AMIGO’s software architecture: performing a RoboCup Challenge

J.J.M. Lunenburg

Technische Universiteit
Eindhoven
University of Technology

Where innovation starts

May 19, 2014

Booting the robot

- roscore

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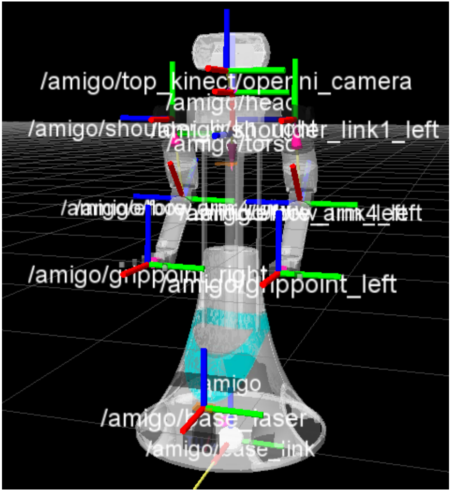
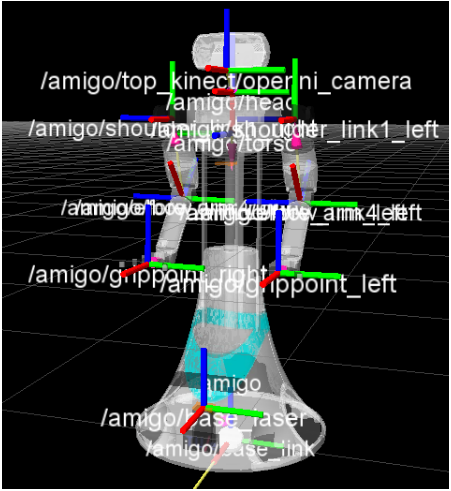
- roscore
- Robot state publisher
    - Subscribes to joint angles
    - Uses URDF model
    - Publishes transformation between frames



Booting the robot

- roscore
- Robot state publisher
  - Subscribes to joint angles
  - Uses URDF model
  - Publishes transformation between frames
- Diagnostics
  - Battery voltage
  - Timing offsets
  - Emergency button states
  - Graphical user interface



Low-level software: actuators

- Open RObot COntrol Software (Orocos) realtime toolkit (rtt)
  - Modular realtime software components
  - Launched in a rosnode
  - Configuration defined in deployment scripts
  - rtt component library

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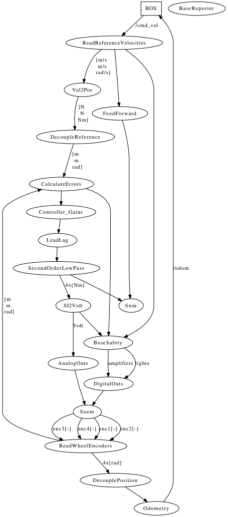
- Deployment structure
  - Hardware communication (SOEM library)
  - Controller architecture



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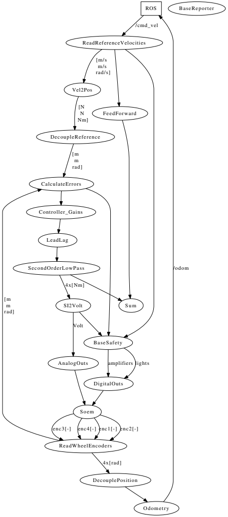
- Safety



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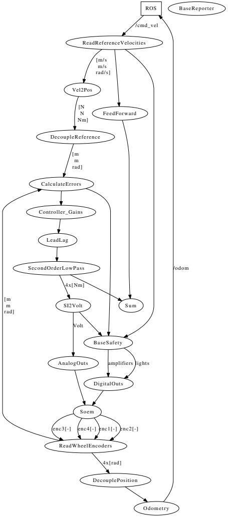
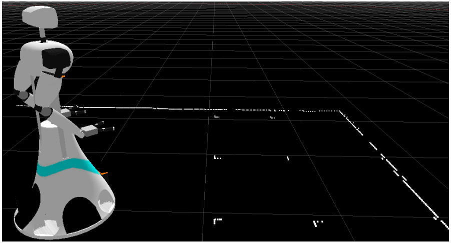


Low-level software: sensors

- Laser range finders
- (Kinect) cameras



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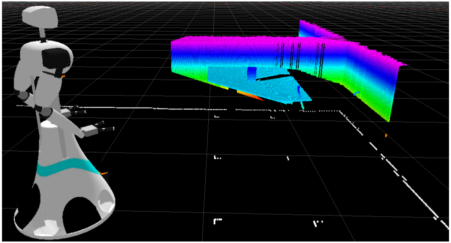

Low-level software: sensors

- Laser range finders
- (Kinect) cameras
- Similar to PICO
- How to design a system architecture?
  - Reuseability

Serving drinks at a cocktail party

- Navigate to party room

Serving drinks at a cocktail party

- Navigate to party room
- Ask for name and desired drink

Serving drinks at a cocktail party

- Navigate to party room
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- Learn faces

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Serving drinks at a cocktail party

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Serving drinks at a cocktail party

- Navigate to party room: navigation
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Navigation

- Localization
    - AMCL
    - GMapping

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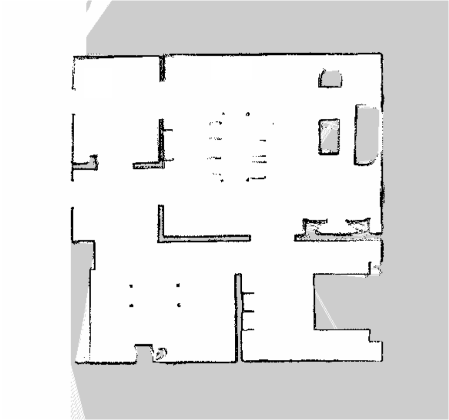

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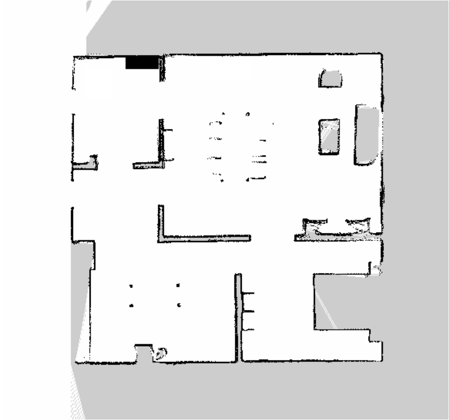

Navigation

- Localization
  - AMCL
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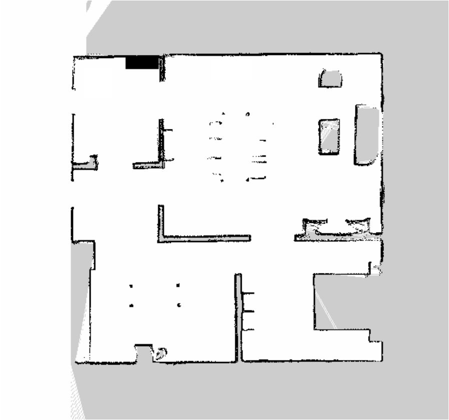
  - Odometry
  - Features such as corners, lines and crossings



Navigation

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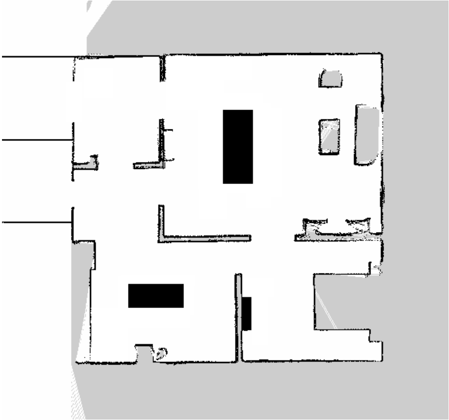

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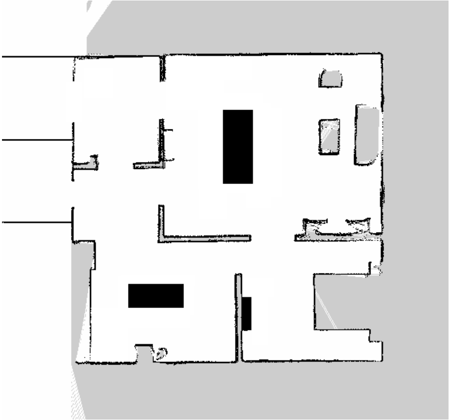

Navigation

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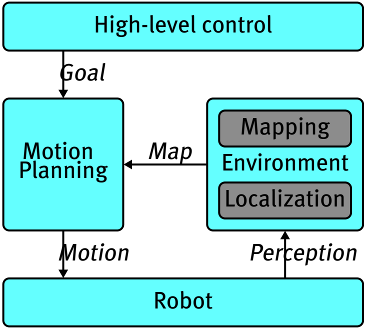
  - Features such as corners, lines and crossings
- Path planning
  - Local (reactive) planning
- Navigation pipeline
  - move base



Navigation

- Localization
  - AMCL
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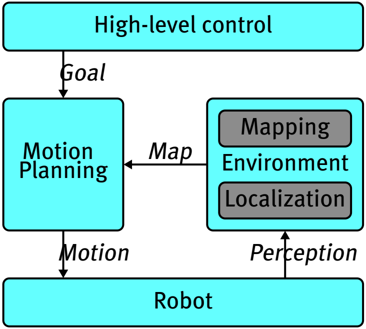
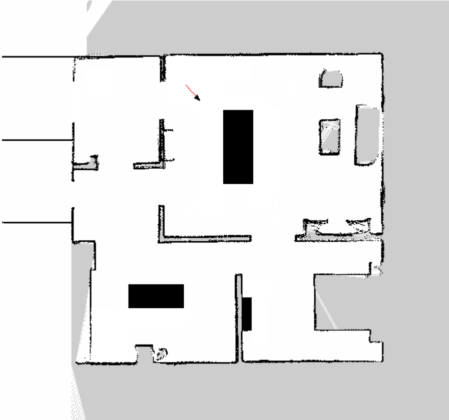
  - Odometry
  - Features such as corners, lines and crossings
- Path planning
  - Local (reactive) planning
- Navigation pipeline
  - move base
- Where are we going?



Navigation goals

- Reasoning interface
  - Expressive, semantic interface
  - `waypoint(rwc2013, cocktailparty, partyroom, pose2d(3.712, -2.506, -1.348)).`



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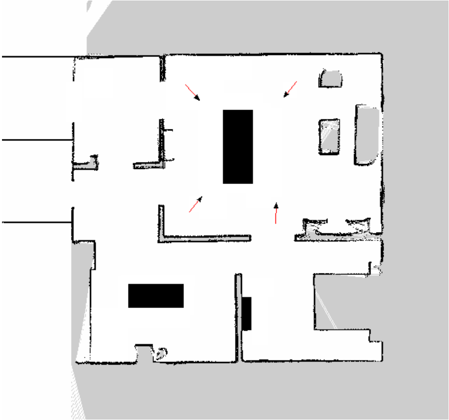
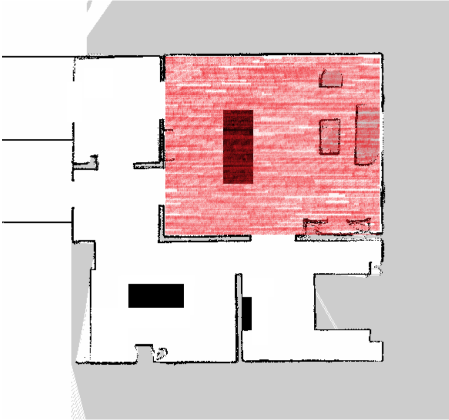
  - `waypoint(rwc2013, cocktailparty, partyroom, pose2d(3.712, -2.506, -1.348)).`
- Robustness
  - Multiple goals



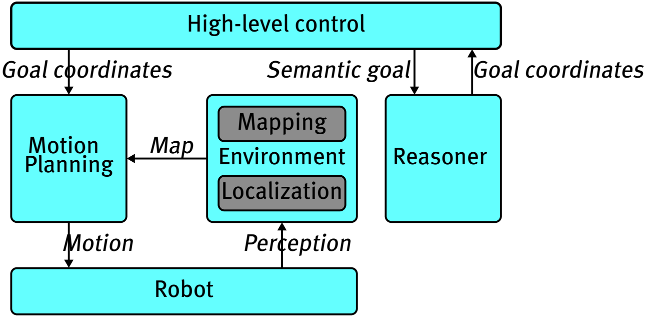
Navigation goals

- Reasoning interface
  - Expressive, semantic interface
  - `waypoint(rwc2013, cocktailparty, partyroom, pose2d(3.712, -2.506, -1.348)).`
- Robustness
  - Multiple goals
  - Goal area



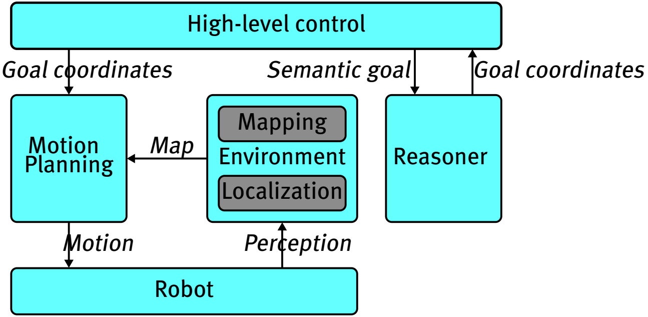
Navigation goals (2)

- Current structure



Navigation goals (2)

- Current structure
- Separate node?



Serving drinks at a cocktail party

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- Ask for name and desired drink
- Learn faces
- Get the drinks
- Deliver the drinks
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Serving drinks at a cocktail party

- Navigate to party room: navigation
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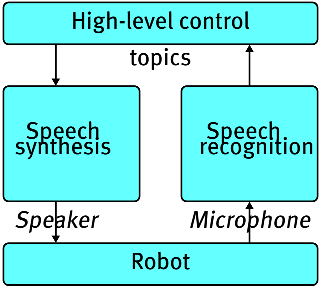
Human-Robot Interaction

- Speech synthesis
  - Festival/eSpeak
  - Google
  - Philips
- Speech recognition
  - (Pocket)Sphinx



Human-Robot Interaction

- Speech synthesis
  - Festival/eSpeak
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- Speech recognition
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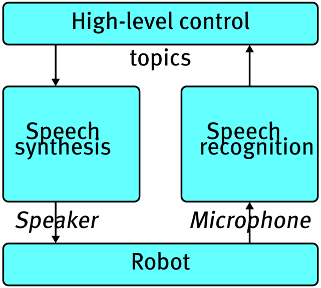
- Issues
  - Multiple dictionaries
  - Advanced commands
  - Confirmations
  - Talking and not listening



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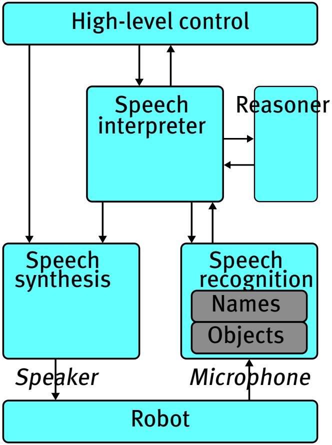
  - Talking and not listening
- Speech interpreter
  - Parameterized request
  - Knowledge from reasoner
  - Active required dictionary


High-level control
Speech interpreter
Reasoner
Speech synthesis
Speech recognition
Names
Objects
Speaker
Microphone
Robot

Human-Robot Interaction

- Speech synthesis
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- Issues
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- Speech interpreter
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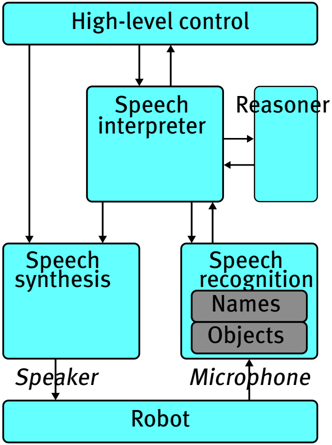
- LED bar



Serving drinks at a cocktail party

- Navigate to party room: navigation
- Ask for name and desired drink: human-robot interaction
- Learn faces
- Get the drinks
- Deliver the drinks
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Serving drinks at a cocktail party

- Navigate to party room: navigation
- Ask for name and desired drink: human-robot interaction
- Learn faces: perception
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- Deliver the drinks
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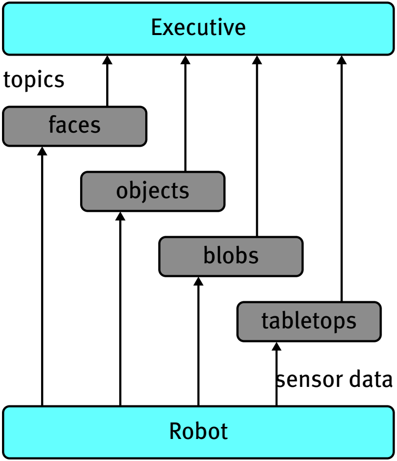
Perception

- Many routines for detecting and recognizing peoples and objects
  - Leg and torso detection
  - Face detection
  - Face recognition
  - Template matching
  - Blob clustering
  - Tabletop segmentation
  - VFH matching



Perception

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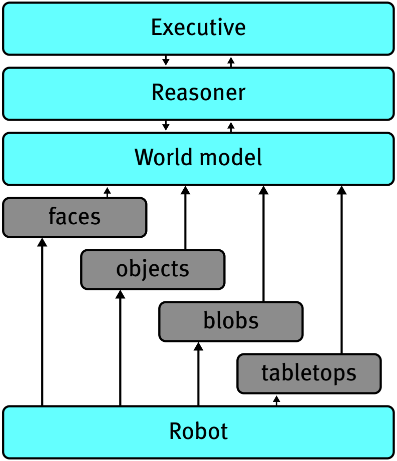
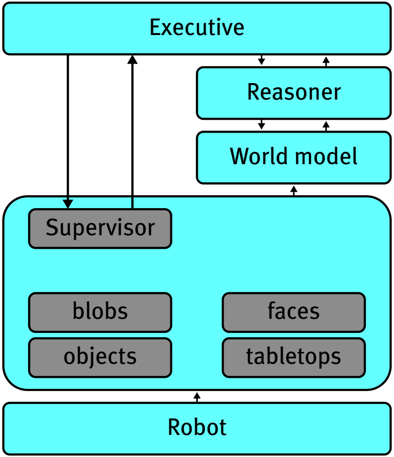
- World model
  - Consistent belief state
  - Sensor fusion
  - Probabilistic multiple hypothesis approach
  - Memory



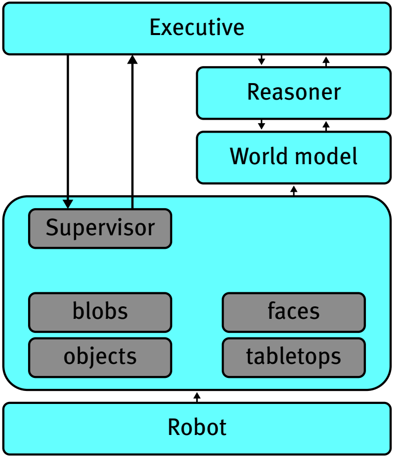
Perception (2)

- PErception INfrastructure
  - Reuse of code
  - Nodelet: prevent needless data copying
  - Modules can be switched on or off through supervisor



Perception (2)

- PErception INfrastructure
  - Reuse of code
  - Nodelet: prevent needless data copying
  - Modules can be switched on or off through supervisor
- Arrow detection
  - Enabling/disabling



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- Get the drinks: manipulation
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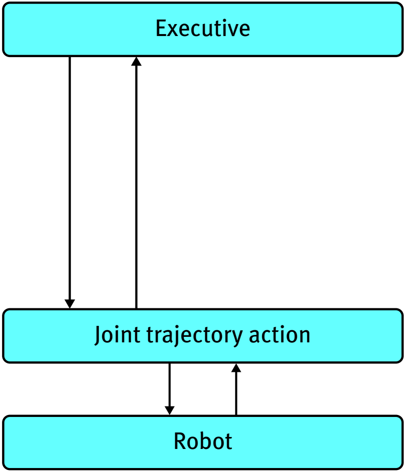
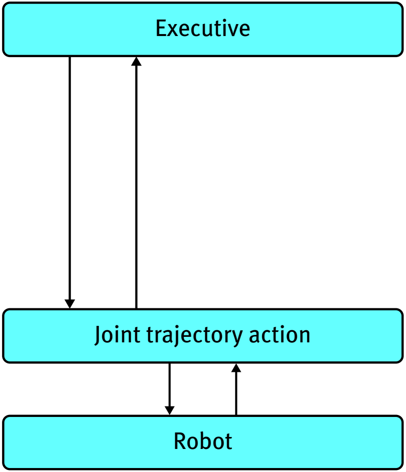
Moving robot arms

- Targets in joint space: Joint trajectory action
  - Actionlib interface



Moving robot arms

- Targets in joint space: Joint trajectory action
  - Actionlib interface
- Targets in Cartesian space



Moving robot arms

- Targets in joint space: Joint trajectory action
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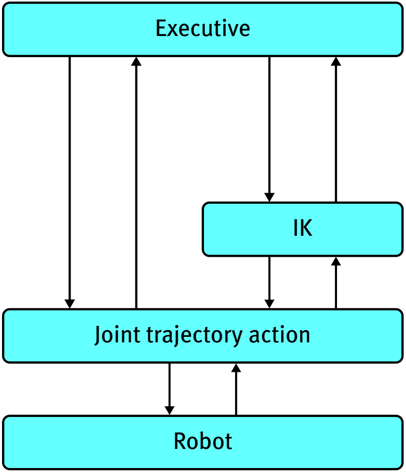
- Targets in Cartesian space
- Joint space control
  - Inverse Kinematics
  - Joint space planning



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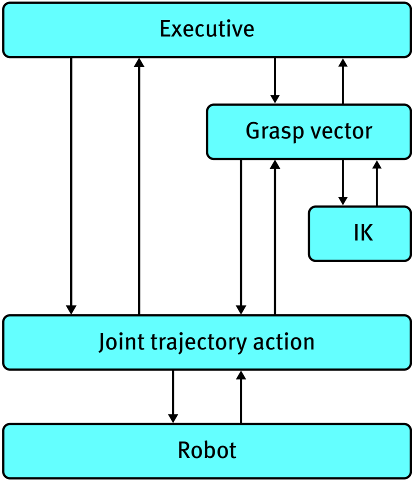

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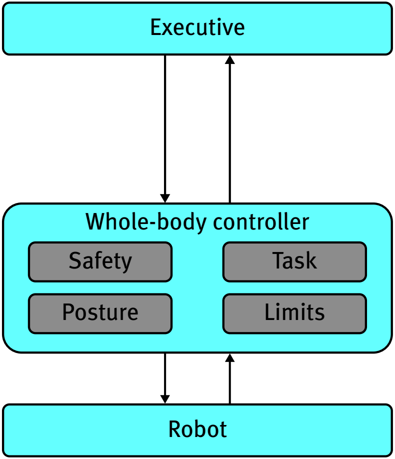
- Cartesian space control
  - No explicit joint goals



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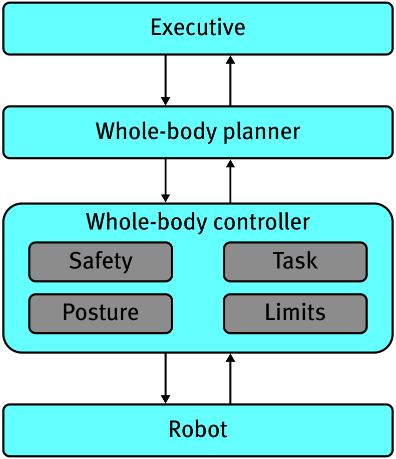
  - Local minima



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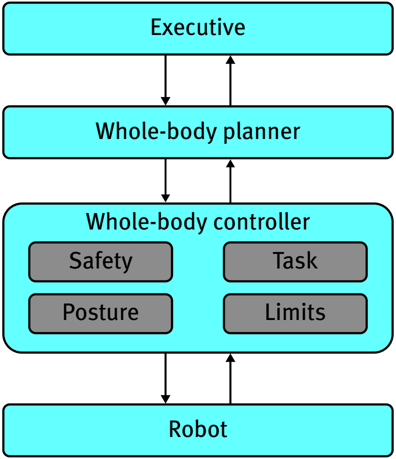
    - Cartesian space planning
- Cartesian space control
    - No explicit joint goals
    - Local minima
- Visual feedback


Executive

Whole-body planner

Whole-body controller

Safety

Task

Posture

Limits

Robot

Serving drinks at a cocktail party

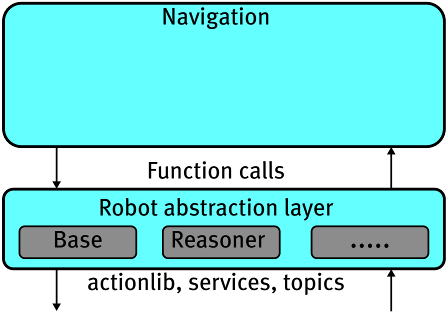
- Navigate to party room: navigation
- Ask for name and desired drink: human-robot interaction
- Learn faces: perception
- Get the drinks: manipulation
- Deliver the drinks
- Leave the arena

Serving drinks at a cocktail party

- Navigate to party room: navigation
- Ask for name and desired drink: human-robot interaction
- Learn faces: perception
- Get the drinks: manipulation
- Deliver the drinks: composing hierarchical state machines
- Leave the arena

Executives

- SMACH state machine
  - Fast prototyping, complex state machines
  - SMACH states (Generic, CB)
  - SMACH containers (StateMachine, Iterator, Concurrence)
- Robot abstraction layer



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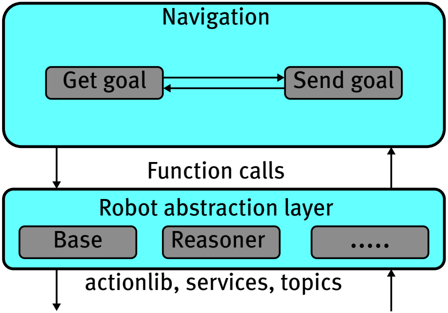

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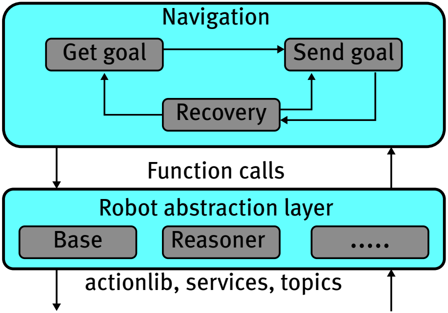
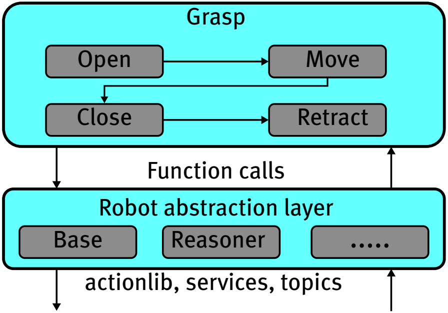
- Robot abstraction layer
- Hierarchical states
  - Scaling
  - Reuse of code



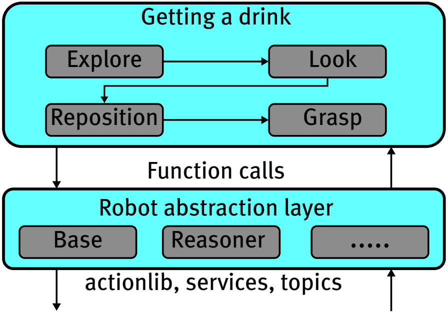
Getting a drink

- Grasping
  - Open gripper
  - Move gripper to object
    - Multiple steps
    - Visual servo update
  - Close gripper
  - Retract arm



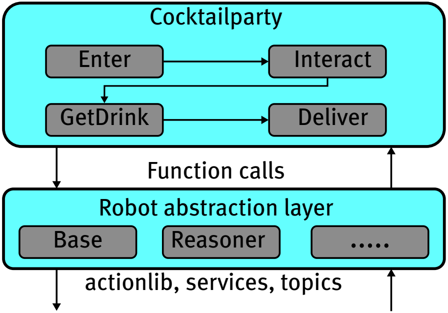
Getting a drink (2)

- Getting a drink
  - Navigate to possible storage locations
    - Get waypoints from reasoner
  - Look for objects
    - Perception algorithms
  - Reposition
    - Inverse reachability
    - Get target location from reasoner
  - Grasp



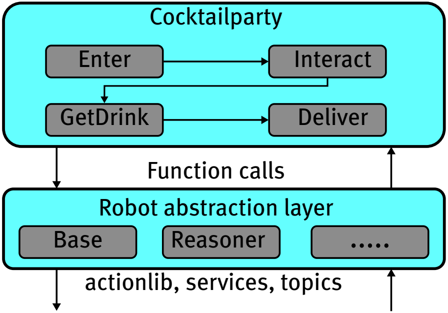
Getting a drink (3)

- Cocktailparty
    - Robot has the drink
    - Delivery



Getting a drink (3)

- Cocktailparty
    - Robot has the drink
    - Delivery
- Example: navigation modes
    - Straight, left, right, back
    - Executive ‘selects’ based on ‘map’ and detected arrows
    - Motion planner performs motion



Getting a drink (3)

- Cocktailparty
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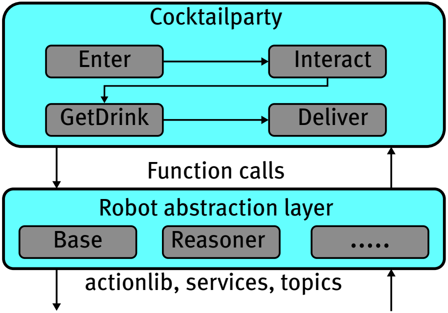
- Example: navigation modes
  - Straight, left, right, back
  - Executive 'selects' based on 'map' and detected arrows
  - Motion planner performs motion
- Robots don't work in a perfect world!



Serving drinks at a cocktail party

- Navigate to party room: navigation
- Ask for name and desired drink: human-robot interaction
- Learn faces: perception
- Get the drinks: manipulation
- Deliver the drinks: composing hierarchical state machines
- Leave the arena

Serving drinks at a cocktail party

- Navigate to party room: navigation
- Ask for name and desired drink: human-robot interaction
- Learn faces: perception
- Get the drinks: manipulation
- Deliver the drinks: composing hierarchical state machines
- Leave the arena: failure handling

Failure handling

- Many sources of failures
    - Location unreachable
    - Cannot detect people
    - Cannot find object
    - Object out of reach
    - Hardware failure
    - ...

Failure handling

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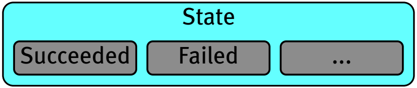
    - Location unreachable
    - Cannot detect people
    - Cannot find object
    - Object out of reach
    - Hardware failure
    - ...
- What should the robot do when something does not work?

Failure handling

- Many sources of failures
  - Location unreachable
  - Cannot detect people
  - Cannot find object
  - Object out of reach
  - Hardware failure
  - ...
- What should the robot do when something does not work?
- Building an application
  - State outcomes
  - Don’t postpone developing fallback scenarios
  - Test *all* transitions


State

Succeeded

Failed

...

Failure handling (2)

- Time-outs
  - Blocking calls

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- Testing!
  - Sensor noise
  - Servo errors
  - People
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- Task planning
  - Mission statemachine is not hardcoded
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- Recovery behavior
  - Navigation safety

Questions

Questions?