semantic role labeling

CS 585, Fall 2018

Introduction to Natural Language Processing

http://people.cs.umass.edu/~miyyer/cs585/

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slides from Dan Jurafsky and Emma Strubell

stuff from last time

- extra credit template released
- HW3???
- progress reports due Friday!
- no class till the 27th! enjoy the break :)

Semantic Role Labeling

Who did *what* to *whom* at *where?*

The police officer detained the suspect at the scene of the crime

Agent Predicate Theme Location

Can we figure out that these have the same meaning?

XYZ corporation **bought** the stock.

They **sold** the stock to XYZ corporation.

The stock was **bought** by XYZ corporation.

The **purchase** of the stock by XYZ corporation...

The stock **purchase** by XYZ corporation...

A Shallow Semantic Representation: Semantic Roles

Predicates (bought, sold, purchase) represent an **event**

semantic roles express the abstract role that arguments of a predicate can take in the event

More specific ⟷ More general

buyer **agent** **proto-agent**

Getting to semantic roles

Neo-Davidsonian event representation:

Sasha broke the window

Pat opened the door

$$\exists e,x,y\; Breaking(e) \wedge Breaker(e, Sasha) \wedge BrokenThing(e,y) \wedge Window(y)$$

$$\exists e,x,y\; Opening(e) \wedge Opener(e, Pat) \wedge OpenedThing(e,y) \wedge Door(y)$$

Subjects of break and open: **Breaker** and **Opener**

Deep roles specific to each event (breaking, opening)

Hard to reason about them for NLU applications like QA

Thematic roles

- **Breaker** and **Opener** have something in common!
  - Volitional actors
  - Often animate
  - Direct causal responsibility for their events
- Thematic roles are a way to capture this semantic commonality between *Breakers* and *Eaters*.
- They are both AGENTS.
- The *BrokenThing* and *OpenedThing*, are THEMES.
  - prototypically inanimate objects affected in some way by the action

Thematic roles

- One of the oldest linguistic models
  - Indian grammarian Panini between the 7th and 4th centuries BCE
- Modern formulation from Fillmore (1966,1968), Gruber (1965)
  - Fillmore influenced by Lucien Tesnière's (1959) *Éléments de Syntaxe Structurale,* the book that introduced dependency grammar
  - Fillmore first referred to roles as *actants* (Fillmore, 1966) but switched to the term *case*

Thematic roles

- A typical set:

Thematic Role	Definition	Example
AGENT	The volitional causer of an event	*The waiter* spilled the soup.
EXPERIENCER	The experiencer of an event	*John* has a headache.
FORCE	The non-volitional causer of the event	*The wind* blows debris from the mall into our yards.
THEME	The participant most directly affected by an event	Only after Benjamin Franklin broke *the ice*...
RESULT	The end product of an event	The city built a *regulation-size baseball diamond*...
CONTENT	The proposition or content of a propositional event	Mona asked *"You met Mary Ann at a supermarket?"*
INSTRUMENT	An instrument used in an event	He poached catfish, stunning them *with a shocking device*...
BENEFICIARY	The beneficiary of an event	Whenever Ann Callahan makes hotel reservations *for her boss*...
SOURCE	The origin of the object of a transfer event	I flew in *from Boston*.
GOAL	The destination of an object of a transfer event	I drove *to Portland*.

Problems with Thematic Roles

Hard to create standard set of roles or formally define them

Often roles need to be fragmented to be defined.

Levin and Rappaport Hovav (2015): two kinds of INSTRUMENTS

intermediary instruments that can appear as subjects

The cook opened the jar with the new gadget.

The new gadget opened the jar.

enabling instruments that cannot

Shelly ate the sliced banana with a fork.

*The fork ate the sliced banana.

Alternatives to thematic roles

1. **Fewer roles**: generalized semantic roles, defined as prototypes (Dowty 1991)

   PROTO-AGENT

   PROTO-PATIENT

   PropBank

2. **More roles**: Define roles specific to a group of predicates

   FrameNet

PropBank

- Palmer, Martha, Daniel Gildea, and Paul Kingsbury. 2005. The Proposition Bank: An Annotated Corpus of Semantic Roles. *Computational Linguistics*, 31(1):71–106

PropBank Roles

Following Dowty 1991

Proto-Agent

- Volitional involvement in event or state
- Sentience (and/or perception)
- Causes an event or change of state in another participant
- Movement (relative to position of another participant)

Proto-Patient

- Undergoes change of state
- Causally affected by another participant
- Stationary relative to movement of another participant

PropBank Roles

- Following Dowty 1991
  - Role definitions determined verb by verb, with respect to the other roles
  - Semantic roles in PropBank are thus verb-sense specific.
- Each verb sense has numbered argument: Arg0, Arg1, Arg2,…

Arg0: PROTO-AGENT

Arg1: PROTO-PATIENT

Arg2: usually: benefactive, instrument, attribute, or end state

Arg3: usually: start point, benefactive, instrument, or attribute

Arg4 the end point

(Arg2-Arg5 are not really that consistent, causes a problem for labeling)

PropBank Frame Files

agree.01

Arg0: Agreer
Arg1: Proposition
Arg2: Other entity agreeing

Ex1: [$_{\text{Arg0}}$ The group] *agreed* [$_{\text{Arg1}}$ it wouldn't make an offer].
Ex2: [$_{\text{ArgM-TMP}}$ Usually] [$_{\text{Arg0}}$ John] *agrees* [$_{\text{Arg2}}$ with Mary] [$_{\text{Arg1}}$ on everything].

fall.01

Arg1: Logical subject, patient, thing falling
Arg2: Extent, amount fallen
Arg3: start point
Arg4: end point, end state of arg1
Ex1: [$_{\text{Arg1}}$ Sales] *fell* [$_{\text{Arg4}}$ to \$25 million] [$_{\text{Arg3}}$ from \$27 million].
Ex2: [$_{\text{Arg1}}$ The average junk bond] *fell* [$_{\text{Arg2}}$ by 4.2%].

Advantage of a ProbBank Labeling

increase.01 "go up incrementally"

Arg0: causer of increase

Arg1: thing increasing

Arg2: amount increased by, EXT, or MNR

Arg3: start point

Arg4: end point

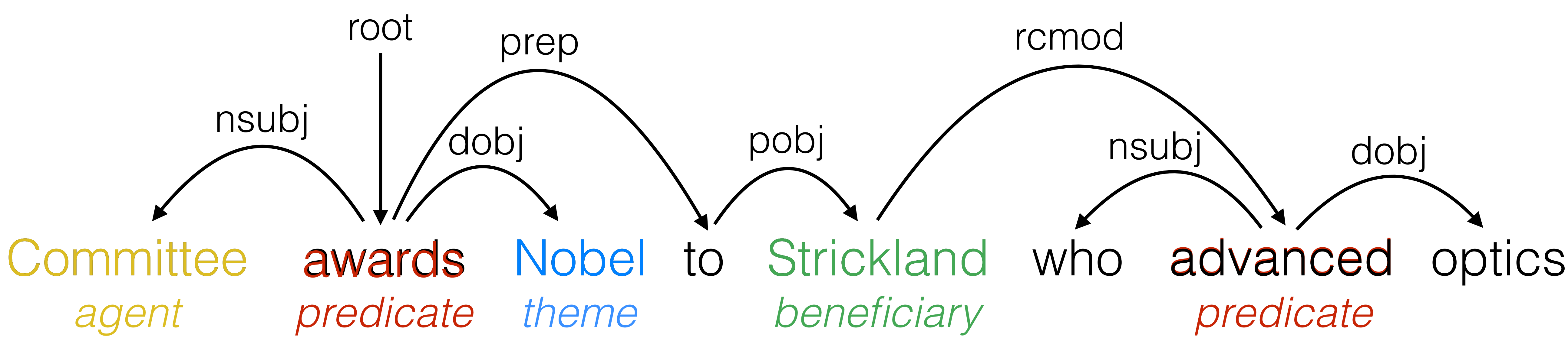
This would allow us to see the commonalities in these 3 sentences:

[$_{\text{Arg0}}$ Big Fruit Co.] increased [$_{\text{Arg1}}$ the price of bananas].

[$_{\text{Arg1}}$ The price of bananas] was increased again [$_{\text{Arg0}}$ by Big Fruit Co.]

[$_{\text{Arg1}}$ The price of bananas] increased [$_{\text{Arg2}}$ 5%].

SRL: Who did what to whom?



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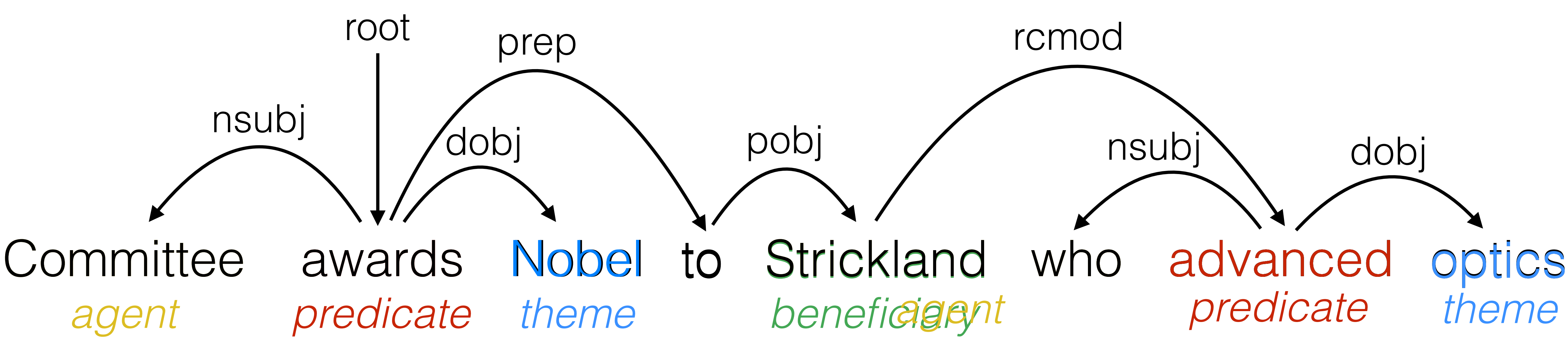

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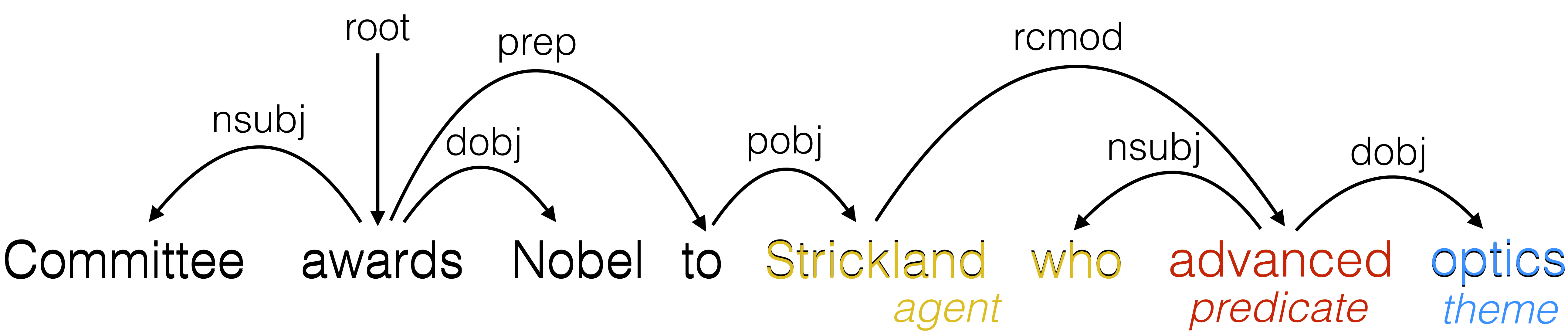
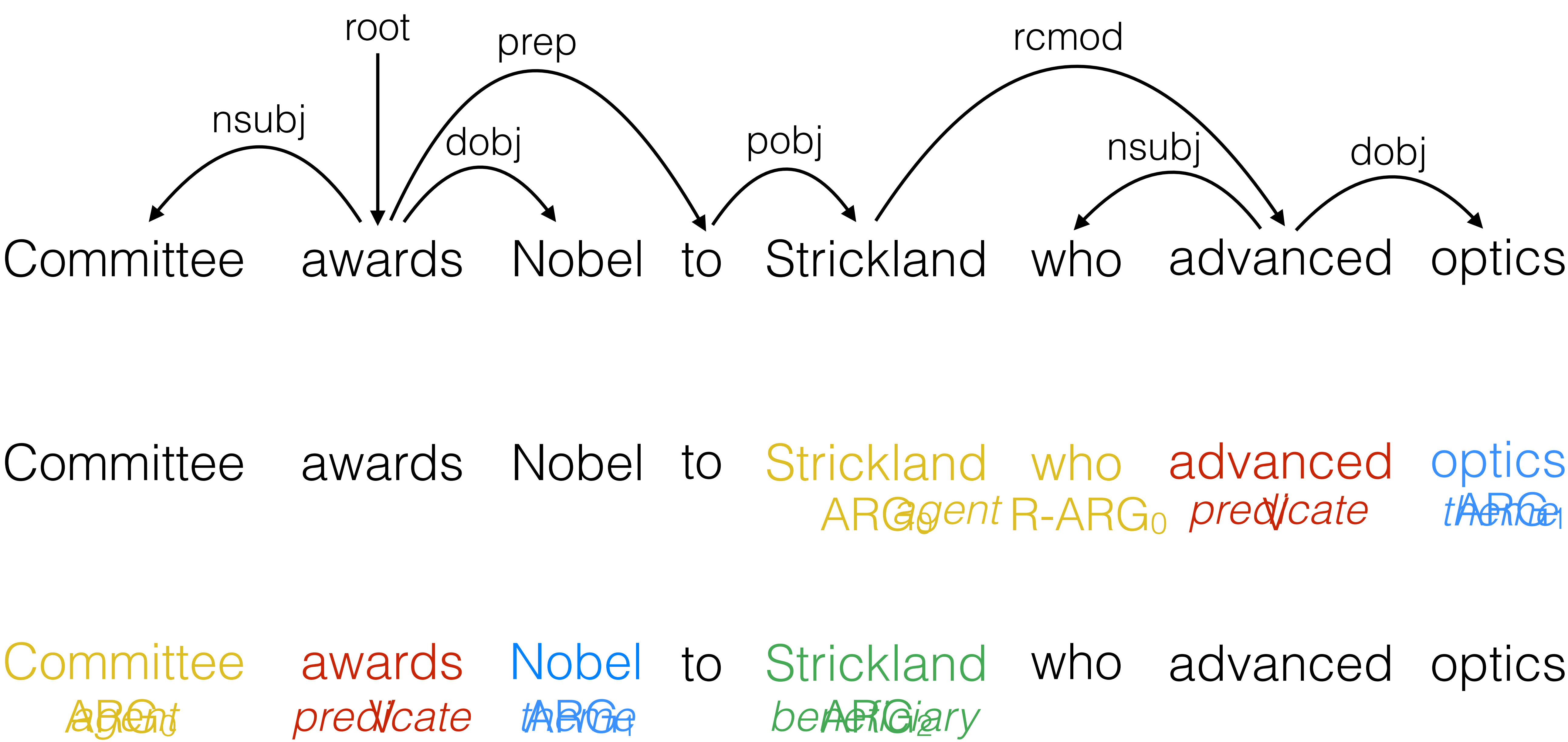


Committee *agent* awards *predicate* Nobel *theme* to Strickland *beneficiary* who advanced optics

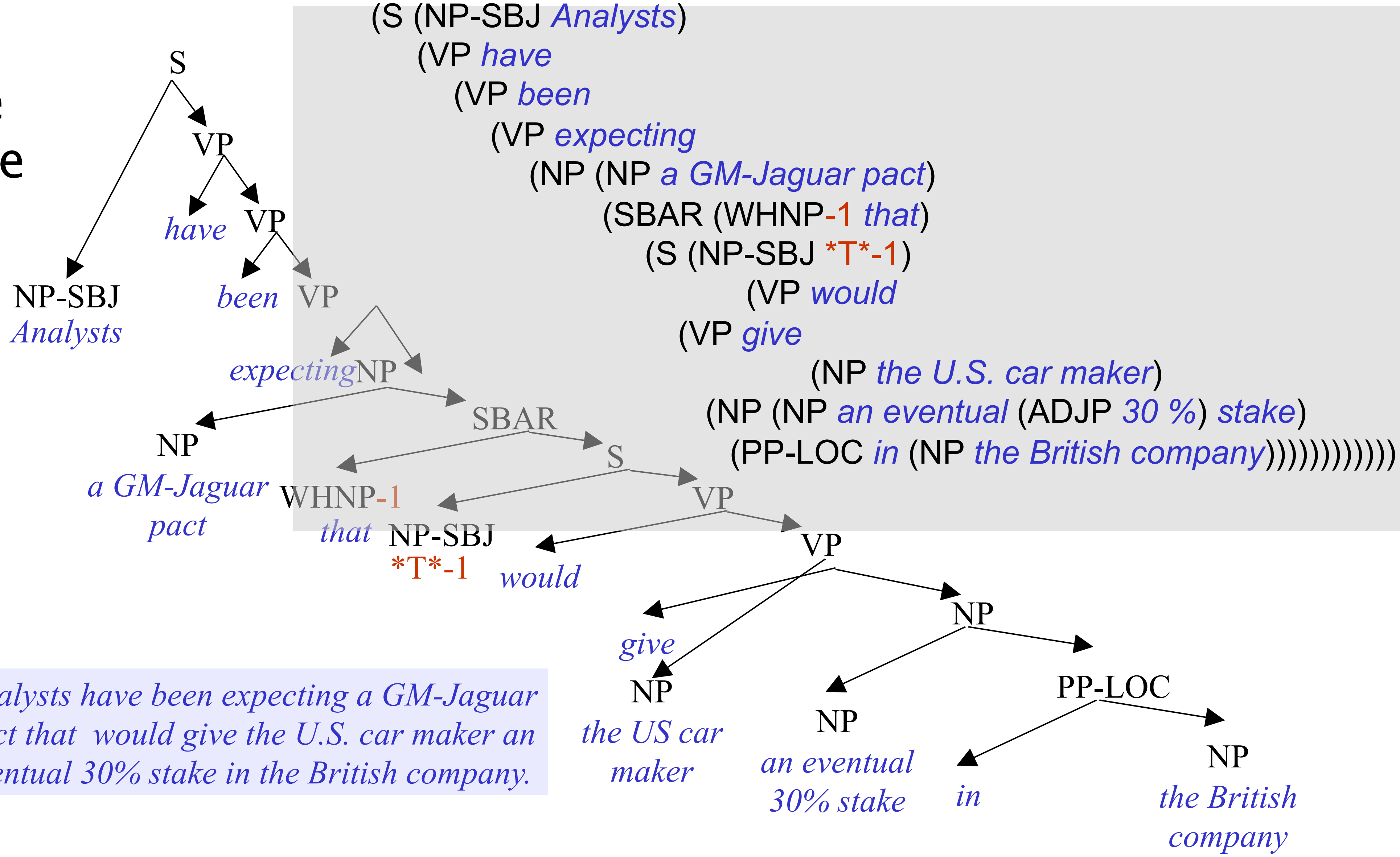
PropBank SRL: Who did what to whom?



PropBanking a Sentence

Martha Palmer 2013

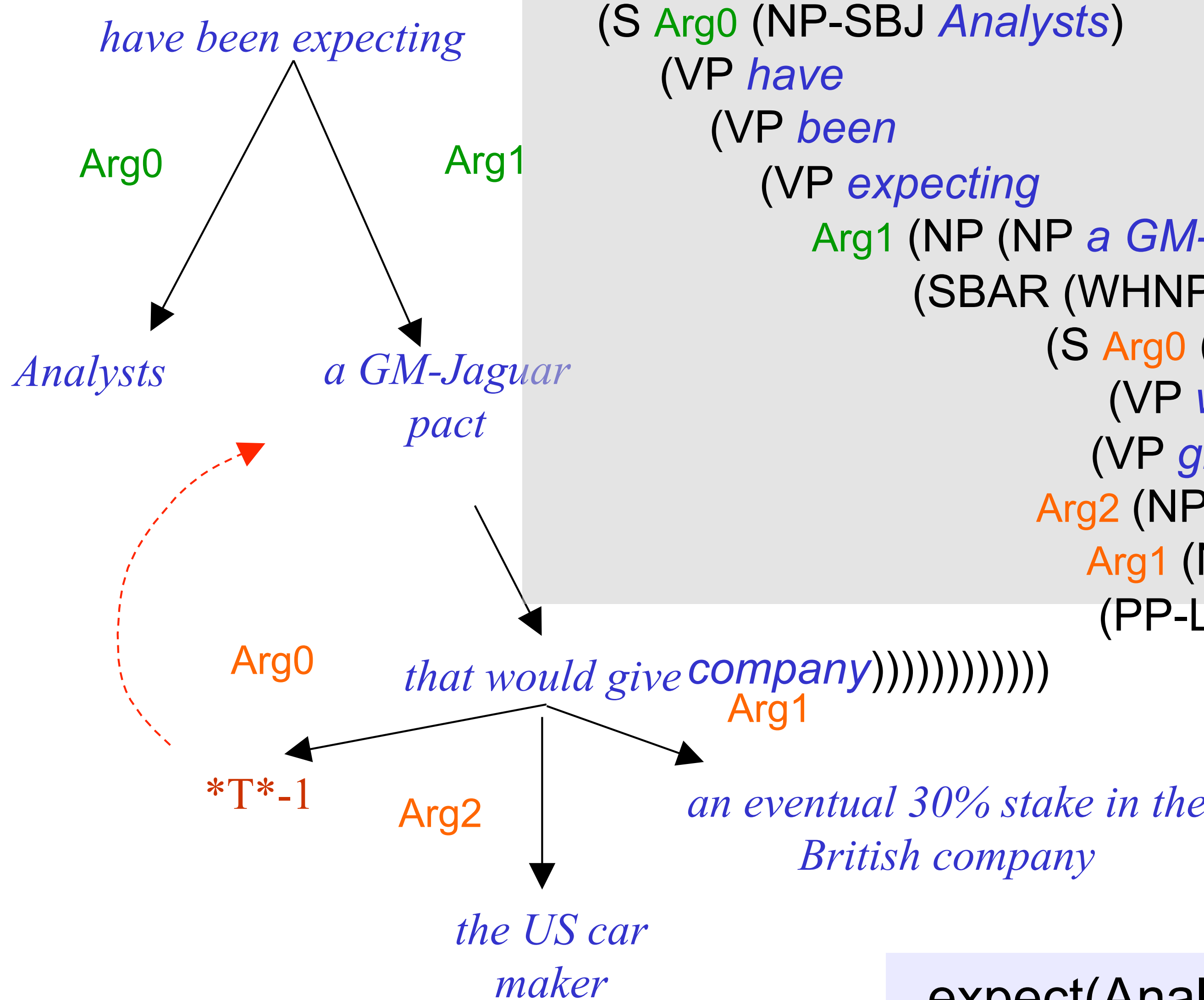
A sample parse tree



Analysts have been expecting a GM-Jaguar pact that would give the U.S. car maker an eventual 30% stake in the British company.

The same parse tree PropBanked

Martha Palmer 2013




```
(S Arg0 (NP-SBJ Analysts)
   (VP have
      (VP been
         (VP expecting
            Arg1 (NP (NP a GM-Jaguar pact)
                     (SBAR (WHNP-1 that)
                           (S Arg0 (NP-SBJ *T*-1)
                              (VP would
                             (VP give
                           Arg2 (NP the U.S. car maker)
                             Arg1 (NP (NP an eventual (ADJP 30 %) stake)
                              (PP-LOC in (NP the British
company))))))))))))
```

expect(Analysts, GM-J pact)
give(GM-J pact, US car maker, 30% stake)

Annotated PropBank Data

- Penn English TreeBank,
  OntoNotes 5.0.
  - Total ~2 million words
- Penn Chinese TreeBank
- Hindi/Urdu PropBank
- Arabic PropBank

2013 Verb Frames Coverage
Count of word sense (lexical units)

Language	*Final Count*
English	**10,615***
Chinese	**24, 642**
Arabic	**7,015**

From Martha Palmer 2013 Tutorial

Semantic Role Labeling

FrameNet

FrameNet

- Baker et al. 1998, Fillmore et al. 2003, Fillmore and Baker 2009, Ruppenhofer et al. 2006
- Roles in PropBank are specific to a verb
- Role in FrameNet are specific to a **frame: a** background knowledge structure that defines a set of frame-specific semantic roles, called **frame elements**,
  - includes a set of pred cates that use these roles
  - each word evokes a frame and profiles some aspect of the frame

The "Change position on a scale" Frame

This frame consists of words that indicate the change of an ITEM's position on a scale (the ATTRIBUTE) from a starting point (INITIAL VALUE) to an end point (FINAL VALUE)

[$_{\text{ITEM}}$ Oil] *rose* [$_{\text{ATTRIBUTE}}$ in price] [$_{\text{DIFFERENCE}}$ by 2%].

[$_{\text{ITEM}}$ It] has *increased* [$_{\text{FINAL\_STATE}}$ to having them 1 day a month].

[$_{\text{ITEM}}$ Microsoft shares] *fell* [$_{\text{FINAL\_VALUE}}$ to 7 5/8].

[$_{\text{ITEM}}$ Colon cancer incidence] *fell* [$_{\text{DIFFERENCE}}$ by 50%] [$_{\text{GROUP}}$ among men].

a steady *increase* [$_{\text{INITIAL\_VALUE}}$ from 9.5] [$_{\text{FINAL\_VALUE}}$ to 14.3] [$_{\text{ITEM}}$ in dividends]

a [$_{\text{DIFFERENCE}}$ 5%] [$_{\text{ITEM}}$ dividend] *increase*...

The “Change position on a scale” Frame

VERBS:
advance
climb
decline
decrease
diminish
dip
double
drop
dwindle
edge
explode
fall
fluctuate
gain
grow
increase
jump
move
mushroom
plummet
reach
rise
rocket
shift
skyrocket
slide
soar
swell
swing
triple
tumble

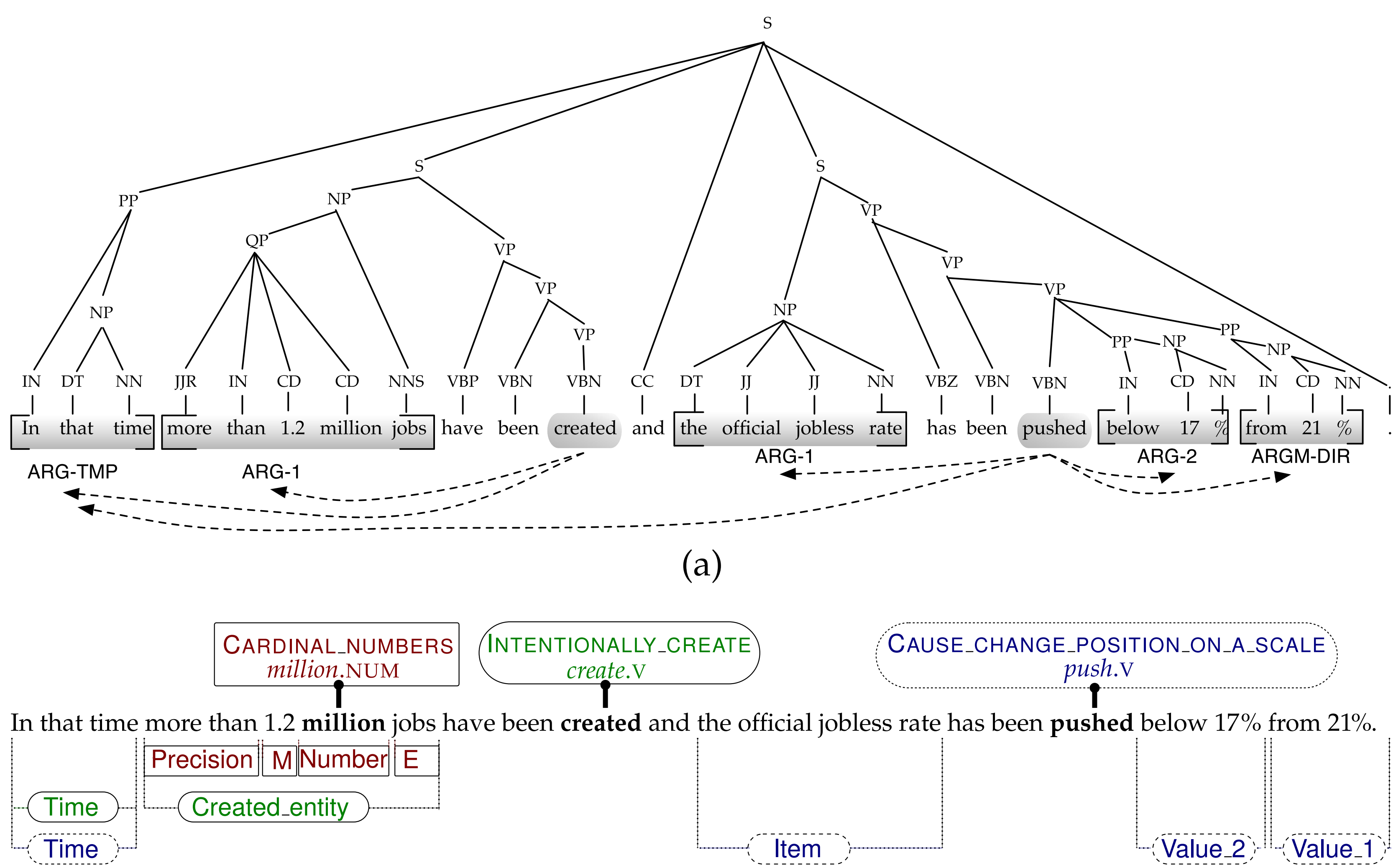
NOUNS:
decline
decrease
escalation
explosion
fall
fluctuation
gain
growth
hike
increase
rise
shift
tumble

ADVERBS:
increasingly

The "Change position on a scale" Frame

Core Roles	
ATTRIBUTE	The ATTRIBUTE is a scalar property that the ITEM possesses.
DIFFERENCE	The distance by which an ITEM changes its position on the scale.
FINAL_STATE	A description that presents the ITEM's state after the change in the ATTRIBUTE's value as an independent predication.
FINAL_VALUE	The position on the scale where the ITEM ends up.
INITIAL_STATE	A description that presents the ITEM's state before the change in the ATTRIBUTE's value as an independent predication.
INITIAL_VALUE	The initial position on the scale from which the ITEM moves away.
ITEM	The entity that has a position on the scale.
VALUE_RANGE	A portion of the scale, typically identified by its end points, along which the values of the ATTRIBUTE fluctuate.
Some Non-Core Roles	
DURATION	The length of time over which the change takes place.
SPEED	The rate of change of the VALUE.
GROUP	The GROUP in which an ITEM changes the value of an ATTRIBUTE in a specified way.

FrameNet and PropBank representations



Semantic role labeling (SRL)

- The task of finding the semantic roles of each argument of each predicate in a sentence.
- FrameNet versus PropBank:

[You]	can't	[blame]	[the program]	[for being unable to identify it]
COGNIZER		TARGET	EVALUEE	REASON

[The San Francisco Examiner]	issued	[a special edition]	[yesterday]
ARG0	TARGET	ARG1	ARGM-TMP

History

- Semantic roles as a intermediate semantics, used early in
  - machine translation (Wilks, 1973)
  - question-answering (Hendrix et al., 1973)
  - spoken-language understanding (Nash-Webber, 1975)
  - dialogue systems (Bobrow et al., 1977)
- Early SRL systems

  Simmons 1973, Marcus 1980:

    - parser followed by hand-written rules for each verb
    - dictionaries with verb-specific case frames (Levin 1977)

Why Semantic Role Labeling

- A useful shallow semantic representation
- Improves NLP tasks like:
  - question answering

    Shen and Lapata 2007, Surdeanu et al. 2011
  - machine translation

    Liu and Gildea 2010, Lo et al. 2013

A simple modern algorithm

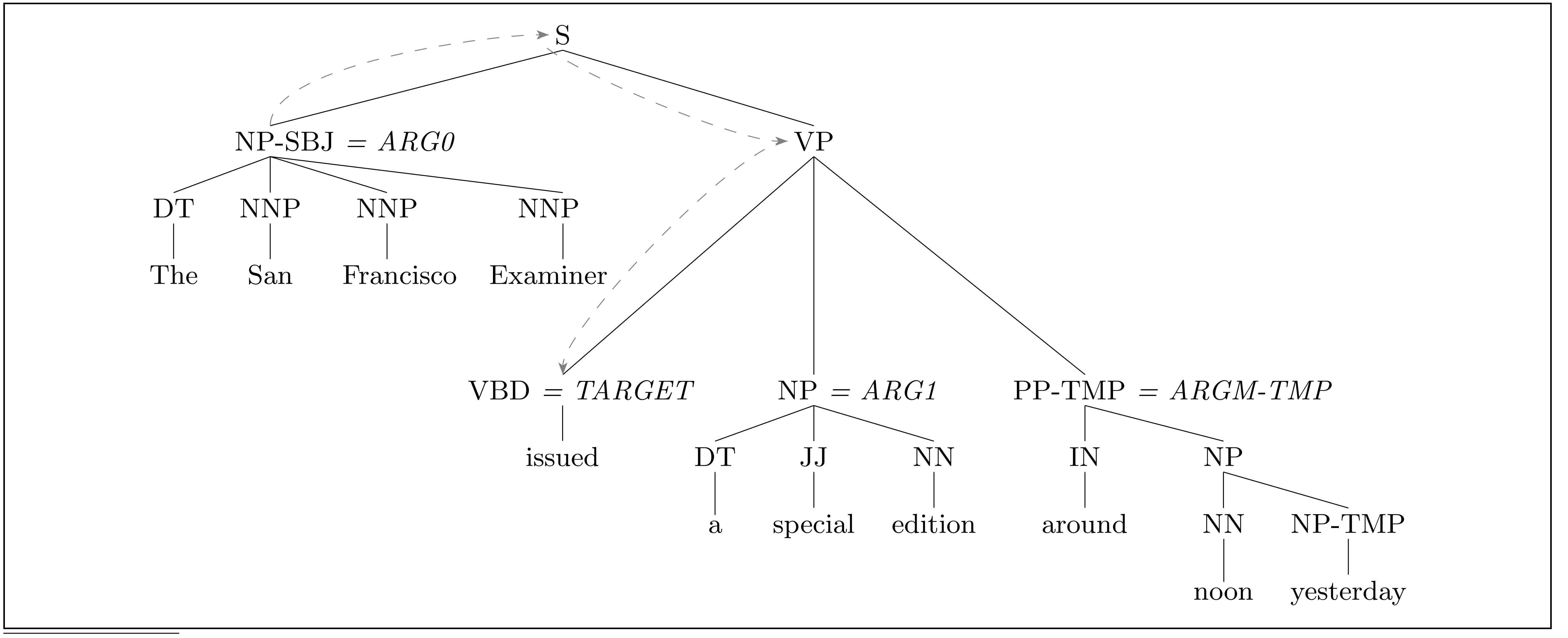
```
function SEMANTICROLELABEL(words) returns labeled tree

    parse ← PARSE(words)
    for each predicate in parse do
        for each node in parse do
            featurevector ← EXTRACTFEATURES(node, predicate, parse)
            CLASSIFYNODE(node, featurevector, parse)
```

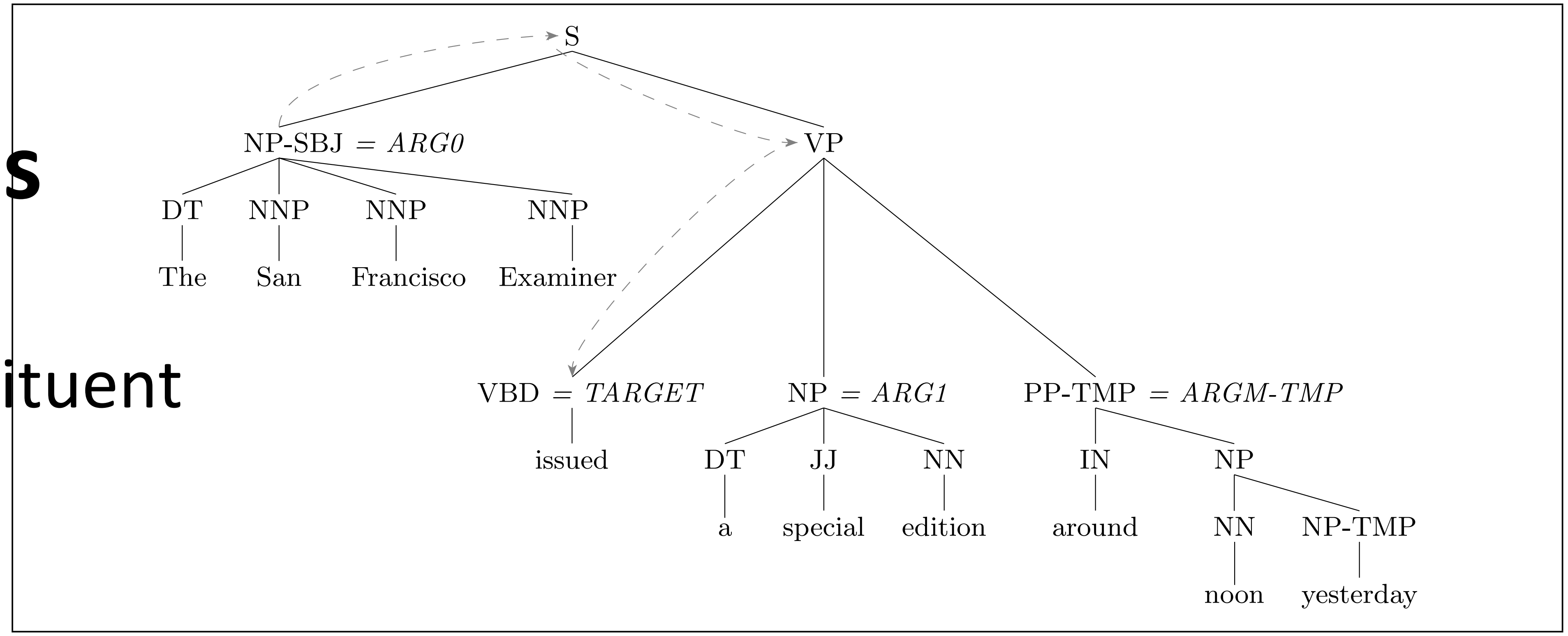
How do we decide what is a predicate

- If we’re just doing PropBank verbs
  - Choose all verbs
  - Possibly removing light verbs (from a list)
- If we’re doing FrameNet (verbs, nouns, adjectives)
  - Choose every word that was labeled as a target in training data

Semantic Role Labeling



Features



Headword of constituent

Examiner

Headword POS

NNP

Voice of the clause

Active

Subcategorization of pred

VP -> VBD NP PP

Named Entity type of constit

ORGANIZATION

First and last words of constit

The, Examiner

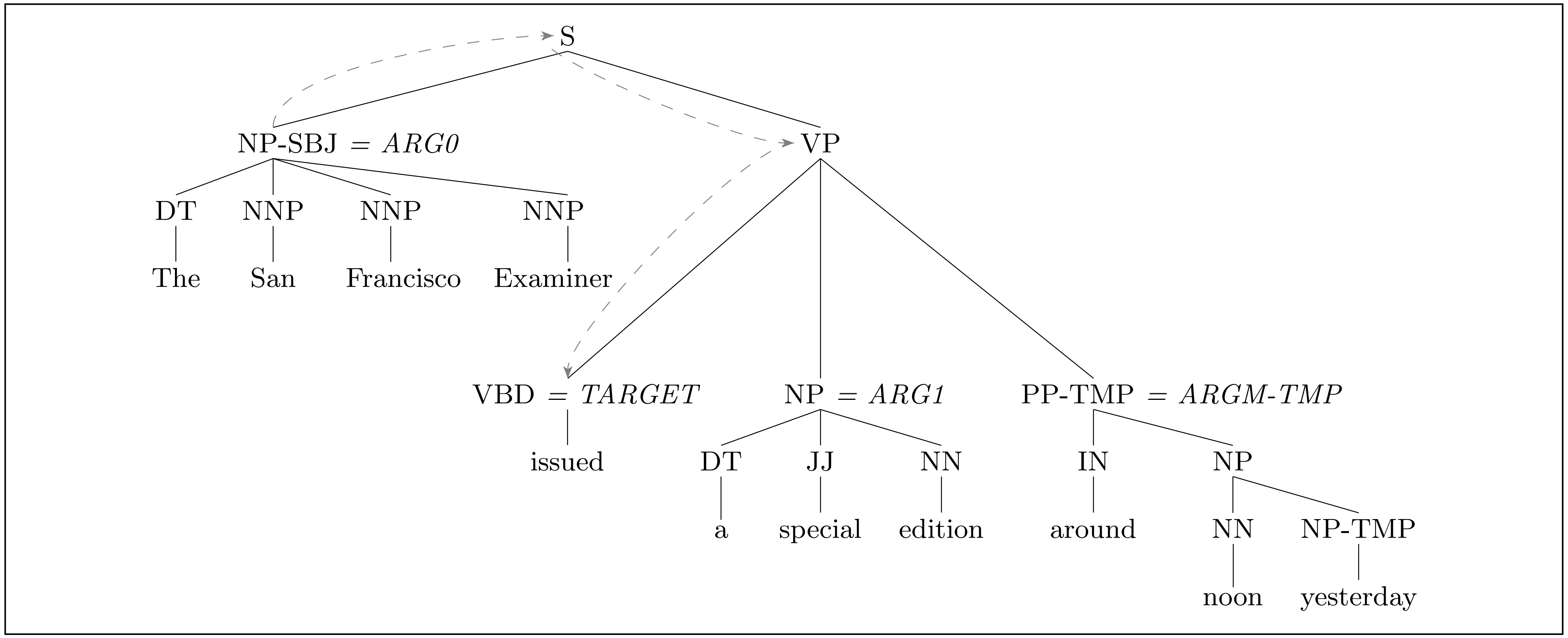
Linear position,clause re: predicate

before

Path Features

Path in the parse tree from the constituent to the predicate

$NP{\uparrow}S{\downarrow}VP{\downarrow}VBD$



3-step version of SRL algorithm

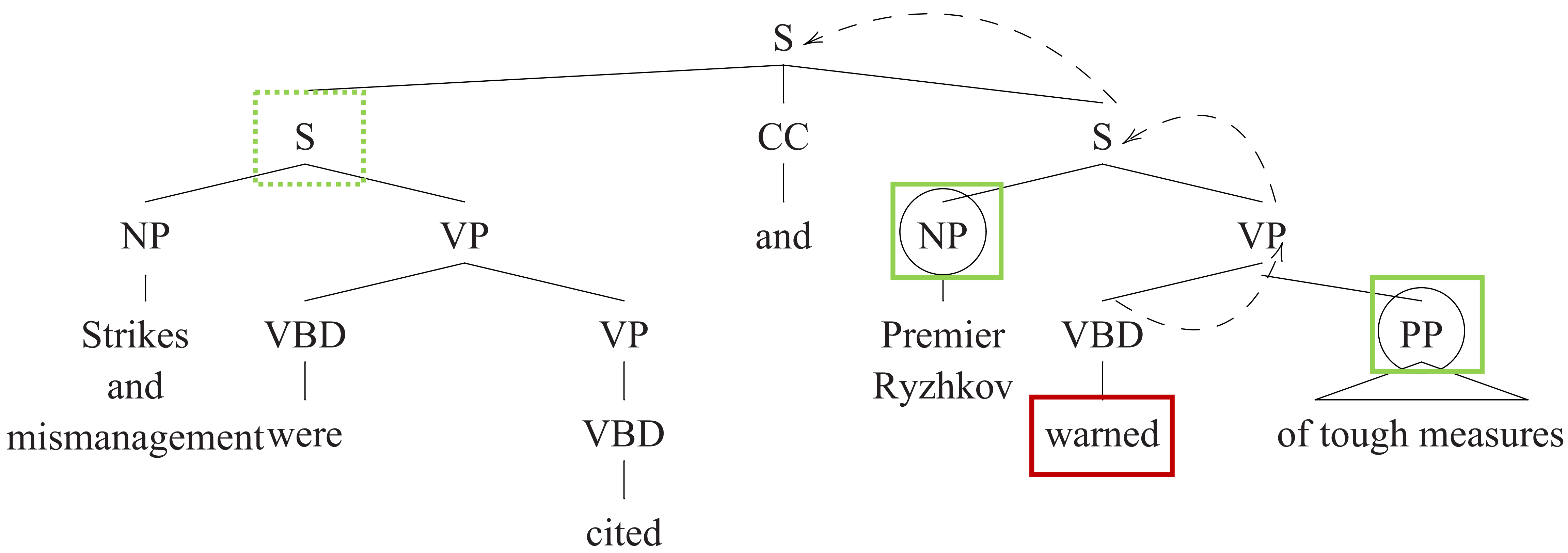
1. **Pruning**: use simple heuristics to prune unlikely constituents.
2. **Identification**: a binary classification of each node as an argument to be labeled or a NONE.
3. **Classification**: a 1-of-*N* classification of all the constituents that were labeled as arguments by the previous stage

Why add Pruning and Identification steps?

- Algorithm is looking at one predicate at a time
- Very few of the nodes in the tree could possible be arguments of that one predicate
- Imbalance between
  - positive samples (constituents that are arguments of predicate)
  - negative samples (constituents that are not arguments of predicate)
- Imbalanced data can be hard for many classifiers
- So we prune the **very** unlikely constituents first, and then use a classifier to get rid of the rest.

Pruning heuristics – Xue and Palmer (2004)

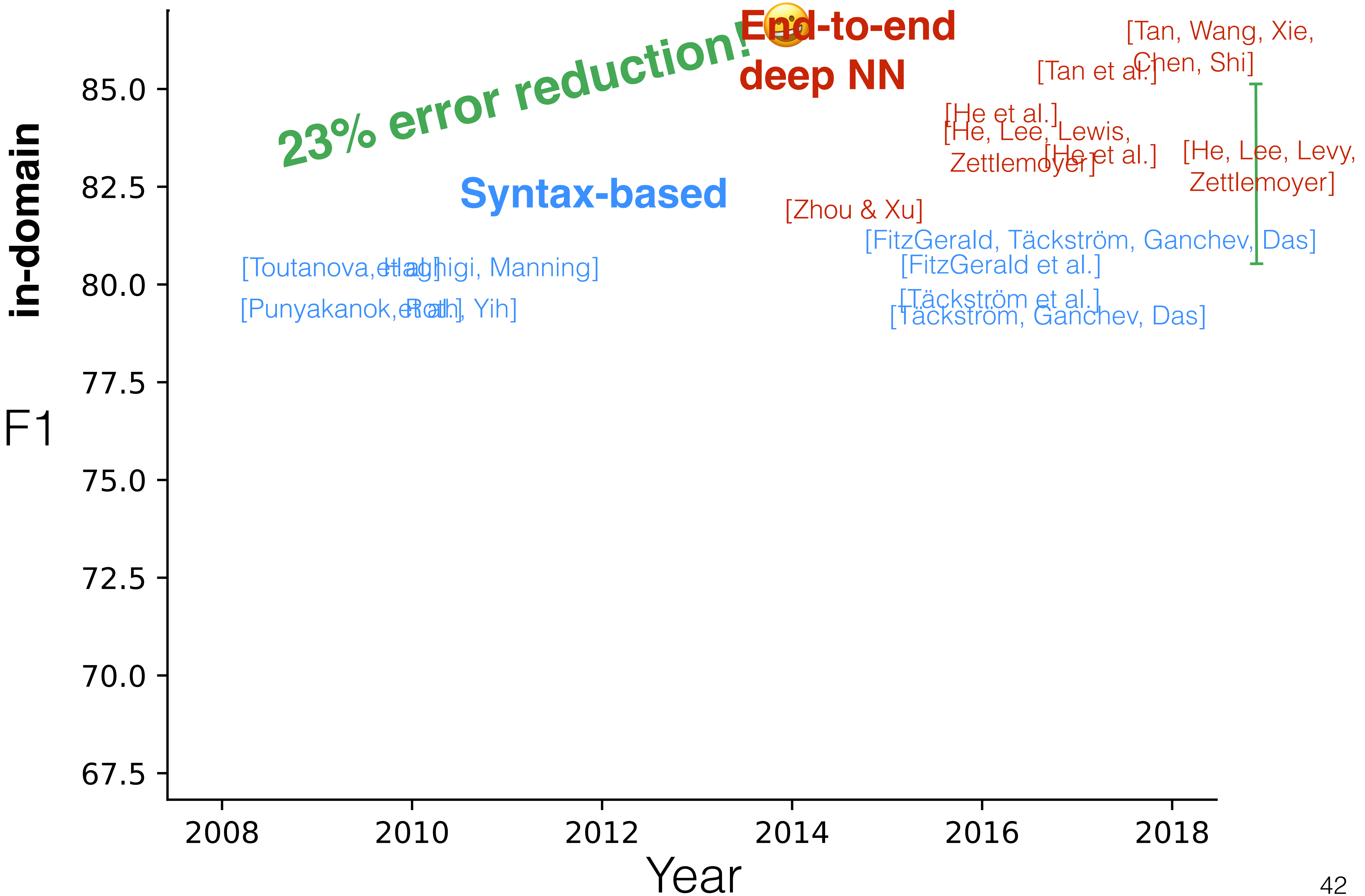
- Add sisters of the predicate, then aunts, then great-aunts, etc
  - But ignoring anything in a coordination structure



Semantic Role Labeling

- A level of shallow semantics for representing events and their participants
  - Intermediate between parses and full semantics
- Two common architectures, for various languages
  - FrameNet: frame-specific roles
  - PropBank: Proto-roles
- Current systems extract by
  - parsing sentence
  - Finding predicates in the sentence
    - For each one, classify each parse tree constituent

10 years of PropBank SRL



Linguistically-Informed Self-Attention

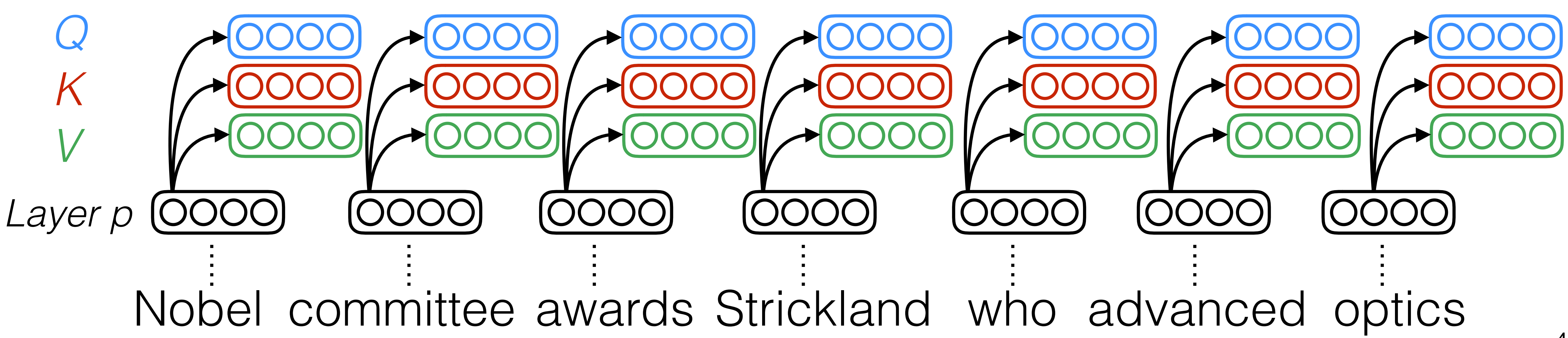
by UMass PhD student Emma Strubell,
won best paper award at EMNLP 2018!

- **Multi-task learning**
  - Part-of-speech tagging
  - Labeled dependency parsing
  - Predicate detection
  - Semantic role spans & labeling

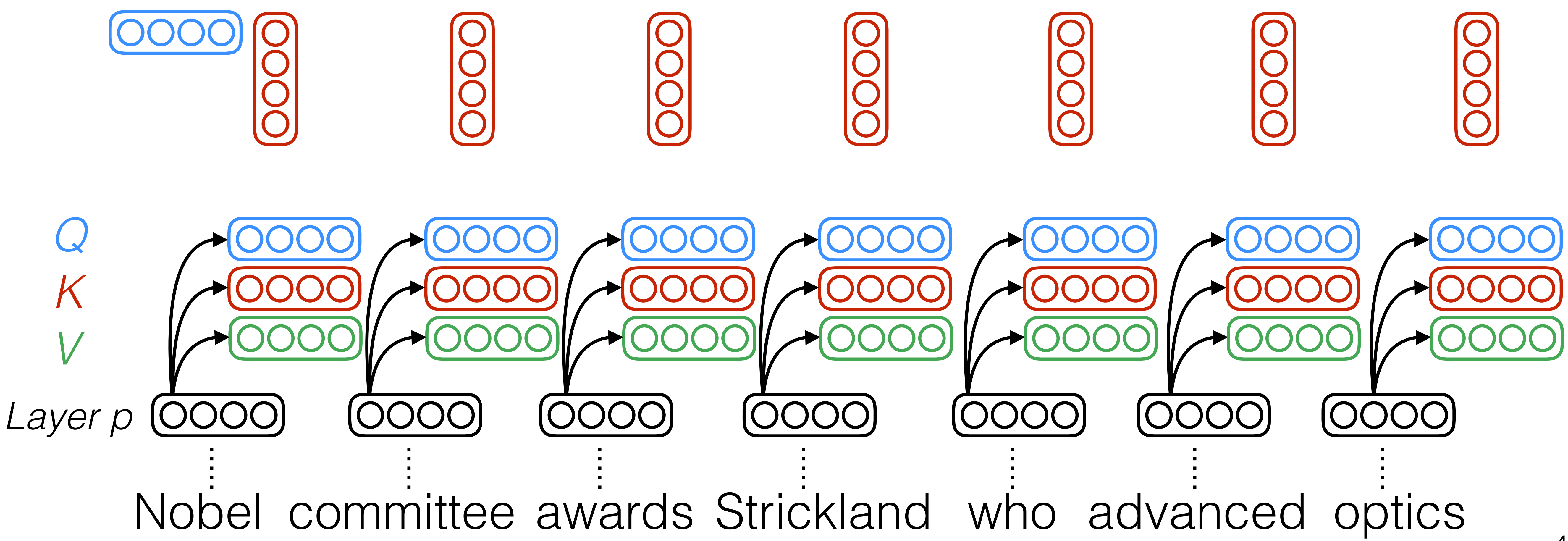
- **Syntactically-informed self-attention**
  - Multi-head self-attention supervised by syntax

[Vaswani et al. 2017]

Self-attention



Self-attention



[Vaswani et al. 2017]

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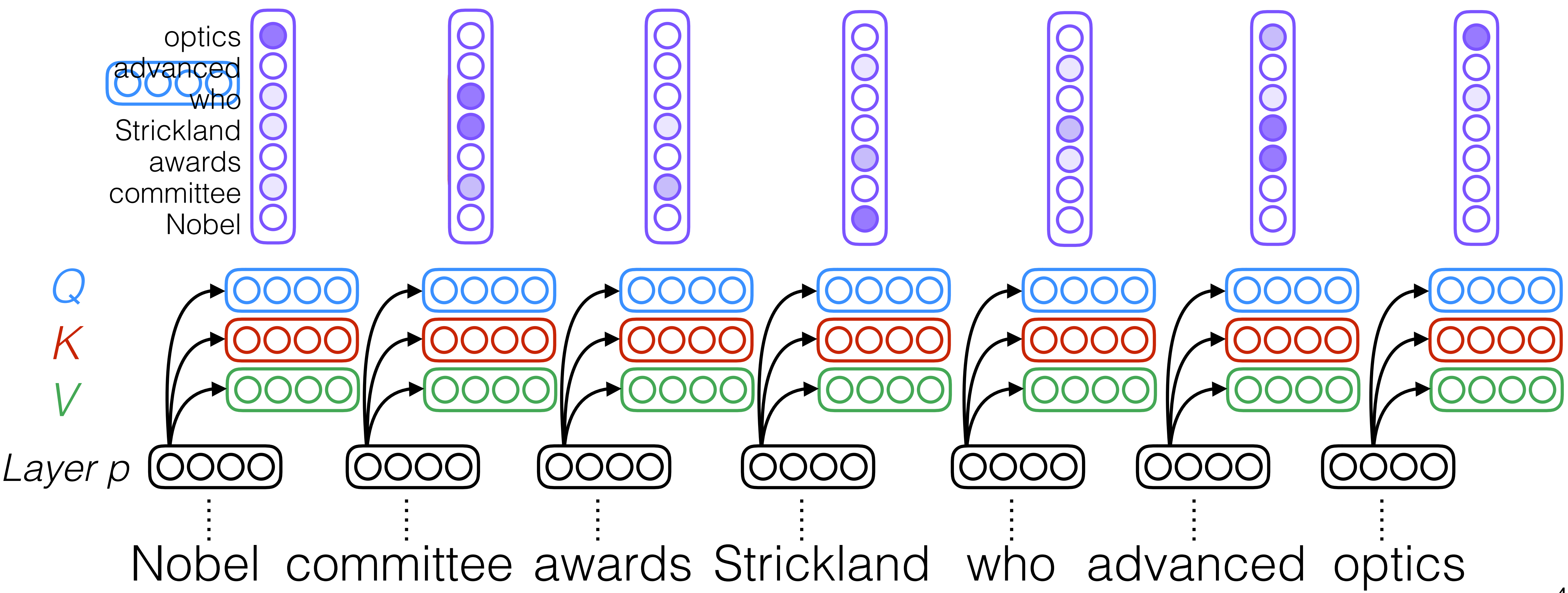

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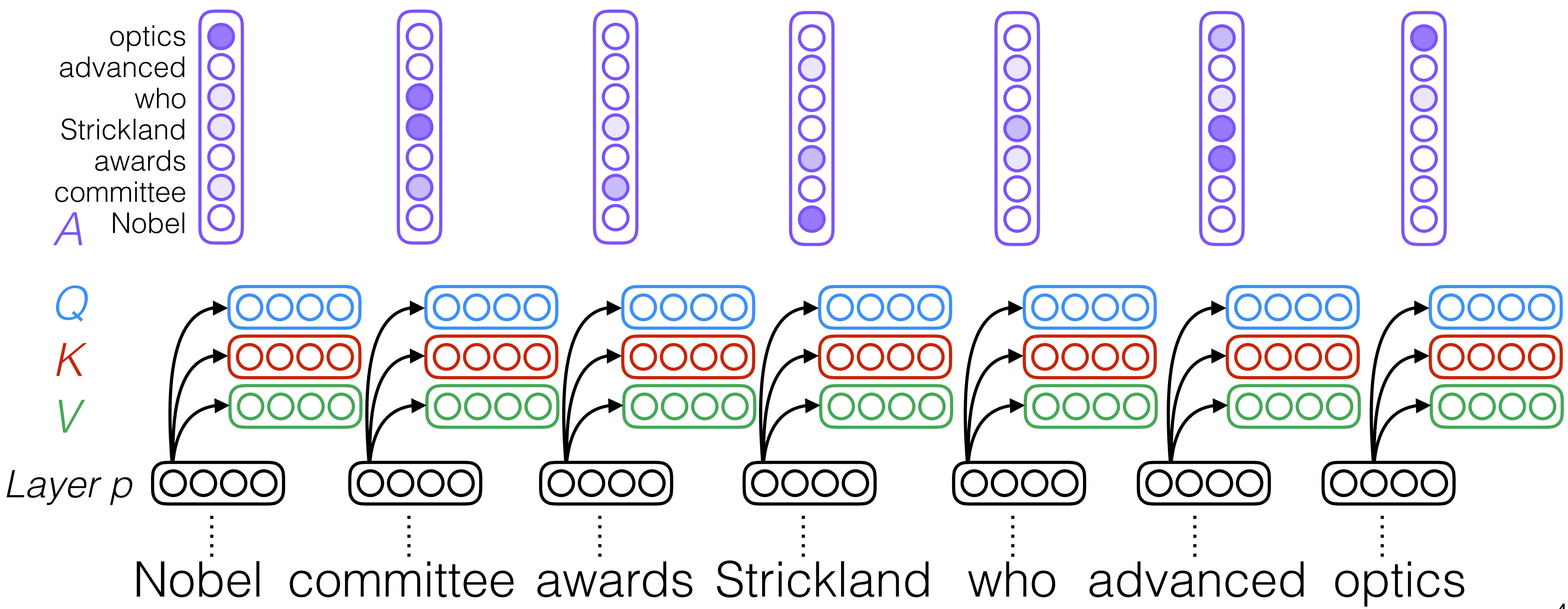

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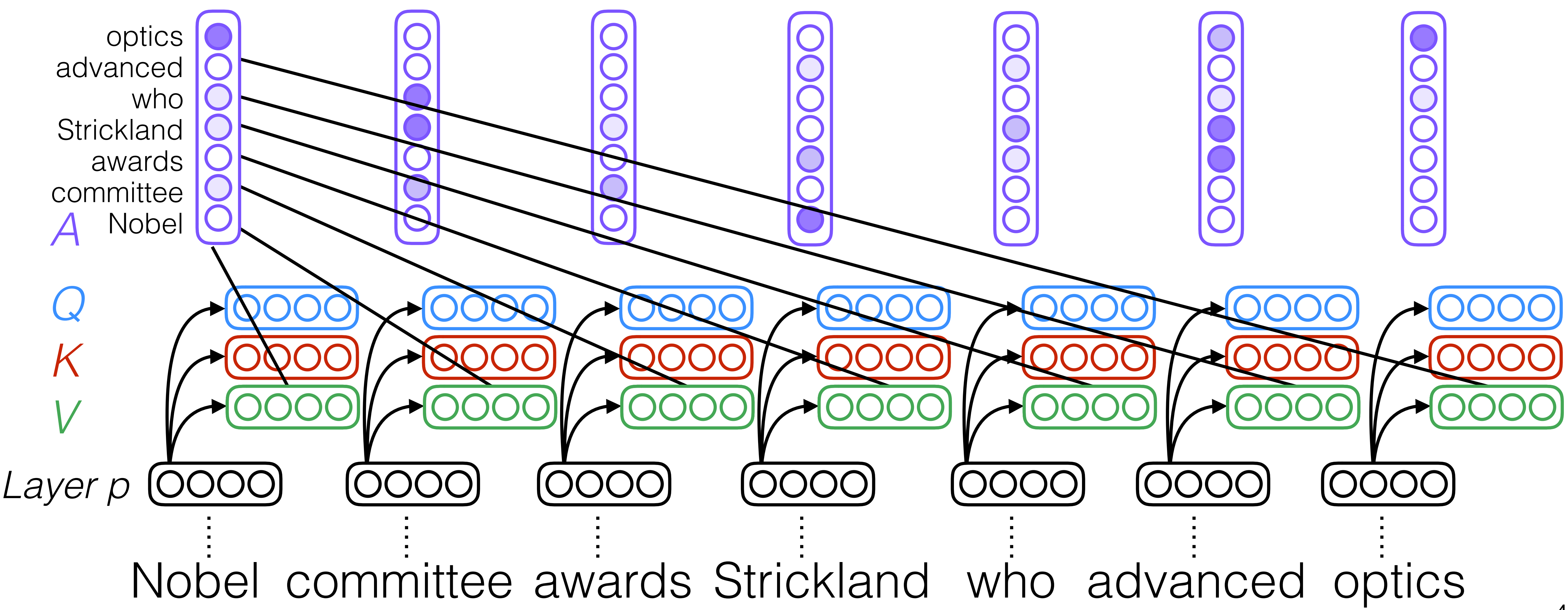

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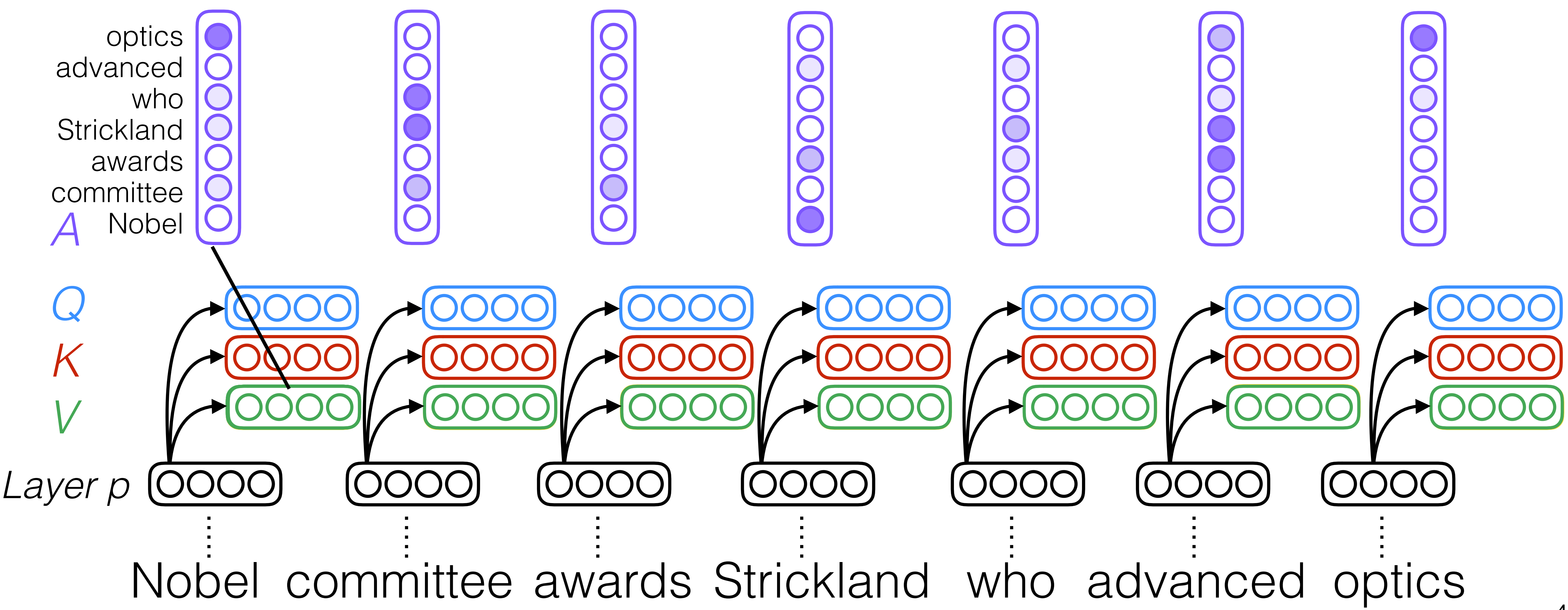

[Vaswani et al. 2017]

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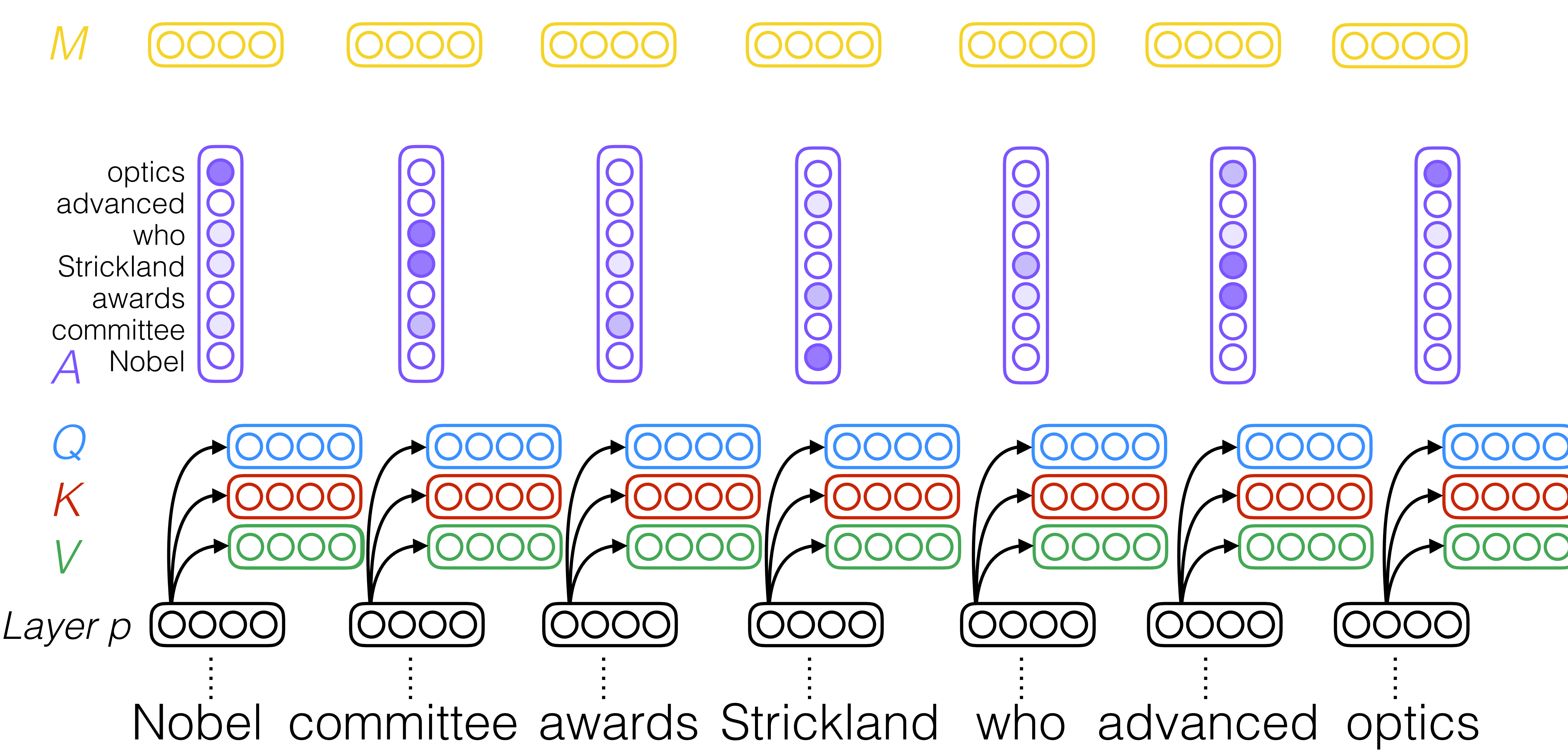

[Vaswani et al. 2017]

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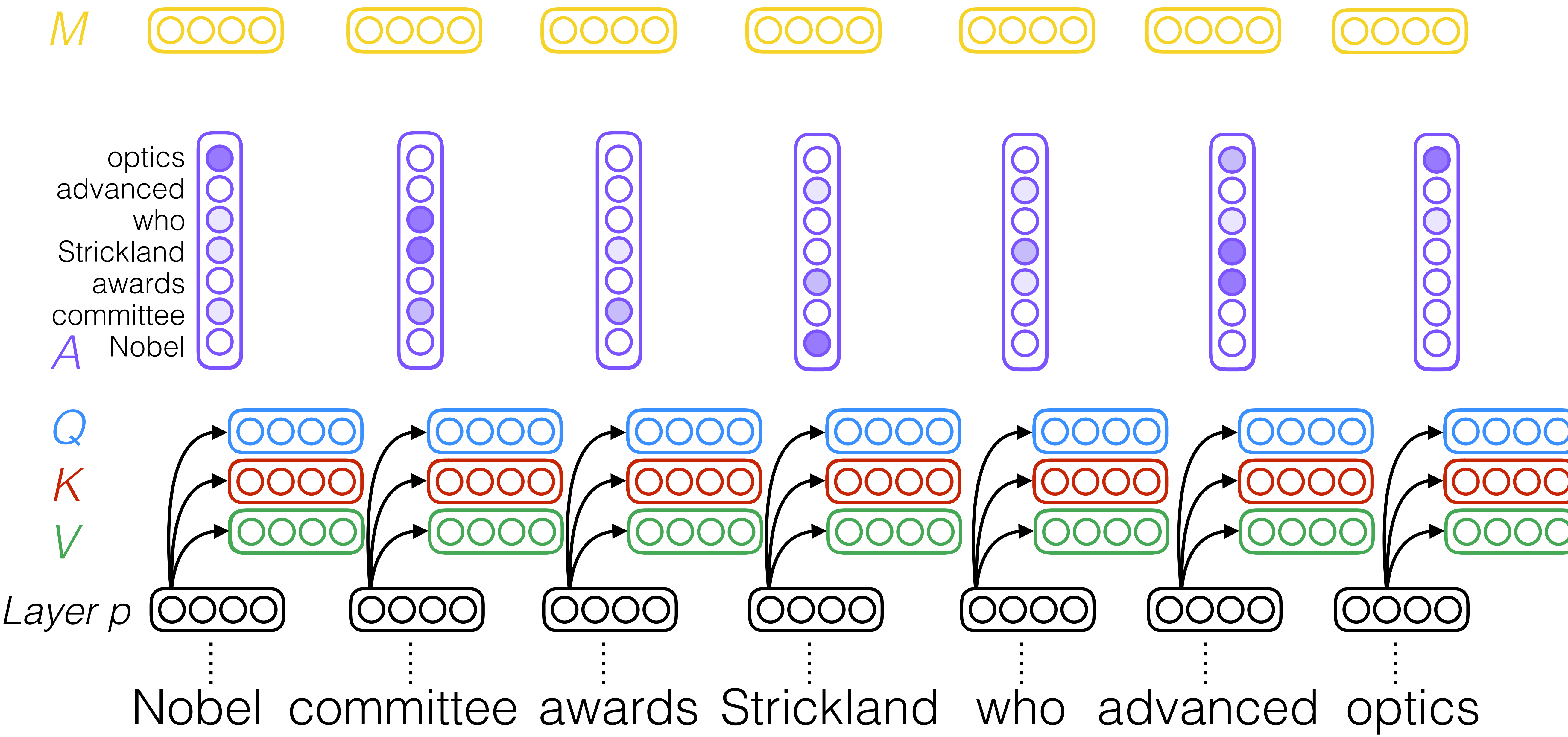
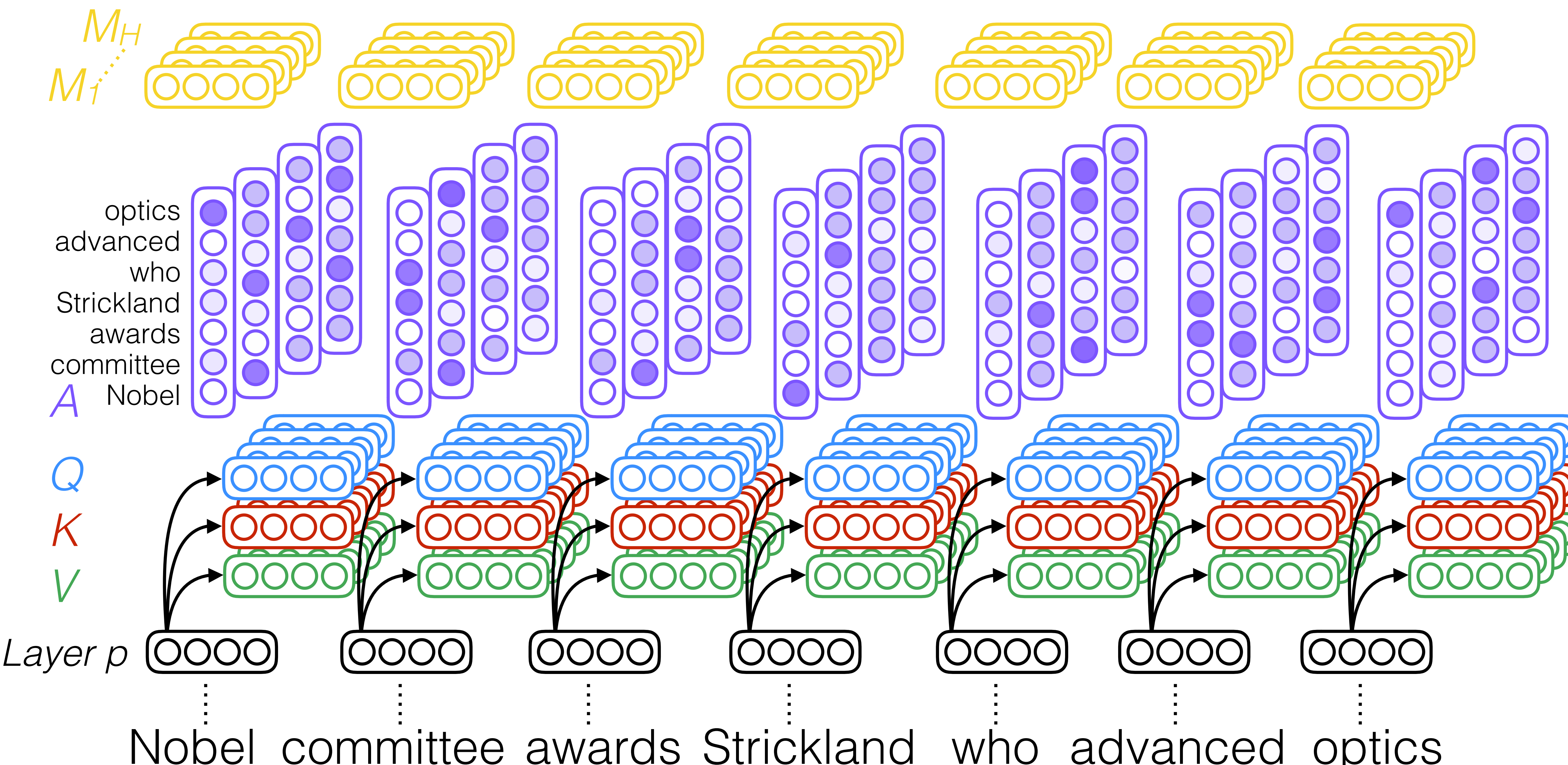


[Vaswani et al. 2017]

Multi-head self-attention



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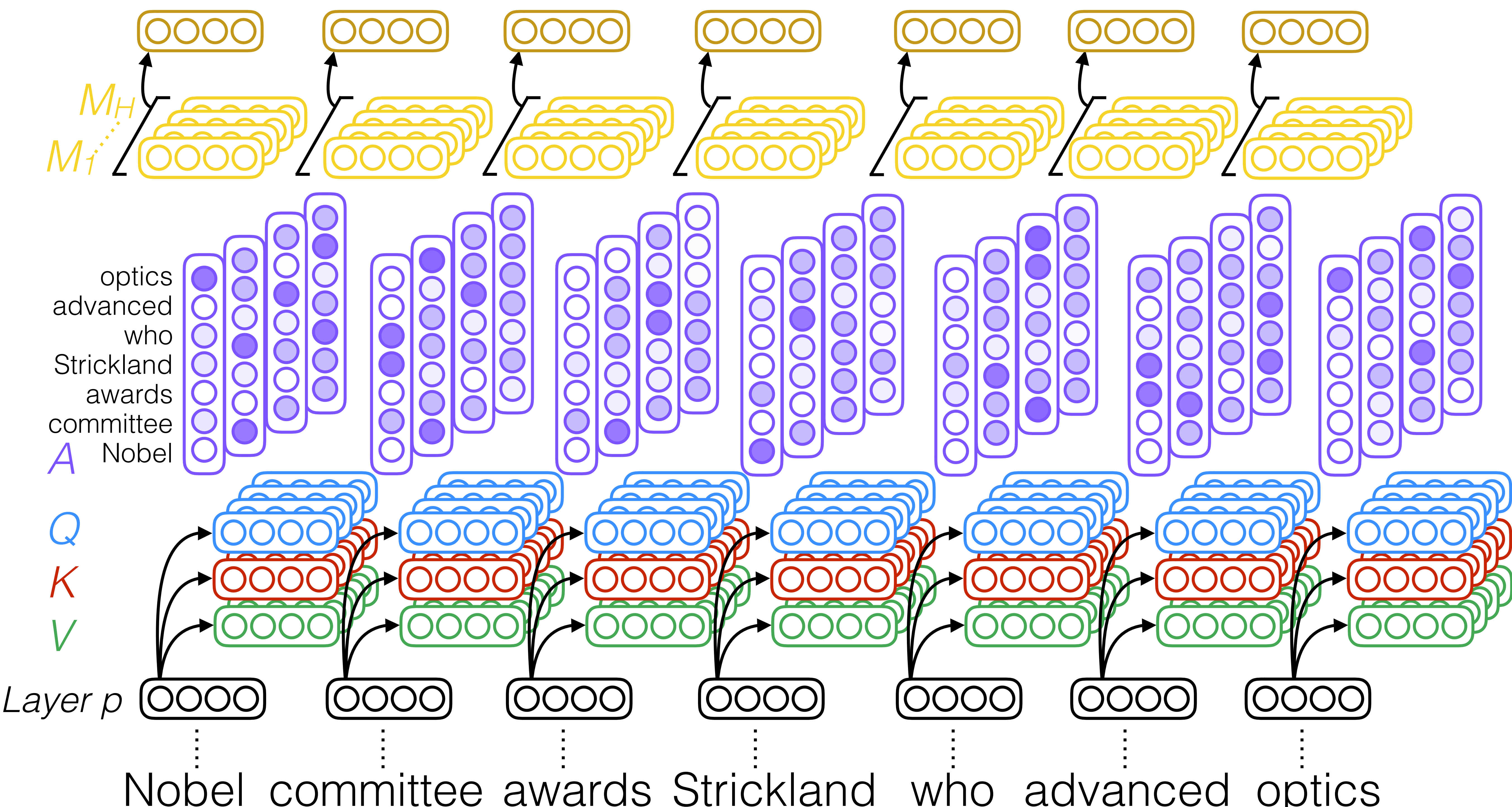

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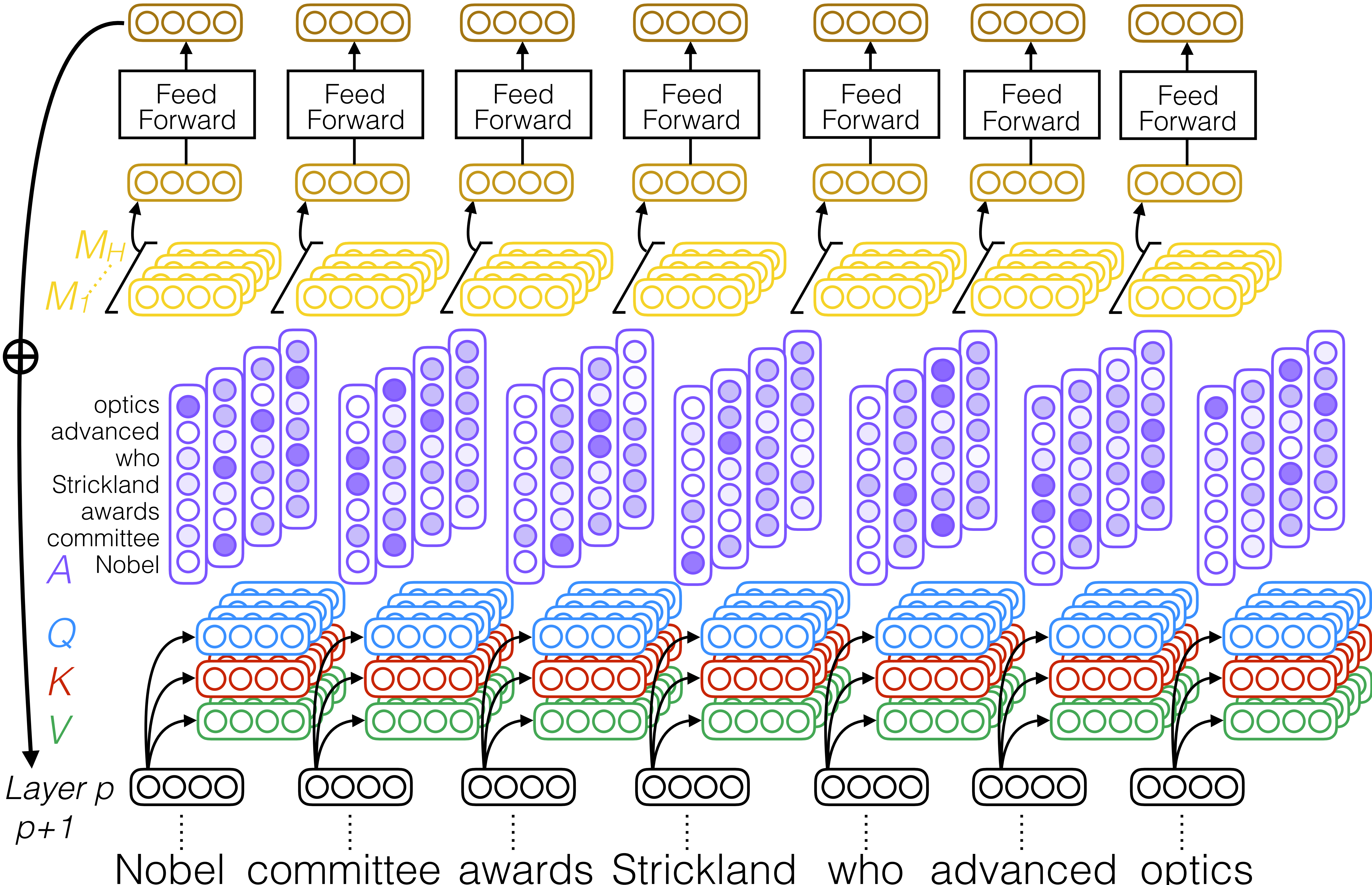

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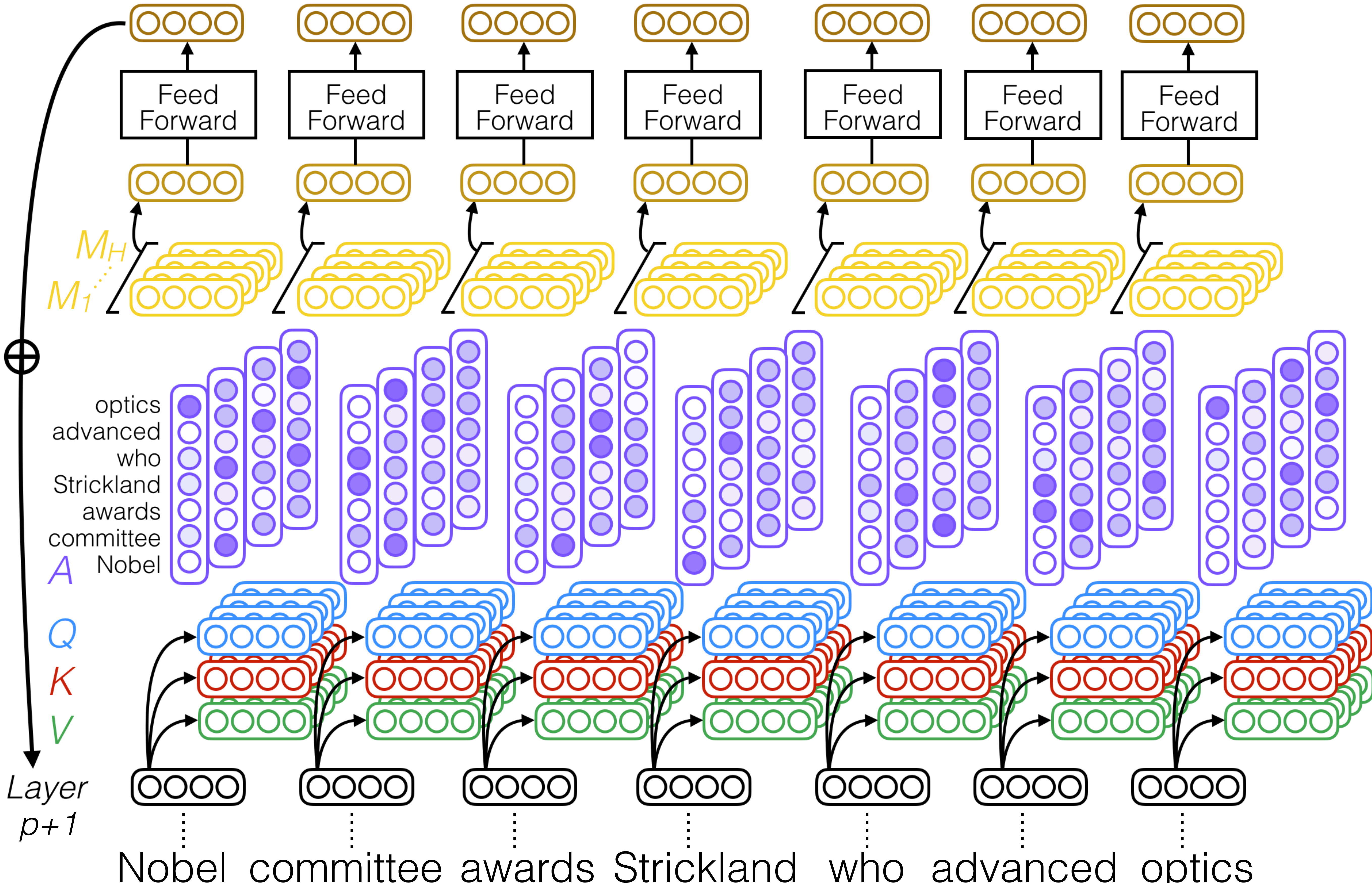

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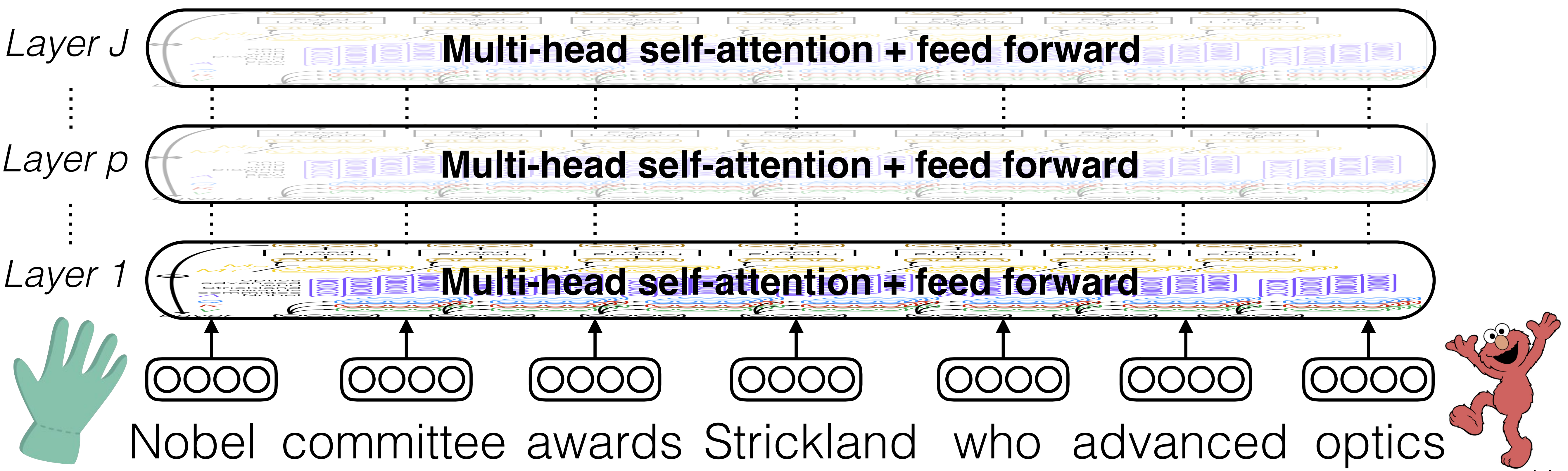
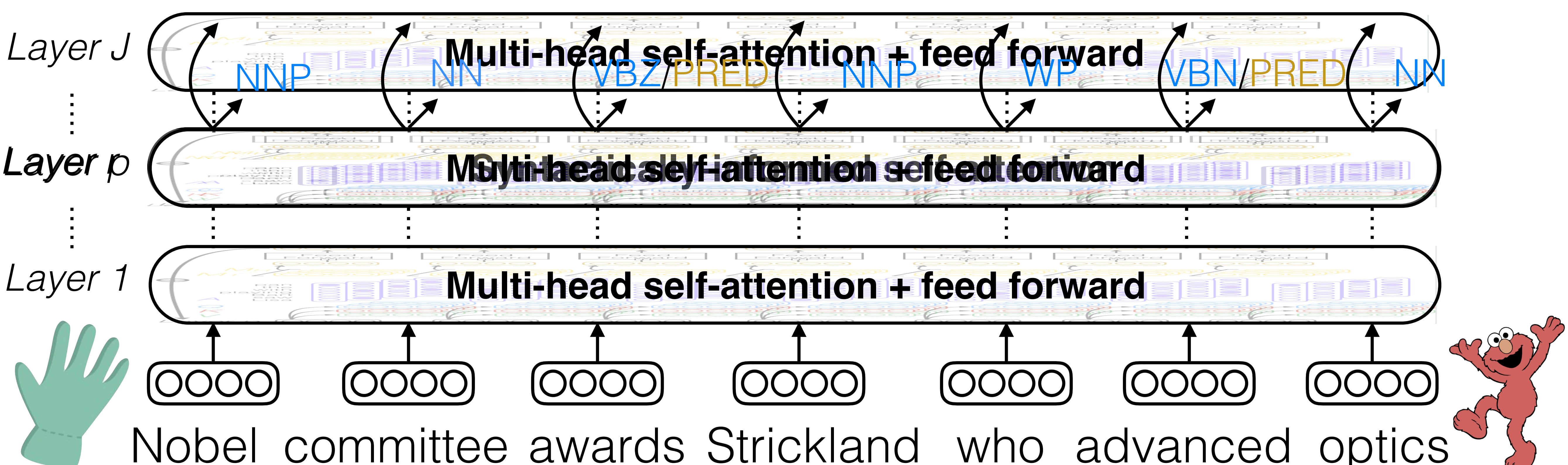


LISA: Linguistically-Informed Self-Attention



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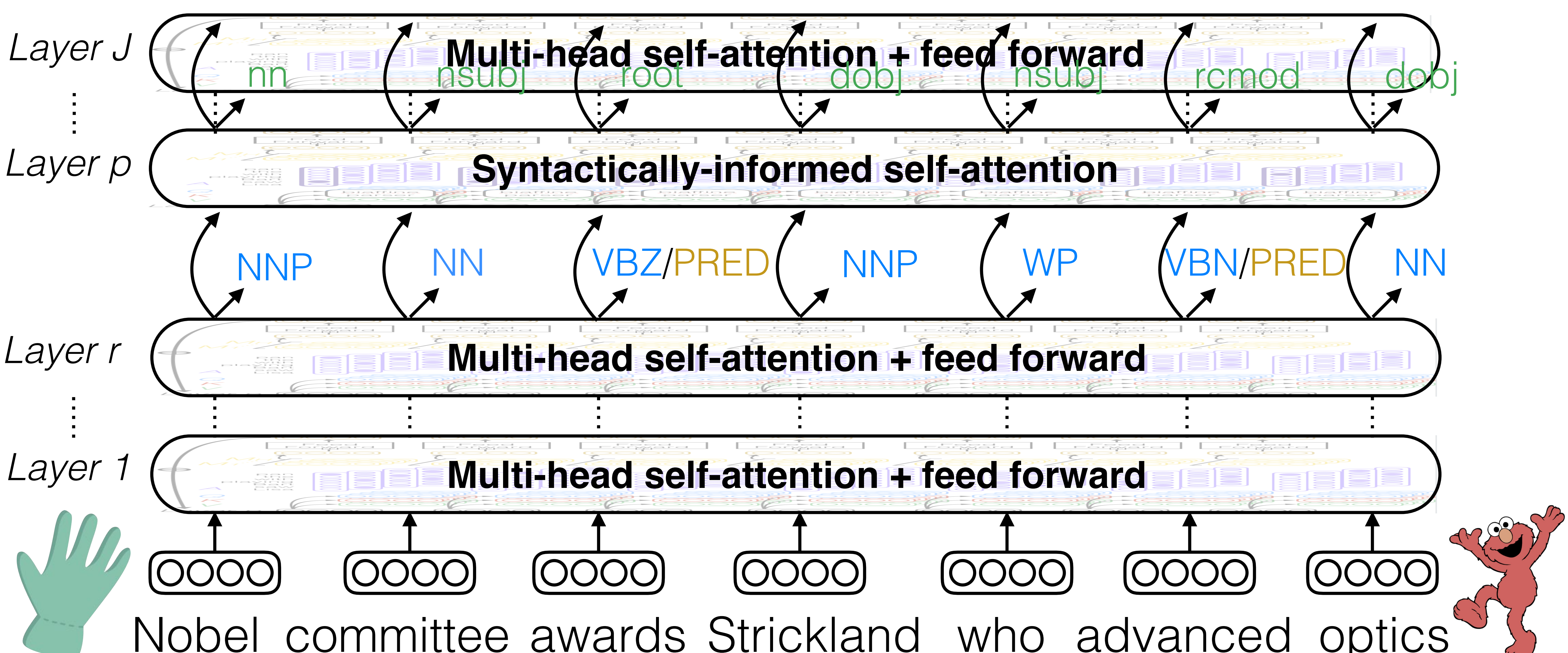

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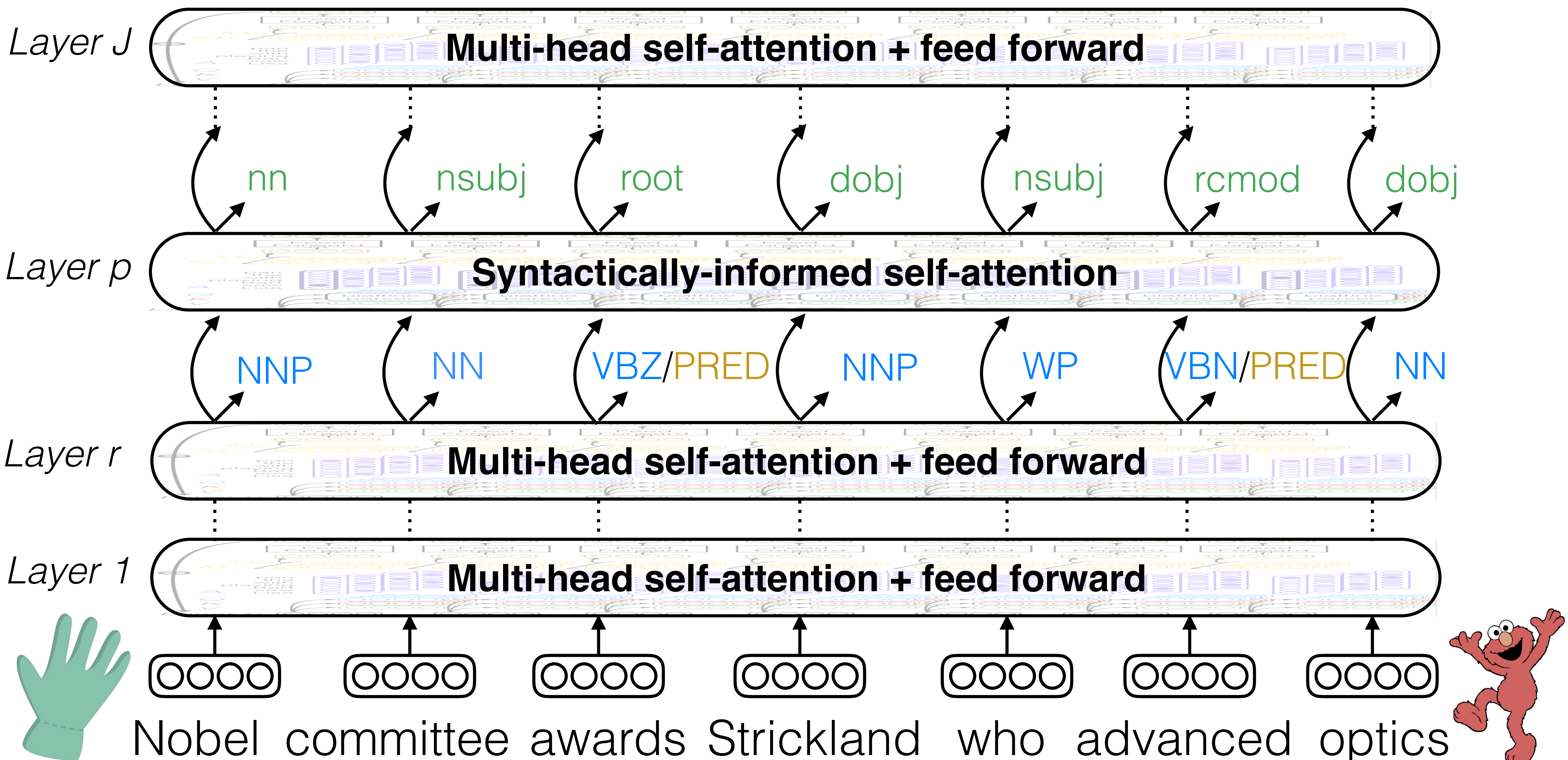

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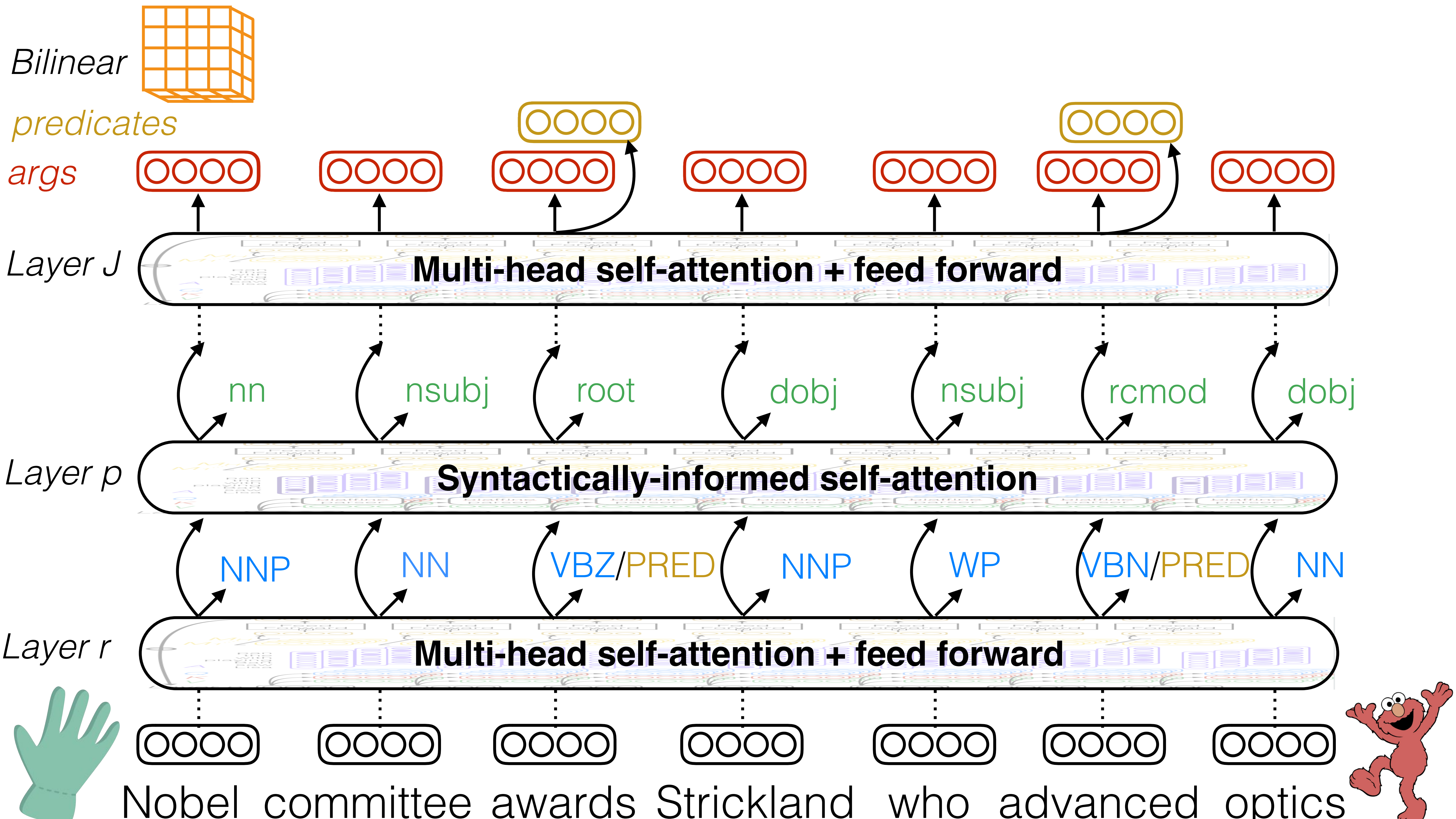

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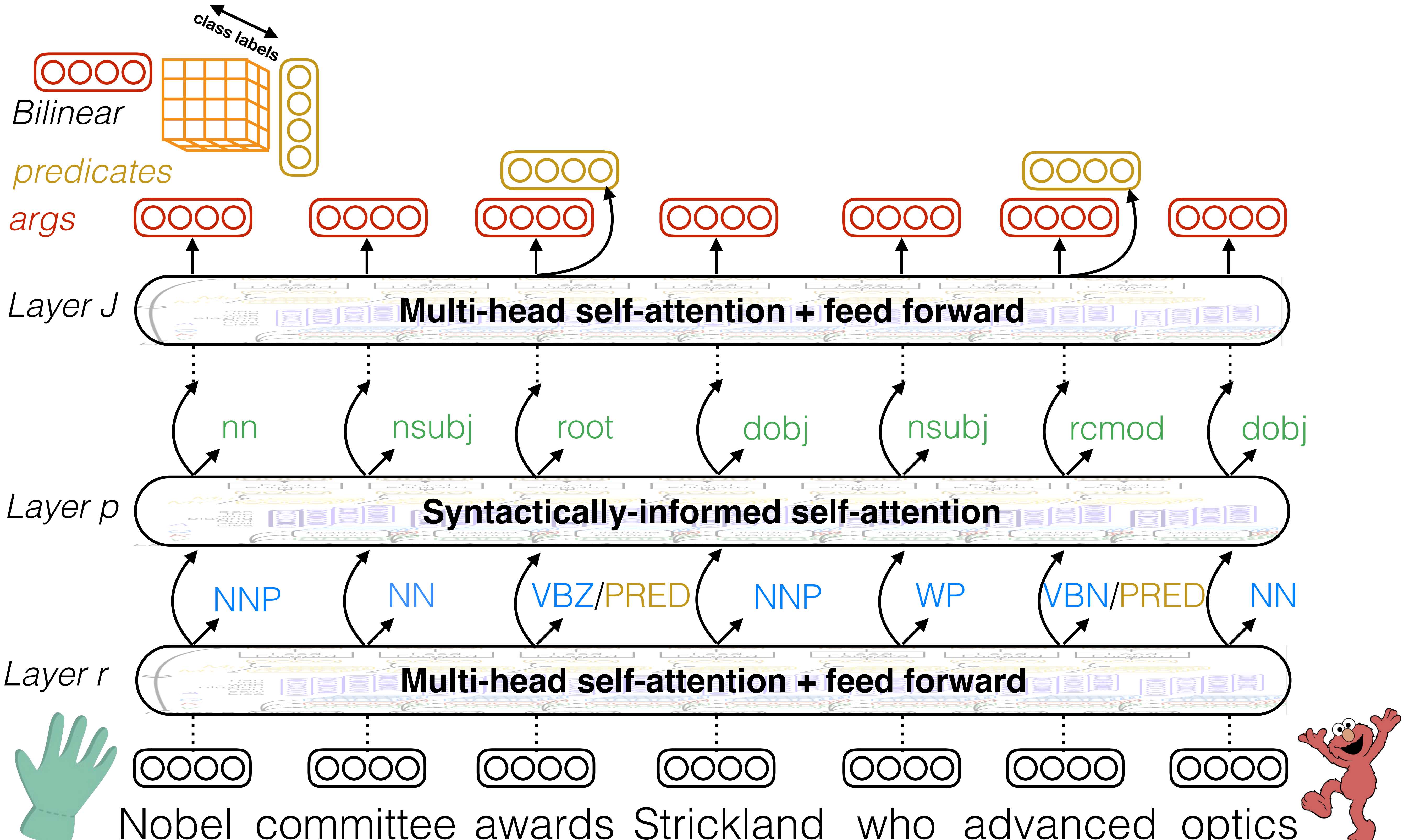

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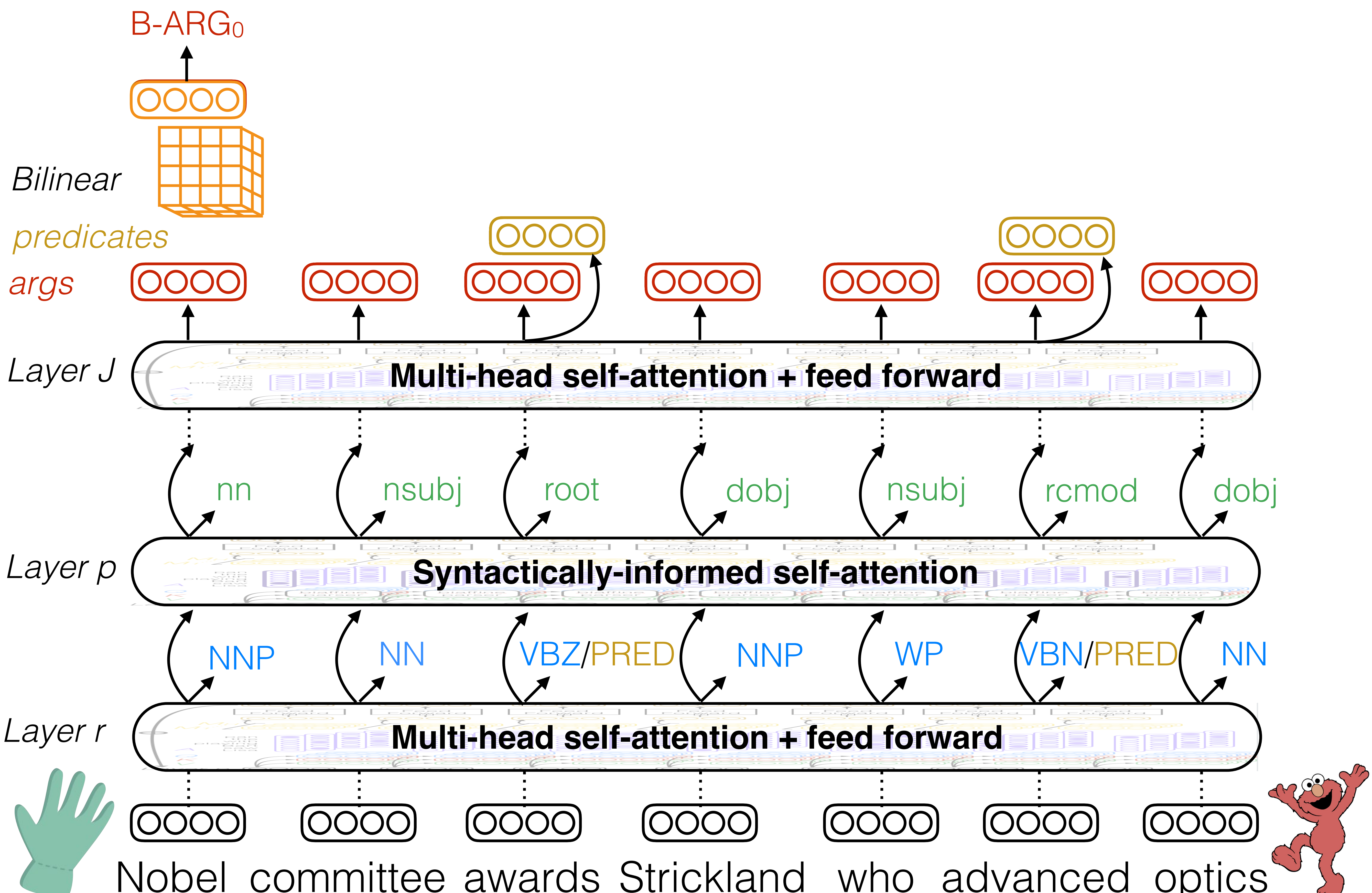

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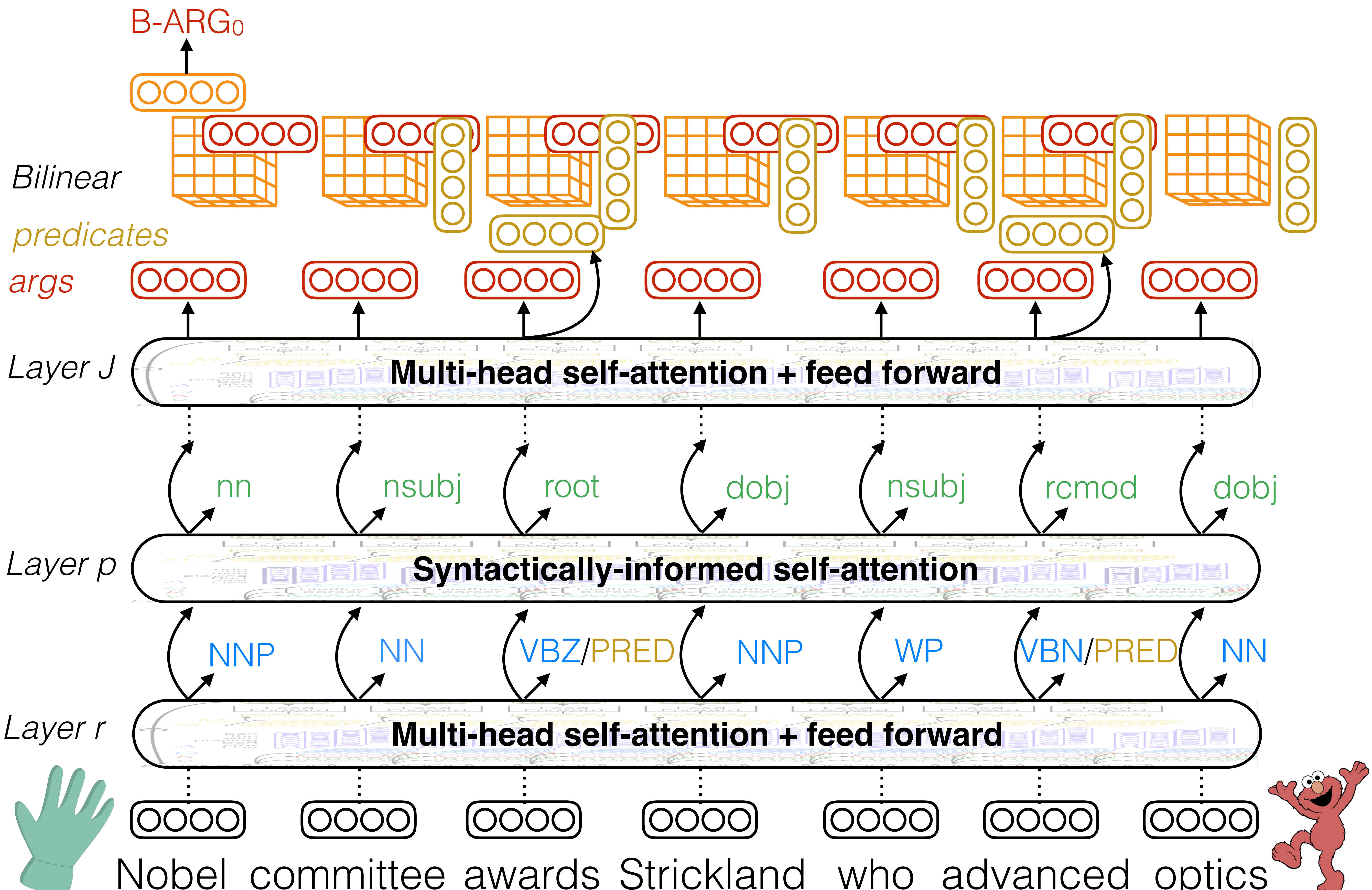

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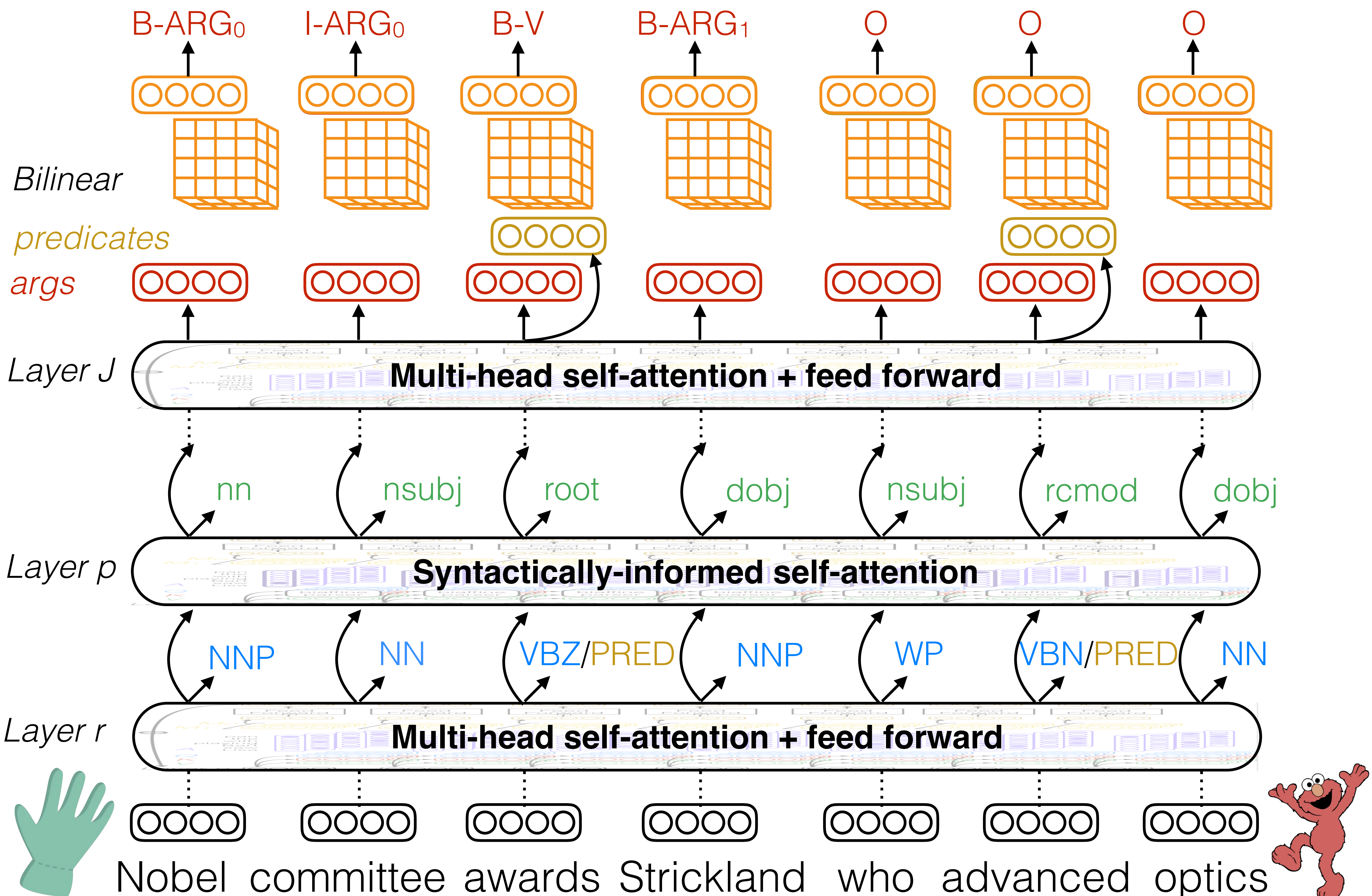

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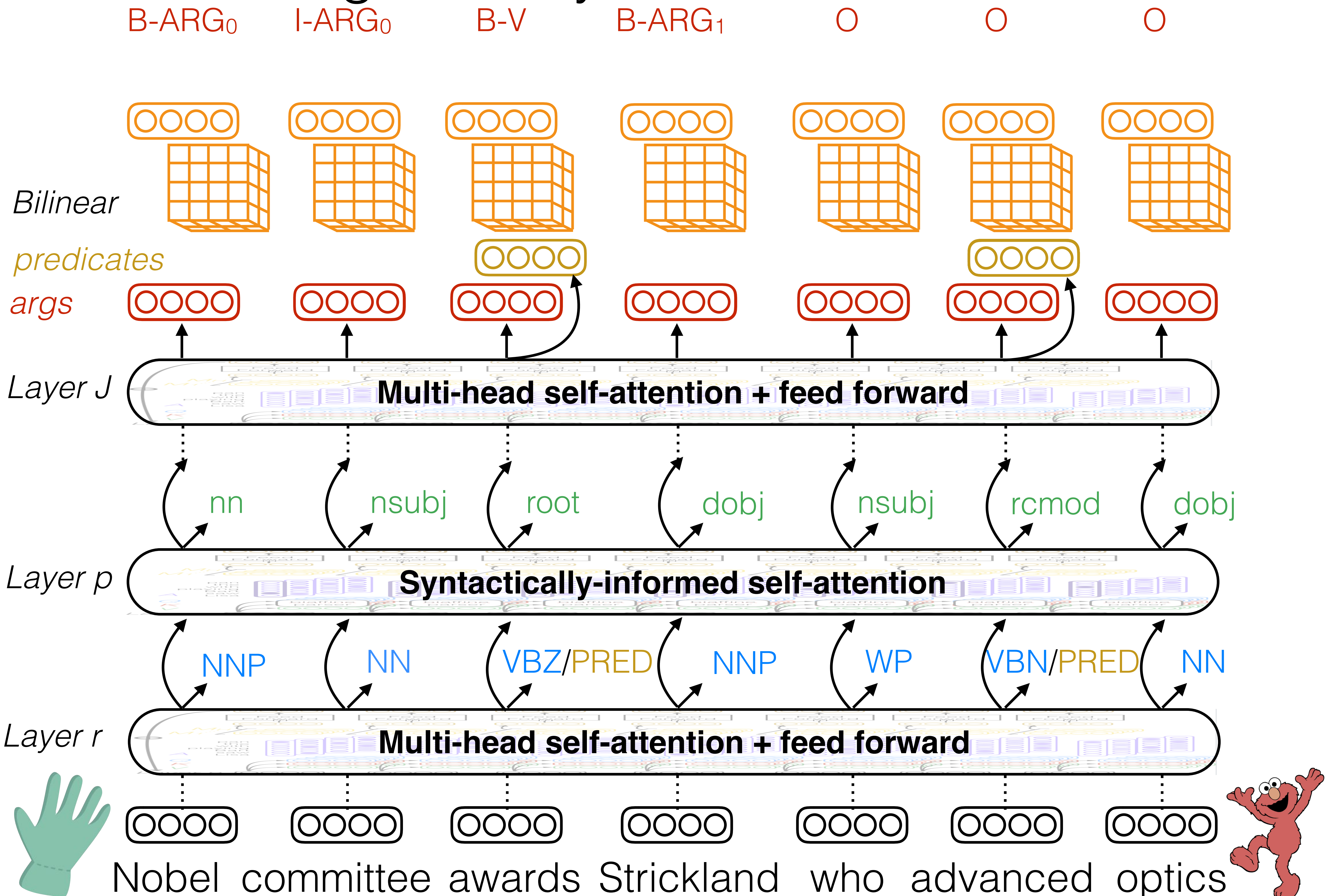
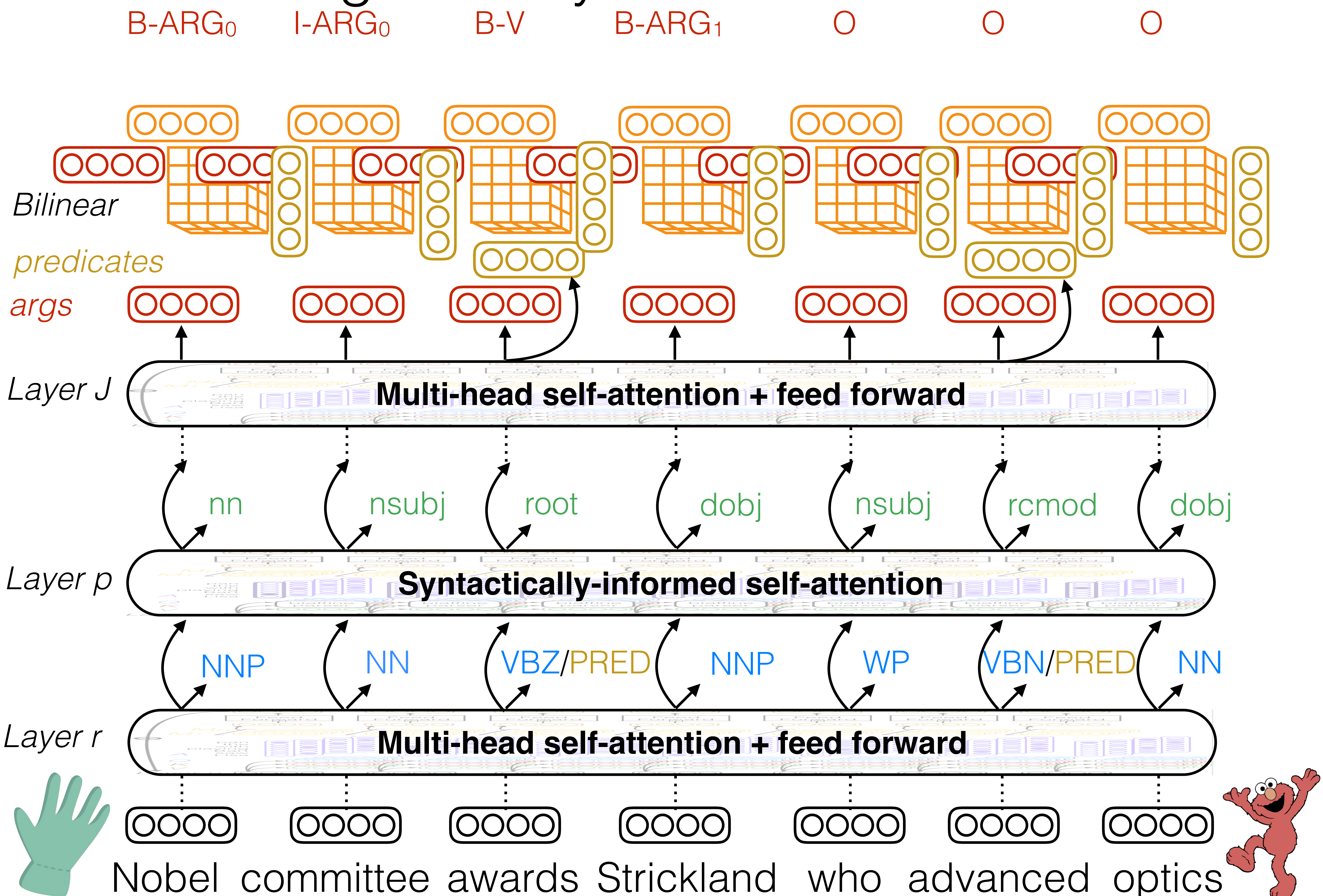
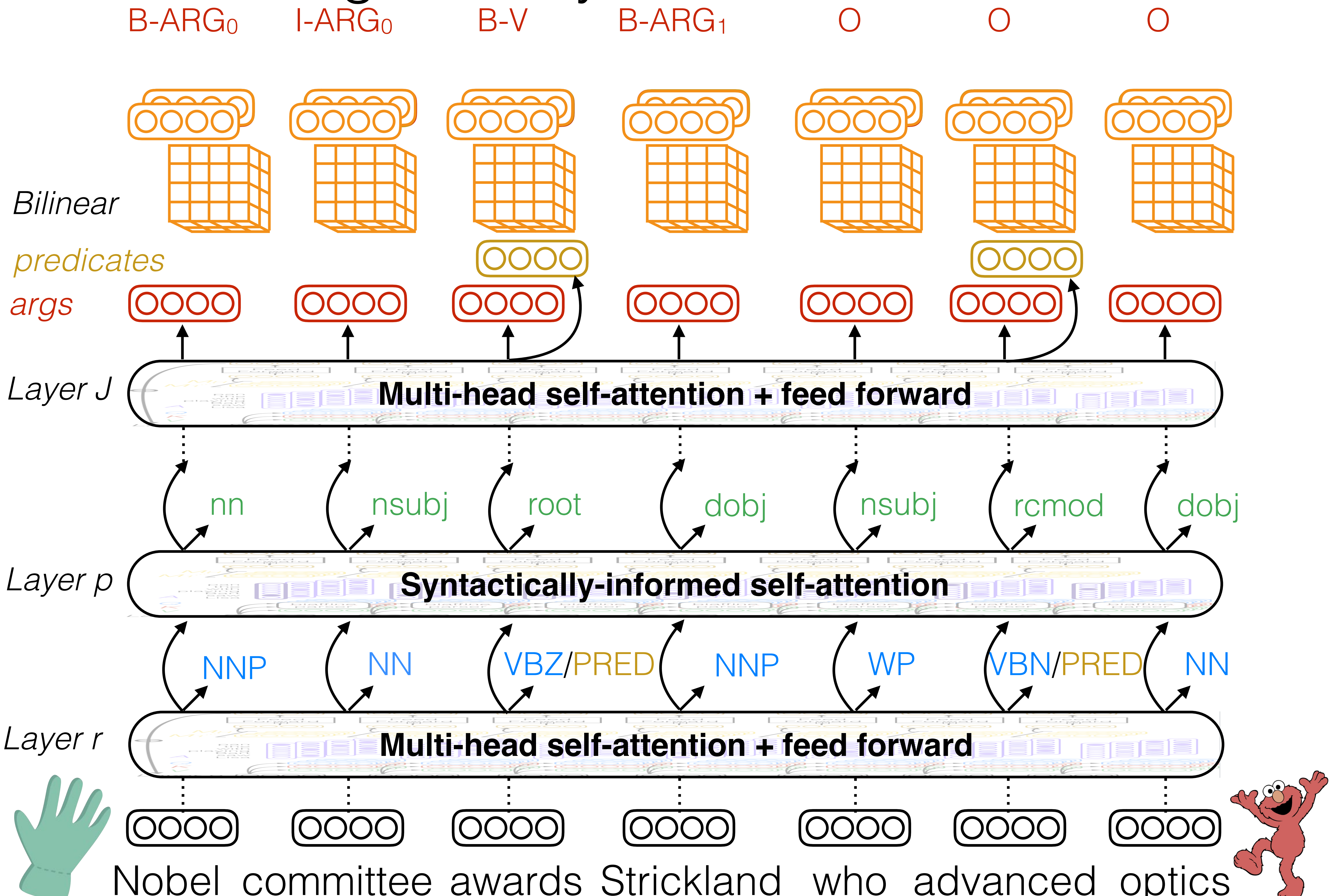


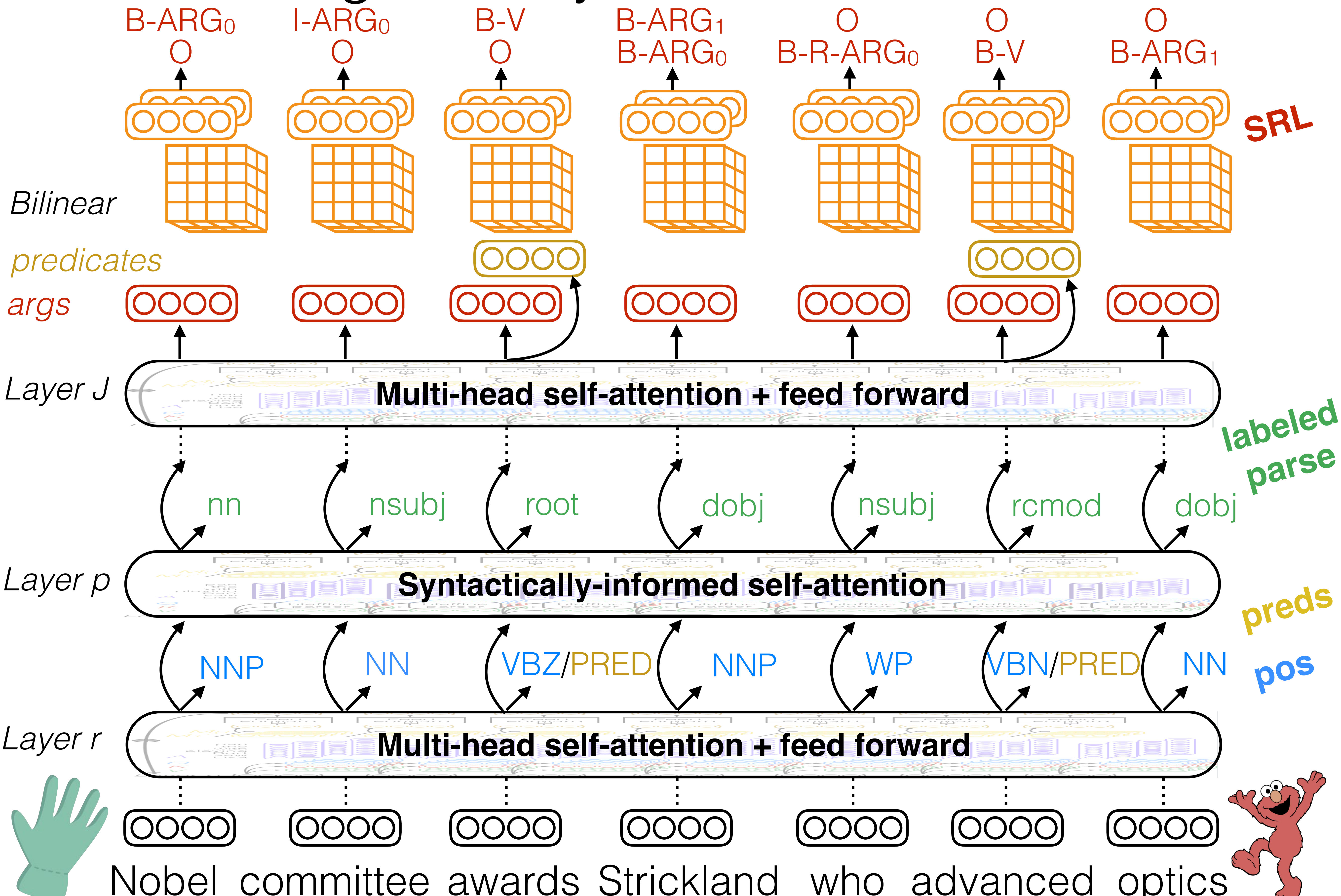
LISA: Linguistically-Informed Self-Attention



LISA: Linguistically-Informed Self-Attention



LISA: Linguistically-Informed Self-Attention



exercise!