



Finding the Needle in the Haystack on the Use of AI in Defect Analysis

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June 13th, 2024

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- Driving insights and innovations from data
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HARDWARE

SOFTWARE

Evaluation and process optimization
InspectionWorks

SERVICES

Services offerings | After-Sales support | Training | selected inspection services

Flow of the story



Why inspect?



Recognizing defects



Automating the analysis – how is it done?



ADR, AI, ML and Neural Networks



Let's make it practical



Case studies



Wrap-up

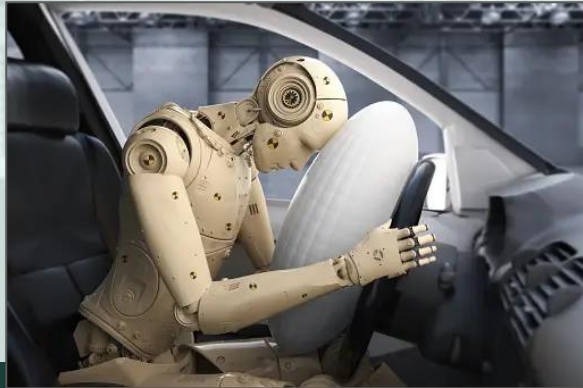
Why inspect?

- Make things better, faster
- Improve performance, life

Waste and risk
reduction



Implementation
cost



NDE/QC:

- Cost
- Structural
- Material defects
- Dimensional/Metrology
- Mfg. equipment trending

In-service:

- Life
- Integrity
- Reliability



Examples: failing airbags, blown
aircraft engines, burning EV's

In general: Greater risk, greater desire
for inspections (quality systems)

ACQUIRE

inspection data

ANALYZE

to gain insight

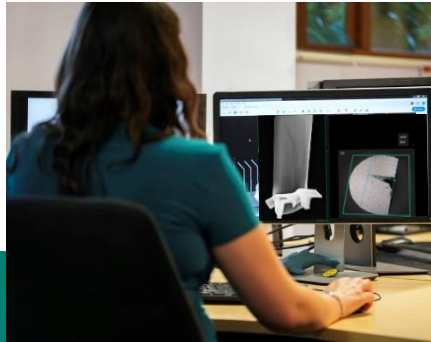
ACT

on insights

Interpreting non-destructive data

Logistical challenges facing NDE

- ✓ Resource burden: skilled, certified
- ✓ Cost and perception
- ✓ Aging workforce
- ✓ Need for speed
- ✓ Data retention
- ✓ Data flow



Technical challenges of NDE

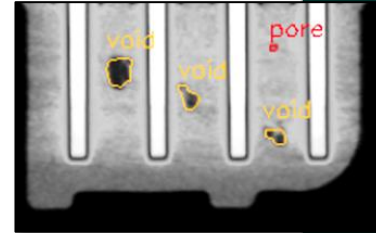
- ✓ Human performance
- ✓ Tech Plans, Maintenance Manuals

Automated Analysis:



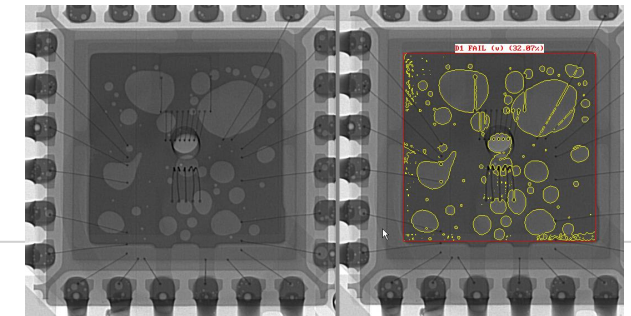
Benefits:

- Speed
- Quality
- Resource
- Comprehensive: NDE 4.0



Considerations:

- Scope
- Performance
- Quality system
- Automate or assist?
- Timing
- Data
- Integration
- Validation and acceptance



ACQUIRE
inspection data



ANALYZE
to gain insight

ACT
on insights

Our history of ADR...

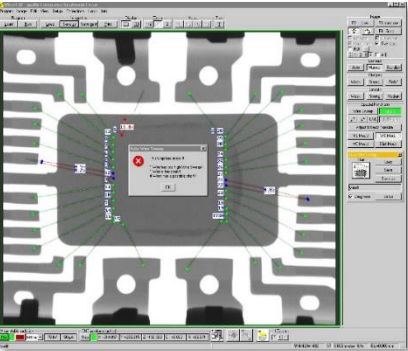
1990s



Seifert SABA,
world's first
commercial X-ray
ADR...

Automatic 2D ADR for
auto safety parts

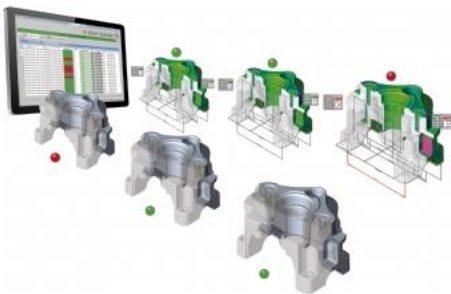
2000s



Phoenix X-ray XE²
ADR targeting
electronics...

Extensively adopted
and used for PCB
/solder ball inspection

2010s



Speed|ADR

High speed 3D ADR for
helically scanned CT
part



2020s

Visual ADR

Still and video image based
ADR

X|approver

ADR for consumer battery
defects

InspectionWorks

Cloud-based data ADR and
data mgmt.

Waygate Technologies has been a pioneer in enhanced inspection techniques for 125 years and has evolved ADR for the last 30 years, starting with rudimentary rules based and pattern recognition techniques through to the most sophisticated machine learning and AI enhanced algorithms.

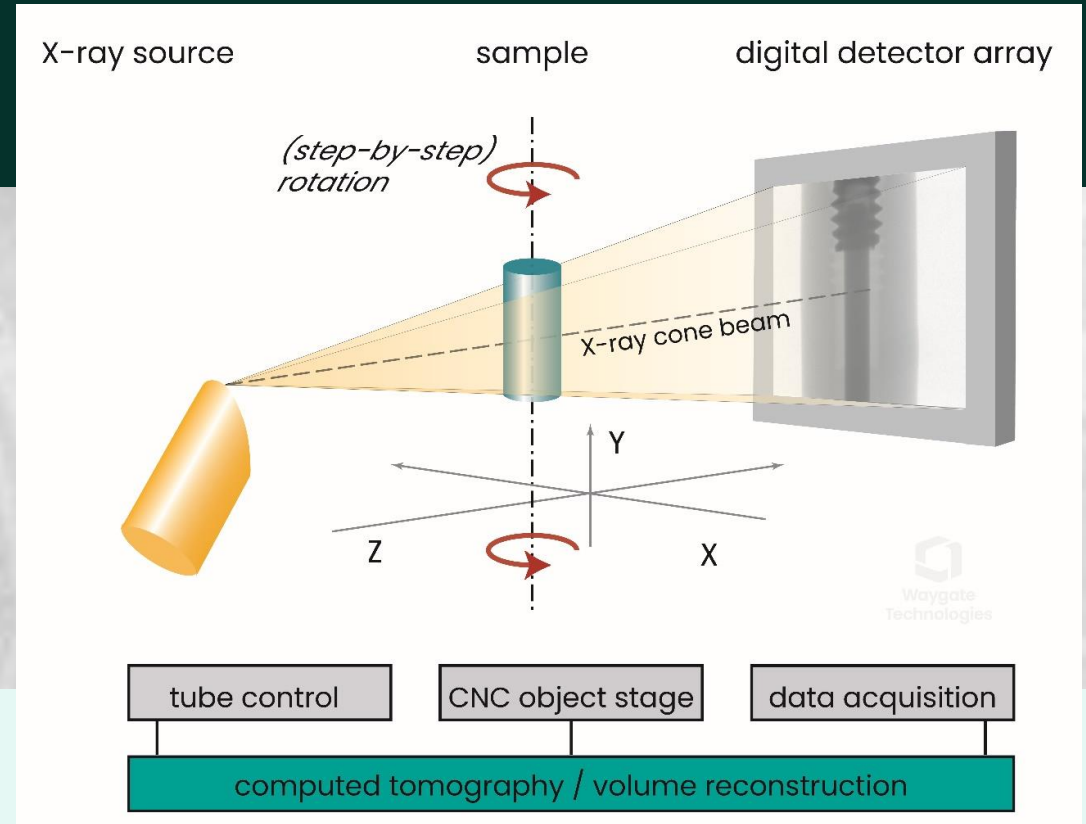
Outcome restricted by your input (GIGO)

Relevant questions to consider:

- What does your data look like?
- Has acquisition been optimized?
- Detection entitlement?
- Challenge of detection task?
- Knowledge of defect scope / impact?
- Binary? Regional dependencies?

AI-specific:

- AI = data
- Capture all defects?
- How frequently encountered?
- What is current and desired performance?



Detection Approaches: AI, ML, and DL

Rules-based morphology

- Pros: Predictable, understood, lower data dependency, allows regional variations
- Cons: Potentially slow, need for descriptive rules, 'fixed' solution

Statistical/Correlation

- Pros: Predictable, straight-forward
- Cons: Data dependency; false call risk upon changes in data

Background Subtraction

- Pros: Simple
Unstable to changes, lower performance

Dictionary Learning

- Model-based anomaly detection
- Pros: Predictable, Fail-safe
- Cons: Data dependency

Principle Component Analysis

- Dimensionality reduction based

Support Vector Machine

- Aimed at classification

CNNs, FFNNs, ...

- Pros: Easy to apply to variety of detection tasks
- Cons: Data dependency, false call risk, not common for regional variation
- E.g. layered CNNs, YOLOvX, FFNN's, ...

Auto-encoders

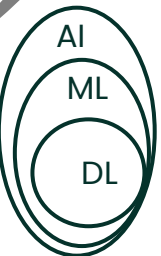
- Model-based anomaly detection
- Pros: Predictable, Fail-safe
- Cons: Data dependency

Unsupervised approaches

- Find anomalies
- Addresses annotation burden

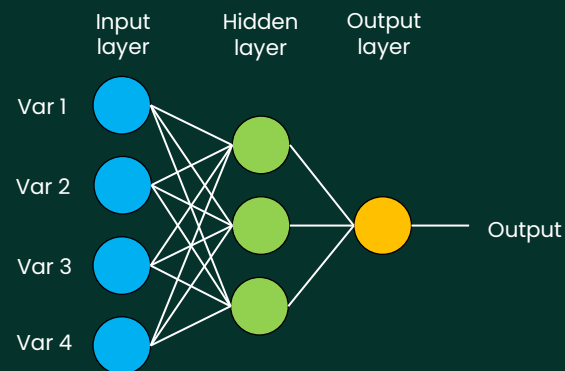
Generative Adversarial Networks

- DL comprised of two networks that try to outdo each other
- Promising
- Reduce data dependencies



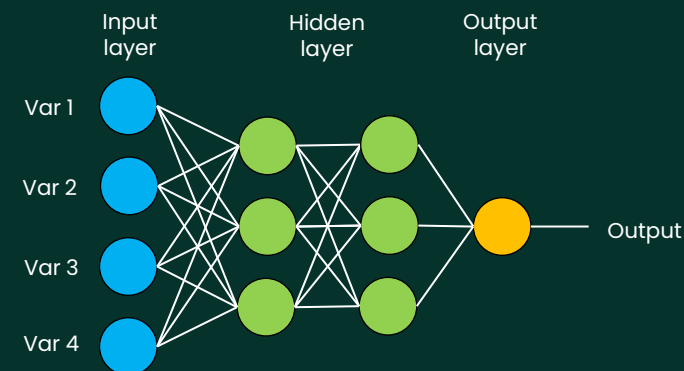
Neural Networks

Simple network:



Neural networks:

- Input, output, and hidden layers
- Layers of nodes
- Combinations and weights
- Analogy to neurons



Classification example:



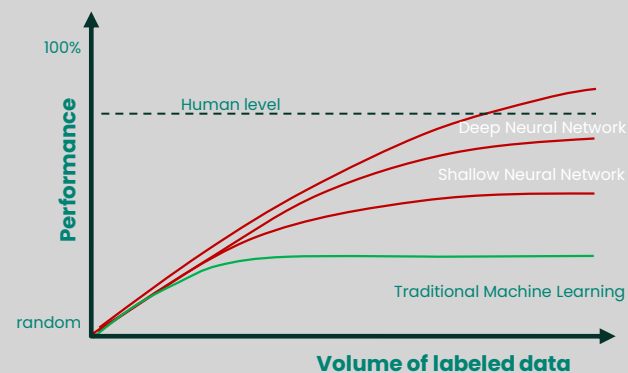
"THE MNIST DATABASE of handwritten digits"

How would you design software to recognize handwritten characters?

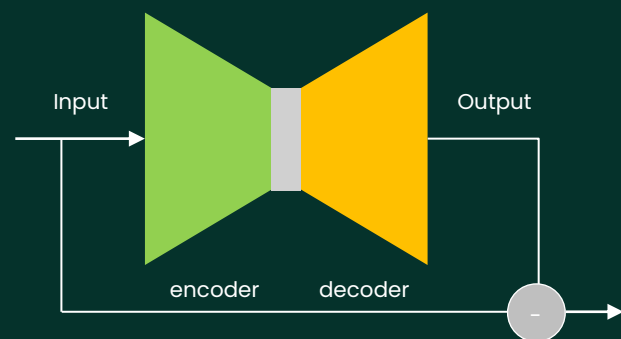
- Image matrix
- Limited output
- Variation on input
- Convolutions

Neural Networks

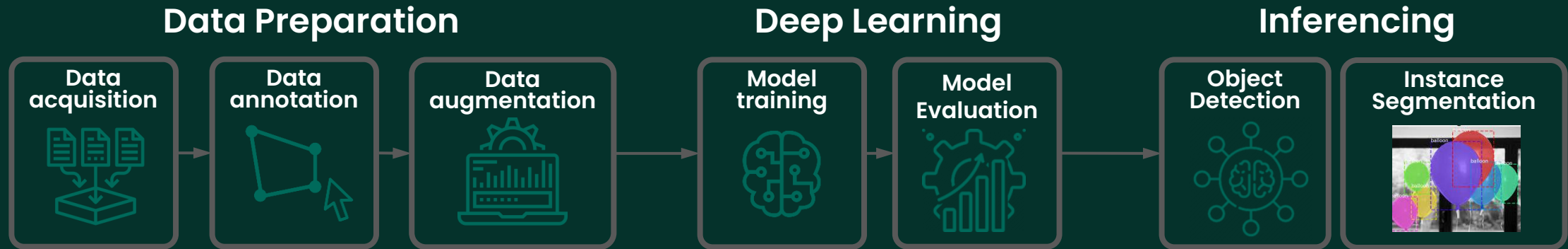
Impressive performance



Magic in stacking networks, e.g.:



Let's make it practical... *almost*

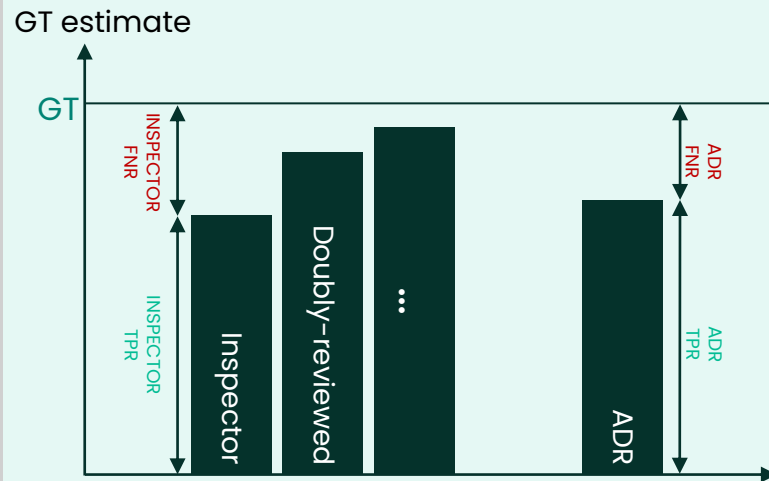


Performance Concepts:

applicable to any inspection modality

BEFOREHAND:

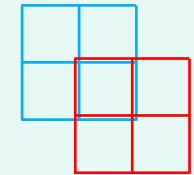
- GT
- TPR, FPR
- IoU



PREDICTOR

GT	PREDICTOR	
	-	+
-	TN	FP
+	FN	TP

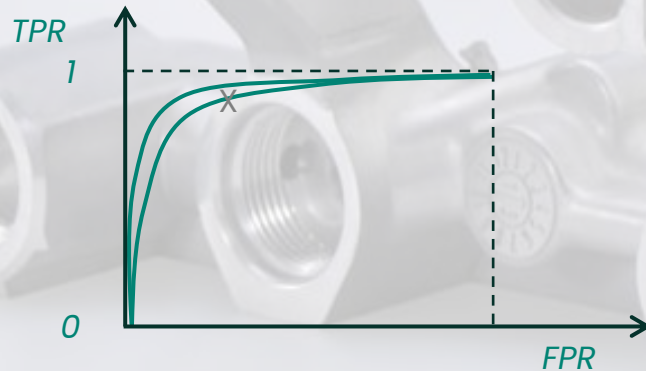
DID WE GET IT?



Let's make it practical: *Using ADR*

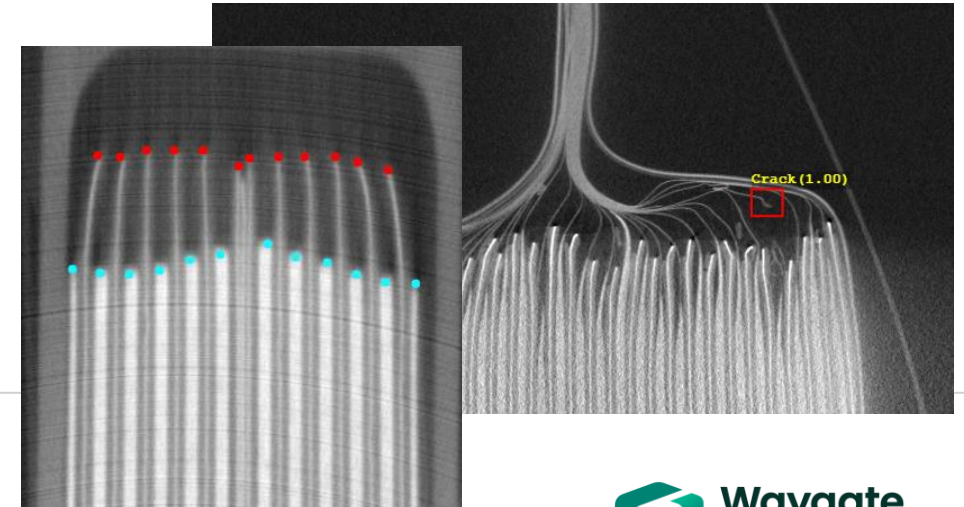
Validate performance (inferencing):

- Detection rates: ROC charts
- Cycle time
- Failure modes
- Stability



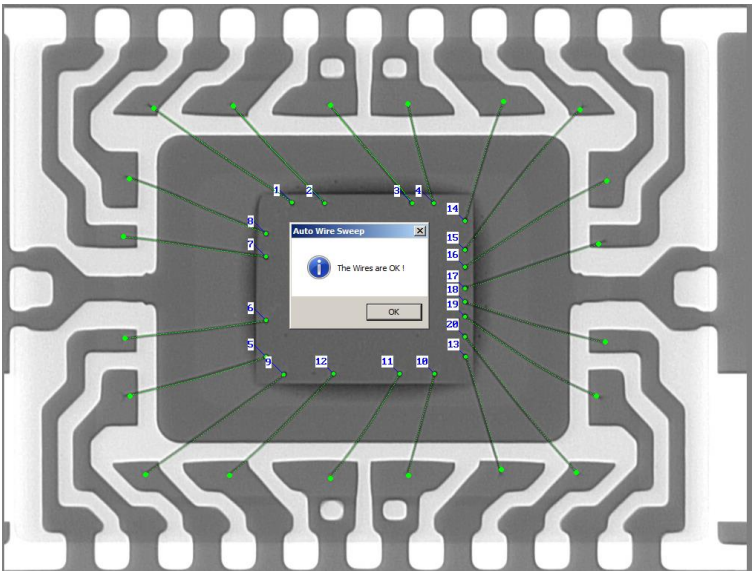
Impact on NDE:

- Perception across roles: business, quality, NDE personnel
- Excitement and fears: transient & expectations
- Big-picture: NDE 4.0 – feedback loops, lifing, etc.
- Increased quality and expectations
- Impact to inspectors
- Capture of information (“blockchain”)



Let's make it really practical: *hardware engineering examples*

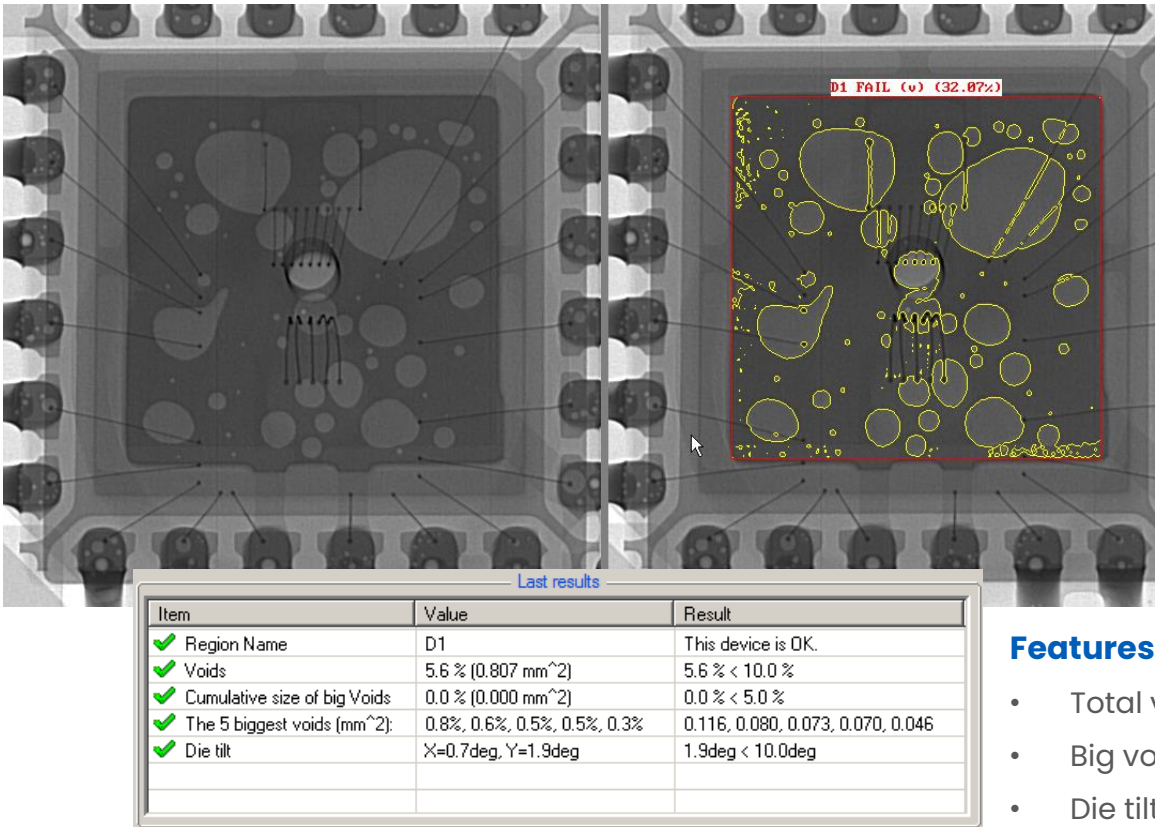
- X|act: Wire Sweep



Defects to be identified

- Short wire – short distance between two wires
- Messy wire – wire with unexpected position
- Residual wire – odd or unsuspected wire
- Wire sweep

- X|act: Voiding Calculation (VC)



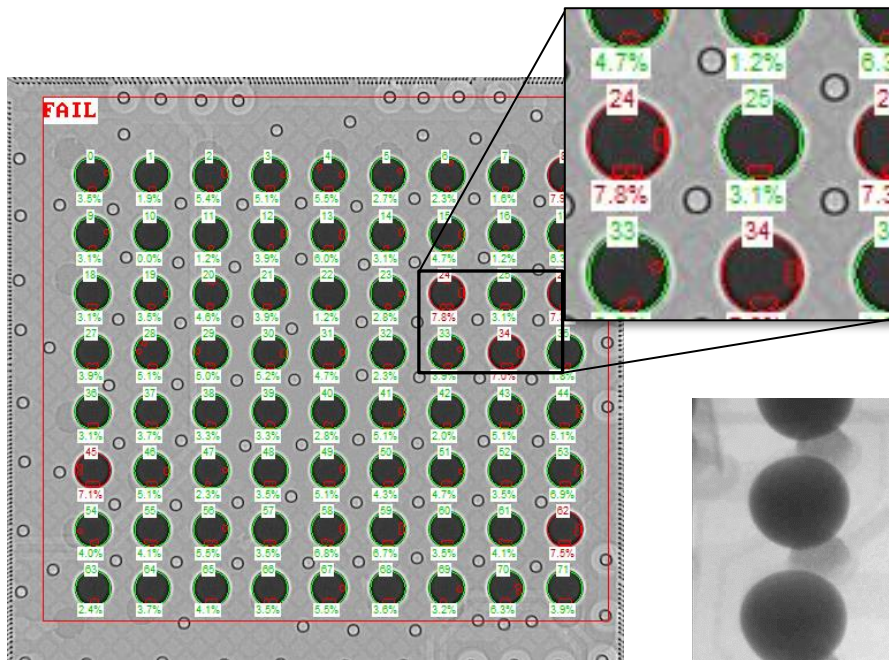
Features to be evaluated

- Total voiding (%)
- Big voids (%)
- Die tilt (°)

Let's make it really practical: *hardware engineering examples*

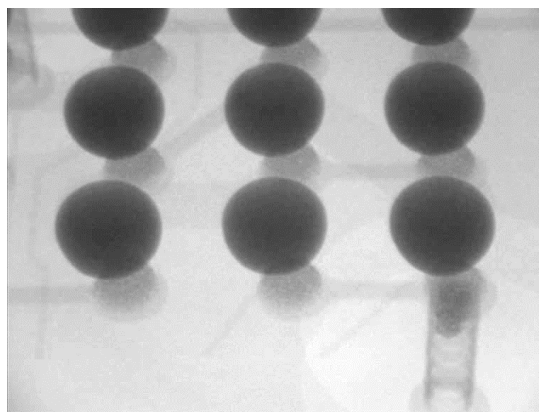


• X|act: Ball Grid Array (BGA, μ BGA, FC)



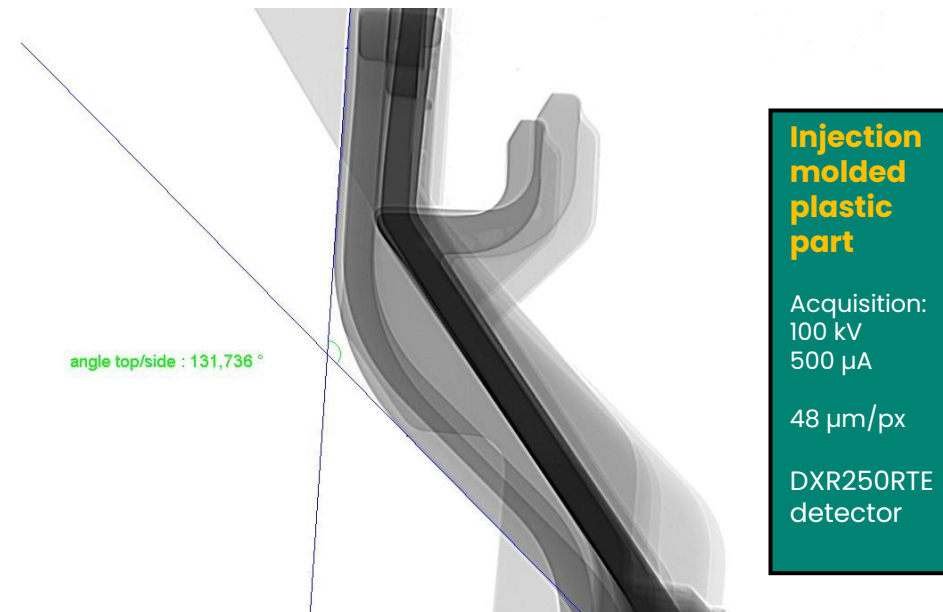
Features :

- Form deviation
- Position offset
- Area deviation
- Missing balls
- Voiding (%)
- Diameter



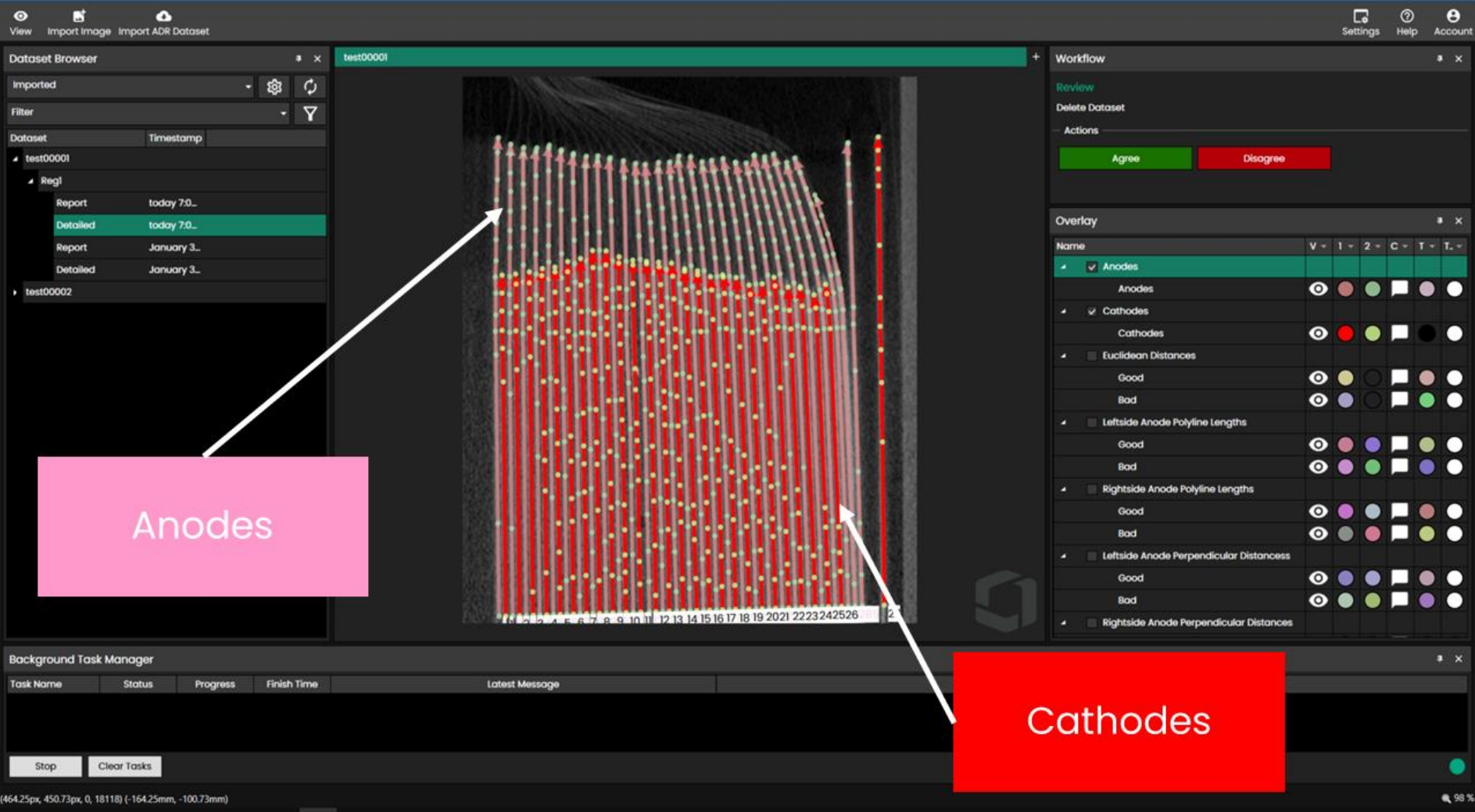
20x time-lapse film shows reflow process.

• X|act: Geometric fitting



- Measurement of an angle from side view
- All structures of the part are overlaid in the X-ray image
- Automatic measurements with flexible, programmable X-ray image evaluation routines (XE²)

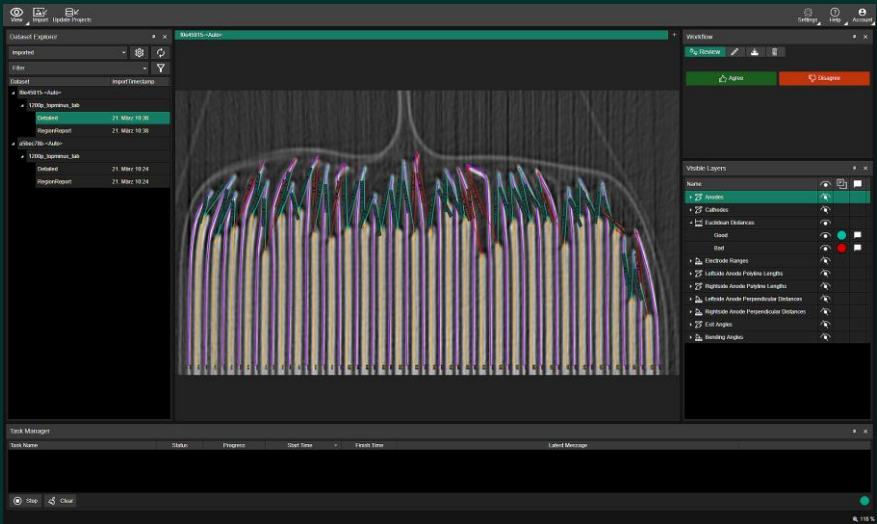
Let's make it really practical: *Teachable ADR*



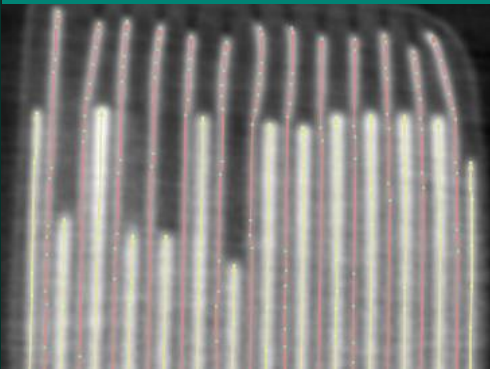
X|approver:

AI software
platform for
X-ray and CT

Let's make it really practical: *X/approver* for battery inspection

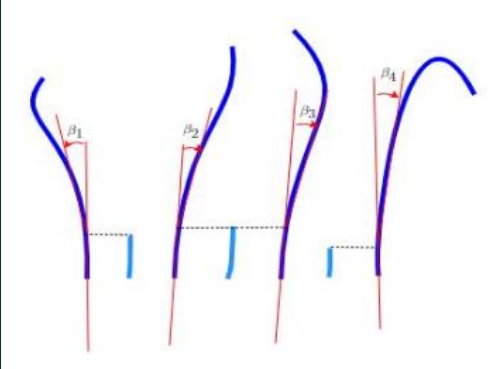


Battery Overhang



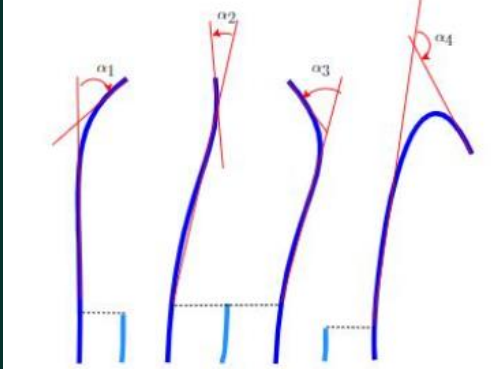
Cathode and anode position

Overhang Exit Angle



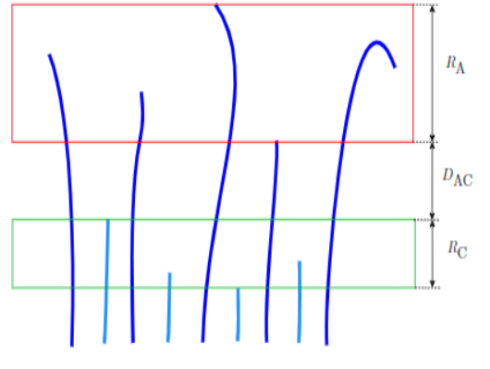
Measure Anode angle, Highest Cathode length neighbor

Overhang Bend Angle



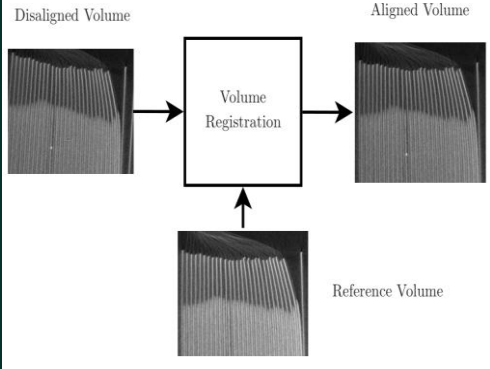
Measure Anode Bending angle

Overhang Tolerance



Electrode Range/Tolerance

Volumetric Registration



Align volume 2D & 3D

Take-home message

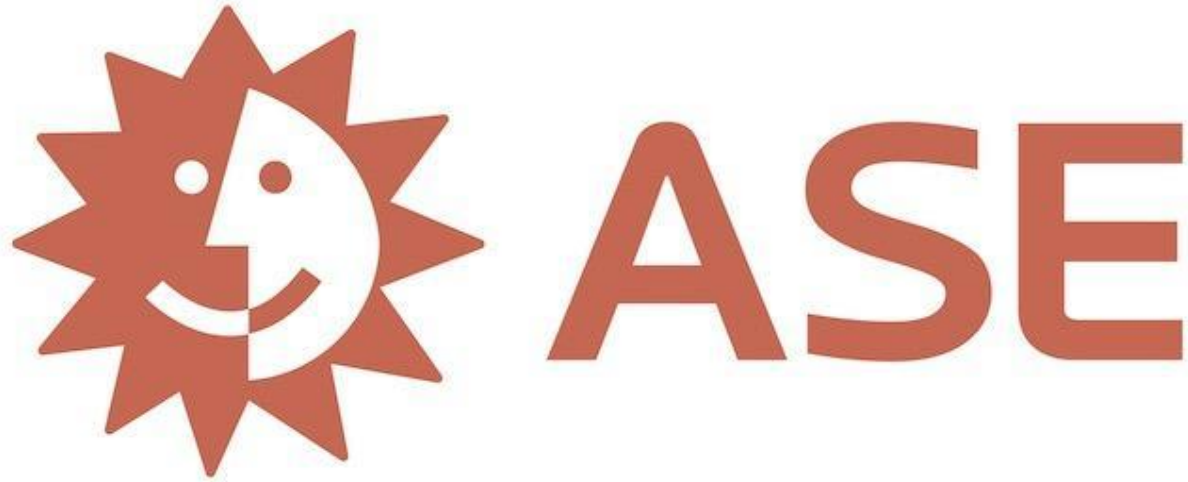
- Inspections / Measurements for QA
- Assisted/Automated Defect Recognition
 - Defects
 - Anomalies
 - Measurements
- There is more to ADR than DL
 - AI/ML/DL
 - Performance Metrics
 - Impact
- Novel AI has opened the door to exciting applications in NDT

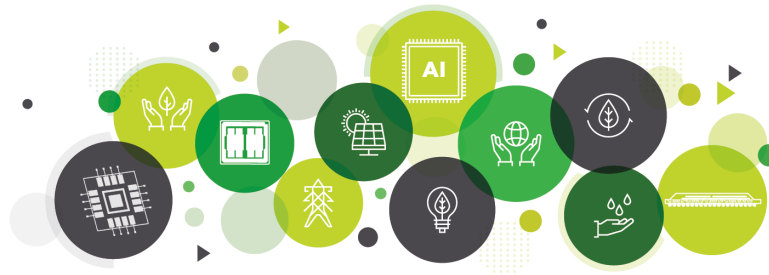


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