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)
  - cloudy ← rained
  - wet ← rained
  - wet ← watered
  - false ← cloudy ∧ sunny
  - false ← watered ∧ cloudy
- Things that I am prepared to assume
  - rained
  - cloudy
  - watered
  - sunny
- 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 $<F,H>$
  - $D$ 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 $<F,H>$
  - 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 razer)
  - $F \cup D \models g$

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

• $H$
  \[ \text{interestedin}(Ag,\text{Topic}) \]

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

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

• 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?

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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

⇒ 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?
  - \( \text{fly}(X) \leftarrow \text{bird}(X) \)
Tweety World

• Tweety is a bird
  - Can it fly?
    - \( fly(X) \leftarrow bird(X) \)

• What if Tweety is an ostrich
  - Need to change previous rule
    - \( fly(X) \leftarrow bird(X) \land \neg ostrich(X) \)
Tweety World

• Tweety is a bird
  - Can it fly?
  - $fly(X) \leftarrow bird(X)$

• What if Tweety is an ostrich
  - Need to change previous rule
  - $fly(X) \leftarrow bird(X) \land \neg ostrich(X)$

• What if Tweety has a broken wing
  - $fly(X) \leftarrow bird(X) \land \neg ostrich(X) \land \neg hurt(X)$
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
  - $\text{fly}(X) \leftarrow \text{bird}(X) \land \neg \text{ostrich}(X) \land \neg \text{hurt}(X) \land \neg \text{baby}(X)$
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
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.
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**
  \[ \text{bird}(tweety) \]
  \[ \text{bird}(X) \leftarrow \text{ostrich}(X) \]
  \[ \text{false} \leftarrow \text{flys}(X) \land \text{ostrich}(X) \]
  \[ \text{false} \leftarrow \text{flys}(X) \land \text{bird}(X) \land \text{hurt}(X) \]
  \[ \text{false} \leftarrow \text{flys}(X) \land \text{bird}(X) \land \text{baby}(X) \]

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

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

- **F \cup D \models \text{flys}(tweety)**

- **D** is a minimal explanation of \( \text{flys}(tweety) \) 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: \( \text{like}(X) \leftarrow \text{disco}(X) \)
      \( \text{false} \leftarrow \text{americanmusic}(X) \land \text{like}(X) \)
    - F: \( \text{disco}(\text{donnasummers}) \)
      \( \text{americanmusic}(\text{donnasummers}) \)
      \( \text{disco}(<\text{beegees}> \land \text{like}(\text{donnasummers}) \land \text{americanmusic}(\text{beegees}) \land \text{like}(\text{donnasummers}) \}

• 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
  + Part of two different extensions
Overriding Assumptions

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

- This rule disallows $D_2$ from being consistent with $F$
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 $<F,H>$