SAPIENZA
UNIVERSITÀ DI ROMA

Artificial Intelligence

2023/2024 Prof: Sara Bernardini

Lab 10:
Causal Graphs, Progression, Regression

Francesco Argenziano
email: argenziano@diag.uniroma1.it

*The slides have been prepared using the textbook material available on the web, and the slides of the previous editions of the course by Prof. Luigia Carlucci Aiello, Prof. Daniele Nardi and Dott. Fabio Previtali.

Exercises: Causal Graphs

Consider the following planning task where a ghost wants to carve some patterns ($CarveTools =$ $\{smiley, cat, bat\}$) on two pumpkins ($Pumpkins = \{Hokkaido, Muskat\}$) using his two hands ($Hands = \{left, right\}$). The ghost uses his hands to grab the carving tools and does not need to lift the pumpkins up. The variable L represents to which of the pumpkins the ghost is currently looking at (or none of them). There is one variable A_c for each carving tool $c \in CarveTools$ that represent whether the carving tool c is available to be picked-up. There is one variable H_h for $h \in Hands$ that represent whether the ghost has hand h empty or has one of the tools. Finally, there is a variable $D_{p,c}$ for each $c \in CarveTools$ and $p \in Pumpkins$ that represents whether pumpkin p has the design c or not (i.e. a pumpkin can be carved with more than one thing at the same time).

Exercises: Causal Graphs

1) Formalize the planning task in FDR

2) Draw the Causal Graph of the planning task. Ignore H_{none} when drawing the graph. We recommend the following order from top to bottom to draw the graph: ”L,D,H,A”.

3) Draw the DTG for Variables L and $D_{Muskat,cat}$. Annotate the transitions with their (outside) conditions. Which of those transitions are invertible according to the definition given in the lecture. This time include ”none” when drawing the DTG for L.

4) Suppose that we pre-assign what to carve to the hands so that we only allow the left hand to carve the cat and the right hand the bat. Re-draw the causal graph. Which facts(instantiated variables) are now unreachable? Can the problem be divided into a fixed amount of subproblems with their own causal graph (You are allowed to duplicate the ”L” variable into different graphs). By subproblems we mean that they can be solved independently of each other.

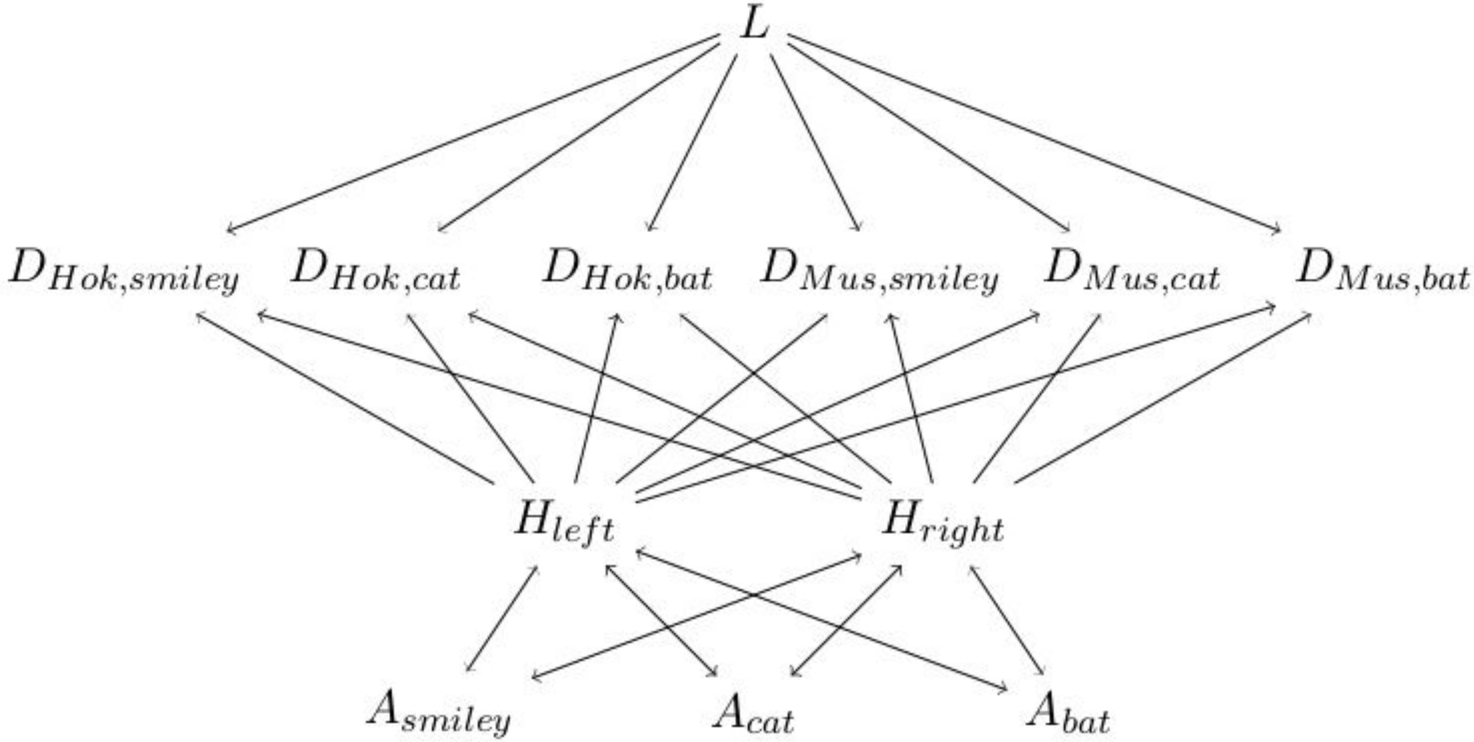
Exercises: Causal Graphs

- $V = \{L, D_{p,c}, A_c, H_h\}$for $p \in Pumpkins, c \in CarveTools, h \in Hands$ with
  $D(L) = \{None\} \cup Pumpkins$
  $D(D_{p,c}) = D(A_c) = \{True, False\}$
  $D(H_h) = \{None\} \cup CarveTools$
- $I = \{L = None, H_{left} = None, H_{right} = None, A_{smiley} = True, A_{cat} = True, A_{bat} = True\} \cup \{D_{p,c} = False \mid p \in Pumpkin, c \in CarveTools\}.$
- $G = \{D_{Muskat,smiley} = True, D_{Muskat,cat} = True, D_{Hokkaido,bat} = True\}$

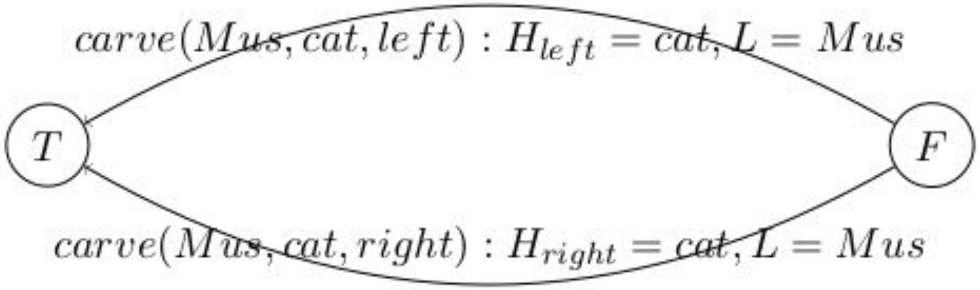
Exercises: Causal Graphs

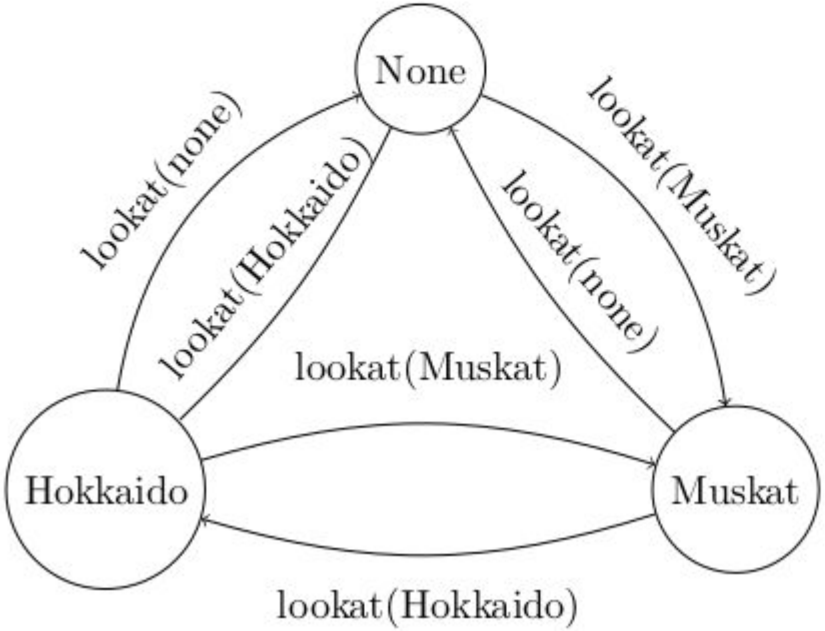
- $A = \{look\_at(p), pick\_up(h,c), drop(c,h), carve(p,c,h)\}$, with
  - $look\_at(p)$ for $p \in Pumpkins$:
    $pre : \{\}$
    $eff : \{L = p\}$
  - $pick\_up(h,c)$ for $h \in Hands, c \in CarveTools$:
    $pre : \{A_c = True, H_h = None\}$
    $eff : \{H_h = c, A_c = False\}$
  - $drop(c,h)$ for $c \in CarveTools, h \in Hands$
    $pre : \{H_h = c\}$
    $eff : \{H_h = None, A_c = True\}$
  - $carve(p,c,h)$ for $p \in Pumpkin, c \in CarveTools, h \in Hands$:
    $pre : \{H_h = c, L = p\}$
    $eff : \{D_{p,c} = True\}$

Exercises: Causal Graphs



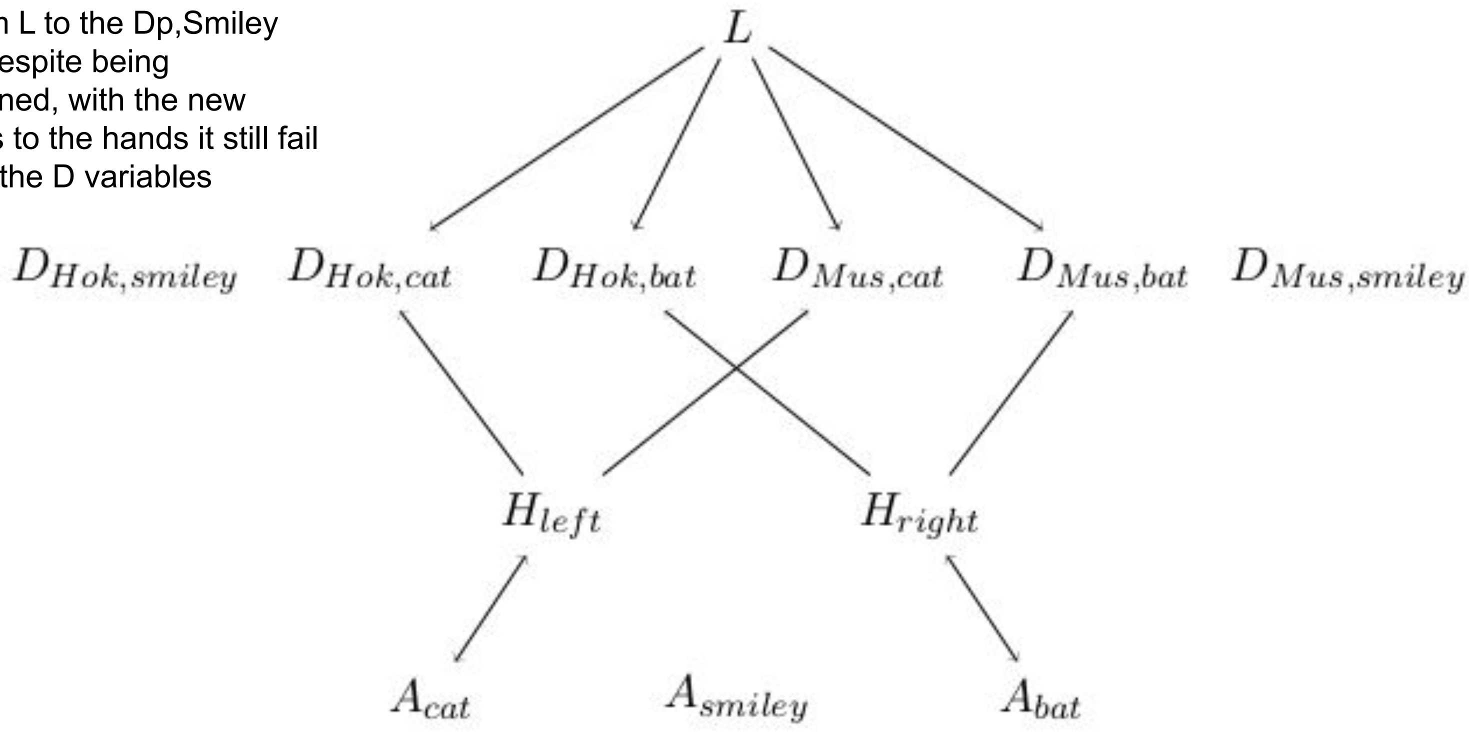
Exercises: Causal Graphs





Exercises: Causal Graphs

Differently from what told in class, we also need to remove the edges from L to the Dp,Smiley because despite being unconstrained, with the new restrictions to the hands it still fail to change the D variables



Exercises: Progression and Regression

XinYue needs more cakes to send them to friends. Since she cannot bake them all, she wants to buy some delicious cakes. She also needs to buy wrapping paper. As she wants to support small local shops, she does not want to go to the supermarket. Please help her to estimate the time she needs to purchase her cakes and wrapping paper. To do so, consider the map in Figure 1. Currently, XinYue is at home at location A, and the wrapping paper and the cakes can be bought at the local shop in location C. In the end, XinYue wants to have cakes and wrapping paper, and to be back at home. Note that she first needs to withdraw money at the cashpoint at location B. The problem is formalized as the following STRIPS planning problem $\Pi = (P, A, I, G)$:

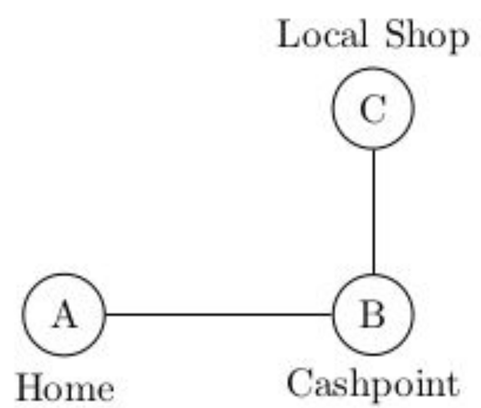


Figure 1: Connection Map for Exercise 1.

Exercises: Progression and Regression

1) Formalize the planning task in STRIPS

2) Draw the progression search graph up to the third level.

3) Draw the regression search graph up to the third level

Exercises: Progression and Regression

$$
\begin{aligned}
P =& \{at(x) \mid x \in \{A, B, C\}\} \cup \{havePaper, haveCake, have2Money, have1Money\} \\
I =& \{at(A)\} \\
G =& \{at(A), havePaper, haveCake\} \\
A =& \{walk(x, y) \mid x, y \in \{A, B, C\} \wedge x, y \text{ } are \text{ } directly \text{ } connected(adjacent)\} \\
& \cup \{buyPaper_2(x) \mid x \in \{C\}\} \cup \{buyPaper_1(x) \mid x \in \{C\}\} \\
& \cup \{buyCake_2(x) \mid x \in \{C\}\} \cup \{buyCake_1(x) \mid x \in \{C\}\} \\
& \cup \{withdrawMoney()\}, \text{ where}
\end{aligned}
$$

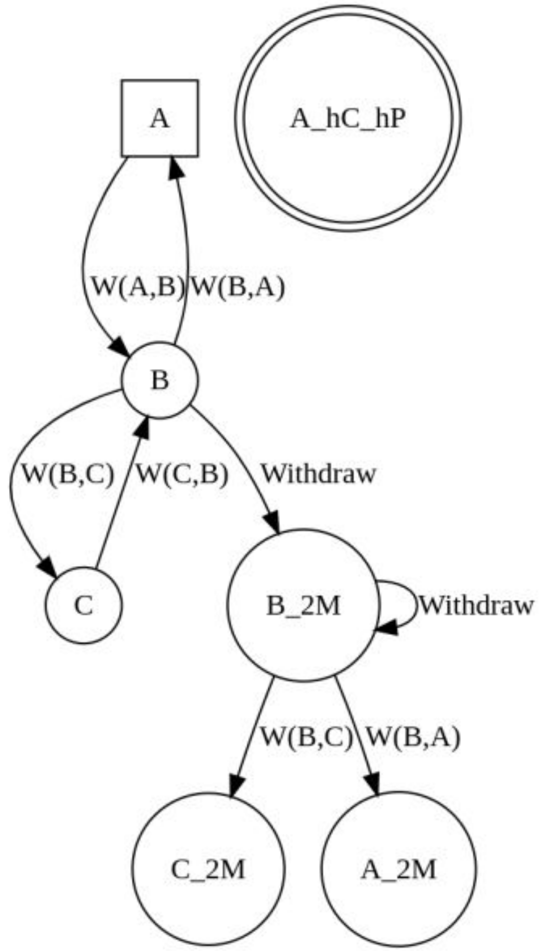
Exercises: Progression and Regression

- $walk(x, y)$ for $x, y \in \{A, B, C\}$, x, y are connected in the map of Figure $\boxed{1}$ and $x \neq y$.
  - $pre : \{at(x)\}$
  - $add : \{at(y)\}$
  - $del : \{at(x)\}$
- $buyPaper_2(x)$ for $x \in \{C\}$
  - $pre : \{at(x), have2Money\}$
  - $add : \{havePaper, have1Money\}$
  - $del : \{have2Money\}$
- $buyPaper_1(x)$ for $x \in \{C\}$
  - $pre : \{at(x), have1Money\}$
  - $add : \{havePaper\}$
  - $del : \{have1Money\}$

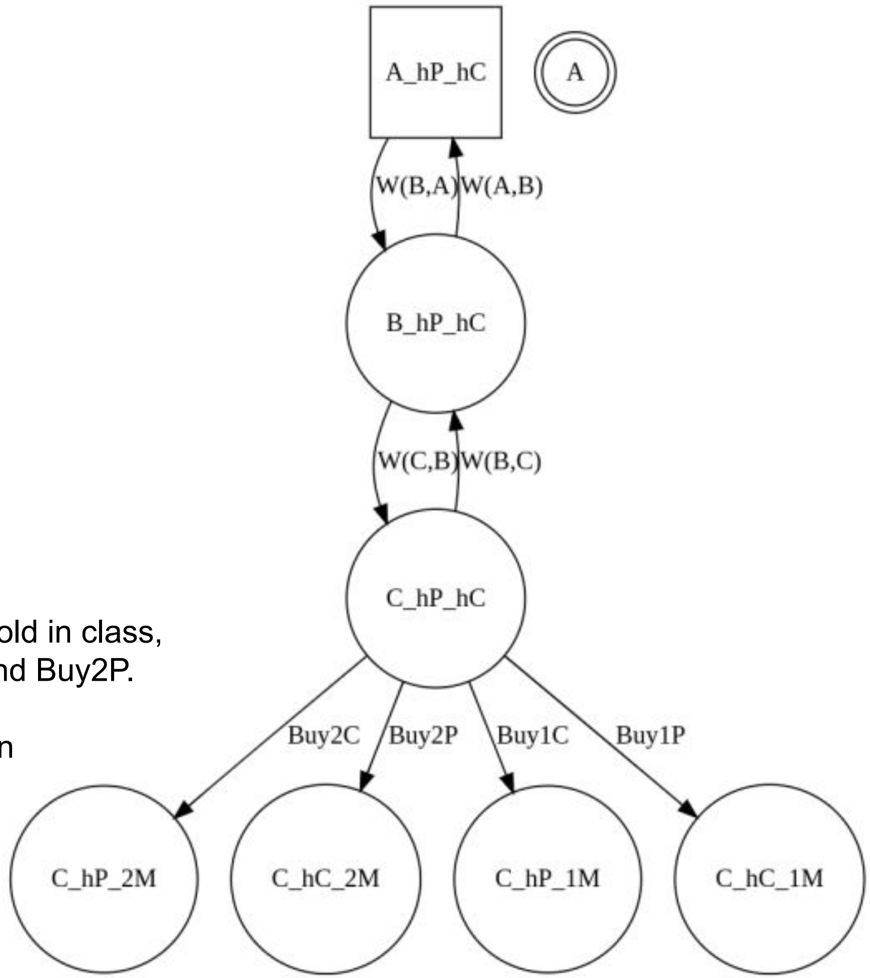
Exercises: Progression and Regression

- $buyCake_2(x)$ for $x \in \{C\}$
  - $pre : \{at(x), have2Money\}$
  - $add : \{haveCake, have1Money\}$
  - $del : \{have2Money\}$
- $buyCake_1(x)$ for $x \in \{C\}$
  - $pre : \{at(x), have1Money\}$
  - $add : \{haveCake\}$
  - $del : \{have1Money\}$
- $withdrawMoney()$
  - $pre : \{at(B)\}$
  - $add : \{have2Money\}$
  - $del : \{have1Money\}$

Exercises: Progression and Regression



Exercises: Progression and Regression



Differently from what told in class, we need the Buy2C and Buy2P.
To understand why:
definition of regr(g,a) in Chapter 17 slide 18