AUTOMATED OPTICAL INSPECTION IN CHIP MANUFACTURING

PUBLIC

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SECURE CONNECTIONS FOR A SMARTER WORLD

AGENDA

The Problem

Proof of concept

Prototype

Live Demo

The Problem

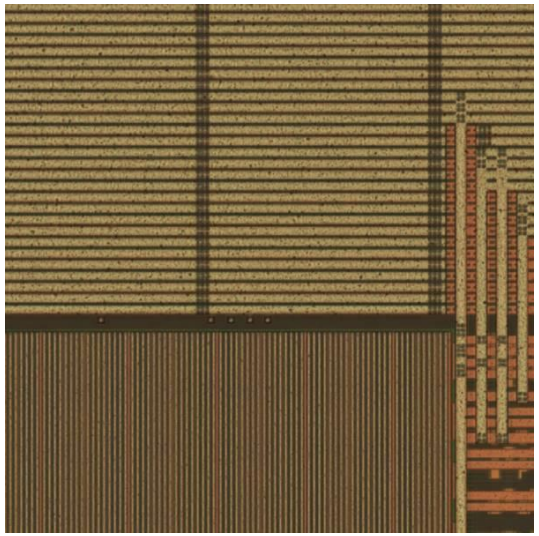
SECURE CONNECTIONS
FOR A SMARTER WORLD

TRADITIONAL WAVER DEFECT DETECTION METHODS

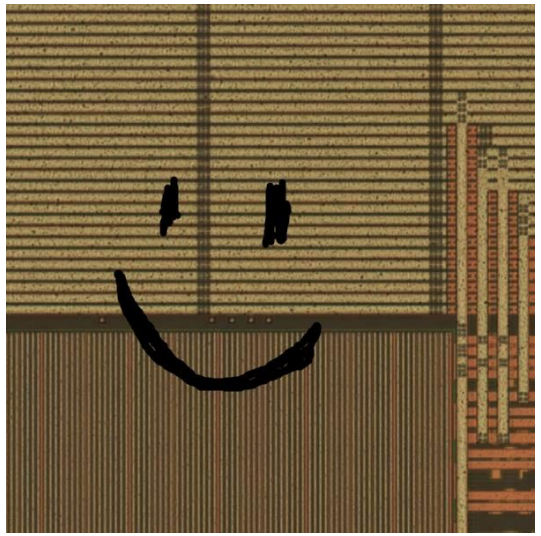
Templates available: isolate defects

Idea: use difference as labels for supervised learning?

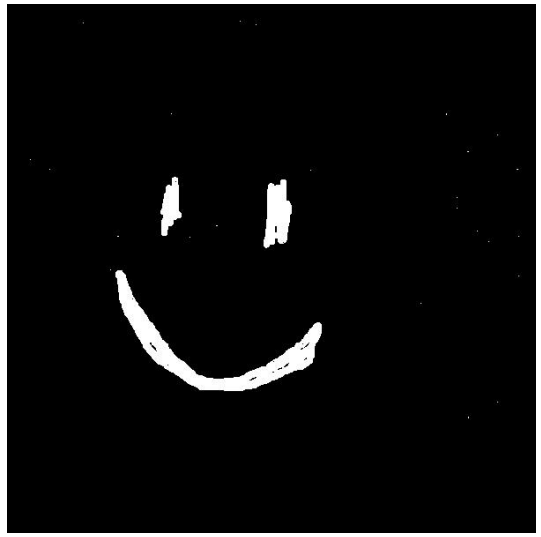
Template



Sample



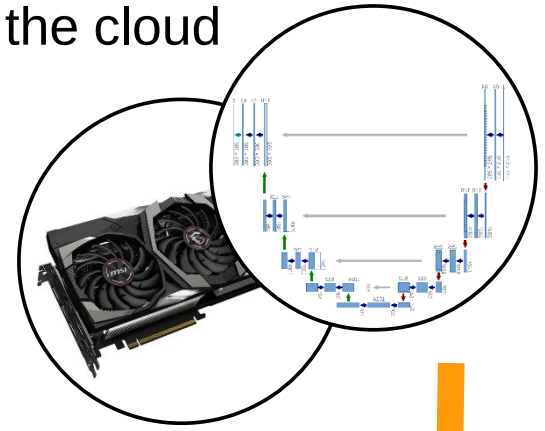
Difference/ label

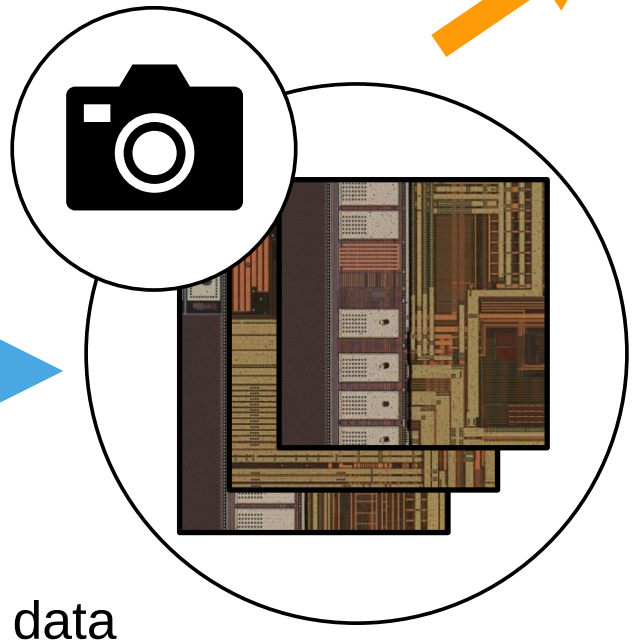


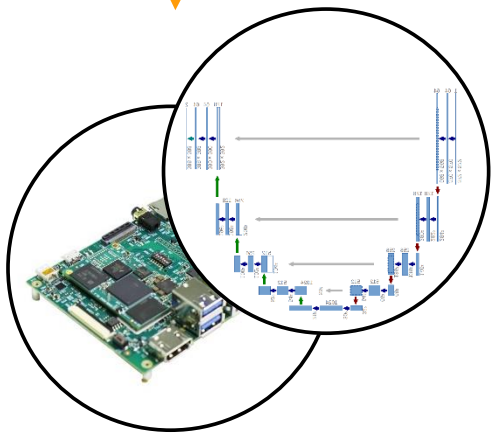
MOTIVATION/ OBJECTIVE

Training on the cloud

Quality inspection







Anomaly?

Image data

Inference on the edge

Proof of concept

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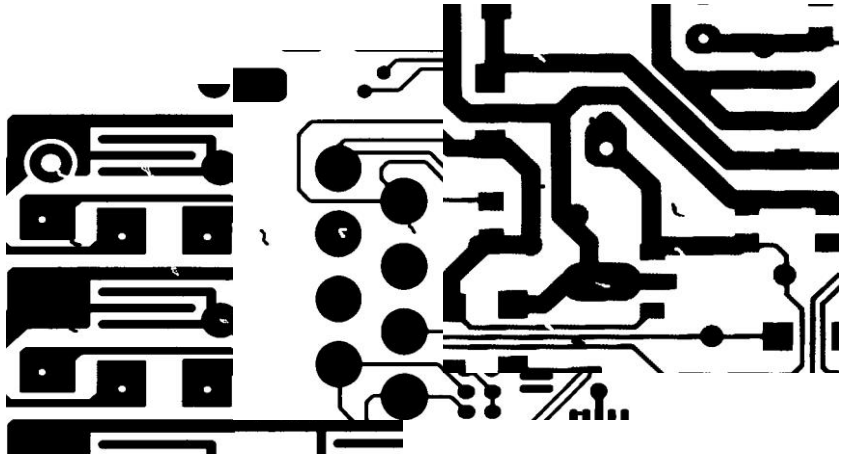
DATASETS

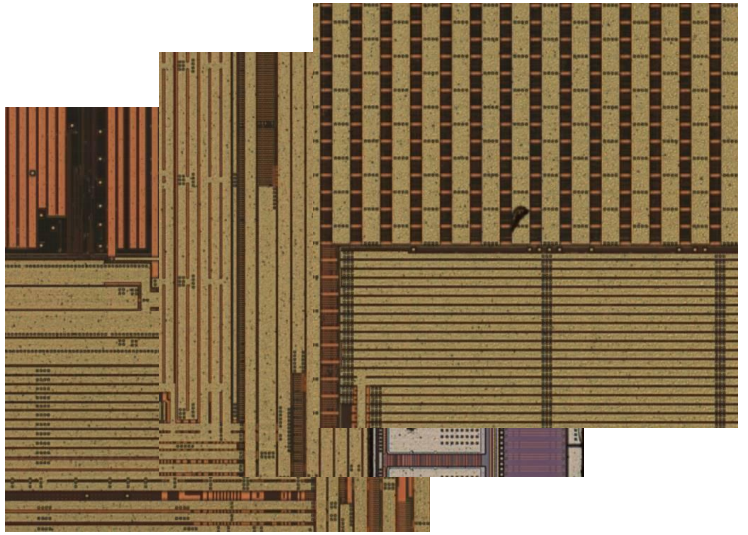
Public Deep PCB Dataset

- 1500 grayscale samples
- Templates available
- 3-12 defects per sample
- Bounding box annotations



Internal NXP Chip defect Dataset

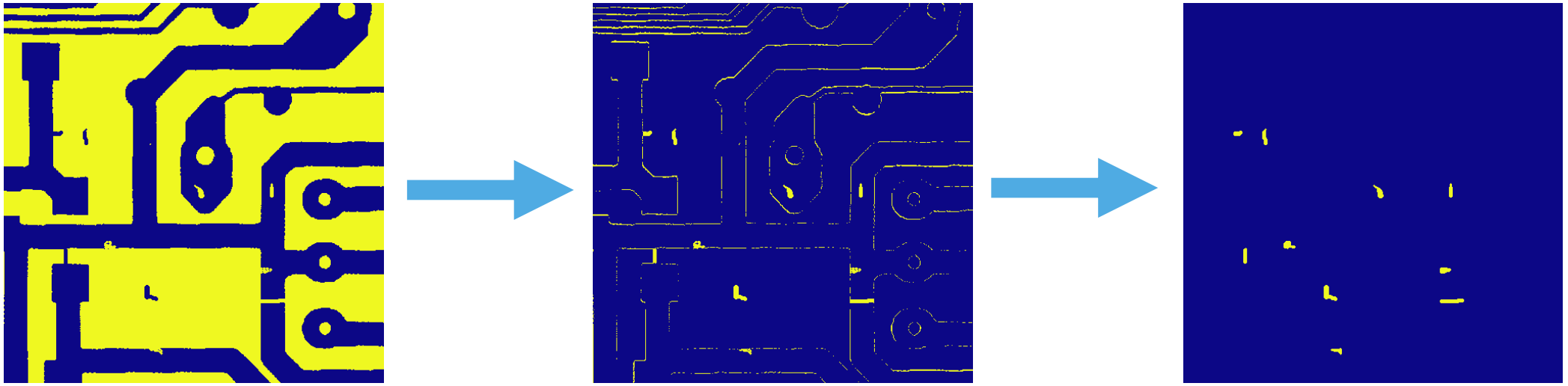
- 1474 color samples
- Templates available
- 1 centered defect per sample



PREPROCESSING – LABEL GENERATION

Pipeline:

- Image registration (≈ align images)
- Defect isolation
- Binarization (chip defect dataset)

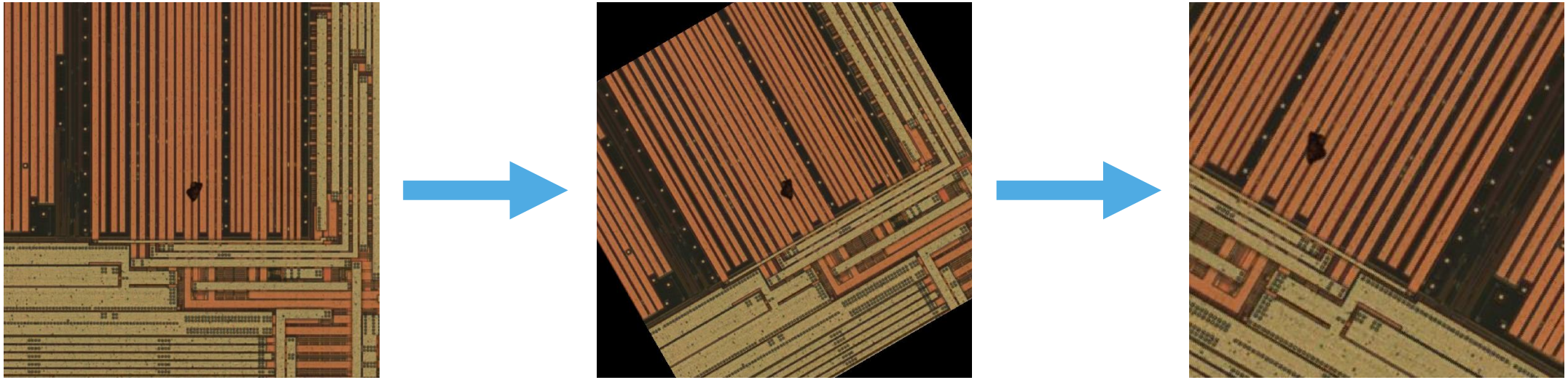


PREPROCESSING – DATA AUGMENTATION

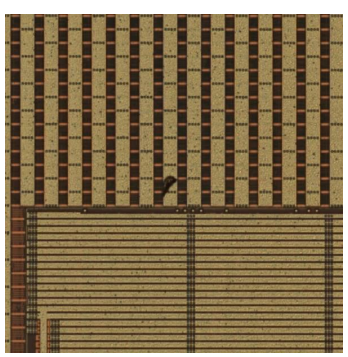
increase the amount of data by adding slightly modified copies of already existing data or newly created synthetic data from existing data

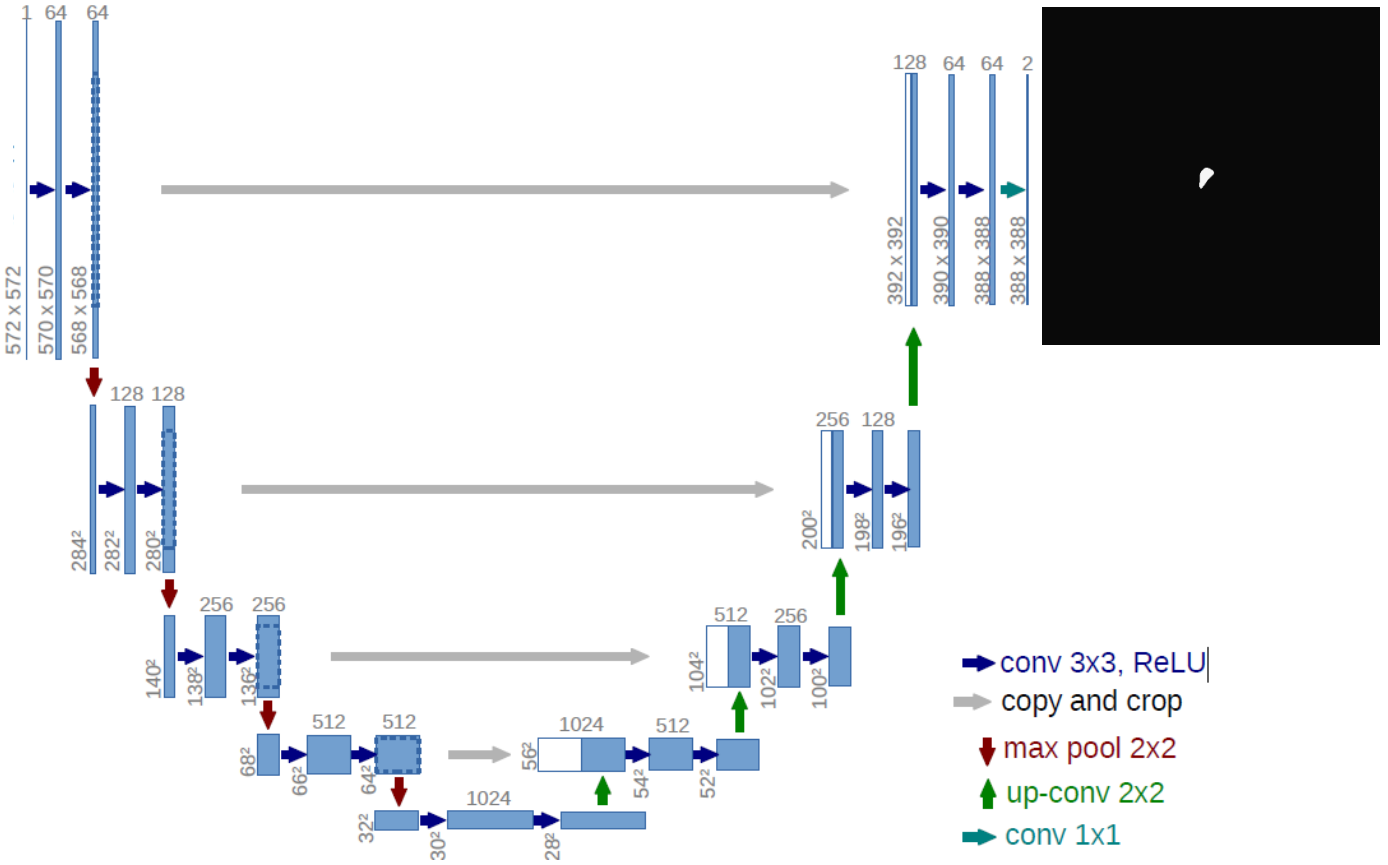
Augmentation transformations:

- Rotation
- Cropping
- Horizontal & vertical flipping



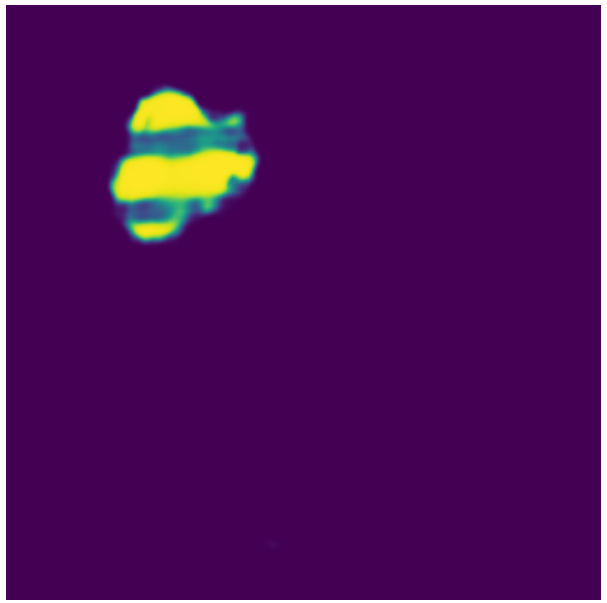
UNET: FULLY CONVOLUTIONAL IMAGE SEGMENTATION MODEL

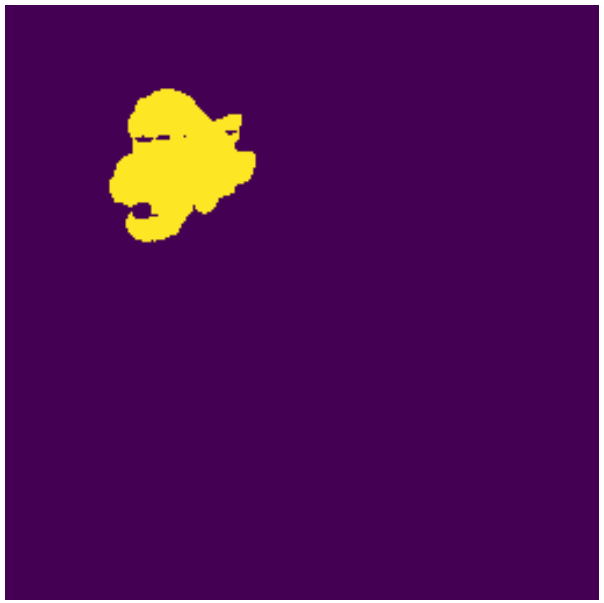


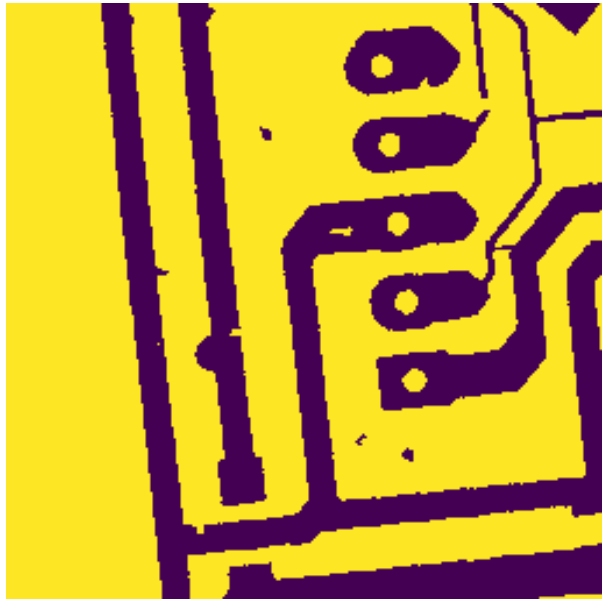


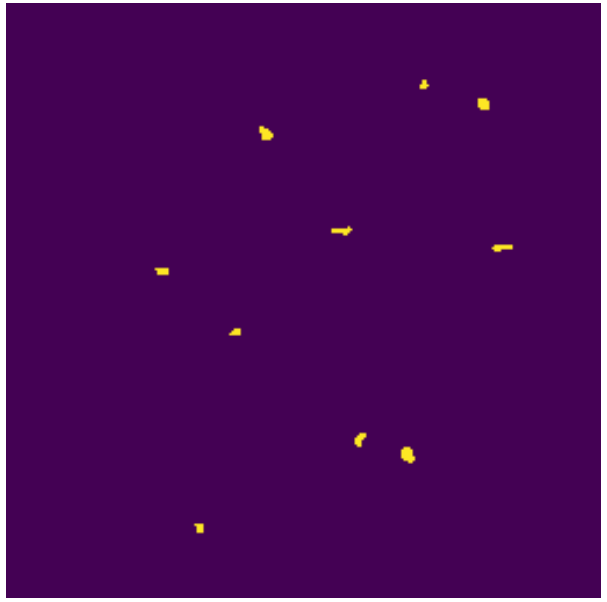
Source: U-Net: Convolutional Networks for Biomedical Image Segmentation, Ronneberger et al. 2015

OUTPUTS



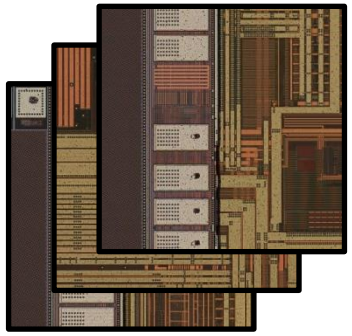


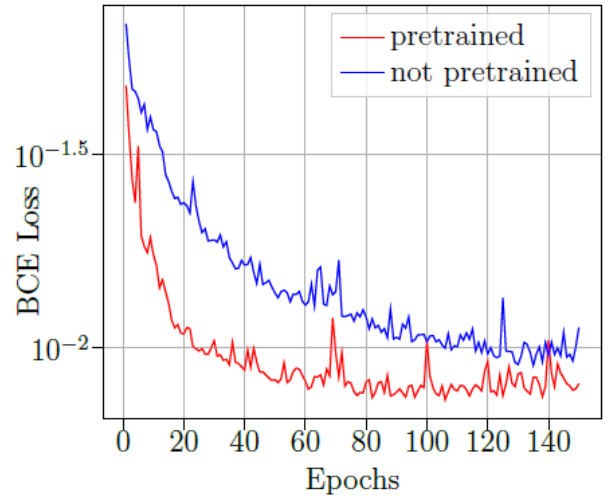




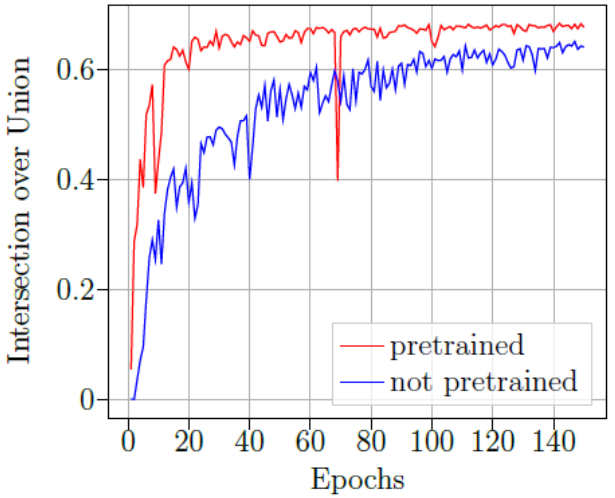
PRETRAINING

- Using pretrained weights (ImageNet) improves results

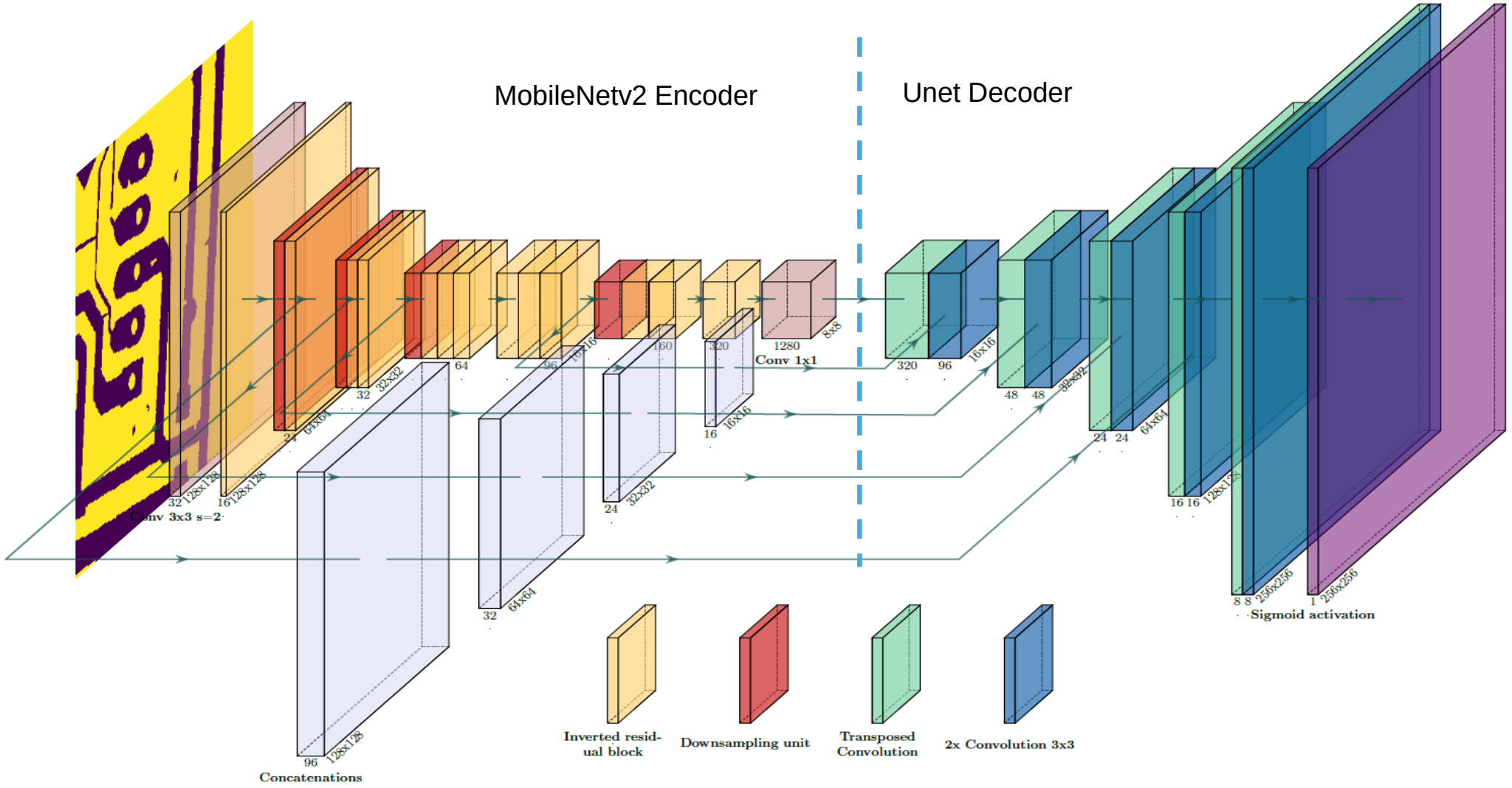




(a) Validation error

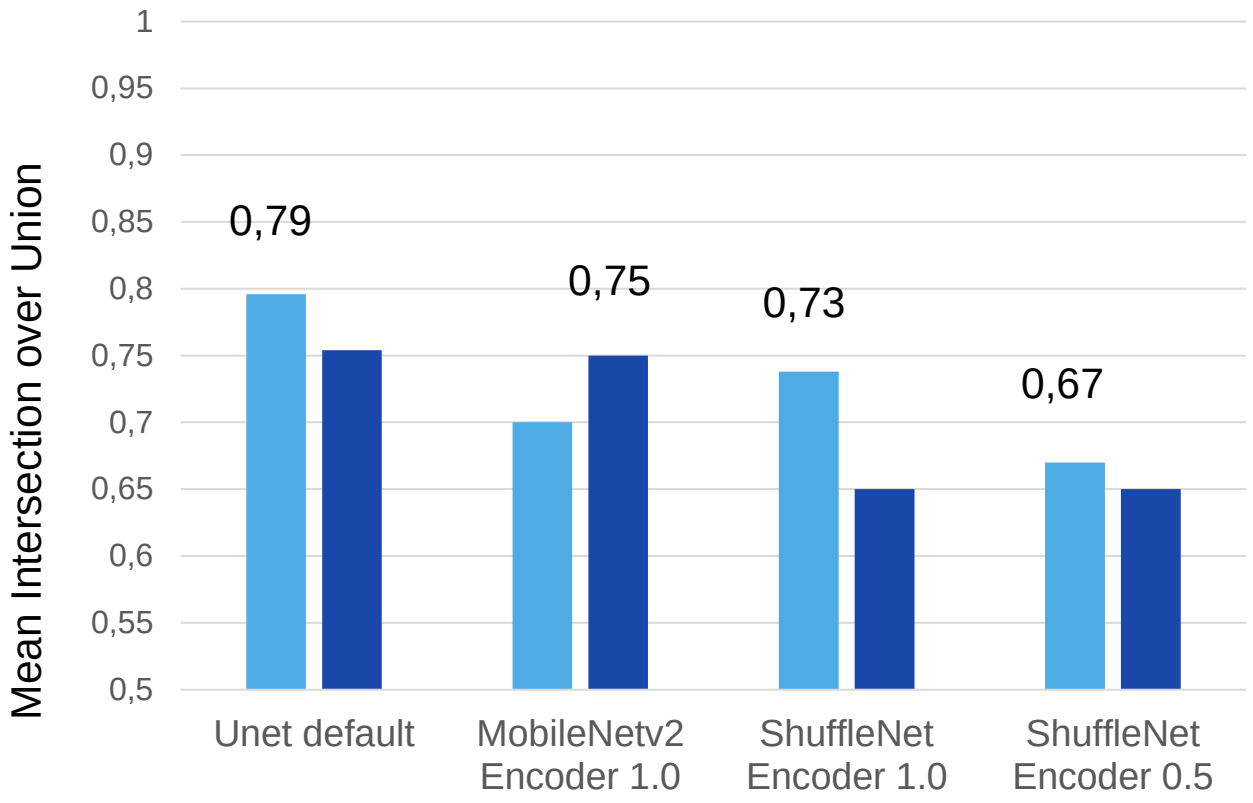


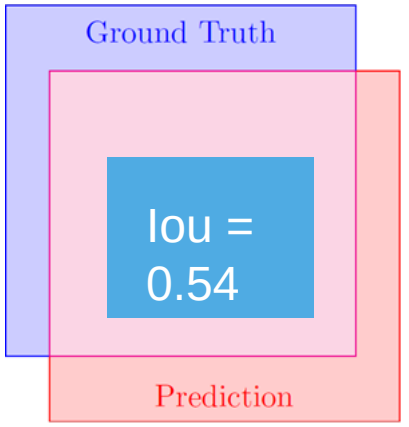
SHUFFELNET & MOBILENET ENCODER

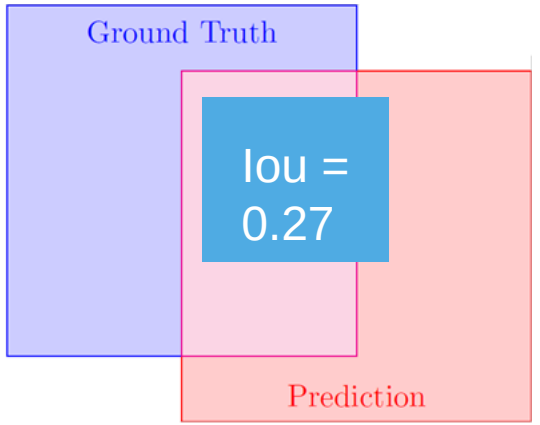


RESULTS/ EVALUATION

Intersection over Union: $\frac{Ground\ Truth \cap Prediction}{Ground\ Truth \cup Prediction}$





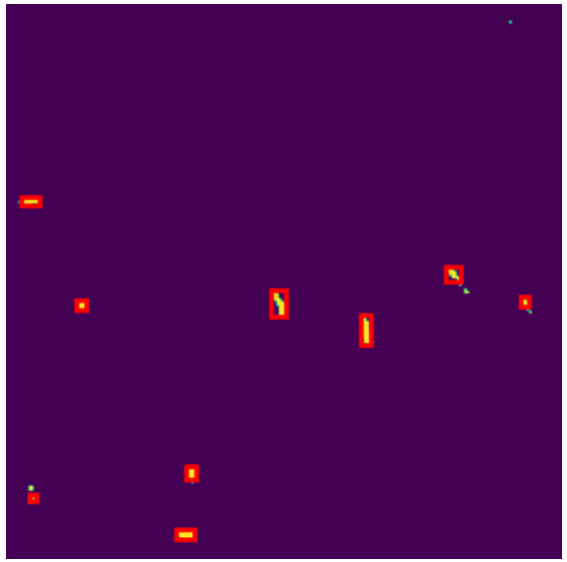


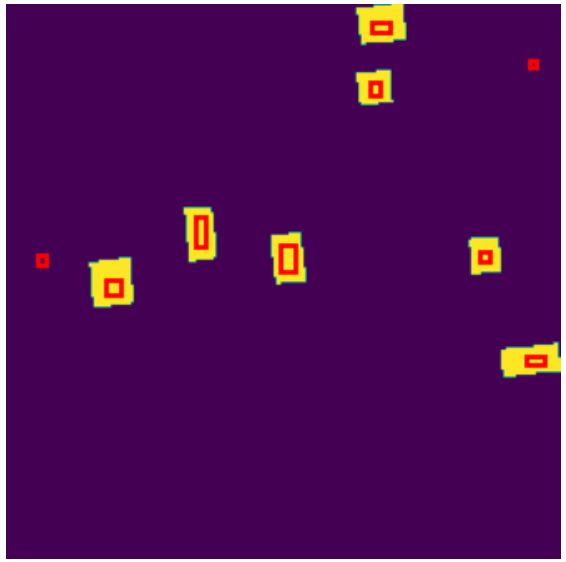
DEFECT DETECTION

- **OpenPCB Dataset**
- Number of defects in Testset: 19610

	Shuffle Unet 0.5	MobileUnet v2 1.0
TP	19040	18919
FP	1770	718
FN	570	718
Precision	**0,915**	**0,964**

DBScan Clustering:





COMPUTATIONAL PERFORMANCE

	UNet			MobileUNetv2 1.0			ShuffleUNet 0.5		
	Encoder	Decoder	**Σ**	Encoder	Decoder	**Σ**	Encoder	Decoder	**Σ**
Parameter	19M	12M	**31M**	2,2M	2,2M	**4,4M**	0,34M	1,2M	**1,6M**
FLOPs	13G	24G	**37G**	0.32G	0.43G	**0.75G**	0.04G	0.56G	**0.61G**

PROOF OF CONCEPT - CONCLUSION

- Good Image segmentation results, as well as classification:
  - IoU: ≈ 0,7
  - Precision: ≥0,96

- Model small enough for embedded applications

- Complement traditional defect detection with a more flexibel system (react to changes in manicaturing, inbetween steps of an assembly line,..)

Prototype

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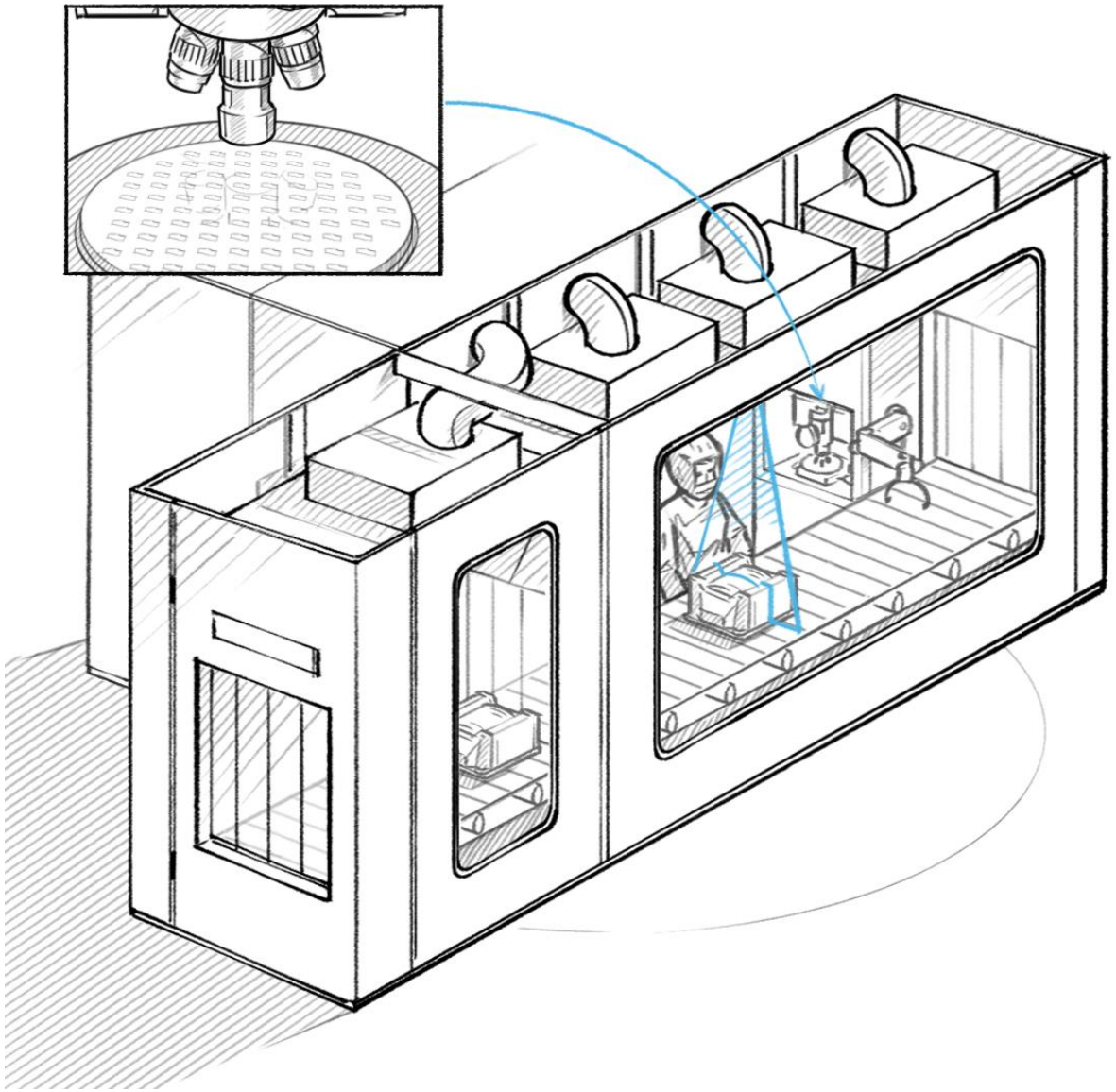
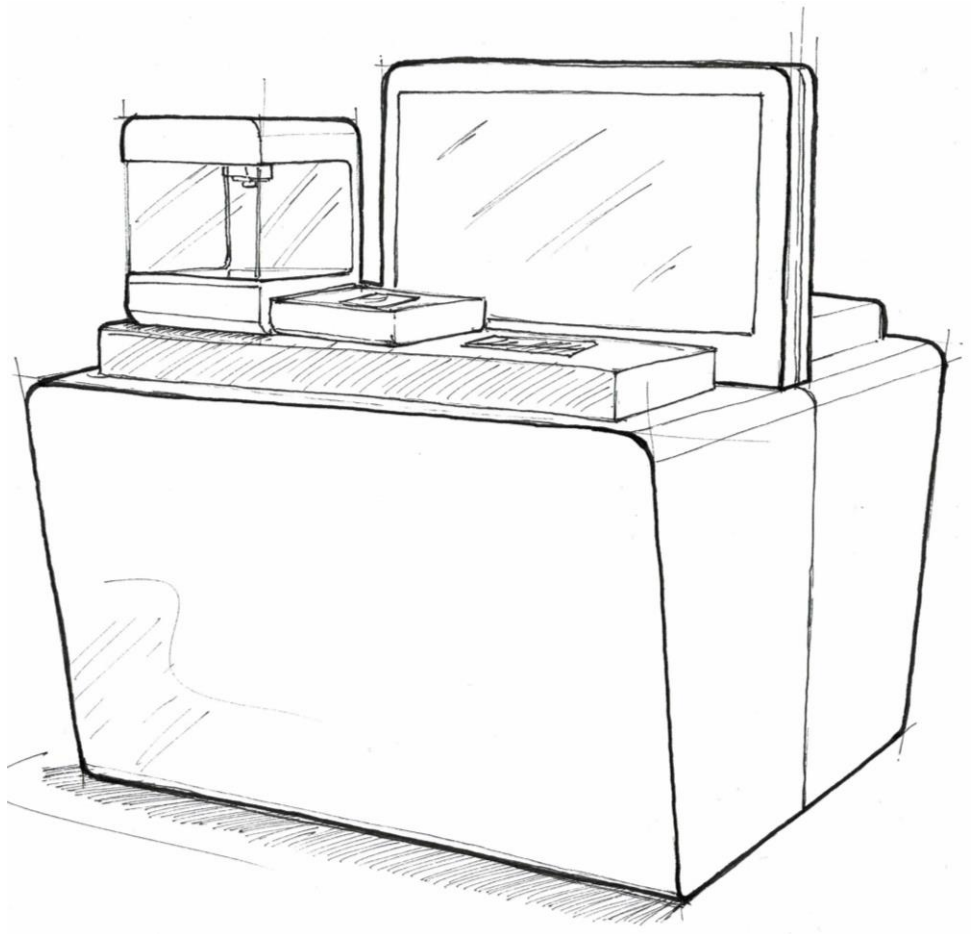
IDEA: AI ENABLED VISUAL INSPECTION





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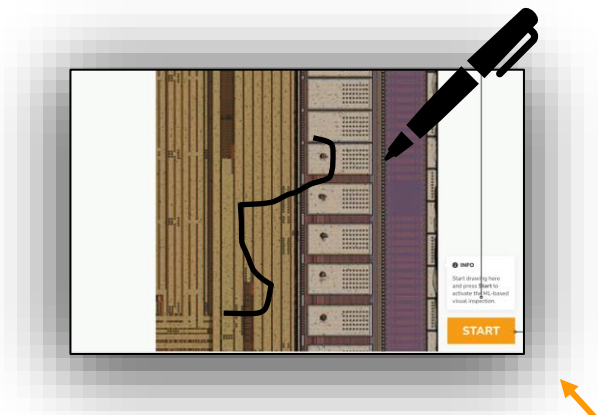
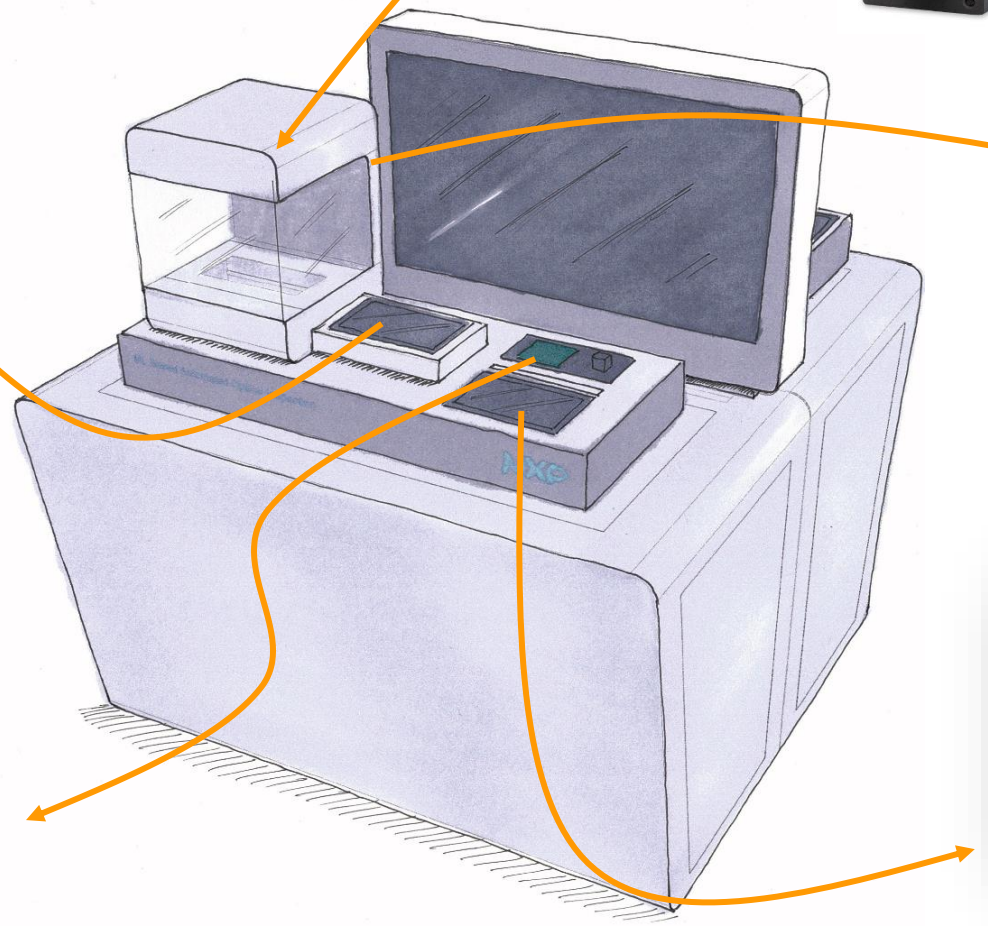


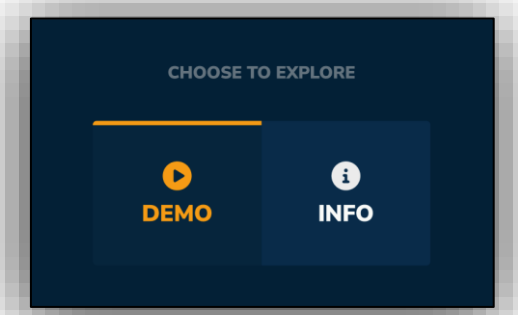
Drawer with tablet showing Wafer pattern and having Start button in tablet

Basler‘s 8MP MIPI Camera

Basler board based on i.MX 8M Plus



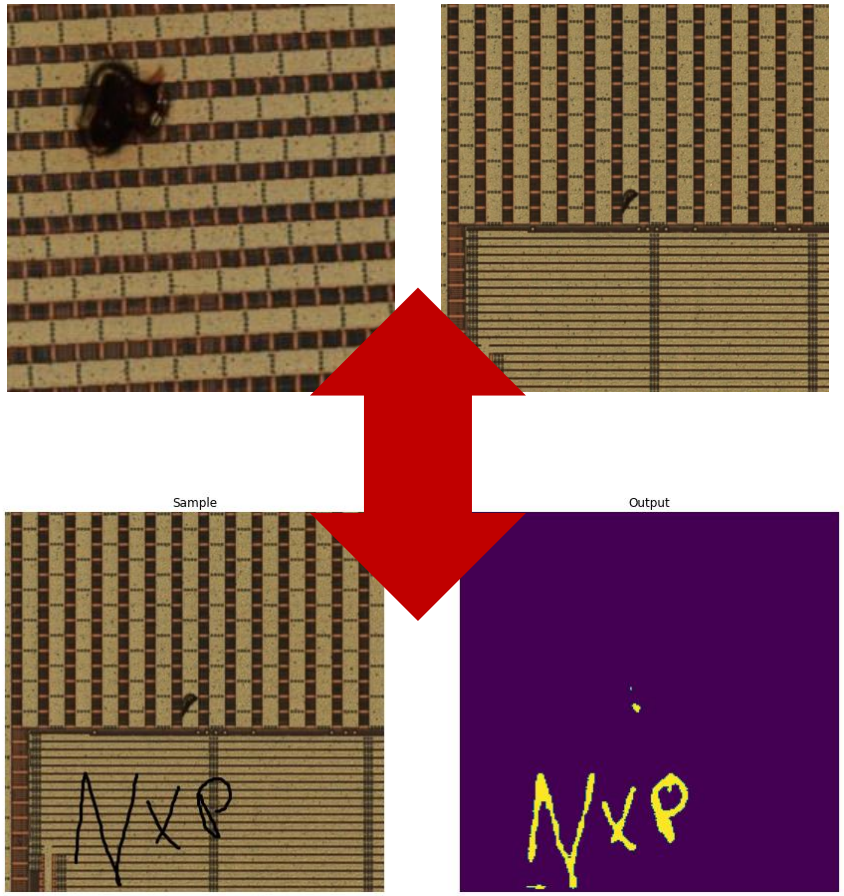
Dummy components for visualization



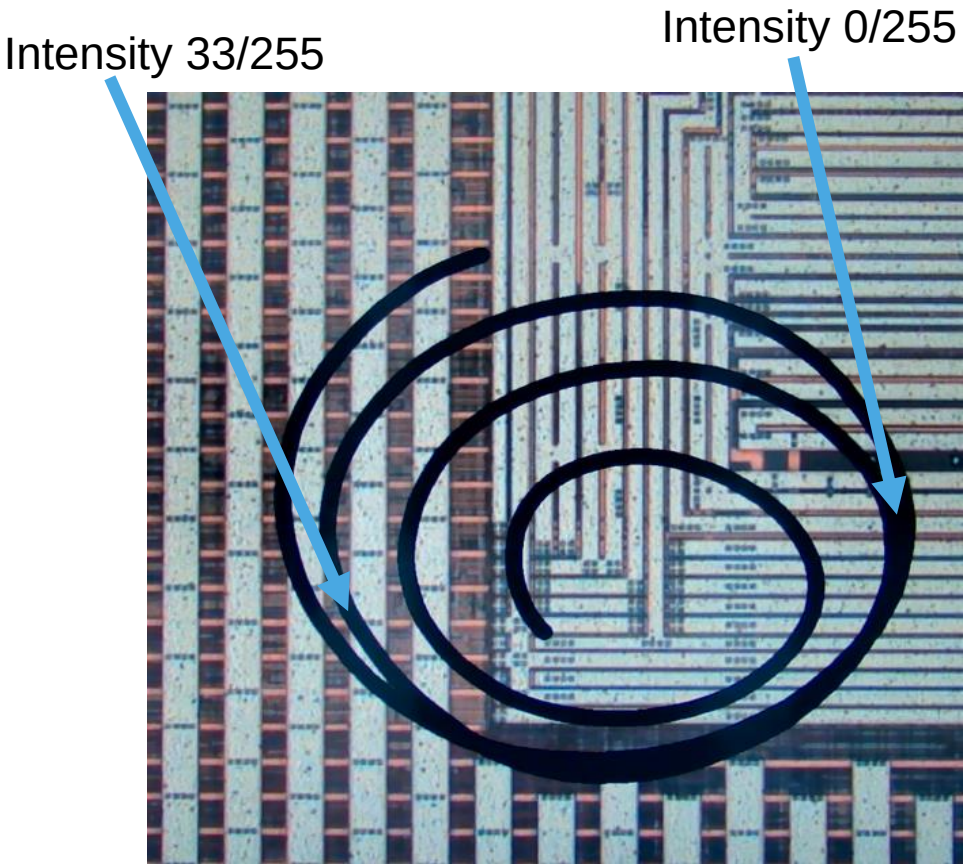
Navigation tablet to go between Demo and Info mode

MODEL RETRAINING – DATA CHALLENGE

Manufacturing related defects vs artificial anomalies



“Photo of Photo on Display”



MODEL RETRAINING – DATA CHALLENGE

Two possibilities:

Utilizes Preprocessing/semisynthetic data to mimic final input

+ no new training data necessary

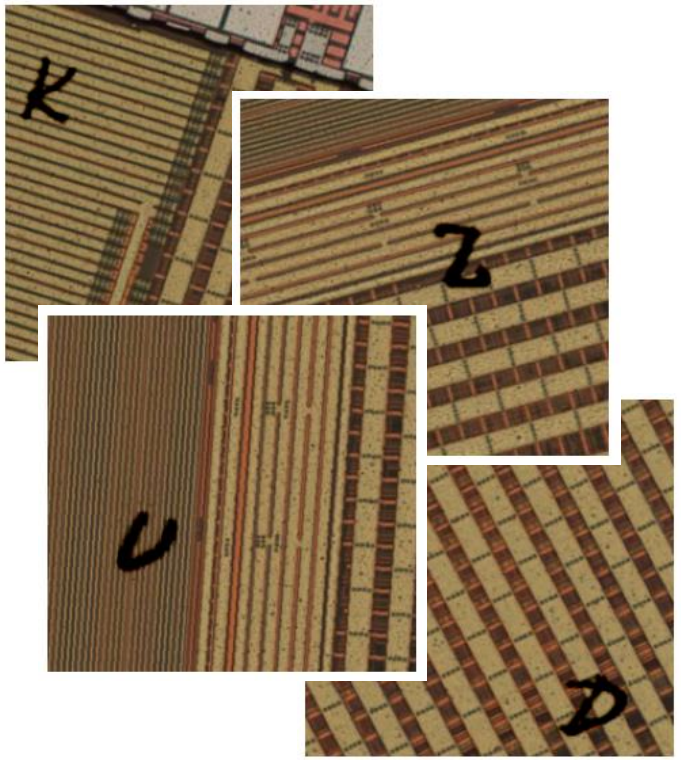
- Performance suffers

Generate new Training set similar to final input data

+ best performance

- Tedious image registration/train set generation (automation process necessary)

- intensity and contrast noise on train samples
- EMNIST Dataset:
  - Handwritten letters as “Anomalies”
  - 70,000 images 28x28 pixels



MODEL QUANTIZATION/ PERFORMANCE

- 32bit, converted from PyTorch to Onnx
- Running on ARM cores
- ARM NN Library
- **≈ 240ms Inference time**

- Fully quantized 8bit TensorFlow Lite model
- Running completely on Neural Processing Unit
- **≈ 9,5ms Inference time**

NXP / Basler Wafer Inspection Demo

@ Embedded world 2022

Hardware Wafer Inspection Demo

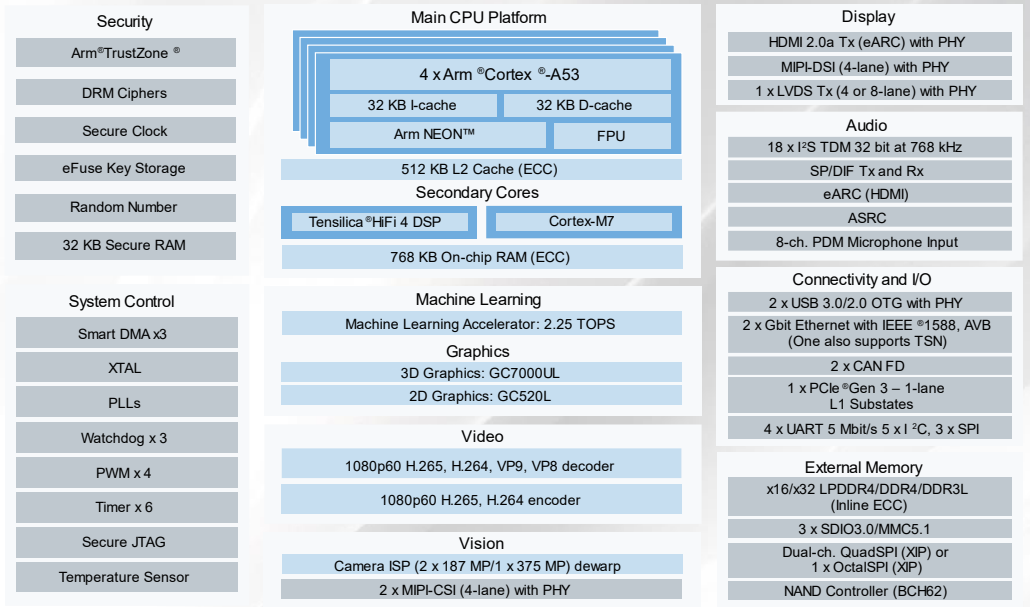
Basler Embedded Vision Processing Kit

- Development Kit for Vision Applications
- Suitable also for series production (population options to reduce unit costs)
- Complete interface population:
  - 2x MIPI-CSI 2, 2x USB 3.0, GigE, HDMI, GPIOs, I2C, SPI, LVDS, UART, CAN, USB 2.0, M 2.0, Bluetooth, Wi-Fi
- Equipped with NXP i.MX8M Plus SoC

Hardware Wafer Inspection Demo

NXP i.MX8M Plus Featureset

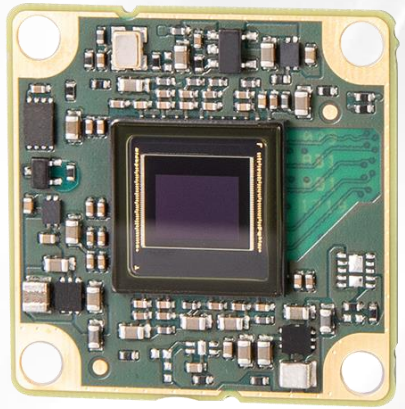
- Neural Processing Unit (NPU) with up to 2.3 TOPS
- Up to 2 cameras with MIPI CSI-2 interface, 1080p60 stereo vision
- Image Signal Processor (ISP) for 4K vision, HDR, de-warp (e.g. fish-eye lens correction)
- High resolution video compression including video encode (including h.265) and decode
- 3D and 2D graphics acceleration GPU based
- Real-time processing with Cortex-M7 @800MHz
- 4x CortexA53 @1.8GHz
- 14nm FinFet, low power, high performance
- Robust control networks supported by dual CAN FD and dual Gigabit Ethernet with Time Sensitive Networking (TSN)



Hardware Wafer Inspection Demo

Basler dart MIPI CSI-2 camera module

- 8 MPix, 30 fps
- MIPI CSI-2 interface
- Uses NXP i.MX8M Plus Image Signal Processor (ISP)
- GenICam compliant – compatible to Basler camera SDK (pylon) or gstreamer
- Wide angle lens using the i.MX8M Plus Dewarping hardware block



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