MONDAY
16:30-18:30
T023

TUESDAY
15:30-18:30
T023

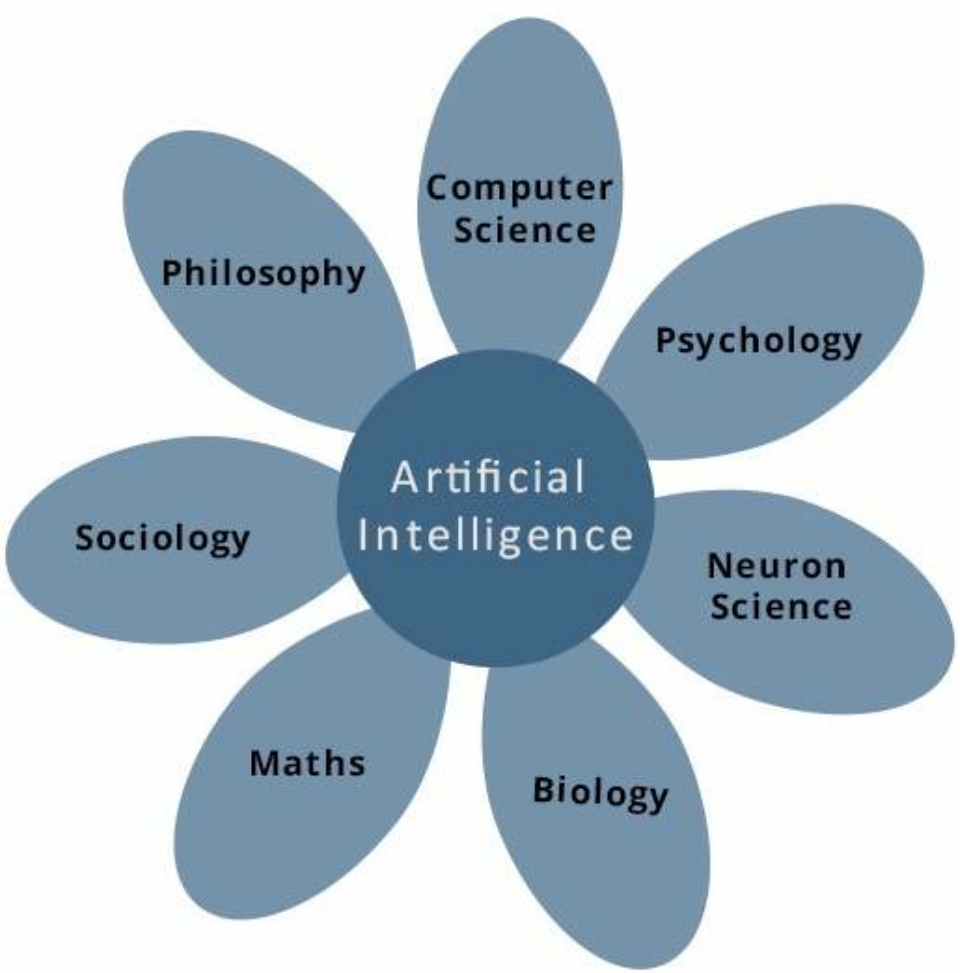
Matteo Palmonari & Federico Bianchi & Stefania Bandini

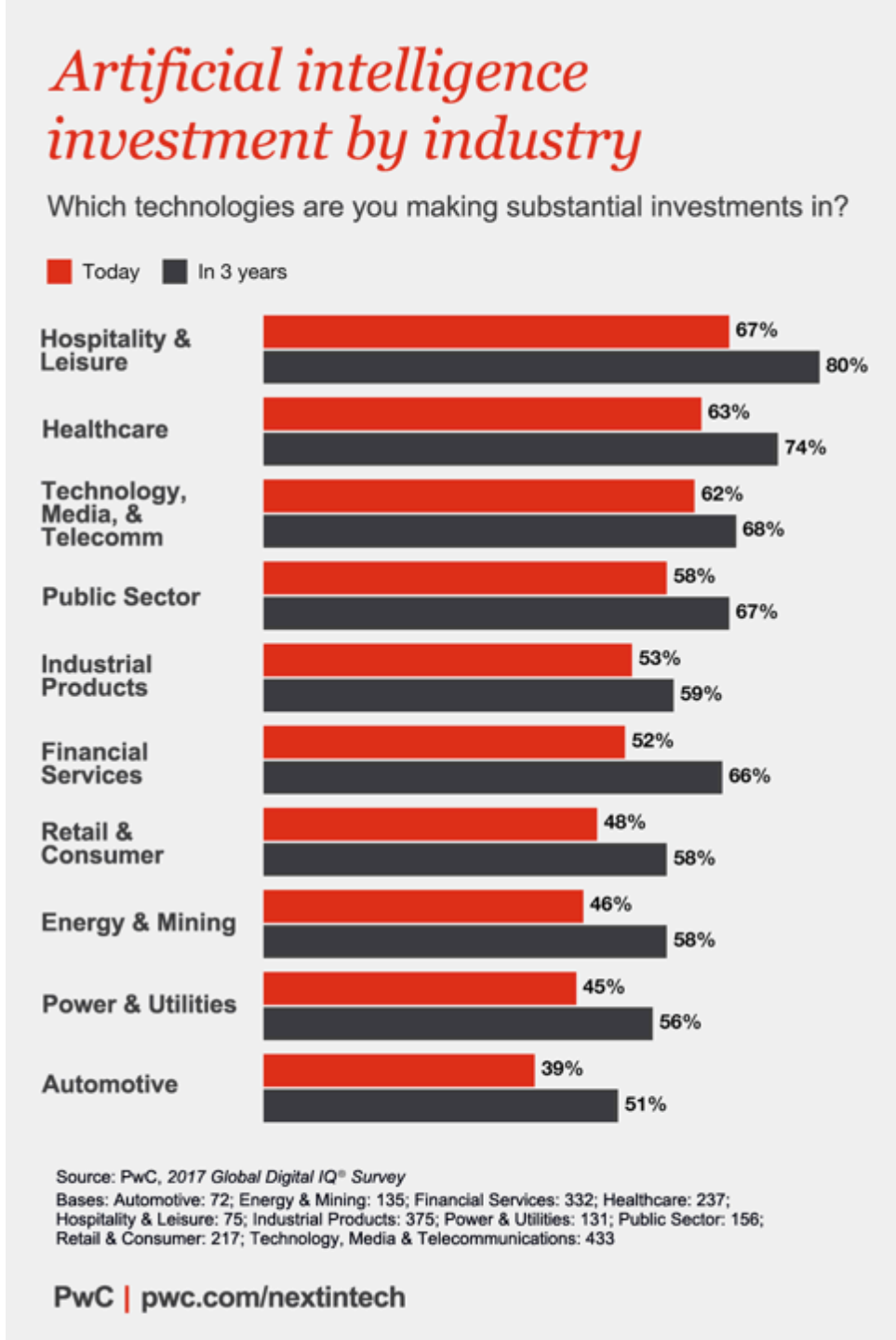
INTELLIGENZA ARTIFICIALE – ARTIFICIAL INTELLIGENCE

Complex Systems & Artificial Intelligence Research Center

Dipartimento di Informatica, Sistemistica e Comunicazione

ARTIFICIAL INTELLIGENCE: SCIENCE & INDUSTRY





INSID&S Lab
Interaction and Semantics
for Innovation with Data & Services

Research Challenges in AI: Tackling the Complexity of Human Intelligence and Applications (a very short introduction)

Matteo Palmonari

INSID&S Lab - inside.disco.unimib.it

University of Milano-Bicocca

Credits to Stafania Bandini & Federico Bianchi

Write to matteo.palmonari AT unimib.it

Impact of Modern Machine Learning on Problem Solving / Games

1997 deep blue beats Kasparov

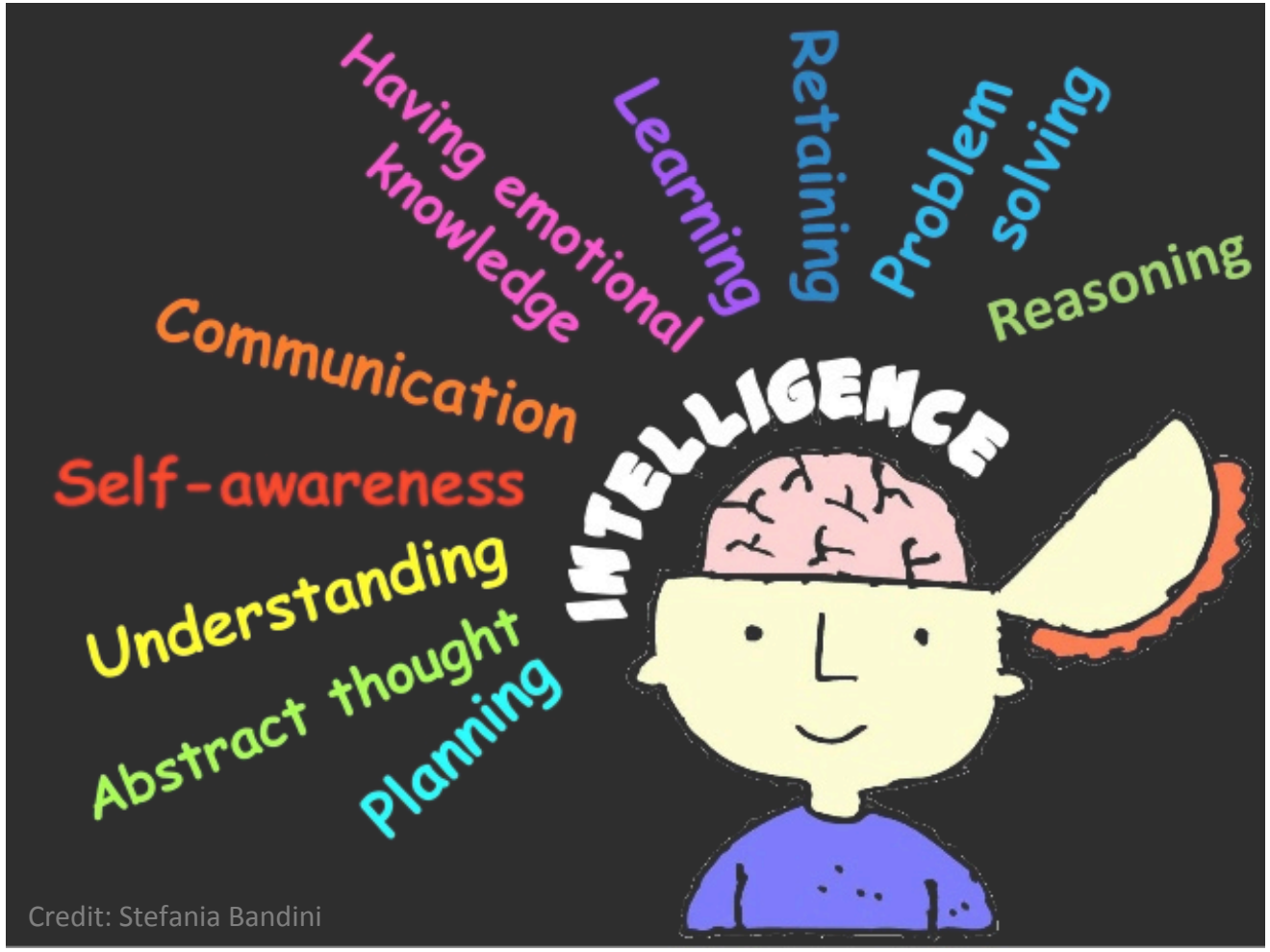
2019 DeepMind's AI beats a pro gamer on Starcraft II (strategic game)

Cons. Humans have limited attention and slower action/m rate

Cons. Humans learn 1000x faster in the Frostbite game [Tsividis et al. AAAI 2017]

Humans use background knowledge

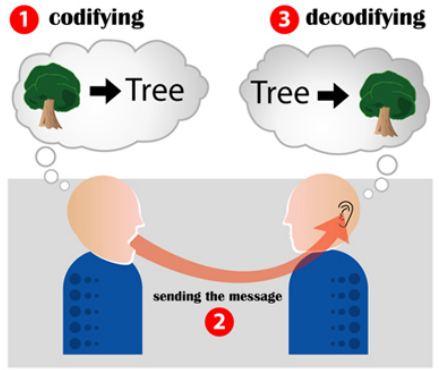
A Multi-faceted Intelligence



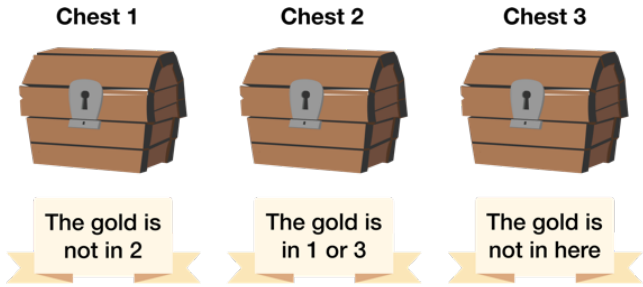
Humans acquire knowledge from different sources…

experience

transmission



inference



Research Trends: Towards Human-level AI

1. **Humans learn faster and without limited training "data"**

2. Different humans' cognitive skills are highly connected and not learnt independently

3. Humans can imagine and reason about things and events that do not exist, and at higher level of depth and abstraction

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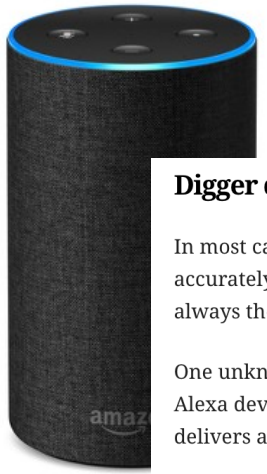
Advances: Natural Language Processing

2011: IBM's Watson beats Jeopardy's champions

Question Answering

2019: 100M of Alexa have been sold

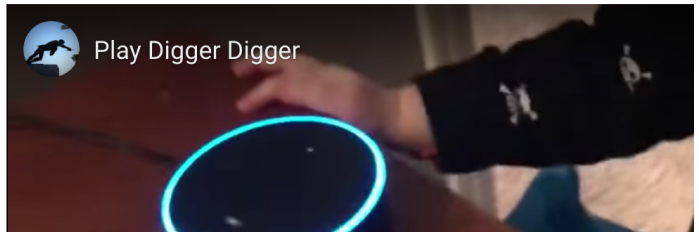


Digger digger kid

In most cases, virtual assistants pick up what you're saying fairly accurately. However, some parents have found out that that isn't always the case.

One unknown YouTube user uploaded footage of his son asking their Alexa device to "play Digger, Digger". Mishearing the toddler, Alexa's delivers a far from PG response as his parents scream for her to stop.

We're warning you – it's probably best not to watch this one at work:



Cons. Alexa proposing adult content at upon a "play Digger, Digger" kid's question

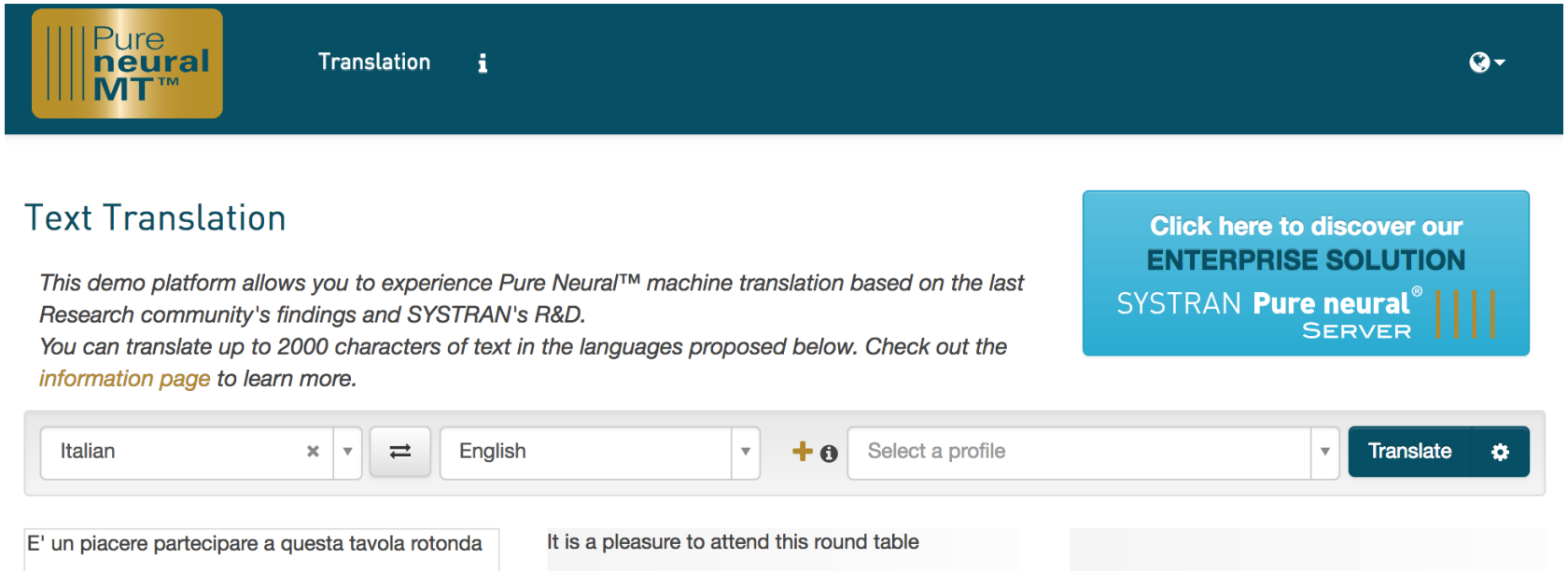
Cons. Alexa suggesting wrong opening hours

ALERT

AI applications requires more than ML:

semantic data management
data quality
user-centric design
…

Neural Machine Translation (NLP)



Cons. What if we ask human vs. AI translators to answer these questions:

What is Calvino's vision?

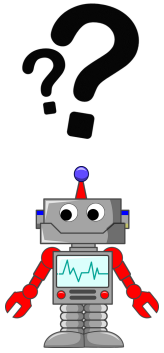
Do you agree with Calvino's viewpoint?

How has the book affected your world vision?

Translating Italo Calvino's Invisible Cities: which one is AI-generated?

"Arrivando a ogni nuova città il viaggiatore ritrova un suo passato che non sapeva più d'avere: l'estraneità di ciò che non sei più o non possiedi più t'aspetta al varco nei luoghi estranei e non posseduti."

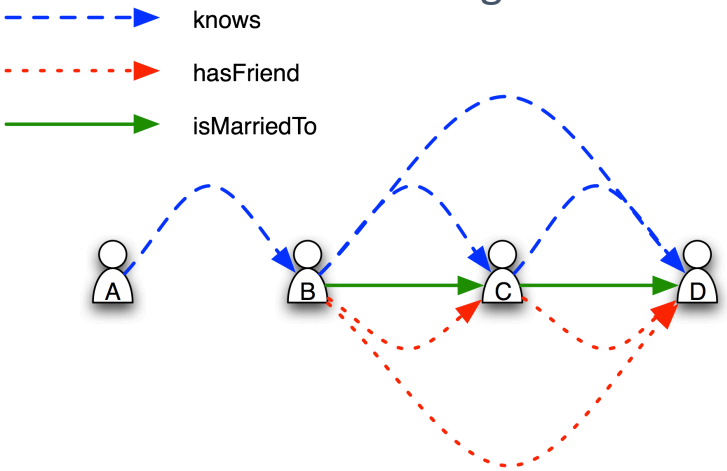
"By reaching every new city, the traveler finds a past that no longer knew: The disenchantment of what you are no longer, or you no longer have, awaits the crossing in foreign and non-owned places."



"Arriving at each new city, the traveler finds again a past of his that he did not know he had: the foreignness of what you no longer are or no longer possess lies in wait for you in foreign, unpossessed places."

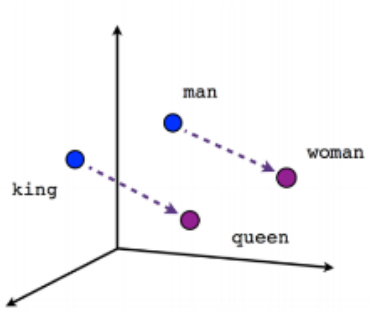
Combining Reasoning and Learning

Symbolic Knowledge Representation & Reasoning

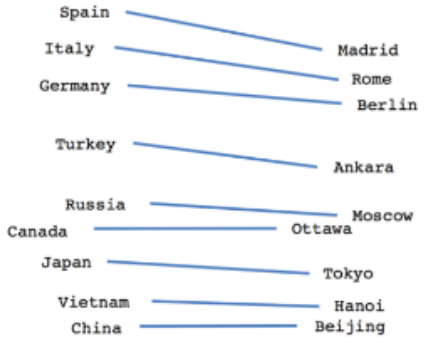


Credit: http://ontogenesis.knowledgeblog.org/1376

Learning Representations for Reasoning

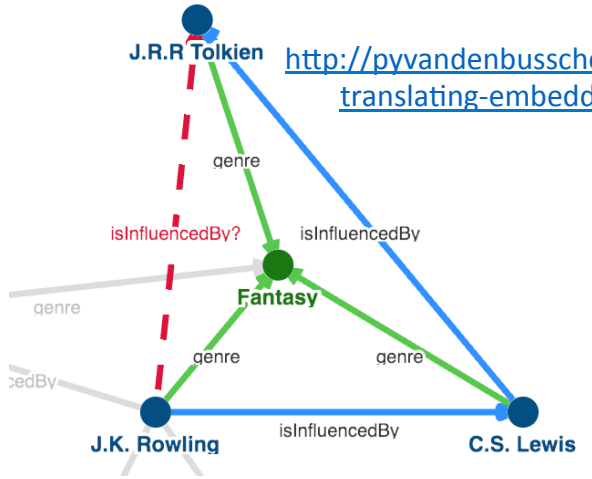


Male-Female



Country-Capital

Analogical reasoning over words [Mikolov, 2013] and entities [Bianchi & al., 2018]



Credit: http://pyvandenbussche.info/2017/translating-embeddings-transe/

Link prediction based on latent factors [Trouillon & al., 2017]

Pros. Accurate reasoning, scalability
Cons. Hand-written rules, rigid inferences

Pros. Data-driven, soft inferences, latent factors
Cons. Limited precision, limited scalability

Combining modern ML and reasoning (neuro-symbolic integration)

2016: Neural Theorem Prover [Rocktaschel & al., 2016]

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Imagination and AI in Creative Processes

2018: DJ Algoriddim - AI-powered music selector and mixer

Neural Music Composition Software by Google

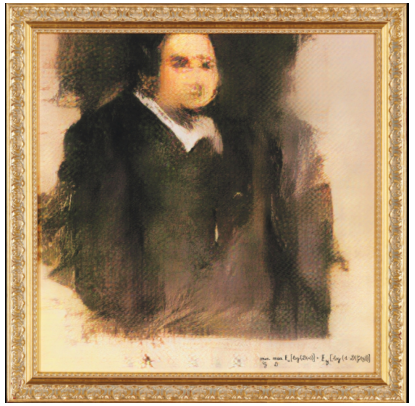
Cons. unfair comparison of resources

AI: deeply listening 40M songs

Human DJ: can't listen more than ~7MIL songs in a lifetime (75 years 12h/day)

2018: Face Generation with BigGAN [Brock, 2018]

Figure 1: Class-conditional samples generated by our model.



Portrait of Edmond Belamy

Sold for $432,500 at Christie's

Painted by Obvious algorithm after training with 15k paintings

Cons. Still errors that many humans would not make even on "AI better than humans" image classification tasks

Research Trends: Towards Human-level AI

1. Humans learn faster and without limited training "data"

   - Transfer learning, few-shot learning, combination of symbolic knowledge and learning

2. Different humans' cognitive skills are highly connected and not learnt independently

   - Transfer learning, multi-modal learning (e.g., text + images, verbal + non-verbal communication, images + emotions, …); multi-task learning (e.g., ~ one model for different tasks); combination of analogical and logical reasoning; cognitively grounded architectures

3. Human can imagine and reason about things and events that do not exist, and at higher level of depth and abstraction

   - Imagination machines, generative models, what-if question answering, counterfactuals

Yoshua Bengio on Combining Two Modes of Thought

Deep Learning Pioneer Yoshua Bengio Says AI Is Not Magic And Intel AI Experts Explain Why And How

Gil Press Contributor ⓘ
Enterprise & Cloud
I write about technology, entrepreneurs and innovation.

At the same time, classical AI aimed to allow computers to do what humans do—reasoning, or combining ideas "in our mind in a very explicit, conscious way," concepts that we can explain to other people. "Although the goals of a lot of things I'm doing now are similar to the classical AI goals, allowing machines to reason, the solutions will be very different," says Bengio. Humans use very few steps when they reason and Bengio contends we need to address the gap that exists between our mind's two modes of thought: "System 1" (instinctive and emotional) and "system 2" (deliberative and logical). This is "something we really have to address to approach human-level AI," says Bengio.

Complementing Logical Reasoning with Sub-symbolic Commonsense

Commonsense Knowledge

- Text annotated with entity linking
- Entities **dbr:cat** and **dbr:tiger** appear in similar contexts.
- **Entity Embeddings**:
- v(dbr:cat) ≃ v(dbr:tiger)

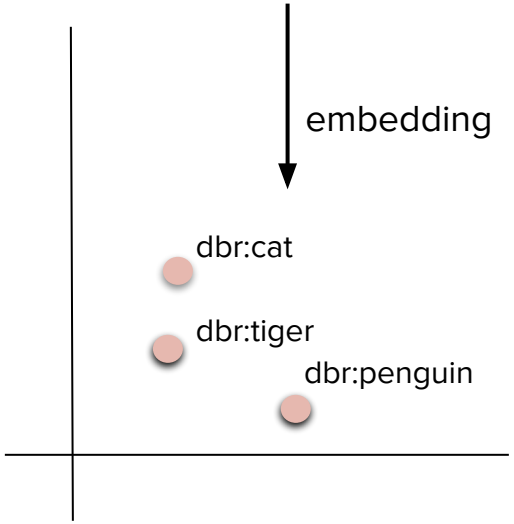
Axiomatic Knowledge

species(**dbr:cat**)
mammal(**dbr:tiger**)
bird(**dbr:penguin**)
[...]

Instantiated atoms

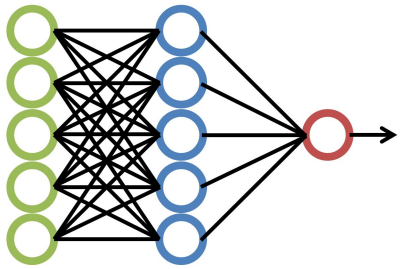
∀ **x** (mammal(**x**) → animal(**x**))

Universally quantified formulas

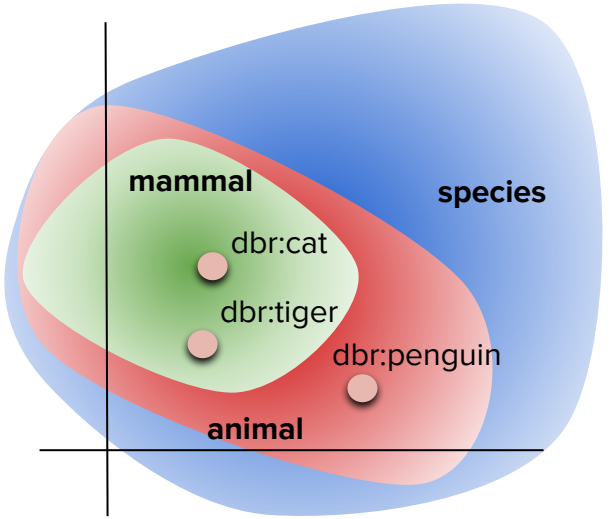


Sub-symbolic commonsense knowledge

learning predicates with commonsense and axiomatic knowledge



LTN



Sub-symbolic commonsense knowledge with learned predicates

After Training Inferences:
animal(**dbr:cat**) ?
∀ **x** (species(**x**) → animal(**x**)) ?

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3. Human can imagine and reason about things and events that do not exist, and at higher level of depth and abstraction

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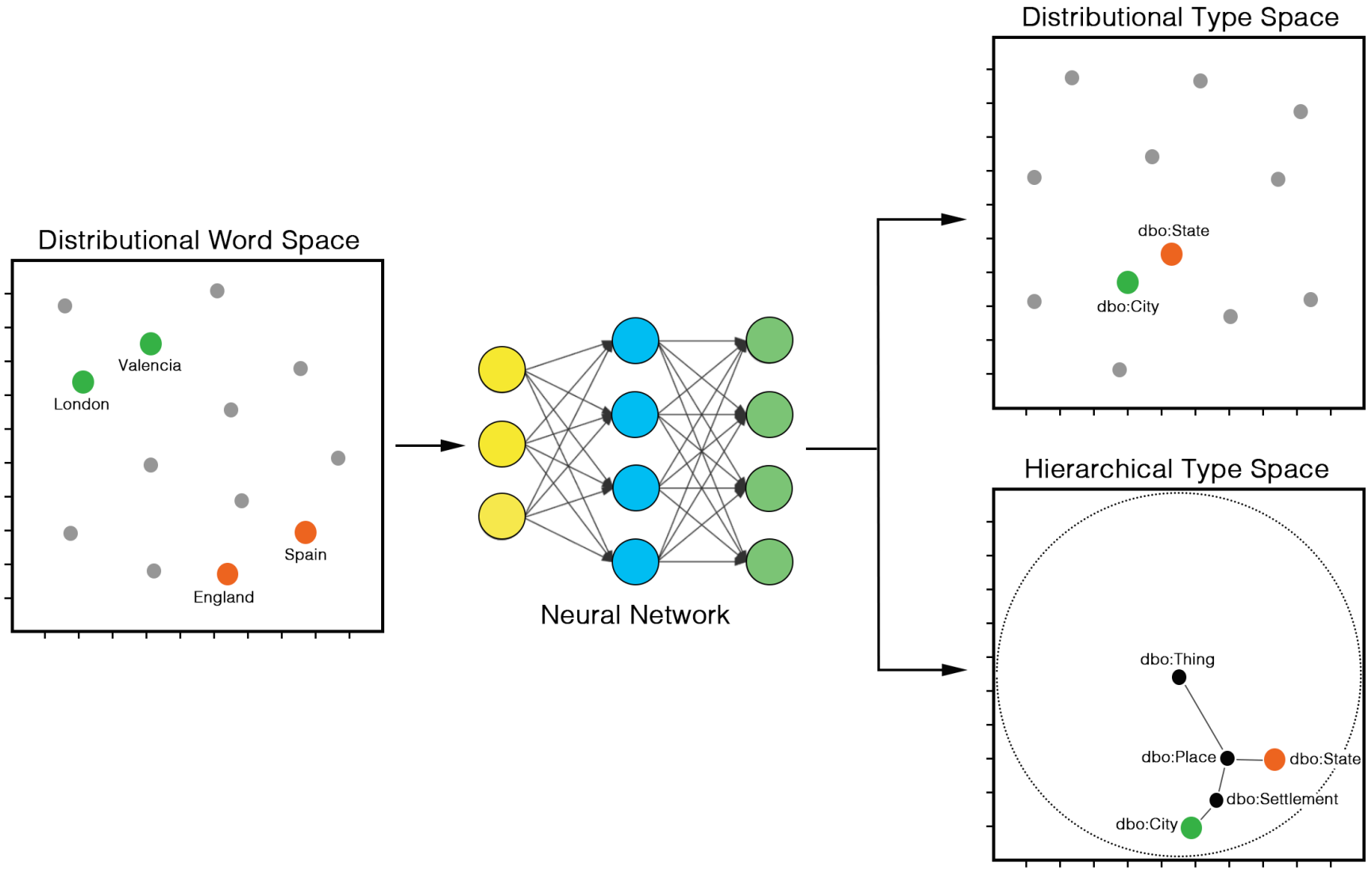
Inventing Concept Representations



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1. Humans learn faster and without limited training “data”

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4. Humans learn, reason and act immersed in an environment
   - Sensor data, enactive computing, embodied knowledge, robotics

Adaptive Behavior with Music Composition

[Shimon, the marimba player]

https://youtu.be/y-p4DZPkYek

Research Trends: Towards Human-level AI

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3. Human can imagine and reason about things and events that do not exist, and at higher level of depth and abstraction
4. Humans learn, reason and act immersed in an environment

Research Trends: Applications

- **Data science: answer complex questions over large amount of data and texts**
  - E.g., what's the **impact of events** covered by media **on the performance of a digital marketing campaign** in a foreign country?
- **Human-computer interaction: support effective cooperation between humans and machines**
  - E.g., help in **child care**
  - E.g., conversational agents we can't laugh about ☺
- **Imagination machines: support human creativity**
  - E.g., can we move from AI-powered film recommendations to AI critics?
  - E.g., can we invent smart ads in a way that they seem natural?
- Accountability: explain and trace AI behavior
  - E.g., what has taken to a certain action?

Figure 12: Correlation between German national handball team matches and online digital indicators in the "SportFitness" category.

Supporting children affected by autism with non-verbal communication (MIT Media Lab)

Making sense of digital marketing analytics … with external events

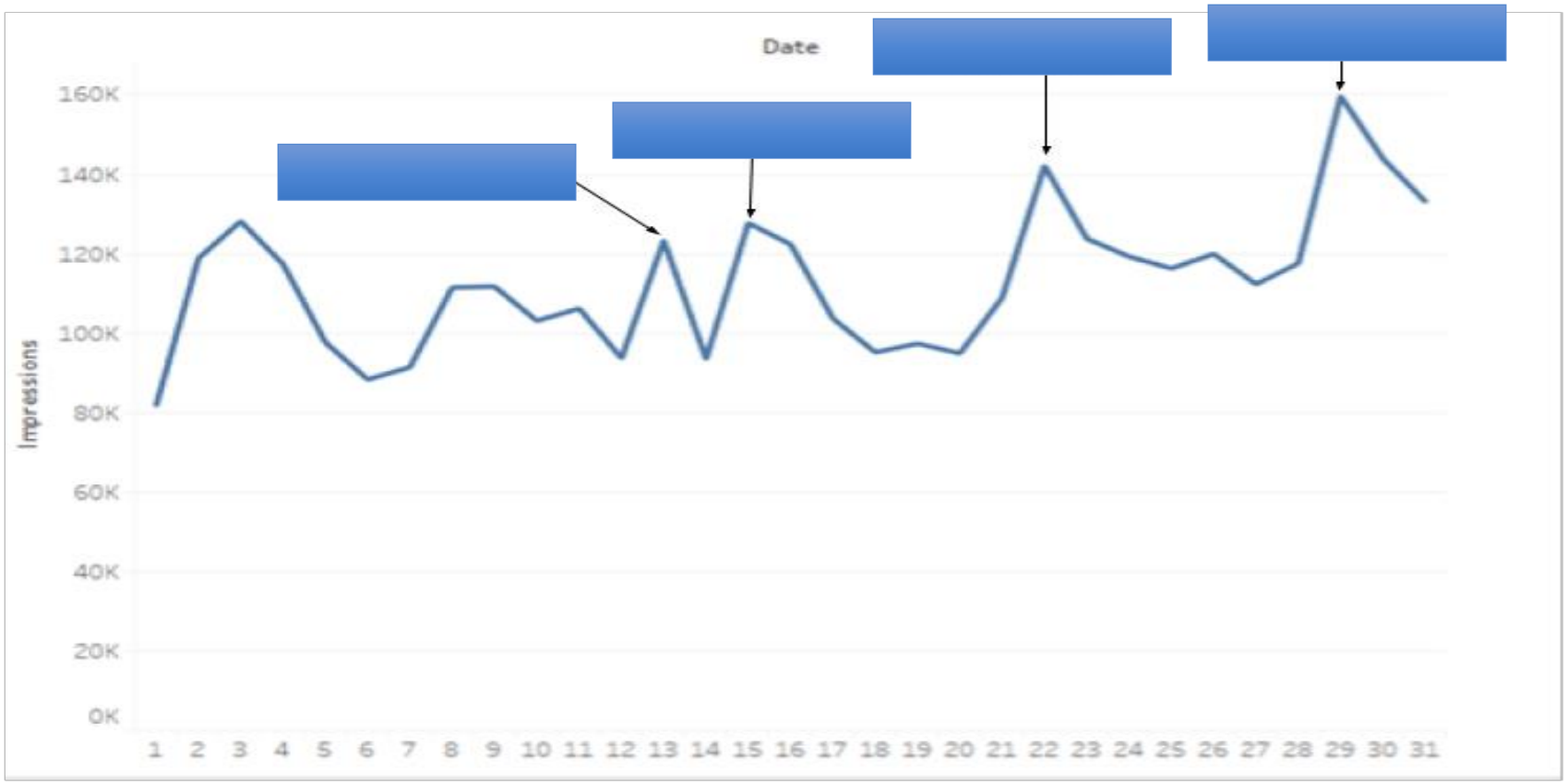
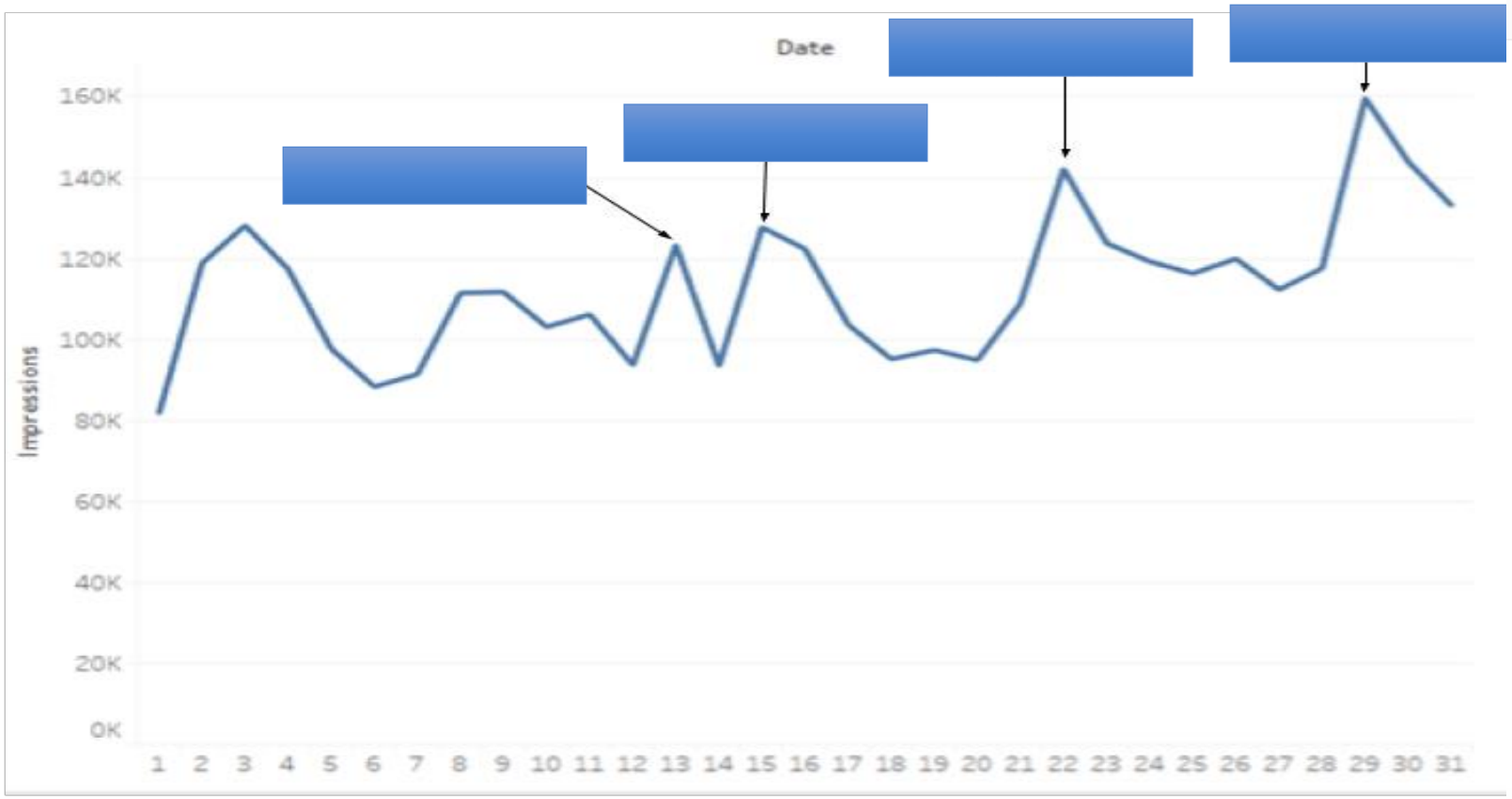
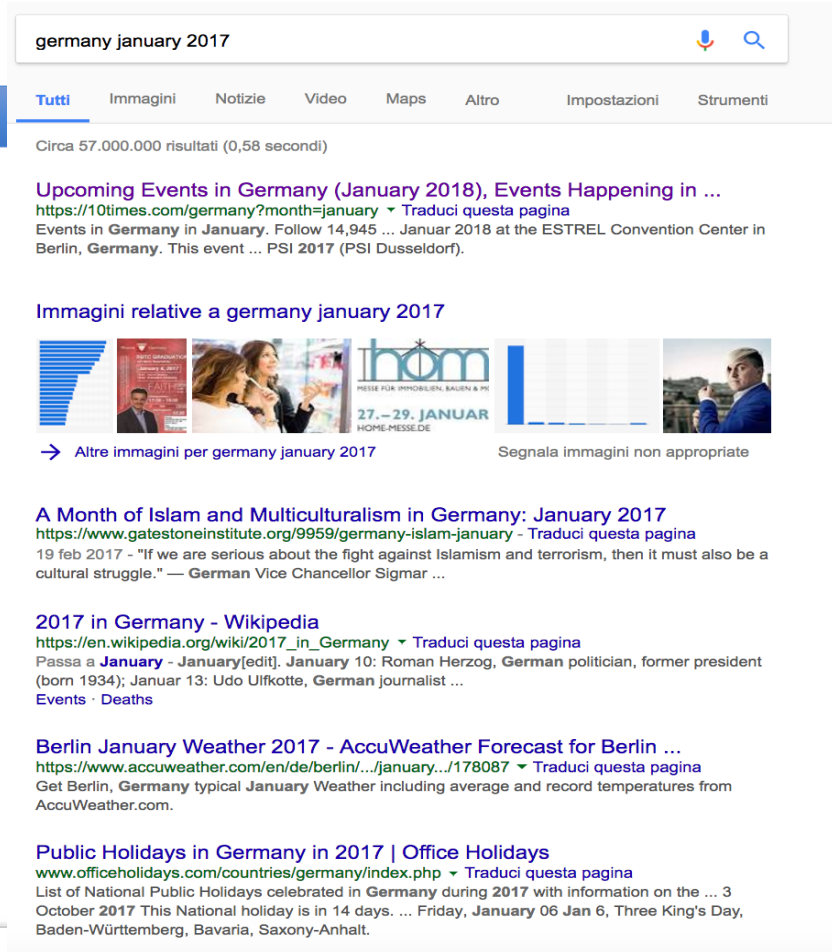


Figure 12: Correlation between [redacted] and online digital indicators in the "SportFitness" category.

Making sense of digital marketing analytics … with external events





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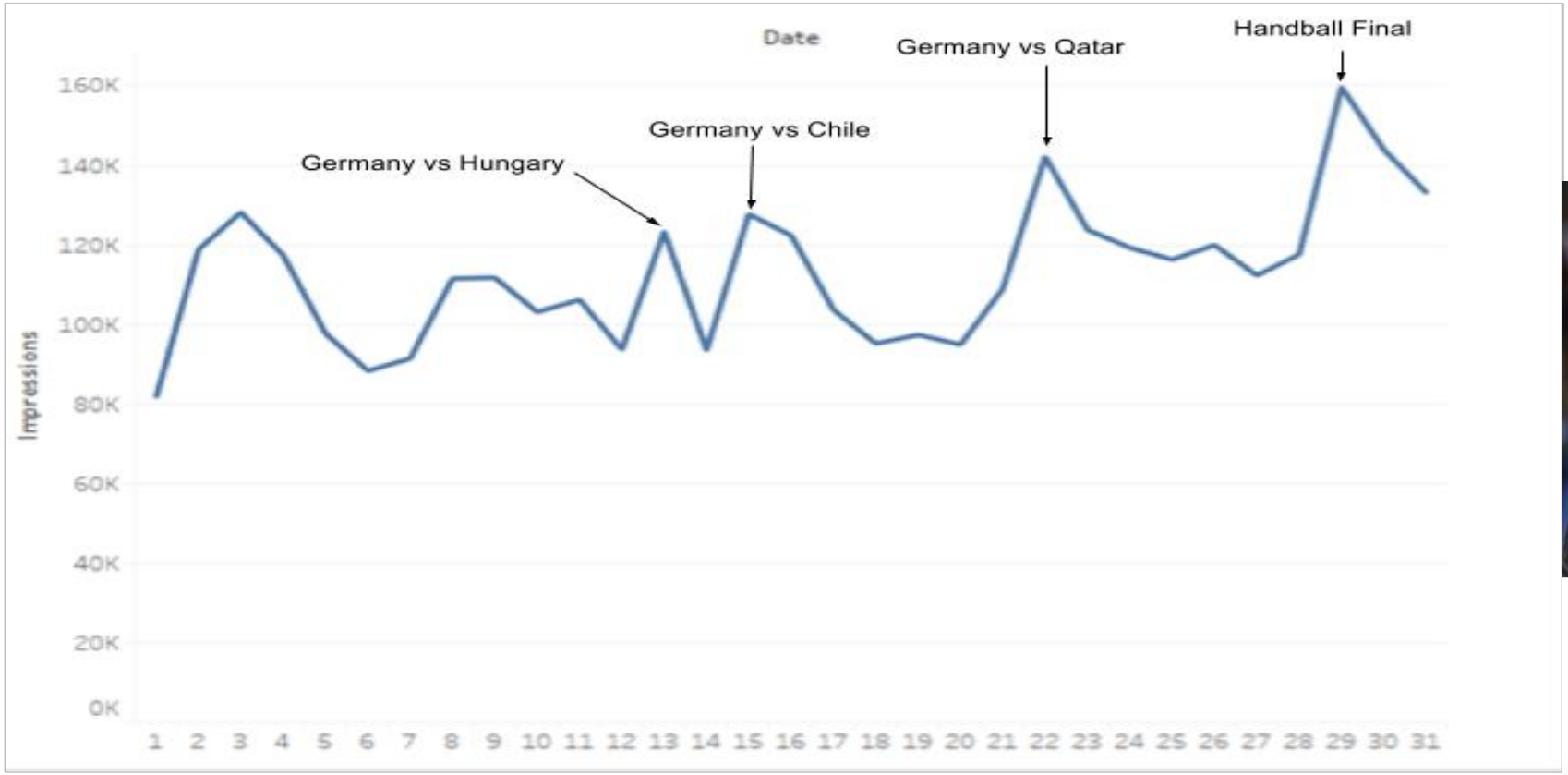


WORLD MEN'S HANDBALL CHAMPIONSHIP MUST SEE MATCHES

By BeIN SPORTS January 11, 2017 11:38 AM

As the 2017 World Handball Championship in France draws near, Sports fans in general and handball fans in particular are looking forward to intense first round showdowns that rival knockout stages.

Figure 12: Correlation between German national handball team matches and online digital indicators in the "SportFitness" category.

Credits & Links

- Much inspiration from the great tutorial on “Imagination Science: Beyond Data Science” by Sridhar Mahadevan (University of Massachusset, Director of Data Science Lab at Adobe Research) at AAAI 2019
  - https://people.cs.umass.edu/~mahadeva/AAAI_2019_Tutorial/Welcome.html
- EW-Shopp: check out the solutions, toolkit and data blog sections
  - www.ew-shopp.eu
- Work on temporal representation learning @INSID&S Lab:
  - Di Carlo, V., Bianchi, F. & Palmonari, M. (2019). Training Temporal Word Embeddings with a Compass. In AAAI
  - Bianchi, F., Palmonari, M., & Nozza, D. (2018, October). Towards Encoding Time in Text-Based Entity Embeddings. In ISWC.

This work has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreements n. 732003 and n. 732590

Program (subject to some changes)

- AI basics: a bit of history. Introduction to reasoning and declarative problem solving
- AI basics: introduction to Datalog
- Applications/advanced research: Introduction to Knowledge Graphs & RDF recap
- Agents & Interaction: Multi-agent Systems 1 & 2
- Learning Agents: Machine Learning, Deep Learning, Reinforcement Learning
- Reasoning Agents: Vocabularies Ontologies & RDFS
- Reasoning Agents: OWL-DLs & Rules
- Exercises: Domain models in OWL-DL
- Applications/advanced research: Concept Invention in DL
- Interpreting Agents: Aligning Agents' Knowledge & Information Extraction
- Interpreting Agents: Entity Linking and Information Extraction
- Applications/advanced research: Recommender Systems & Similarity
- Learning & Reasoning Agents (Representation Learning): Distributional Semantics & Similarity-based Reasoning
- Learning & Reasoning Agents (Representation Learning): Alignment of Distributional Models with CADE
- Learning & Reasoning Agents (Representation Learning): Knowledge Graph Embeddings & Similarity-based Reasoning
- Learning & Reasoning Agents (Representation Learning): Ontology Embeddings and Interpretations in Vector-based Models
- Exercises: Word Embeddings & CADE
- Exercises: Knowledge Graph Embeddings
- Reasoning & Learning Agents: Neuo-symbolic Reasoning with LTN
- Exercises: Ne3uro-Symbolic LTN + TEE

TEACHING MATERIAL

TEXTBOOK

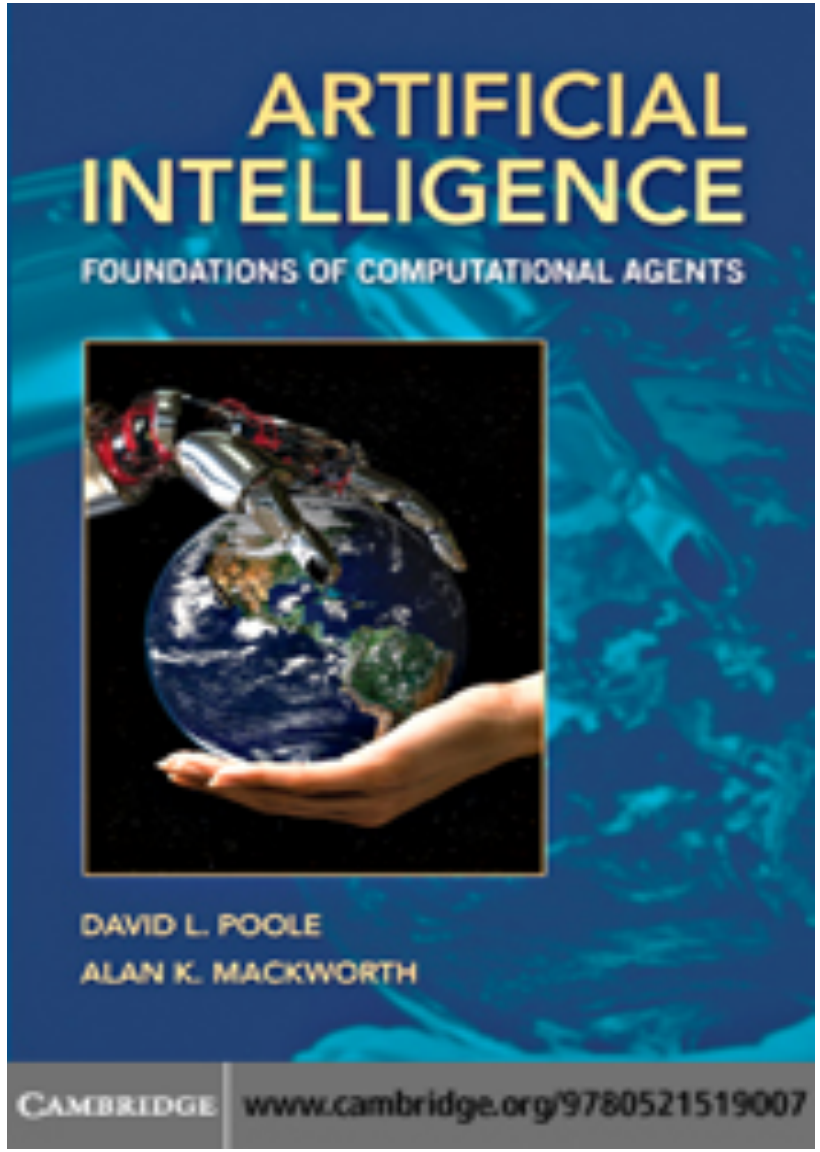
David L. Poole, Alan K. Mackworth:
Artificial Intelligence. Foundations of Computational Agents
Cambridge University Press, 2010

See: https://artint.info/2e/slides/index.html

ADDITIONAL MATERIAL

Selected scientific articles for newer topics (each topic will be associated with articles)

Slides



FOCUS OF THIS COURSE

- Key concepts:
  - Interaction (agents and agents / environment)
  - Logic-inspired Reasoning & Neural Learning (incl. the integration of reasoning & learning)
  - Interpretation (from input data / models to target models)
- Information sources:
  - Structured (knowledge bases defined as knowledge graphs)
  - Unstructured (texts … similar concepts valid for images, videos, audio, but see other courses for techniques dedicated to these streams)
- Objectives:
  - Learn specific techniques relevant today and not covered in other courses
  - Understand key concepts needed to frame other techniques into the AI big picture and learn more techniques autonomously

TEXTBOOK & COURSE

- Chapter 1: Artificial Intelligence and Agents
  - Lecture 1: introduction to artificial intelligence and the role of agents.
  - Lecture 2: dimensions of complexity.
  - Lecture 3: applications domains.
  - Lecture 4: introduction to knowledge representation.
- Chapter 2: Agent Architectures and Hierarchical Control
  - Lecture 1: agent architecture and control
  - Lecture 2: hierarchical control.

Introduction
+
book

TEXTBOOK & COURSE

- Chapter 3: Searching for Solutions
  - Lecture 1: searching and graphs.
  - Lecture 2 uninformed search strategies.
  - Lecture 3 heuristic search, including best-first search and A* search.
  - Lecture 4 refinements to search strategies, including loop checking, multiple-path pruning, bidirectional search, and dynamic programming.
  - Lecture 5 bounded search, iterative deepening, branch and bound.
- Chapter 4: Reasoning with Constraints
  - Lecture 1 constraint satisfaction problems and consistency algorithms (arc consistency).
  - Lecture 2 local search, randomized algorithms and genetic algorithms for solving CSPs.
  - Lecture 3 CSPs revisited, including dual representations and variable elimination.

NO:
Something in
Operational Research
and algorithms courses

TEXTBOOK & COURSE

- Chapters 5: Propositions and Inference
  - Lecture 1 propositional reasoning and definite clauses.
  - Lecture 2 bottom-up proof procedure.
  - Lecture 3 top-down proof procedure.
  - Lecture 4 ask-the-user and knowledge-level explanation and debugging.
  - Lecture 5 proof by contradiction, conflicts, and consistency-base diagnosis.
  - Lecture 6 complete knowledge assumption and negation as failure.
  - Lecture 7 assumption-based reasoning.
  - Lecture 8 default reasoning.
  - Lecture 9 evidential and causal reasoning.
- Chapter 6: Planning with Certainty
  - Lecture 1 action semantics and representations.
  - Lecture 2 forward planning.
  - Lecture 3 regression planning.
  - Lecture 4 constraint-based planning.

Something in the intro, not in detail (but reading is highly recommended)

NO: We don't address planning

TEXTBOOK & COURSE

- Chapter 7: Supervised Machine Learning
  - Lecture 1 introduction to machine learning and the issues facing any learning algorithm.
  - Lecture 2 simplest cases of learning
  - Lecture 3 basic models of supervised learning (decision trees, linear classifiers, Bayesian classifiers)
  - Lecture 4 handling overfitting (regularization and cross validation).
  - Lecture 5 composite models, neural networks and ensembles.
  - Lecture 6 case-based reasoning.

NO:
Assume you know it
(not even too
necessary)

TEXTBOOK & COURSE

- Chapter 8: Reasoning with Uncertainty
  - Lecture 1 probability.
  - Lecture 2 conditional independence and belief networks.
  - Lecture 3 properties of conditional independence, representing conditional probabilities.
  - Lecture 4 exact inference using variable elimination.
  - Lecture 5 probabilistic reasoning and time; Markov models.
  - Lecture 6 approximate inference using stochastic simulation.
- Chapter 9: Planning with Uncertainty
  - Lecture 1 utility theory.
  - Lecture 2 decision theory and finite stage decision networks
  - Lecture 3 decision processes.
- Chapter 10: Learning with Uncertainty
  - Lecture 1: learning probabilities.
  - Lecture 2: unsupervised learning.
  - Lecture 3: learning belief networks.
  - Lecture 4: Bayesian learning.

NO:
Very relevant but
other courses cover
most of this
(probabilistic models etc.)

We will cover uncertainty with
Logic Tensor Network
(more based on fuzzy than on
probabilities)

TEXTBOOK & COURSE

- Chapter 11: Multiagent Systems
  - Lecture 1 introduction to game theory.
- Chapter 12: Learning to Act
  - Lecture 1 reinforcement learning.
- Chapter 13: Individuals and Relations
  - Lecture 1 Datalog: syntax and semantics
  - Lecture 2 semantics of variables
  - Lecture 3 proof procedures with variables
  - Lecture 4 complete knowledge assumption and negation-as-failure
  - Lecture 5 logic for natural language processing
- Chapter 14: Ontologies and Knowledge-Based Systems
  - Lecture 1 flexible representations, semantic networks, frames, and property inheritance.
  - Lecture 2 knowledge sharing and ontologies.
  - Lecture 3 knowledge-based systems architectures and ask-the-user.
  - Lecture 4 knowledge-based explanation and debugging.
  - Lecture 5 meta-interpreters.
  - Lecture 6 more-advanced meta-interpreters.

YES
In the first part
of the course

YES
Introduction to Datalog….
…. much in details
knowledge-based
systems

TEXTBOOK & COURSE

- Chapter 15: Relational Planning, Learning, and Probabilistic Reasoning
  - Lecture 1 relational representations of actions and situation calculus.
  - Lecture 2 relational learning.
  - Lecture 3 probabilistic relational models.

NO:
Mentioned in Knowledge Graph embeddings, but it should covered in other courses (probabilistic models etc.)

EVALUATION

- Aggregation of the scores obtained in two independent assessments.
- First assessment:
  - exam-tailored project or a survey (individuals or groups)
  - oral presentation supported by slides lasting about 20 minutes (with short demo of the project if any)
  - **project**: in-depth knowledge and/or hands-on experience of a specific topic covered in the course or linked to topics covered in the course;
  - **survey**: bibliographic review on a topic, in which the student discusses and compares proposed solutions in the state of the art to a specific problem of interest for him.
  - Evaluated by: significance, methodological soundness, mastery of the in-depth topic.
- Second assessment (to choose between):
  - Two **tests** consisting of exercises and open questions
  - **oral exam** taken in conjunction with the discussion of the first evaluation;