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

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 know to be true is false
- Assumption-Based Reasoning
  - Specify what things might be true given a set of facts
  - Where you have a KB of facts
- Assumption-Based Reasoning
  - Where you have a KB of facts
Explanations

Explanation

Making Assumptions

The Assumption-based Framework
Recap

- Facts about the world, and assumables
- A scenario of \( <F, H> \)
  - \( D \) is a set of ground instances of elements of \( H \)
  - \( F \cup H \) is satisfiable
- \( D \) is an explanation of \( g \) if \( F \cup D \models g \)
  - \( D \) is minimum explanation if no strict subset of \( D \) also explanation
- \( D \) is a maximal scenario
  - \( D \) is a scenario of \( H \) that is maximal
  - \( D \) is not a strict subset of any other scenario of \( H \)
- Scenario \( D \) is a maximal scenario
- Logical closure of \( F \cup D \) is called an extension

Extensions

- 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
- 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?

- How do the extensions differ?
- There can be a number of different extensions
- But unlike an extension, hard to pin down why it might be true
- Anything that can be explained will be in an extension

Extensions Continued

- Each extension is like a different world
- But unlike an extension, hard to pin down why it might be true
- Extensions are not necessarily consistent
- \( E \) is an extension of \( F \cup H \)
- \( E \) is a consistent extension of \( F \cup H \)
- \( E \) is an extension of \( F \cup H \)
- \( E \) is a consistent extension of \( F \cup H \)
- \( E \) is an extension of \( F \cup H \)
Abduction

• You observe something being true in the world, and want to conjecture what may have produced this observation.

• Given facts \( F \) about the world, and assumables \( H \), find a minimal explanation \( D \):
  - \( D \) is a ground subset of \( H \)
  - \( F \cup D \) is satisfiable: scenario
  - \( D \) is as small as possible (Ockham’s razor)
  - Given \( g \), facts \( F \) about the world, and assumables \( H \), conjecture what may have produced this observation.

Can use this for expert systems, say for diagnosing a disease.

\[ \sigma = \{ D \cap \sigma \} \]

\( g \) is as small as possible (Ockham’s razor)

\( g \) is a ground subset of \( H \)

\( F \cup D \) is satisfiable: scenario

\( D \) is as small as possible (Ockham’s razor)

• Can use this for expert systems, say for diagnosing a disease.

Overview

• Assumption-Based Reasoning

⇒ Abduction

• Default Reasoning

⇒ Abduction

⇒ Assumption-Based Reasoning

Default Reasoning

Example: If Tweety is a bird, can it fly?

- Finding an explanation for \( g \) is evidence it is true.
- Finding an explanation for \( \neg g \) is evidence it is false.
- Whether the truth of \( g \) is unknown and is to be determined.

Abduction

- \( g \) is unknown, and we are interested in explaining it.

Abduction

Two applications of using the assumption-based framework:

Default Reasoning and Abduction
**Implementation 2: Top-down Approach**

- Set $D$ to $\{}$
- Do top-down proof (breadth-first)
- Allow proof algorithm to use $F$, $D$ and $H$
- Each time you use something from $H$, say $H$
- Do top-down proof (breadth-first)

**Implementation 1: Bottom-up Approach**

- Set $D$ to $\{}$
- Loop
  - Take ground instance $d$ of something from $H$
  - Ensure $F \cup D \not\models d$ ⇒ $F \cup D \cup \{\neg d\} \not\models false$
  - Can do this efficiently if horn, using unit resolution
  - Ensure $F \cup D \cup \{d\}$ is consistent ⇒ $F \cup D \cup \{d\} \not\models false$
  - Add $d$ to $D$
  - Check if $F \cup D \not\models g$ ⇒ $F \cup D \cup \{\neg g\} \not\models false$
  - If yes, record it, and don't pursue this explanation further
- Need to do this as a breadth-first search
- This is like a bottom-up search
- In order to find all possible different explanations
- Need to do this as a breadth-first search
- If $H$ is a horn literal and don't record the explanation
- Loop
- Set $D$ to $\{}$

**Example**

- What values should we instantiate for it?
- Note that $H$ here is an atom (fact) with variables in it
- Set $d = \text{select Artikel (Article) from Topic (Topic)}$
- \text{select Artikel (Article) from Topic (Topic)}
- \text{select Artikel (Article) from Topic (Topic)}
- $H$
Tweety World

• Tweety is a bird

  fly(X) ← bird(X)

• What if Tweety is an ostrich

  fly(X) ← bird(X) ∧ ¬ ostrich(X)

• What if Tweety has a broken wing

  fly(X) ← bird(X) ∧ ¬ ostrich(X) ∧ ¬ hurt(X)

• What if Tweety is a baby bird

  fly(X) ← bird(X) ∧ ¬ ostrich(X) ∧ ¬ hurt(X) ∧ ¬ baby(X)

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 \( ¬ g \) 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 which things are assumable, and ensure extension is
  satisfiable

Overview

• Assumption-Based Reasoning

  Default Reasoning

  Abduction

  Overiew
• An explanation of $g$ gives an argument for $g$.
• If $g$ holds, then follows from the assumptions.
• If $g$ is a non-trivial assumption, it can be modeled using default reasoning.

**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**

- If $KB \models g$ then $KB \cup A \models g$.
- The general knowledge is used for cases you don't know are exceptional.
- We cannot simply add new rules.
- Every time we think of new exception, we have to change our KB.
- We cannot just add a new rule.
- Adding more rules to the KB does not make them less true because false.

**Implication in Classical Logic**

- If $A \land B \models C$, then $A \models C$.
- If $A \models B$, then $A \cup B \models C$.

---

**Classical Logic is Monotonic**

- If $KB \models g$ and $KB \cup A \models h$, then $KB \cup A \models g \land h$.
Overriding Assumptions

- Add cancellation rule to $F$ 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?

- $H$: like$(X) \leftarrow \text{disco}(X)$
  - false $\leftarrow \text{americanmusic}(X) \land \text{like}(X)$

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

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

Default Example

- $H$: flys$(X) \leftarrow \text{bird}(X)$
- $F$: $\text{bird}(\text{tweety})$
  - $\text{bird}(X) \leftarrow \text{ostrich}(X)$
  - false $\leftarrow \text{flys}(X) \land \text{ostrich}(X)$
  - false $\leftarrow \text{flys}(X) \land \text{bird}(X) \land \text{hurt}(X)$
  - 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 flys$(\text{tweety})$ from $< H, F >$. 

Default Example
Resolving Competing Arguments

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