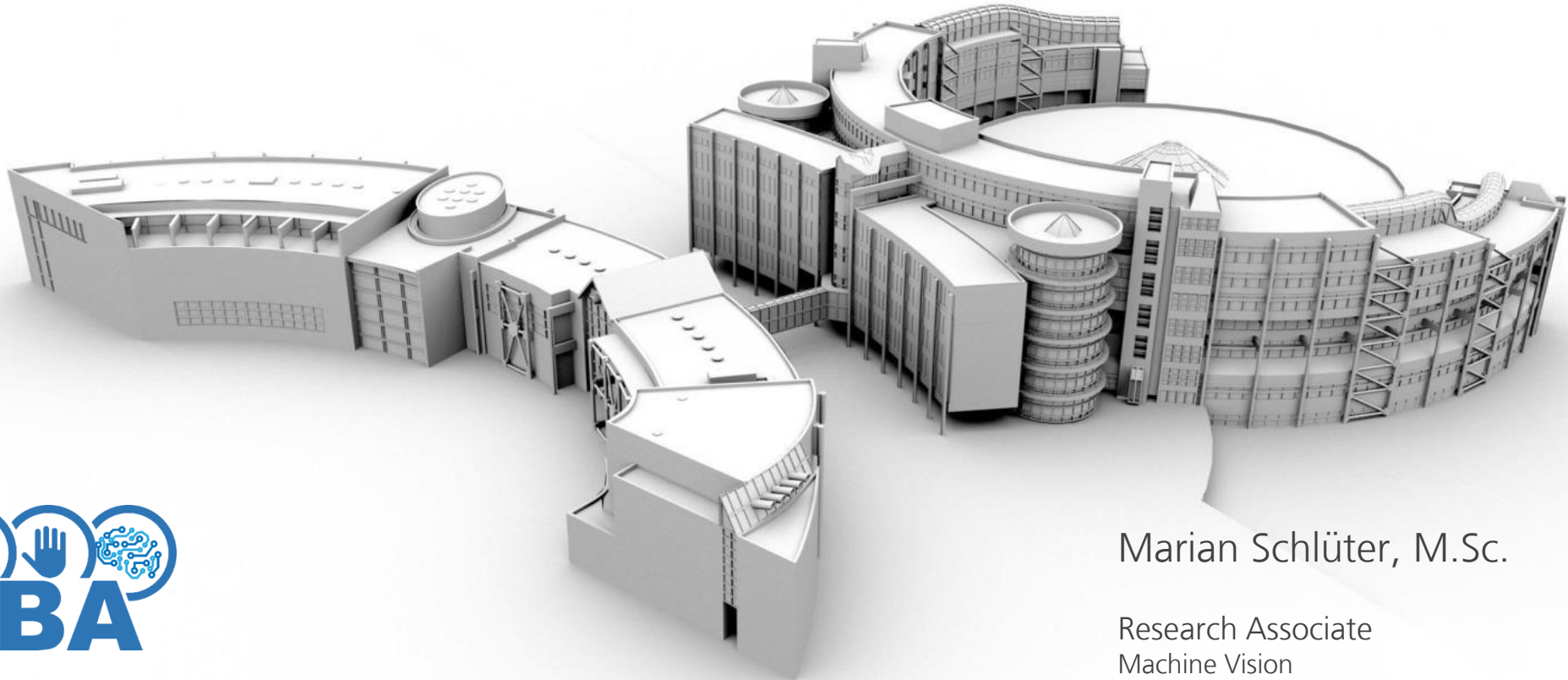


TOWARDS AN AI-ENHANCED CIRCULAR ECONOMY

AI-enhanced identification, inspection and sorting for reverse logistics



Marian Schlüter, M.Sc.

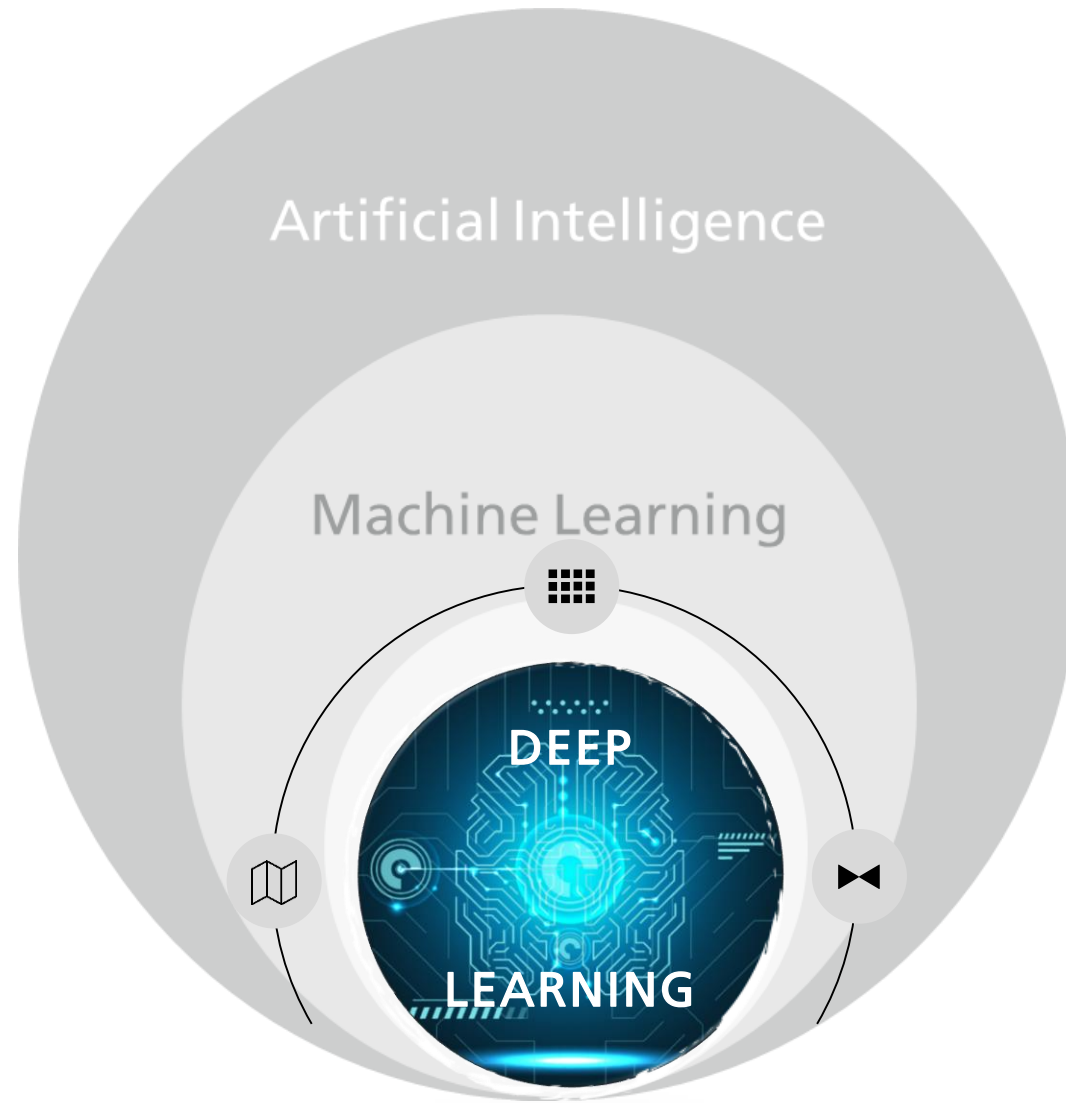
Research Associate
Machine Vision
Automation Technology

SPONSORED BY THE



AI IN MACHINE VISION

Mostly Deep Learning



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FRAUNHOFER IPK – MACHINE VISION

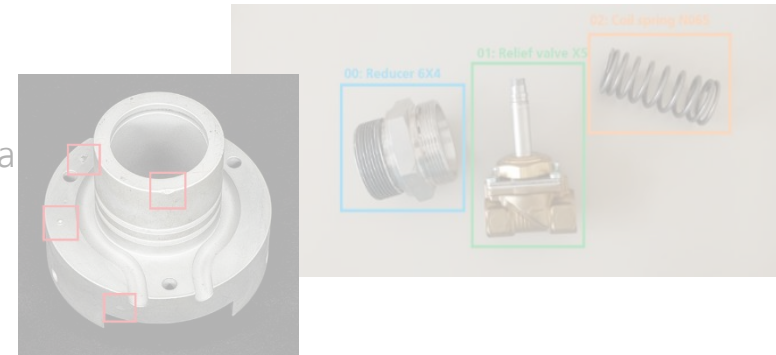
Machine Vision is our Mission

Detection (Regional – CNN)

Classification and localisation in image data

Applications:

- Defect detection in QM
- completeness check of assembly kits



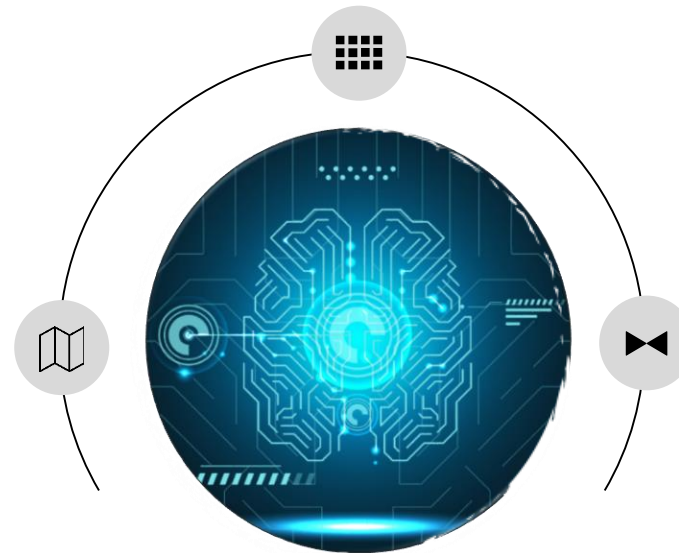
Recognition (CNN)

Classification of image data

Applications:

- Logistics (eg. Incoming or outgoing goods)
- E.g. Spare parts management

Sehr wahrscheinlich	Unwahrscheinlich	Unwahrscheinlich	Unwahrscheinlich	Unwahrscheinlich
Rank #1	Rank #2	Rank #3	Rank #4	Rank #5
99.82%	0.13%	0.03%	0.01%	0.00%
Zahnrad Messing Durchmesser 90mm	Überdruckventil M18 Doppelanschluss	Verlängerung Edelstahl Länge 140mm	Kugelhahn aus Grundbauteil	Reduzierer M14 22bar

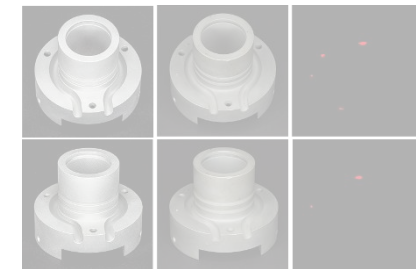


Anomaly detection (CNN)

Detection of deviations from a target state.

Applications:

- Quality control
- Sub-assembly inspection after assembly



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FRAUNHOFER IPK – MACHINE VISION

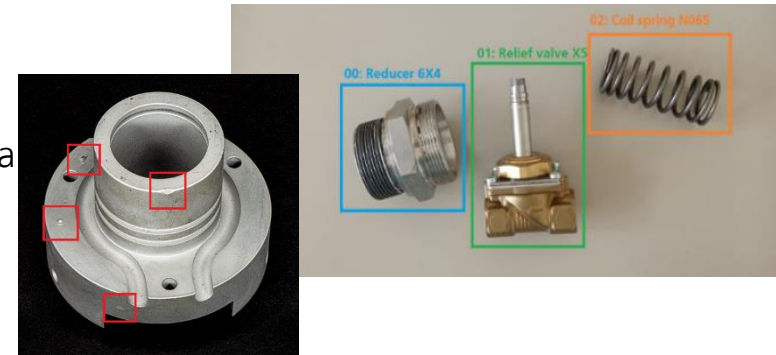
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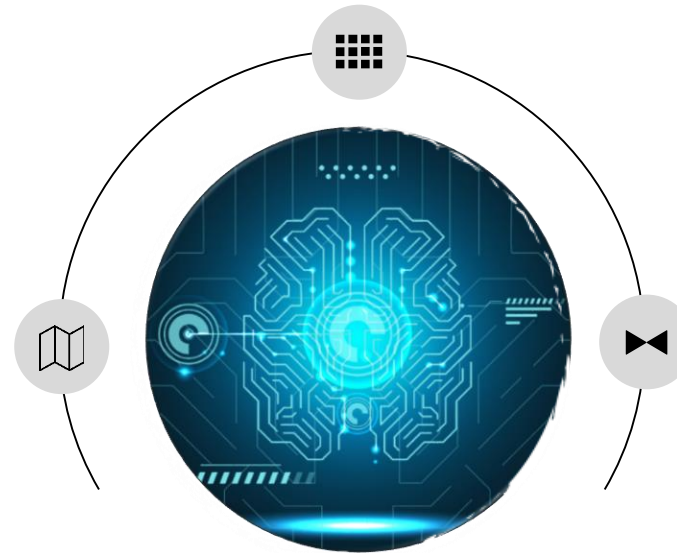


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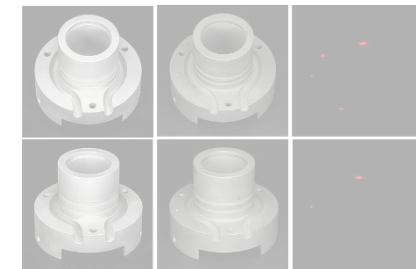
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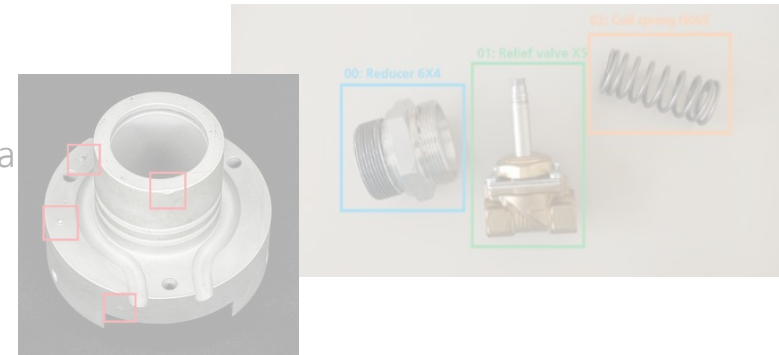
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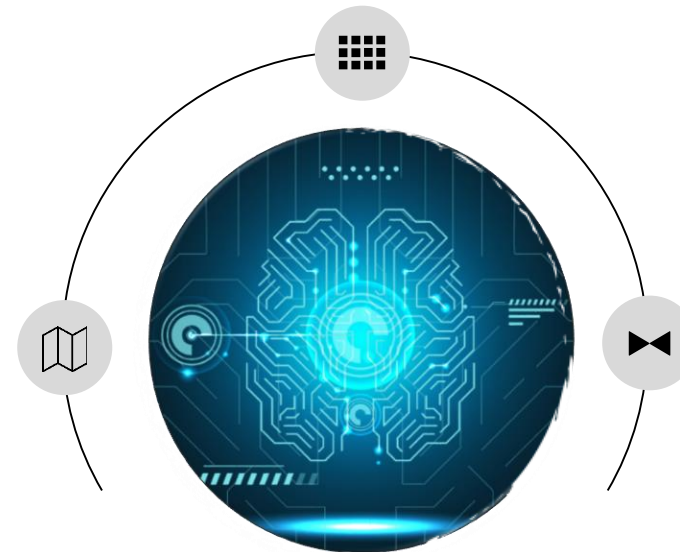
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Zahnrad Messing Durchmesser 30mm	Überdruckventil mit Doppelventiltrieb	Verstellzange Standard Länge 140mm	Kumpfenwaage Grundbauteil	Reduzierventil 1/4x 1/2" 120bar

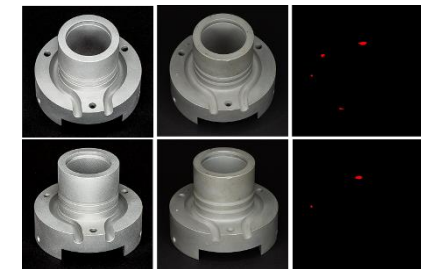


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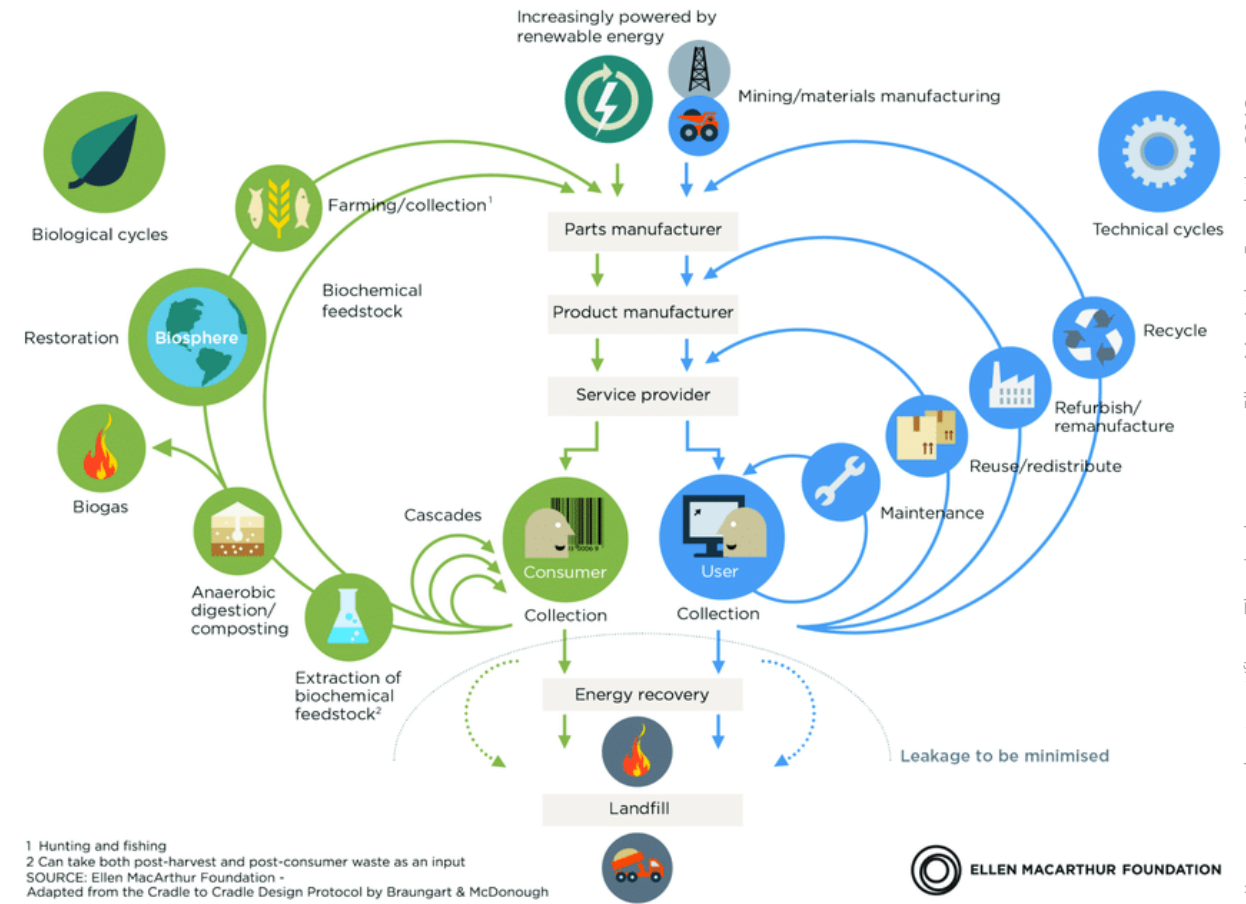


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REVERSE LOGISTICS IS ENABLER

For the circular economy as regenerative system

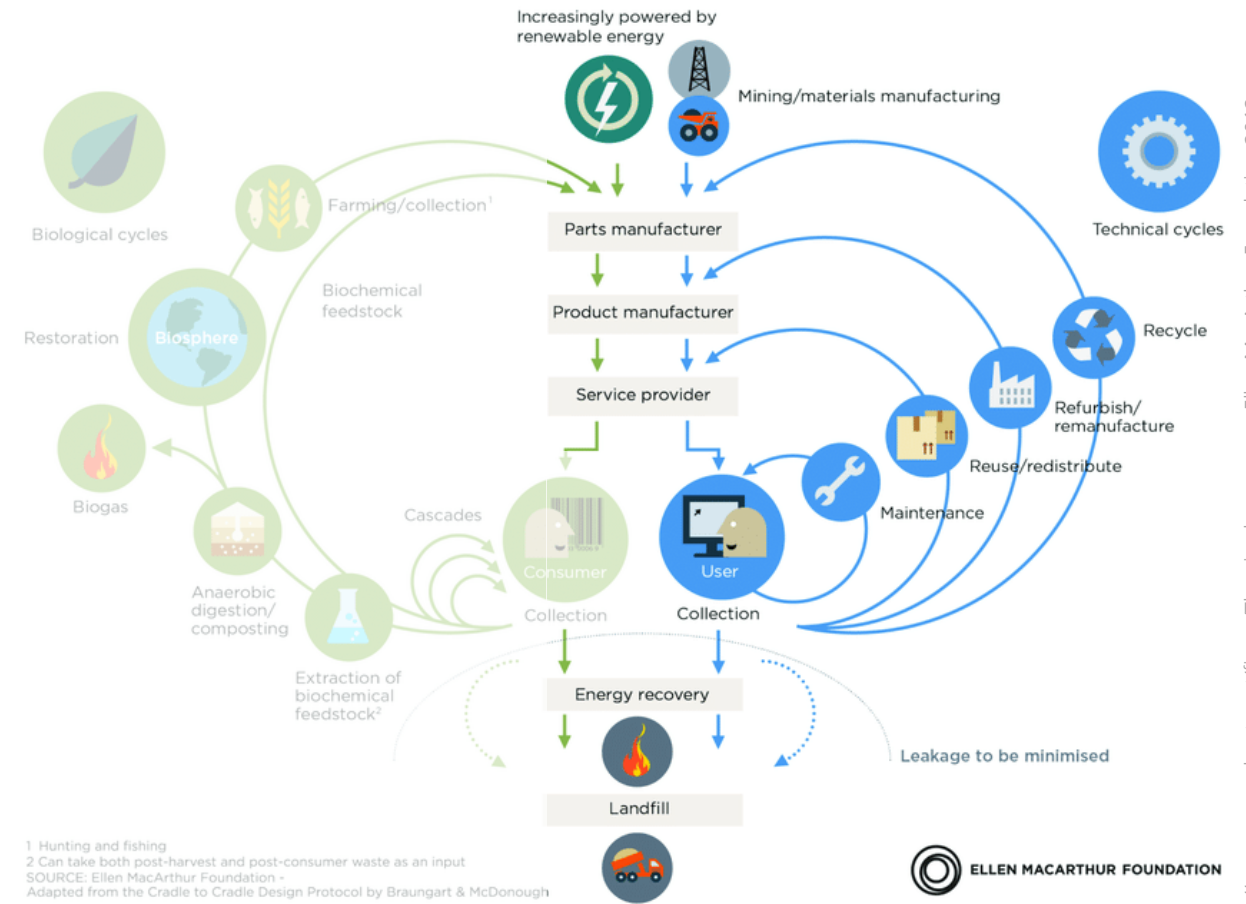
- Life cycle does not end after use (linear economy)
- As full as possible recycling or reprocessing of products in the "end-of-life"
- Reduction of need for new raw materials, labor and energy required
- Germany is an importing country for raw materials
 - Share of secondary raw materials (metals) between 60% - 40%



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For the circular economy as regenerative system

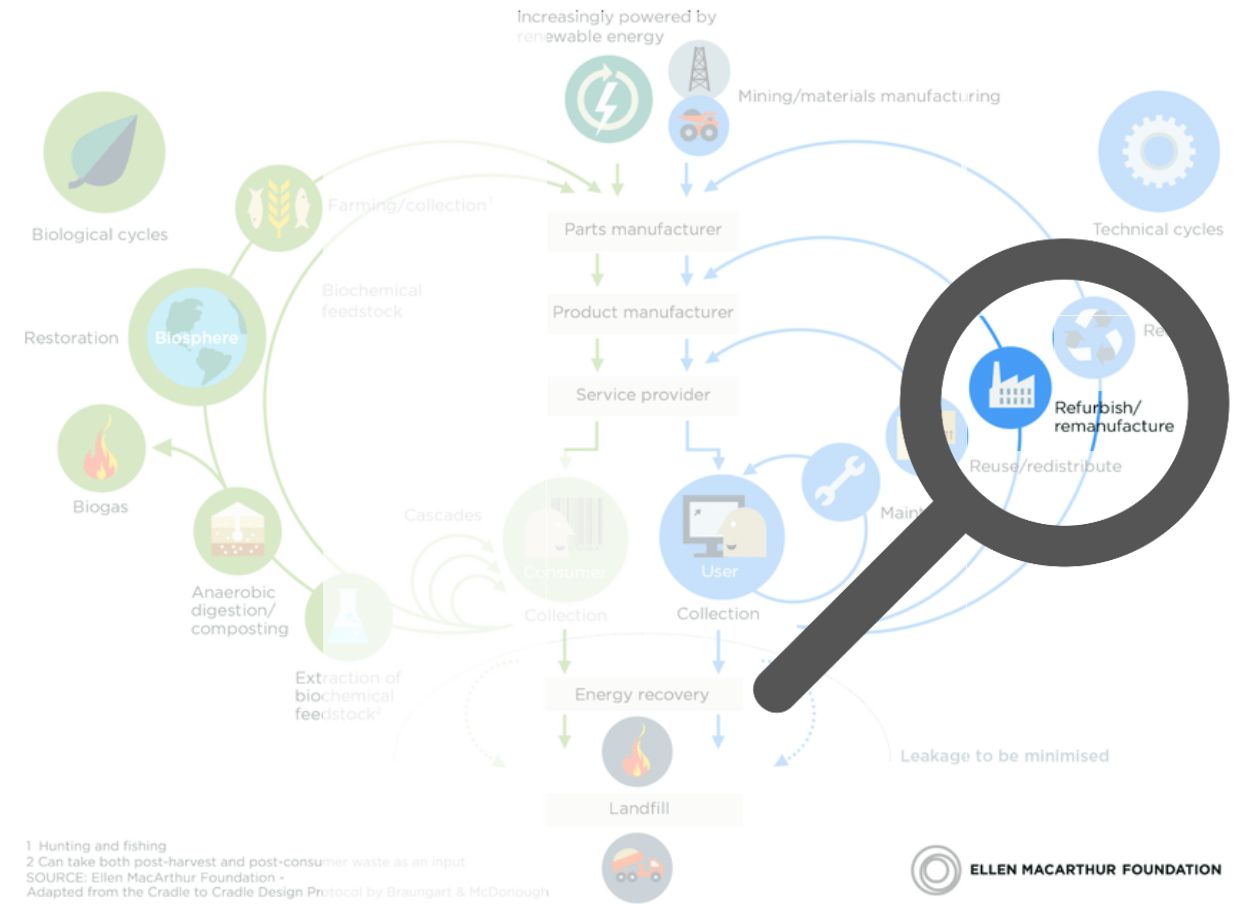
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REMANUFACTURING NEEDS REVERSE LOGISTICS

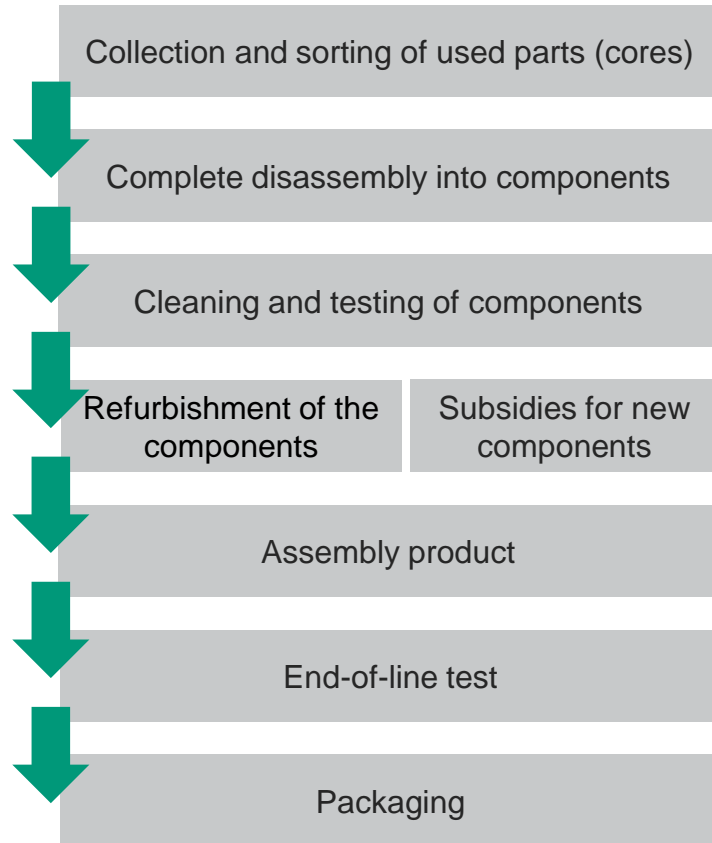
Keeping value in the circle

- Reman is on the 2. level in waste pyramid
- Most value-preserving method
- Legal requirements 85% by weight of a car must be recyclable
- Working industry for Automotive Parts
 - €2.36 bn/year in German reman market
- Challenges:
 - **high uncertainty in timing and quantity of incoming goods**
 - **high complexity in reverse logistics**

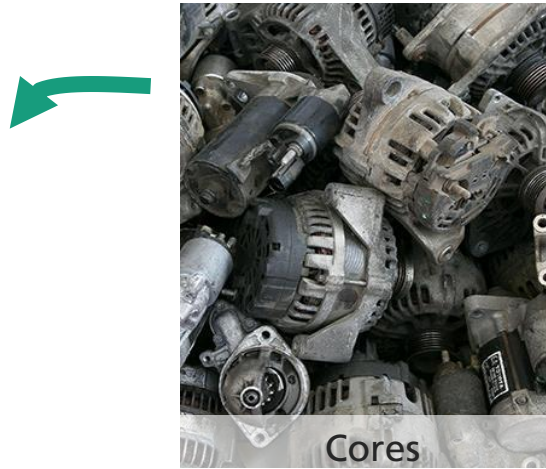


REMANUFACTURING – PROCESS STEPS

Make used parts as good as new again

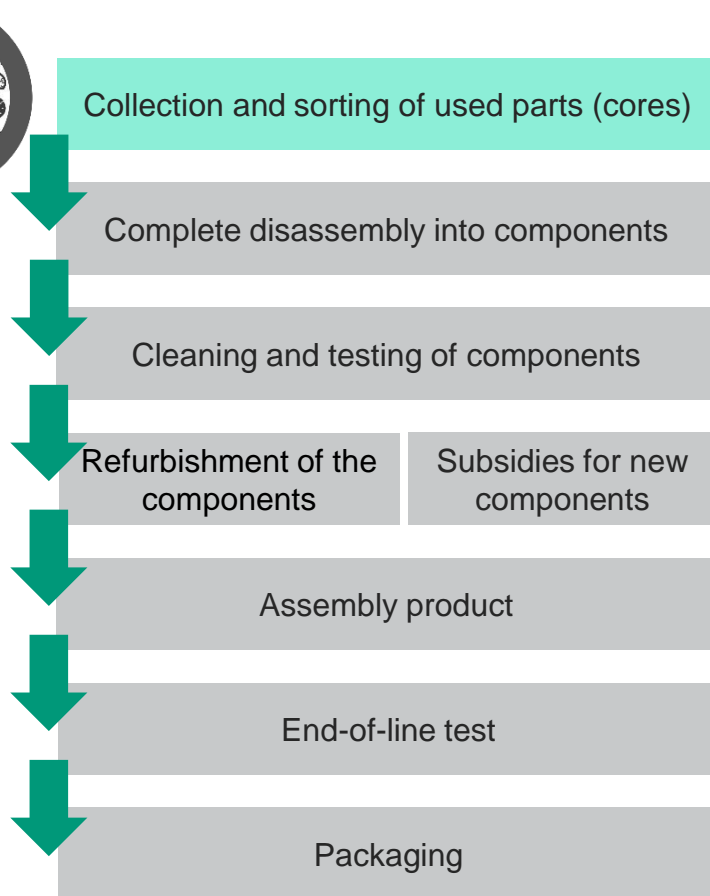


Source: APRA, adapted



REMANUFACTURING – PROCESS STEPS

Make used parts as good as new again



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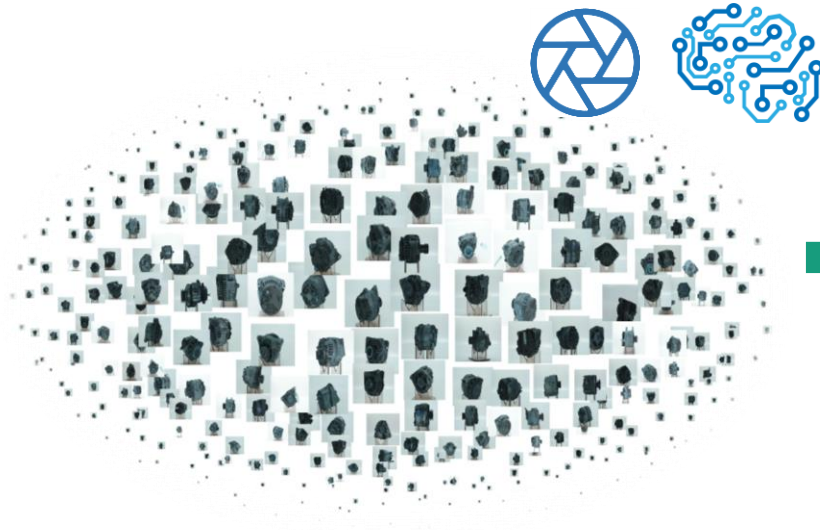


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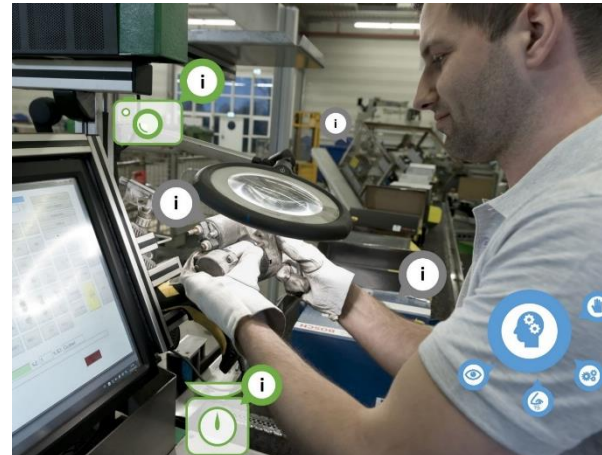
EIBA PROJECT

Sensor-based acquisition, automated identification and evaluation of used parts on the basis of product data and information on previous deliveries

AI-driven combination of data from different sensors e.g. 3D image processing, depth cameras, scales



Human senses and cognitive abilities

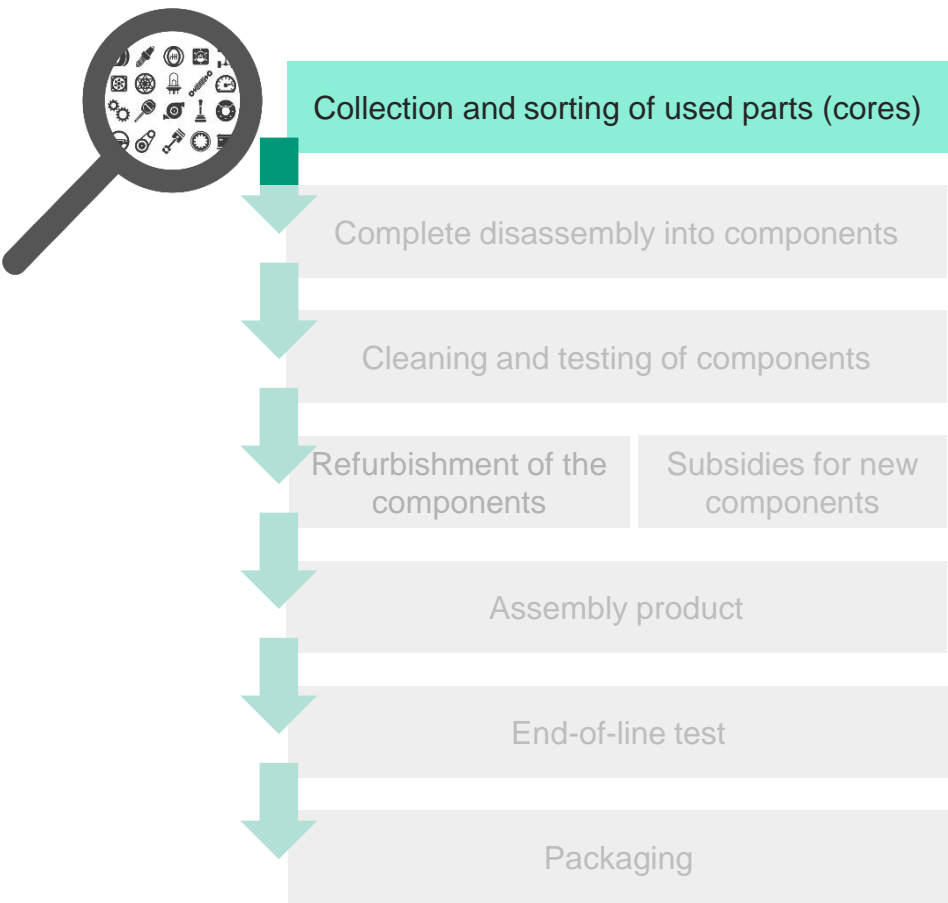


Statistical business process data (e.g. purchasing or return delivery behavior)



REMANUFACTURING – THE SELECTION PROCESS

The selection is a key process for reverse logistics



Source: APRA, adapted



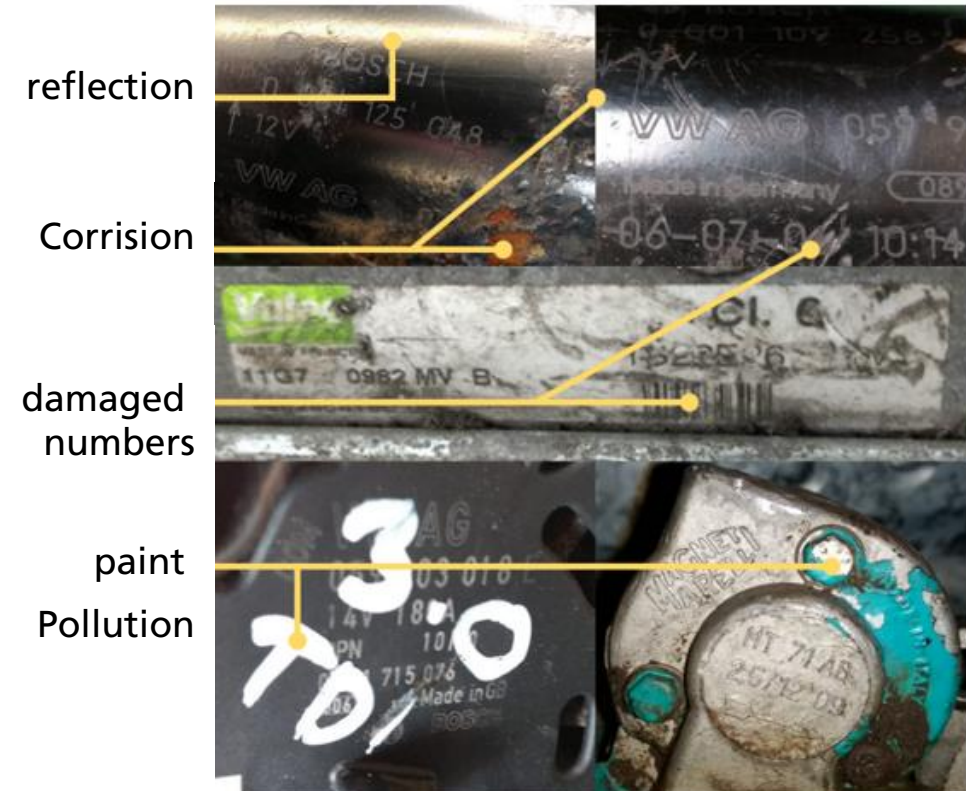
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CHALLENGES IN CORE SELECTION

Identification is prone to damages of tags

Problem Statement:

- Returns warehouses have a high variety of stockable parts
 - 140,000 variants
 - 30 – 40 product groups
- 1,000,000 parts flow / year per warehouse
- Identification only based on numbers
 - no readable tags
 - multiple numbers on part



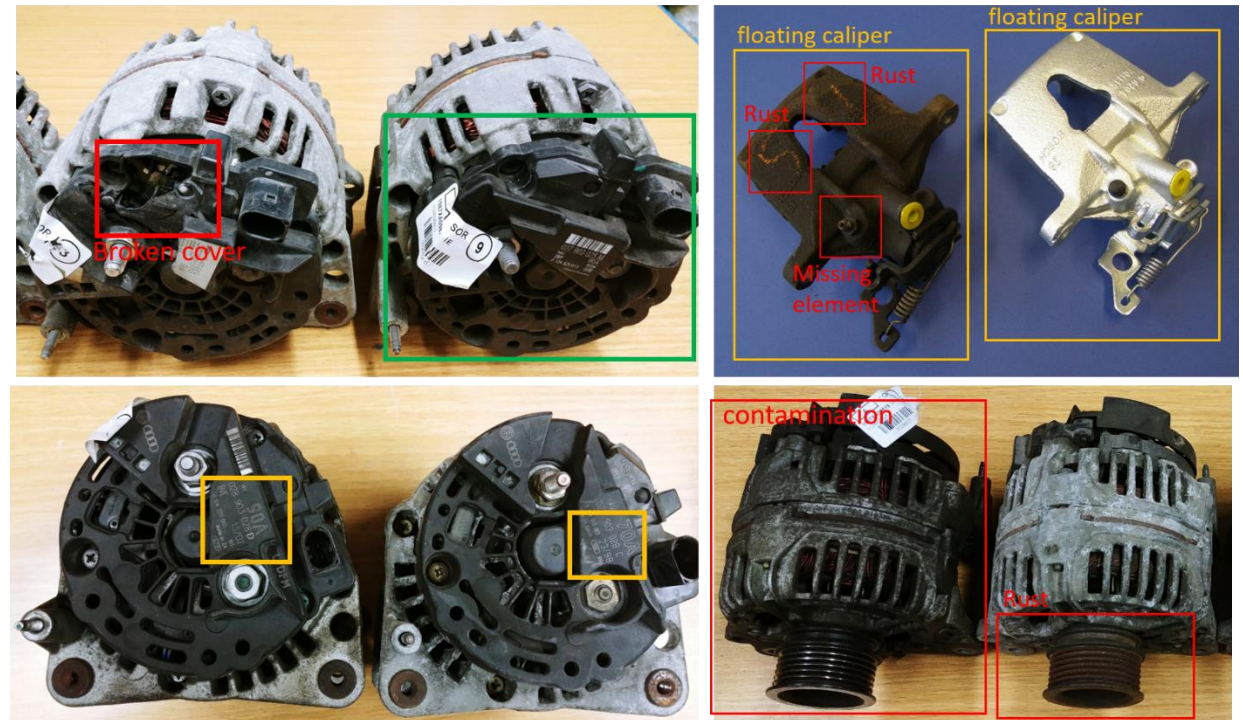
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CHALLENGES IN CORE SELECTION

Inspection is subjective

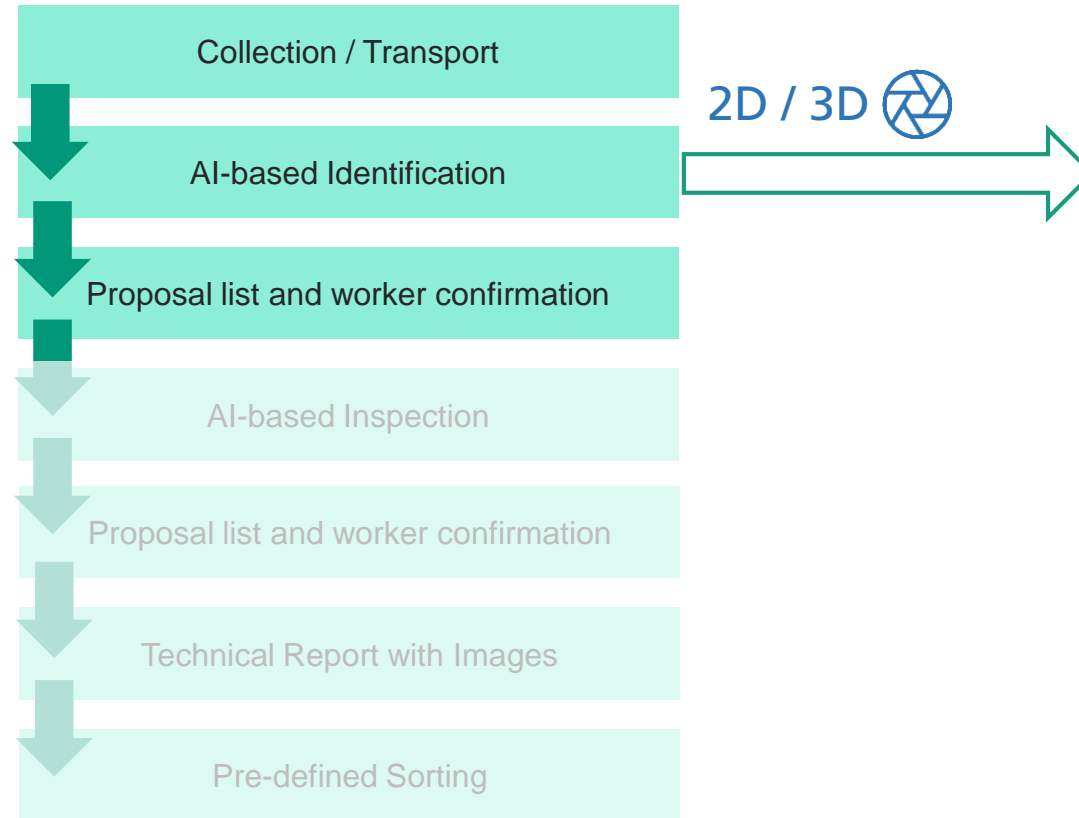
Problem Statement:

- Subjective Evaluation of criteria
 - Different results on different days
- All parts are different!
- Regional and weather-based influences result in very different conditions of cores
- Based on workers' experience
 - Long training times for workers

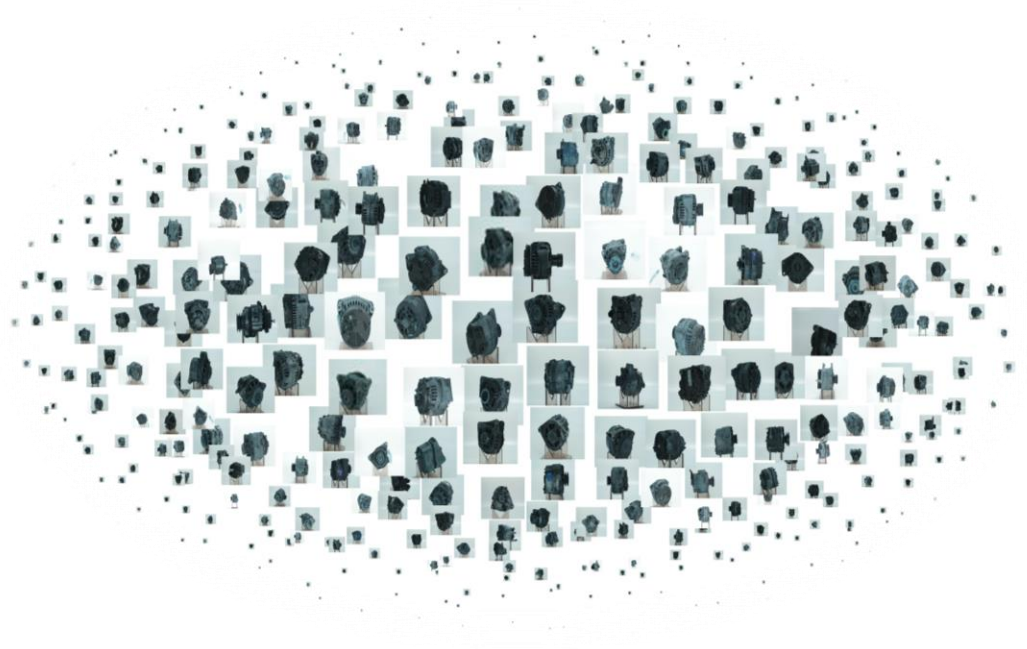


AI ASSISTS WORKERS IN REVERSE LOGISTICS

Identification of untagged products with Assistant Systems



2D / 3D 



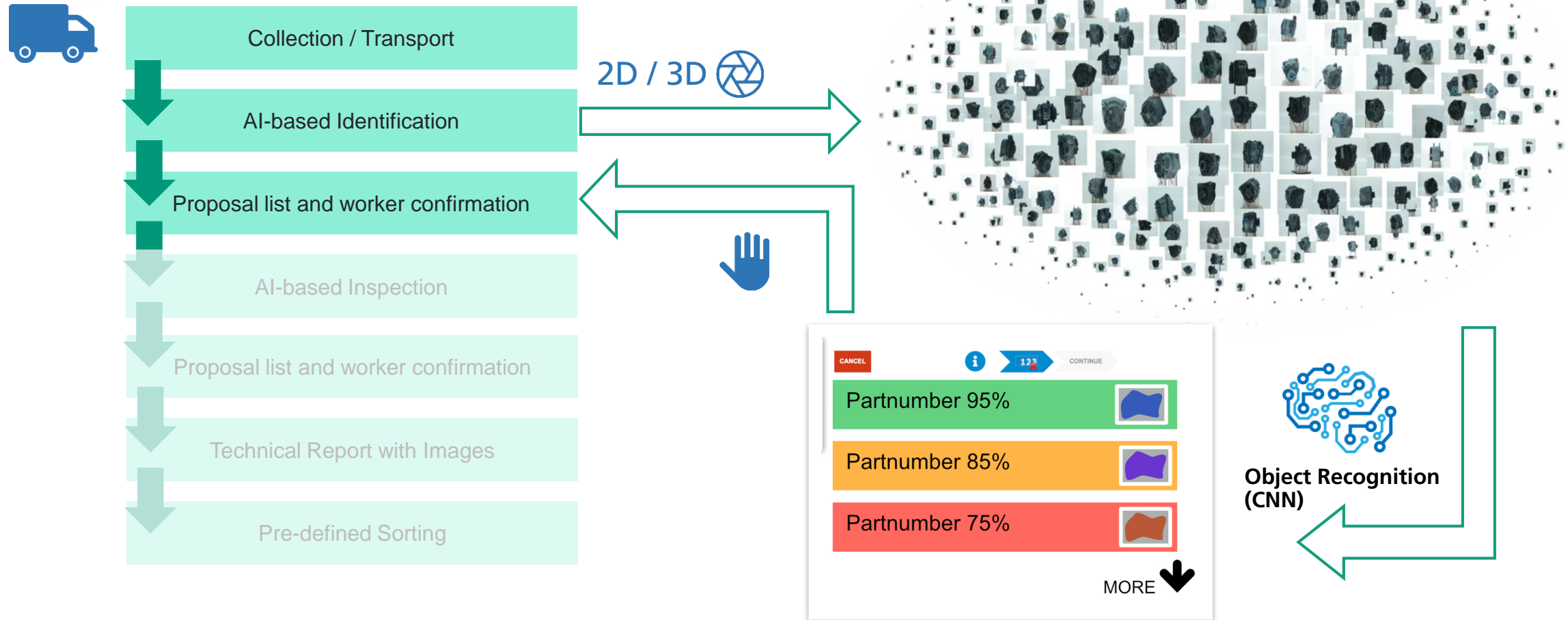
**Object Recognition
(CNN)**



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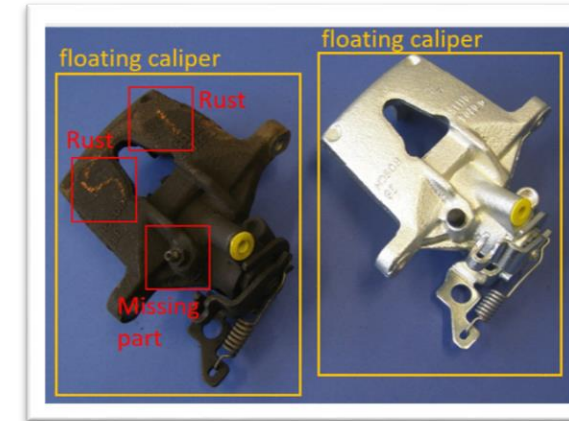
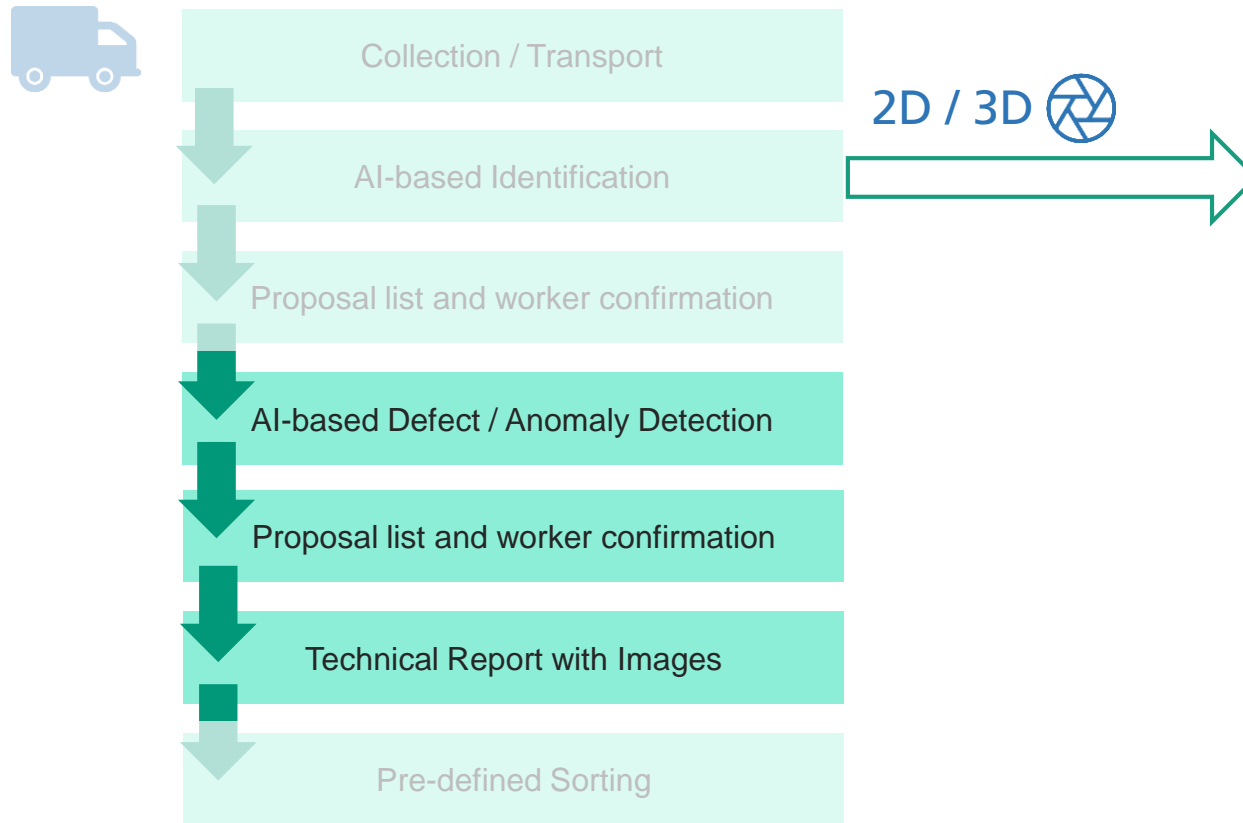
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AI ASSISTS WORKERS IN REVERSE LOGISTICS

4-eye principle inspection and criteria check of used products



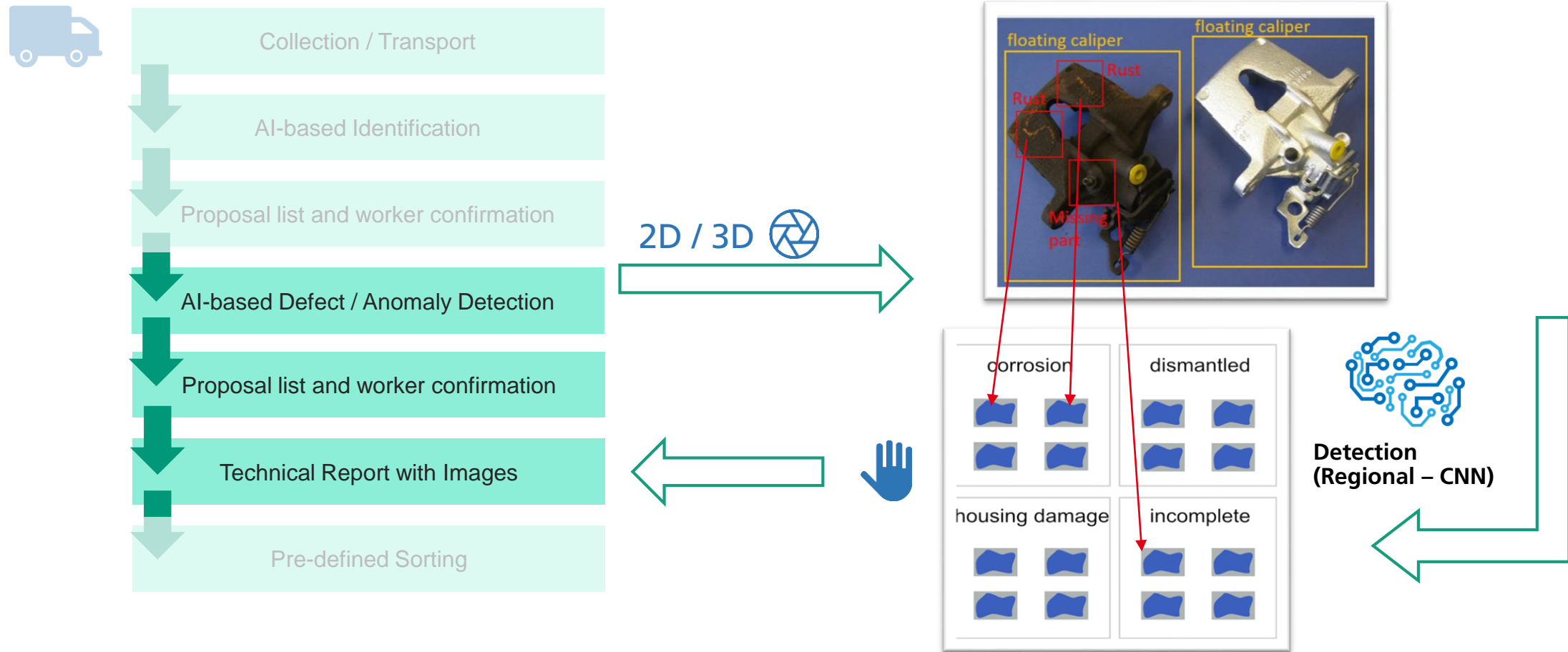
Detection
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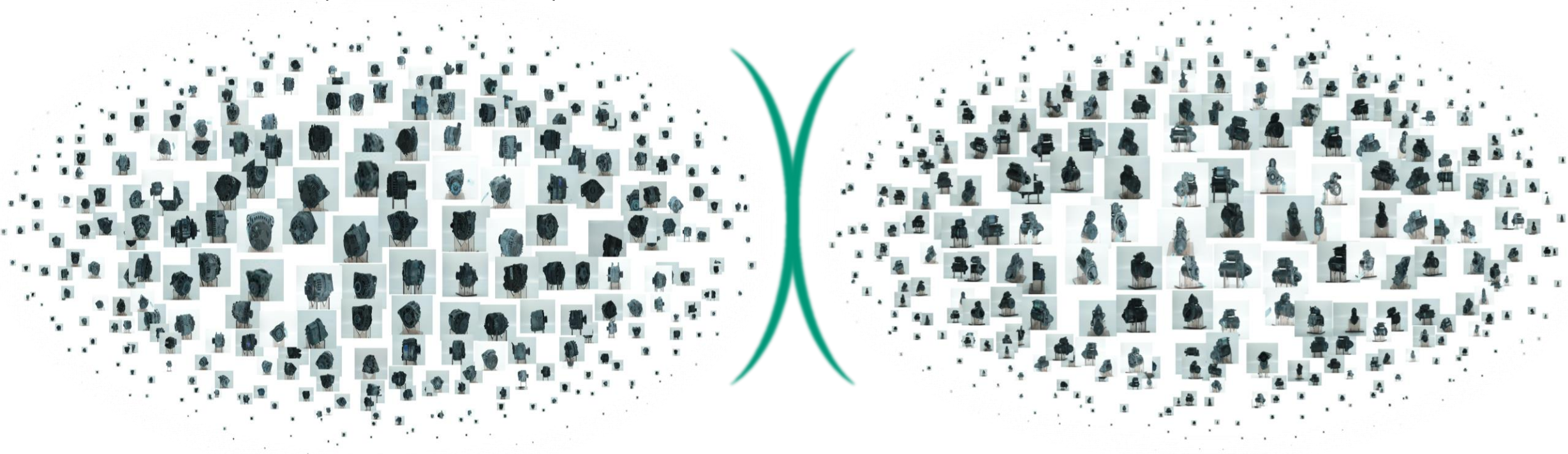
AI ASSISTS WORKERS IN REVERSE LOGISTICS

4-eye principle inspection and criteria check of used products



CASE STUDY - AI-BASED CORE IDENTIFICATION TEST

First Results from experiments with OpenSource AI-models



Automotive Cores	# Objects	Top 1 [%]
Alternators	507	-
Starters	884	-
	1391	96.36

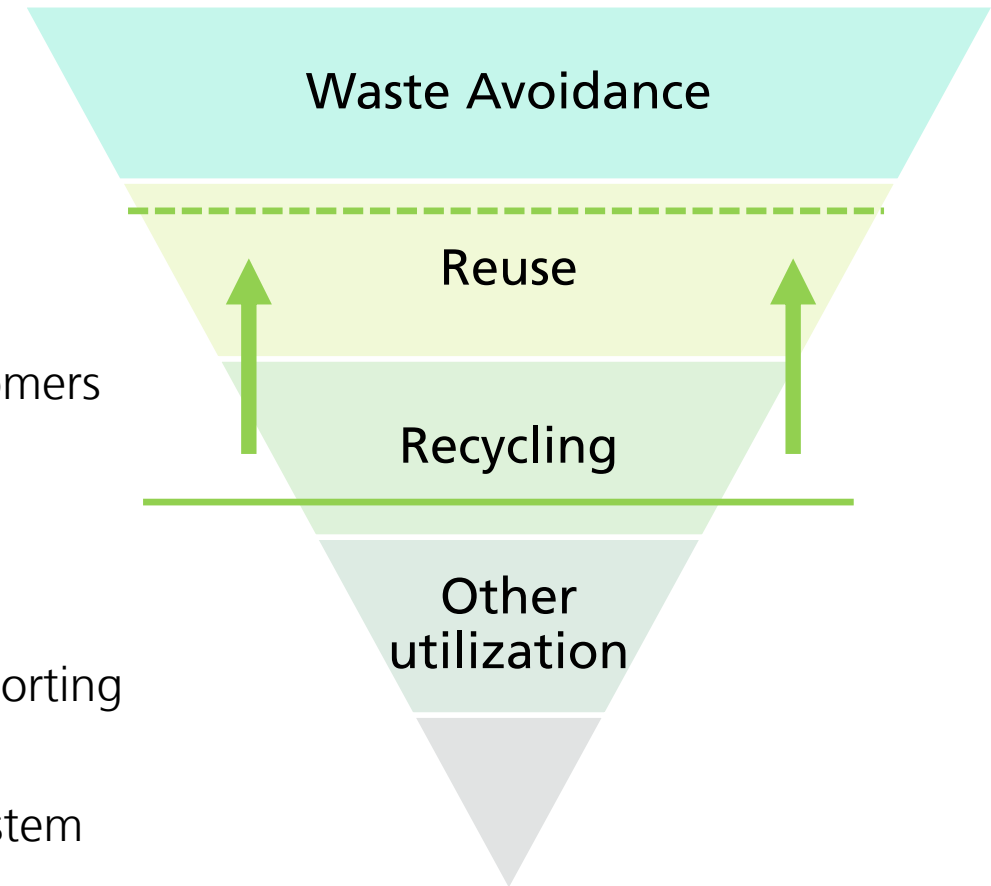
CONCLUSION & OUTLOOK

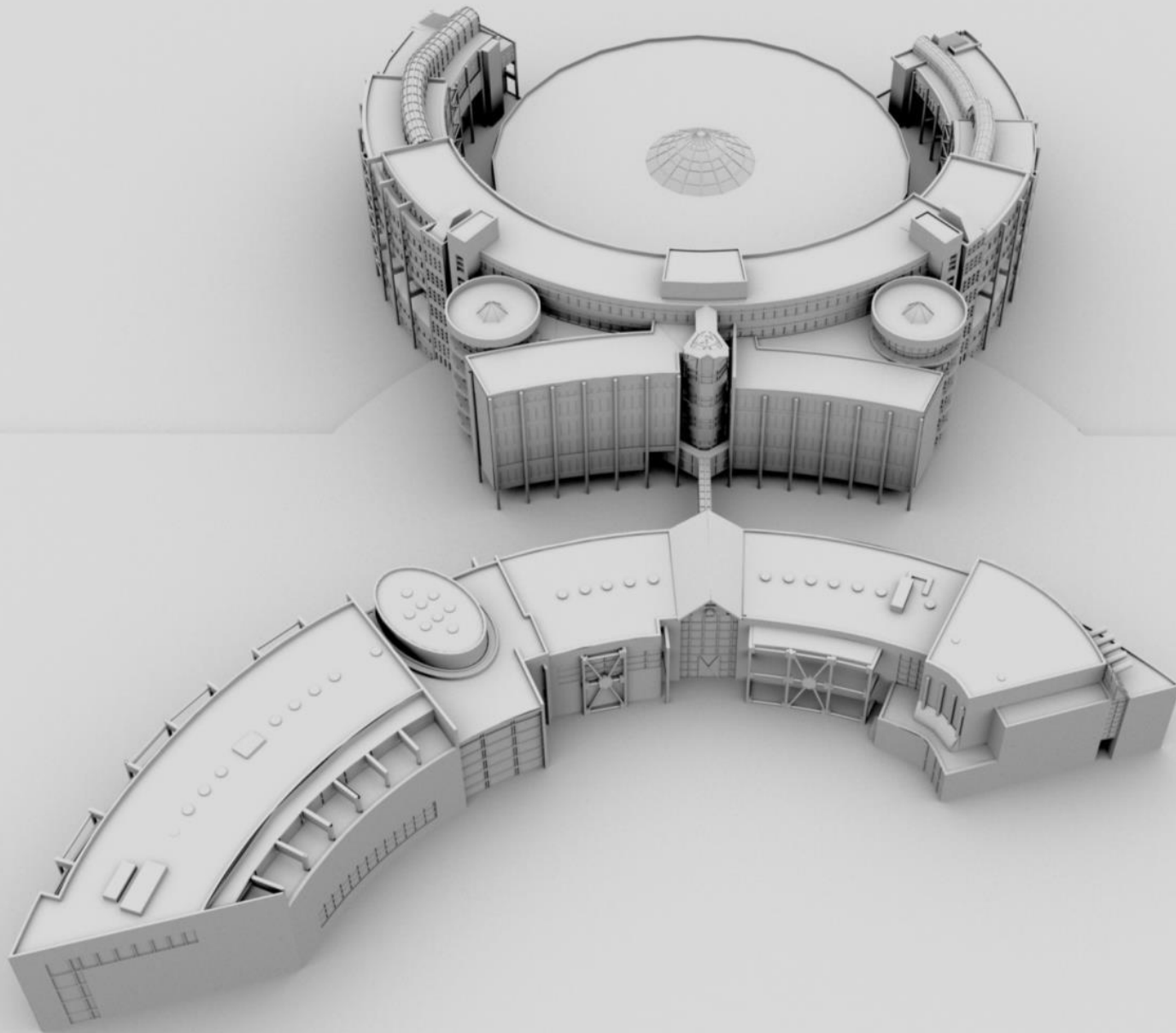
AI-enhanced identification, inspection and sorting for reverse logistics

- Identification of cores independent from tags is feasible
 - Allows new products to be shifted from material recycling to functional remanufacturing
- Faster process by assistance of AI-systems
- Technical image-based reports support transparency towards customers and reduce reclamations

Next Steps:

- Testing joint evaluation the context of the EIBA research project
 - Extension of the data set with real application data from the sorting station
 - Implementation and Evaluation of AI-enhanced Assistance System





**Thank you very
much for your
attention!**

Marian Schlüter, M.Sc.

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Machine Vision
Automation Technology

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