Commonsense Knowledge Graphs

USC Information Sciences Institute
## Agenda

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Introduction to commonsense knowledge

Pedro Szekely
What Is Common Sense?

Common sense is sound practical judgement concerning everyday matters,

or a basic ability to perceive, understand, and judge that is shared by ("common to") nearly all people.

Wikipedia
Essential for humans to live and interact with each other in a reasonable and safe way.

Essential for AI to understand human needs and actions better.

For example, it’s ok to keep the closet door open, but it’s not ok to keep the fridge door open, as the food inside might go bad.

Slide by Yejin Choi
Humans reason about the world with mental models [Graesser, 1994]

Personal experiences [Conway et al., 2000]

World knowledge [Kintsch, 1988]
Humans reason about the world with mental models [Graesser, 1994]

Personal experiences
[Conway et al., 2000]

World knowledge
[Kintsch, 1988]
A Common Sense Task

**Input:** a set of common concepts

| dog | frisbee | catch | throw |

**Output:** a sentence using these concepts

https://inklab.usc.edu/CommonGen/
A Common Sense Task

Input: a set of common concepts

Output: a sentence using these concepts

- A dog leaps to catch a thrown frisbee.
- The dog catches the frisbee when the boy throws it.
- A man throws away his dog's favorite frisbee expecting him to catch it in the air.

https://inklab.usc.edu/CommonGen/
A Common Sense Task

**Input:** a set of common concepts

**Output:** a sentence using these concepts

- A dog leaps to catch a thrown frisbee.
- The dog catches the frisbee when the boy throws it.
- A man throws away his dog's favorite frisbee expecting him to catch it in the air.

**[Humans]**

GPT2: A dog throws a frisbee at a football player.  
UniLM: Two dogs are throwing frisbees at each other.
BART: A dog throws a frisbee and a dog catches it.
T5: dog catches a frisbee and throws it to a dog

**[Machines]**

https://inklab.usc.edu/CommonGen/
Role Of Knowledge

dog
play
game
catch frisbee

has property
fun for dog

created by
related to
is a
type of
located at
antonym

PersonX throws a frisbee

wants to
capable of
used for
located at
throw
used for
subclass of

play frisbee
play game
frisbee
flying disk
disc

Information Sciences Institute
USC Viterbi
Dimensions Of Common Sense Knowledge

Representation
- symbolic
- natural language
- neural

Creation method
- expert input
- crowdsourcing
- information extraction, machine learning

Knowledge type
- entities and actions
- inferential/rules

Topic
- general
- social

Tools:
- COMET
- Atomic
- WebChild
- ConceptNet
- NELL
- Wikidata
- OpenCyc
- OpenCyc
Representation Method

**Representation**
- **symbolic**: frisbee, dog
- **natural language**: "PersonX throws a frisbee"
- **neural**: <black box>

**Creation method**
- expert input
- crowdsourcing
- information extraction, machine learning

**Knowledge type**
- entities and actions
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**Topic**
- general
- social
Creation Method

**Representation**
- symbolic
- natural language
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**Knowledge type**
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**Topic**
- general
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Knowledge Type

**Representation**
- symbolic
- natural language
- neural

**Creation method**
- expert input
- crowdsourcing
- information extraction, machine learning

**Knowledge type**
- entities and actions: frisbee, dog, throw, catch
- inferential/rules: PersonX throws frisbee, as a result others then, catches frisbee

**Topic**
- general
- social
Representation
- symbolic
- natural language
- neural

Creation method
- expert input
- crowdsourcing
- information extraction, machine learning

Knowledge type
- entities and actions
- inferential/rules

Topic
- general
- social
Design Approach

**Representation**
- symbolic
- natural language
- neural

**Creation method**
- expert input
- crowdsourcing
- information extraction, machine learning

**Knowledge type**
- entities and actions
- inferential/rules

**Topic**
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Review of top-down commonsense knowledge graphs

Mayank Kejriwal
Why is top-down knowledge necessary?

“In Artificial intelligence, commonsense knowledge is the set of background information that an individual is intended to know or assume and the ability to use it when appropriate.”

Argument: This knowledge cannot be acquired simply through text (or in an otherwise ‘inductive’ fashion)
Some important concepts necessary in a top-down CSKG

- Scales, time, spaces and dimension, material, causal connections, (in other domains) force, shape, systems and functionality, hitting, abrasion, wear (and related concepts)
- Competency vs. coverage theories
- Naive physics vs. psychology theories
All reasoning (ultimately) depends on axioms...

What are the ‘axioms’ of commonsense ‘psychology’?

This is a controversial question

A more fruitful approach might be to understand the ‘representational areas’ of commonsense psychology (Gordon and Hobbs, 2004)
30 representational areas

Gordon (2001a) noted that there is an interesting relationship between concepts that participate in commonsense psychology theories and planning strategies.

Described 30 representational areas by studying planning strategy.
Taxonomy of 30 representational areas
Examples of representational areas

**Explanations:** the process of generating satisfying explanations for effects that have unknown causes

**Similarity Comparison:** the mental process of making comparisons and drawing analogies in order to find similarities and differences

**Managing knowledge:** concepts of knowledge, belief, assumptions, justifications and the mental processes that manipulate these concepts in reasoning
Example of ‘theory’: Accessibility by association

- Memory retrieval by association is well-known in psychology
- ‘Encode’ it as a theory by defining appropriate predicates and concepts
‘Encoding knowledge’ of commonsense psychology

Not an easy problem, reminiscent of ‘expert system’ era

Two eventualities \( e_1 \) and \( e_2 \) are “causally linked” in a set of “causally involved” relations if there is a chain of relations in \( s \) between \( e_1 \) and \( e_2 \), regardless of direction.

\[
(\forall e_1, e_2, s)[\text{causally-linked}(e_1, e_2, s)] \\
\equiv [(\exists r)[\text{causally-involved}'(r, e_1, e_2) \land \text{member}(r, s)] \\
\lor (\exists r)[\text{causally-involved}'(r, e_2, e_1) \land \text{member}(r, s)] \\
\lor (\exists e_3, r)[[\text{causally-involved}'(r, e_1, e_3) \lor [\text{causally-involved}'(r, e_3, e_1)] \\
\land \text{member}(r, s) \land \text{causally-linked}(e_3, e_2, s - \{r\})]]]
\]

Open question how we can encode such knowledge in a way that makes it robust to noisy or incomplete data
Some more examples (belief in goals)

It will be useful below to state that if one believes he or she has a goal, then defeasibly he or she really does have the goal. Though not always true, we are usually pretty reliable about knowing what we want.

\[(\forall (e\; el\; a)\]
\[\ (if\ (and\ (goal\'\ e\ el\ a)(believe\ a\ e))\]
\[\ (Rexist\ e))\]

However, it is possible for an agent to have a goal without knowing it.
Some more examples (trying, succeeding and failing)

When we try to bring about some goal, we devise at least a partial plan to achieve it, including subgoals of the original goal which are actions on our part, and we execute some of those subgoals. Moreover, our executing those actions is a direct result of our having those actions as subgoals. We can take this as a definition of “trying”.

\[
\begin{align*}
&\text{(forall } e \ a \ e1) \\
&\quad \text{(iff } \text{try'} e a e1) \\
&\quad \text{(exist } e0 e2 e3 e4) \\
&\quad \quad \text{(and } \text{goal } e1 a)(\text{subgoal'} e3 e2 e1 a) \\
&\quad \quad \quad \text{(instanceOf } e4 e2)(\text{Rexist'} e0 e4) \\
&\quad \quad \quad \quad \text{(agentOf } a e4)(\text{cause } e3 e0)(\text{gen } e e0)) \text{))))
\end{align*}
\]
A person has a body and a mind.

\[
\text{(forall } (p) \\
\text{(if } (\text{person } p) \\
\text{(exists } (b \ m) \\
\text{(and } (\text{body } b \ p) \\
\text{(mind } m \ p)))))
\]  

(1)

Bodies are intact, damaged, or destroyed.

\[
\text{(forall } (b \ p) \\
\text{(if } (\text{body } b \ p) \\
\text{(xor } (\text{intact } b) \\
\text{(damaged } b) \\
\text{(destroyed } b)))
\]  

(2)

Minds are active, impaired, or inactive.

\[
\text{(forall } (m \ p) \\
\text{(if } (\text{mind } m \ p) \\
\text{(xor } (\text{active } m) \\
\text{(impaired } m) \\
\text{(inactive } m)))
\]  

(3)
CYC: Using Common Sense Knowledge to Overcome Britteness and Knowledge Acquisition Bottlenecks

Doug Lenat, Mayank Prakash, & Mary Shepherd
Microelectronics & Computer Technology Corporation, 9360 Research Boulevard, Austin, Texas 78759

The major limitations in building large software systems have always been (a) its brittleness when confronted by problems that were not structured, by its builders, and (b) the amount of manpower required. The recent history of expert systems, for example, highlights how constraining the brittleness and knowledge acquisition bottlenecks are. Moreover, standard software methodologies (e.g., working from a detailed "spec") have proven of little use in AI, a field which by definition tackles ill-structured problems. How can these bottlenecks be widened? Attractive, elegant answers have included machine learning, automatic programming, and natural language understanding. But decades of work on such systems (Green et al., 1974; Lenat et al., 1985; Lenat & Brown, 1984; Schank & Abelson, 1977) have convinced us that each of these approaches has difficulty "scaling up" for want of a substantial base of real-world knowledge.

Making AI Programs More Flexible

[Expert systems'] performance in their specialist domains are often very impressive. Nevertheless, hardly any of them have certain commonsense knowledge and ability possessed by any sensible-minded human. This lack makes them "brittle." By this, we mean that they are difficult to expand beyond the scope originally contemplated by their designers, and they usually do not recognize their own limitations. Many important applications will require commonsense abilities... Common-sense facts and methods are only very partially understood today, and understanding the key problem is facing artificial intelligence.


How do people flexibly cope with unexpected situations? As our specific 'experts' knowledge fails to apply, we draw on increasingly more general knowledge. This general knowledge is less powerful, so we may fall back on it reluctantly.

“General knowledge” can be broken down into a few types. First, there is real world factual knowledge, the sort found in an encyclopedia. Second, there is common sense, the sort of knowledge that an encyclopedia would assume the reader knows without being told (e.g., an object can’t be in two places at once).

Abstract

MCG’s CYC project in the building, over the coming decades, of a large knowledge base (or KB) of real-world facts and heuristics and—as a part of the KB itself—methods for efficiently reasoning over the KB. As the title of this article suggests, our hypothesis is that the two major limitations to building large intelligent programs might be overcome by using such a system. We briefly illustrate how common sense reasoning and analogy can widen the knowledge acquisition bottleneck. The next section (“How CYC Works”) illustrates how these same two abilities can solve problems of the type that require current expert systems. We then report how the project is being conducted currently: its strategic philosophy, its tactical methodology, and a case study of how we are currently putting that into practice. We conclude with a discussion of the project’s feasibility and timetable.

What is Cyc?

- Very large, multi-contextual knowledge base and inference engine.
- Founded in 1984 by Stanford professor Doug Lenat (president and founder of the Cycorp, Inc.).

What is the objective of Cyc?

- to assemble an comprehensive ontology and Knowledge Base of common sense knowledge.
- to codify, in machine-useable form, millions of pieces of knowledge that comprise human common sense.

Example:

- "Every tree is a plant" & "Plants eventually die" from which we can infer "All trees die".
Example of a ‘top-down’ CSKG: Cyc
Evolution of Cyc

Knowledge Users

User Interface (with Natural Language)

Knowledge Authors

Cyc

Reasoning Modules

Cyc Ontology & Knowledge Base

Interface to External Data Sources

External Data Sources

Data Bases

Web Pages

Text Sources

Other KBs

Cyc API

Other Applications
Limitations of top-down CSKGs

- Many of the same issues that other top-down systems (including, famously, expert systems) have, such as brittleness, expense of acquisition...
- When does work in AI stop, and work in philosophy and psychology begin?
- Even if it were possible, we can never get away from language models completely
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Review of bottom-up commonsense knowledge graphs: ConceptNet

Mayank Kejriwal
ConceptNet: An introduction

“a freely-available semantic network, designed to help computers understand the meanings of words that people use”

“an open, multi-lingual knowledge graph”

https://www.conceptnet.io/
The many faces of ConceptNet
Sources of knowledge

- Similar to previous versions, relational knowledge contributed to Open Mind Common Sense and its sister projects in other languages
- Subset of DBpedia
- Wiktionary (a dominant source)
  - Dictionary-style information also used from Open Multilingual WordNet
- High-level ontology from OpenCyc
Human-generated knowledge: Games with a purpose (GWAP)

“multi-player online game that is designed to be fun and accomplish tasks that are easy for humans but beyond the capability of today's computers.”

Example: Verbosity

https://www.cs.cmu.edu/~biglou/Verbosity.pdf
Lesson: GWAPs are useful for acquiring crowdsourcing CS acquisition
Accessing ConceptNet

- ConceptNet has a Linked Open Data API
  - Available as JSON-LD
- ExternalURL links in ConceptNet are used to fulfill LD Principle 4
  - Linked to several other vocabularies, including WordNet, DBPedia, and OpenCyc
- API documentation:
  https://github.com/commonsense/conceptnet5/wiki/API
With all this knowledge...

- Why not use it to understand the nature of commonsense knowledge?
- **Key idea:** Analyzing ConceptNet using a rigorous methodology can enable data-driven understanding of concepts like ‘context’ and ‘negation’
Early work

- In 2013, a report showed what we would expect from inductively derived KGs like ConceptNet: inconsistency.

- Structural analysis showed that some concepts are much more frequent than others.
More recent work: using ConceptNet to study ‘context’

- What is context and why is it important?
- We used PBG for getting KG embeddings on a 4 million-triples sample, and Fit-SNE for visualizations
Findings: HasContext sub-structures

Example triples from two ‘obvious’ clusters (1 and 6)

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Example Triples</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>/c/fr/sapide/a, /c/hu/szir?n/n, /c/ga/eo/n/wikt/en_3, /c/af/elk/n, /c/ga/gair/v/wikt/en_1</td>
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Similar results
Another experiment: Understanding ‘negation’

- Can we distinguish between a relation, its negation and its ‘unknowns’ in a visual space?
- What if we train a classifier on the embeddings?
Results (Desires/NotDesires)

- Answer to the first question is no, though ‘unknowns’ are more distinctive.
- Answer to the second question is yes.
- May help explain why language models don’t (or can’t) do well on negation tasks without extra work.
Review of bottom-up commonsense knowledge graphs: Other KGs

Filip Ilievski
ATOMIC:
inferential knowledge in natural language form

https://mosaickg.apps.allenai.org/kg_atomic

Slides adapted from Sap et al. https://homes.cs.washington.edu/~msap/acl2020-commonsense/
Humans have **theory of mind**, allowing us to
- make inferences about **people’s mental states**
- understand **likely events** that precede and follow
  (Moore, 2013)

AI systems struggle with **inferential** reasoning
- only find **complex correlational patterns** in data
- limited to the domain they are trained on
  (Pearl; Davis and Marcus 2015; Lake et al. 2017; Marcus 2018)
**ATOMIC:** 880,000 triples for AI systems to reason about *causes* and *effects* of everyday situations.
X repels Y's attack because X wanted to protect others, X needed to train hard, X needed to know self-defense, and X is skilled. As a result, Y feels weak and ashamed, and Y wants to run home and attack X again. X feels angry and tired, and Y gets hurt. X's heart races and Y falls back. X wants to file a police report and leave the scene.
X repels Y's attack

九个推论维度

X 想要保护他人
X 想要保护自己
X 想要训练
X 需要进行自我防御
因为 X 想要
在 X 需要之前
X 是熟练
X 是勇敢
X 是强壮
X 被认为是
作为结果，Y 感到
作为结果，Y 想要
作为结果，Y 感受到
作为结果，Y 想要
X 想要离开现场
X 想要提出警报
X 感到生气
X 感到疲惫
X 的心脏加速
X 获得敌人的优势
Y 感到后退
Y 受伤
Y 想要再次攻击 X
Y 感到羞愧
Y 感到虚弱
Y 想要回家
Causes:
1. X wanted to protect others
2. X wanted to save themselves
3. X needs to train hard
4. X needs to know self-defense

Effects:
1. X repels Y's attack
2. Y feels weak
3. Y feels ashamed
4. Y wants to run home
5. Y wants to attack X again
X repels Y’s attack

**Dynamic**
- X wants to file a police report
- X wants to leave the scene

**Static**
- X is seen as
  - X is skilled
  - X is brave
  - X is strong

as a result, Y feels
- Y feels weak
- Y feels ashamed
- Y feels...', change the remaining part of the sentence to something more natural.
X repels Y’s attack

X wanted to protect others
X wanted to save themselves
X feels angry
X feels tired
X feels threatened

because X wanted to
before, X needed to

has an effect on X
has an effect on Y

X's heart races
X gains an enemy
X gains self-defense
X needs to know self-defense
X needs to train hard

as a result, X feels
as a result, Y feels

Y feels weak
Y feels ashamed
Y wants to run home
Y gets hurt
Y falls back

as a result, Y wants

Y wants to attack X again

X is skilled
X is brave
X is strong

involuntary
voluntary
Agent

- X wanted to protect others
- X wanted to save themselves
- X wanted to file a police report
- X wants to leave the scene
- X feels angry
- X feels tired

Theme

- X repels Y's attack because X wanted to
- X needed to
- before, X needed to
- X is skilled
- X is brave
- X is strong

- X is seen as
- as a result, Y feels
- as a result, Y wants
- as a result, Y feels weak
- Y feels ashamed
- Y wants to run home
- Y wants to attack X again
- Y falls back
- Y gets hurt
- X gains an enemy
- X's heart races
300,000 event nodes to date

880,000 if-Event-then-* knowledge triples
<table>
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<th>Type of relations</th>
<th>Inference examples</th>
<th>Inference dim.</th>
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<tr>
<td>“PersonX pays PersonY a compliment”</td>
<td>If-Event-Then-Mental-State</td>
<td>PersonX wanted to be nice, PersonY will feel good, PersonY will feel flattered</td>
<td>xReact, oReact</td>
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<td>If-Event-Then-Event</td>
<td>PersonX will want to chat with PersonY, PersonY will smile, PersonY will compliment PersonX back</td>
<td>xWant, oWant, oEff</td>
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<td>If-Event-Then-Persona</td>
<td>PersonX is flattering, PersonX is caring</td>
<td>xAttr, xAttr</td>
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<td>“PersonX makes PersonY’s coffee”</td>
<td>If-Event-Then-Mental-State</td>
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<td>If-Event-Then-Event</td>
<td>PersonX needs to put the coffee in the filter, PersonX gets thanked, PersonX adds cream and sugar</td>
<td>xNeed, xEffect, xWant</td>
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<tr>
<td></td>
<td>If-Event-Then-Persona</td>
<td>PersonX is helpful, PersonX is deferential</td>
<td>xAttr, xAttr</td>
</tr>
<tr>
<td>“PersonX calls the police”</td>
<td>If-Event-Then-Mental-State</td>
<td>PersonX wants to report a crime, Others feel worried</td>
<td>xReact</td>
</tr>
<tr>
<td></td>
<td>If-Event-Then-Event</td>
<td>PersonX needs to dial 911, PersonX wants to explain everything to the police, PersonX starts to panic, Others want to dispatch some officers</td>
<td>xNeed, xWant, oWant</td>
</tr>
<tr>
<td></td>
<td>If-Event-Then-Persona</td>
<td>PersonX is lawful, PersonX is responsible</td>
<td>xAttr</td>
</tr>
</tbody>
</table>
Best-effort mappings to ConceptNet

- **Wants**: MotivatedByGoal, HasSubevent, HasFirstSubevent, CausesDesire
- **Effects**: Causes, HasSubevent, HasFirstSubevent, HasLastSubevent
- **Needs**: MotivatedByGoal, Entails, HasPrerequisite
- **Intents**: MotivatedByGoal, CausesDesire, HasSubevent, HasFirstSubevent
- **Reactions**: Causes, HasLastSubevent, HasSubevent
- **Attributes**: HasProperty
COMET Commonsense Transformers for Automatic Knowledge Graph Construction

Antoine Bosselut ♦ Hannah Rashkin ♦ Maarten Sap ♦ Chaitanya Malaviya ♦
Asli Celikyilmaz ♦ Yejin Choi ♦
♦ Allen Institute for Artificial Intelligence, Seattle, WA, USA
♣ Paul G. Allen School of Computer Science & Engineering, Seattle, WA, USA
♦ Microsoft Research, Redmond, WA, USA

Abstract

We present the first comprehensive study on automatic knowledge base construction for two prevalent commonsense knowledge graphs: ATOMIC (Sap et al., 2019) and ConceptNet (Speer et al., 2017). Contrary to many conventional KBs that store knowledge with canonical templates, commonsense KBs only store loosely structured open-text descriptions of knowledge. We posit that an important step toward automatic commonsense completion is the development of generative models of commonsense knowledge, and propose COMMonsEnse Transformers (COMET) that learn to generate rich and complete commonsense knowledge for unseen events.
Building Common Sense KGs Is Hard

- Commonsense knowledge is immeasurably vast, making it impossible to manually enumerate.
- Commonsense knowledge is often implicit, and often can’t be directly extracted from text.

Slide by Antoine Bosselut
Traditional KB Completion

Gather training set of knowledge tuples

Learn relationships among entities

Predict new relationships

Store in knowledge graph

(person, CapableOf, buy)

(Socher et al., 2013)
(Bordes et al., 2013)
(Riedel et al., 2013)
(Toutanova et al., 2015)
(Yang et al., 2015)
(Trouillon et al., 2016)
(Nguyen et al., 2016)
(Dettmers et al., 2018)
COMET Idea

Gather training set of knowledge tuples

Learn relationships among entities

Predict new relationships

Store in knowledge graph

ATOMIC Input Template and ConceptNet Relation-only Input Template

PersonX goes to the mall [MASK] <xIntent> to buy clothes

ConceptNet Relation to Language Input Template

go to mall [MASK] [MASK] has prerequisite [MASK] have money

Transformer Architecture

COMET
Symbolic Knowledge Graph

Knowledge stored as triples

Knowledge is not contextualized

Knowledge is incomplete
Symbolic Knowledge Graph

- Knowledge stored as triples
- Knowledge is not contextualized
- Knowledge is incomplete

COMET Knowledge Base Transformer

- Knowledge generated dynamically
- Input format is natural language

Kai knew that things were getting out of control and managed to keep his temper in check

- Kai wants to avoid trouble
- Kai intends to be calm
- Kai stays calm
- Kai is viewed as cautious
Randomly selected novel generations from ATOMIC

<table>
<thead>
<tr>
<th>Seed Concept</th>
<th>Relation</th>
<th>Generated</th>
<th>Plausible</th>
</tr>
</thead>
<tbody>
<tr>
<td>X holds out X’s hand to Y</td>
<td>xAttr</td>
<td>helpful</td>
<td>✓</td>
</tr>
<tr>
<td>X meets Y eyes</td>
<td>xAttr</td>
<td>intense</td>
<td>✓</td>
</tr>
<tr>
<td>X watches Y every ____</td>
<td>xAttr</td>
<td>observant</td>
<td>✓</td>
</tr>
<tr>
<td>X eats red meat</td>
<td>xEffect</td>
<td>gets fat</td>
<td>✓</td>
</tr>
<tr>
<td>X makes crafts</td>
<td>xEffect</td>
<td>gets dirty</td>
<td>✓</td>
</tr>
<tr>
<td>X turns X’s phone</td>
<td>xEffect</td>
<td>gets a text</td>
<td>✓</td>
</tr>
<tr>
<td>X pours ____ over Y’s head</td>
<td>oEffect</td>
<td>gets hurt</td>
<td>✓</td>
</tr>
<tr>
<td>X takes Y’s head off</td>
<td>oEffect</td>
<td>bleeds</td>
<td>✓</td>
</tr>
<tr>
<td>X pisses on Y’s bonfire</td>
<td>oEffect</td>
<td>gets burned</td>
<td>✓</td>
</tr>
<tr>
<td>X spoils somebody rotten</td>
<td>xIntent</td>
<td>to be mean</td>
<td>✓</td>
</tr>
<tr>
<td>X gives Y some pills</td>
<td>xIntent</td>
<td>to help</td>
<td>✓</td>
</tr>
<tr>
<td>X provides for Y’s needs</td>
<td>xIntent</td>
<td>to be helpful</td>
<td>✓</td>
</tr>
<tr>
<td>X explains Y’s reasons</td>
<td>xNeed</td>
<td>to know Y</td>
<td>✓</td>
</tr>
<tr>
<td>X fulfils X’s needs</td>
<td>xNeed</td>
<td>to have a plan</td>
<td>✓</td>
</tr>
<tr>
<td>X gives Y everything</td>
<td>xNeed</td>
<td>to buy something</td>
<td>✓</td>
</tr>
<tr>
<td>X eats pancakes</td>
<td>xReact</td>
<td>satisfied</td>
<td>✓</td>
</tr>
<tr>
<td>X makes ____ at work</td>
<td>xReact</td>
<td>proud</td>
<td>✓</td>
</tr>
<tr>
<td>X moves house</td>
<td>xReact</td>
<td>happy</td>
<td>✓</td>
</tr>
<tr>
<td>X gives birth to the Y</td>
<td>oReact</td>
<td>happy</td>
<td>✓</td>
</tr>
<tr>
<td>X gives Y’s friend ____</td>
<td>oReact</td>
<td>grateful</td>
<td>✓</td>
</tr>
<tr>
<td>X goes ____ with friends</td>
<td>oReact</td>
<td>happy</td>
<td>✓</td>
</tr>
<tr>
<td>X eats all the supplies</td>
<td>xReact</td>
<td>to make a list</td>
<td>✓</td>
</tr>
</tbody>
</table>
Randomly selected novel generations from ConceptNet

<table>
<thead>
<tr>
<th>Seed</th>
<th>Relation</th>
<th>Completion</th>
<th>Plausible</th>
</tr>
</thead>
<tbody>
<tr>
<td>piece</td>
<td>PartOf</td>
<td>machine</td>
<td>✓</td>
</tr>
<tr>
<td>bread</td>
<td>IsA</td>
<td>food</td>
<td>✓</td>
</tr>
<tr>
<td>planet</td>
<td>AtLocation</td>
<td>space</td>
<td>✓</td>
</tr>
<tr>
<td>dust</td>
<td>AtLocation</td>
<td>fridge</td>
<td></td>
</tr>
<tr>
<td>puzzle</td>
<td>AtLocation</td>
<td>your mind</td>
<td>😞</td>
</tr>
<tr>
<td>college</td>
<td>AtLocation</td>
<td>town</td>
<td>✓</td>
</tr>
<tr>
<td>dental chair</td>
<td>AtLocation</td>
<td>dentist</td>
<td>✓</td>
</tr>
<tr>
<td>finger</td>
<td>AtLocation</td>
<td>your finger</td>
<td></td>
</tr>
<tr>
<td>sing</td>
<td>Causes</td>
<td>you feel good</td>
<td>✓</td>
</tr>
<tr>
<td>doctor</td>
<td>CapableOf</td>
<td>save life</td>
<td>✓</td>
</tr>
<tr>
<td>post office</td>
<td>CapableOf</td>
<td>receive letter</td>
<td>✓</td>
</tr>
<tr>
<td>dove</td>
<td>SymbolOf</td>
<td>purity</td>
<td>✓</td>
</tr>
<tr>
<td>sun</td>
<td>HasProperty</td>
<td>big</td>
<td>✓</td>
</tr>
<tr>
<td>bird bone</td>
<td>HasProperty</td>
<td>fragile</td>
<td>✓</td>
</tr>
<tr>
<td>earth</td>
<td>HasA</td>
<td>many plant</td>
<td>✓</td>
</tr>
<tr>
<td>yard</td>
<td>UsedFor</td>
<td>play game</td>
<td>✓</td>
</tr>
<tr>
<td>get pay</td>
<td>HasPrerequisite</td>
<td>work</td>
<td>✓</td>
</tr>
<tr>
<td>print on printer</td>
<td>HasPrerequisite</td>
<td>get printer</td>
<td>✓</td>
</tr>
<tr>
<td>play game</td>
<td>HasPrerequisite</td>
<td>have game</td>
<td>✓</td>
</tr>
<tr>
<td>live</td>
<td>HasLastSubevent</td>
<td>die</td>
<td>✓</td>
</tr>
<tr>
<td>swim</td>
<td>HasSubevent</td>
<td>get wet</td>
<td>✓</td>
</tr>
<tr>
<td>sit down</td>
<td>MotivatedByGoal</td>
<td>you be tire</td>
<td>✓</td>
</tr>
<tr>
<td>all paper</td>
<td>ReceivesAction</td>
<td>recycle</td>
<td>✓</td>
</tr>
<tr>
<td>chair</td>
<td>MadeOf</td>
<td>wood</td>
<td>✓</td>
</tr>
<tr>
<td>earth</td>
<td>DefinedAs</td>
<td>planet</td>
<td>✓</td>
</tr>
</tbody>
</table>
How to distill commonsense knowledge?

Slides from Ilievski et al. (2020). Commonsense Knowledge in Wikidata. Wikidata Workshop at ISWC 2020
Principles of Commonsense Knowledge

P1: Concepts, not entities

*houses have rooms*

*Versailles Palace has 700 rooms*

WD guidelines on entity capitalization
Principles of Commonsense Knowledge

P1: Concepts, not entities

- houses have rooms
- Versailles Palace has 700 rooms

WD guidelines on entity capitalization

P2: Common concepts

- Container used for storage
- Noma subclass of aphthous stomatitis

Corpus frequency
### After step 1 & 2:

- **414 relations**
- **421k edges**

<table>
<thead>
<tr>
<th>Relation</th>
<th>#edges</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>subclass of (P279)</td>
<td>172,535</td>
<td>saxophone - woodwind instrument</td>
</tr>
<tr>
<td>instance of (P31)</td>
<td>141,499</td>
<td>happiness - positive emotion</td>
</tr>
<tr>
<td>part of (P361)</td>
<td>9,118</td>
<td>shower - bathroom</td>
</tr>
<tr>
<td>different from (P1889)</td>
<td>7,767</td>
<td>vein - artery</td>
</tr>
<tr>
<td>has part (P527)</td>
<td>6,252</td>
<td>senses - touch</td>
</tr>
<tr>
<td>cell component (P681)</td>
<td>5,607</td>
<td>cholesterol - cell membrane</td>
</tr>
<tr>
<td>property constraint (P2302)</td>
<td>5,180</td>
<td>votes received - integer constraint</td>
</tr>
<tr>
<td>facet of (P1269)</td>
<td>4,792</td>
<td>wind - weather</td>
</tr>
<tr>
<td>strand orientation (P2548)</td>
<td>4,345</td>
<td>sac-1 - forward strand</td>
</tr>
<tr>
<td>use (P366)</td>
<td>3,045</td>
<td>crystal ball - psychic reading</td>
</tr>
<tr>
<td>opposite of (P461)</td>
<td>3,028</td>
<td>political opposition - government</td>
</tr>
<tr>
<td>properties for this type (P1963)</td>
<td>2,382</td>
<td>human - date of birth</td>
</tr>
<tr>
<td>molecular function (P680)</td>
<td>2,369</td>
<td>protein kinase - kinase activity</td>
</tr>
<tr>
<td>see also (P1659)</td>
<td>2,344</td>
<td>position held - member of head stand - gymnastics</td>
</tr>
<tr>
<td>sport (P641)</td>
<td>2,338</td>
<td>middle school - secondary school</td>
</tr>
<tr>
<td>followed by (P156)</td>
<td>2,244</td>
<td>queen - jack</td>
</tr>
<tr>
<td>follows (P155)</td>
<td>2,234</td>
<td>ice cream cone - wafer</td>
</tr>
<tr>
<td>material used (P186)</td>
<td>2,047</td>
<td>list of major opera composers - human</td>
</tr>
<tr>
<td>is a list of (P360)</td>
<td>1,914</td>
<td>president - head of government</td>
</tr>
<tr>
<td>Wikidata property (P1687)</td>
<td>1,746</td>
<td>elder sister - female</td>
</tr>
<tr>
<td>has quality (P1552)</td>
<td>1,739</td>
<td>belief - conviction</td>
</tr>
<tr>
<td>said to be the same as (P460)</td>
<td>1,664</td>
<td>jockey - horse racing</td>
</tr>
<tr>
<td>field of this occupation (P425)</td>
<td>1,616</td>
<td>hypothetical protein - cell differentiation</td>
</tr>
<tr>
<td>biological process (P682)</td>
<td>1,509</td>
<td>reading - written work</td>
</tr>
<tr>
<td>uses (P2283)</td>
<td>1,431</td>
<td></td>
</tr>
</tbody>
</table>
Principles of Commonsense Knowledge

P1: Concepts, not entities

*houses have rooms*

*Versailles Palace has 700 rooms*

WD guidelines on entity capitalization

P2: Common concepts

*Container used for storage*

*Noma subclass of aphthous stomatitis*

Corpus frequency

P3: General-domain relations

*wheel is part of a car*

*cholesterol has component cell membrane*

Mapping to ConceptNet
### Mapping general-domain relations to ConceptNet

<table>
<thead>
<tr>
<th>Category</th>
<th>ConceptNet</th>
<th>Wikidata</th>
</tr>
</thead>
<tbody>
<tr>
<td>distinctness</td>
<td>/r/DistinctFrom</td>
<td>different from (P1889)</td>
</tr>
<tr>
<td>antonymy</td>
<td>/r/Antonym</td>
<td>opposite of (P461)</td>
</tr>
<tr>
<td>synonymy</td>
<td>/r/Synonym</td>
<td>said to be the same as (P460)</td>
</tr>
<tr>
<td>similarity</td>
<td>/r/SimilarTo</td>
<td>partially coincident with (P1382)</td>
</tr>
<tr>
<td>derivation</td>
<td>/r/DerivedFrom</td>
<td>named after (P138), fictional analog of (P1074)</td>
</tr>
<tr>
<td>inheritance</td>
<td>/r/IsA</td>
<td>instance of (P31), subclass of (P279), subproperty of (P1647)</td>
</tr>
<tr>
<td>meronomy</td>
<td>/r/PartOf</td>
<td>part of (P361), *has part (P527), *has parts of the class (P2670)</td>
</tr>
<tr>
<td>material</td>
<td>/r/MadeOf</td>
<td>material used (P186), is a list of (P360), *has list (P2354)</td>
</tr>
<tr>
<td>attribution</td>
<td>/r/CreatedBy</td>
<td>*product or material produced (P1056)</td>
</tr>
<tr>
<td>utility</td>
<td>/r/UsedFor</td>
<td>use (P366), *uses (P2283), used by (P1535)</td>
</tr>
<tr>
<td>properties</td>
<td>/r/HasProperty</td>
<td>color (P462), has quality (P1552), properties of this type (P1963), Wikidata property (P1687), sex or gender (P21)</td>
</tr>
<tr>
<td>causation</td>
<td>/r/Causes</td>
<td>*has cause (P828), has effect (P1542), symptoms (P780)</td>
</tr>
<tr>
<td>ordering</td>
<td>/r/HasPrerequisite</td>
<td>*followed by (P156), follows (P155)</td>
</tr>
<tr>
<td>context</td>
<td>/r/HasContext</td>
<td>facet of (P1269), sport (P641), field of this occupation (P425), health specialty (P1995), competition class (P2094), genre (P136), studied by (P2579), field of work (P101), afflicts (P689), *practiced by (P3095), depicts (P180), main subject (P921)</td>
</tr>
<tr>
<td>other</td>
<td>/r/RelatedTo</td>
<td>see also (P1659), subject item of this property (P1629)</td>
</tr>
</tbody>
</table>
**Wikidata-CS = 0.01% * Wikidata**

<table>
<thead>
<tr>
<th></th>
<th>Wikidata-CS</th>
<th>Wikidata</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td># nodes</td>
<td>71,243</td>
<td>84 million</td>
<td>0.08%</td>
</tr>
<tr>
<td># edges</td>
<td>101,771</td>
<td>1.5 billion</td>
<td>0.01%</td>
</tr>
</tbody>
</table>
Commonsense Knowledge in Wikidata

- shower part of bathroom
- reading uses written work
- queen follows jack
- political opposition opposite of government
Has it been growing over time?

<table>
<thead>
<tr>
<th>Relation</th>
<th>2017-12-27</th>
<th>2018-12-10</th>
<th>2020-05-04</th>
</tr>
</thead>
<tbody>
<tr>
<td>/r/IsA</td>
<td>31,668</td>
<td>45,606 (144%)</td>
<td>72,707 (230%)</td>
</tr>
<tr>
<td>/r/PartOf</td>
<td>3,390</td>
<td>4,416 (130%)</td>
<td>7,938 (234%)</td>
</tr>
<tr>
<td>/r/HasContext</td>
<td>1,968</td>
<td>3,189 (162%)</td>
<td>6,152 (313%)</td>
</tr>
<tr>
<td>/r/DistinctFrom</td>
<td>782</td>
<td>2,011 (257%)</td>
<td>4,934 (631%)</td>
</tr>
<tr>
<td>/r/HasPrerequisite</td>
<td>413</td>
<td>1,965 (476%)</td>
<td>4,131 (1,000%)</td>
</tr>
<tr>
<td>/r/UsedFor</td>
<td>735</td>
<td>1,215 (165%)</td>
<td>2,469 (336%)</td>
</tr>
<tr>
<td>/r/Antonym</td>
<td>1,109</td>
<td>1,530 (138%)</td>
<td>2,184 (197%)</td>
</tr>
<tr>
<td>/r/MadeOf</td>
<td>415</td>
<td>834 (201%)</td>
<td>1,426 (344%)</td>
</tr>
<tr>
<td>/r/Synonym</td>
<td>478</td>
<td>655 (137%)</td>
<td>1,070 (224%)</td>
</tr>
<tr>
<td>/r/HasProperty</td>
<td>339</td>
<td>650 (192%)</td>
<td>1,049 (309%)</td>
</tr>
<tr>
<td>/r/Causes</td>
<td>150</td>
<td>238 (159%)</td>
<td>651 (434%)</td>
</tr>
<tr>
<td>/r/DerivedFrom</td>
<td>190</td>
<td>293 (154%)</td>
<td>540 (284%)</td>
</tr>
<tr>
<td>/r/SimilarTo</td>
<td>28</td>
<td>77 (275%)</td>
<td>345 (1,232%)</td>
</tr>
<tr>
<td>/r/CreatedBy</td>
<td>51</td>
<td>68 (133%)</td>
<td>187 (367%)</td>
</tr>
<tr>
<td>/r/RelatedTo</td>
<td>33</td>
<td>40 (121%)</td>
<td>42 (127%)</td>
</tr>
<tr>
<td>edges (Wikidata-CS)</td>
<td>41,769</td>
<td>62,787 (150%)</td>
<td>101,771 (244%)</td>
</tr>
<tr>
<td>edges (Wikidata)</td>
<td>405,081,219</td>
<td>696,605,955 (172%)</td>
<td>1,105,944,515 (273%)</td>
</tr>
<tr>
<td>nodes (Wikidata-CS)</td>
<td>32,620</td>
<td>47,056</td>
<td>71,243</td>
</tr>
<tr>
<td>nodes (Wikidata)</td>
<td>42,187,222</td>
<td>53,004,762</td>
<td>84,601,621</td>
</tr>
</tbody>
</table>
Growth per relation type (12-month)
Wikidata-CS Is Small But Novel

ConceptNet

3.4M edges

2.4K edges

Wikidata-CS
102K edges
Never-Ending Language Learning (NELL)

NELL architecture

Knowledge base
  Beliefs
  Candidate beliefs
  Knowledge integrator

Text context patterns (CPL)
Orthographic classifier (CMC)
URL specific HTML patterns (SEAL)
Learned embeddings (LE)
Actively search for web text (OpenEval)
Infer new beliefs from old (PRA)
Image classifier (NEIL)
Ontology extender (OntExt)

Human advice

NELL statistics

100M candidate beliefs

3M high-confidence facts

~3K predicates

# Latest learned facts

## Recently-Learned Facts

<table>
<thead>
<tr>
<th>instance</th>
<th>iteration</th>
<th>date learned</th>
<th>confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>translucent_paper is an office supply</td>
<td>1111</td>
<td>06–Jul–2018</td>
<td>93.4</td>
</tr>
<tr>
<td>the_barbirolli_string_quartet is a musical artist</td>
<td>1111</td>
<td>06–Jul–2018</td>
<td>99.2</td>
</tr>
<tr>
<td>private_support is an event outcome</td>
<td>1111</td>
<td>06–Jul–2018</td>
<td>99.8</td>
</tr>
<tr>
<td>vancouver_olympic_games is an instance of the olympics</td>
<td>1111</td>
<td>06–Jul–2018</td>
<td>95.2</td>
</tr>
<tr>
<td>eddie_mathews is a person</td>
<td>1111</td>
<td>06–Jul–2018</td>
<td>98.9</td>
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<tr>
<td>roswell_road is a street in the city atlanta</td>
<td>1116</td>
<td>12–Sep–2018</td>
<td>93.8</td>
</tr>
<tr>
<td>james_madison is a U.S. politician who holds the office of secretary</td>
<td>1115</td>
<td>03–Sep–2018</td>
<td>98.4</td>
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<tr>
<td>rice was born in the city orleans</td>
<td>1116</td>
<td>12–Sep–2018</td>
<td>100.0</td>
</tr>
<tr>
<td>republic is a country also known as china</td>
<td>1111</td>
<td>06–Jul–2018</td>
<td>100.0</td>
</tr>
<tr>
<td>dodge is a specific automobile maker dealer in utah</td>
<td>1115</td>
<td>03–Sep–2018</td>
<td>93.8</td>
</tr>
</tbody>
</table>
WebChild

Automatic acquisition and organization of common sense

>18M assertions

>2M disambiguated concepts and activities

Tandon et al. (2017). Webchild 2.0: Fine-grained commonsense knowledge distillation. ACL 2017
WebChild relations

1. **object properties**
   hasTaste, hasShape, evokesEmotion

2. **comparative**
   fasterThan, smallerThan

3. **part-of**
   member of, physical part of, substance of

4. **activities**
WebChild label propagation
WebChild activity extraction

Scripts
- Movies
- TV Series
- Sitcoms
- Novels

Semantic Parsing
- ClausIE
- OpenNLP
- ILP for WSD

Graph Inference
- Statistical Priors
- PSL Inference

Taxonomy Construction
- Synsets
- Hierarchy

Knowlywood
Activity Knowledge Base
The word "mountain" is defined as a land mass that projects well above its surroundings; higher than a hill.

<table>
<thead>
<tr>
<th>TYPE OF</th>
<th>natural elevation</th>
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</thead>
<tbody>
<tr>
<td>PHYSICAL</td>
<td></td>
</tr>
<tr>
<td>PROPERTIES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>large, high, heavy, cold, hard, More</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
</tr>
<tr>
<td>PROPERTIES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>elegant, old, safe, holy, risky, More</td>
</tr>
<tr>
<td>COMPARABLES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mountain, hill, mountain, mount, mountain, high hill, valley, mountain, More</td>
</tr>
<tr>
<td>HAS PHYSICAL</td>
<td></td>
</tr>
<tr>
<td>PARTS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mountain peak, mountainside, slope, tableland, hill, More</td>
</tr>
<tr>
<td>HAS SUBSTANCE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mixture, metallic element, material, page, wood, More</td>
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<tr>
<td>IN SPATIAL</td>
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<tr>
<td>PROXIMITY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>coast, tunnel, lake, sea, river, More</td>
</tr>
<tr>
<td>ACTIVITIES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>climb mountain, cross mountain, move mountain, see mountain, ascend mountain</td>
</tr>
</tbody>
</table>
Visual Genome

108k images

annotated with scene graphs

canonicalized to WordNet senses

Components

1. region descriptions
2. objects
3. attributes
4. relationships
5. region graphs
6. scene graphs
7. question-answer pairs
Statistics

- 108,077 images
- 50 descriptions per image
- objects
  - 3.8M in total (35 objects per image)
  - 33,877 categories (synsets)
- attributes
  - 26 per image
  - 68,111 categories (synsets)
- relationships
  - 21 per image
  - 42,374 categories (synsets)
- QA pairs
  - 1.7 million
Top 10 synsets
- ski
- ballplayer, baseball player
- racket, racquet
- traffic light, traffic signal, stoplight
- zebra
- street sign
- streetcar, tram, tramcar, trolley, trolley car
- unicycle, monocycle
- passenger car, coach, carriage
- umbrella

Top 10 object categories
- man
- woman
- tree
- sky
- person
- building
- window
- shirt
- wall
- sign

Top 10 words
- white
- black
- man
- blue
- green
- red
- wearing
- brown
- tree
- woman

Top 10 phrases
- tree distance
- grass green
- sky blue
- tree background
- window building
- cloud sky
- clear blue sky
- tree green
- sky blue color
- person standing
Visual Genome as a KG

Objects = WordNet senses

‘red shoe’ is the label

shoe#n#1 is the node
Visual Genome as a KG

Objects = WordNet senses
‘red shoe’ is the label
shoe#n#1 is the node

Relationships = proximity
‘on top of’ is the label
/r/LocatedNear is the relation
Visual Genome as a KG

Objects = WordNet senses
‘red shoe’ is the label
shoe#n#1 is the node

Relationships = proximity
‘on top of’ is the label
/r/LocatedNear is the relation

Attributes
(POS=v) /r/CapableOf
(POS=a) mw:MayHaveProperty
(POS=n) -
<table>
<thead>
<tr>
<th>Some other CKGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>WordNet</td>
</tr>
<tr>
<td>FrameNet</td>
</tr>
<tr>
<td>VerbNet</td>
</tr>
<tr>
<td>ROGET</td>
</tr>
<tr>
<td>Tuple KB</td>
</tr>
<tr>
<td>Quasimodo KB</td>
</tr>
<tr>
<td>PropStore</td>
</tr>
</tbody>
</table>
Demos
https://caninehq.com/best-dog-breeds-for-playing-frisbee/
Dog and Frisbee

Wikidata:
https://sqid.toolforge.org/#/view?id=Q144 (dog)
https://sqid.toolforge.org/#/view?id=Q131689 (frisbee)

ConceptNet:
https://www.conceptnet.io/c/en/dog
https://www.conceptnet.io/c/en/dogs
http://conceptnet.io/c/en/frisbee
https://www.conceptnet.io/c/en/dogs_catching_frisbees

VisualGenome
https://visualgenome.org/VGViz/explore?query=throwing%20frisbee%20dog

ATOMIC:
https://mosaickg.apps.allenai.org/kg_atomic/?l=PersonX%20throws%20a%20frisbee

COMET:
comet dog
https://mosaickg.apps.allenai.org/comet_atomic/?l=PersonX%20throws%20frisbee

DICE
https://dice.mpi-inf.mpg.de/subject/dog
PersonX throws frisbee

ATOMIC or COMET?

Causes for PersonX

Because PersonX wanted
- to play disc golf
- to have fun.
- to play with his dog

Before, PersonX needed
- to have a frisbee
- to buy a frisbee
- search for frisbee
- to go to park

Causes for PersonX

Because PersonX wanted
- to have fun
- to get exercise
- to play
- have fun
- to play with his dog

Before, PersonX needed
- to go outside
- to get a frisbee
- to have a ball
- to go to the park
- none
PersonX throws frisbee

**ATOMIC**

Causes for PersonX

Because PersonX *wanted*

- to play disc golf
- to have fun
- to play with his dog

Before, PersonX *needed*

- to have a frisbee
- to buy a frisbee
- search for frisbee
- to go to park

**COMET**

Causes for PersonX

Because PersonX *wanted*

- to have fun
- to get exercise
- to play
- have fun
- to play with his dog

Before, PersonX *needed*

- to go outside
- to get a frisbee
- to have a ball
- to go to the park
- none
PersonX throws frisbee

ATOMIC or COMET?

As a result, others feel
- none
- happy
- playful
- excited
- competitive

As a result, others want
- none to have fun
- to catch the frisbee
- to catch it
- to play

As a result, others feel
- none
- happy

As a result, others want
- none

Others then
- none catches the frisbee
- gets exercise
- gets hit by frisbee
- gets hit

None
- person y catches frisbee
- person y throws frisbee back
PersonX throws frisbee

**COMET**

As a result, others feel
- none
- happy
- playful
- excited
- competitive

As a result, others want
- none
to have fun
to catch the frisbee
to catch it
to play

Others then
- none
catches the frisbee
gets exercise
gets hit by frisbee
gets hit

**ATOMIC**

As a result, others feel
- none
- happy

As a result, others want
- none

Others then
- none
person y catches frisbee
person y throws frisbee back
Catch and Throw

Wikidata:
- https://sqid.toolforge.org/#/view?id=Q17144564 (throw)
- https://sqid.toolforge.org/#/view?id=Q91553195 (catch)

ConceptNet:

VisualGenome
- https://visualgenome.org/VGViz/explore?query=catch%20frisbee
### Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Duration</th>
<th>Session</th>
<th>Content</th>
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</thead>
<tbody>
<tr>
<td>08:00 PST</td>
<td>1 hr 50 mins</td>
<td><strong>Part I - Review of CSKGs</strong></td>
<td><strong>Introduction to commonsense knowledge (slides)</strong> - Pedro</td>
</tr>
<tr>
<td></td>
<td>15 min</td>
<td></td>
<td><strong>Review of top-down commonsense knowledge graphs (slides)</strong> - Mayank</td>
</tr>
<tr>
<td></td>
<td>25 min</td>
<td></td>
<td><strong>Review of bottom-up commonsense knowledge graphs (slides+demo)</strong> - Mayank, Filip, Pedro</td>
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<tr>
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<td>10 min</td>
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<td><strong>Break</strong></td>
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<tr>
<td>10:00 PST</td>
<td>45 min</td>
<td><strong>Part II - Integration and analysis</strong></td>
<td><strong>Consolidating commonsense graphs (slides)</strong> - Filip</td>
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<tr>
<td></td>
<td>35 min</td>
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<td><strong>Consolidating commonsense graphs (demo)</strong> - Pedro</td>
</tr>
<tr>
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<td>10 min</td>
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<td><strong>Break</strong></td>
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<tr>
<td>10:55 PST</td>
<td>1 hr 05 mins</td>
<td><strong>Part III - Downstream use of CSKGs</strong></td>
<td><strong>Answering questions with CSKGs (slides+demo)</strong> - Filip</td>
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<td><strong>Wrap-up (slides)</strong> - Mayank</td>
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