Selected results of MILAB – Artificial Intelligence National Laboratory Hungary

Vera Könyves
Institute for Computer Science and Control

SZTAKI

ARTIFICIAL INTELLIGENCE National Laboratory

HUNGARIAN NATIONAL LABORATORY

Supported by the European Union project RRF-2.3.1-21-2022-00004 within the framework of the Artificial Intelligence National Laboratory Program

NEMZETI KUTATÁSI, FEJLESZTÉSI ÉS INNOVÁCIÓS HIVATAL

INNOVÁCIÓS ÉS TECHNOLÓGIAI MINISZTÉRIUM

MILAB – AI National Laboratory Hungary (2020–2025)

Consortium Leader:

Institute for Computer Science and Control
(Scientific director of MILAB: András Benczúr)

Partners:

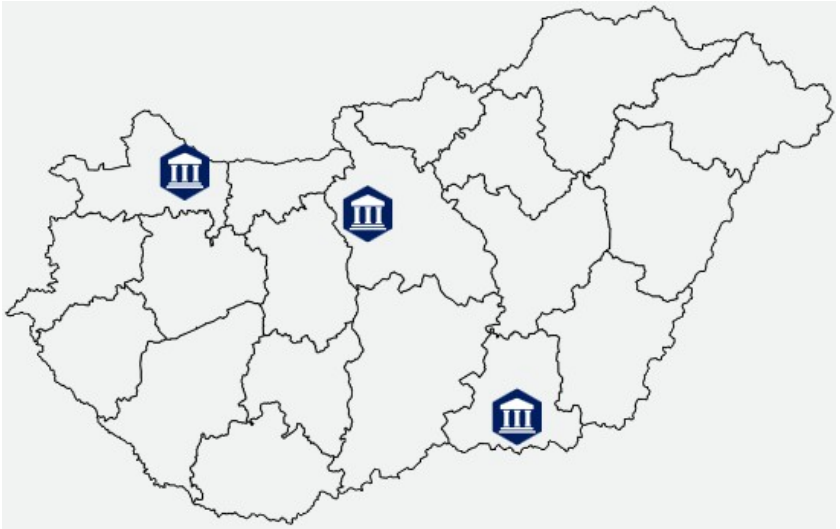
- Alfréd Rényi Institute of Mathematics
- Budapest University of Technology and Economics
- Eötvös Loránd University
- University of Szeged
- Semmelweis University
- Institute of Experimental Medicine
- Centre for Social Sciences
- Széchenyi István University
- Special Service for National Security
- KINCSINFO Nonprofit Ltd.

External partners in Hungary:

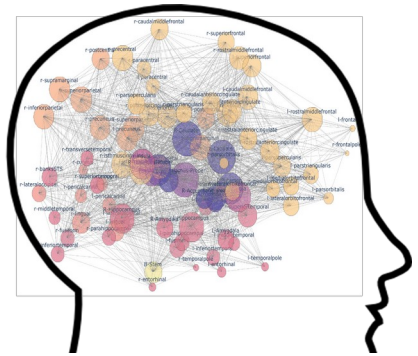
Audi, Bosch, Continental, Ericsson, Nokia,...

Places of Implementation:

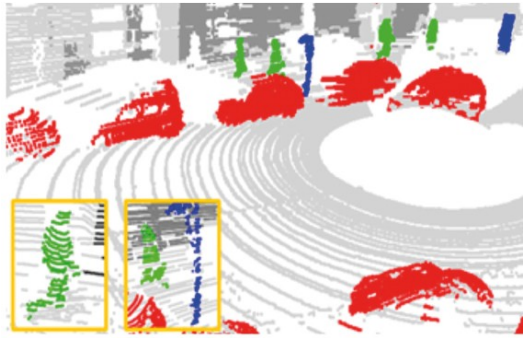
Budapest, Győr, Szeged



MILAB – Research Fields

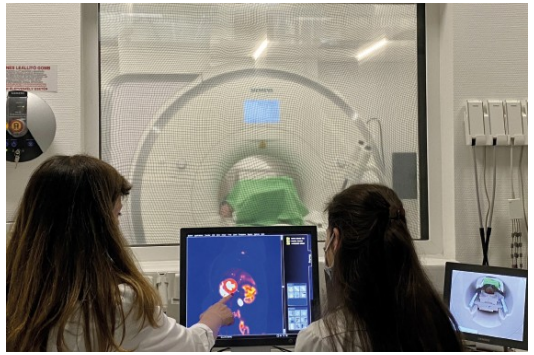


WP1: **Foundations of AI**
(B. Szegedy, Rényi)

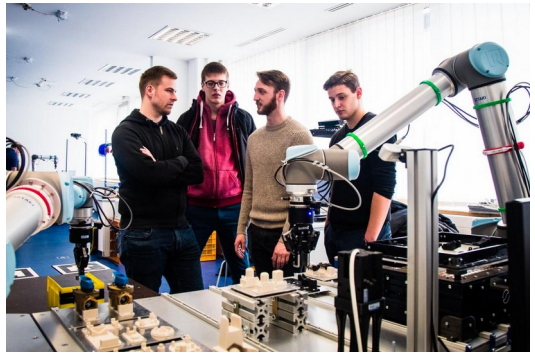


WP2: **Machine perception**
(I. Csabai, ELTE)

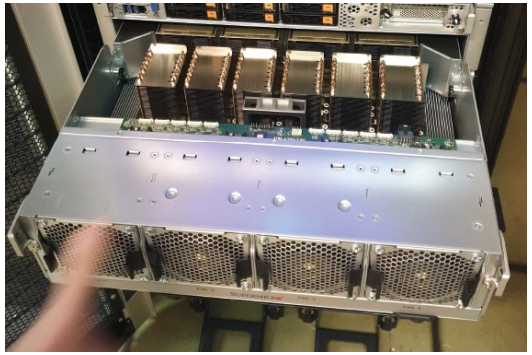
WP3: **Human Language Proc.**
(R. Farkas, SZTE)



WP4: **Medical, Health & Bio.**
(D. Becker, SE)

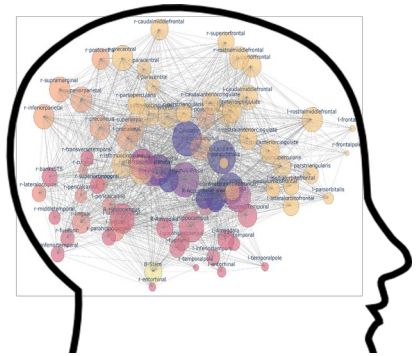


WP5: **Sensors, IoT, Telecomm.**
(J. Levendovszky, BME)

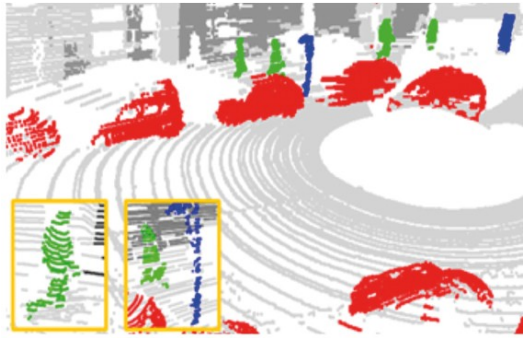


WP6: **Security & Privacy**
(R. Ferenc, SZTE)

MILAB – Research Fields & Computing facilities

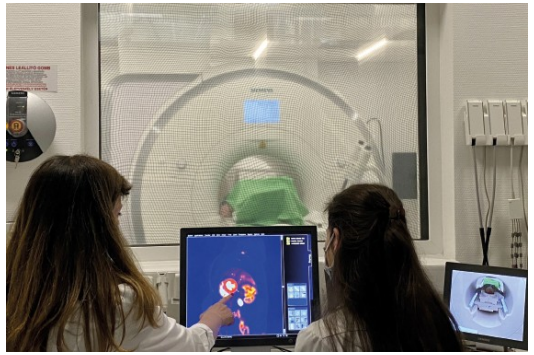


WP1: **Foundations of AI**
(B. Szegedy, Rényi)
A100s in SZTAKI & Rényi

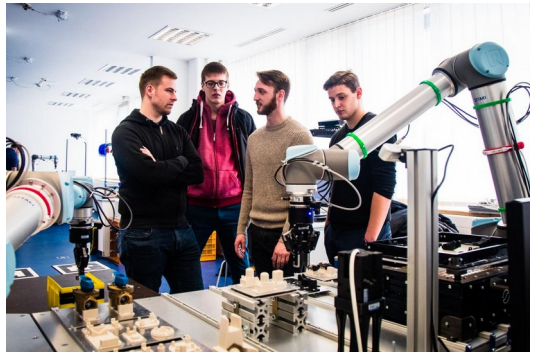


WP2: **Machine perception**
(I. Csabai, ELTE)
ELKH Cloud, WSCLAB

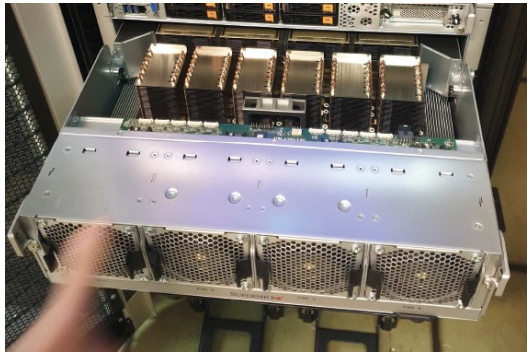
WP3: **Human Language Proc.**
(R. Farkas, SZTE)
ELKH Cloud, OTP SambaNova, ...



WP4: **Medical, Health & Bio.**
(D. Becker, SE)
ELKH Cloud, WSCLAB, other A100s



WP5: **Sensors, IoT, Telecomm.**
(J. Levendovszky, BME)
Local smaller GPUs



WP6: **Security & Privacy**
(R. Ferenc, SZTE)

MILAB – Research+Development+Industry Relations

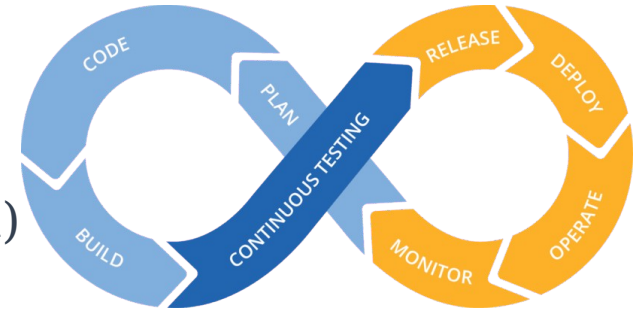
	Data, Solutions	Technology	Explanation Supervision Operational guarantees	Applications	
Language Apps.	Digital Heritage NL Corpus, LLM OTP SambaNova	**WP3** NLP HuSpaCy Rule + LLM	**WP1** Theory Double descent Generalization Info. geometry	**WP3** NLP Upstream tasks Social Sci., Nat. Security	Digital Heritage-, Infocomm. NL
Other Applications	Health Security-, Cardiovascular-, Tumor Biology NL	**WP2** Machine perception	**WP6** Security & vulnerability SW Security	**WP4** Medical imaging sys.	Health Security-, Cardiovascular-, Tumor Biology NL
	Autonomous Sys. NL			**WP5** Production Telecomm. Robotics	Autonomous Sys. NL Industry

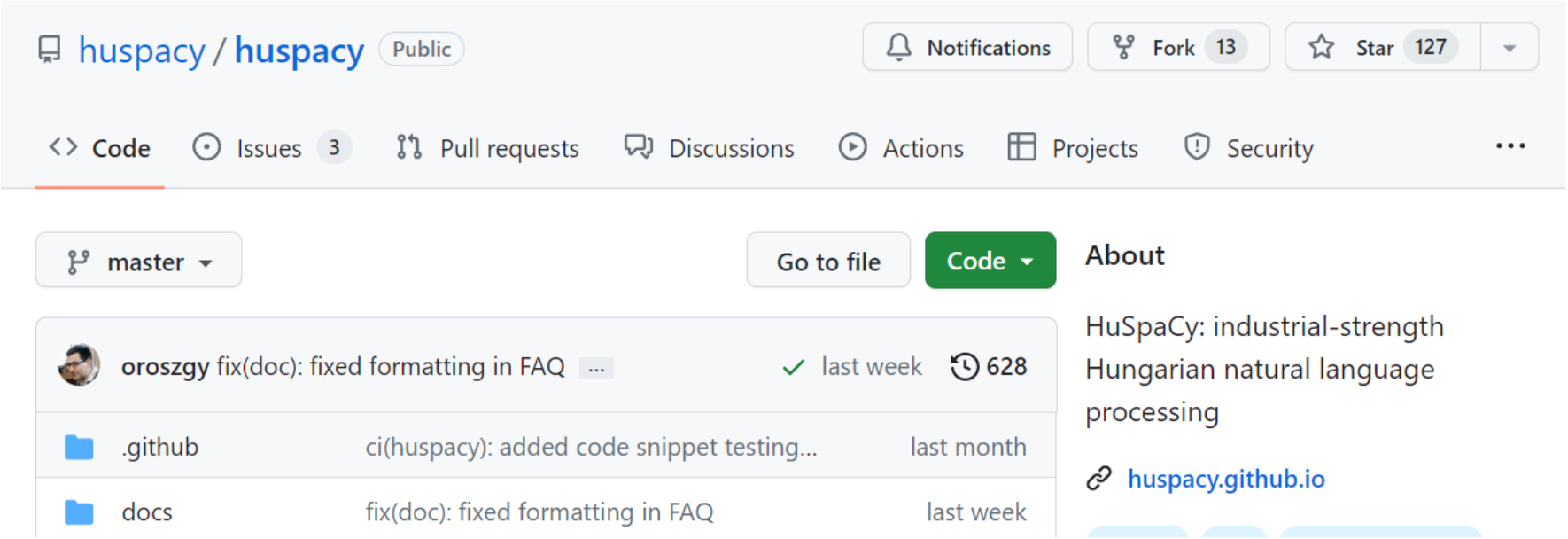
MESTERSÉGES INTELLIGENCIA
Nemzeti Laboratórium

Natural Language Processing

MILAB – NLP: HuSpaCy

- A spaCy library providing industrial-strength Hungarian language processing facilities through spaCy models (Orosz et al., 2022)
- Tackles important **text pre-processing tasks**:
  tokenization, sentence splitting, PoS tagging, lemmatization,...
- **4 benchmarked pipelines** (LLM-based, e.g., huBERT, XLM-Roberta)
- **Publicly available** (GitHub, huggingface)

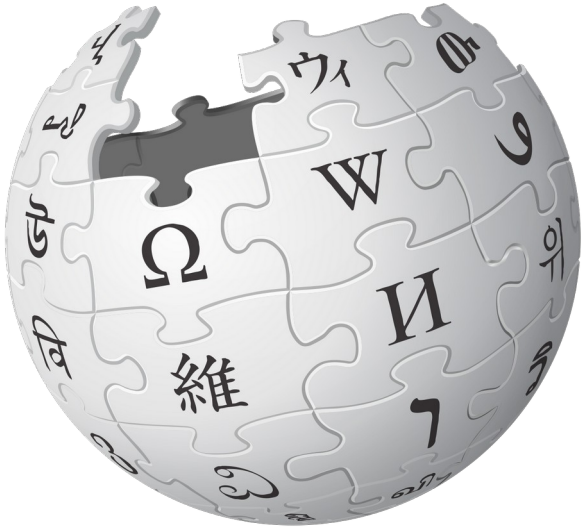




MILAB – NLP: Question Answering from Hun. Wikipedia

MILQA database (Novák, Novák, 2023, public soon)

- Extractive & abstractive QA
- **Good quality Wikipedia articles** as context for Qs
- ~10K Q-A of different types in the database
- Includes Qs: Y/N; arithmetics; not answered in text
- Short/long answer



Can be built in a chatbot, **but**:

- „always” factual
- no hallucinations
- underlying knowledge is quickly updated
- shows source of text

MILAB – NLP Problems: Factual Error

Input article	Model output (Bert2bert)
A férfi 2020 áprilisában felkereste barátnőjét, hogy rendezzék a párkapcsolati vitáikat, és hazavigye a lányt, aki ekkor a rokonainak miskolci lakásában lakott. A pár a ház előtt beszélgetett, amikor a házigazda kiment hozzájuk és számonkérte a férfit, hogy minek ment oda, majd a jobb kezében lévő villáskulccsal, illetve a bal kezében lévő asztallábbal támadóan közelített felé, és a villáskulccsal mellkason ütötte. A bántalmazott férfinak eltört a bordája, a sérülés miatt légmelle lett, amely közvetetten életveszélyes állapotot idézett elő. A férfi beismerte a bűncselekmény elkövetését. A törvényszék a férfival szemben életveszélyes testi sértés miatt másfél [illegible], 4 évre felfüggesztett börtönt szabott ki, és ennek tartama alatt pártfogó felügyeletét rendelte el. A büntetővégzés joge	A Miskolci Járási Ügyészség életveszélyes testi sértés miatt emelt vádat azzal a férfival szemben, aki 2020 - ban megverte a barátnőjét Miskolcon, mert az elhagyta őt.

abused man

He beat his girlfriend

Barta, Lakatos et al. (2023)

MILAB – NLP Problems: Hallucination

Input article	Model output (mT5-small)
Sajtótájékoztatóján Stoltenberg arról beszélt, hogy a NATO -nak számos kihívással meg kell küzdenie a mai megváltozott, kihívásokkal teli biztonsági környezetben, de továbbra is nagy szükség van a katonai szövetségre. Bennfentesek szerint a NATO szerdán kezdődő kétnapos ülése főként James Mattis új amerikai védelmi miniszter bemutatkozása miatt fontos, aki várhatóan ismertetni fogja a nemrég hivatalba lépett, Donald Trump vezette kormányzat elképzeléseit. …	Jens Stoltenberg, az Európai Unió (EU) főtitkára a NATO csütörtöki kétnapos ülésén elmondta, hogy Donald Trump amerikai elnök által vezetett kormányzati elképzelései mellett továbbra is fontos a szövetségre vonatkozó erőfeszítések - jelentette be Jenson Button NATO-főtitkár az MTI-nek adott interjújában, amelyben a tagállamok vezetői úgy vélik, a jövő héten kezdődő NATO-találkozón az amerikai katonai

Jenson Button is the Secretary General of NATO

Barta, Lakatos et al. (2023)

MILAB – NLP: Mapping between Languages

Multilingual pretrained language models (**PLM**s)

- Convenient solution to zero-shot cross lingual problems
- Suffer from multilinguality (Conneau et al., 2020)
- Unstable performance across supported langs. (Wu & Drezde, 2020)
- Improper tokenization is an issue (Rust et al., 2021)

Monolingual PLMs to the rescue

- Take pair of independently pretrained monoling. BERT models
- Dissect source and target language models into two halves
- Determine mapping between chosen layers of source/target

G. Berend (2022)

Contextual translation pairs from the Tatoeba corpus

Snails move slowly.

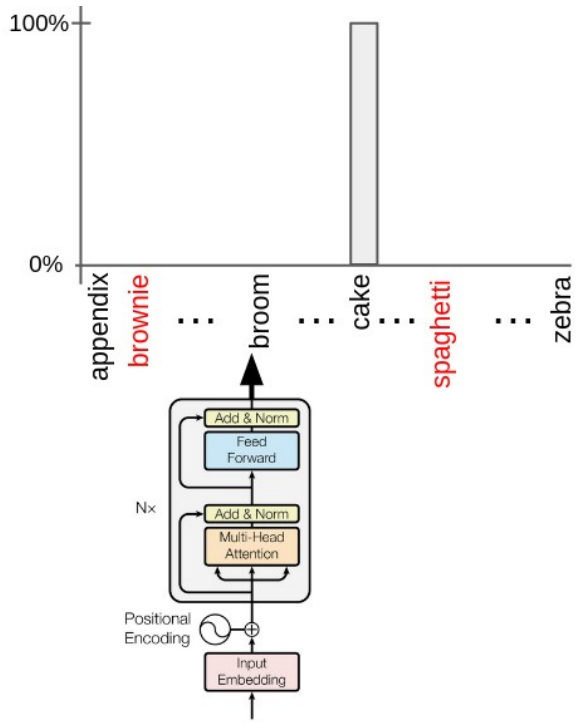
A csigák lassan mozognak.

MILAB – NLP: Pre-training of medium-sized models

Exploiting sparsity during pre-training

Pre-trained LMs excel at continuing/infilling partial/masked (token) sequences

- **Masked Language Modeling** is a typical training task for LMs
- Misalignment in pre-training objective and behavior of well pre-trained model



Alice is eating a cake.

G. Berend et al.

MILAB – NLP: Pre-training of medium-sized models

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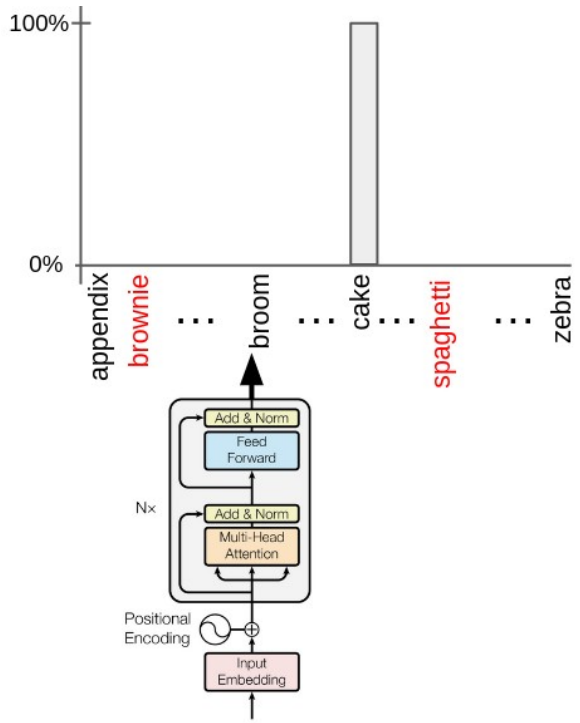
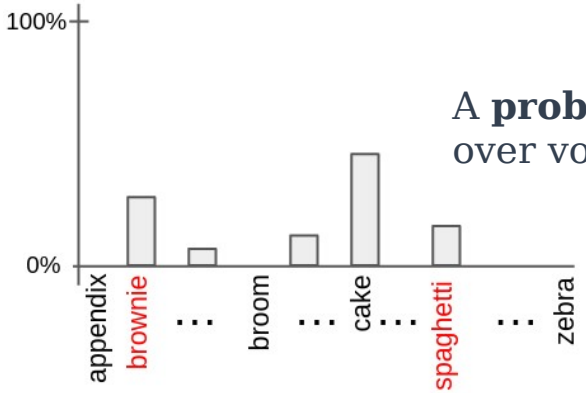


vs.



A **probability distribution** over vocabulay is preferred

Alice is eating a **[MASK]**.

Possible remedies to the problem:

- 'Real' word distributions
- Knowledge bases (e.g. WordNet)
- Unsupervised sparse contextual representations

G. Berend et al.

NLP, LLMs
Theory & Applications

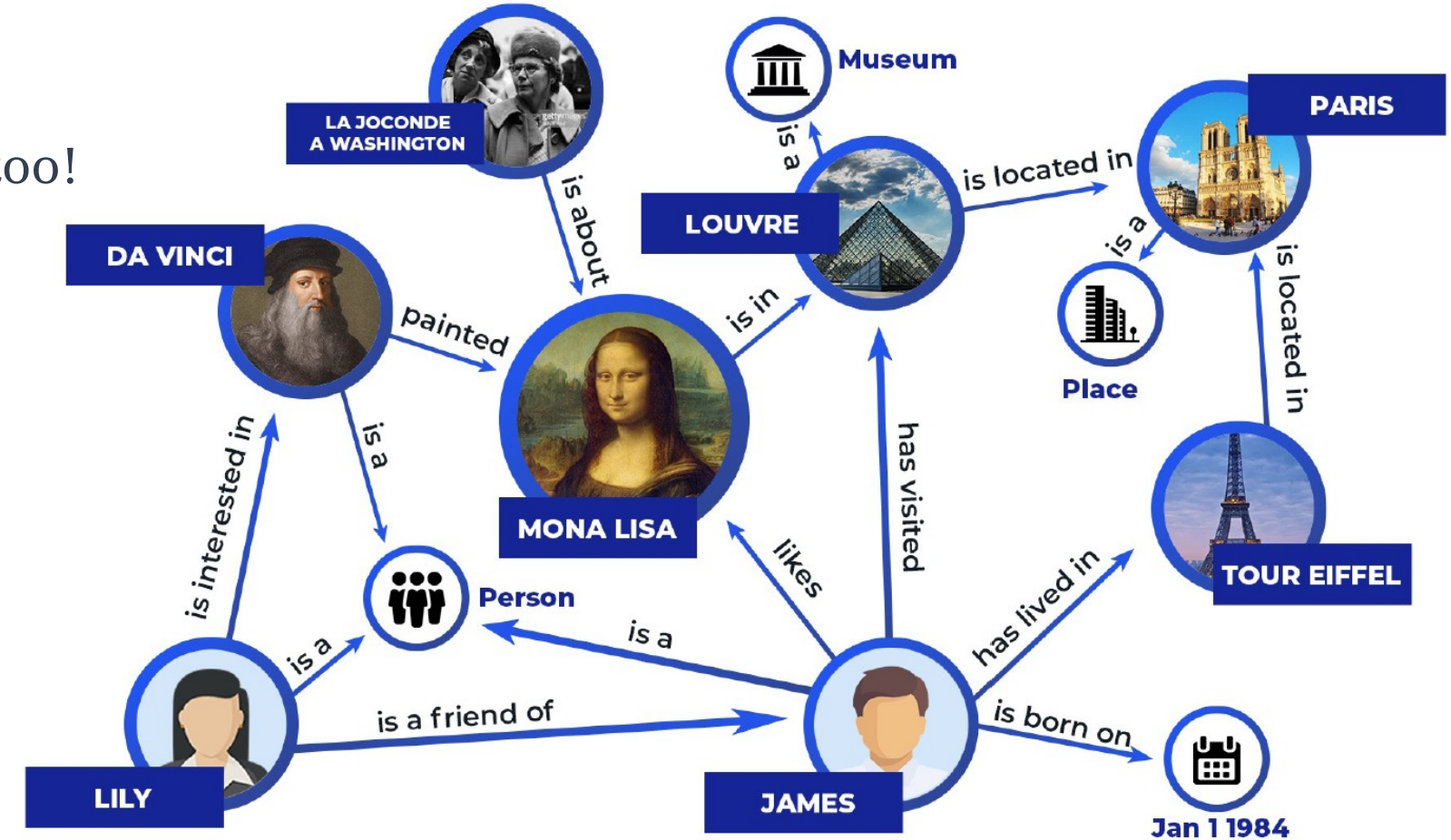
MILAB – NLP: Fundamental research

Cost−accuracy trade-off

- Smaller LLMs
- Reduce data hunger
- Text & speech technology too!

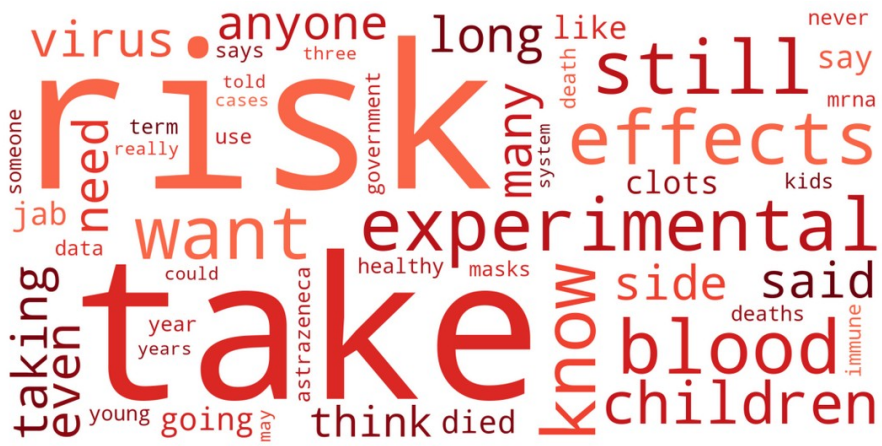
Using environmental info

- **Knowledge graphs**
- Dialogue history
- ”Microcosm” of the system



MILAB – Recognising vaccination-skeptic content

pro-vaxxer



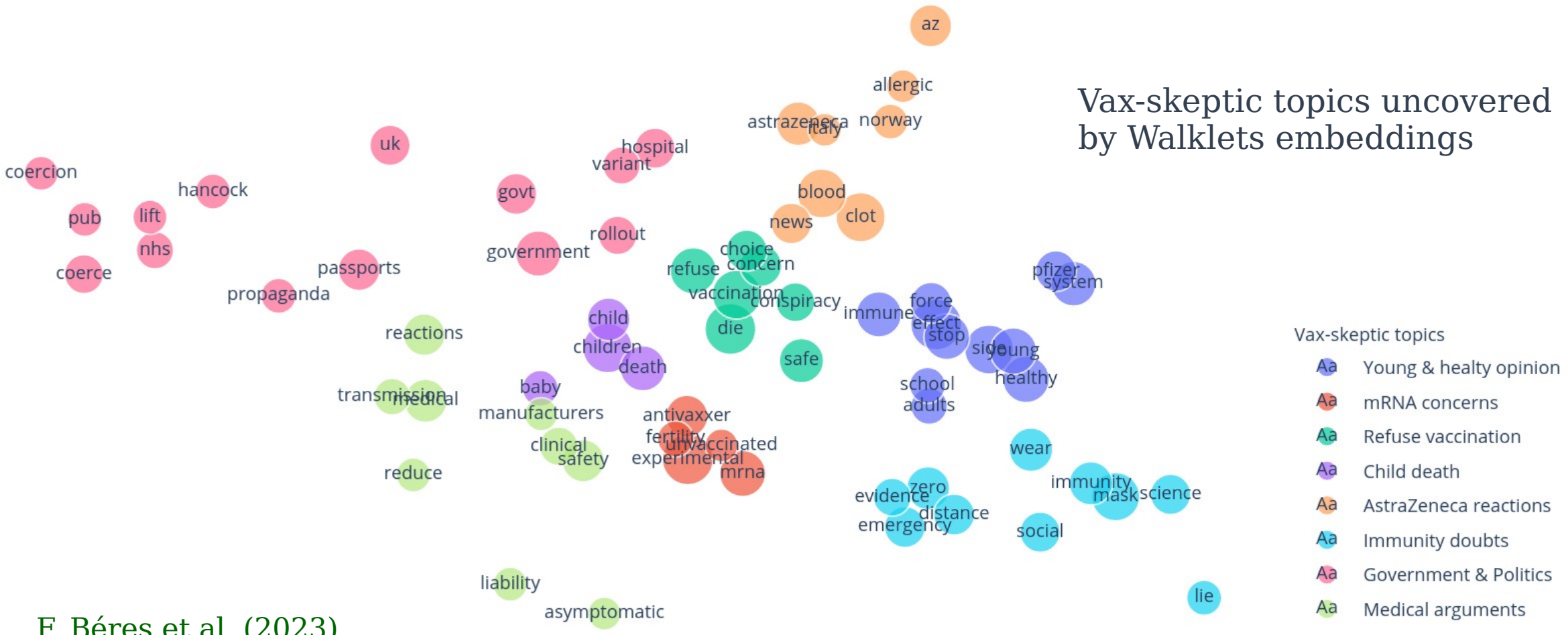
vax-skeptic

F. Béres et al. (2023)

Model	Vax-skeptic AUC	Time
Vaccinating-covid-tweets (Pak and Paroubek 2010)	**0.81**	12.98
Bert-small (Bhargava et al. 2021; Turc et al. 2019)	0.793	3.88
Covid-twitter-bert (Müller et al. 2020)	0.787	34.72
Bert-medium (Bhargava et al. 2021; Turc et al. 2019)	0.779	6.17
Bertweet-covid19-base (Nguyen et al. 2020)	0.766	12.89
Bertweet-base (Nguyen et al. 2020)	0.765	13.01
Bert-mini (Bhargava et al. 2021; Turc et al. 2019)	0.751	2.66
Bert-tiny (Bhargava et al. 2021; Turc et al. 2019)	0.709	1.84
Bert-base (Devlin et al. 2018)	0.709	13.53
Bertweet-large (Nguyen et al. 2020)	0.575	34.05
Bert-large (Devlin et al. 2018)	0.556	34.52

MILAB – Vaccine skepticism with network embedding

Vax-skeptic topics uncovered by Walklets embeddings



F. Béres et al. (2023)

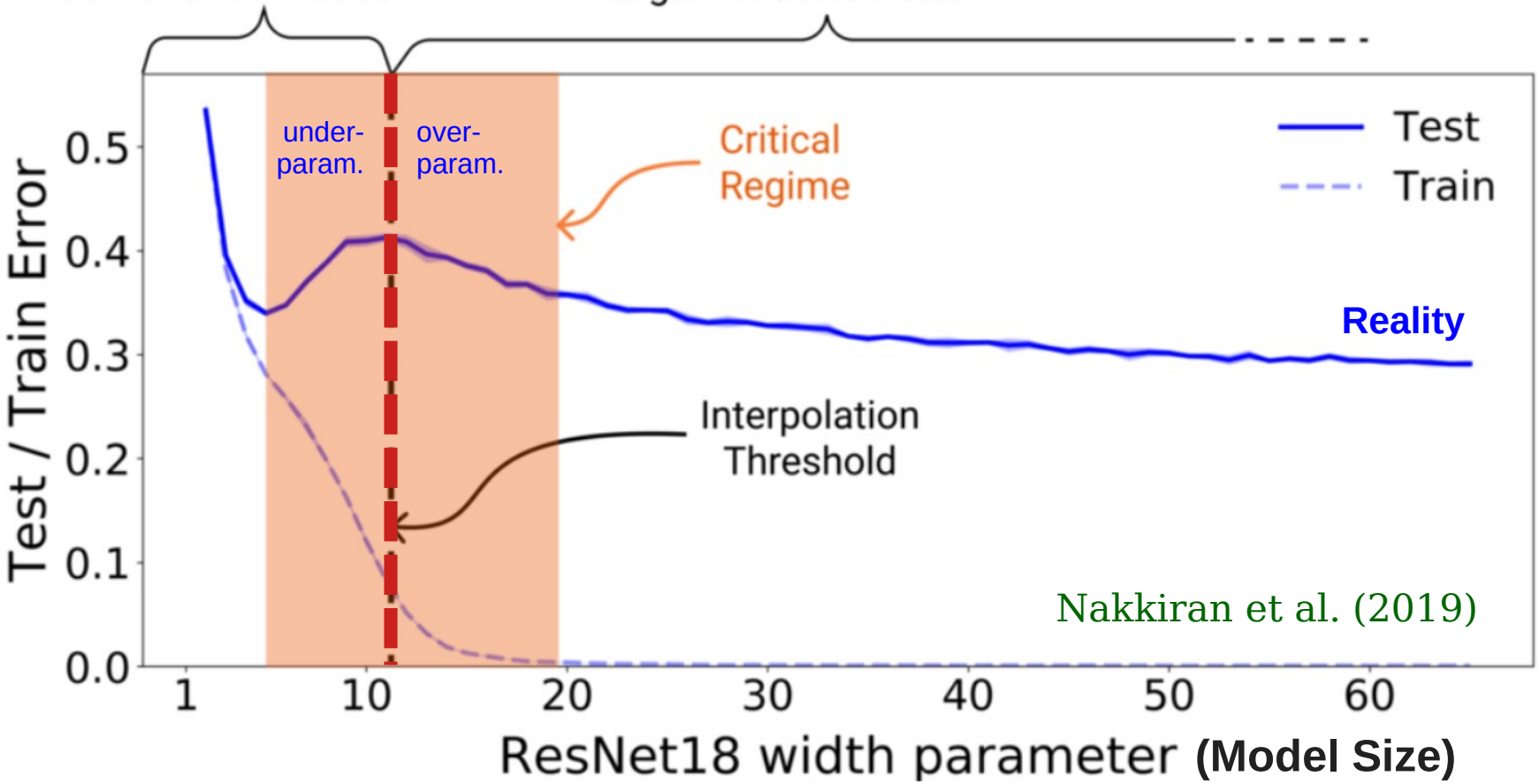
Rozemberczki, … Kiss, Béres et al., CIKM (2021), **Best Resource Paper**

MILAB – Theory: Double Descent of big models

(e.g., Hastie et al., 2005) (e.g., Szegedy et al., 2015)

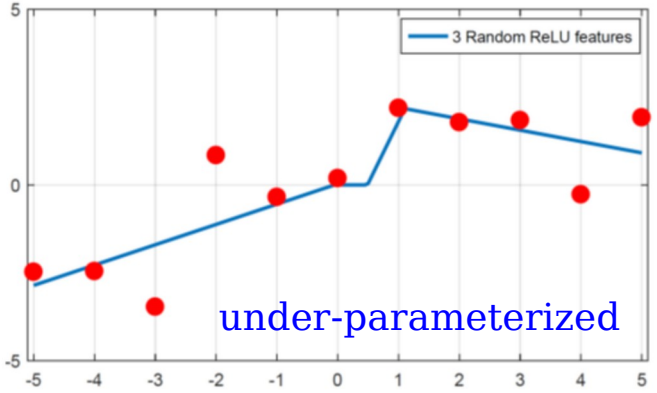
Classical Regime **Modern ML**

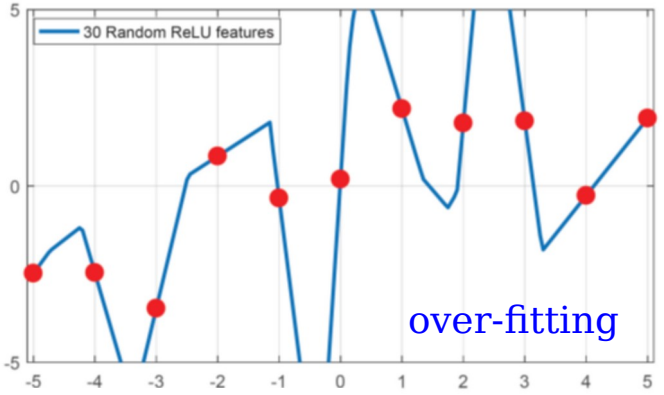
Bias-Variance Tradeoff Larger Model is Better

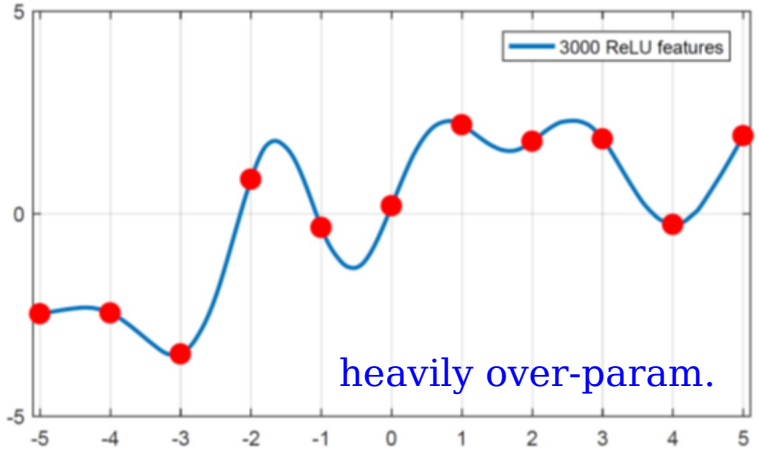


MILAB – Theory: Over-parameterized NNs

Illustration of double descent for random ReLU networks in 1D (Smoothness)

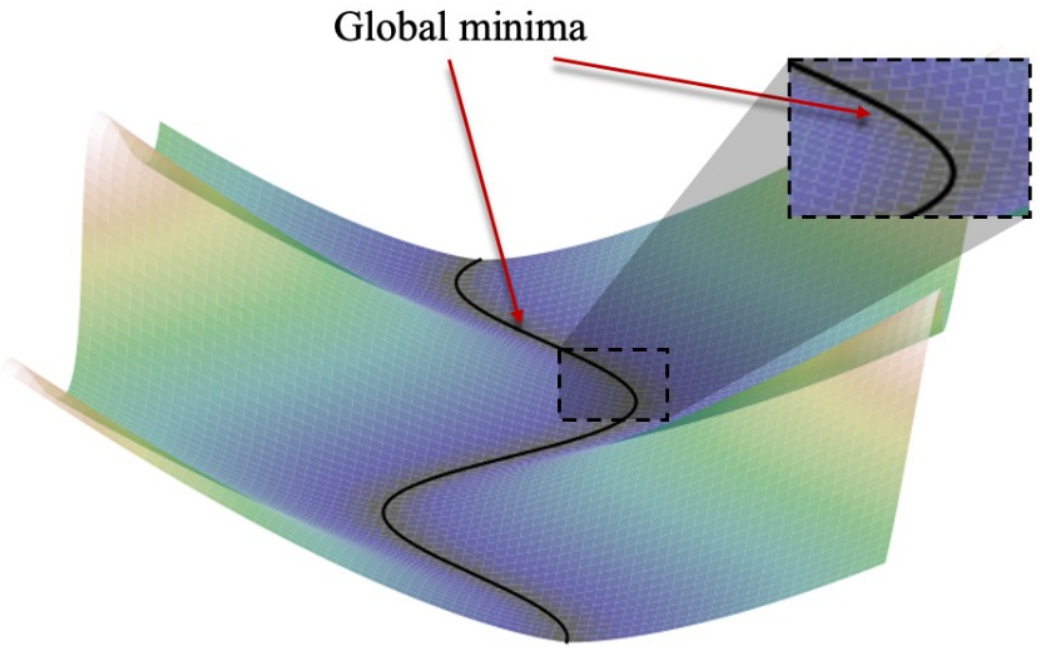






Belkin (2021)

Loss landscape of over-param. models (Non-convex optimization)



Liu, Zhu & Belkin (2021)

Security & Privacy

MILAB – NN Model Limitations

Pointer Value Retrieval (**PVR**) benchmark with sequence of images to **understand generalization and reasoning** capabilities of NNs

Works based on **indirection** - component of human-like reasoning

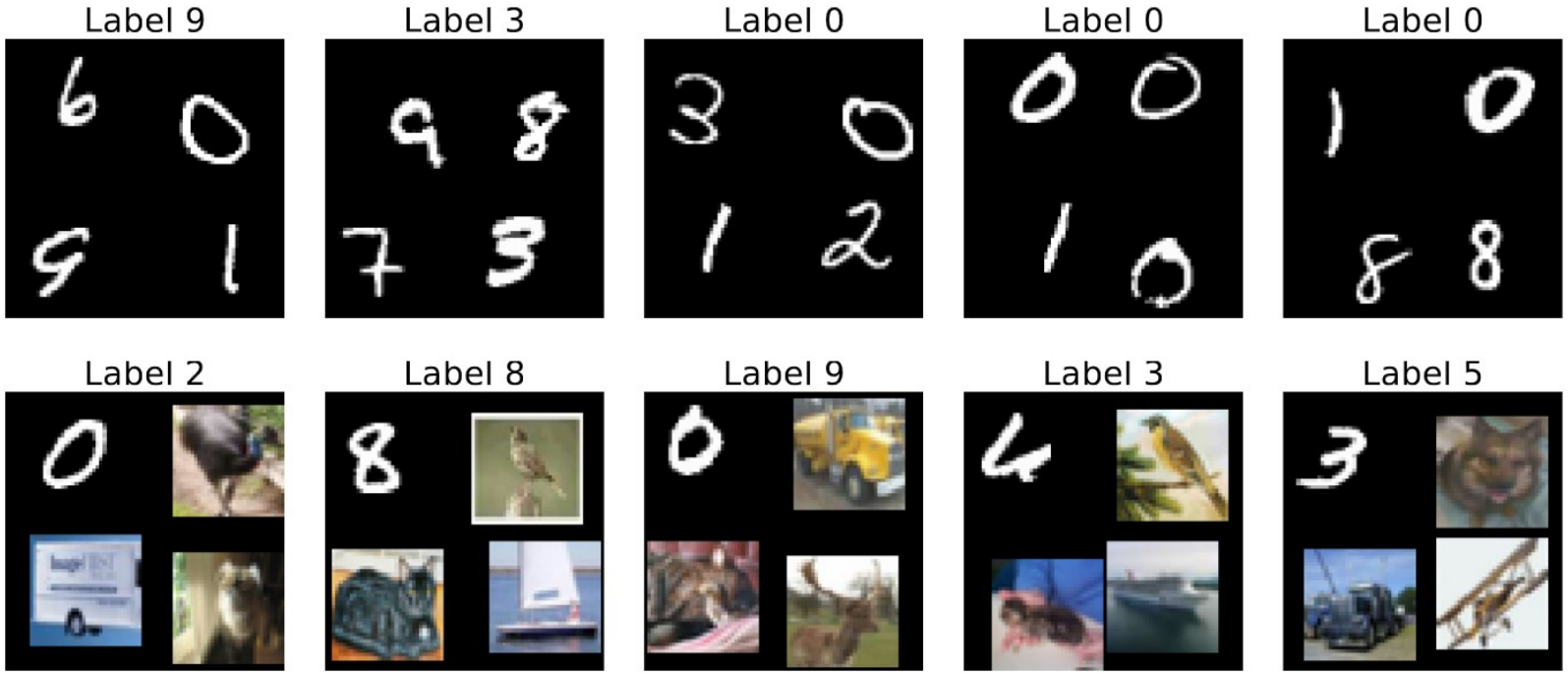
2 x 2 Block Style Image PVRs (MNIST, CIFAR-10)

Pointer (1st task) **- top left image** gives indication for next image to be examined (2nd task):

digits 0−3: upper right

4−6: lower left

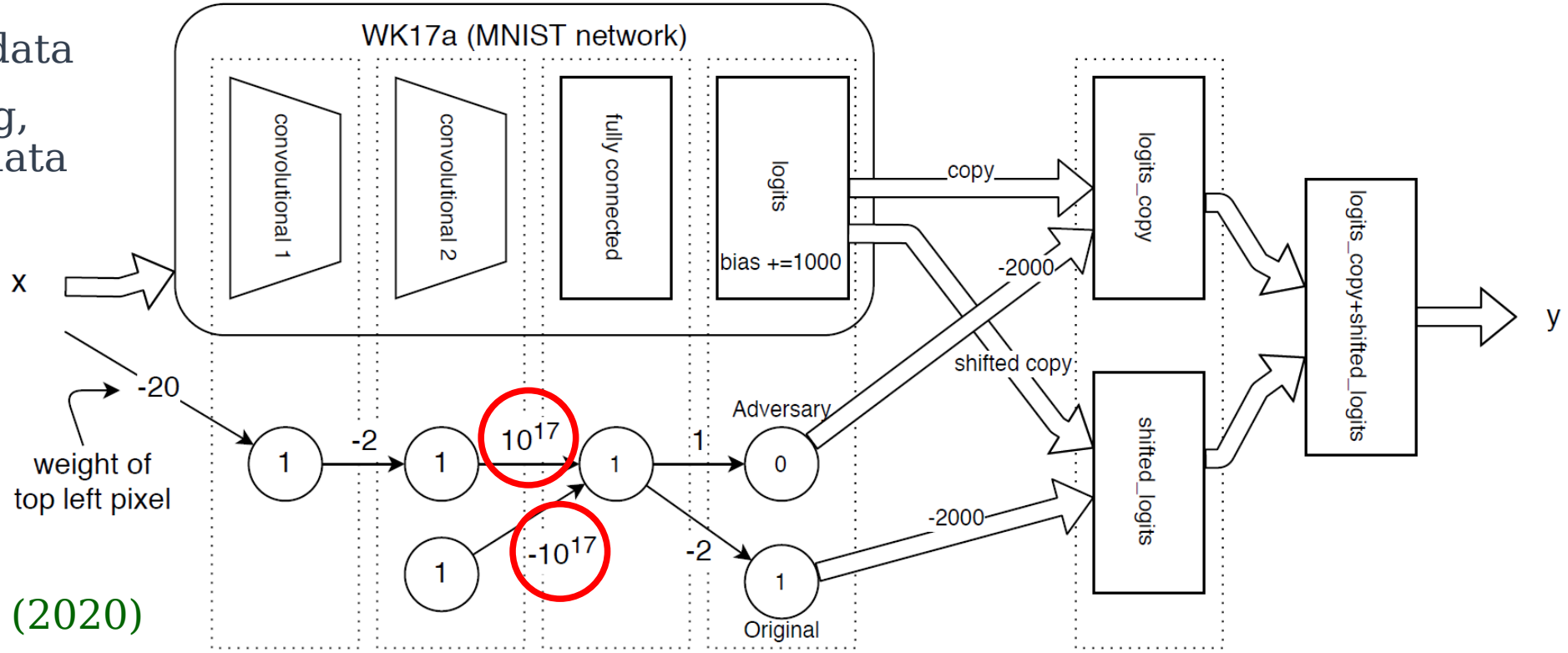
7−9: bottom right



C. Zhang, … S. Bengio (2021)

MILAB – Security Issues of AI Systems

- Difficult to verify
  - Not possible to count every case
  - Unexpected input – unexpected operation
- Backdoors cannot be detected
- „Poisoning" teaching data
- Exploiting overtraining, generation of hostile data



Zombori et al., ICLR (2020)

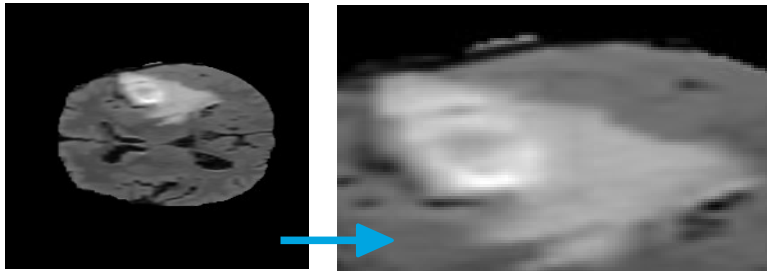
Machine Perception

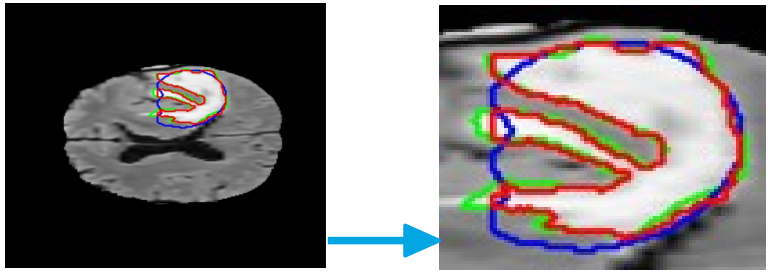
Medical, Health & Biology projects

The promise of LLMs…

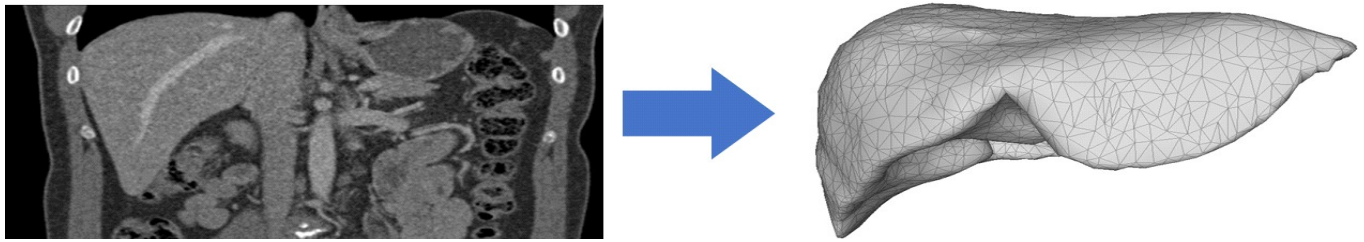
MILAB – Medical, Health & Biology

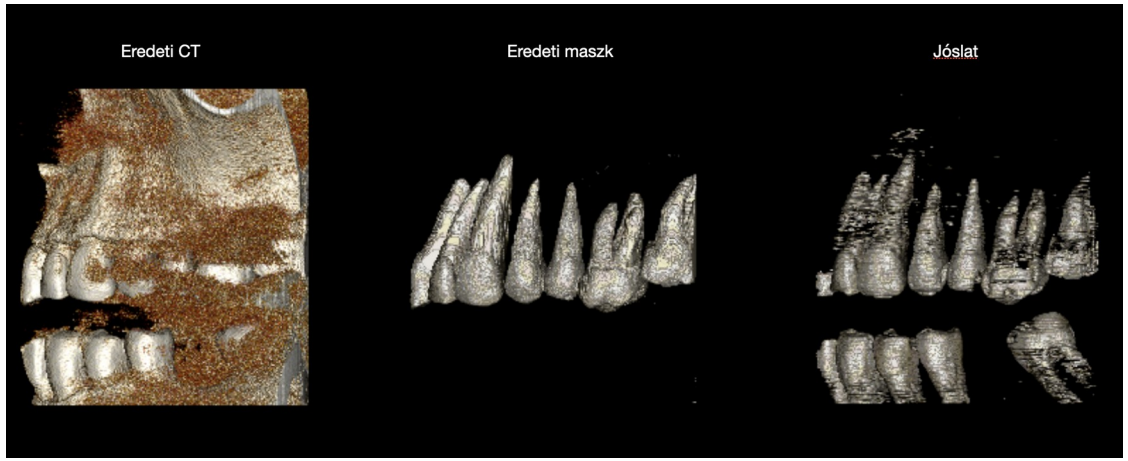
Tumour screening & segmentation

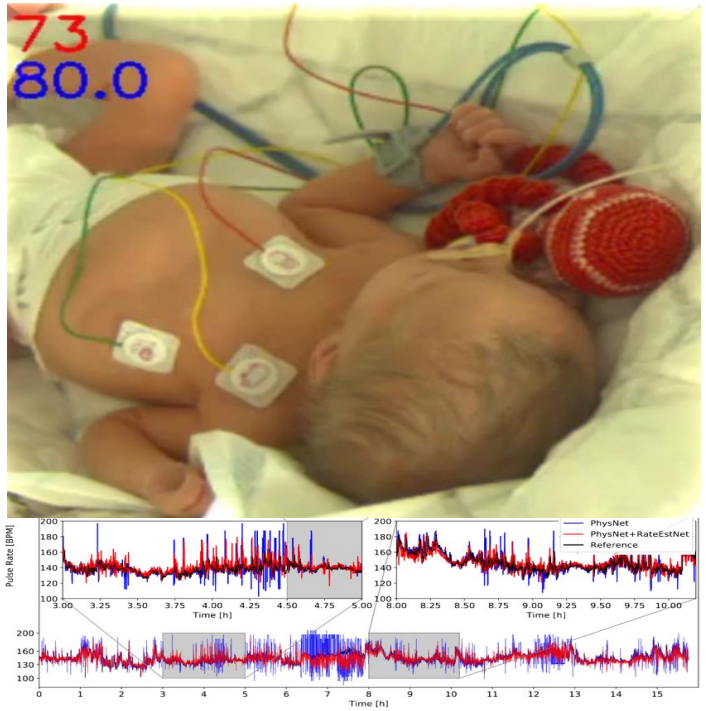




Automatic 3D organ reconstruction







MILAB – Medical: Influenza...

To understand the evolution and functional properties of Influenza virus

"Combining Influenza hemagglutinin antigenic maps with deep mutational scanning data"
(**GPU-Lab run**, Á. Gellért, O. Kilim, A. Mentes, I. Csabai)

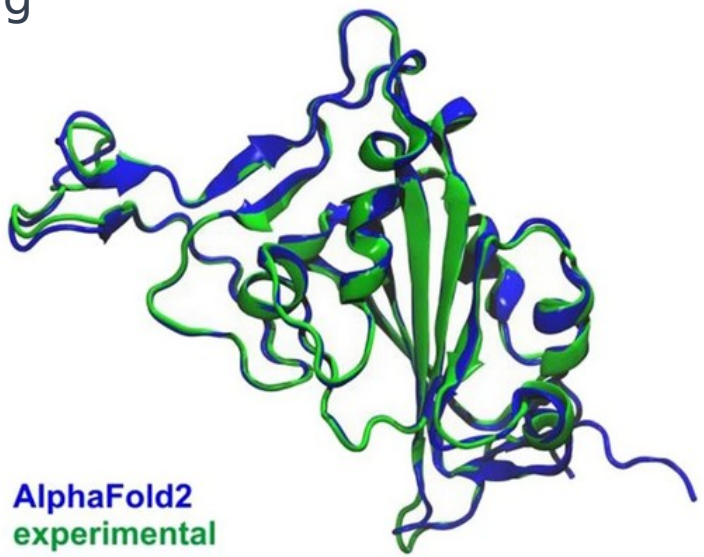
- How different mutations affect the ability of virus to evade the immune response
- Which regions of the virus are critical for this evasion

→ how to predict the phenotypic properties of influenza viruses using mutations in the genetic sequence alone.

ML:

- Protein 3D-structure pred.: AlphaFold2 (J. Jumper et al., 2021), ESMFold2 (Z. Lin et al., 2022)
- Predict phenotypes

SARS-CoV-2 virus:
O. Kilim et al., Nat. Sci. Data (2023)



MILAB – Medical: Gigapixel whole-slide image analysis

A machine learning competition to **predict the stage of patient's cancer, using only slide images generated by breast biopsy.**

Data: 4200 cases, 72000 high-res pathological sections, 130 TB data
Winning techniques: smart image proc., transfer learning, multiple-instance learning.

https://app.nightingalescience.org/contests/vd8g98zv9w0p/leaderboard

NIGHTINGALE
OPEN SCIENCE

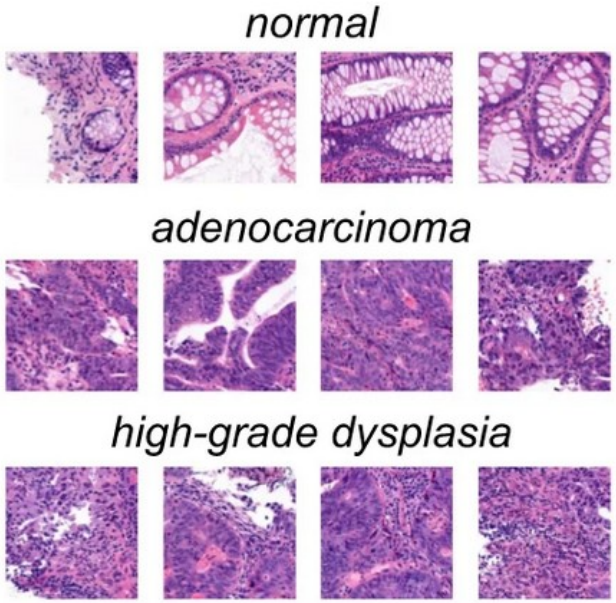
Contests / Predicting High Risk Breast Cancer - Phase 2 (2023) (vd8g98zv9w0p)

Predicting High Risk Breast Cancer - Phase 2 (2023)

Ranking	Team Name	Score	Description
1	csabAIbio	0.7606058	Seventh submission
2	Bonaventure Dossou	0.7305834	preds_all_geo_times_arith_mean

•
•
•

Earlier results: HunCRC – annotated pathological slides
B. Á. Pataki et al., Nat. Sci. Data (2022)



Pathology tissue sections with stages of colorectal cancer.

MILAB – Human–AI Interaction

Machine Learning = statistics + lot of data

AI = ML + sensors + HW (robot) + restrictive rules

Human intervention required

Physically enclosed, shuts down when people enter

Thanks for the Attention!