MINIMALITY IN MULTI-ROBOT SYSTEMS

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Sunday
Partly Cloudy

120 °F | °C

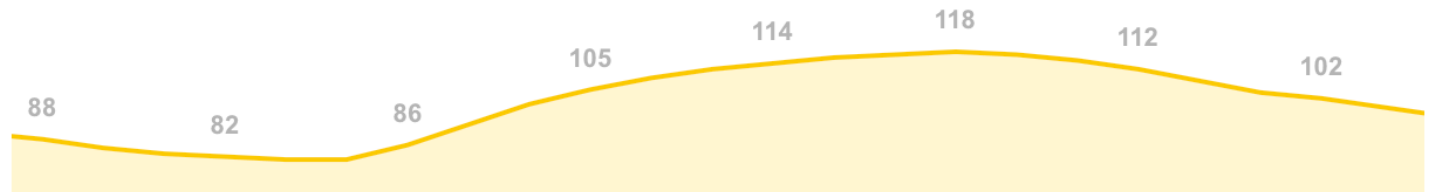Precipitation: 0%
Humidity: 5%
Wind: 10 mph

| Temperature | Precipitation | Wind |

88   82   86   105   114   118   112   102

| 2 AM | 5 AM | 8 AM | 11 AM | 2 PM | 5 PM | 8 PM | 11 PM |

Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu
102° 72°	107° 74°	113° 79°	120° 83°	119° 82°	114° 83°	115° 84°	114° 84°

Excessive Heat Warning

Central Arizona

9 hours ago – National Weather Service

remains in effect from 10 AM MST /10 AM pdt/ Sunday to 9 PM MST /9 PM pdt/ Wednesday ...
Temperature: highs Sunday and Monday of 115 to 120 degrees ... illness will be likely ...

**During AAAI 2016 in winter!**

Very Good

| View: | February ▼ | 2016 ⬍ |

7	8	9	10	11	12	13
Actual Temp	Actual Temp	Actual Temp	Actual Temp	Actual Temp	Actual Temp	Actual Temp
79° Lo 47°	85° Lo 50°	86° Lo 59°	86° Lo 54°	85° Lo 55°	87° Lo 55°	87° Lo 53°
Hist. Avg. 70° Lo 48°	Hist. Avg. 70° Lo 48°	Hist. Avg. 70° Lo 48°	Hist. Avg. 70° Lo 48°	Hist. Avg. 70° Lo 48°	Hist. Avg. 70° Lo 48°	Hist. Avg. 70° Lo 48°

14	15	16	17	18	19	20
Actual Temp	Actual Temp	Actual Temp	Actual Temp	Actual Temp	Actual Temp	Actual Temp
82° Lo 52°	85° Lo 52°	87° Lo 55°	90° Lo 57°	82° Lo 57°	81° Lo 59°	86° Lo 54°
Hist. Avg. 70° Lo 48°	Hist. Avg. 71° Lo 49°	Hist. Avg. 71° Lo 49°	Hist. Avg. 71° Lo 49°	Hist. Avg. 71° Lo 49°	Hist. Avg. 71° Lo 49°	Hist. Avg. 72° Lo 50°

Minimality in single-robot systems

Environment
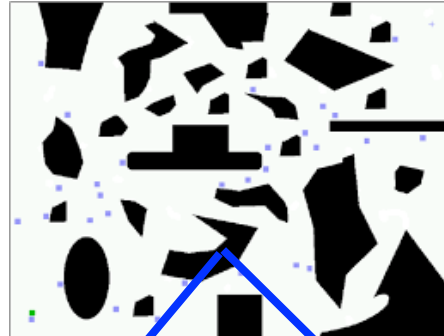
Design

Resource

Task

5 min   7 min   10 min

12 min
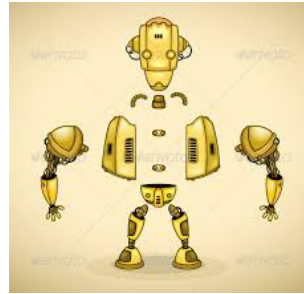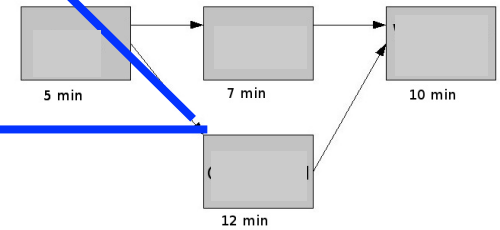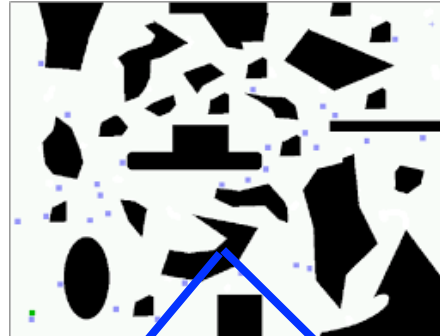
What is minimality in multi-robot systems?

Environment

> What is the minimal set of robots required for a task?

10 Turtlebot > 2 Baxter?
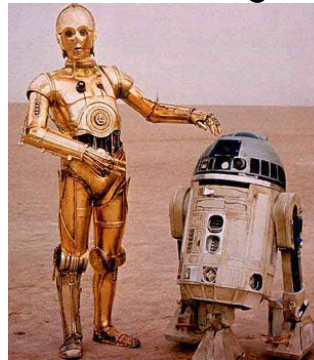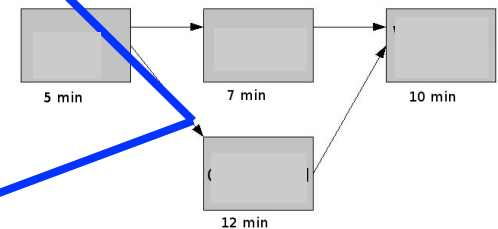Domain dependent

We won't tell you how we were built!

Modeling

Resource

State

Task

5 min 7 min 10 min

12 min

Important for task allocation and scheduling etc.

Today's outline

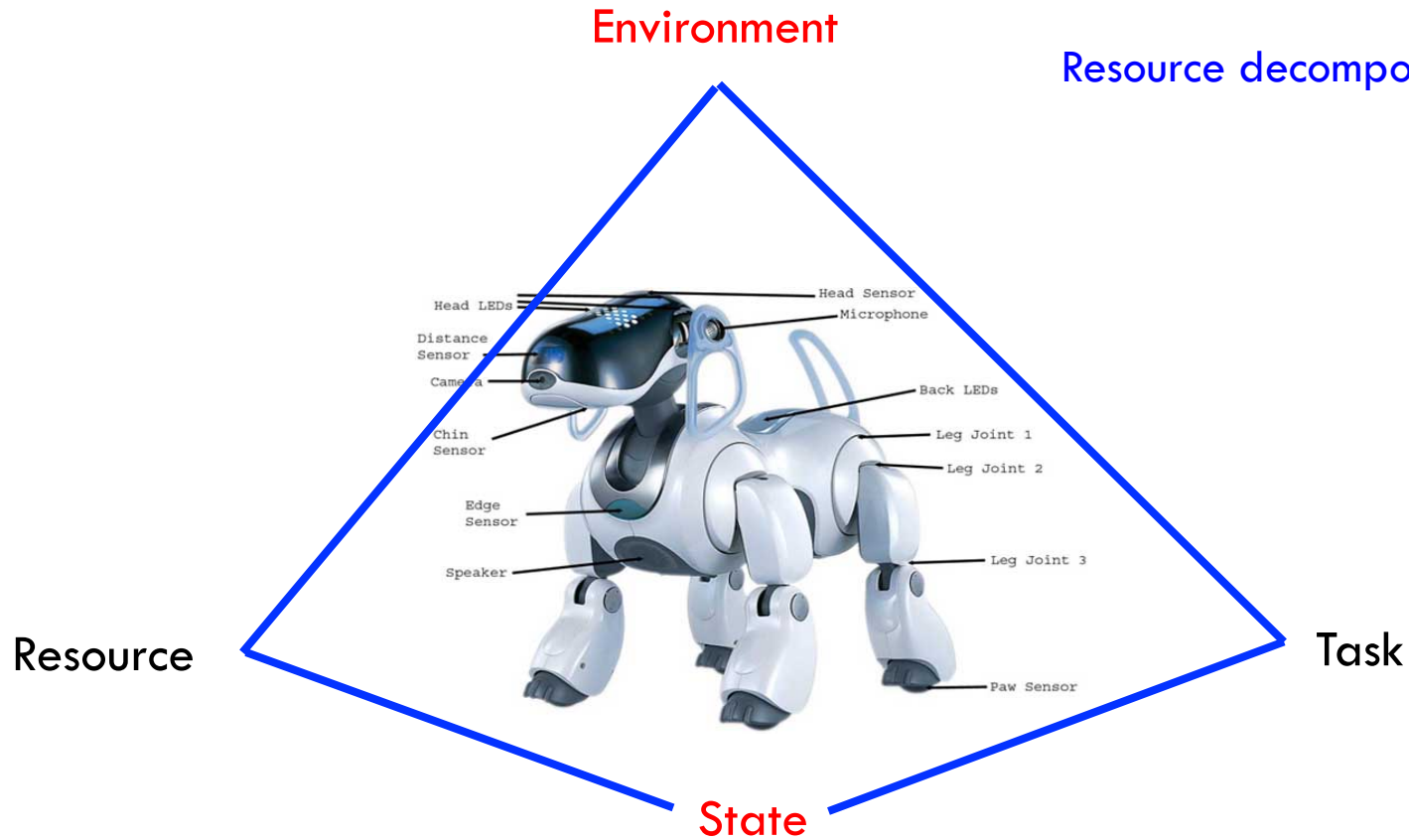What is the minimal set of robots required for a task?

1. Agent functional (capability) representation
    a. Resource, action, behavior based decompositions

2. Minimal set of robots for action based agent decomposition

3. Minimal set of robots for mixed agent decompositions

Today's outline
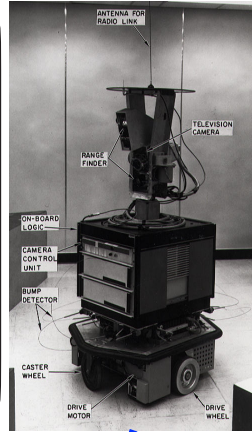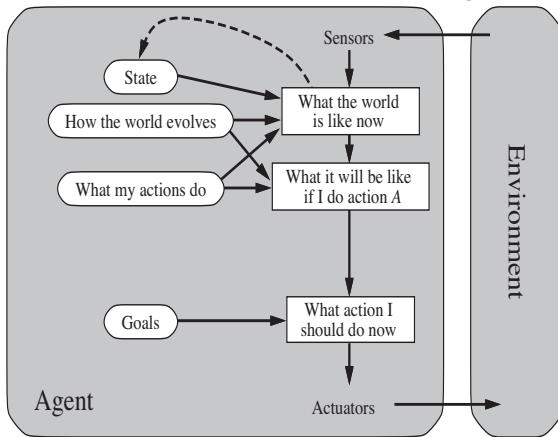
What is the minimal set of robots required for a task?

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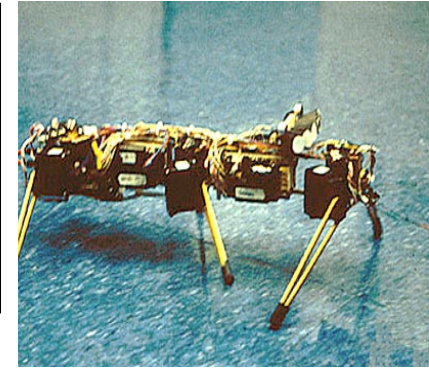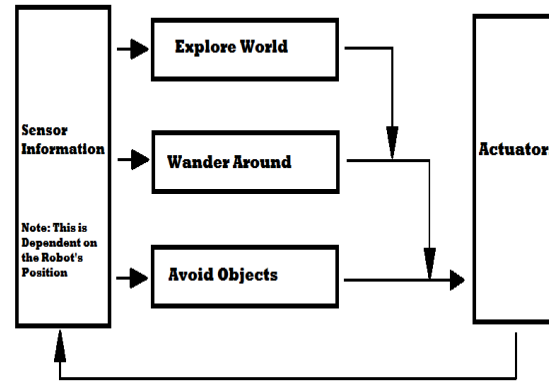
Resource based agent functional decomposition

Environment

Resource decomposition is static

Resource

Task

State

Action and behavior based agent functional decomposition

Proactive agent

Reactive agent

➢ Atomic: MDP/POMDP
➢ Factored: STRIPS, RDDL, HTN
  • World model
  • Non-local
  • Goal-oriented
  • Interpretable

Proactivity Level

➢ Subsumption
➢ Motor Schema based
  • Simplicity
  • Computationally tractable
  • Robust against failures
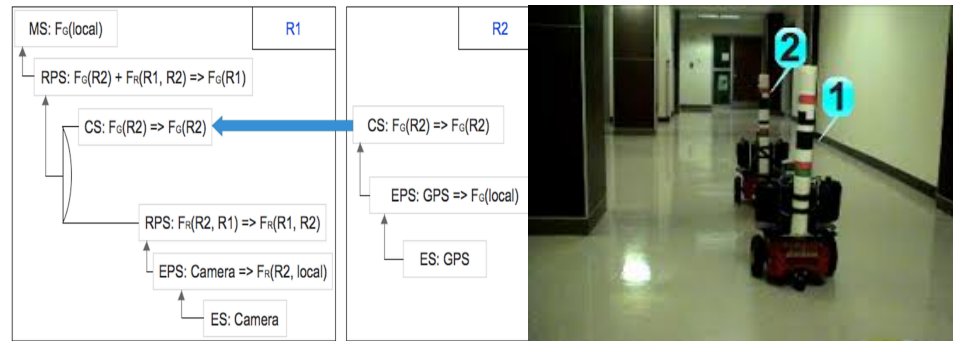
➢ Layered architecture
  • Automatic composition and flexible coordination
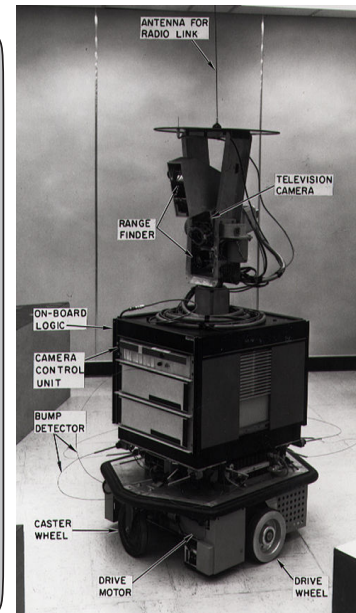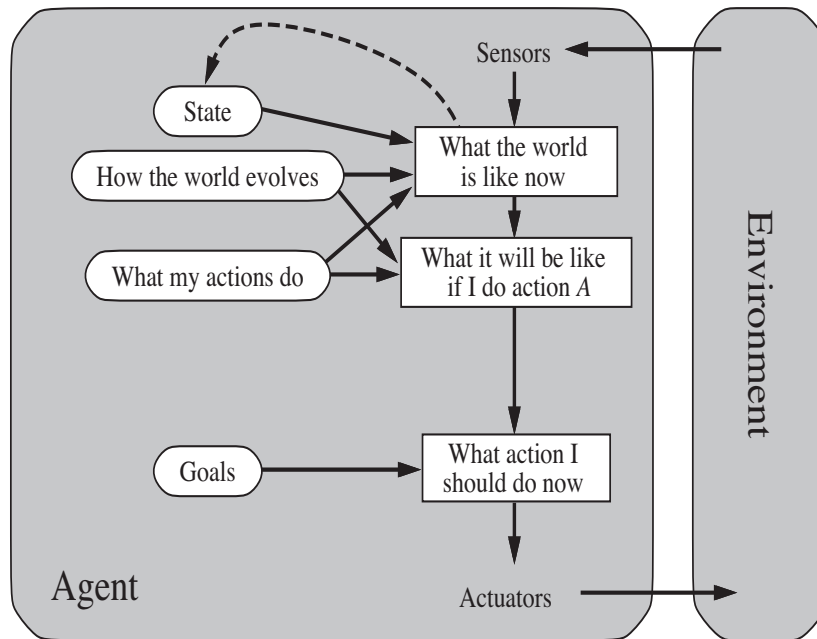 • Information sharing

Agent with mixed decompositions

Today's outline

What is the minimal set of robots required for a task?

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   a. Resource, action, behavior based decompositions

2. Minimal set of robots for action based agent decomposition

3. Minimal set of robots for mixed agent decompositions
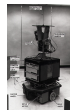
Action based agent decomposition

> Atomic: MDP/POMDP
> Factored: STRIPS, RDDL, HTN
>   • World model
>   • Non-local
>   • Goal-oriented
>   • Interpretable

Expensive representation
PSPACE-complete

> What is the minimal set of robots required for a task?

Simplifications:
• Sequential action
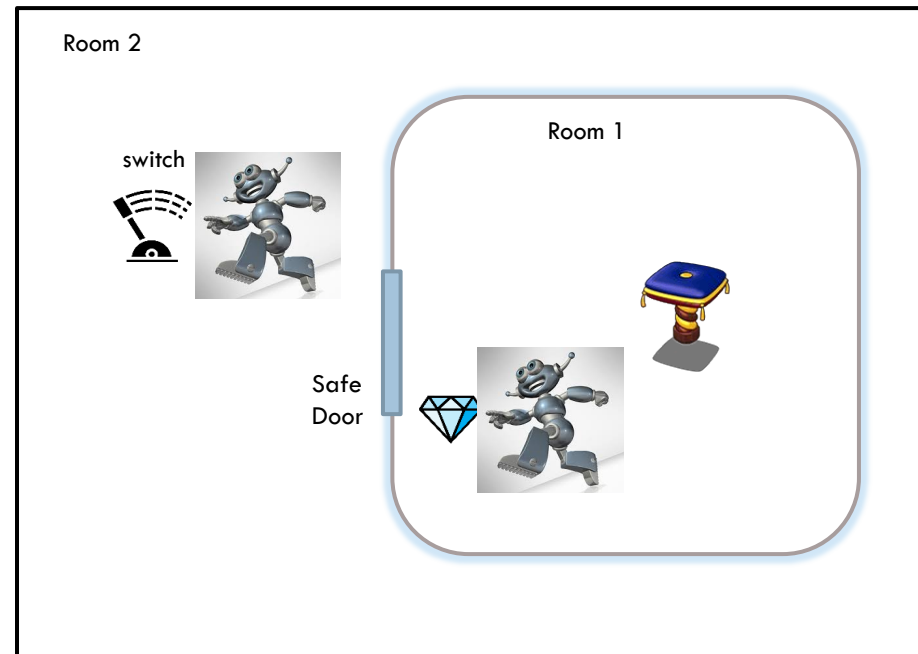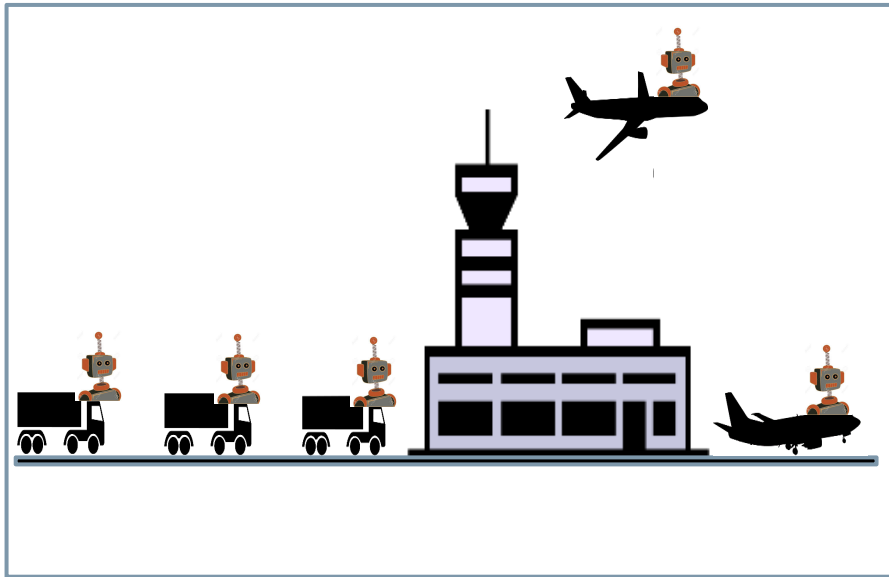• Instantaneous execution (~~deadline~~)

What causes required cooperation

➢ **What is the minimal set of robots required for a task?**

Simplifications:

- Sequential action
- Instantaneous execution

Room 2

Room 1

switch

Safe
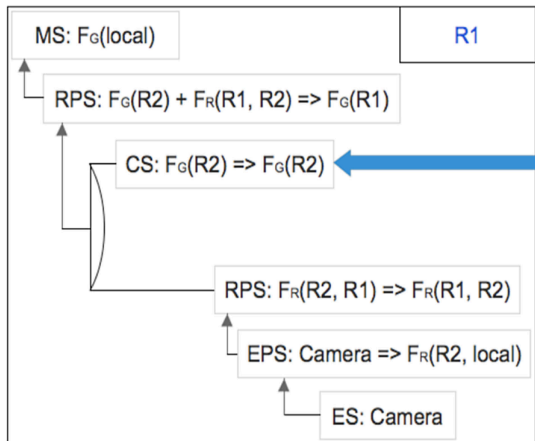Door

➢ **The analysis of the causes of required cooperation allows us to provide upper bounds**

Today's outline

What is the minimal set of robots required for a task?

1. Agent functional (capability) representation
    a. Resource, action, behavior based decompositions

2. Minimal set of robots for action based agent decomposition

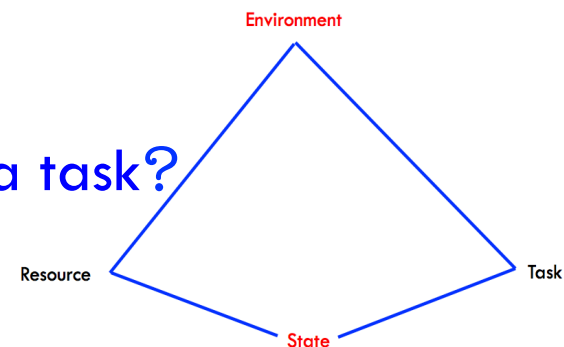3. Minimal set of robots for mixed agent decompositions

Agent with mixed decompositions

MS: F_G(local)	R1

$$RPS: F_G(R2) + F_R(R1, R2) \Rightarrow F_G(R1)$$

$$CS: F_G(R2) \Rightarrow F_G(R2)$$

$$RPS: F_R(R2, R1) \Rightarrow F_R(R1, R2)$$

$$EPS: Camera \Rightarrow F_R(R2, local)$$

ES: Camera

➢ Layered architecture,
  - Automatic composition and flexible coordination
  - Information sharing

E.g., IQ-ASyMTRe
Built upon motor schema based architecture

➢ **What is the minimal set of robots required for a task?**

No world model – environment and state must be considered based only on local information, which together forms a team quality measure

Combine local information to form team quality measure

E.g., coverage, uncertainty etc.

➢ Team quality measure provides answers in dynamic environment using only local information

Summary

What is the minimal set of robots required for a task?

1. Agent functional (capability) representation
   a. Resource, action, behavior based decompositions

2. Minimal set of robots for action based decomposition
   ➢ The analysis of the causes of required cooperation allows us to provide upper bounds

3. Minimal set of robots for mixed agent decomposition
   ➢ Team quality measure provides answers in dynamic environment using only local information