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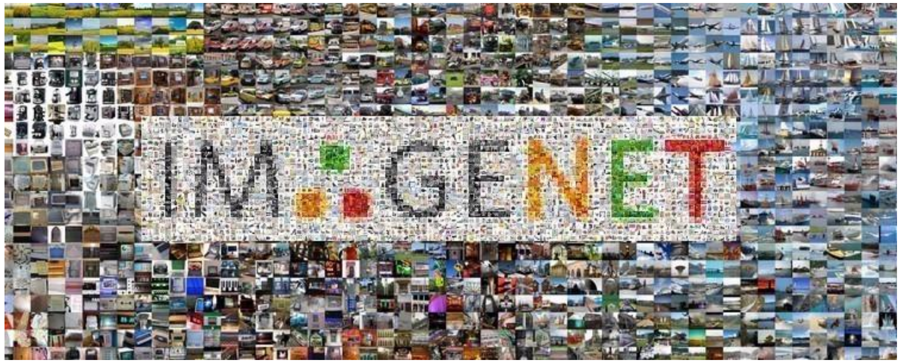
Deep Learning in the Wild

8th IAPR TC3 Workshop on Artificial Neural Networks in Pattern Recognition, September 19-21, 2018, Siena, Italy

T. Stadelmann, M. Amirian, I. Arabaci, M. Arnold, G. F. Duivesteijn, I. Elezi,
M. Geiger, S. Lörwald, B. B. Meier, K. Rombach & L. Tuggener

Research type A and B

Research type A and B



Motivated by general progress

- Given *known environment* (learning target, data, evaluation metric)

➔ Goal: *fundamental advance* in method

Research type A and B

Motivated by application

- Facing *unclear*/unprecedented *learning target & data quality / quantity* issues

➔ Goal: new *product & advance* in method

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Research type A and B

Motivated by application

- Facing *unclear*/unprecedented *learning target & data quality / quantity* issues

→ Goal: new *product & advance* in method

LETTER

Human-level control through deep reinforcement learning

Motivated by general progress

- Given *known environment* (learning target, data, evaluation metric)

→ Goal: *fundamental advance* in method

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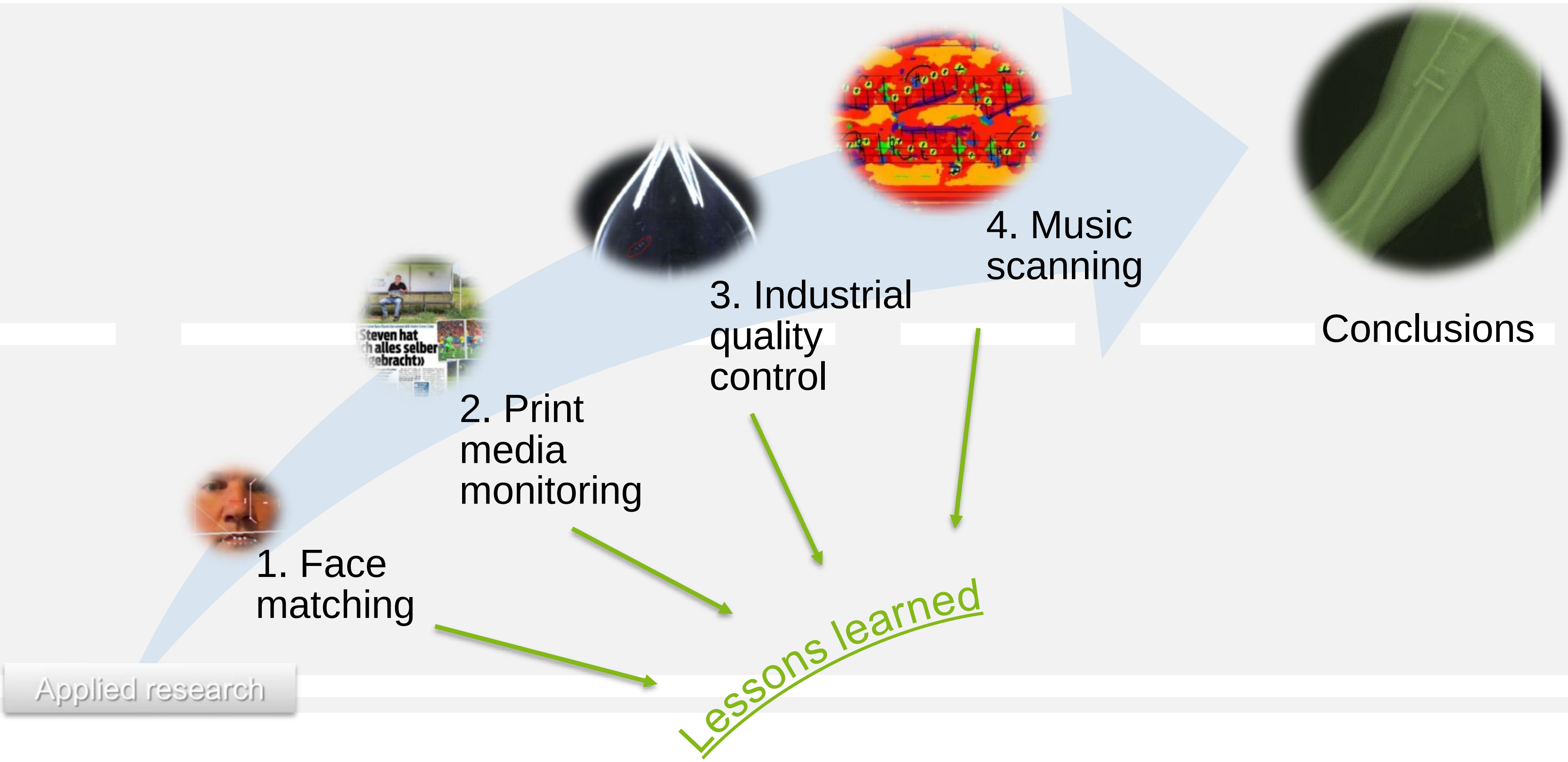
Roadmap



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1. Face matching

[!] DEEPIMPACT

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1. Face matching – challenges & solutions

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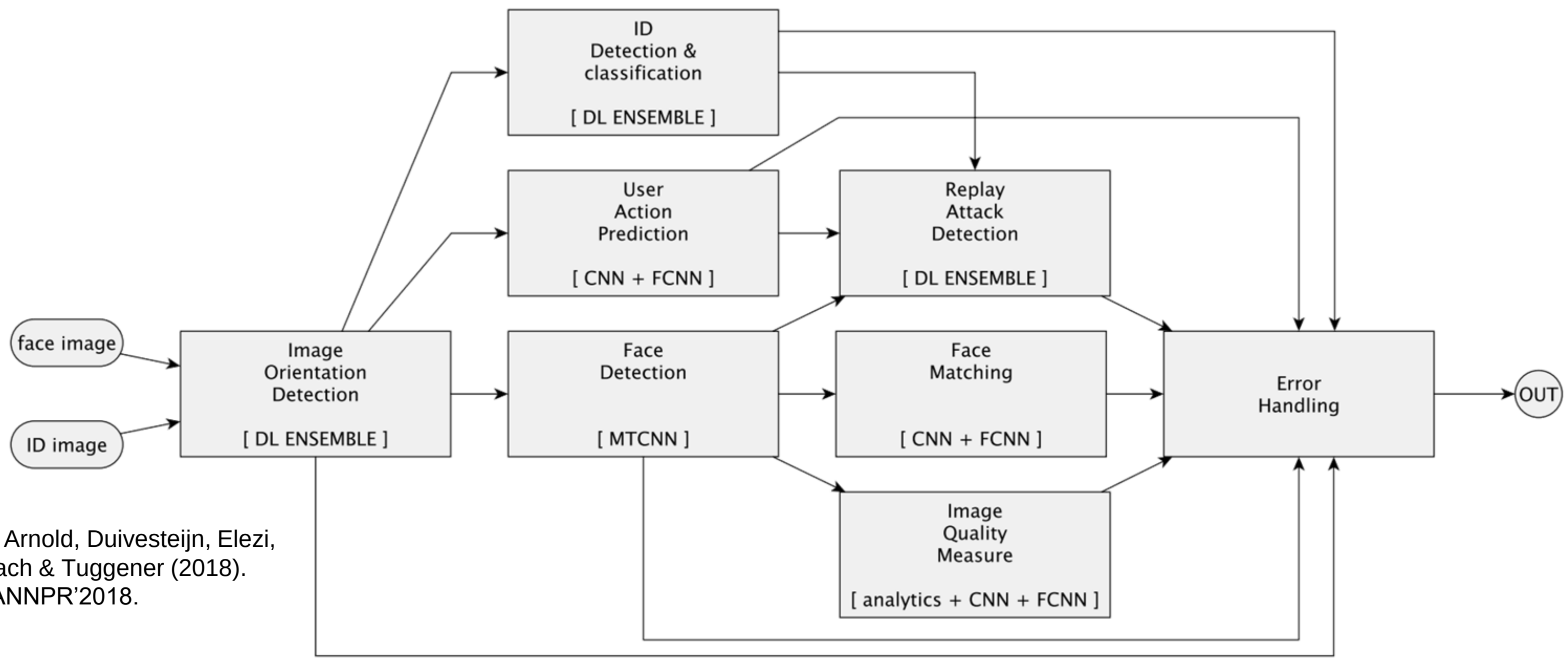
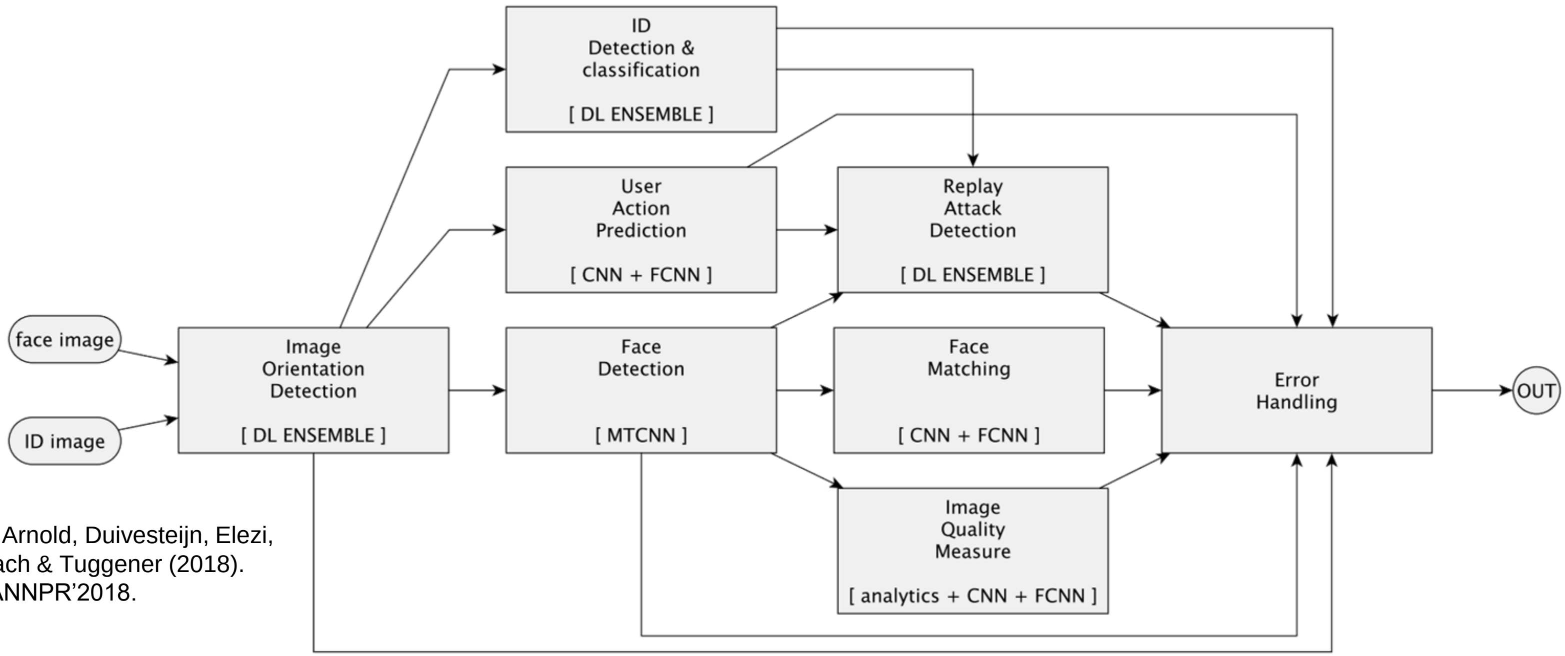


Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.

1. Face matching – challenges & solutions



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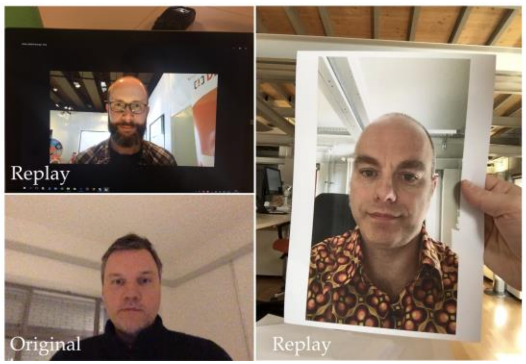
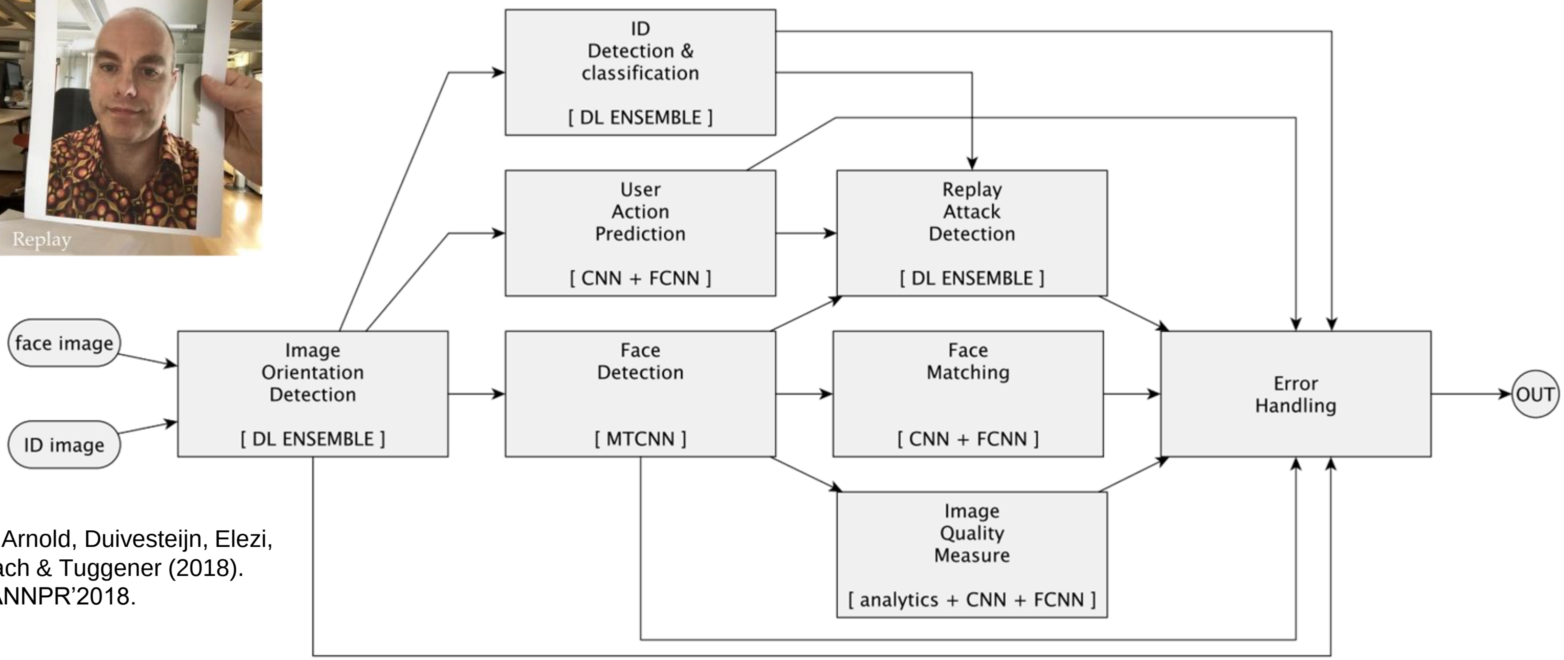
1. Face matching – challenges & solutions





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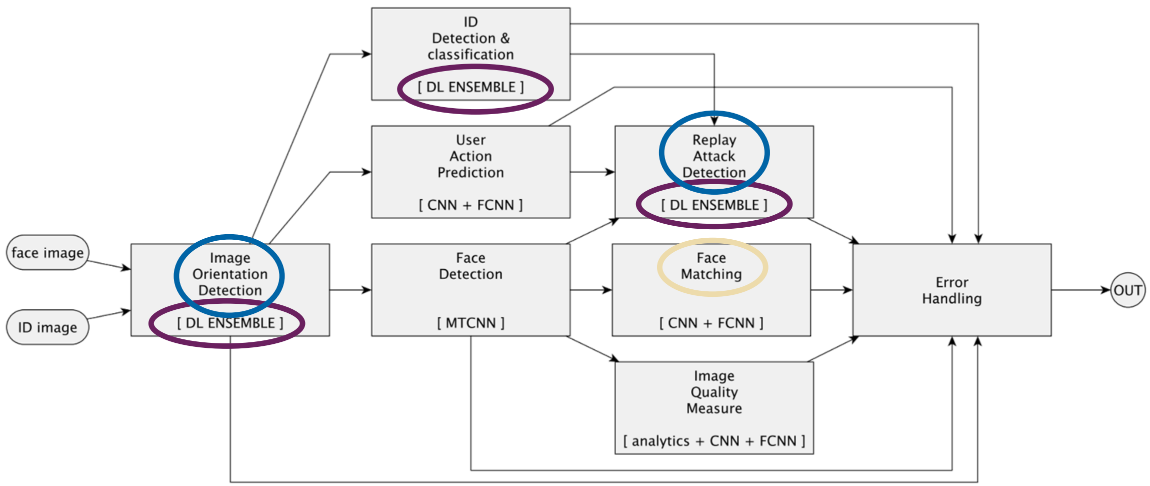
Lessons learned 1/4

Deployment

- Might involve the buildup of up to dozens of **other machine learning** models to flank the original core part.



- **Specialized models** for identifiable sub-problems increase the accuracy in production systems over all-in-one solutions, and **ensembles** of experts help where no single method reaches adequate performance.

Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.

2. Print media monitoring

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Task

International.

Spionage für den Erzfeind Iran

Israelischer Ex-Minister arbeitete als Agent für die Mullahs. Jetzt droht ihm lebenslänglich

Asylbewerber können bleiben

Nordkoreanischer Diktator zu Besuch in Peking

Challenge

«Steven hat sich alles selber beigebracht»

Unsere Nati ist gegen Serbien unter Druck

Verlieren verboten!

Transfer TICKER

Liverpool will Yann Sommer!

Nuisance

Das Tages-Horoskop

Liebling der Sterne

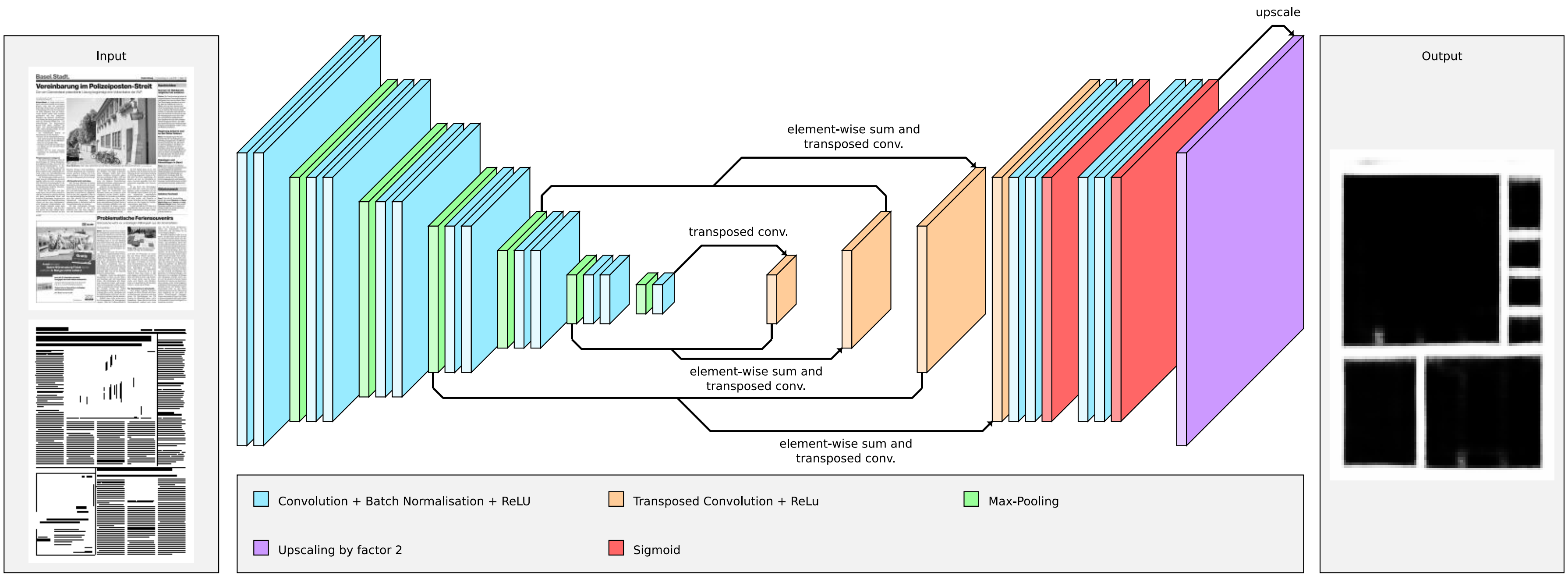
15,1 Millionen

SCHWEDEN-RÄTSEL

SUDOKU

Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.

2. Print media monitoring – ML solution



Meier, Stadelmann, Stampfli, Arnold & Cieliebak (2017). «*Fully Convolutional Neural Networks for Newspaper Article Segmentation*». ICDAR'2017.
Stadelmann, Tolkachev, Sick, Stampfli & Dürr (2018). «*Beyond ImageNet - Deep Learning in Industrial Practice*». In: Braschler et al., «Applied Data Science», Springer.

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2. Print media monitoring – deployment

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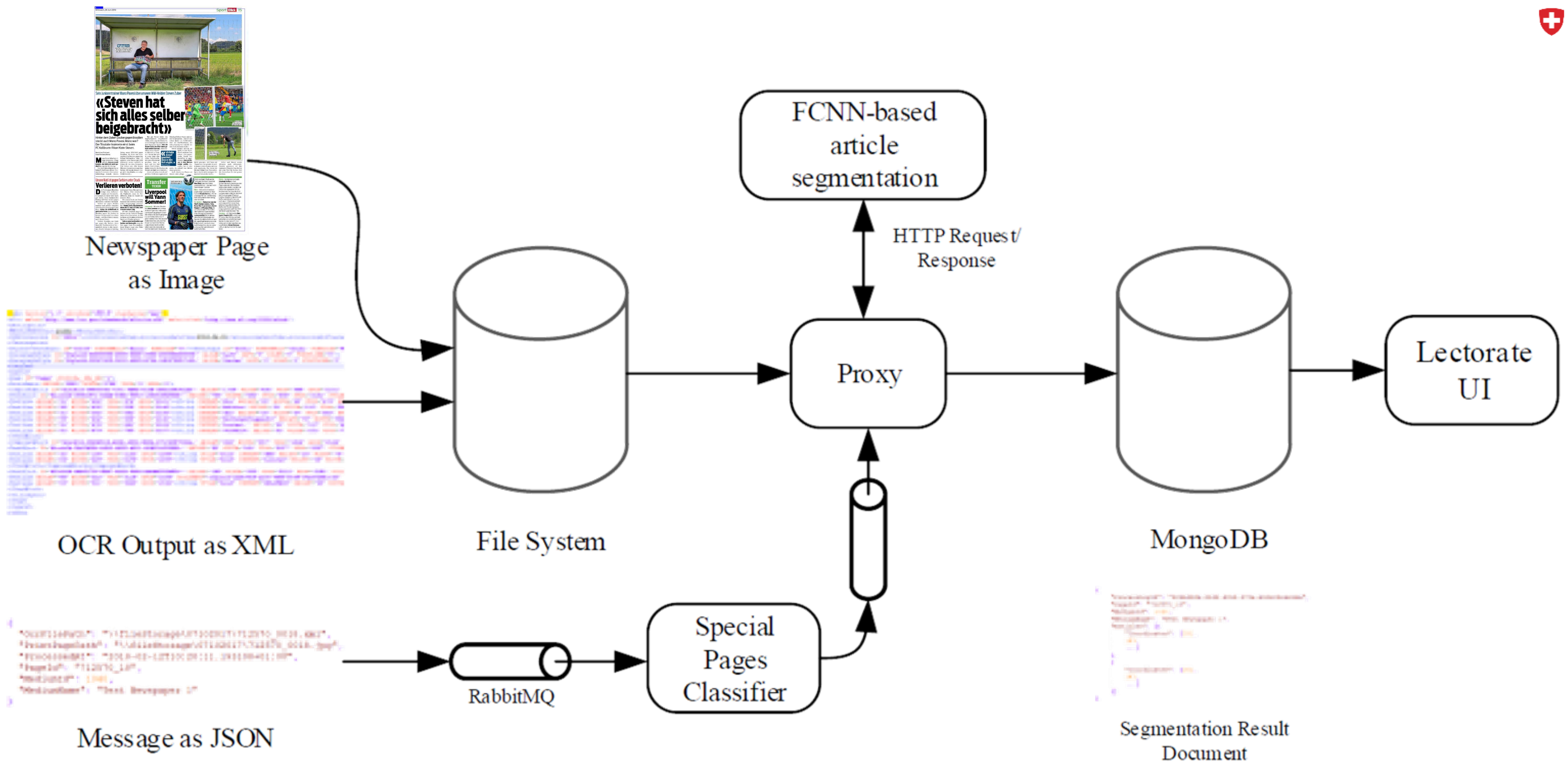

Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.

Lessons learned 2/4

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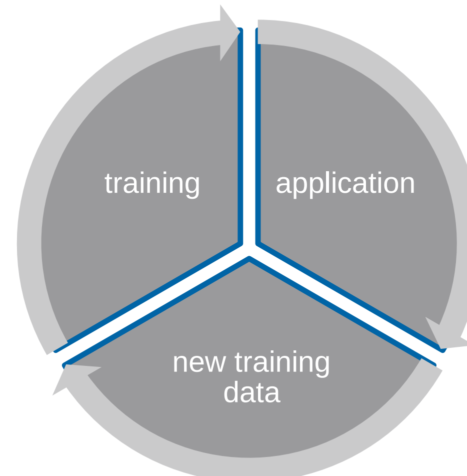
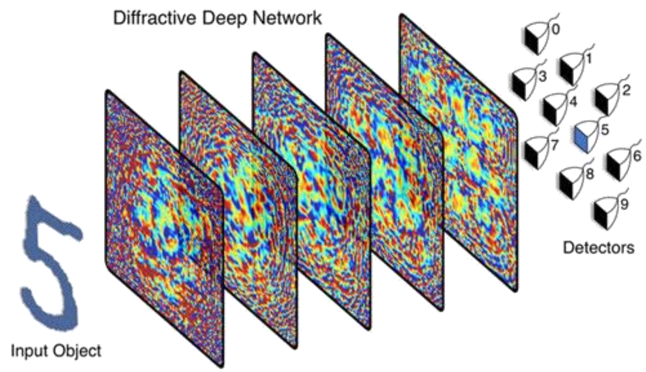
Deployment

- Should include **continuous learning**



- Needs to take care of **processing speed** / efficiency



Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.
Lin, Rivenson, Yardimci, Veli, Luo, Jarrahi & Oczan (2018). *«All-optical machine learning using diffractive deep neural networks»*. Science, 26. Jul 2018.

3. Industrial quality control

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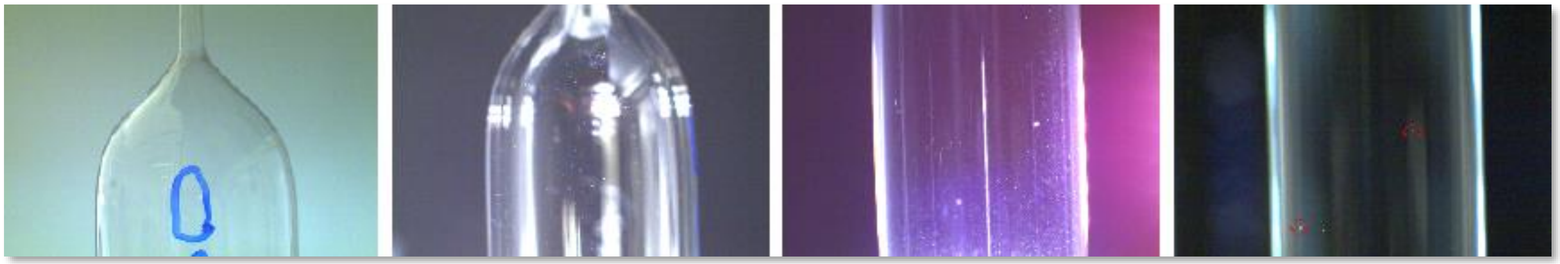
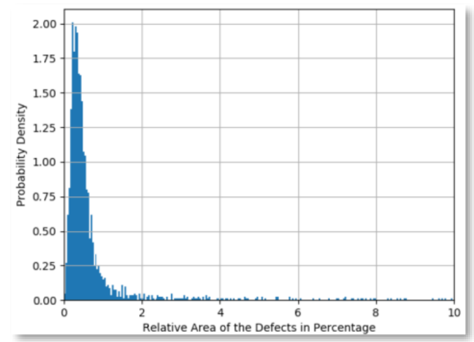
Task

- Reliably **sort out faulty balloon catheters** in image-based production quality control



Challenges

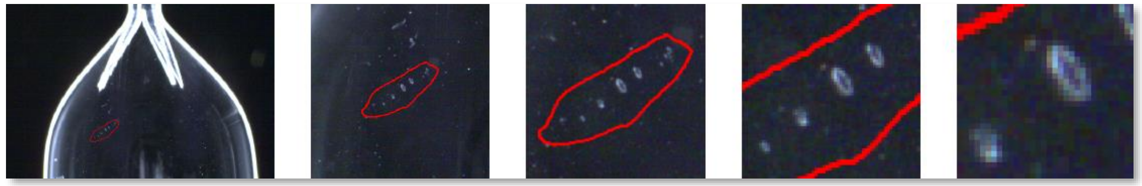
- **Non-natural** image source, class **imbalance**, **optic**al conditions, **variation** in defect size & shape



Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR’2018.

3. Industrial quality control – solutions
(Work in progress)

Ingredients
- Weighted loss
- Defect cropping
- Secret sauce



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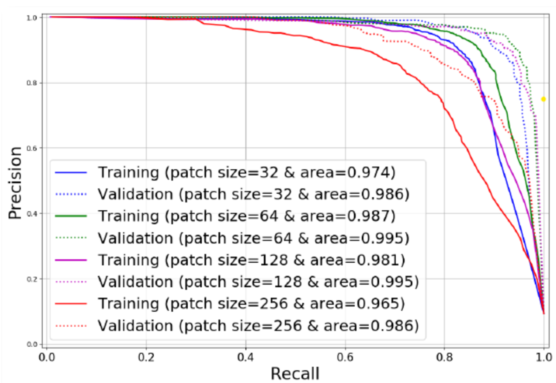
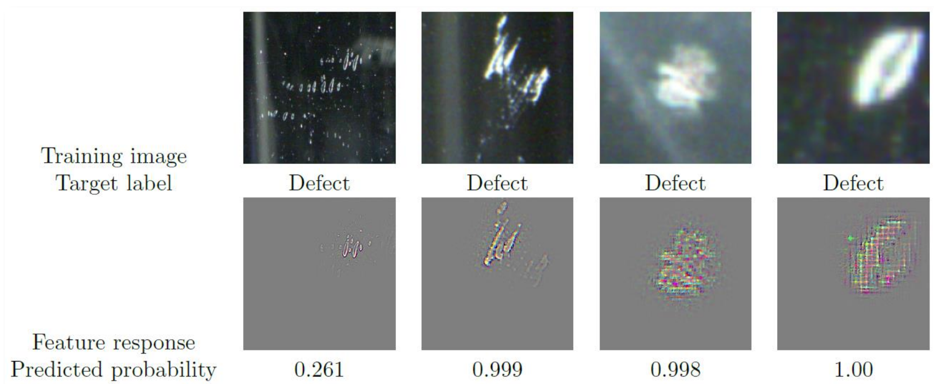
Preliminary results





Lessons learned 3/4

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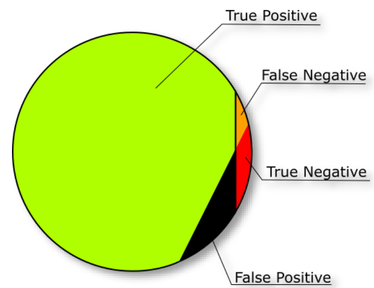
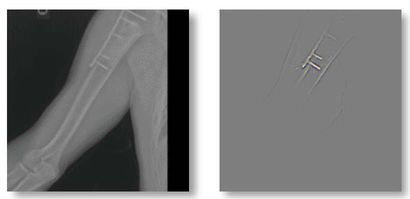
Data

- Acquisition usually **needs much more time** than expected, yet is the basis for all subsequent success
- Class **imbalance** & **covariate shift** are usual



Understanding

- **What has been learned** and **how decisions emerge** help both the user and the developer of neural networks to build trust and improve quality



- **Operators and business owners** need a basic understanding of used methods to produce usable ground truth and provide relevant subject matter expertise

Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.

Lessons learned 3/4 (contd.)

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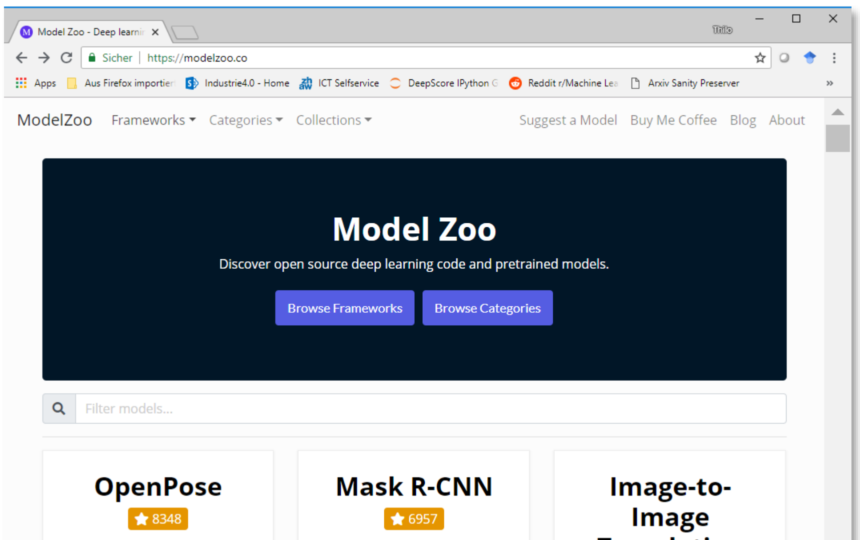
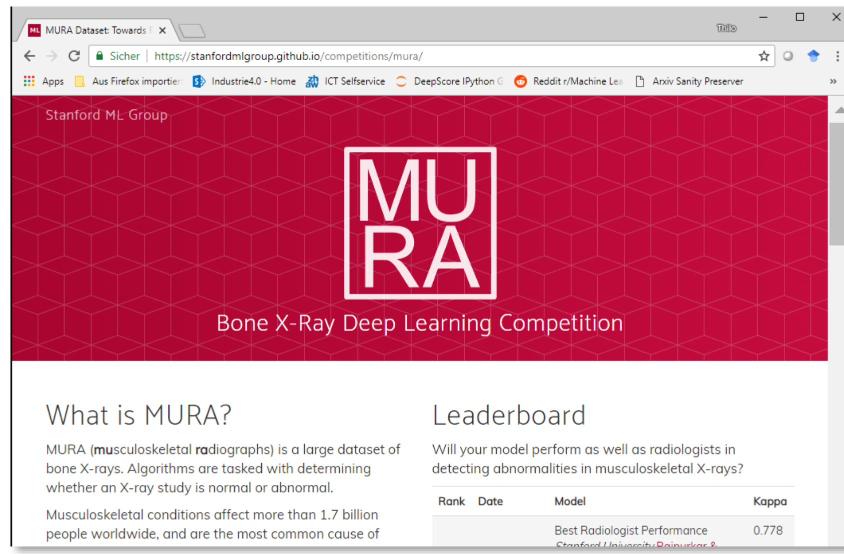
Simple baselines

- Do a good job in **determin**ing the **feasibility** as well as the **potential** of the task at hand when final datasets or novel methods are not yet seen





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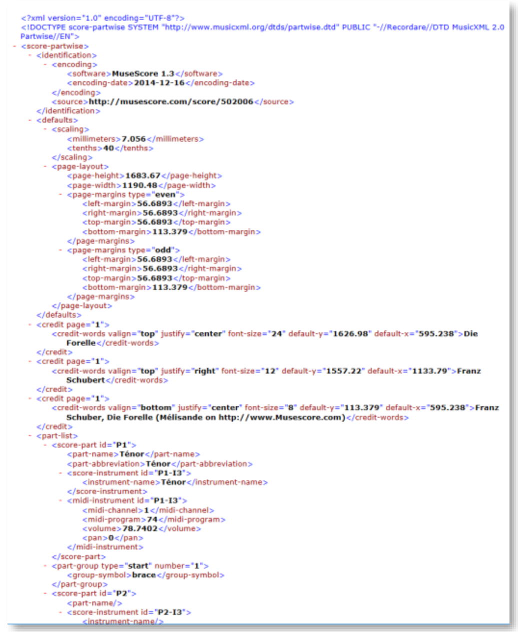
4. Music scanning



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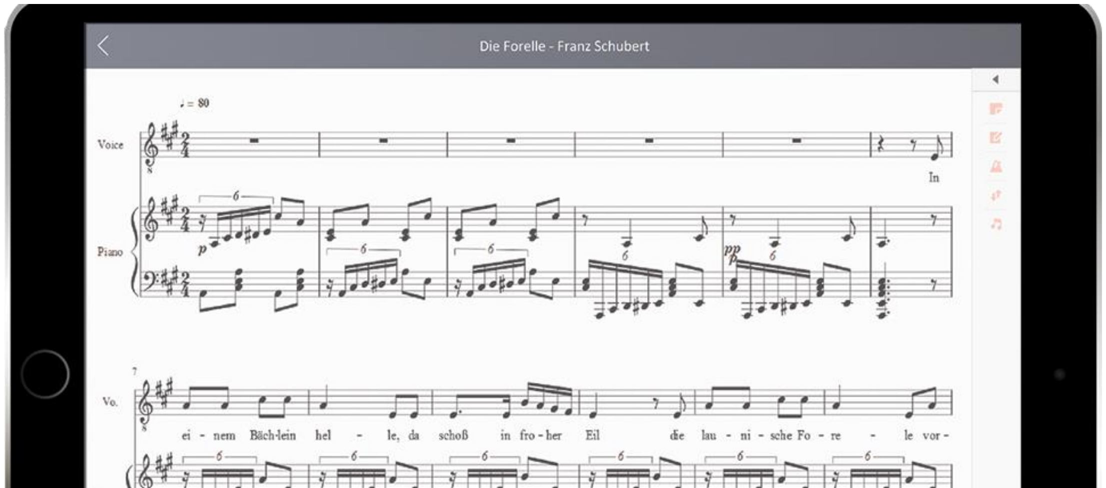

4. Music scanning – challenges & solutions

Tuggener, Elezi, Schmidhuber, Pelillo & Stadelmann (2018). *«DeepScores – A Dataset for Segmentation, Detection and Classification of Tiny Objects»*. ICPR'2018.

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4. Music scanning – challenges & solutions

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4. Music scanning – challenges & solutions

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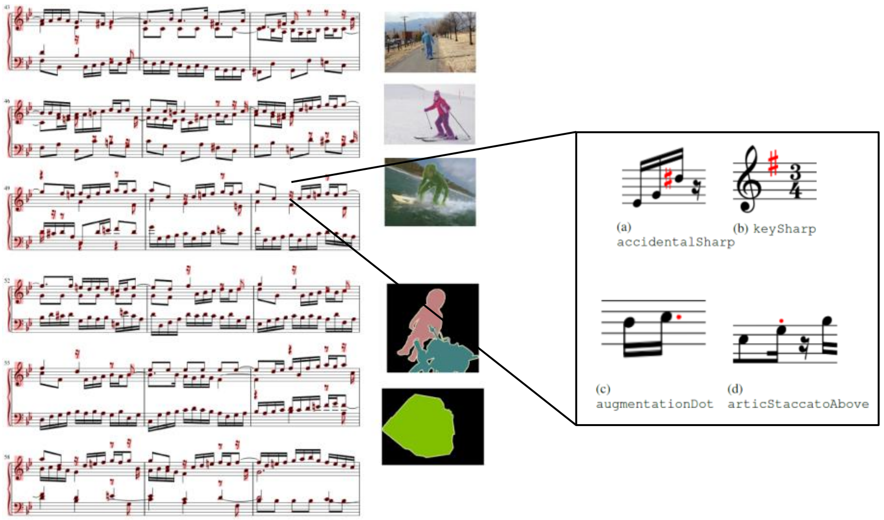

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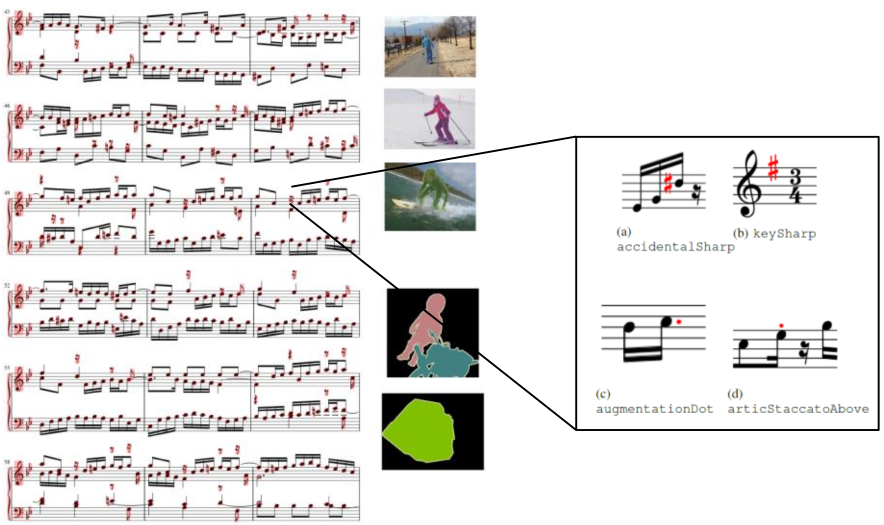

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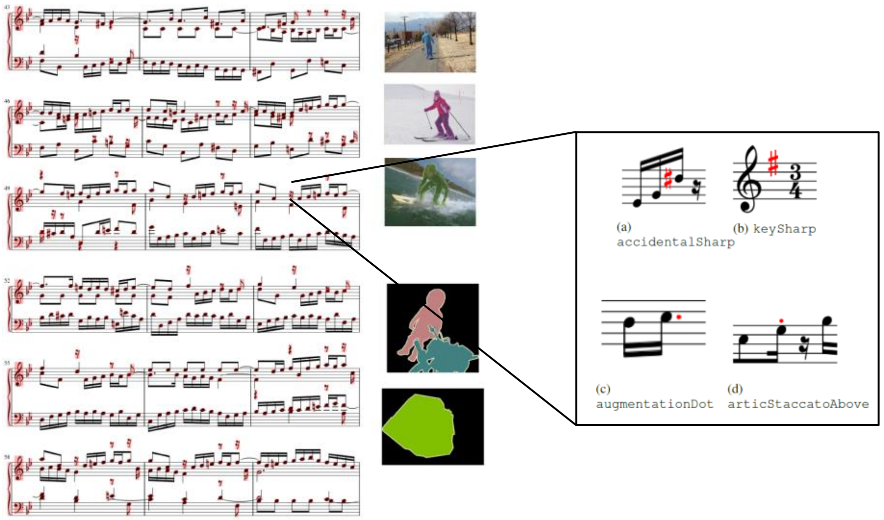

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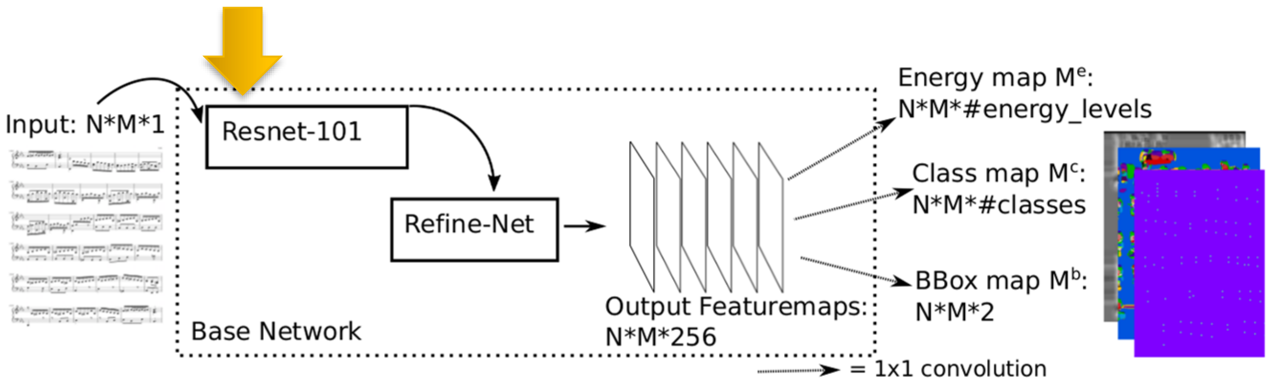
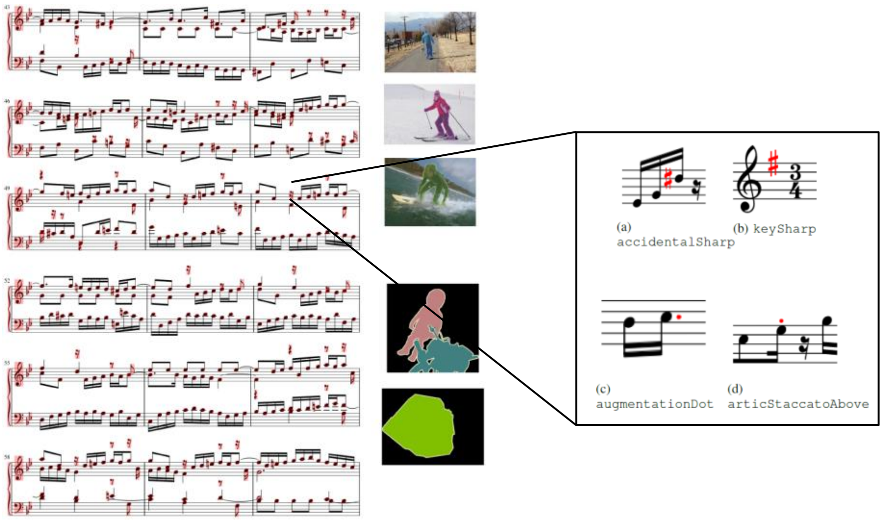


Tuggener, Elezi, Schmidhuber, Pelillo & Stadelmann (2018). *«DeepScores – A Dataset for Segmentation, Detection and Classification of Tiny Objects»*. ICPR'2018.
Tuggener, Elezi, Schmidhuber & Stadelmann (2018). *«Deep Watershed Detector for Music Object Recognition»*. ISMIR'2018.

4. Music scanning – challenges & solutions



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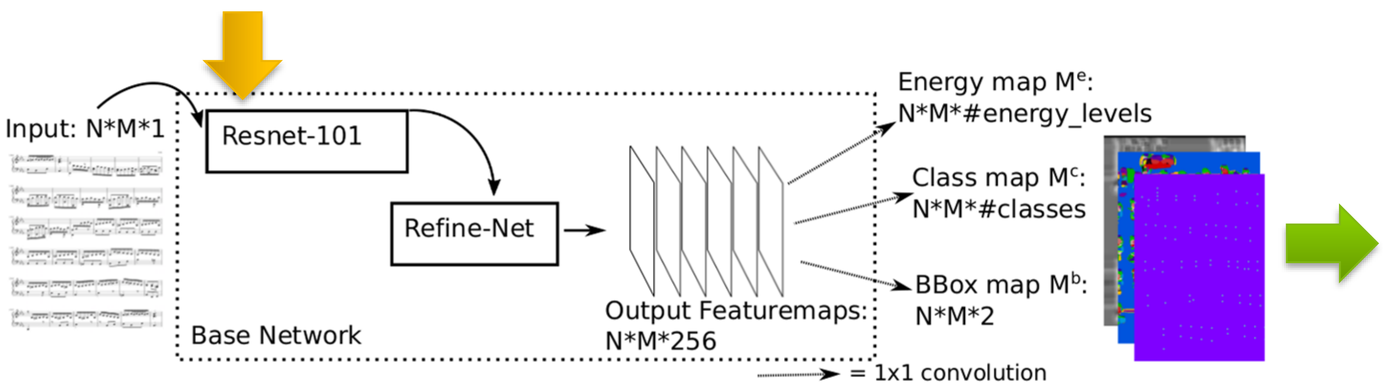

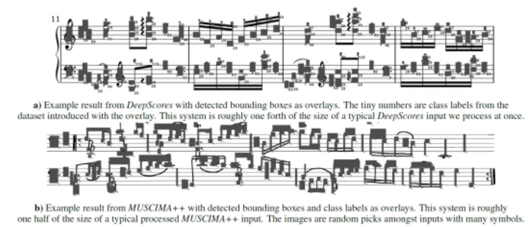

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Tuggener, Elezi, Schmidhuber & Stadelmann (2018). *«Deep Watershed Detector for Music Object Recognition»*. ISMIR'2018.

4. Music scanning – industrialization
(Work in progress)

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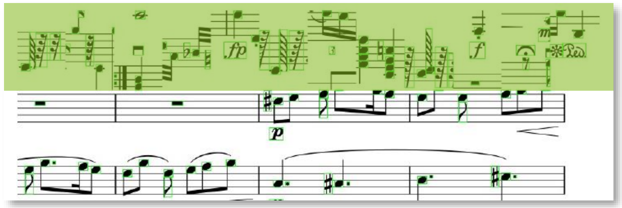
Recent results on class imbalance and robustness challenges

1. Added sophisticated **data augmentation** in every page's margins



2. Put additional effort (and compute) into hyperparameter **tuning** and **longer training**
3. Trained also on scanned (more **real-worldish**) scores

➔ **Improved mAP** from 16% (on purely synthetic data) **to 47.5%** on more challenging real-world data set (previous state of the art: 24.8%)

Elezi, Tuggener, Pelillo & Stadelmann (2018). *«DeepScores and Deep Watershed Detection: current state and open issues»*. WoRMS @ ISMIR'2018.
Pacha, Hajic, Calvo-Zaragoza (2018). *«A Baseline for General Music Object Detection with Deep Learning»*. Appl. Sci. 2018, 8, 1488, MDPI.

Lessons learned 4/4

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Loss shaping

- Usually necessary to enable learning of very complex target functions

*“Initially, the training was **unstable** […] if directly trained on the **combined weighted loss**. **Therefore**, we now **train** […] on each of the **three tasks separately**. We further observed that while the network gets trained on the bounding box prediction and classification, the energy level predictions get worse. To avoid this, the network is **fine-tuned only for the energy level loss** […]. Finally, the network is retrained on the combined task […] for a few thousand iterations […].”*

- This includes encoding expert knowledge manually into the model architecture or training setup

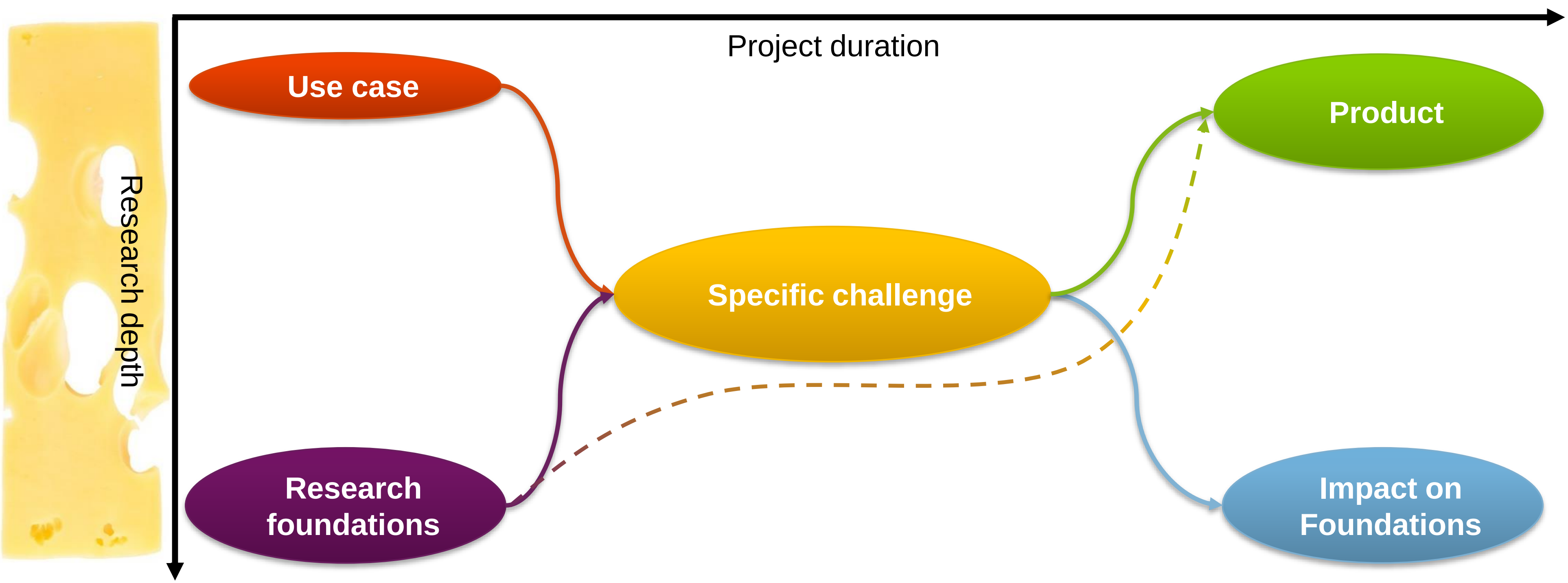
*“The **size of the anomaly** in classifying balloon catheters as good or bad is **quite decisive**. Thus, rescaling the training images is not allowed, and we used a fixed size window around the center of each defect to extract the training images.”*

Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR’2018.

Hypothesis: basic & applied research converge

Speed of "digital" innovation makes complementary skills necessary at the same time:

- Rigor to come up with completely new methodical approaches
- Creativity to solve completely new scenario, thereby "filling wholes"



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Conclusions

- Deep learning **is applied** and deployed in «normal» businesses (non-AI, SME)
- It does not need big-, but some **data** (**effort usually underestimated**)
- DL/RL **training** for new use cases **can be tricky** (→ needs thorough experimentation)
- The **simultaneity** of research **types A$^{\mathbf{pplied}}$ and B$^{\mathbf{asic}}$** speaks out loud for **collaboration**

datalab
www.zhaw.ch/datalab

swiss group for artificial intelligence and cognitive science

Swiss Alliance for Data-Intensive Services

On me:

- Prof. AI/ML, head ZHAW Datalab, board SGAICO & Data+Service
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- +41 58 934 72 08
- https://stdm.github.io/

On the topics:

- AI: https://sgaico.swissinformatics.org/
- Data+Service Alliance: www.data-service-alliance.ch
- Collaboration: datalab@zhaw.ch

→ Happy to answer questions & requests.

APPENDIX

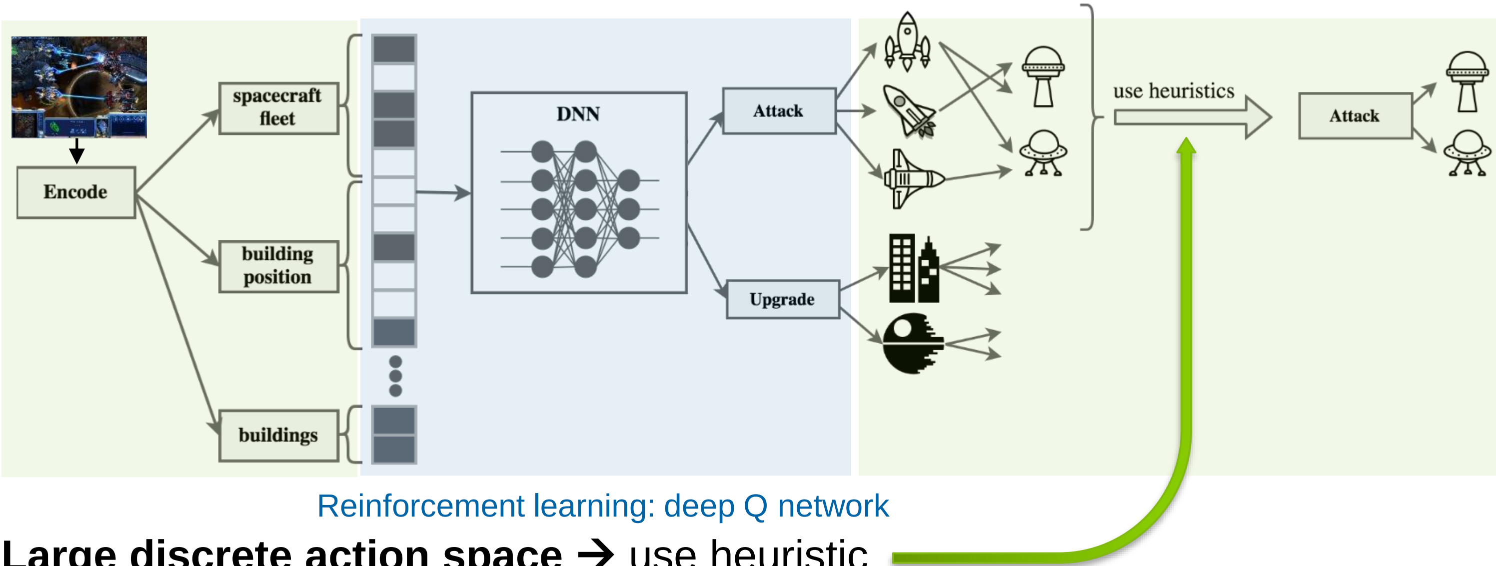
Zürcher Hochschule
für Angewandte Wissenschaften

5. Game playing
(work in progress)

GIANTS SOFTWARE
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Innosuisse – Swiss Innovation Agency

(symbolic figure)

5. Game playing – challenges & solutions
(work in progress)



Reinforcement learning: deep Q network

**Large discrete action space → ** use heuristic
- makes exploration difficult
- elongates training time

**Delayed and sparse reward → ** do reward shaping
- sequence of actions crucial to get a reward

**Distance encoding → ** use reference points

**Transfer Learning → ** difficult: more complex environment needs other action sequence

Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.

6. Automated machine learning
(work in progress)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Innosuisse – Swiss Innovation Agency

The project

- Target: inhouse solution of industrial partner to improve turnover in standard analytics projects
- Challenge: optimize hyperparameters smarter than with well initialized random perturbations
- Idea: use reinforcement learning to meta-learn from past analytics projects

Initial experiments

			Auto-Sklearn		TPOT		DSM	
Dataset	**Task**	**Metric**	**Validation**	**Test**	**Validation**	**Test**	**Validation**	**Test**
Cadata	Regression	Coefficient Of Determination	0.7913	0.7801	**0.8245**	**0.8017**	0.7078	0.7119
Christine	Binary Classification	Balanced Accuracy Score	0.7380	0.7405	**0.7435**	**0.7454**	0.7362	0.7146
Digits	Multiclass Classification	Balanced Accuracy Score	**0.9560**	**0.9556**	0.9500	0.9458	0.8900	0.8751
Fabert	Multiclass Classification	Accuracy Score	**0.7245**	**0.7193**	0.7172	0.7006	0.7112	0.6942
Helena	Multiclass Classification	Balanced Accuracy Score	**0.3404**	**0.3434**	0.2654	0.2667	0.2085	0.2103
Jasmine	Binary Classification	Balanced Accuracy Score	0.7987	0.8348	**0.8188**	0.8281	0.8020	**0.8371**
Madeline	Binary Classification	Balanced Accuracy Score	**0.8917**	**0.8769**	0.8885	0.8620	0.7707	0.7686
Philippine	Binary Classification	Balanced Accuracy Score	0.7787	0.7486	**0.7839**	**0.7646**	0.7581	0.7406
Sylvine	Binary Classification	Balanced Accuracy Score	0.9414	0.9454	**0.9512**	**0.9493**	0.9414	0.9233
Volkert	Multiclass Classification	Accuracy Score	**0.7174**	**0.7101**	0.6429	0.6327	0.5220	0.5153
Average Performance			**0.7678**	**0.7654**	0.7586	0.7497	0.7048	0.6991

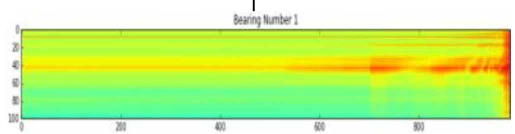
Stadelmann, Amirian, Arabaci, Arnold, Duivesteijn, Elezi, Geiger, Lörwald, Meier, Rombach & Tuggener (2018). *«Deep Learning in the Wild»*. ANNPR'2018.

7. Condition monitoring
Maintaining machines on predicted failure only

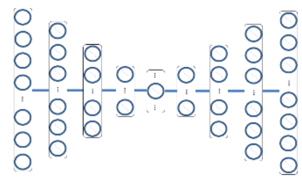
We use machine learning approaches for anomaly detection to learn the normal state of each machine and deviations of it purely from observed sensor signals; the approach combines classic and industry-proven features with e.g. deep learning auto-encoders.

vibration sensors

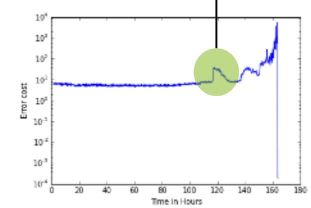
feature extraction



e.g., RNN autoencoder

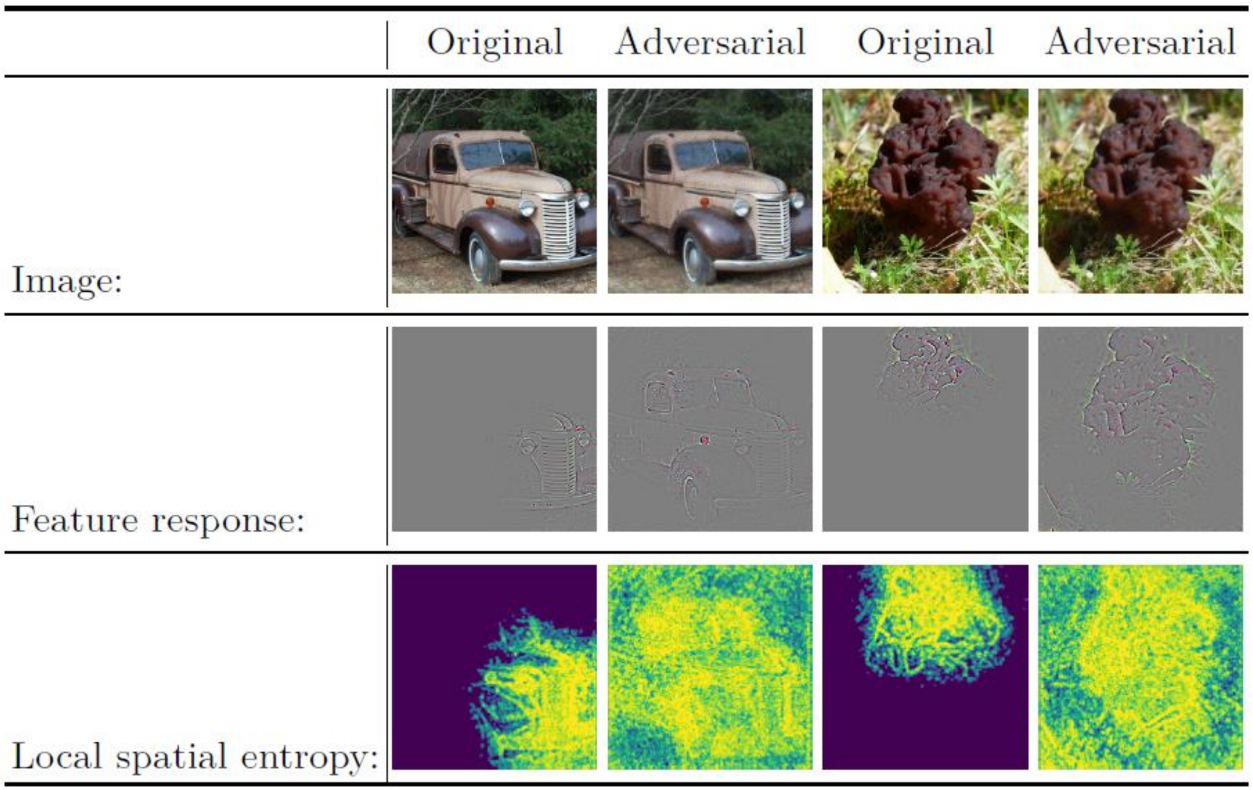


early detection of fault



Stadelmann, Tolkachev, Sick, Stampfli & Dürr (2018). «*Beyond ImageNet - Deep Learning in Industrial Practice*». In: Braschler et al., «Applied Data Science», Springer.

8. Trace & detect adversarial attacks
…using average local spatial entropy of feature response maps



Amirian, Schwenker & Stadelmann (2018). *«Trace and Detect Adversarial Attacks on CNNs using Feature Response Maps»*. ANNPR'2018.

ML @ Information Engineering Group

Institute of Applied Information Technology, ZHAW School of Engineering

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Machine learning-based
Pattern Recognition

- Robust Deep Learning
- Voice Recognition
- Document Analysis
- Learning to Learn & Control