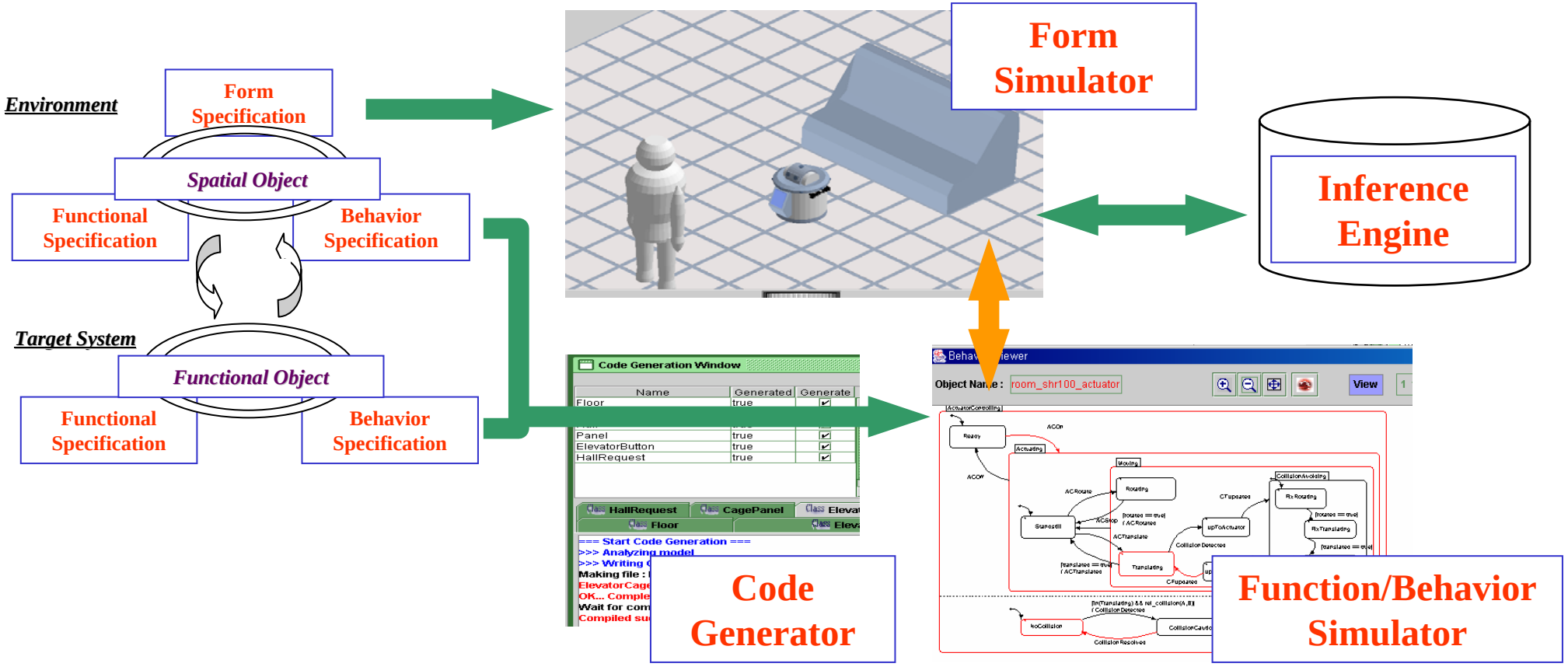






Validation Process

The form simulator visualizes transformation of dynamic objects, while inference engine checks constraints and updates spatial relations between objects.



The function/behavior simulator is capable of performing stochastic data flow analysis, reachability analysis, and non-determinism analysis.

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Prototyping HSR with ASADAL/OBJ

Single Board Computer

•Controlling peripherals

Input peripheral

Ceiling Camera

•Map building
•Self-positioning

Front Camera

•Face Recognition
•User following
•Remote Surveillance

8 channel Microphones

•Speaker Localization

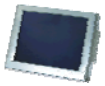
Structured Light Sensor

• Obstacle Detection
• Foot Step Detection

Output peripheral

Speaker

•Sound generation



LCD

•Information Display

Actuator

•Movement

Input/Output peripheral

Wireless LAN

•Communication to Home Server

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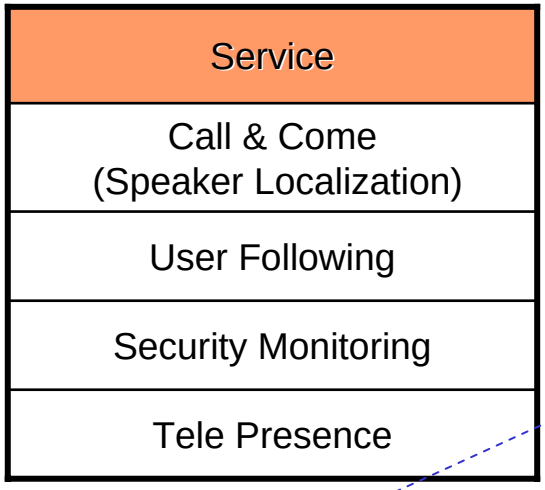
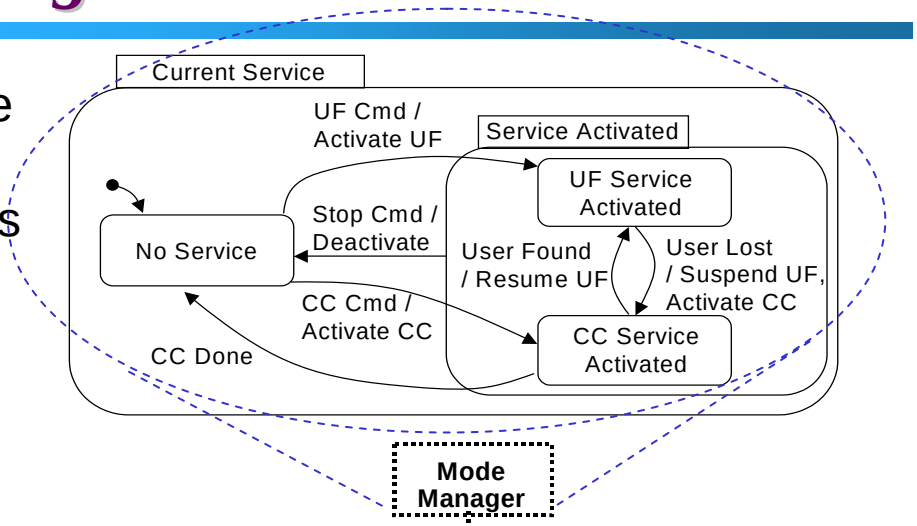
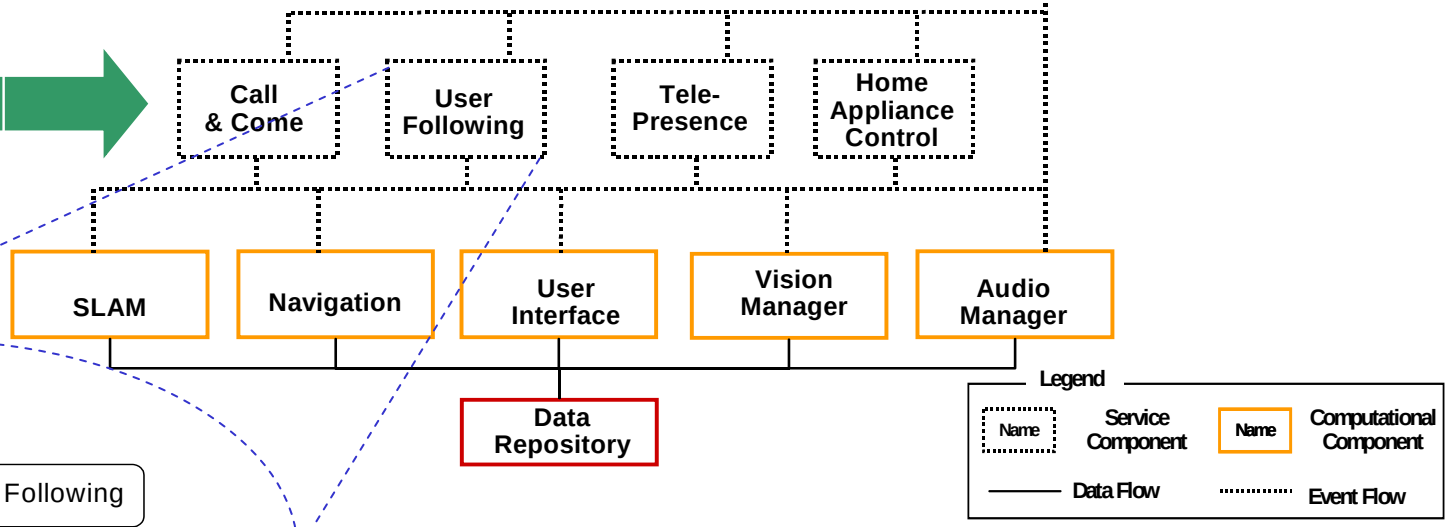
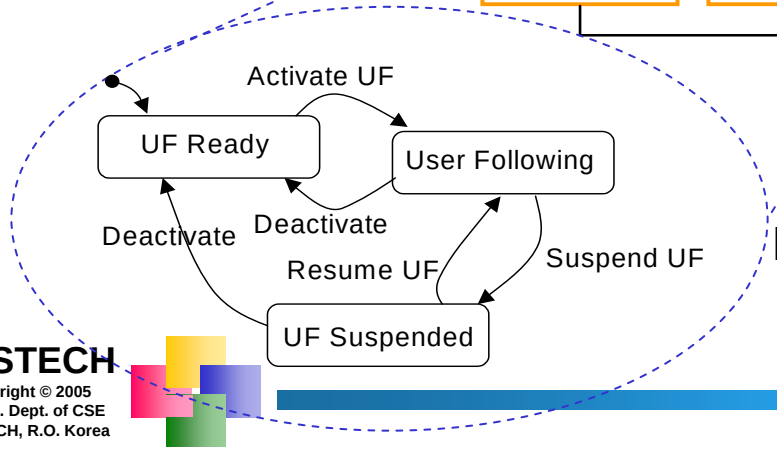
HSR Controller Architecture

Mode Manager component defines the system mode (e.g., initialization, termination, power saving) and the interaction policy between service components









Each of service components controls the computational components to generate data for the services

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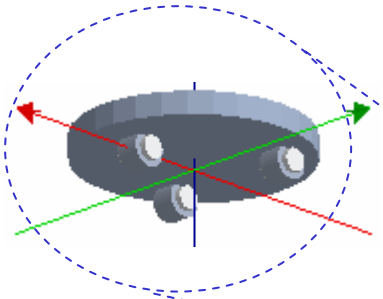
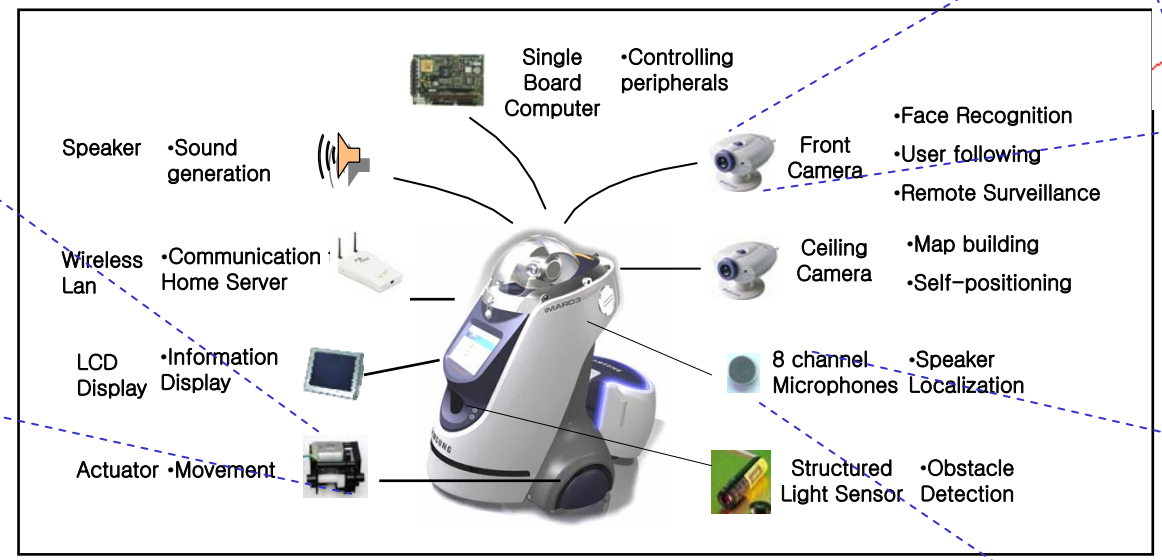
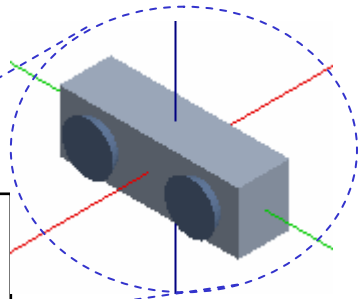
Prototyping HSR with ASADAL/OBJ

Front camera: an ideal one in that the camera detects human without failure within view angle of 60 degrees and within 4 meter range.

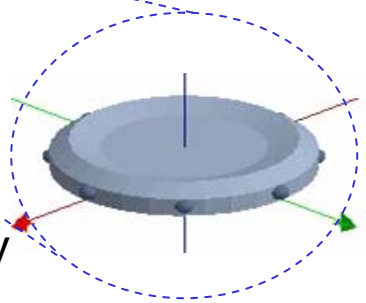






Actuator: it does not fail to rotate a given rotation of angle.

8ch microphones: it always detect the direction of sound recognize commands of the user correctly regardless of distance from the human



These simplified assumption helps rapid prototyping and quick validation.

After validation, we can refine devices with more realistic characteristics.

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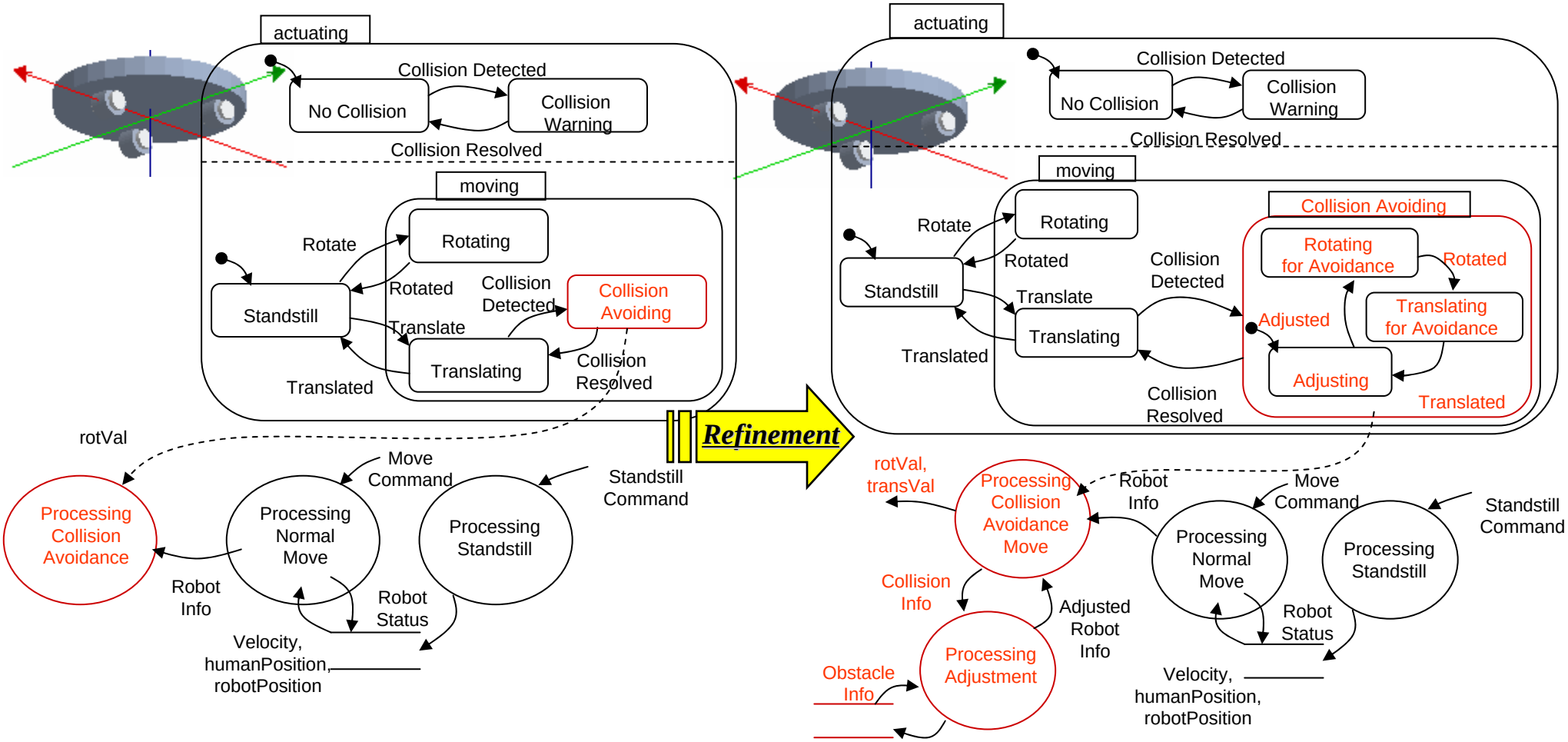

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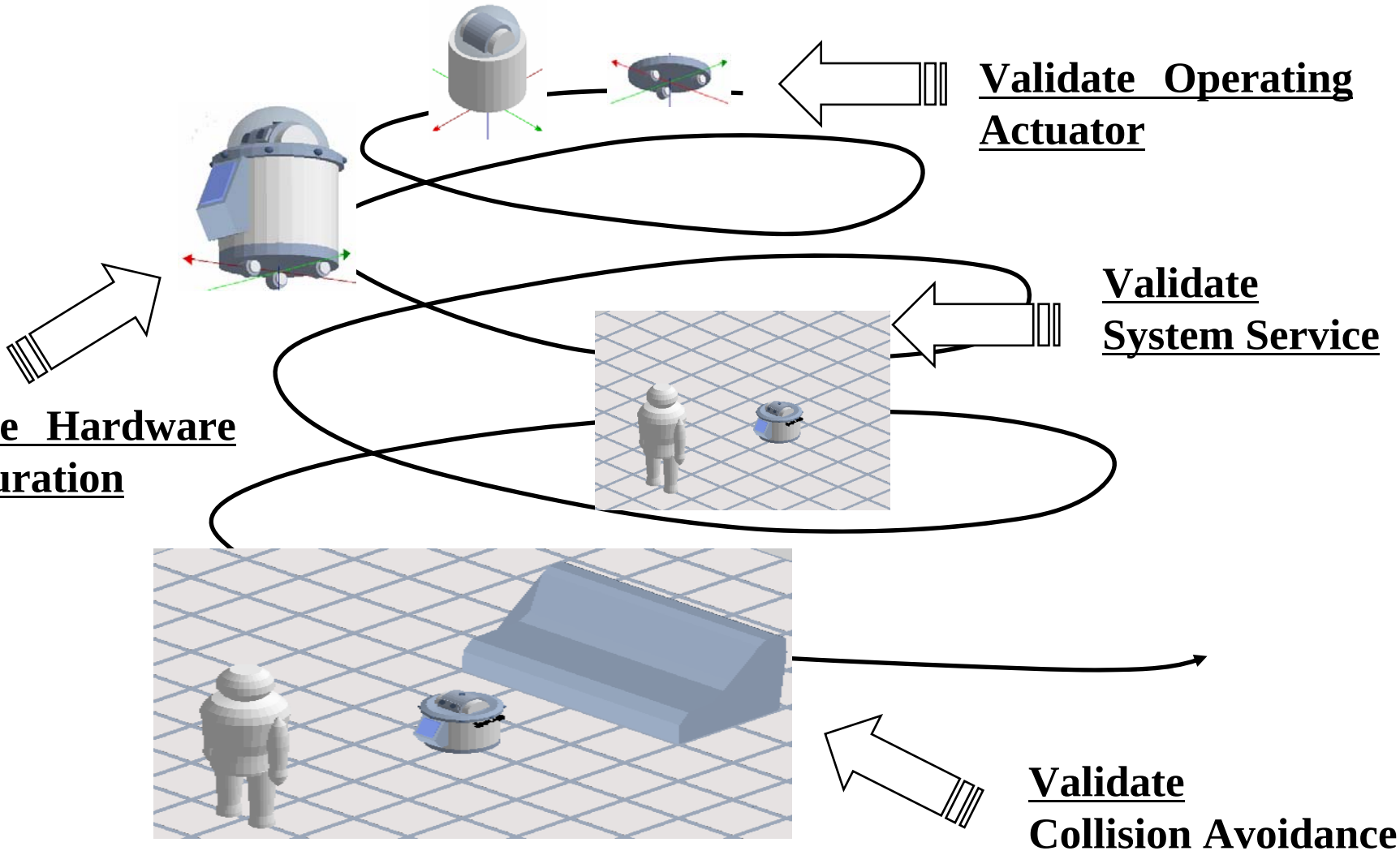
Prototyping HSR with ASADAL/OBJ



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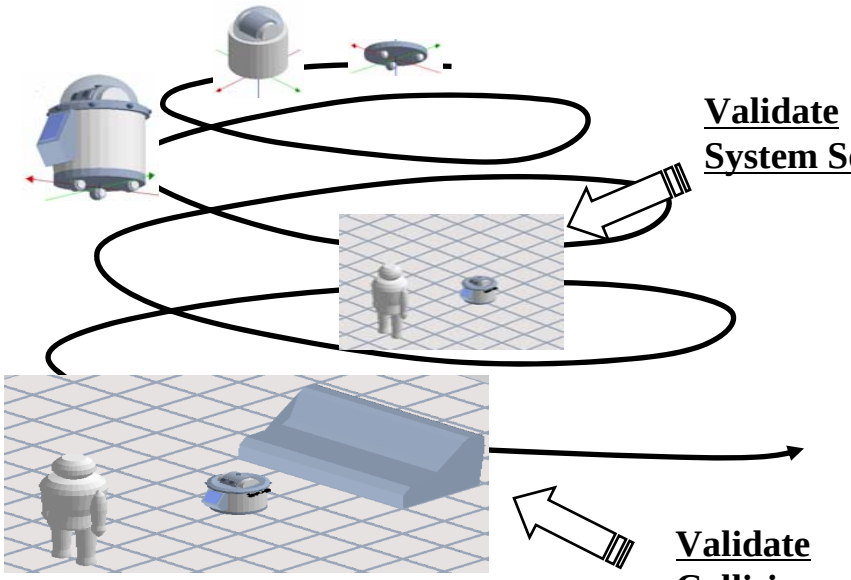

- We observed that HSR sometimes did not stop ignoring a “stop” command that turned out to be a ***feature interaction problem*** between UF and CC

- We tried two different collision avoidance algorithms, we could validate visually the ***effectiveness of refined collision avoidance algorithm*** compared to the original one.

Simple Avoiding Smart Avoiding

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Conclusion

- Incremental co-development
  - We started developing and validating the virtual prototype of HSR piece by piece
- Rapid prototyping
  - A graduate student w/o prior experience with ASADAL/OBJ built/validated the virtual HSR in a week.
- Visual validation
  - We found feature interaction problem and validate collision avoidance algorithm visibly.
- Related work
  - Formal Verification of Robot Movements [ICRA'05]
  - Re-engineering of Home Service Robot – a Case Study [ICSE'05]
  - Feature-oriented Re-engineering of a Legacy System into Product Line Assets – a Case Study [Submitted to SPLC'05]

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