Chapter 1

Introduction

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Deliberative Acting

- **Action**: something an *actor* does to make a change in its environment
  - exert a force, make a motion
  - perceive something, communicate something

- **Deliberation** for acting:
  - *What* actions to perform to achieve an objective
  - *How* to perform those actions
Deliberative Acting

Deliberative acting can rely on

- *Innate* behavior – preprogrammed or evolved
- *Learned* behavior
- *Model-based* behavior

Study computational models and principles which permit an artificial *actor* to act deliberately

- *Understand* deliberative acting
- *Experiment* with deliberative actors
- *Develop technologies* that are socially useful
When is Deliberation Needed?

[Intuitive Surgical]

Not autonomous
When is Deliberation Needed?

- Needed when the actor is both
  - autonomous
  - versatile

Autonomous but not versatile

[Kiva Systems]
When is Deliberation Needed?

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When is Deliberation Needed?

- Needed when the actor is both
  - autonomous
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Conceptual View of an Actor

Actor

Deliberation functions

Execution platform

Commands

Percepts

Actuations

Signals

External World

Objectives

Messages

Other actors
Conceptual View of an Actor

Actor

Deliberation components

Planning

Queries

Acting

Plans

Commands

Percepts

Execution platform

Other actors

Objectives

Messages

Actuations

Signals

External World

Nau – Lecture slides for Automated Planning and Acting
Planning

- Synthesize an organized set of actions to achieve some purpose

- Relies on \textit{prediction} + \textit{search}
  - \textit{Descriptive models} of actions to predict their effects
  - Search over \textit{predicted states} and possible organizations of feasible actions

\begin{align*}
  s & \quad \xrightarrow{a} \quad s' = \gamma(s,a) \\
\end{align*}

\textit{predicted state}

\textbf{Function:} \\
Models $\times$ Problems $\rightarrow$ Plans
Planning

- Different types of actions =>
  - Different predictive models
  - Different planning problems and techniques

- Motion and manipulation planning
- Perception planning
- Navigation planning
- Communication planning
- Task planning

![Diagram of planning and acting components](attachment:planning_diagram.png)
Acting

- *How* to perform chosen actions
- Acting ≠ Execution
- Actor is situated in a dynamic unpredictable environment
  - Adapt actions to current context
  - React to events
- Relies on
  - *Operational models* of actions
  - Observations of *current state*
- Acting ≠ Planning

**Operational models**

- Plans → Acting → Output
- Input → Environment

*Transduction:*
Closed loop on I/O streams
General Characteristics

- **Multiple levels of abstraction**
  - Actors are organized into physical subsystems
  - Deliberation reflects this

- **Continual online planning**
  - Can’t plan everything in advance
  - Plans are abstract and partial until more detail is needed

- **Heterogeneous reasoning**
  - Different at different levels
  - Different components at the same level
## Example: the Key to Room 215

<table>
<thead>
<tr>
<th>Actions</th>
<th>Thoughts</th>
<th>Deliberation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dana Nau at a hotel in Italy, eating breakfast with Malik Ghallab</td>
<td>I have things to do before we go to Paolo’s office</td>
<td>Retrieve abstract plan</td>
</tr>
<tr>
<td>Dana left breakfast before Malik finished, went toward stairs</td>
<td>Is there enough time?</td>
<td>Evaluate roughly from past experience</td>
</tr>
<tr>
<td>Came back, said he had forgotten his room key, picked it up</td>
<td>Only if I go now</td>
<td>Refine plan into actions, and perform them</td>
</tr>
<tr>
<td>Went toward stairs, saw empty elevator, took it to his floor</td>
<td>What will I need to do?</td>
<td>Predictive simulation and monitoring</td>
</tr>
<tr>
<td></td>
<td>I’ll need my room key</td>
<td>Replan for error recovery</td>
</tr>
<tr>
<td></td>
<td>I left it on the table</td>
<td>Replan opportunistically</td>
</tr>
<tr>
<td></td>
<td>Go back and get it</td>
<td>Compare two plans, choose new one</td>
</tr>
<tr>
<td></td>
<td>Elevator is here now</td>
<td>Refine while executing</td>
</tr>
<tr>
<td></td>
<td>Can go up two floors faster than stairs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recover lost time</td>
<td></td>
</tr>
</tbody>
</table>
Multiple levels of abstraction
- Go to room upstairs
  - What route?
  - How to open the door?

Continual online planning
- Forgot room key, must replan
- Elevator is here now, is another plan better?

Heterogeneous reasoning
- Enough time for what I need to do?
- How to get to the stairwell?
- What to tell Malik when I go back for my key?
Example: Service Robot

- Activities for a service robot to perform
  - Multiple levels of abstraction
    - bring o7 to room2
    - open door
  - Multiple levels of abstraction
    - bring o7 to room2
      - abstract steps
    - open door
      - reactive
  - Continual online planning
    - Is o7 really in room1?
    - What kind of door?
    - Close enough to the doorknob?

- Multiple levels of abstraction
  - bring o7 to room2
  - open door
- Continual online planning
  - Is o7 really in room1?
  - What kind of door?
  - Close enough to the doorknob?

- Continual online planning
  - Is o7 really in room1?
Example: Harbor Management

- Harbor management system for importing/exporting cars
  - Based on Bremen Harbor
- Multiple levels of abstraction
  - Reflect physical organization of harbor
- Continual online planning
  - Top level can be planned offline
  - The rest is online, based on current conditions
- Heterogeneous reasoning
  - Different components work in different ways
  - Online synthesis of automata to control their interactions
Outline of Book

1: *Introduction* (this lecture)
2: Deliberation with *deterministic models*
   - Conventional (*classical*) AI planning
   - Integrating it with acting
3: Deliberation with *refinement methods*
   - Abstract activities → collections of less-abstract activities
   - Reactive execution, lookahead planning, combining them
4: Deliberation with *temporal models*
   - Reasoning about time constraints during planning and acting
5: Deliberation with *nondeterministic models*
   - Actions with multiple possible outcomes
6: Deliberation with *probabilistic models*
   - Multiple possible outcomes, with probabilities
7: *Other*: perceiving, monitoring, goal reasoning, learning, hybrid models, ontologies
Cover image: *The Conjuror*. Hieronymus Bosch (c.1450–1516)