






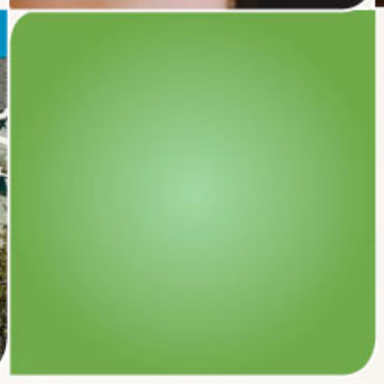

Automated Story Generation

Mark Riedl

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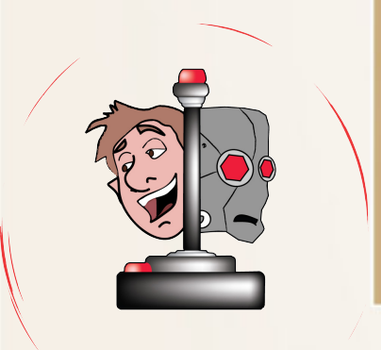


Georgia Tech College of Computing

School of Interactive Computing

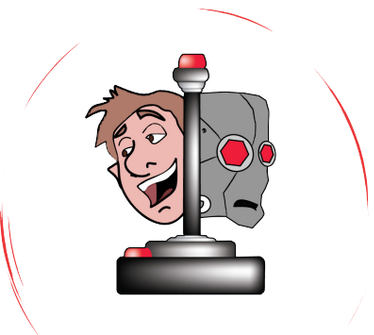
History

- Can computers communicate with humans in natural language?

- News stories, fairy tales, children's stories were readily available and considered "simple enough"

- A lot of early natural language understanding was narrative understanding

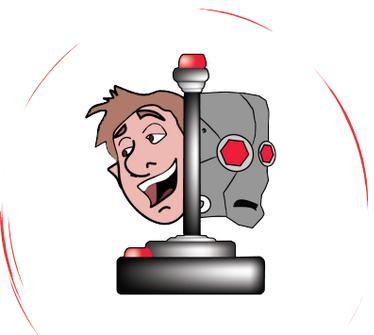
- What about generating narratives?



Generative grammar

Grimes, c. 1960s

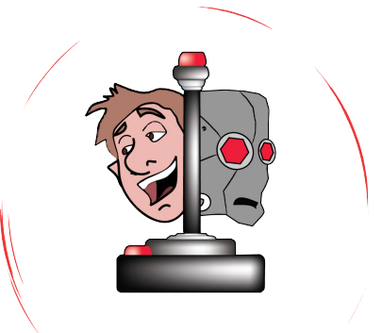
```
A LION HAS BEEN IN TROUBLE FOR A LONG TIME. A DOG STEALS SOMETHING THAT
BELONGS TO THE LION. THE HERO, LION, KILLS THE VILLAIN, DOG, WITHOUT A
FIGHT. THE HERO, LION, THUS IS ABLE TO GET HIS POSSESSION BACK.
```



Rule systems

Talespin, Meehan, 1975

ONCE UPON A TIME GEORGE ANT LIVED NEAR A PATCH OF GROUND. THERE WAS A NEST IN AN ASH TREE. WILMA BIRD LIVED IN THE NEST. THERE WAS SOME WATER IN A RIVER. WILMA KNEW THAT THE WATER WAS IN THE RIVER. GEORGE KNEW THAT THE WATER WAS IN THE RIVER. ONE DAY WILMA WAS VERY THIRSTY. WILMA WANTED TO GET NEAR SOME WATER. WILMA FLEW FROM HER NEST ACROSS A MEADOW THROUGH A VALLEY TO THE RIVER. WILMA DRANK THE WATER. WILMA WAS NOT THIRSTY ANY MORE.



Stories exist as written artifacts

Stories exist as cognitive structures

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Natural language processing

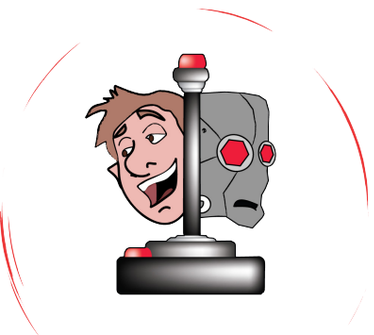
Stories exist as written artifacts

Stories exist as cognitive structures

Natural language processing

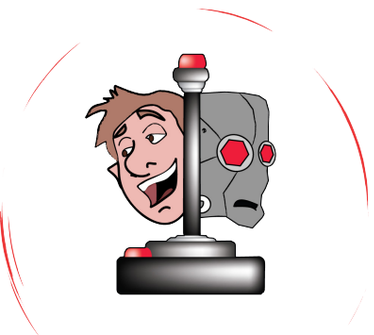
Story generation

Computer as author



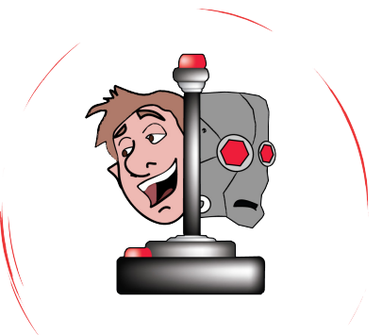
Computer as author

- Creative writing is a problem-solving activity



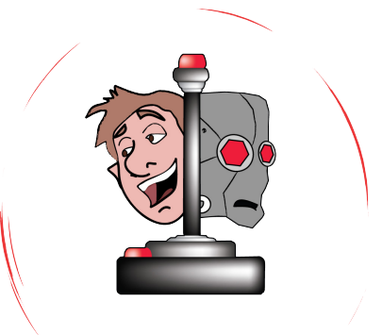
Computer as author

- Creative writing is a problem-solving activity
- We know how to build AI problem-solvers



Computer as author

- Creative writing is a problem-solving activity
- We know how to build AI problem-solvers
- Sentences vs. semantic constructs



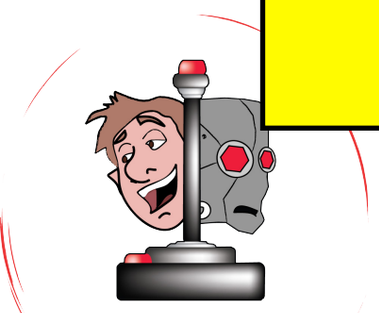
Computer as author

- Creative writing is a problem-solving activity
- We know how to build AI problem-solvers
- Sentences vs. semantic constructs

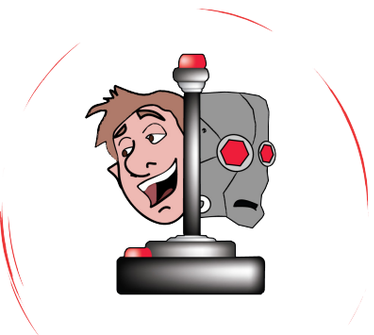
⟨ Sally killed John with umbrella ⟩

vs.

"Sally swung her umbrella with all her might. She knew that she would never be bothered by John's mansplaining again."

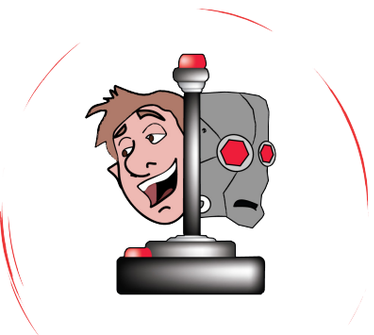


Hierarchical planning



Hierarchical planning

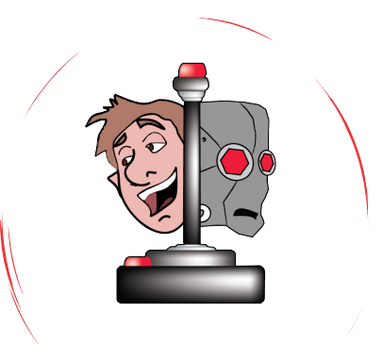
- Universe (Lebowitz, 1985)



Hierarchical planning

- Universe (Lebowitz, 1985)

```
PLOT FRAGMENT: forced-marriage
CHARACTERS: ?him ?her ?husband ?parent
CONSTRAINTS: (has-husband ?her)       {the husband character}
             (has-parent ?husband)    {the parent character}
             ( <  (trait-value ?parent 'niceness)  -5)
             (female-adult ?her)
             (male-adult ?him)
GOALS: (churn ?him ?her) {prevent them from being happy}
SUBGOALS: (do-threaten ?parent ?her "forget it") {threaten ?her}
          (dump-lover ?her ?him)        {have ?her dump ?him}
          (worry-about ?him)            {have someone worry about ?him}
          (together * ?him)             {get ?him involved with someone else}
          (eliminate ?parent)           {get rid of ?parent (breaking threat)}
          (do-divorce ?husband ?her)    {end the unhappy marriage}
          (or (churn ?him ?her)         {either keep churning or}
              (together ?her ?him))     {try and get ?her and ?him back together}
```



* (tell '(((churn neil liz)))

working on goal – (CHURN NEIL LIZ)
Several plans to choose from FORCED-MARRIAGE LOVERS-FIGHT JOB-PROBLEM
– using plan FORCED-MARRIAGE

working on goal – DO-THREATEN STEPHANO LIZ "forget it")
– using plan THREATEN

⋙ STEPHANO threatens LIZ: "forget it"

working on goal – (DUMP-LOVER LIZ NEIL) – using plan BREAK-UP

⋙ LIZ tells NEIL she doesn't love him

working on goal – (WORRY-ABOUT NEILL) – using plan BE-CONCERNED
Possible candidates – MARLENA JULIE DOUG ROMAN DON CHRIS KAYLA
Using MARLENA for WORRIER

⋙ MARLENA is worried about NEIL

working on goal – (TOGETHER * NEIL)
Several plans to choose from SEDUCTION DRUNKEN-SNEAK-IN
SYMPATHETIC-UNION JOB-TOGETHER
– using plan SEDUCTION
Possible candidates – DAPHNE RENEE
Using DAPHNE for SEDUCER

⋙ DAPHNE seduces NEIL

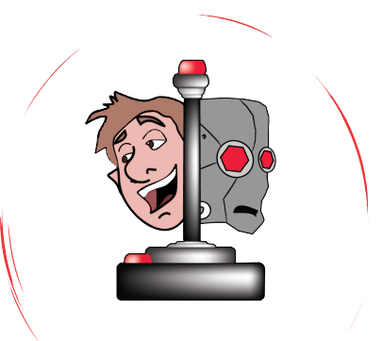
working on goal – (ELIMINATE STEPHANO)
Several plans to choose from ATTEMPTED-MURDER EXPOSE
– using plan ATTEMPTED-MURDER
Possible candidates – RENEE ALEX
Using RENEE for KILLER

⋙ RENEE tries to kill STEPHANO

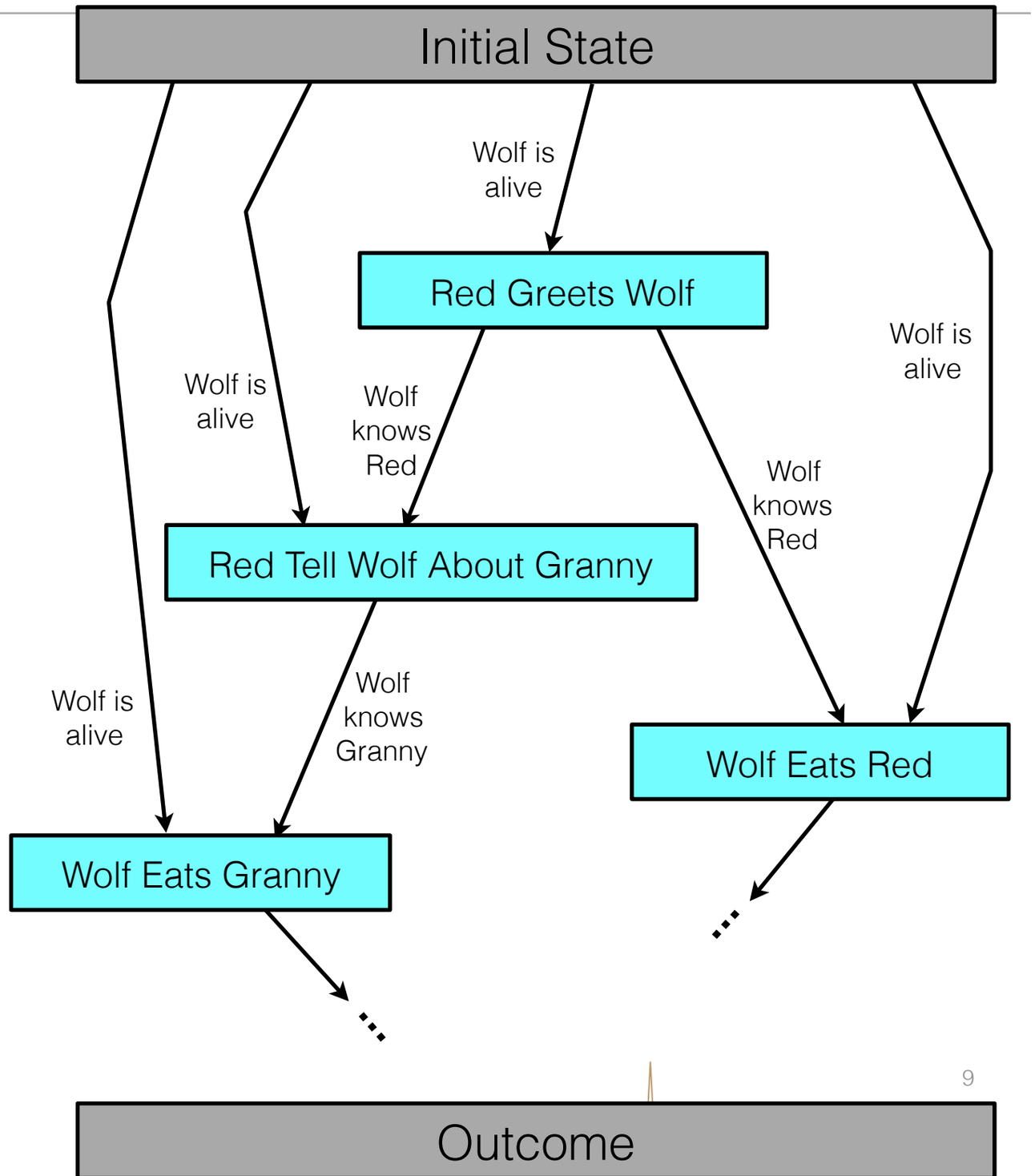
working on goal – (DO-DIVORCE TONY LIZ) – using plan DIVORCE

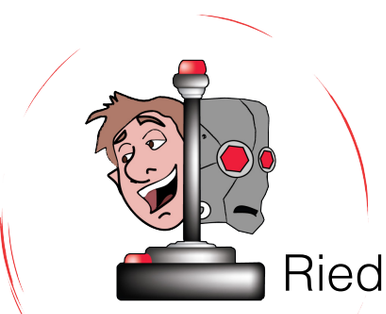
⋙ LIZ and TONY got divorced

working on goal – (TOGETHER LIZ NEIL)
no acceptable plans



Narratives as logical proofs

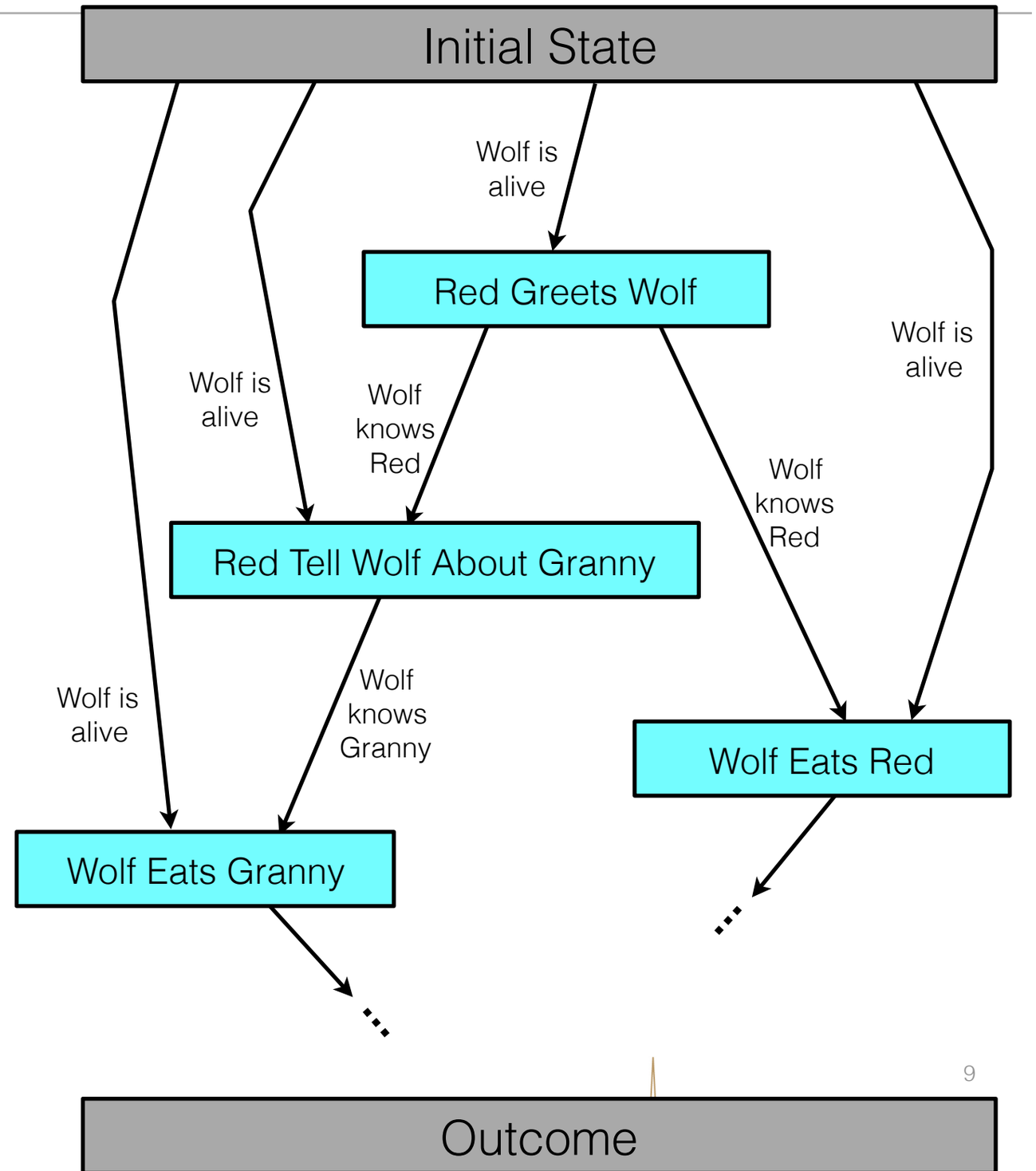


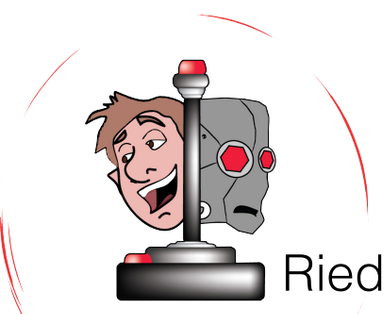


Riedl & Young. Journal of AI Research, 2010.

Narratives as logical proofs

- Actions have logical constraints
  - Pre-conditions
  - Post-conditions





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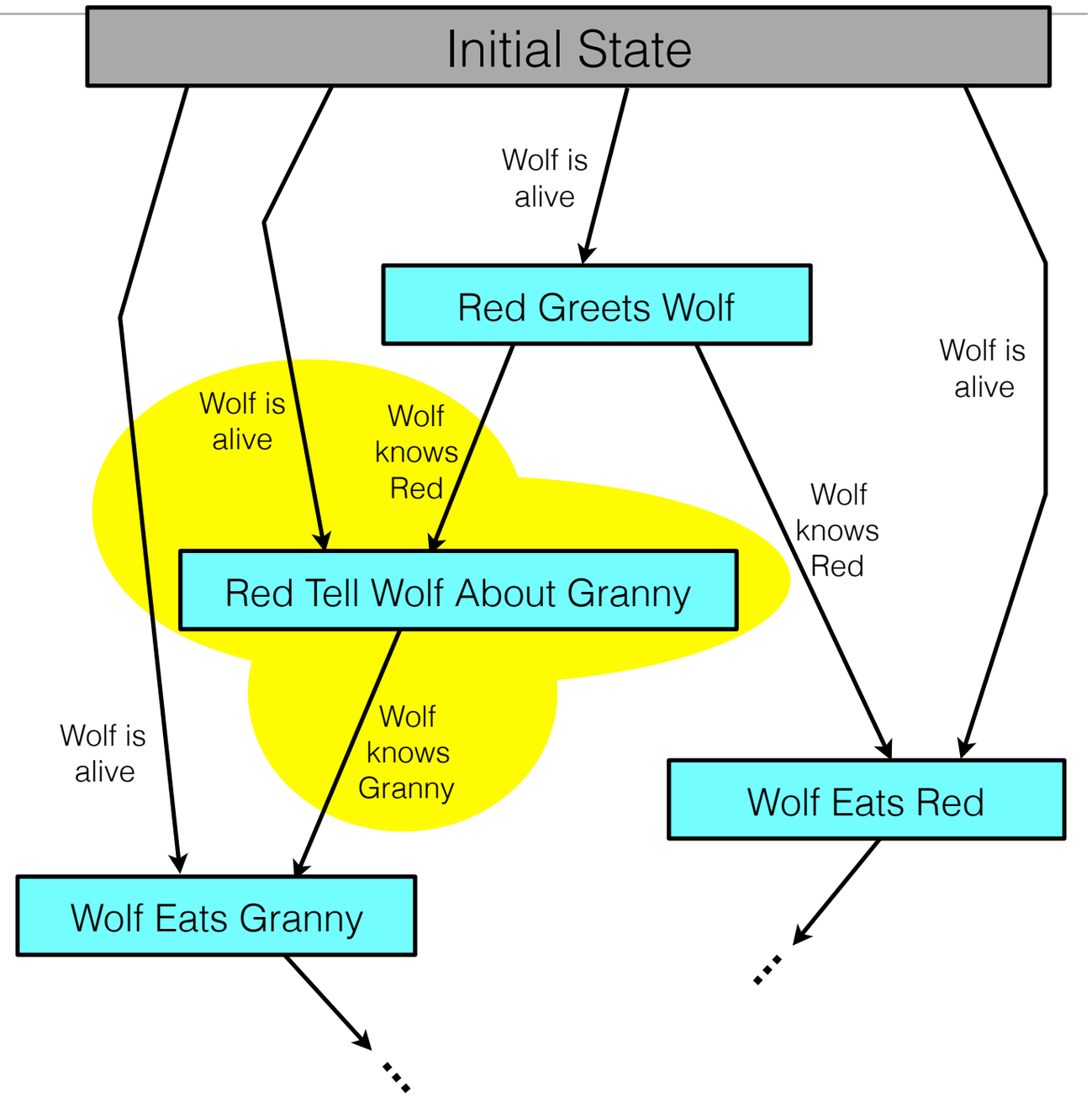

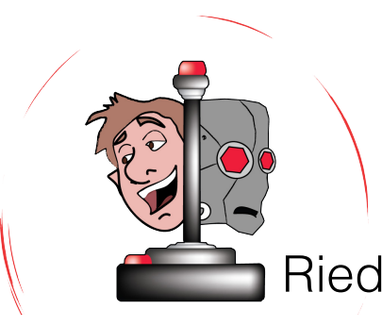

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Narratives as logical proofs

- Actions have logical constraints
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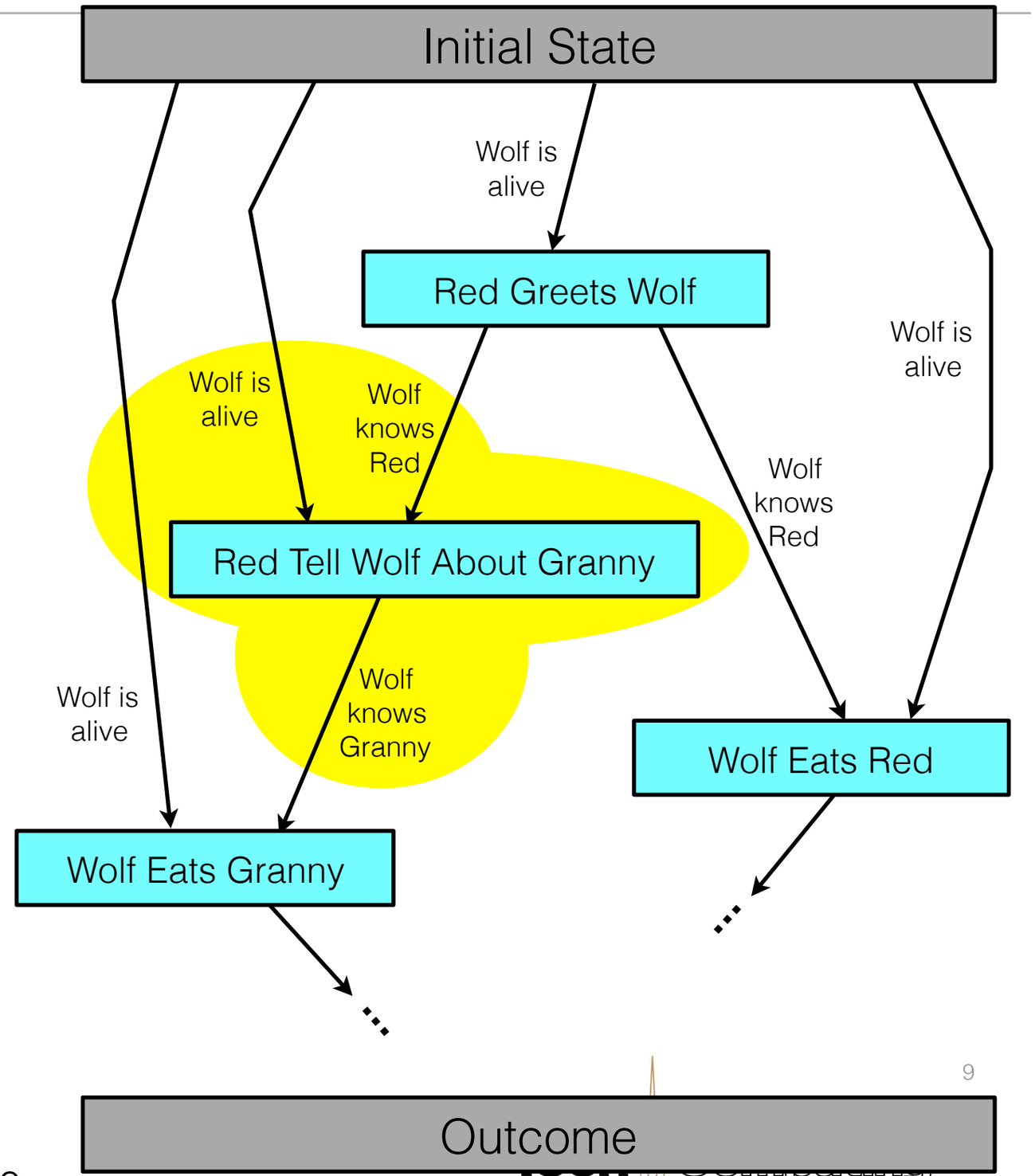
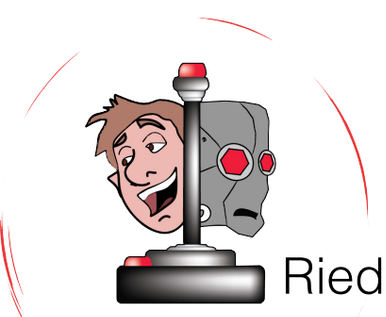
- Find a sequence of actions that proves the goal state is reachable from an initial state





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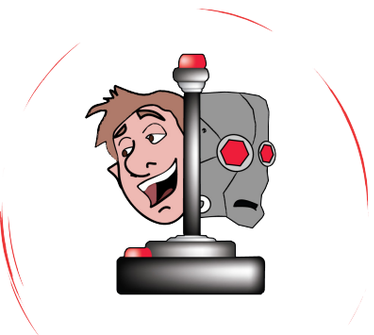
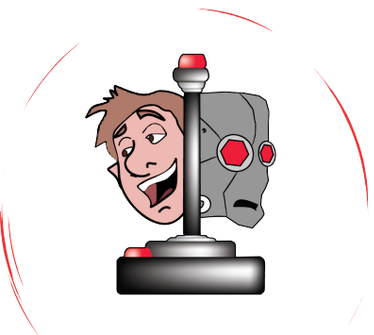


Domain knowledge

```
(define (action eat)
  :parameters (?monster ?victim)
  :constraints ((monster ?monster) (person ?victim))
  :precondition ((knows ?monster ?victim)
                 (alive ?monster) (alive ?victim)
                 (:not (eaten ?victim))
                 (:not (asleep ?monster))
                 (:neq ?monster ?victim))
 :effect ((eaten ?victim) (in ?victim ?monster)
          (full ?monster)))
```



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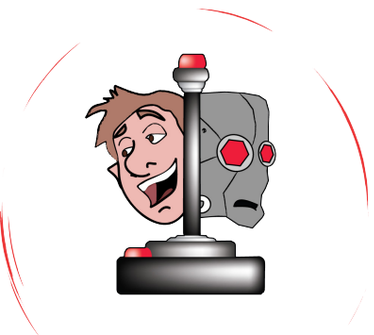
          (full ?monster)))
```

Initial state

```
(person aladdin) (king jafar) ...
(monster dragon) (can-use-magic genie)
```



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          (full ?monster)))
```
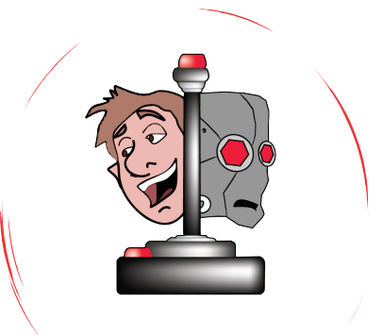

Initial state

```
(person aladdin) (king jafar) ...
(monster dragon) (can-use-magic genie)
```

Outcome state

```
(:not (alive genie)) (married jasmine jafar)
```



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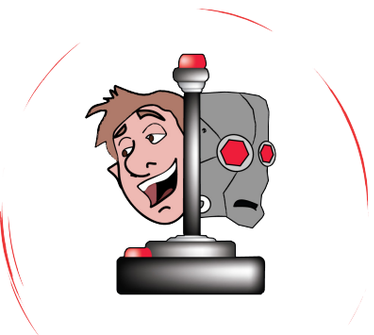
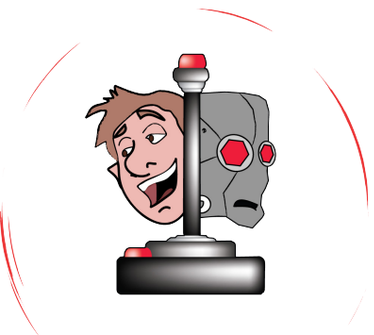
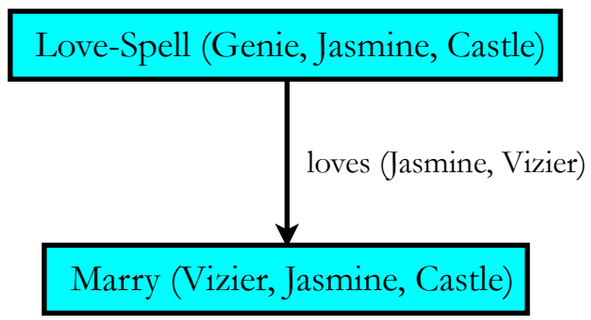


Marry (Vizier, Jasmine, Castle)

Slay (Aladdin, Genie, Castle)

Riedl & Young. Journal of AI Research, 2010.





Slay (Aladdin, Genie, Castle)

Riedl & Young. Journal of AI Research, 2010.

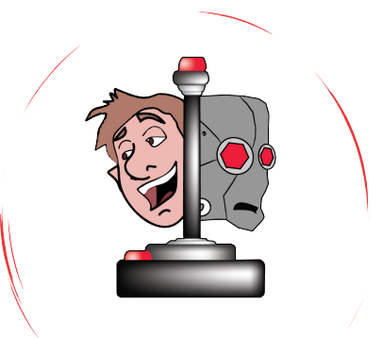
Falls-in-Love (Vizier, Jasmine, Castle)

loves (King, Jasmine)

Love-Spell (Genie, Jasmine, Castle)

loves (Jasmine, Vizier)

Marry (Vizier, Jasmine, Castle)



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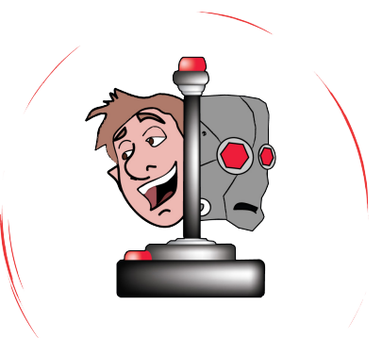


Slay (Aladdin, Genie, Castle)

Riedl & Young. Journal of AI Research, 2010.

Falls-in-Love (Vizier, Jasmine, Castle)

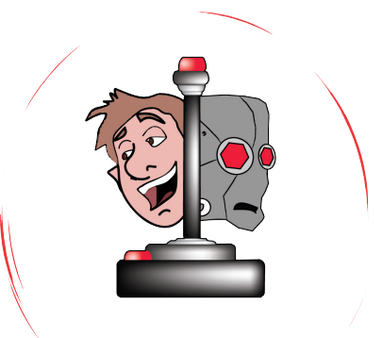
loves (King, Jasmine)

Command (Vizier, Genie, loves(Jasmine, Vizier))

Love-Spell (Genie, Jasmine, Castle)

loves (Jasmine, Vizier)

Marry (Vizier, Jasmine, Castle)



Slay (Aladdin, Genie, Castle)

Riedl & Young. Journal of AI Research, 2010.

Falls-in-Love (Vizier, Jasmine, Castle)

loves (King, Jasmine)

Command (Vizier, Genie, loves(Jasmine, Vizier))

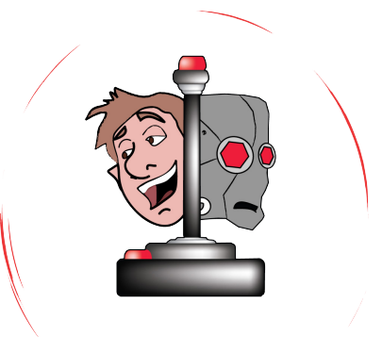
Love-Spell (Genie, Jasmine, Castle)

loves (Jasmine, Vizier)

Marry (Vizier, Jasmine, Castle)

Appear-Threatening (Genie, Aladdin, Castle)

Slay (Aladdin, Genie, Castle)



Riedl & Young. Journal of AI Research, 2010.

Falls-in-Love (Vizier, Jasmine, Castle)

Summon (Vizier, Genie, Lamp, Castle)

at (Genie, Castle)
controls (Vizier, Genie)

Command (Vizier, Genie, loves(Jasmine, Vizier))

Love-Spell (Genie, Jasmine, Castle)

loves (Jasmine, Vizier)

Marry (Vizier, Jasmine, Castle)

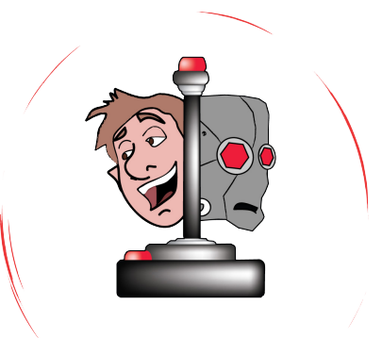
loves (King, Jasmine)

at (Genie, Castle)

Appear-Threatening (Genie, Aladdin, Castle)

at (Genie, Castle)

Slay (Aladdin, Genie, Castle)



Riedl & Young. Journal of AI Research, 2010.

Falls-in-Love (Vizier, Jasmine, Castle)

Give (Aladdin, Lamp, Vizier, Castle)

has (Vizier, Lamp)

Summon (Vizier, Genie, Lamp, Castle)

at (Genie, Castle)

Appear-Threatening (Genie, Aladdin, Castle)

at (Genie, Castle)
controls (Vizier, Genie)

Command (Vizier, Genie, loves(Jasmine, Vizier))

loves (King, Jasmine)

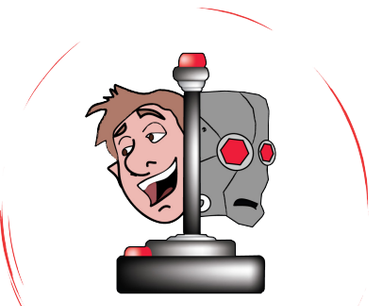
Love-Spell (Genie, Jasmine, Castle)

at (Genie, Castle)

Slay (Aladdin, Genie, Castle)

loves (Jasmine, Vizier)

Marry (Vizier, Jasmine, Castle)



Riedl & Young. Journal of AI Research, 2010.

Falls-in-Love (Vizier, Jasmine, Castle)

Travel (Aladdin, Mountain, Castle)

at (Aladdin, Castle)

Give (Aladdin, Lamp, Vizier, Castle)

has (Vizier, Lamp)

Summon (Vizier, Genie, Lamp, Castle)

at (Genie, Castle)

at (Genie, Castle)
controls (Vizier, Genie)

Command (Vizier, Genie, loves(Jasmine, Vizier))

loves (King, Jasmine)

Love-Spell (Genie, Jasmine, Castle)

loves (Jasmine, Vizier)

Marry (Vizier, Jasmine, Castle)

at (Aladdin, Castle)

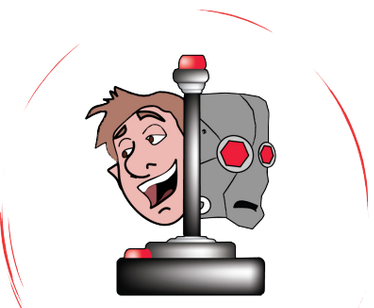
at (Aladdin, Castle)

at (Genie, Castle)

Appear-Threatening (Genie, Aladdin, Castle)

at (Genie, Castle)

Slay (Aladdin, Genie, Castle)



Riedl & Young. Journal of AI Research, 2010.

Falls-in-Love (Vizier, Jasmine, Castle)

Pillage (Aladdin, Lamp, Dragon, Mountain)

has (Aladdin, Lamp)

Travel (Aladdin, Mountain, Castle)

at (Aladdin, Castle)

Give (Aladdin, Lamp, Vizier, Castle)

has (Vizier, Lamp)

Summon (Vizier, Genie, Lamp, Castle)

at (Genie, Castle)

at (Genie, Castle)
controls (Vizier, Genie)

Command (Vizier, Genie, loves(Jasmine, Vizier))

loves (King, Jasmine)

Love-Spell (Genie, Jasmine, Castle)

loves (Jasmine, Vizier)

Marry (Vizier, Jasmine, Castle)

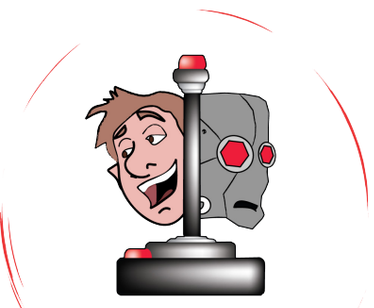
at (Aladdin, Castle)

at (Aladdin, Castle)

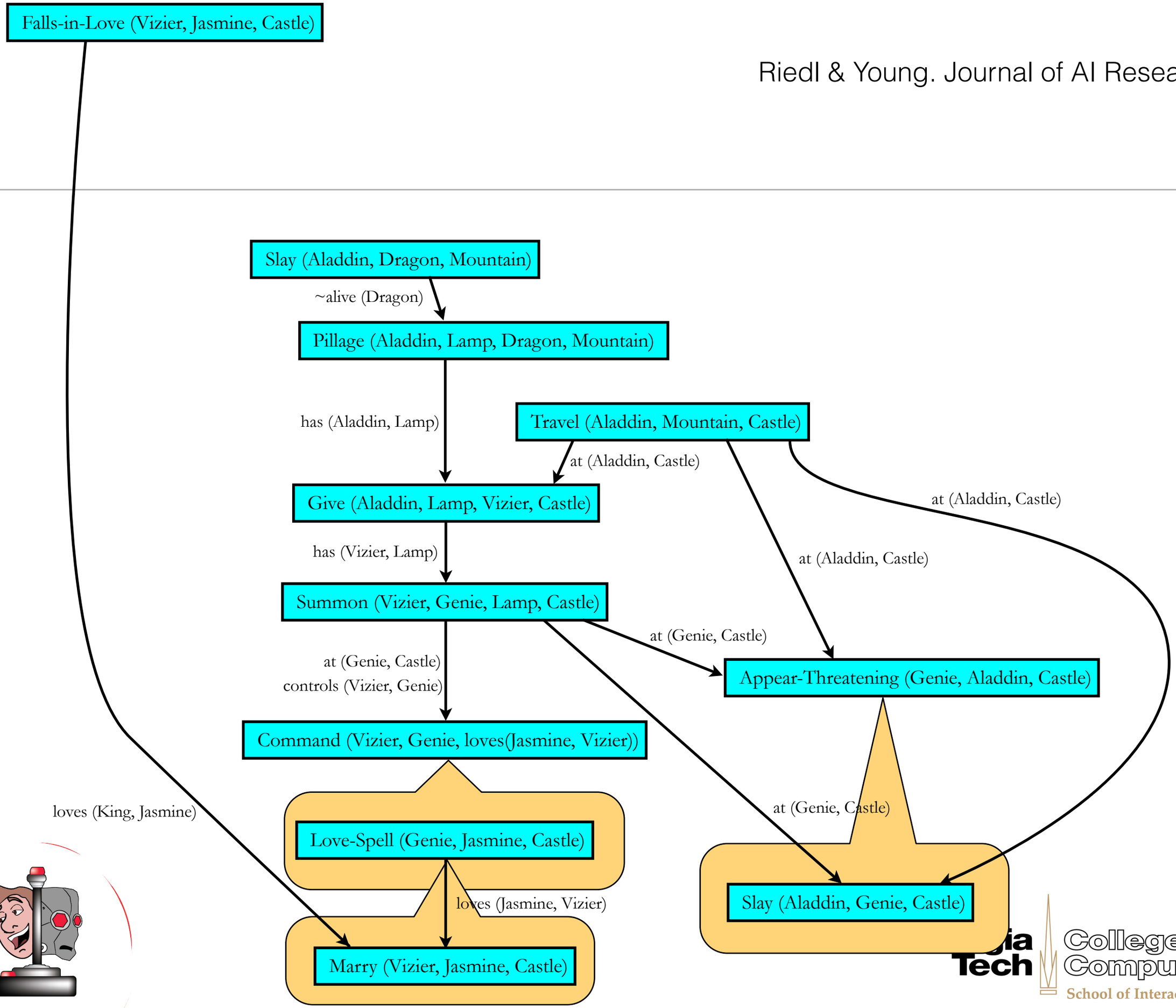
Appear-Threatening (Genie, Aladdin, Castle)

at (Genie, Castle)

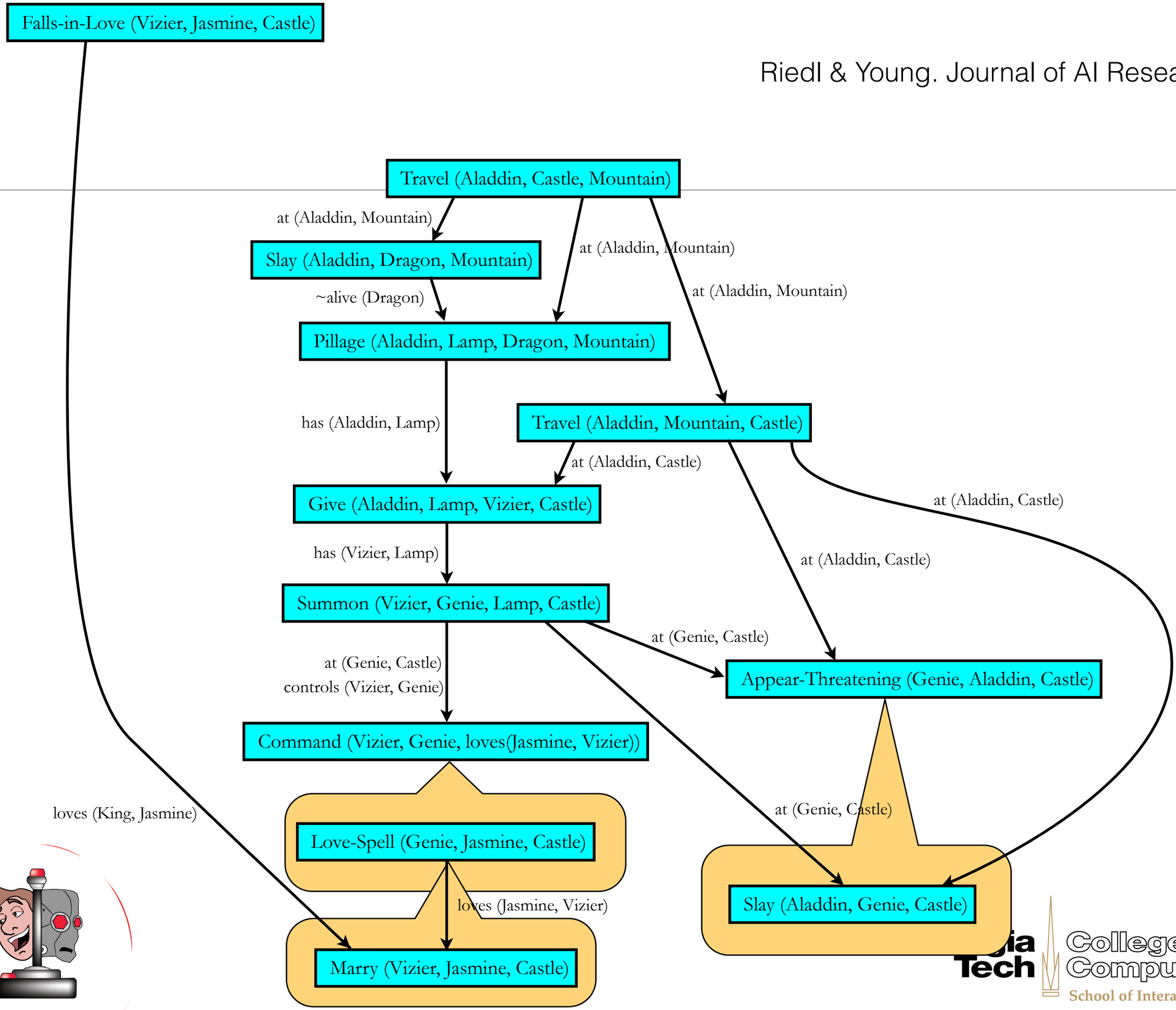
Slay (Aladdin, Genie, Castle)



Riedl & Young. Journal of AI Research, 2010.



Riedl & Young. Journal of AI Research, 2010.



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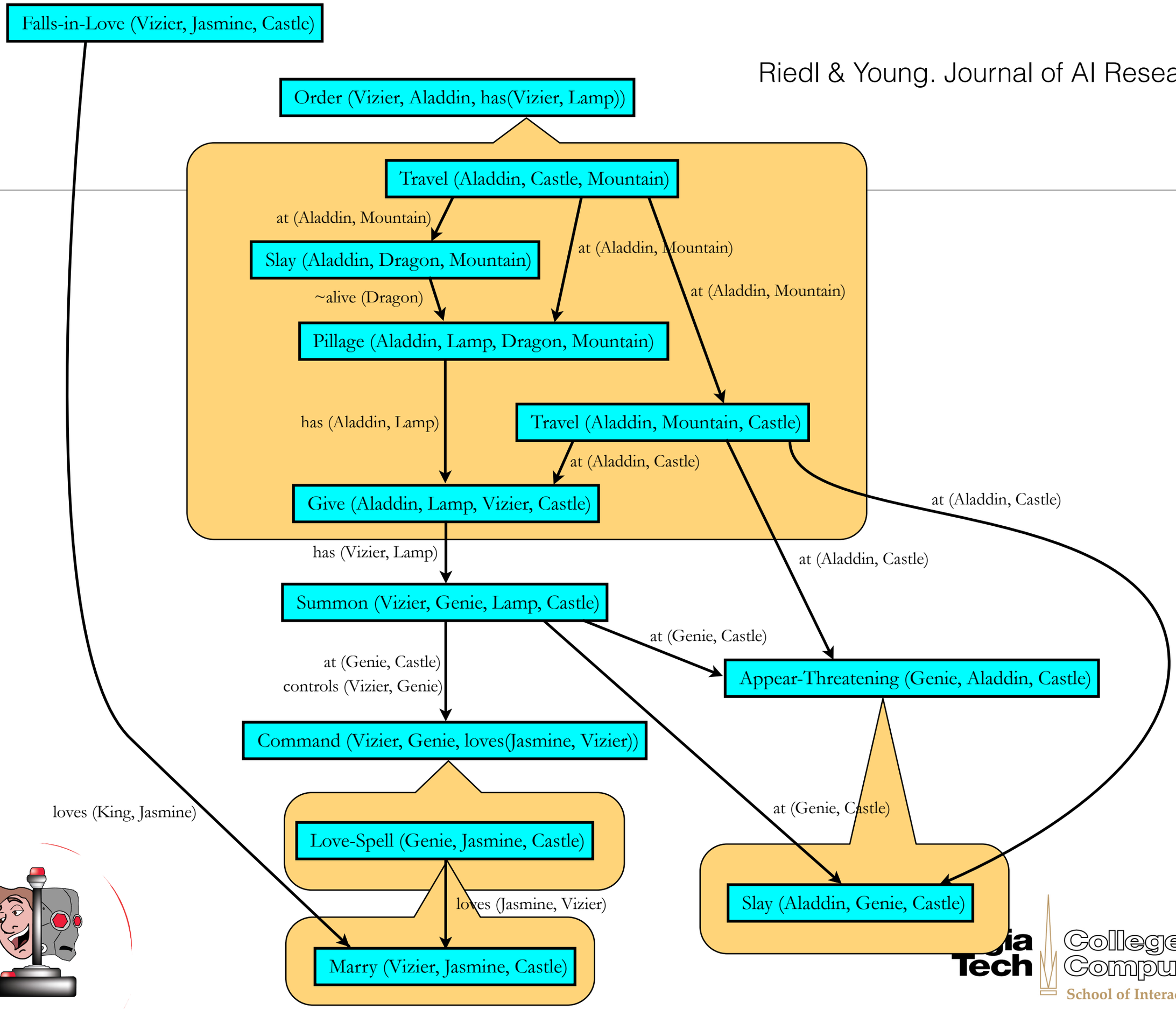

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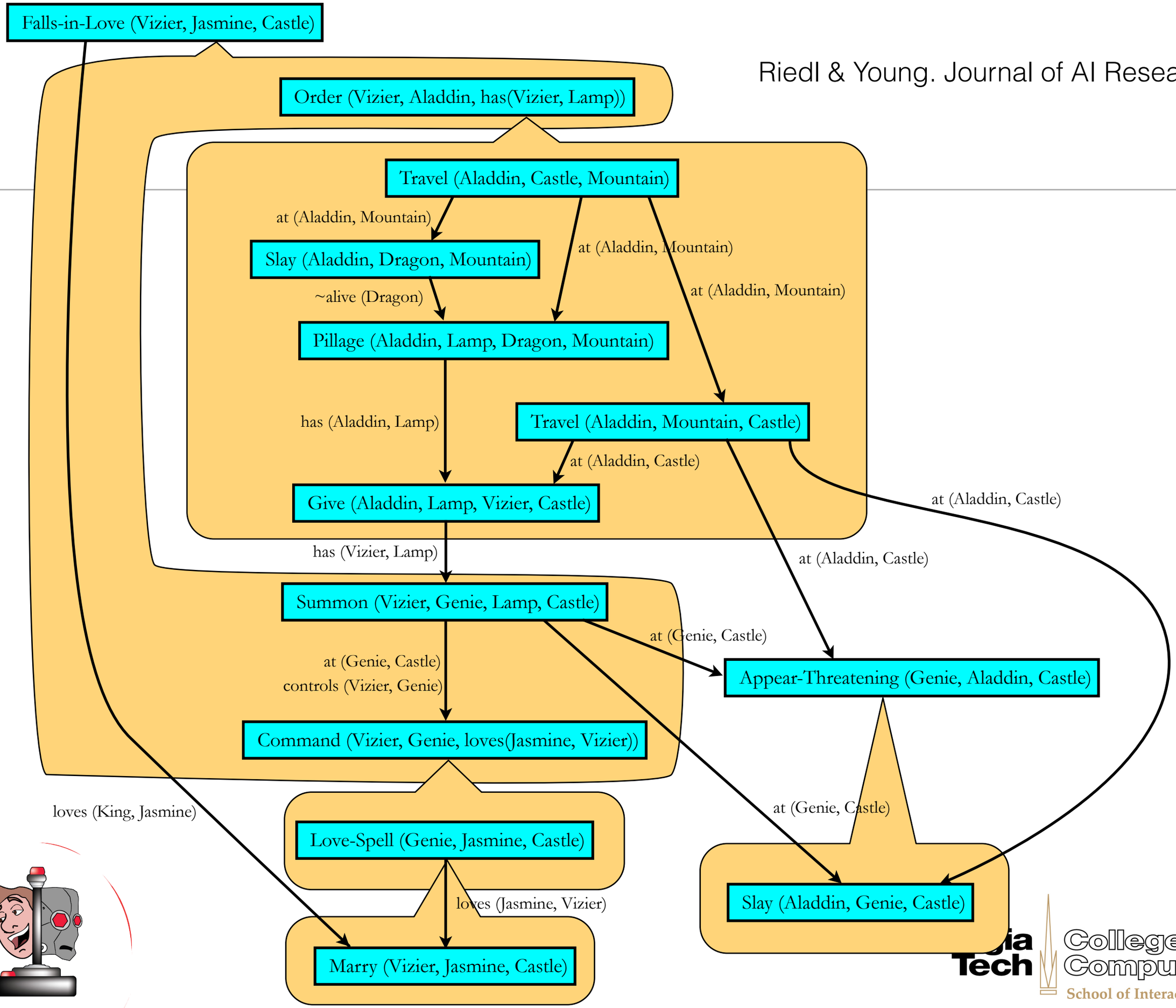
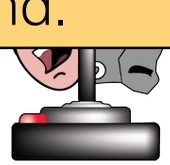


There is a woman named Jasmine. There is a vizier named Jafar. This is a story about how Jafar becomes married to Jasmine. There is a magic genie. This is also a story about how the genie dies.

There is a magic lamp. There is a dragon. The dragon has the magic lamp. The genie is confined within the magic lamp.

Jafar is not married. Jasmine is very beautiful. Jafar sees Jasmine and instantly falls in love with her. Jafar wants to marry Jasmine. There is a brave knight named Aladdin. Aladdin is loyal to the death to Jafar. Jafar orders Aladdin to get the magic lamp for him. Aladdin wants Jafar to have the magic lamp. Aladdin travels from the castle to the mountains. Aladdin slays the dragon. The dragon is dead. Aladdin takes the magic lamp from the dead body of the dragon. Aladdin travels from the mountains to the castle. Aladdin hands the magic lamp to Jafar. The genie is in the magic lamp. Jafar rubs the magic lamp and summons the genie out of it. The genie is not confined within the magic lamp. Jafar controls the genie with the magic lamp. Jafar uses the magic lamp to command the genie to make Jasmine love him. The genie wants Jasmine to be in love with Jafar. The genie casts a spell on Jasmine making her fall in love with Jafar. Jasmine is madly in love with Jafar. Jasmine wants to marry Jafar. The genie has a frightening appearance. The genie appears threatening to Aladdin. Aladdin wants the genie to die. Aladdin slays the genie. Jafar and Jasmine wed in an extravagant ceremony.

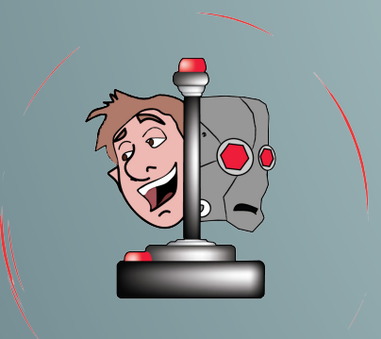
The genie is dead. King Jafar and Jasmine are married. The end.



Riedl & Young. Journal of AI Research, 2010.

Open story generation

- Story generation is knowledge-intensive and overly reliant on micro-worlds
- Generate a story about any topic



Open story generation

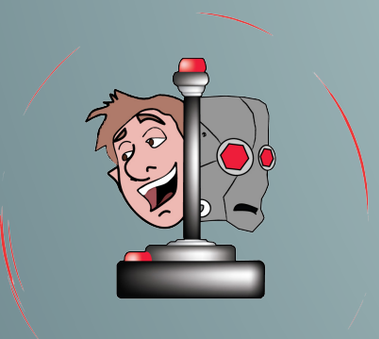
- Story generation is knowledge-intensive and overly reliant on micro-worlds

- Generate a story about any topic

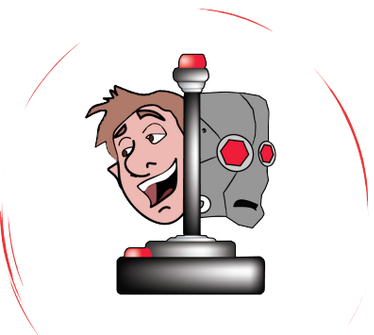
- Challenges:

    1. Acquire a model of how to tell a story

    2. Operate on the model to create novel story contet

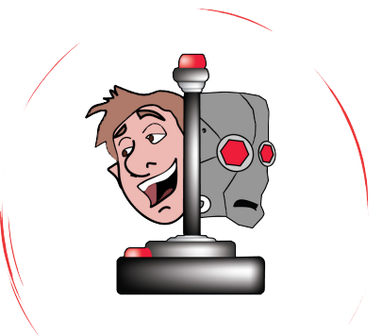


Turn to common knowledge



Turn to common knowledge

- Humans rely on a lifetime of experiences from which to explain stories, tell stories, or act in the real-world



Turn to common knowledge

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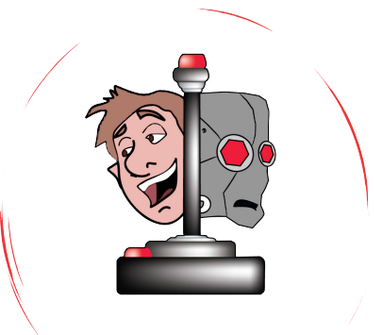
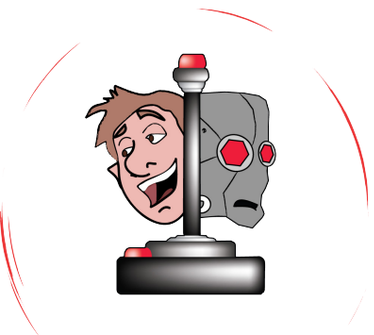
- Mine common sense knowledge bases (😜)



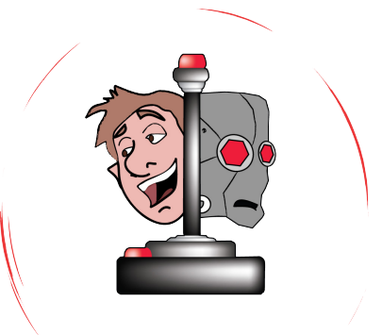
Turn to common knowledge

- Humans rely on a lifetime of experiences from which to explain stories, tell stories, or act in the real-world
- Mine common sense knowledge bases (😜)
- Read natural language corpora (🤔)



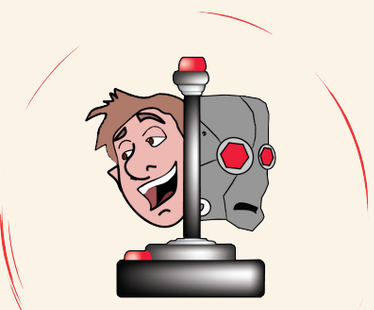
Turn to common knowledge

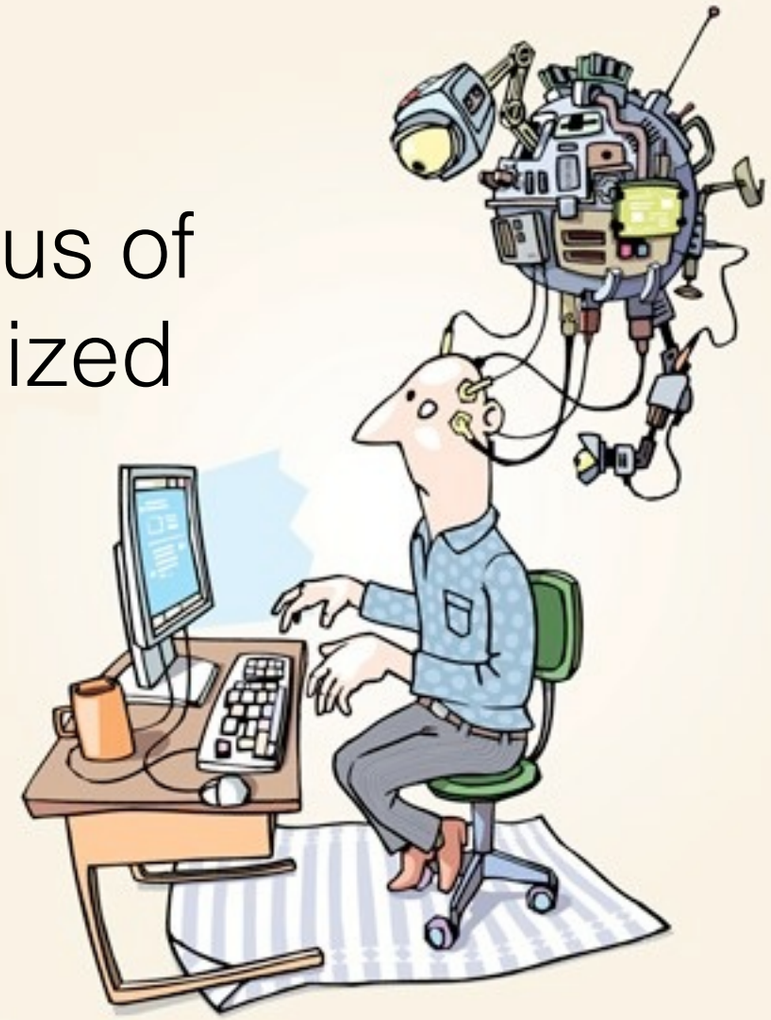
- Humans rely on a lifetime of experiences from which to explain stories, tell stories, or act in the real-world
- Mine common sense knowledge bases (😜)
- Read natural language corpora (🤔)
- Learn directly from humans (😄)



Crowdsourcing narrative intelligence

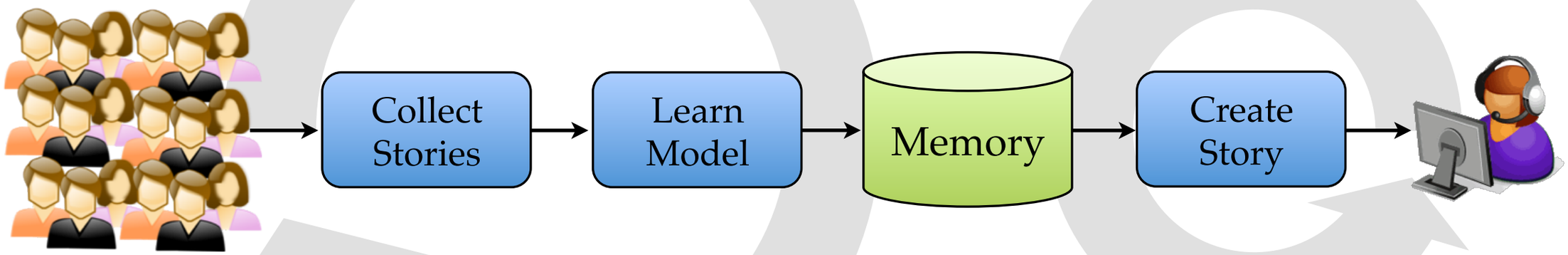
- A crowd of humans on the web → a supercomputer
- Use a crowd to simulate a lifetime of experiences by asking people to tell stories about a specific type of situation
- Crowdsource a highly specialized corpus of narrative examples and learn a generalized model of how to do something

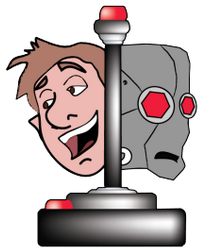




Scheherazade

- Just-in-time knowledge acquisition
  - Learn a model of how to do things and store in memory
- Generate stories
  - About everyday common sense activities

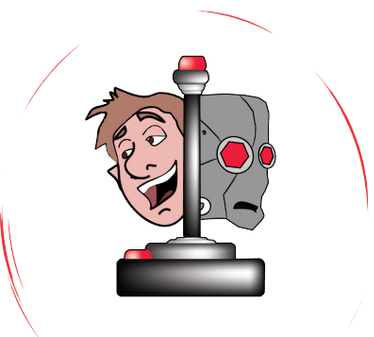




Li, Lee-Urban, Johnston & Riedl. AAAI 2013 Conference.

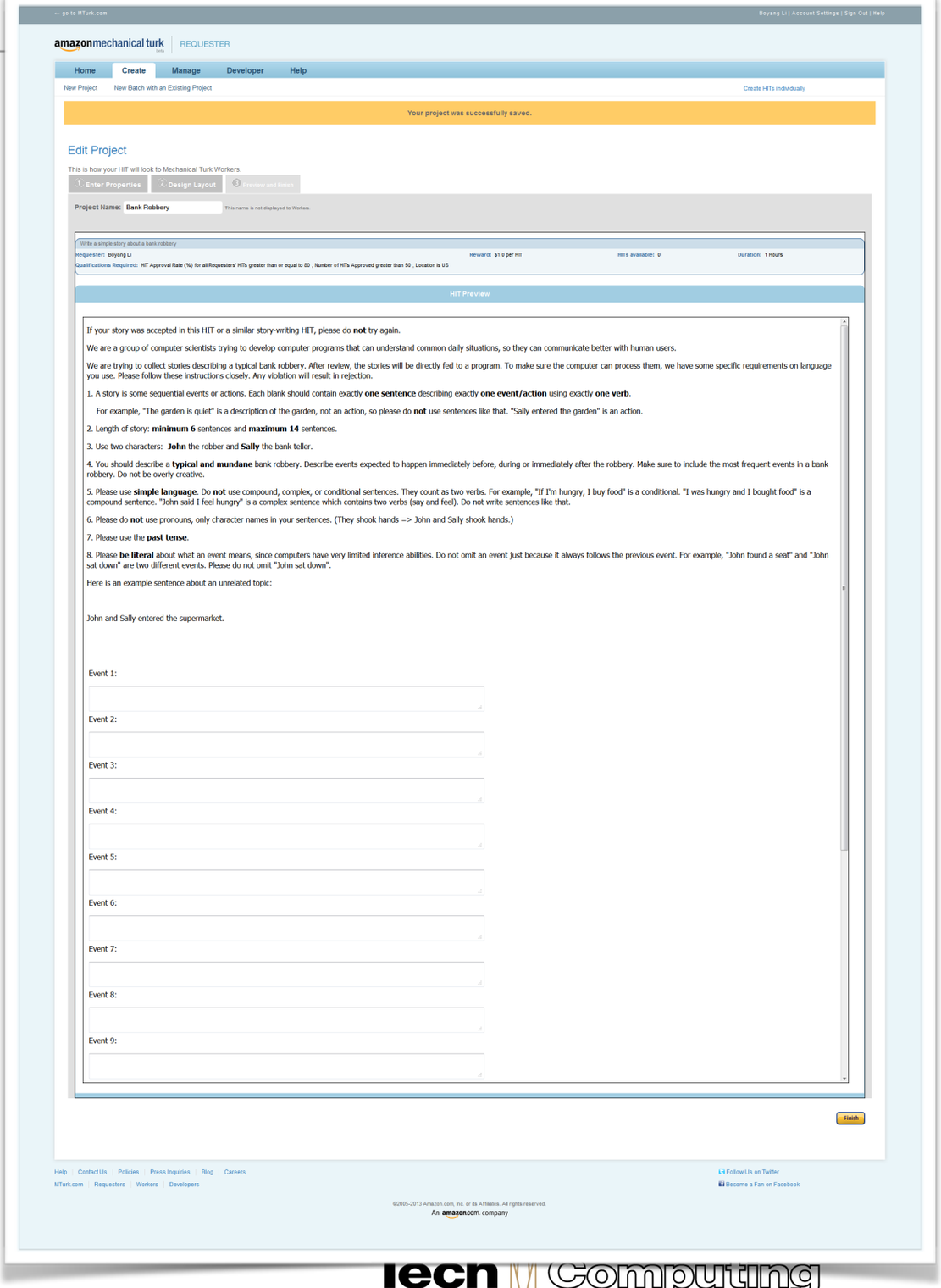
Learning from stories is hard

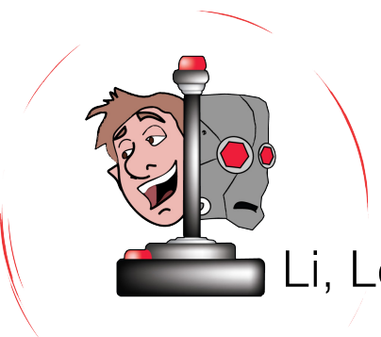
- Stories tend to skip “obvious” steps
- Humans are noisy
- Intuitions:
  1. Crowdsource data
  2. Semantic lifting



Crowdsourcing stories

- Amazon Mechanical Turk
- Write a typical story about X
- Result: parallel stories featuring sentence transitions





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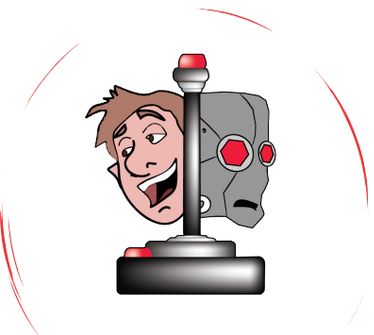
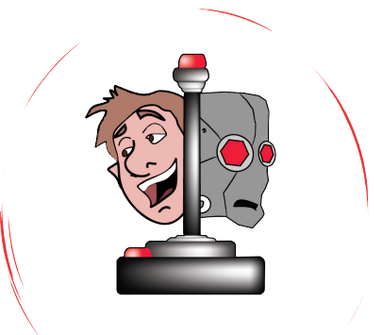
Semantic lifting



Semantic lifting

- If sentence transition is in a example story, it is good



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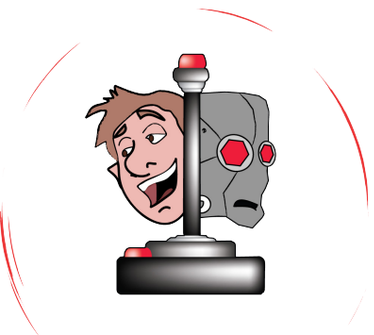
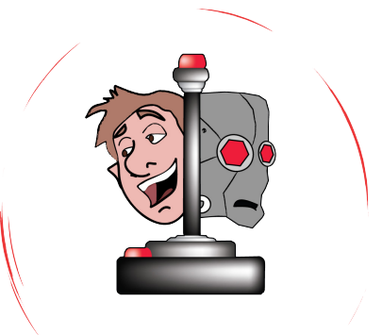


Semantic lifting

- ~~If sentence transition is in a example story, it is good~~

- Gappy stories

Gappy stories:
John went to the restaurant.
John ate dinner and left.



Semantic lifting

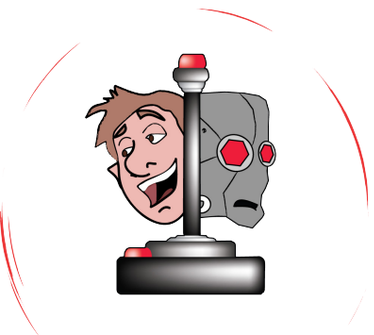
- ~~If sentence transition is in a example story, it is good~~

- Gappy stories

- Malicious storytellers

Gappy stories:
John went to the restaurant.
John ate dinner and left.

Malicious stories:
John went to the restaurant.
John took the food and ran.



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Gappy stories:
John went to the restaurant.
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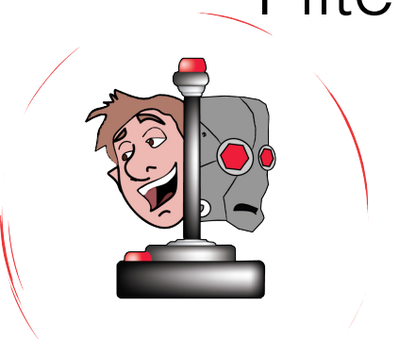
Malicious stories:
John went to the restaurant.
John took the food and ran.

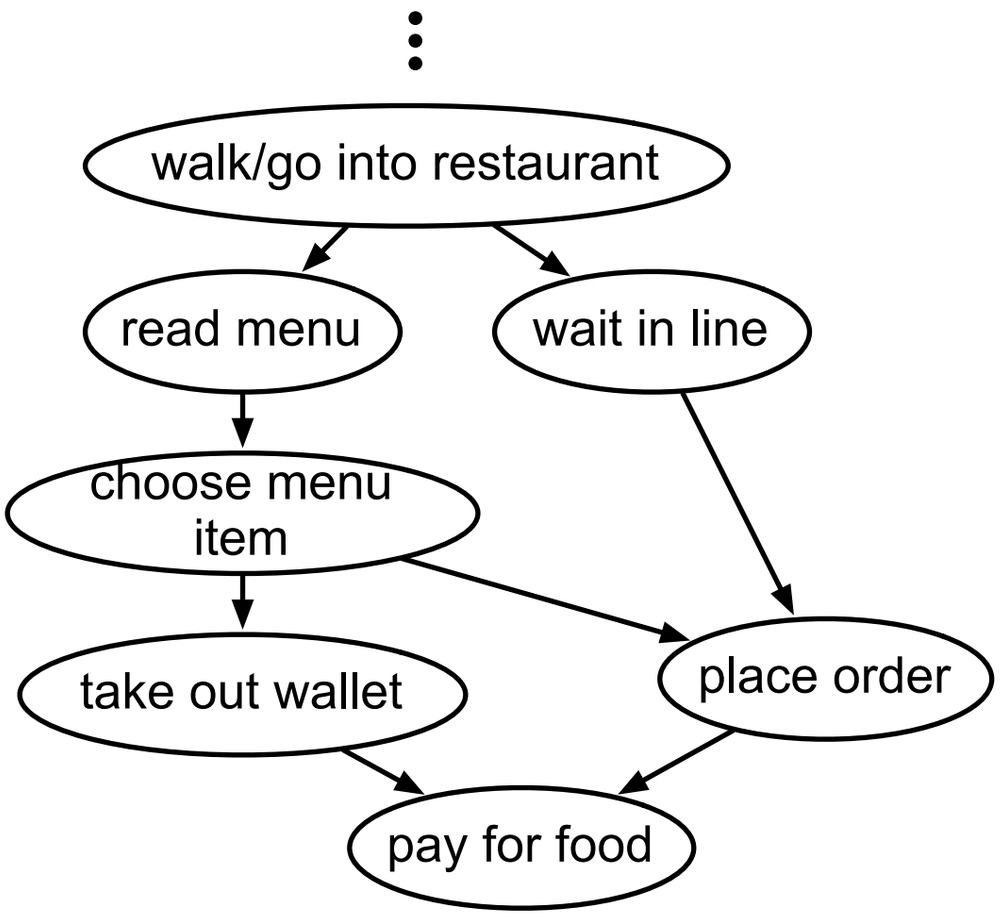
- Learn a model that abstracts away from language to events
  - Fill gaps
  - Filter outliers

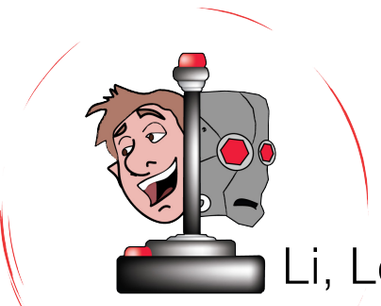


Plot graphs

- Script-like representation with temporal relations between events

- Learned from natural language





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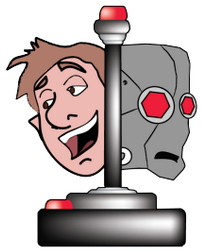
Plot graph learning

Story A	Story B
a. John drives to the restaurant.	a. Mary looks at the menu.
b. John stands in line.	b. Mary decides what to order.
c. John orders food.	c. Mary orders a burger.
d. John waits for his food.	d. Mary finds a seat.
e. John sits down.	e. Mary eats her burger.
f. John eats the food.	…
…	



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Plot graph learning

1. Identify the salient events via semantic clustering

Story A	Story B
a. John drives to the restaurant.	a. Mary looks at the menu.
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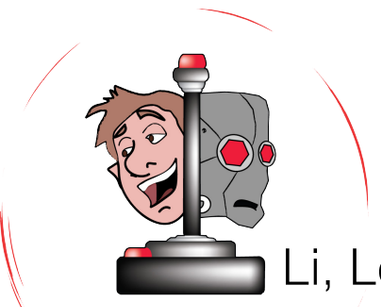
d. John waits for his food.	d. Mary finds a seat.
e. John sits down.	e. Mary eats her burger.
f. John eats the food.	…
…	

Order food

Eat food



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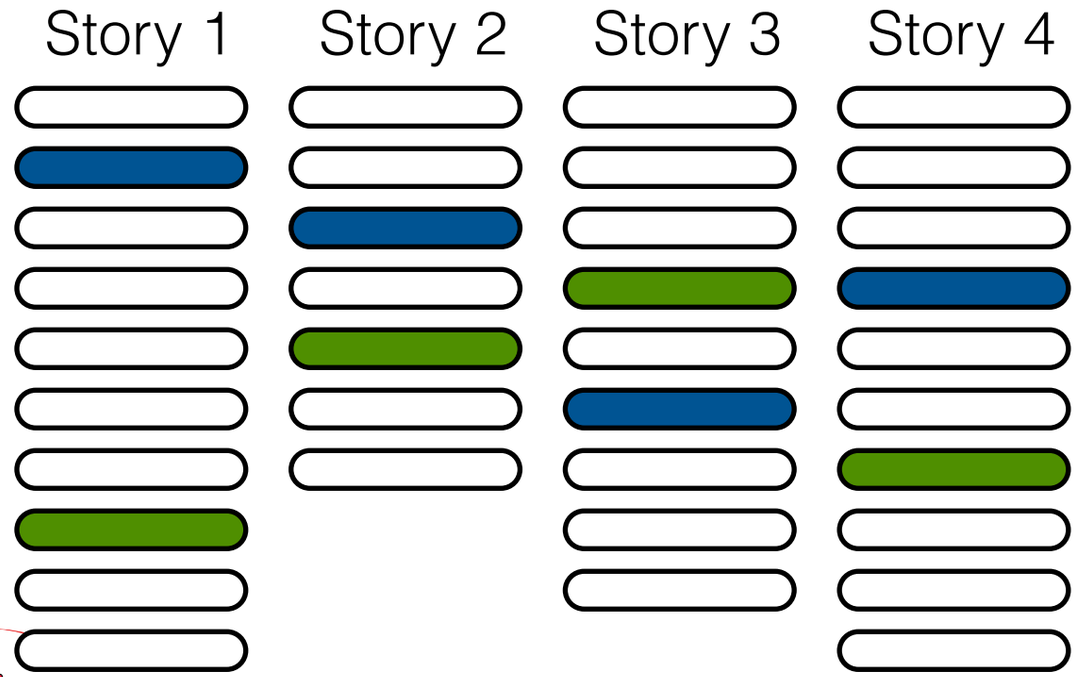
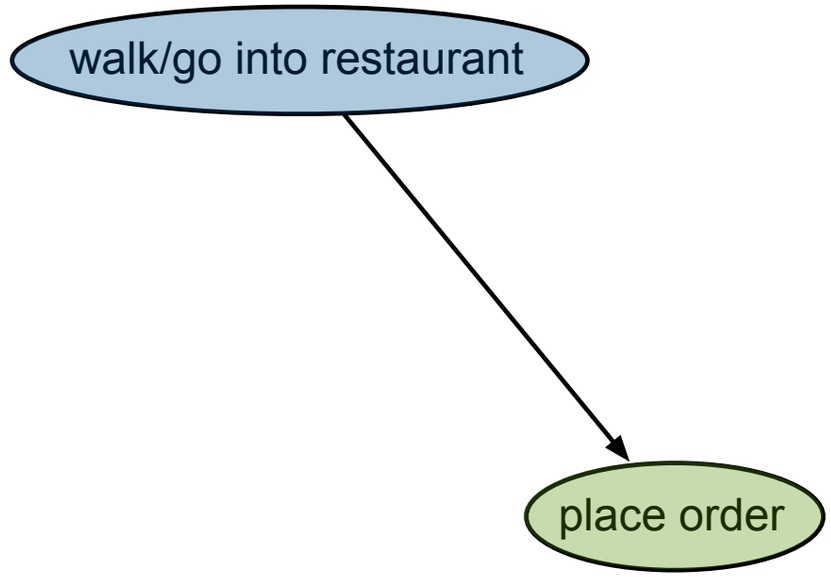
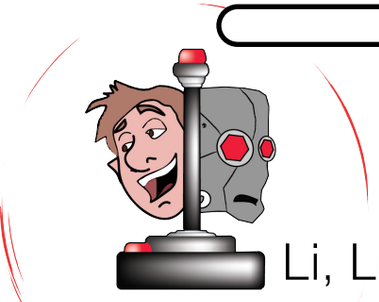
Plot graph learning

1. Identify the salient events via semantic clustering

2. Determine event ordering







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Plot graph learning

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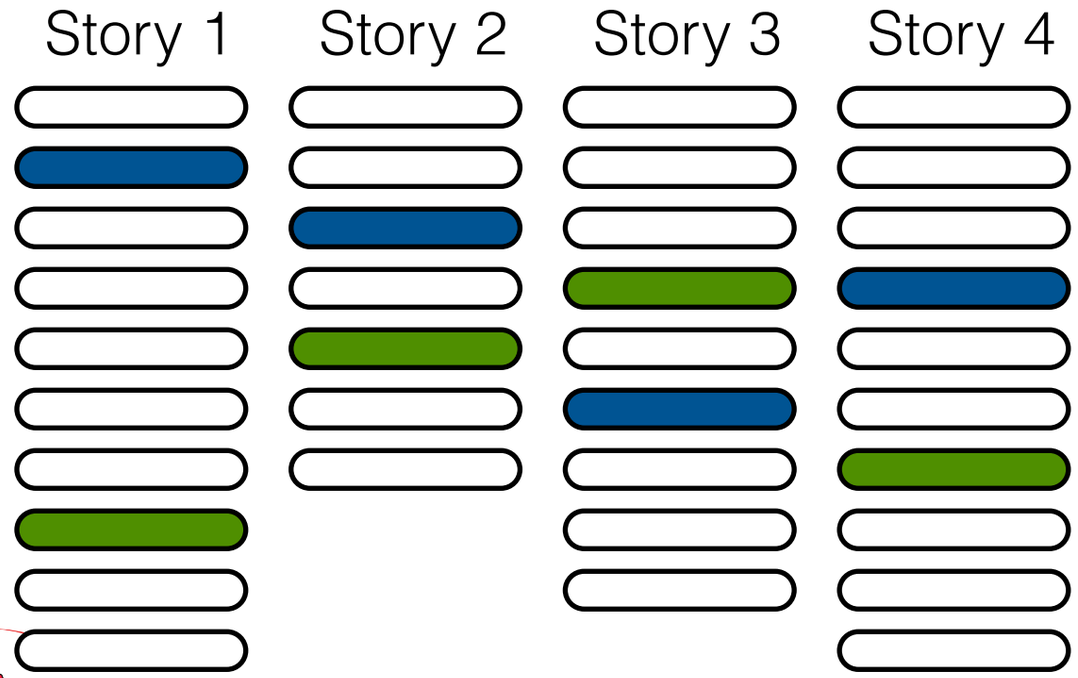

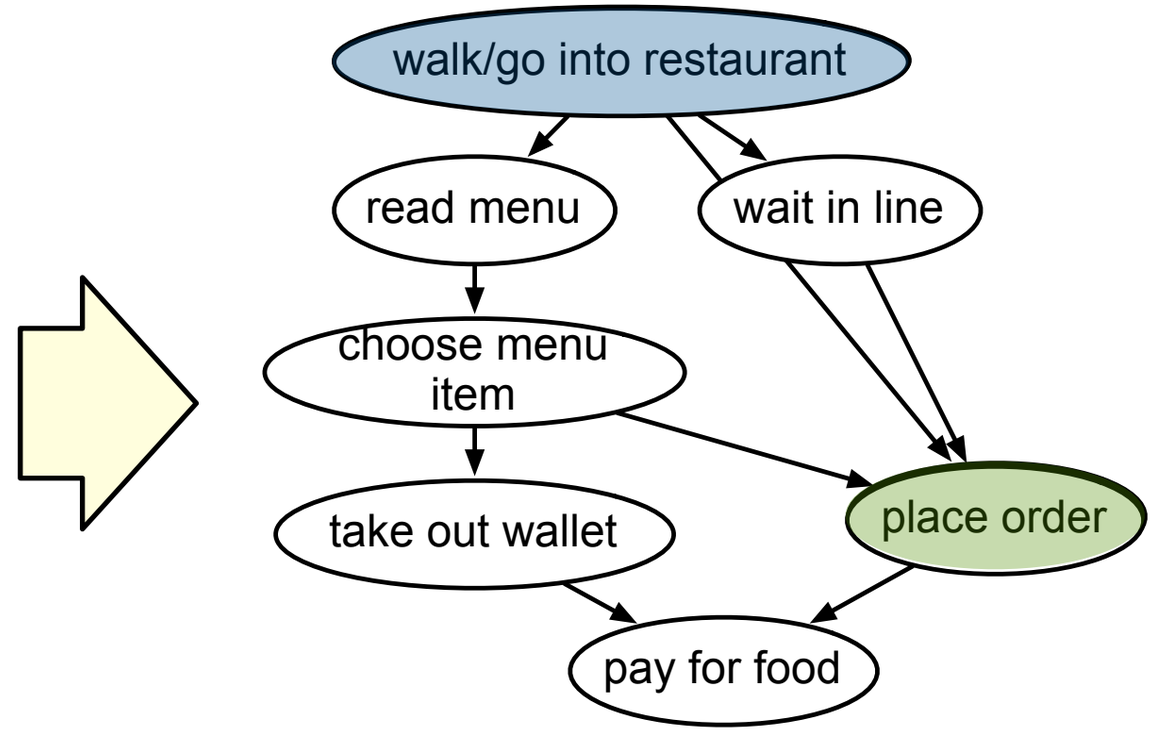

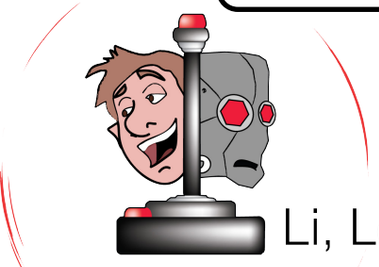

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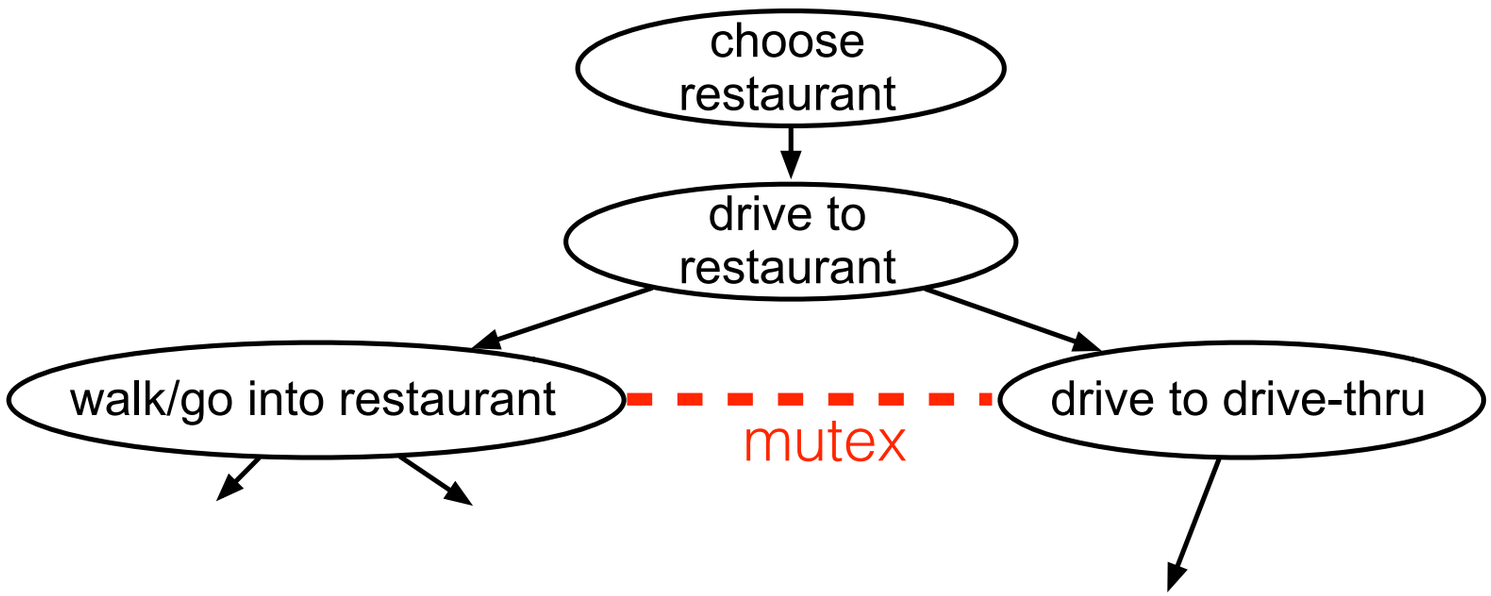
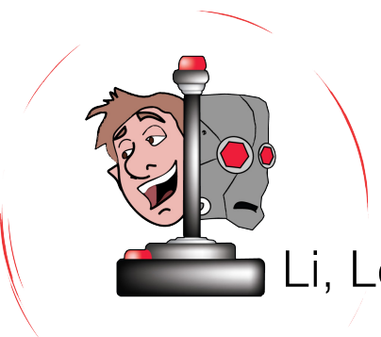
Plot graph learning

1. Identify the salient events via semantic clustering

2. Determine event ordering

3. Mutually exclusive events





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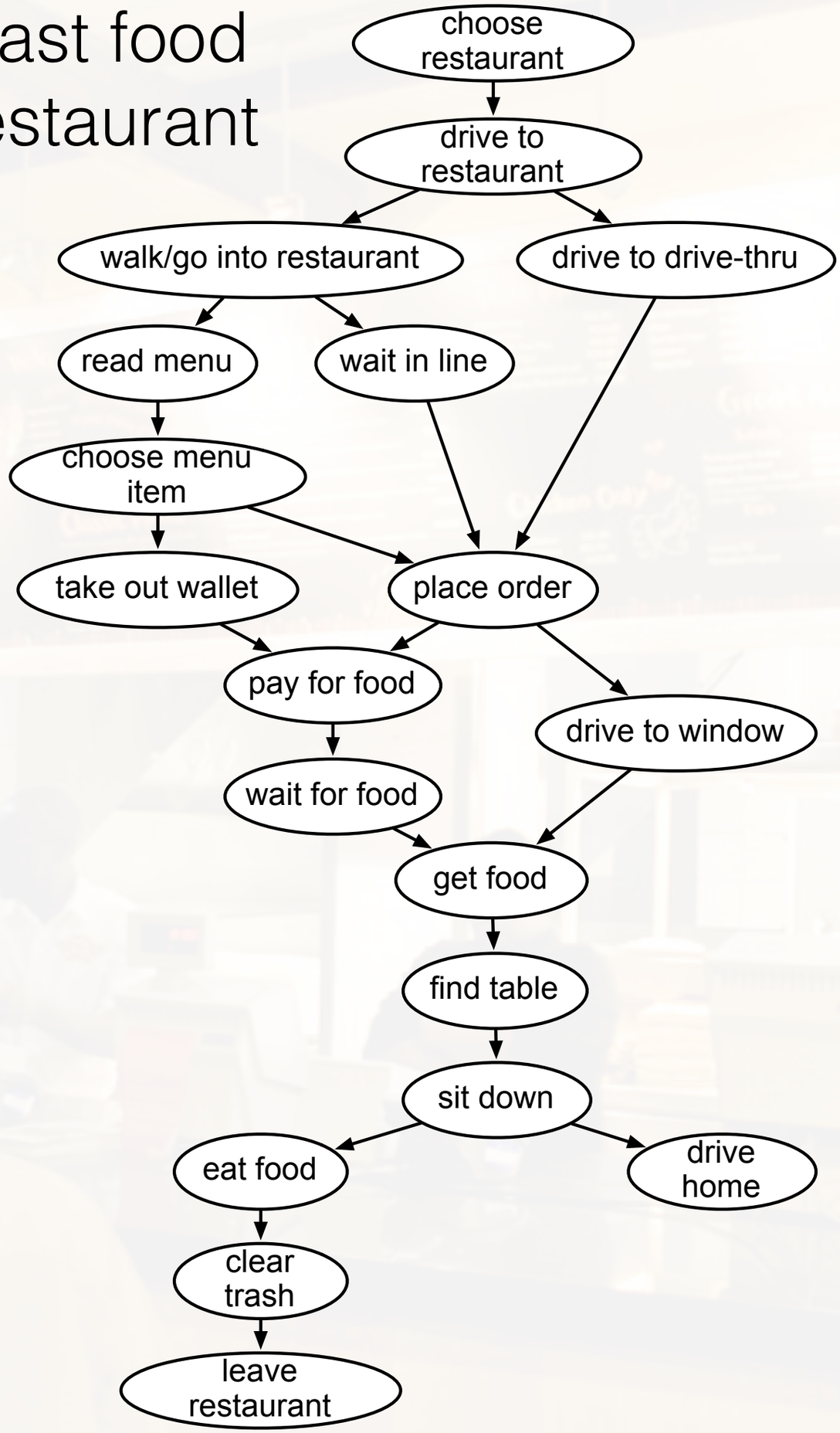
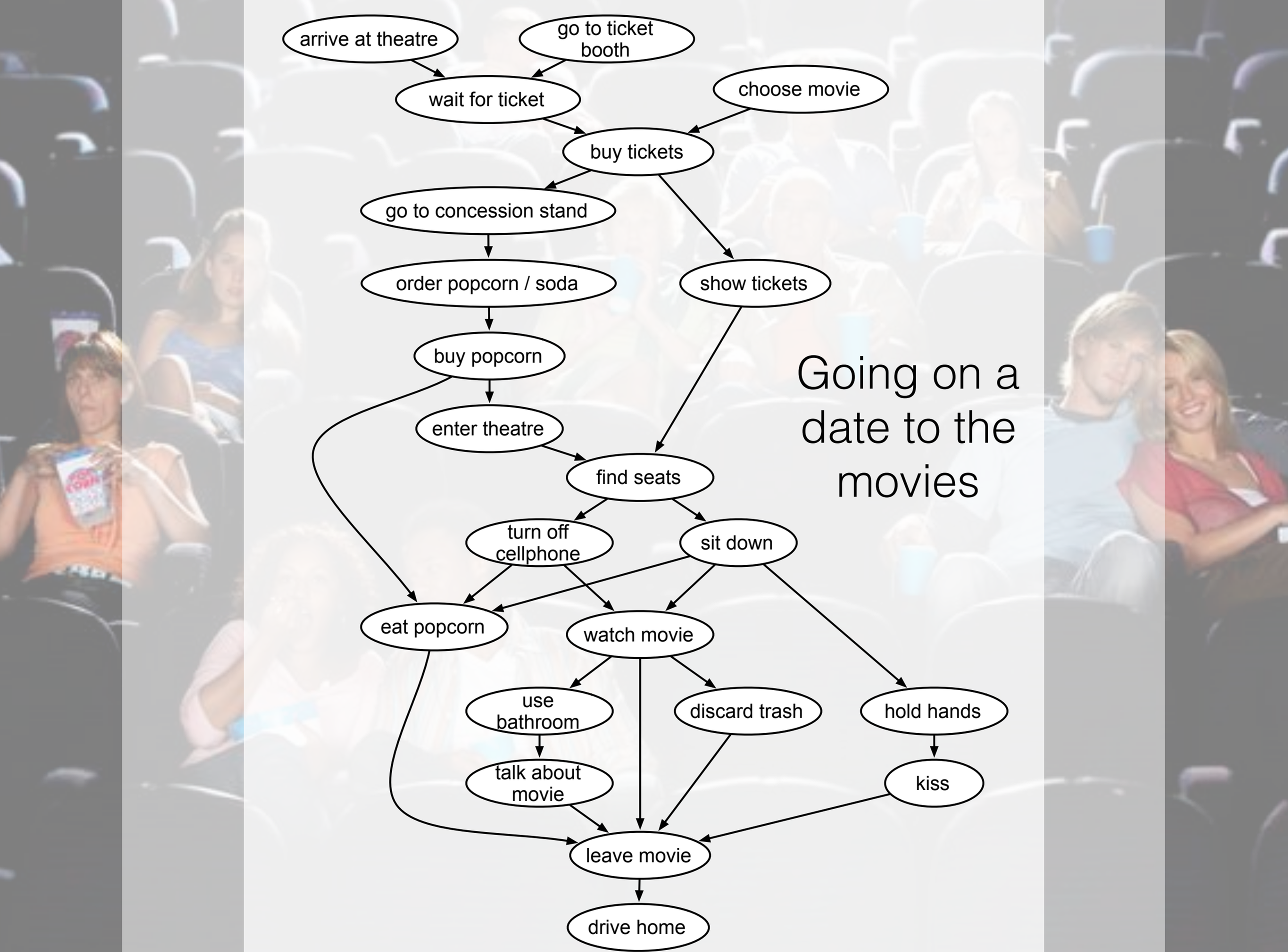
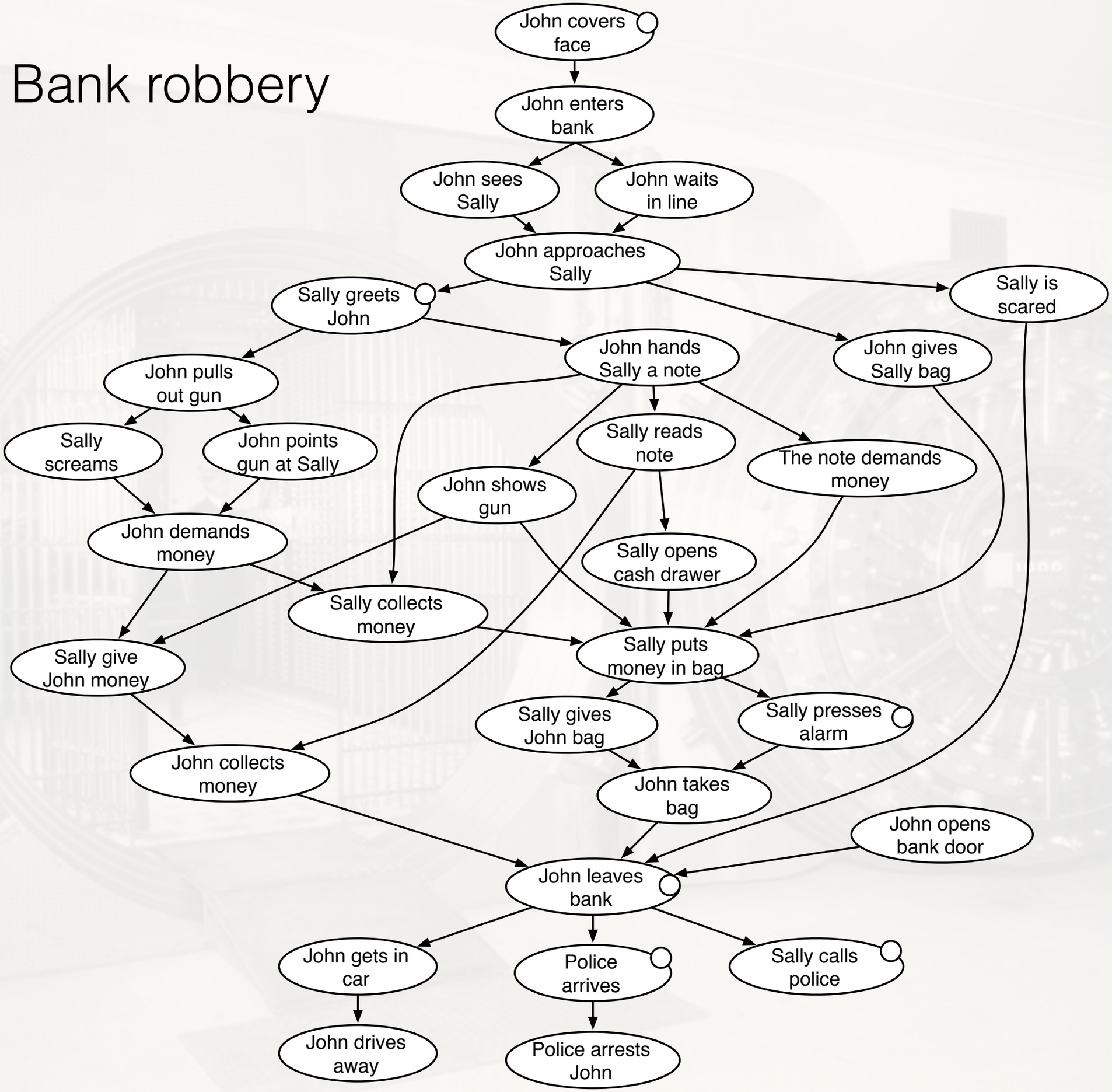
Fast food restaurant





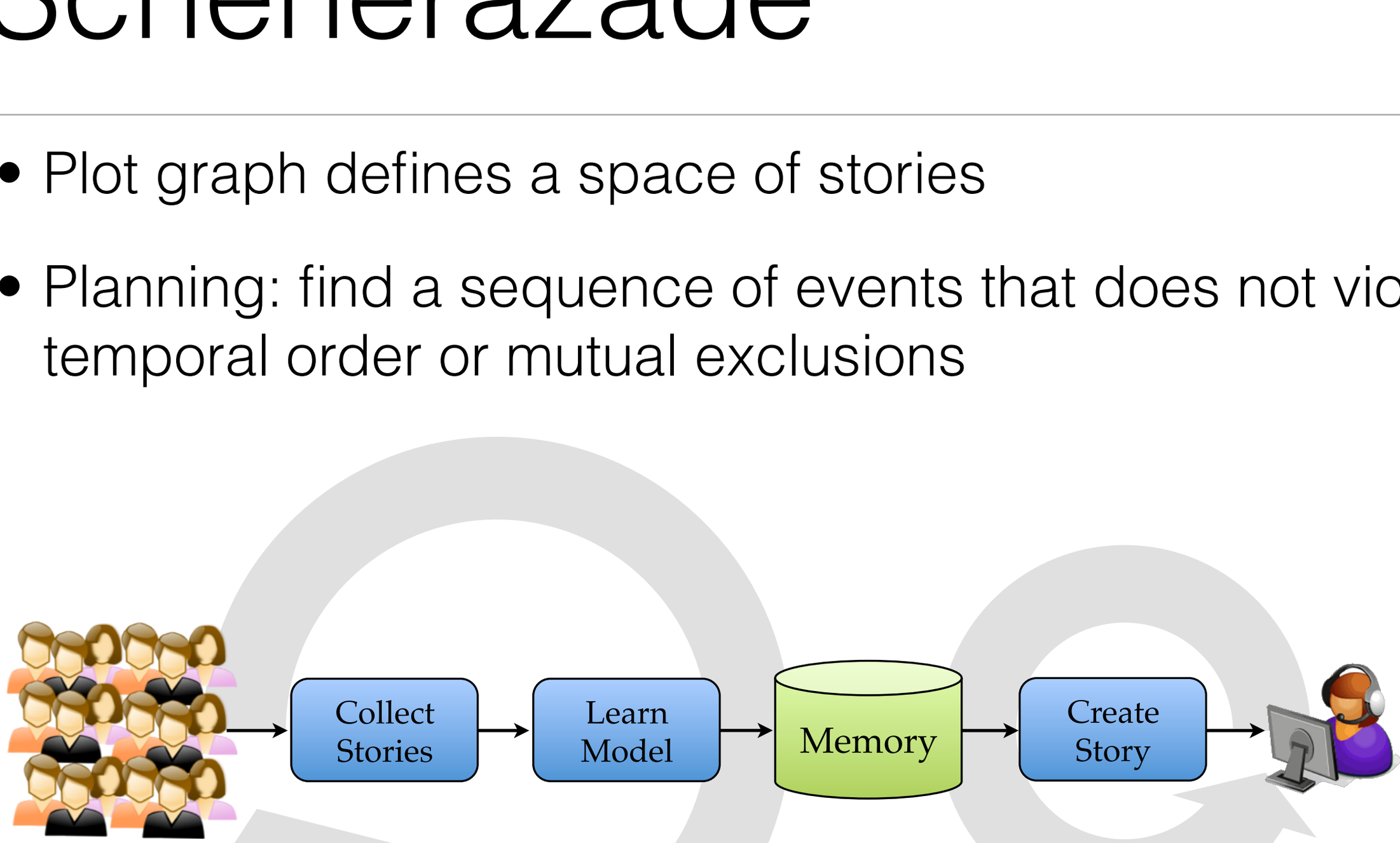
Going on a date to the movies

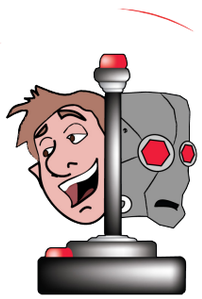
Bank robbery



Scheherazade

- Plot graph defines a space of stories
- Planning: find a sequence of events that does not violate temporal order or mutual exclusions





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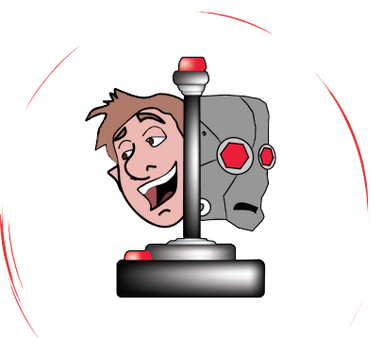
arrive at theatre
go to ticket booth
wait for ticket
choose movie
buy tickets
go to concession stand
order popcorn / soda
show tickets
buy popcorn
enter theatre
find seats
turn off cellphone
sit down
eat popcorn
watch movie
use bathroom
discard trash
hold hands
talk about movie
kiss
leave movie
drive home



arrive at theatre

wait for ticket

buy ticket

show ticket

go to concession stand

order popcorn / soda

buy popcorn

enter theatre

find seats

sit down

watch movie

use bathroom

talk about movie

hold hands

kiss

leave

arrive at theatre

go to ticket booth

wait for ticket

choose movie

buy tickets

go to concession stand

order popcorn / soda

show tickets

buy popcorn

enter theatre

find seats

turn off cellphone

sit down

eat popcorn

watch movie

use bathroom

discard trash

hold hands

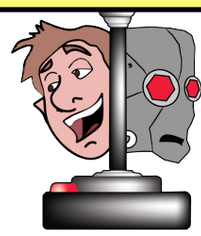
talk about movie

kiss

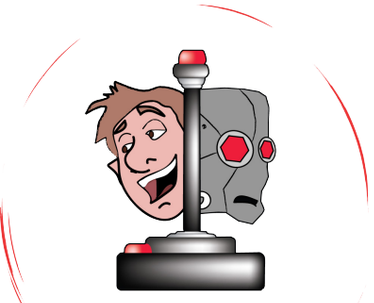
leave movie

drive home

With sweaty palms and heart racing, John drove to Sally's house for their first date. Sally, her pretty white dress flowing in the wind, carefully entered John's car. John and Sally drove to the movie theater. John and Sally parked the car in the parking lot. Wanting to feel prepared, John had already bought tickets to the movie in advance. A pale-faced usher stood before the door; John showed the tickets and the couple entered. Sally was thirsty so John hurried to buy drinks before the movie started. John and Sally found two good seats near the back. John sat down and raised the arm rest so that he and Sally could snuggle. John paid more attention to Sally while the movie rolled and nervously sipped his drink. Finally working up the courage to do so, John extended his arm to embrace Sally. He was relieved and ecstatic to feel her move closer to him in response. Sally stood up to use the restroom during the movie, smiling coyly at John before that exit. John and Sally also held hands throughout the movie, even though John's hands were sweaty. John and Sally slowly got up from their seats. Still holding hands, John walked Sally back to his car through the maze of people all scurrying out of the theater. The bright sunshine temporarily blinded John as he opened the doors and held them for Sally as they left the dark theater and stepped back out onto the street. John let go of Sally's hand and opened the passenger side door of his car for her but instead of entering the car, she stepped forward, embraced him, and gave him a large kiss. John drove Sally back to her home.

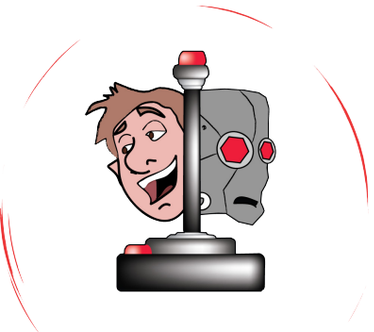


Corpora in the wild



Corpora in the wild

- Learn everything by reading the internet
  - Project Gutenberg
  - Reddit Writing Prompts
  - Scrape amateur fiction sites
  - Wikipedia movie and book plots



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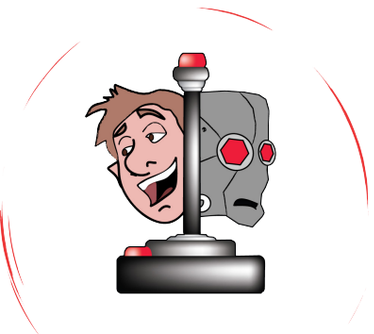

Corpora in the wild

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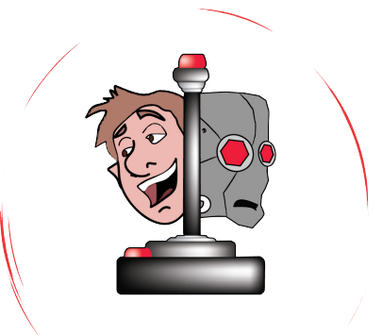
- Deep neural networks
  - Recurrent neural networks
  - Pr(tok_n | tok_{n-1}, tok_{n-2}, …; θ)
  - Tokens can be chars, words, sentences



Recurrent neural networks

- LSTMs

I was walking in the streets going to my friend's house. While I was walking , I stumbled upon the hustle and bustle of my surroundings. instead of my win, i begin to weave out into the air with a second moments, eventually my discomfort becomes apparent and closer to the cars. suddenly, i feel the strangely gay being of chibs suddenly, only this long i try not to stare too. where am i like? i question. but, you have a point, jonah says. when i was in there for a moment, my mind drifting almost i have ever seen in this situation; no living longer in our game. as i said this was the hunk hand, and i know this about the man in a situation so much more than i have to really right about this. i understand, that's how i want to do and handsome, love. of course, it is, i really believe that i really want. ever before, i don't know. my wife explains, the rich man explains. this was amazing, i remind him. the dinosaur takes a few steps behind the top of the stage and immediately standing up the front screen.

Khalifa, Barros, Togelius, 2017

Recurrent neural networks

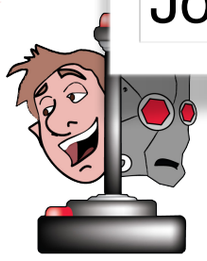
- Transformers

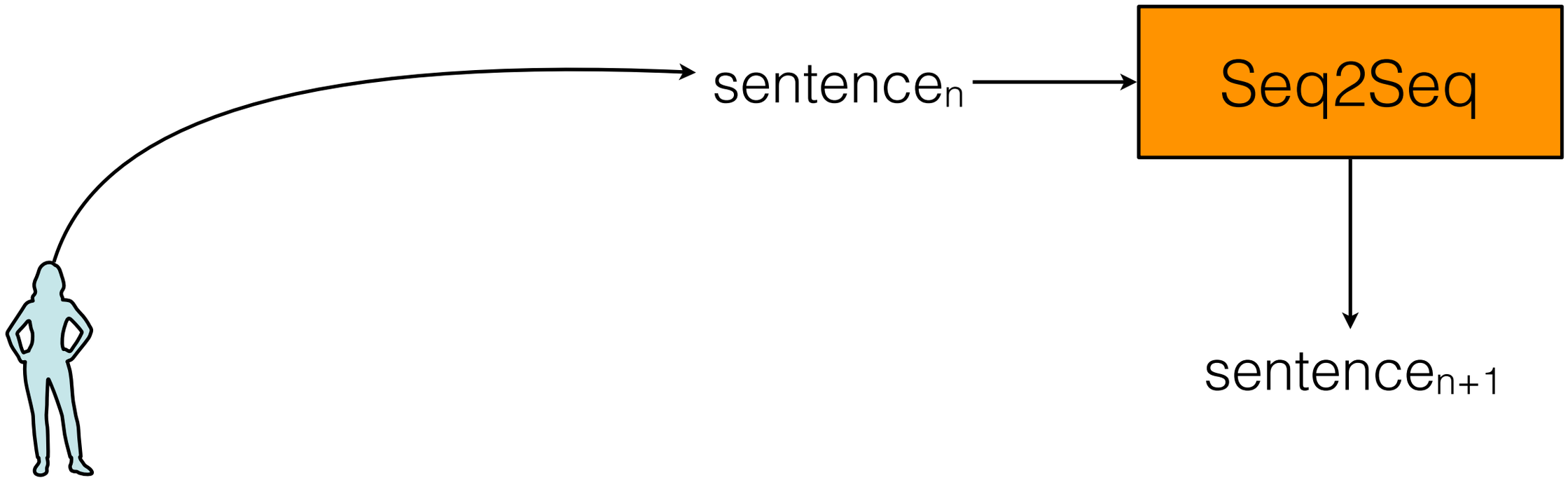
The hungry dog licked her lips as she watched her owner eat. She could see the white teeth in his jaw, then moving behind his right ear.

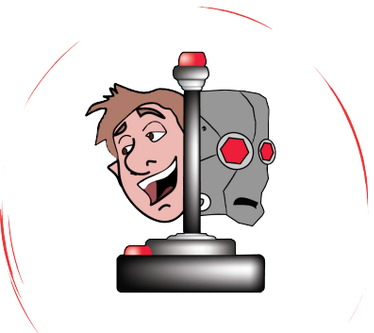
The hunter picked up his sword, directing the dogs in a cloud of mutterings. "Did you just feed a dog?" she demanded, suddenly even more agitated than before.

"Yes." Jack's voice was rough, and he hated that word. His face was tight and angry. "She has killed something important to us, and now the house is filled with blood. It makes me sad. She is one of the most dangerous wolves I have ever met, and if she bites me she will lose."

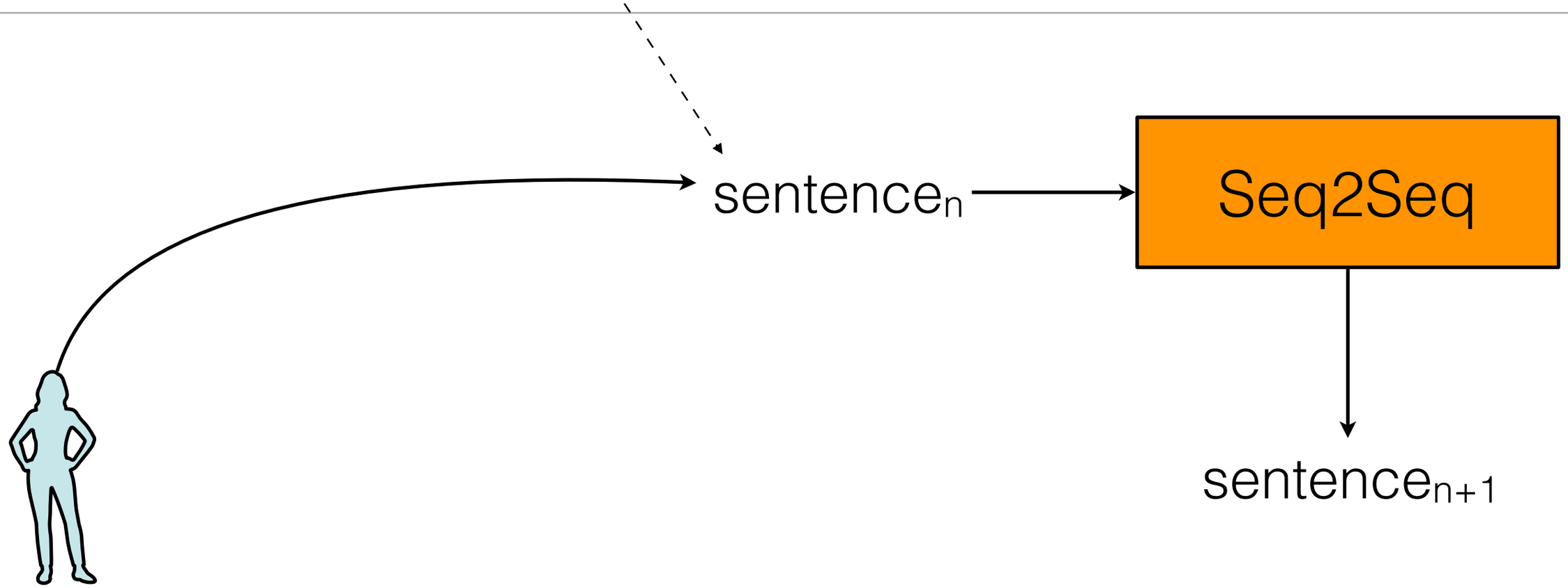
John shrugged. "Well, it's not your fault," he said

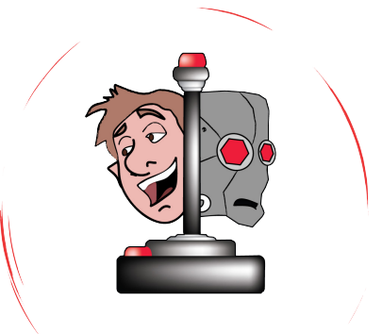



sentence$_n$
Seq2Seq
sentence$_{n+1}$



"John unwittingly unleashes an insidious pox"





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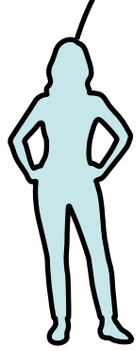
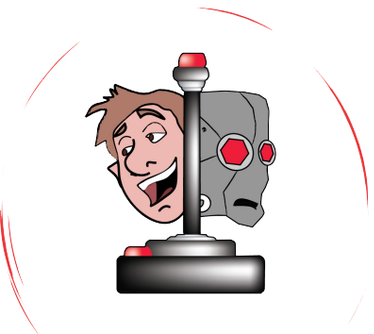


sentence$_n$

Seq2Seq

sentence$_{n+1}$

"He crumples and is about to be husk"



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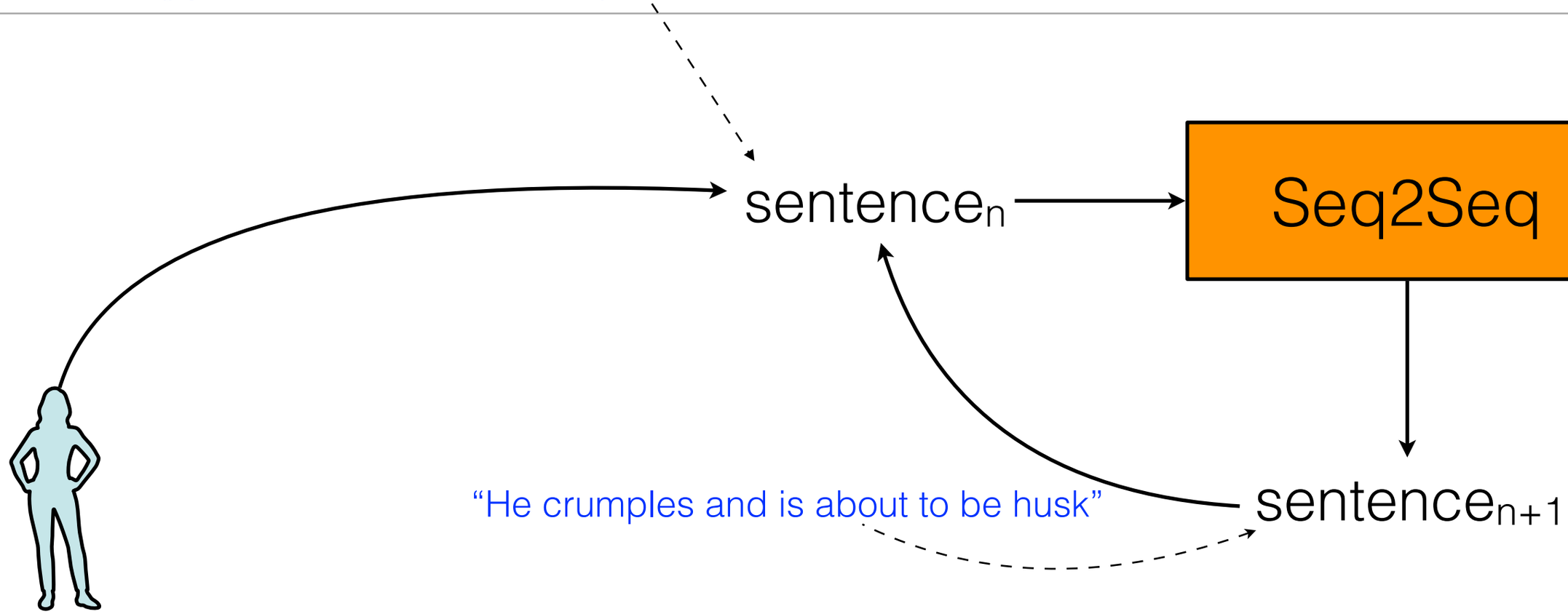
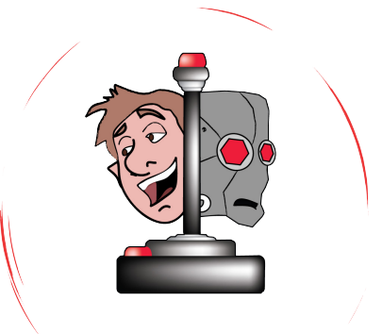
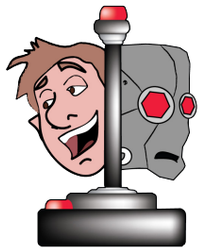




r 2 d 2 carrying some drinks on a tray strapped to his back passes yoda who uses his force powers to hog the drinks

---



Martin et al. AAAI 2018 Conference.

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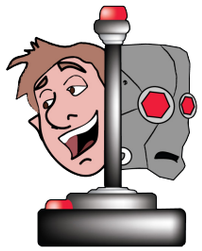

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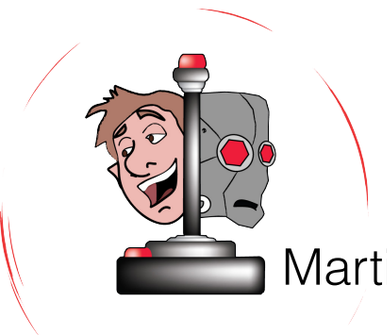
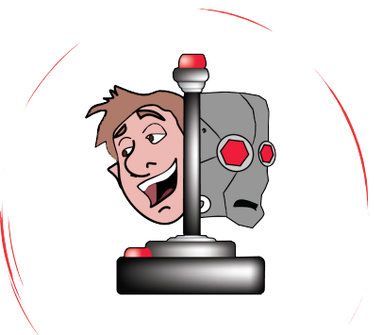


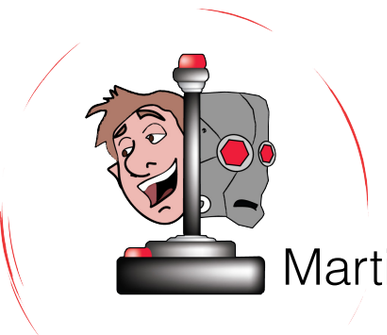
Martin et al. AAAI 2018 Conference.

Neural generation challenges

- Limitations of cross entropy as a loss function
- Many sentences transitions are unique
- (Data quality)
- Are words the right level of abstraction?
- Neural generators are not goal-driven (controllable)



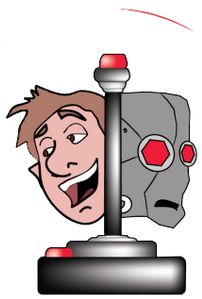
Event representation



Martin et al. AAAI 2018 Conference.

Event representation

- Pre-process corpus



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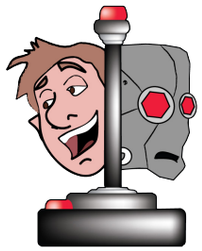
Event representation

- Pre-process corpus

Event:
⟨ subject, verb, object, preposition, helper ⟩



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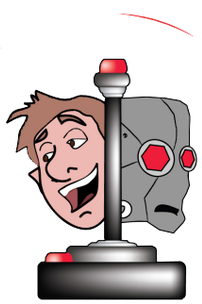
- Many sentences will map to the same event, forcing network to find new ways to reduce cross-entropy



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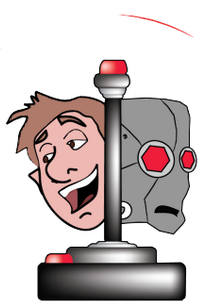
- Further generalize with WordNet and VerbNet



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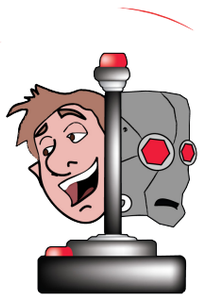
Event:
⟨ subject, verb, object, preposition, helper ⟩

- Many sentences will map to the same event, forcing network to find new ways to reduce cross-entropy

- Further generalize with WordNet and VerbNet

Generalized Event:
⟨ WordClass, VerbClass, WordClass, preposition, WordClass ⟩



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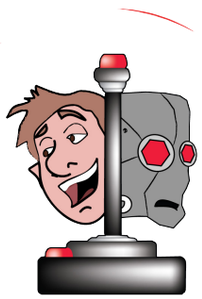
VerbNet



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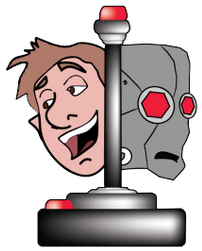
VerbNet

NP V NP PP.LOCATION

EXAMPLE	"He rowed Penny across the lake."
SYNTAX	AGENT V THEME {{+PATH}} LOCATION
SEMANTICS	MOTION(DURING(E0), THEME) PREP(E0, THEME, LOCATION) CAUSE(AGENT, E0) EQUALS(E0, E1) MOTION(DURING(E1), AGENT) PREP(E1, AGENT, LOCATION)



Martin et al. AAAI 2018 Conference.

r 2 d 2 carrying some drinks on a tray strapped to his back passes yoda who uses his force powers to hog the drinks

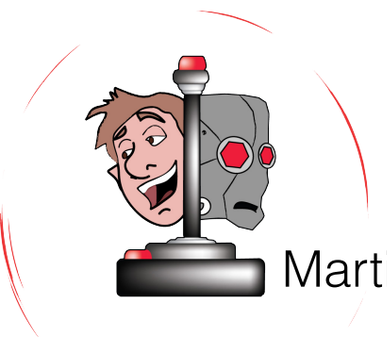
---

Expected

obi wan and anakin are drinking happily when chewbacca takes a polaroid picture of anakin and obi wan

Predicted

can this block gives him the advantage to personally run around with a large stick of cheese



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r 2 d 2 carrying some drinks on a tray strapped to his back passes by and the obi wan is the person carrying the drinks

<NE0> carry drinks tray

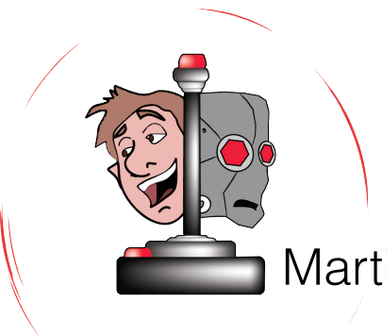
<NE1> uses force drinks

Expected

obi wan and anakin are drinking happily when chewbacca takes a polaroid picture of anakin and obi wan

Predicted

can this block gives him the advantage to personally run around with a large stick of cheese



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<NE0> carry drinks tray

<NE1> uses force drinks

Expected

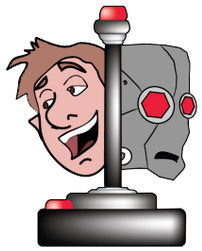
<NE2> drink ∅ ∅

<NE3> drink ∅ ∅

<NE4> takes picture <NE3>

Predicted

can this block gives him the advantage to personally run around with a large stick of cheese



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r 2 d 2 carrying some drinks on a tray strapped to his back passes by and the user uses the force to grab the drinks

<NE0> carry drinks tray

<NE1> uses force drinks

Expected

<NE2> drink ∅ ∅

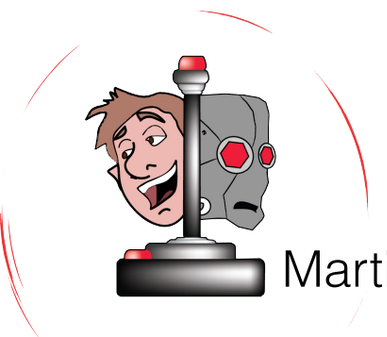
<NE3> drink ∅ ∅

<NE4> takes picture <NE3>

a polaroid picture of anakin and obi wan

Predicted

can this block gives him the ad ??? age to personally run around with a large stick of cheese



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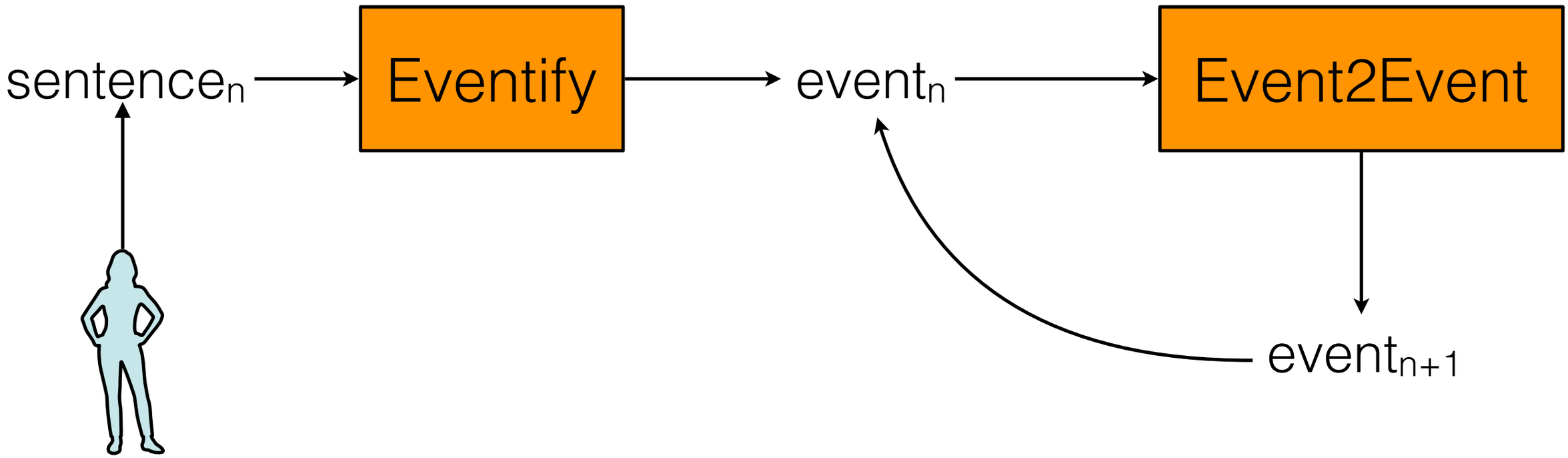

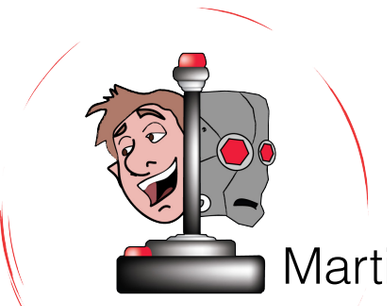

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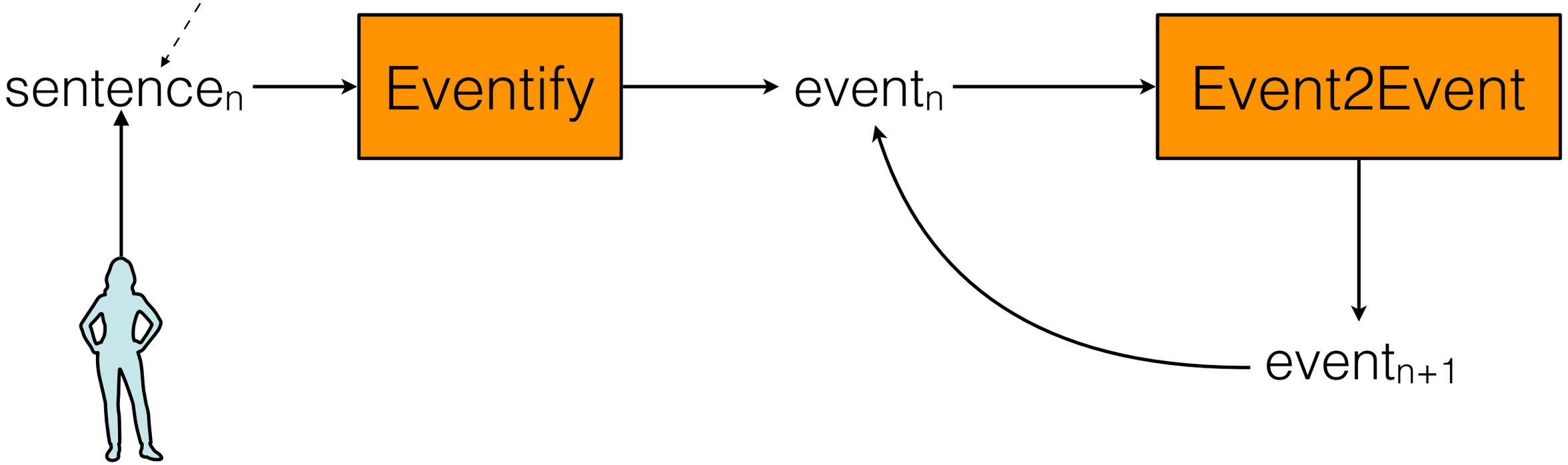
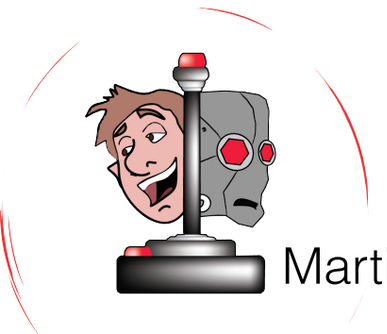
"John unwittingly unleashes an insidious pox"





Martin et al. AAAI 2018 Conference.

{<PERSON>0, disassemble-23.3, contageous_disease.n.01, ∅}

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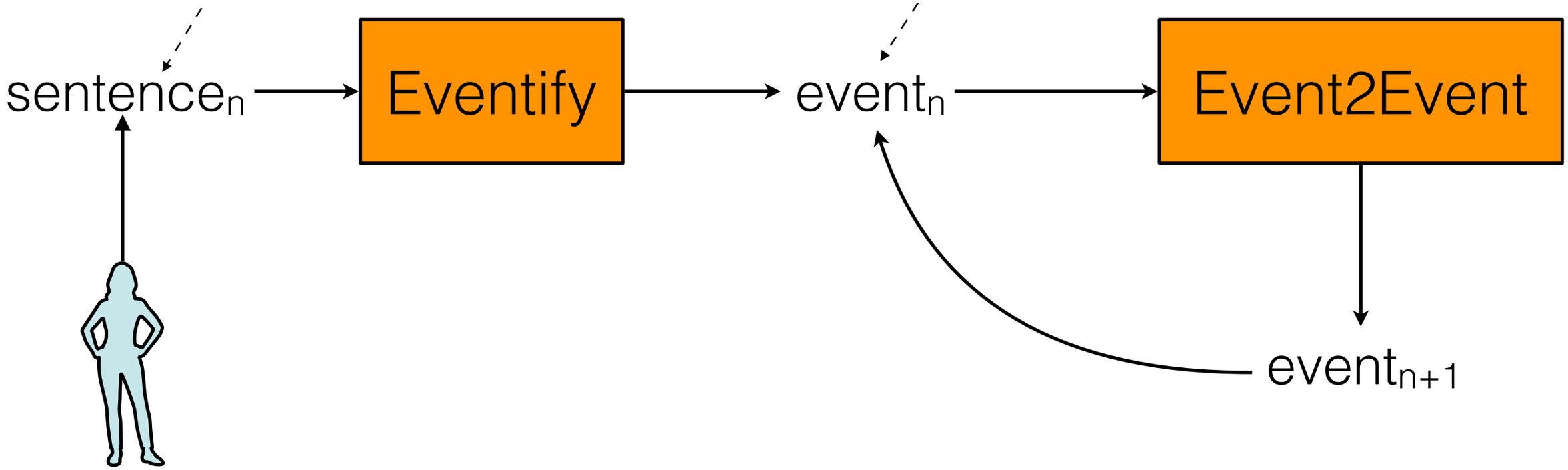

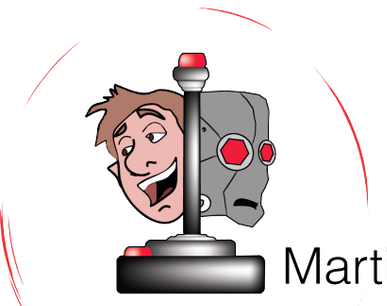

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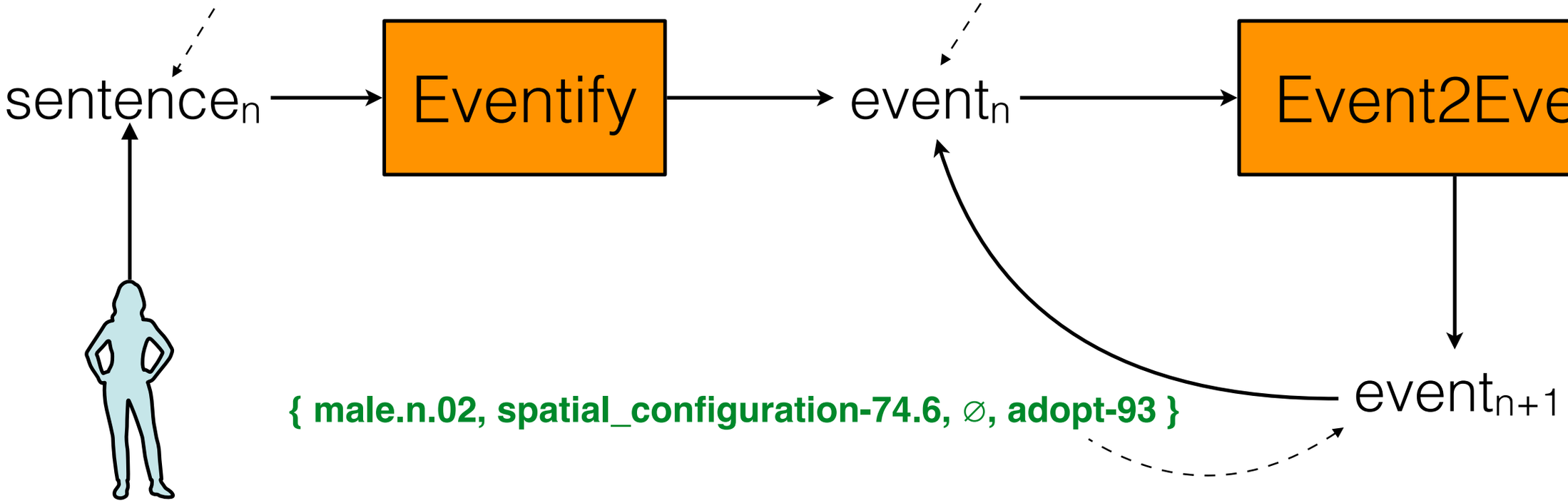

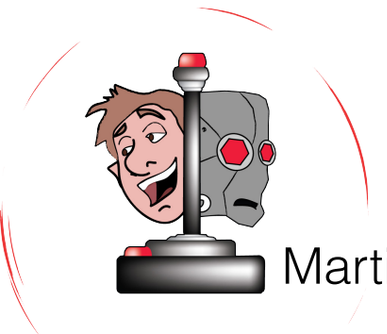

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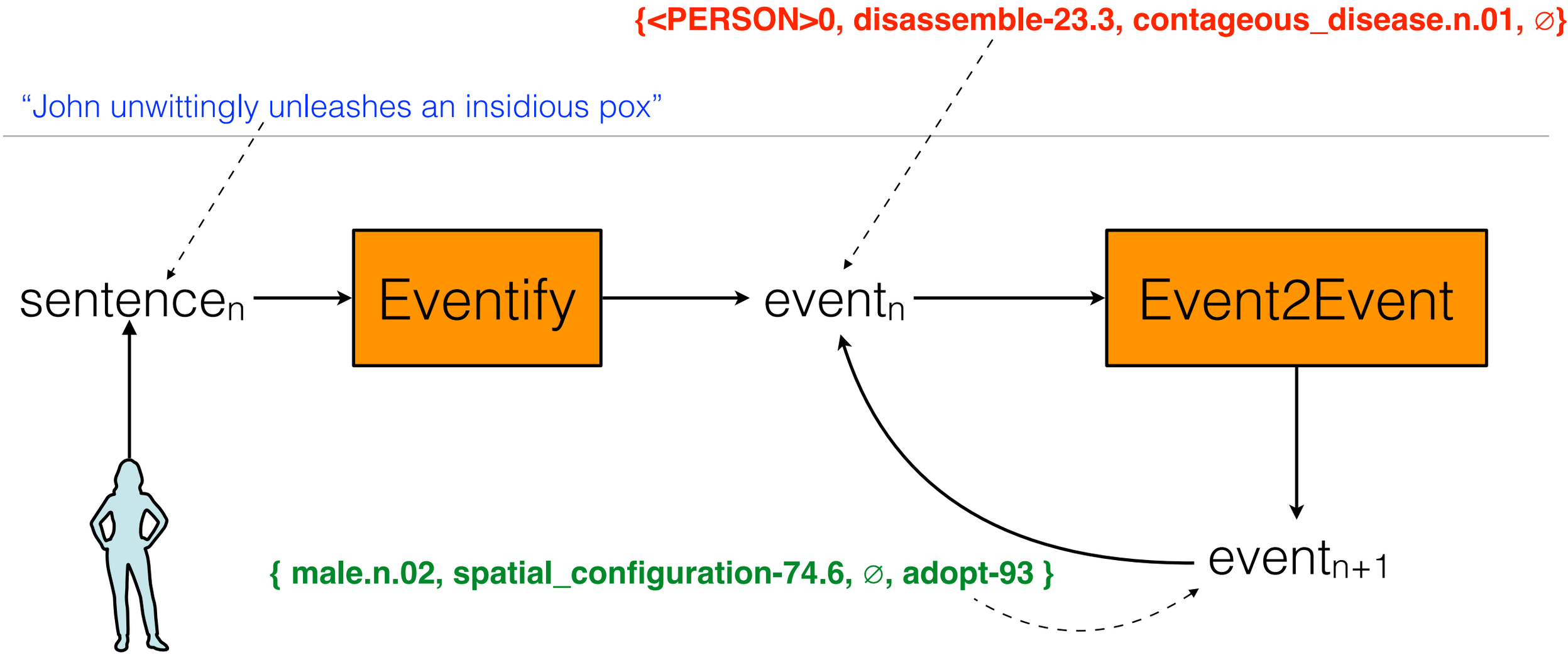
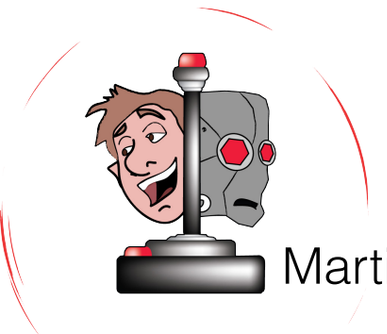


Representation	Perplexity
Original sentences	704.8
Events	748.9
Events w/ NEs	166.6
Generalized events	54.2
Generalized events, split sentences	**45.2**



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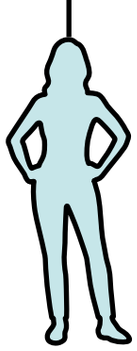
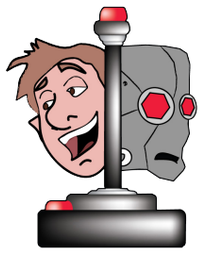
sentence$_n$ → Eventify → event$_n$ → Event2Event → event$_{n+1}$ → Event2Sentence → generalized sentence$_{n+1}$



{ male.n.02, spatial_configuration-74.6, ∅, adopt-93 }



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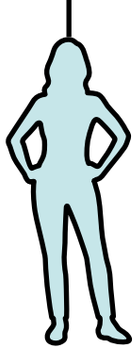
"John unwittingly unleashes an insidious pox"

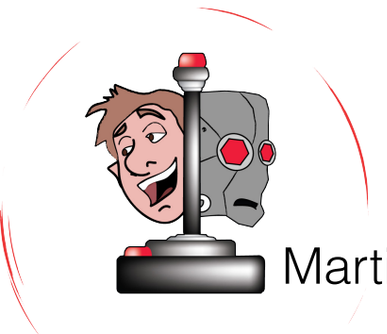
sentence$_n$ → Eventify → event$_n$ → Event2Event



{ male.n.02, spatial_configuration-74.6, ∅, adopt-93 }

event$_{n+1}$ → Event2Sentence → generalized sentence$_{n+1}$

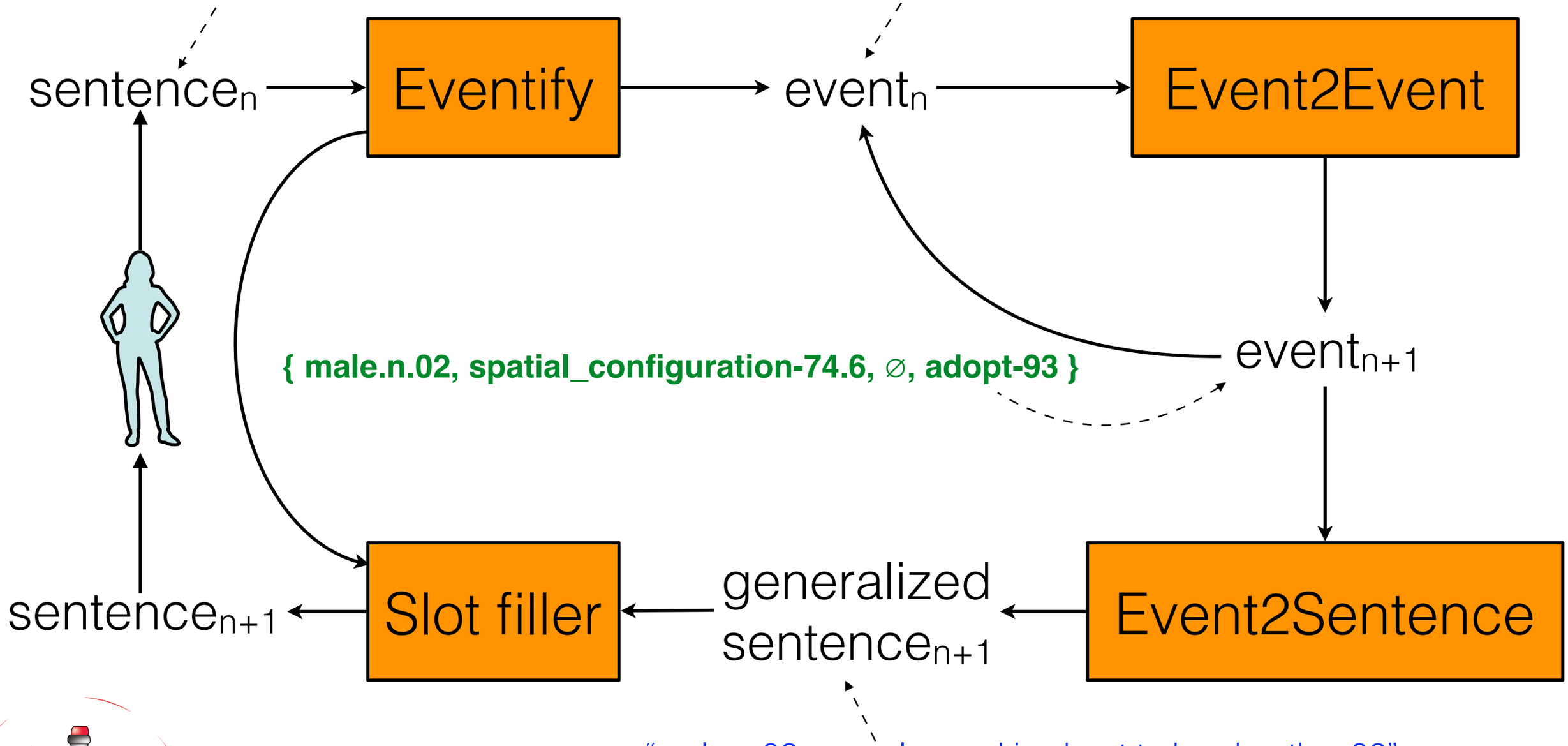
"male.n.02 crumples and is about to be sheath.n.02"



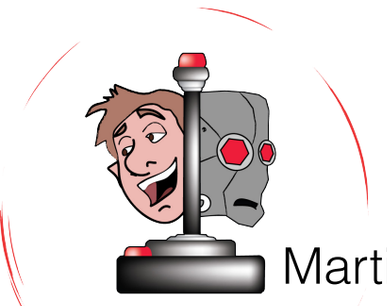
Martin et al. AAAI 2018 Conference.

{<PERSON>0, disassemble-23.3, contageous_disease.n.01, ∅}

"John unwittingly unleashes an insidious pox"



"male.n.02 crumples and is about to be sheath.n.02"



Martin et al. AAAI 2018 Conference.

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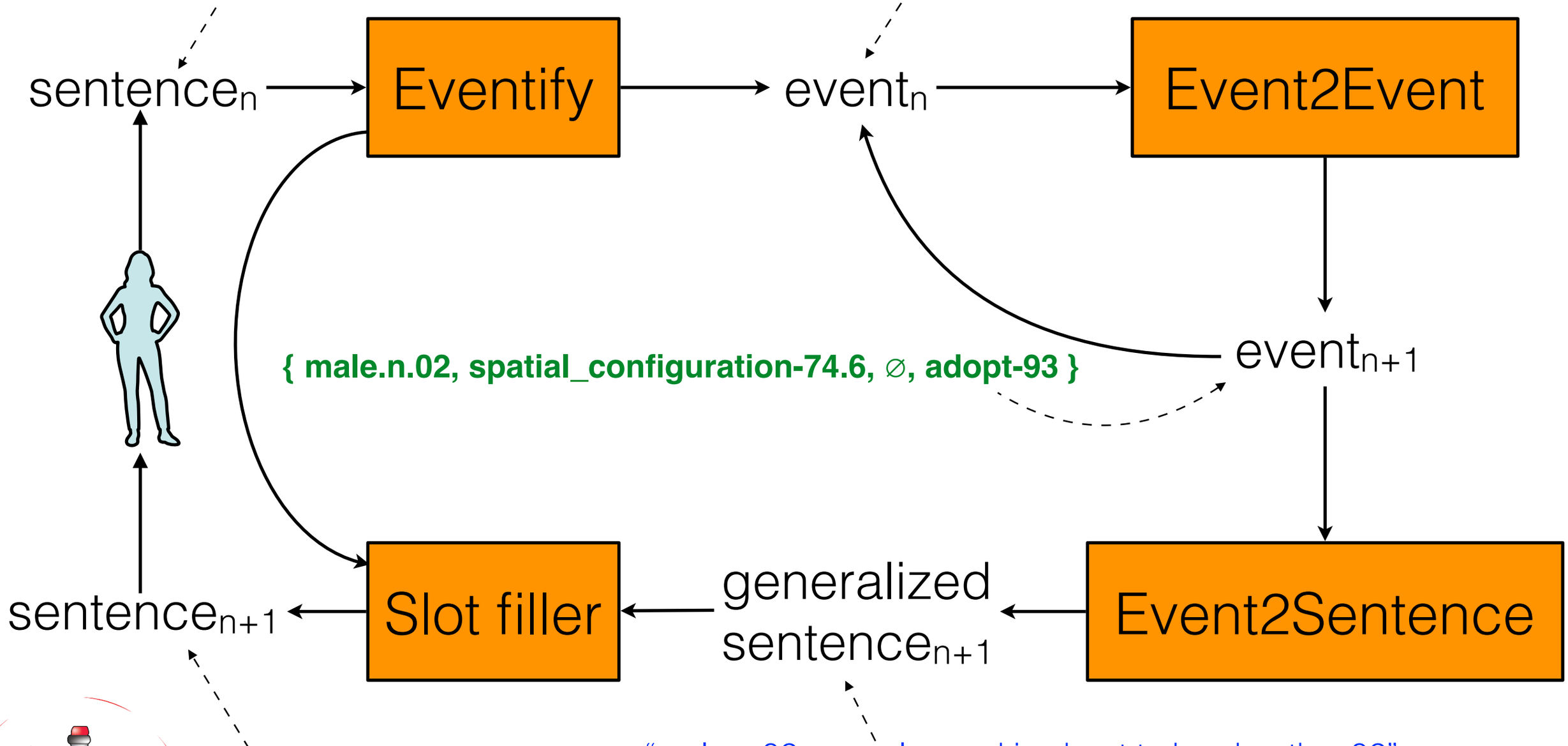
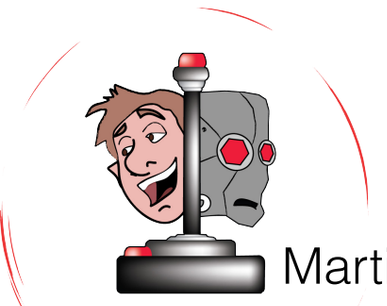


"male.n.02 crumples and is about to be sheath.n.02"

"John crumples and is about to be husk"



Martin et al. AAAI 2018 Conference.

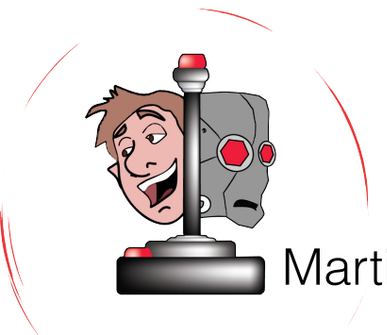
Examples

In: He reaches out to Remus Lupin, a Defence Against the Dark Arts teacher who is eventually revealed to be a werewolf.

Out: When *monster.n.01 nemesis.n.01* describes who finally realizes *male.n.02* can not, dangerous *entity.n.01 male.n.02* is released from *penal_institution.n.01*.

In: John unwittingly unleashes an insidious pox that rapidly spreads across the Caribbean.

Out: *male.n.02* crumples and is about to be *sheath.n.02*.



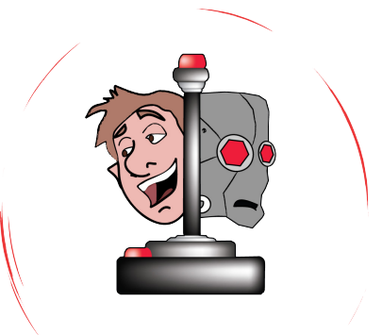
Martin et al. AAAI 2018 Conference.

Controllability

- Recall language models approximate
  Pr(tok_n | tok_{n-1}, tok_{n-2}, …; θ)

- Sampling from the distribution is uncontrolled generation

- Stochastic sampling means an unlikely choice can cascade



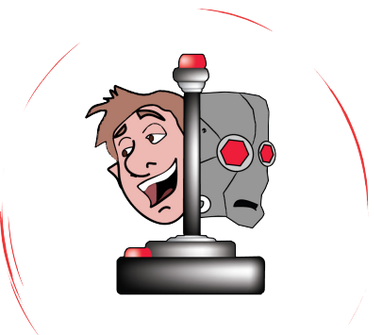
Other neural approaches

Using Reddit Writing Prompts:

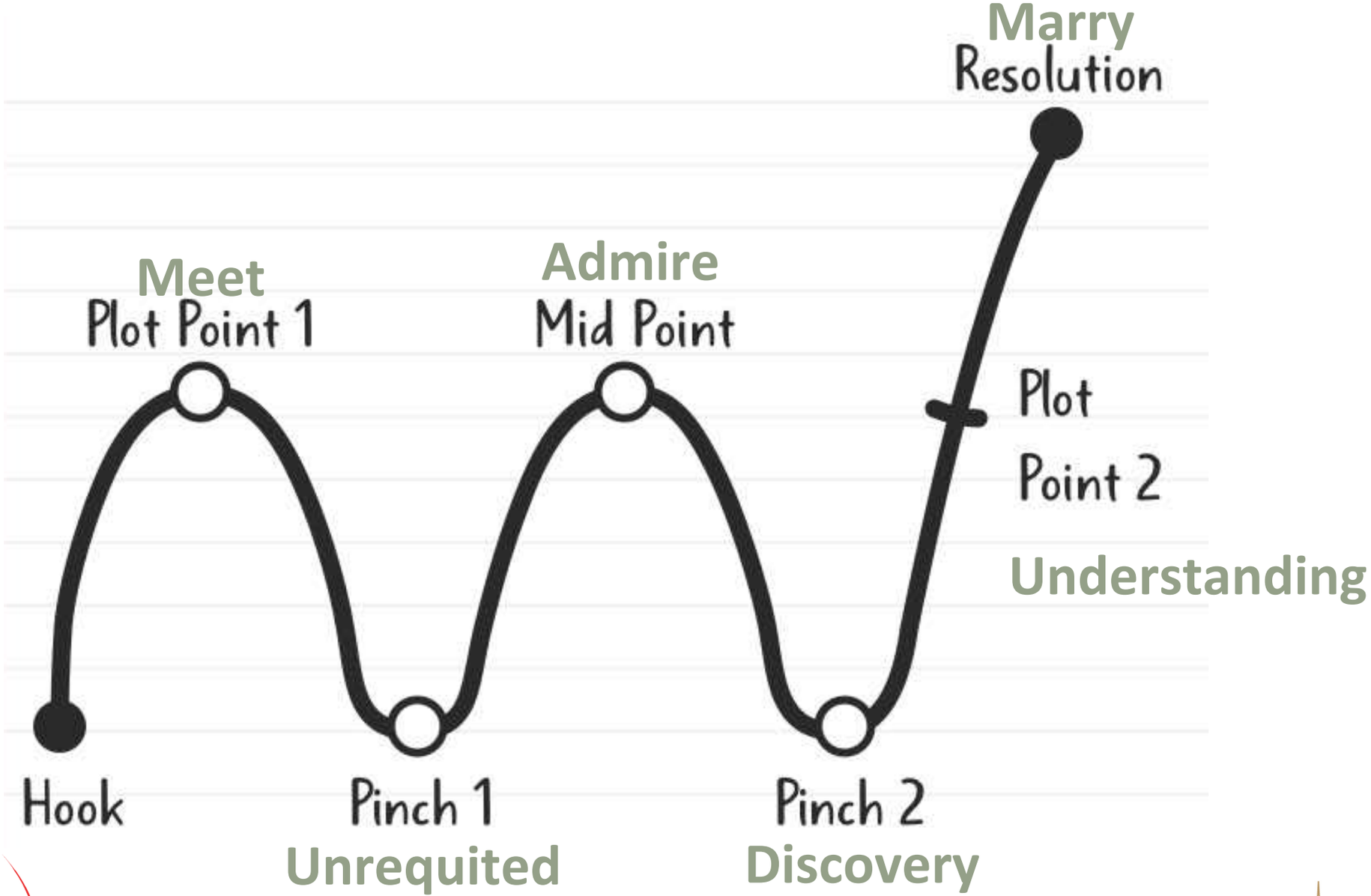
Fan et al. (Facebook), arXiv:1805.04833

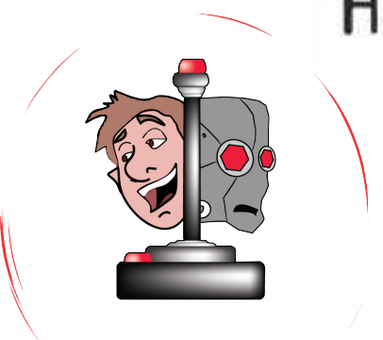
Example Prompt 1: Aliens start abducting humans

It has been two weeks, and the last of my kind has gone. It is only a matter of time until there will be nothing left. I'm not sure what the hell is going on... I can't think. I can hear a distant scream. I think of a strange, alien sound. I try to speak, but am interrupted by something, something that feels like a drum, I ca not tell. I mean I'm just a little bit older than an average human. But I can, and I can feel the vibrations . I hear the sound of a ship approaching. The ground quakes at the force of the impact, and a loud explosion shatters the silence.

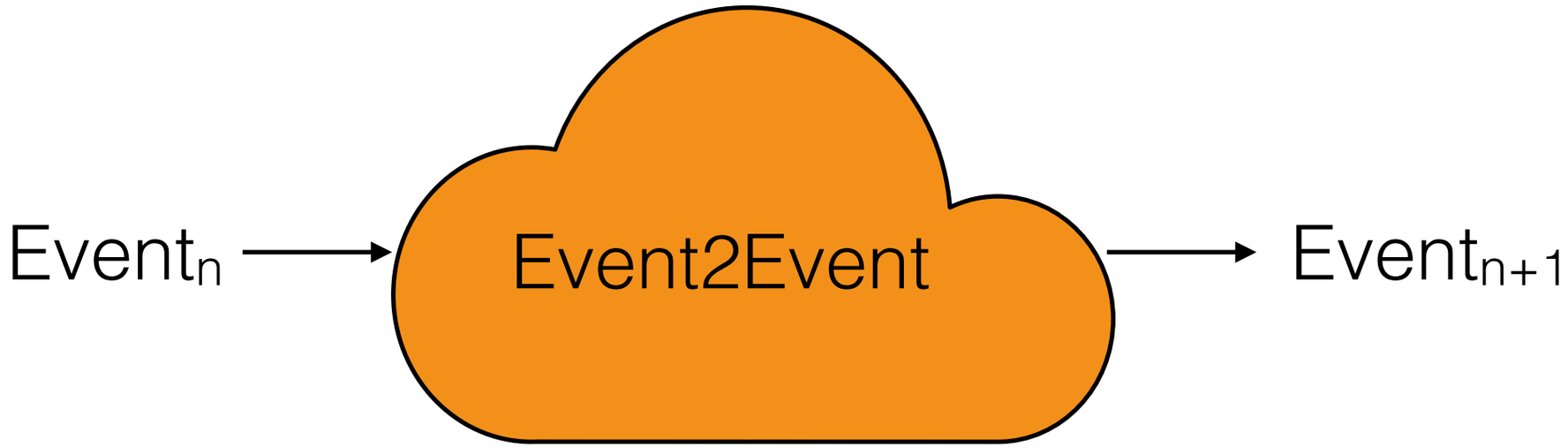


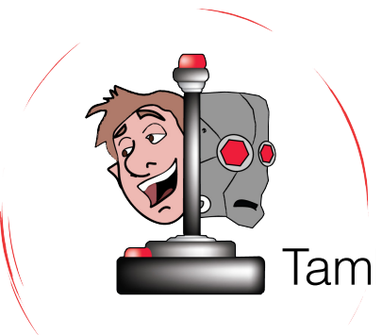
Goal-driven coherence





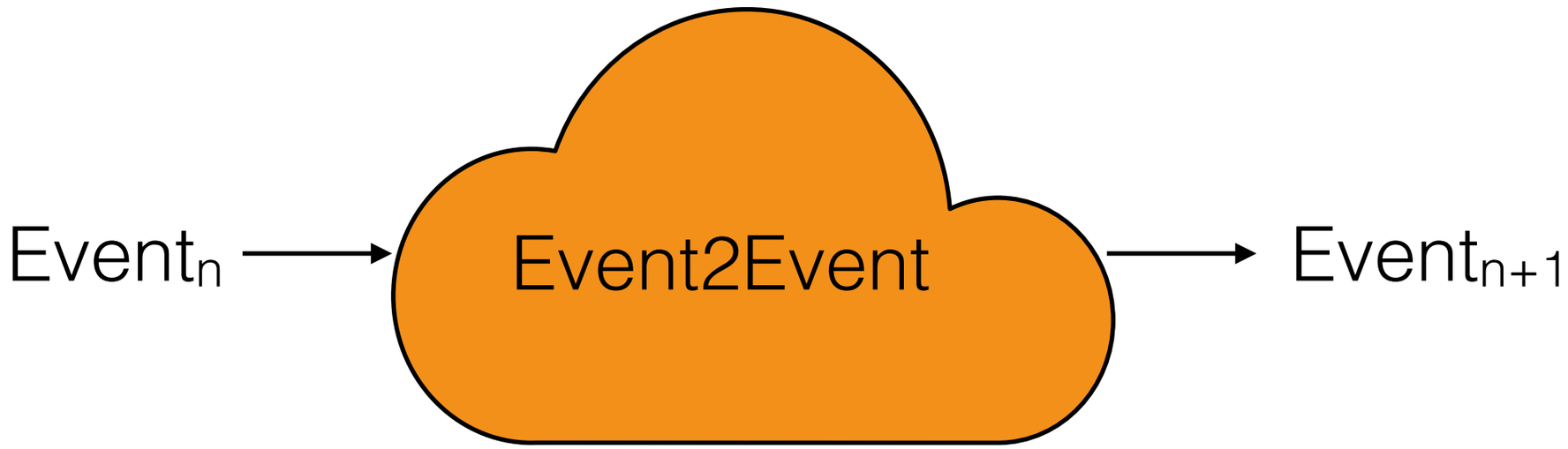
Rewarding goal-driven stories

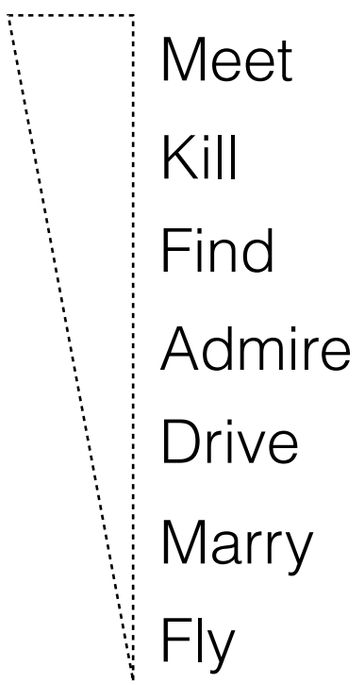


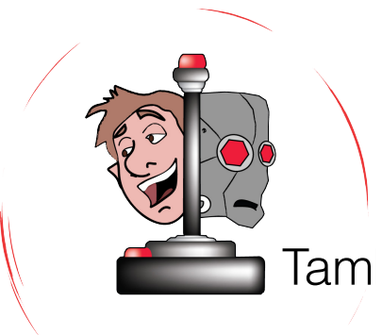


Tambwekar et al. IJCAI 2019 Conference.

Rewarding goal-driven stories

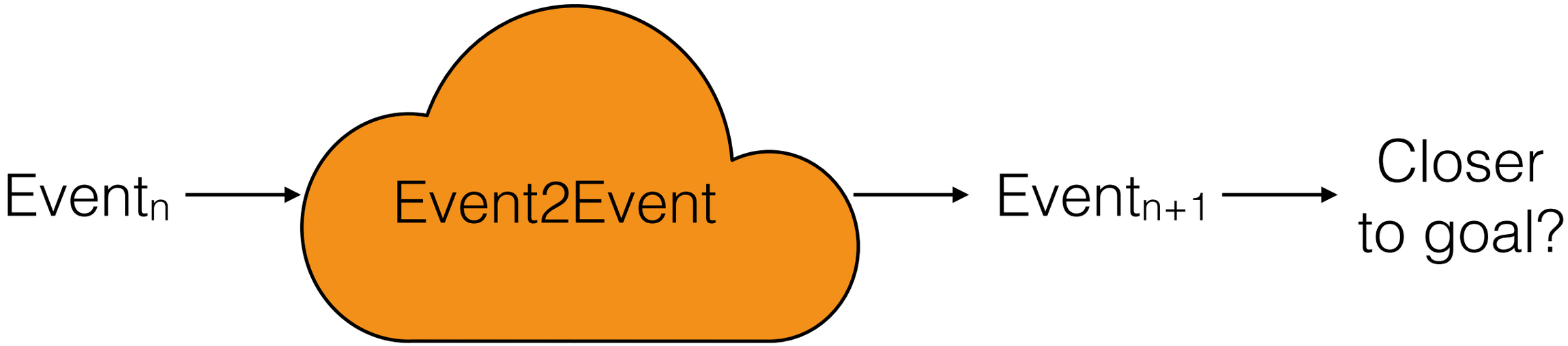


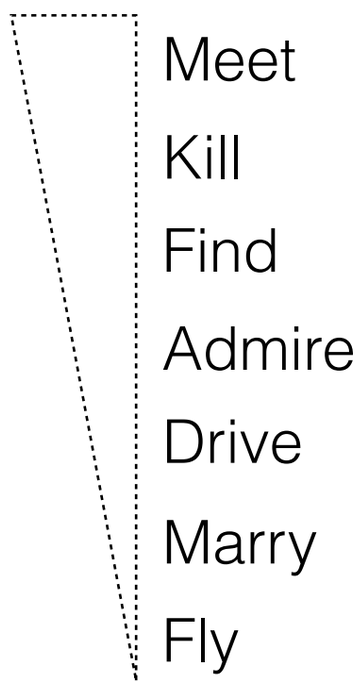


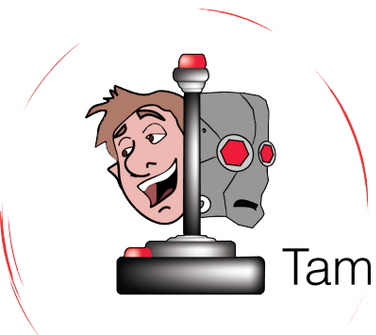


Tambwekar et al. IJCAI 2019 Conference.

Rewarding goal-driven stories







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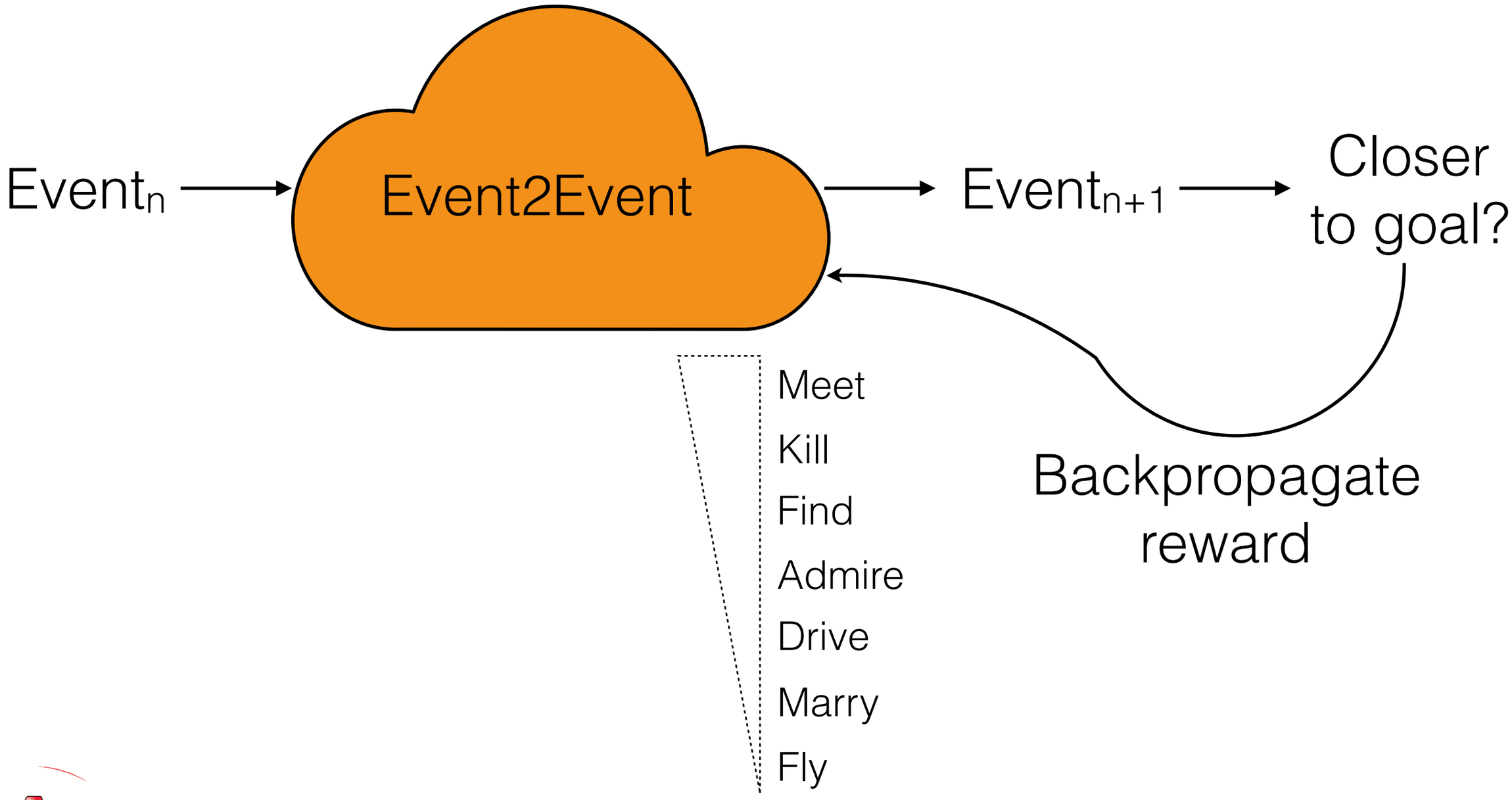

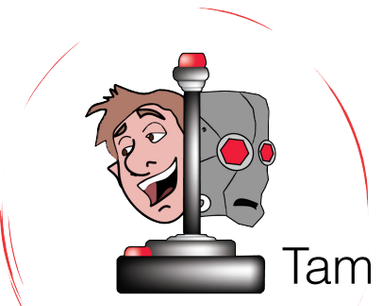

Tambwekar et al. IJCAI 2019 Conference.

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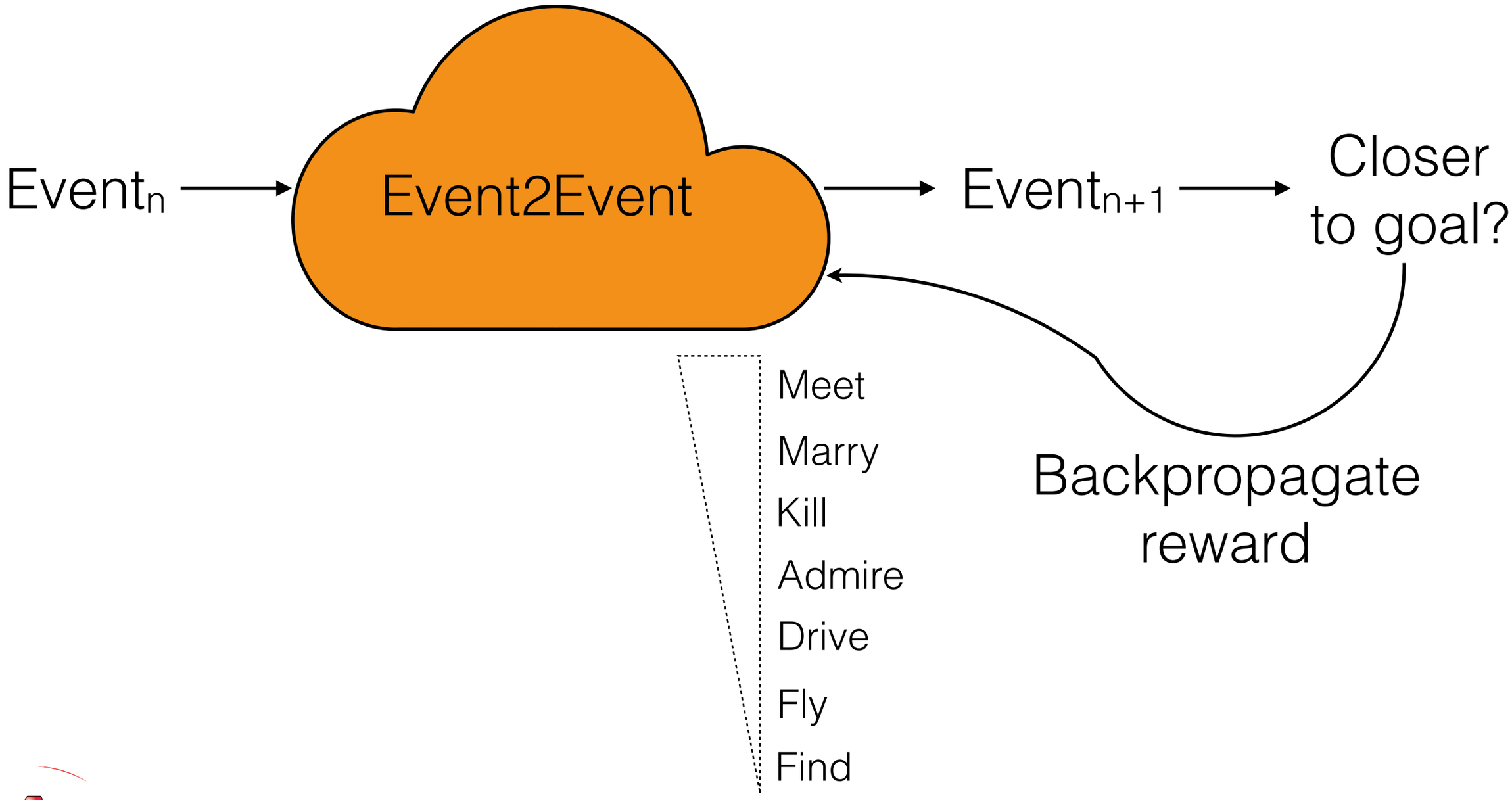
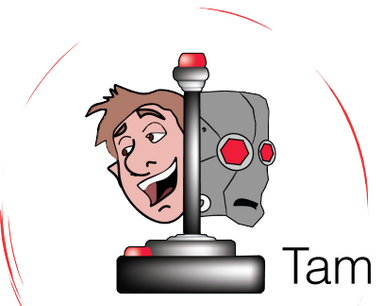
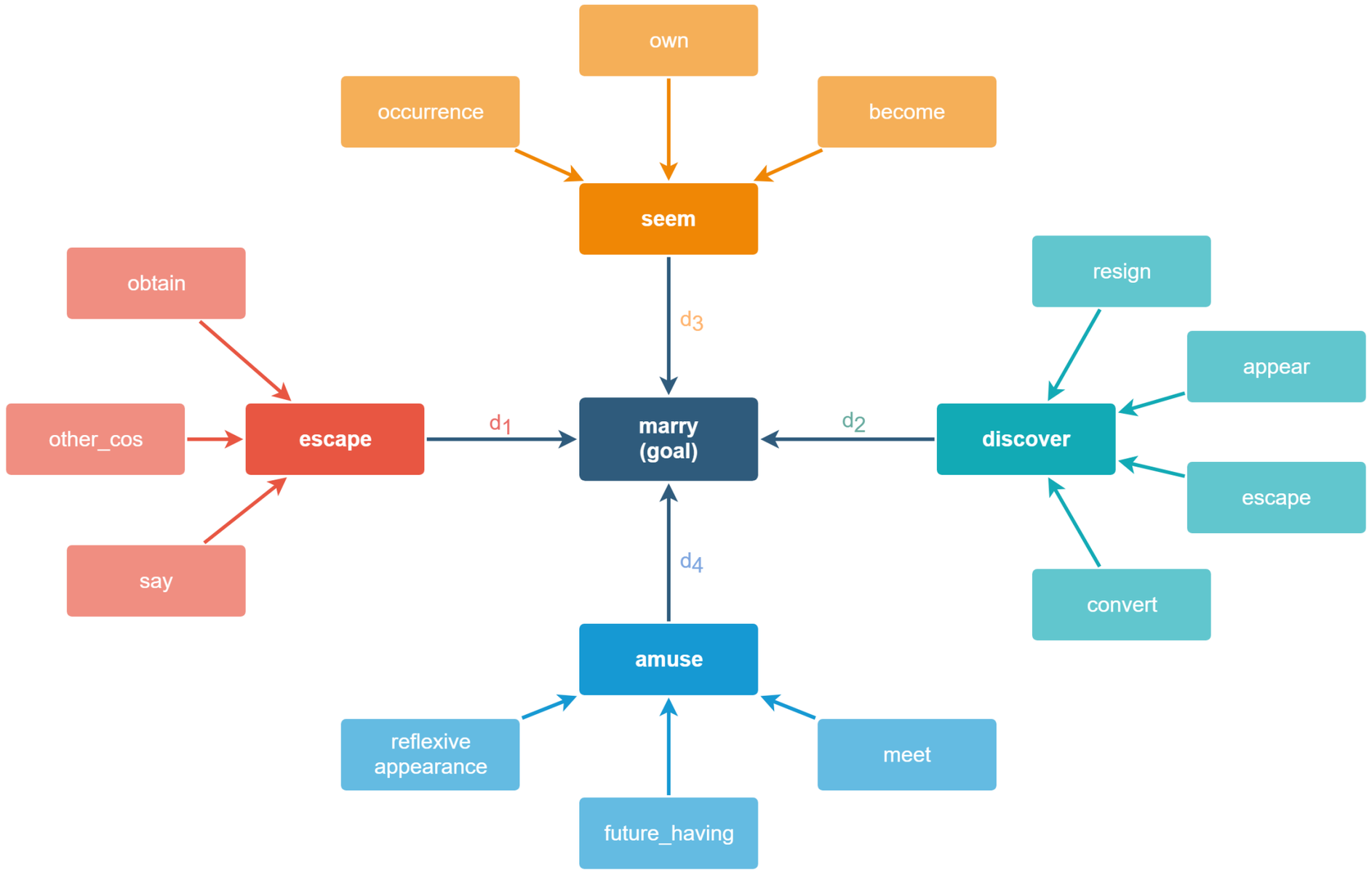
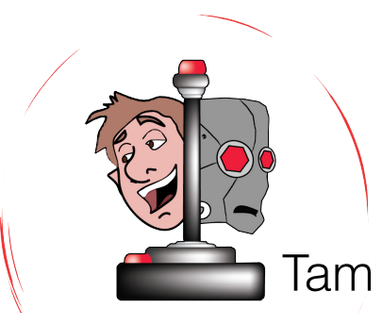




Tambwekar et al. IJCAI 2019 Conference.

Reward shaping

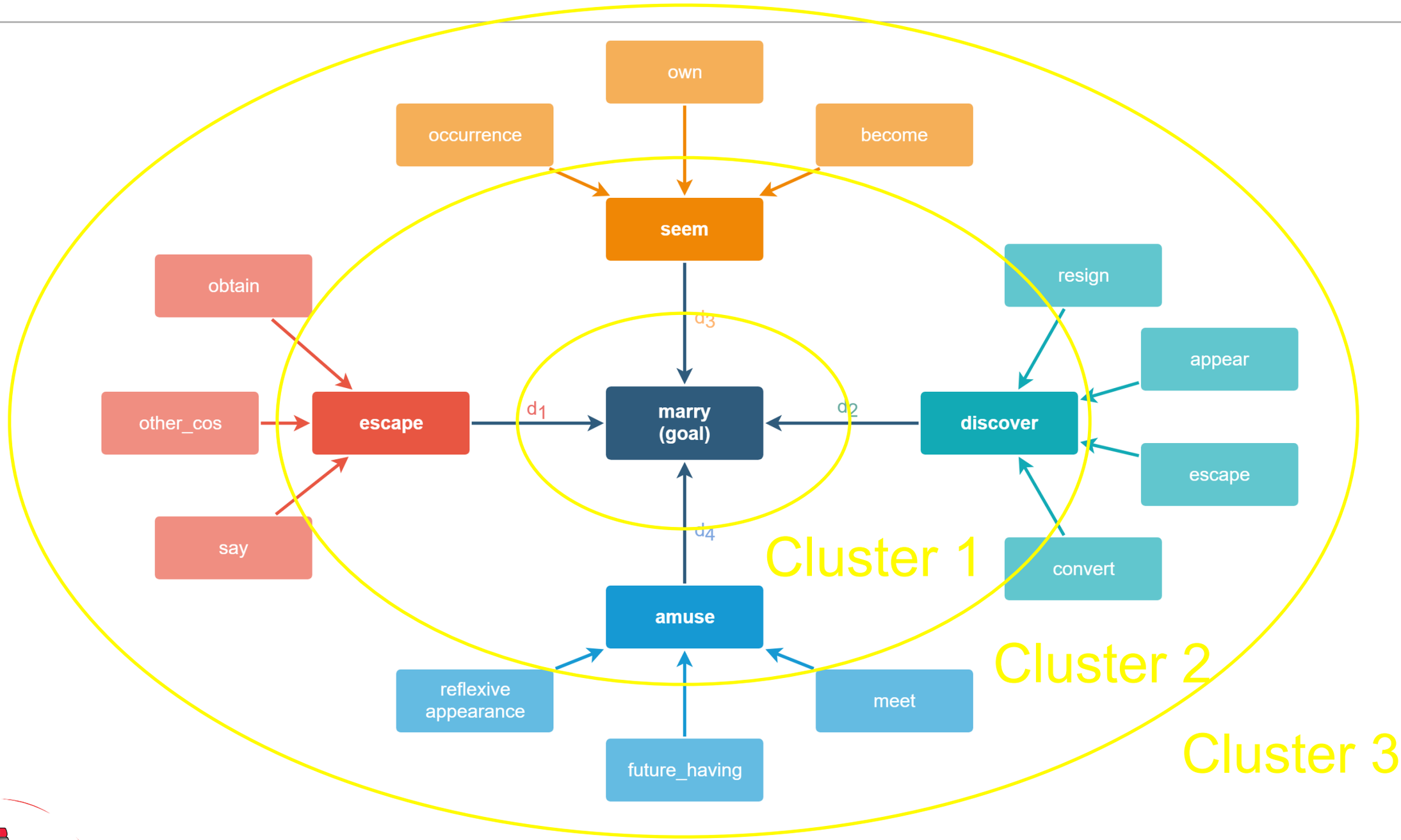


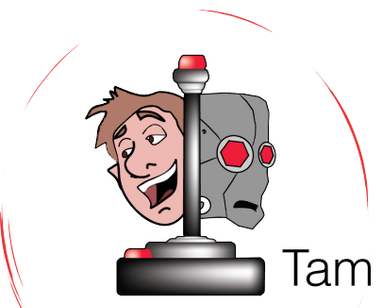


Higher reward == closer to goal

Tambwekar et al. IJCAI 2019 Conference.

Reward shaping





Higher reward == closer to goal

Tambwekar et al. IJCAI 2019 Conference.

Goal: hate/admire verb frame

Our sister died.

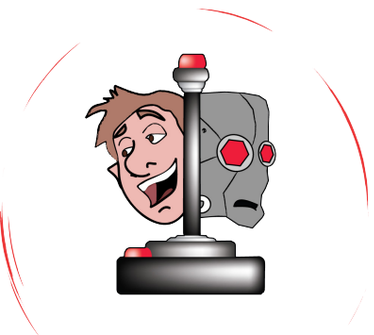
Greggory executed during the visit.

Greggory adopted the girl.

The girl looked like her mom.

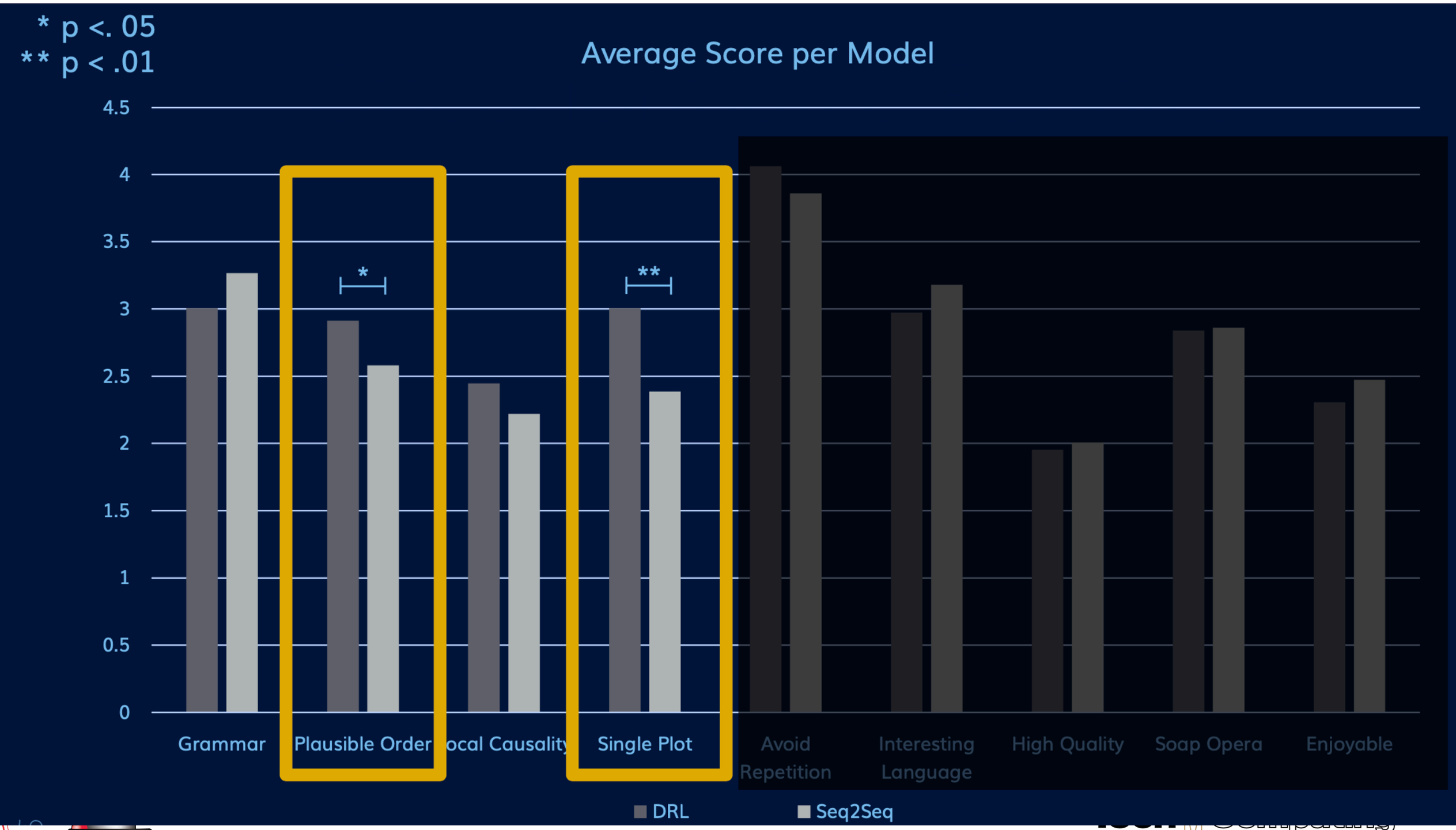
She was appalled.

Penelope detested the jungle gym.

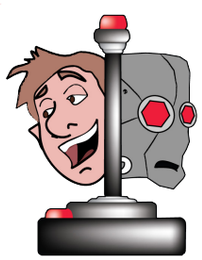


Goal achievement rate: > 93%

Perplexity: ~45.0 —> ~7.0

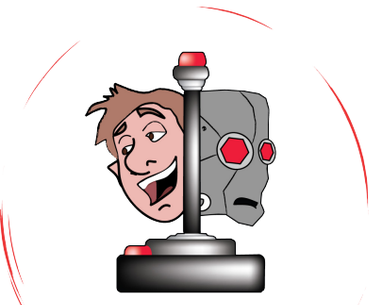


DRL Event Output ⟨ subject, verb, object, modifier ⟩	Translated Sentence
⟨ relative.n.01, disappearance-48.2, Ø, Ø ⟩	My cousin died.
⟨ NE1, say-37.7-1, visit, Ø ⟩	Alexander insisted on a visit.
⟨ NE1, meet-36.3-1, female.n.02, Ø ⟩	Alexander met her.
⟨ NE0, correspond-36.1, Ø, NE1 ⟩	Barbara commiserated with Alexander.
⟨ physical_entity.n.01, marry-36.2, Ø, Ø ⟩	They hugged.
⟨ group.n.01, contribute-13.2-2, Ø, LOCATION ⟩	The gathering dispersed to Hawaii.
⟨ gathering.n.01, characterize-29.2-1-1, time_interval.n.01, Ø ⟩	The community remembered their trip.
⟨ physical_entity.n.01, cheat-10.6, pack, Ø ⟩	They robbed the pack.
⟨ physical_entity.n.01, admire-31.2, social_gathering.n.01, Ø ⟩	They adored the party.



Tambwekar et al. IJCAI 2019 Conference.

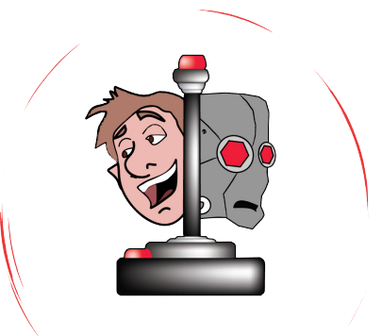
Explicit world states



Explicit world states

- Latent state in a neural network probably not the state of the story world

- Example: Sally picks up umbrella … Sally hits John with umbrella



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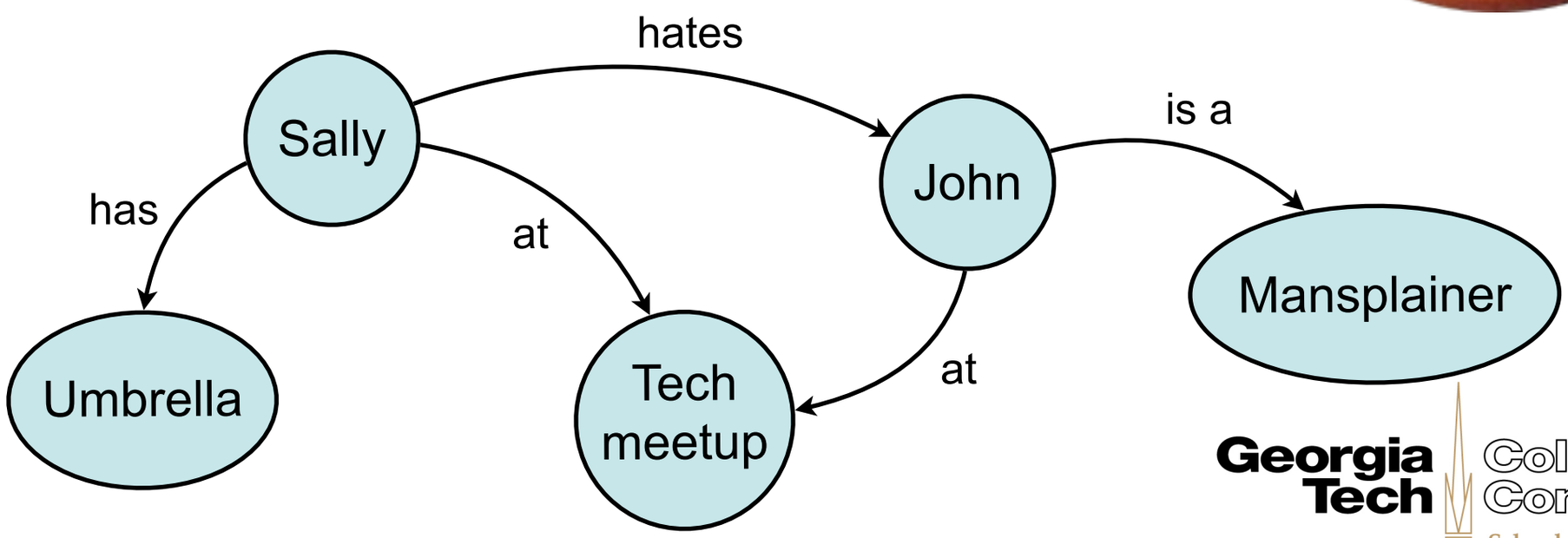
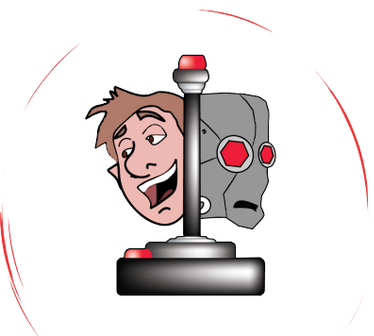
- Example: Sally picks up umbrella … Sally hits John with umbrella

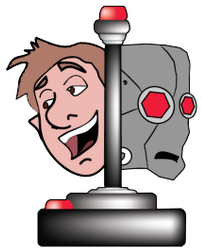
- Knowledge graphs





Back to story generation

- Can knowledge graph state representation help with story generation?
- No ground truth simulation
- Not much descriptive text to extract relations from



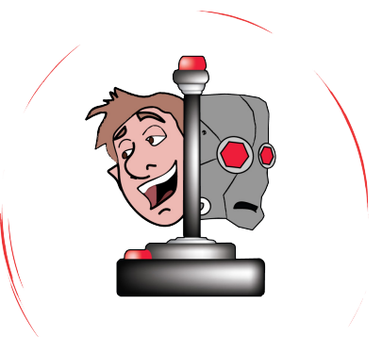
Martin et al. Dungeons and DQNs, 2018.

Infer ground state

Jen sent the book to Remy from Atlanta

Frame: sent

has_location(e1, theme, initial_location)	initial_locations: location
do(e2, agent)	
cause(e2, e3)	
motion(e3, theme)	theme: concrete
~has_location(theme, initial_location)	
has_location(theme, destination)	agent: animate or organization
Predicates	**Selectional restrictions**



Infer ground state

Jen sent the book to Remy from Atlanta

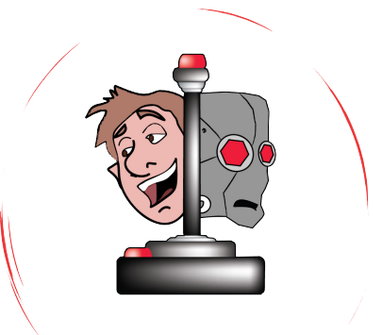
(agent) (theme) (destination) (initial_location)

has_location(e1, book, Atlanta)
do(e2, Jen)
cause(e2, e3)
motion(e3, book)
~has_location(book, Atlanta)
has_location(book, Remy)

Atlanta: location

book: concrete

Jen: animate or organization



Infer ground state

Jen sent the book to Remy from Atlanta

(agent) (theme) (destination) (initial_location)

has_location(e1, book, Atlanta)

Atlanta: location

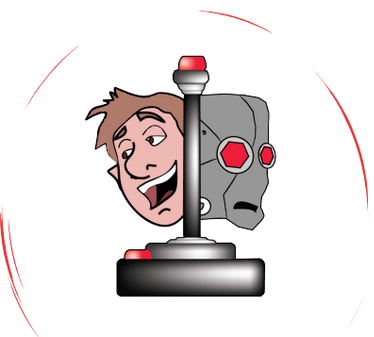
book: concrete

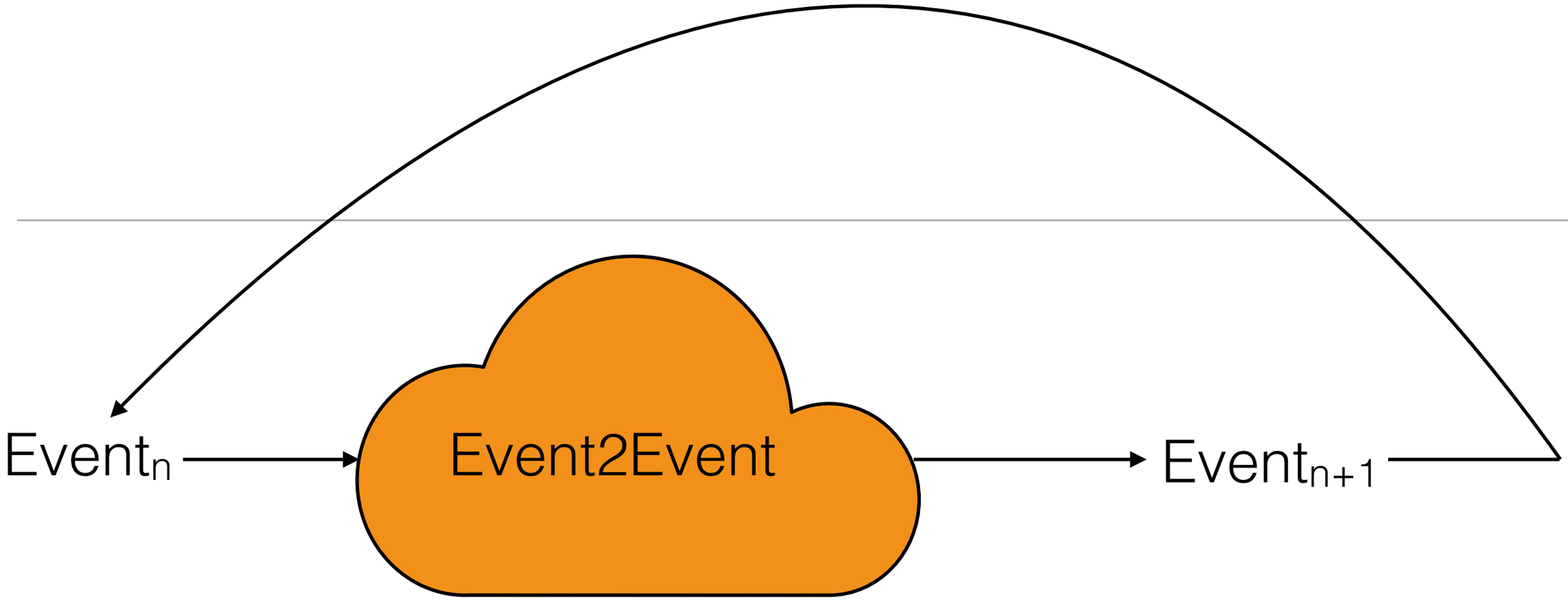
Jen: animate or organization

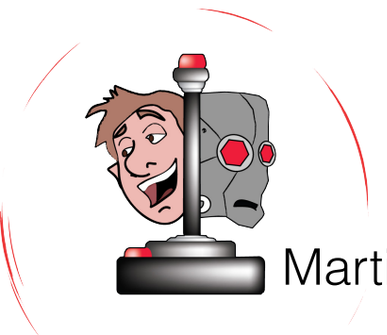
Preconditions

~has_location(book, Atlanta)
has_location(book, Remy)

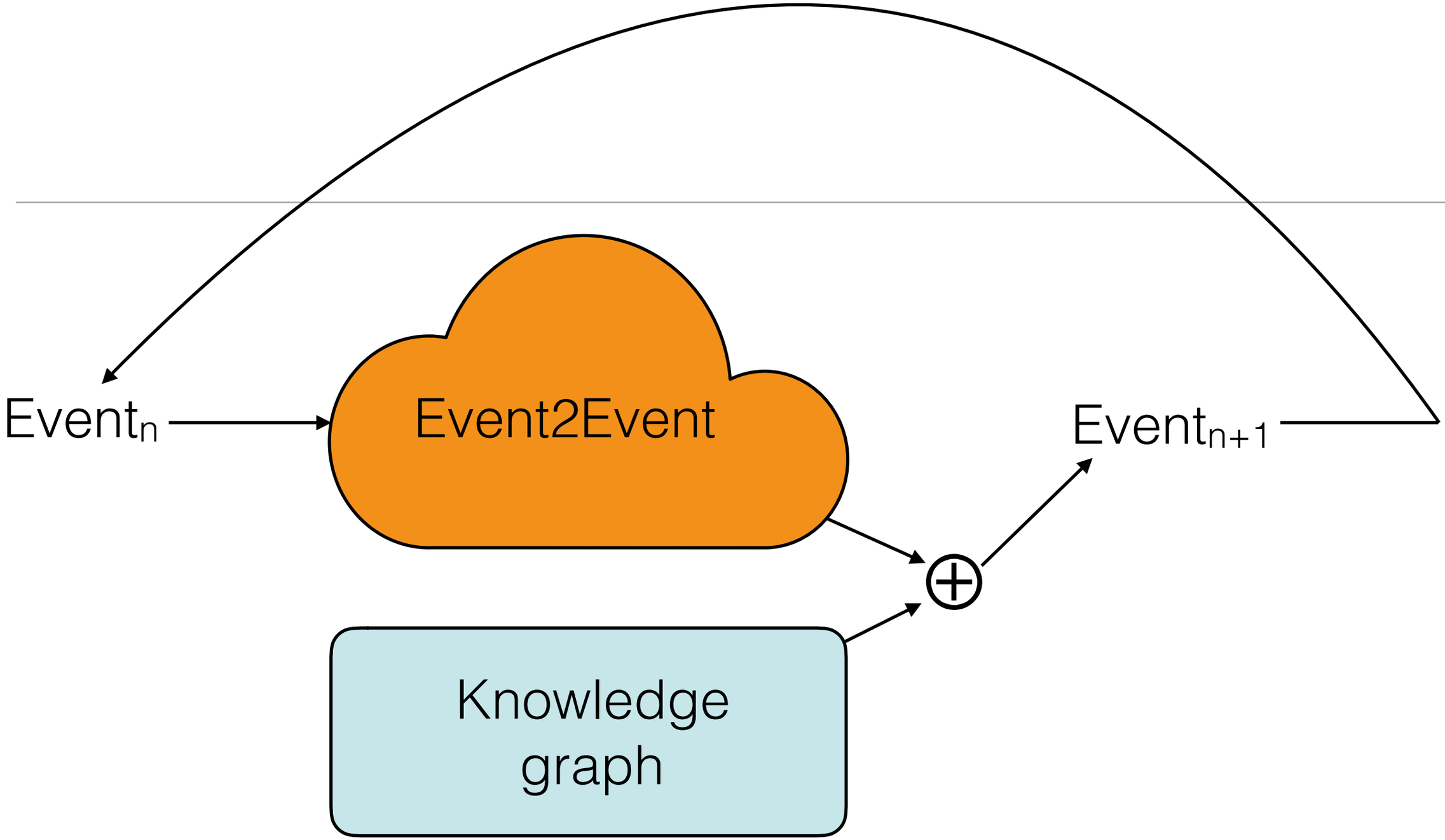
Effects

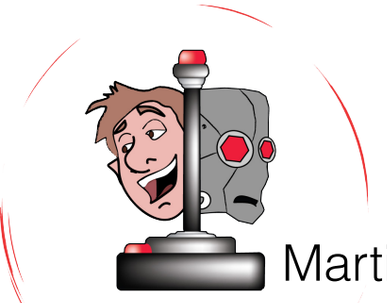






Martin et al. Dungeons and DQNs, 2018.





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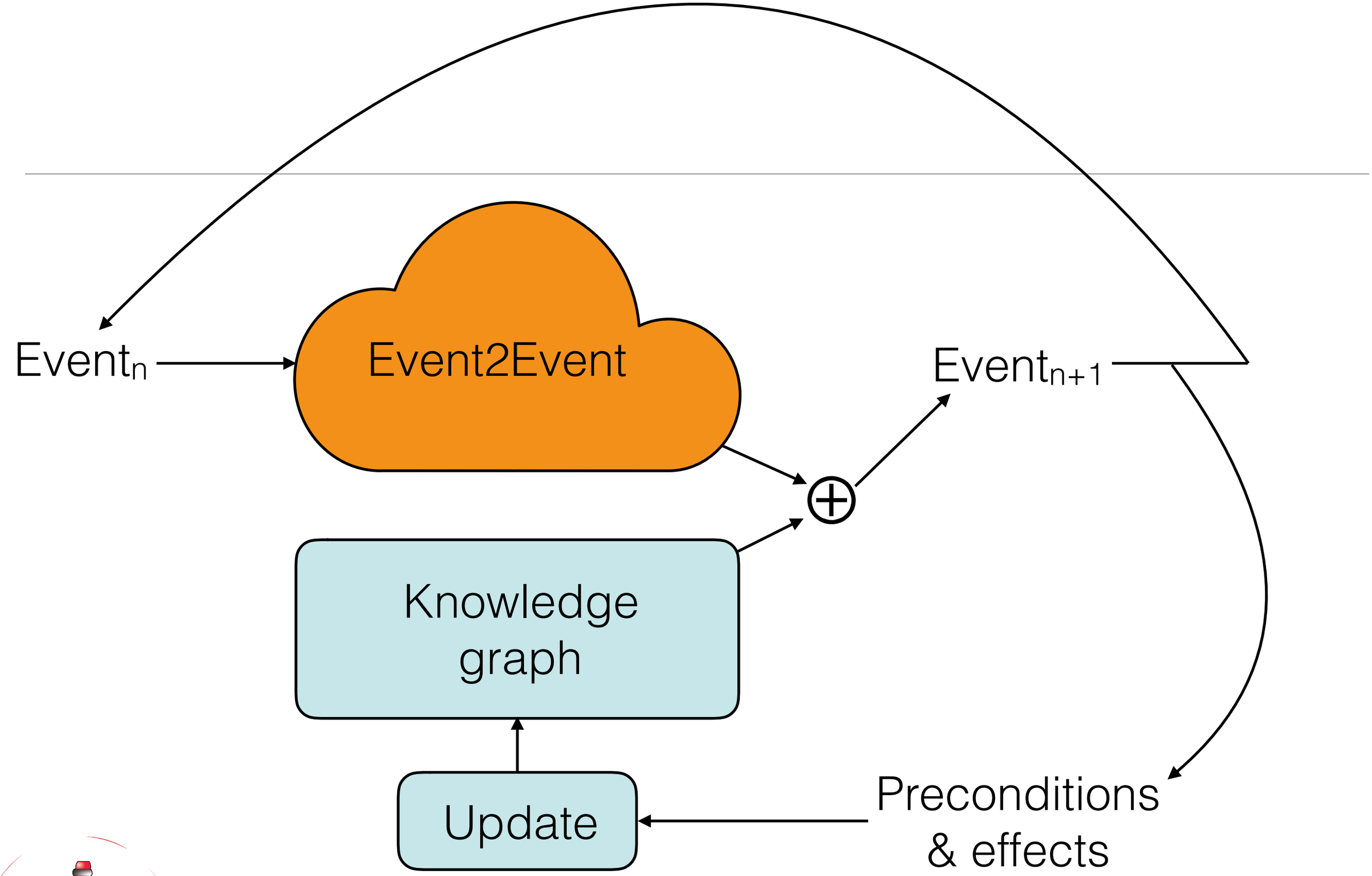
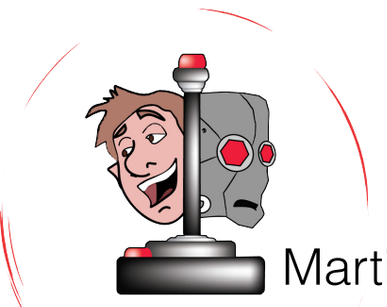
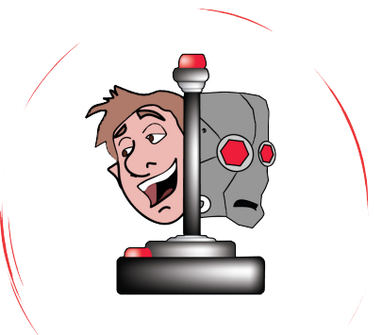




Martin et al. Dungeons and DQNs, 2018.

Causal filtering

1. The traveler succeeded.
2. The traveler materialized the Voyager.
3. The traveler vaporized the Voyager.
4. Evelyn sought the Voyager to Paul.
5. What found the farewell order to the Voyager?
6. Wendy demanded to judge for the vote.
7. Wendy asked the vote up Kevin.
8. Ruby consulted the draft to the Voyager.
9. The Voyager inquired on the refusal on the draft



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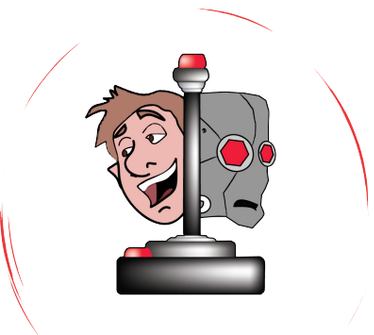
No causal filtering

1. The traveler succeeded.
2. The tape died.
3. The tape repeated.
4. The effect authorized the tape.
5. The tape burned.
6. The tape expelled the starboard.
7. The starboard continued.
8. The starboard confessed.
9. The starboard depicted the builder

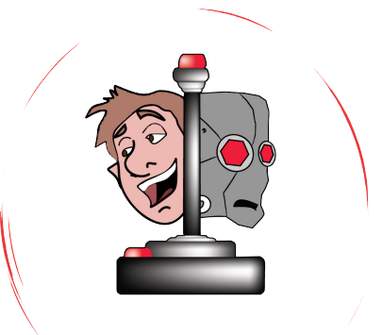


Interactive storytelling

- User is an active participant in a story that can make changes in the world that affect the subsequent actions of the story

- Experience manager

- Players



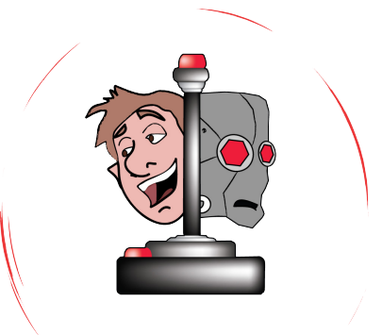
Experience manager

- Observes the world and the state of the story and intervenes to make the story interesting, meet dramatic (or pedagogical) goals

- "Dungeon Master"

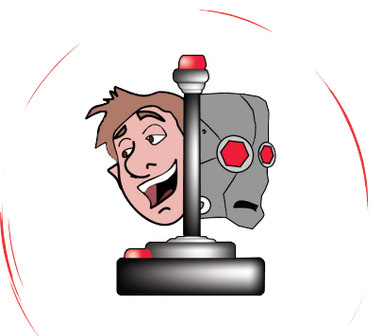
- Experience management is a planning process

- Player is a source of stochasticity



Why AI should play D&D

- Graphical computer games
  - Large state spaces, but highly regular
  - Small, finite action spaces
  - Reactive strategies work well
  - Explicit reward
- Dungeons & Dragons
  - Nearly infinite state space
  - Nearly infinite action space (all possible sentences)
  - Theory of mind — can skip obvious steps
  - Progression can't be too random
  - Intrinsic reward
  - Collaboration



Improv player

- Improvisational role-playing is planning and action in the space of language
- Neural net taking turns with a human player
- Neural net thinking forward toward a goal
- Neural net tracking state changes in the world and doing roll outs to anticipate changes