A Uniform Meaning Representation for NLP Systems:

Lecture 2: Quantification and Discourse Anaphora in UMR

Martha Palmer and James Pustejovsky

Joint work with Jens Van Gysel, Meagan Vigus, Jin Zhao, Nianwen Xue, Jayeol Chun, Kenneth Lai, Sara Moeller, Jiarui Yao, Tim O'Gorman, Andrew Cowell, William Croft, Chu-Ren Huang, Jan Hajič, James Martin, Stephan Oepen, Rosa Vallejos

ESSLLI 2023 Summer School

Ljubljana, Slovenia

August 7-11, 2023

Course Outline

- Monday: Formal Foundations of UMR and Extensions beyond AMR
- Tuesday: UMR Mechanisms for Quantification and Discourse Anaphora
- Wednesday: Annotation in UMR for Multiple Languages and Parsing UMRs
- Thursday: Extensions of UMR for Multimodal Communication and Situated Grounding
- Friday: UMR for Knowledge Grounding and Logical Inference

Initial Representation Ideas for Scope in AMR

Everyone in the room listened to a talk.

```
(l / listen-01
      :ARG0 (p / person
         :mod (a / all)
         :location (r / room))
      :ARG1 (t / talk))
```

Everyone drank a coffee at noon.

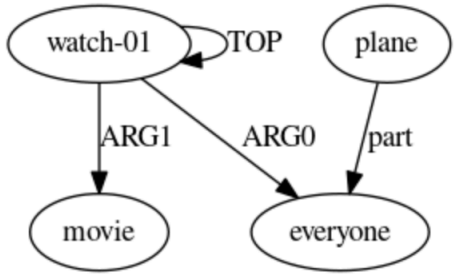
```
(d / drink-01
      :ARG0 (p / person
         :mod (a / all))
      :ARG1 (c / coffee)
      :time (n / noon))
```

- How many talks were there? How many (cups of) coffee?

Quantifier Scope in AMR

Everyone in the room was listening to a talk.
$\exists y[talk(y) \wedge \forall x[person(x) \wedge inRoom(x) \rightarrow listen(x, y)]]$

Everyone on the plane was watching a movie.
$\forall x[[person(x) \wedge onPlane(x)] \rightarrow \exists y[movie(y) \wedge watch(x, y)]]$

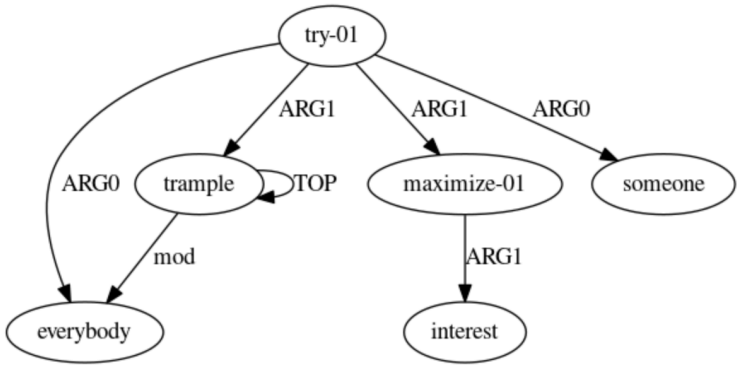


Quantifier Scope in AMR

Everyone drank a coffee at break.
b. $\forall x[person(x) \rightarrow \exists y[coffee(y) \wedge drink(x, y)]]$

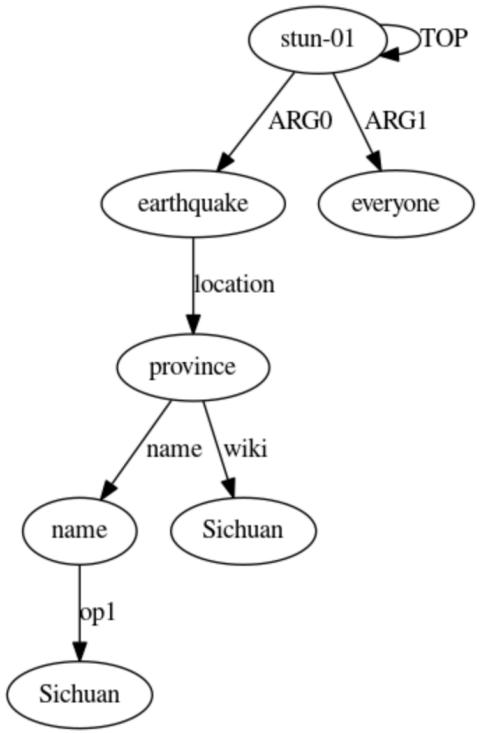
No Account for Quantifier Scope

Everybody tramples over someone trying to maximize their own interests.



No Account for Quantifier Scope

An earthquake in Sichuan stunned everyone.



a. Everyone here has had a COVID vaccine shot.
b. Everyone here has had the Moderna vaccine.

Initial Representation Ideas for Scope in AMR

- In many cases, there is a natural "default" reading. But consider the following:

Someone didn't answer all the questions.

```
(a / answer-01
     :ARG0 (p / person)
     :ARG1 (q / question
        :mod (a / all))
     :polarity -)
```

Negation Re-interpretation

Argument-to-predicate Raising

- No passengers survived.
  $\forall x[passenger(x) \rightarrow \neg\exists e[survive(e, x)]]$
- There were no survivors.
  $\neg\exists x\exists e[person(x) \wedge survive(e, x)]$

Neg-Raising à la Horn

- Bill doesn't think that Mary likes fish.
  $\Longrightarrow think(Bill, \hat{}\neg like(Mary, fish))$
- Bill didn't say Mary was sick.
  $\not\Longrightarrow say(Bill, \neg sick(Mary))$

Negation Lowering over Comparison Sets

- We don't want to revitalize the nation through trials and tribulations.
  presup:
  $want(we, \hat{\exists}x, e[revitalize(e, we, Nation) \wedge means(e, x)])$
  $\overset{\circ}{\textbf{but}}\ \neg[trial(x) \vee tribulation(x)]$
- He doesn't want to have dinner at the Thai restaurant.
  presup: $want(he, \hat{\exists}x, e[dine(e, he) \wedge locate(e, x)])$
  $\overset{\circ}{\textbf{but}}\ \neg[Thai\_Restaurant(x)]$
- I don't want you going to university in Europe.
  ditto

Initial Representation Ideas for Scope in AMR

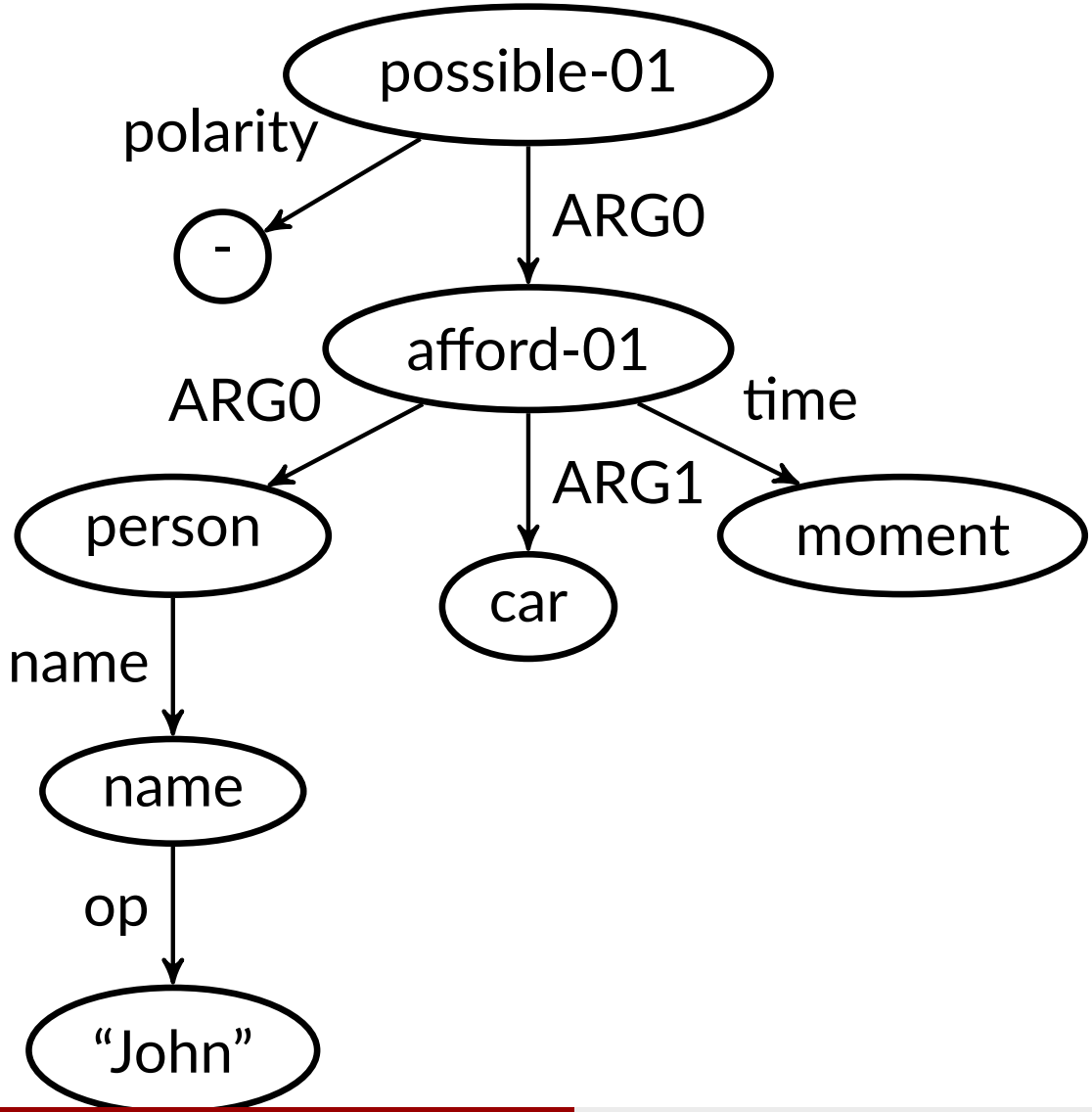
- Goal: represent scope in AMR/UMR while maintaining the predicative core of the sentence and the syntactic integrity of the quantified expression
- Solution: represent scope relationally, with a scope node

AMR Modal with Polarity Feature

John can't afford a car at the moment.

a.
```
(p / possible-01
      :ARG0 (a / afford-01
         :ARG0 (p2 / person
            :name (n / name
               :op "John"))
         :ARG1 (c /car)
         :time (m / moment))
      :polarity -)
```

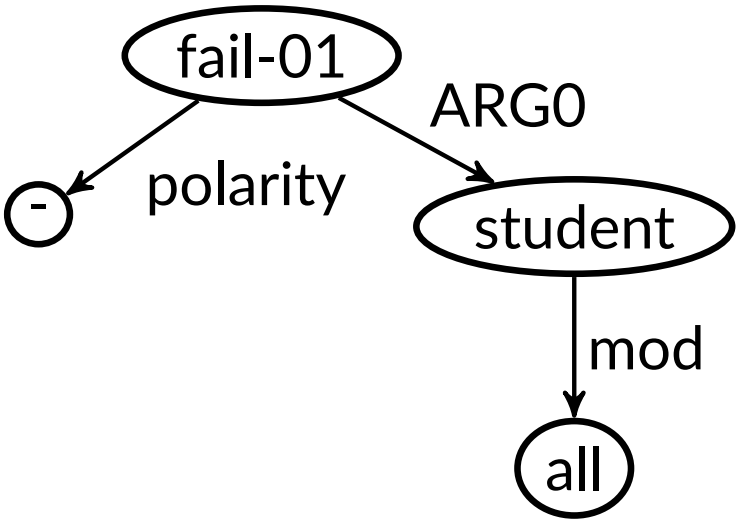
AMR Modal with Polarity Feature



Quantifiers and Negation

a. Every student did not fail.

b.
```
(d / fail-01
   :ARG0 (s / student
      :mod (a / all))
   :polarity -)
```



- No student failed.
  $\neg\exists x[student(x) \wedge fail(x)]$
- It is not the case that every student failed.
  $\exists x[student(x) \wedge \neg fail(x)]$

Adopting Scope Relation from ISO-TimeML

Pustejovsky, Xue, and Lai (2019)

A towel$_{se1}$ covered every cookie$_{se2}$.

$\exists x[\mathit{towel}(x) \wedge \forall y[\mathit{cookie}(y) \rightarrow \mathit{cover}(x, y)]]$

<spatialEntity id="se1" pred="towel"
quant="1" scopes="#se1"/>
<spatialEntity id="se2" pred="cookie"
quant="every" scopes="∅"/>

A computer$_{se1}$ is on$_{ss1}$ every desk$_{se2}$.

$\forall y[\mathit{desk}(y) \rightarrow \exists x[\mathit{computer}(x) \wedge \mathit{on}(x, y)]]$

<spatialEntity id="se1" pred="computer"
quant="1" scopes="∅"/>
<spatialEntity id="se2" pred="desk"
quant="every" scopes="#se1"/>

Adopting Scope Relation from ISO-TimeML

$\forall t[Monday(t)) \rightarrow \exists e[teach(e, \text{teacher}) \wedge on(e, t)]]$

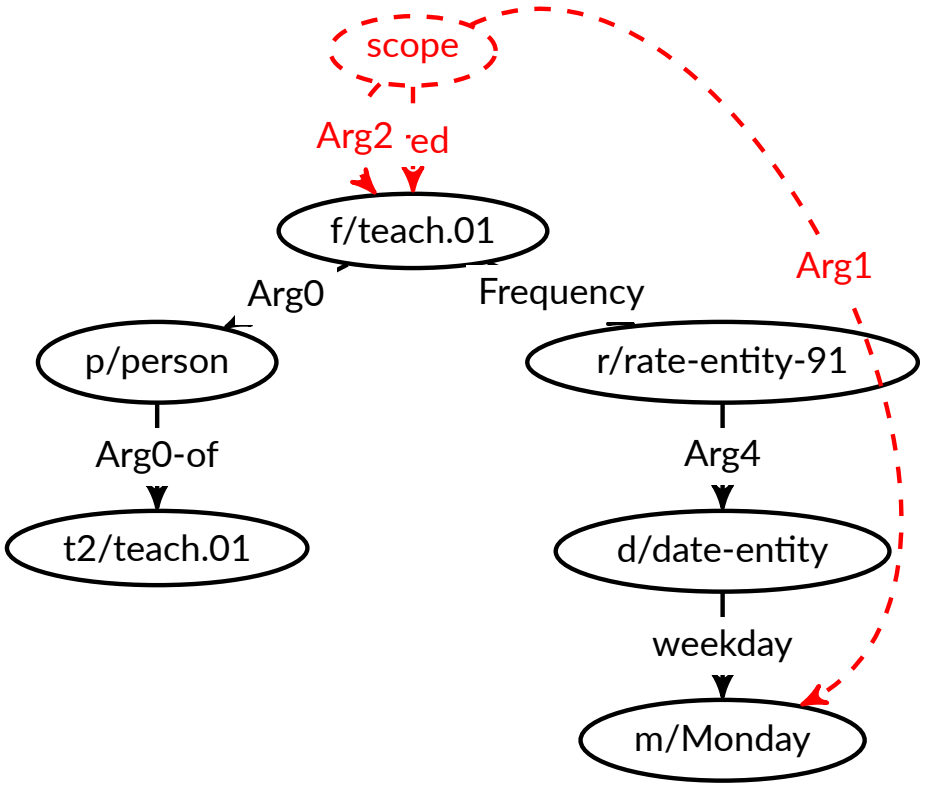


Figure: "The teacher taught every Monday"

Uniform Meaning Representation for Scope (UMR)

- scopeLink($arg_1, arg_2, relType$)
- <scopeLink arg1="a1" arg2="a2" relType="wider"/>
- We modify this scoping relation by introducing the predicative domain as an additional argument:
  - λpred$\lambda a_2 \lambda a_1$[**scope**$(a_1, a_2,$ pred$)$]
- Argument position determines scope relation
  - <scopeLink arg1="a1" arg2="a2" predVal ="pred"/>

UMR with the Scope Relation

- Some person fed every dog.
- $\exists x[person(x) \wedge \forall y[dog(y) \rightarrow feed(x, y)]]$

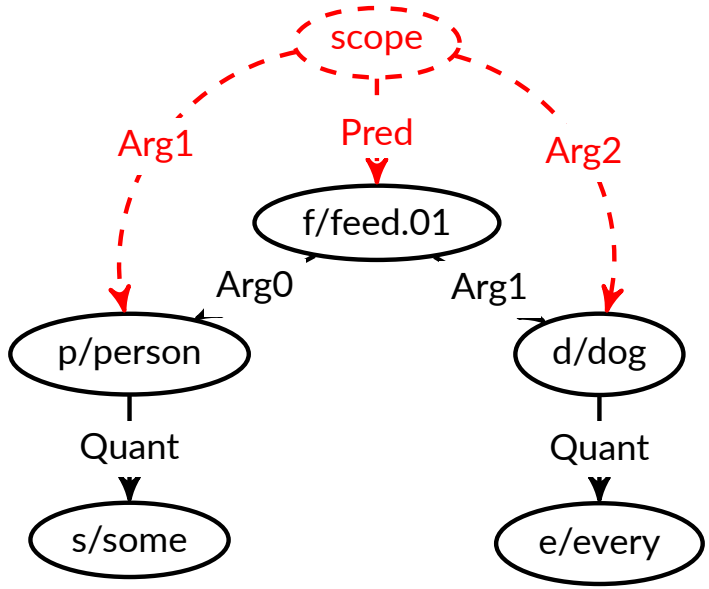
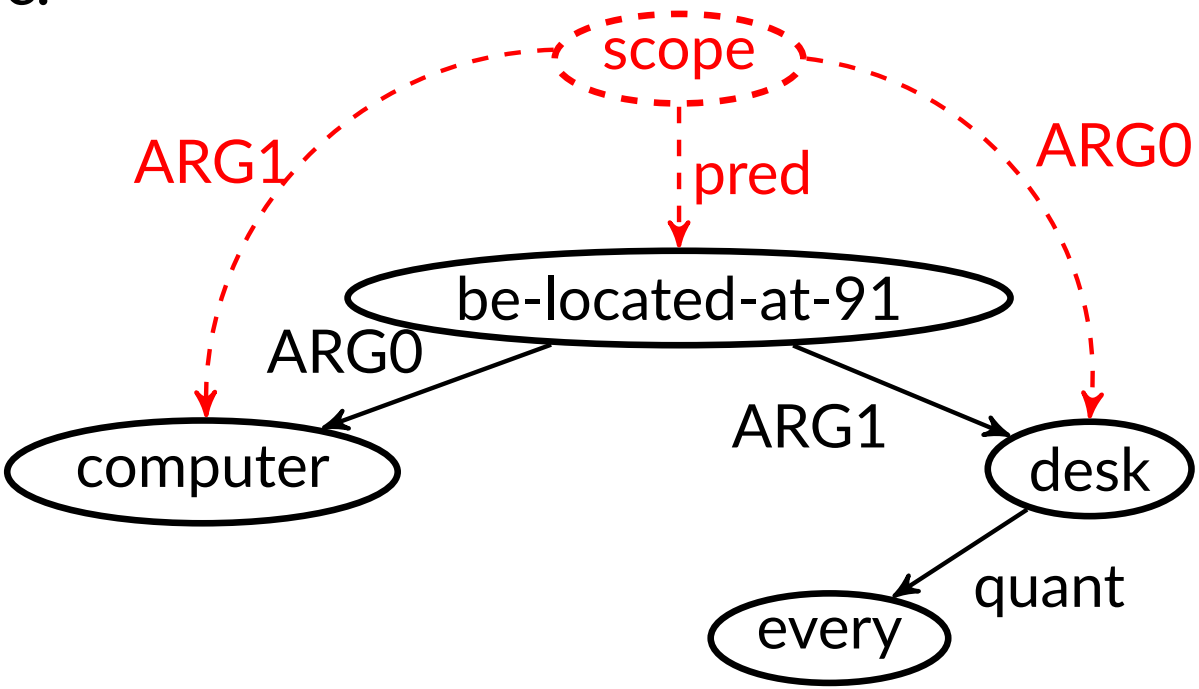


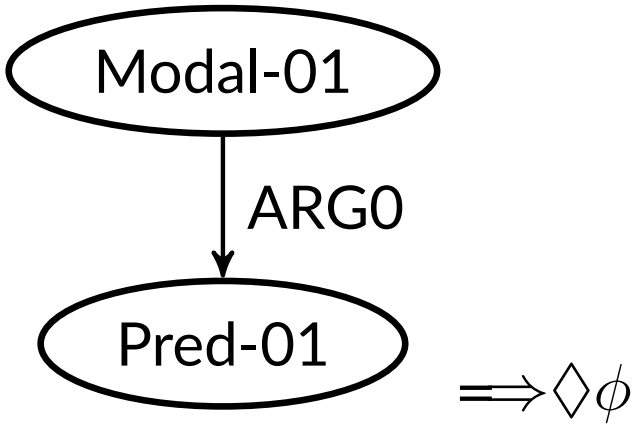
Figure: Wide scope for existential quantifier

Expressing Relative Scope in UMR

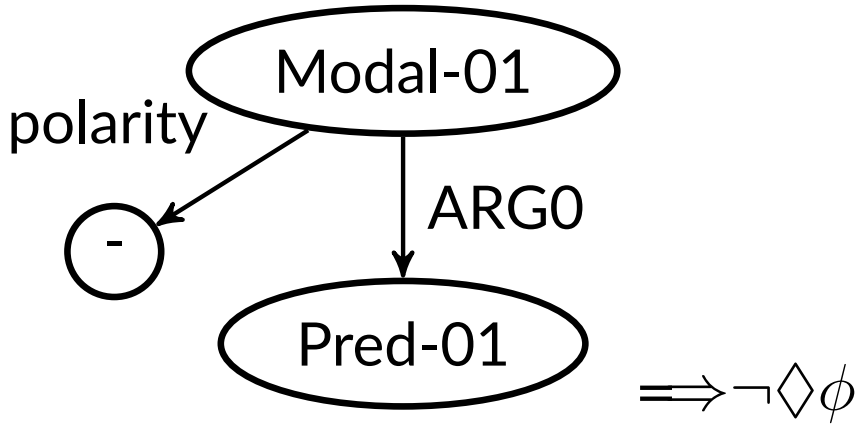
a. A computer is on every desk.
b.
```
(s / scope
        :pred (b / be-located-at-91
              :ARG0 (c / computer)
              :ARG1 (d / desk
                    :quant (e / every)))
        :ARG0 d
        :ARG1 c)
```
c.



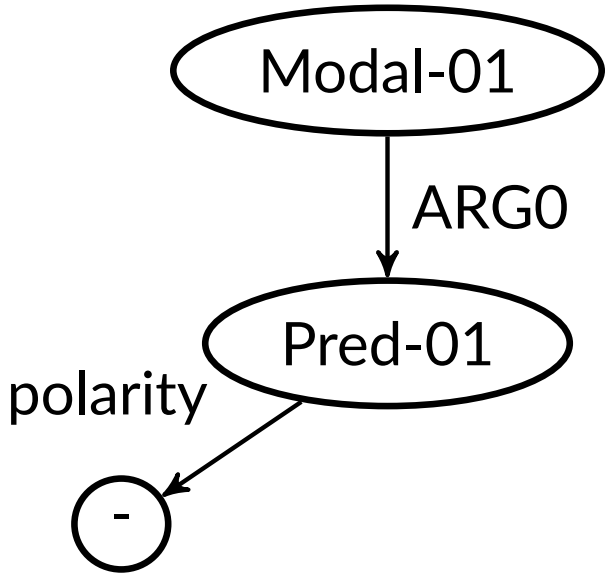
Scope of Modals and Negation



Scope of Modals and Negation - Wide



Scope of Modals and Negation - Narrow



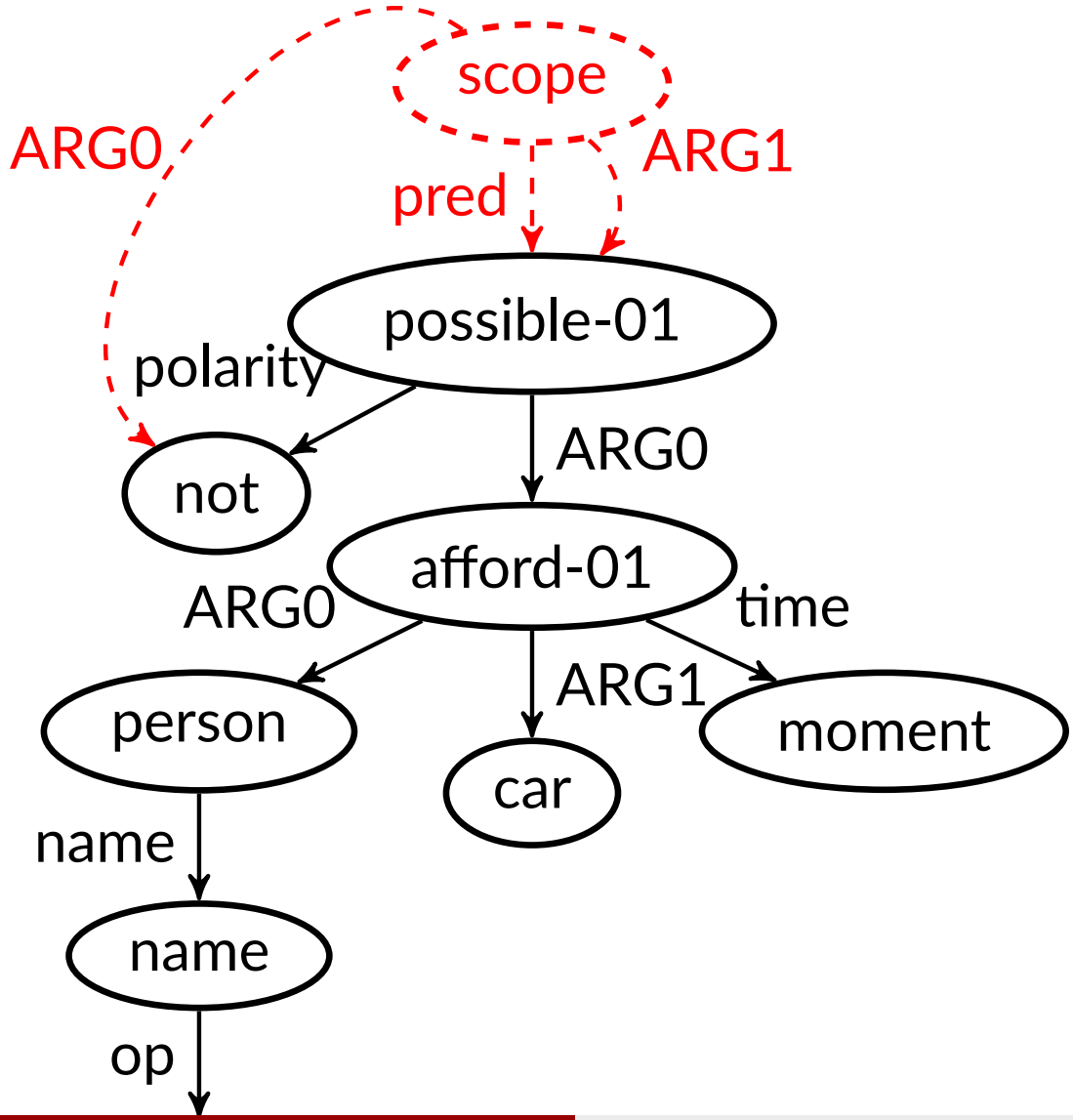
$$\Rightarrow \Diamond \neg \phi$$

Scope of Negation 1/2

a. John can't afford a car at the moment.

b.
```
(s / scope
      :pred (p / possible-01
         :ARG0 (a / afford-01
            :ARG0 (p2 / person
               :name (n / name
                  :op "John"))
            :ARG1 (c /car)
            :time (m / moment))
         :polarity (n2 / not))
      :ARG0 n2
      :ARG1 p)
```

Scope of Negation 2/2



Two Problems with this Solution

- It does not provide a direct compositional semantic interpretation of the graph associated with the sentence;
- It introduces a non-predicative root note, contrary to the general spirit of AMR/UMR.

Reinterpreting the Scope relation in UMR

- Create an inverse edge for `pred`: `pred-of`
- Push the `scope` node under the usual root node of the verb: as the value of `pred-of`.

Reinterpreting the Scope relation in UMR

Someone didn't answer all the questions.

```
(a / answer-01
      :ARG0 (p / person)
      :ARG1 (q / question
         :mod (a / all)
         :polarity -)
      :pred-of (s / scope
         :ARG0 p
         :ARG1 q))
```

$\exists p(\text{person}(p) \wedge \neg\forall q(\text{question}(q) \rightarrow$
$\exists a(\text{answer-01}(a) \wedge \text{ARG1}(a, q) \wedge \text{ARG0}(a, p))))$

"There exists some person who didn't answer every question"

Reinterpreting the Scope relation in UMR

Someone didn't answer all the questions.

```
(a / answer-01
      :ARG0 (p / person)
      :ARG1 (q / question
         :mod (a / all)
         :polarity -)
      :pred-of (s / scope
         :ARG0 q
         :ARG1 p))
```

$\neg\forall q(\text{question}(q) \rightarrow \exists p(\text{person}(p) \wedge$
$\exists a(\text{answer-01}(a) \wedge \text{ARG1}(a, q) \wedge \text{ARG0}(a, p))))$

"Not every question was answered by someone"

Quantification scope annotation

- Scope will not be annotated for summation readings, nor is it annotated where a distributive or collective reading can be predictably derived from the lexical semantics.
  - The linguistics students ran 5 kilometers to raise money for charity.
  - The linguistics students carried a piano into the theater.
  - Ten hurricanes hit six states over the weekend.
- The scope annotation only comes into play when some overt linguistic element forces an interpretation that diverges from the lexical default
  - The linguistics students together ran 200 kilometers to raise money for charity.
  - The bodybuilders each carried a piano into the theater.
  - Ten hurricanes each hit six states over the weekend.