International Center for
Quantum-field Measurement Systems for
Studies of the Universe and Particles
WPI research center at KEK

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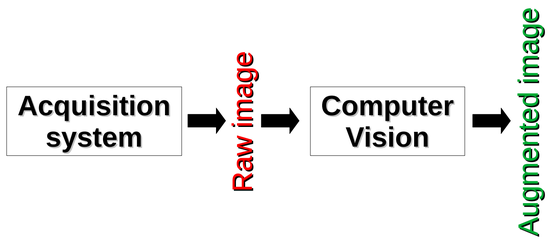
Improving new detectors Quality Control procedures with AI-powered defect detection

Objectives

– New Detectors for uncovering New Physics
  The search for N**ew Physics** require **New Detectors**
    More sensitivity
    More complexity
  Ensure the fabrication and assembly of New Detectors
    => For a successful experiment

– The challenge of optimal quality
  Visual Inspection of detector components is one the the main challenge for Quality Control
  Manual Visual Inspection "*by eyes*" is difficult
    Time consuming
    Error prone
  Using advance AI techniques to improve the procedure
  => Increase efficiency and reliability



Strategy

– Combines two complementary approaches
  Unsupervised defect detection
    Use **anomaly detection** to *localize rare/unknown defects*
  Supervised defect classification
    Use **multi-class classifier** to *identify common/recurrent defects*

– Requirements
  Efficiency
    Must combine fast inference and high precision for *optimal performances*
  Portability
    Must be flexible and adaptable for an *easy integration in any setup*

Algorithms overview

Unsupervised

Denoising Auto-encoder architecture

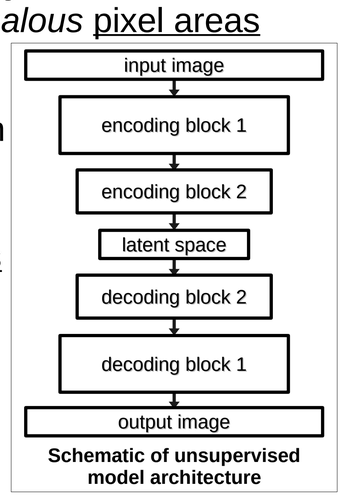
Objectives:
  reconstruct main input features
  remove *defect-like patterns*

Use difference between input and output as **anomaly score**
  Select *anomalous* pixel areas

Filtering based on clustering

Identify relevant defect candidates

Reduce *fake defect selection*



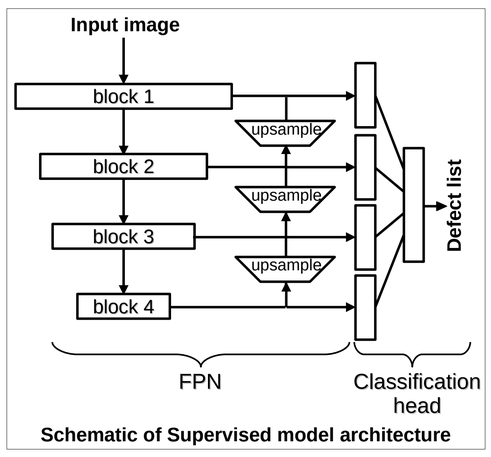
Schematic of unsupervised model architecture

Supervised

Feature Pyramid Network (FPN) with *custom* classification head

Objectives:
  Extract high level features (FPN)
  Identify *specific defect categories*

Multiple binary classification
  Individual scores for **each class**

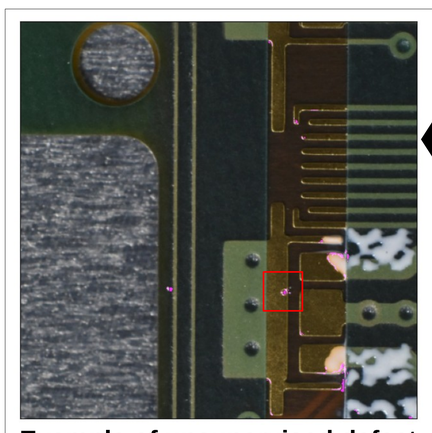


Schematic of Supervised model architecture

Demonstration

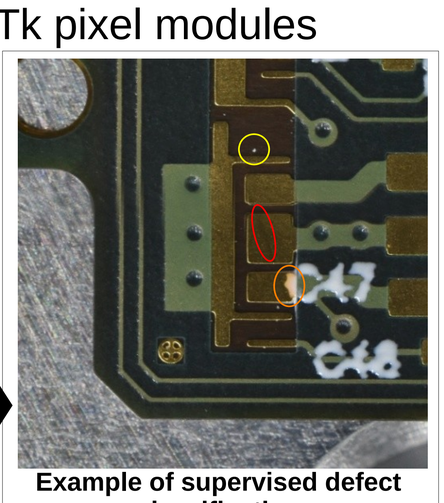
– New Inner Tracker for ATLAS detector
  New detector for the High Luminosity upgrade of ATLAS
  2800 pixel modules to be produce in Japan
    Each components undergo QC at *various stages*
  Major challenge to ensure Quality Control

– Test on real PCB images
  Model trained on one component of ITk pixel modules


Example of unsupervised defect detection

Defects **correctly detected**
Unique defect (only with unsupervised)

3 defect categories **properly identified**
  Scratch
  contamination
  dust


Example of supervised defect classification

Application

– Integration to ITk QC workflow
  Objective :
    Include the new tools into an existing framework
  Unsupervised algorithm has been **successfully integrated**
    Usage in *real detector production* **has started**
    Achieved fast inference for **best performance** (<10s)

– Generic API for better portability
  Facilitate development and integration in *any setup*
    Based on pytorch
  Key features :
    – Dataset generation (with data augmentation)
    – Model definition and training methods
    – Configuration files with *simple format*
    – Automatic hardware selection (CPU/GPU)
  API available on PyPI for **easy installation**

Going further

– Next steps
  Final validation of the method during ITk production campaign
  Extension to different components at **each stage**
  Optimization and integration of the **supervised algorithm**

– Longer term opportunities
  Open API to *public* for a wider range of use
    Application to **different experimental projects**
    Application in **various field of science**
    Possible extension outside of academic research (*industries ?*)

QUP is making *New Eyes for humanity*
=> New detection technologies

AI-powered Quality Control procedures will help us make tomorrow's detectors even better