Abduction

Abduction is an assumption-based reasoning strategy where

- H is a set of assumptions about what could be happening in a system
- F axiomatizes how a system works
- g to be explained is an observation or a design goal

Example: in diagnosis of a physical system:
H contain possible faults and assumptions of normality,
F contains a model of how faults manifest themselves
g is conjunction of symptoms.

Abduction versus Default Reasoning

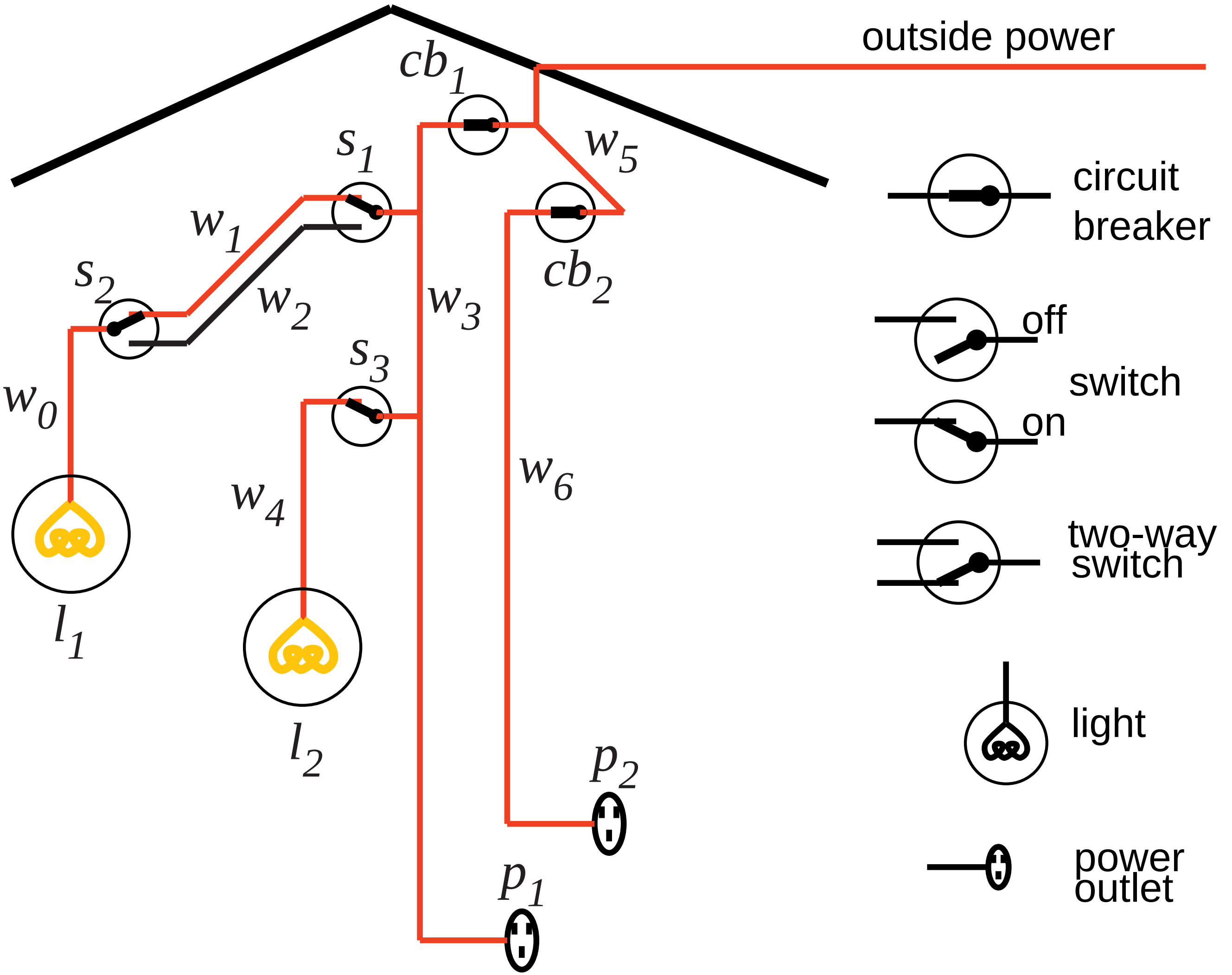
Abduction differs from default reasoning in that:

- The explanations are of interest, not just the conclusion.
- H contains assumptions of abnormality as well as assumptions of normality.
- We don't only explain normal outcomes. Often we want to explain why some abnormal observation occurred.
- We don't care if $\neg g$ can also been explained.

Abductive Diagnosis

- You need to axiomatize the effects of normal conditions and faults.
- We need to be able to explain all of the observations.
- Assumables are all of those hypotheses that require no further explanation.

Electrical Environment



$$lit(L) \Leftarrow light(L) \,\&\, ok(L) \,\&\, live(L).$$

$$dark(L) \Leftarrow light(L) \,\&\, broken(L).$$

$$dark(L) \Leftarrow light(L) \,\&\, dead(L).$$

$$live(W) \Leftarrow connected\_to(W, W_1) \,\&\, live(W_1).$$

$$dead(W) \Leftarrow connected\_to(W, W_1) \,\&\, dead(W_1).$$

$$dead(W) \Leftarrow unconnected(W).$$

$$connected\_to(l_1, w_0) \Leftarrow true.$$

$$connected\_to(w_0, w_1) \Leftarrow up(s_2) \,\&\, ok(s_2).$$

$$unconnected(w_0) \Leftarrow broken(s_2).$$

$$unconnected(w_1) \Leftarrow broken(s_1).$$

$$unconnected(w_1) \Leftarrow down(s_1).$$

$$false \leftarrow ok(X) \wedge broken(X).$$

assumable $ok(X)$, $broken(X)$, $up(X)$, $down(X)$.

Explaining Observations

- To explain $lit(l1)$ there are two explanations:
  $\{ok(l1), ok(s2), up(s2), ok(s1), up(s1), ok(cb1)\}$
  $\{ok(l1), ok(s2), down(s2), ok(s1), down(s1), ok(cb1)\}$
- To explain $lit(l2)$ there is one explanation:
  $\{ok(cb1), ok(s3), up(s3), ok(l2)\}$

Explaining Observations (cont)

- To explain $dark(l1)$ there are 8 explanations:

$\{broken(l1)\}$

$\{broken(cb1), ok(s1), up(s1), ok(s2), up(s2)\}$

$\{broken(s1), ok(s2), up(s2)\}$

$\{down(s1), ok(s2), up(s2)\}$

$\{broken(cb1), ok(s1), down(s1), ok(s2), down(s2)\}$

$\{up(s1), ok(s2), down(s2)\}$

$\{broken(s1), ok(s2), down(s2)\}$

$\{broken(s2)\}$

Explaining Observations (cont)

- To explain $dark(l1) \wedge lit(l2)$ there are explanations:

$\{ok(cb1), ok(s3), up(s3), ok(l2), broken(l1)\}$

$\{ok(cb1), ok(s3), up(s3), ok(l2), broken(s1), ok(s2), up(s2)\}$

$\{ok(cb1), ok(s3), up(s3), ok(l2), down(s1), ok(s2), up(s2)\}$

$\{ok(cb1), ok(s3), up(s3), ok(l2), up(s1), ok(s2), down(s2)\}$

$\{ok(cb1), ok(s3), up(s3), ok(l2), broken(s1), ok(s2), down(s2$

$\{ok(cb1), ok(s3), up(s3), ok(l2), broken(s2)\}$

Abduction for User Modeling

Suppose the infobot wants to determine what a user is interested in. We can hypothesize the interests of users:

$$H = \{interested\_in(Ag, Topic)\}.$$

Suppose the corresponding facts are:

$$selects(Ag, Art) \leftarrow$$
$$about(Art, Topic) \wedge$$
$$interested\_in(Ag, Topic).$$

$$about(art\_94, ai).$$

$$about(art\_94, info\_highway).$$

$$about(art\_34, ai). \qquad about(art\_34, skiing).$$

Explaining User's Actions

There are two minimal explanations of $selects(fred, art\_94)$:

$$\{interested\_in(fred, ai)\}.$$

$$\{interested\_in(fred, information\_highway)\}.$$

If we observe $selects(fred, art\_94) \wedge selects(fred, art\_34)$, there are two minimal explanations:

$$\{interested\_in(fred, ai)\}.$$

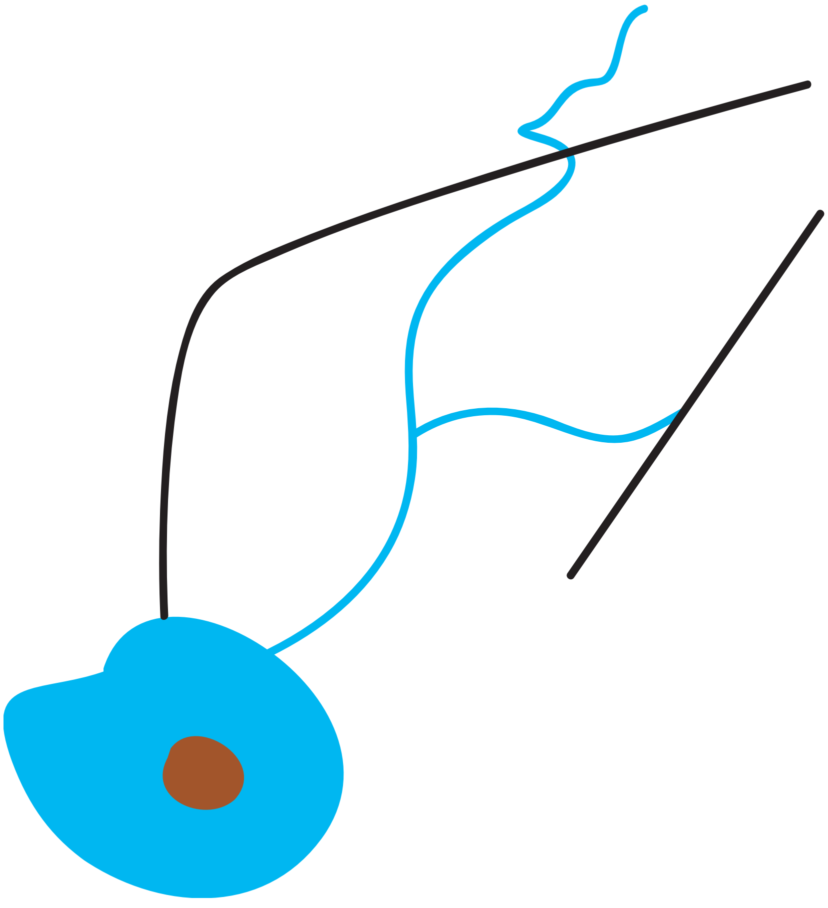
$$\{interested\_in(fred, information\_highway),$$
$$interested\_in(fred, skiing)\}.$$

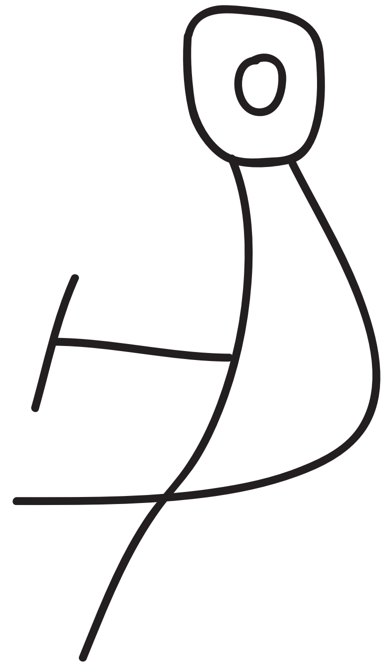
Image interpretation

- A **scene** is the world that the agent is in.
- An **image** is what the agent sees.
- **Vision:** given an image try to determine the scene.
- Typically we know more about the *scene* $\rightarrow$ *image* mapping than the *image* $\rightarrow$ *scene* mapping.

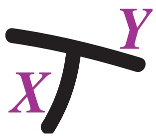
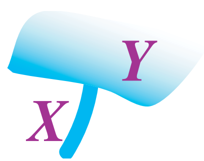
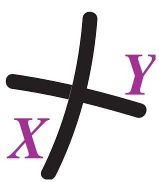
Example Scene and Image

Scene ***Image***





Scene and Image Primitives

Scene Primitives	Image Primitives
land, water	region
river, road, shore	chain
joins(X, Y, E) 	tee
($E \in \{0, 1\}$ specifies which end of X)	
mouth(X, Y, E) 	
cross(X, Y) 	chi

Scene and image primitives (cont.)

Scene Primitives		Image Primitives
beside(C, R)		bounds(C,R)
source(C, E)		open(C,E)
loop(C)		closed(C)
inside(C, R)		interior(C,R)
outside(C, R)		exterior(C,R)

Axiomatizing the Scene $\rightarrow$ Image map

$chain(X) \leftarrow river(X) \vee road(X) \vee shore(X).$

$region(X) \leftarrow land(X) \vee water(X).$

$tee(X, Y, E) \leftarrow joins(X, Y, E) \vee mouth(X, Y, E).$

$chi(X, Y) \leftarrow cross(X, Y).$

$open(X, N) \leftarrow source(X, N).$

$closed(X) \leftarrow loop(X).$

$interior(X, Y) \leftarrow inside(X, Y).$

$exterior(X, Y) \leftarrow outside(X, Y).$

assumable $road(X), river(X), shore(X), land(X), \ldots$

assumable $joins(X, Y, E), cross(X, Y), mouth(L, R, E) \ldots$

Scene Constraints

$$false \leftarrow cross(X, Y) \wedge river(X) \wedge river(Y).$$

$$false \leftarrow cross(X, Y) \wedge (shore(X) \vee shore(Y)).$$

$$false \leftarrow mouth(R, L1, 1) \wedge river(R) \wedge mouth(R, L2, 0).$$

$$start(R, N) \leftarrow river(R) \wedge road(Y) \wedge joins(R, Y, N).$$

$$start(X, Y) \leftarrow source(X, Y).$$

$$false \leftarrow start(R, 1) \wedge river(R) \wedge start(R, 0).$$

$$false \leftarrow joins(R, L, N) \wedge river(R) \wedge (river(L) \vee shore(L)).$$

$$false \leftarrow mouth(X, Y, N) \wedge (road(X) \vee road(Y)).$$

$$false \leftarrow source(X, N) \wedge shore(X).$$

$$false \leftarrow joins(X, A, N) \wedge shore(X).$$

$$false \leftarrow loop(X) \wedge river(X).$$

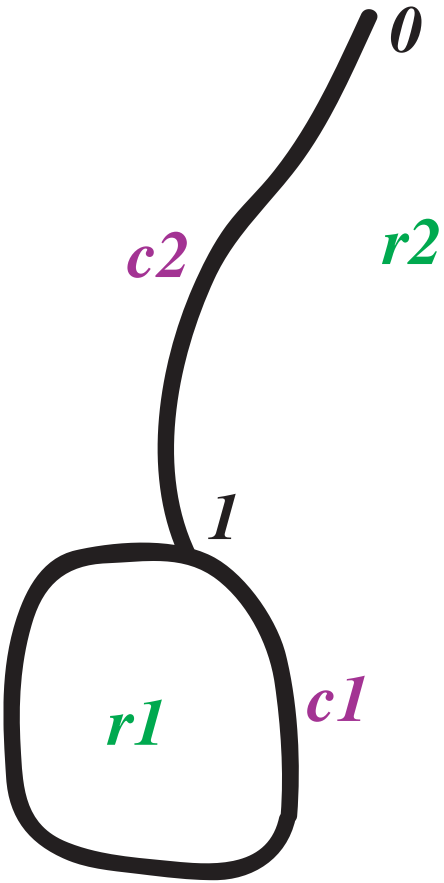
Scene constraints (continued)

$$false \leftarrow shore(X) \wedge inside(X, Y) \wedge outside(X, Z) \wedge land(Y) \wedge land(Z).$$

$$false \leftarrow shore(X) \wedge inside(X, Y) \wedge outside(X, Z) \wedge water(Z) \wedge water(Y).$$

$$false \leftarrow water(Y) \wedge beside(X, Y) \wedge (road(X) \vee river(X)).$$

Describing an image



$chain(c1) \wedge chain(c2) \wedge$

$region(r1) \wedge region(r2) \wedge$

$tee(c2, c1, 1) \wedge$

$bounds(c2, r2) \wedge$

$bounds(c1, r1) \wedge$

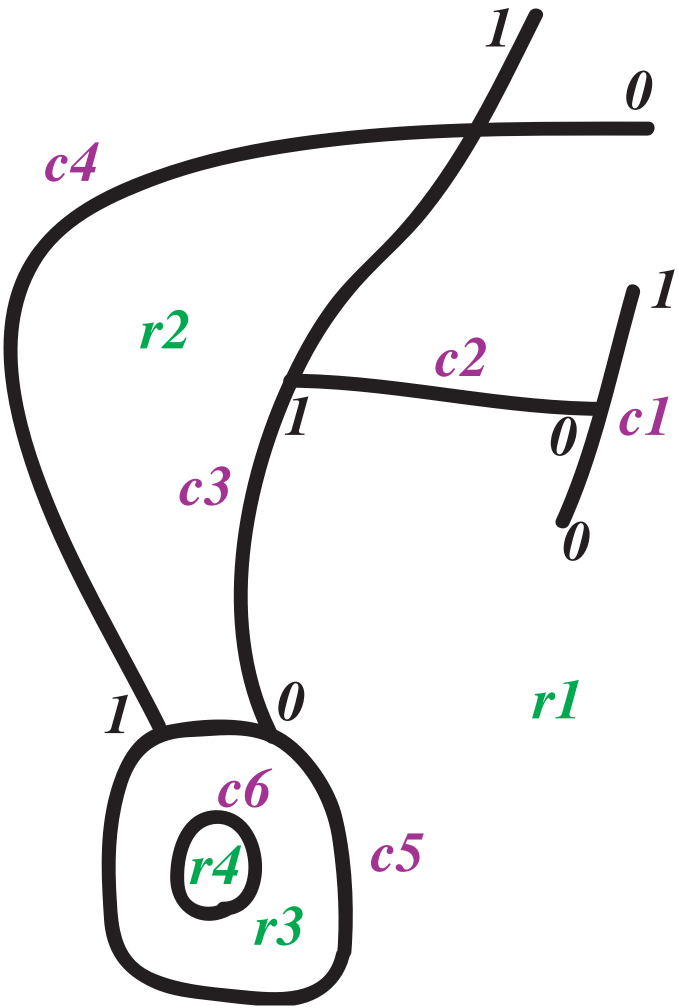
$bounds(c1, r2) \wedge$

$interior(c1, r1) \wedge$

$exterior(c1, r2) \wedge open(c2, 0)$

$\wedge\ closed(c1)$

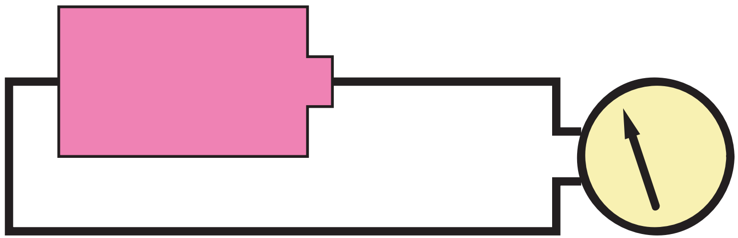
A more complicated image



$chain(c1) \wedge open(c1, 0) \wedge$
$open(c1, 1) \wedge region(r1) \wedge$
$bounds(c1, r1) \wedge chain(c2) \wedge$
$tee(c2, c1, 0) \wedge bounds(c2, r1)$
$\wedge\ chain(c3) \wedge bounds(c3, r1) \wedge$
$region(r2) \wedge bounds(c3, r2) \wedge$
$chain(c5) \wedge closed(c5) \wedge$
$bounds(c5, r2) \wedge$
$exterior(c5, r2) \wedge region(r3) \wedge$
$bounds(c5, r3) \wedge$
$interior(c5, r3) \wedge \ldots$

Parameterizing Assumables

Suppose we had a battery *b* connected to voltage meter:



To be able to explain a measurement of the battery voltage, we need to parameterize the assumables enough:

assumable $flat(B, V)$.

assumable $tester\_ok$.

$measured\_voltage(B, V) \leftarrow flat(B, V) \wedge tester\_ok.$

$false \leftarrow flat(B, V) \wedge V > 1.2.$