check out all these logos

Verb Physics

and factor graphs

Max Forbes pretending to be Yejin Choi

January 29, 2020

CSE 447 / 547

Today's takeaways

1. NLP needs commonsense

2. We can learn (some) commonsense from text!

Today's takeaways

1. NLP needs commonsense
PART I

2. We can learn (some) commonsense from text!
PART II

Today's takeaways

1. NLP needs commonsense
PART I

2. We can learn (some) commonsense from text!
PART II

[Factor graphs
PART II — INTERLUDE]

PART I

NLP needs commonsense

COMMONSENSE IN: SYNTACTIC PARSING

I shot the elephant in my pajamas.

COMMONSENSE IN: COREFERENCE RESOLUTION

Obama met Jobs to discuss the economy, technology, and education. After the meeting, he signed a bill to introduce [...]

?

[Bansal 2015]

COMMONSENSE IN: SPEECH RECOGNITION

"… go ahead and grill the ______"

dish	0.5
fish	0.3
miss	0.1
…	

?

vs

- Preheat the oven to 350 F.
- Tenderize the chicken with a large mallet.
- Season the chicken with the spice mixture.
- Serve chicken on top of a bed of rice.

Done!?

The large ball crashed right through the table because it was made of **steel**.

What was made of **steel**?

The large ball crashed right through the table because it was made of **styrofoam**.

What was made of **styrofoam**?

[Levesque 2012]

PART II

Verb Physics

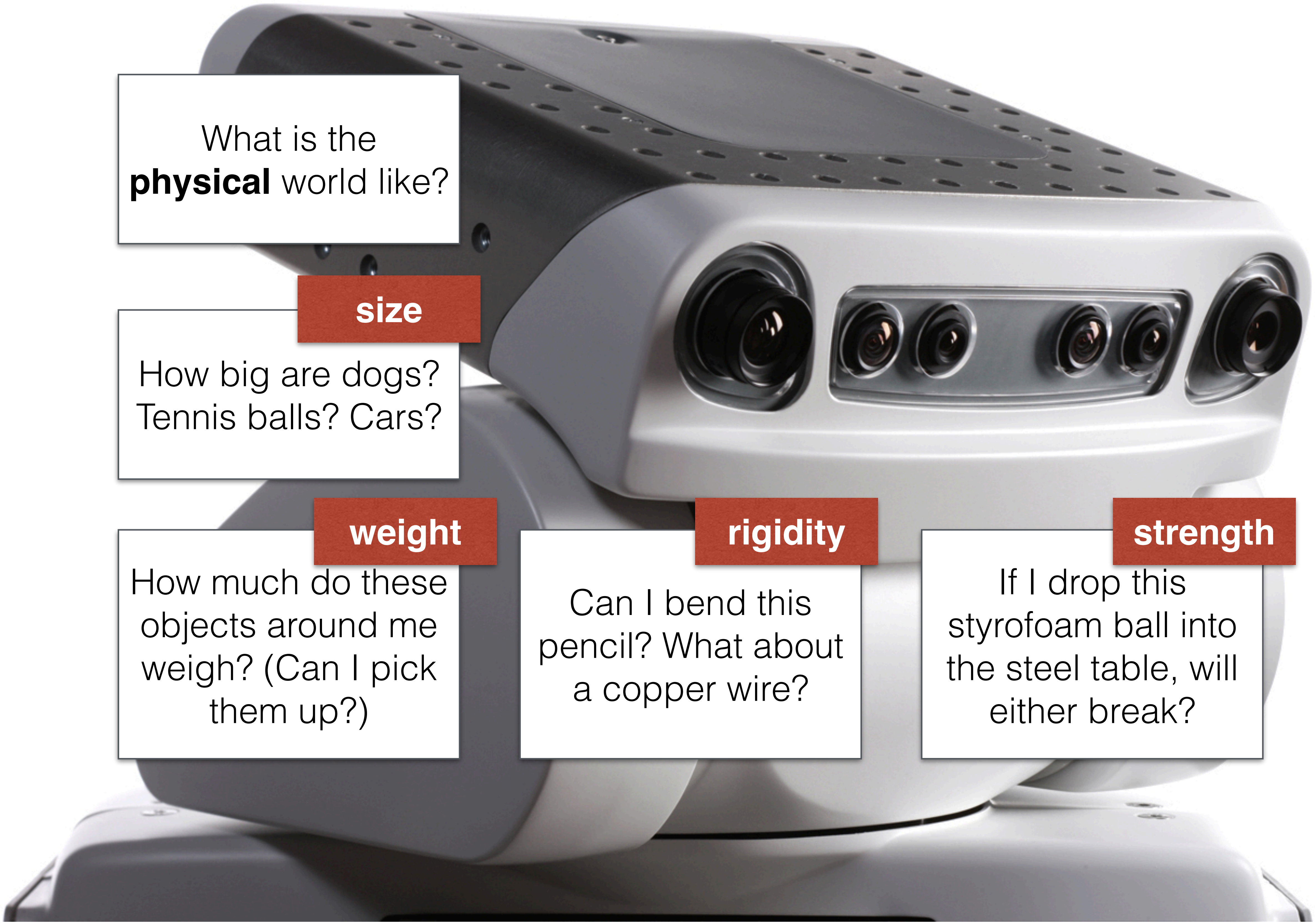

[Gao et al., 2016]


[Angeli and Manning, 2014]


[Gordon and Schubert, 2012]

[Li et al., 2014]

Physical properties of objects



What is the **physical** world like?

size

How big are dogs? Tennis balls? Cars?

weight

How much do these objects around me weigh? (Can I pick them up?)

rigidity

Can I bend this pencil? What about a copper wire?

strength

If I drop this styrofoam ball into the steel table, will either break?

“I am larger than a chair”

~~“I am larger than a chair”~~

~~*"I am larger than a pen"*~~

~~*"I am larger than a stone"*~~

~~*"I am larger than a chair"*~~

~~*"I am larger than a ball"*~~

~~*"I am larger than a towel"*~~

[Grice, 1975] [Sorower et al., 2011] [Misra et al., 2016]

"The horse was as small as a dog!"

$\Longrightarrow$ horse $=^{size}$ dog ?


“Hey robot, pass me the <unk>.”
“OK.” (attempts to pick up table)

"I **picked up** the <thing>."

"I took a **drink from** the <thing>."

"The <thing> **shattered** when it hit the ground

Two related problems

Physical properties implied by predicates

*"I **picked up** the <thing>."*

*"I took a **drink from** the <thing>."*

*"The <thing> **shattered** when it hit the ground*

Physical properties of objects

1. Introduction
2. Related work
3. Approach
4. Model
5. Data
6. Evaluation

Two related problems

Physical properties implied by predicates

*"I **picked up** the <unk>."*

*"I took a **drink from** the <unk>."*

*"The <unk> **shattered** when it hit the ground*

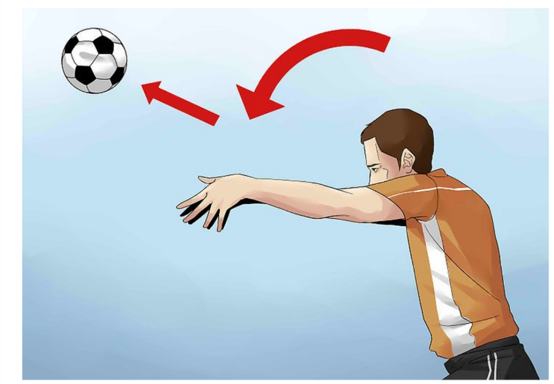
Physical properties of objects

Attributes

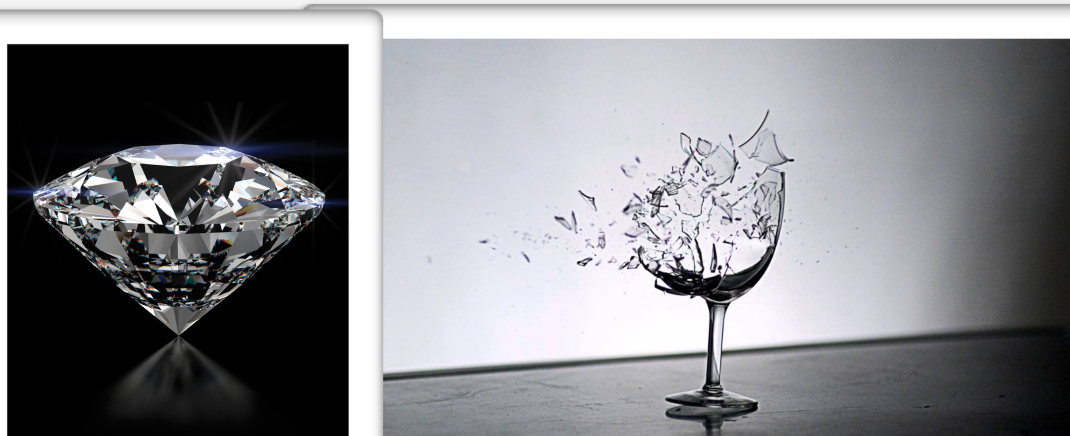
$x >_{\text{size}} y$

$x >_{\text{weight}} y$

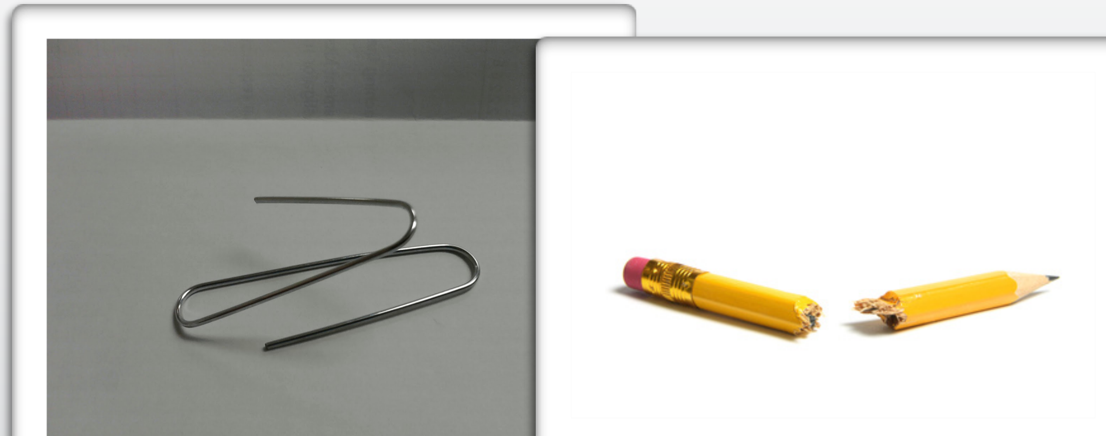
$x >_{\text{speed}} y$



$x >_{\text{strength}} y$



$x <_{\text{rigidness}} y$



$x >^{size} y$

$x >^{weight} y$

$x <^{rigidness} y$

$x <^{strength} y$

Individual-level

Always true

$x <^{speed} y$

Stage-level

True in window surrounding predicate

[Carlson, 1977]

“I threw the ______”

“I threw the ______”

ball

stone

chair

“I threw the ______”

ball

stone

chair

~~game~~

~~party~~

"I threw the ______"

ball

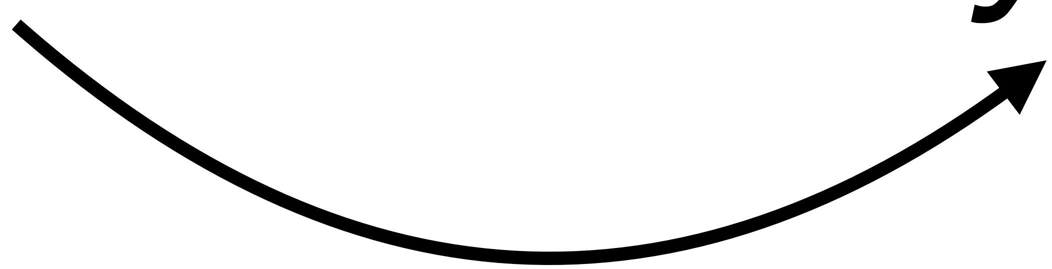
stone

chair

x threw y


x threw *y*
x is bigger than y

x threw *y*



x is bigger than y

x weighs more than y

as a result, y will be moving faster than x

Action frame

x threw y

$$\Longrightarrow x >^{size} y$$

$$\Longrightarrow x >^{weight} y$$

$$\Longrightarrow x <^{speed} y$$

Terminology

Action frames — *simple syntax-based verb constructions that compare two objects*

Terminology

Action frames — *simple syntax-based verb constructions that compare two objects*

x threw *y*

PERSON threw *x* into *y*

PERSON threw on *x*

distinct action frames for the same verb

Terminology

Action frames — *simple syntax-based verb constructions that compare two objects*

x threw *y*

PERSON threw *x* into *y*

PERSON threw on *x*

Objects — *non-abstract nouns*

✓ ball ✗ ~~evil~~

✓ train ✗ ~~time~~

Two related problems

Physical properties implied by predicates

"I ***picked up*** the <thing>."

"I took a ***drink from*** the <thing>."

"The <thing> ***shattered*** when it hit the ground

Physical properties of objects

size

weight

strength

Two related problems

Physical properties implied by predicates	***Physical properties of objects***

Example

takes values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

F = "x threw y"

attribute: size

correct value: $\boxed{>}$

intuition: "x threw y"

$\Longrightarrow x >^{size} y$

Two related problems

Physical properties implied by predicates	Physical properties of objects

Example

takes values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

F = "x threw y"

attribute: size

correct value: $\boxed{>}$

intuition: "x threw y" $\implies$ x $>^{\text{size}}$ y

Example

takes values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

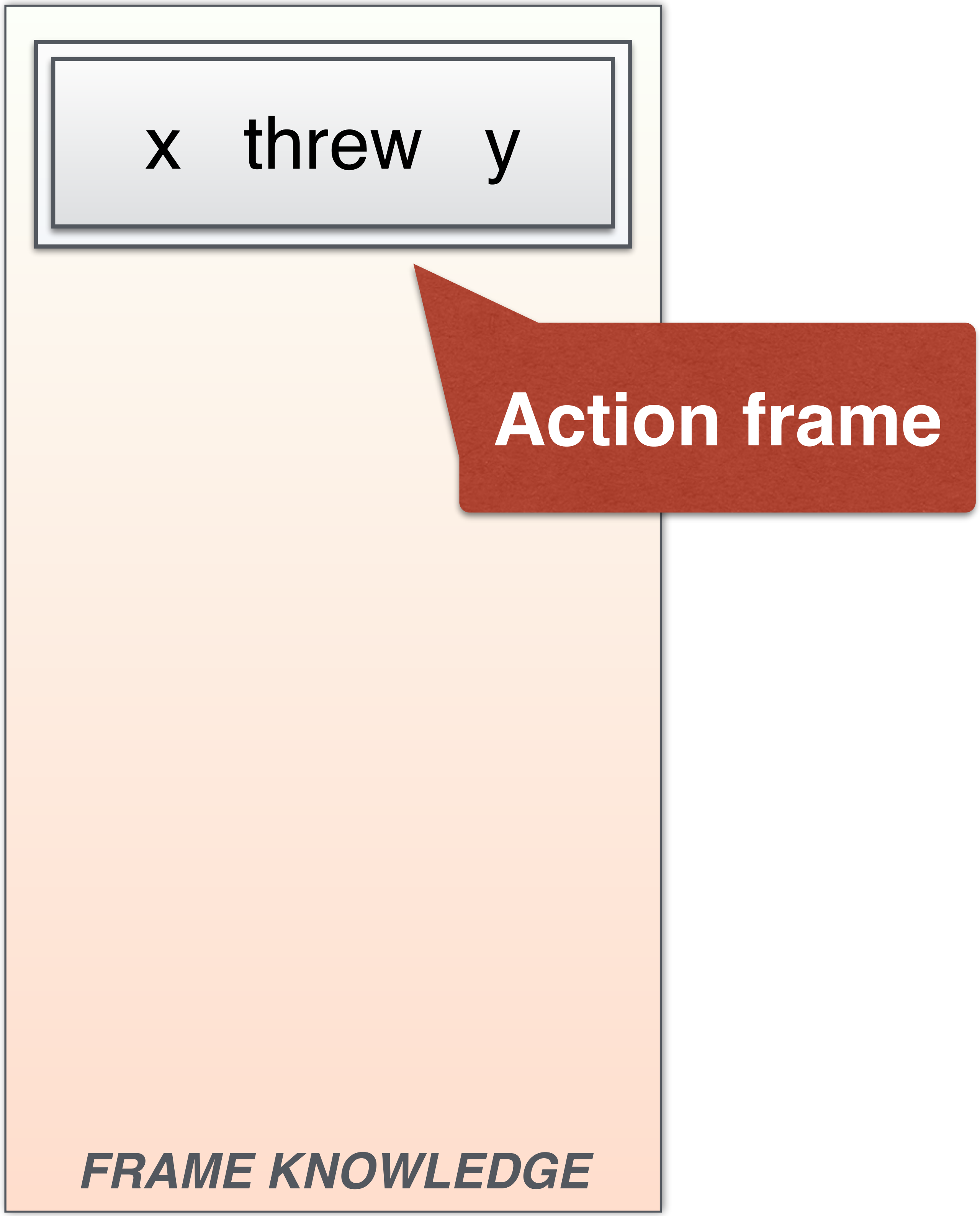
$J_{p,q}$ = (person, ball)

attribute: size

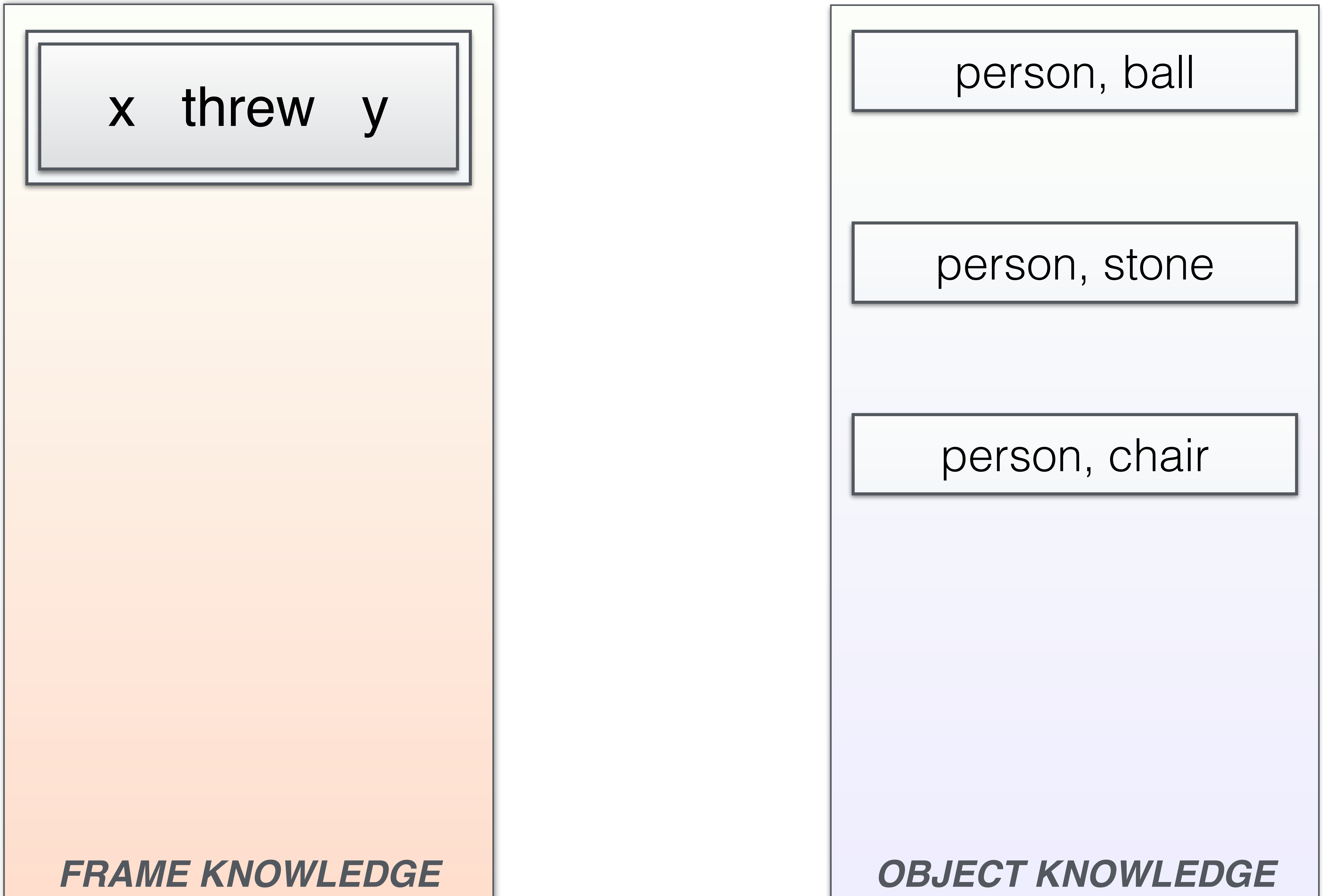
correct value: $\boxed{>}$

intuition: people are generally larger than balls

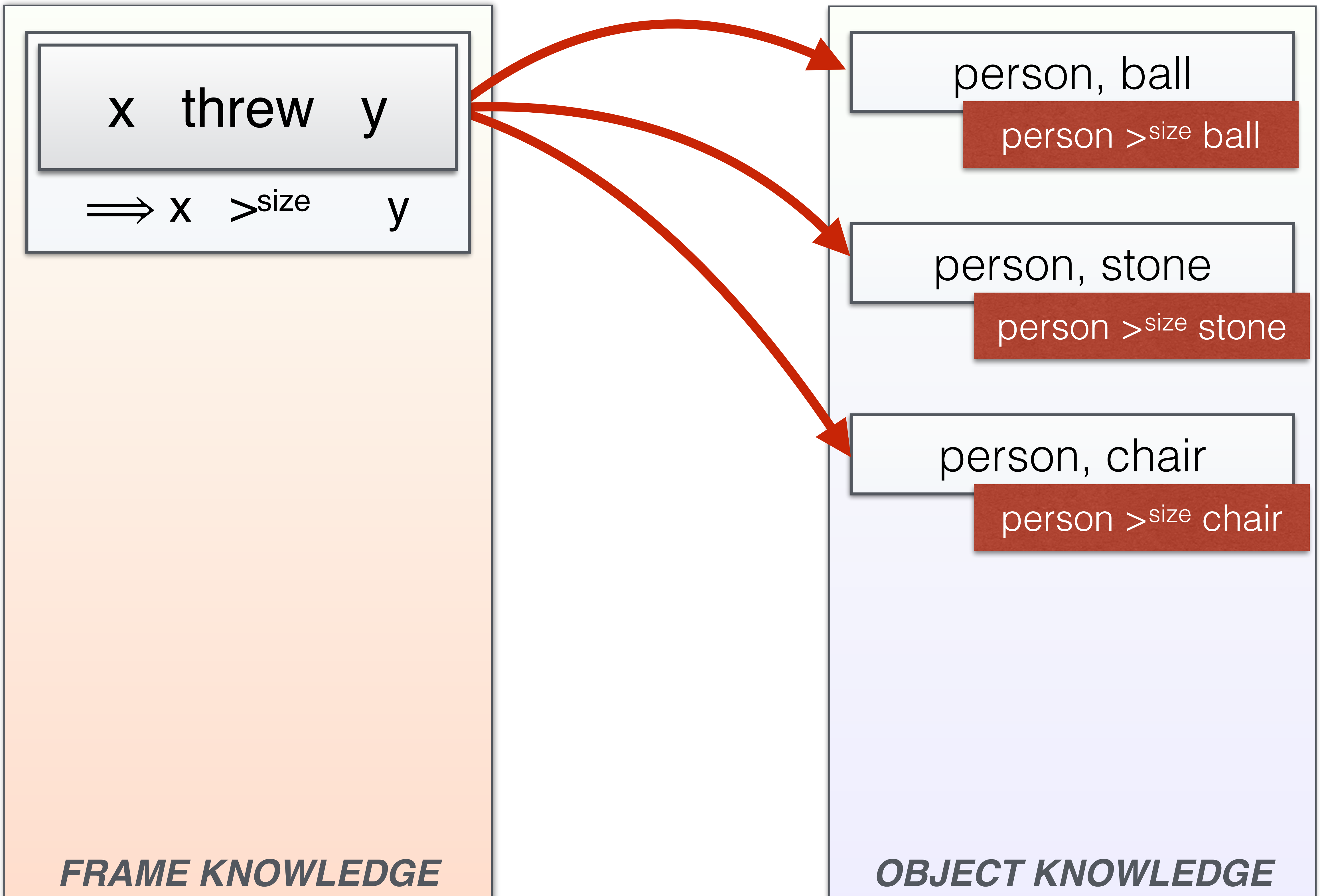
Solving both puzzles together



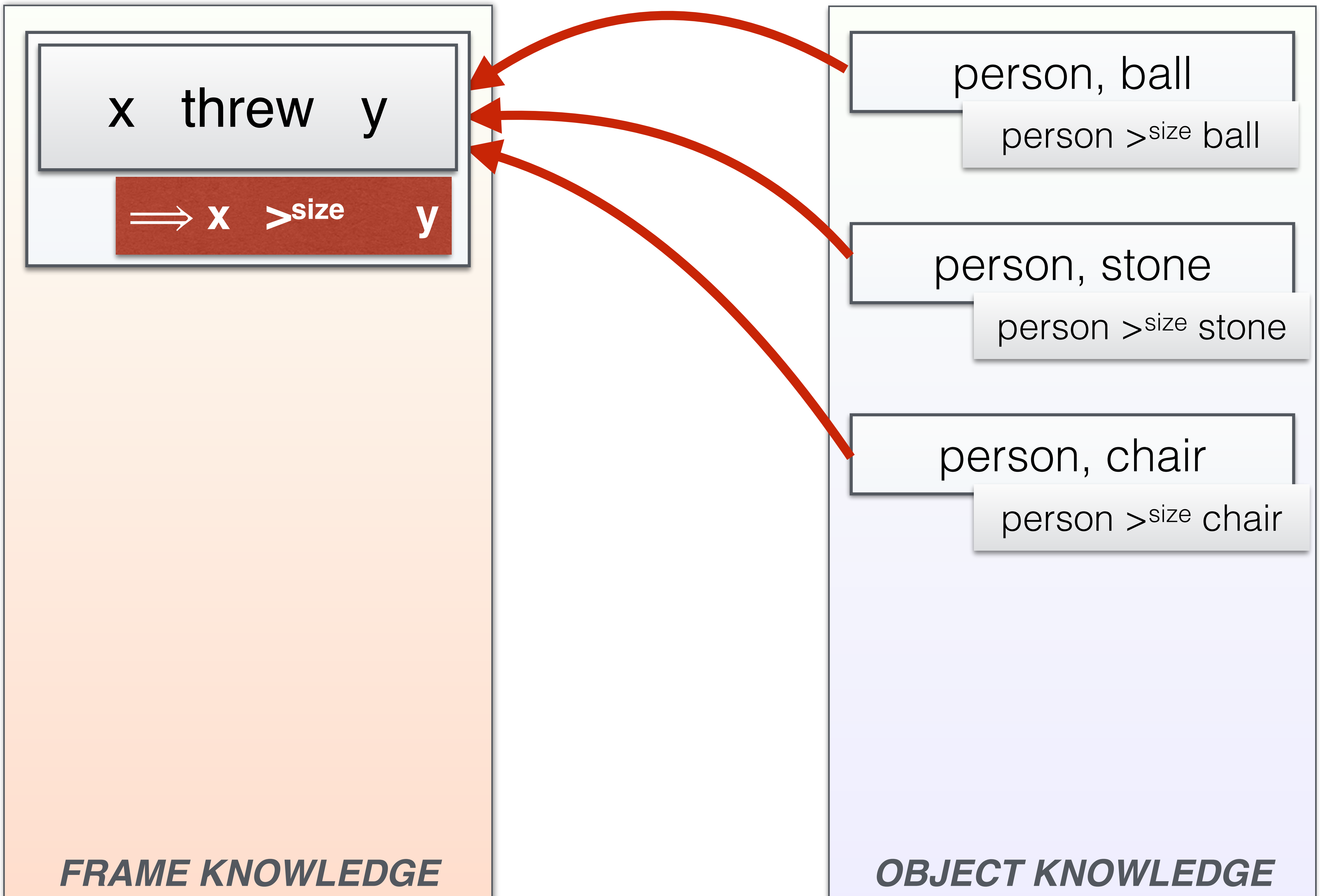
Solving both puzzles together

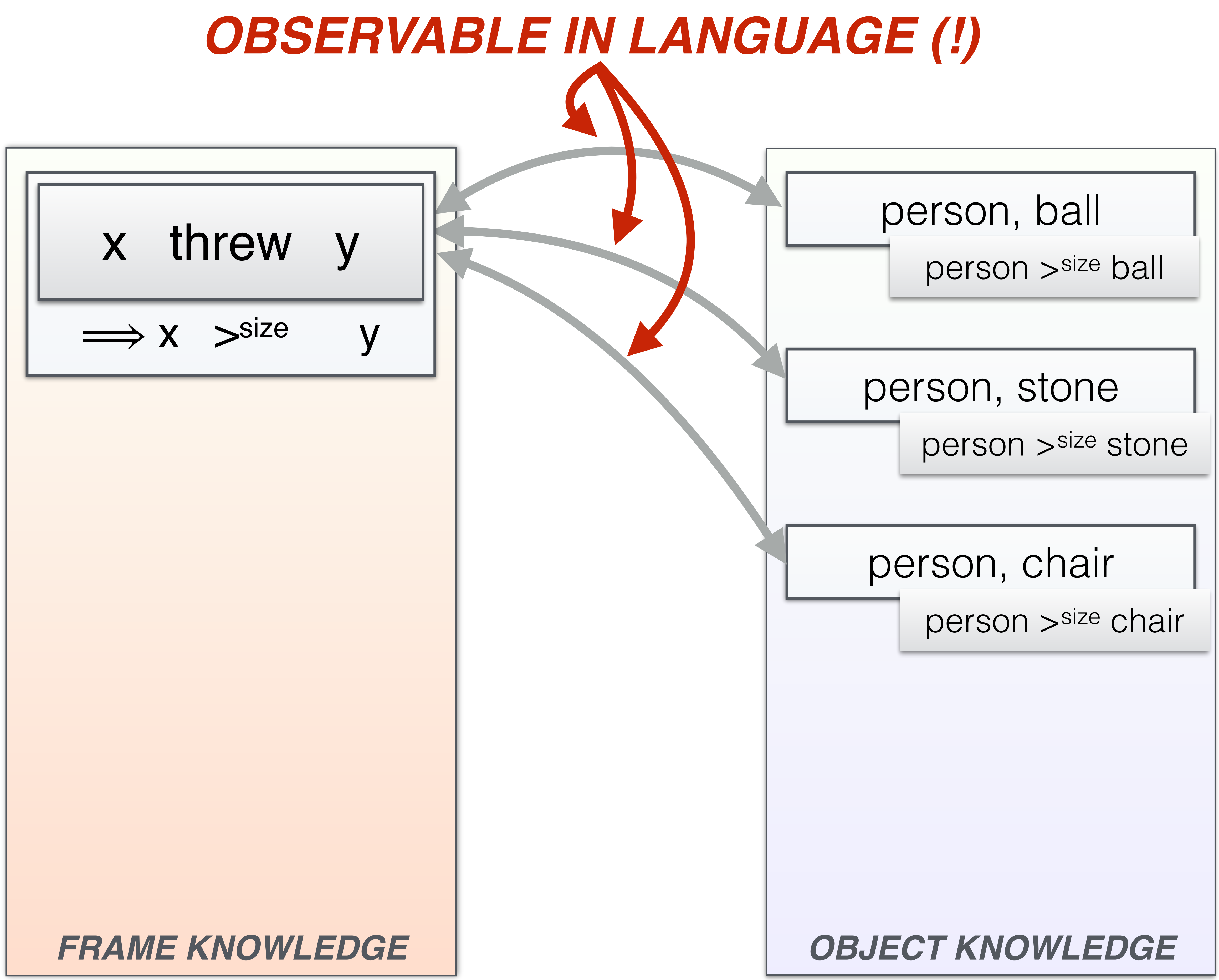


Solving both puzzles together

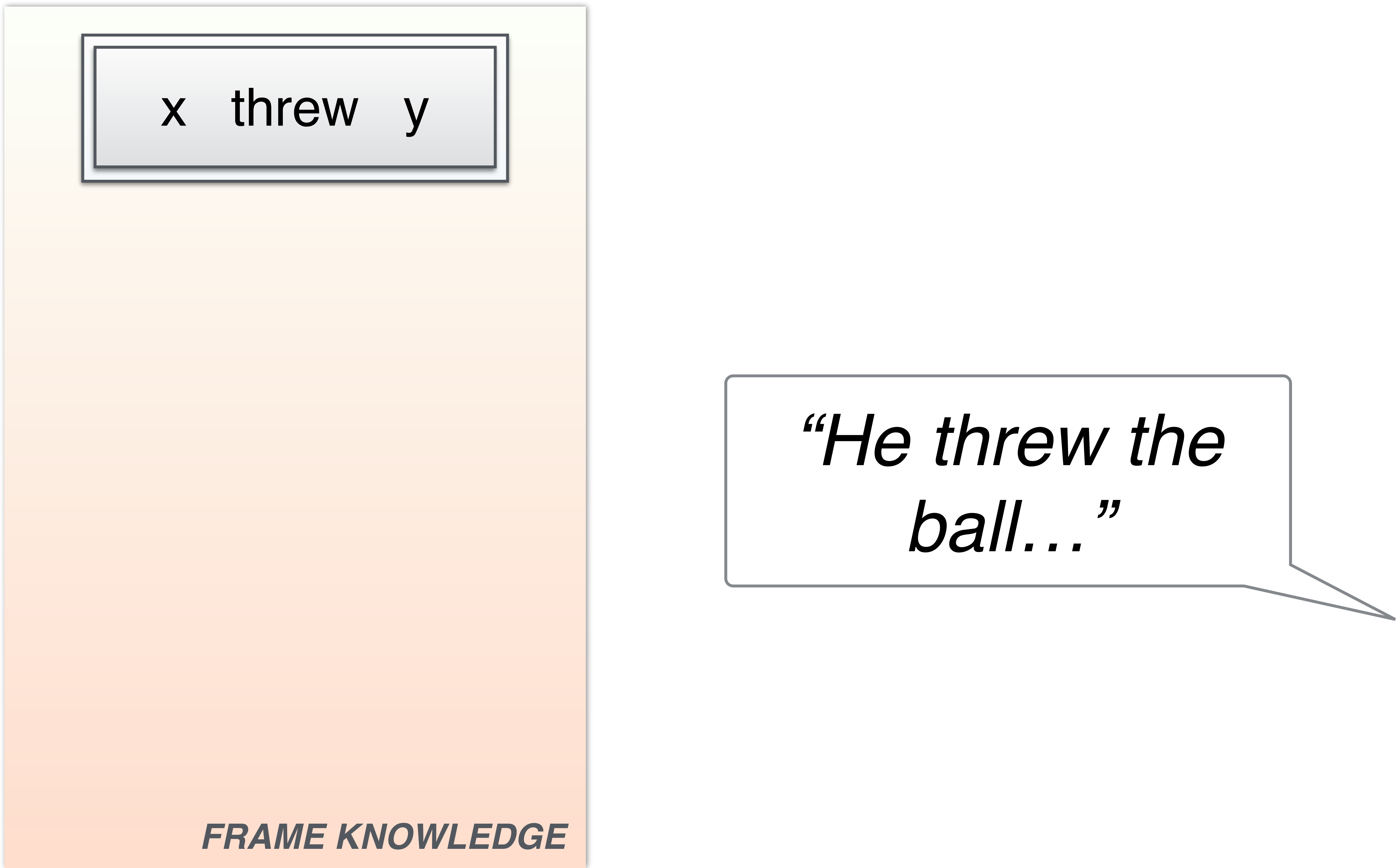


Solving both puzzles together

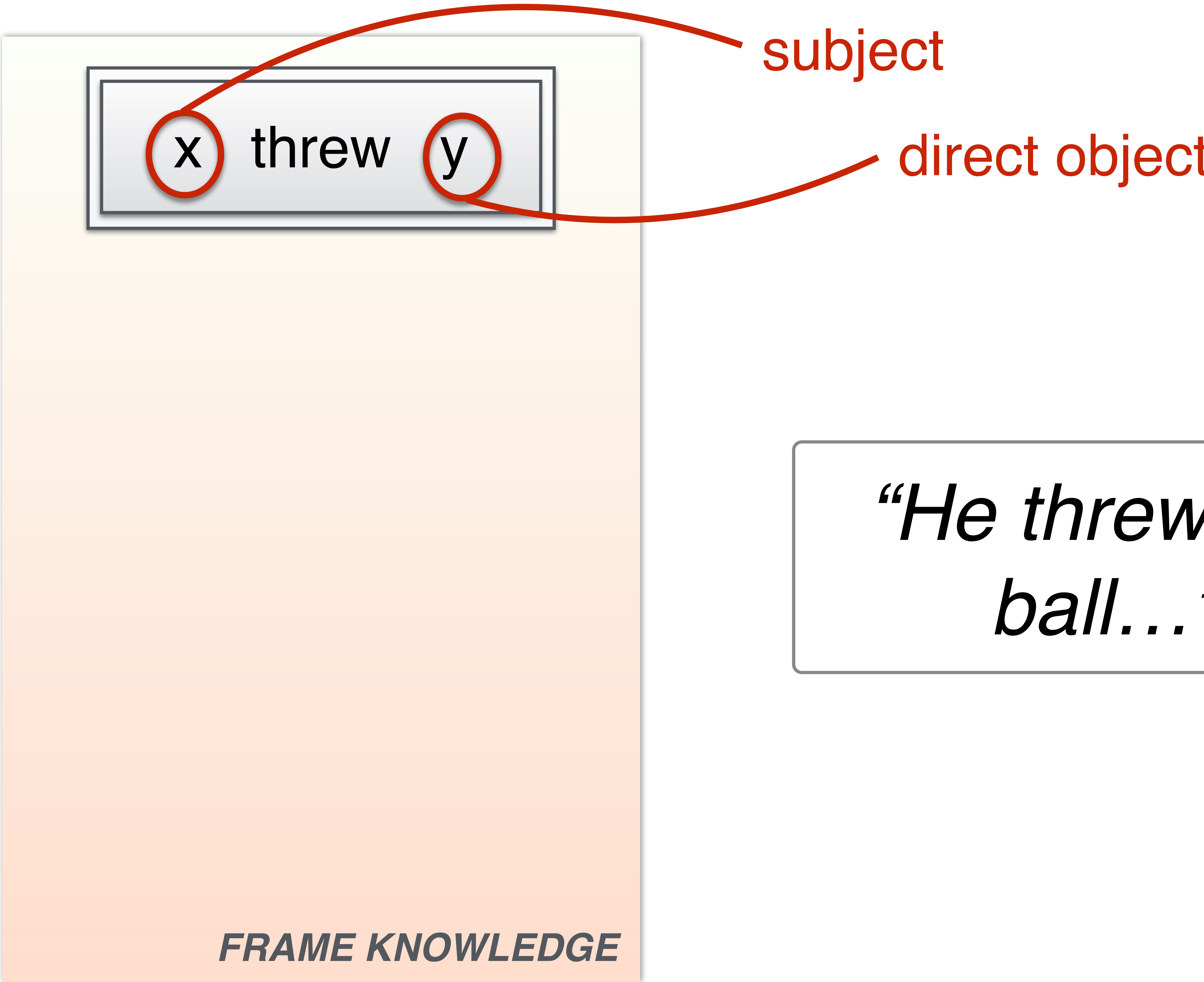



OBSERVABLE IN LANGUAGE (!)
x threw y
⟹ x >size y
person, ball
person >size ball
person, stone
person >size stone
person, chair
person >size chair
FRAME KNOWLEDGE
OBJECT KNOWLEDGE

Action frame constructions



Action frame constructions



"He threw the ball…"

Action frame constructions

x threw y

FRAME KNOWLEDGE

x walked into y

subject

object of preposition

"I walked into my office …"

"I walked into the library …"

Action frame constructions

x threw y

x walked into y

FRAME KNOWLEDGE

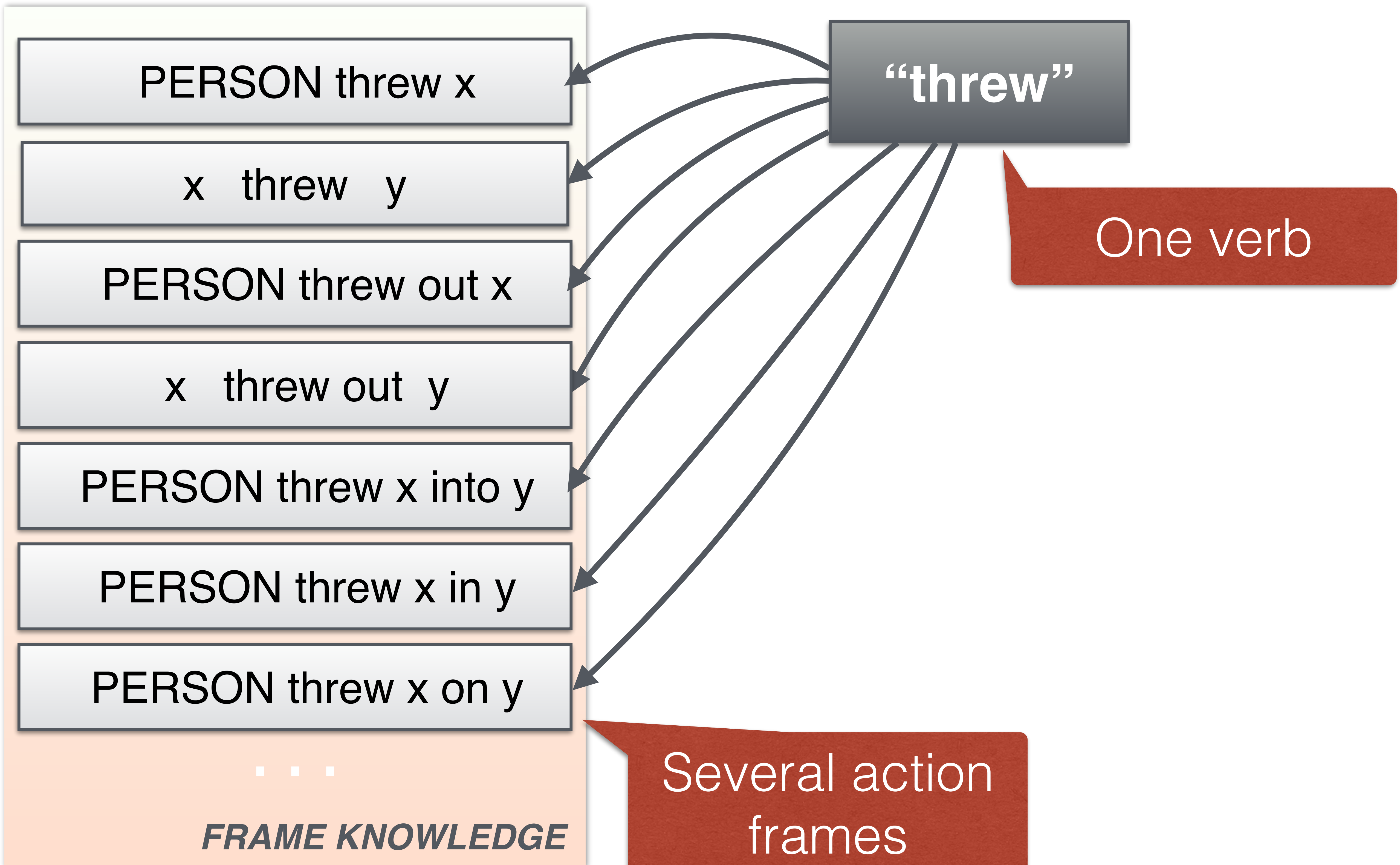
I squashed x with y

direct object

object of preposition

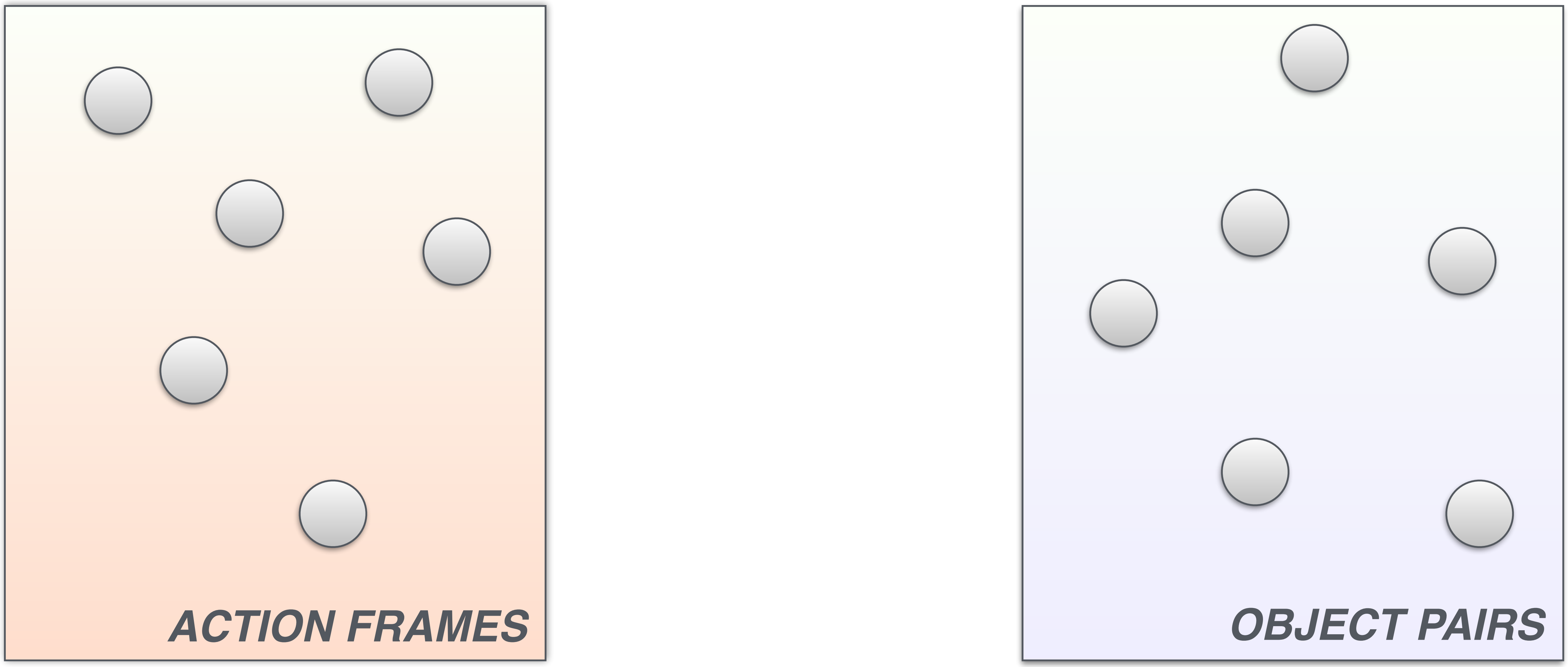
"I squashed the bug with my

Action frame constructions

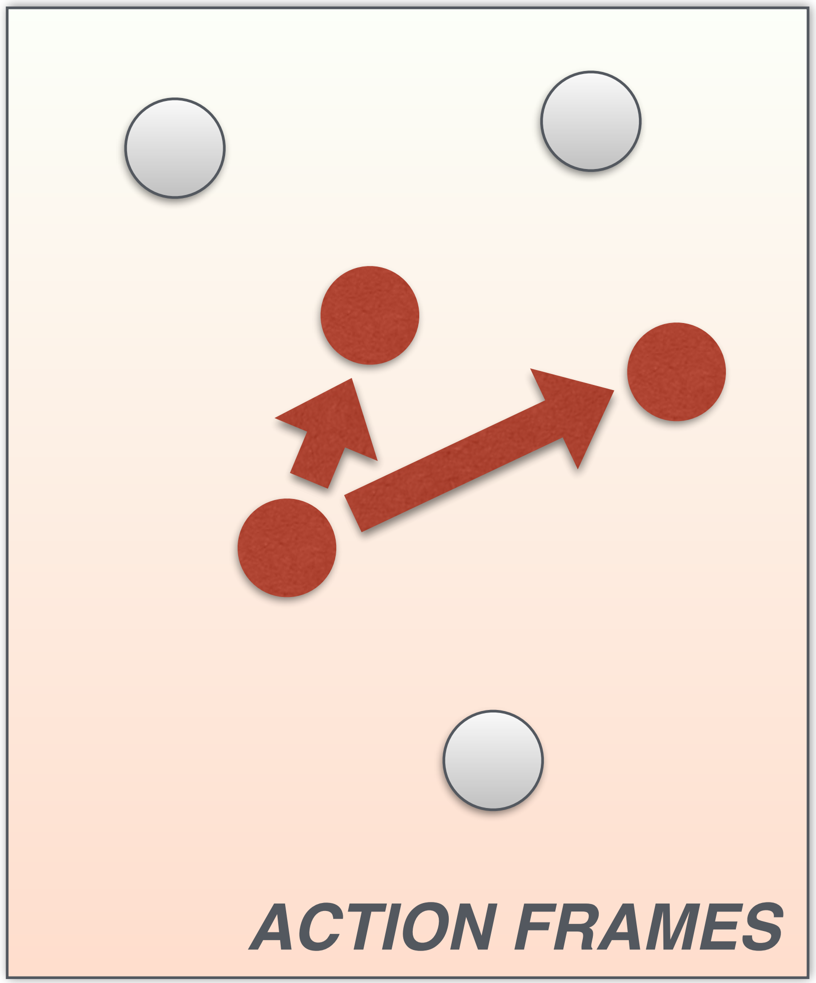


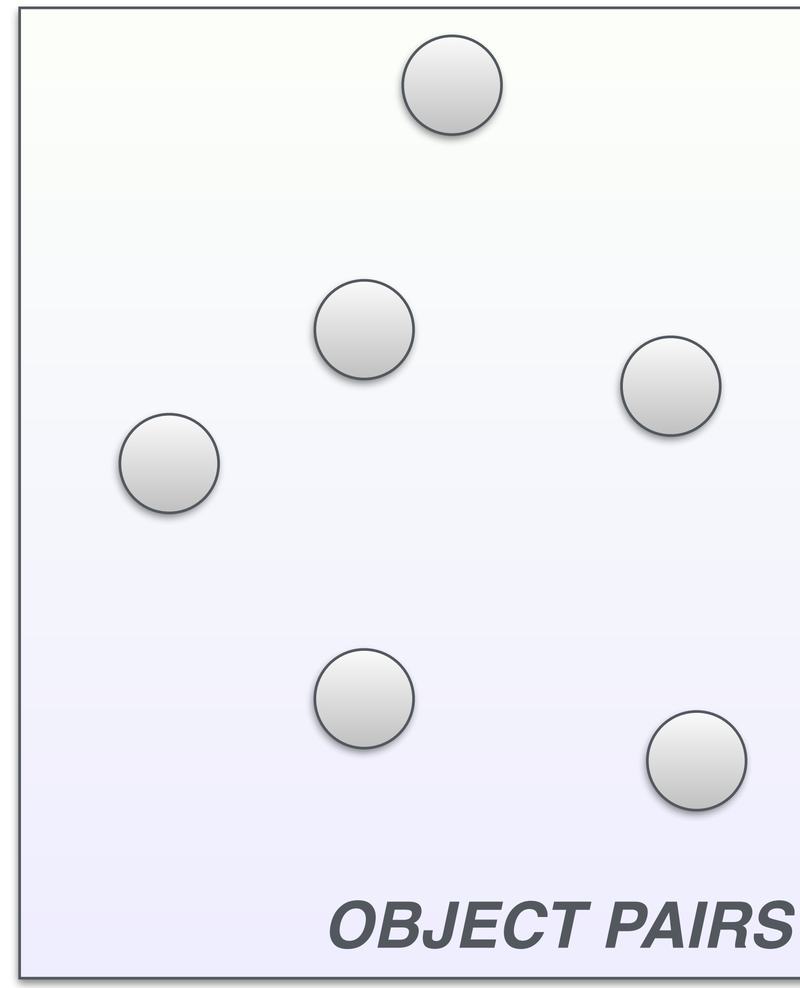
1. Introduction
2. Related work
3. Approach
4. Model
5. Data
6. Evaluation

High level model

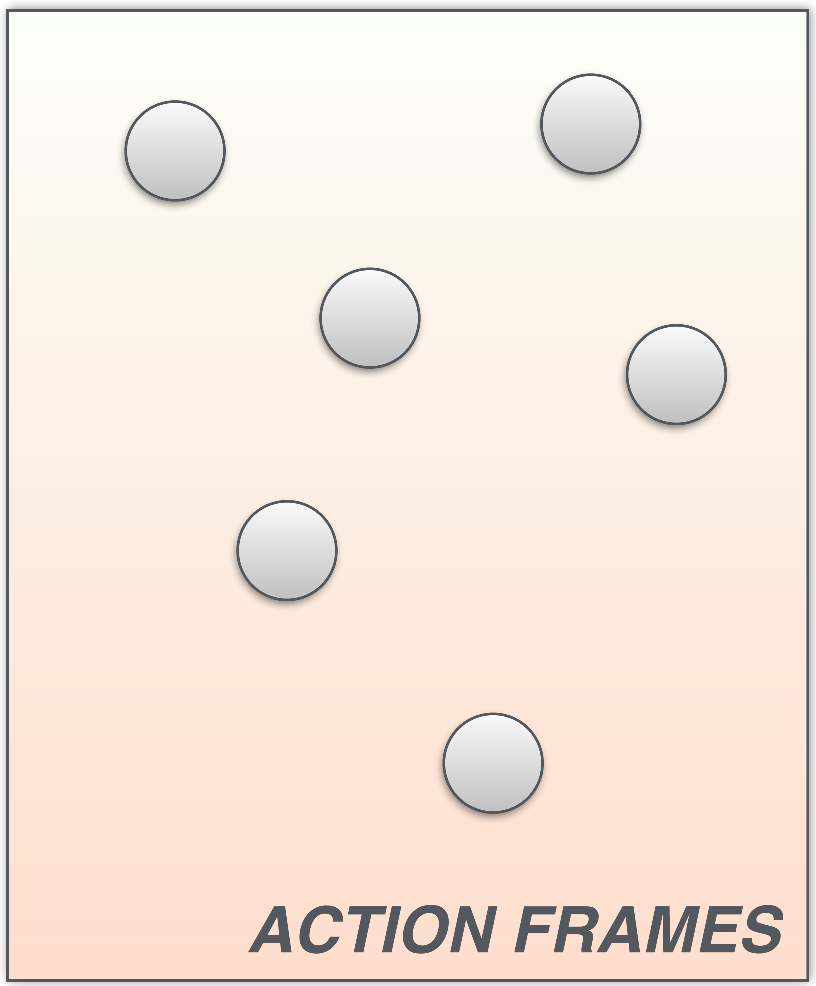


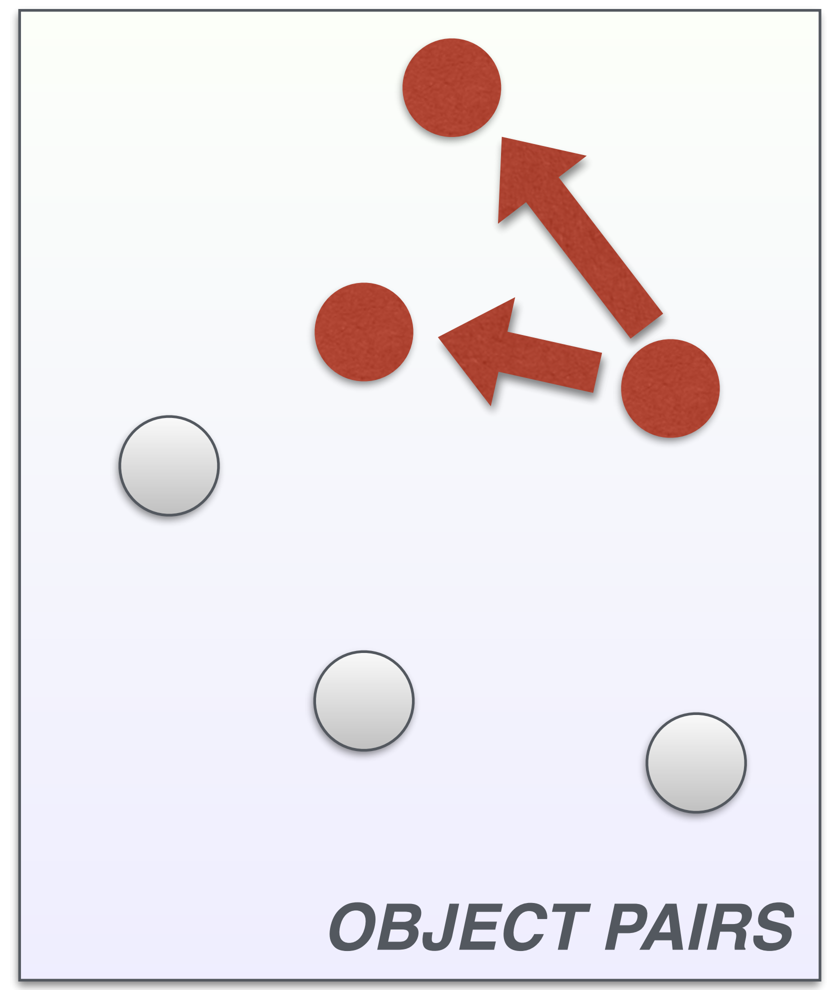
High level model



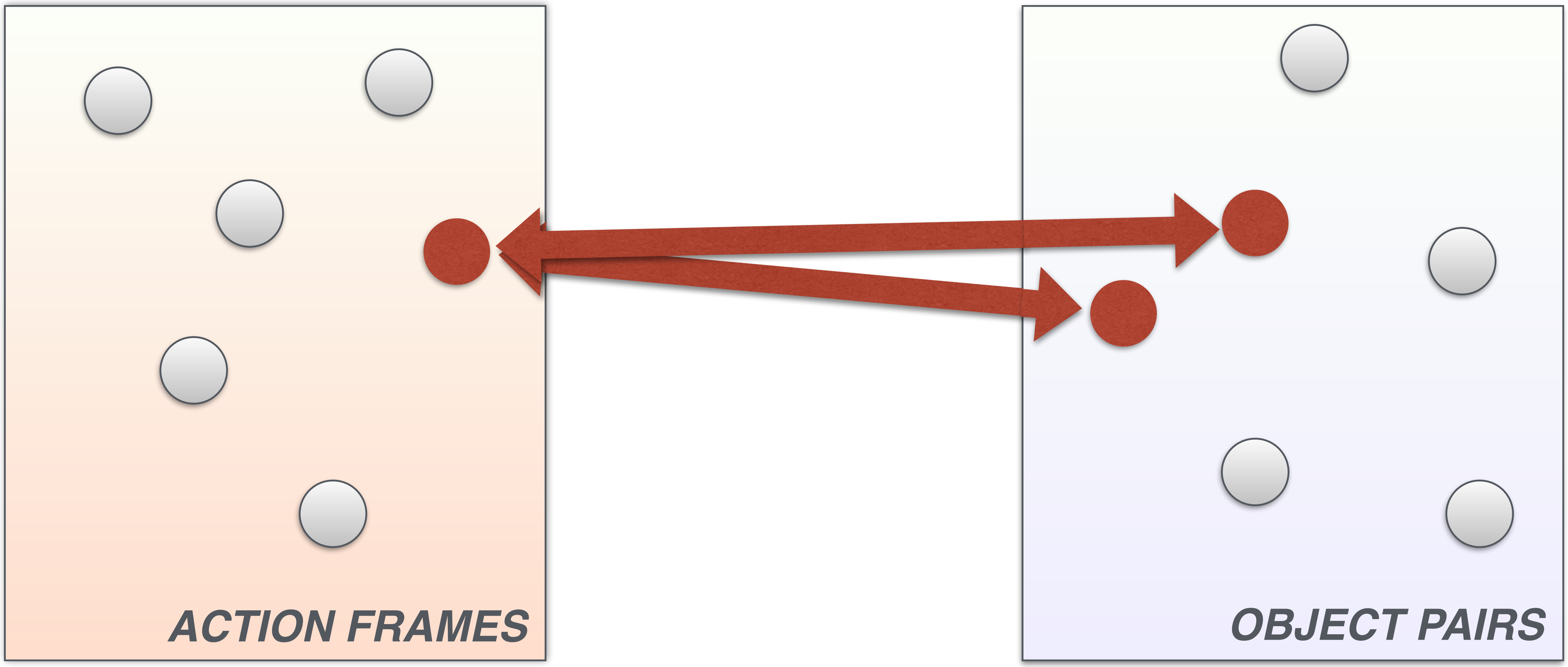


High level model



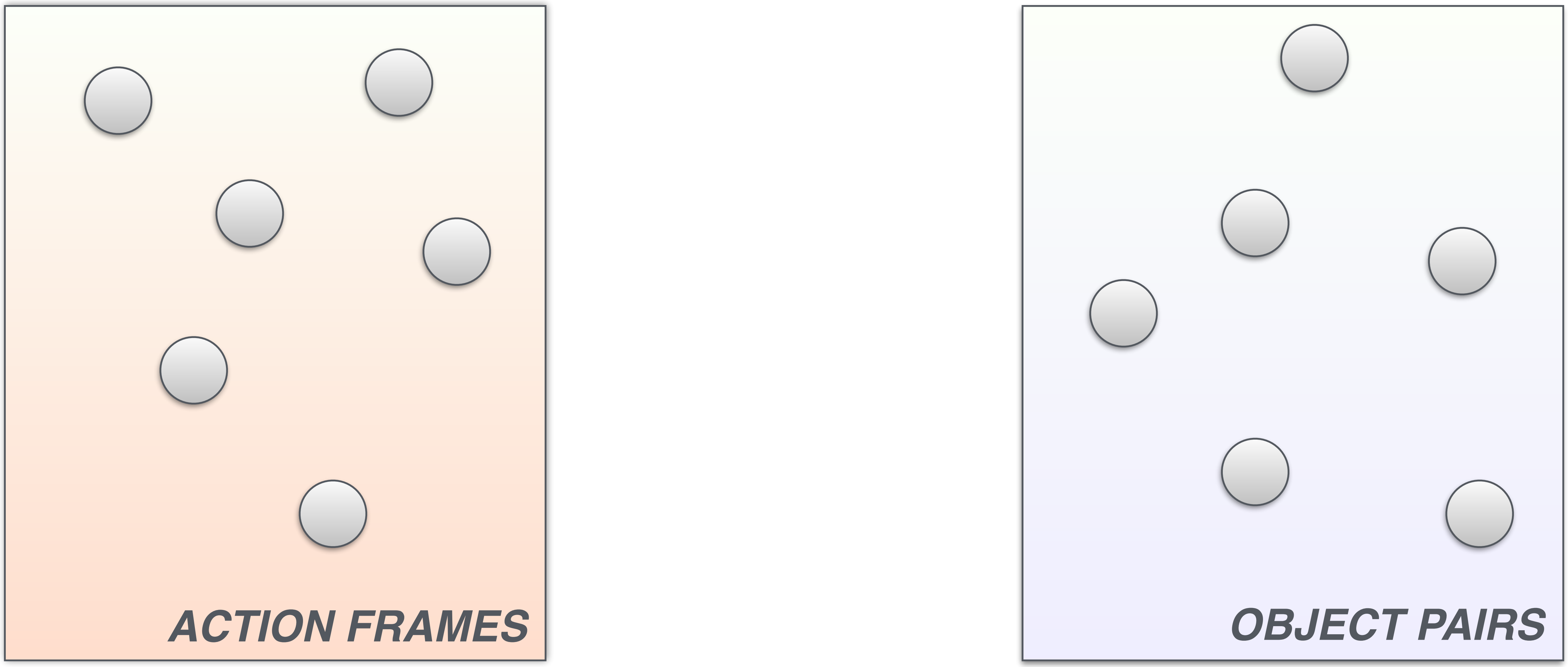


High level model



Random variables $F^{a}_{v_t}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$



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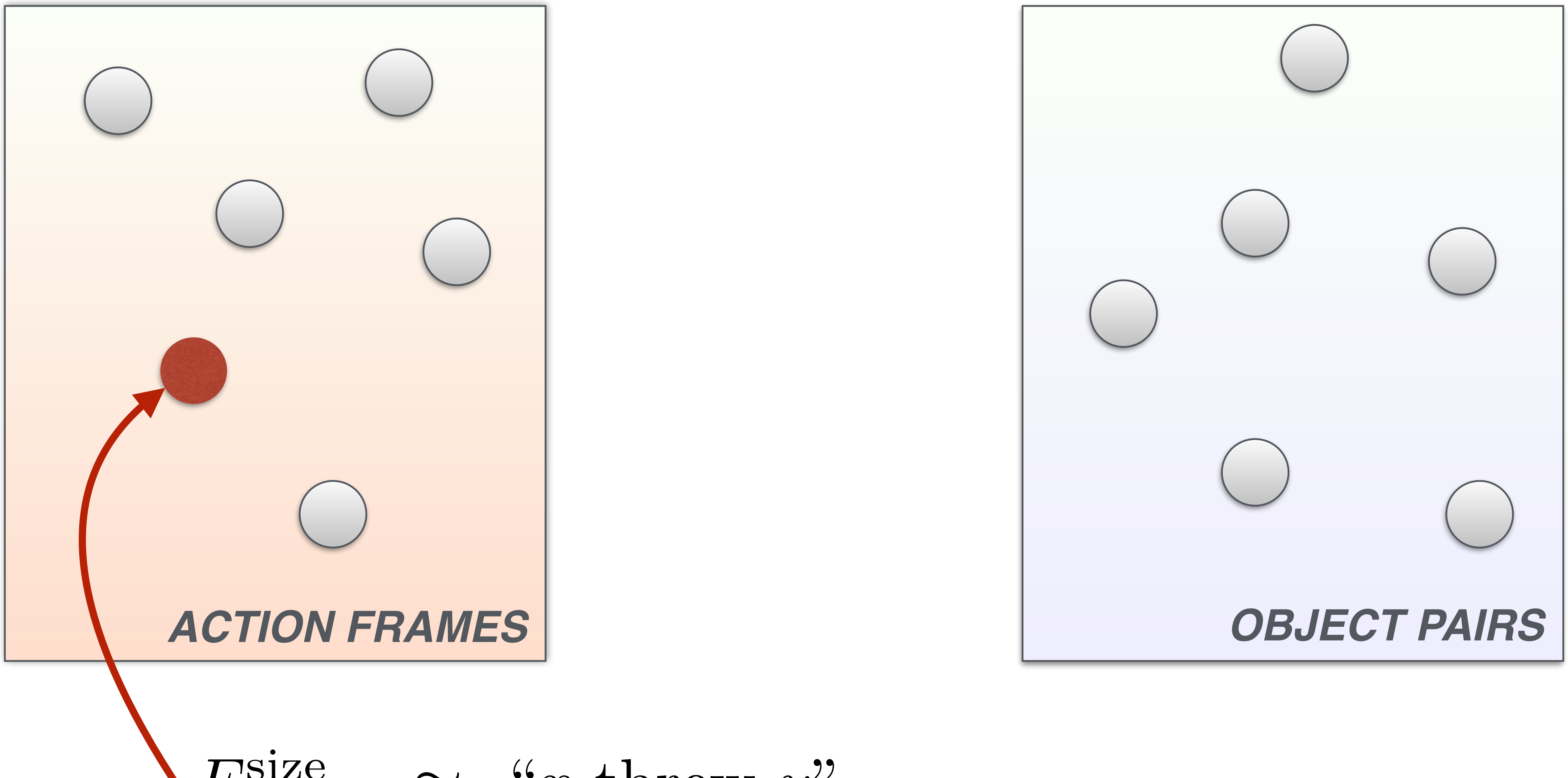
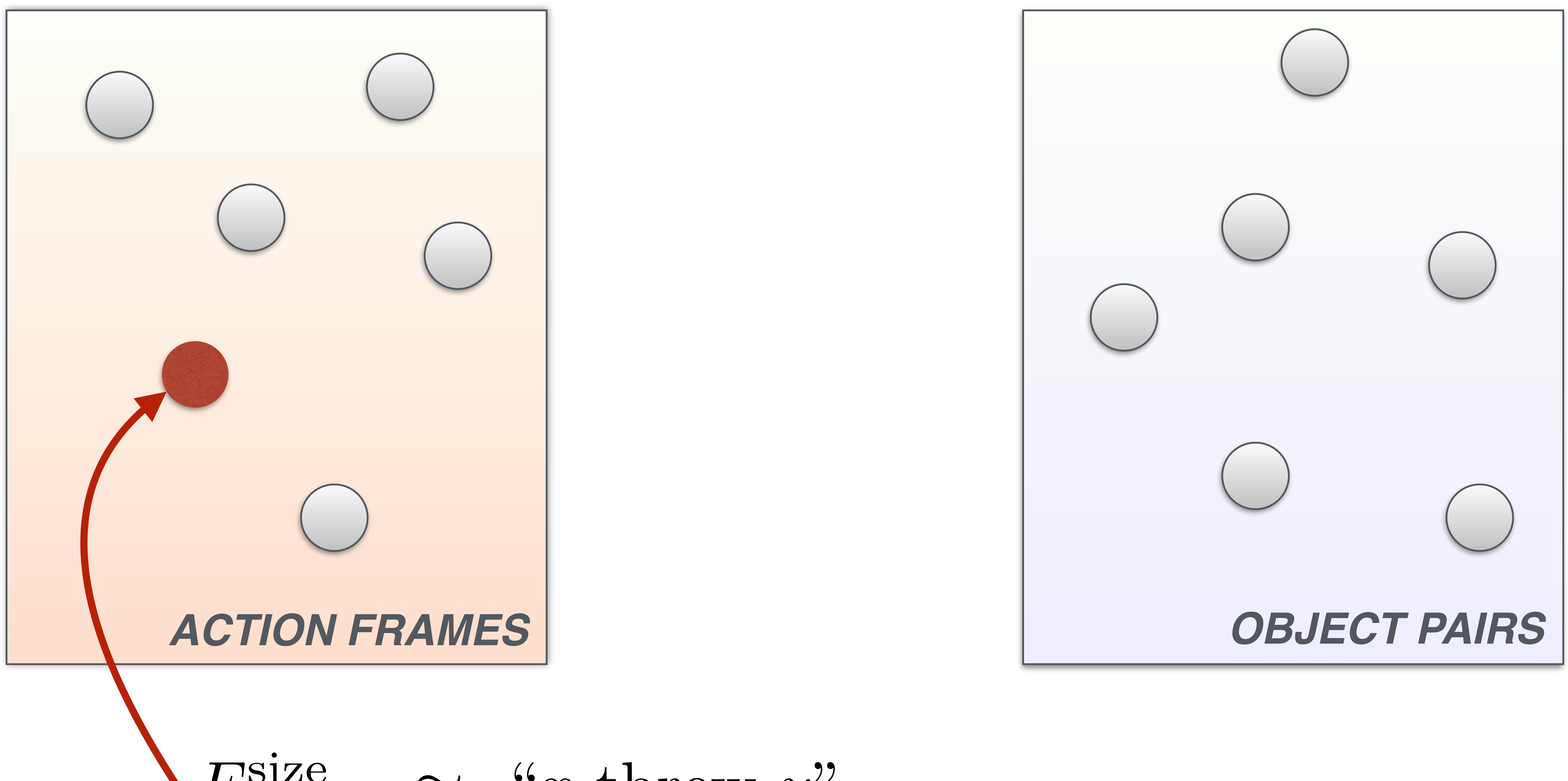


$$F^{\text{size}}_{\text{threw}_1} \approx \text{“}x \text{ threw } y\text{”}$$

Random variables $F^{a}_{v_t}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

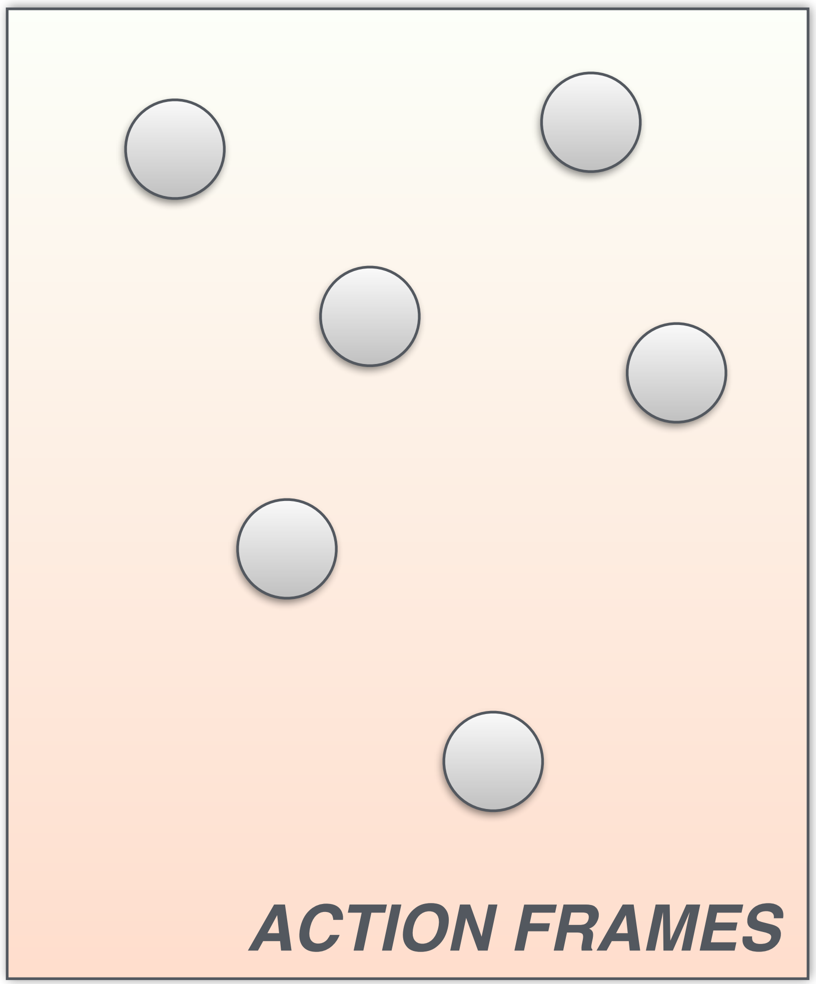


$$F^{\text{size}}_{\text{threw}_1} \approx \text{“}x \text{ threw } y\text{”}$$

$$p(F^{\text{size}}_{\text{threw}_1} = \boxed{>}) := p(\text{“}x \text{ threw } y\text{”} \Rightarrow x >^{\text{size}} y)$$

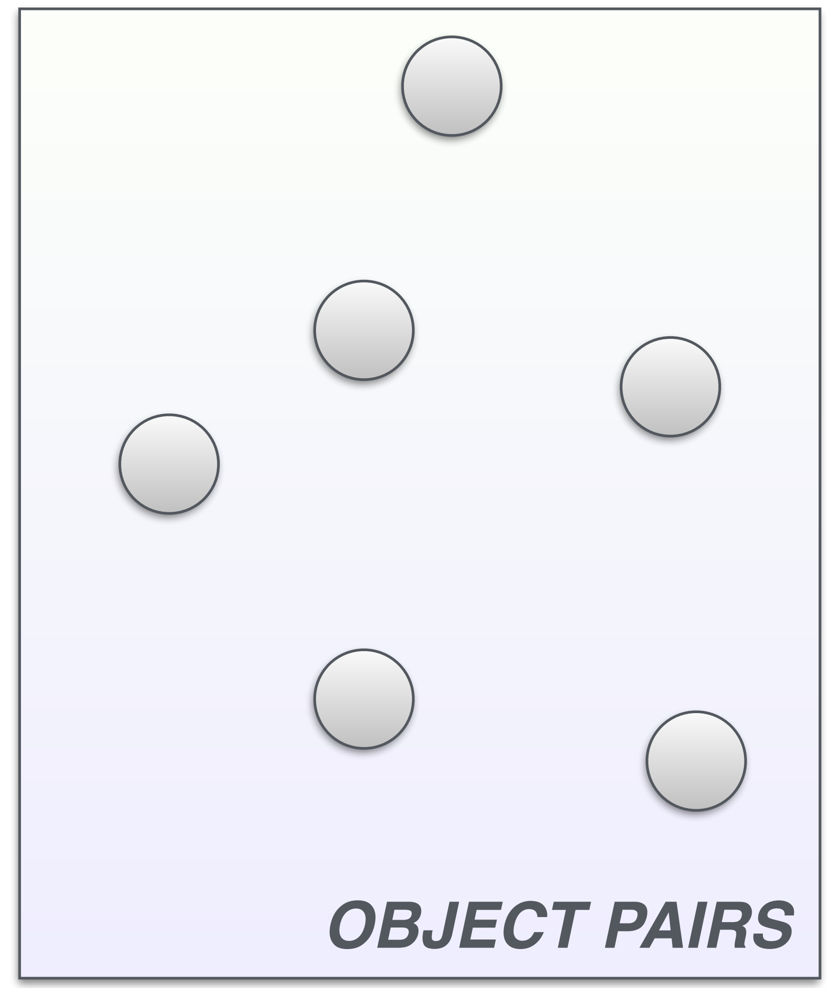
Random variables $F^{a}_{v_t}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$



Random variables $J^{a}_{p,q}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

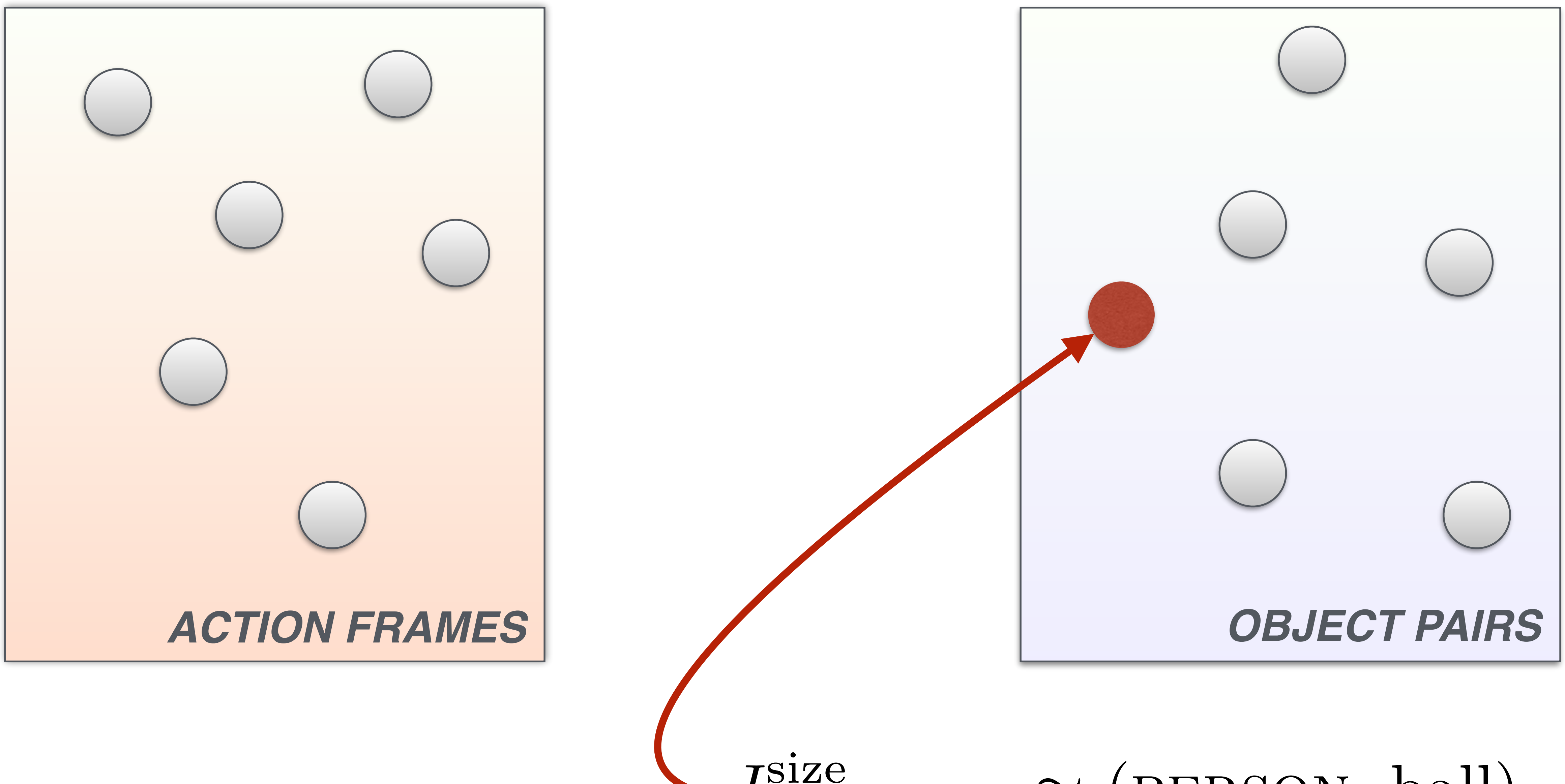


Random variables $F^{a}_{v_t}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

Random variables $J^{a}_{p,q}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$



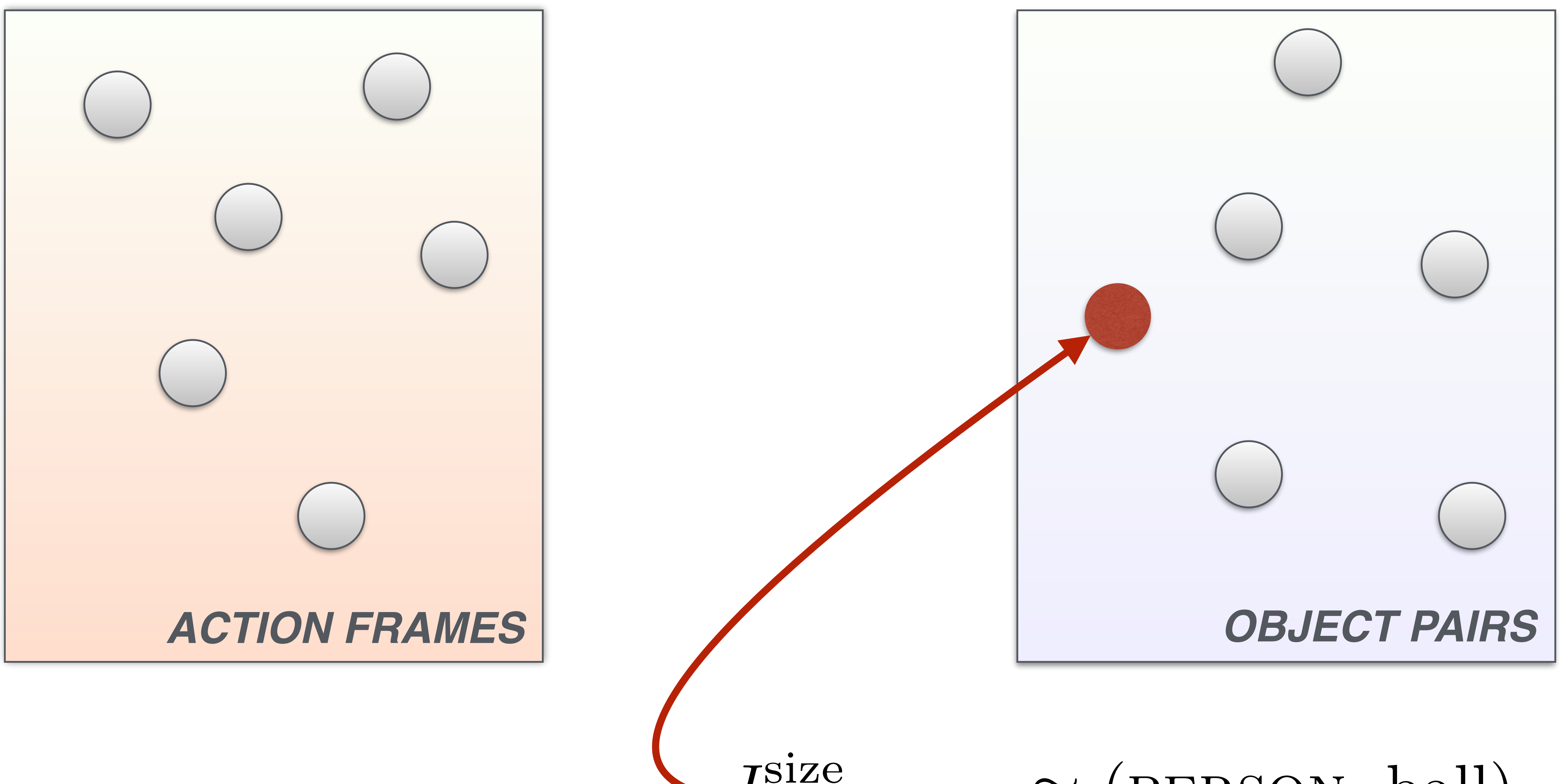
$$J^{\text{size}}_{\text{PERSON},ball} \approx (\text{PERSON, ball})$$

Random variables $F^{a}_{v_t}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

Random variables $J^{a}_{p,q}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$

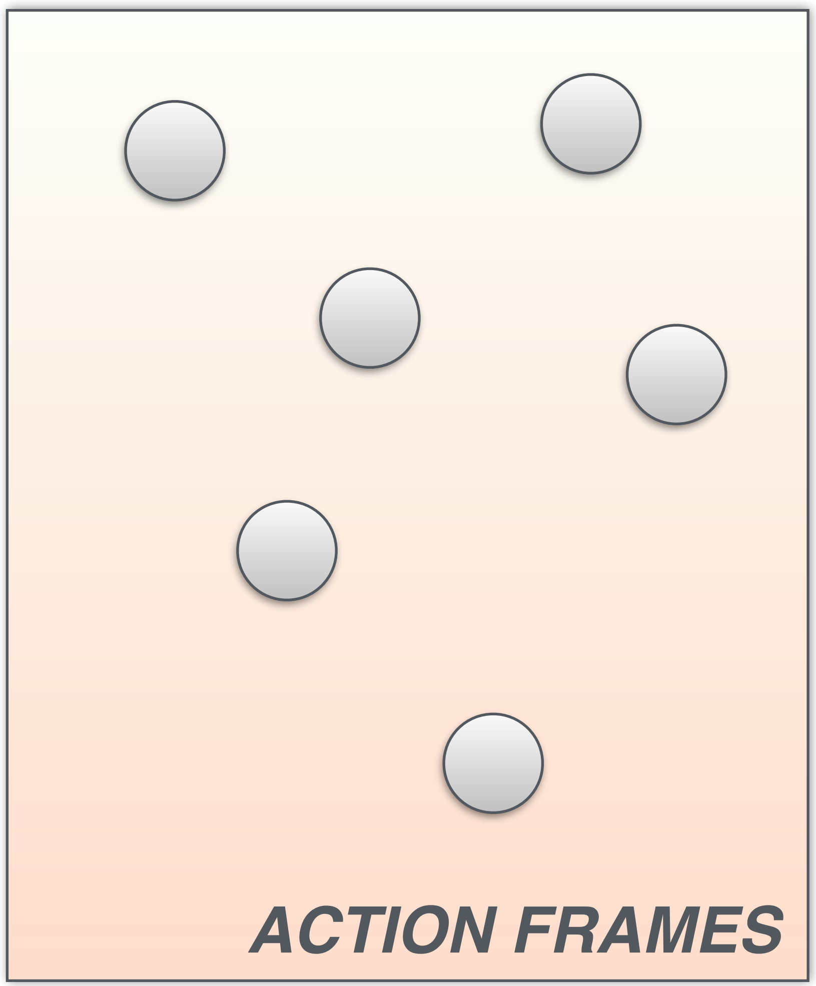


$$J^{\text{size}}_{\textsc{person},ball} \approx (\textsc{person},\ \text{ball})$$

$$p(J^{\text{size}}_{\textsc{person},\text{ball}} = \boxed{>}) := p(\textsc{person} >^{\text{size}} \text{ball})$$

Random variables $F^a_{v_t}$

Take values in $\{\boxed{>}, \boxed{<}, \boxed{\simeq}\}$



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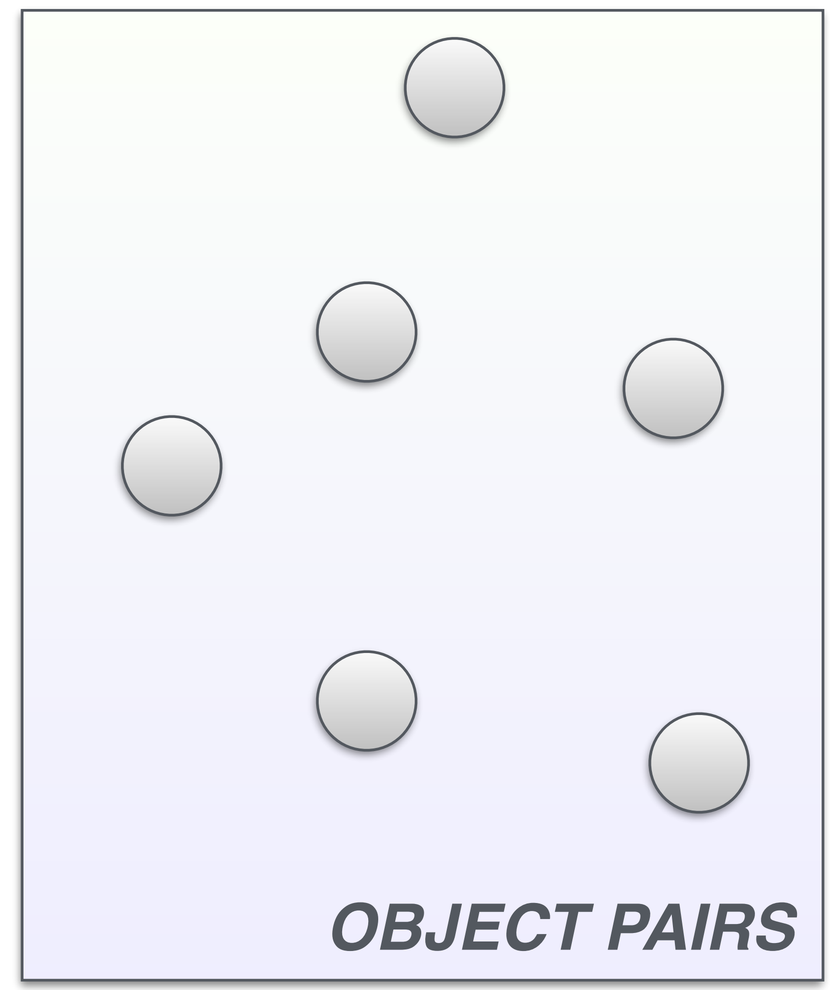

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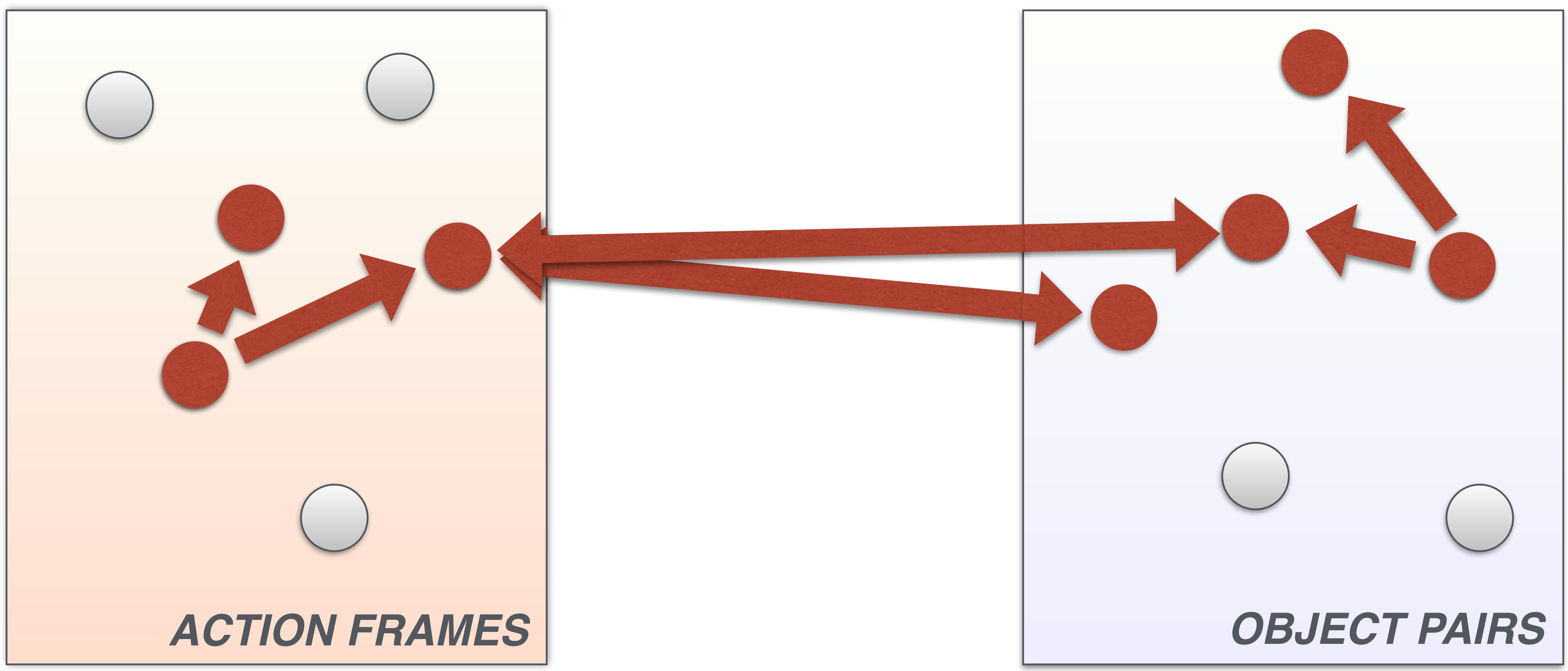
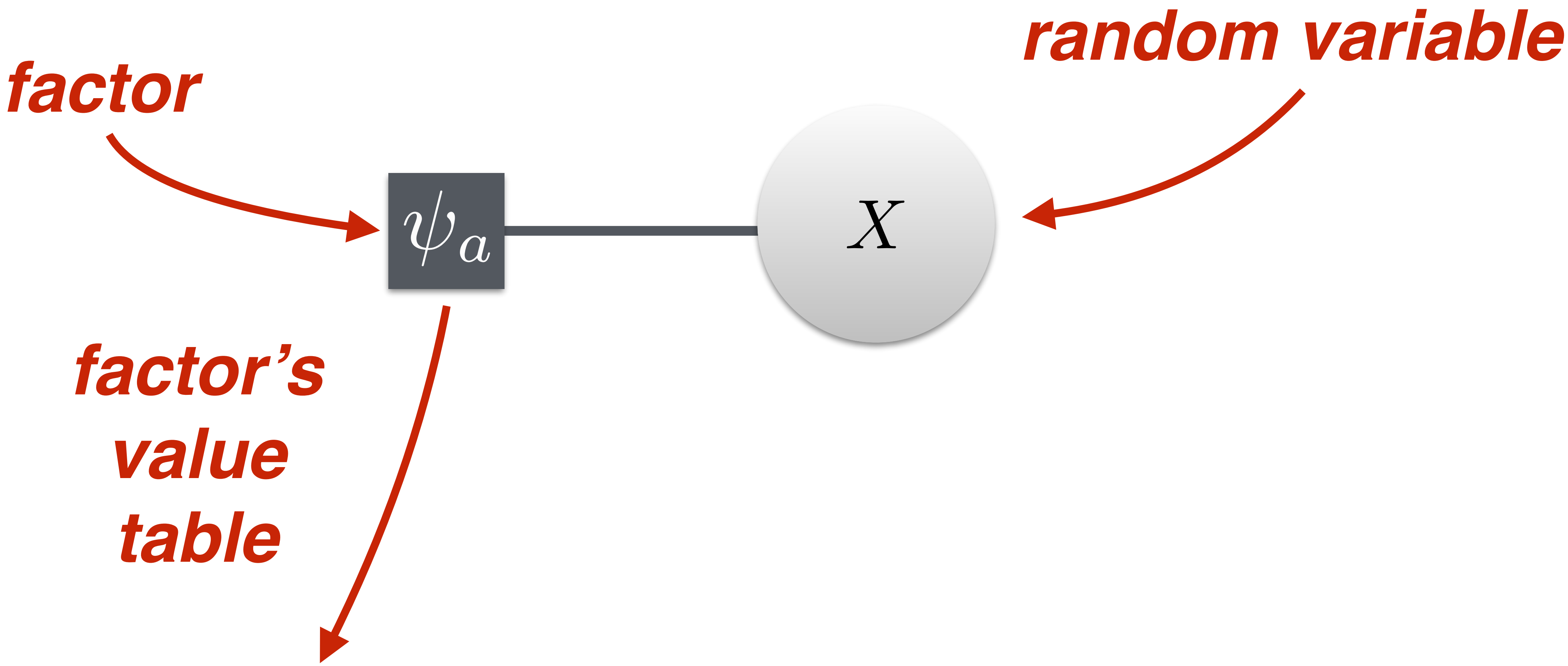


PART II — INTERLUDE

Factor graphs

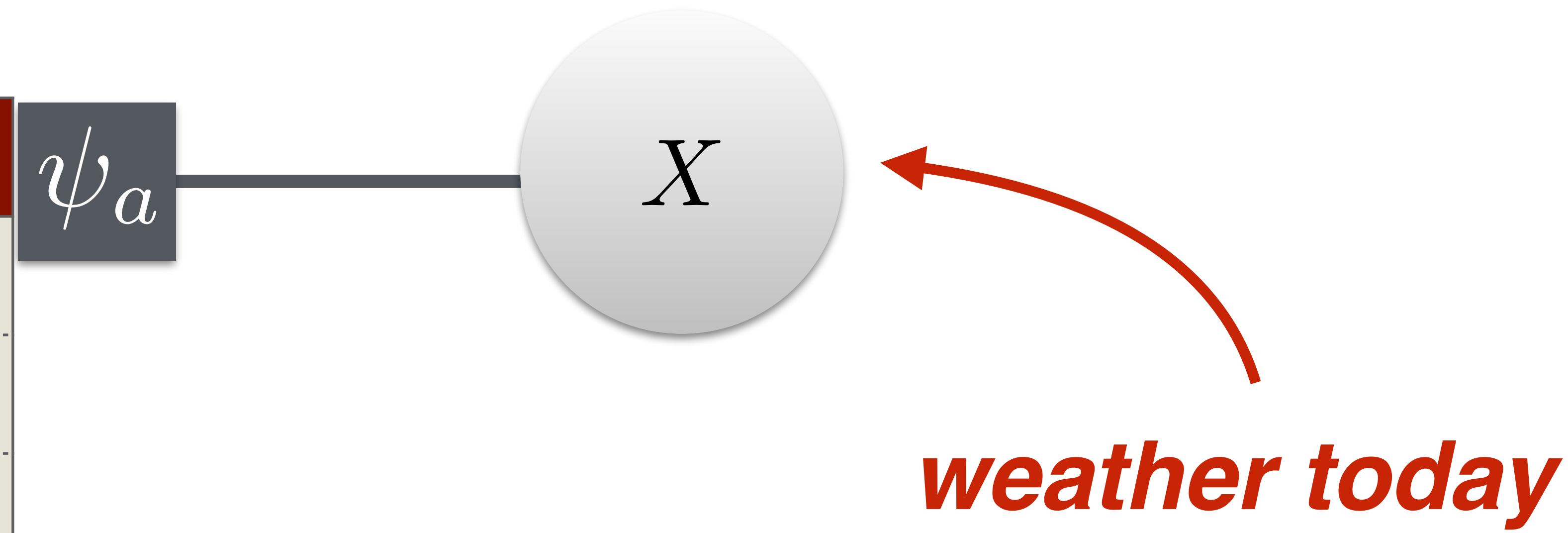
Factor Graphs
BASICS



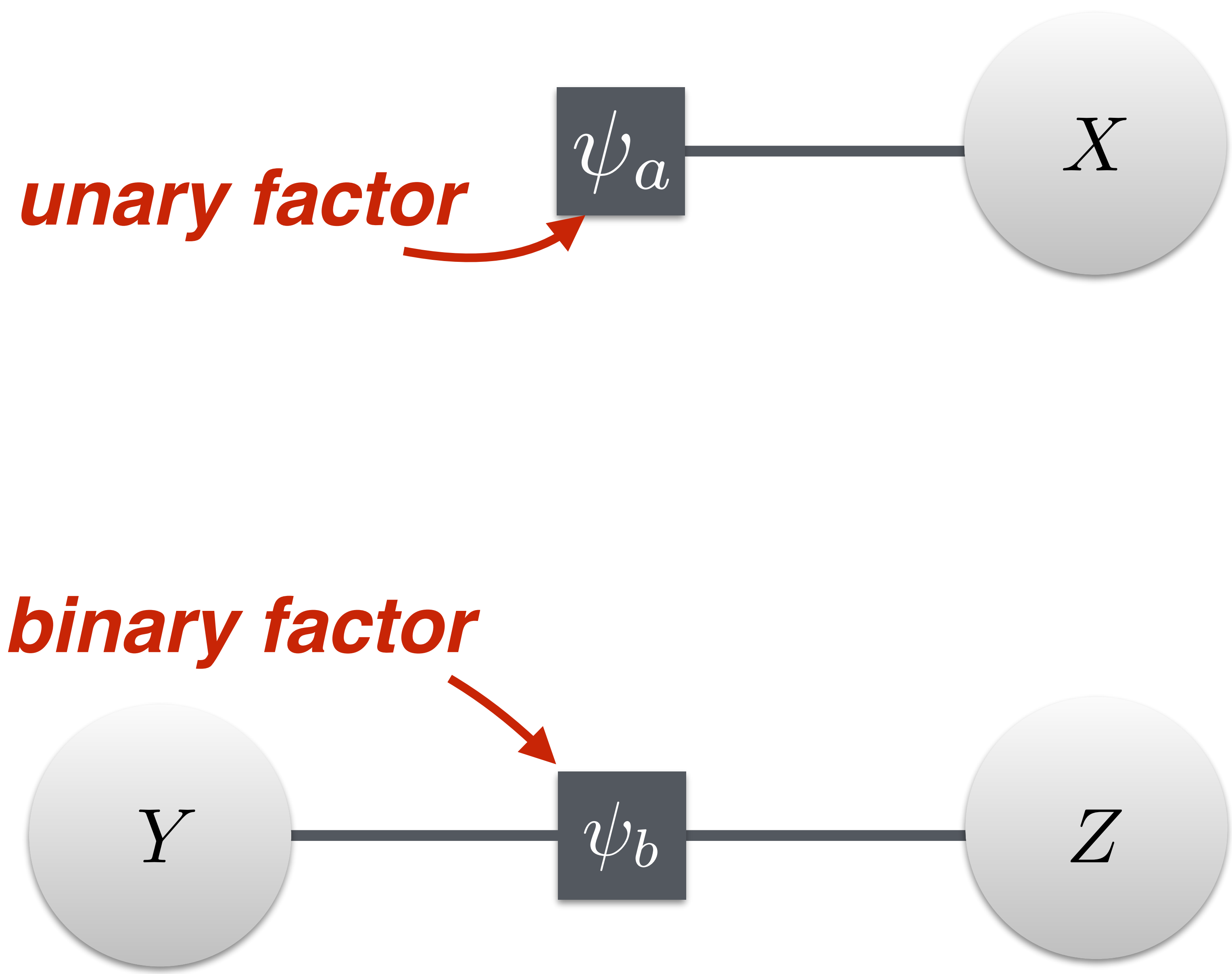
value	number
X=x	$\mathbb{R} \geq 0$
X=y	$\mathbb{R} \geq 0$
X=z	$\mathbb{R} \geq 0$

Factor Graphs
BASICS

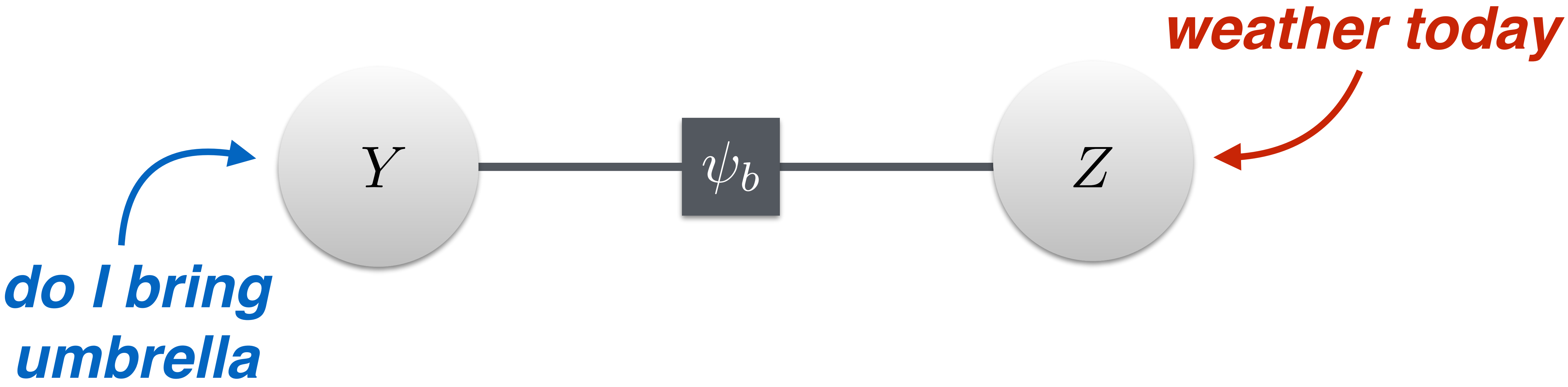
value	number
rain	0.7
sun	0.2
snow	0.1



Factor Graphs
BINARY FACTORS



FACTOR GRAPHS
BINARY FACTORS



FACTOR GRAPHS
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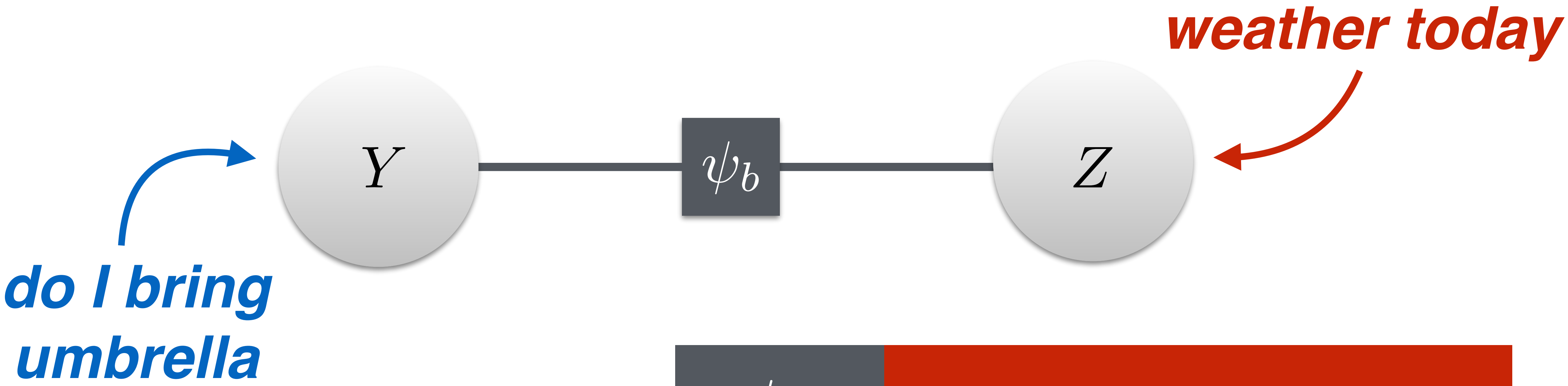
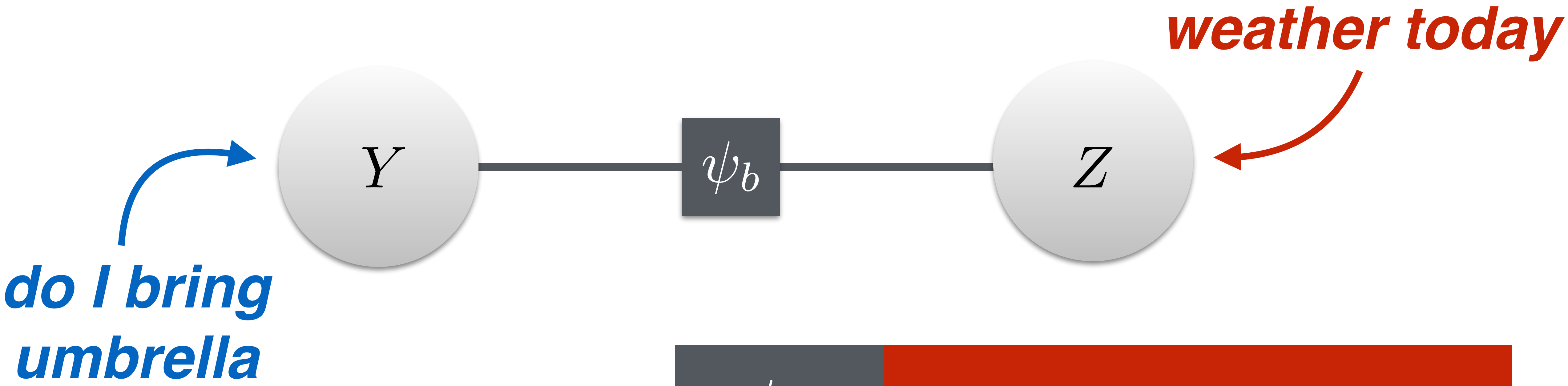


ψ_b	sun	rain	snow
yes	?	?	?
no	?	?	?

FACTOR GRAPHS
BINARY FACTORS

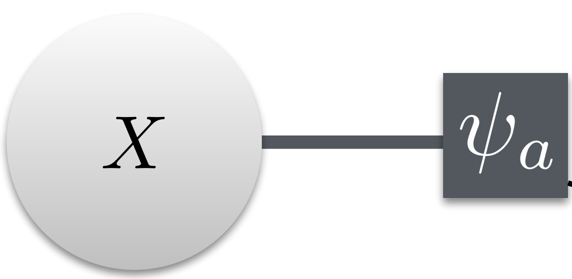


ψ_b	sun	rain	snow
yes	0.1	0.8	0.7
no	0.9	0.2	0.3

p(umbrella|weather)

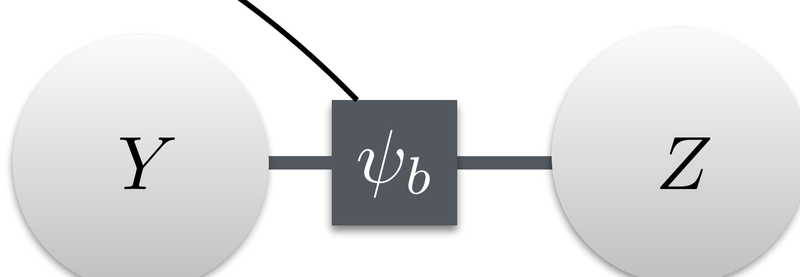
FACTOR GRAPHS
DESIGN SPACE

What numbers are in the factors' value tables?



value	number
x	**?**
y	**?**
z	**?**

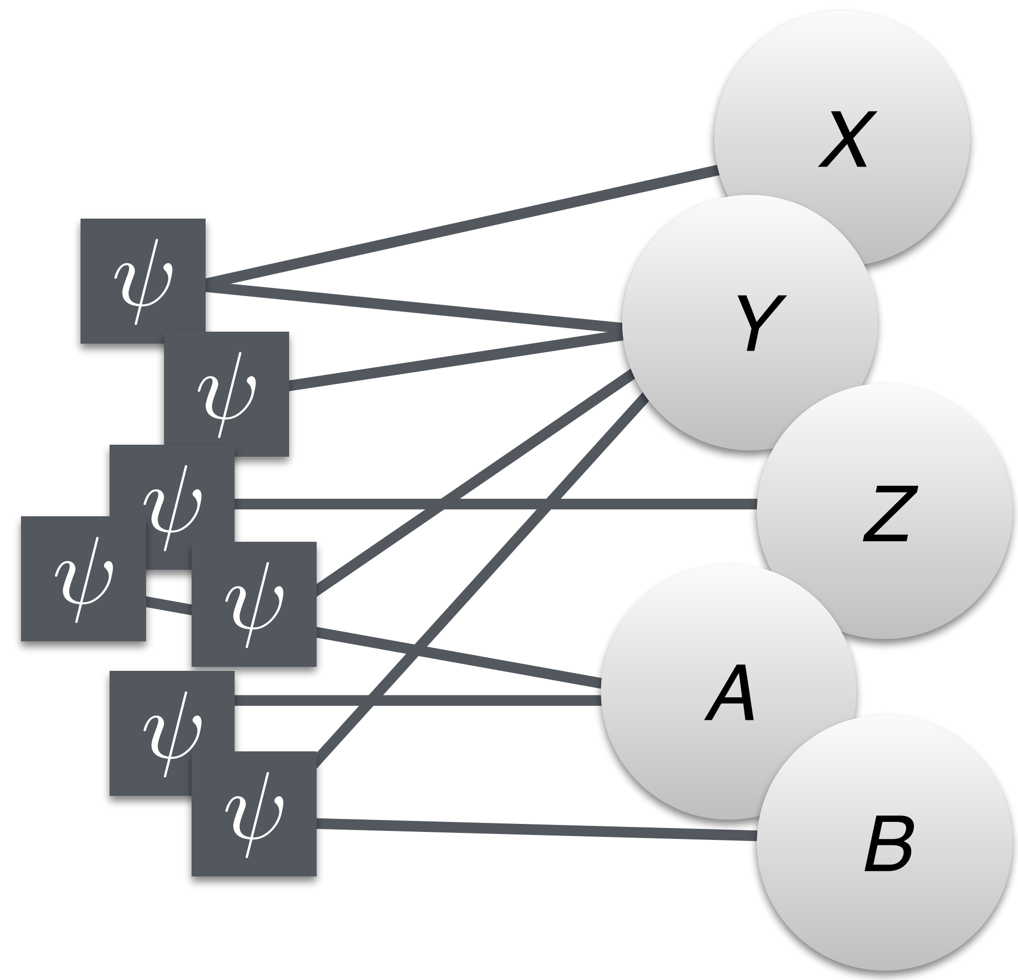
	z_1	z_2	z_3
y_1	?	?	?
y_2	?	?	?



FACTOR GRAPHS
DESIGN SPACE

What numbers are in the factors' value tables?

What is the graph structure?



FACTOR GRAPHS
DESIGN SPACE

Factors can contain

1. conditional probability tables

   can use to construct "old-school" graphical models

p(umbrella|weather)

	sun	rain	snow
yes	0.1	0.8	0.7
no	0.9	0.2	0.3

col *Σ = 1.0*

p(**u**="no"|**w**="snow")

FACTOR GRAPHS
DESIGN SPACE

Factors can contain

1. conditional probability tables

   can use to construct "old-school" graphical models

2. potential functions
   (arbitrary nonnegative values)

   can use to construct Markov random fields (MRFs) (AKA "Markov networks")

Φ(**u**="no" ; **w**="snow")

	sun	rain	snow
yes	0.01	29.7	0.17
no	14.0	1.2	0.13

Φ(umbrella ; weather)

FACTOR GRAPHS
DESIGN SPACE

Factors can contain

1. conditional probability tables

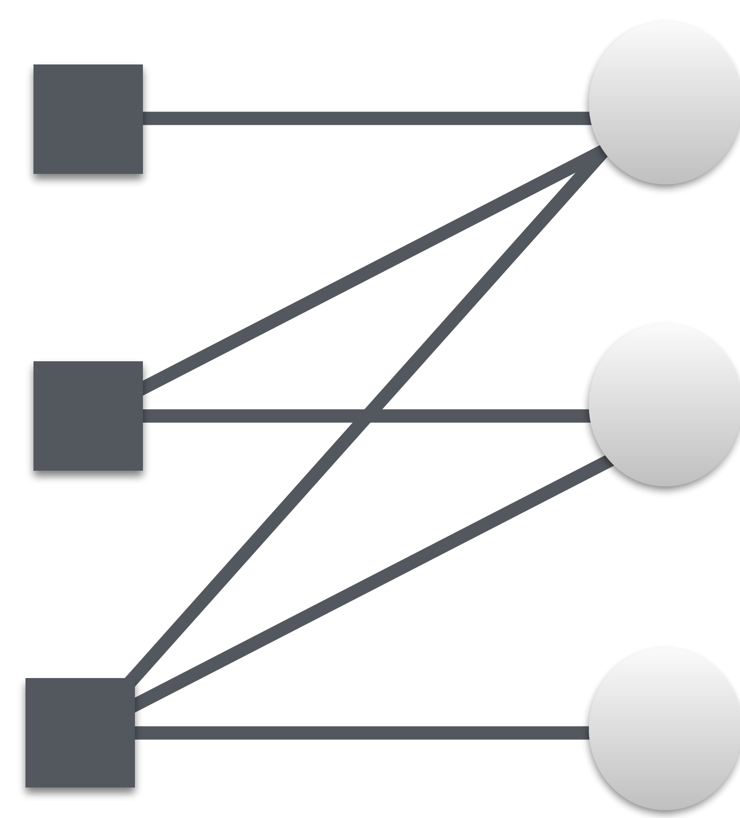
   can use to construct "old-school" graphical models

2. potential functions
   (arbitrary nonnegative values)

   can use to construct Markov random fields (MRFs) (AKA "Markov networks")

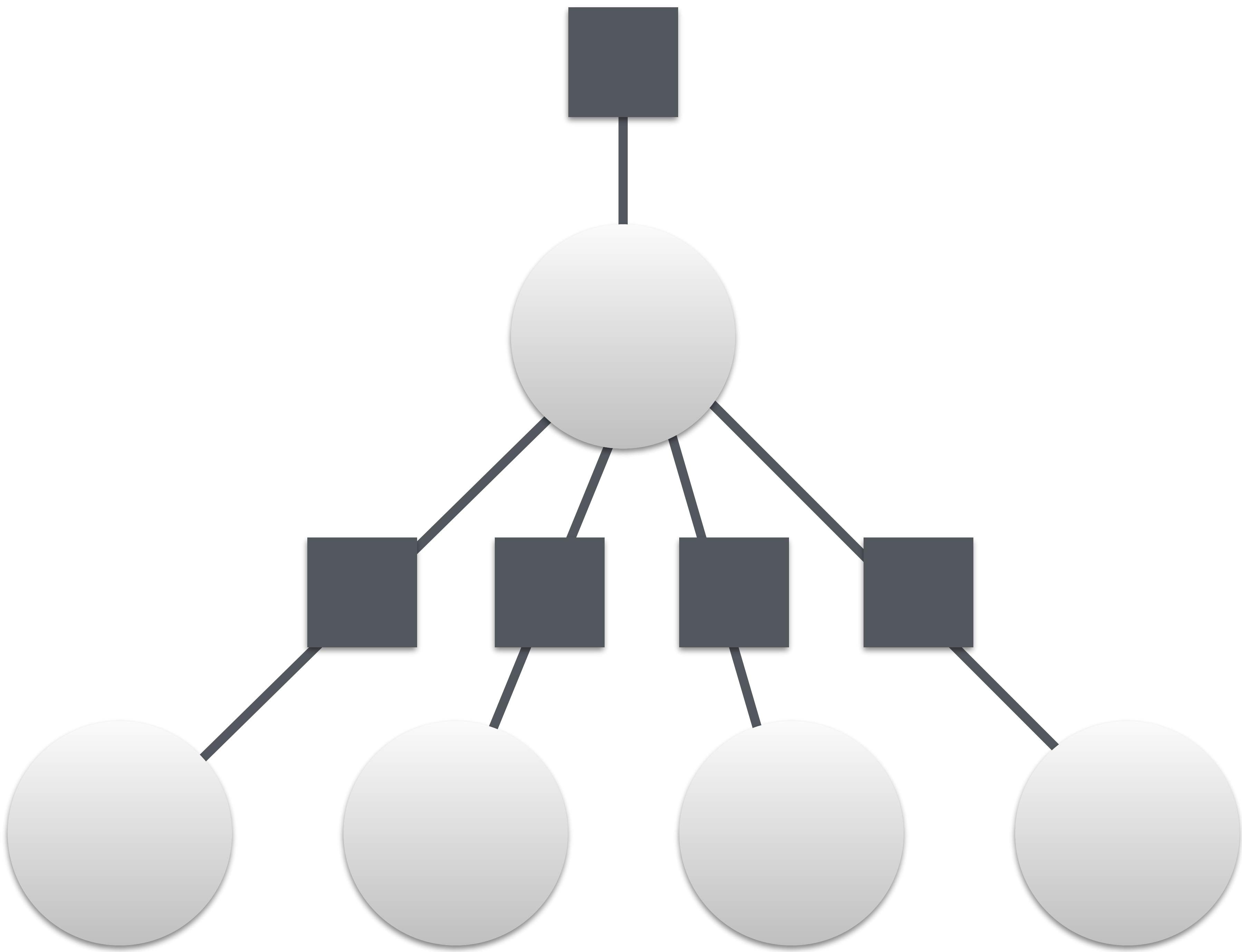
Graph structure

arbitrary bipartite graphs!

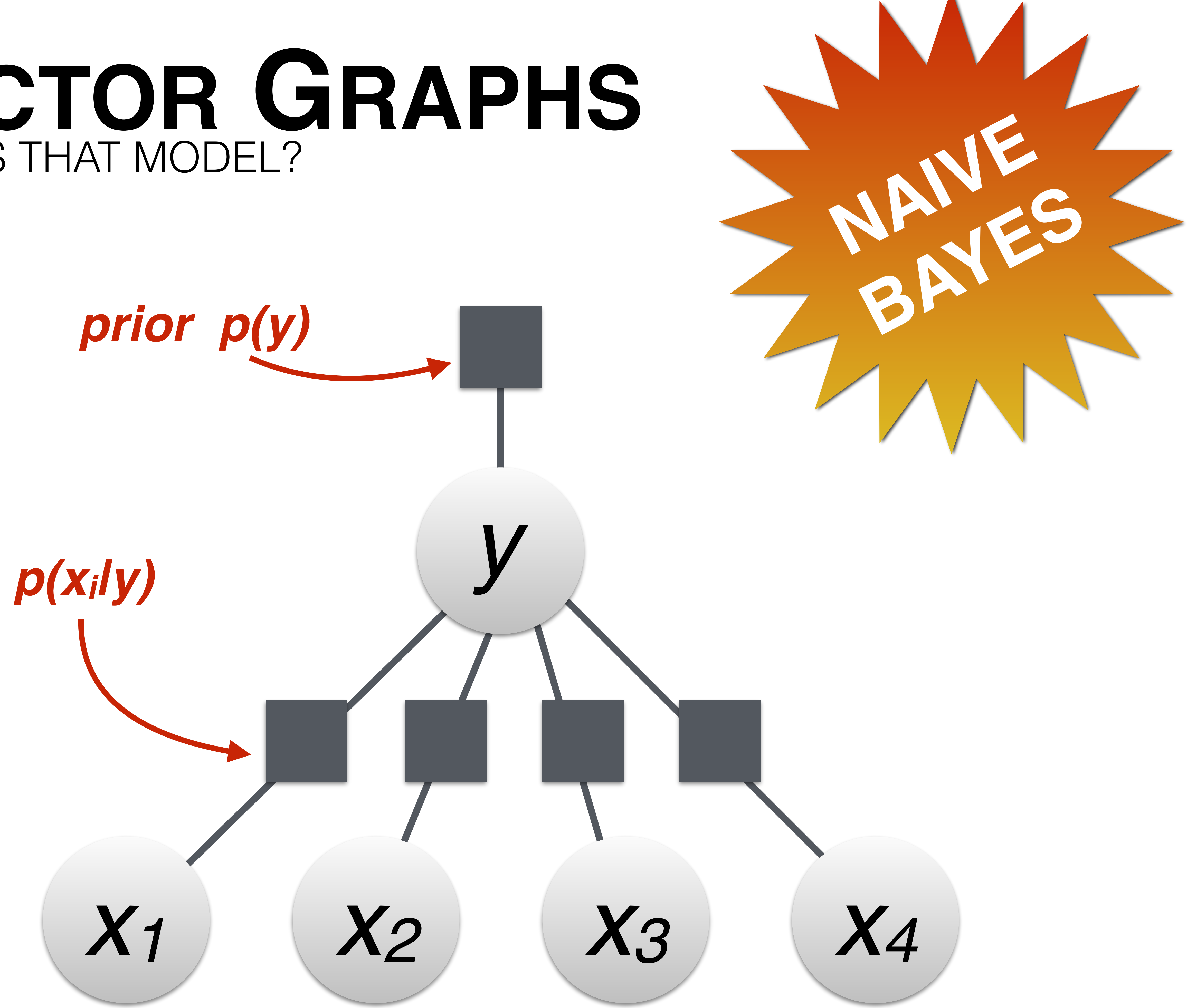


Factor Graphs

WHAT'S THAT MODEL?

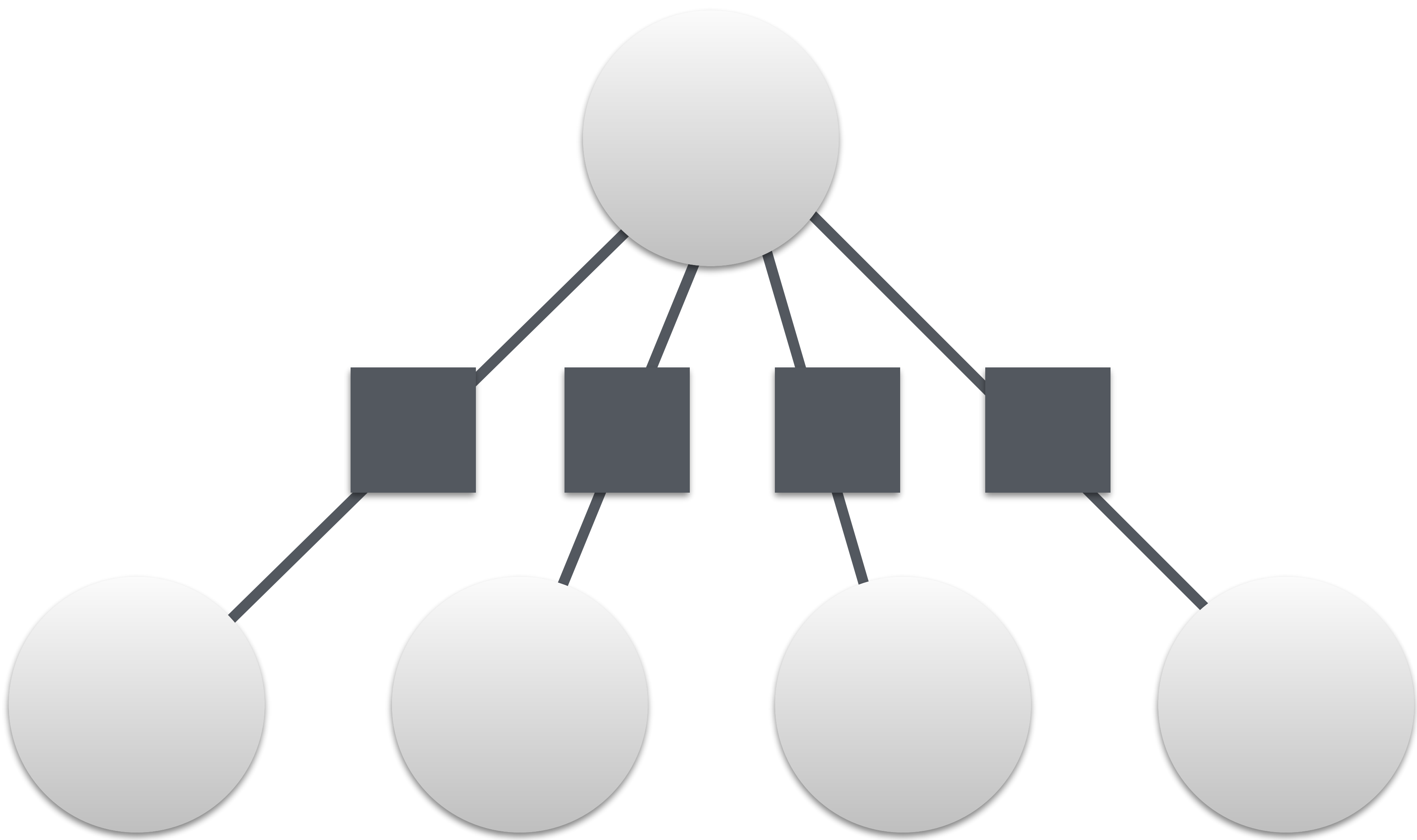


FACTOR GRAPHS
WHAT'S THAT MODEL?



FACTOR GRAPHS

WHAT'S THAT MODEL?



FACTOR GRAPHS

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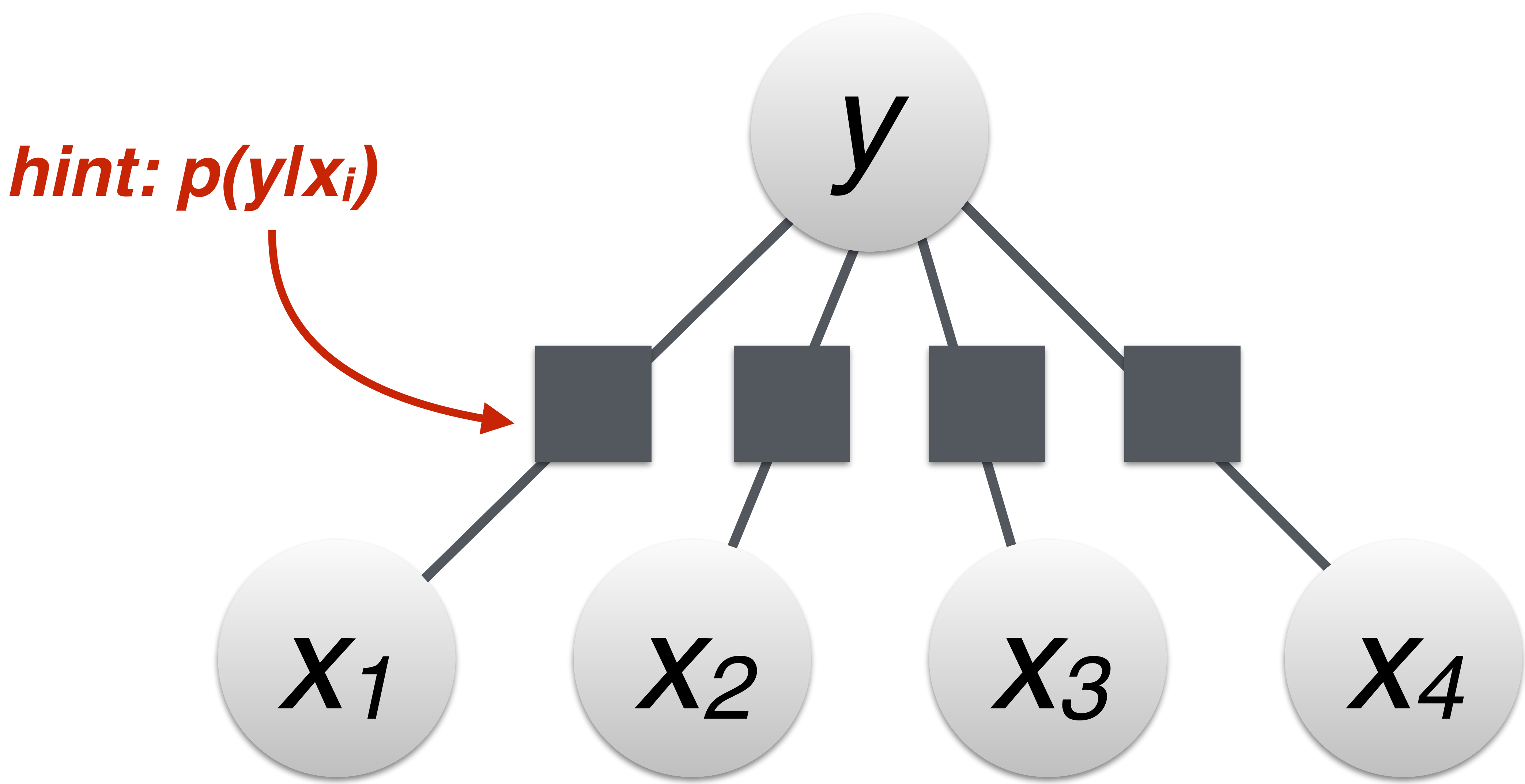
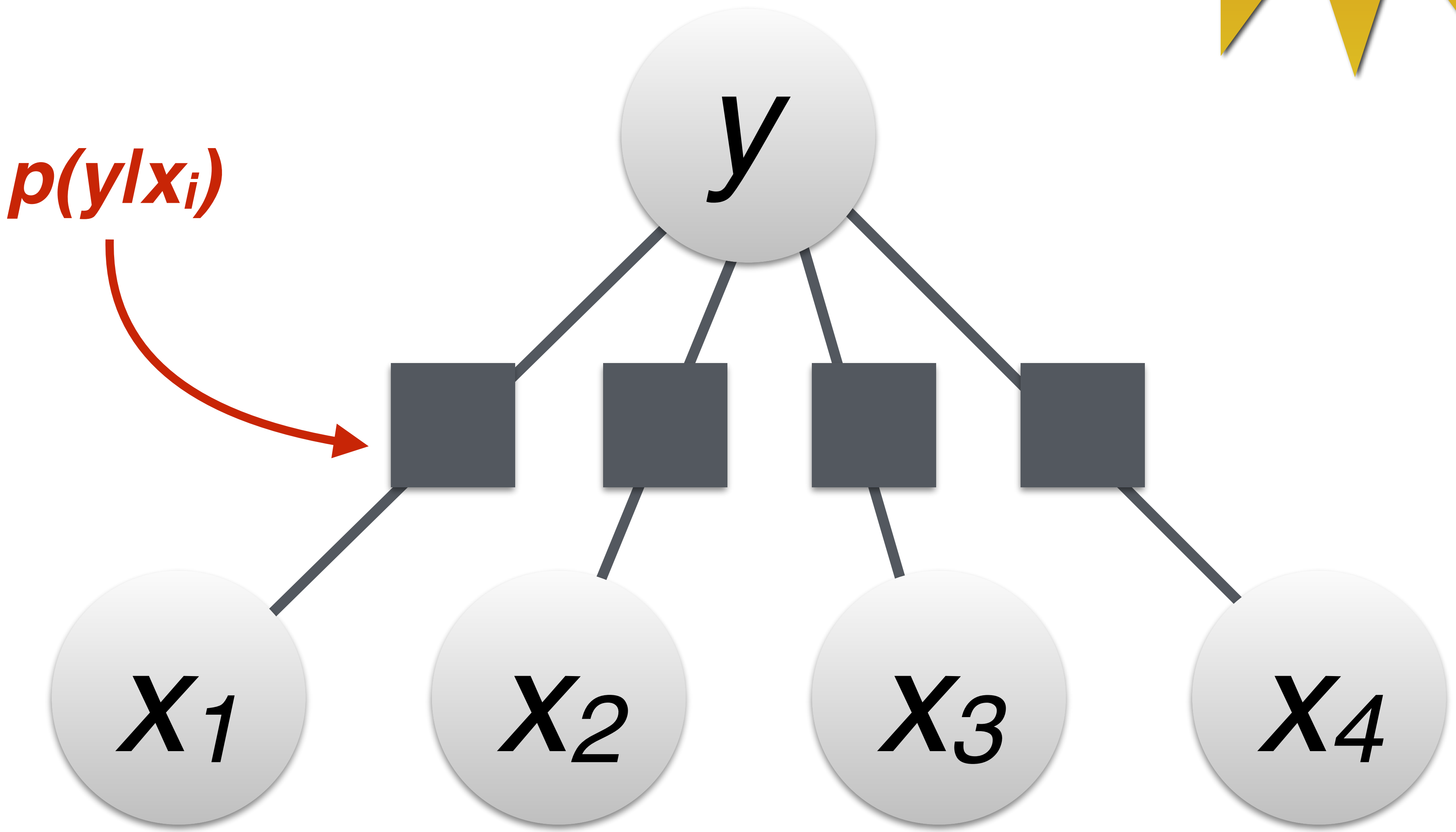
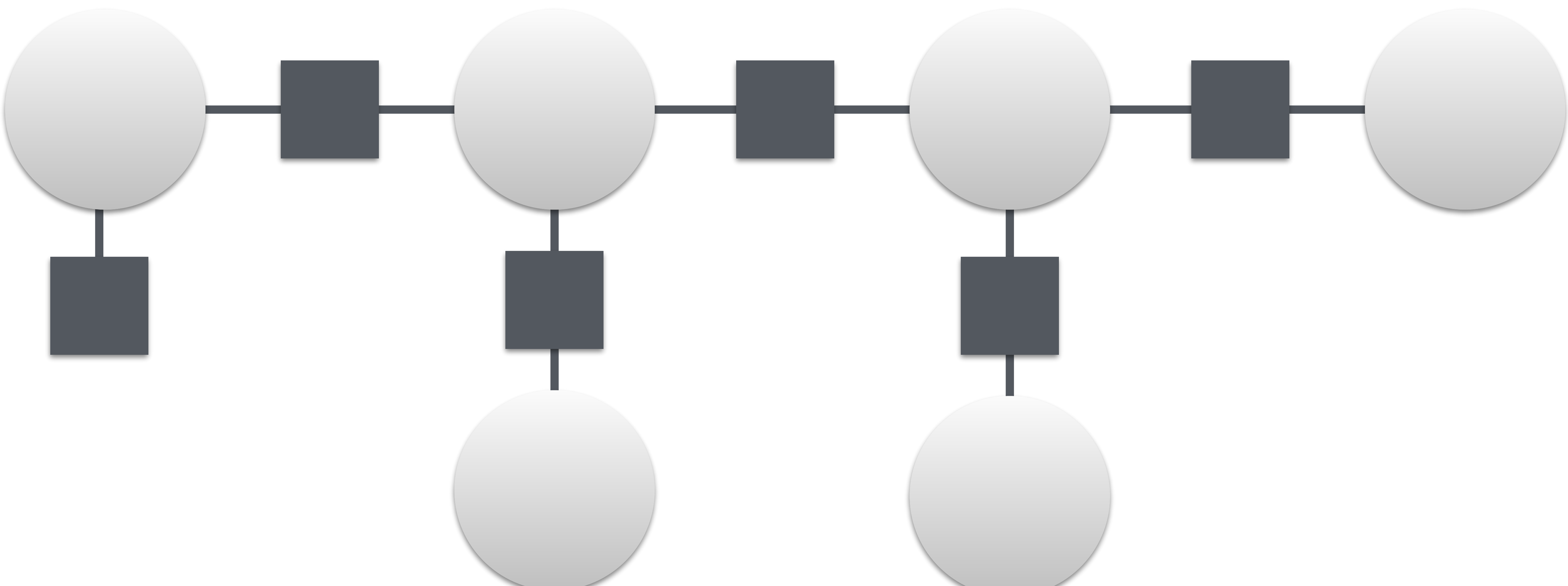


FACTOR GRAPHS
WHAT'S THAT MODEL?



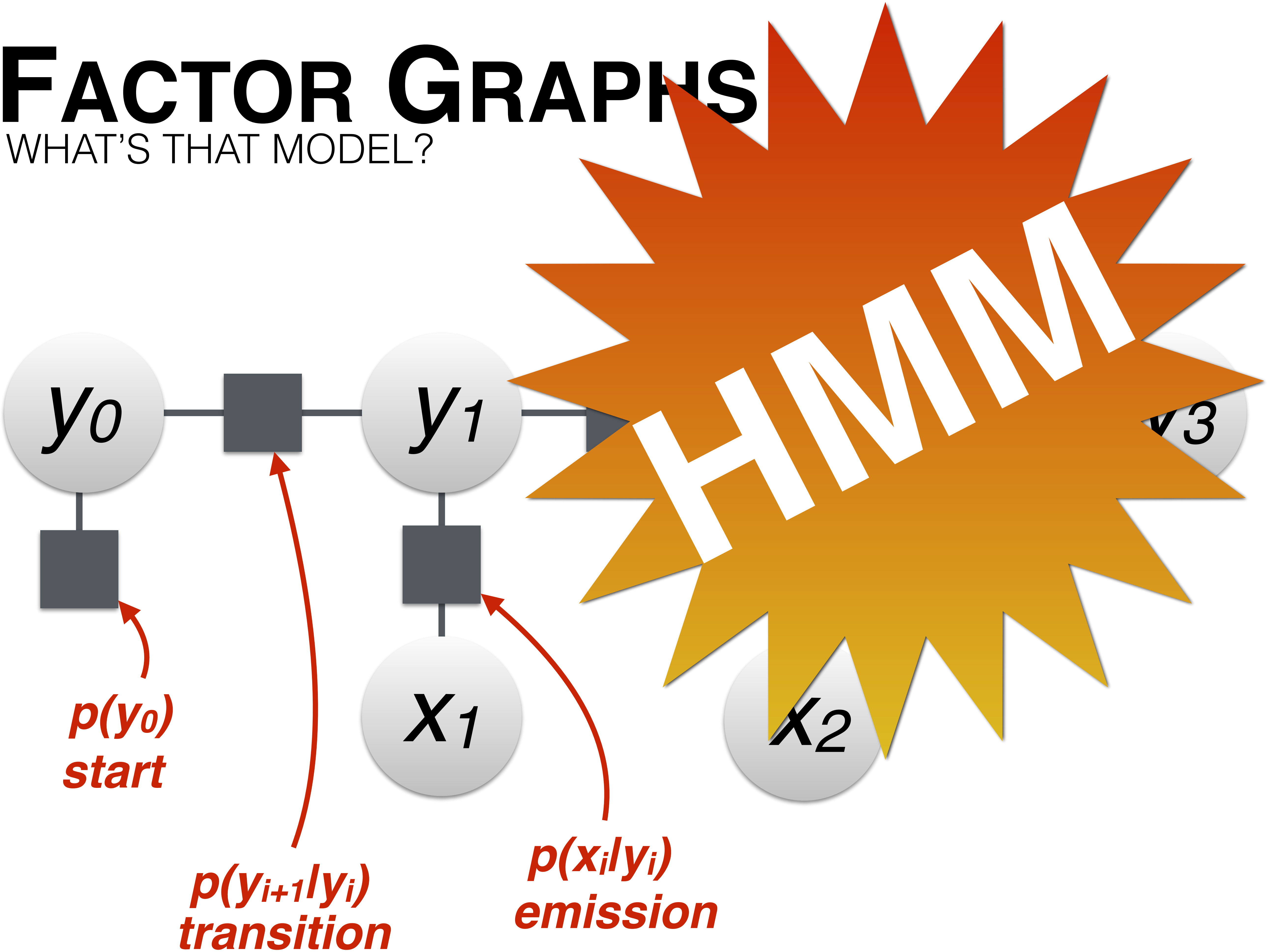
FACTOR GRAPHS

WHAT'S THAT MODEL?



Factor Graphs

WHAT'S THAT MODEL?



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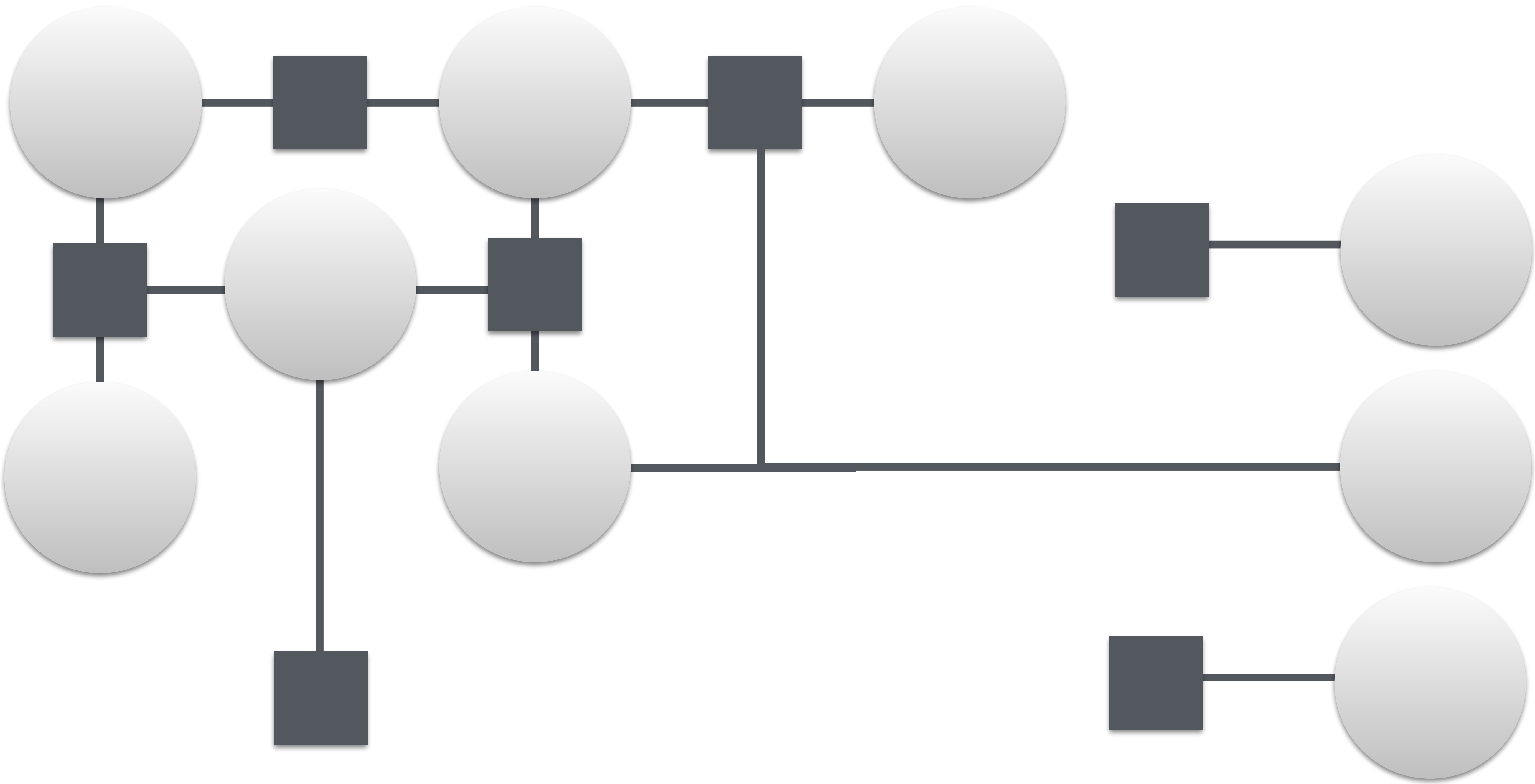
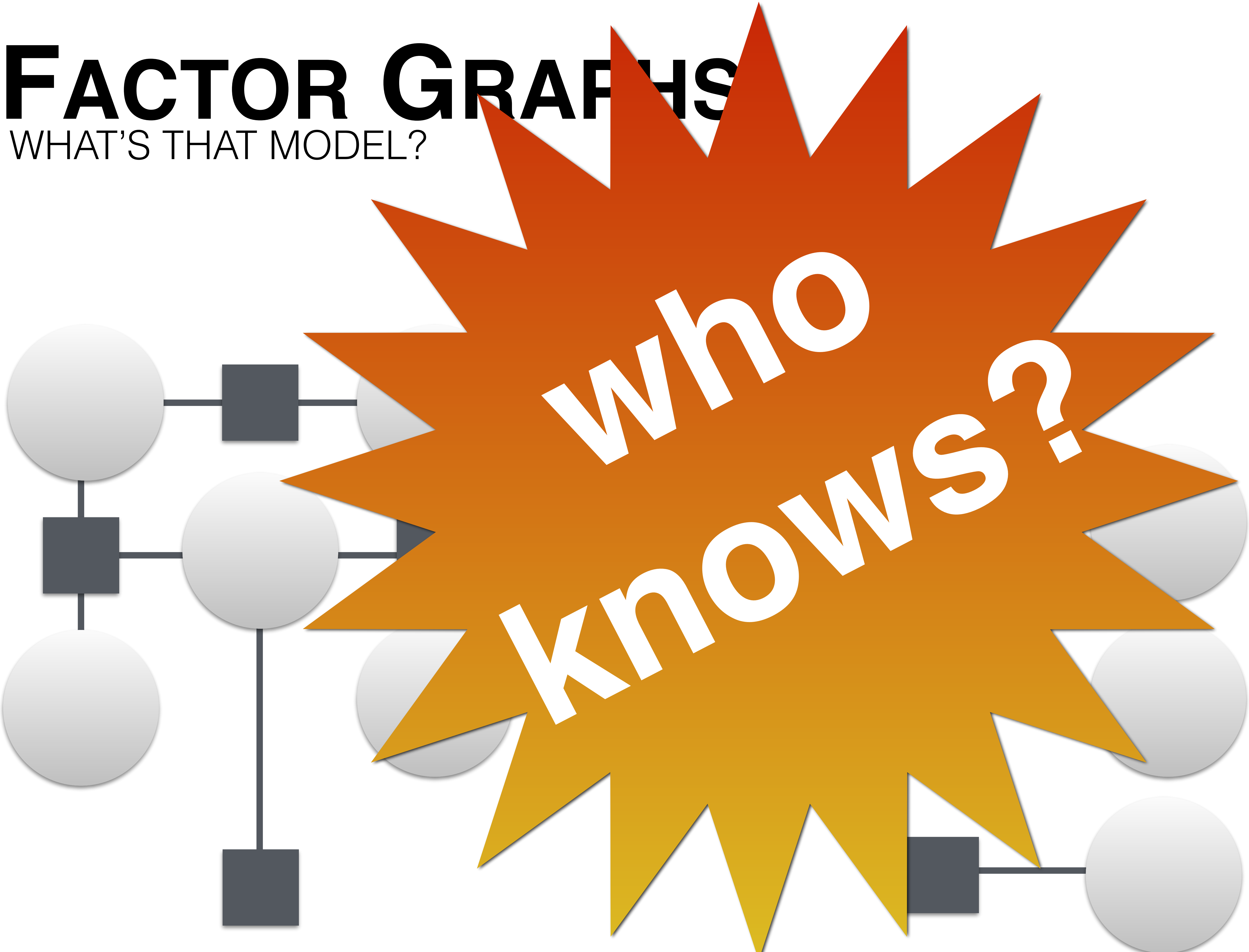
WHAT'S THAT MODEL?



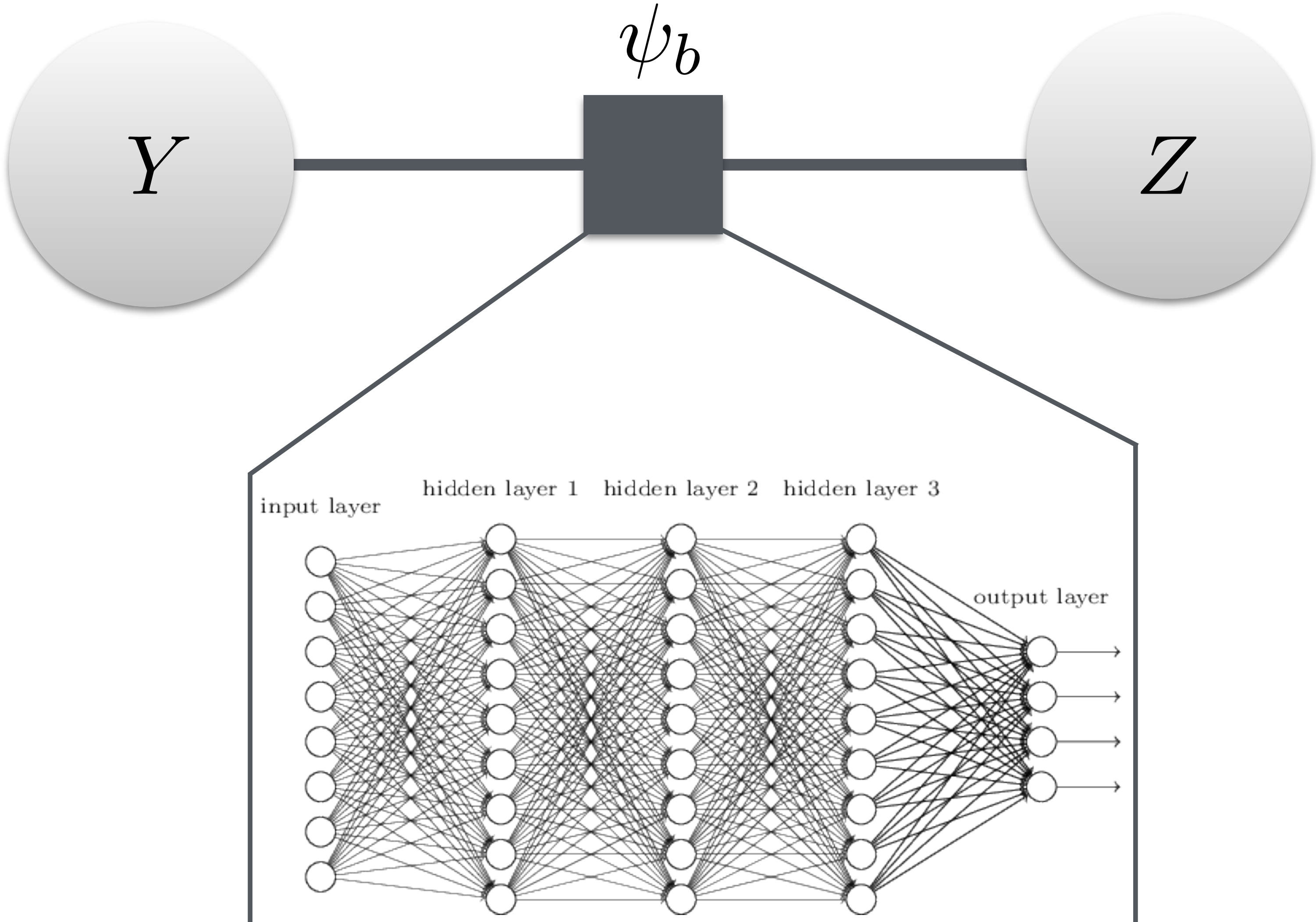
Factor Graphs

WHAT'S THAT MODEL?



FACTOR GRAPHS

IT'S 2020. PUT A NEURAL NET ON IT.



PART II — INTERLUDE

Factor graphs] *finished*

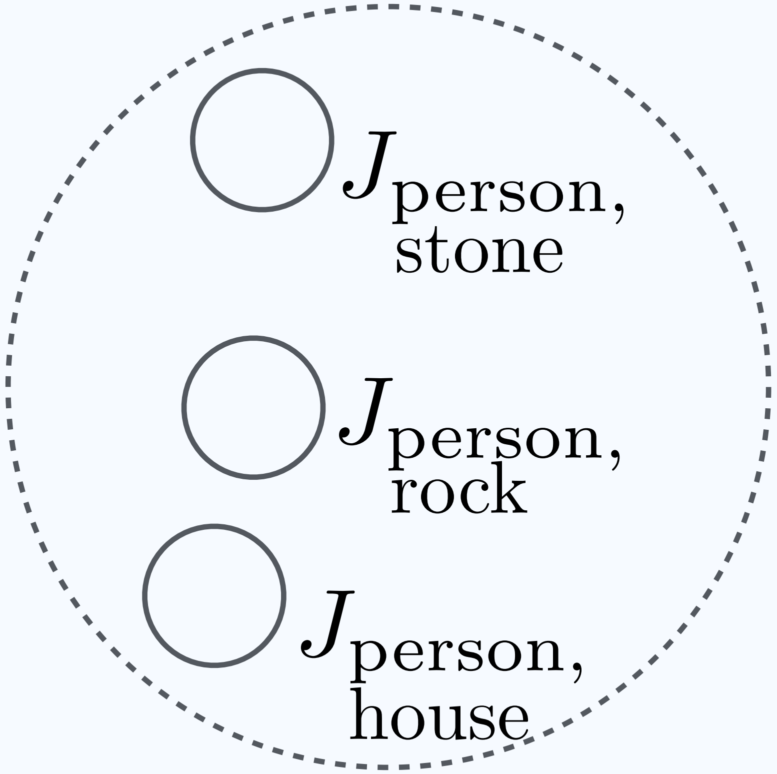
PART II

Verb Physics] *resuming*

1. Introduction
2. Related work
3. Approach
4. Model
5. Data
6. Evaluation

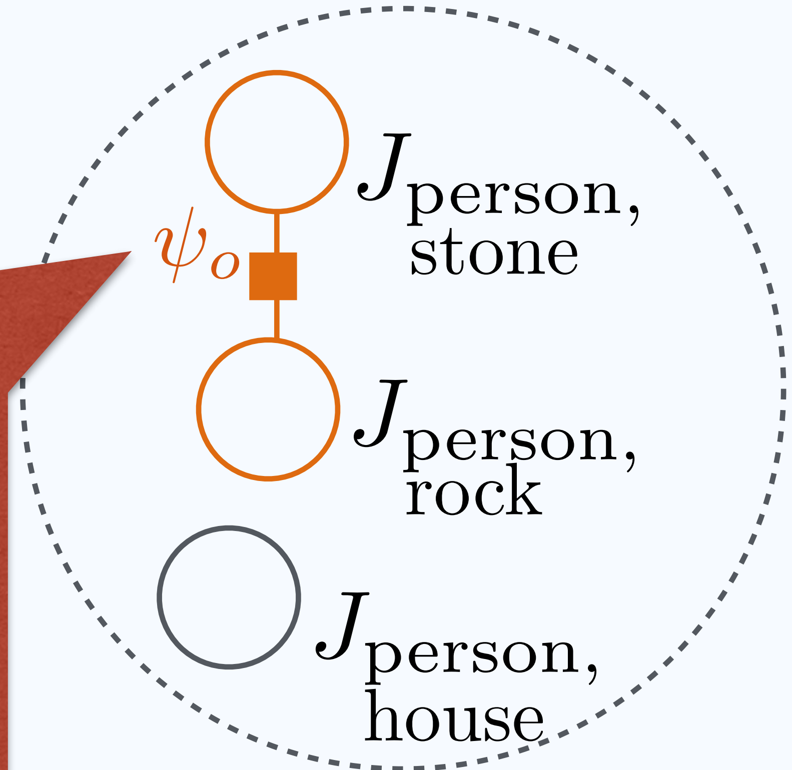
Object pair
random variables

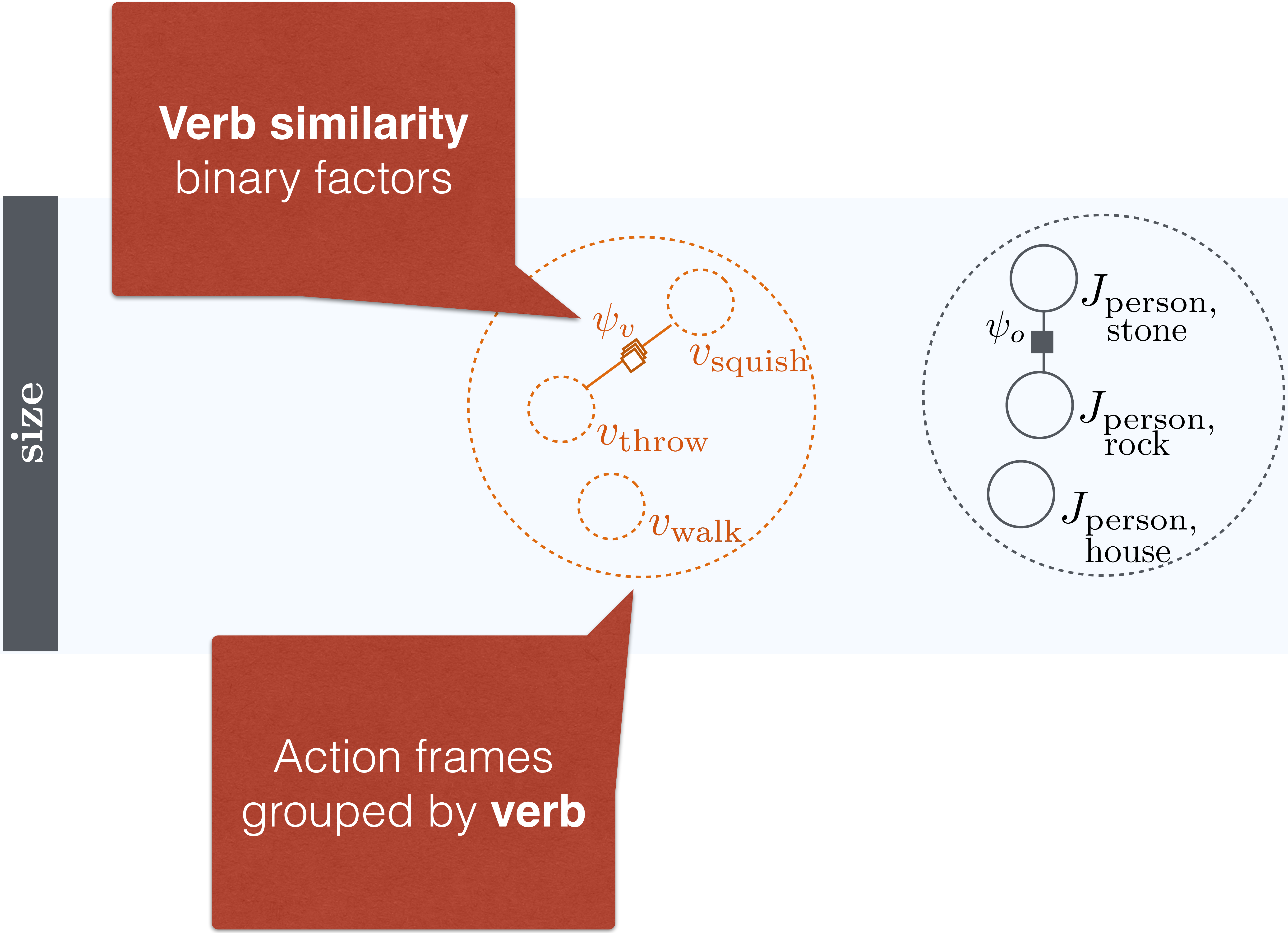
size



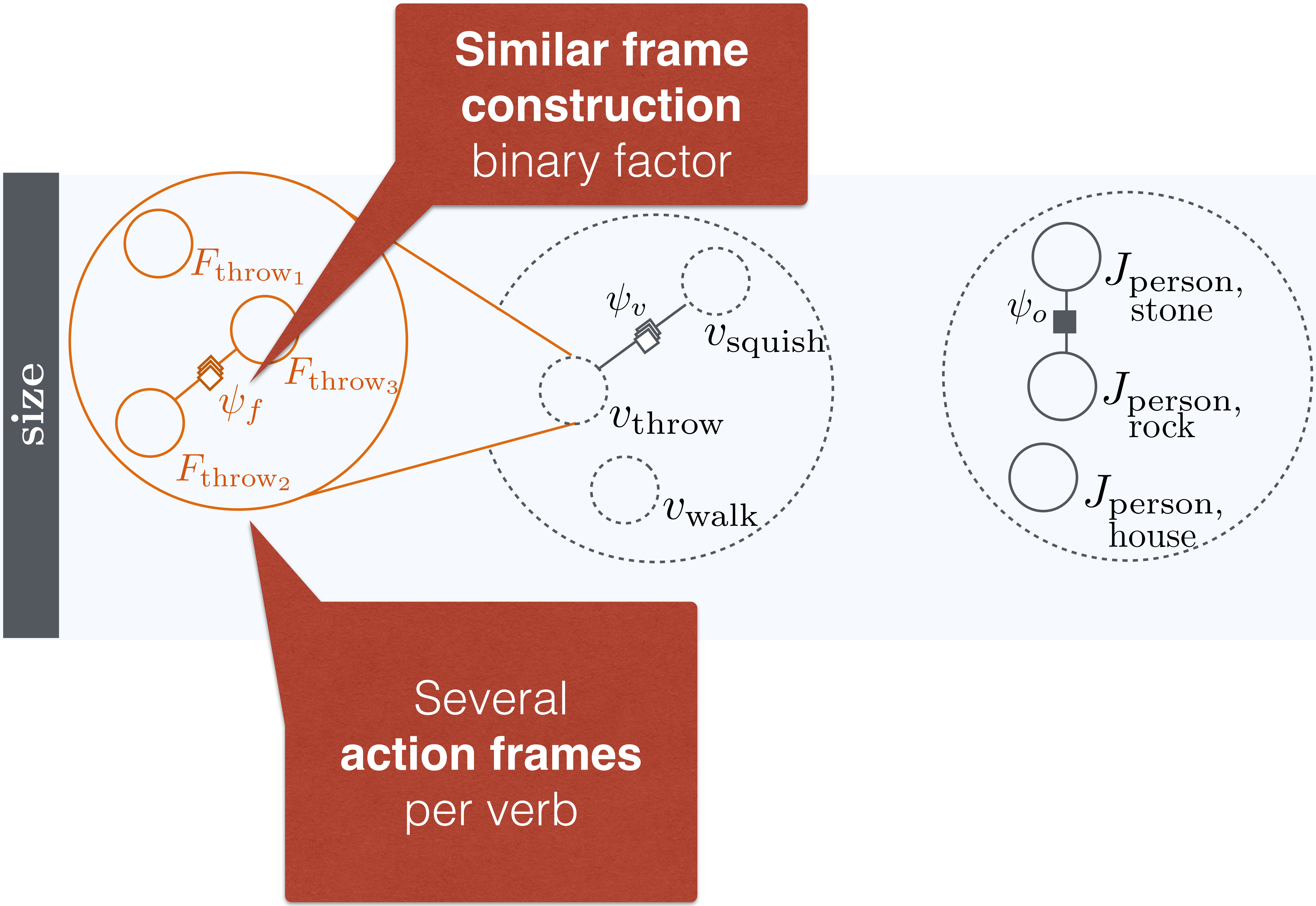
size

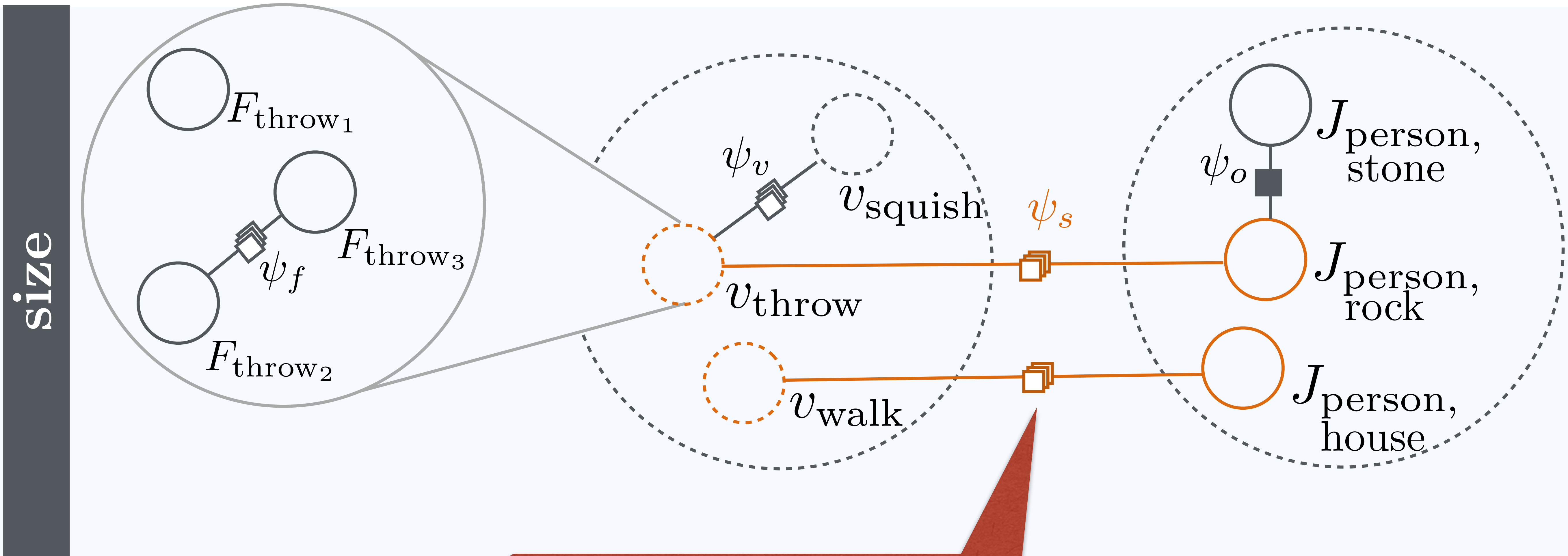
Object similarity
binary factors



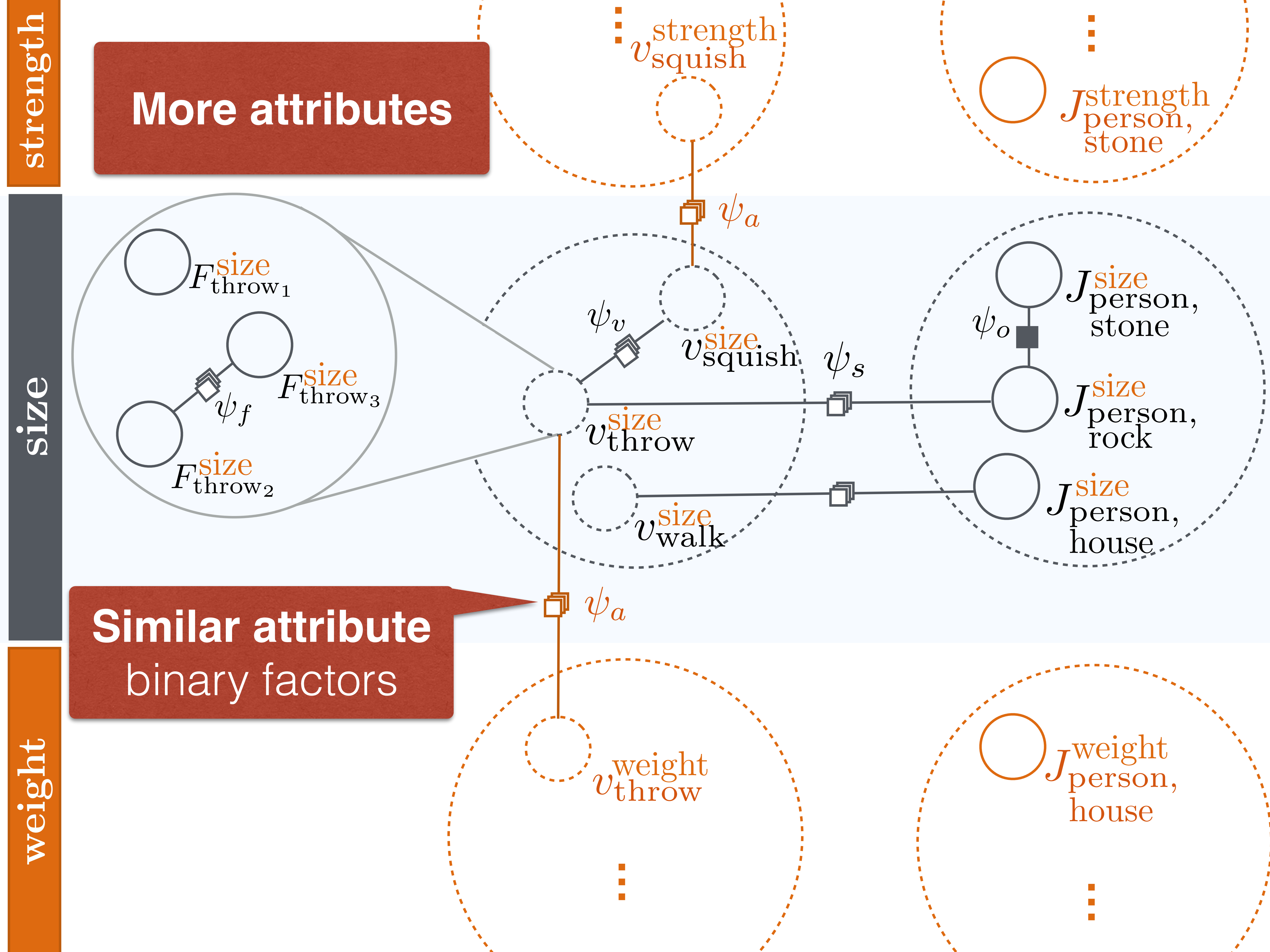


Verb similarity
binary factors
size
ψ_v
v_{squish}
v_{throw}
v_{walk}
ψ_o
$J_{\text{person, stone}}$
$J_{\text{person, rock}}$
$J_{\text{person, house}}$
Action frames
grouped by **verb**


Similar frame construction binary factor
Several action frames per verb
size
F_{throw_1}
F_{throw_2}
F_{throw_3}
ψ_f
ψ_v
v_{squish}
v_{throw}
v_{walk}
ψ_o
$J_{\text{person, stone}}$
$J_{\text{person, rock}}$
$J_{\text{person, house}}$



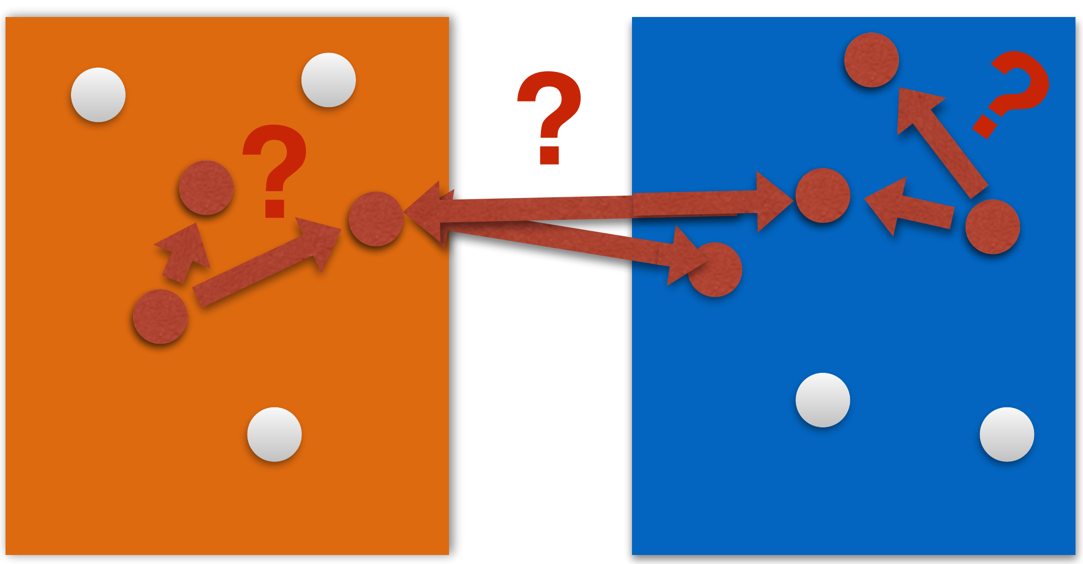
Action-object compatibility
binary factors



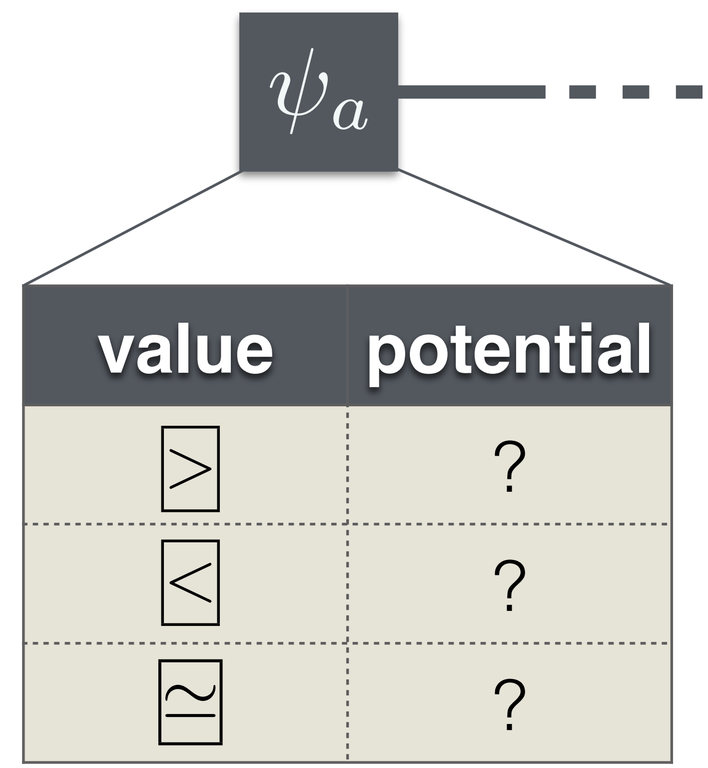
strength
size
weight
More attributes
Similar attribute
binary factors
$v^{\text{strength}}_{\text{squish}}$
$J^{\text{strength}}_{\text{person, stone}}$
ψ_a
$F^{\text{size}}_{\text{throw}_1}$
$F^{\text{size}}_{\text{throw}_3}$
$F^{\text{size}}_{\text{throw}_2}$
ψ_f
ψ_v
$v^{\text{size}}_{\text{squish}}$
$v^{\text{size}}_{\text{throw}}$
$v^{\text{size}}_{\text{walk}}$
ψ_s
ψ_o
$J^{\text{size}}_{\text{person, stone}}$
$J^{\text{size}}_{\text{person, rock}}$
$J^{\text{size}}_{\text{person, house}}$
ψ_a
$v^{\text{weight}}_{\text{throw}}$
$J^{\text{weight}}_{\text{person, house}}$

Two main model questions

(1) What subset of nodes should we **connect** with each type of factor?



(2) What should the **potential** functions be?



Model: (1) Connections

Unary factors

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Unary factors

- **Max-ent** factors (all nodes)
- **Seed** factors (nodes in seed set)

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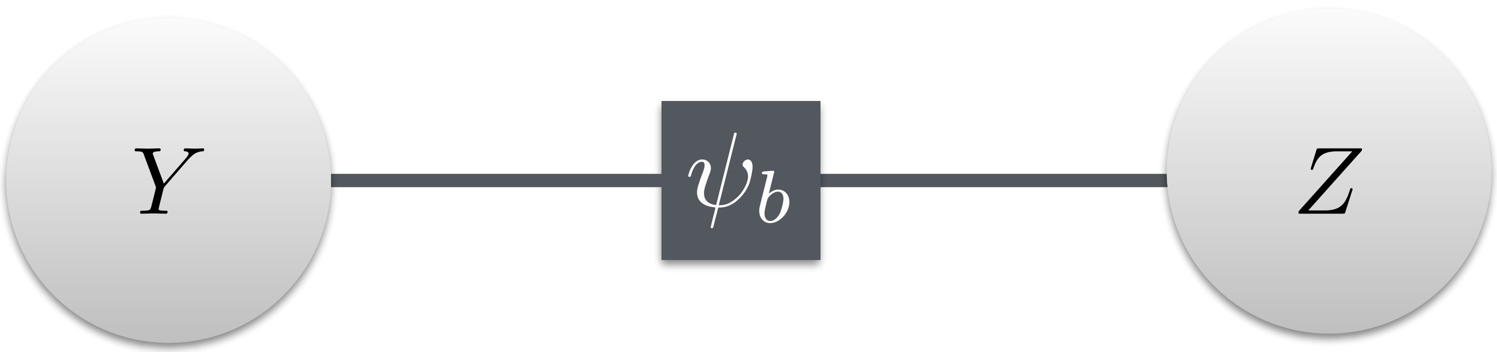
Binary factors



Model: (1) Connections

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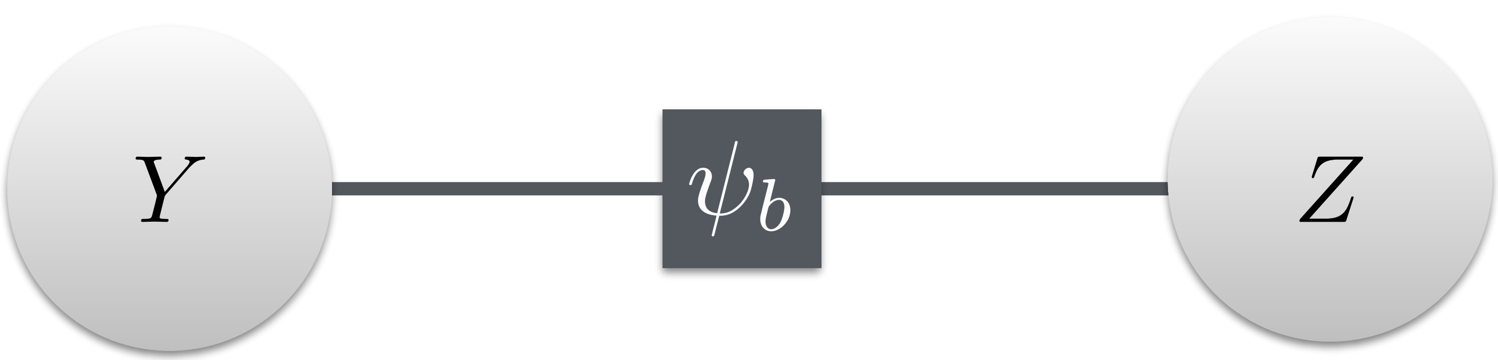
- **Seed** factors (nodes in seed set)

NOTE:

advanced topic not covered today

Binary factors



Similarity metrics
(e.g., cosine similarity of word embeddings)

Model: (1) Connections

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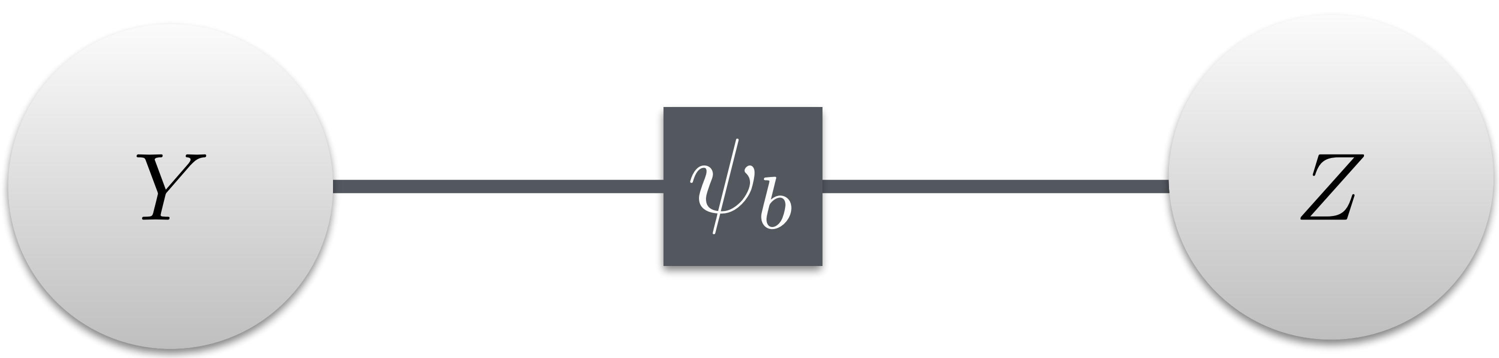

Similarity metrics
(e.g., cosine similarity of word embeddings)

Empirical agreement
(on seed set)

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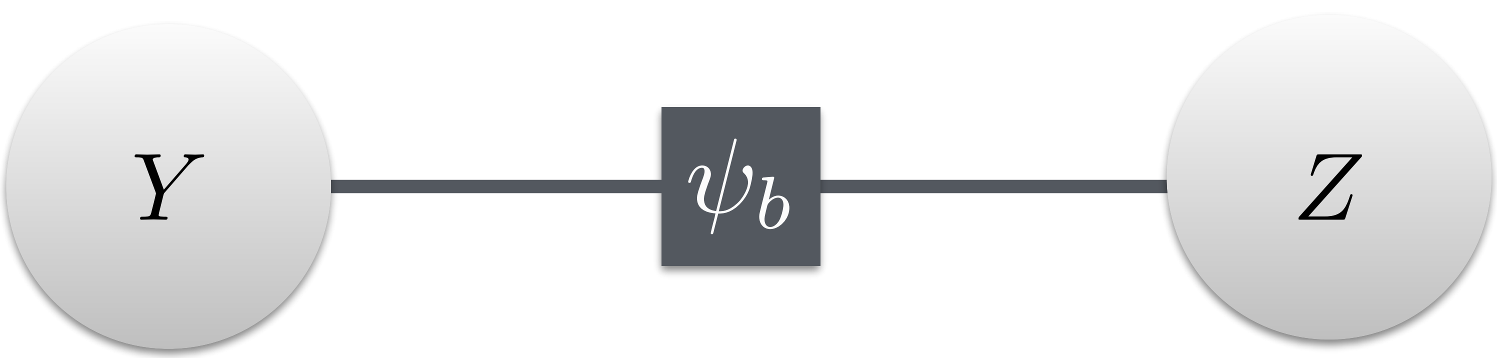

Similarity metrics
(e.g., cosine similarity of word embeddings)

Empirical agreement
(on seed set)

Usage in text
(e.g., high PMI using Google Syntax Ngrams; for action-object compatibility)

Model: (2) Potential functions

Log-linear classifier

$$p(X^a = v) \propto e^{w_a \cdot f(X^a)}$$

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Object feature function

$$f(O^a_{p,q}) := \langle g(p), g(q) \rangle$$

Reference

$g(\cdot)$ GloVe

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Example

$$f(O^{\text{size}}_{\text{PERSON},\text{ball}}) := \langle g(\text{PERSON}), g(\text{ball}) \rangle$$

Reference

$g(\cdot)$ GloVe

Model: (2) Potential functions

Log-linear classifier

$$p(X^a = v) \propto e^{w_a \cdot f(X^a)}$$

Object feature function

$$f(O^a_{p,q}) := \langle g(p), g(q) \rangle$$

Frame feature function

$$f(F^a_{v_t}) := \langle h(t), g(v), g(t) \rangle$$

Reference

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$h(\cdot)$ One-hot frame type

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Frame feature function

$$f(F^a_{v_t}) := \langle h(t), g(v), g(t) \rangle$$

Example

"PERSON threw x into y"

$$f(F^{\text{size}}_{\text{threw}_4}) :=$$

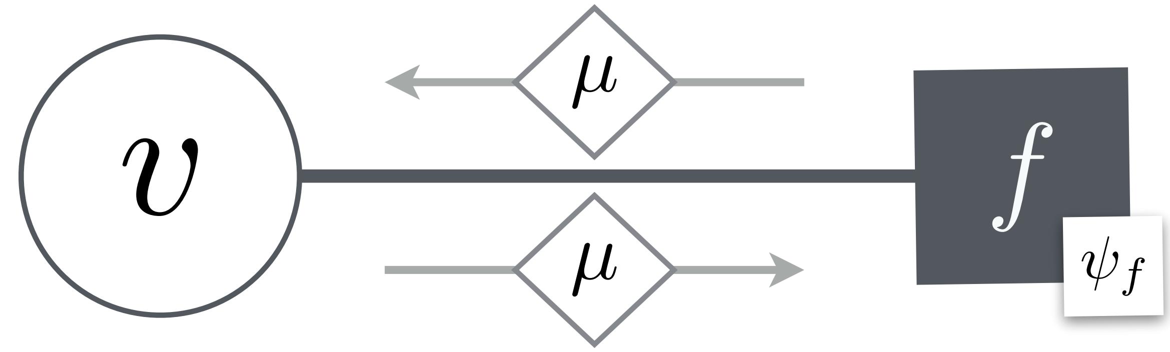
$$\langle [0, 0, 0, 1, 0], g(\text{threw}), g(\text{into}) \rangle$$

Reference

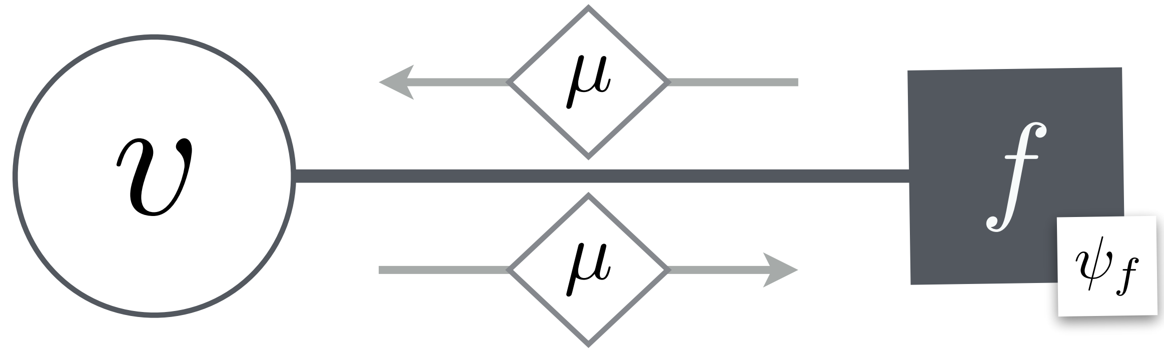
$g(\cdot)$ GloVe

$h(\cdot)$ One-hot frame type

Loopy belief propagation



Loopy belief propagation



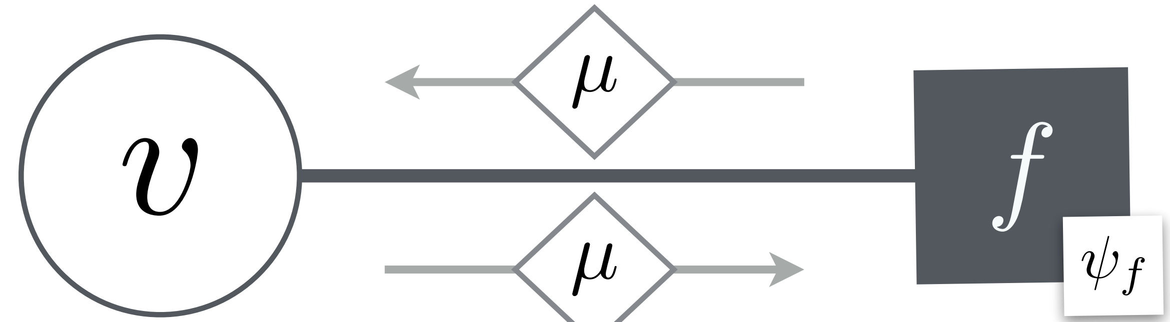
$$\mu_{v \to f}(x) \propto \prod_{f' \in N(v) \setminus \{f\}} \mu_{f' \to v}(x)$$

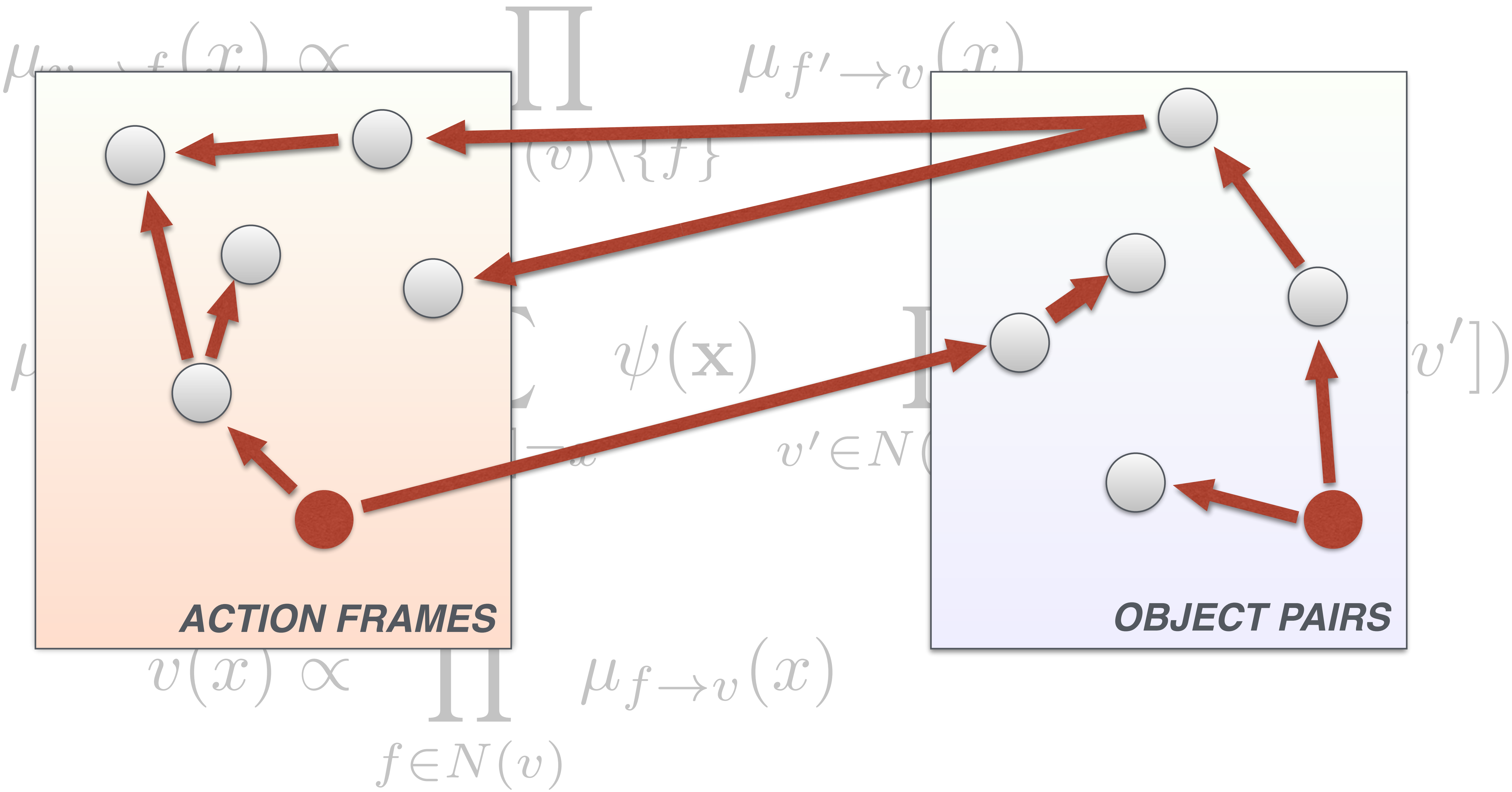
sum **product**

$$\mu_{f \to v}(x) \propto \sum_{\mathbf{x}:\mathbf{x}[v]=x} \psi(\mathbf{x}) \prod_{v' \in N(f) \setminus \{v\}} \mu_{v' \to f}(\mathbf{x}[v'])$$

$$v(x) \propto \prod_{f \in N(v)} \mu_{f \to v}(x)$$

Loopy belief propagation





1. Introduction
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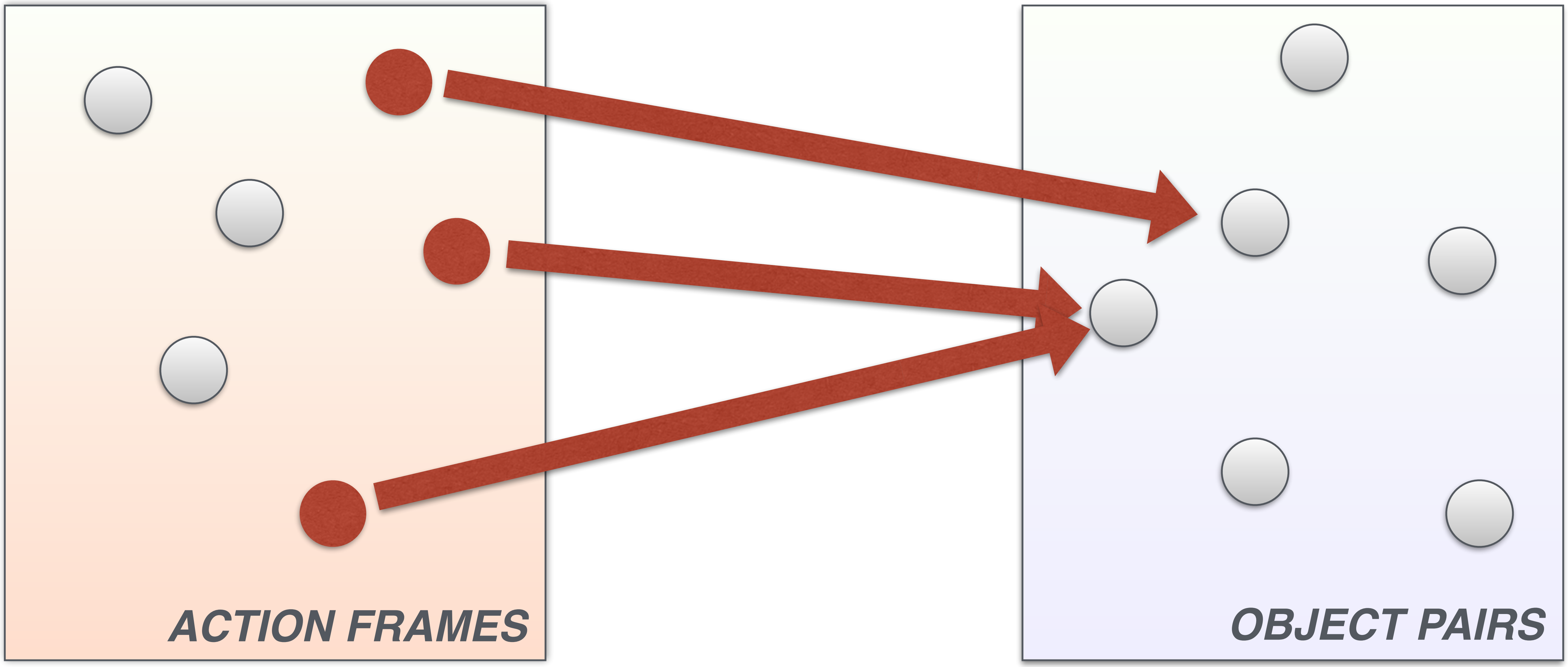
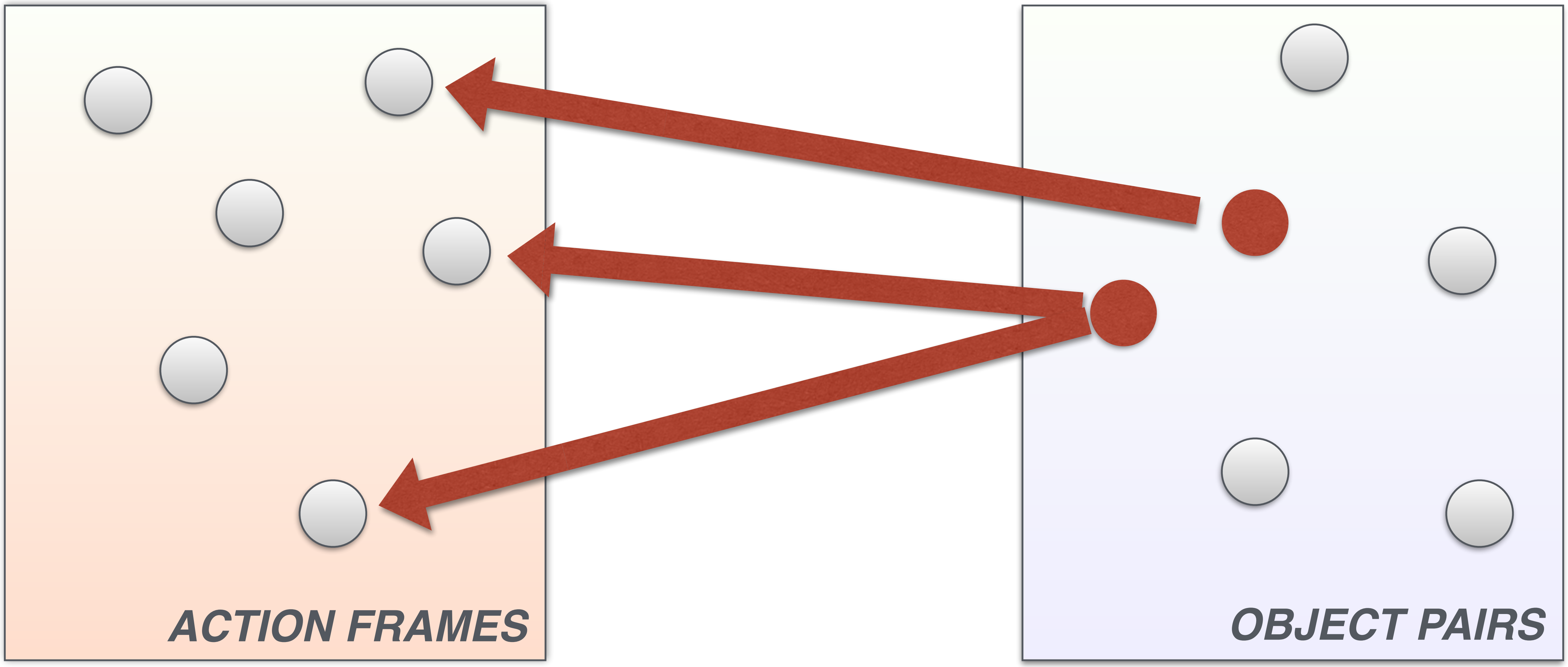
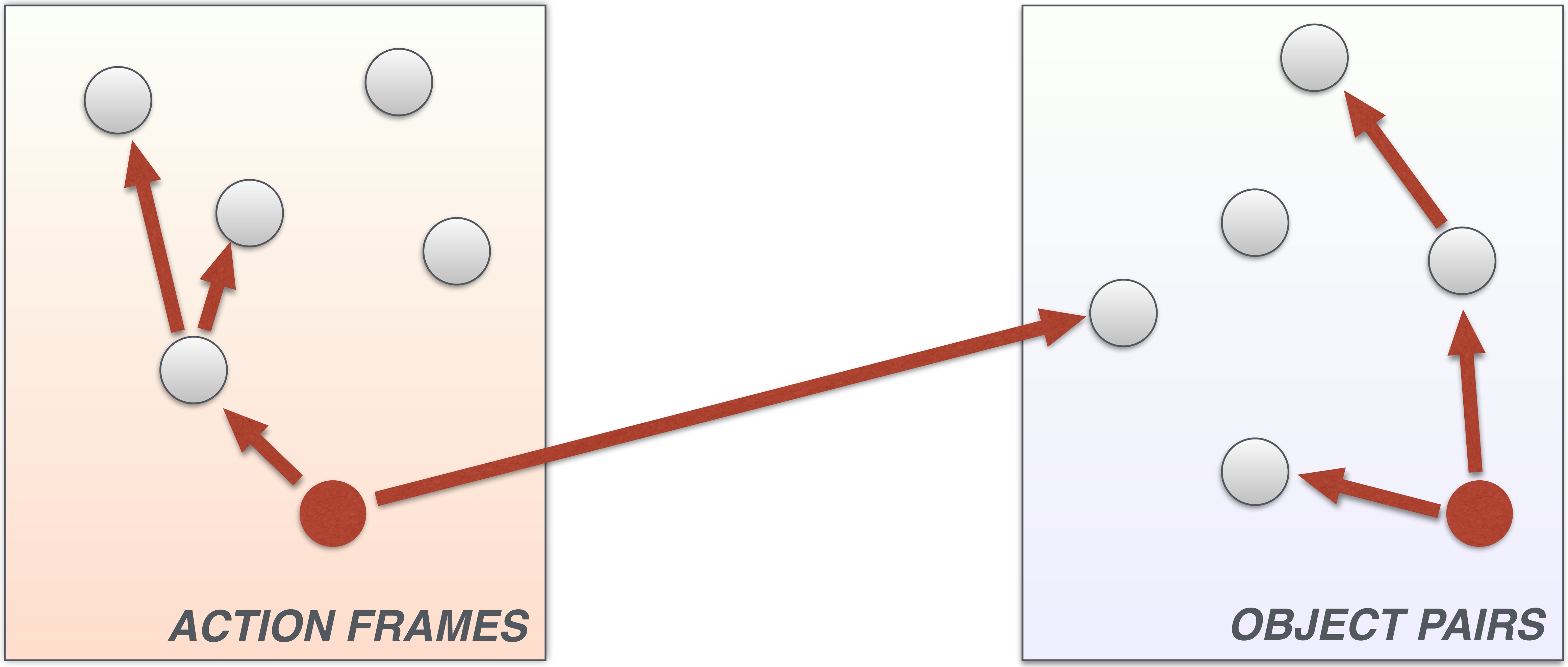
Why collect data?



Why collect data?



Why collect data?



- Small **seed set** (5%) breaks symmetry
- **Evaluate** generalizability (dev = 45%, test = 50%)

Selecting frames and objects

<u>Verbs</u>

- took
- grew
- washed
- trimmed
- squished
- got
- looked
- wrote
- entered
- kept
- lived
- played
- …

"Action" verbs

[Levin, 1993]

Selecting frames and objects

Verbs

- took
- grew
- washed
- trimmed
- squished
- got
- looked
- wrote
- entered
- kept
- lived
- played
- …

Action frames

…

- *x* squished *y*
- ~~*x* squished on *y*~~
- PERSON squished *x* with *y*
- PERSON squished *x* on *y*

…

Syntax + surface + crowdsourcing

Selecting frames and objects

Verbs

- took
- grew
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- trimmed
- squished
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- looked
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- kept
- lived
- played
- …

Action frames

…
- x squished y
- ~~x squished on y~~
- PERSON squished x with y
- PERSON squished x on y

…

Object pairs

…
- spider, boot
- ~~spider, glee~~

…

PMI > 0 on Google Syntax Ngrams

[Goldberg and Orwant, 1993]

not abstract *via* Wordnet

[Miller, 1995]

Given the sentence fragment

"He squished __x__ with __y__"

Given the sentence fragment

"He squished ___**x**___ *with* ___**y**___*"*

What are some (physical, non-abstract) examples of **x** and **y** ?

priming

- *He squashed the **bug** with his **boot***
- *He squashed the **fly** with the **newspaper***
- *…*

Given the sentence fragment

“He squished ___**x**___ *with* ___**y**___*”*

What are some (physical, non-abstract) examples of **x** and **y** ?

In general, what does *“He squished **x** with **y**”* imply about the relative **size** of **x** and **y** ?

- [ ] **x** is generally **bigger** than **y**
- [x] **x** is generally **smaller** than **y**
- [ ] **x** is generally **about the same size as** **y**
- [ ] no general relation holds

For the two objects

person *and* ***shoe***

In general, what are their relative sizes ?

- [x] person is generally **bigger** than shoe
- [ ] person is generally **smaller** than shoe
- [ ] person is generally **about the same size as** shoe
- [ ] no general relation holds

… relative weight ?

… relative rigidness ?

…

Data statistics

	Total
Verbs	100
Frames	813
Object pairs	3656

~8 action frames / verb

~200 distinct objects

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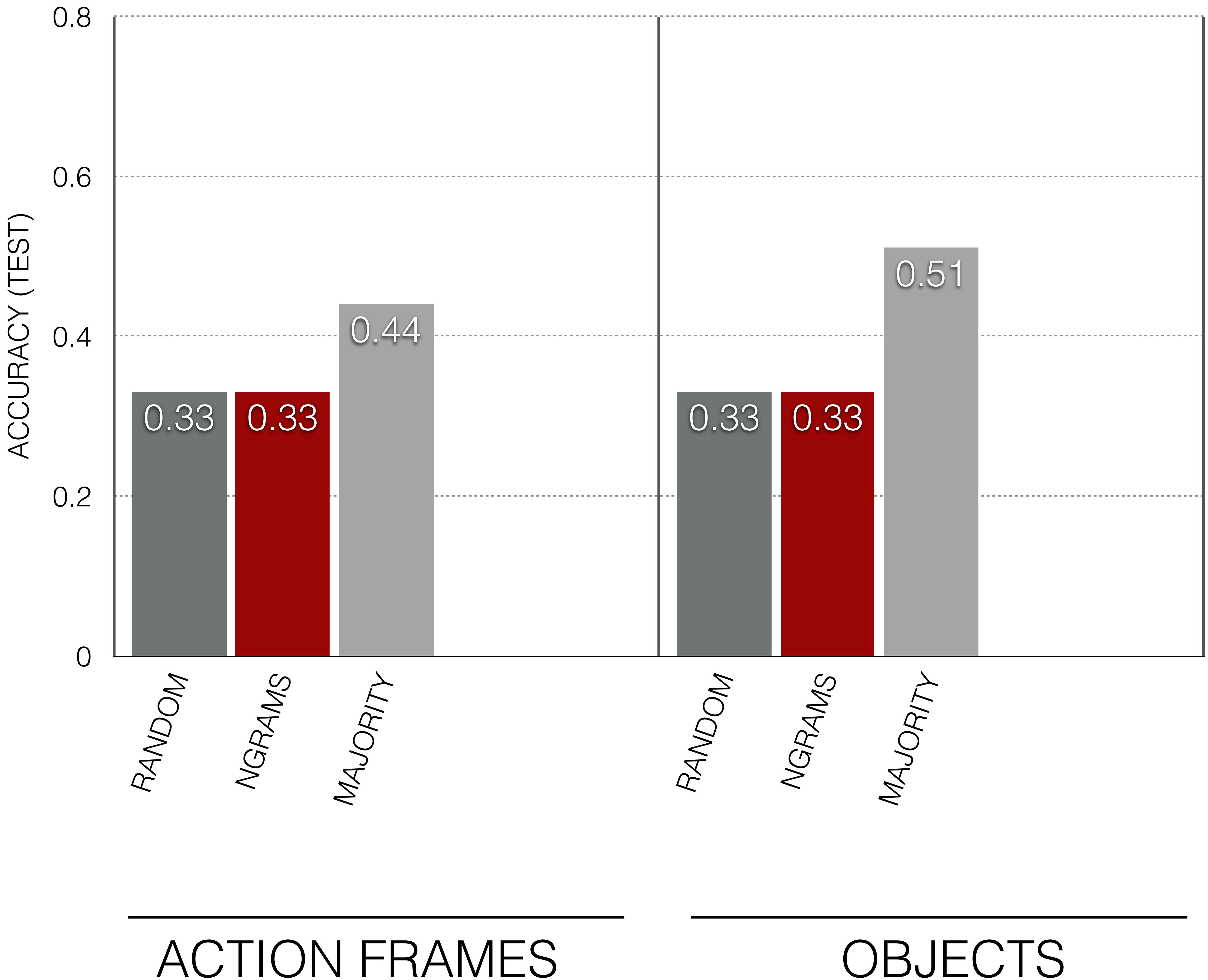
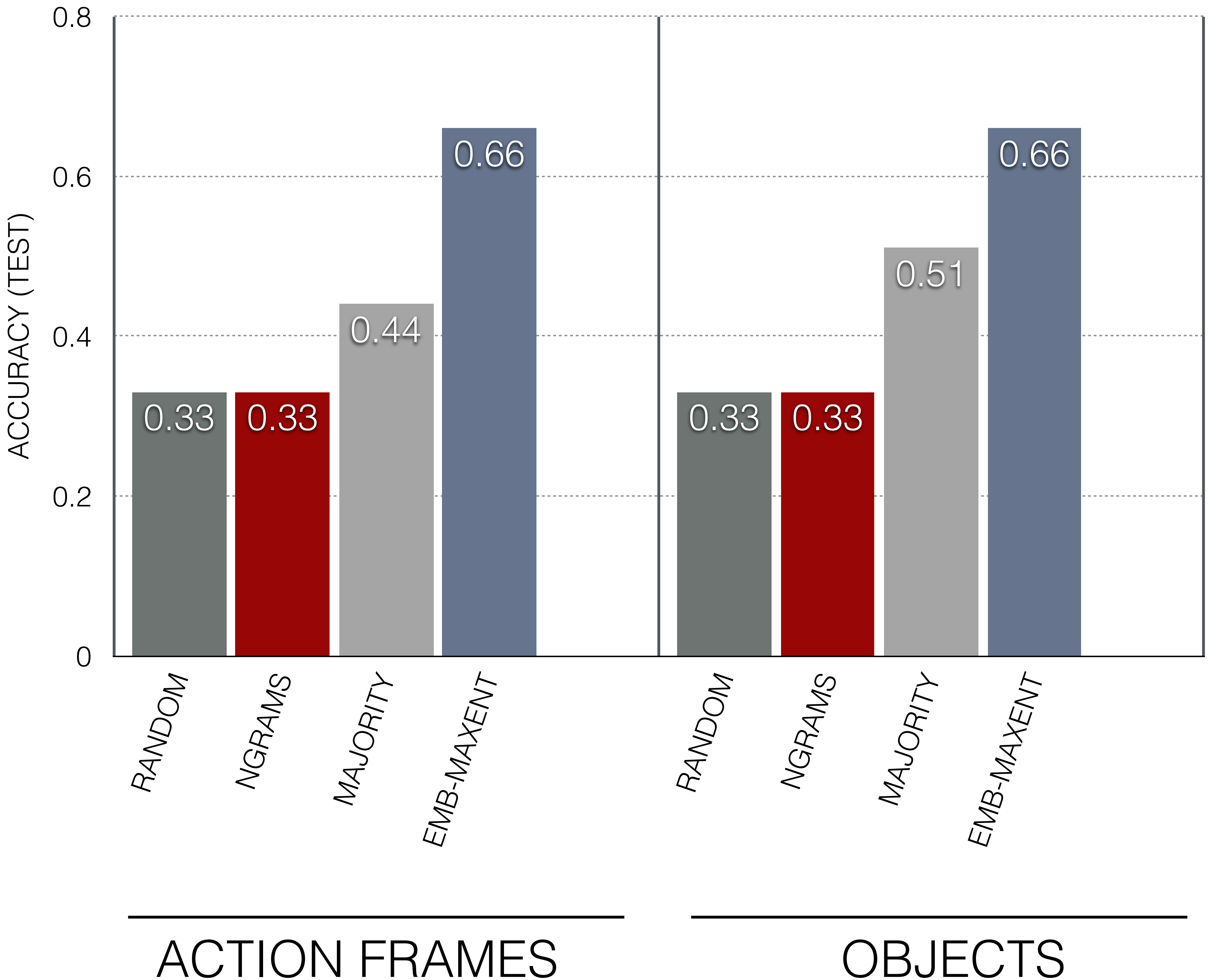

0.8
0.6
0.4
0.2
0
ACCURACY (TEST)
0.33
0.33
0.44
0.33
0.33
0.51
RANDOM
NGRAMS
MAJORITY
RANDOM
NGRAMS
MAJORITY
ACTION FRAMES
OBJECTS


0.8
0.6
0.4
0.2
0
ACCURACY (TEST)
0.33
0.33
0.44
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0.33
0.51
0.66
RANDOM
NGRAMS
MAJORITY
EMB-MAXENT
RANDOM
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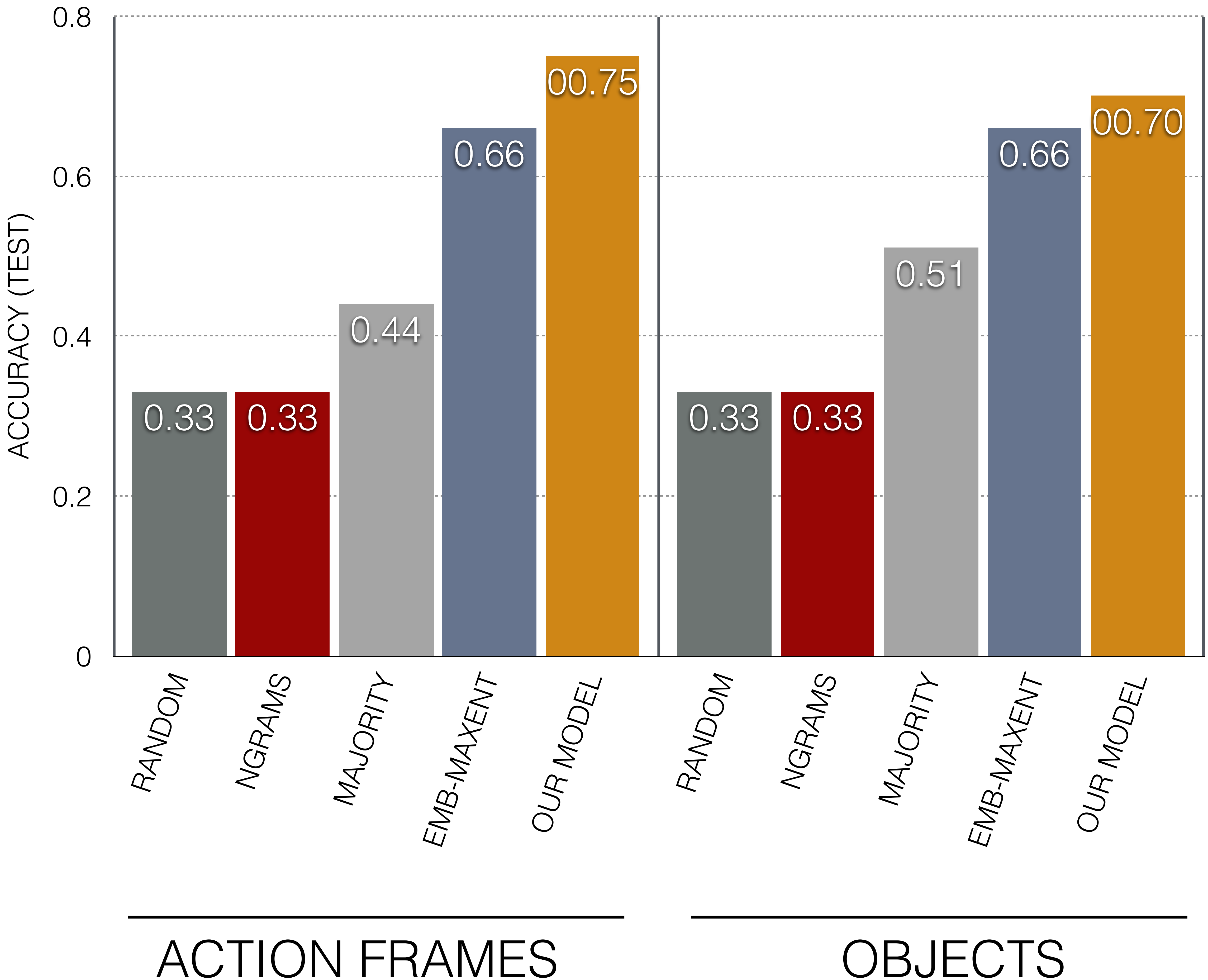
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ACCURACY (TEST)
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0.51
0.66
00.70
RANDOM
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OUR MODEL
ACTION FRAMES
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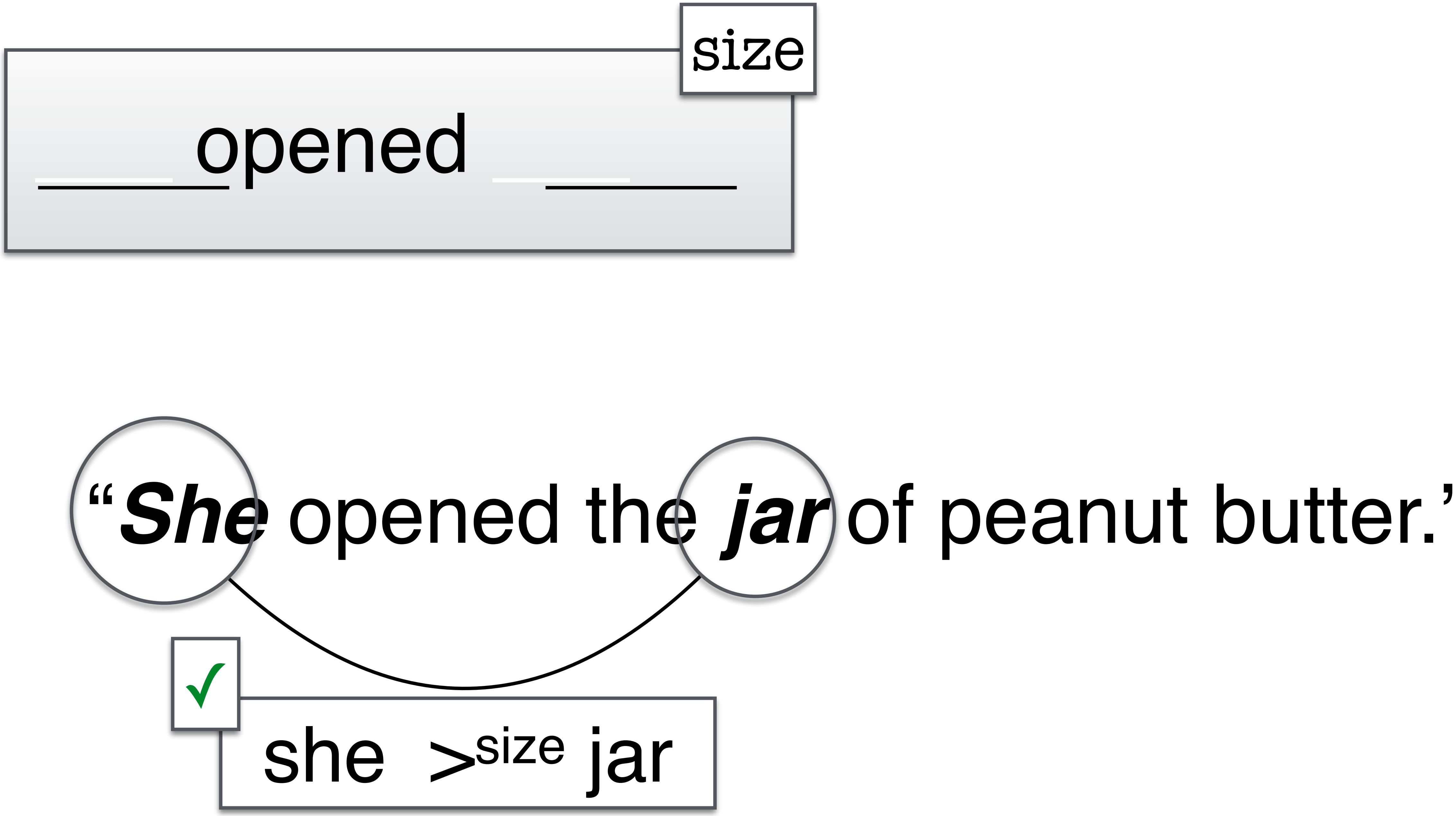


Correct dev set examples

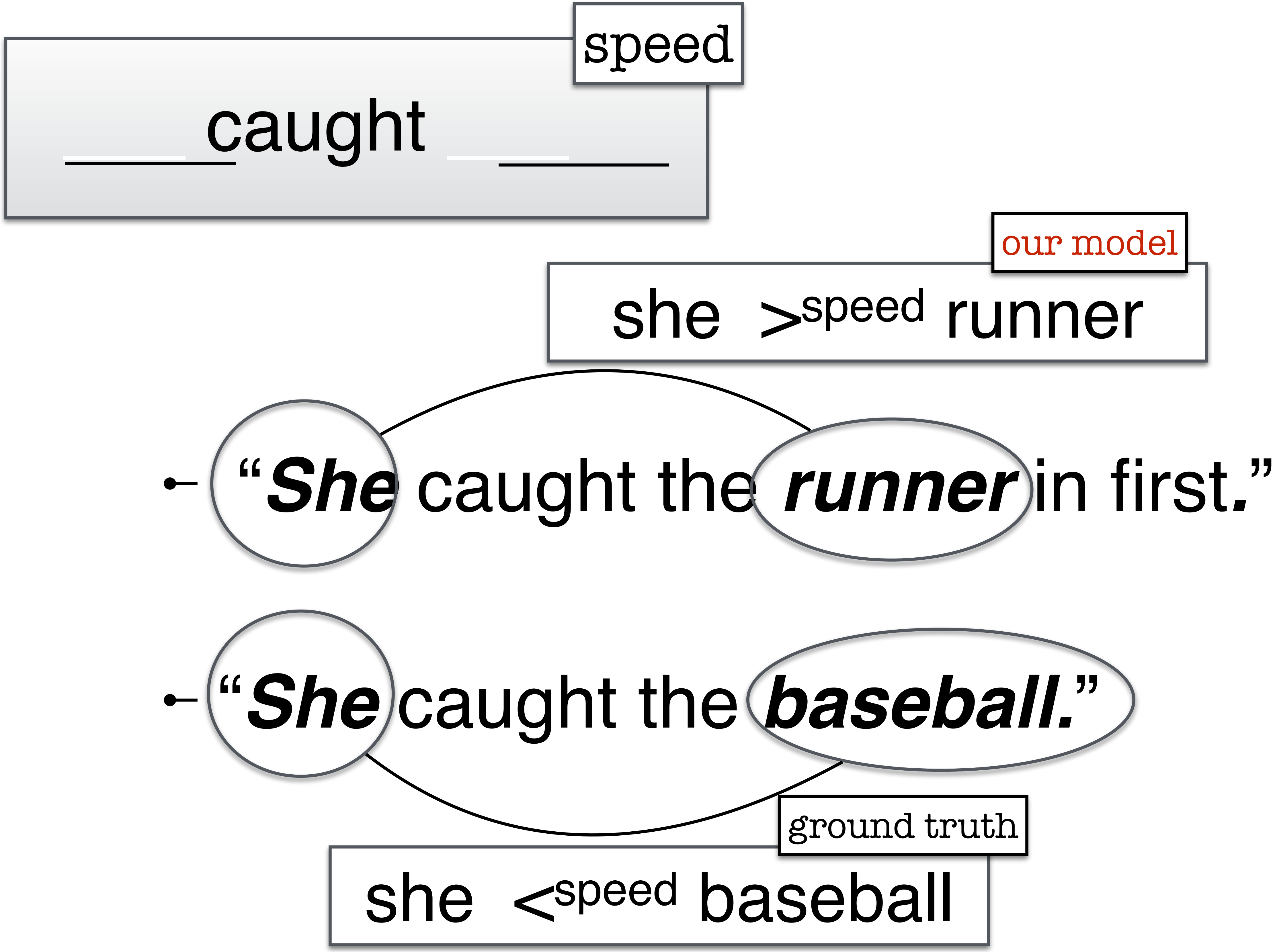
weight

PERSON set _____ upon ______

"He set the ***kettle*** upon the ***stove.***"

✓ kettle $<^{\text{weight}}$ stove

Correct dev set examples



polysemy

Incorrect *dev set examples*

weight

PERSON stopped ____ with ____

our model

fly $<^{weight}$ jar

- “He stopped a ***fly*** with a ***jar.***”
- “She stopped the ***car*** with the ***brake.***”

ground truth

car $>^{weight}$ brake

complex physics

Incorrect *dev set examples*

PERSON drove ______ for ______ size

- “He drove the ***car*** for ***work.***”
- “She drove the ***car*** for ***hours.***”

?

?

nonsensical comparison

Incorrect *dev set examples*

Metaphorical language?

size

x contained y

$\Longrightarrow x >^{size} y$

Physical		**Metaphorical**	
x	y	x	y
bag	book	dictator	revolution
taco	tomato	firefighters	forest fire
cup	coffee		

VerbPhysics Summary

- Reverse engineer **commonsense physical knowledge**

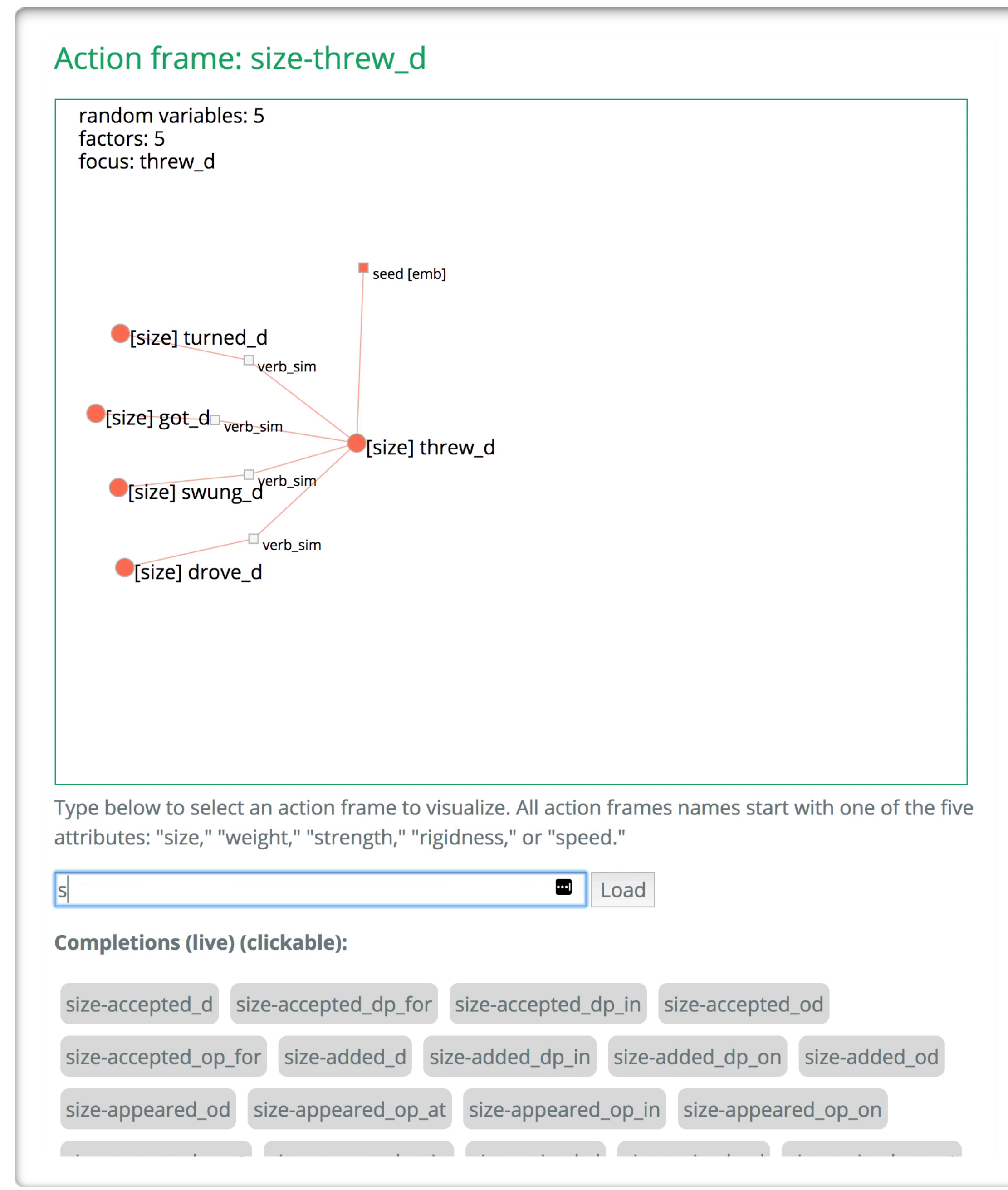
- Overcome **reporting bias** by modeling frames and objects

VerbPhysics Summary

- Reverse engineer **commonsense physical knowledge**

- Overcome **reporting bias** by modeling frames and objects

- New dataset VERBPHYSICS
  `uwnlp.github.io/verbphysics/`



Today's takeaways

1. NLP needs commonsense
PART I

2. We can learn (some) commonsense from text!
PART II

[Factor graphs
PART II — INTERLUDE]

References

Verb Physics
https://arxiv.org/abs/1706.03799
(contains actual citations for all references in Part II)

Factor Graphs and Loopy Belief Propagation Tutorial
https://www.cs.cmu.edu/~mgormley/bp-tutorial/

Noah Smith's factor graph slides
https://courses.cs.washington.edu/courses/cse517/16wi/slides/an-gm-slides.pdf

my Verb Physics code (python)
https://github.com/uwnlp/verbphysics

my factor graph code (python)
https://github.com/mbforbes/py-factorgraph