COMP 543: Tools & Models for Data Science

Relational Calculus

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Relational Calculus

- Nothing more than a First Order Logic predicate...
- Embedded within a set constructor

Example: Cold Brew Drinkers

LIKES (DRINKER, COFFEE)
FREQUENTS (DRINKER, CAFE)
SERVES (CAFE, COFFEE)

- ? Query: Who goes to a cafe serving Cold Brew?

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- Query: Who goes to a cafe serving Cold Brew?

$$\{f.\text{DRINKER} \mid \text{FREQUENTS}(f) \wedge \exists(s)(\text{SERVES}(s) \wedge s.\text{COFFEE} = \text{'Cold Brew'} \wedge s.\text{CAFE} = f.\text{CAFE})\}$$

Example: Cold Brew Haters

LIKES (DRINKER, COFFEE)
FREQUENTS (DRINKER, CAFE)
SERVES (CAFE, COFFEE)

- ? Query: Who has not gone to a cafe serving Cold Brew?

Example:Cold Brew Haters, Common Approach

LIKES (DRINKER, COFFEE)
FREQUENTS (DRINKER, CAFE)
SERVES (CAFE, COFFEE)

- Query: Who has not gone to a cafe serving Cold Brew?

$$\{f.\text{DRINKER} \mid \text{FREQUENTS}(f) \land \neg\exists(s)(\text{SERVES}(s) \land s.\text{COFFEE} = \text{'Cold Brew'} \land s.\text{CAFE} = f.\text{CAFE})\}$$

Example: Cold Brew Haters, Common Approach

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- Wrong! This gives us “Who has gone to a cafe that does not serve Cold Brew”
- In parenthesis we have cafes that serve ‘Cold Brew’ that someone has visited.
- Negating it, and checking for existence, gives us cafes that someone has visited that do NOT serve Cold Brew.

Walk–through Data

FREQUENTS

DRINKER	CAFE
Chris	A
Chris	B
Chris	C
Risa	A
Risa	B

SERVES

CAFE	COFFEE
A	Drip
A	Cold Brew
A	Espresso
B	Drip
C	Espresso

Common Approach

Who has gone to a cafe that does not serve 'Cold Brew'?

$$\{f.\text{DRINKER} \mid \text{FREQUENTS}(f) \wedge \neg\exists(s)(\text{SERVES}(s)$$
$$\wedge\ s.\text{COFFEE} = \text{'Cold Brew'} \wedge\ s.\text{CAFE} = f.\text{CAFE})\}$$

For convenience, let's say:

hasCB $= \text{SERVES}(s) \wedge\ s.\text{CAFE} = f.\text{CAFE} \wedge\ s.\text{COFFEE} = \text{'Cold Brew')}$

Common Approach Steps

1. Start with the FREQUENTS table
2. Then look at matches in the SERVES table, where s.CAFE = f.CAFE
3. Evaluate the predicate
4. Is it TRUE?
   - If Yes, then include f.DRINKER in the result set
5. When f.CAFE = ‘B’, Risa gets included in the result set.

DRINKER	CAFE	CAFE	COFFEE	hasCB	¬hasCB	Result Set
Risa	B	B	Drip	F	T	{Risa}

6. When f.CAFE = ‘A’, Risa does NOT get add to the result set

DRINKER	CAFE	CAFE	COFFEE	hasCB	¬hasCB	Result Set
Risa	A	A	Drip	T	F	{ }
		A	Cold Brew			
		A	Espresso			

Common Approach Final Result

- To get the final result set, we union together all the results from the final column

						{ Risa }

- The final result set is { Risa } ∪ { } = { Risa }
- However, Risa shouldn't be in the result set, because she frequents Cafe B, which serves Cold Brew
- Issue: We want to look at ALL of the coffees served at ALL of the cafes Risa frequents all at one time

Correct Approach

Who has not gone to a cafe serving ‘Cold Brew’?

- To answer this question, we need to introduce a second variable:
  $\{f_1.\mathrm{DRINKER}\ |\mathrm{FREQUENTS}(f_1) \wedge\ \neg\exists(f_2, s)(FREQ(f_2)$
  $\quad\quad \wedge\ SERVES(s) \wedge f_2.CAFE = s.CAFE$
  $\quad\quad \wedge\ s.COFFEE = \text{'Cold Brew'} \wedge\ f_1.DRINKER = f_2.DRINKER)\}$
- Again, for convenience, let’s say:
  hasCB $= (FREQ(f_2)$
  $\quad\quad \wedge\ SERVES(s) \wedge f_2.CAFE = s.CAFE$
  $\quad\quad \wedge\ s.COFFEE = \text{'Cold Brew'} \wedge\ f_1.DRINKER = f_2.DRINKER)\}$

Correct Approach

In this case, by having the second variable, we are able to look at all the data for every place Risa frequents as a whole.

- Here, we have another variable, f_2
- We consider each drinker in turn from the FREQUENTS relation. Basically, we are using this table as our master list of drinkers, and are ignoring the CAFE attribute.
  Again, look just at Risa.
- Now, look at all the combinations of FREQUENTS and SERVES where the CAFE matches and the drinker is f_1.DRINKER

f_1.DRINKER	f_2.DRINKER	CAFE	CAFE	COFFEE	hasCB	$\neg$hasCB	Result Set
Risa	Risa	A	A	Cold Brew	T	F	{ }
	Risa	A	A	Drip			
	Risa	A	A	Espresso			
	Risa	B	B	Drip			

- If there is any tuple where the Coffee is 'Cold Brew', we exclude the drinker
- Now, in this case, one of the cafes that Risa frequents does serve Cold Brew, so Risa is not added to the result set

Example: People Who Like to Drink Coffee

LIKES (DRINKER, COFFEE)
FREQUENTS (DRINKER, CAFE)
SERVES (CAFE, COFFEE)

- ? Query: Who goes to a cafe that serves a coffee they like?

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SERVES (CAFE, COFFEE)

- Query: Who goes to a cafe that serves a coffee they like?

$$\{f.\text{DRINKER} \mid \text{FREQUENTS}(f) \wedge \exists(s,l)(\text{SERVES}(s) \wedge \text{LIKES}(l)$$
$$\wedge\ s.\text{COFFEE} = l.\text{COFFEE}$$
$$\wedge\ s.\text{CAFE} = f.\text{CAFE}$$
$$\wedge\ l.\text{DRINKER} = f.\text{DRINKER})\}$$

? We didn't refer to any table more than once. Why not?

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- We didn’t refer to any table more than once. Why not?
- It wasn’t needed since we didn’t have any ‘Always’ or ‘Never’ predicates
- We were looking for ‘Any’

Example: People Who Avoid Bad Cafes

LIKES (DRINKER, COFFEE)
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SERVES (CAFE, COFFEE)

? Query: Which people only go to cafes that serve a coffee they like?

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- Query: Which people only go to cafes that serve a coffee they like?

$$\{f.\text{DRINKER} \mid \text{FREQUENTS}(f) \wedge \forall(f_2)(\text{if } f_2 \text{ tells us a cafe that } f.\text{DRINKER goes to then that cafe needs to serve a coffee that } f.\text{DRINKER likes})\}$$

Example: People Who Avoid Bad Cafes

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FREQUENTS (DRINKER, CAFE)
SERVES (CAFE, COFFEE)

- Query: Which people only go to cafes that serve a coffee they like?

$$
\begin{aligned}
\{f.\mathrm{DRINKER} \mid\ & \mathrm{FREQUENTS}(f) \wedge \forall(f_2)(\mathrm{FREQUENTS}(f_2) \\
& \wedge f.\mathrm{DRINKER} = f_2.\mathrm{DRINKER} \rightarrow \exists(s,l)(\mathrm{SERVES}(s) \\
& \wedge \mathrm{LIKES}(l) \wedge s.\mathrm{CAFE} = f_2.\mathrm{CAFE} \wedge l.\mathrm{COFFEE} = s.\mathrm{COFFEE} \\
& \wedge l.\mathrm{DRINKER} = f_2.\mathrm{DRINKER}))\}
\end{aligned}
$$

Implication

$$
\begin{aligned}
\{f.\mathrm{DRINKER} \mid\ & \mathrm{FREQUENTS}(f) \wedge \forall(f_2)(\mathrm{FREQUENTS}(f_2) \\
& \wedge f.\mathrm{DRINKER} = f_2.\mathrm{DRINKER} \rightarrow \exists(s,l)(\mathrm{SERVES}(s) \\
& \wedge \mathrm{LIKES}(l) \wedge\ s.\mathrm{CAFE} = f_2.\mathrm{CAFE} \wedge\ l.\mathrm{COFFEE} = s.\mathrm{COFFEE} \\
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$$

? Note: we invariably have a "$\rightarrow$" within a $\forall$ quantifier. Why?

Implication

$$\{f.\text{DRINKER} \mid \text{FREQUENTS}(f) \wedge \forall (f_2)(\text{FREQUENTS}(f_2)$$
$$\wedge\, f.\text{DRINKER} = f_2.\text{DRINKER} \rightarrow \exists (s,l)(\text{SERVES}(s)$$
$$\wedge\, \text{LIKES}(l) \wedge\; s.\text{CAFE} = f_2.\text{CAFE} \wedge\; l.\text{COFFEE} = s.\text{COFFEE}$$
$$\wedge\; l.\text{DRINKER} = f_2.\text{DRINKER}))\}$$

- Note: we invariably have a "$\rightarrow$" within a $\forall$ quantifier. Why?
  - $\rightarrow$ is a logical IF–THEN statement

Questions?