

08:00 PST	1 hr 50 mins	Part I - Review of CSKGs
	15 min	Introduction to commonsense knowledge (slides) - Pedro
	25 min	Review of top-down commonsense knowledge graphs (slides) - Mayank
	70 min	Review of bottom-up commonsense knowledge graphs (slides+demo) - Mayank, Filip, Pedro
	10 min	Break
10:00 PST	45 min	Part II - Integration and analysis
	35 min	Consolidating commonsense graphs (slides) - Filip
	10 min	Consolidating commonsense graphs (demo) - Pedro
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10:55 PST	1 hr 05 mins	Part III - Downstream use of CSKGs
	50 min	Answering questions with CSKGs (slides+demo) - Filip
	15 min	Wrap-up (slides) - Mayank

# Consolidating Commonsense Knowledge Graphs

Filip Ilievski



#### ConceptNet

- -Information about everyday objects, actions, states and relationships among them, extensive links to WordNet
- -Incomplete coverage, "related-to" accounts for 75% of statements



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- -Only 25% of nodes have links to ConceptNet, difficult to combine with other resources



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- -No description of the properties of objects or roles in verbs, only is-a and part-of relations

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#### VerbNet, FrameNet

-Defines participants/roles for a large number of situations/frames, links to verbs, syntactic forms and example sentences -No semantic typing of roles, many roles are very abstract (e.g., Agent), lacks info about state changes, or pre-post conditions

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-"Visual" commonsense, many possible attributes, relationships/actions among objects, linked to WordNet, many edges for a KG
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7



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#### •Wikidata

- -Comprehensive descriptions of objects, both specific (named entities) and generic (nouns)
- -Sparse information about events and states, much knowledge is on instance-level and abstraction is non-trivial



## **Consolidation Hypothesis**

## Integrating multiple knowledge sources in CSKG is beneficial for downstream reasoning tasks.



### On stage, a woman takes a seat at the piano. She

- 1. sits on a bench as her sister plays with the doll.
- 2. smiles with someone as the music plays.
- 3. is in the crowd, watching the dancers.
- 4. <u>nervously sets her fingers on the keys.</u>





#### ConceptNet: pianos have keys, are used to perform music

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piano is used for performing music + music + accompanying an orchestra + Things located at piano	ConceptNet: pianos have keys, are used to perform music
n keys → n black keys → n hammers → n a keyboard →	<ul> <li><u>S:</u> (n) piano, pianoforte, forte-piano (a keyboard instrument that is played by depressing keys that cause hammers to strike tuned strings and produce sounds)</li> </ul>
	WordNet: pianos are played by pressing keys

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piano is used for	ConceptNet: pianos have keys, are used to perform music
n performing music →	
en music → en accompanying an orchestra →	
Things located at piano	
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Visual Genome: person can play a piano while sitting, his hands are on the keyboard

man plays piano keys ON piano woman watches man pillow ON couch light ON wall window IN room person playing piano guy ON bench hands ON keyboard

#### USC Viterbi School of Engineering



ATOMIC: to play piano, a person needs to sit at it, on stage and reach for the keys; feelings







### Information Sciences Institute

USC Viterbi School of Engineering

## **Challenge: Modeling of relations**

Web Child

#### **ConceptNet**





# **Challenge: Knowledge** granularity

Concept 36 Net 36 Net no Web 4 r Child no ATOMIC 9 no Wikidata 1.2 ob CEO 12 eve	relations, 8M odes, 21M edges	/c/en/piano /c/en/piano/n /c/en/piano/n/wn
Net no Web 4 r Child no ATOMIC 9 no Wikidata 1.2 ob CEO 12 eve	odes, 21M edges	/c/en/piano/n /c/en/piano/n/wn
Web 4 r Child no ATOMIC 9 no Wikidata 1.2 ob CEO 12 eve		/c/en/piano/n/wn
Web 4 m Child no ATOMIC 9 no Wikidata 1.2 ob CEO 12 eve	1	/ / ] - + - JT-
Web 4 n Child no ATOMIC 9 no Wikidata 1.2 ob CEO 12 eve	1	/r/relatedlo
Child no ATOMIC 9 no Wikidata 1.2 ob CEO 12 eve	relation groups, 2M	hasTaste
ATOMIC 9 no Wikidata 1.2 ob CEO 12 eve	odes, 18M edges	fasterThan
Vikidata 1.2 ob CEO 12 eve	relations, 300k	wanted-to
Wikidata 1.2 ob CEO 12 eve	odes, 877k edges	impressed
CEO 12 eve WordNat 10	2k relations, 75M	wd:Q1234 wdt:P31
CEO 12 eve	jects, 900M edges	
eve WordNat 10	1 properties, 223	ceo:Damaging
WandNat 10	ents	hasPostSituation
woranet 10	relations, 155k	dog.n.01
WC	ords, 176k synsets	hypernymy
Roget 2	relations, 72k	truncate
WC	ords, 1.4M edges	antonym
VerbNet 27	3 top classes 23	perform-v
rol	les, 5.3k senses	performance-26.7-1
FrameNet 1.9	9k edges, 1.2k	Activity
fra	ames, 12k roles,	Change_of_leadership
13	la locational constant	New_leader
Visual 42	K lexical units	
Genome no	k relations, 3.8M	fire hydrant
2.8	k relations, 3.8M odes, 2.3M edges,	fire hydrant white dog

## **Challenge: Imprecise descriptions**





#### creation

Concept	crowd-
Net	sourcing

# Challenge: Different creation methods and quality

Web	curated
Child	automatic
	extraction
ATOMIC	crowd-
	sourcing
Wikidata	crowd-
	sourcing
CEO	manual
WordNet	manual
Roget	manual
VerbNet	manual
FrameNet	manual

Visual crowd-Genome sourcing



#### mappings

Concept	WordNet,
Net	DBpedia,
	OpenCyc,
	Wiktionary
Web	WordNet
Child	
ATOMIC	ConceptNet,
	Cyc
Wikidata	various
CEO	FrameNet,
	SUMO
WordNet	
Roget	
VerbNet	FrameNet,
	WordNet
FrameNet	
Visual	WordNet
Genome	

# Challenge: Sparse overlap and mappings

Other source Both Wikidata-CS only Other source only

97,473 (97.6%)

99,560 (99.7%)

98,246 (98.4%)

[n]	formation	Sciences	Institute	

ConceptNet 2,386

299

1.613

Roget

WordNet

3,320,935 (99.9%)

1,403,162 (99.9%)

419,103 (99.6%)



### P1. Embrace heterogeneity of nodes

objects, classes, words, actions, frames, states



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### P5. Enable access to labels

text labels and aliases are the key, in particular for NLP use cases



## **Hyper-relational graph**



B. Hyper-relational facts



Image by: Michael Galkin et al. (2020)

**USC**Viterbi

## Hyper-relational graph in tabular format

## How: KGTK format

**Row = Fact + Qualifiers** 

## Main Why: Tool integration

Pandas, PyTorchBigGraph, Graph-tool, ...



### primary edges

id	node1	relation	node2
/c/en/angel_hair/n-/r/RelatedTo-/c/en/s paghetti-0000	/c/en/angel_hair/n	/r/RelatedTo	/c/en/spaghetti
/c/en/animals-/r/CapableOf-/c/en/eat_s paghetti-0000	/c/en/animals	/r/CapableOf	/c/en/eat_spaghet ti
/c/en/bavette/n/wikt/en_2-/r/RelatedTo -/c/en/spaghetti-0000	/c/en/bavette/n/wikt/en_2	/r/RelatedTo	/c/en/spaghetti
/c/en/bigoli/n-/r/RelatedTo-/c/en/spagh etti-0000	/c/en/bigoli/n	/r/RelatedTo	/c/en/spaghetti
/c/en/black_hole/n-/r/SimilarTo-/c/en/s paghettification-0000	/c/en/black_hole/n	/r/SimilarTo	/c/en/spaghettific ation
/c/en/bolognese_pasta_sauce/n/wn/foo d-/r/lsA-/c/en/pasta/n/wn/food-0000	/c/en/bolognese_pasta_sau ce/n/wn/food	/r/IsA	/c/en/pasta/n/wn/f ood
/c/en/bucatini/n-/r/RelatedTo-/c/en/spa ghetti-0000	/c/en/bucatini/n	/r/RelatedTo	/c/en/spaghetti
/c/en/carbonara/n/wn/food-/r/IsA-/c/en /pasta/n/wn/food-0000	/c/en/carbonara/n/wn/food	/r/lsA	/c/en/pasta/n/wn/f ood
/c/en/carbonara/n-/r/RelatedTo-/c/en/s paghetti-0000	/c/en/carbonara/n	/r/RelatedTo	/c/en/spaghetti
/c/en/cheese/n/wn/food-/r/LocatedNea r-/c/en/spaghetti/n/wn/food-0000	/c/en/cheese/n/wn/food	/r/LocatedNear	/c/en/spaghetti/n/ wn/food



### primary edges

### 'lifted' edges

id	node1	relation	node2	node1;label	node2;label	relation;label
/c/en/angel_hair/n-/r/RelatedTo-/c/en/s paghetti-0000	/c/en/angel_hair/n	/r/RelatedTo	/c/en/spaghetti	angel hair	spaghetti	related to
/c/en/animals-/r/CapableOf-/c/en/eat_s paghetti-0000	/c/en/animals	/r/CapableOf	/c/en/eat_spaghet ti	animals	eat spaghetti	capable of
/c/en/bavette/n/wikt/en_2-/r/RelatedTo -/c/en/spaghetti-0000	/c/en/bavette/n/wikt/en_2	/r/RelatedTo	/c/en/spaghetti	bavette	spaghetti	related to
/c/en/bigoli/n-/r/RelatedTo-/c/en/spagh etti-0000	/c/en/bigoli/n	/r/RelatedTo	/c/en/spaghetti	bigoli	spaghetti	related to
/c/en/black_hole/n-/r/SimilarTo-/c/en/s paghettification-0000	/c/en/black_hole/n	/r/SimilarTo	/c/en/spaghettific ation	black hole	spaghettification	similar to
/c/en/bolognese_pasta_sauce/n/wn/foo d-/r/IsA-/c/en/pasta/n/wn/food-0000	/c/en/bolognese_pasta_sau ce/n/wn/food	/r/IsA	/c/en/pasta/n/wn/f ood	bolognese pasta sauce	pasta sauce spaghetti sauce	is a
/c/en/bucatini/n-/r/RelatedTo-/c/en/spa ghetti-0000	/c/en/bucatini/n	/r/RelatedTo	/c/en/spaghetti	bucatini	spaghetti	related to
/c/en/carbonara/n/wn/food-/r/IsA-/c/en /pasta/n/wn/food-0000	/c/en/carbonara/n/wn/food	/r/IsA	/c/en/pasta/n/wn/f ood	carbonara	pasta sauce spaghetti sauce	is a
/c/en/carbonara/n-/r/RelatedTo-/c/en/s paghetti-0000	/c/en/carbonara/n	/r/RelatedTo	/c/en/spaghetti	carbonara	spaghetti	related to
/c/en/cheese/n/wn/food-/r/LocatedNea r-/c/en/spaghetti/n/wn/food-0000	/c/en/cheese/n/wn/food	/r/LocatedNear	/c/en/spaghetti/n/ wn/food	cheese	spaghetti	on



### primary edges

'lifted' edges

qualifiers

id	node1	relation	node2	node1;label	node2;label	relation;label	source	sentence
/c/en/angel_hair/n-/r/RelatedTo-/c/en/s paghetti-0000	/c/en/angel_hair/n	/r/RelatedTo	/c/en/spaghetti	angel hair	spaghetti	related to	CN	
/c/en/animals-/r/CapableOf-/c/en/eat_s paghetti-0000	/c/en/animals	/r/CapableOf	/c/en/eat_spaghet ti	animals	eat spaghetti	capable of	CN	[[Animals]] can [[eat spaghetti]]
/c/en/bavette/n/wikt/en_2-/r/RelatedTo -/c/en/spaghetti-0000	/c/en/bavette/n/wikt/en_2	/r/RelatedTo	/c/en/spaghetti	bavette	spaghetti	related to	CN	
/c/en/bigoli/n-/r/RelatedTo-/c/en/spagh etti-0000	/c/en/bigoli/n	/r/RelatedTo	/c/en/spaghetti	bigoli	spaghetti	related to	CN	
/c/en/black_hole/n-/r/SimilarTo-/c/en/s paghettification-0000	/c/en/black_hole/n	/r/SimilarTo	/c/en/spaghettific ation	black hole	spaghettification	similar to	CN	
/c/en/bolognese_pasta_sauce/n/wn/foo d-/r/IsA-/c/en/pasta/n/wn/food-0000	/c/en/bolognese_pasta_sau ce/n/wn/food	/r/IsA	/c/en/pasta/n/wn/f ood	bolognese pasta sauce	pasta sauce spaghetti sauce	is a	CN WN	[[bolognese pasta sauce]] is a type of [[spaghetti sauce]]
/c/en/bucatini/n-/r/RelatedTo-/c/en/spa ghetti-0000	/c/en/bucatini/n	/r/RelatedTo	/c/en/spaghetti	bucatini	spaghetti	related to	CN	
/c/en/carbonara/n/wn/food-/r/IsA-/c/en /pasta/n/wn/food-0000	/c/en/carbonara/n/wn/food	/r/IsA	/c/en/pasta/n/wn/f ood	carbonara	pasta sauce spaghetti sauce	is a	CN WN	[[carbonara]] is a type of [[spaghetti sauce]]
/c/en/carbonara/n-/r/RelatedTo-/c/en/s paghetti-0000	/c/en/carbonara/n	/r/RelatedTo	/c/en/spaghetti	carbonara	spaghetti	related to	CN	
/c/en/cheese/n/wn/food-/r/LocatedNea r-/c/en/spaghetti/n/wn/food-0000	/c/en/cheese/n/wn/food	/r/LocatedNear	/c/en/spaghetti/n/ wn/food	cheese	spaghetti	on	VG	



## **Individual sources**

ATOMIC

## WordNet

ConceptNet

### **VisualGenome-KG**

**FrameNet** 

Wikidata-CS

## ROGET

## **Recap: VisualGenome-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) -



## **Recap: Extraction of Wikidata-CS**

P1: Concepts, not entities

houses have rooms

Versailles Palace has 700 rooms

WD guidelines on entity capitalization

**P2: Common concepts** 

<u>Container</u> used for <u>storage</u> <u>Noma</u> subclass of <u>aphthous</u> stomatitis

**Corpus frequency** 

**P3: General-domain relations** 

wheel *is part* of a car

cholesterol <u>has component cell</u> membrane

Mapping to ConceptNet



## Recap: Mapping Wikidata-CS to ConceptNet

Category	ConceptNet	Wikidata
distinctness	/r/DistinctFrom	different from (P1889)
antonymy	/r/Antonym	opposite of (P461)
synonymy	/r/Synonym	said to be the same as (P460)
similarity	/r/SimilarTo	partially coincident with (P1382)
derivation	/r/DerivedFrom	named after (P138), fictional analog of (P1074)
inheritance	/r/IsA	instance of (P31), subclass of (P279), subproperty of (P1647)
meronymy	/r/PartOf	part of (P361), *has part (P527), *has parts of the class (P2670)
material	/r/MadeOf	material used (P186), is a list of (P360), *has list (P2354)
attribution	/r/CreatedBy	*product or material produced (P1056)
utility	/r/UsedFor	use (P366), *uses (P2283), used by (P1535)
properties	/r/HasProperty	color (P462), has quality (P1552), properties of this type (P1963), Wikidata property (P1687), sex or gender (P21)
causation	/r/Causes	*has cause (P828), has effect (P1542), symptoms (P780)
ordering	/r/HasPrerequisite	*followed by (P156), follows (P155)
context	/r/HasContext	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)
other	/r/RelatedTo	see also (P1659), subject item of this property (P1629)

# **Overview of node mappings**

Mapping from	Mapping to	Relation	Resource used
WordNet 3.0 senses	WordNet 3.1 senses	mw:SameAs	Interlingual Index (ILI)
lexical nodes in ConceptNet	lexical nodes in ATOMIC and ROGET	mw:SameAs	1
ConceptNet nodes	FrameNet LUs	mw:SameAs	Predicate matrix
ConceptNet concepts	FrameNet FEe	mw:HasInstance	rule-based system
Wikidata Qnodes	WordNet senses	mw:SameAs	XLNet-based description similarity

## **Node mapping statistics**

### 251,517 mw:SameAs

Applied to merge identical nodes

## 45,659 mw:HasInstance



## From concatenated sources to CSKG

- append node mappings
- compute identity clusters
- deduplicate identical triples



## **CSKG** snippet



## **CSKG** snippet





## **CSKG** statistics

#nodes	2,160,968
#edges	6,003,237
#relations	81
mean degree	5.56
std degree	0.027

## **Integration statistics**

	AT	CN	FN	RG	WN	WD	VG	CSKG (concat)	CSKG
#nodes	304,909	1787373	15,652	71,804	91,294	71,243	11,264	2,344,938	2,160,968
#edges	732,723	3423004	54,109	1,403,955	111,276	101,771	2,587,623	6,054,261	6,003,237
#relations	9	34	23	2	3	15	3	81	81
mean degree	4.81	3.83	6.91	39.1	2.44	2.86	459.45	5.16	5.56
std degree	0.07	0.02	0.73	0.34	0.02	0.05	35.81	0.02	0.03



## **PageRank distribution**



max = 0.0015



# **Top PageRank nodes**

- 1. /c/en/chemical\_compound/n
- 2. /c/en/change/n/wn/artifact
- 3. /c/en/natural\_science/n/wn/cognition
- 4. /c/en/chromatic/a/wn
- 5. /c/en/organic\_compound



# **Open challenge: Node resolution**

#### Node label: scene

fn:lu:sensation:scene	FN
fn:lu:locale_by_event:scene	FN
fn:fe:scene	FN
Q7430735	WD
Q67943498	WD
Q16675888	WD
Q1185607	WD
Q282939	WD
/c/en/scene/n/wn/location	CN, WN
/c/en/scene/n/wn/event	CN, WN

/c/en/scene/n/wn/cognition	CN, WN
/c/en/scene/n/wn/artifact	CN, WN
/c/en/scene/n/wn/state	CN, WN
/c/en/scene/n/opencyc/scene_dramatic	CN
/c/en/scene/n/opencyc/image_space	CN
/c/en/picture/n/wn/state	CN, WN
/c/en/scene/n	CN
/c/en/scene	CN
/c/en/scenery/n/wn/artifact	CN, WN



## **Open challenge: Ambiguity of nodes**





## **Open challenge: Variance of nodes**

### coffee has...

en caffeine -> en caffein → 💼 the active ingredient caffeine 🔿 en caffeine which raises brain reaction time -> 🛯 caffiene 🔿 😐 caffiene in it 🔿 en caffine -> en large amounts of caffeine -> 🛯 en a slightly bitter taste 🔿 💼 a stimulant drug: caffeine 🔿



# **Open challenge: Relation granularity**

Web Child

#### **ConceptNet**



# **Open challenge: Knowledge filtering**

	Documentation
en noma	FAQ
An English term in ConceptNet 5.8 Sources: DBPedia 2015, JMDict 1.07, English Wiktionary, and Open Multilingual WordNet View this term in the API	

### Synonyms

ja 水癌 →

### **Related terms**



# Etymological roots of "noma"



### noma is a type of...





## **Open challenge: Missing facts**

## Location of barbecue

en austrailia →
en Australia →
en Detroit →
en a garage →
en a Michigan park →
en a retail store →





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