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)

- Cloudy → Rained
- Rain → Wet
- Wet → Watered
- False → Cloudy ∧ Sunny
- False → Watered
- False → Rained

Things I am prepared to assume

- Rain
- Cloudy
- Watered

What might be true of the world?

- What might cause my flower-beds to be wet?

Deduction versus Assumption-Based Reasoning

- 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 know to be true is true

Assumption-Based Reasoning

- Specify what things might be true given a set of facts
- Assumption-based reasoning

Default Reasoning

- When you have a KB of facts
- Where you have a KB of facts

Abduction

- Where you have a KB of facts
- Assumption-Based Reasoning

Deduction
Explanations

- \( \text{D is an explanation of } \phi \)
- If \( \text{D is a scenario of } <F,H> \)
- \( F \cup D \) is satisfiable
  - \( \text{No strict subset of } D \text{ is also an explanation} \)
- \( \text{D is a minimal explanation of } \phi \)

Want a minimal explanation as it indicates the smallest number of assumptions needed to prove \( \phi \)

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- Prefer 'watered' over 'watered and sunny'
- For medical diagnosis, prefer single disease rather than multiple

Making Assumptions

- \( \text{D is a scenario of } <F,H> \)
- \( F \cup D \) is satisfiable
- \( \text{No strict subset of } D \text{ is also an explanation} \)
- \( \text{D is a minimal explanation of } \phi \)

Want to be careful what you put in \( D \)

- Some subsets of ground instances of \( H \) will not work
- \( D \) is a scenario if \( D \) is satisfiable
- \( F \cup D \) is satisfiable
- \( \text{If } D \text{ is a set of ground instances of assumables of } H \)
- \( \text{D is a scenario of } <F,H> \)

The Assumption-based Framework

- Ground instances of the assumables can be assumed if consistent with \( F \)
- \( \text{H is a set of ground instances of assumables} \)
- \( \text{Assume the top-level Horn clauses} \)
- \( \text{F is called the facts} \)

Defined in terms of two sets of formulæ.
Recap

- Scenario \( D \) is a maximal scenario if it is minimal explanation of \( H \).
- \[ D = \{ \phi \in H : \phi \text{ is satisfiable} \} \]

Anything that can be explained will be in an extension.

Extensions Continued

- Each extension is like a different world.
- Each extension is the logical closure of \( F \) and \( D \) with respect to \( H \).
- \[ F \cup D \]
- \[ \neg g \text{ must be in } E \]
- \[ g \text{ is not in extension } E \]
- \[ E \text{ includes as much of } H \text{ as is consistent} \]

What are the extensions of water world?

- \[ \text{If } g \text{ is in extension } E \text{ but not in } E', \text{ then } \neg g \text{ must be in } E' \]
- \[ \text{How do the extensions differ?} \]
- \[ \text{There can be a number of different extensions} \]
- \[ \text{But unlike an extension, hard to pin down why it might be true} \]
- \[ \text{Anything that can be explained will be in an extension} \]
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
Implementation 2: Top-down Approach

- Do breath-first search to find all different explanations

  - ADD $p$ to $D$ 
  - Change $p$ to consistent with $F$ and $D$ 
  - Ensure $p$ is ground (or delay until it is ground) 
  - Each time you use something from $H$, say $H$ 
  - Allow proof algorithm to use $F$ and $D$

Set $D$ to

Example
Tweety World

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, allows things to be assumed if you cannot prove otherwise
  - But can control what things are assumable and ensure extension is satisfiable

Default Reasoning:

\[
\begin{align*}
\text{Tweety is a bird} & \Rightarrow \\
\text{When Tweety is a baby bird} & \\
\text{When Tweety has a broken wing} & \\
\text{When Tweety is an ostrich} & \\
\text{Tweety is a bird} &
\end{align*}
\]
Defaults as Assumptions

• Default reasoning can be modeled using $H$ as normality assumptions
• $F$ states what follows from the assumptions

Default Reasoning

• When giving information, you don't want to enumerate all 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 - Adding more stuff to KB does not make our KB become false
• Every time we think of new exception, we cannot just add a new rule
• We cannot just add a new rule

When giving information, you don't want to enumerate all of the exceptions.

Classical Logic is Monotonic

$KB \models g$ if and only if $KB \cup A \models g$
Overriding Assumptions

- Add cancellation rule to $F$
  
  $\text{like}(X) \leftarrow \text{americanmusic}(X) \land \text{disco}(X)$

Contradictory Explanations

- **Music World**
  - I dislike most American music and I like most disco songs
  - Do I like music by Donna Summers?

  $F$
  - $\text{disco}(\text{donnasummers})$
  - $\text{americanmusic}(\text{donnasummers})$
  - $\text{disco}(\text{beegees})$
  - $\neg \text{americanmusic}(\text{beegees})$

- Two different explanations
  - $D_1 = \{\text{like}(\text{donnasummers}) \leftarrow \text{disco}(\text{donnasummers})\}$
  - $D_2 = \{\text{false} \leftarrow \text{americanmusic}(\text{donnasummers}) \land \text{like}(\text{donnasummers})\}$

- Explanations $D_1$ and $D_2$ give two different answers

Default Example

- $\text{flys}(X) \leftarrow \text{bird}(X)$
- $F$
  - $\text{bird}(\text{tweety})$
  - $\text{bird}(X) \leftarrow \text{ostrich}(X)$
  - $\text{false} \leftarrow \text{flys}(X) \land \text{ostrich}(X)$
  - $\text{false} \leftarrow \text{flys}(X) \land \text{bird}(X) \land \text{hurt}(X)$
  - $\text{false} \leftarrow \text{flys}(X) \land \text{bird}(X) \land \text{baby}(X)$

- $D = \{\text{flys}(\text{tweety}) \leftarrow \text{bird}(\text{tweety})\}$

- $F \cup D$ is consistent, so it is a scenario

- $D$ is a minimal explanation of $\text{flys}(\text{tweety})$ from $\langle F, H \rangle$
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 $\langle F, H \rangle$