AI tea party

December 20, 2023
EP 110, FEL

UNIVERSITY
OF WEST
BOHEMIA

AI tea initiative:

- AI is a new trend in research with potential in many applications
- This great opportunity is not used as well as it could
  - Fragmentation
  - Insufficient knowledge sharing

Web: http://ai.zcu.cz

Bi-weekly schedule: FEL, FAV

- AI tea initiative aims to establish a space for face-to-face meeting between groups
  - technical talks
  - educational talks
  - open discussions
- An **open** concept
  - feel free to contribute

Václav Šmídl:
Bayesian Optimization for data acquisition

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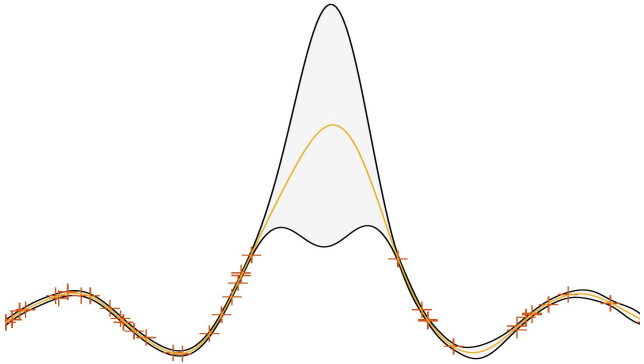
RICE

Aim: areas with expensive data acquisition

- minimize the **cost** of exploration
- experiment design

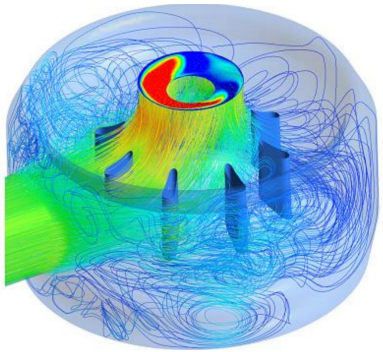


Technology:

- Gaussian Processes, Bayesian Neural Networks

Cool factor:

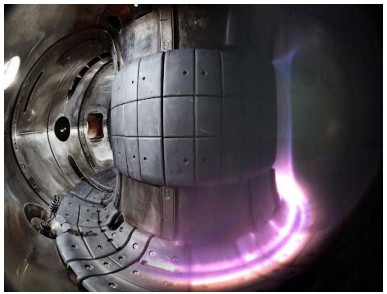
- statistics + ML + simulation + physics



Partners/Users:

- institute of plasma physics,
- material research, controller tuning
- optimization of machine design, Sigma

T A
Č R



Vojtěch Lapuník:
Equation learning and extrapolation using neural networks

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Aim:

- simplify the design and production of magnetically controlled soft-robots

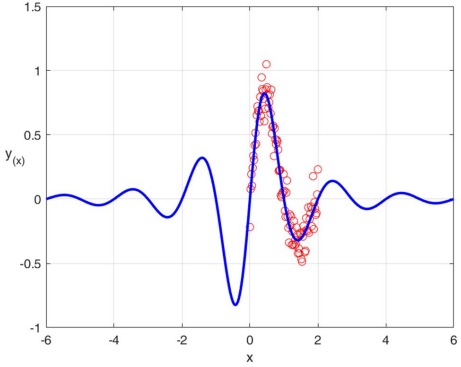
Cool factor:

- discovery of analytical equations by machine learning
- model extrapolation capability

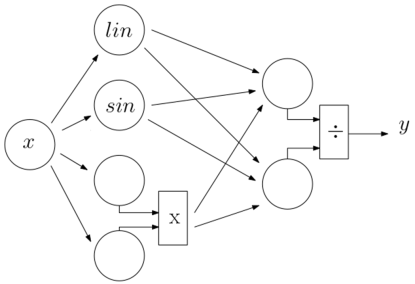
Technology:

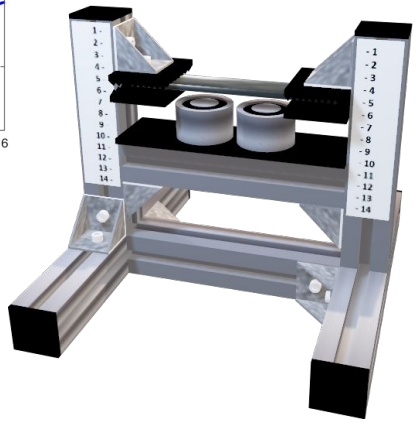
- white-box neural networks
- symbolic regression

Illustration:



$$y(x) = \frac{sin(\pi x)}{x^2 + 1}$$





Jakub Ševčík:
Neural ODE for electric drive identification

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Aim:

- identify accurate dynamic model of an electric drive

Cool factor:

- combining physical ODE with NN
- training using higher-order gradient descent
- application in embedded

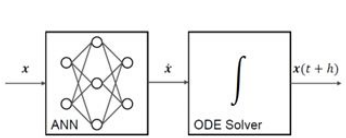
Technology:

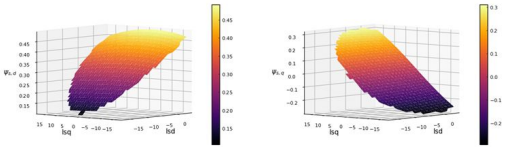
- neural ODE
- scientific machine learning

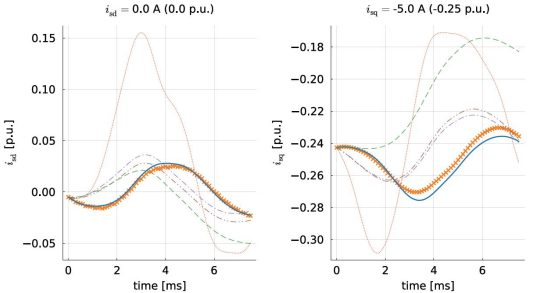
julia

Illustration:

$$\frac{dx}{dt}(t) = f_{phys,\theta}(t, \boldsymbol{x}(t), \text{ANN})$$







T. Komrska, J. Štengl, V. Šmídl: Identification of Earth Faults in Distribution Power Grids

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Aim:

- To detect the beginning and end of an earth fault

Training and validation data set:

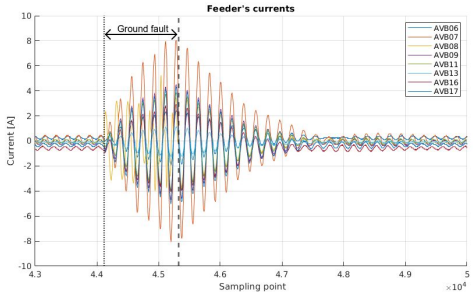
- Over 800 earth faults measured in real distribution power grid of 22 kV
- Manual labelling (150 so far)

Partners/Users:

- ČEZ Distribuce
- Pilot prototype of 1.35 MVA/22 kV has been installed in MV power grid for 2.5 years

Machine learning method:

- InceptionTime network for time series



Serge Pacome Bosson:
Function approximators in industrial HW

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RICE

Aim:

- implementation of function approximators in industrial computer systems

Cool factor:

- survey of approximators that admit efficient real-time implementation: ANN, PWA, LATTICE
- supervised learning regression on system with N-D inputs: 2D….15D
- inference in low level hardware

Partners/Users:

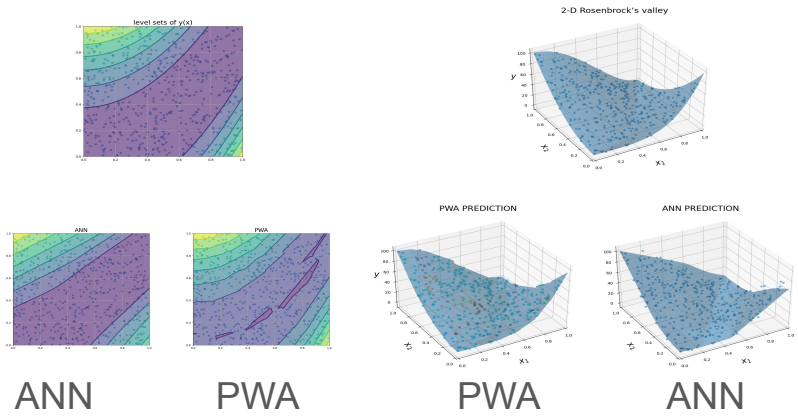
- embedded AI: guide AI practitioners toward the deployment of function approximation for nonlinear multi-dimensional LUT in embedded systems

Technology:

- machine learning: PyTorch TensorFlow Keras
- computer systems: DSP, FPGA, SoC, SoM
- high level synthesis: Intel® HLS, HLS4ML

Illustration:

2D Rosenbrock’s valley



ANN PWA PWA ANN

František Mach:

human-less design approach and autonomous operation

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Aim and cool factors:

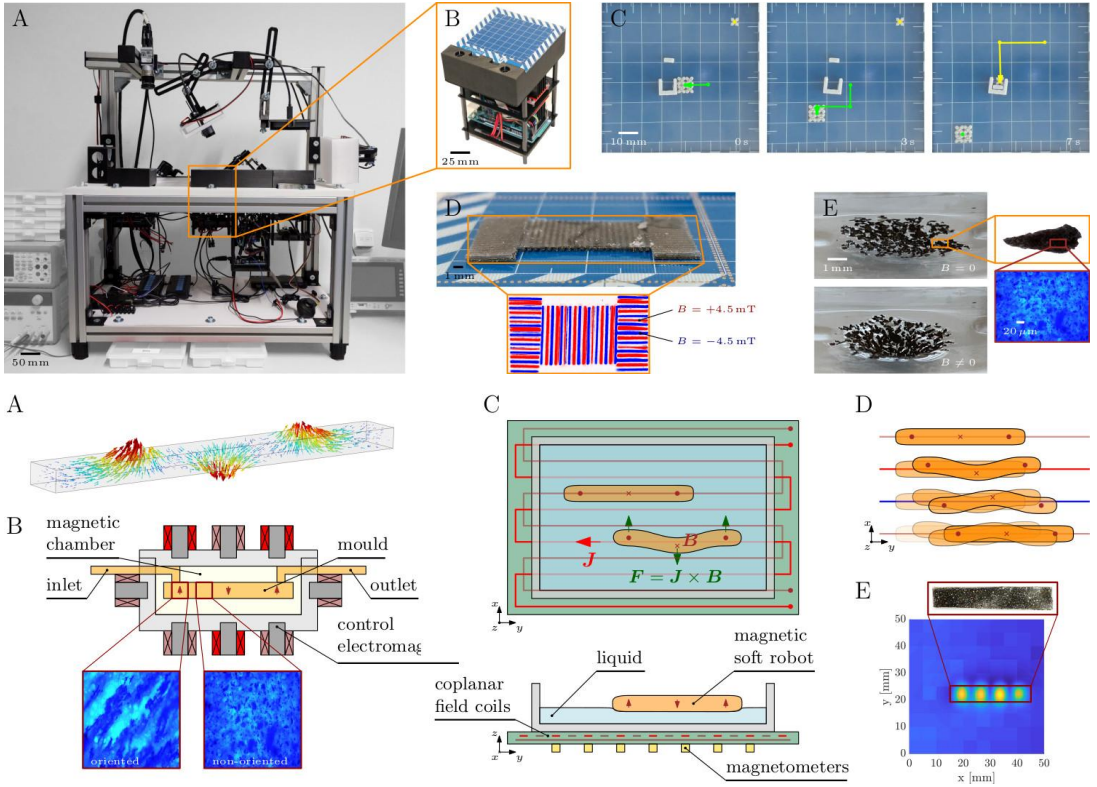
- multi-modal and multi-functional **insect-scale** reconfigurable, **magnetically guided**, untethered **robots**
- **learning-based** approaches with exploiting causalities using **physics-informed methods**

Technology:

- Design: **evolutionary robotics** (FEM-based models; white-box neural networks; symbolic regression)
- Control: **neural PDE**; reinforcement learning

Partners/Users:

- CTU:ComRob (Faigl) + AA4CC (Zemánek)
- UCT:Hydrogel Machines (Řehoř)



Martin Juřík:
Electronic waste separation

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Aim:

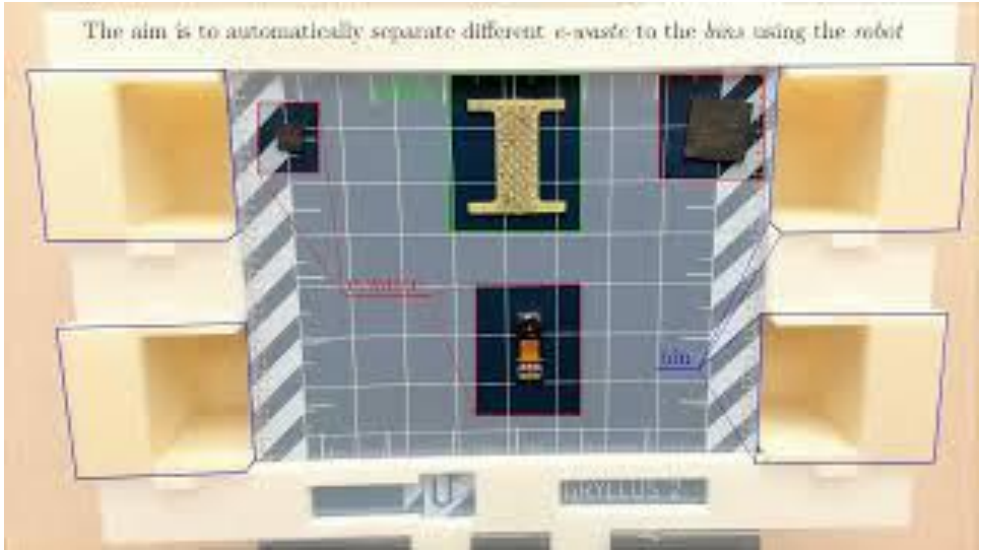
- Automate potential application of our minirobotic platform

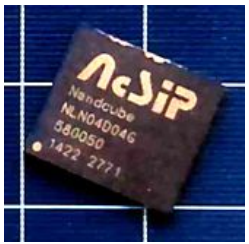
Cool factor:

- Fully autonomous demonstration

Technology:

- part detection (yolo) and tracking (KLT)
- path planning (Astar)
- direct HW control in closed-loop





Jan Pospíšil:
Deep understanding of the order book big data

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Aims:

- Development of reliable, innovative and accurate DNN-based models for order book big data and their flow,
- Improving efficiency of DNN training by choosing the most suitable or designing a new SGD optimizer,
- Robustness and sensitivity analysis of studied models.

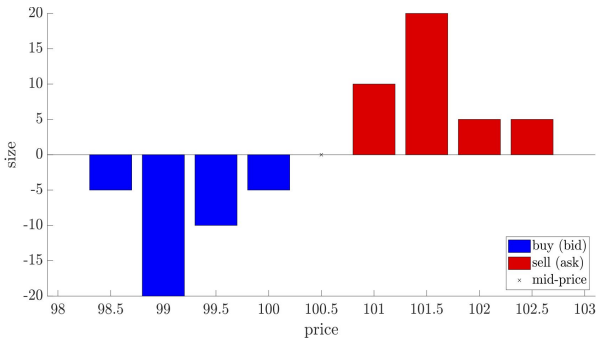
Cool factor:

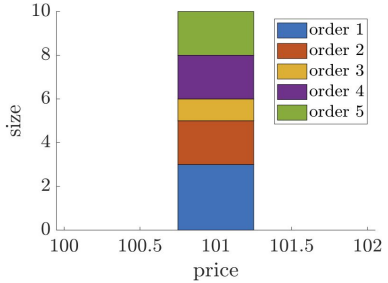
- Enhanced Order Book Interface (EOBI) Big (65 TB/year) high-frequency (10bn msgs/day, ca 100k msgs/s) data from Deutsche Börse AG
- Data Transmogrification

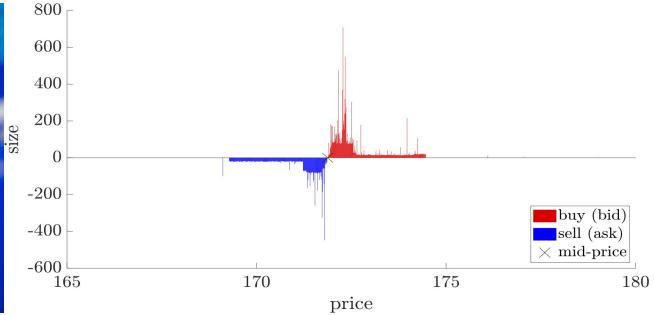
Partners/Users:

- Eurex (international electronic exchange - it is the largest European futures and options market)
- e-INFRA / MetaCentre - object storages

Illustration:







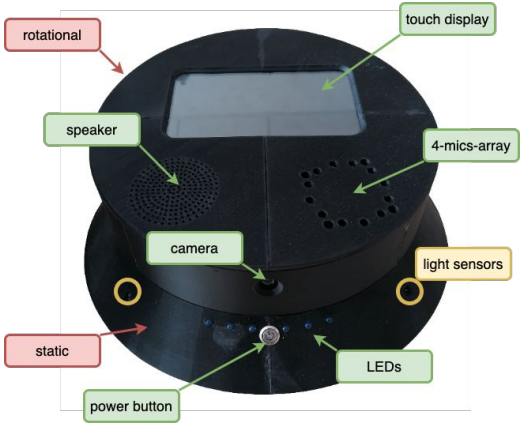
Martin Bulín:
Multimodal Low-Cost Device for PoC Validation

DEPARTMENT OF CYBERNETICS

bulinm@kky.zcu.cz

- 3D-printed **low-cost** (*~10K CZK*) robotic entity
- **RPi 4B**, ROS, ASR, TTS, camera, touch display, stepper motor, solar panel, sensors, LEDs, ...

→ **PoC validation** of “AI” solutions in real-world conditions



*Design: **Anton Smirnov** (student @ Ladislav Sutnar Faculty of Design and Art)*

Successfully implemented applications:

- *J. Čedík (BP 23)*: T5-based chatbot & ChatGPT deployment
- *V. Kimlová (BP 23)*: Intent classification & interactive learning dialog
- *M. Adamec (BP 23)*: Face recognition & object recognition

DEMO:

Ongoing projects:

- *Y. Varabyou (BP 24)*: Keyword spotting & sound source localization

NEW TECHNOLOGIES
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Jiří Martan:
Prediction of internal body temperature from thermography image of the face

Aim:

- Knowledge of real body temperature for medicine and safety in pandemics
- Elimination of influence of cold or hot environment outside

Cool factor:

- Location of eyes in the image
- Internal temperature from temperature distribution in the face

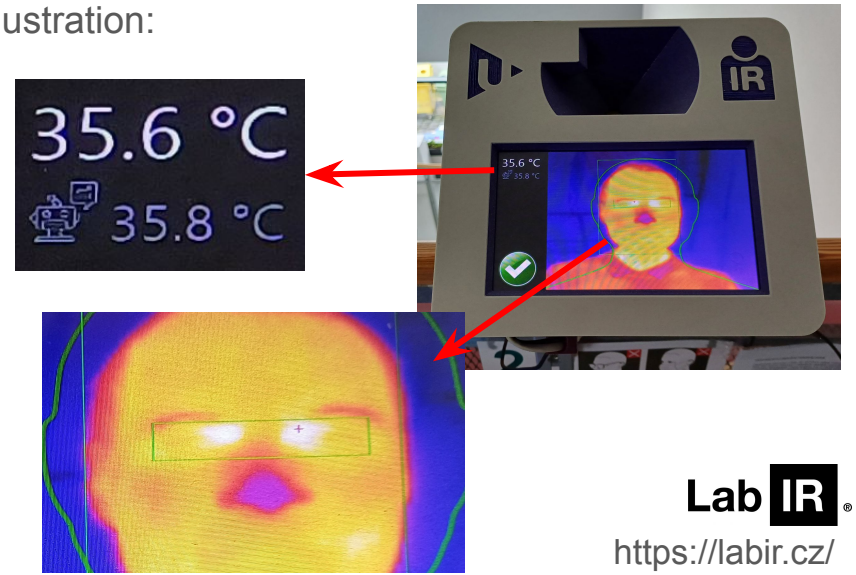
Partners/Users:

- Undergoing testing in hospital, pharmacy and school

Technology:

- Convolution neural networks
- Searching for signs in the image

Illustration:



Lab IR
https://labir.cz/

Jan Krejčí:
Multitarget visual tracking

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Aim:

- Estimate trajectories
- Predict future positions to avoid collisions

Cool factor:

- Tracking by detection, not by entire video

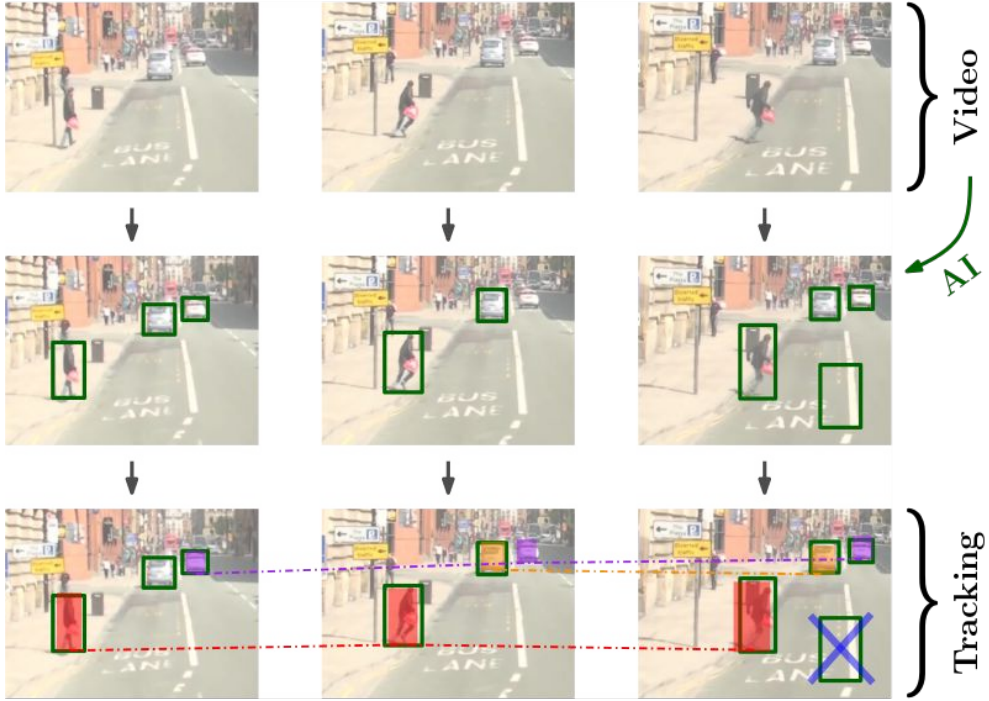
Use case:

- Autonomous driving
- Video surveillance

Technology:

- Visual detectors (SSD, F-RCNN, YOLO)
- Bayesian multitarget tracking
- Random finite sets, point processes

Illustration:



Eduard Rohan
Multiscale modelling of liver for personalized medicine

katedra MECHANIKY

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Aim: To develop a virtual liver model for improved diagnostics and medical treatment planning - hepatectomy, surgical interventions (*Research project - open to join*)

Idea: Precision and more objectivity in decision making, Virtual liver functionality - support for surgery planning,

Using large data (many cases, in-vitro)

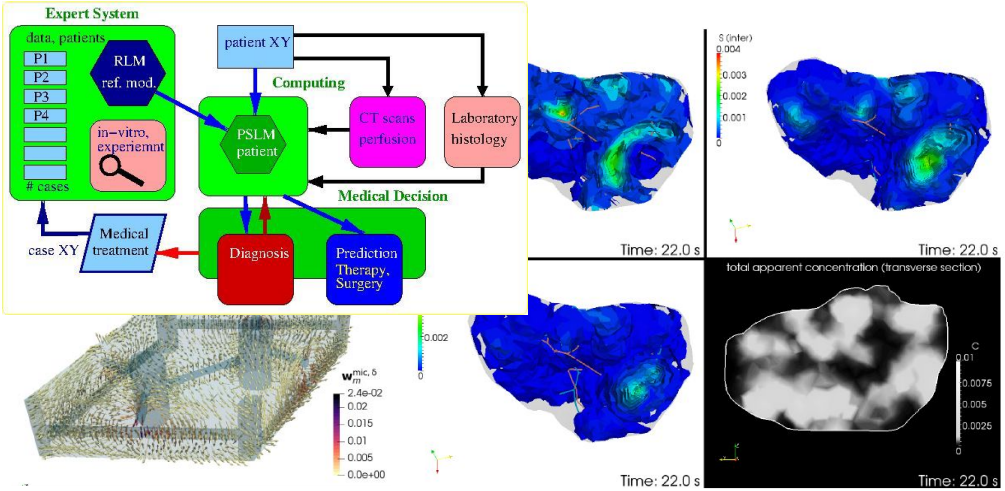
& small data (Patient) => efficiency

Partners/Users: Medical care in hospitals, hepatologist surgeons / BC LF UK Plzeň

Team: V. Lukeš, J. Camprová Turjanicová, A. Jonášová

Technology: Multiscale, hierarchical modelling (PDE homogenization), model order reduction (1D, 3D), DNN, PINNs (intended),

Optimisation / parameter identification



Jan Švec:
AI for understanding humans

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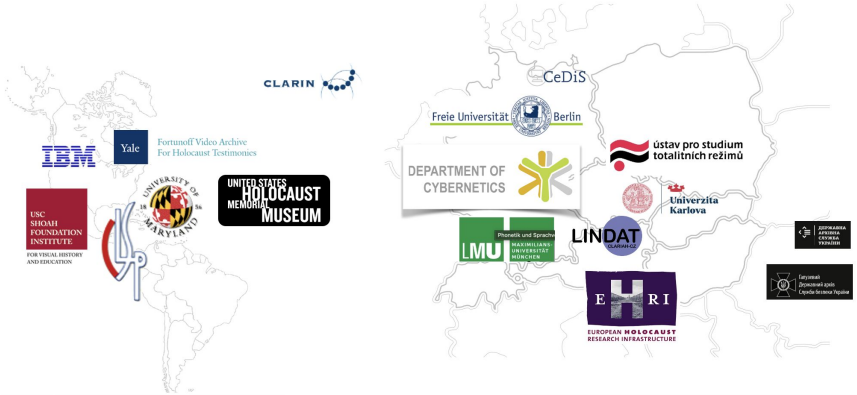
DEPARTMENT OF CYBERNETICS

honzas@kky.zcu.cz

- **Technologies for understanding human communication, interactions, artifacts**
  - on-line & off-line setups
- **Speech is not spoken text**
  - Rich speech transcription
  - Spoken language understanding
  - Natural language & speech generation
- **Applications**
  - Spoken **dialog** systems
  - Oral history **archives**
  - Processing of scanned **documents**
- **Multimodal** systems
  - speech ↔ image ↔ text ↔ interaction

Transformers, T5, BERT, Wav2Vec 2.0, Generative AI, LLMs, GPTs, ChatGPT

- https://malach-aq.kky.zcu.cz/
- https://archivkgb.zcu.cz/en
- https://uwebasr.zcu.cz/



Jindřich Duník / IDM Research Group:

Data-augmented Modelling, Num. Integration, and Uncertainty Eval.

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IDM THE IDENTIFICATION AND DECISION MAKING RESEARCH GROUP

Aim:

- Improve navigation and tracking performance
- Minimise user interaction decision

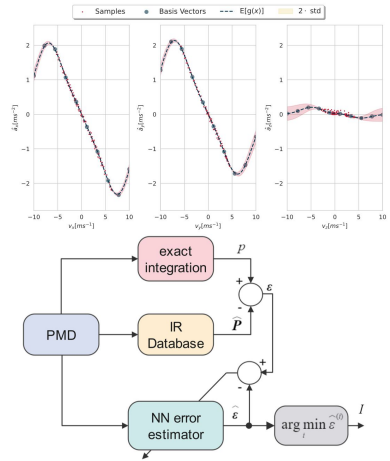
Cool factor:

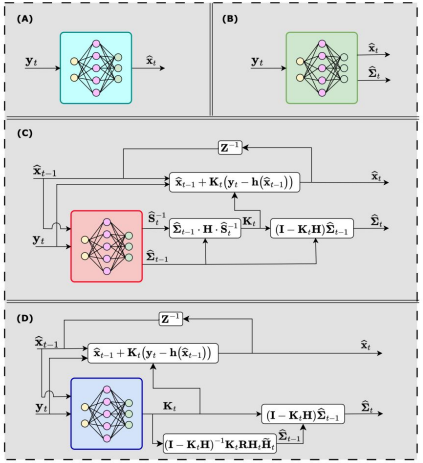
- Preserved **explainability**/certifiability
- Realistic **uncertainty** evaluation

Partners/Users:

- Northeastern Univ., Boston (**data-augmented modelling**)
- Ben-Gurion Univ./ETH Zürich (**uncertainty evaluation**)
- CAS (**data-augmented control**)
- Dept. of Mathematics, UWB (**integration rule selection**)

Technology: (deep) neural networks, recursive Gaussian processes





References:

- Dohan, Revach, Dunik, Shlezinger: **Uncertainty Quantification in deep learning based Kalman filters**, ICASSP24.
- Dunik, Straka, Kost, Tang, Imbiriba, Closas: **Data-augmented Physics-based Models: Noise Identification**. Submitted to SYSID24.
- Dunik, Kral, Matousek, Straka, Brandner: **Data-Augmented Numerical Integration**, Submitted to SYSID24.

Ondřej Bublík:

Neural network-based fluid-structure interaction solver

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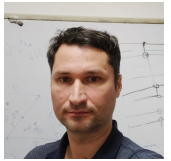


Aim:

- Predict unsteady flow field around moving object.
- Couple CFD neural network solver with structural solver.
- Perform numerical tests on vortex induced vibration of the cylinder.

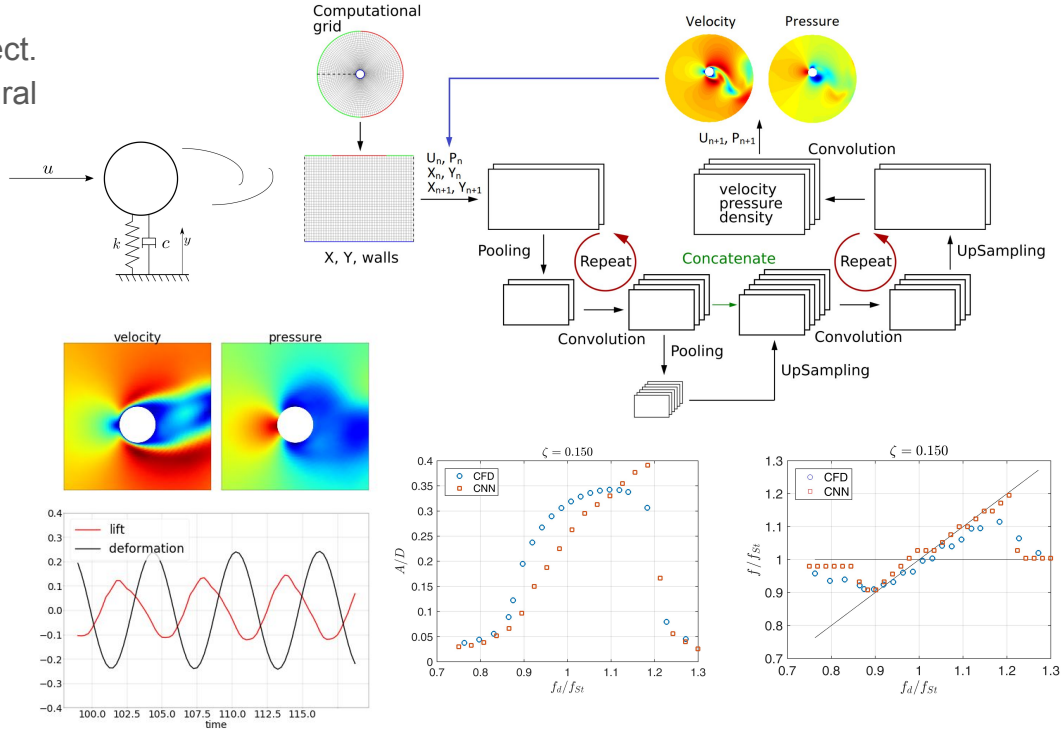
Cool factor:

- Massive speed-up of FSI simulations.
- Capture all non-linear phenomena.

Technology:

- TensorFlow, Keras

Illustration:



Roman Čada:

Using nature inspired extensions of mathematical optimization

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Aim:

- development of fast special purpose optimization techniques and solvers

Cool factor:

- combining standard optimization methods with black box approach (e.g. semidefinite programming with PDE-constraints with help of Bayesian approach)
- can (sometimes) get provably optimal solution

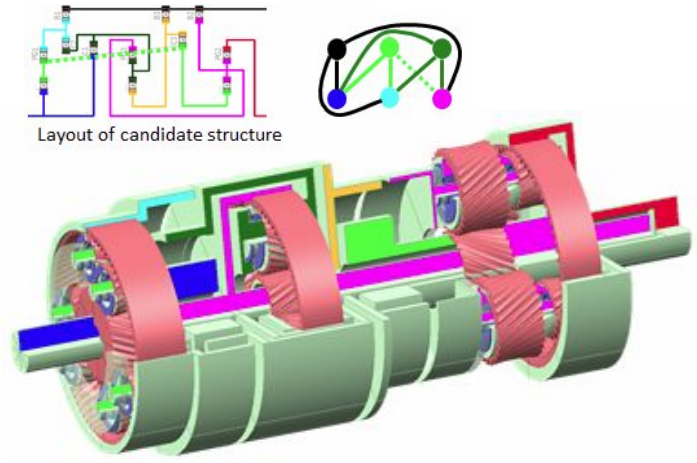
Partners/Users:

- pre-application research with potential for industrial implementation
- Škoda JS, a.s.
- Ricardo UK Ltd.

Technology:

- C, C++
- mathematical optimization
- black-box optimization using AI and other heuristics

Illustration:



Ondřej Straka / IDM Research Group:

Augmented Physics-based Models (APBM)

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IDM THE IDENTIFICATION AND DECISION MAKING RESEARCH GROUP

Aim:

- Advance system modeling solutions in navigation and tracking by leveraging AI techniques,
- AI is used to better represent the complexities of real systems (inaccurately described by physics-based models)
- Quantify the augmentation contribution
- Preserve the model explainability provided by the PBM

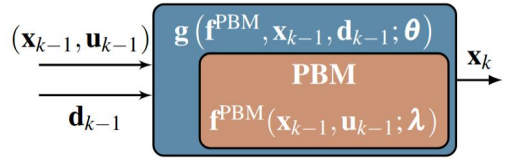
Cool factor:

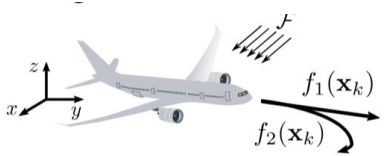
- Preserved **explainability**
- **Online** learning

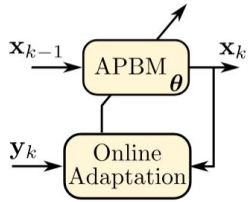
Partners/Users:

- Northeastern Univ., Boston

Technology: neural networks, system identification, state estimation







References:

- Dunik, Straka, Kost, Tang, Imbiriba, Closas: **Data-augmented Physics-based Models: Noise Identification**. Submitted to SYSID24.
- Imbiriba, Straka, Duník, Closas: **Augmented physics-based machine learning for navigation and tracking**, IEEE TAES 2023.
- Imbiriba, Demirkaya, Duník, Straka, Erdoğmuş, Closas: **Hybrid Neural Network Augmented Physics-based Models for Nonlinear Filtering**, FUSION 2022

Kamil Ekštein / PARMAL@kiv.zcu.cz: Data Cesspools – Building Knowledge Bases using Entropy-driven Big (Meta-)Data Analysis

Aim: Assess data importance, significance of information, detect incidents and extrinsic factor influences, identify information nature.

Technology: blob2vec, Bekenstein-Hawking entropy, DCNN pooping, projective re-assessment of data (PRD), semantic space heterogeneity-inducing transformation (S-SHIT) via PCA and divergence & rotation (cesspool “bubbles”) analysis

Cool factor: all-new science, provides deep insight into information collections

Partners/Users:
– misinformation detection/identification services

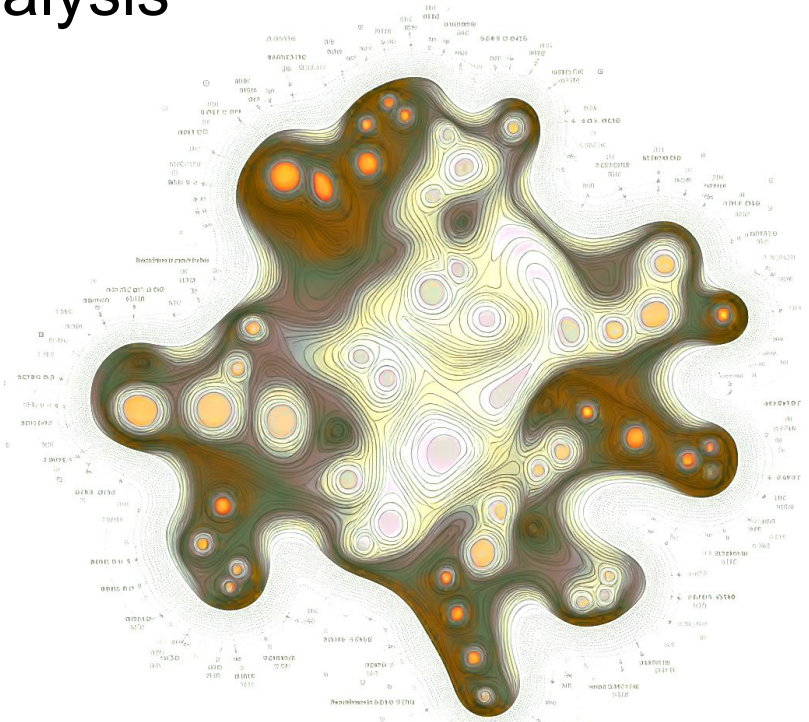


Image: Visualisation of a data cesspool created from journalists’ texts covering Czech politics.

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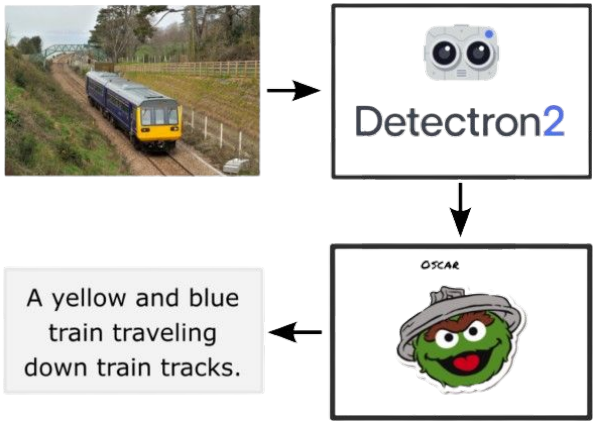
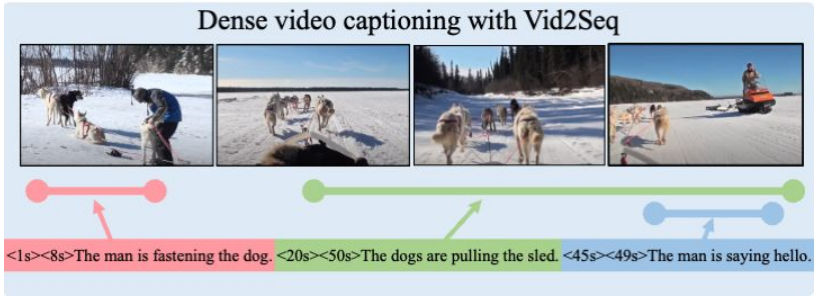
Tomáš Železný:
Image Captioning with subsequent use for Video Captioning

Aim:
- Generate textual description of given image
- Video scene and activity understanding

Cool factor:
- Scene understanding
- Sequence understanding

Technology:
- Image processing (Faster-RCNN, ViT)
- Language models (BERT, T5, Llama)
- Frameworks (Oscar, Vid2Seq)





Jakub Straka:
Computer vision for segmentation, pose estimation, and re-identification

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Aim:

- Conservation of endangered species

Cool factor:

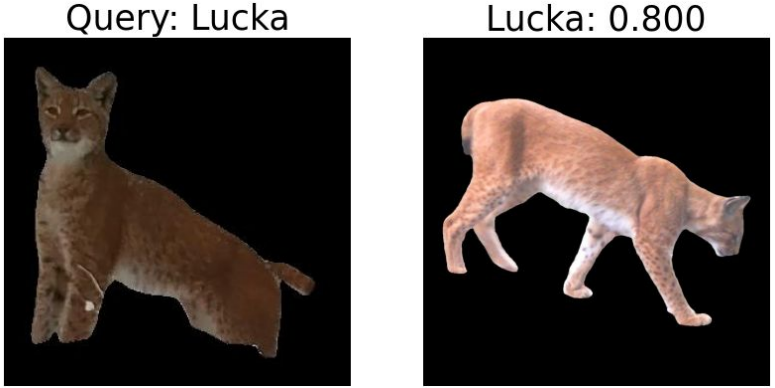
- Identification of individual animals from a single image
- Improved pose estimation using synthetic data

Technology:

- Pose estimation – Top-down (ResNet, HRNet)
- Identification – Swin transformer, SAM
- Pytorch, Unity Game Engine

Synthetic images for pose estimation:

Lynx re-identification:



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Ivan Gruber: Structured data mining from documents

Aim:

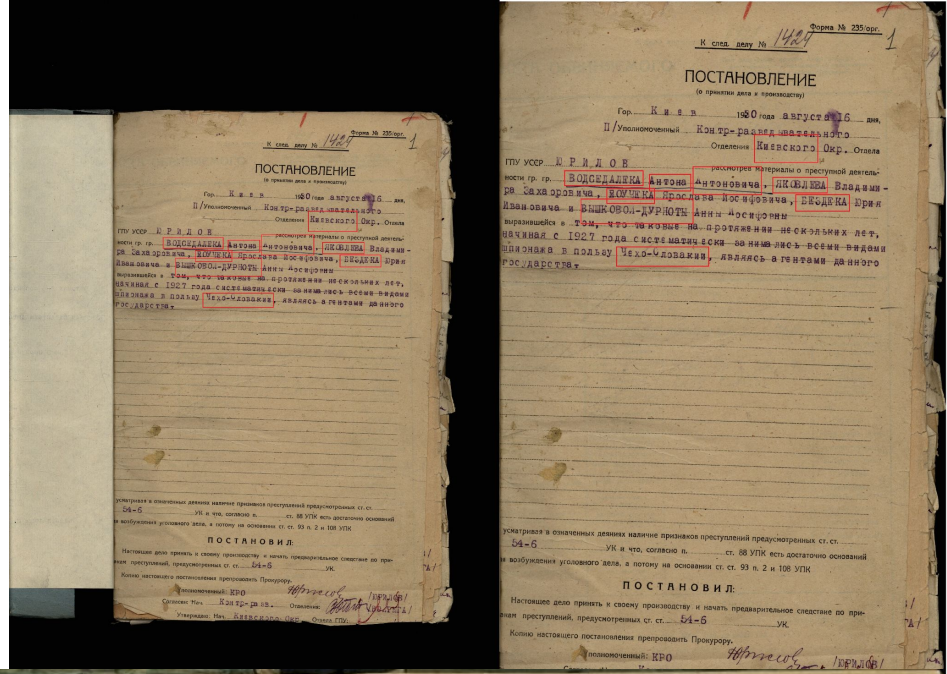
- Interpretation of structured data in scanned documents

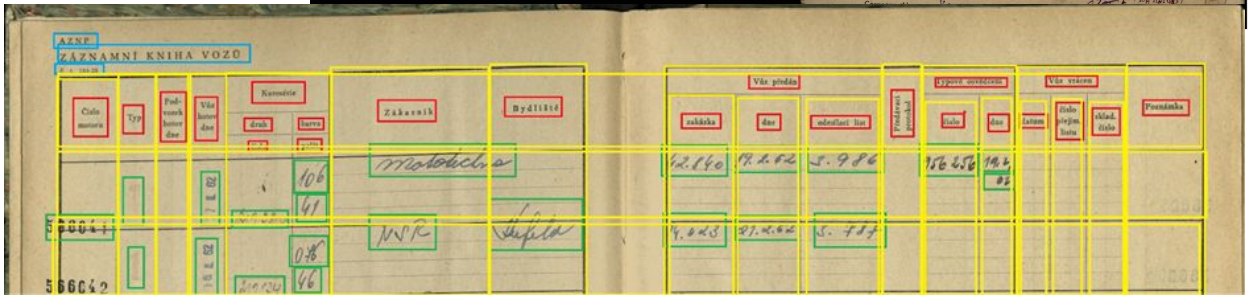
Cool factor:

- We can obtain historical data for modern systems

Technology:

- Faster R-CNN, YOLO
- CV pre-processing





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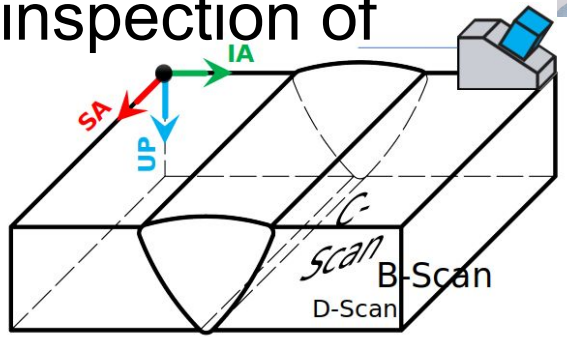
Marek Hrúz: Advanced AI robotics for inspection of composite materials



Aim:

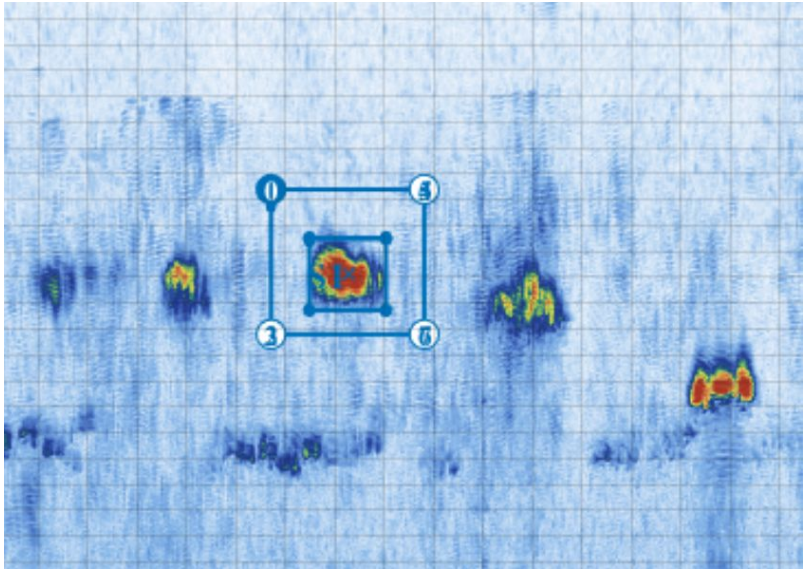
- Automatic detection of defects in welded materials

Cool factor:

- AI inspection of piping in nuclear power plants

Technology:

- Robotic arm for ultrasound scanning
- CNN/Transformer for classification, later detection



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Marek Hrúz: Traffic analysis on the Edge

Aim:

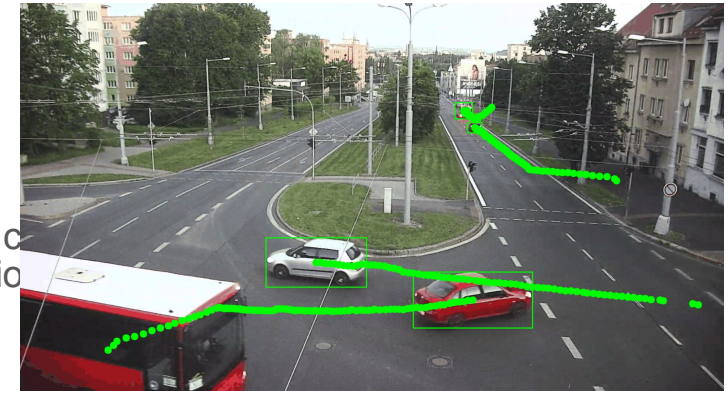
- Analysis of traffic in Pilsen

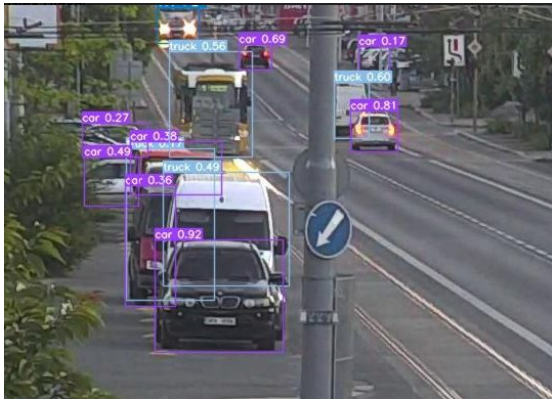
Cool factor:

- Prediction of traffic jams, city infrastructure planning

Technology:

- YOLO, ByteTrack, Re-ID
- ETA from google maps
- Scene detection for rotating c
  - SIFT, background subtractio





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Jiří Vyskočil: Mirror Selfies Analysis

Aim:

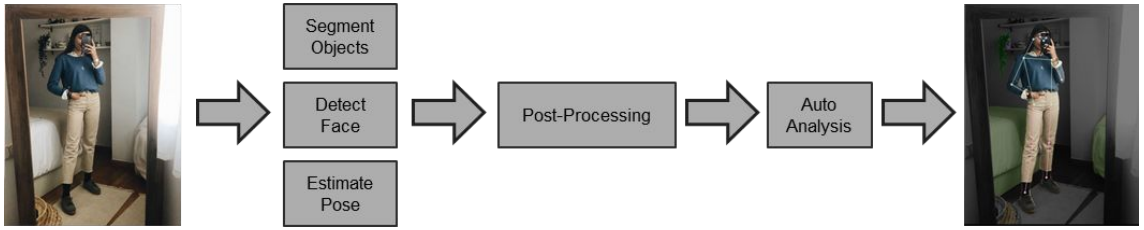
- Analysis of Instagram poses

Cool factor:

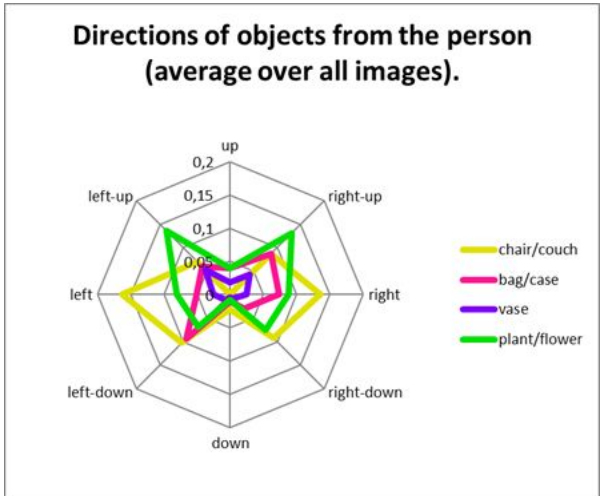
- Statistical analysis of scene for furniture design

Technology:

- YOLO
- Pose, Instance Segmentation
- MT-CNN for Face detection



Object Segmentation (COCO)
- person, cell phone
- bed
- chair/couch
- table
- bag/case
- vase
- plant/flower
- door
- stairs
- cabinet



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Jiří Egermaier:
Neural networks for CFD optimization problems

Aim:

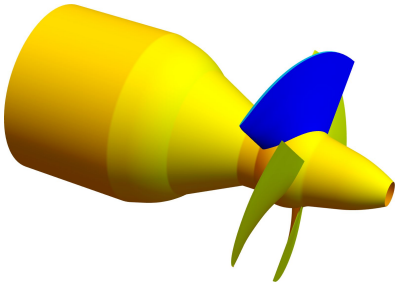
- Auxiliary tool for shape optimization of water turbine blades based on isogeometric analysis

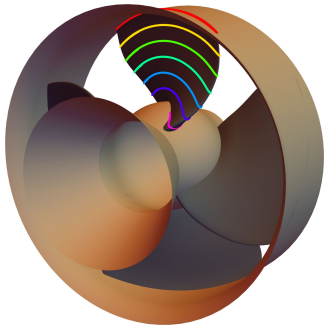
Cool factor:

- Acceleration of the optimization process by avoiding a large number of incompressible flow calculations
- Suitable for both gradient-based and gradient-free optimization

Technology:

- ANN - prediction of the objective function value
- CNN (+PINN) - prediction of the complete flow field





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Jan Kaska:

Bayesian Experiment Design for the Development of a Degradation Model

Aim:

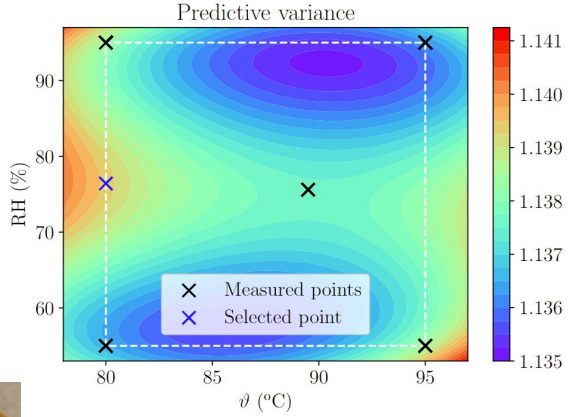
- Find a suitable model for degradation (temperature + humidity) of epoxy resin used in all electric motors
- Minimize a number of very time-expensive experiments (couple of weeks for one measurement)

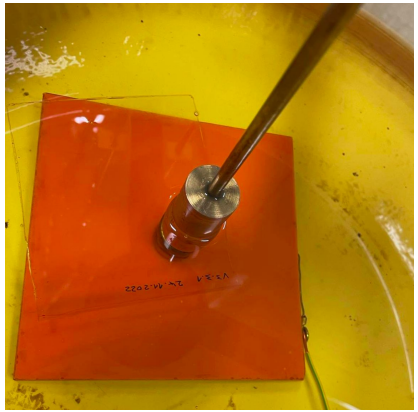
Technology:

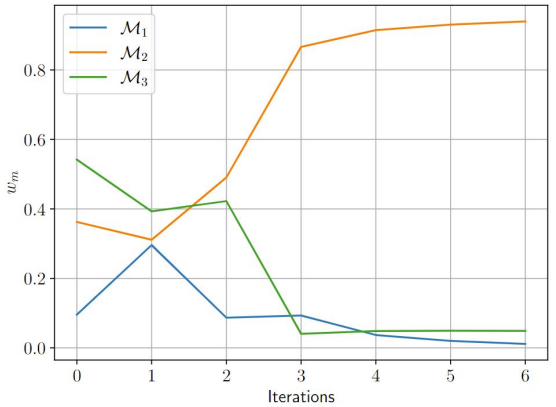
- Bayesian design of experiments
- Multiple candidate models

Cool factors:

- We can select the most informative conditions for measurement based on information gain
- We can find new interesting structures of models







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David Pánek:

Optimization of Pump Impeller

Aim and cool factors:

- Shape / Robust optimization of the impeller to achieve highest possible efficiency
- Computationally complex forward task - tents of hours
- Tents of parameters describing geometry of the impeller

Technology:

- Trust Region Bayesian Optimization

Partners/Users:

- Sigma Group a.s.

Luboš Šmídl:
AI for research and commercial applications

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DEPARTMENT OF CYBERNETICS

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Artificial Intelligence section @ KKY

… it is difficult to describe a number of scientific and commercial results in one minute …

… let's look at **OUR** results of the **AI awards 2023:**

- first prize in the social contribution category
  - DOAZARC Project - archive of NKVD/KGB historical documents about citizens of Czechoslovakia persecuted on the territory of Ukraine (https://archivkgb.zcu.cz/en/about)

- finalist in the social contribution category
  - SpeechTech - implementation of speech technologies (https://www.speechtech.cz/)

- first prize in the public administration category
  - JALUD Embedded - acoustic event detector (https://soundeventdetector.eu/cs/)

- finalist in the public administration category
  - ČEPS AI team - predictor of technical losses (https://www.ceps.cz/cs/inovace)

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NEW TECHNOLOGIES
RESEARCH CENTRE
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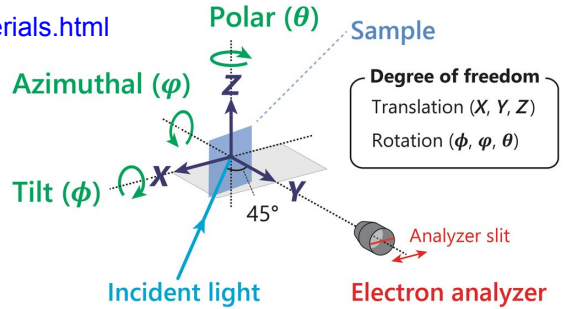
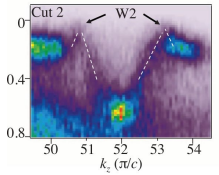
Trung-Phuc Vo:
Genetic algorithm for angle-resolved photoemission spectroscopy

https://www.ntc.zcu.cz/en/Research/Research_topics/Advanced_Materials.html

SPR-KKR H. Ebert et al., **74**, Rep. Prog. Phys., 2011





H. Iwasawa et al., **8**, Sci. Rep., 2018

S. Y. Xu et al., **349**, Science, 2015

Aim:

- Mapping electronic band structure

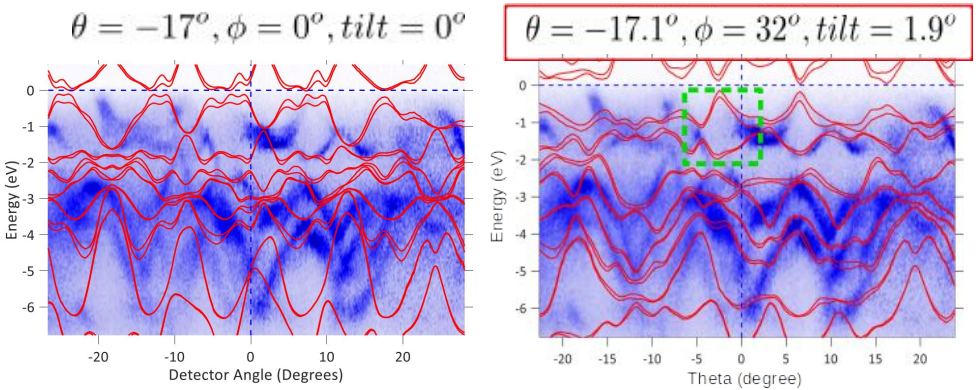
Cool factor:

- Comparing images to guide expensive photoemission calculations and experiments
- Good input for CNNs

Technology:

- Genetic algorithm
- Matlab, Python
- TensorFlow, Keras

Before and after applying genetic algorithm:



Pavel Král:
Natural Language Processing (NLP) https://nlp.kiv.zcu.cz/

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

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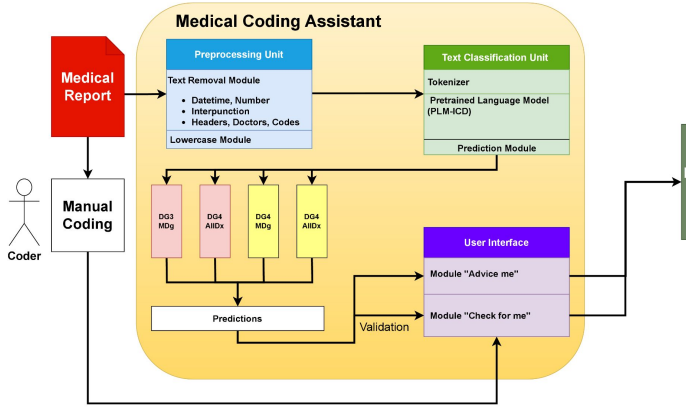
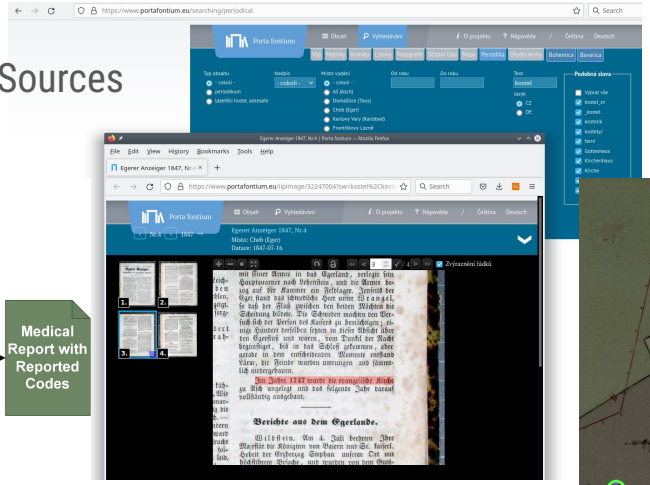
- **Focus: text** understanding and image processing
  - Semantic analysis
  - Medical document analysis
  - Historical document processing
- **Approaches:**
  - “Deep” neural nets &
  - Standard methods
  - Minimal supervision
- **Recent Projects**
  - Modern Access to Historical Sources
  - Medical Coding Assistant
  - BAGOM - map analysis





Miloslav Konopík:
Natural Language Understanding

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Aims:

- Research in semantics of text (15 years)
- Train a Czech generative model

Cool factor:

- First team to train a large Czech language model (Czert)

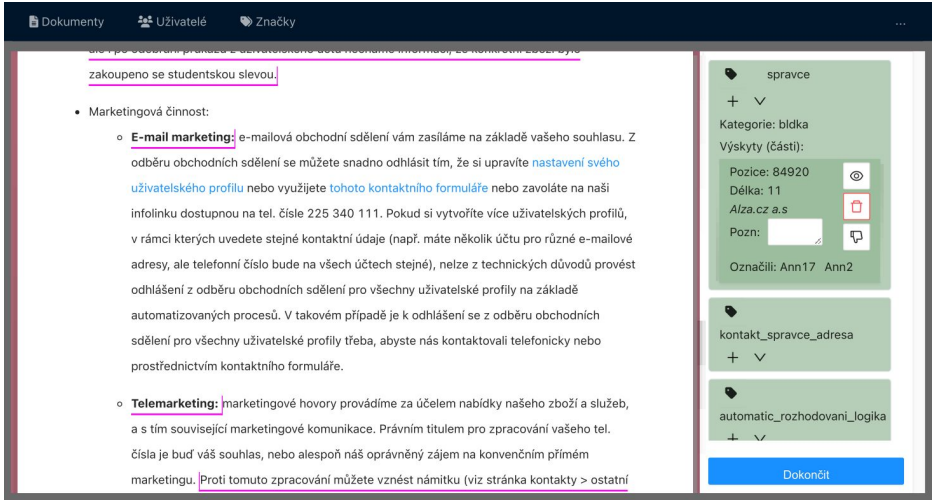
  (Sido, Pražák, Přibáň, Pašek, Seják, Konopík)

Partners/Users:

- Institute of State and Law of the Czech Academy of Sciences
- Various companies

Projects:

- Coreference Resolution
- Privacy Policy Analysis



Filip Polák:
DigiDiaDem - Early Detection of Dementia

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polakf@kky.zcu.cz

Aim:

- create an app that could detect cognitive disorders
- mobile and web-browser app

Technologies:

- ASR, SLU, TTS from the SpeechCloud network
- frontend in React, backend in Python
- neural networks for analyzing user's speech

Partners:

- prof. MUDr. Aleš Bartoš, Ph.D. (National Institute of Mental Health)
- Mgr. Martin Víta, Ph.D. (Czech Academy of Sciences)

diadem.kky.zcu.cz

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Martin Kryl:
Predicting stroke outcome

Aim:

- Create a support tool for neurologists to assist with the treatment planning for stroke patients

Cool factor:

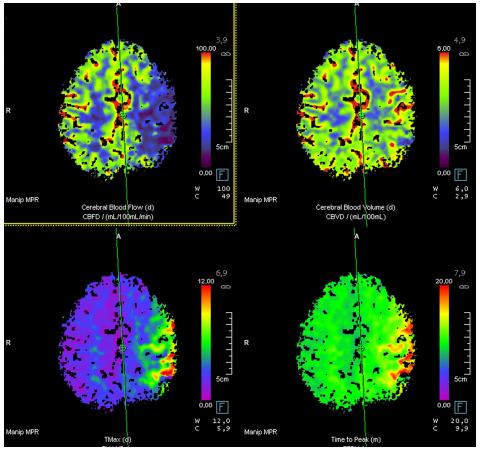
- Predicting changes in the reversibly injured area.

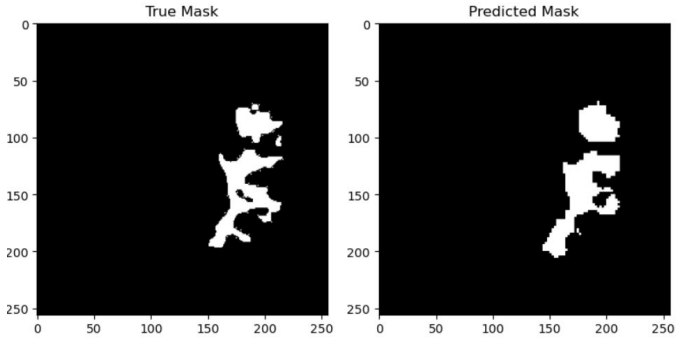
Technology:

- PyTorch, SPARQL/RDF, DICOM, DASTA

Partners:

- FN Plzeň





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Jana Klečková
Integration and processing of big medical data

Aim:

- Enable application of AI methods on large collection of medical data

Cool factor:

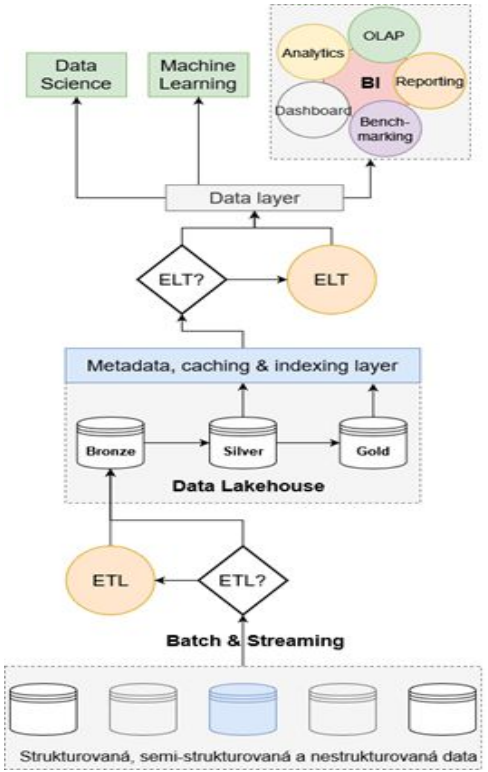
- Combination classical data mining method and modern AI approaches

Technology:

- Data Lakehouse, RDF, No SQL databases, DICOM, HL7, DASTA

Partners:

BC LFP UK, FN Plzeň, International Registry SITS, RES-Q



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Blanka Šedivá:
Identification of outliers

Aim:

- Identifying potential outliers in large-scale multivariate data

Cool factor:

- Methods that interdisciplinary intersect statistics, graph theory , cluster analysis and numerical principles.
- Clear connection to real datasets and problem with practical interpretations.

Technology:

- Openness to new approaches.