

Design Knowledge Representation with Technology Semantic Network

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Motivation & Hypothesis

- A long and complex technical text may be hard to comprehend
- Topic mapping methods provide only high-level associations / disassociations.
- How do we map / associate concepts within the designs?
- A semantic network trained on technical knowledge may provide more meaningful network representations of technical texts.

Semantic Networks in ED

WordNet, ConceptNet vs. TechNet

	Construction method	Data Source	Relations	Quantitative Relations
WordNet	Hand-built	Lexicographers	Synonym, hyponym, meronym, troponym, antonym	Shortest path, information content
ConceptNet	Unsupervised	DBPedia, Wiktionary, WordNet, OpenCyc, common webcrawl, common-sense,	34 types of qualitative relations such as RelatedTo, FormOf, IsA, PartOf, etc.	Cosine similarity of word- embeddings trained on ConceptNet
TechNet	Unsupervised	USPTO Patent Database	-	Cosine similarity of word- embeddings trained on patent texts

TechNet Technology Semantic Network Talining sample

Characters Left: 987

More than 4 million terms

Cosine similarity

• $\sim 10^{12}$ possible relations

• Infrastructure: Public APIs

www.tech-net.org www.github.com/SerhadS/TechNet

prediction model

TechNet: Technology Semantic Network

Discover the most relevant technical concepts from a root term or text through a tree-expansion graph search from a root term or paragraph. Click any term in the tree to discover branches to other concepts most relevant to the one clicked. Continually clicking the same term multiple times generate more branches, representing width-oriented searches. The algorithm generates the branches to the most relevant new terms first. Otherwise, one can also click a newly discovered leaf term to further extend to another new leaf term and continually do so for a depth-oriented search. A deep branch may lead to the discovery of rather distant concepts from the root. Thus, the graph search procedure is flexible for both local exploitation and discoveries around a term (i.e., width-oriented) are the rapid exploration into its distant fields in the technology semantic network (ie., depth-oriented).

heterogeneous, network, discover service, level solar, energy, production independent, slave solar, energy, production independent, slave solar, energy, production independent, slave solar, energent, and production and productio

pattern_recognition

classification_system

Data Source

USPTO Database Granted: 1976 - Oct. 2017

Term Extraction NLP Tools

Term VectorizationLanguage Models



~5.6M Titles & Abstracts Punctuation Removal

Phrasing

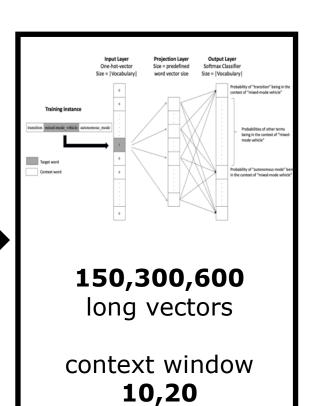
Denoising

Lemmatization

Stopwords Removal

Tokenization

~26M Tokenized Sentences



Semantic Networks in ED

A Spherical Robot or ball-shaped robot is a mobile robot with spherical external shape.

WordNet	ConceptNet	TechNet
Spherical	Spherical	Spherical robot
Robot	Robot	Ball-shaped
Ball-shaped	Ball-shaped	Robot
Mobile	Mobile	Mobile robot
External	External	Spherical
shape	shape	External shape

Overview of Methodology

Technical Description

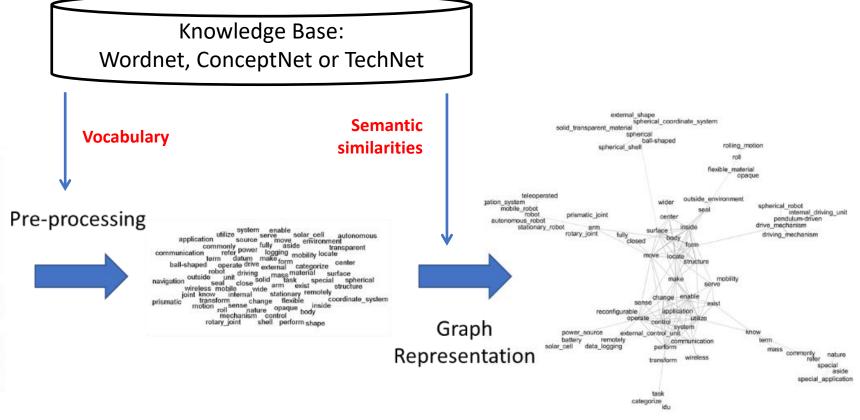
A Spherical Robot, also known as spherical mobile robot, or ball-shaped robot is a mobile robot with spherical external shape. A spherical robot is typically made of a spherical shell serving as the body of the robot and an internal driving unit (IDU) that enables the robot to move. Spherical mobile robots typically move by rolling over surfaces. The rolling motion is commonly performed by changing the robot's center of mass (i.e., pendulum-driven system), but there exist some other driving mechanisms. In a wider sense, however, the term "spherical robot" may also be referred to a stationary robot with two rotary joints and one prismatic joint which forms a spherical coordinate system (e.g., stanford arm.).



A pendulum driven spherical mobile robot (The white arrow is used to determine the position and orientation of the robot via a vision-based algorithm.)

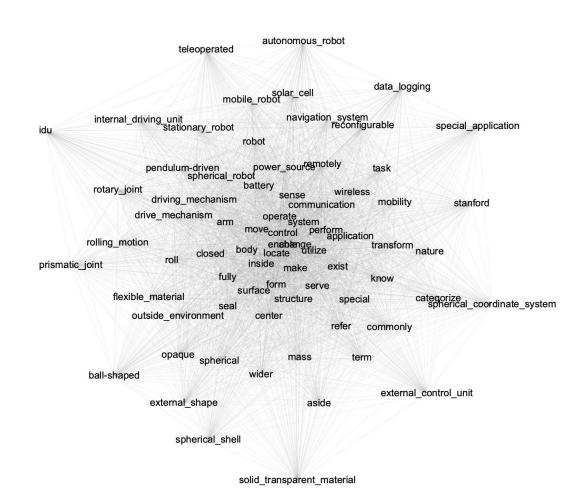
The spherical shell is usually made of solid transparent material but it can also be made of opaque or flexible material for special applications or because of special drive mechanisms. The spherical shell can fully seal the robot from the outside environment. There exist reconfigurable spherical robots that can transform the spherical shell into other structures and perform other tasks aside from rolling.

spherical robots can operate as autonomous robots, or as remotely controlled (teleoperated) robots. In almost all the spherical robots, communication between the internal driving unit and the external control unit (data logging or navigation system) is wireless because of the mobility and closed nature of the spherical shell. The power source of these robots is mostly a battery located inside the robot but there exist some spherical robots that utilize solar cells. Spherical mobile robots can be categorized either by their application or by their drive mechanism.



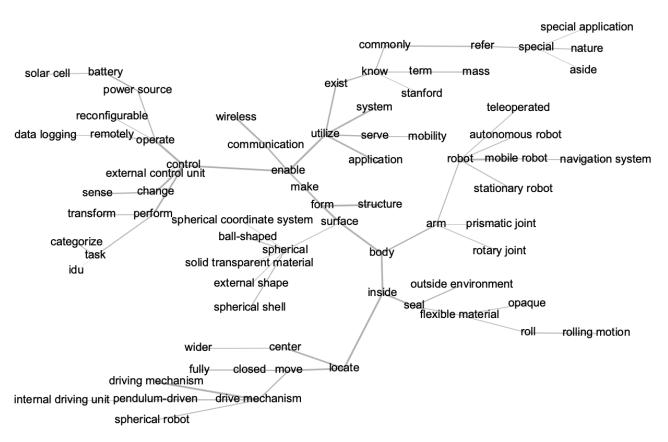
Graph Representation Approach

1) Link the terms by edges weighted by referring to terms' semantic similarities in corresponding knowledge base (i.e. either WordNet, ConceptNet or TechNet)



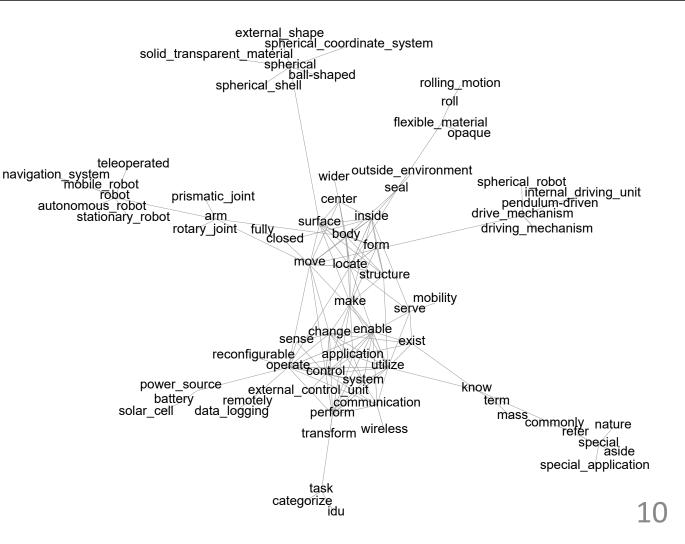
Graph Representation Approach

2) Generate maximum spanning tree of the graph

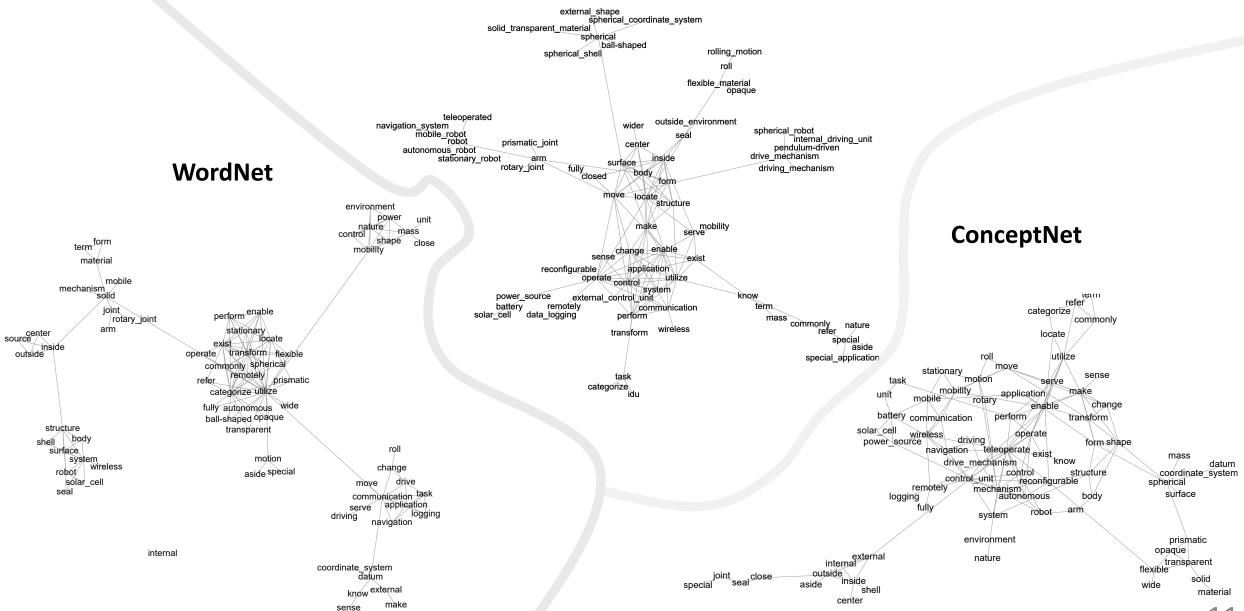


Graph Representation Approach

3) Add next N+1 highest weighted edges and run Force Atlas layout algorithm to achieve final visualization



TechNet



Survey Setup

1) Reading comprehension Summarization

2) Evaluation of individual visualizations

3) Redundant question asking the best visualization

Technical Description

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>50 words summaries

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How well does this graph represent the **specific** design of "spherical robot"?

Which of the three graphs is the best representation of the **specific** design of "spherical robot"?

Participants

56 participants

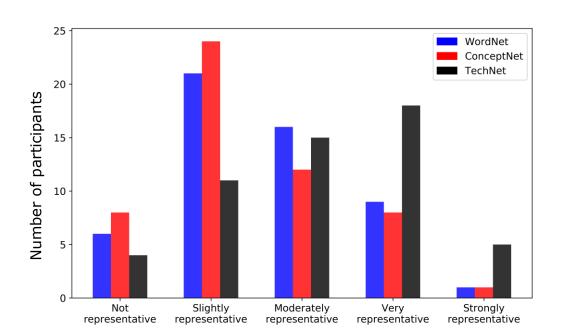
PhD students from SUTD and NTU, who have engineering backgrounds

Conducted informal interviews with 25 of participants

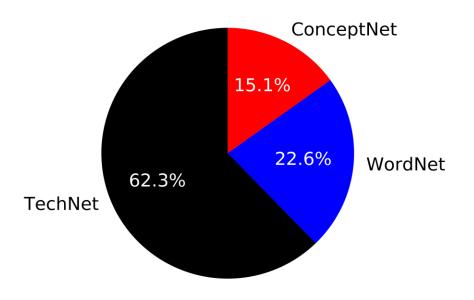
 3 participants removed since they admit they did not pay attention to the questions asked

Results

How well does this graph represent the **specific** design of "spherical robot"?



Which of the three graphs is the best representation of the **specific** design of "spherical robot"?



Participant comments

 TechNet can create distinct groups of highly relevant concepts

"The nodes of the graph include **Multi-Word Units** (MWUs - e.g., spherical coordinate system) that are **important for the reproduction of entities** in the text description. The entities that comprise **MWUs carry a specific meaning in this context**, which is lost when these are decomposed into single word units"

"Visually it splits my attention into a few key components which I associate as different parts that can be used to describe a spherical robot"

 Comments point out engineers' tendency to favor more modular and detailed representation

Findings and Limitations

- Knowledge base with a technical focus seems to support better visualizations of a technical text for technical eyes comparing to common-sense knowledge bases
- A first step to explore visual summarization techniques based on semantic networks and knowledge graphs

• Limitations:

- o Depends on specific graph filtering and visualization methods
- o Graphs are not the only possible visualization technique
- o There exists other potential knowledge bases

