# Primitive and Derived Atoms

- A primitive atom is an atom that is defined using facts.
- A derived atom is an atom that is defined using rules.
- Typically, the designer writes axioms for the derived atoms and then expects a user to specify which primitive atoms are true.

# Primitive and Derived Atoms

Consider two propositions, $a$ and $b$, both of which are true.

- They can both be primitive, as in the knowledge base:

  $a.$

  $b.$

- Atom $a$ can be primitive, and $b$ derived:

  $a.$

  $b \leftarrow a.$

- Atom $a$ can be derived, and $b$ primitive:

  $a \leftarrow b.$

  $b.$

- Can they both be derived?

  $a \leftarrow b.$

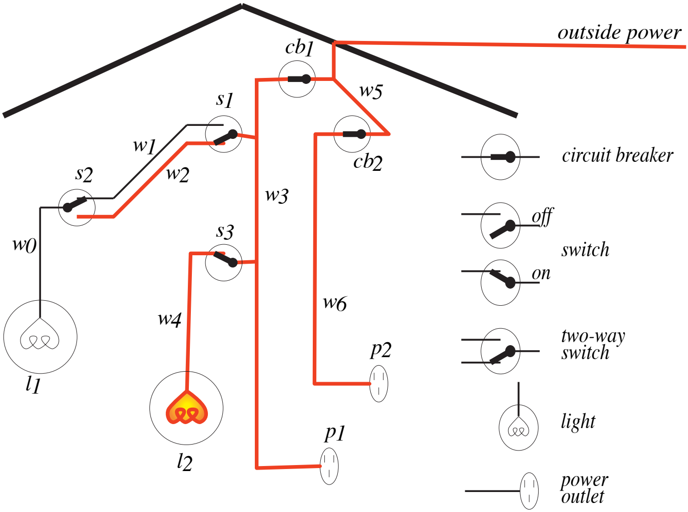
  $b \leftarrow a.$

- What if the world changes to make $a$ no longer true? What happens to $b$?

# Causal Models

- A causal model is a representation of a domain that predicts the results of interventions.
- An intervention is an action that forces a variable (proposition) to have a particular value.
- An intervention on a variable changes the value of the variable in some way other than as a side-effect of manipulating other variables in the model.
- Other variables may be affected by an intervention on a variable.
- A structural causal model defines a causal mechanism for each atom. This causal mechanism specifies when the atom is true in terms of other atoms.
- If the model is manipulated to make an atom true or false, the clauses for that atom are replaced by the atomic fact or are removed.

# Electrical Environment



# Combining Evidential & Causal Reasoning

$$lit\_l_1 \leftrightarrow (up\_s_1 \leftrightarrow up\_s_2) \tag{1}$$

is logically equivalent to

$$up\_s_1 \leftrightarrow (lit\_l_1 \leftrightarrow up\_s_2).$$

This formula is symmetric between the three propositions; it is true if and only if an even number of the propositions are false.

- The relationship between these propositions is not symmetric:
  - Suppose both switches were up and the light was lit.
  - Putting $s_1$ down does not make $s_2$ go down to preserve $lit\_l_1$.
  - Putting $s_1$ down makes $lit\_l_1$ false, and $up\_s_2$ remains true.
- Structural causal model:

$$lit\_l_1 \leftrightarrow (up\_s_1 \leftrightarrow up\_s_2)$$

$$up\_s_1$$

$$\neg up\_s_2$$

# Structural causal model as logic program

- Structural causal model:

$$lit\_l_1 \leftrightarrow (up\_s_1 \leftrightarrow up\_s_2)$$

$$up\_s_1$$

$$\neg up\_s_2$$

- As a logic program using negation as failure:

$$lit\_l_1 \leftarrow up\_s_1 \wedge up\_s_2.$$

$$lit\_l_1 \leftarrow \sim up\_s_1 \wedge \sim up\_s_2.$$

$$up\_s_1.$$

- An evidential model

$$up\_s_1 \leftarrow lit\_l_1 \wedge up\_s_2.$$

$$up\_s_1 \leftarrow \sim lit\_l_1 \wedge \sim up\_s_2$$

  can be used to answer questions about whether $s_1$ is up based on the position of $s_2$ and whether $l_1$ is lit.
  It does not accurately predict the effect of interventions.