WhatisPracticalReasoning?

• Practicalreasoningisreasoningdirectedtowards actions—theprocessoffiguringoutwhattodo:
  • Practicalreasoningisamatterofweighing conflictingconsiderationsforandagainst competingoptions,wheretherelevant considerationsareprovidedbywhattheagent desires/values/caresaboutandwhattheagent believes. (Bratman)

Distinguishpracticalreasoningfromtheoretical reasoning.

Theoreticalreasoningisdirectedtowardsbeliefs.

1. Intentionsposeproblemsforagents,whoneedto adopt anintention $\phi$ that was incompatible with $\psi$.
   • IfIhaveanintentionto$\phi$,youwouldnotexpectmeto
     intentions,whichmustnotconflict.
   2. Intentionsprovidea“filter”foradoptingother
     developresourcestodetermininghowtobringabout $\phi$.
     • IfIhaveanintentionto$\phi$,youwouldexpectmeto do
       determinewaysofachievingthat.

IntentionsinPracticalReasoning

1. IntentionsinPracticalReasoning

TheComponentsofPracticalReasoning

• Humanpracticalreasoningconsistsoftwoactivities:
  • Intentionsofdeliberationareplanningandreasoning.
  • Intentionsofmeans-endsreasoningareplans.
     - theoutputsofmeans-endsreasoningarethecriteria
       • decidinghowtoachievethese criteria of affairs.
     - theoutputsofdeliberationareintentions:
       • decidingwhatstateoffairswevanttoachieve.

TheComponentsofPracticalReasoning
Chapter 4: An Introduction to Multiagent Systems

3. Agents track the success of their intentions, and are inclined to try again if their attempts fail. If an agent's first attempt to achieve \( \phi \) fails, then all other things being equal, it will try an alternative plan. If an agent's first attempt to achieve \( \phi \) fails, then all other things being equal, it will try an alternative plan. If an agent's first attempt to achieve \( \phi \) fails, then all other things being equal, it will try an alternative plan. If an agent's first attempt to achieve \( \phi \) fails, then all other things being equal, it will try an alternative plan.

4. Intentions are stronger than desires. My desire to play basketball this afternoon is merely a potential influencer of my conduct, this afternoon. If I believe \( \phi \Rightarrow \psi \) and I intend that \( \phi \), I do not necessarily intend \( \psi \). (Intentions are not closed under implication.) This last problem is known as the side effect problem.

5. Agents need not intend all the expected side effects of their intentions. This is clearly illustrated by the example of going to the dentist. If I believe that going to the dentist involves pain, then I may believe that going to the dentist involves pain. If I believe that going to the dentist involves pain, then I may believe that going to the dentist involves pain. If I believe that going to the dentist involves pain, then I may believe that going to the dentist involves pain. If I believe that going to the dentist involves pain, then I may believe that going to the dentist involves pain.

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Planning is the design of a course of action that will achieve some desired goal. This is automatic programming.

Question: How do we represent...

- Plan itself:
- Representation of goal/intention to achieve;
- Representation of actions available to agent;
- State of environment;
- Action to be achieved.

We'll illustrate the techniques with reference to the blocks world.

- Contains a robot arm, 2 blocks (A and B) of equal size, and a table-top.
- We'll illustrate the techniques with reference to the blocksworld.
Chapter 4: An Introduction to Multiagent Systems

To represent this environment, need an ontology.

\[(x, y) \quad \text{obj} \quad (x, y) \quad \text{obj} \quad y \quad \text{on top of obj} \quad x\]

Here is a representation of the blocks world described above:

\[
\{\text{OnTable}(A), \text{OnTable}(B), \text{OnTable}(C)\}
\]

A goal is represented as a set of formulae.

A goal is assumed to be false.

Use the closed world assumption: anything not stated above is a representation of the blocks world described.

A goal is represented in the STRIPS representation.

Each action has:
- a name – which may have arguments;
- a delete list – list of facts that are no longer true after action is performed;
- a precondition list – list of facts which must be true for action to be executed;
- a name – which may have arguments;
- an add list – list of facts made true by executing the action.

Actions:

- \text{OnTable}(x)
- \text{On}(x, y)
- \text{Clear}(x)
- \text{Holding}(x)

To represent this environment, need an ontology.
• Example 1: The stack action occurs when the robot arm places the object $x$ it is holding is placed on top of object $y$.

```
Stack(x, y)
pre Clear(y) ∧ Holding(x)
del Clear(y) ∧ Holding(x)
add ArmEmpty ∧ On(x, y)
```

• Example 2: The unstack action occurs when the robot arm picks an object $x$ up from object $y$.

```
UnStack(x, y)
pre On(x, y) ∧ Clear(x) ∧ ArmEmpty
del On(x, y) ∧ Clear(x) ∧ ArmEmpty
add Holding(x) ∧ Clear(y) ∧ ArmEmpty
```

Stack and Unstack are inverses of one another.

• Example 3: The pickup action occurs when the arm picks up an object $x$ from the table.

```
Pickup(x)
pre Clear(x) ∧ OnTable(x) ∧ ArmEmpty
del OnTable(x) ∧ ArmEmpty
add Holding(x) ∧ Clear(x) ∧ ArmEmpty
```

• Example 4: The putdown action occurs when the arm places the object $x$ on the table.

```
PutDown(x)
pre Holding(x)
del Holding(x)
add Holding(x) ∧ ArmEmpty
```

The object $x$ it is holding is placed on top of another object $y$.

The **stack** action occurs when the robot arm places an object $x$ on top of another object $y$.

The **unstack** action occurs when the robot arm picks up an object $x$ from the table.

The **pickup** action occurs when the arm picks up an object $x$ from the table.

The **putdown** action occurs when the arm places the object $x$ on the table.
• What is a plan?

A sequence (list) of actions, with variables replaced by constants.

Problem: deliberation and means-ends reasoning processes are not instantaneous.

They have a time cost.

But the world may change.

• Problem: deliberation and means-ends reasoning processes are not instantaneous.

Let’s make the algorithm more formal.

\begin{verbatim}
I := !g! /* initial beliefs */
2. while true do
3. get next percept \( \rho \);
4. \( B := \text{brf}(B, \rho) \);
5. \( I := \text{deliberate}(B) \);
6. \( \pi := \text{plan}(B, I) \);
7. execute(\pi);
8. end while
\end{verbatim}

8. end while
7. execute(\pi)
6. !plan(!p!)
5. deliberate(!p!)
4. \( d, q = !p! \)
3. get next percept ?
2. while true do
1. !g! = g! /* initial beliefs */

Implementing Practical Reasoning Agents

A first pass at an implementation of a practical

Implemening Practical Reasoning Agents

end while
execute(\pi)
execute(\pi)
deliberate(\pi)
plan(\pi)
plan(\pi)
determine action which maximizes\( \Delta r \)
deck the internal world model
observe the world
while true
observe the world
end while
execute the plan
execute the plan
a plan for the information
use means-ends reasoning to get
a plan for the information
adapt the internal world model
adapt the internal world model

end while
end while
end while
end while
execute(\pi)
execute(\pi)
deliberate(\pi)
deliberate(\pi)
plan(\pi)
plan(\pi)
run(\pi)
run(\pi)
educa the plan
educa the plan

We will not be concerned with stages (2) or (3).
agent uses a **filter** function.

In order to select between competing options, an agent chooses between competing alternatives, and commits to achieving them.

The **deliberation** function can be decomposed into two distinct functional components:

- **Option Generation**
  - In which the agent generates a set of possible alternatives.
  - Represent option generation via a function, \( \text{options} \), which takes the agent's current beliefs and current intentions as inputs.

- **Filtering**
  - In which the agent chooses between competing alternatives, and commits to achieving them.
  - In order to select between competing options, an agent uses a **filter** function.

**Chosen options are then intentions.**
commitment become unachievable.

be dropped when nullified or impossible to achieve. By smashing the bottle, the
specifications, it keeps the commitments as long as required — commitments must
be abandoned as commitments. The robot replies that according to his
intended task, all the beer in the plan was introduced by a specific service so why
another appearance, it’s less keen on doing anything stupid. You ask, ‘If you
left the beer out here, you made a mistake, right?’, and as usual, you ask it to bring you
across the rear deck into your house. But as usual, you ask it to bring you
above a lack of commitment.

else: ‘Mister, you send the wees gy back to the manufactory, compounding
answers. Well, I intended to get you the bear, but decided to do something
Twenty minutes later you receive. ‘Mister, why didn’t you bring me that beer?’
household task. You say, ‘Mister, bring me a bear.’ The robot replies: ‘OK boss.
some time in the not-so-distant future, you are having trouble with your new

Undercommitment:

Commitment Strategies

Overcommitment:

And a wise guy:
Degrees of Commitment

- **Blind commitment**: A blindly committed agent will continue to maintain an intention until it believes the intention has actually been achieved. Blind commitment is sometimes referred to as **fanatical commitment**.
- **Single-minded commitment**: An agent has commitment both to ends (i.e., the state it wishes to achieve) and means (i.e., the means of achieving the ends it wishes to bring about). Currently, a single agent will continue to maintain an intention until it believes that either the intention has been achieved or else that it is no longer possible to achieve the intention.

Still overcommitted to intentions: Never stops to consider whether or not its intentions are appropriate.

Modification: Stop to determine whether intentions have succeeded or whether they are impossible.

An agent has commitment both to ends (i.e., the state it wishes to bring about) and means (i.e., the means of achieving the ends it wishes to bring about). Currently, a single agent will continue to maintain an intention until it believes that either the intention has been achieved or else that it is no longer possible to achieve the intention.

Modification: Replan if ever a plan goes wrong.

An agent's control loop is overcommitted, both to means and ends. Currently, our agent control loop is overcommitted, the state of affairs.

Single-minded commitment is also sometimes referred to as **fanatical commitment**.
2. \[ B \colon= B_0; \]
3. \[ I \colon= I_0; \]
4. while true do
5.   get next percept \( \rho \);
6.   \[ B \colon= \text{brf}(B, \rho); \]
7.   \[ D \colon= \text{options}(B, I); \]
8.   \[ I \colon= \text{filter}(B, D, I); \]
9.   \[ \pi \colon= \text{plan}(B, I); \]
10. while not \( \text{empty}(\pi) \) or succeeded \( I, B \) or impossible \( I, B \) do
11.     \[ \alpha \colon= \text{hd}(\pi); \]
12.     \[ \text{execute}(\alpha); \]
13.     \[ \pi \colon= \text{tail}(\pi); \]
14.     get next percept \( \rho \);
15.     \[ B \colon= \text{brf}(B, \rho); \]
16.     \[ D \colon= \text{options}(B, I); \]
17.     \[ I \colon= \text{filter}(B, D, I); \]
18.     if not sound \( \pi, I, B \) then
19.       \[ \pi \colon= \text{plan}(B, I); \]
20.     end-if
21. end-while
22. end-while

**Intention Reconsideration**

- An agent that constantly reconsider its intentions is costly.

**The Dilemma of Intention Reconsideration**

- But intention reconsideration is costly.

Every action

- Modification: Reconsider intentions after executing Reconside rits intentions.
- This is limited in the way that it permits an agent to
- If believes its current intentions are no longer
- If believes its current intentions are no longer
- If has completely executed a plan to achieve its
- Time around the outer control loop, i.e., when:

Our agent gets to reconsider its intentions once every
Controlling Intention Reconsideration

- Incorporate an explicit meta-level control component that decides whether or not to reconsider.

Optimal Intention Reconsideration

- Kinny and Georgeff's experimentally investigated effectiveness of intention reconsideration strategies.
- Two different types of reconsideration strategy used:
  - Bold agents never pause to reconsider intentions, and cautious agents stop to reconsider after every action.
- The possible interactions between meta-level control and deliberation are:

<table>
<thead>
<tr>
<th>Situation</th>
<th>Chosen?</th>
<th>Changed?</th>
<th>Would have reconsidered?</th>
<th>Meta-level control?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Stop</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Never</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Never</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

- Dynamism in the environment is represented by the rate of world change, $\gamma$.

- Kinny and Georgeff's experimentally investigated effectiveness of intention reconsideration strategies.
Results:

- If $\gamma$ is low (i.e., the environment does not change quickly), then bold agents do well compared to cautious ones. This is because cautious agents waste time reconsidering their commitments.

- If $\gamma$ is high (i.e., the environment changes frequently), then cautious agents tend to outperform bold agents. This is because they are able to recognize when intentions are doomed, and adapt to new situations before their goals are compromised.

Implemented BDI Agents: PRS

We now make the discussion more concrete by introducing an actual agent architecture: the PRS.

Example PRS (JAM) System

GOALS:

ACHIEVE blocks_stacked;

FACTS:

- //Block1 on Block2 initially needs to clear Block2 before stacking.
- FACT ON "Block1" "Block2";
- FACT ON "Block2" "Table";
- FACT ON "Block3" "Table";
- FACT CLEAR "Block1";
- FACT CLEAR "Block3";
- FACT CLEAR "Table";
- FACT initialized "False";
Plan:

NAME: "Top-level plan"

DOCUMENTATION:
"Establish Block 1 on Block 2 on Block 3."

GOAL:
ACHIEVE blocks_stacked;

CONTEXT:

BODY:
EXECUTE print "Goals: Block 1 on Block 2 on Block 3 on Table."
EXECUTE print "World Model at start is:

EXECUTE print World Model;
EXECUTE print "ACHIEVE:  ing Block 3 on Table."
ACHIEVEON "Block 3" "Table";
EXECUTE print "ACHIEVE:  ing Block 2 on Block 3."
ACHIEVEON "Block 2" "Block 3";
EXECUTE print "ACHIEVE:  ing Block 1 on Block 2."
ACHIEVEON "Block 1" "Block 2";
EXECUTE print "World Model at end is:

EXECUTE print World Model;"


Chapter 4 - An Introduction to Multiagent Systems

BDI Theory & Practice

• We now consider the semantics of BDI architectures:

  - BDI Logic

Belief goal compatibility:

\[ \text{Bel } \alpha \Rightarrow \text{Des } \alpha \]

Belief goal compatibility:

\[ \text{Bel } \alpha \Rightarrow \text{Des } \alpha \]

Let us now look at some possible axioms of BDI logic:

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\[ \text{Bel } \alpha \Rightarrow \text{Des } \alpha \]

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Chapter 4: An Introduction to Multiagent Systems

• Goal-intention compatibility:

\[
(\text{Int } \alpha) \Rightarrow (\text{Des } \alpha)
\]

States that having an intention to optionally achieve something implies having it as a goal (i.e., there are no intentions that are not goals).

Operationalized in the deliberate function:

\[
(\text{Des } \phi) \Rightarrow (\text{Bel (Des } \phi))
\]

\[
(\text{Int } \phi) \Rightarrow (\text{Bel (Int } \phi))
\]

Awareness of goals & intentions:

Operationalized in the execute function:

\[
(\text{Swim}(a)) \Rightarrow (\text{Bel (Swim}(a))
\]

If an agent does some action, then it is aware that it has done the action.

Volitional commitment:

If you intend to perform some action next, then you do it next.

\[
\text{int does}(a) \Leftrightarrow (a) \text{ does}(a)
\]

Events.

Requires that new intentions and goals be posted as:

\[
(\text{Des } \phi) \Rightarrow (\text{Bel (Des } \phi))
\]

\[
(\text{Int } \phi) \Rightarrow (\text{Bel (Int } \phi))
\]

No unconscious actions.

Awareness of goals & intentions:

Operationalized in the deliberate function:

\[
(\text{Des } \phi) \Rightarrow (\text{Bel (Des } \phi))
\]

\[
(\text{Int } \phi) \Rightarrow (\text{Bel (Int } \phi))
\]

ACTIONS that are not goals.

Operationalized in the deliberate function:

\[
(\text{Des } \phi) \Rightarrow (\text{Bel (Des } \phi))
\]

\[
(\text{Int } \phi) \Rightarrow (\text{Bel (Int } \phi))
\]

Volitional commitment:

If an agent does some action, then it is aware that it has done the action.

\[
\text{done}(a) \Rightarrow (\text{Bel (done}(a))
\]

No unconscious actions.
else drop it.

An agent will eventually either act for an intention, or

\[ \text{Int} \phi \Leftrightarrow \text{Act} \phi \]

No infinite deferral.