TEXT2MODEL: A Conceptual Model-Based Knowledge and Intelligence Management System

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TECHNION
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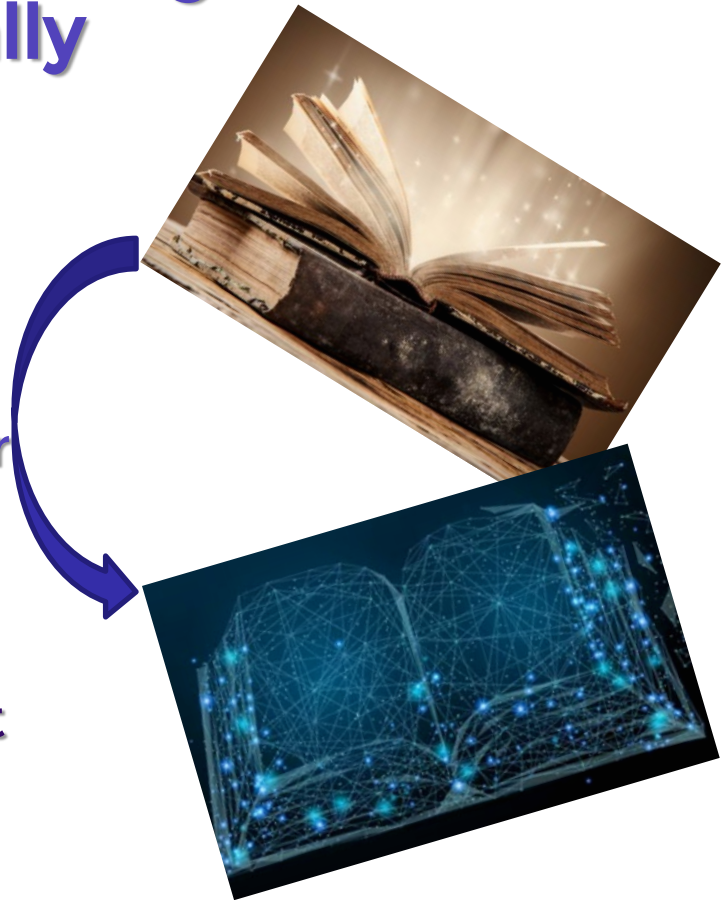
Knowledge management (KM):

The human ability to perform knowledge-related processes:
acquiring, capturing,
eliciting, storing,
preserving, curating,
querying, inferring,
evolving, and
gaining new knowledge.

The amount of human knowledge available in free text grows exponentially

- The scientific, engineering, and intelligence communities have been amassing knowledge in a rapidly accelerating rate.
- This knowledge explosion hinders our knowledge management effectiveness
- Raising the need for an intelligent knowledge management system that improves knowledge utilization.



Symbols and Connections: Two competing AI approaches

- **Symbolic AI: Explicitly teaching computers about the world**

Expert Systems – a computer system emulating the decision-making ability of a human expert.

- **Connectionist AI: Learning from examples via artificial neural networks**

Deep Neural Networks (DNNs) – a multi-layered network of artificial neurons inspired by the brain…

to perform deep learning (DL) of patterns, classify, generalize, and manipulate text in ways that *seem* intelligent

Symbolic AI: Explicitly teaching computers about the world

Expert Systems - emulate a human expert decision-making ability

My PhD 1995-1998… LISP

Predicates are functions which return a Boolean value. A predicate is defined in Lisp as the following function:

(defun **predicate-name** (list-of-parameters)
body)

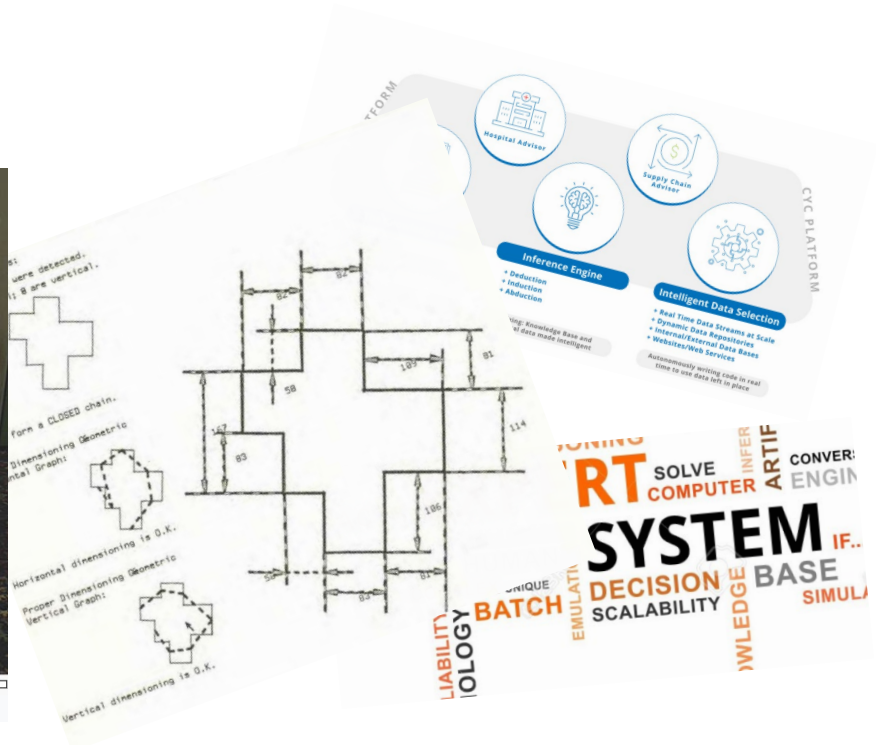
The name of the predicate, **predicate-name**, is an **assertion**, formulated as a sentence in English. When body is evaluated, the assertion is checked and found to be either t (true) or nil (false). The predicate returns the result of the evaluation of body. For example, the predicate

(**vectors-are-parallel** vector1 vector2 maximal-deviation-angle)

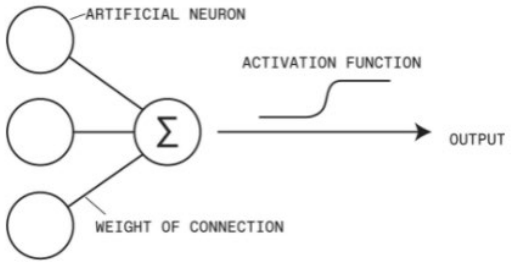
returns t if the deviation from parallelism between vector1 and vector2 does not exceed maximal-deviation-angle, else the predicate returns nil. It is defined as follows:

(defun **vectors-are-parallel** (first second maximal-deviation-angle)
(< (**angle-between-vectors** first second) maximal-deviation-angle))

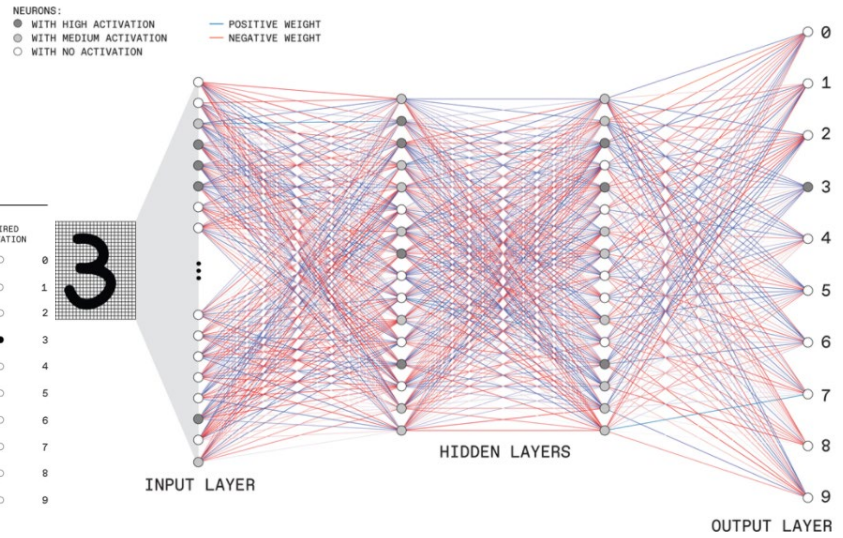
A Symbolics Lisp Machine: an early platform for expert systems.



Connectionist AI: Learning from examples via artificial neural networks



Deep Neural Network (DNN) – a multi-layered network of interconnected **neurons**, where each neuron **sums** its **inputs** and applies an **activation function** to determine its **output**.



Training applies **backpropagation** to update the **weights** on the connections.

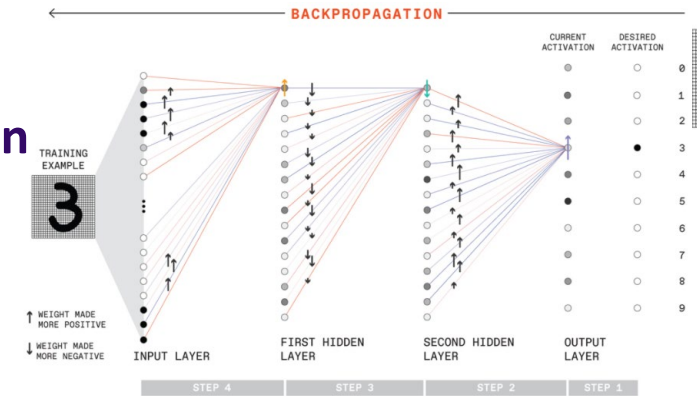


Illustration by David Schneider

Symbolic and Connectionist AI have been adversaries

It has looked like the **connectionist** approach has been **winning over** the **symbolic** one.

Really? **Not so fast!**

Recently, the idea of symbolic and connectionist AI **convergence** is picking up, e.g.:

EDGE INTELLIGENCE FOR OBJECT DETECTION IN BLOCKCHAIN-BASED INTERNET OF VEHICLES: CONVERGENCE OF SYMBOLIC AND CONNECTIONIST AI

Xiantao Jiang, F. Richard Yu, Tian Song, and Victor C. M. Leung

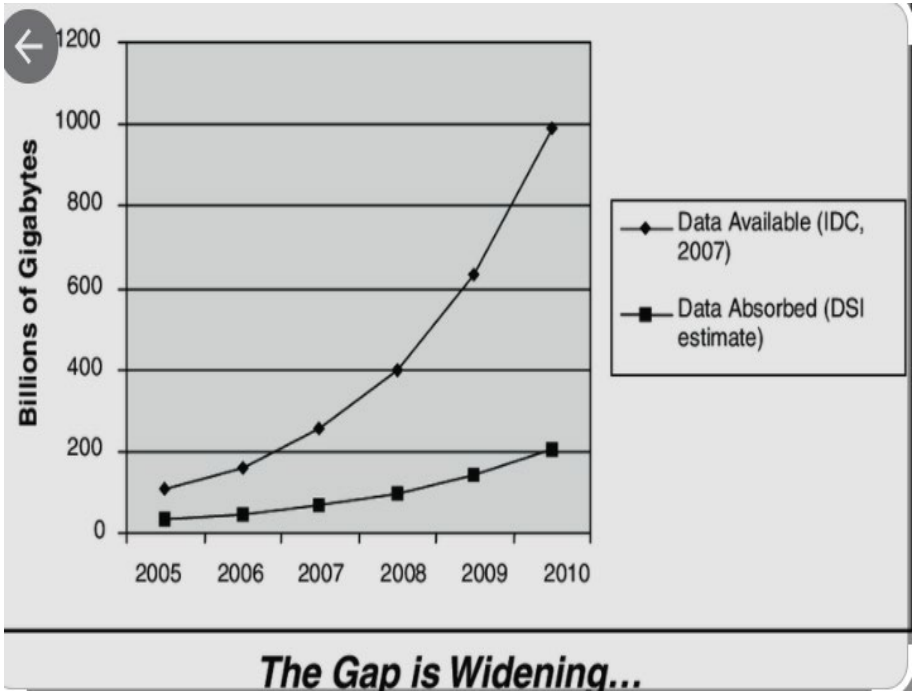
IEEE Wireless Communications • August 2021

Symbolic AI and Systems Engineering are closely related

- **Symbolic AI** also **encodes human knowledge** into a set of rules aimed at solving problems
- In the contexts of **Systems Engineering** (SE), the **Model-Based SE** (MBSE) approach is a close relative of Symbolic AI
- Conceptually modeling a system creates a **network of knowledge** on how a system functions, and what its structure and behavior are
- A conceptual **model of a system** can be considered the encoding of our understanding (or design) of the system's function, structure and behavior
- **The model** solves the problem of explaining (or building) the system similar to the way expert systems solve problems symbolically

Knowledge explosion calls for a radically new approach

- The **amount** of human **knowledge** available in **free text** in science, technology, military intelligence… **grows exponentially**
- No single human or a group of humans can put their arms around it
- There is a pressing **need** for an intelligent **knowledge management system** that improves knowledge utilization



Synergizing MBSE with Deep Learning

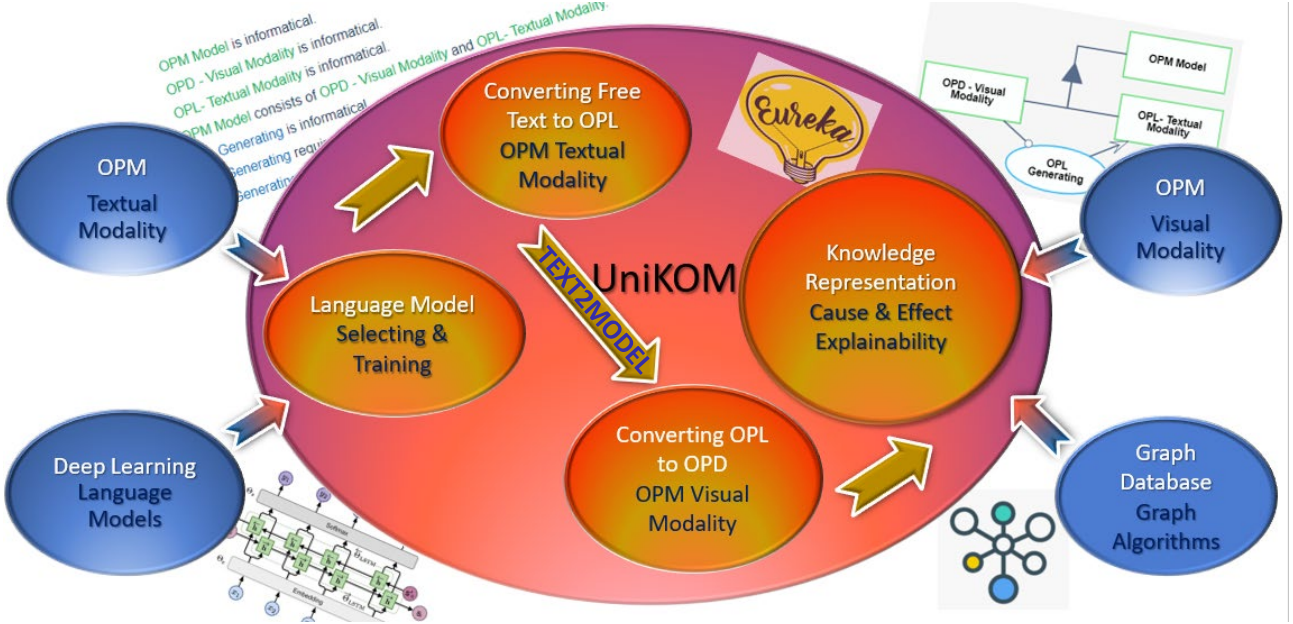
- **MBSE** is **analogous** to **Symbolic AI**
- MBSE **does not** currently **have a learning** element
- We propose to leverage the **synergy** between **MBSE** and **Deep Learning** using a **Language Model (LM)** e.g., BERT, GPT3…
- Our case in point: converting **free text** to a **model – TEXT2MODEL**
- Part of **UniKOM** – a **hybrid** connectionist-symbolic system for **Universal Knowledge Management**

UniKOM – a system for Universal Knowledge Management

Combines two disparate cutting-edge technologies:

- language models (LMs) — a new, powerful statistics-based approach to natural language processing (NLP)
- OPM ISO 19450 — a holistic paradigm and conceptual modeling language for systems engineering and exploration of phenomena of all kinds

UniKOM overview



Blue: existing components;

Red: to be developed

Deep Learning (DL)

- Statistics-based **machine learning algorithms** that successfully **mimic human skills** of finding patterns in data
- Employs computational models composed of **deep neural networks**
- Some DL systems already exhibit “shocking” (Heaven, 2020) human-like performance
- Has taken the world by storm: outstanding performance, keeps improving
- Can **learn** representations of data with **many abstraction levels**
- Dramatically improving NLP tasks: neural machine translation (NMT), **paraphrasing**, summarization …
- Has major problems: can be fooled; cannot explain its decisions…

Deep Neural networks (DNNs) can be easily fooled

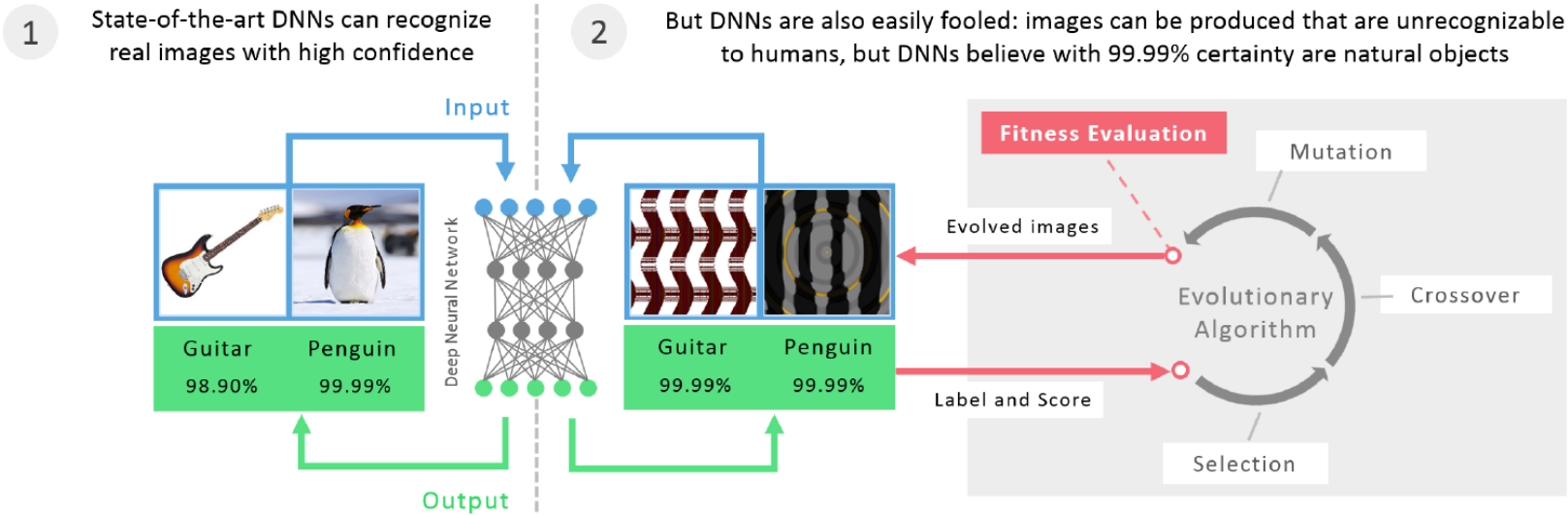


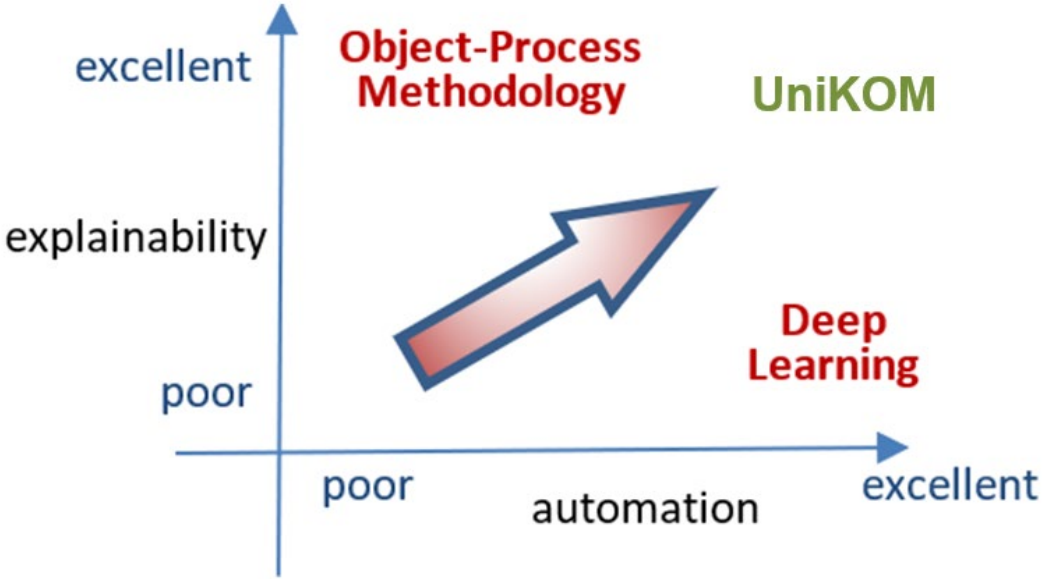
Figure 2. Although state-of-the-art deep neural networks can increasingly recognize natural images (*left panel*), they also are easily fooled into declaring with near-certainty that unrecognizable images are familiar objects (*center*). Images that fool DNNs are produced by evolutionary algorithms (*right panel*) that optimize images to generate high-confidence DNN predictions for each class in the dataset the DNN is trained on (here, ImageNet).

Nguyen et al., Deep Neural Networks are Easily Fooled: High Confidence Predictions for Unrecognizable Images. CVPR2015.

AI Explainability (AIX) Problem

- Another major problem with DL systems: **lack of explainability**
- Stems from their **black-box nature** of a complex neural network that performs numerous **intractable transformations**.
- **Precludes DL** from being part of knowledge-intensive, **cognitively-demanding** human activities:
  - Scientific research – creating new knowledge
  - Engineering critical socio-technical systems: healthcare, aviation…
  - Military intelligence interpretation and forecasting

Explainability vs. Automation



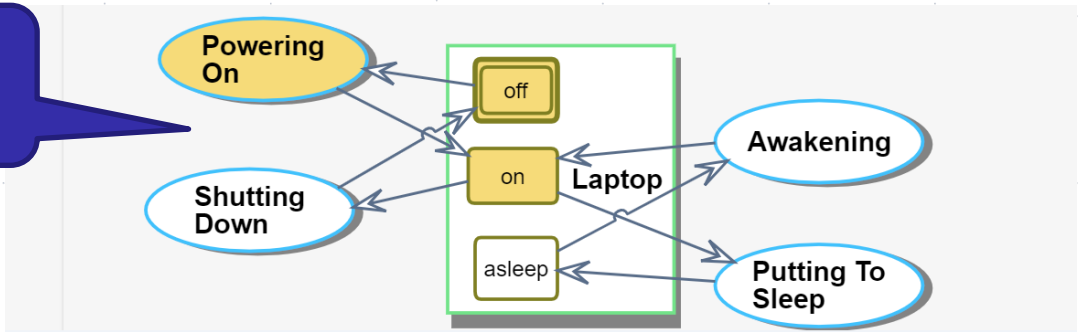
The synergy between OPM and DL provides UniKOM with excellent explainability and excellent automation levels

Why is OPM ISO 19450 up to this task?

- OPM features **bimodal graphic-textual** conceptual modeling
- Caters to **human cognition** – the second multimedia learning assumption (Mayer, 2010)
- Makes it most adept for **representing free text** knowledge in UniKOM's **formal graph structure**.

Bi-modality demonstrated: OPM model of laptop state transitions using OPCloud

Graphic modality – Object-Process Diagram (OPD)



OPL

Laptop is physical and systemic.
Laptop can be off, on, or asleep.
State off is initial and final.
Powering On is physical and systemic.
Powering On changes Laptop from off to on.

Textual modality – Object-Process Language (OPL)

Previous work

arXiv:1909.01066v2 [cs.CL] 4 Sep 2019

"…our investigation seeks to answer to what extent pretrained language models store factual and commonsense knowledge by comparing them with symbolic knowledge bases..."

Checked simple facts: date and place of birth, date of death

"The surprisingly strong ability of these models to recall factual knowledge without any fine-tuning demonstrates their potential as unsupervised open-domain QA systems."

Language Models as Knowledge Bases?

Fabio Petroni[1] **Tim Rocktäschel**[1,2] **Patrick Lewis**[1,2] **Anton Bakhtin**[1]
Yuxiang Wu[1,2] **Alexander H. Miller**[1] **Sebastian Riedel**[1,2]
[1]Facebook AI Research
[2]University College London

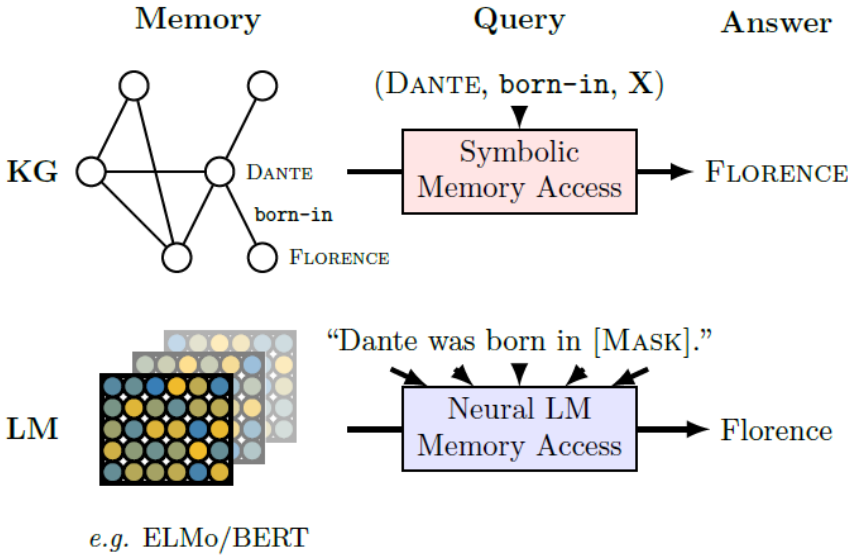
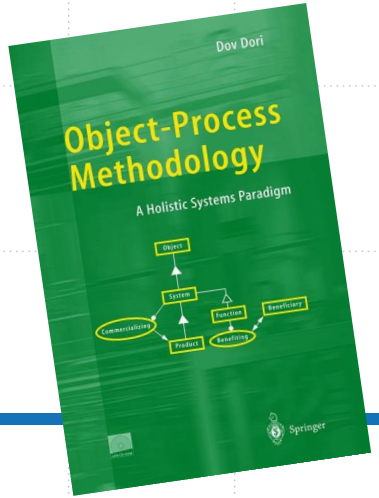
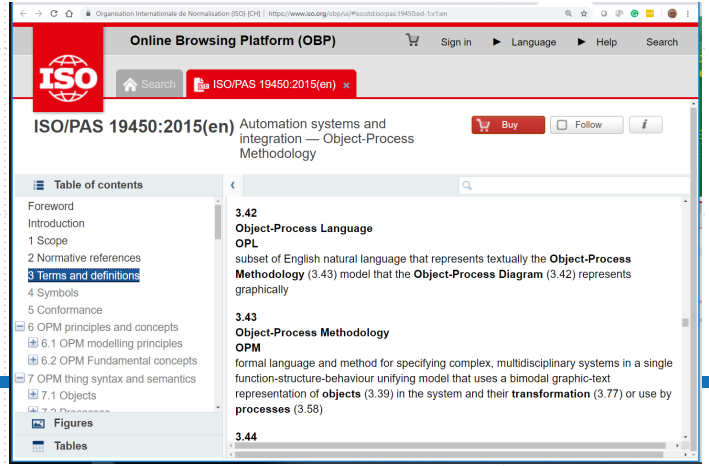


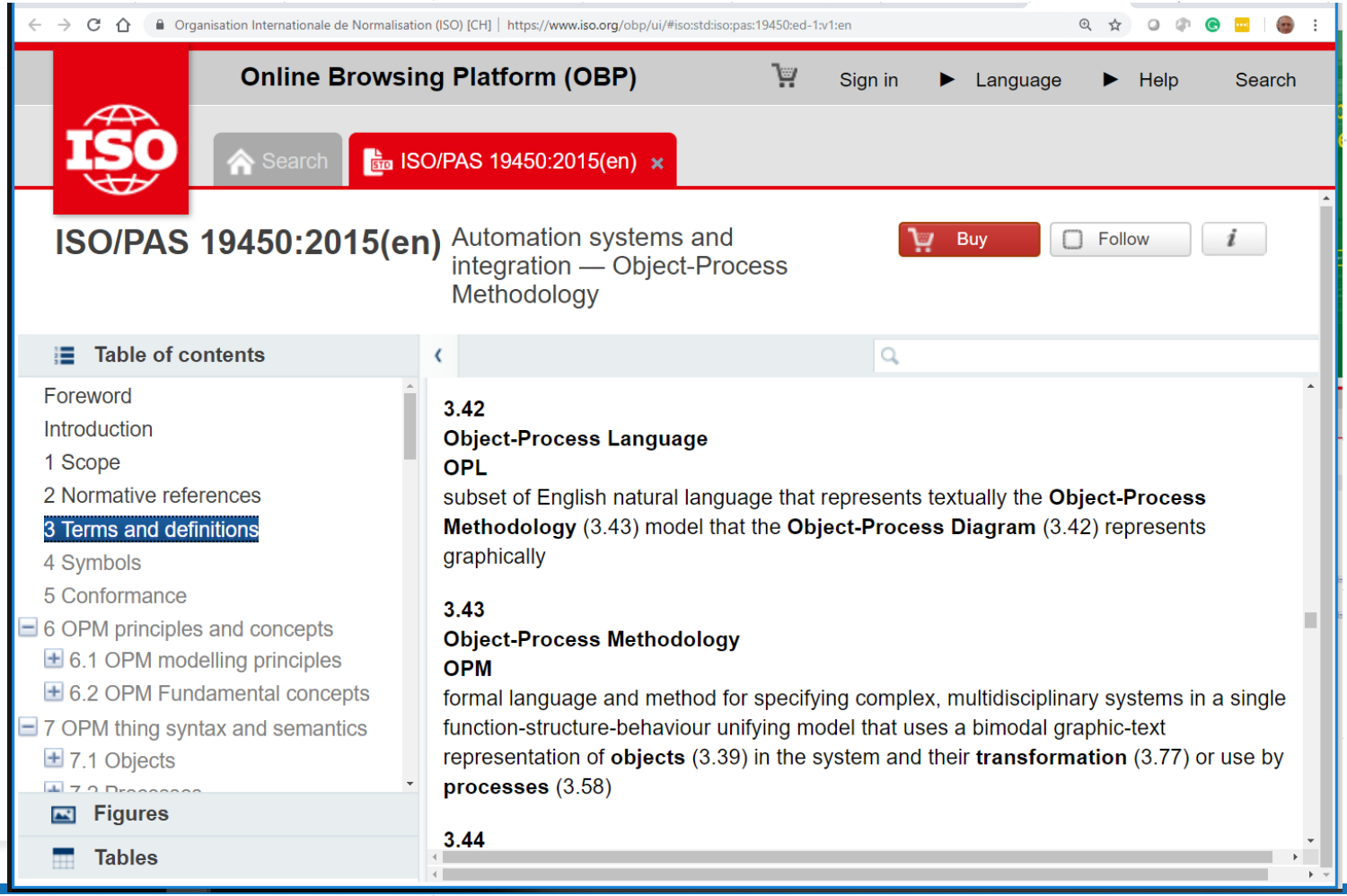
Figure 1: Querying knowledge bases (KB) and language models (LM) for factual knowledge.

Let's examine
Object-Process Methodology
OPM ISO 19450





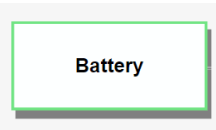
2015: OPM becomes ISO 19450 (work started 2009)

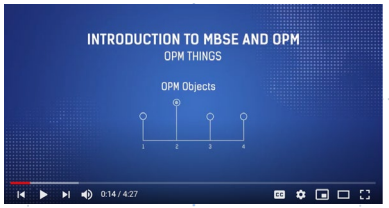


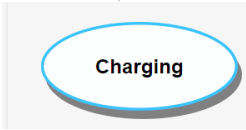
Only two OPM Things:
Objects and Processes

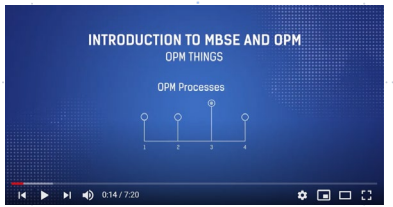
Object: A thing that *exists* or might exist physically or informatically *at a given point in time*.

Process: A thing that *transforms* or might transform one or more *objects over time*.





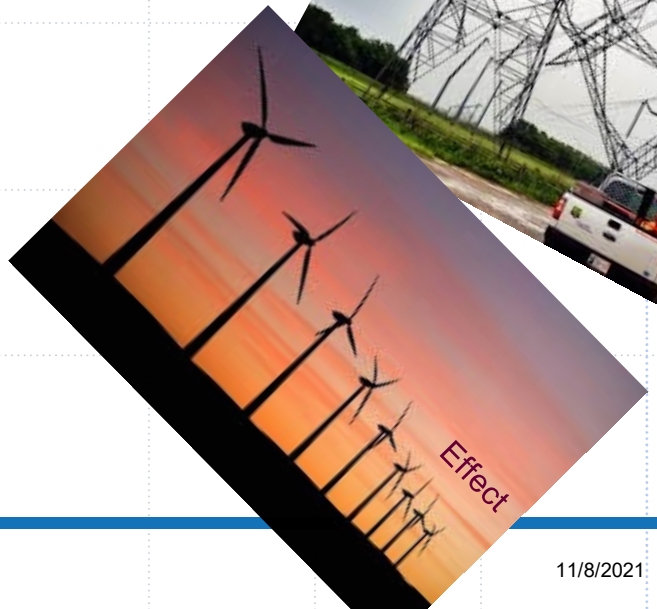




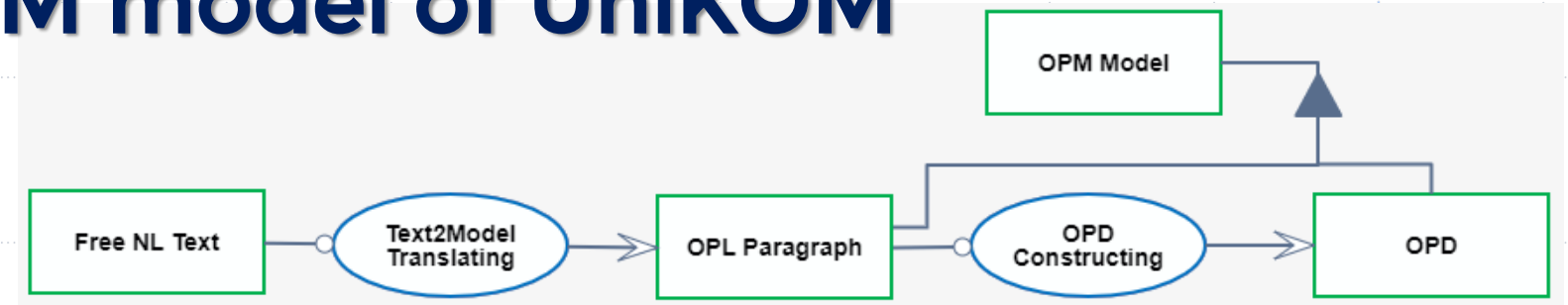
Processes transform objects.

A process can transform an object in three ways:

1. *Generating* an object
2. *Consuming* an object
3. *Affecting* an object



An OPM model of UniKOM



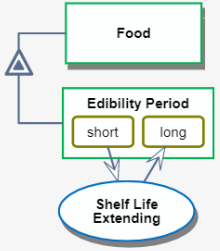
OPM Model consists of OPD and OPL Paragraph.

Text2Model Translating requires Free NL Text.

Text2Model Translating yields OPL Paragraph.

OPD Constructing requires OPL Paragraph.

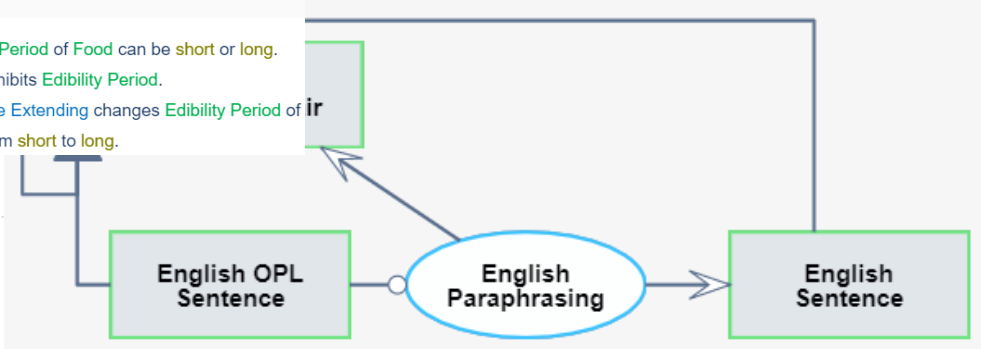
OPD Constructing yields OPD.



ing of the LM uses paraphrasing to convert to free text, creating input-output pair

OPL

Edibility Period of Food can be short or long.
Food exhibits Edibility Period.
Shelf Life Extending changes Edibility Period of Food from short to long.



English Text-OPL Pair consists of English OPL Sentence and English Sentence.

English Paraphrasing requires English OPL Sentence.

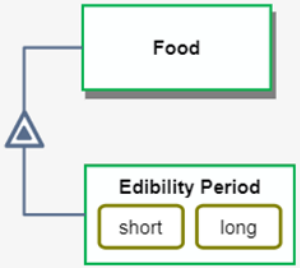
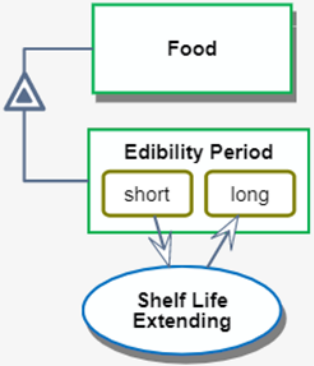
English Paraphrasing yields English Sentence and English Text-OPL Pair.

Training of the LM uses pairs of OPL and its paraphrased free text

Natural text example

"Food is characterized by shelf life, i.e., the period of time during which the food is edible, which can vary from being long to being short. Making the food available for a longer period extends its shelf life."

The expected output

Input OPL Sentence	(1) Food exhibits Edibility Period.	(2) Edibility Period of Food can be short or long.	(3) Shelf Life Extending changes Edibility Period of Food from short to long.
Output OPM model	 OPL Food exhibits Edibility Period.	 OPL Edibility Period of Food can be short or long. Food exhibits Edibility Period.	 OPL Edibility Period of Food can be short or long. Food exhibits Edibility Period. Shelf Life Extending changes Edibility Period of Food from short to long.

Gradual sentence-by-sentence construction of the OPD from the OPL paragraph OPM Model.

Graph database as knowledge management foundation

- Graph database: an online graph-based data management system
- Leverages complex, dynamic relations in highly connected data
- Provides index-free adjacency via explicit graph structure
- Enables graph-oriented operations using graph-theoretic algorithms.

The UniKOM Vision: Summary

- Convert knowledge in free-text to a queryable model
- Leverage the synergy of a connectionist LM approach and a symbolic-like MBSE one
- Fine-tune the LM by OPL-free text sentence pairs
- Query and create knowledge from a graph database holding the extracted knowledge model using graph-theoretic algorithms.

Thanks for listening!

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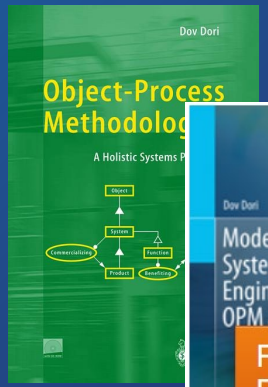

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