Verb Physics

Relative Physical Knowledge of Actions and Objects

Max Forbes

Yejin Choi

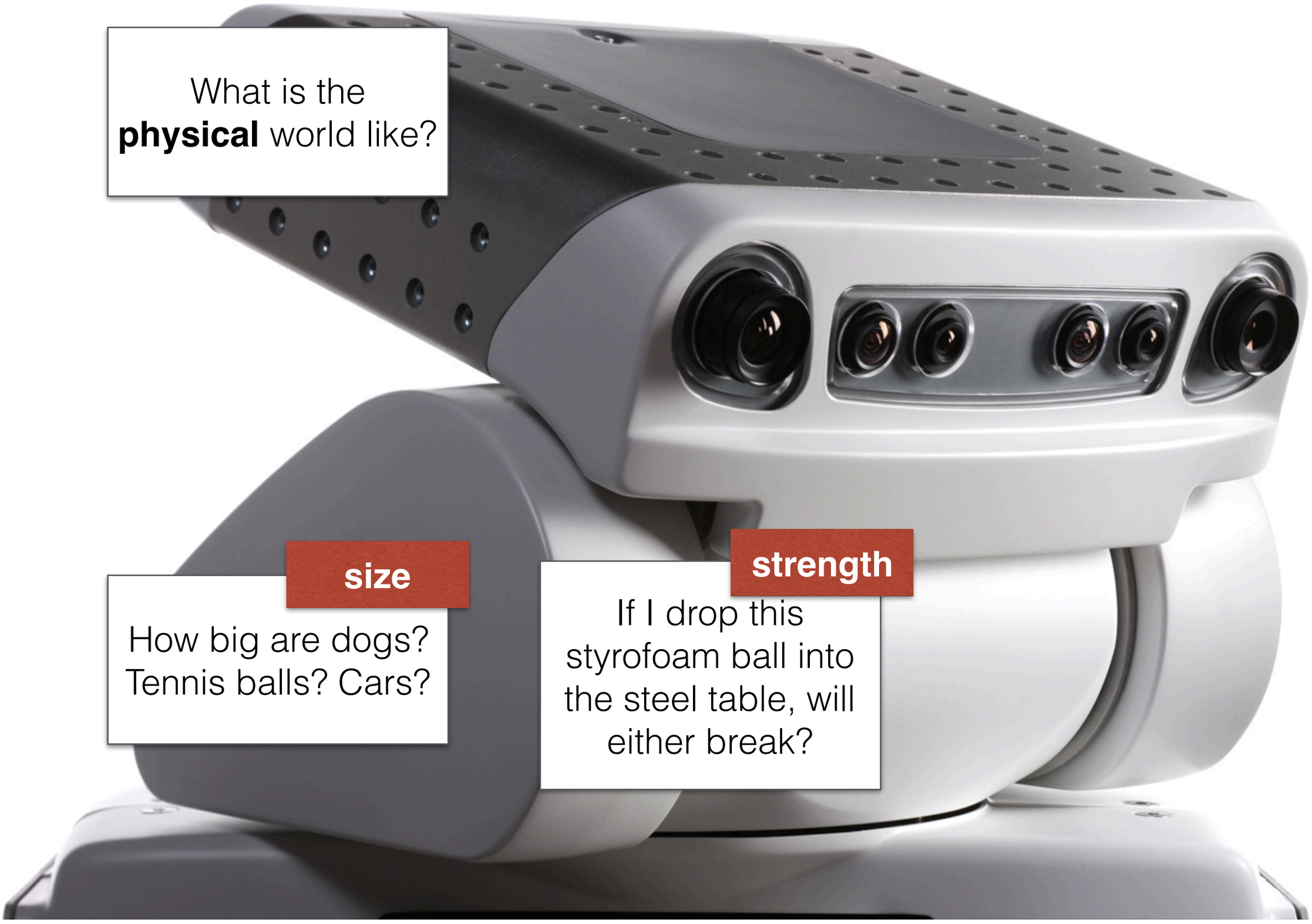

[Gao et al., 2016]


[Angeli and Manning, 2014]


[Gordon and Schubert, 2012]


49 PURDUE WEST
GREATER LAFAYETTE PUBLIC TRANSPORTATION CORPORATION
CityBus
Welcome Back
[Li et al., 2014]

Physical properties of objects



What is the **physical** world like?

size

How big are dogs? Tennis balls? Cars?

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!"

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


“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>."*

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Physical properties of objects

strength

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

Pattern-based IE

[Gordon et al., 2010]
[Gordon and Schubert, 2012]

"how often do you sleep?"

Word embeddings *[Rubinstein et al., 2015]*

"is yellow" *"is large"*

"not all birds can fly"

Commonsense knowledge base completion

[Angeli and Manning, 2013]
[Li et al., 2016]
[Angeli and Manning, 2014]

Verbs grounded in robotics + vision

[Tellex et al., 2011]

[Misra et al., 2014]

[She and Chai, 2016]

[Gao et al., 2016]

"*cutting changes the number of pieces*"

Semantic proto-roles

[Dowty, 1991]

[Kako, 2006]

[Reisinger et al., 2015]

Overcoming reporting bias

[Sorower et al., 2011]

[Misra et al., 2016]

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Physical properties of objects

strength

weight

Attributes

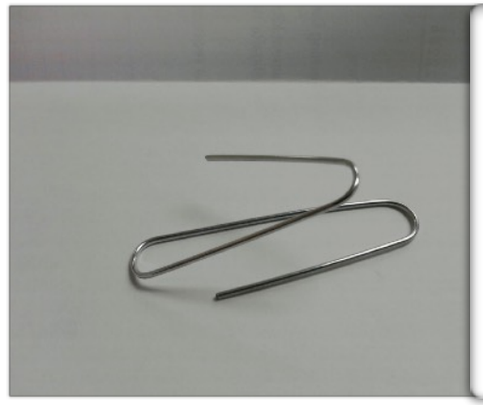
$x \quad >^{\text{size}} \quad y$

$x \quad >^{\text{weight}} \quad y$

$x \quad >^{\text{speed}} \quad y$

$x \quad >^{\text{strength}} \quad y$

$x \quad <^{\text{rigidness}} \quad y$



“I threw the _____”

“I threw the _____”

ball

stone

chair

“I threw the _____”

ball

stone

chair

~~*game*~~

~~*party*~~

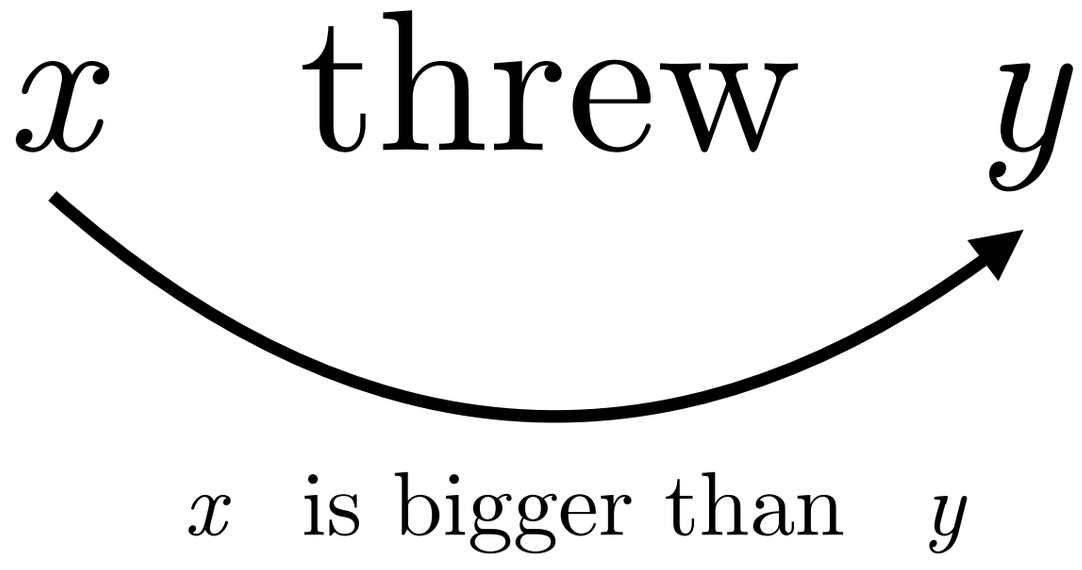
“I threw the _____”

ball

stone

chair

$$x \quad \text{threw} \quad y$$


x threw y
x is bigger than y

x is bigger than y

x weighs more than y

as a result, y will be moving faster than x

Action frame

$$x \quad \text{threw} \quad y$$

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

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

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

Terminology

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

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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

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

Physical properties of objects

weight

strength

Two related problems

Physical properties implied by predicates

Example

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

F = "x threw y"

attribute: size

correct value: $\boxed{>}$

intuition: "x threw y"

$$\implies x >^{\text{size}} y$$

Physical properties of objects

strength

Two related problems

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$$\implies x >^{\text{size}} y$$

Physical properties of objects

Example

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

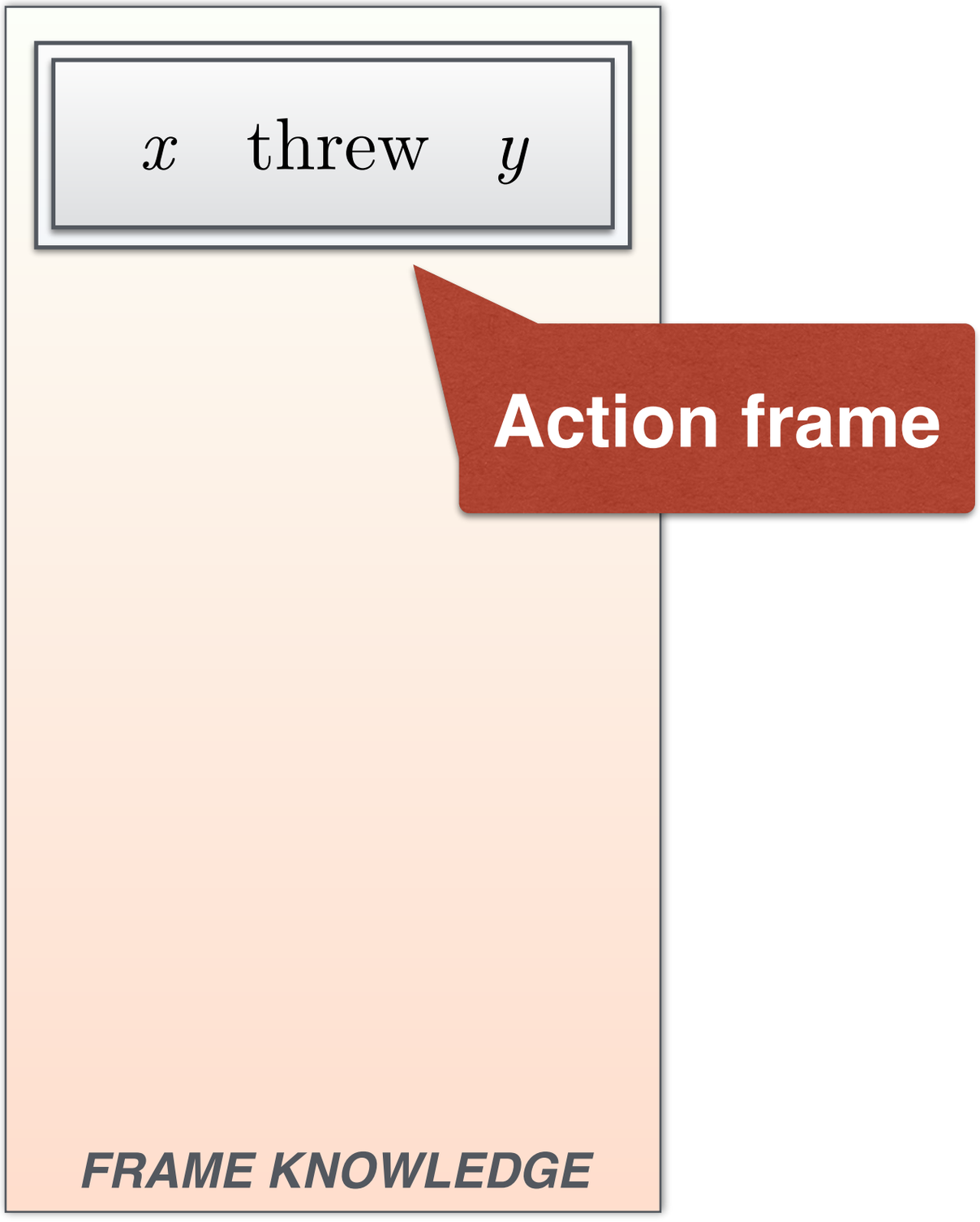
$J_{p,q}$ = (person, ball)

attribute: size

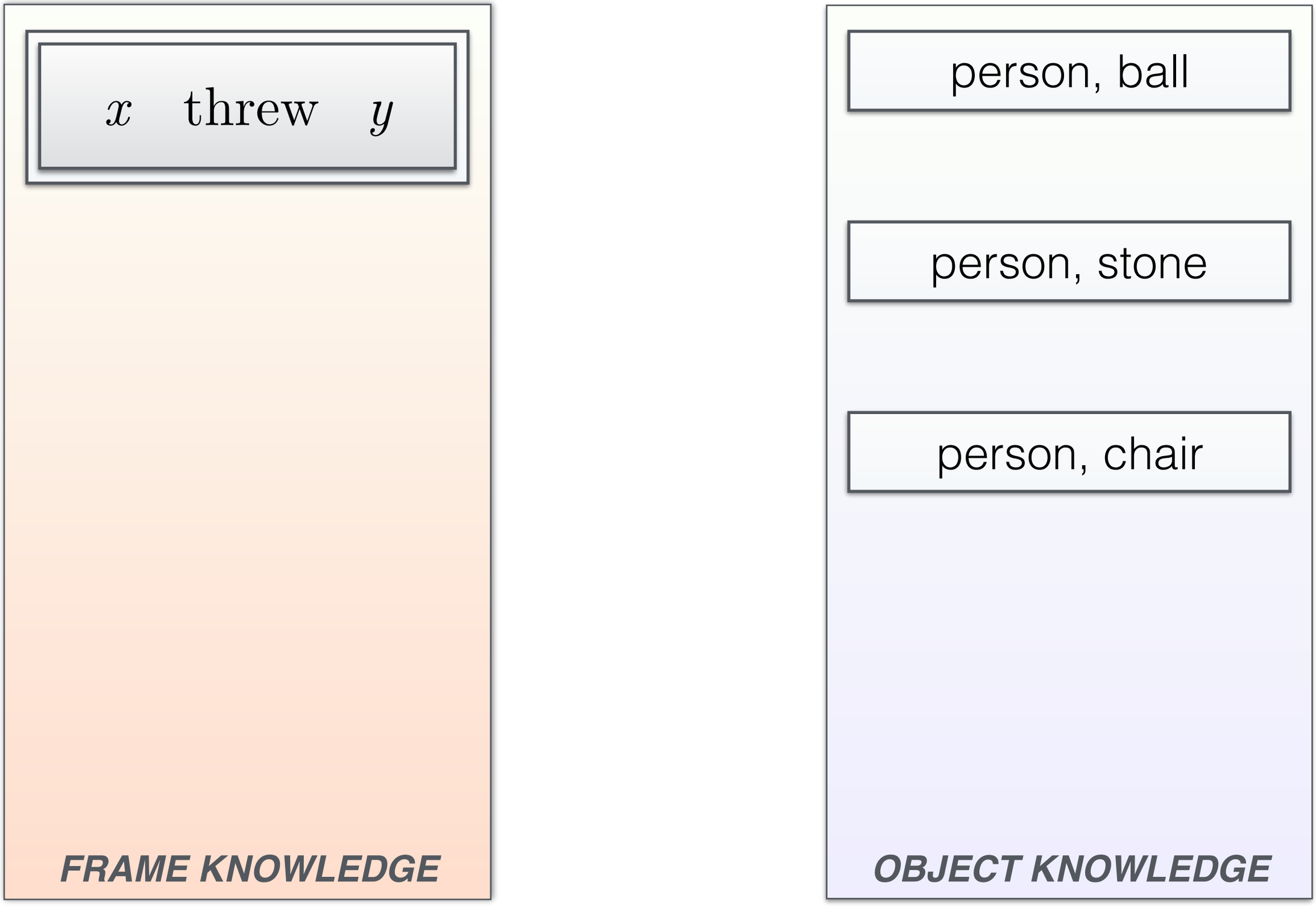
correct value: $\boxed{>}$

intuition: *people are generally larger than balls*

Solving both puzzles together



Solving both puzzles together



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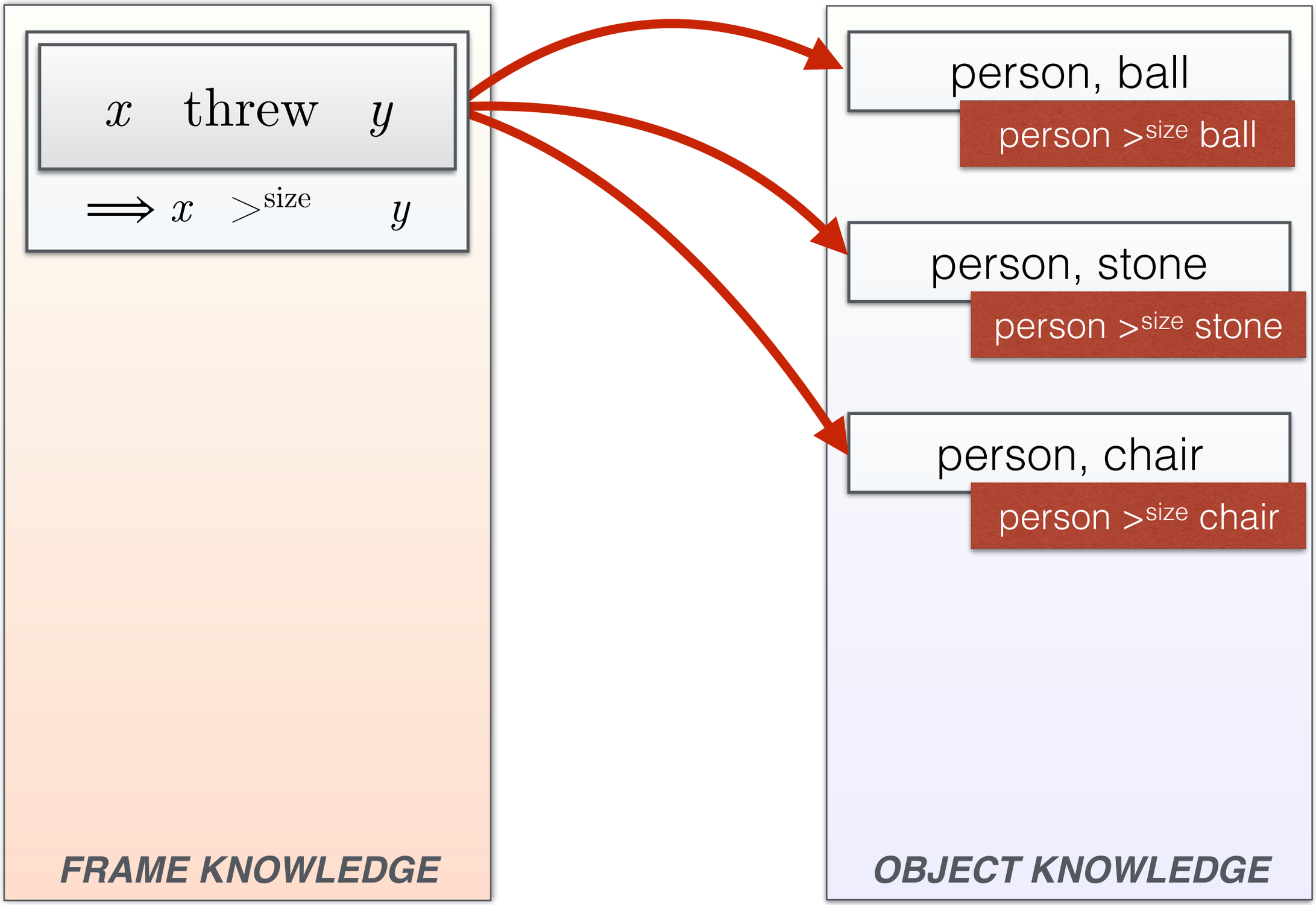

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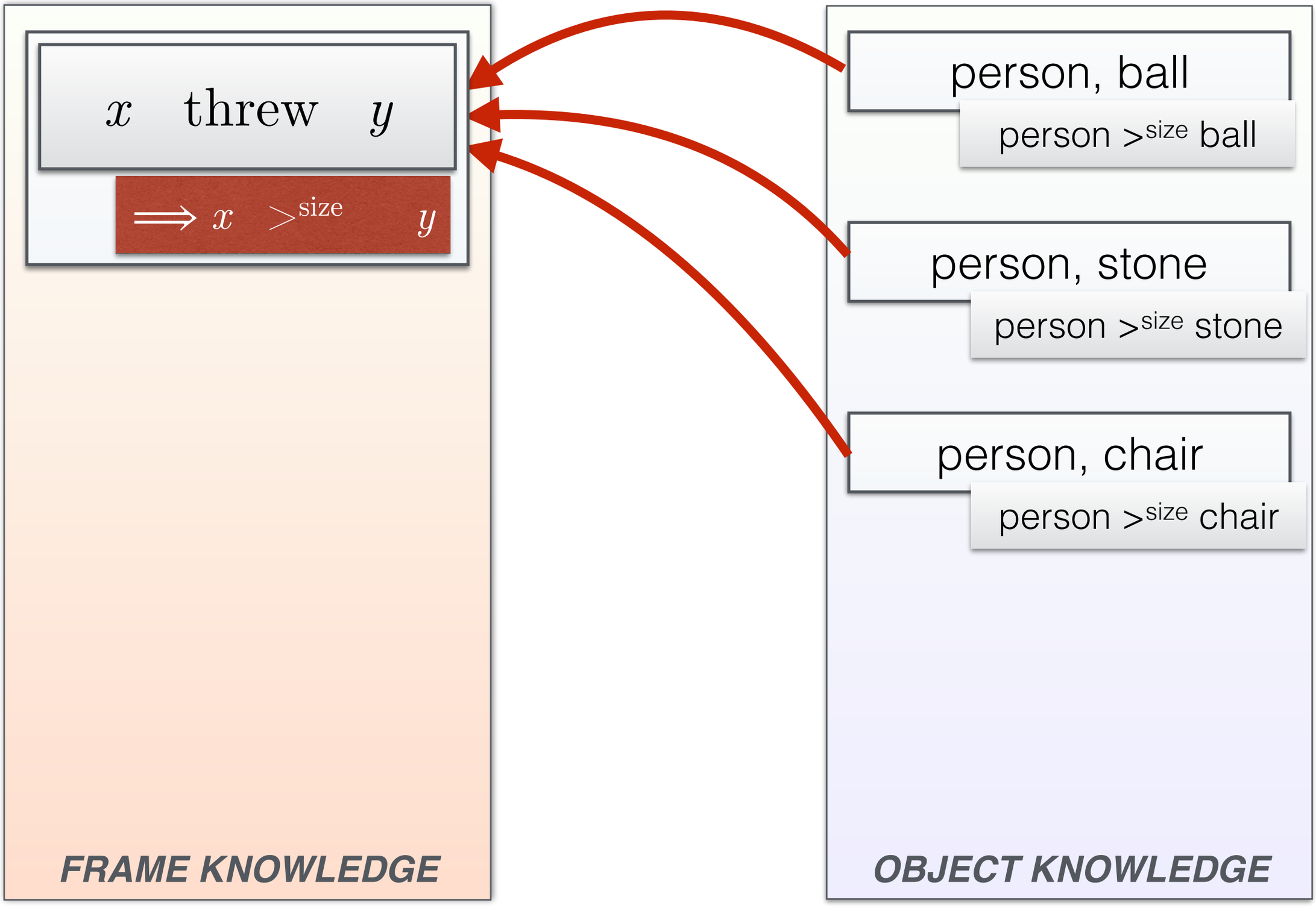
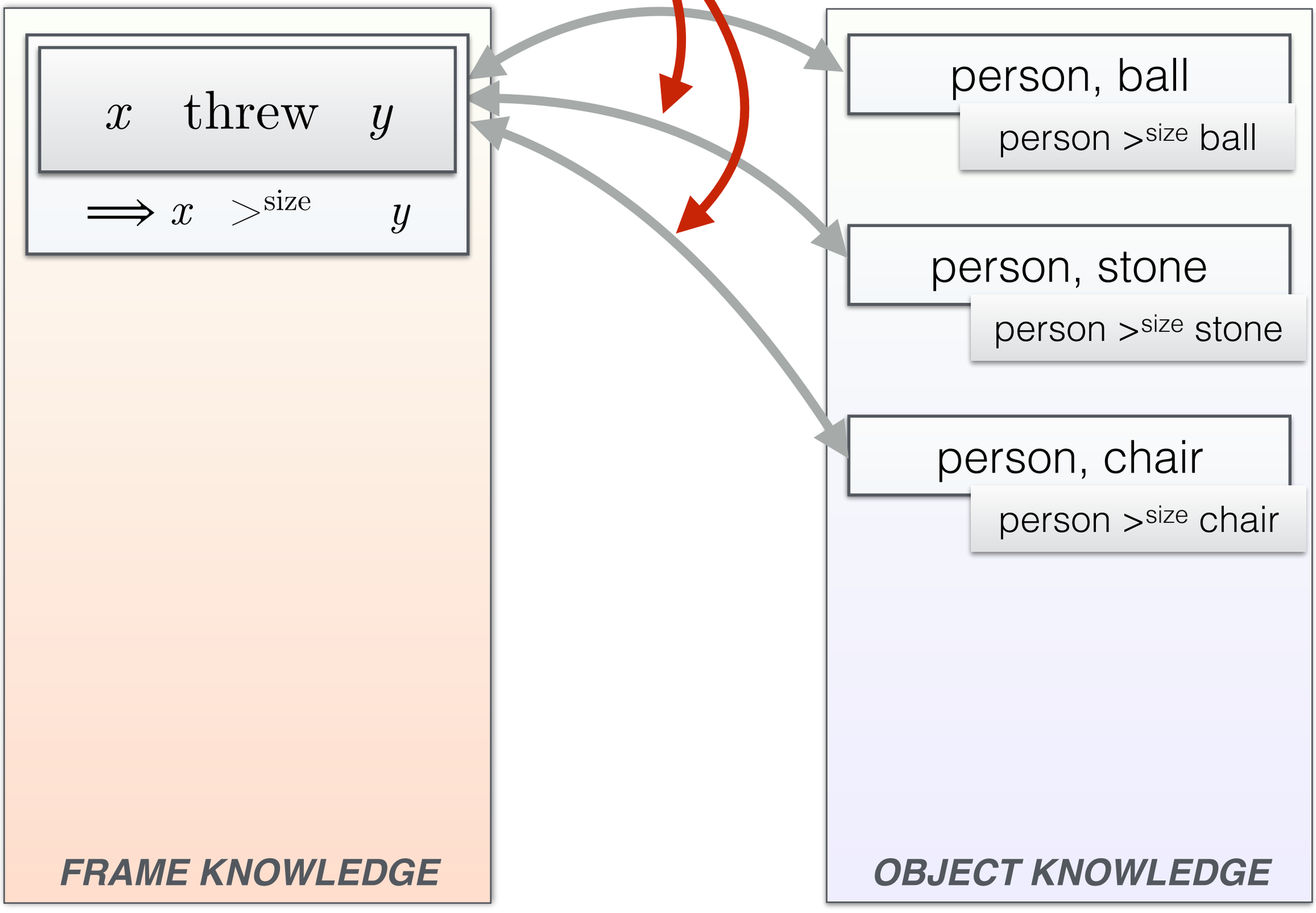


OBSERVABLE IN LANGUAGE (!)



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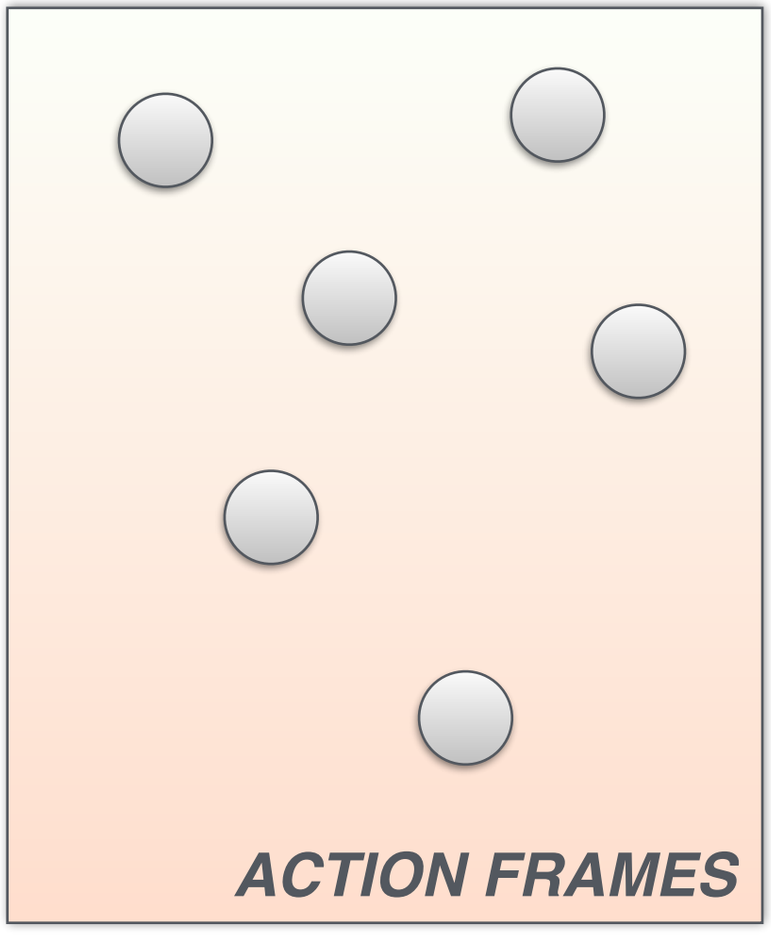
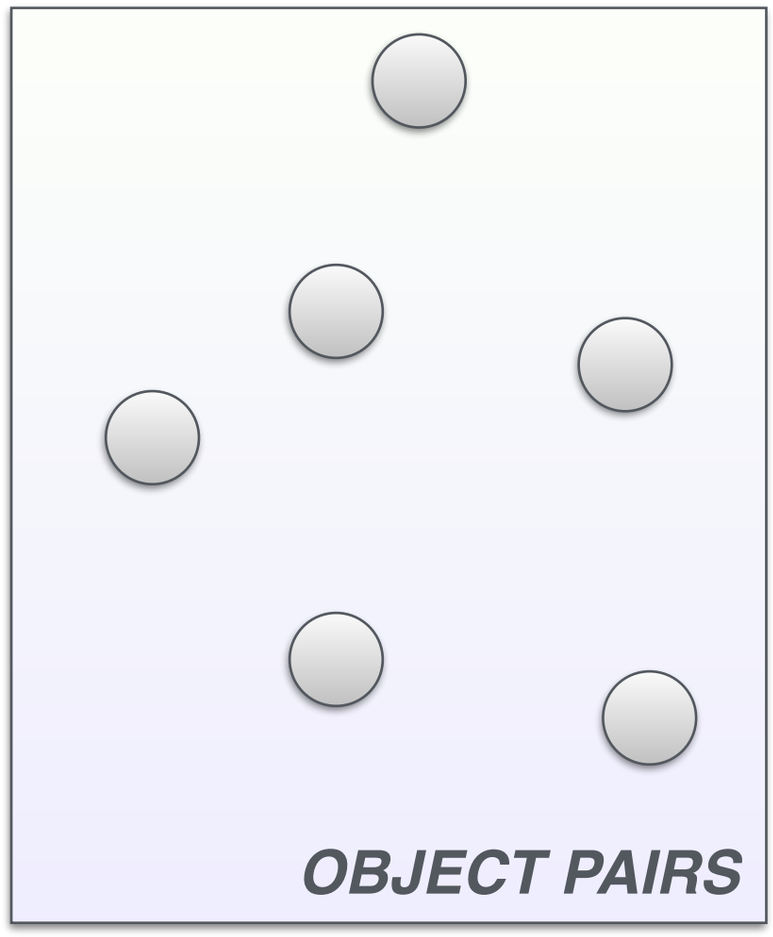
High level model





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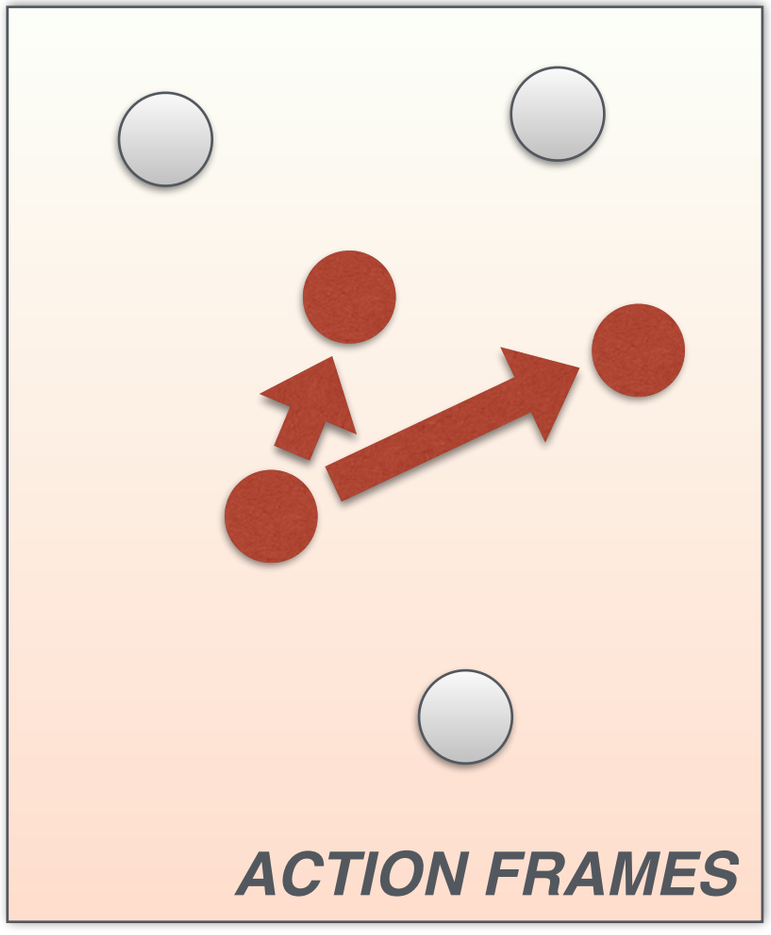

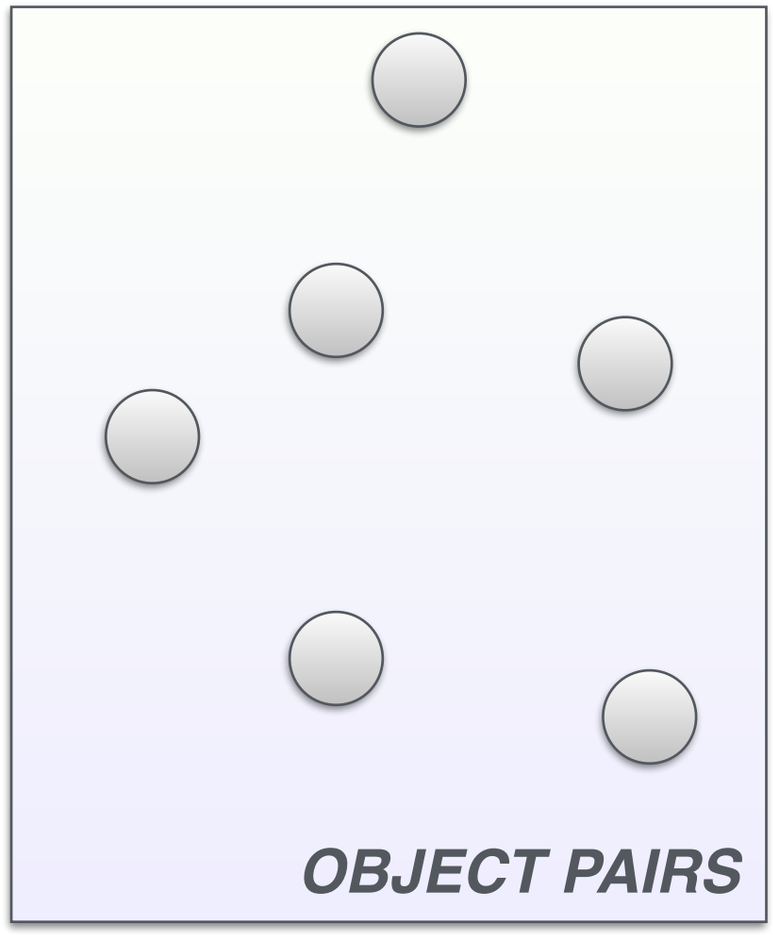

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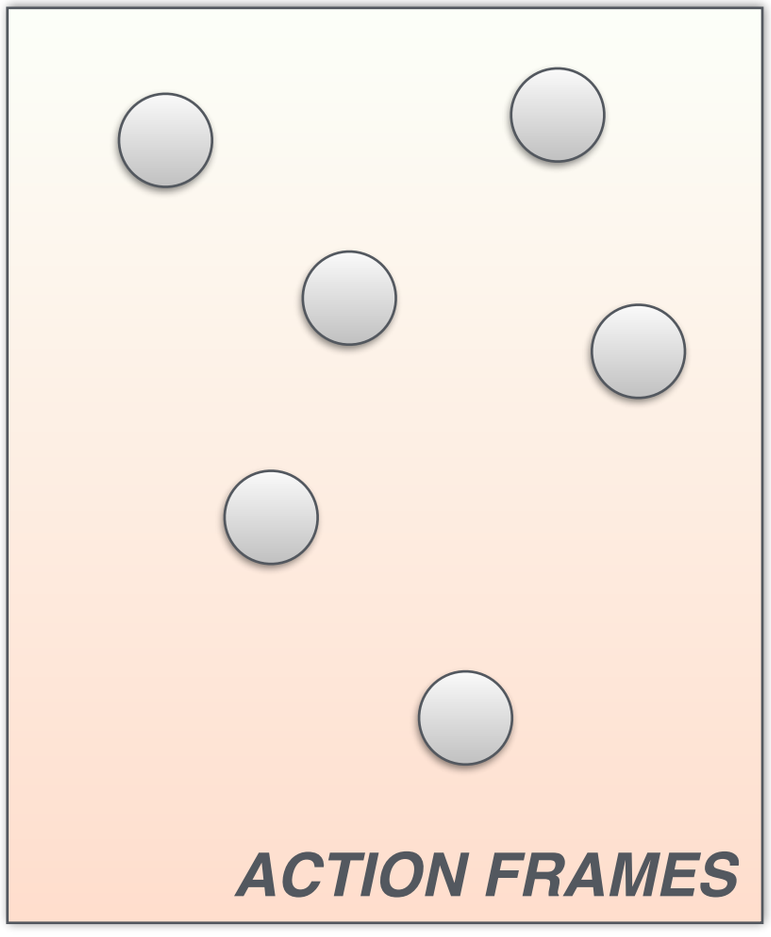

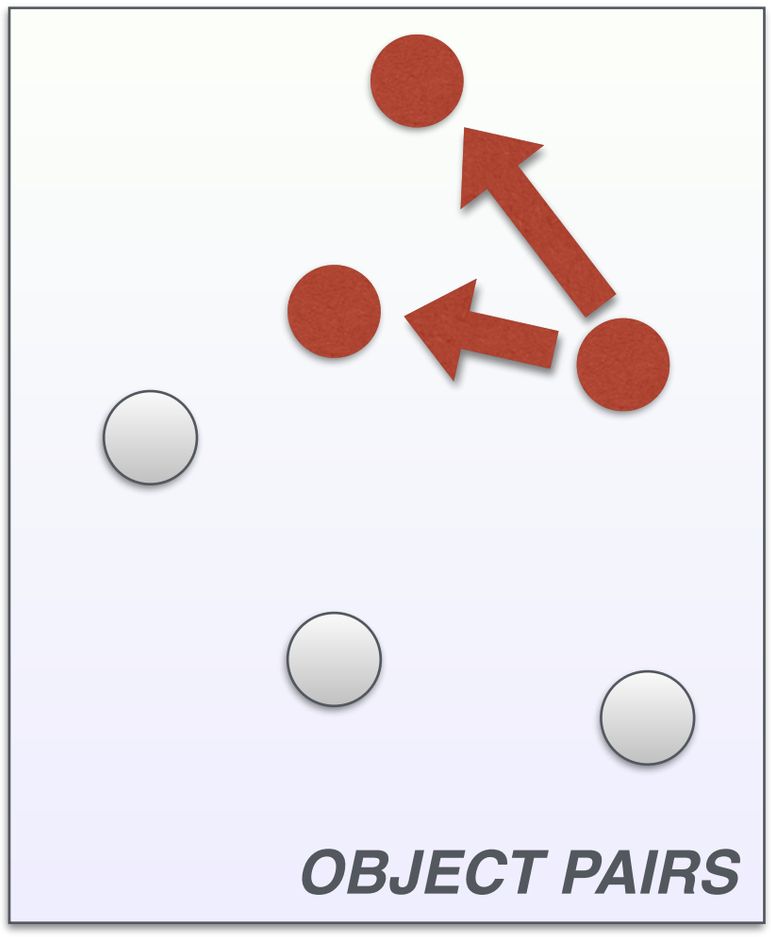

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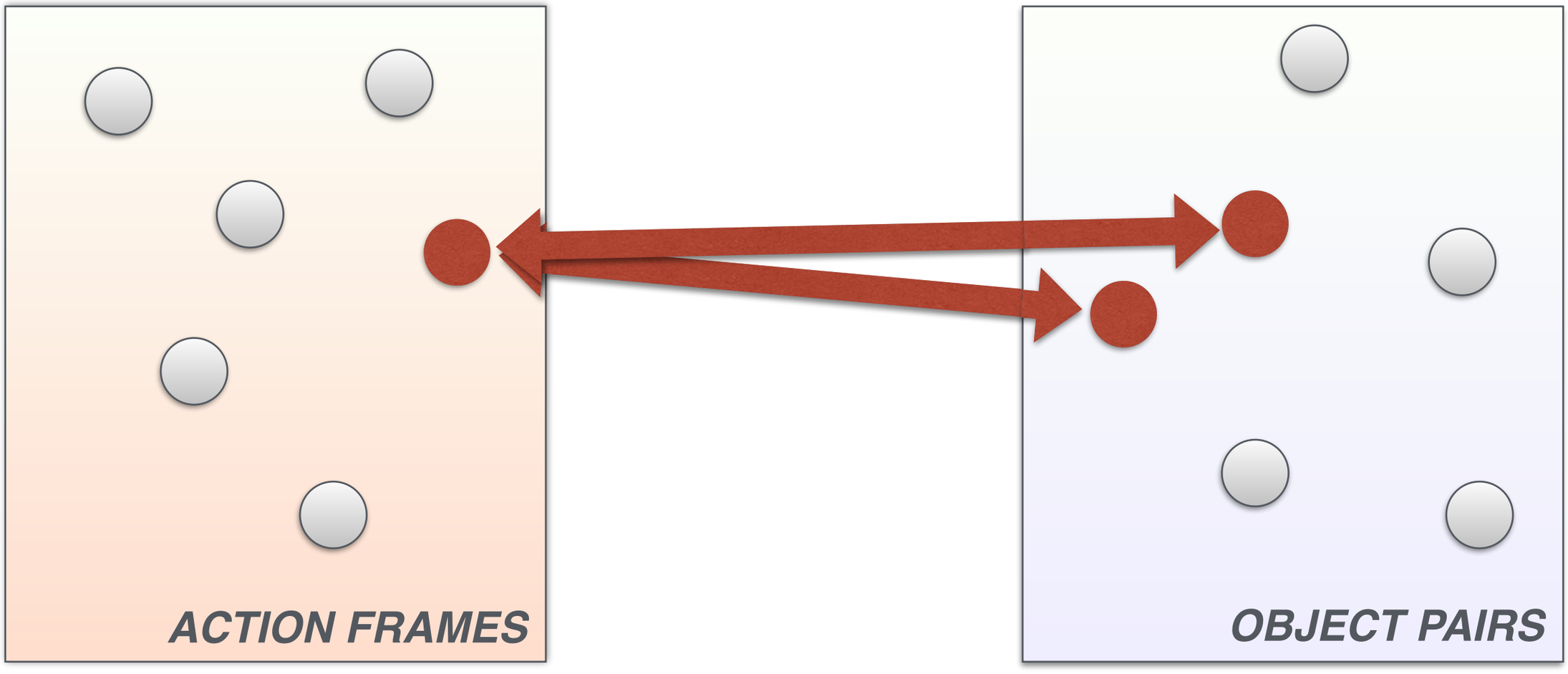
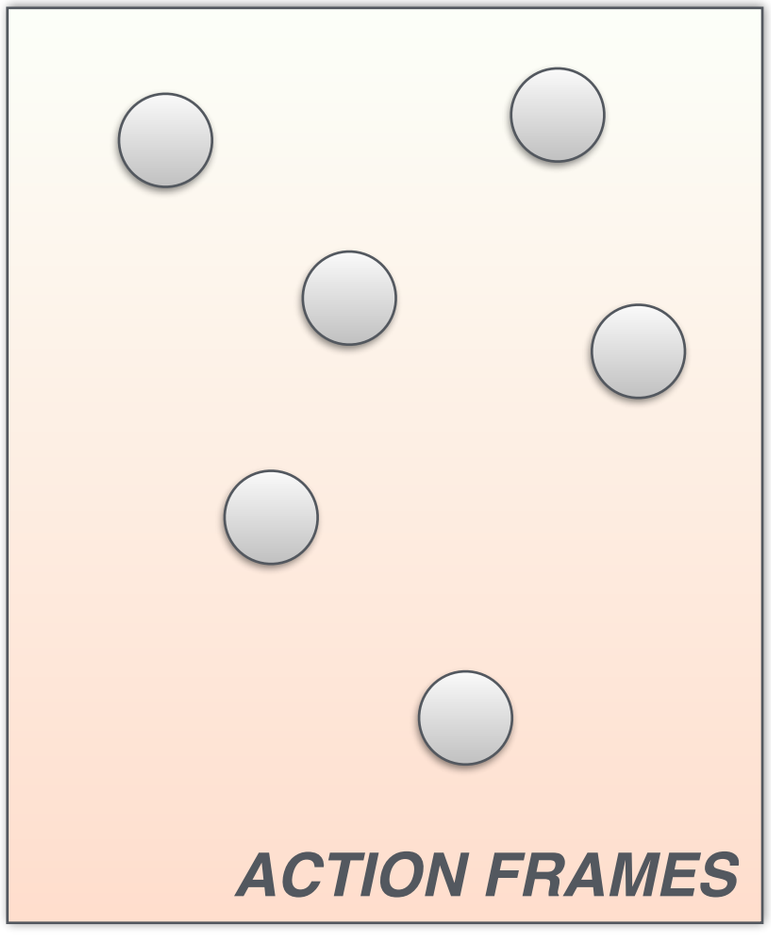
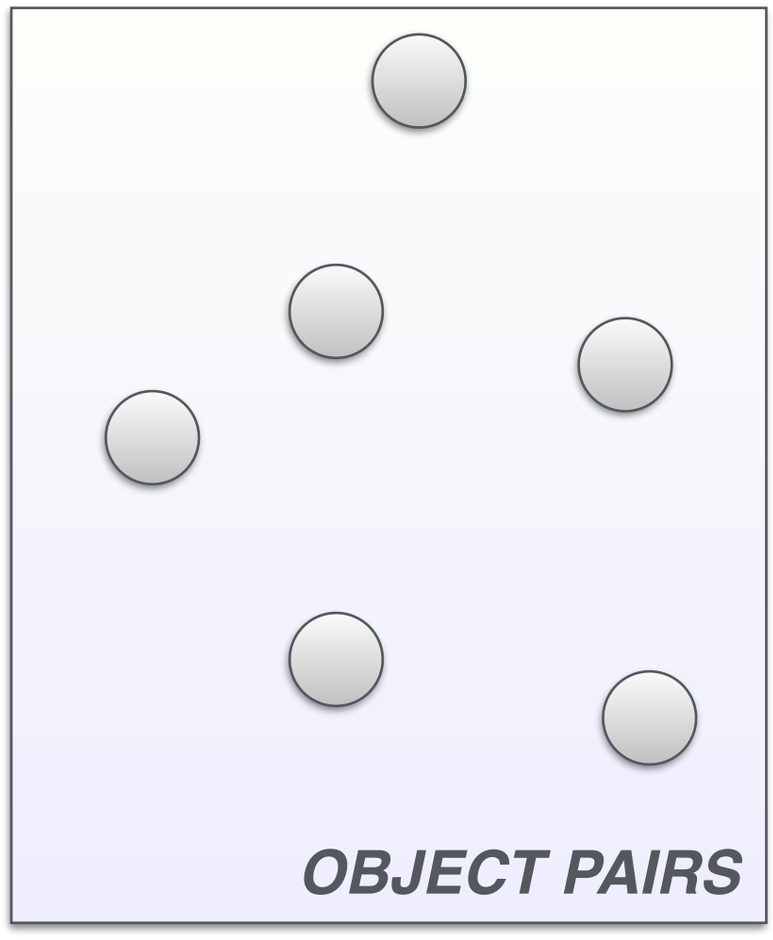


Random variables $F^a_{v_t}$

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





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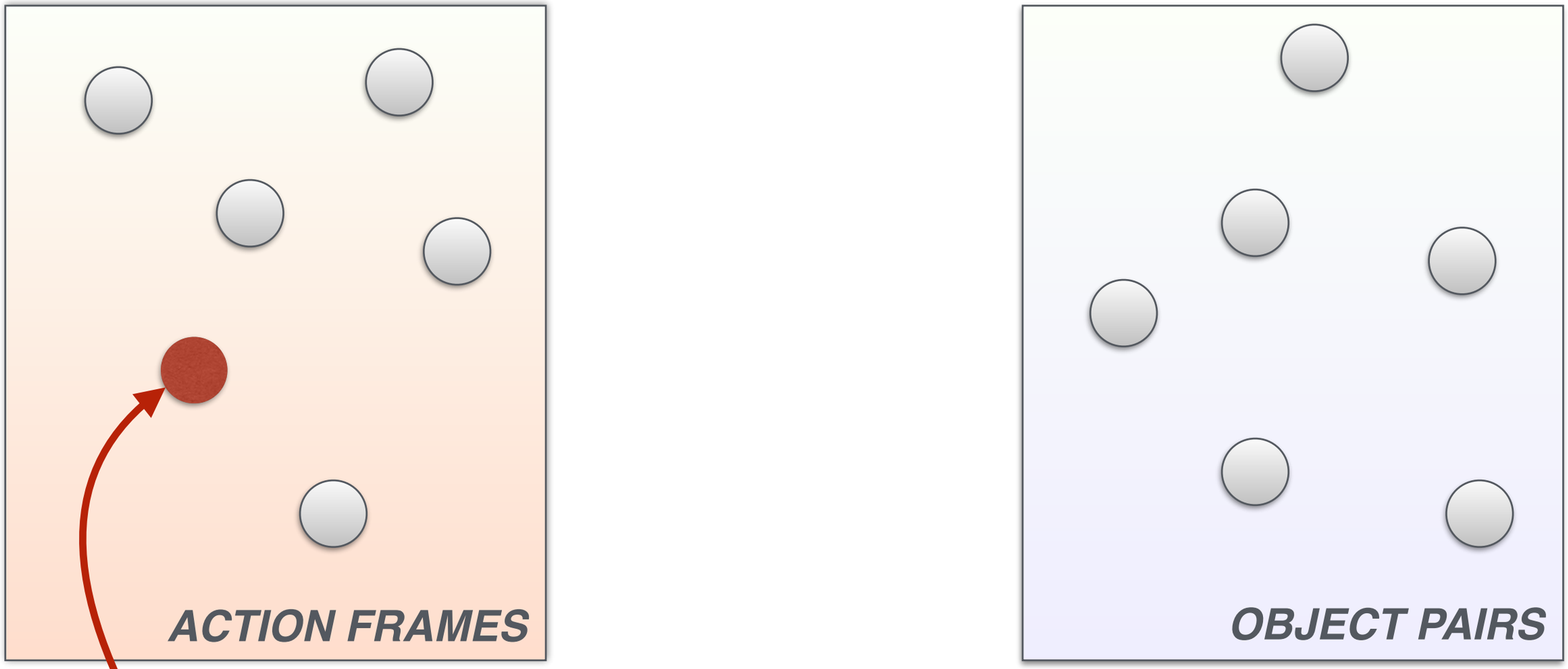

$$F^{\text{size}}_{\text{threw}_1} \approx \text{“}x \text{ threw } y\text{”}$$

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

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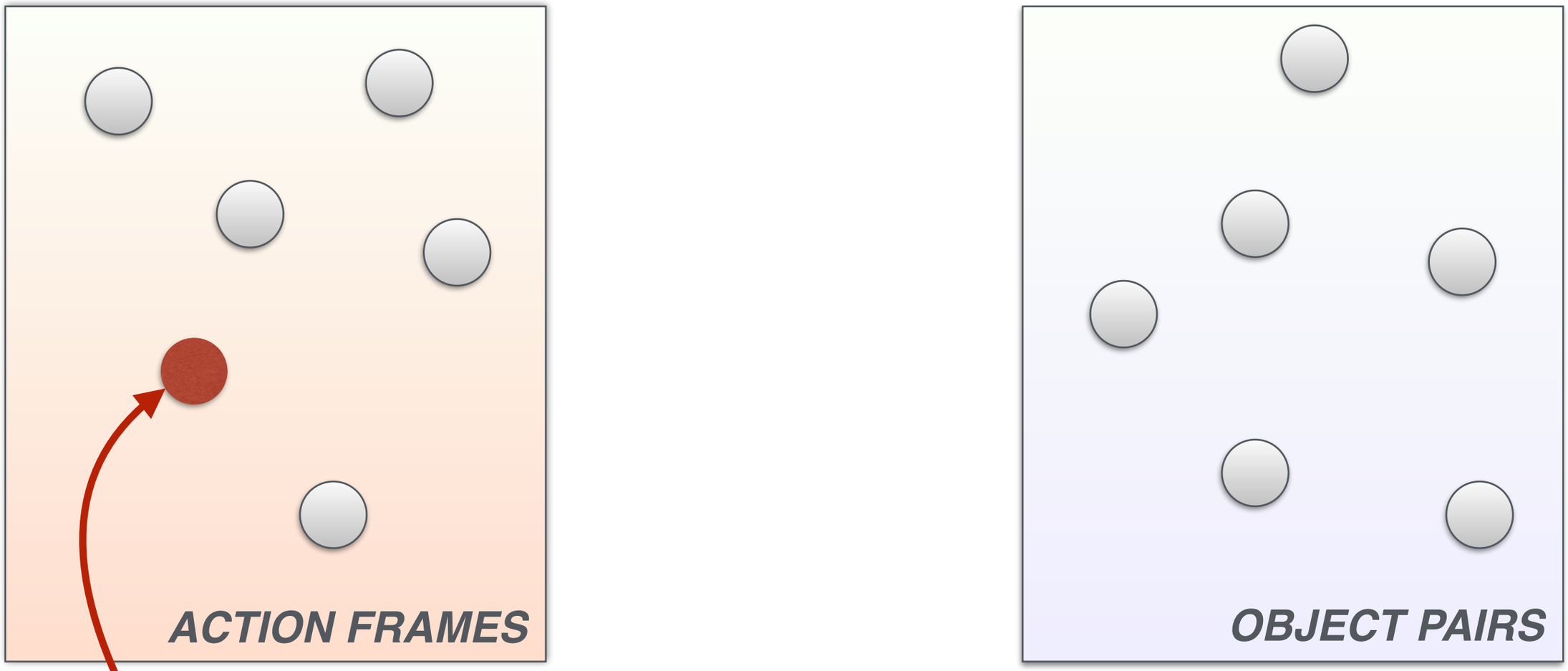
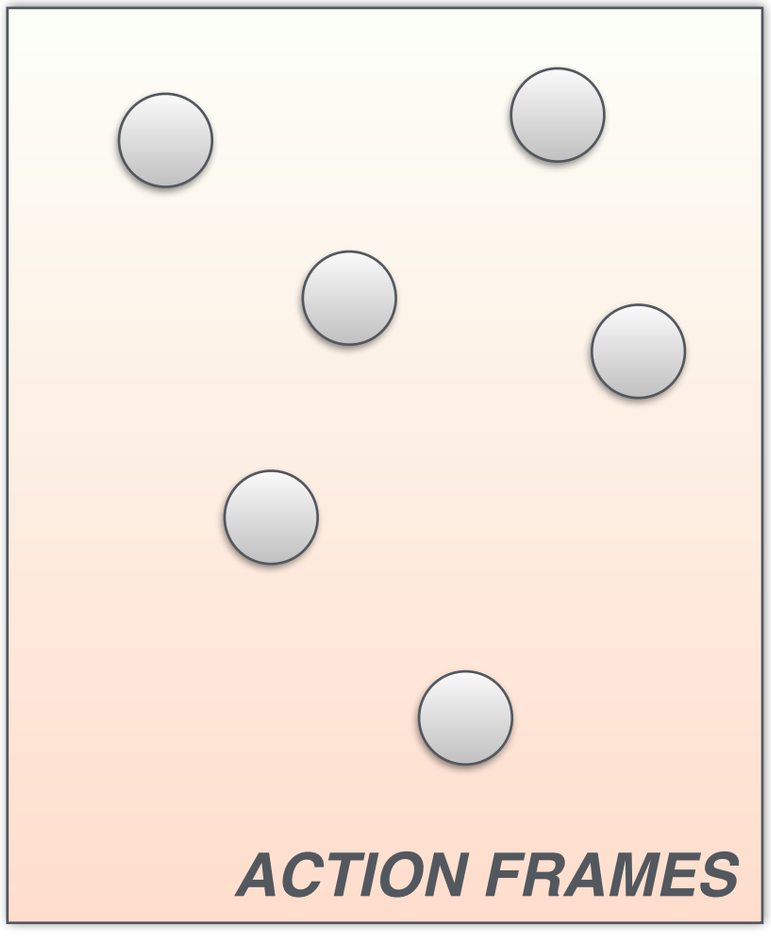


$$F^{\text{size}}_{\text{threw}_1} \approx \text{“}x \text{ threw } y\text{”}$$

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

Random variables $F^a_{v_t}$

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



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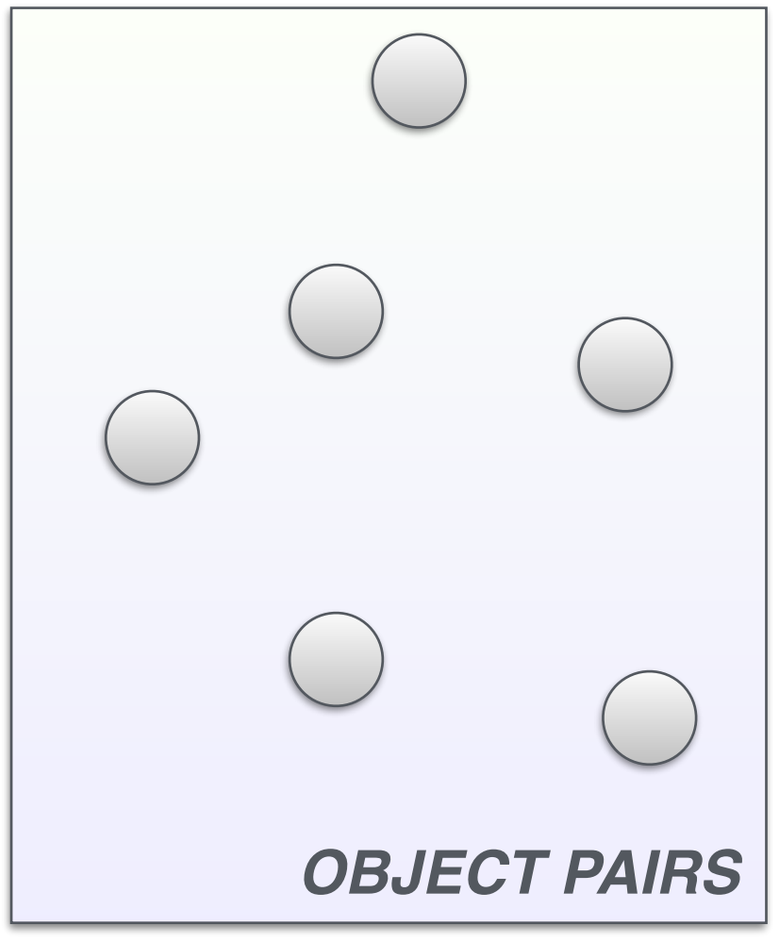

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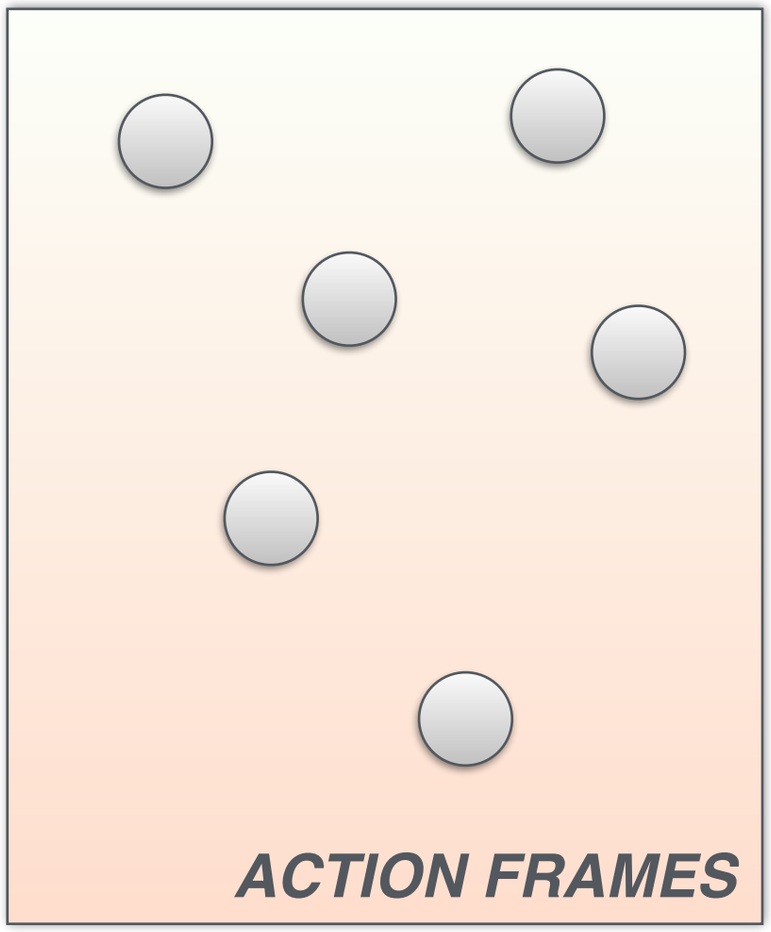

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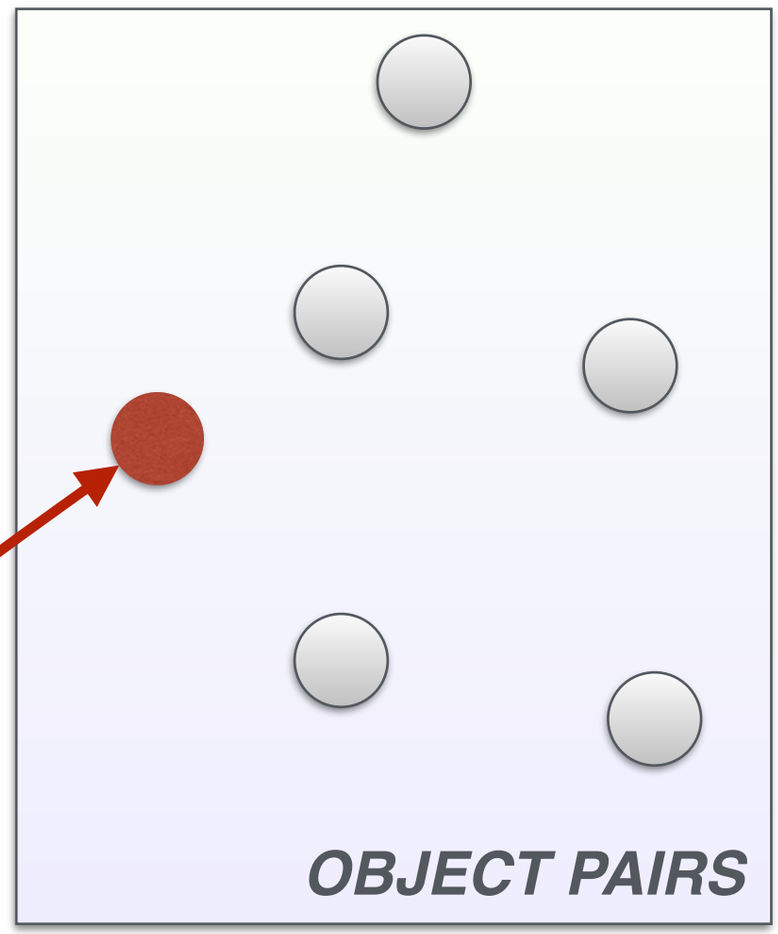

$$J^{\text{size}}_{\text{PERSON},ball} \approx (\text{PERSON},\ \text{ball})$$

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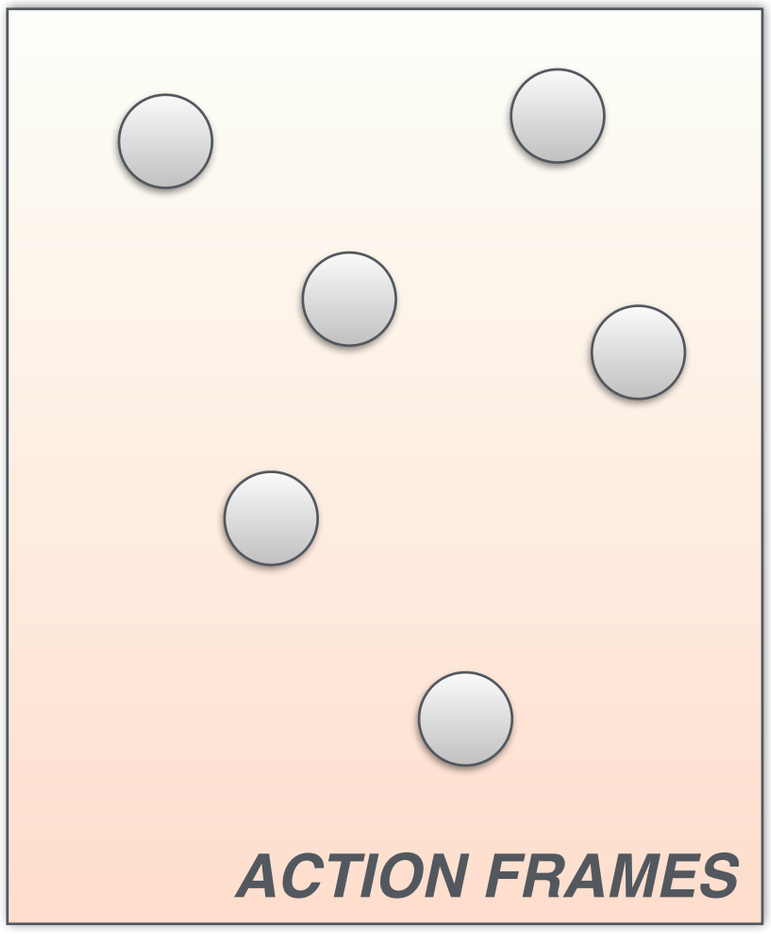

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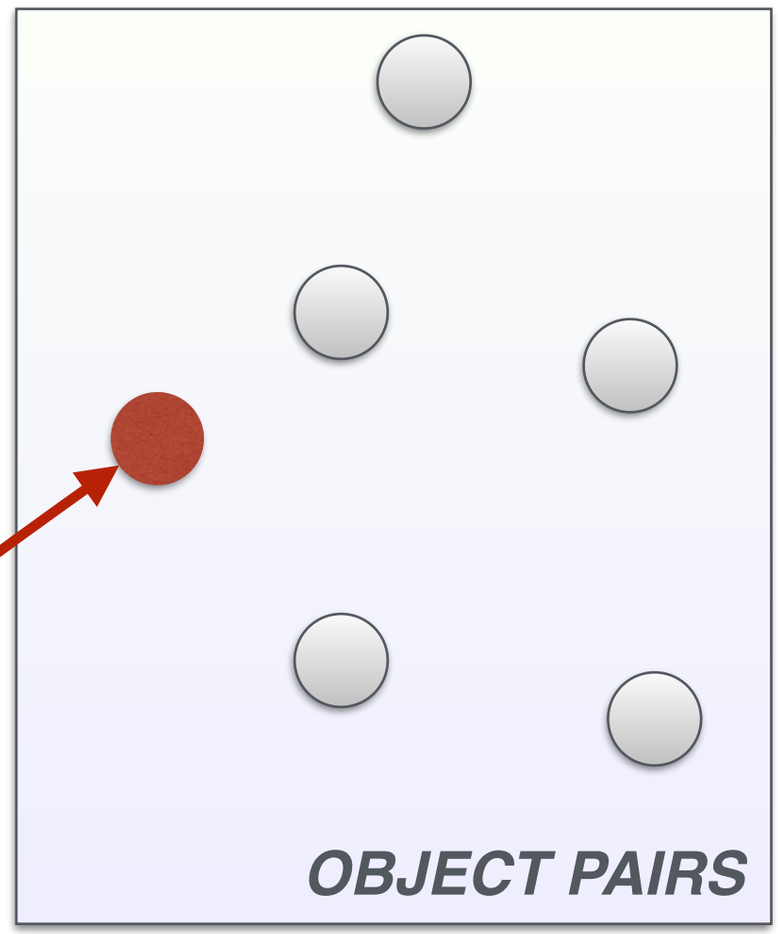

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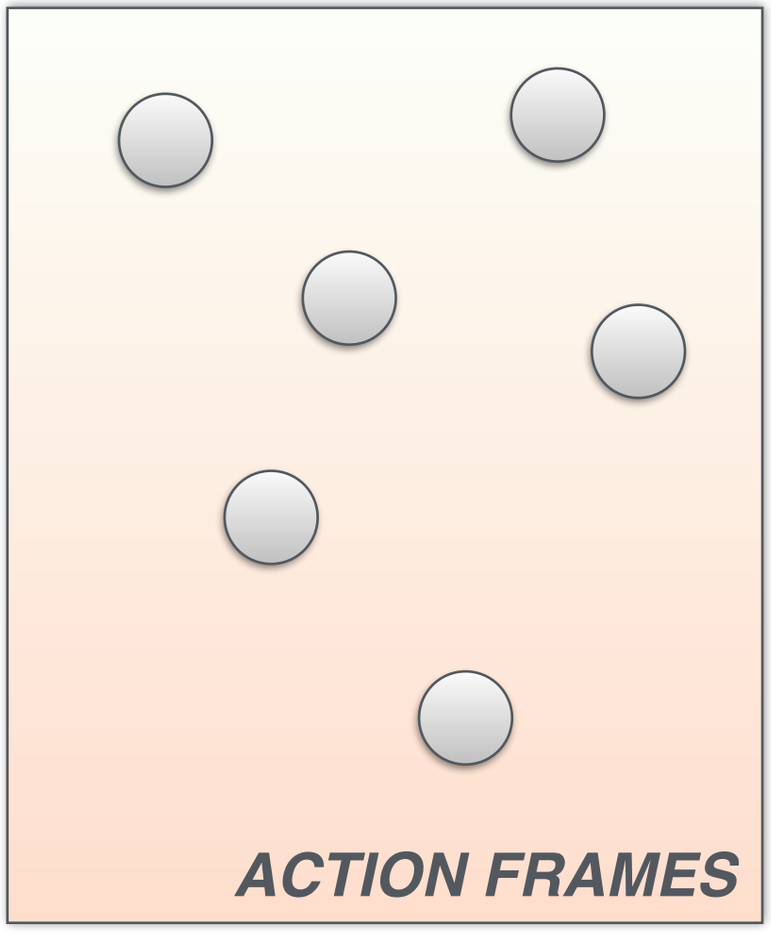

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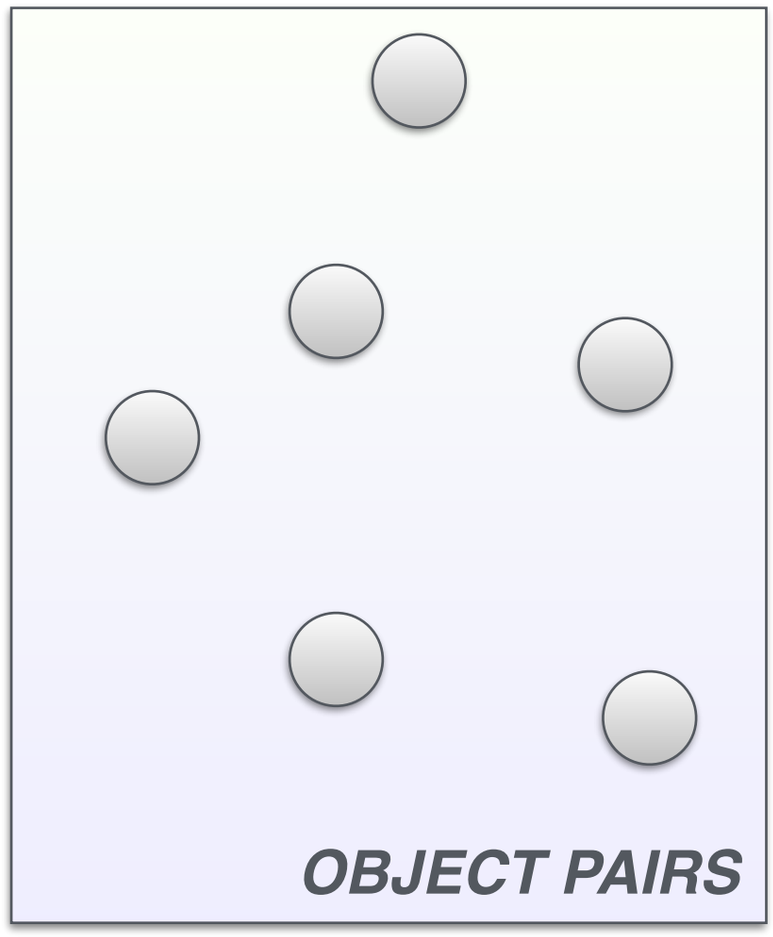

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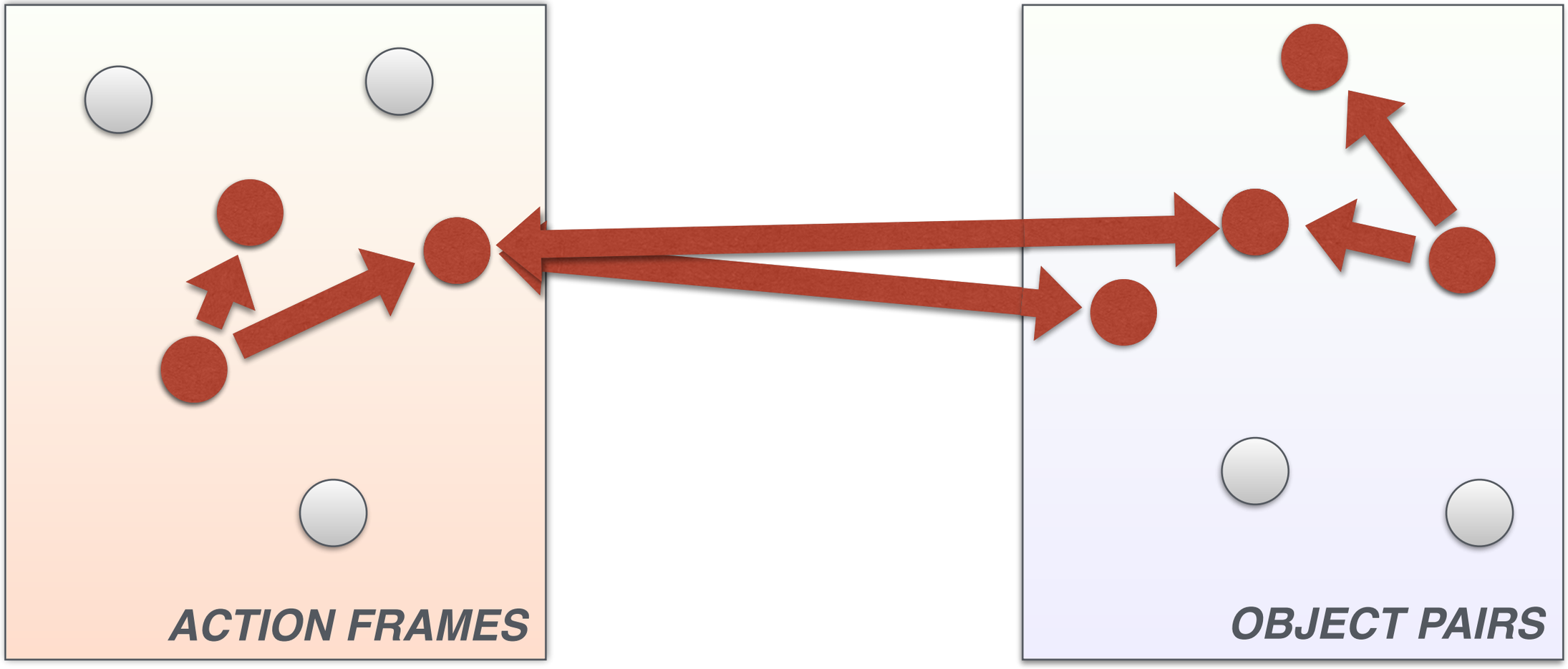
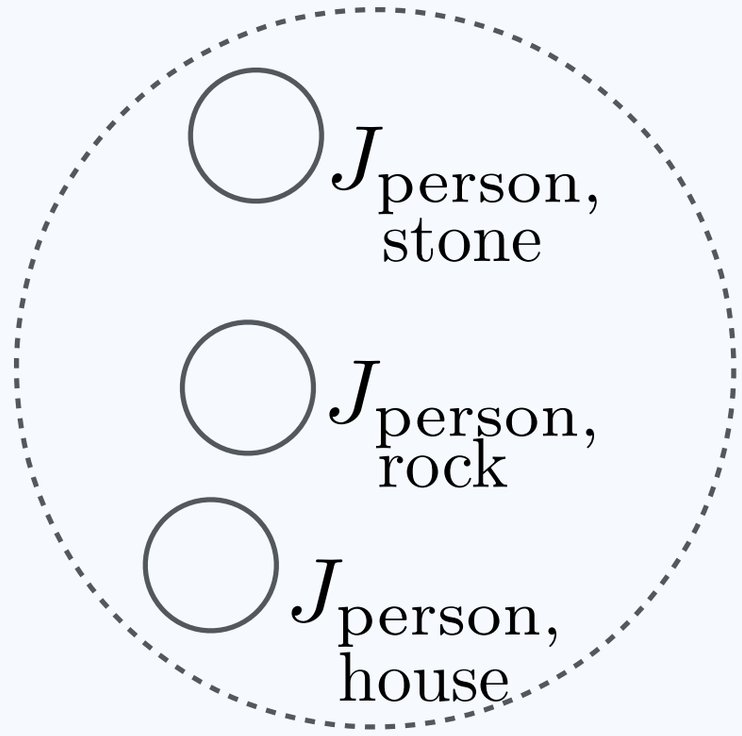


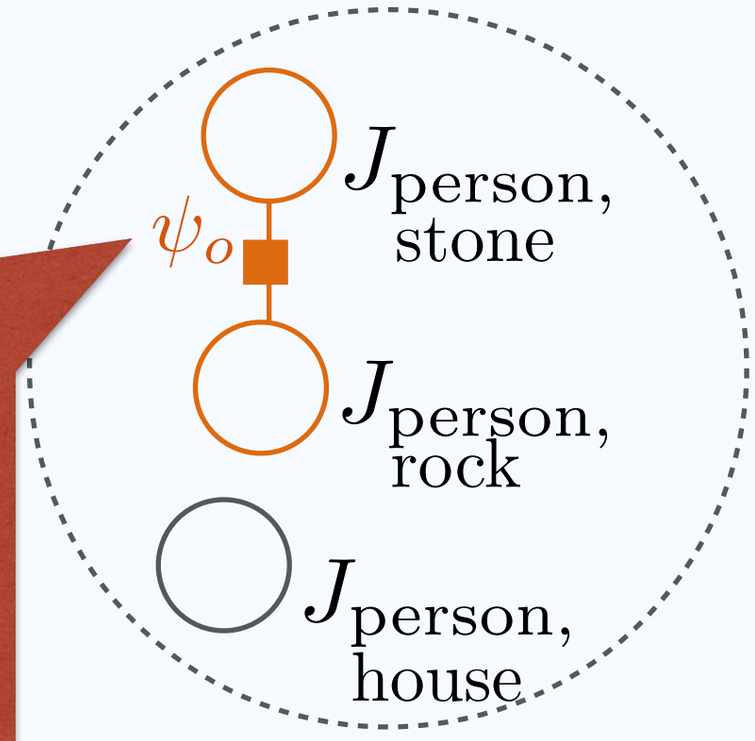
Object pair
random variables



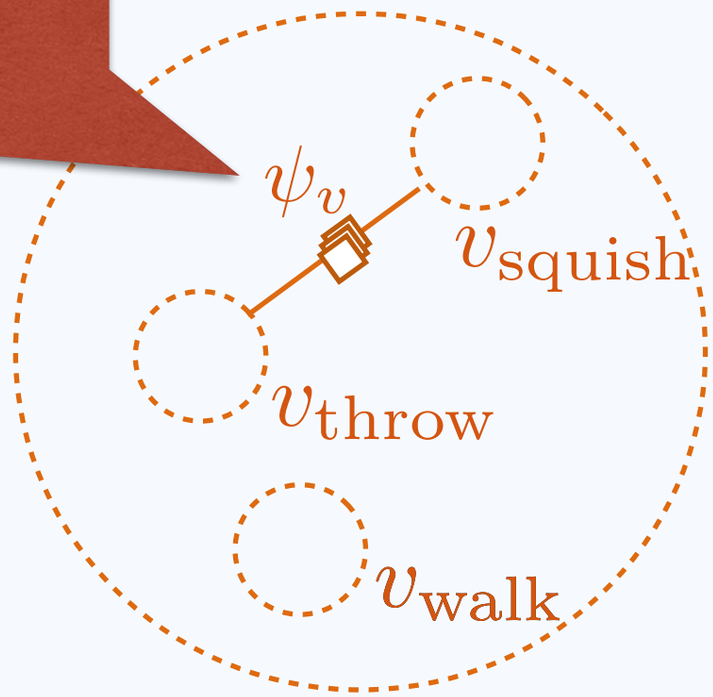
size

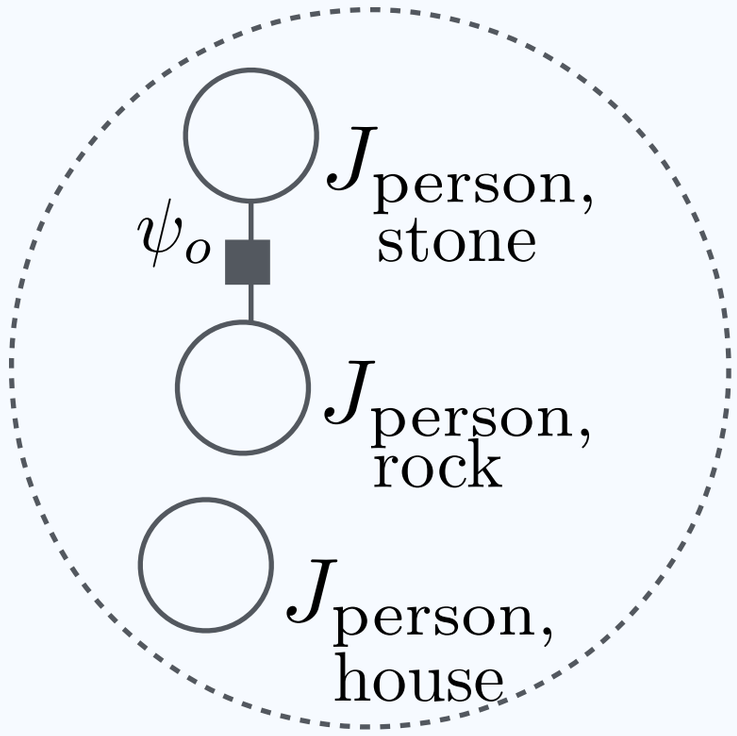
size

Object similarity
binary factors



Verb similarity
binary factors



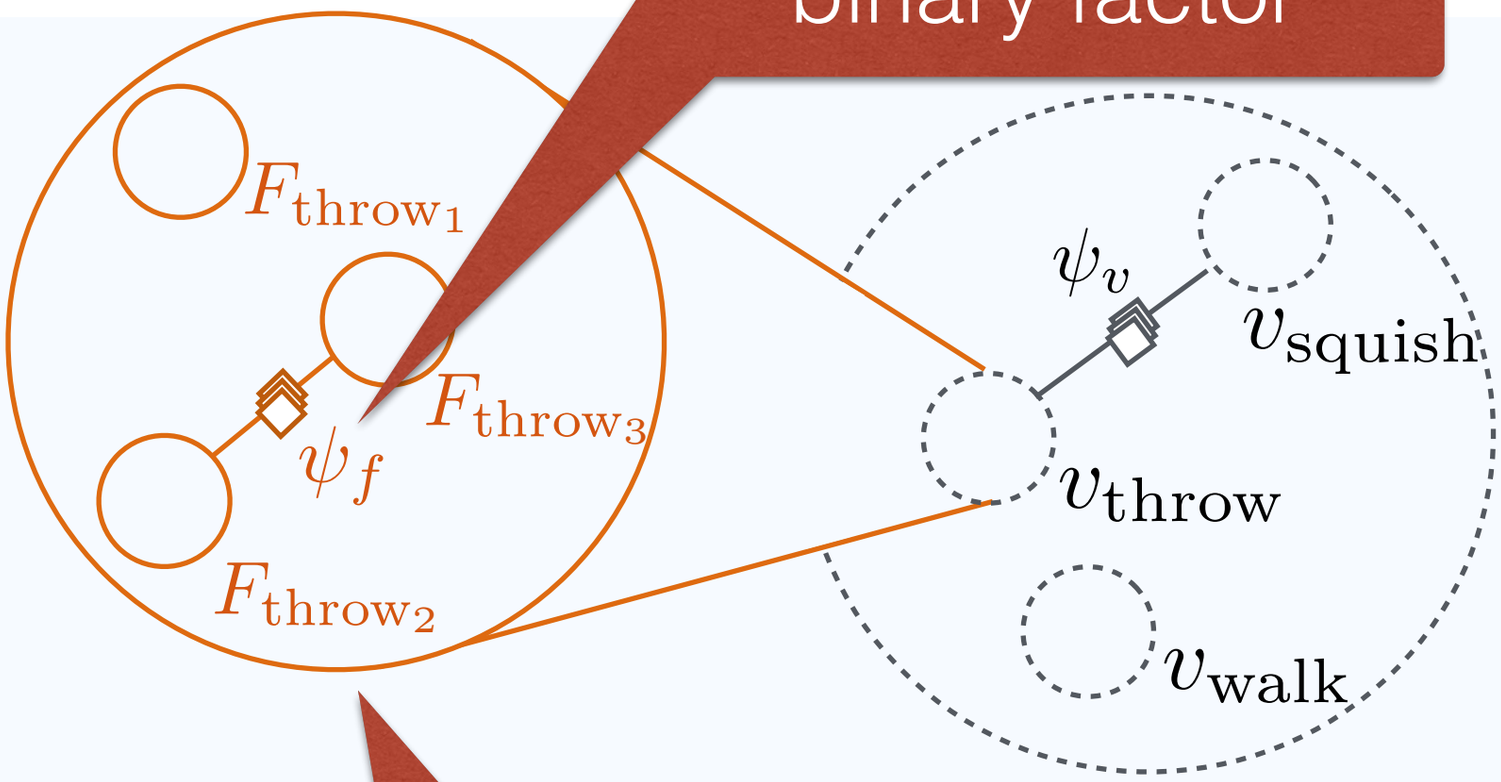


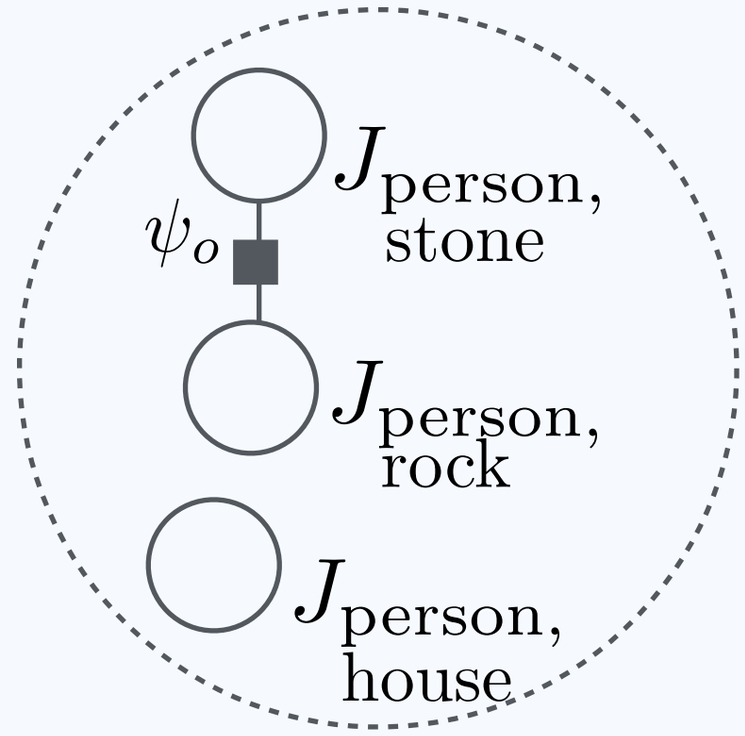
Action frames
grouped by **verb**

size

Similar frame construction
binary factor

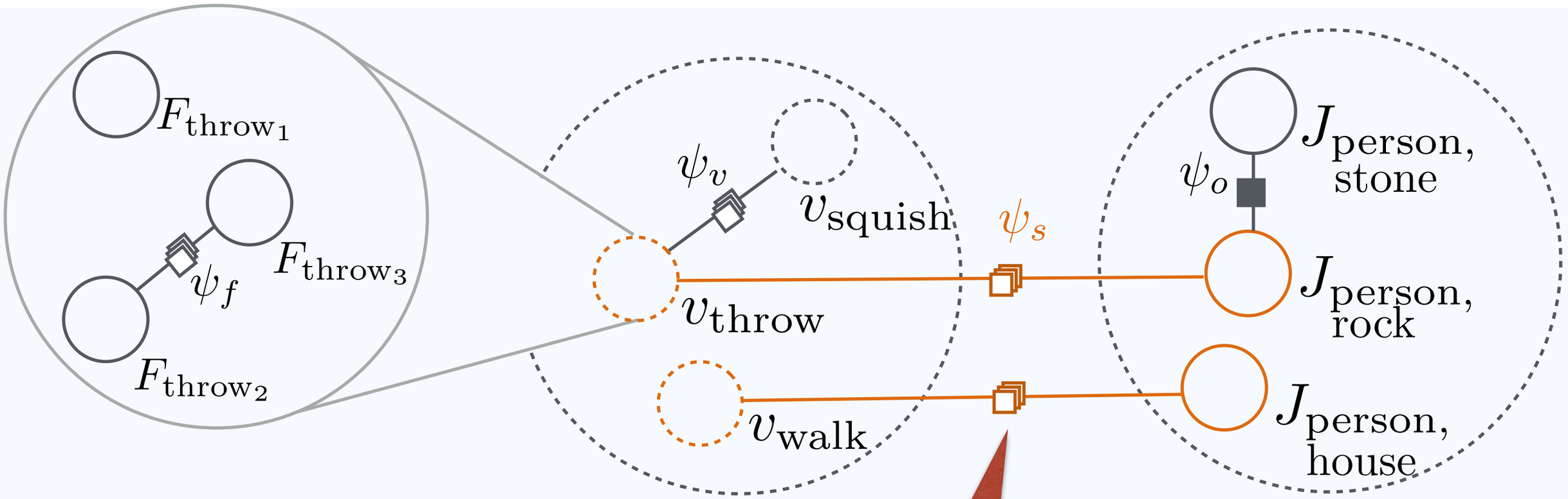
size





Several
action frames
per verb

size



Action-object compatibility
binary factors

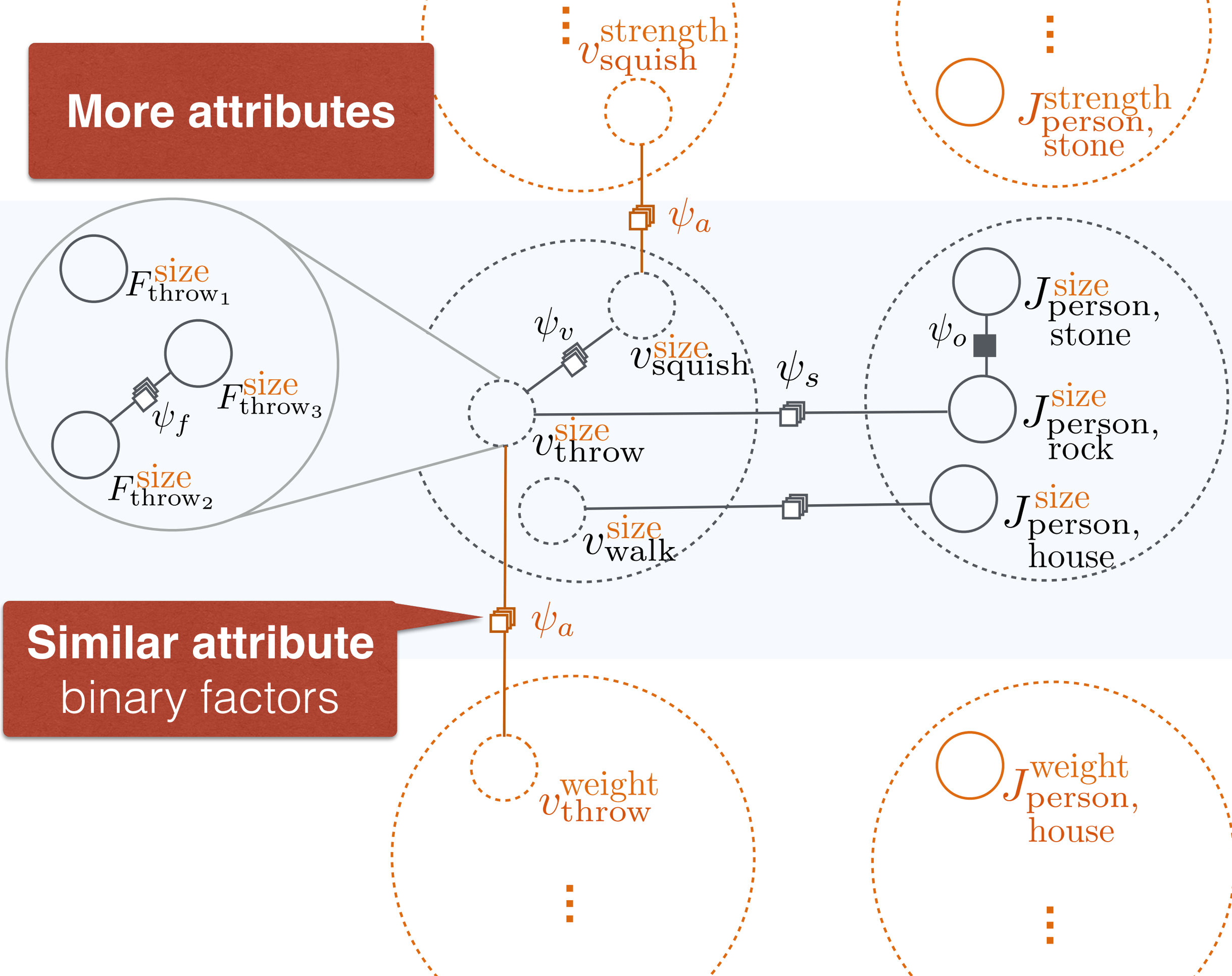
strength

size

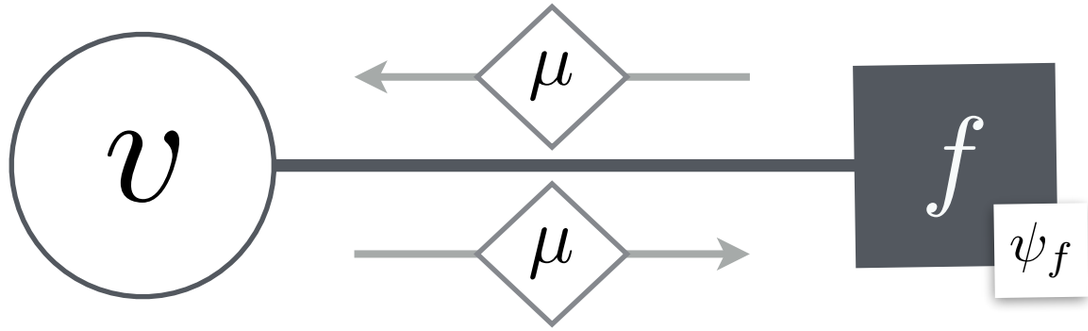
weight

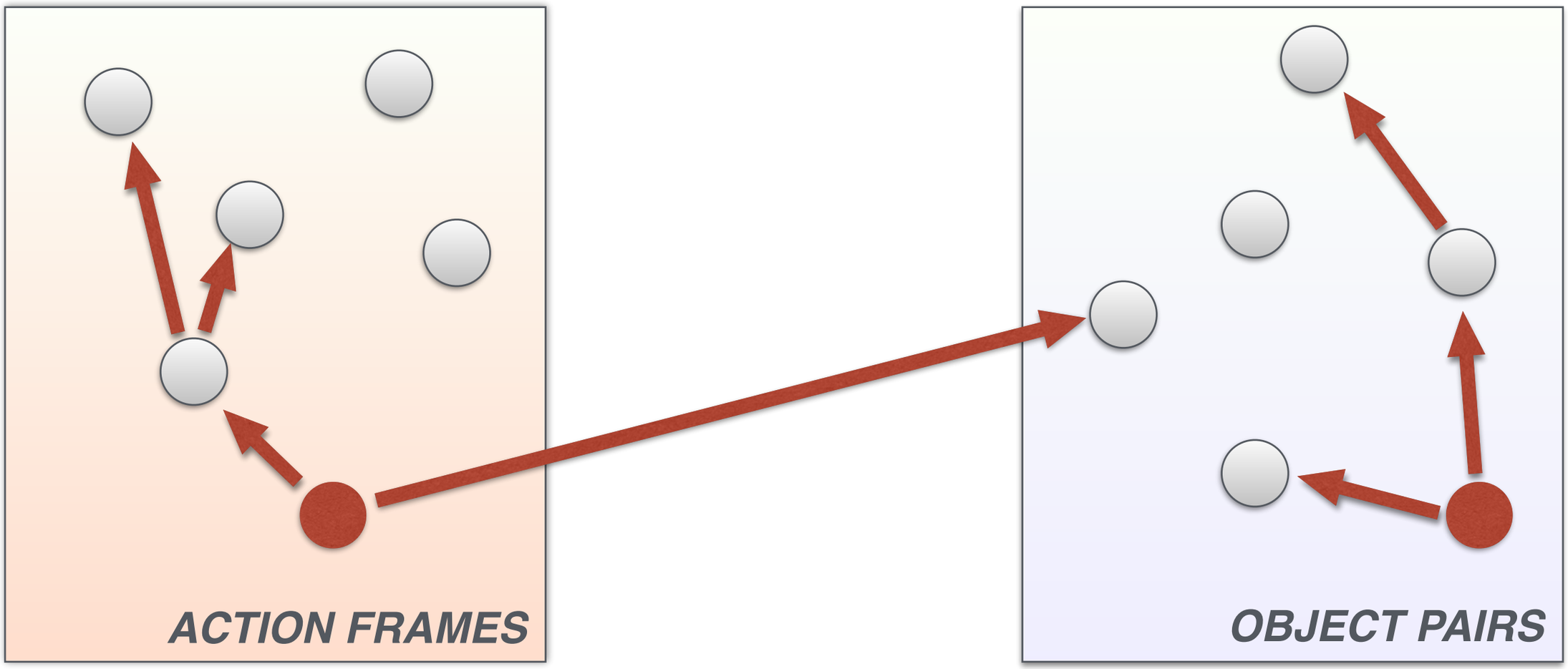
More attributes

Similar attribute
binary factors



Loopy belief propagation





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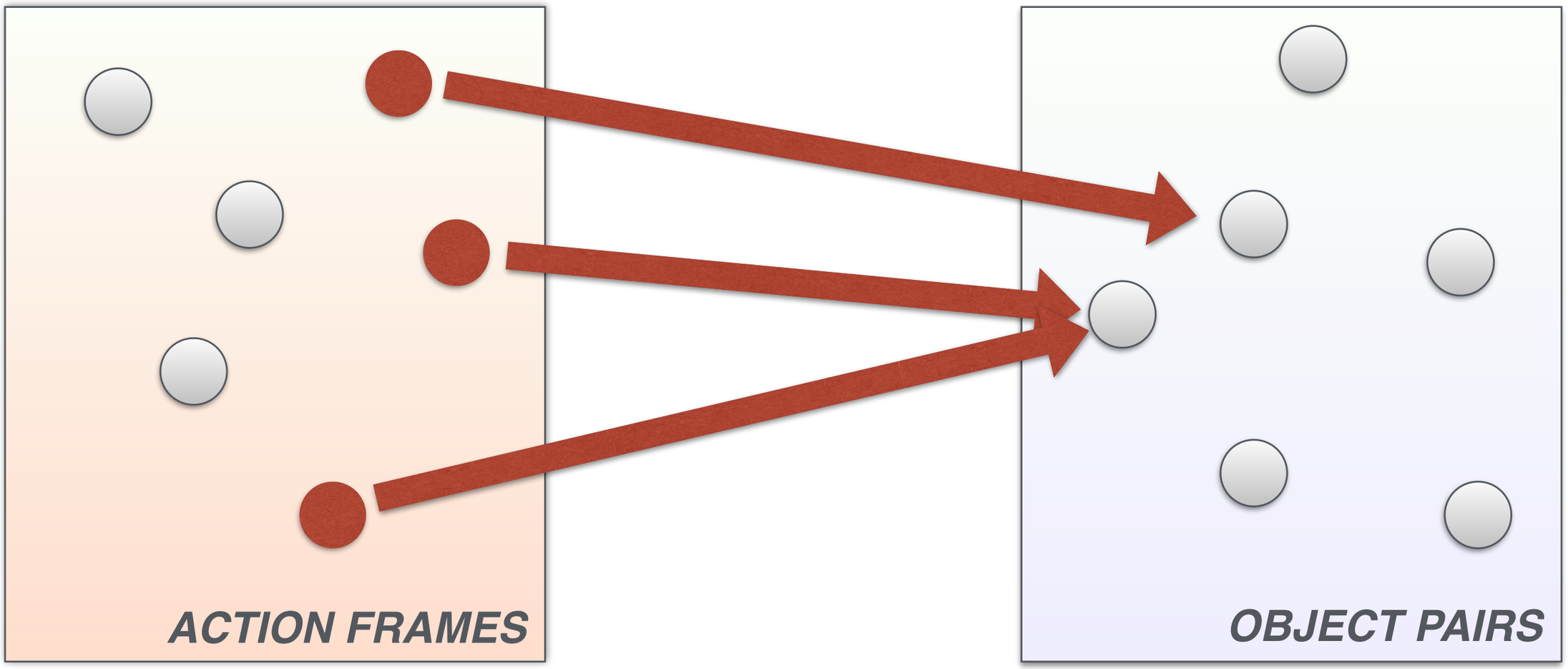
Why collect data?



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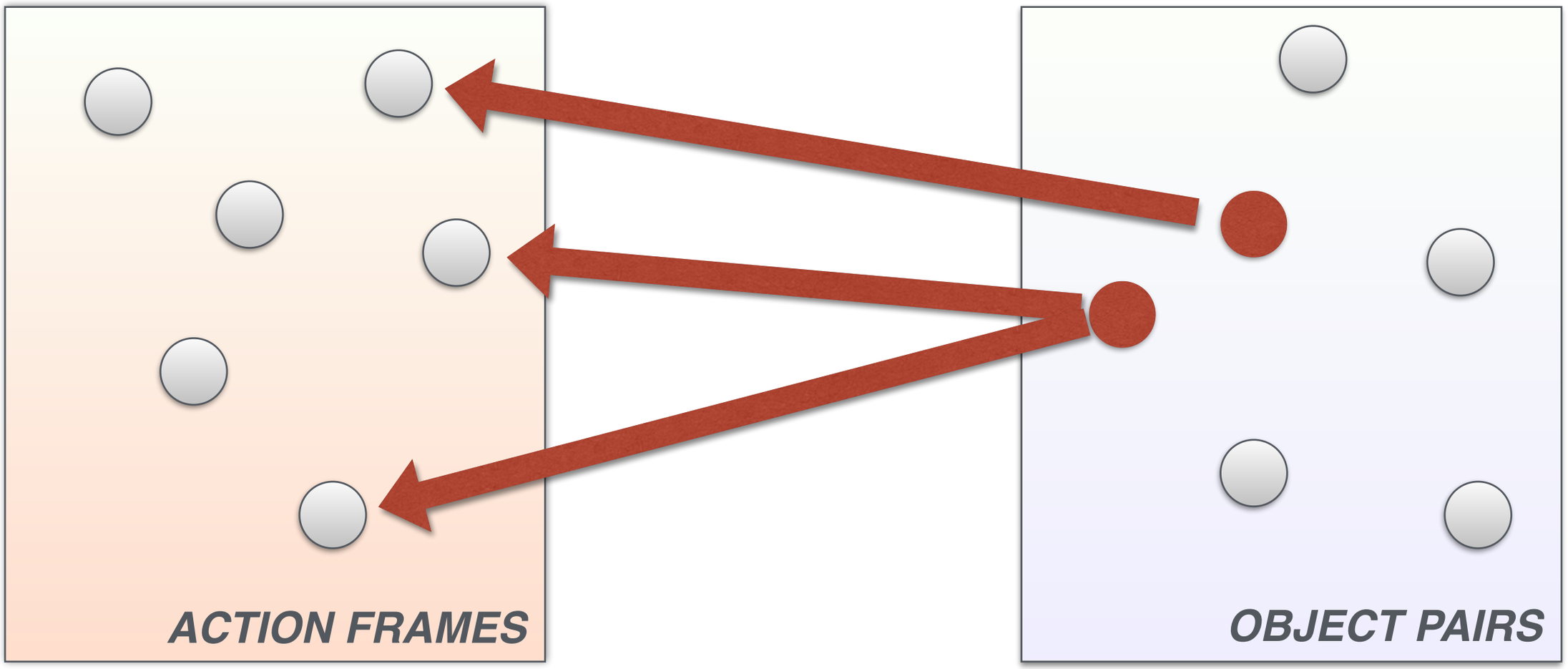

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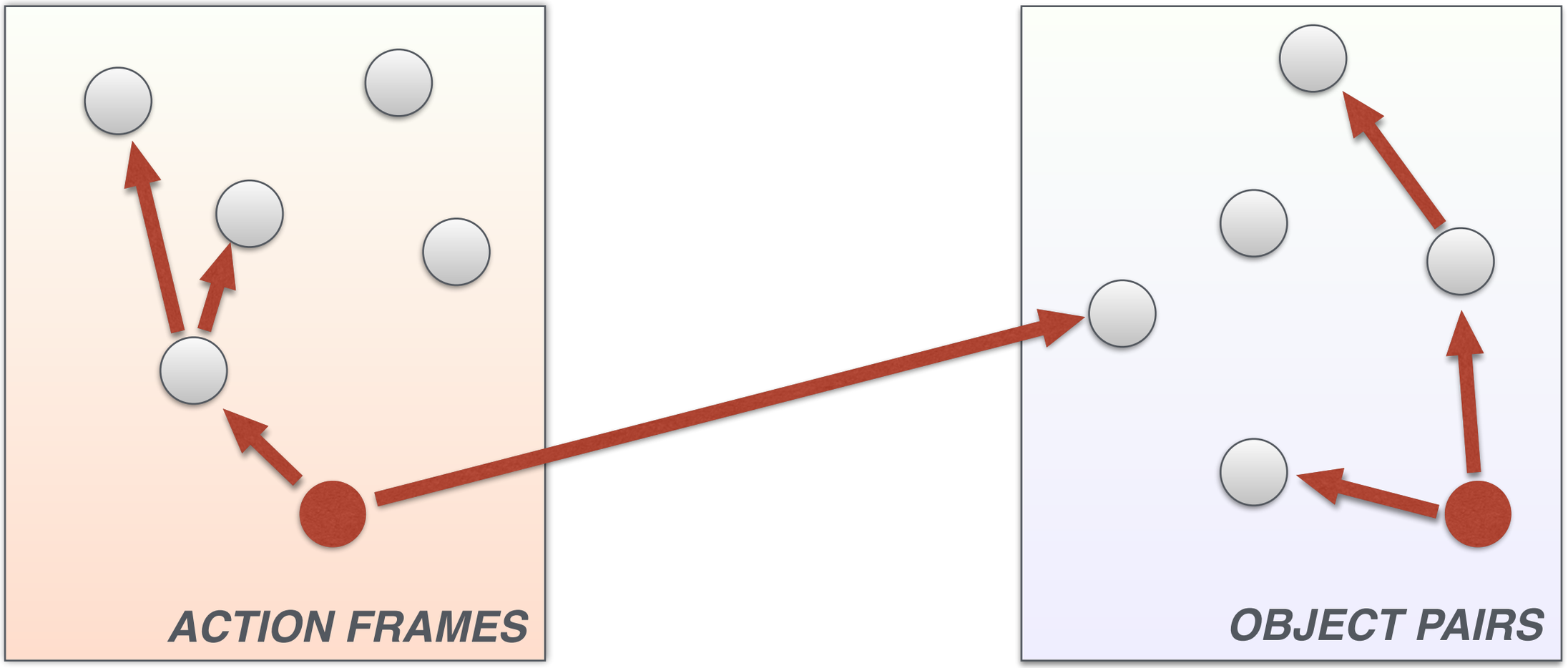

- Small **seed set** (5%) breaks symmetry
- **Evaluate** generalizability (dev = 45%, test = 50%)

Selecting frames and objects

Verbs

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

“Action” verbs

[Levin, 1993]

Selecting frames and objects

Verbs

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- …

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

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Action frames

…

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- ~~*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]

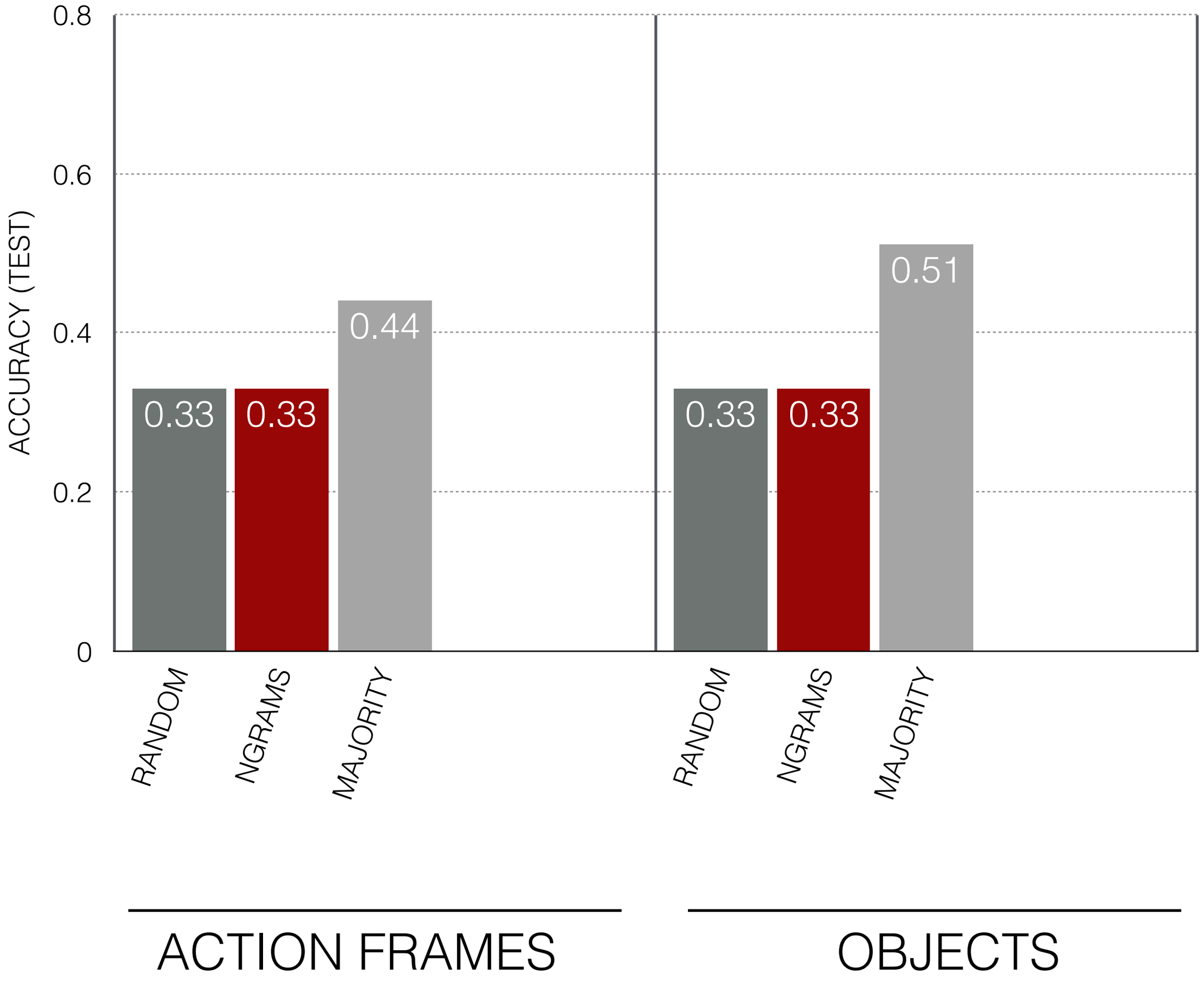
Data statistics

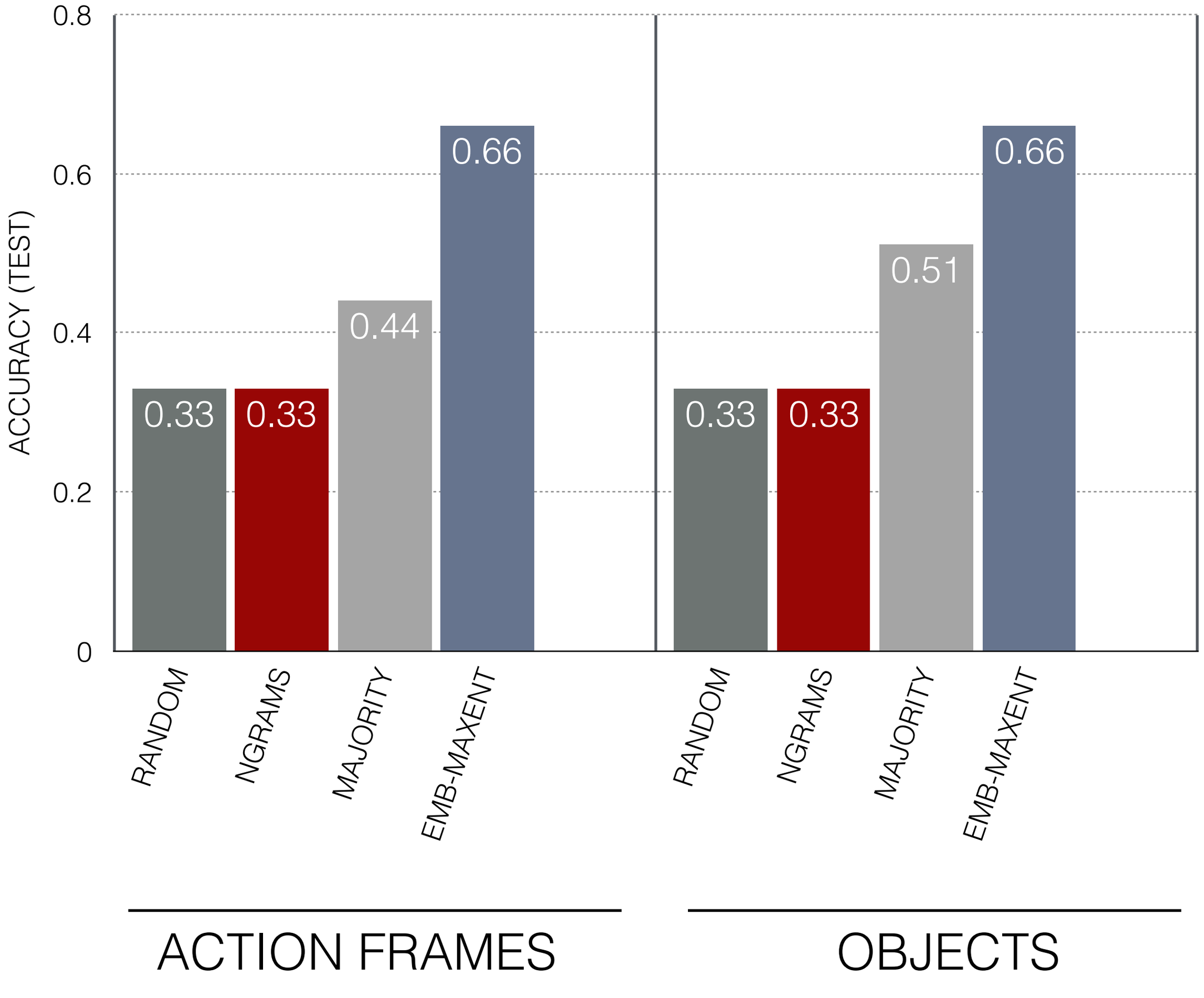
	Total
Verbs	100
Frames	813
Object pairs	3656

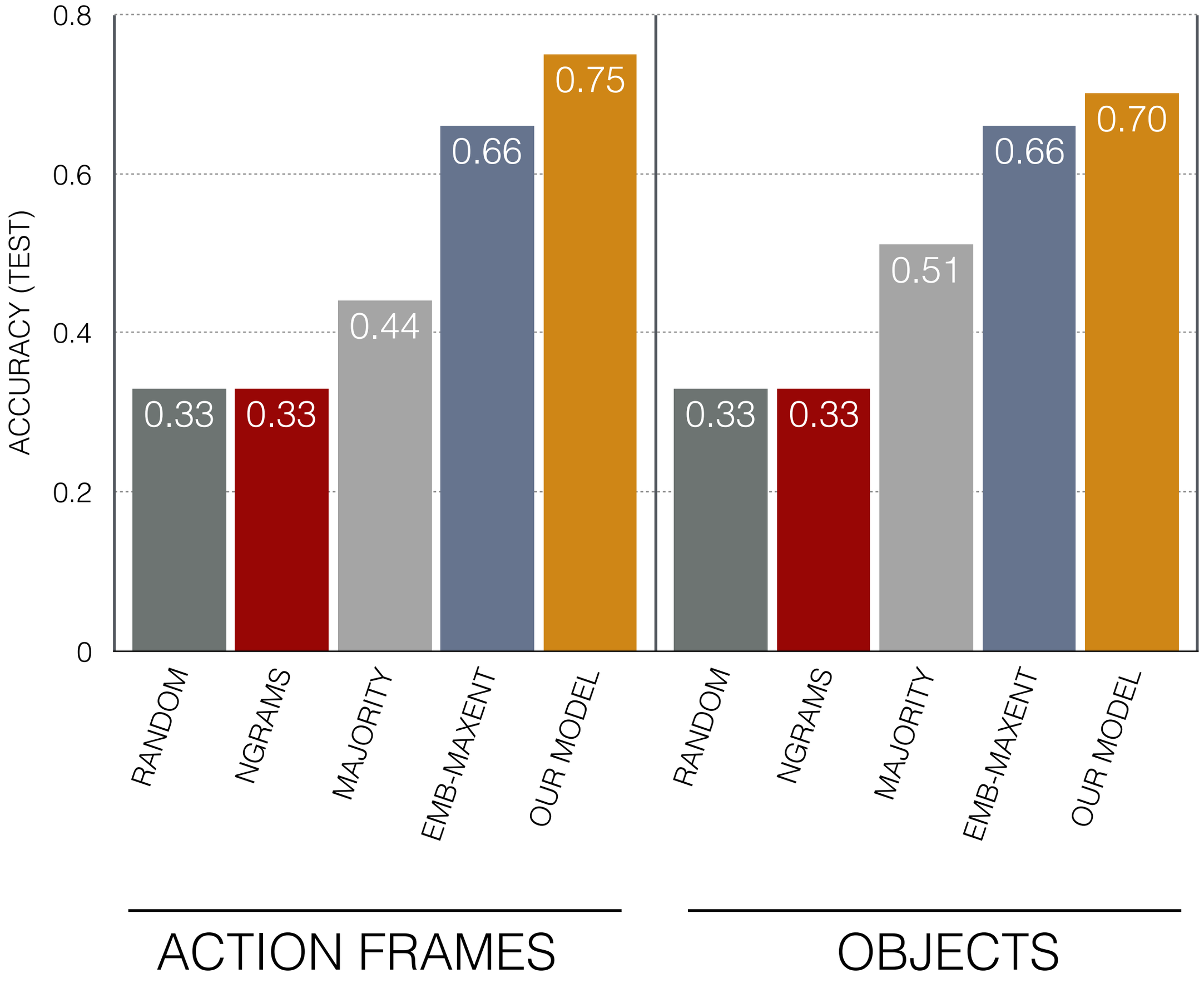
~8 action frames / verb

~200 distinct objects

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


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


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


ACCURACY (TEST)
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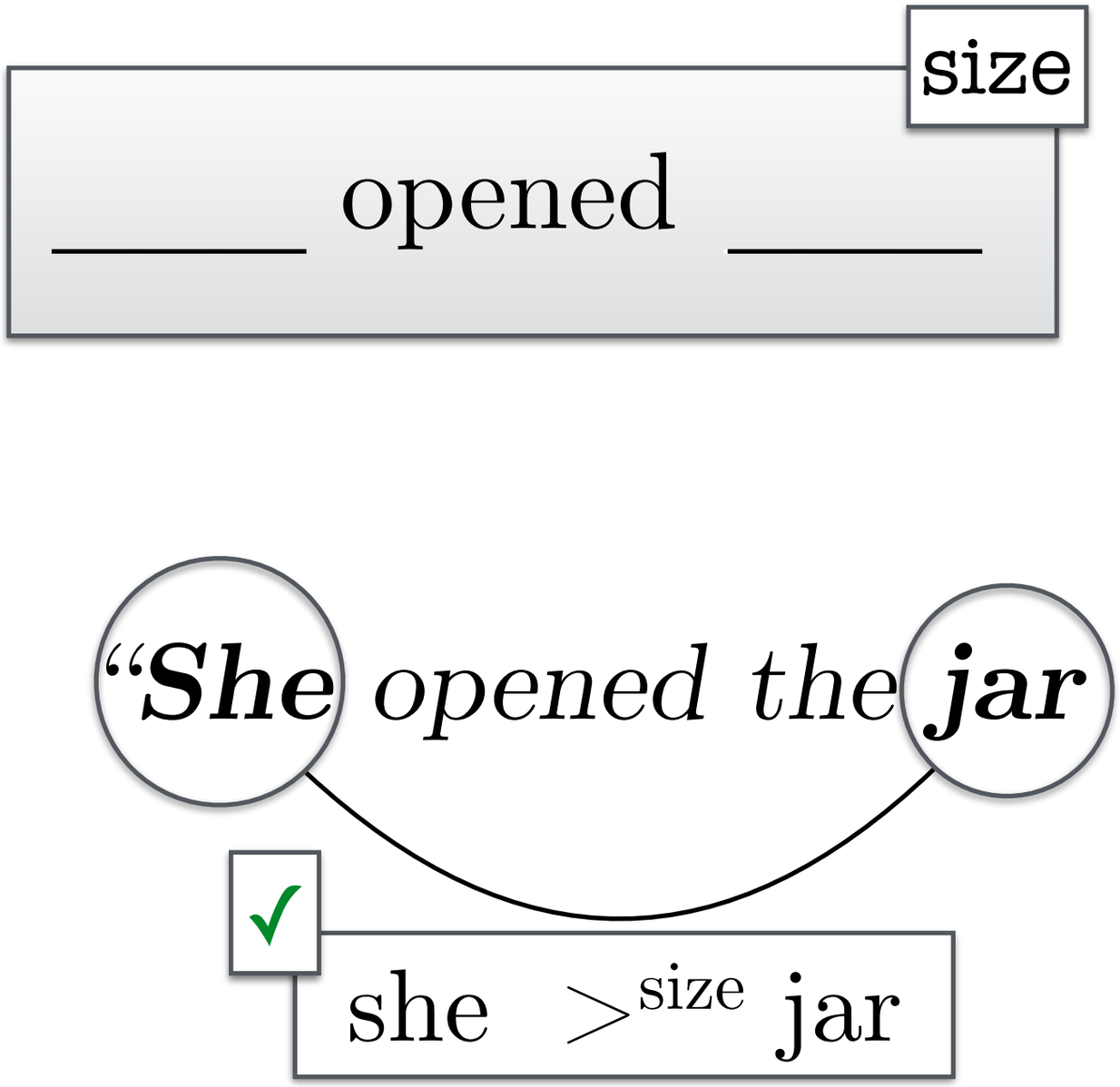
0.6
0.4
0.2
0
0.33
0.33
0.44
0.66
0.75
0.33
0.33
0.51
0.66
0.70
RANDOM
NGRAMS
MAJORITY
EMB-MAXENT
OUR MODEL
RANDOM
NGRAMS
MAJORITY
EMB-MAXENT
OUR MODEL
ACTION FRAMES
OBJECTS



Correct dev set examples

weight

PERSON set _____ upon _____

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

✓

kettle $<^{\text{weight}}$ stove

Correct dev set examples

speed

_____ caught _____

our model

she $>^{\text{speed}}$ runner

– “***She*** *caught the* ***runner*** *in first.”*

– “***She*** *caught the* ***baseball.”***

ground truth

she $<^{\text{speed}}$ baseball

polysemy

Incorrect *dev set examples*

PERSON stopped _____ with _____

weight

our model

fly $<^{\text{weight}}$ jar

- *"He stopped a **fly** with a **jar**."*

- *"She stopped the **car** with the **brake**."*

ground truth

car $>^{\text{weight}}$ brake

complex physics

***Incorrect** dev set examples*

Summary

- Reverse engineer **commonsense physical knowledge**

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

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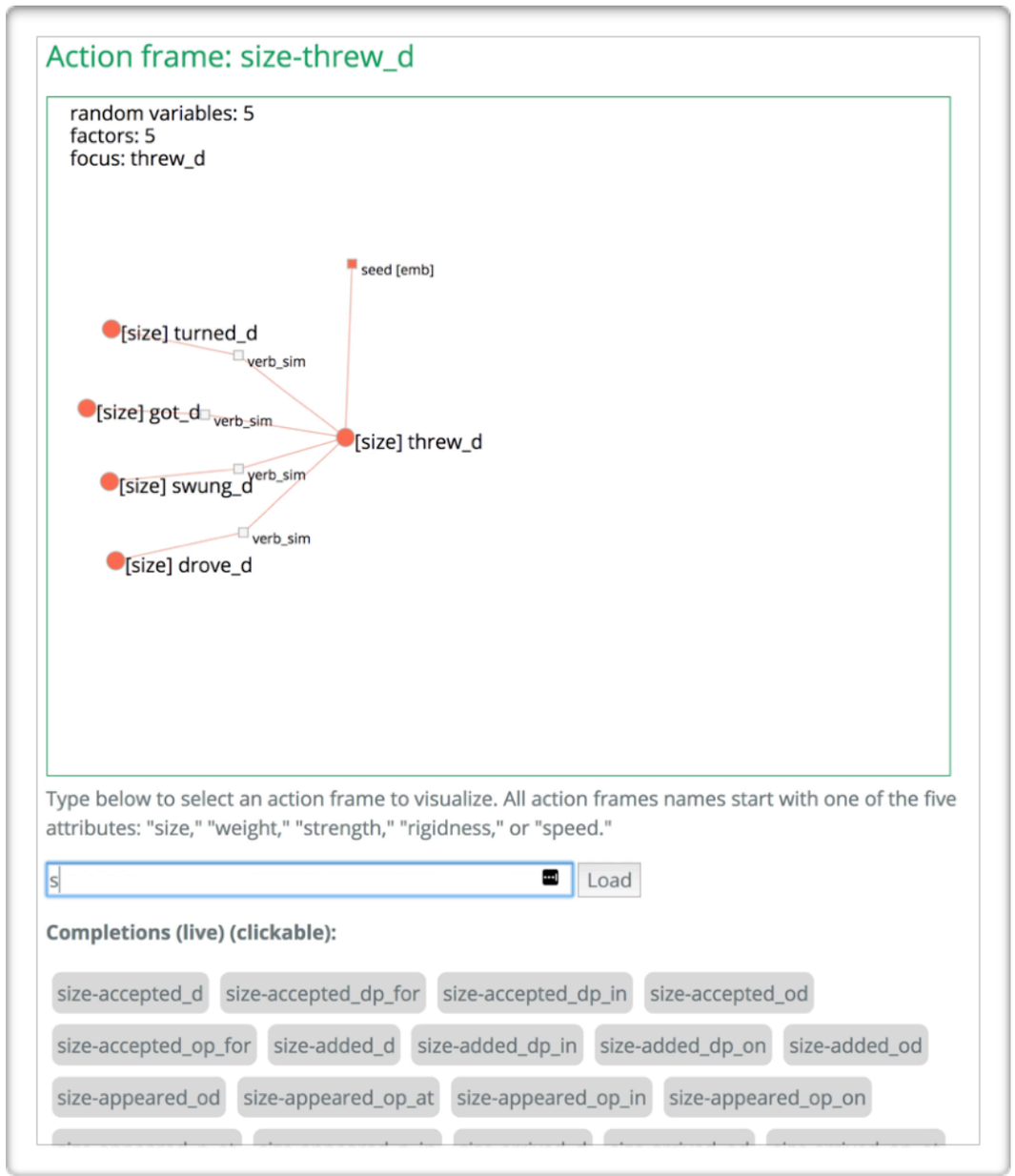
Summary

- Reverse engineer **commonsense physical knowledge**

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

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



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