covision lab

Automating and scaling visual inspection using anomaly detection by transformer – based deep learning models.

Internationales Forum Mechatronik

25.09.2024

Agenda

covision lab

1. **<u>Covision Lab introduction</u>**
2. Quality Control with Unsupervised Deep learning
3. Selected Projects

Covision Lab is an open innovation technology consortium

Covision Lab is a leading Computer Vision and Machine Learning technology center made of 7 mid-size multinational industry companies, based in South-Tyrol, Italy.

The Covision Partners

Durst

Manufacturer of advanced **digital printing**.

Microtec

Scanning solutions for the **wood processing industry**.

TTControl

High-performance control systems and electronics for off-highway **vehicles**.

The Covision Partners

Microgate / MPD
Timing, Training & Sport,
Medical Rehab and engineering.

Alupress
Automotive **Die Casting** Components.

Barbieri
Spectrophotometers for color measurement in professional digital printing.

Enabling technologies - industrial research and application pillars

1

Deep Learning

Image and video analysis based on the learning from examples.

2

3D Sensing

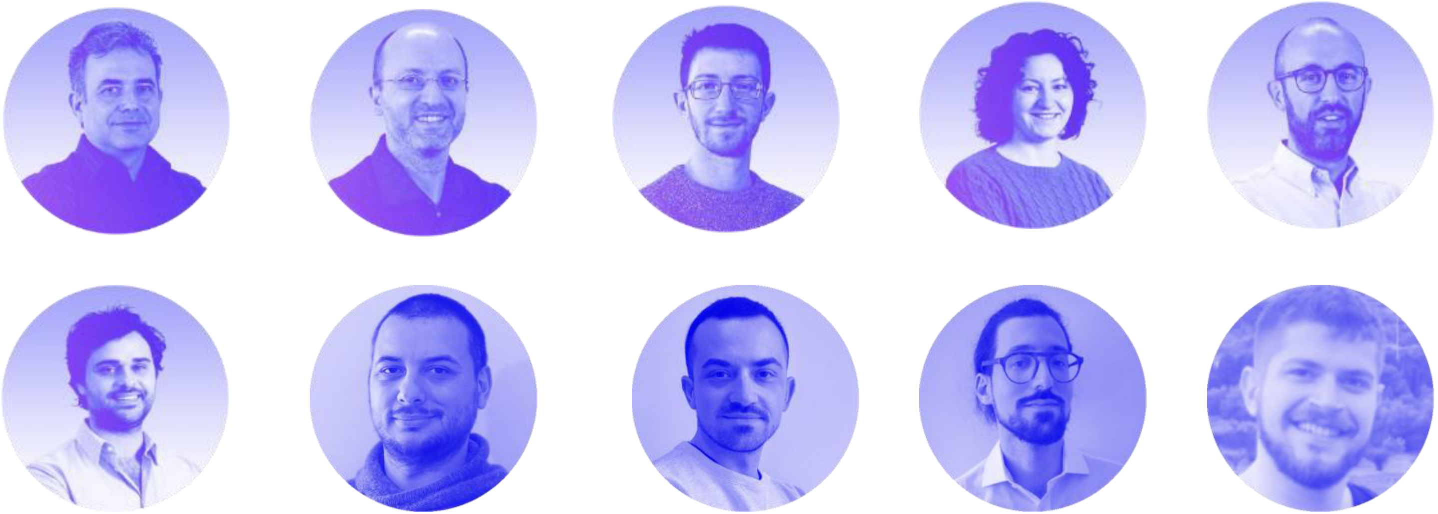
To capture, perceive, and interpret objects, people and scenes in 3D.

3

Embedded Vision

Visual intelligence on powerful and energy-efficient processors.

The Covision Team - CV/ML specialists



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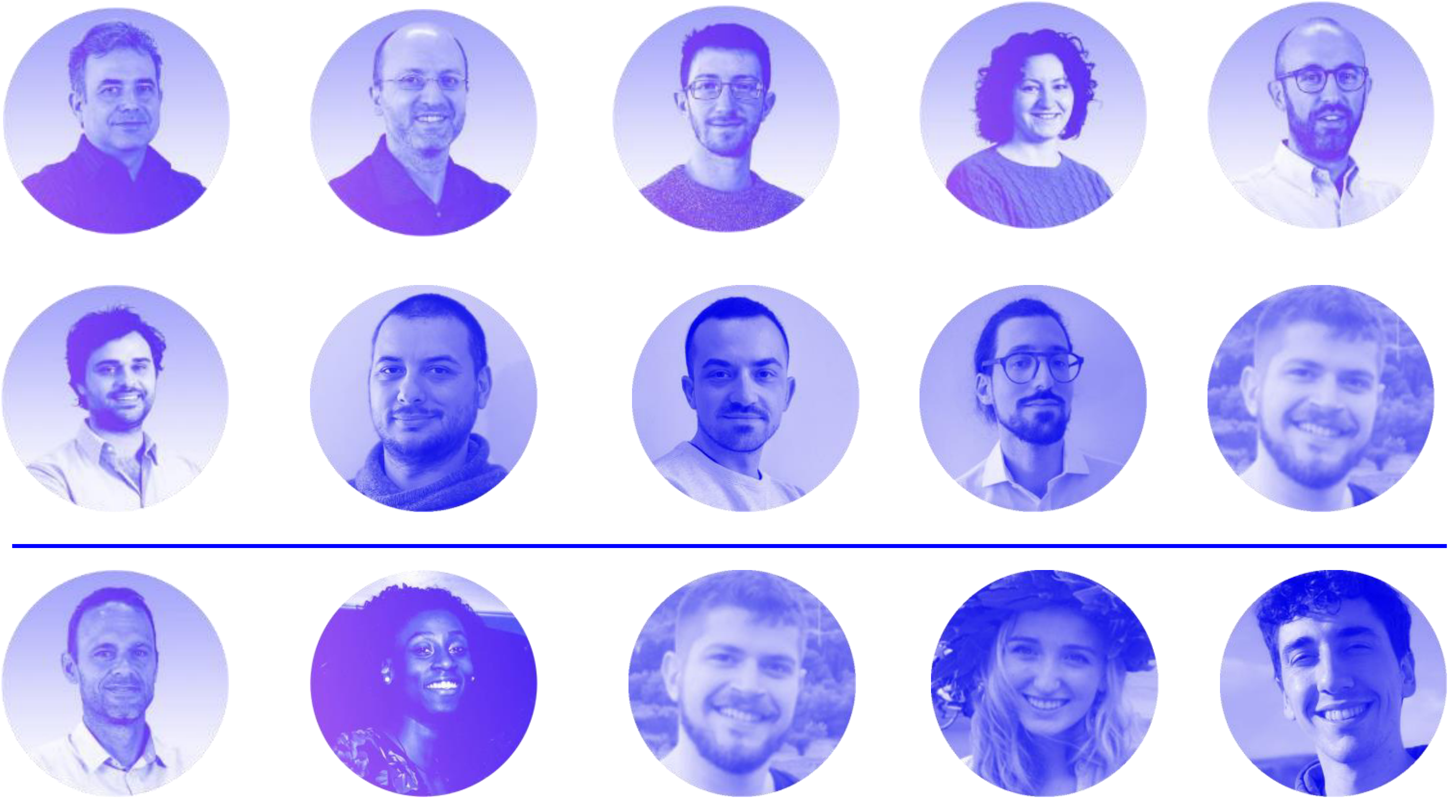

Scientific Committee

The scientific committee consists of international relevant experts in Computer Vision. They strategically guide CoVision Lab's research and technology efforts.

Prof. Pietro Perona

Pietro is an Allen E. Puckett Professor of Electrical Engineering and of Computation and Neural Systems at the California Institute of Technology (**Caltech**) and an Amazon Fellow, contributing to building the machine learning team of AWS.

amazon Caltech

Prof. Rita Cucchiara

Rita is Full Professor of Computer Vision at the University of Modena and Reggio Emilia (**Unimore**) and the Director of the CINI National Lab of Artificial Intelligence and Intelligent Systems.

iit ISTITUTO ITALIANO DI TECNOLOGIA

AImageLab University of Modena and Reggio Emilia

cini consorzio interuniversitario nazionale per l'informatica

NVIDIA

Prof. Paolo Lugli

Paolo is the Rector of the **Free University of Bozen-Bolzano**.
Previously he was the Dean of the Department of Electrical and Computer Engineering at the Technical University of Munich.

unibz

Collaborative innovation >>> Excellence in computer vision & ML

Applications, driving force, connections

covision lab · alupress · MiCROTEC · TTControl HYDAC INTERNATIONAL · durst · MICROGATE · MPD · barbieri

Excellence in computer vision & ML

Research, talent fostering, relationship building

unibz · FONDAZIONE BRUNO KESSLER · NVIDIA · SCHAEFFLER

Funding & Awareness

AUTONOME PROVINZ BOZEN SÜDTIROL · PROVINCIA AUTONOMA DI BOLZANO ALTO ADIGE

NOI TECHPARK SÜDTIROL / ALTO ADIGE

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2. **Quality Control with Unsupervised Deep learning**

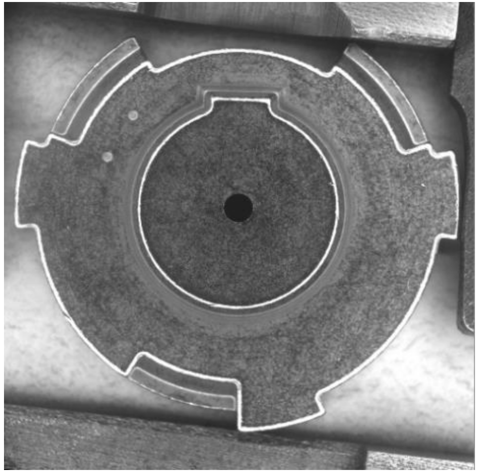
3. Selected projects

Quality control is applied in different context

Diffused Anomalies

Any object has multiple anomalies.

e.g. biological diversity



Sparse Anomalies

Most of the objects has no anomalies.

e.g. industrial mass production

Problems with heuristic vision systems applied to quality control

1. Vision systems are difficult to program (4 weeks on average)

2. Personnel who can program is rare and costly

3. Outcomes of visual inspection often unsatisfactory.

Problems with supervised ML vision systems applied to quality control

1

Labelling of high number of anomalies is necessary (5000 on average)

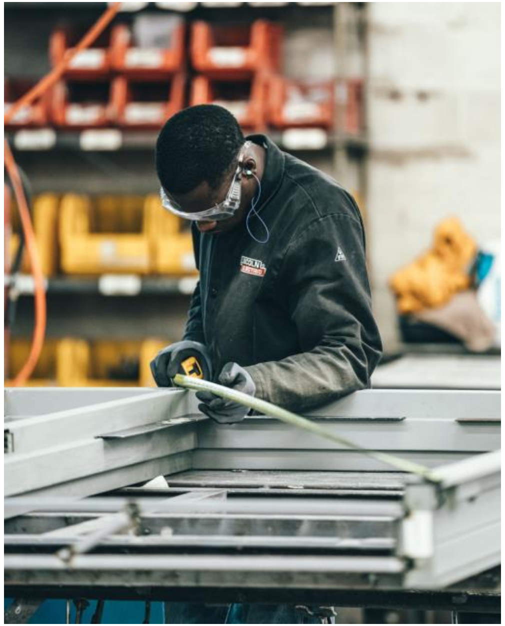
2

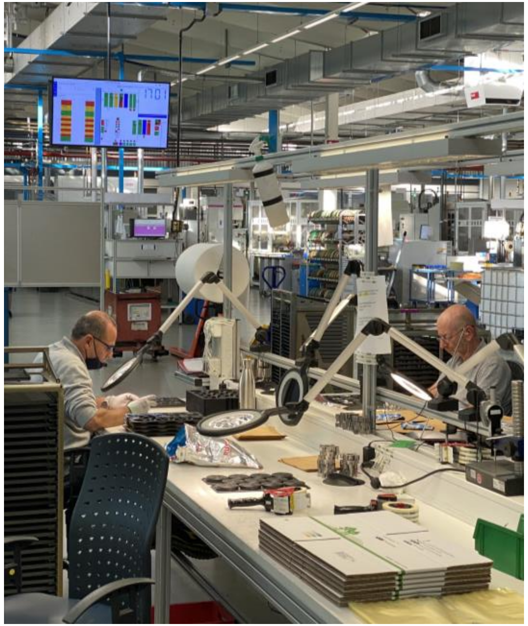
Sample collection is labour intensive especially in case of sparse anomalies

3

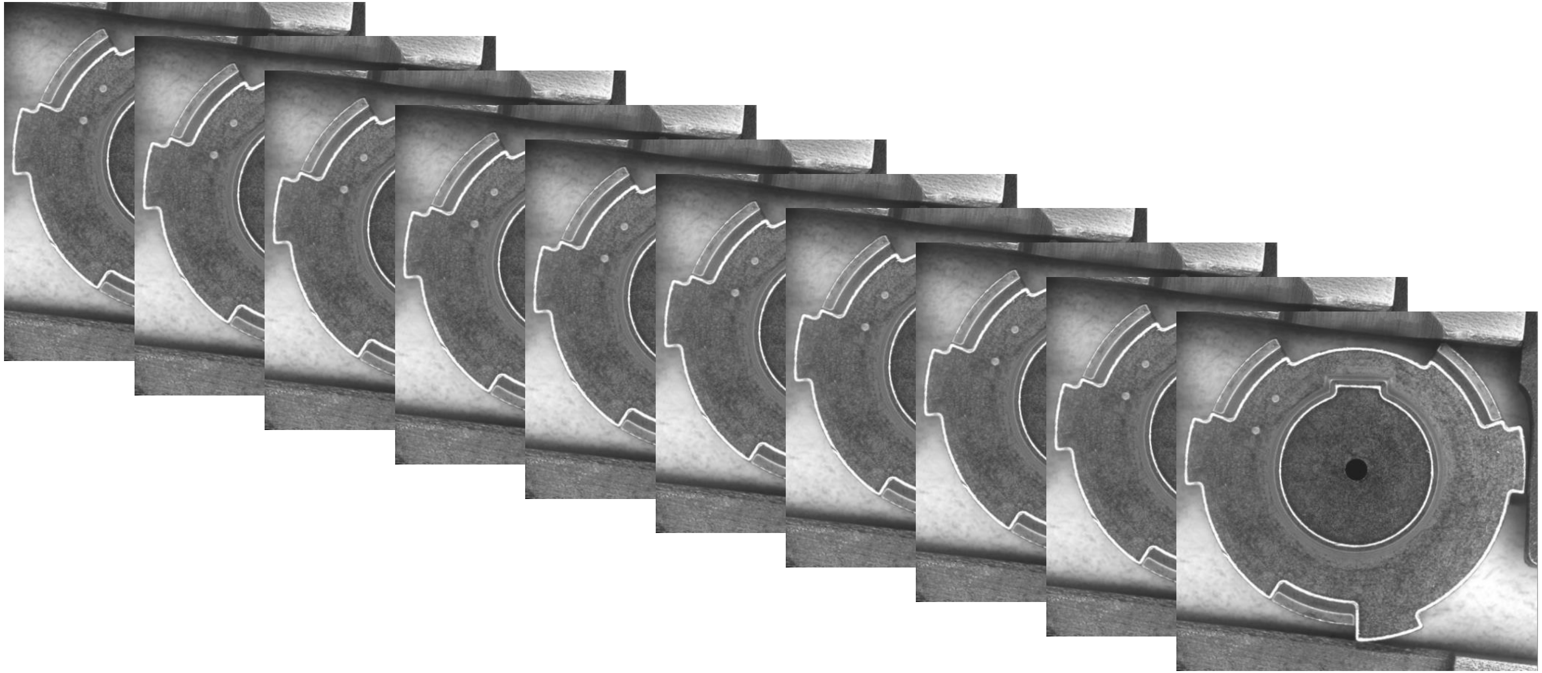
In case of unsatisfactory results relabelling is necessary

Reality: visual inspection is to a large extent still a manual job today





Unsupervised machine learning (A.I.)



Learning patterns of normality from the majority of samples

Training is a key part in deploying AI in production

1 **Image capturing**
OK & NG images

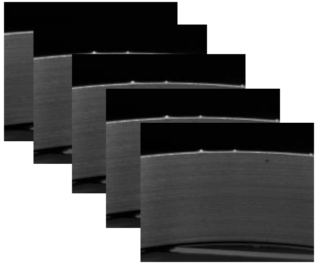
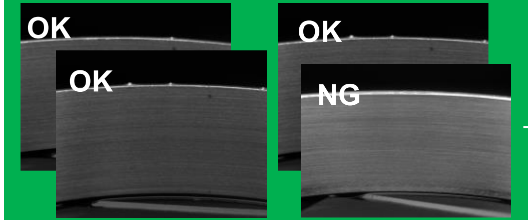


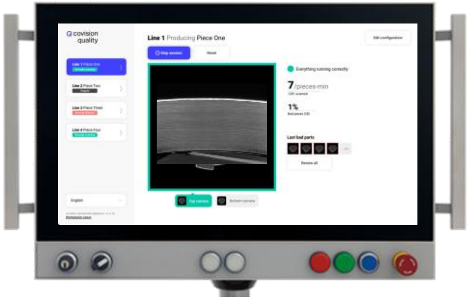
Image homogeneity in capturing is important:
- Lighting
- Focus

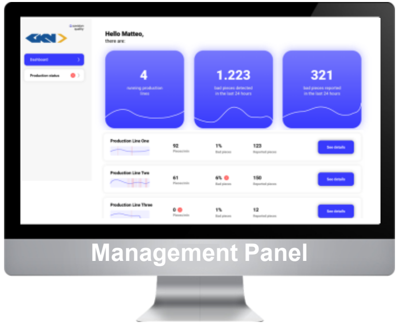
2 Pre-processing & Registration

3 **Training**



4 **Deploying inline**





State-of-the-art computer vision and ML

Unsupervised Deep Learning

The **unsupervised deep learning approach** allows to not require labelling and to **not be disrupting the production and quality control process.**

Transfer Learning

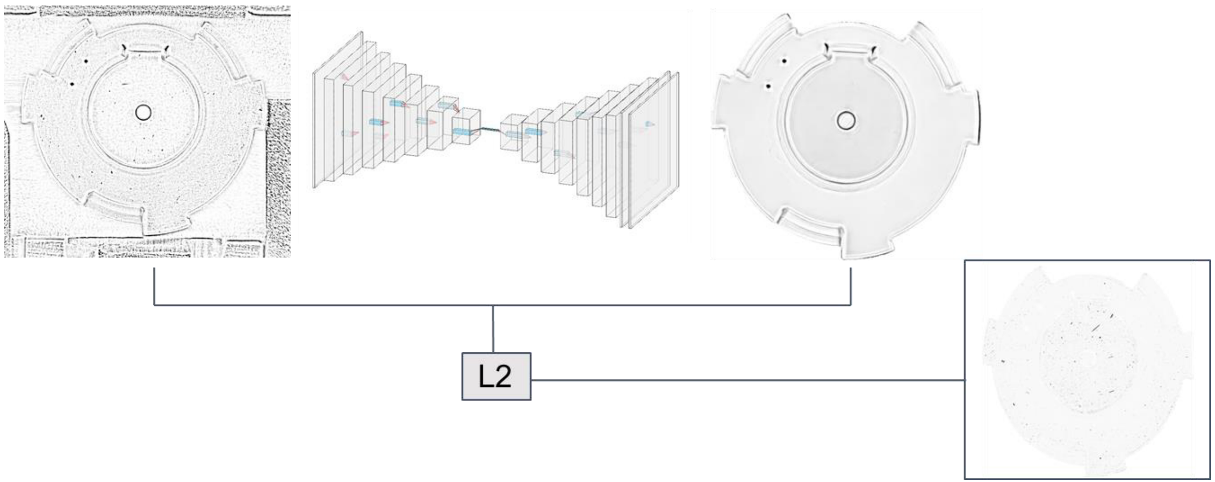
Learnings **from existing and proven deployments are transferred to other objects** with similar defects.

Continuous Learning

The **algorithms get continuously improved** via our continual learning approach.

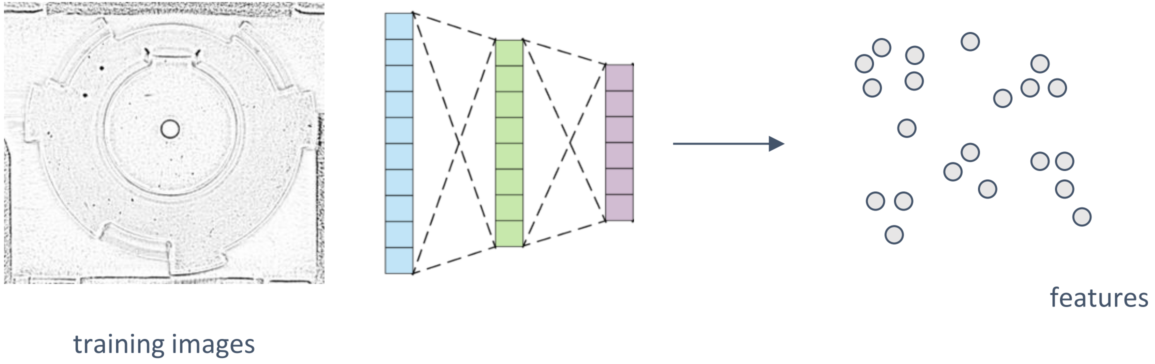
Autoencoder-based approach

- Image reconstruction using **autoencoders**: a compact latent space is used to ensure it retains only the information needed to model normal patterns in the images
- The comparison between the original and the reconstructed image shows what is anomalous
- Reconstruction of fine-grained images may be hard, especially if there is excessive variation in training data



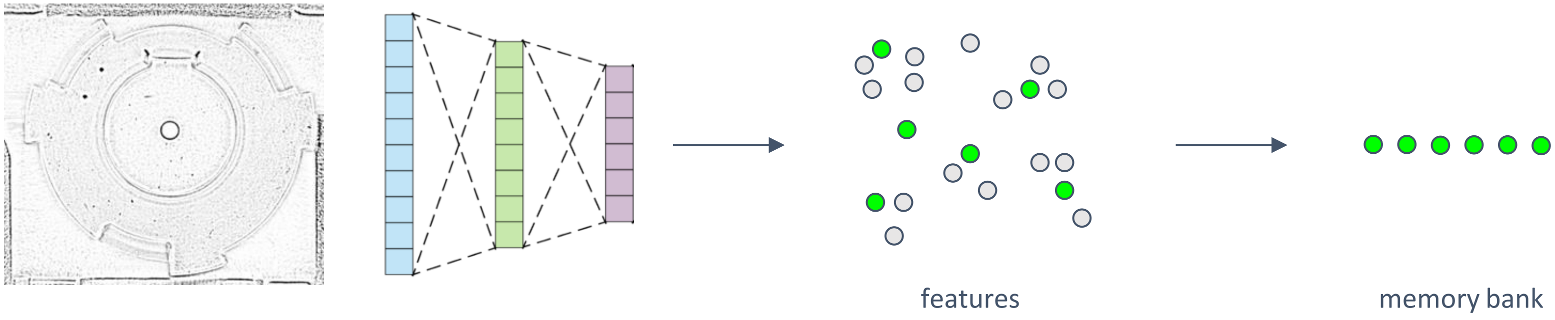
Feature-based approach

- **Feature-based** approaches handle data variability more effectively, because they use an encoder (e.g. ResNet, ViT etc.) to extract features that are invariant to changes in scale, rotation and lightning
- Such features are used to model normality in different ways, depending on the specific method



Feature-based approach, memory-bank

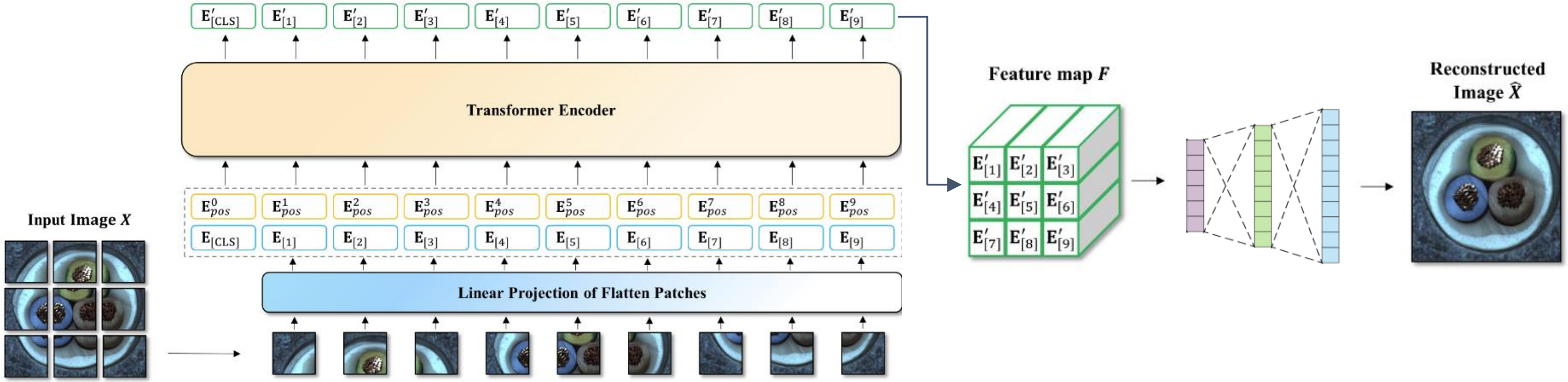
- **Feature-based** approaches handle data variability more effectively, because they use an encoder (e.g. ResNet, ViT etc.) to extract features that are invariant to changes in scale, rotation and lightning
- Such features are used to model normality in different ways, depending on the specific method
- ***Memory Bank*-based** methods (like *PatchCore*) creates a set of normal features (the memory bank) and compare new image features against this reference to detect anomalies



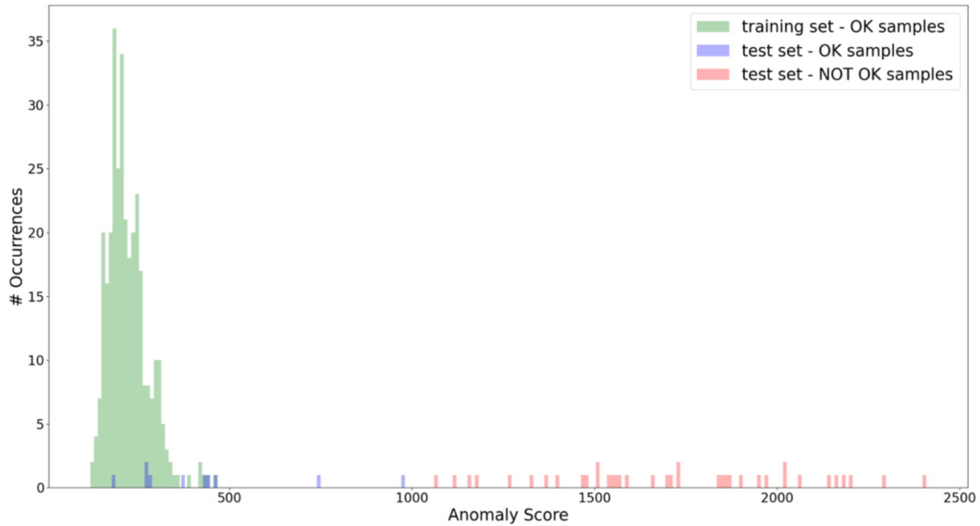
training images

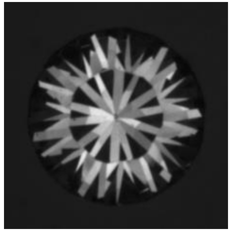
Transformer-based approach

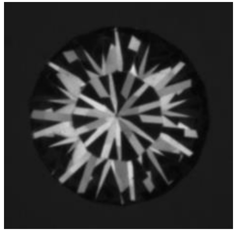
- Encoders typically extract features using either convolutional networks or vision transformers (ViT)
- Vision transformers have the advantage of capturing global context and long-range dependencies in the image through self-attention, providing a more comprehensive understanding of the entire image
- *For example, AnoViT adopts a **reconstruction-based*** approach like classic autoencoders, but leverages ViT to extract features that capture global relationships between image patches, enhancing image reconstruction

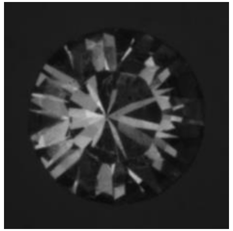


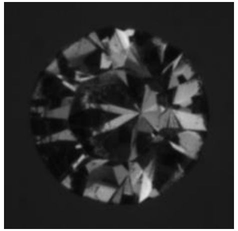
Covision Lab's "anomaly score"











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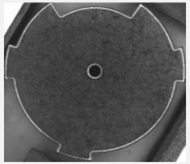
Covision Quality - Application Park Samples

2D



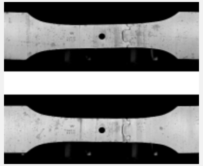
Powder Metal
Scratches
260 parts/min

GKN POWDER METALLURGY

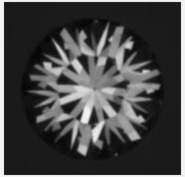
Powder Metal
Scratches
40 parts/min

GKN POWDER METALLURGY

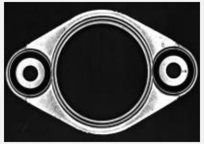
Metal
Welding seams
8 parts/min



Stamping copper
Thrust points
12 parts/min



Jewellery
Various defects
300 parts/min

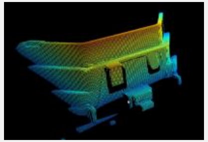


Stamping
impact marks
30 parts/min

Packaging
Various defects
400 parts/min

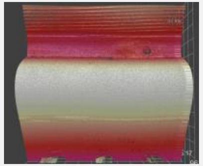
Composite materials
Various defects
20 parts/min

3D



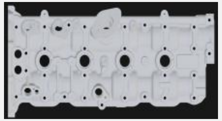
Die-cast
Burrs
8 parts/min

alupress



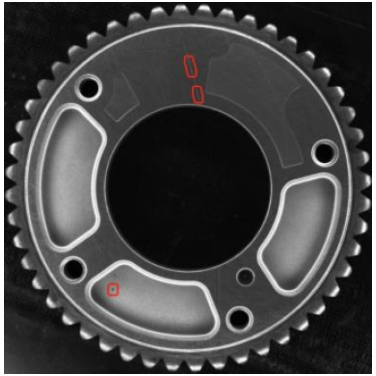
Metal deep drawing
Weld seam control
4 parts/min

Metal forge
pressure point/chips
8 parts/min



Die-cast
geometric defects
2 parts/min

Powder Metal – Bad Brückenau (Germany)



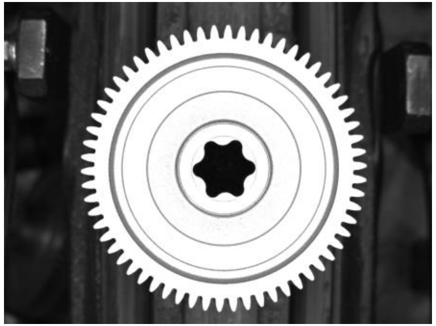
Raw data from Keyence

Covision Quality Algorithm
+ own Shape from Shading

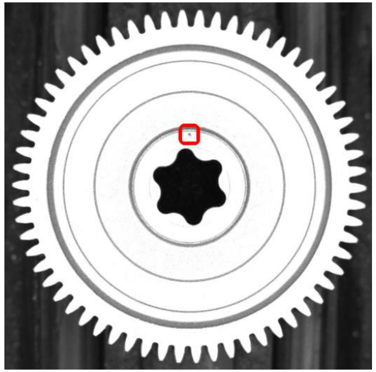
- Typical Defects:
  - Scratches
  - Missing dents, teeth
  - Missing pockets
- Speed: 40-60 Parts / min
- Source Setup:
  - Keyence Matrix Camera

Powder Metal – St. Louis (USA)

GKN POWDER METALLURGY



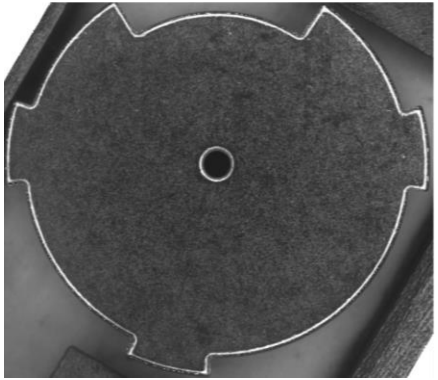
Raw data from Keyence



Covision Lab Algorithm

- Typical Defects:
  - Scratches
  - Missing geometry
- Speed: 100 Parts / min
- Source Setup:
  - Cognex Inside Camera

Powder Metal – Brunico (Italy)



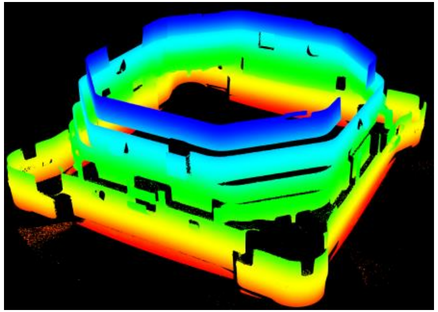
Raw data from Keyence

Covision Quality Algorithm
+ own Shape from Shading

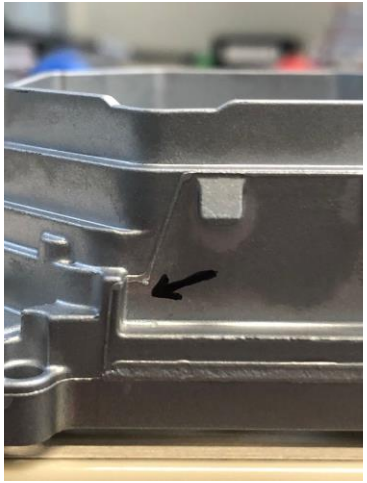
- Typical Defects:
  - Scratches mostly
  - Missing material
- Speed: 260 Parts / min
- Source Setup:
  - Keyence Matrix Camera

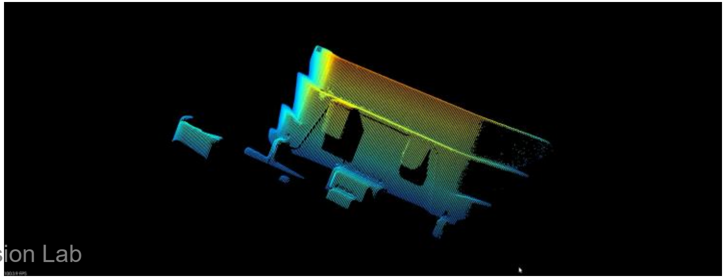
Aluminium die casting – Bressanone (Italy)

alupress



Raw data from LMI 3D sensor





- Typical Defects:
  - Burs
  - Under forming
- Speed: 8 Parts / min
- Source Setup:
  - 4x LMI 3D Sensor + 2D Camera
  - Robot handling
- Challenges:
  - Handling between different machine + sub systems (robot, turntable)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