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Trusting Artificial Intelligence in Safety Critical Systems - towards a comprehensive verification framework

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Winterthur, Switzerland

1. Introduction

About Me

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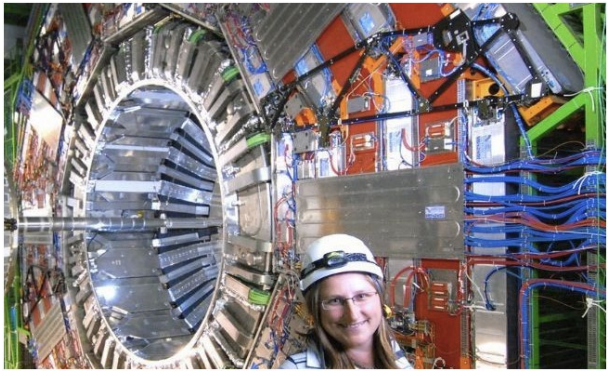

10 years in research in Particle Physics@CERN, Geneva Switzerland

- Commissioning & monitoring of CMS detector
- Data analysis of first LHC collider data
- Discovery of Higgs Boson

Safety analysis & project management @NPP Mühleberg

- Probabilistic Safety Analysis
- First Swiss decommissioning safety analysis
- Presenting results to Swiss regulator

Zurich University of Applied Sciences (ZHAW)

School of Engineering

Senior Lecturer (Mathematics & Physics) & Applied Research:

- Safety-Critical Systems (SKS) group
- Associate Faculty Centre of AI (CAI)
  close collaboration with AI experts
- **TÜV Certified Functional Safety Engineer**
- **IEEE CertifAIEd Lead Assessor**

IEEE SA

TÜVRheinland®
Precisely Right.

Mission: Applied research projects in safety critical systems together with industry partner, research facilities or governmental agencies.

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CAI Centre for Artificial Intelligence

Research Funding: Directly by industry partners or national/international funding agencies

2. Example Project: ESS

European Spallation Source (ESS)

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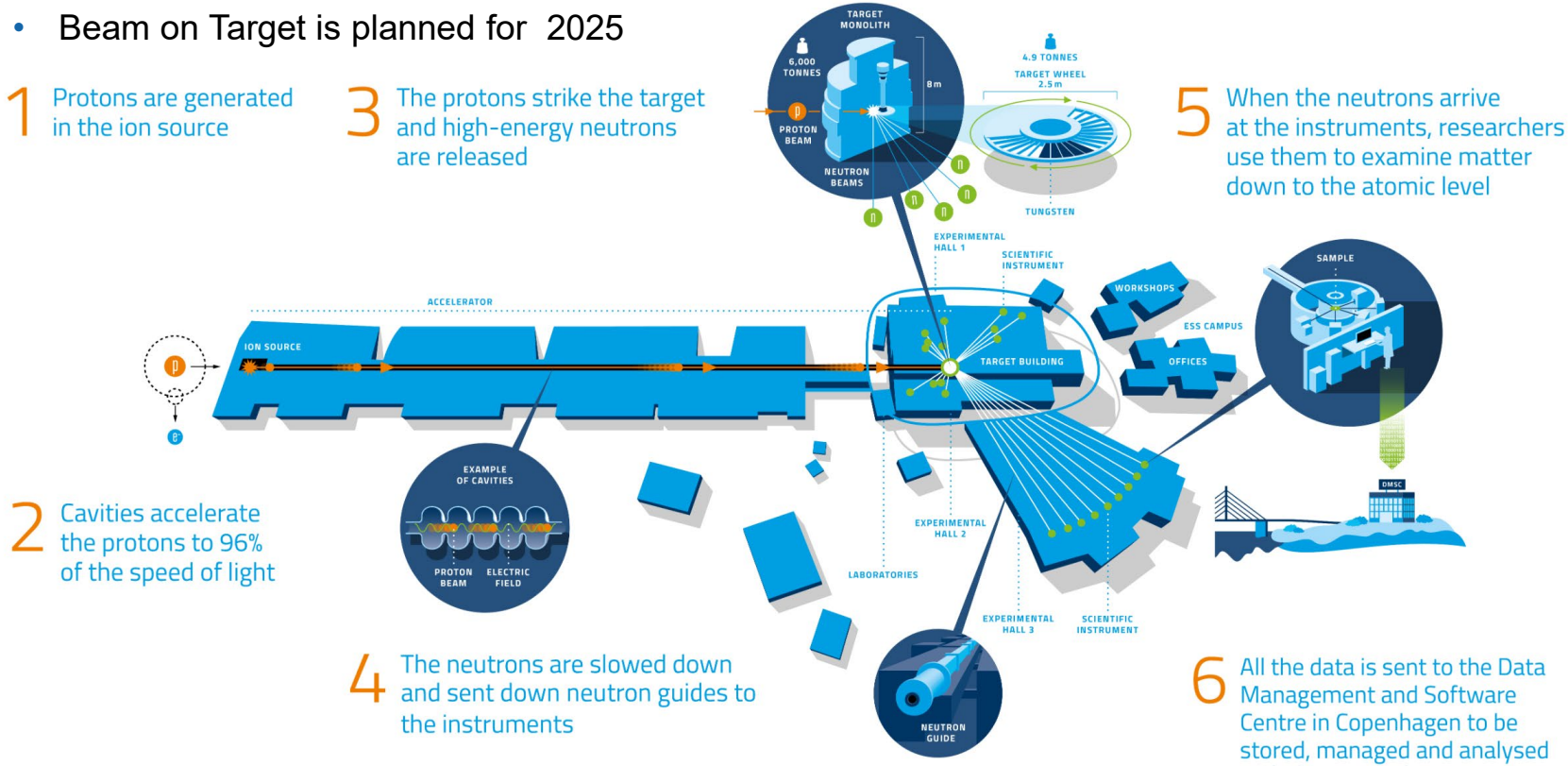
- ESS (Lund, Sweden) will be the brightest Neutron Source worldwide
- Beam on Target is planned for 2025



ESS Project

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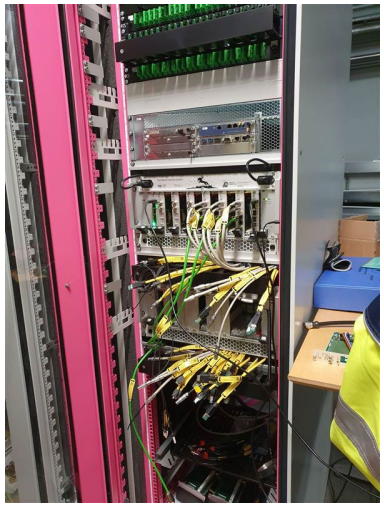
Successful collaboration with ESS since 2015:
(https://europeanspallationsource.se/)

- Designed, build and tested a distributed Fast Beam Interlock System (**FBIS**) in our lab at ZHAW
- Developed verification for FBIS modules (Hardware in the Loop (HIL) simulation)
- Performed FBIS Hardware Integrity assessment (Functional Safety Standards IEC61508, IEC61511)
- Support in Machine Protection System (MPS) Design and Reliability Assessment (FTA, RBD, ET)
- Design and Functional Safety assessment of ESS Personal Safety System (PSS) as externa assessor
- Support towards Swedish regulator in Licencing Process



FBIS

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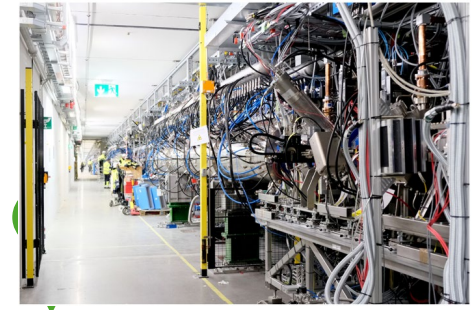

Pilot project APBIS: Autonomous Predictive Beam Interlock System@ESS

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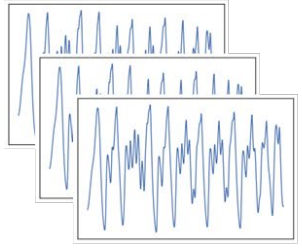
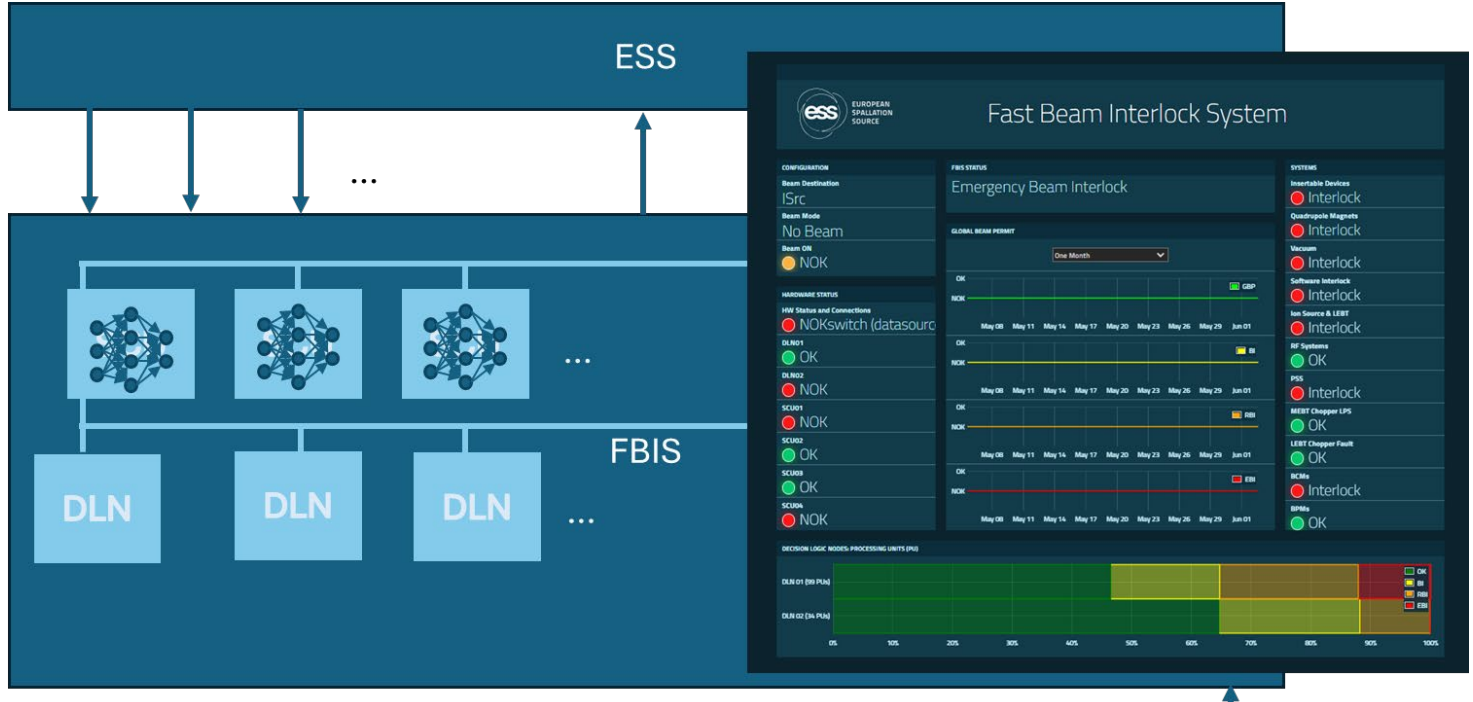
- Machine-learning model capable of analyzing sequential data streams in real-time
- ML-model is implemented on existing FBIS hardware (FPGAs)
- Assist FBIS in predicting the beam behavior
- Detect unwanted system conditions for further analysis purposes (anomaly detection)

ESS Sensor Inputs



APBIS



Additional Sensor Input to FBIS from APBIS

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3. Research on AI in in Safety Critical Systems: Verification& Certification

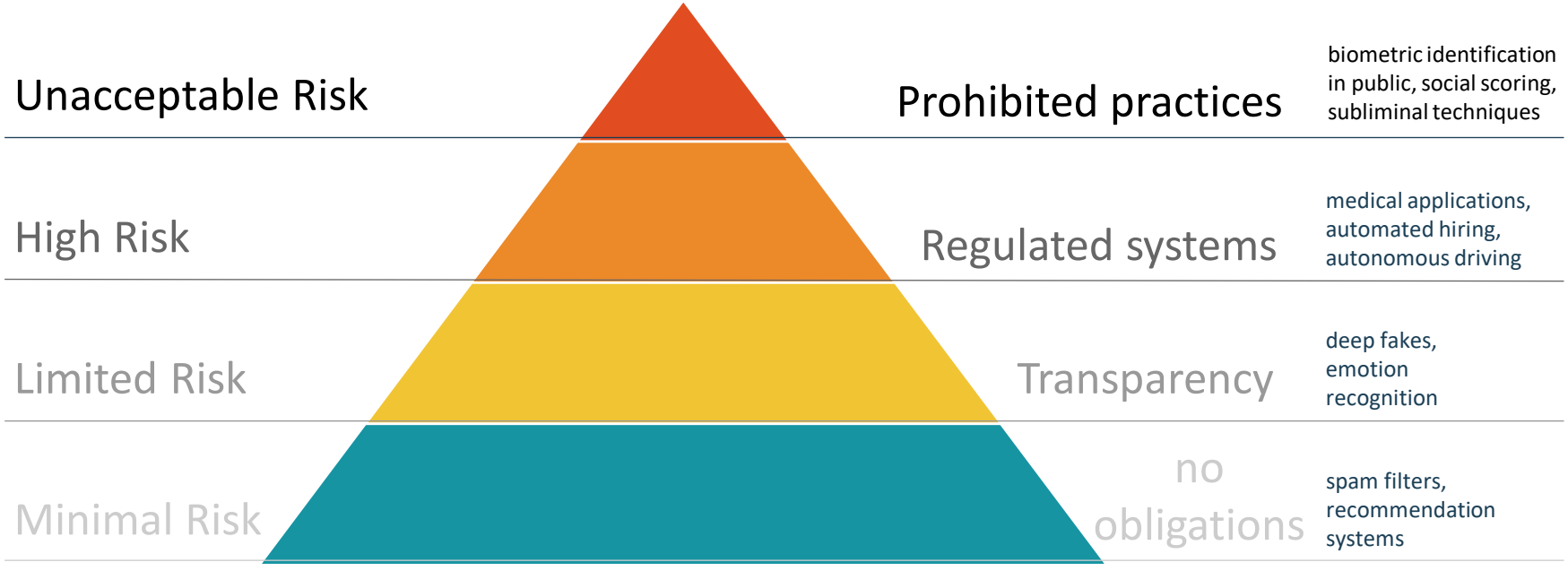
The EU AI Act

- After final approval by the Council of the EU on May 21, 2024, the EU AI Act is now set to be published in the EU's Official Journal.
- The EU AI Act will enter into force on the 20th day after publication
- Companies will have **2-3 years** to adapt to the regulation if they want to access the EU market

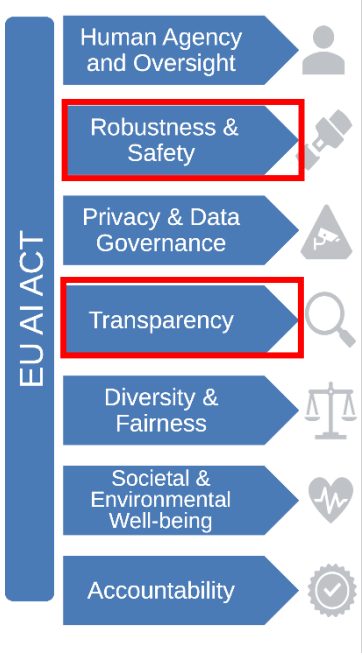
EU AI Act follows risk-based approach:

High risk systems (e.g. AI systems in critical infrastructure) will be **regulated**.

EU AI Act: Risk-based approach



EU AI Act: Dimensions of trustworthy AI



What degree of **autonomy** is appropriate?

Is the behaviour of the AI component **consistent** and **functionally safe**?
How does it hold up against **attacks**?

Do the (training and input) data protect **privacy** and **company secrets**?

Are the AI functions and decisions made by the AI **comprehensible**?

Are **minorities** fairly treated?

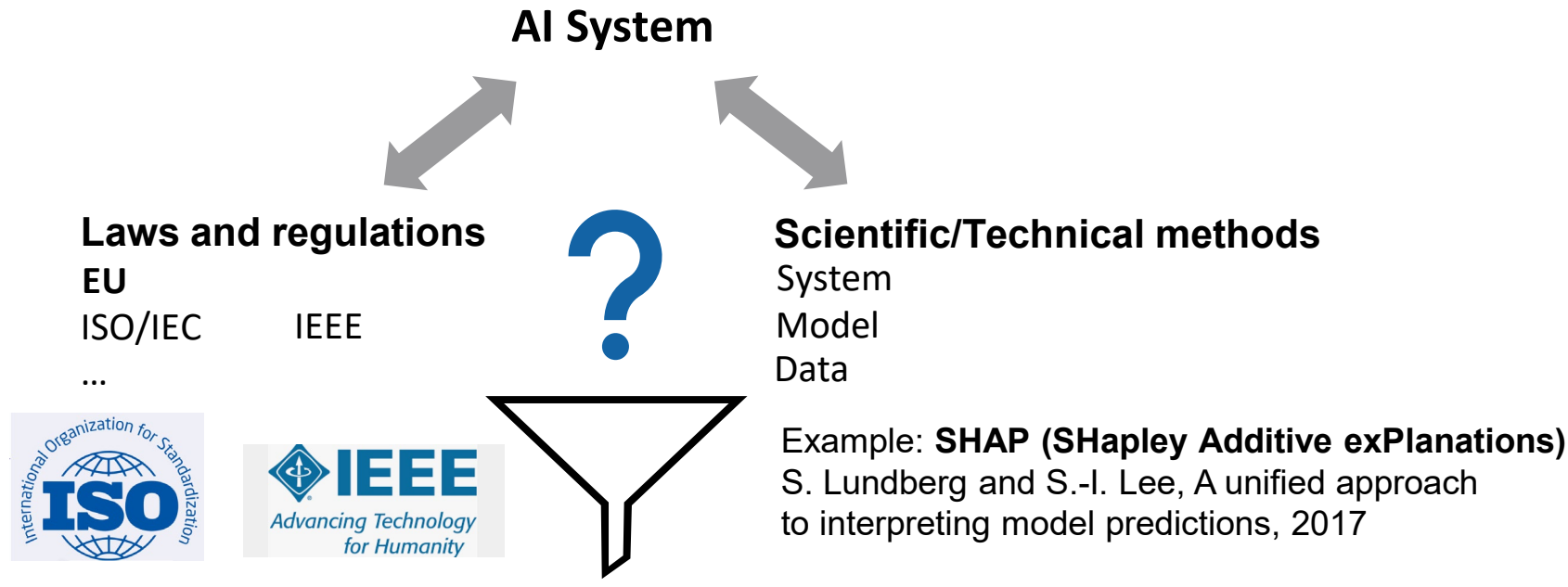
What is the **impact** on society and the environment?

Who is responsible for the correct **development**, **deployment**, and **operation**?

Bridging the Gap

There is a s gap between current (developing) **regulations** for AI trustworthiness and **concrete guidelines** including **scientific methods.**

Our research aims to bridge this gap.



Project certAInty

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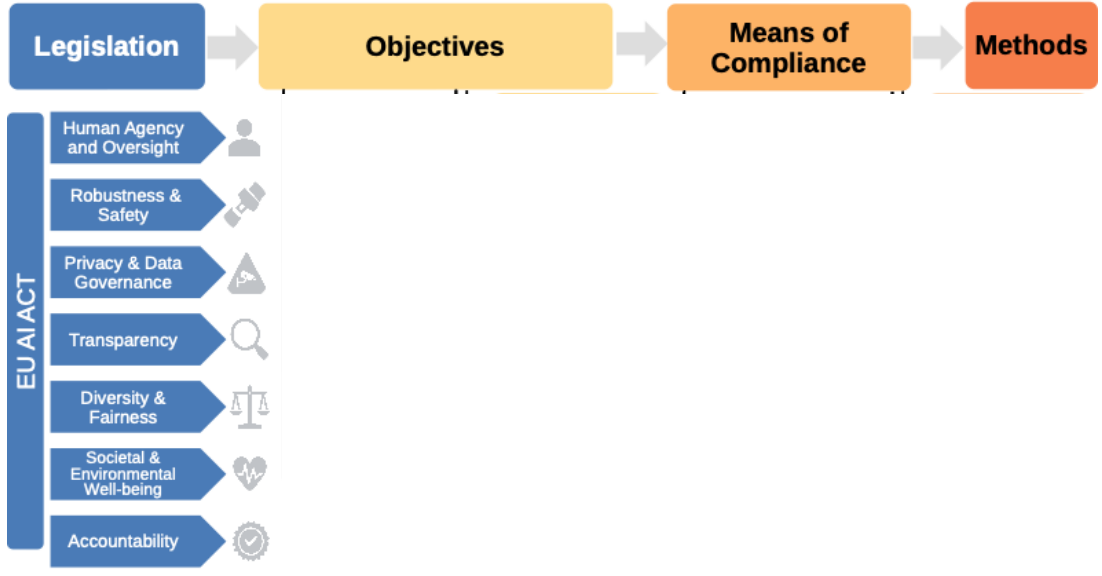
Development of a **certification scheme** for AI-based systems (together with Swiss certification company CertX as research partner)

- Dimensions for trustworthy AI in line with the EU AI act



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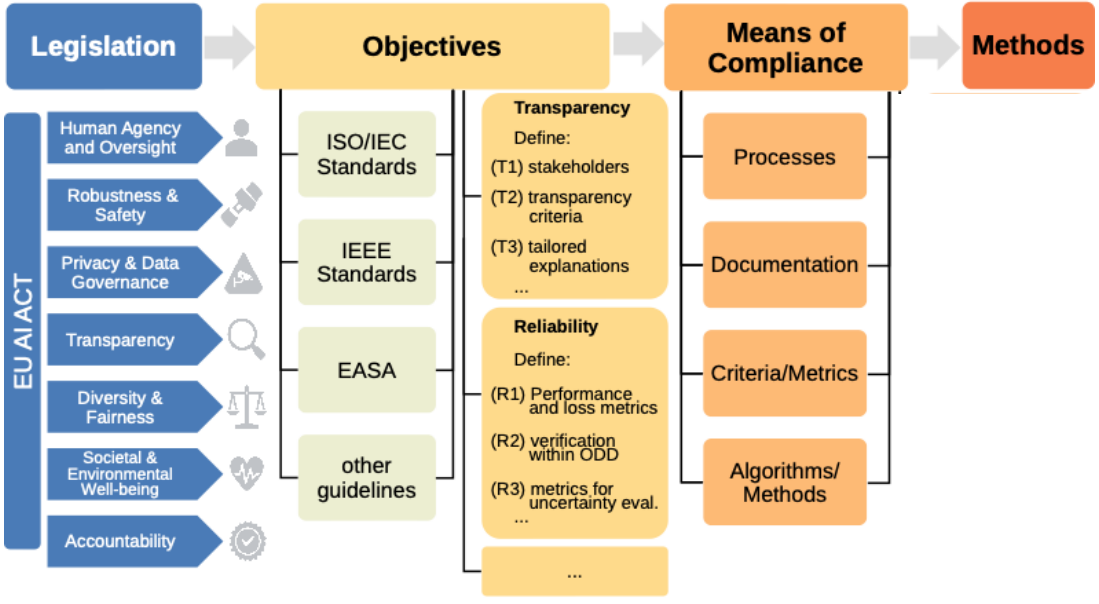
Project certAInty

School of Engineering

Development of a **certification scheme** for AI-based systems

- Objectives and Means of Compliance derived from these legal obligations and standards



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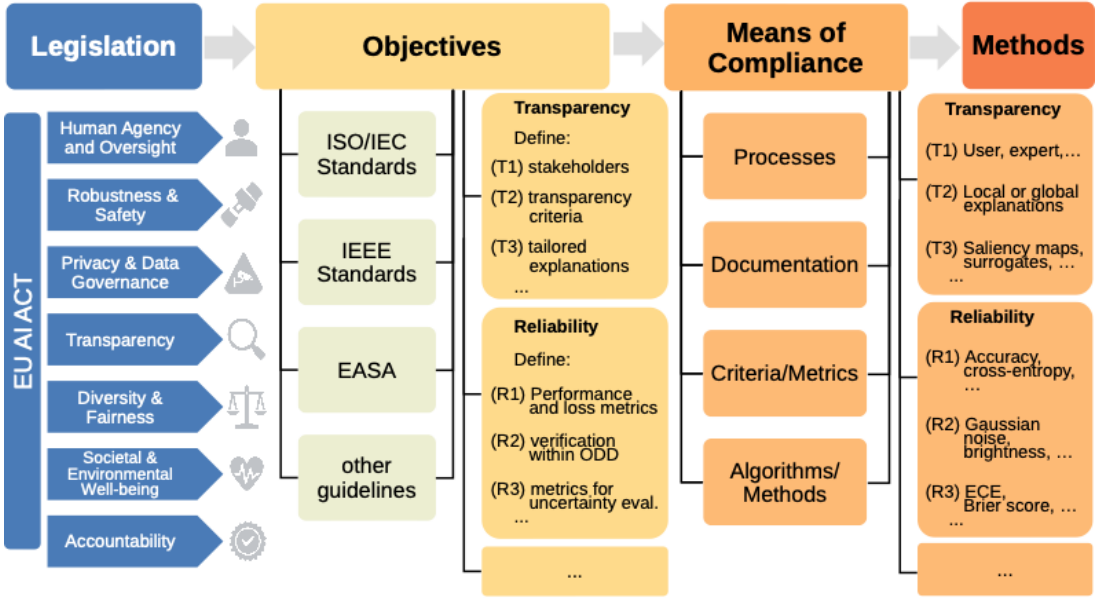
Project certAInty

School of Engineering

Development of a certification scheme for AI-based systems

- Link between objectives and technical methods



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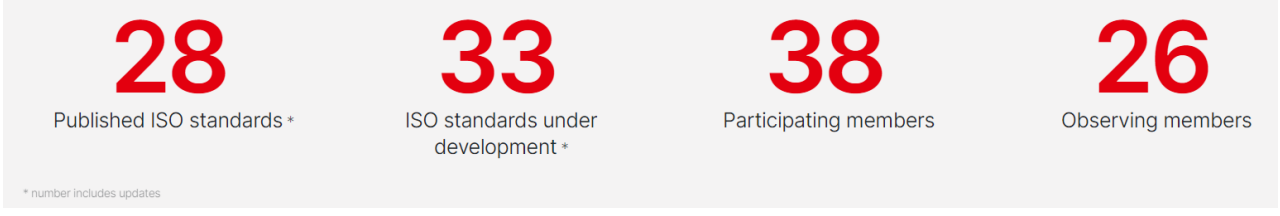
Example standards: ISO/IEC

The International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) are global organizations that develop and publish international standards for a wide range of industries.

Focus

Sociotechnical systems
Technical standards

Topics of EU AI act covered (JTC 1/SC 42)



ISO/IEC

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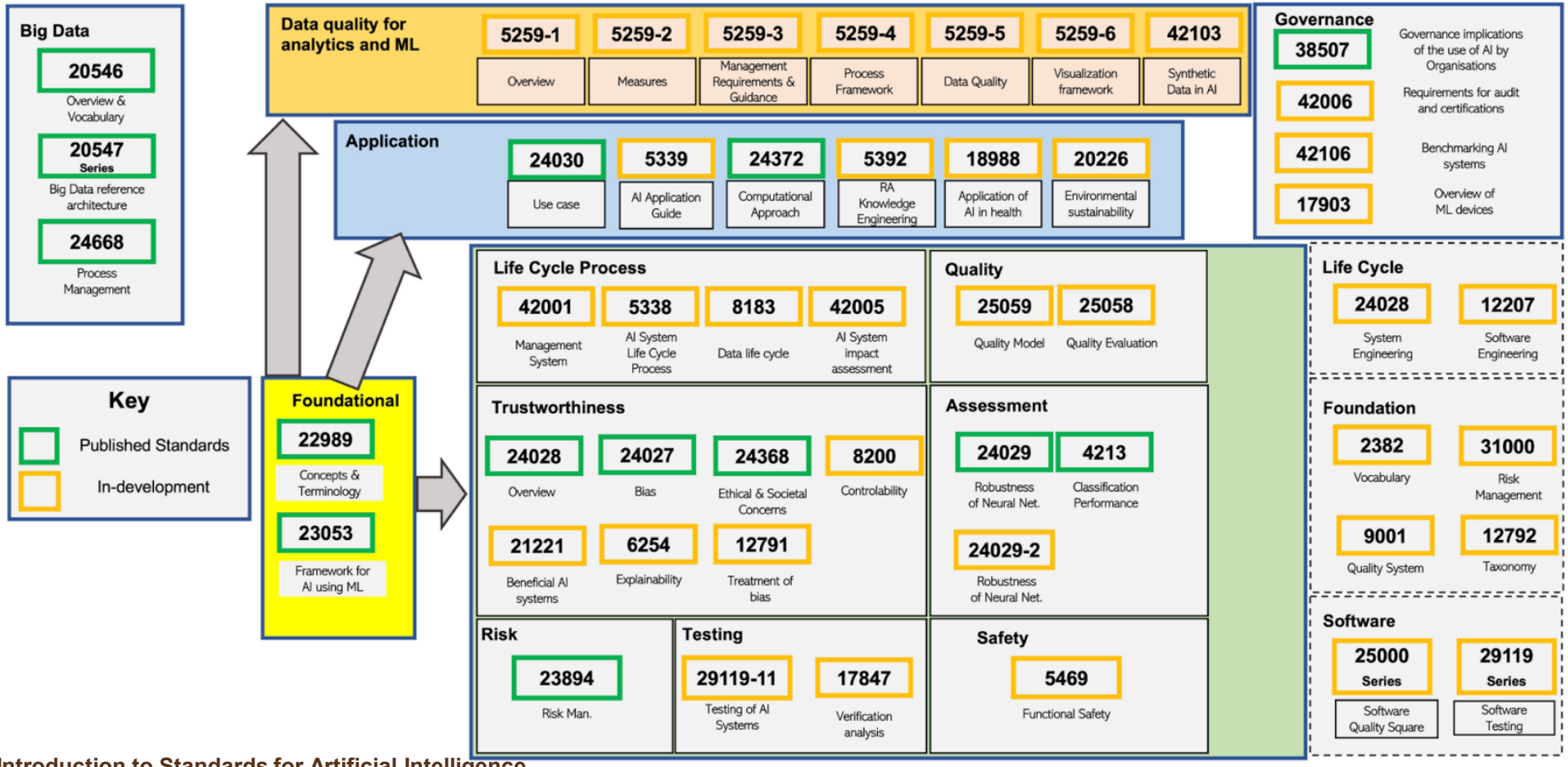


Ref.: Introduction to Standards for Artificial Intelligence

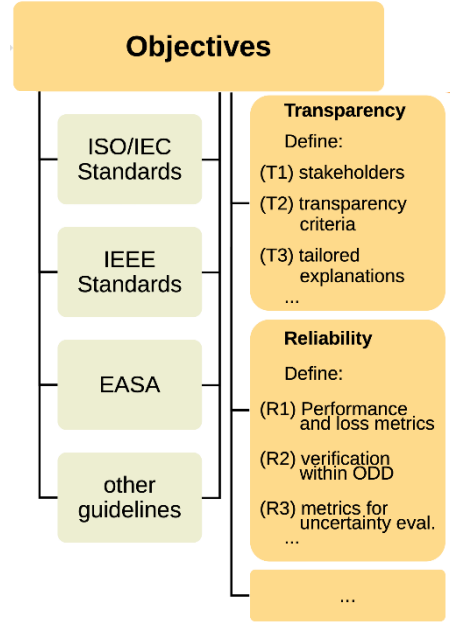
Certification Scheme: Objectives

Objectives based on different **standards and guidelines**
(38 documents in total)

- ISO/IEC
- IEEE
- EASA
- Fraunhofer Institute

Objectives specified for **specific** trustworthiness **dimensions**, e.g.

- Transparency objective (29 objectives)
  Example: Define transparency criteria for stakeholders
- Reliability objective (44 objectives):
  Example: Demonstrate robust behaviour against relevant perturbations



Certification Scheme: Means of Compliance and Methods

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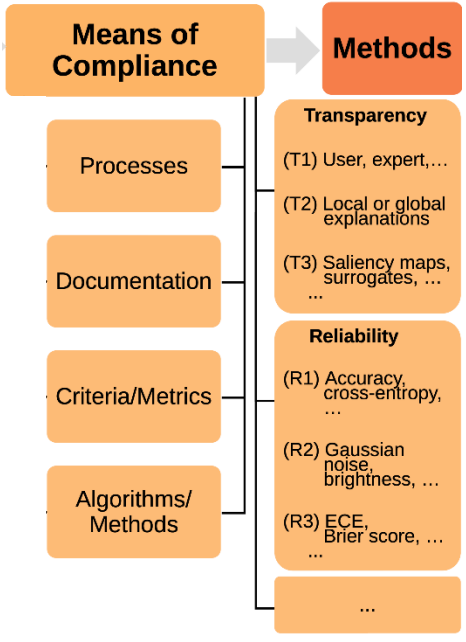
- Set of **means** to achieve **compliance with objectives** (29 + 44 objectives)
- Linked Means of Compliance (100 + 156 means of compliance)
- **Criteria/metrics for assessing means of compliance** (55 in total)
  - Qualitative criteria
  - Quantitative metrics
- **Algorithms/technical methods** (95 in total)
  Goal: providing compliance with objectives/criteria/metrics for different trustworthiness dimensions, e.g.
  - *Transparency*: LIME, SHAP, …
  - *Reliability*: perturbations, symbolic abstractions, ...



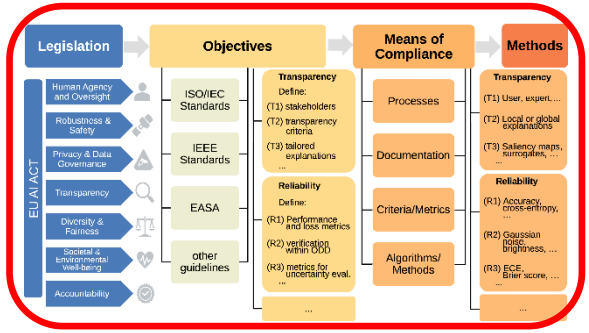
4. Example Use Case

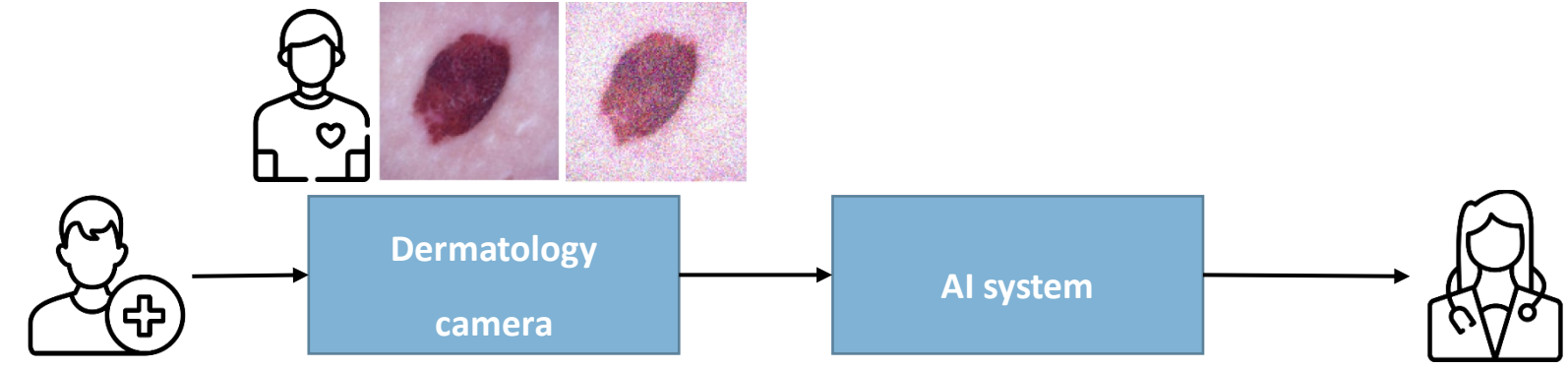
Use case

Third party use cases with industry (high and limited risk, computer vision) – **confidential**

Exemplary use case (high risk): **Skin lesion classification**

- Benign and malignant skin lesions

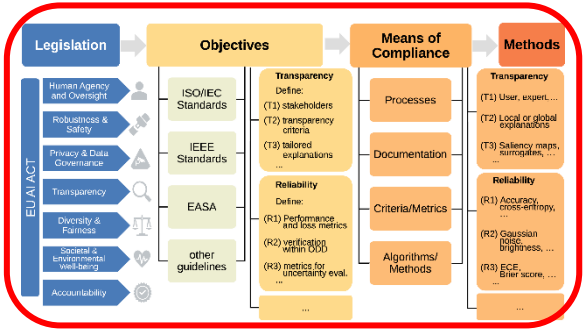


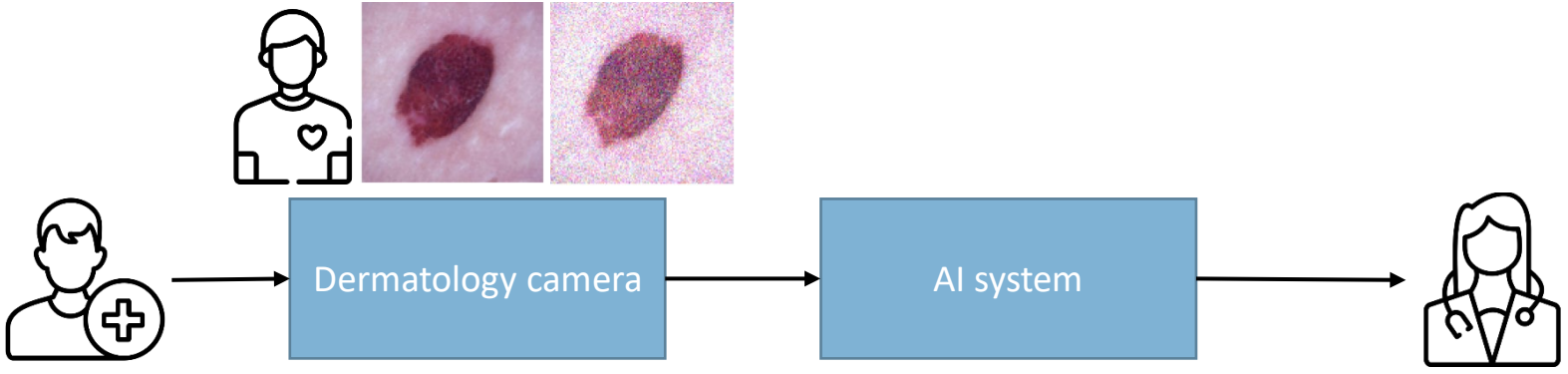


Use case

AI system must be **reliable** and **transparent**

- High risk
- **Need for certification** (compliance with objectives)





Reliability dimension

Reliability vs. Robustness

- **Reliability** = Property of **consistent intended** behaviour and results
- **Robustness** = Ability of an AI system to maintain its level of performance **under any circumstances**

Reliability includes **different aspects** within the certification scheme, e.g.:

- Data coverage
- Robustness
- Uncertainty

Reliability: Data coverage and Robustness

Objective (data coverage):
Data coverage of the Operational Design Domain (ODD)

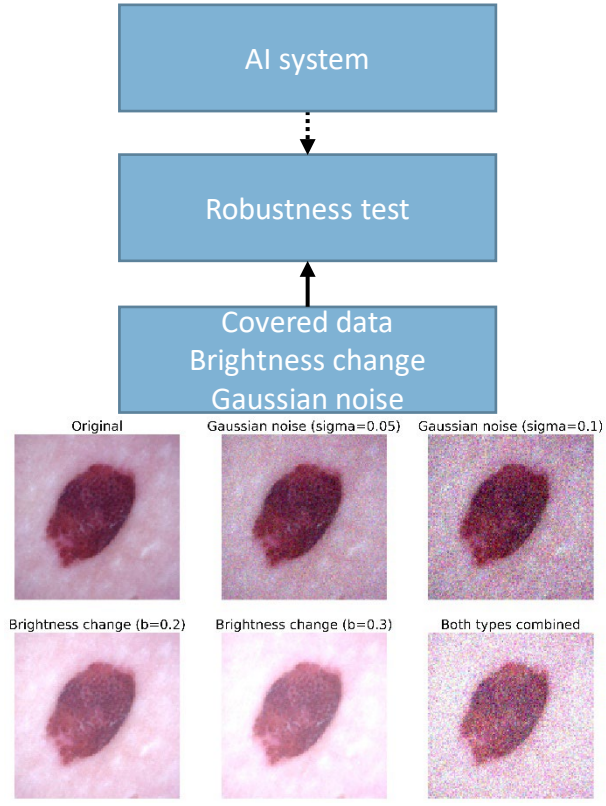
- ODD contains all application relevant perturbations including their intensity
- Area where the AI system must function reliably and robustly

Means of compliance:
Simulation of the relevant perturbations

Objective (robustness):
Robust behaviour against ODD relevant perturbations

Means of compliance:
Robustness tests

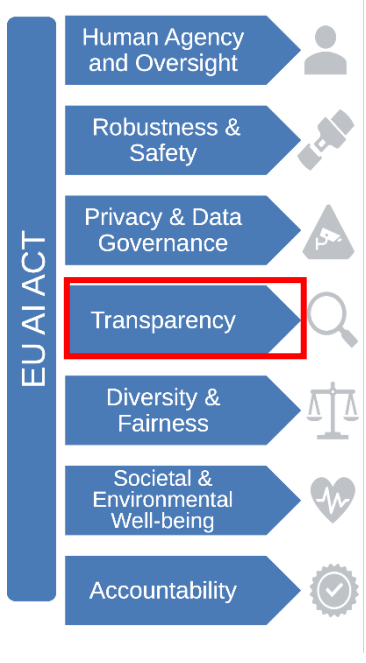
- Confidence interval (CI) tests
- Symbolic abstractions
- Exhaustive search (with constraints)



Robustness tests typically use the ODD data (original or simulated) as input to assess the robustness of the AI system

Transparency dimension

- Is the decision by the AI system **comprehensible**?
- What **stakeholders** are involved, what are their requirements?
- Does the AI system provide appropriate **explanations**?
  Pertaining to the data, model behaviour (**global**), or output (**local**)?
- Explanations: What **features** mainly caused a decision?

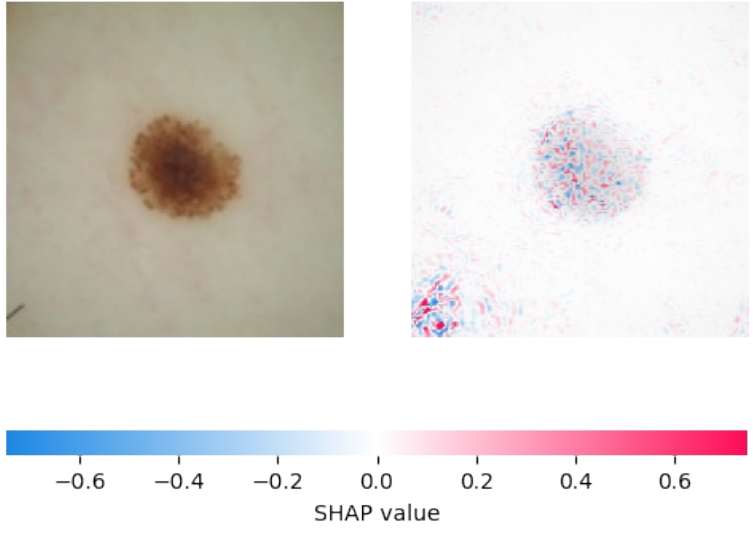


Transparency dimension: local explanations

Objective: “Provide the physician with explanation what lead to a malignant classification”

Means of compliance: Local explanations, e.g.

- saliency maps (gradient-based methods)
- SHAP

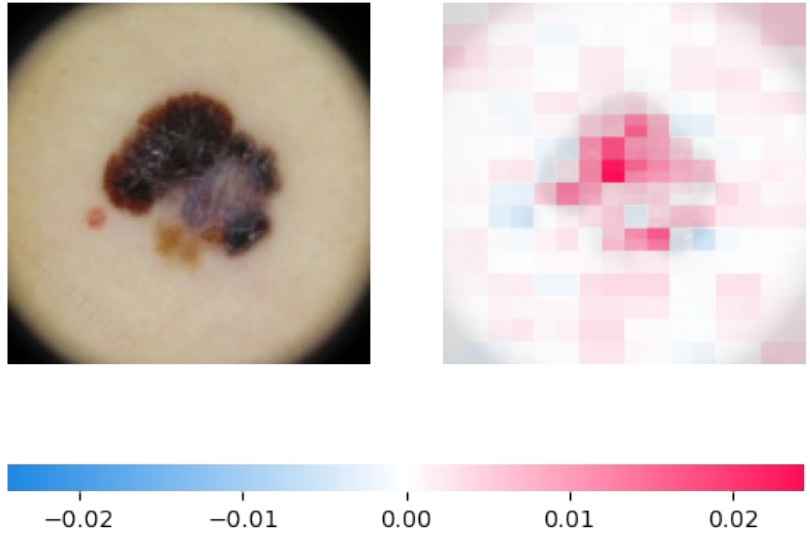


Explanation from SHAP using a gradient-based approach

Which explanation would a **physician** trust?

Malignant lesions typically have

- less defined border
- irregular shape and colour profile



Explanation from SHAP using a patch-based approach

Conclusion

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- **Problem: gap** between high level regulations and technical assessment methods
- **Our Contribution:** a **methodology** with **actionable directives** for the certification of AI-based systems
  - so far: 73 objectives, 256 means of compliance, 55 metrics, 95 methods in certification scheme
- Methodology is generally applicable for **real-world** use cases;
- **Future Research Plans:**
  - **AI in safety-critical systems**: combination of new methods with classical methods from risk analysis and functional safety.
  - **Develop verification frameworks for AI in safety-critical systems** with research partners, tailored to the specific use case

Thank you!

About me:

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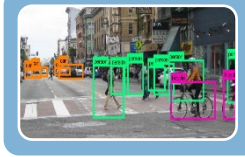
Collaboration With CAI on AI-related projects

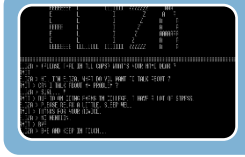
Autonomous Learning Systems

- *Reinforcement Learning*
- *Multi-Agent Systems*
- *Embodied AI*



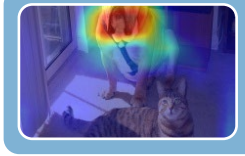
Computer Vision, Perception and Cognition

- *Pattern Recognition*
- *Machine Perception*
- *Neuromorphic Engineering*



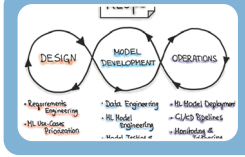
Natural Language Processing

- *Dialogue Systems*
- *Text Analytics*
- *Spoken Language Technologies*



Trustworthy AI

- *Explainable AI*
- *Robust Deep Learning*
- *AI & Society*



AI Engineering

- MLOps
- Data-Centric AI
- Continuous Learning

https://www.zhaw.ch/en/engineering/institutes-centres/cai/