Practical reasoning is reasoning directed towards actions—the process of figuring out what to do.

A. If an agent's first attempt to achieve fails, then all other attempts fail.
B. Practical reasoning involves the process of weighing conflicting considerations against competing options.
C. The relevant considerations are provided by what the agent desires/values/cares about and what the agent believes.
D. Practical reasoning is a matter of weighing conflicting considerations to determine the best course of action.


distinguish practical reasoning from theoretical reasoning.

Theoretical reasoning is directed towards beliefs.

Practical reasoning is directed towards actions.

Practical reasoning involves making decisions based on the agent's desires, values, and beliefs.

Theoretical reasoning involves making decisions based on the agent's beliefs about the world.

Practical reasoning is about what to do, whereas theoretical reasoning is about what is.

1. Intentions in Practical Reasoning

1. Intentions pose problems for agents, who need to determine ways of achieving them.
2. Intentions provide a "filter" for adopting other intentions, which must not conflict.
3. The output of deliberation are intentions.

2. Intentions in Practical Reasoning

1. If I have an intention to φ, you would expect me to adopt an action that achieves φ.
2. If I have an intention to φ, you would expect me to adopt an action that achieves φ.
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Planning has been well-developed.

Planning algorithms have been proposed, and the theory of planning largely on the early work of Fikes & Nilsson, many

any artificial agent.

some form of AI planning system will be a central component of

within the symbolic AI community, it has long been assumed that

of course of action that will achieve some desired goal.

Planning is essentially automatic programming: the design of a

closely concerned with the design of artificial agents.

Since the early 1970s, the AI planning community has been

2.1 Planning agents

Lecture 4

An Introduction to Multiagent Systems

Noticing that intentions are much stronger than mere desires:

My desire to play basketball this afternoon is merely a

http://www.csc.liv.ac.uk/~mjw/pubs/imas/

He Sims, 1990

If as an intention, you make sense that if I believe I would adopt

would not normally be rational of me to believe that I would

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Under certain circumstances, agents believe they will bring about

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checking that each of these side effects of their

Agents need not intend all the expected side effects of their

implies that I intend to suffer pain — and I may also intend to go to the dentist — but this does not

This last problem is known as the side effect of packaged deal

If I believe φ and I intend that φ, I do not necessarily intend

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What is Means-Ends Reasoning?

Basic idea is to give an agent:

- representation of goal/intention to achieve;
- representation of environment;
- representation of actions it can perform;
- to generate a plan to achieve the goal.

Essentially, this is automatic programming.

We'll illustrate the techniques with reference to the blocks world.
Each of these may contain variables: 

- an add list: list of facts made true by executing the action.
- 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.

Each action has:

• a name

The STRIPS planner:

Actions are represented using a technique that was developed in the STRIPS planner.

A goal is represented as a set of formulae.

Use the closed world assumption: anything not stated is assumed to be false.

Here is a representation of the blocks world described above:

\{ \text{onTable}(A'), \text{onTable}(B'), \text{onTable}(C) \}

\text{Holding}(x) \quad \text{Clean}(x) \quad \text{OnTable}(x) \quad \text{OnTopOf}(x, y) \quad \text{On}(x, y) \quad \text{Clear}(x) \quad \text{OnTable}(x) \quad \text{OnTopOf}(x, y) \quad \text{Clean}(x)

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

\[
\begin{align*}
\text{Stack} &\quad x &\quad y \\
\text{pre} &\quad \text{Clear} &\quad \text{Holding} \\
\text{del} &\quad \text{Clear} &\quad \text{Holding} \\
\text{add} &\quad \text{ArmEmpty} &\quad \text{On} &\quad x &\quad y
\end{align*}
\]

Example 2:
The unstack action occurs when the robot arm picks an object up from on top of another object.

\[
\begin{align*}
\text{UnStack} &\quad x &\quad y \\
\text{pre} &\quad \text{On} &\quad \text{Clear} &\quad \text{ArmEmpty} \\
\text{del} &\quad \text{On} &\quad \text{Clear} &\quad \text{ArmEmpty} \\
\text{add} &\quad \text{Holding} &\quad \text{Clear} &\quad \text{ArmEmpty}
\end{align*}
\]

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

\[
\begin{align*}
\text{Pickup} &\quad x \\
\text{pre} &\quad \text{Clear} &\quad \text{OnTable} &\quad \text{ArmEmpty} \\
\text{del} &\quad \text{OnTable} &\quad \text{ArmEmpty} \\
\text{add} &\quad \text{Holding} &\quad \text{Clear}
\end{align*}
\]

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

\[
\begin{align*}
\text{PutDown} &\quad x \\
\text{pre} &\quad \text{Holding} \\
\text{del} &\quad \text{Holding} \\
\text{add} &\quad \text{Holding}
\end{align*}
\]
Lecture 4: An Introduction to Multiagent Systems

What is a plan?
A sequence (list) of actions, with variables replaced by constants.

We will not be concerned with stages (2) or (3).

Implementing Practical Reasoning Agents

Agent Control Loop Version 1
1. while true
2. observe the world;
3. update internal world model;
4. deliberate about what intention to achieve next;
5. generate a plan for the intention;
6. execute the plan;
7. endwhile

(We will not be concerned with stages (2) or (3).)

Further suppose that deliberation is optimal in that if it selects some intention to achieve, then this is the best thing for the agent. (Maximises expected utility.)

So at time $t$, the agent has selected an intention to achieve that would have been optimal if it had been achieved at $t$.

But unless deliberation is vanishingly small, then the agent runs the risk that the intention selected is no longer optimal by the time the agent has fixed upon it.

This is calculative rationality.

Deliberation is only half of the problem: the agent still has to determine how to achieve the intention.

Problem: deliberation and means-ends reasoning processes are not instantaneous. They have a time cost.

Suppose the agent starts deliberating at $t_0$, begins means-ends reasoning at $t_1$, and begins executing the plan at time $t_2$.

Time to deliberate is $t_{deliberation} = t_1 - t_0$

Time for means-ends reasoning is $t_{means} = t_2 - t_1$
So, this agent will have overall optimal behavior in the following circumstances:

1. When deliberation and means-ends reasoning take a vanishingly small amount of time.
2. When the world is guaranteed to remain static while the agent is deliberating and performing means-ends reasoning, so that the assumptions upon which the choice of intention is based are not invalidated.
3. When an intention that is optimal when achieved at time \( t \) remains optimal until \( t \) is guaranteed to remain static while the agent is deliberating and performing means-ends reasoning.
4. When the world is guaranteed to remain static while the agent is deliberating and performing means-ends reasoning.

5. When an action to achieve the intention has remained optimal until \( t \) (the time at which the agent has found a course of action to achieve the intention).

Let's make the algorithm more formal.

```
Agent Control Loop Version 2
1. B; /* initial beliefs */
2. while true do
3. get next percept P;
4. if \( \neg P \) then exit;
5. B \( \leftarrow \) beliefnet;
6. I \( \leftarrow \) deliberate \( B \);
7. plan \( B \leftarrow I \);
8. execute \( B \); /* external */
9. end while
```

Functional components:

- Deliberation function can be decomposed into two distinct

Chosen options are then intentions.

- Choose between them and commit to some.
- You are:
  - begin by trying to understand what the options available to
  - How does an agent deliberate?

S Deliberation
Commitment Strategies

The following commitment strategies are commonly discussed in the literature of rational agents:

- **Blind Commitment**: A blindly committed agent will continue to maintain an intention as long as it believes that the intention has been achieved, or until it believes that it is no longer possible to achieve the intention.

- **Single-Minded Commitment**: A single-minded agent will continue to maintain an intention until it believes that the intention has actually been achieved.

- **Open-Minded Commitment**: An open-minded agent will maintain an intention as long as it believes that it is still possible to achieve the intention.

- **General Commitment**: Blind commitment is also sometimes referred to as 'fanatical commitment'.

An agent has commitment both to ends (i.e., the state of affairs it wishes to achieve) and means (i.e., the mechanism via which the agent wishes to achieve the state of affairs). Currently, our agent control loop is overcommitted, both to ends and means.

Modification: replan if ever a plan goes wrong.

An open-ended agent will maintain an intention as long as it believes that it is no longer possible to achieve the intention.

An open-ended agent will continue to maintain an intention until it believes that the intention has been achieved, or until it believes that it is no longer possible to achieve the intention.
7 Intention Reconsideration

Our agent gets to reconsider its intentions once every time around the outer control loop, i.e., when:

- it has completely executed a plan to achieve its current intentions;
- it believes it has achieved its current intentions or intentions it has completely executed a plan to achieve its current intentions;
- it believes its current intentions are no longer possible.

This is limited in the way that it permits an agent to reconsider its intentions. Modification: reconsider intentions after executing every action.
Butintentionreconsiderationis costly! Adilemma: – anagentthatdoesnotstoptoreconsideritsintentions sufficientlyoftenwillcontinueattemptingtoachieveits intentionsevenafteritisclearthattheycannotbeachieved, or thatthereisno longer any reason for achieving them; – an agentthat does not stop to reconsider its intentions sufficiently often will continue attempting to achieve its intentions even after it is clear that they cannot be achieved.

Solution: incorporate an explicit meta-level control component, thatdecides whetheror not to reconsider. The possibleinteractions between meta-level control and deliberation are:

<table>
<thead>
<tr>
<th>Situation Chosen</th>
<th>Changed Would Have</th>
<th>Number Deliberated? Intention? Changed Intentions? Optimal?</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

A dilemma: Butintentionreconsiderationiscostly!
In Situation (1), the agent did not choose to deliberate, and as a consequence, did not choose to change intentions. Moreover, if it had chosen to deliberate, it would not have changed intentions. In this situation, the reconsider function is behaving optimally.

In Situation (2), the agent chooses to deliberate. If it would have changed intentions, it would have done so. If it would not have changed intentions, and it has chosen to deliberate, it is behaving optimally. In this situation, the reconsider function is behaving optimally.

In Situation (3), the agent did not choose to deliberate, and as a consequence, did not choose to change intentions. Moreover, if it had chosen to deliberate, it would not have changed intentions. In this situation, the reconsider function is behaving optimally.

In Situation (4), the agent chooses to deliberate. If it would have changed intentions, it would have done so. If it would not have changed intentions, and it has chosen to deliberate, it is behaving optimally. In this situation, the reconsider function is behaving optimally.

In Situation (5), the agent chooses to deliberate. If it would have changed intentions, it would have done so. If it would not have changed intentions, and it has chosen to deliberate, it is behaving optimally. In this situation, the reconsider function is behaving optimally.
From classical logic:

- \( \phi \) be an arbitrary formula.
- \( \psi \) be an \( \omega \)-formula, i.e., one which contains no possible
  occurrences of \( \Box \).

Let us now look at some possible axioms of BDI logic, and see to
what extent the BDI architecture could be said to satisfy these
axioms.

In what follows, let

- \( \phi \) be an arbitrary formula.
- \( \psi \) be an \( \omega \)-formula, i.e., one which contains no possible
  occurrences of \( \Box \).

\( \Diamond \phi \) must be \( \phi \).

\( \Box \psi \) must be \( \psi \).

Semantic of BDI components are given via accessibility
relations over 'worlds', where each world is like a branching
semantics of D-1 components are given via accessibility
relations over worlds, where each world is like a branching
structure.

Properties required of accessibility relations ensure belief logic
infinite.

Belief goal compatibility:

- States that if the agent has a goal to optionally achieve
  something, then it must be an option.

This axiom is operationalized in the function
\( \Delta \text{options} \): an option should not be produced if it is not believed possible.

Goal-intention compatibility:

- States that if the agent has an intention to optionally achieve
  something, then it must be a goal to optionally achieve

\( \Delta \text{goals} \) (\( \Box \phi \)).
Volitional commitment: agents will believe goals.

If you intend to perform some action \(a\) next, then you do \(a\) next.

Operationalized in the execute function.

Voluntary commitment:

\[
\text{if } \text{does}(a) \text{ next, then you do } a \text{ next.}
\]
1. We now make the discussion even more concrete by introducing 12 Implemented BDI Agents: PRS.

2. In addition, PRS agents have explicit representations of beliefs.

3. The options available to an agent are directly determined by the realism of its beliefs.

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5. In addition, PRS agents have explicit representations of beliefs.

6. The options available to an agent are directly determined by the realism of its beliefs.
EXAMPLE DIALOGUE 1
U: What is in front of you?
H: A log.
U: Do you own the log?
H: No, I don't.
U: The log belongs to you.
H: Oh.
U: Turn away from your log.
H: OK, I am turning.
H: OK, I am moving.
U: Turn around.
H: OK, I'm turning.
H: I've lost the log!

EXAMPLE DIALOGUE 2
U: Drop the package at the barge next Saturday at 9pm.
H: OK.
[HOMER GENERATES PLAN]
U: Are you going to the barge next Saturday?
H: Yes.
U: What time?
H: 8.56pm.
[USER ADDS CONTRADICTORY INSTRUCTIONS, WHICH HOMER DETECTS.]