CS686: High-level Motion/Path Planning Applications

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(윤성의)

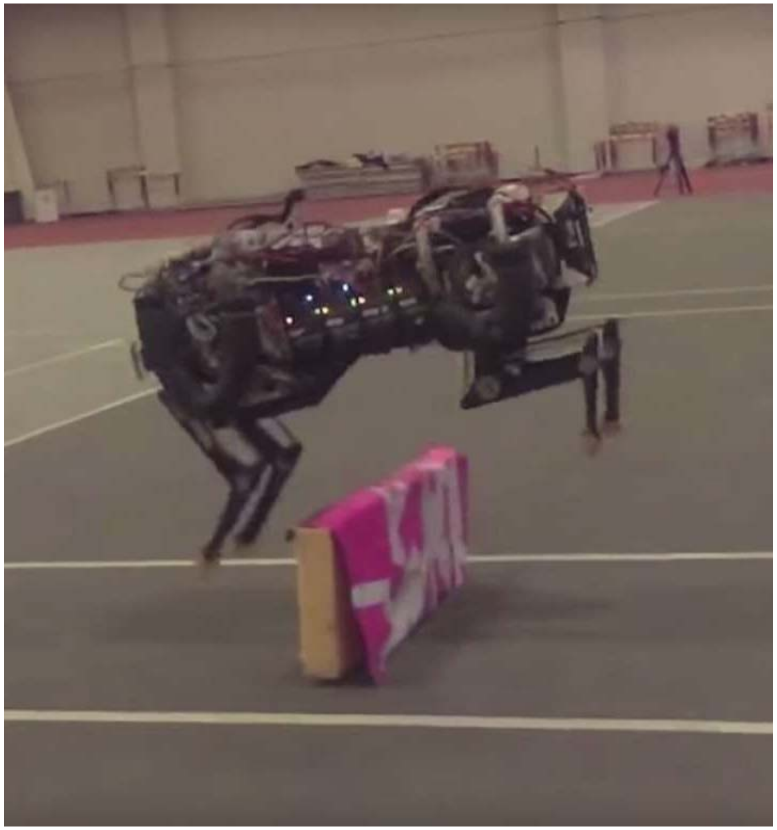
Course URL:
http://sglab.kaist.ac.kr/~sungeui/MPA

Class Objectives

- Discuss my general research view on motion planning
  - Discuss related applications
- Study task planning

Our Research Directions

- Many robots are available
  - Different sensors and controls
- Basic controls are developed with such robots
  - Primitive motions are developed together
- Therefore, motion/path planning are widely researched



Our Research Directions

- General motion planning tools
  - Primitive controls are available at HW vendors
  - How can we design a standard MP library working with those different robots?
  - For example, OpenGL for the robotics field; vendors support OpenGL, and programmer uses OpenGL for their applications

Our Research Directions

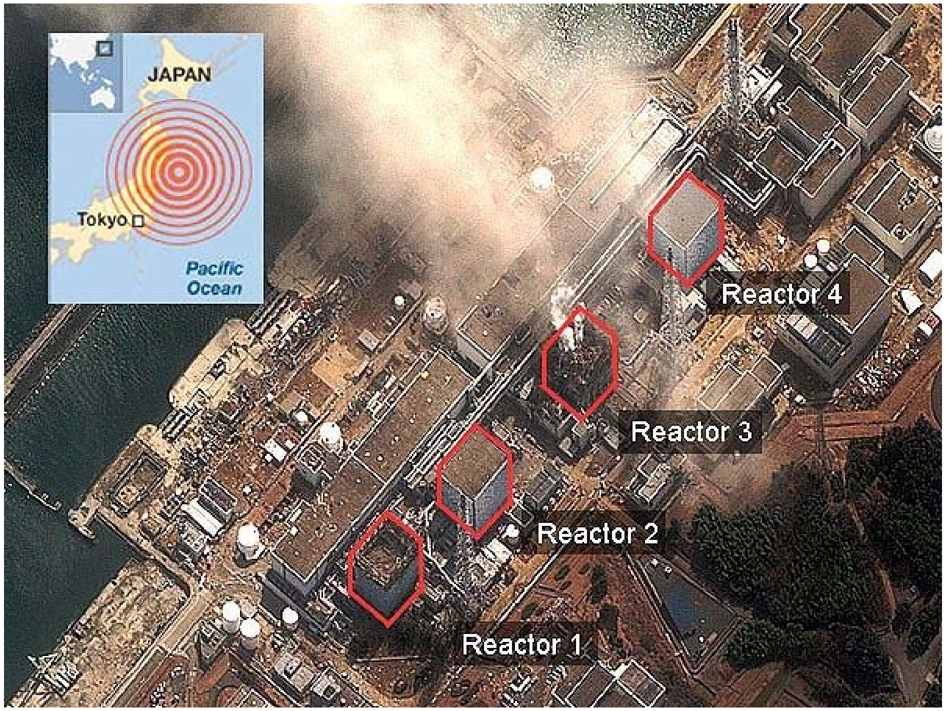
- High-level motion strategy are necessary
    - Optimal paths given constraints
    - Handling multiple robots for certain tasks
    - E.g., how can we efficiently assemble and disassemble the Boeing plane?

Our Research Directions

- High-level motion strategy are necessary
  - Optimal paths given constraints
  - Handling multiple robots for certain tasks
  - E.g., “Clean them!”

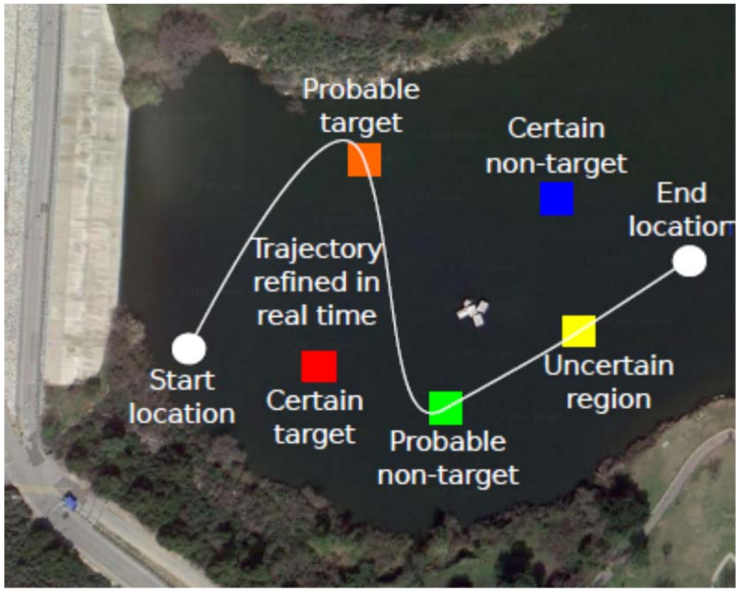
Our Research Directions

- High-level motion strategy are necessary
  - Optimal paths given constraints
  - Handling multiple robots for certain tasks
  - E.g., dangerous places for human



Task Search and Classification

- Identify and classify a number of initially unknown targets
  - Useful for tedious, dangerous, or impossible for humans (underwater, disaster sites, etc.)
  - How can effectively perform this process during limited deployment time?



Long-horizon Robotic Search and Classification using Sampling-based Motion Planning
Hollinger, et al.

Task Search and Classification

- **Environment (e.g., ocean) monitoring**

Different marine sensors, Smith et al.

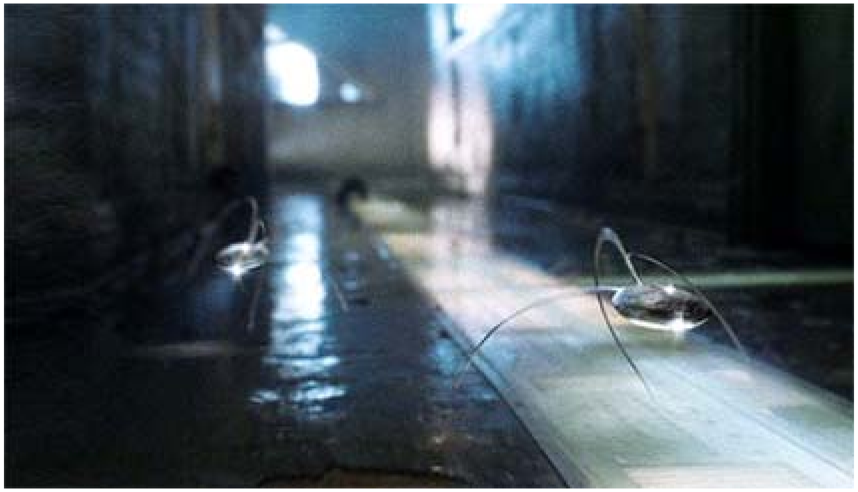
Use robotic sensor networks

- **each node can move autonomously or work with others**

King Harbor Marina
Redondo Beach Freewave Site

Marine sampling

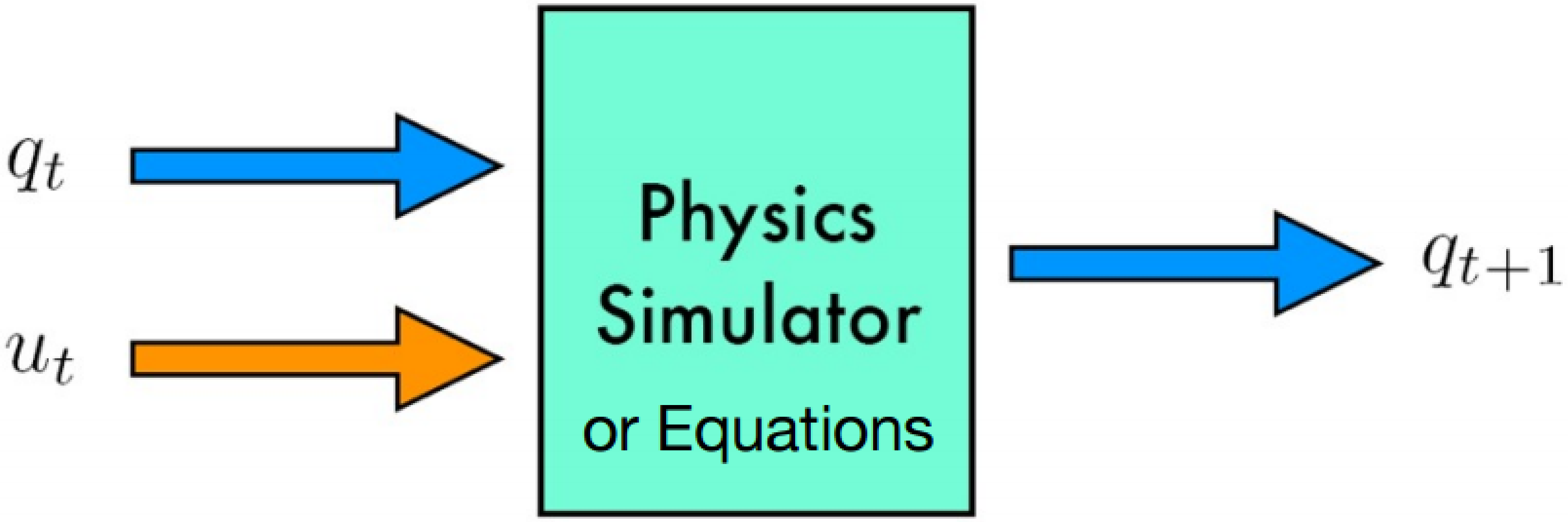
Minority Report



Planning with Dynamics

tribuneindia

Physical Systems Planning

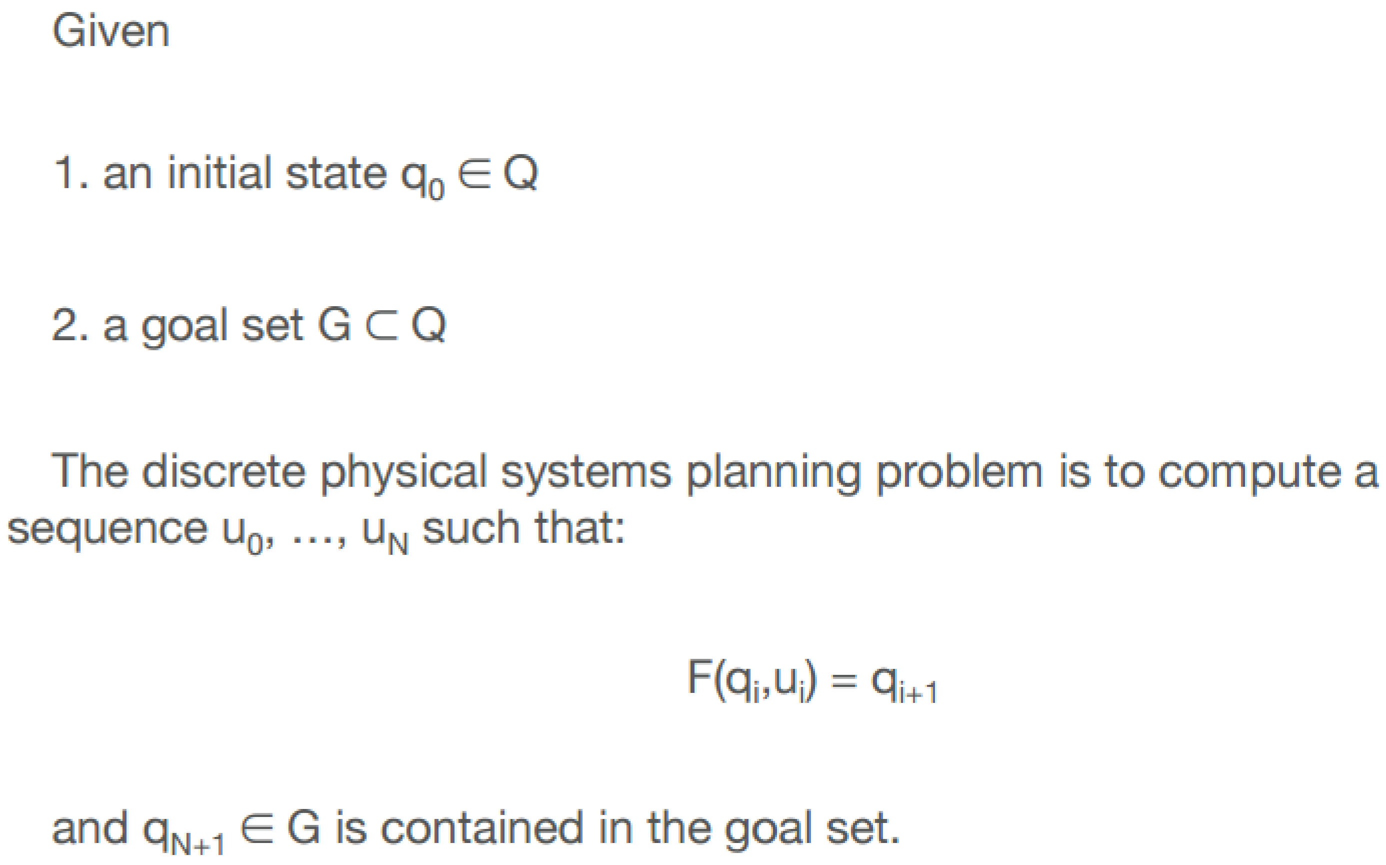


$$F(q_t, u_t) = q_{t+1}$$

Space of controls is defined

Kavraki

Physical System Planning



Given

1. an initial state $q_0 \in Q$

2. a goal set $G \subset Q$

The discrete physical systems planning problem is to compute a sequence $u_0, \ldots, u_N$ such that:

$$F(q_i,u_i) = q_{i+1}$$

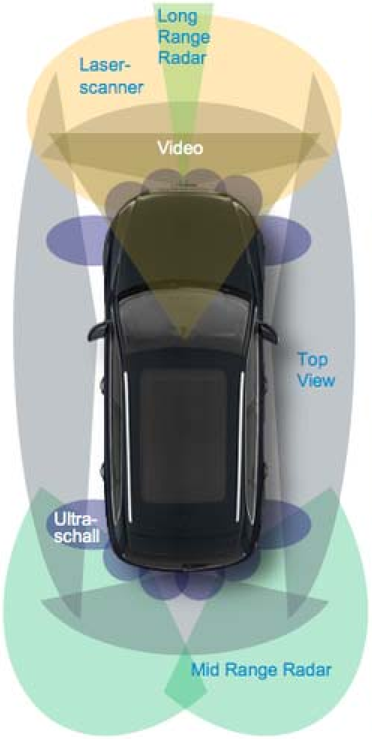
and $q_{N+1} \in G$ is contained in the goal set.

Planning with Dynamics

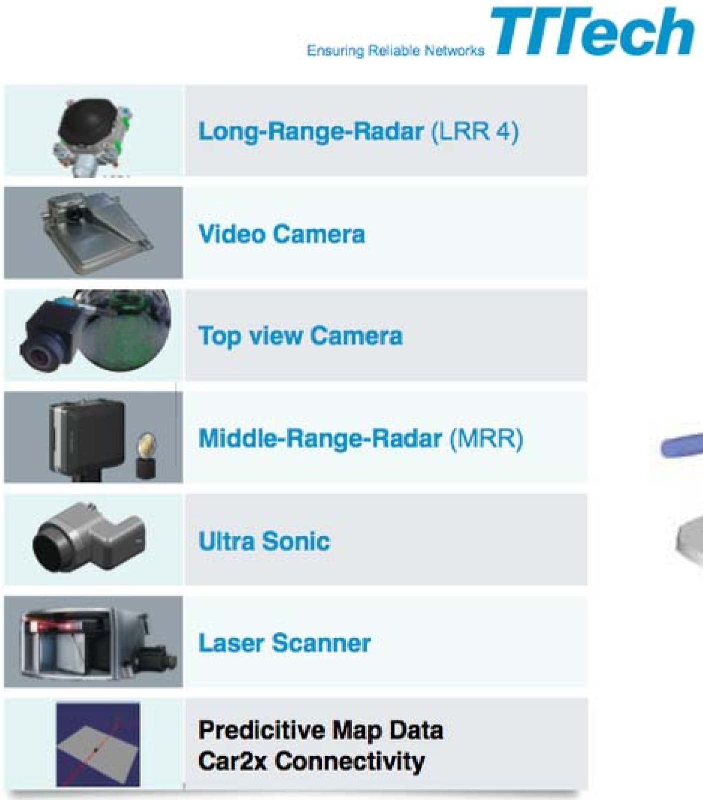
- Adding dynamics is essential to increase physical realism
- Techniques from control theory can be used to create better paths
- Still fairly open

Case Study: Self-Driving Cars

Typical systems of autonomous vehicles: many sensors and ECUs



Sensors



Ensuring Reliable Networks TTTech

Long-Range-Radar (LRR 4)

Video Camera

Top view Camera

Middle-Range-Radar (MRR)

Ultra Sonic

Laser Scanner

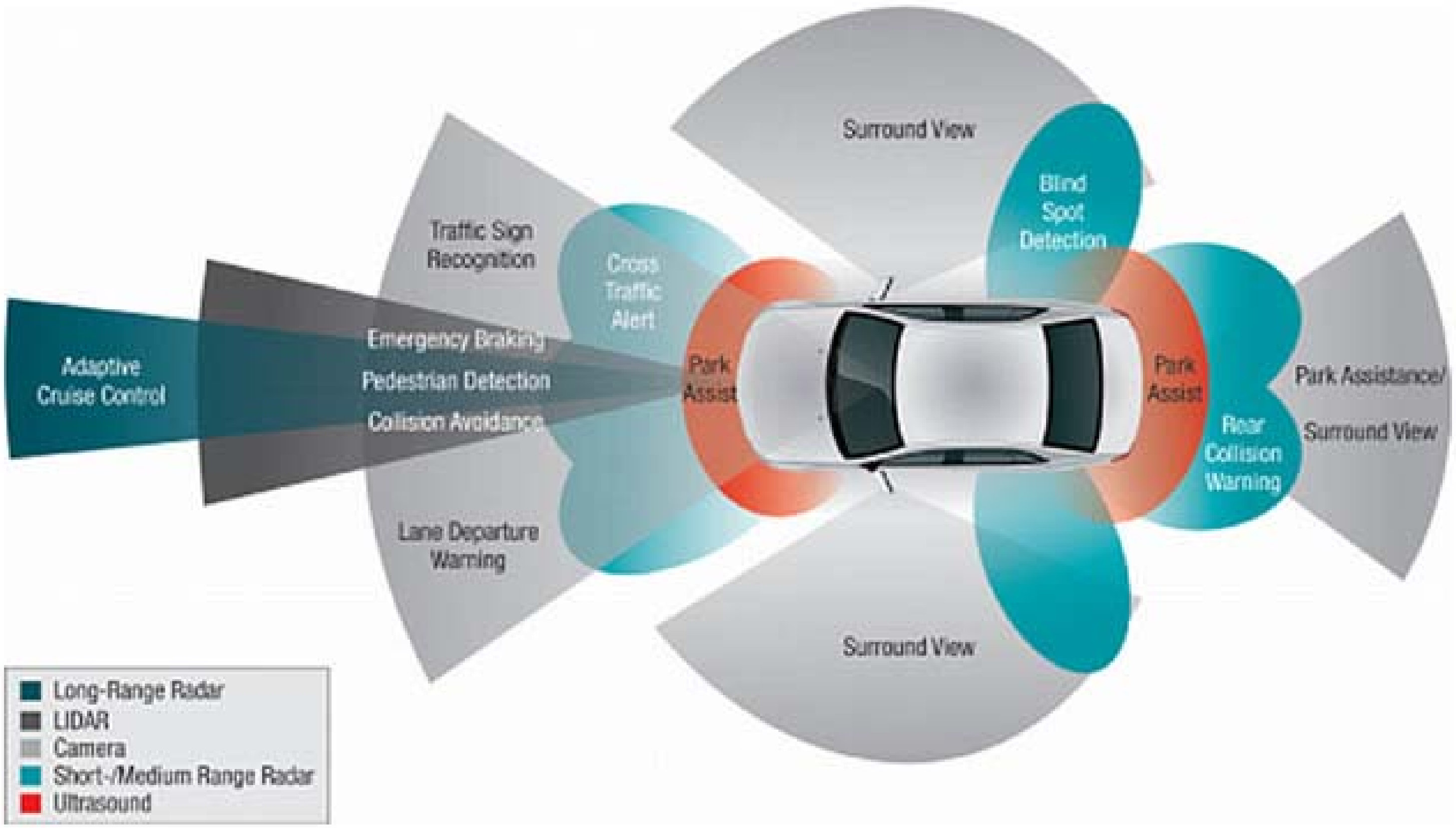
Predicitive Map Data
Car2x Connectivity

ECU
Actuator

Google images

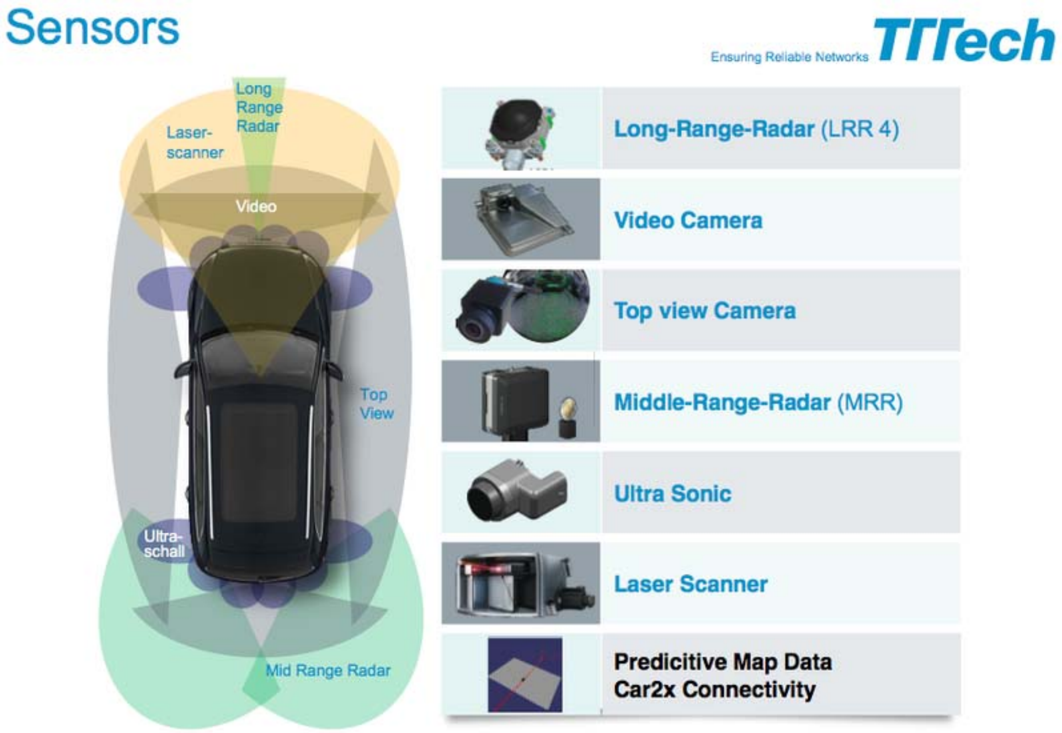
Plan of Development: Response to Plan

Evolve ADAS (Advanced Driver Assistance Systems) focusing on fast response to autonomous driving (high-level reasoning)



ADAS Sensors

- Need to identify lanes, pedestrians, traffic signs, other nearby cars
- Combine radar for detection and camera for recognition



Sensors

Ensuring Reliable Networks TTTech

Long-Range-Radar (LRR 4)

Video Camera

Top view Camera

Middle-Range-Radar (MRR)

Ultra Sonic

Laser Scanner

Predicitive Map Data
Car2x Connectivity

Technical Issues

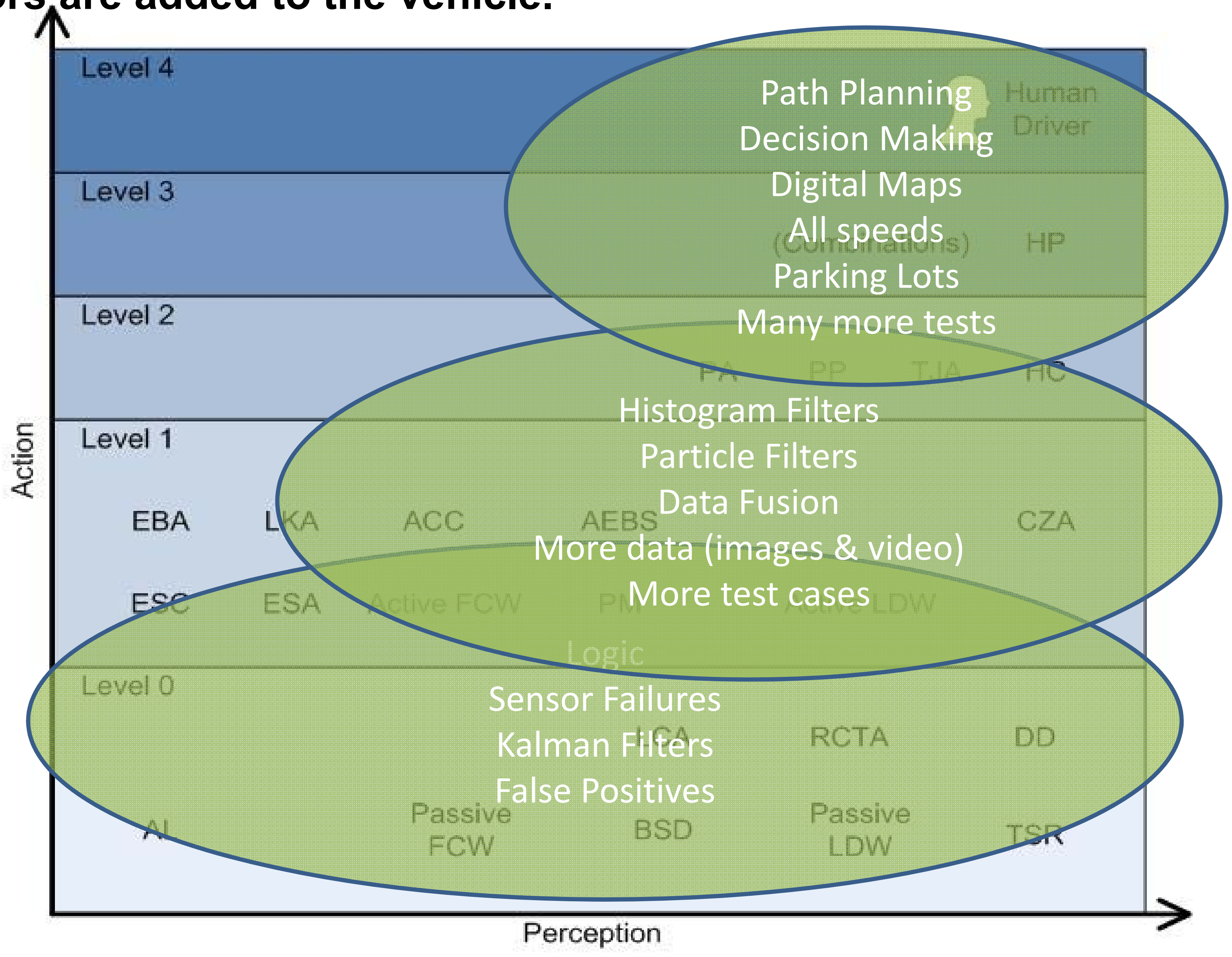
- **High accuracy**
  - **99.99% is not enough for detection and recognition problems (e.g., detecting red signs)**

- **Weather challenges**

Bob Donaldson / Post-Gazette

Testing & Certification

Testing becomes exponentially more complex as more sensors and actuators are added to the vehicle.



Path Planning
Decision Making
Digital Maps
All speeds
Parking Lots
Many more tests

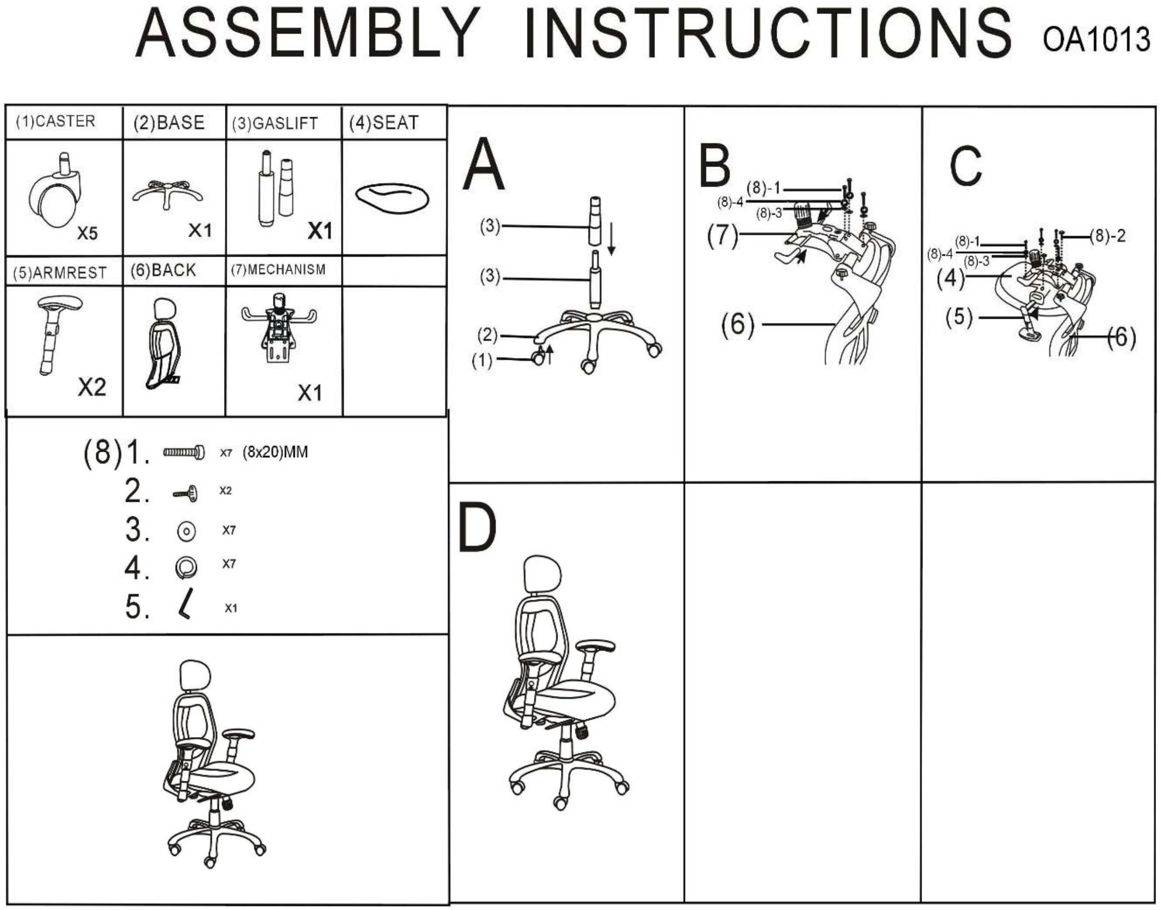
Histogram Filters
Particle Filters
Data Fusion
More data (images & video)
More test cases

Sensor Failures
Kalman Filters
False Positives

National Advanced Driving Simulator

Automated Planning w/ Motion Planning

- **Assemble the chair w/ or even w/o the instruction**



Task Planning

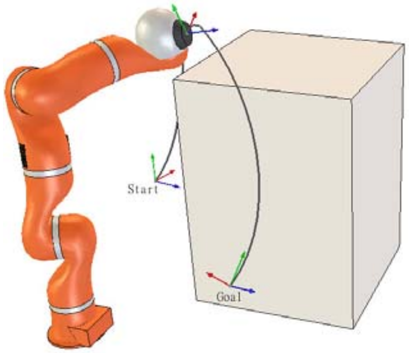
- Works on a high-level sequence of tasks
  - Commonly use motion planners

Slides are from Kang's work

E.g., Desk cleaning

Task and Motion Planning

- **Motion planner**
  - Find a collision-free path from a given start position to a goal position
- **Task planner**
  - Find a discrete sequence of actions to transition from a given start state to a desired goal state



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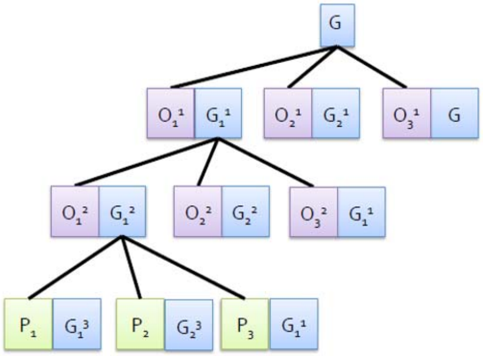

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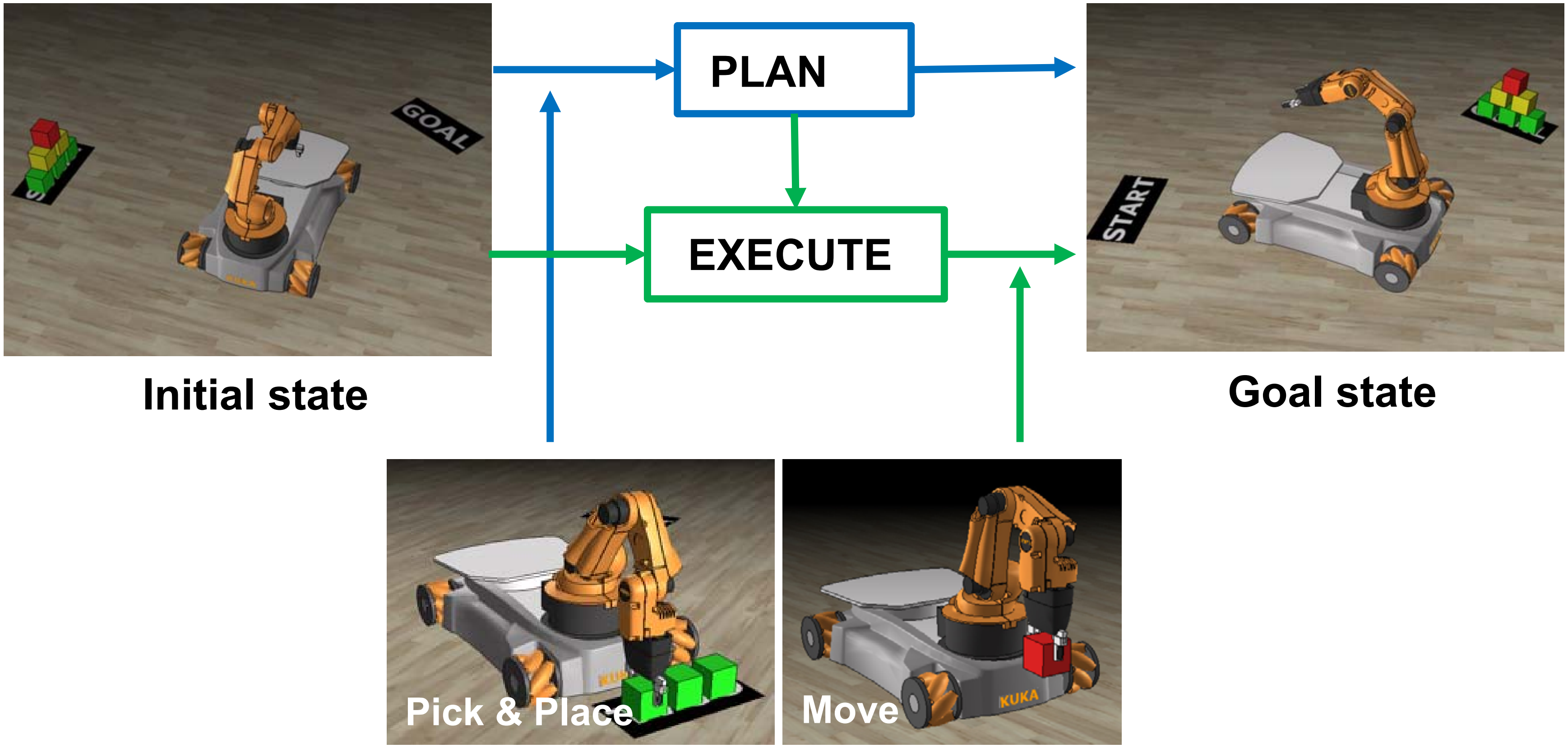
Overall Process of Task and Motion Planning



PLAN

EXECUTE

Initial state

Goal state

Pick & Place

Move

Motion primitives (Actions)

HPN

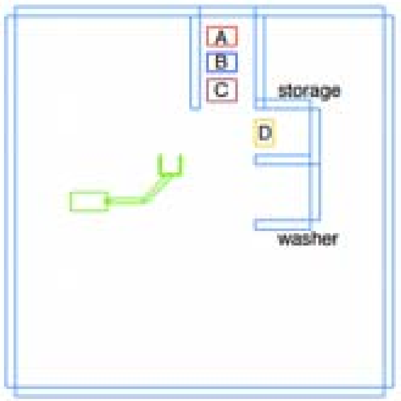
- Hierarchical task and motion Planning in the Now – [ICRA11]

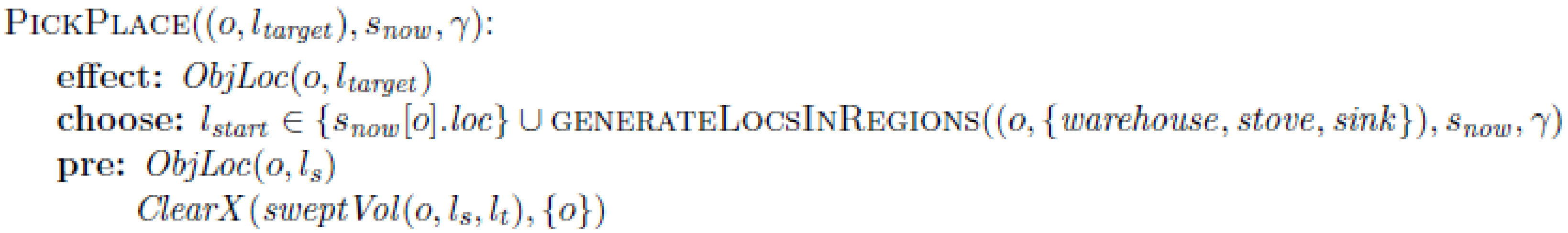
Large continuous and discrete state space

Long planning and execution horizon

HPN

- **Fluent : A set of symbolic predicates**
  - **In(O,R), ClearX(R, Os), Clean(O), …**
- **Operator : A set of primitive actions**
  - **Pick, Place, Wash, …**

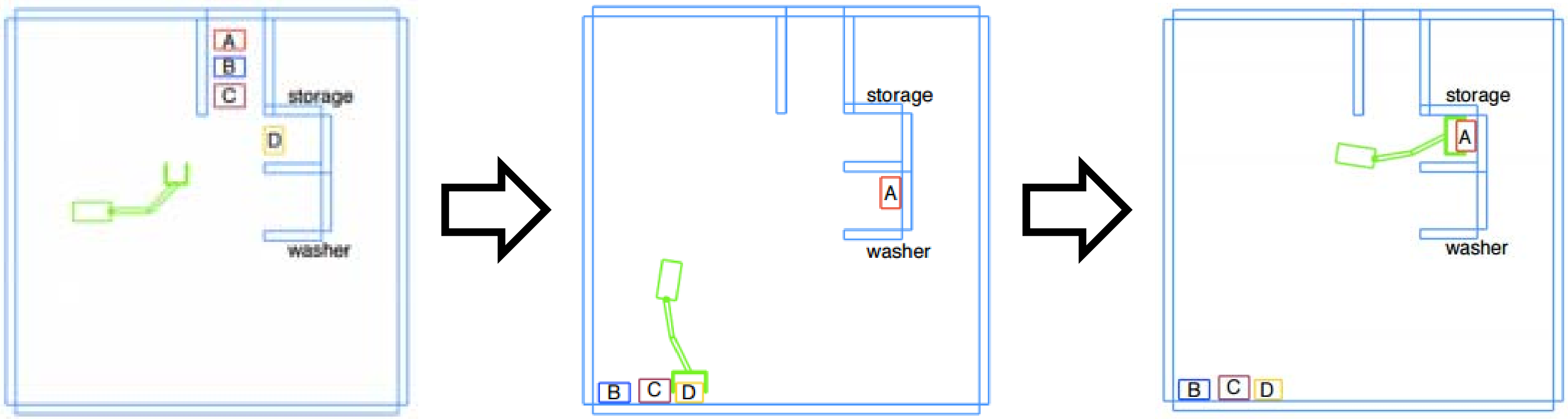




```
$\textsc{PickPlace}((o, l_{target}), s_{now}, \gamma)$:
    effect: $ObjLoc(o, l_{target})$
    choose: $l_{start} \in \{s_{now}[o].loc\} \cup \textsc{generateLocsInRegions}((o, \{warehouse, stove, sink\}), s_{now}, \gamma)$
    pre: $ObjLoc(o, l_s)$
         $ClearX(sweptVol(o, l_s, l_t), \{o\})$
```

Running Process of HPN

- Goal : In(A, storage), Clean(A)



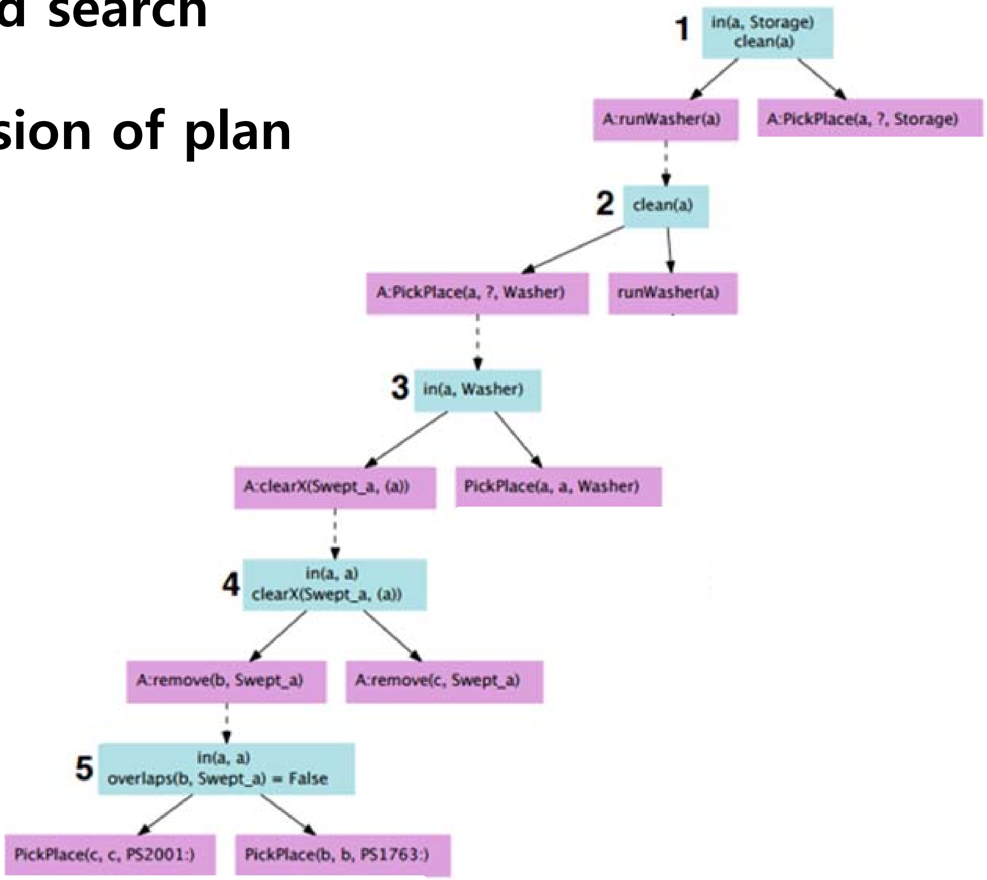
Initial state

Clean (A)

In(A, storage)
Clean(A)

Running Process of HPN

- Works in a backward search
- Maintain left expansion of plan tree



1 in(a, Storage) clean(a)

A:runWasher(a)

A:PickPlace(a, ?, Storage)

2 clean(a)

A:PickPlace(a, ?, Washer)

runWasher(a)

3 in(a, Washer)

A:clearX(Swept_a, (a))

PickPlace(a, a, Washer)

4 in(a, a) clearX(Swept_a, (a))

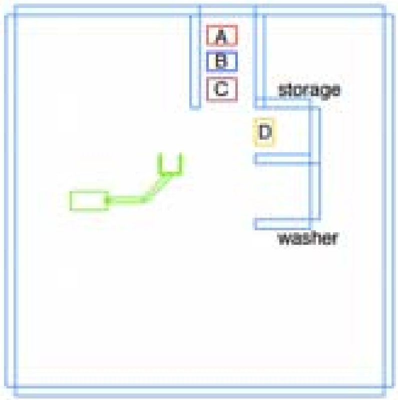
A:remove(b, Swept_a)

A:remove(c, Swept_a)

5 in(a, a) overlaps(b, Swept_a) = False

PickPlace(c, c, PS2001:)

PickPlace(b, b, PS1763:)



Class Objectives were:

- **Discussed my general research view on motion planning**
- **Discussed related applications**
- **Studied task planning**

Next Time..

- **RRT techniques**

Homework for Every Class

- Submit summaries of 2 ICRA/IROS/RSS/WAFR/TRO/IJRR papers
- Go over the next lecture slides
- Come up with one question on what we have discussed today and submit at the end of the class