Overview

⇒ Assumption-Based Reasoning
• Abduction
• Default Reasoning

Deduction versus Assumption-Based Reasoning

• Deduction
  - Where you have a KB of facts
  - Conclude things that must be true

• Complete Knowledge Assumption
  - Starting to veer away from deduction
  - Assume that everything you do not know to be true is false

• Assumption-Based Reasoning
  - Specify what things might be true given a set of facts
  - And perhaps some other assumptions
  - Want assumptions to be consistent
Example: Water World

• I have a sensor that tells if my flower-beds are wet
• But, I want to know why they are wet
• Facts about the world (a simplification)

\[
\begin{align*}
\text{cloudy} & \leftarrow \text{rained} \\
\text{wet} & \leftarrow \text{rained} \\
\text{wet} & \leftarrow \text{watered} \\
\text{false} & \leftarrow \text{cloudy} \land \text{sunny} \\
\text{false} & \leftarrow \text{watered} \land \text{cloudy}
\end{align*}
\]

• Things that I am prepared to assume

\[
\begin{align*}
\text{rained} \\
\text{cloudy} \\
\text{watered} \\
\text{sunny}
\end{align*}
\]

• What might be true of the world?
• What might cause wet to be true?

The Assumption-based Framework

Defined in terms of two sets of formulae:

• F is called the facts
  - Assume that they are Horn clauses
• H is called the possible hypotheses or assumables
  - Thing that we might want to consider as being true
  - Ground instances of the assumables can be assumed if consistent with F
Making Assumptions

- \( D \) is a scenario of \( <F,H> \)
  - If \( D \) is a set of ground instances of elements of \( H \)
  - And \( F \cup D \) is satisfiable
    - In other words, it has a model
    - In other words, \( F \cup D \not\models false \)
  - In other words, be careful what you put in \( D \)
    - Some subsets of ground instances of \( H \) will not work
- What are the scenarios of water world?

Explanations

- \( D \) is an explanation of \( g \) from \( <F,H> \)
  - If \( D \) is a scenario of \( <F,H> \)
    - So \( F \cup D \) is satisfiable
  - And \( F \cup D \models g \)
- \( D \) is a minimal explanation of \( g \) from \( <F,H> \)
  - No strict subset of \( D \) is also an explanation
  - Want a minimal explanation as it indicates the smallest number of assumptions we need to make to prove \( g \)
    - Prefer ‘watered’ over ‘watered and sunny’
    - For medical diagnosis, prefer single disease rather than multiple
- What are the
  - explanations of wet?
  - minimal explanations of wet?
Extensions

- $E$ is an extension of $<F,H>$
  - $D$ is a scenario of $H$ that is maximal
    - $D$ is not a strict subset of any other scenario of $H$
    - Opposite of explanation. Want it as big as possible
  - $E$ is the logical closure of $F \cup D$
    - $E$ includes $F \cup D$ and everything that can be derived from that
    - Definition in textbook is difficult to parse, but this is what they mean
- Each extension is like a different world
  - that includes $F$
  - and includes as much of $H$ as is consistent
  - and includes all consequences
  - but no other things

Extensions Continued

- Anything that can be explained will be in an extension
  - But unlike an extension, hard to pin down why it might be true
- There can be a number of different extensions
  - How do the extensions differ?
  - If $g$ is in extension $E_1$ but not in $E_2$, $\neg g$ must be in $E_2$
- What are the extensions of water world?
Recap

- $F$: facts about the world, and $H$ assumables
- $D$ is a scenario of $\langle F, H \rangle$
  - $D$ is a set of ground instances of elements of $H$
  - $F \cup H$ is satisfiable
- Scenario $D$ is an explanation of $g$ if $F \cup D \models g$
  - $D$ is minimum explanation if no strict subset of $D$ also explanation
- Scenario $D$ is a maximal scenario
  - ... if no strict subset of $D$ is also scenario of $\langle F, H \rangle$
  - Logical closure of $F \cup D$ is called an extension

Default Reasoning and Abduction

- Two applications of using the assumption-based framework:
  - Abduction
    - Where $g$ is given, and we are interested in explaining it $wet.$ so either it rained or we watered
  - Default reasoning
    - Where the truth of $g$ is unknown and is to be determined
      + Finding an explanation for $g$ is evidence it is true
      + Finding an explanation for $\neg g$ is evidence it is not true
    - Example: if tweety is a bird, can it fly?
Overview

- Assumption-Based Reasoning
  ⇒ Abduction
- Default Reasoning

Abduction

- You observe something being true in the world, and want to conjecture what may have produced this observation
- Given $g$, facts $F$ about world, and assumables $H$,
  find a minimal explanation $D$
  - $D$ is a ground subset of $H$ and $F \cup D$ is satisfiable: scenario
  - $D$ is as small as possible (occam’s razor)
  - $F \cup D \models g$
- Can use this for expert systems, say for diagnosing a disease
Example

- \( H \)
  \( \text{interestedin}(Ag,\text{Topic}) \)

- \( F \)
  \( \text{about(article94,ai)} \)
  \( \text{about(article34,informationhighway)} \)
  \( \text{about(article34,ai)} \)
  \( \text{about(article34,skiing)} \)
  \( \text{selects}(Ag,Art) \leftarrow \text{about}(Art,\text{Topic}) \land \text{interestedin}(Ag,\text{Topic}) \)

- \( g = \text{selects}(fred,\text{article94}) \)

Note that \( H \) here is an atom (fact) with variables in it
- What values should we instantiate for it?
- Minimal explanations?

Implementation 1: Bottom-up Approach

- Set \( D \) to \( \{ \} \)
- Loop
  - Take ground instance \( d \) of something from \( H \)
  - Ensure \( F \cup D \not\models d \Rightarrow F \cup D \cup \{\neg d\} \not\models false \)
    + Can do this efficiently if horn, using unit resolution
  - Ensure \( F \cup D \cup \{d\} \) is consistent \( \Rightarrow F \cup D \cup \{d\} \not\models false \)
  - Add \( d \) to \( D \)
    + Check if \( F \cup D \models g \Rightarrow F \cup D \cup \{\neg g\} \models false \)
    + If yes, record it, and don’t pursue this explanation further
  - Need to do this as a breadth first search
    (in order to find all possible different explanations)
- This is like a bottom-up search
  - Could take a LONG time
  - Are the explanations minimal?
Implementation 2: Top-down Approach

• Set $D$ to $\{\}$
• Do top-down proof (breath-first)
• Allow proof algorithm to use $F$, $D$ and $H$
• Each time you use something from $H$, say $d$
  - Ensure it is ground (or delay until it is ground)
  - Ensure $F \cup D \not\models d$
  - Ensure $d$ is consistent with $F \cup D$
  - Add $d$ to $D$
• Do breath-first search to find all different explanations

Overview

• Assumption-Based Reasoning
• Abduction
  $\Rightarrow$ Default Reasoning
Default Reasoning

- Where the truth of $g$ is unknown and is to be determined
  - Finding an explanation for $g$ is evidence it is true
  - Finding an explanation for $\neg g$ is evidence it is not true
  - Do not care about the actual explanation
- Default reasoning allows information to be incorporated that is not always true, but might have exceptions
  - Like the CKA, allow things to be assumed if you cannot prove otherwise
  - But can control what things are assumable, and ensures extension is satisfiable

Tweety World

- Tweety is a bird
  - Can it fly?
    - $\text{fly}(X) \leftarrow \text{bird}(X)$
- What if Tweety is an ostrich
  - Need to change previous rule
    - $\text{fly}(X) \leftarrow \text{bird}(X) \land \neg \text{ostrich}(X)$
- What if Tweety has a broken wing
  - $\text{fly}(X) \leftarrow \text{bird}(X) \land \neg \text{ostrich}(X) \land \neg \text{hurt}(X)$
- What if Tweety is a baby bird
  - $\text{fly}(X) \leftarrow \text{bird}(X) \land \neg \text{ostrich}(X) \land \neg \text{hurt}(X) \land \neg \text{baby}(X)$
Default Reasoning

• When giving information, you don’t want to enumerate all of the exceptions, even if you could think of them all.

• In default reasoning, you specify general knowledge and modularly add exceptions. The general knowledge is used for cases you don’t know are exceptional.

• Default reasoning is non-monotonic: When you add that something is exceptional, you can’t conclude what you could before.

Classical Logic is Monotonic

• If $KB \models g$ then $KB \cup A \models g$
  - Classical logic is monotonic
  - Adding more stuff to KB does not make stuff that was true become false

• Every time we think of new exception,
  - We cannot just add a new rule
  - We have to change our KB

• Adding new rules is much better than changing rules
Defaults as Assumptions

- Default reasoning can be modeled using
  - \( H \) as normality assumptions
  - \( F \) states what follows from the assumptions
- An explanation of \( g \) gives an argument for \( g \)

Default Example

- \( H \)
  \[ \text{flys}(X) \leftarrow \text{bird}(X) \]
- \( F \)
  \[ \begin{align*}
  \text{bird}(\text{tweety}) \\
  \text{bird}(X) & \leftarrow \text{ostrich}(X) \\
  \text{false} & \leftarrow \text{flys}(X) \land \text{ostrich}(X) \\
  \text{false} & \leftarrow \text{flys}(X) \land \text{bird}(X) \land \text{hurt}(X) \\
  \text{false} & \leftarrow \text{flys}(X) \land \text{bird}(X) \land \text{baby}(X)
  \end{align*} \]
- \( D = \{ \text{flys}(\text{tweety}) \leftarrow \text{bird}(\text{tweety}) \} \)
- \( F \cup D \) is consistent, so it is a scenario
- \( F \cup D \models \text{flys}(\text{tweety}) \)
- \( D \) is a minimal explanation of \( \text{flys}(\text{tweety}) \) from \( <F,H> \)
Contradictory Explanations

- **Music World**
  - I dislike most American music and I like most disco songs
  - Do I like music by Donna Summers?
  - **H:** \[\text{like}(X) ← \text{disco}(X)\]
    \[\text{false} ← \text{americanmusic}(X) ∧ \text{like}(X)\]
  - **F:** \[\text{disco}(\text{donnasummers})\]
    \[\text{americanmusic}(\text{donnasummers})\]
    \[\text{disco}(\text{beegees})\]
    \[\neg \text{americanmusic}(\text{beegees})\]

- **Two different explanations**
  - \[D_1 = \{\text{like}(\text{donnasummers}) ← \text{disco}(\text{donnasummers})\}\]
  - \[D_2 = \{\text{false} ← \text{americanmusic}(\text{donnasummers}) ∧ \text{like}(\text{donnasummers})\}\]

Overriding Assumptions

- **Add cancellation rule to** \(F\)
  - \[\text{like}(X) ← \text{americanmusic}(X) ∧ \text{disco}(X)\]
  - This rule disallows \(D_2\) from being consistent with \(F\)
Explanations $D_1$ and $D_2$ give two different answers.

Part of two different extensions.
Resolving Competing Arguments

• But what if no cancellation rule?
  - What do you do when there are multiple extensions that give different answers?
• Could require $g$ to be in all extensions of $<F,H>$