

When Spiderwebs Build Bridges

Mapping the Universal Solution Space

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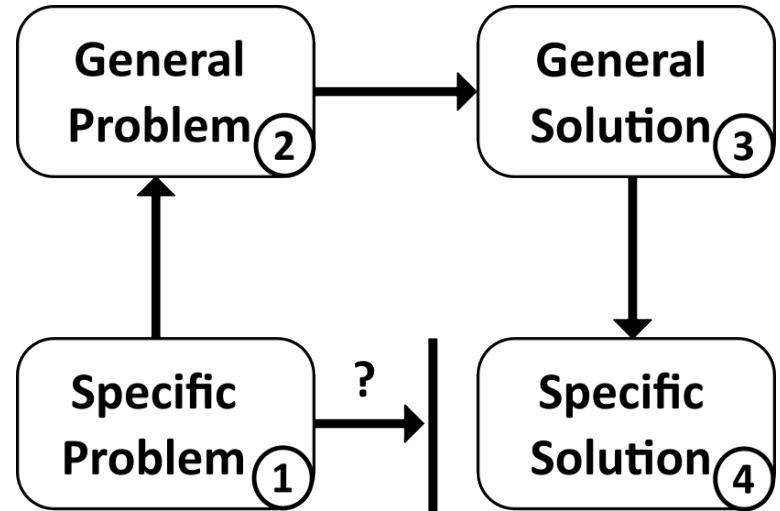
03 Creating a common solution space

04 What's next? Utilizing the common solution space

The Idea



- Creative ideas and innovative breakthroughs are very hard
- Yet, thousands of solutions already exist
- Idea: Generalize these solutions and decouple them from their original domain
- Use technical (patents) and biological solutions in particular



Technical solutions: Patents



First gramophone



First motor car

First plane (Wright brothers)

Biological solutions: Biomimetics



Burrs => Velcro

Kingfisher => Bullet-train



Lotus flower => Lotus effect

01

Human technology and biology

Different solution spaces?



-
- Diagram illustrating the Semantic Gap between Engineering and Biology. Two stylized figures are shown, one on the left representing Engineering and one on the right representing Biology. The Engineering figure's head contains a word cloud with terms like Patents, Algorithms, Design, Prototypes, and Systems. The Biology figure's head contains a word cloud with terms like Evolution, Bio-inspiration, Organisms, Homeostasis, and Biomimicry. A dashed arrow labeled "Semantic Gap" points from the Engineering figure to the Biology figure. Below the arrow, text reads "Same functions, different vocabularies".

The Barriers



- Biological literature uses physiological terminology
- Patents rely on technical jargon
- Same function, different vocabularies → traditional methods fail
- Existing solutions (e.g., AskNature): manual curation, limited scale, keyword-centric

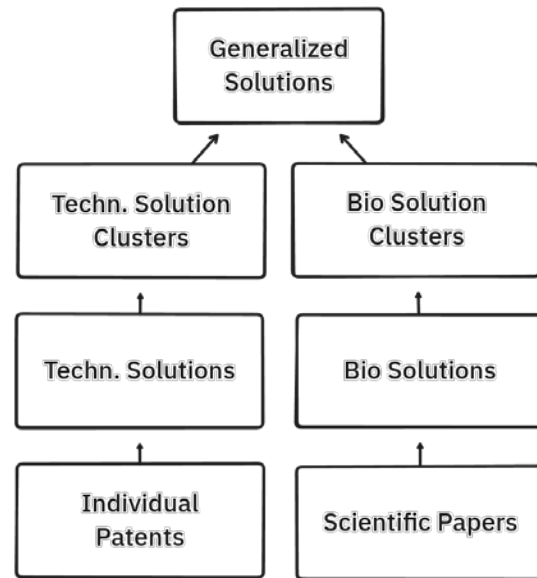
Biology	Engineering
self-cleaning via hydrophobic microstructures	anti-fouling coating system
reversible dry adhesion mimicking in gecko toe-pads	detachable contact-fastening system employing hierarchical fibrillar microstructures
cranial shock absorption in woodpeckers	gradient-density kinetic energy attenuator

Our Vision



To build a knowledge graph, representing and connecting technological and biological solution spaces using a generalized taxonomy.

- Extract problems & solutions from patents at scale
- Use semantic embeddings to transcend vocabulary barriers
- Cluster and generalize into hierarchical taxonomy
- Integrate biological solutions into the same space



02

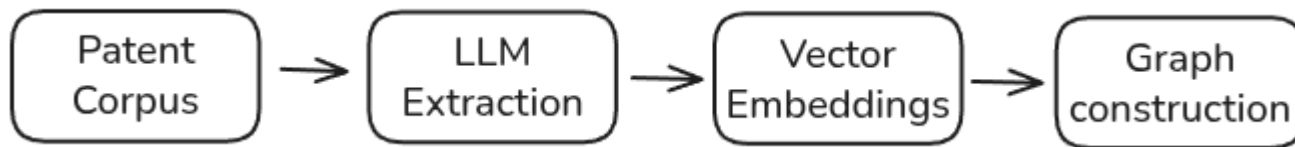
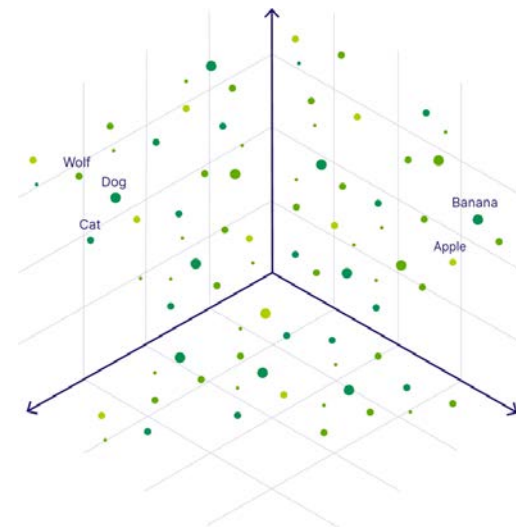
Inferring a universal solution taxonomy



From Patents to Knowledge Graph



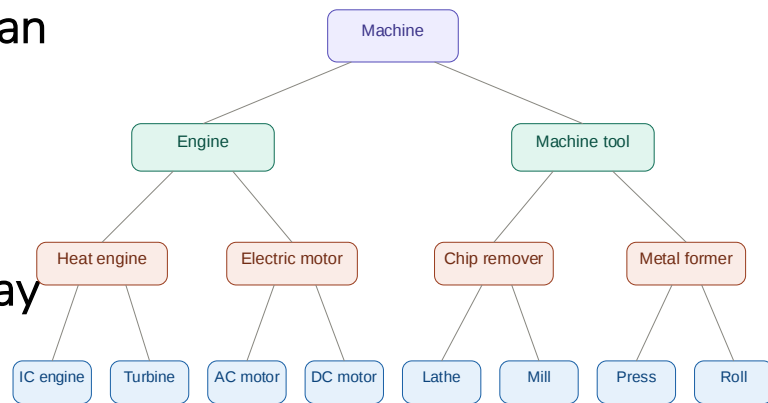
- 1. Data Collection:** USPTO / Google patents
- 2. Extraction:** Large Language Model (LLM) extracts problem/solution pairs from patent text
- 3. Embedding:** Instruction tuned embeddings models map a semantic vector space
- 4. Graph Construction:** Similarity-based edges should exist between similar problems and similar solutions



Hierarchical Generalization



- Community detection (*Leiden algorithm*) identifies related solutions
- NLP data extraction + LLM summarization + human decision
→ generalized problem / solution groups
- Extracted data and summaries assist the generalization process while human experts stay in control (“human in the loop”)
- **Repeat recursively:** Generate embeddings for generalized problems / solutions and group again
- **Result:** Multi-level hierarchy of human technological knowledge



Generalization hierarchy — arrows point from specific to general

03

Creating a common solution space



Integrating Nature's Solutions

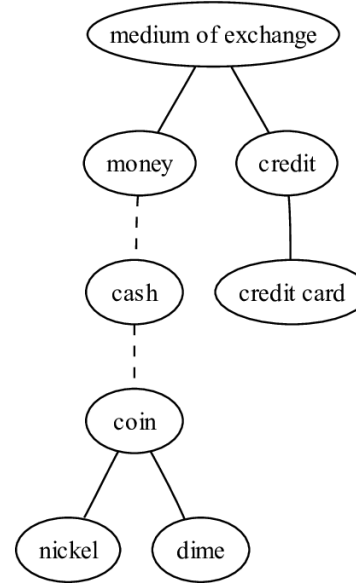


- **Source:** Scientific literature (Semantic Scholar dataset): 21 million articles
- Filter relevance using BERTopic and fine-tuned BERT
- Extract biological strategies (adapted NASA PeTaL bio-strategy-extractor)
- Create vector embeddings for these strategies / solutions
- Connect to human solutions - edges weighted by cosine similarity

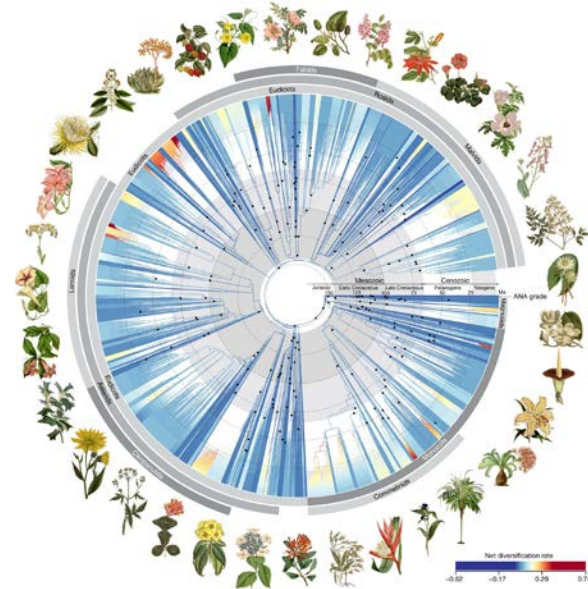


How could a common taxonomy look like?

- Inspiration: WordNet
- Common concepts practically non-existing
- Abstraction & selection needed
- Could be verbs (e.g. rotate, heal, ...)
- Integration of existing biological taxonomic concepts like “Energy acquisition”, “Ambush Strategies”, etc.



WordNet taxonomy of hyponyms



Phylogenetic tree of life for plants

Validation Strategy



- **Qualitative validation:** Process a small subset of selected patents; human experts analyze the resulting graph network to identify shortcomings of the approach
- **Quantitative benchmark:** Rediscover known biomimetic innovations
 - Remove historical biomimetic solutions from the graph beforehand
 - Query the system with the original problem
 - Measure success: **does it propose solutions similar to the known biomimetic solutions?**

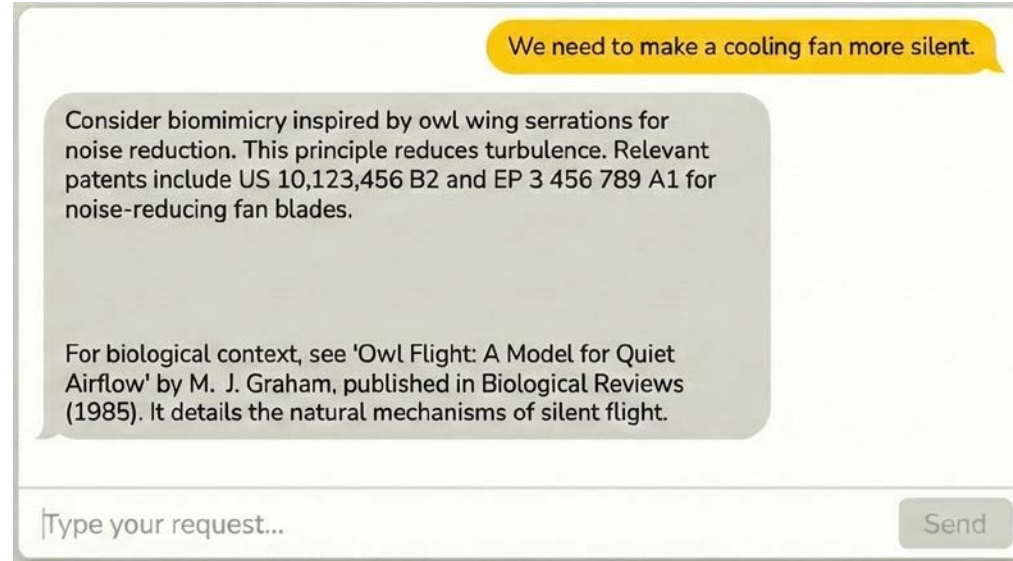
04

And then? Utilizing the knowledge graph

Applications



- **Functional search:** Query by functions instead of keywords
- **AI assisted ideation:** AI agents can navigate the graph and use structural information and knowledge as **grounding**
 - Reduced hallucinations and allows direct verification and linking
- **Identification of innovation potential:** Graph analysis methods can suggest existing problems that can be solved using biologic solutions
- **Democratizing access:** Domain expertise less important for solution development



References



- [1] Park, M., Leahey, E., & Funk, R. J. (2023). Papers and patents are becoming less disruptive over time. *Nature*, 613, 138–144. <https://doi.org/10.1038/s41586-022-05543-x>
- [2] Vincent, J. F. V., Bogatyreva, O. A., Bogatyrev, N. R., Bowyer, A., & Pahl, A.-K. (2006). Biomimetics: Its practice and theory. *Journal of the Royal Society Interface*, 3(9), 471–482. <https://doi.org/10.1098/rsif.2006.0127>

Image sources



Burrs: <https://pixabay.com/photos/burr-burdock-greens-thickets-3570658/>

Embeddings: <https://weaviate.io/blog/vector-embeddings-explained>

Grammophone: <https://pixabay.com/photos/gramophone-music-musical-retro-3412265/>

Hierarchy: created with Claude Pro

Kingfisher: <https://pixabay.com/photos/kingfisher-bird-wood-perched-881594/>

Lotus flower: <https://pixabay.com/photos/lotus-lotus-leaf-flowering-flower-563455/>

Motor car: <https://pixabay.com/photos/isolated-patent-motor-car-2448349/>

Spiderweb: <https://pixabay.com/photos/spiderweb-web-dew-dawn-nature-8430411/>

TRIZ: own creation

Wordnet: https://www.researchgate.net/figure/An-example-of-the-WordNet-taxonomy-showing-lowest-superordinates-of-nickel-and-dime_fig6_253857313

Wright brothers (plane): <https://pixabay.com/photos/plane-wright-brothers-74020/>

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We work for
tomorrow