

# **Development of intelligent systems (RInS)**

## **Surface anomaly detection**

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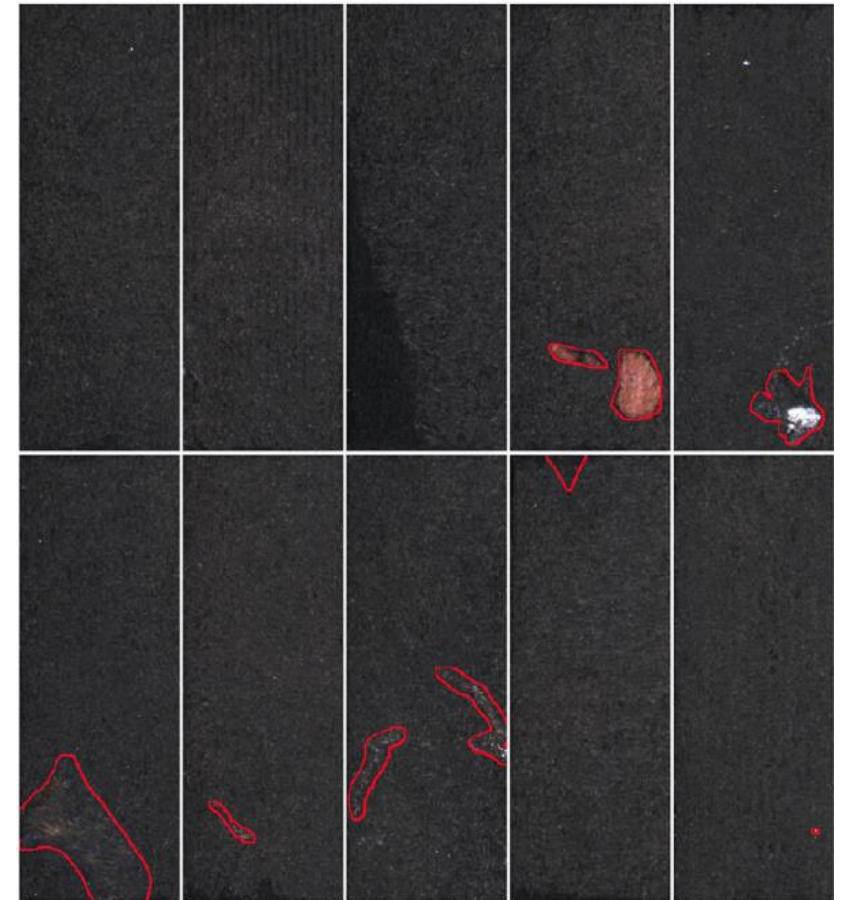
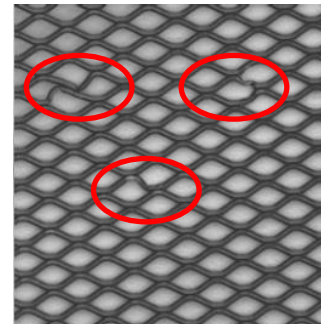
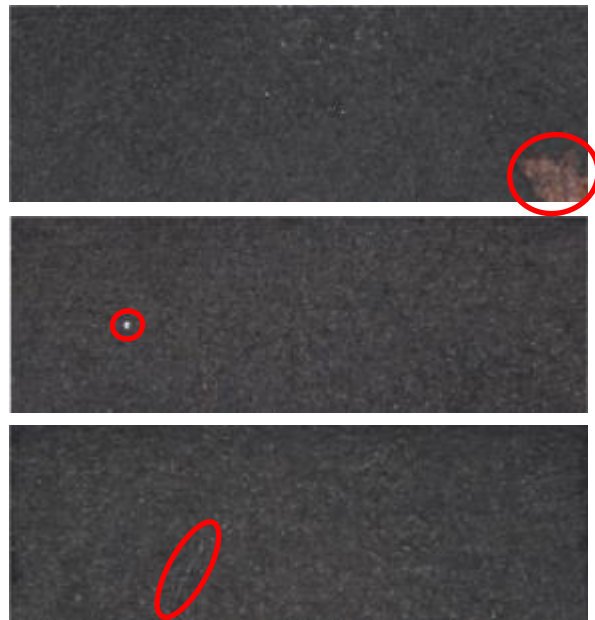
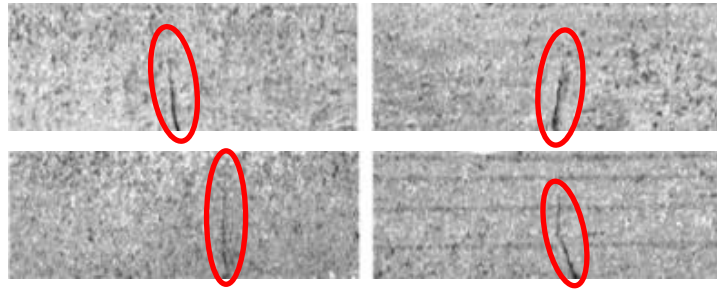
Academic year: 2023/24

# Anomaly detection

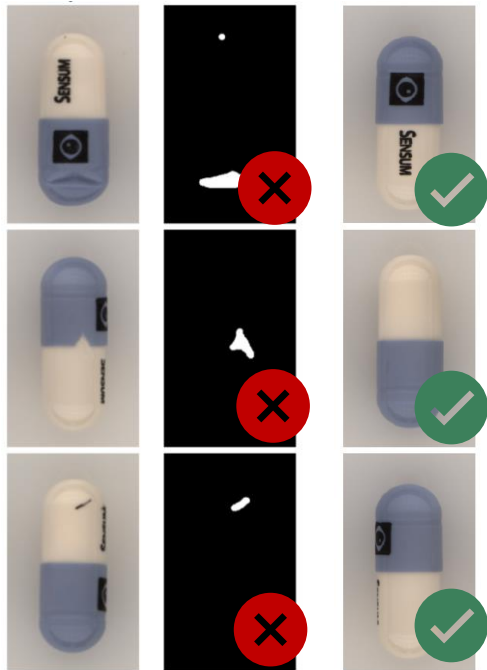
- Learn normality
- Detect discrepancies as anomalies



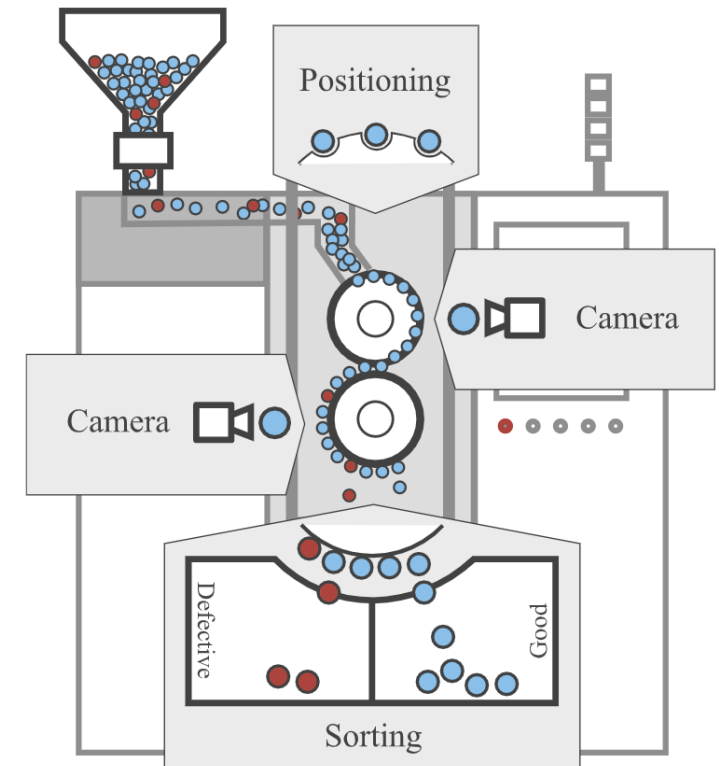
# Surface defect detection



# Example: Visual inspection of pharmaceutical products



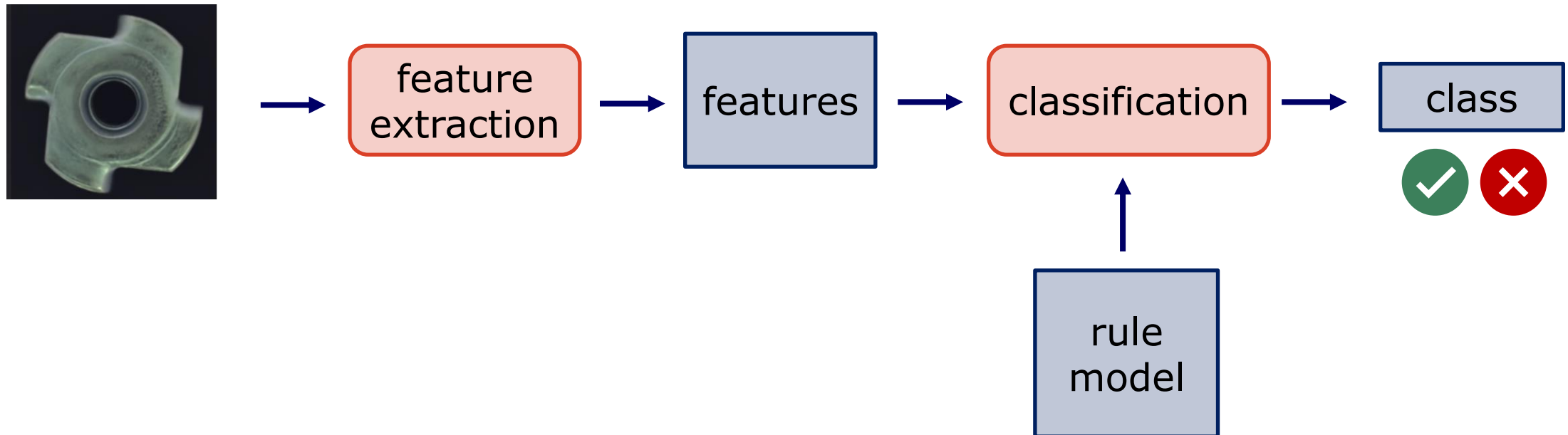
sensum.eu



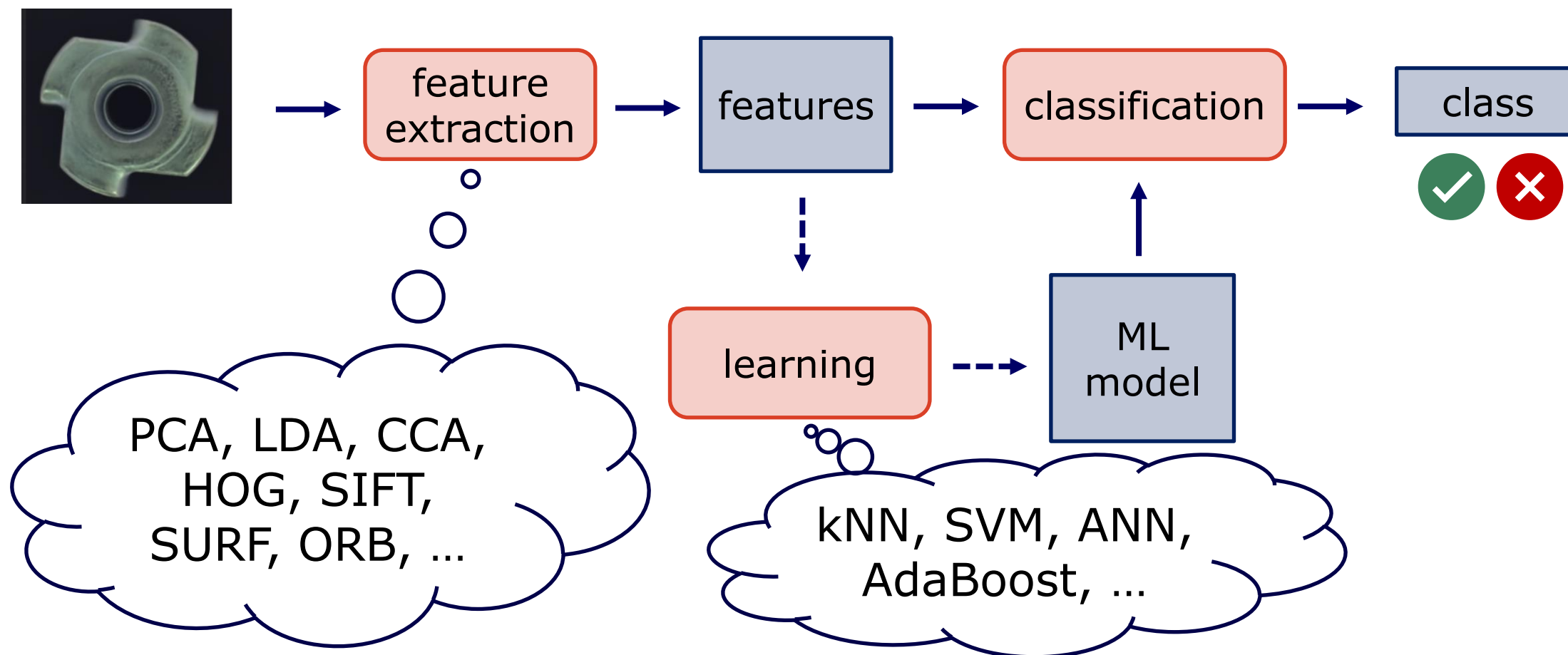
NCAA 2021

# Rule-based machine vision

- Rule-based approach

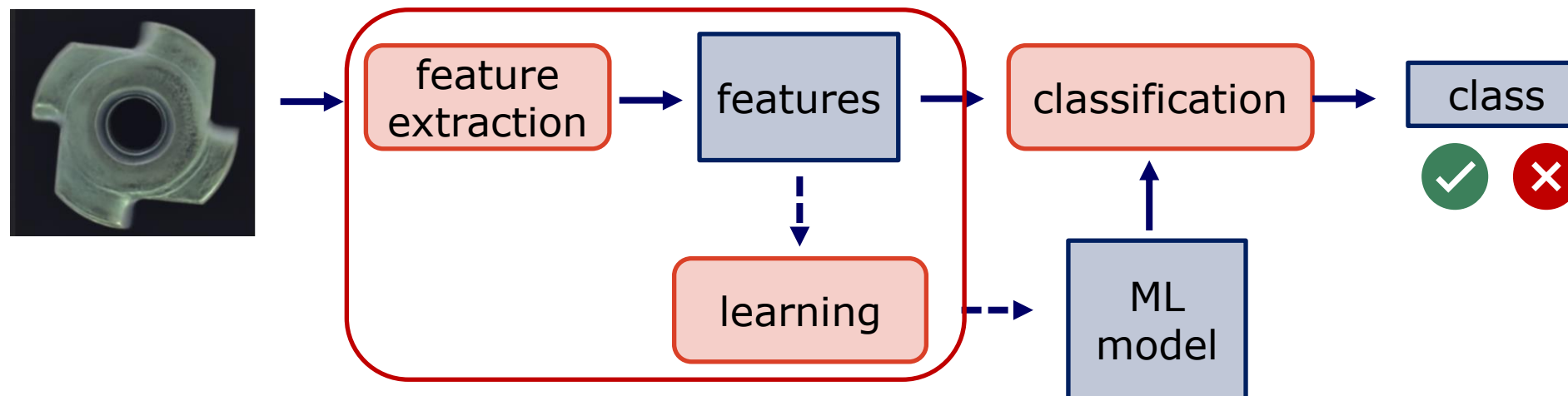


- Conventional ML approach

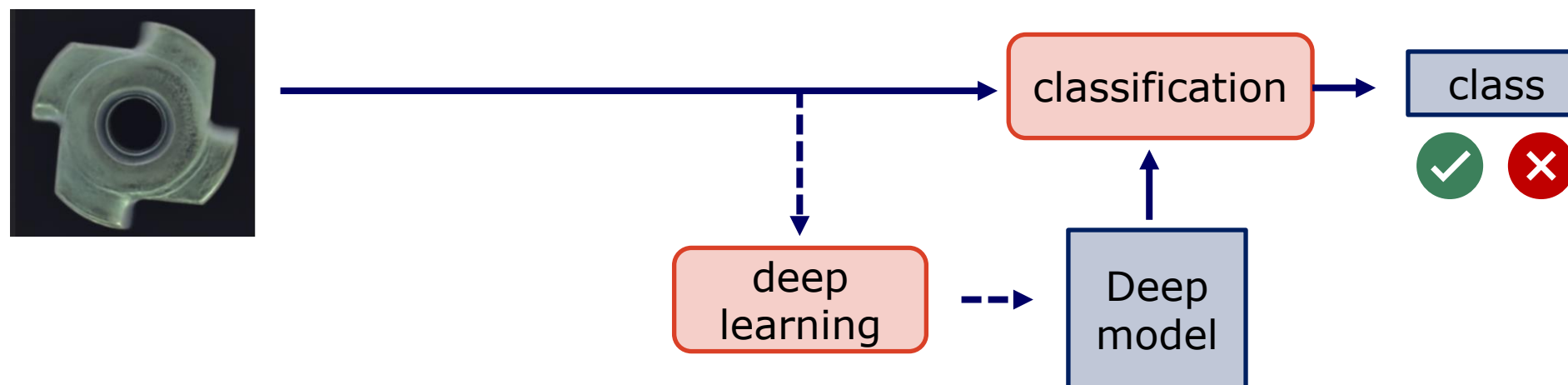


# Deep learning in computer vision

- Conventional machine learning approach in computer vision



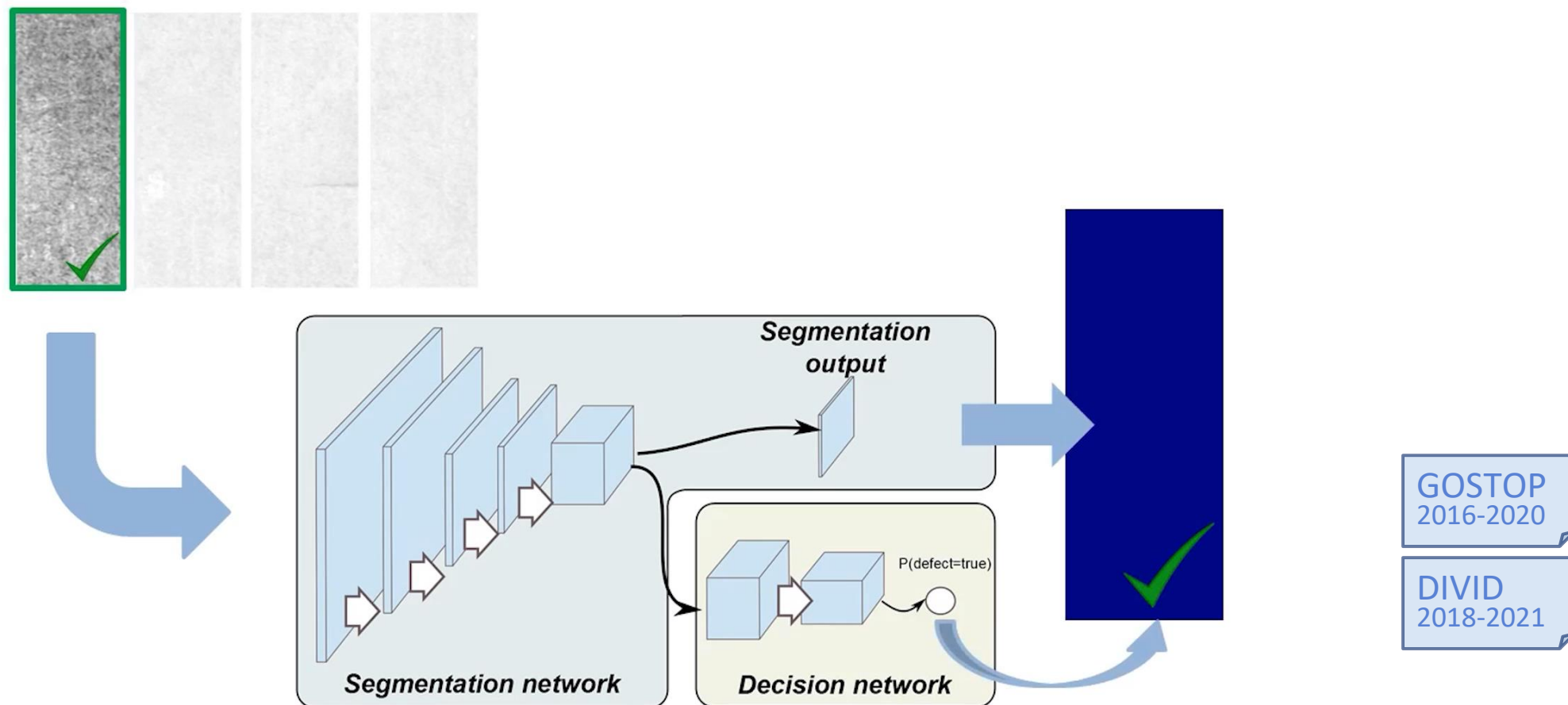
- Deep learning approach



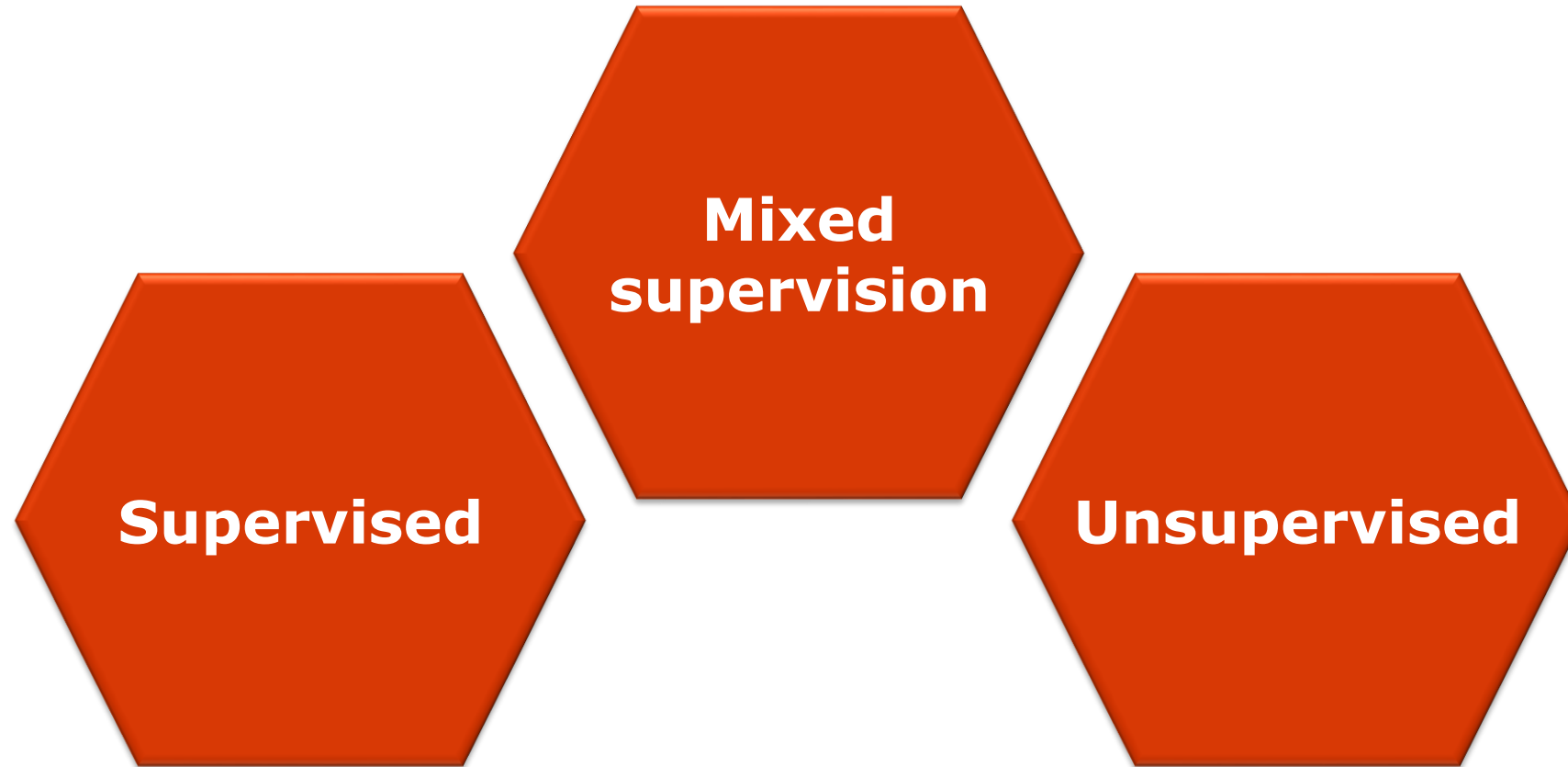


# New paradigm

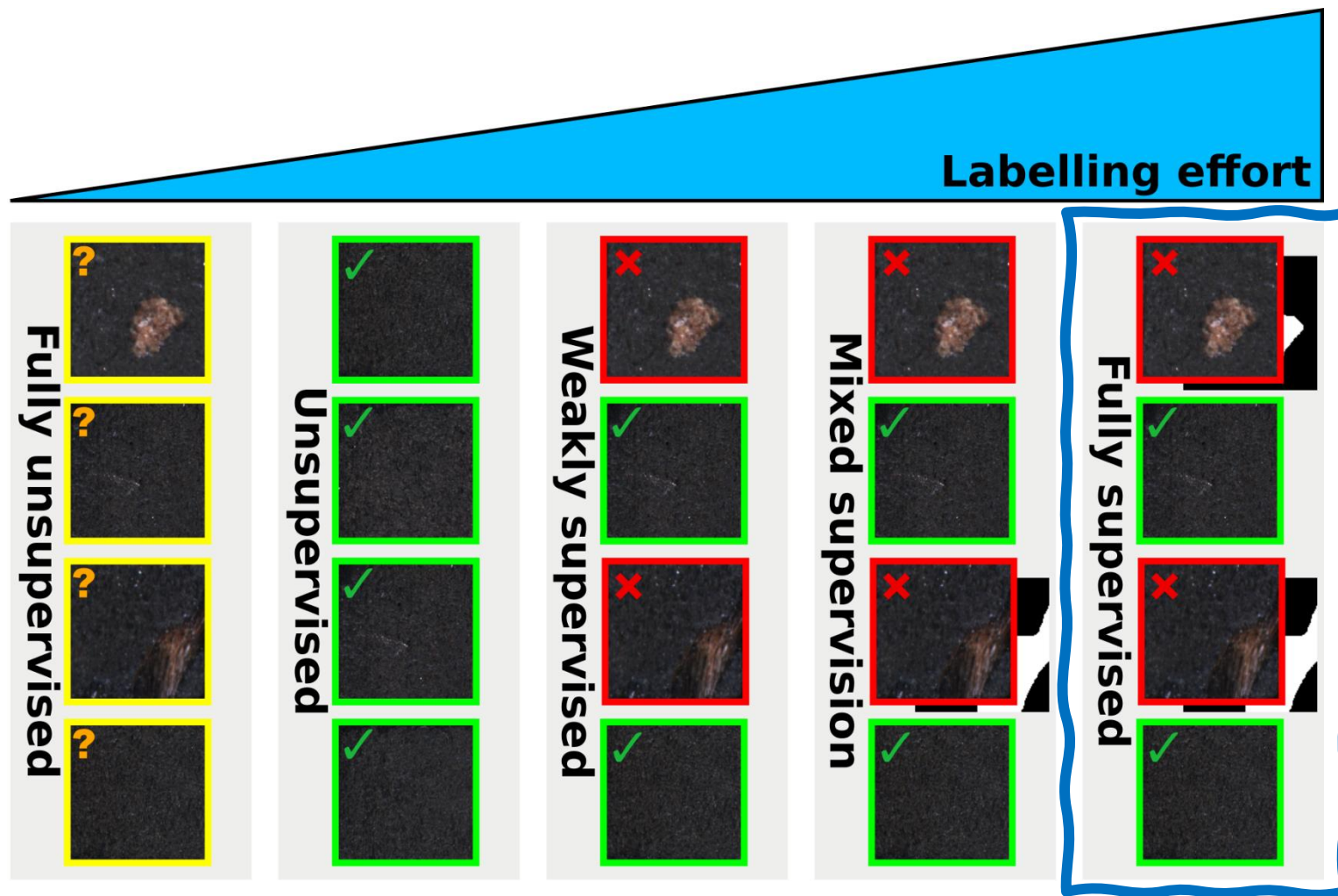
- Conventional approach: programming specific solutions
- New paradigm: data-driven learning-based solutions



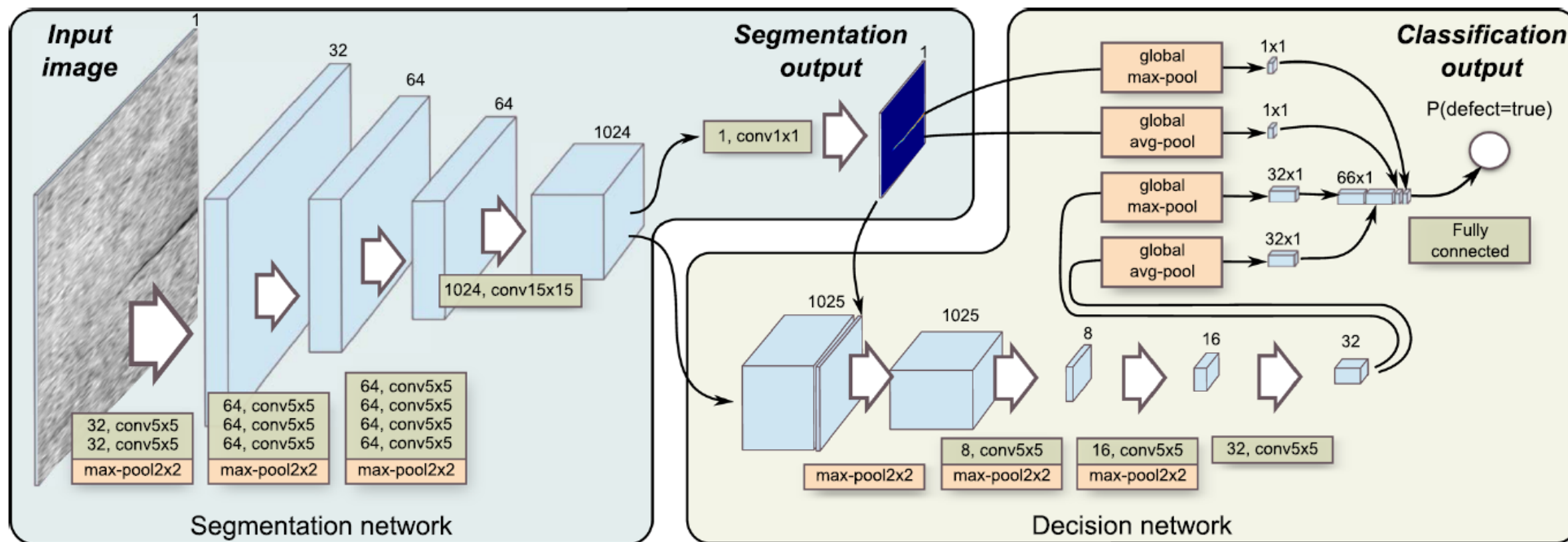




# Learning regimes



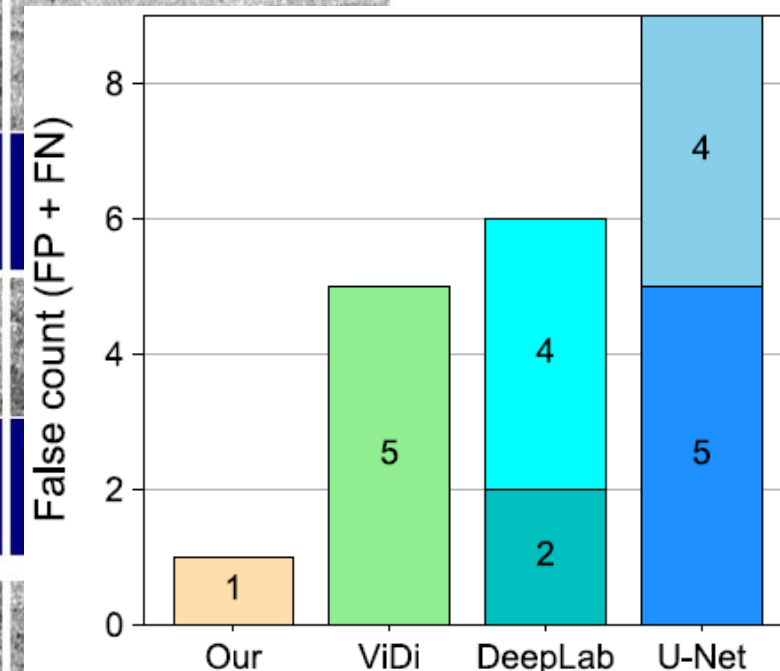
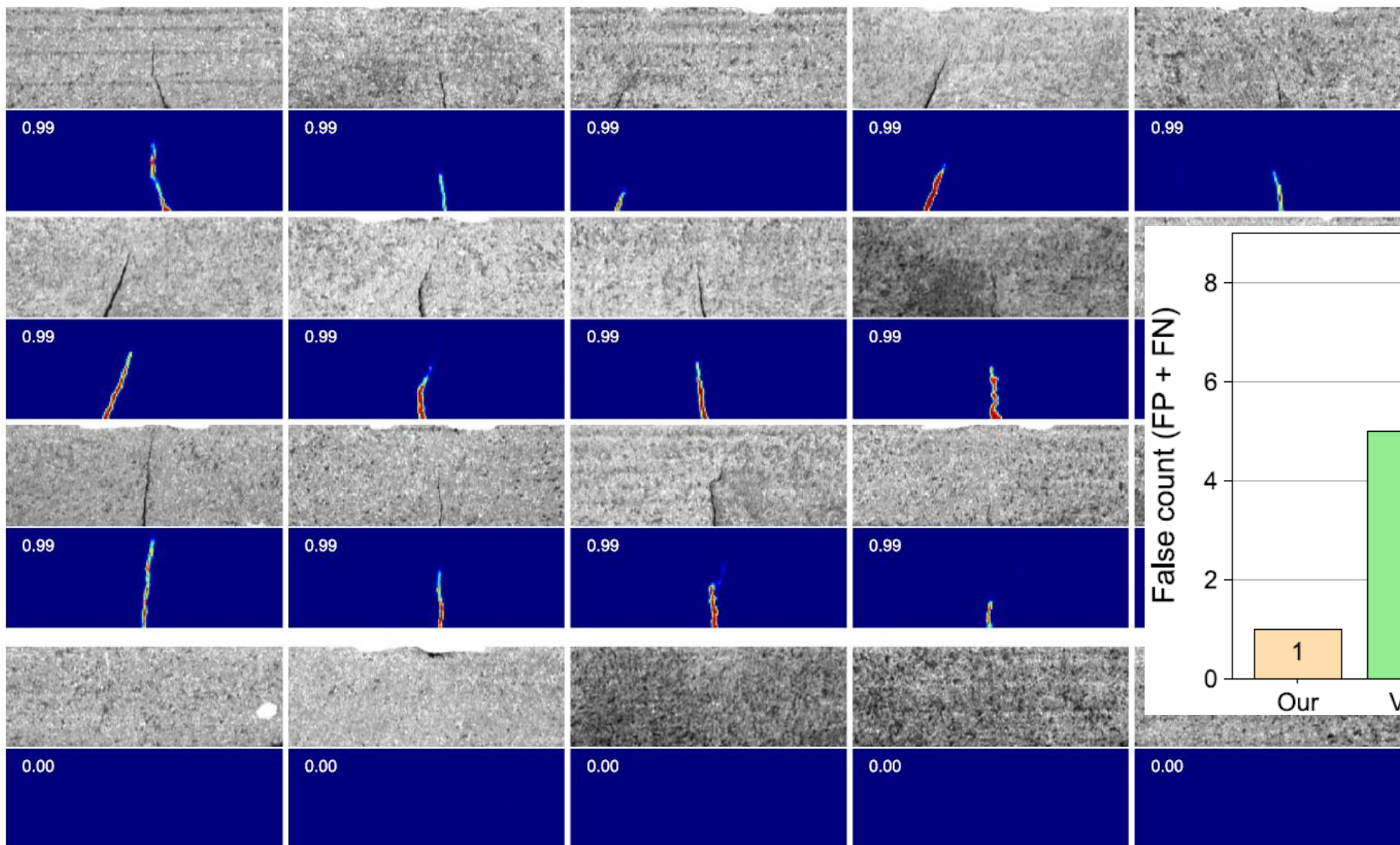
# Supervised learning



ICVS 2019

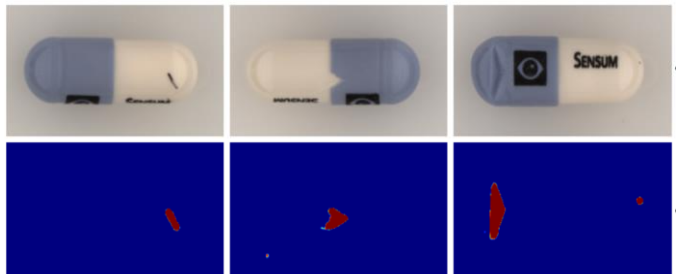
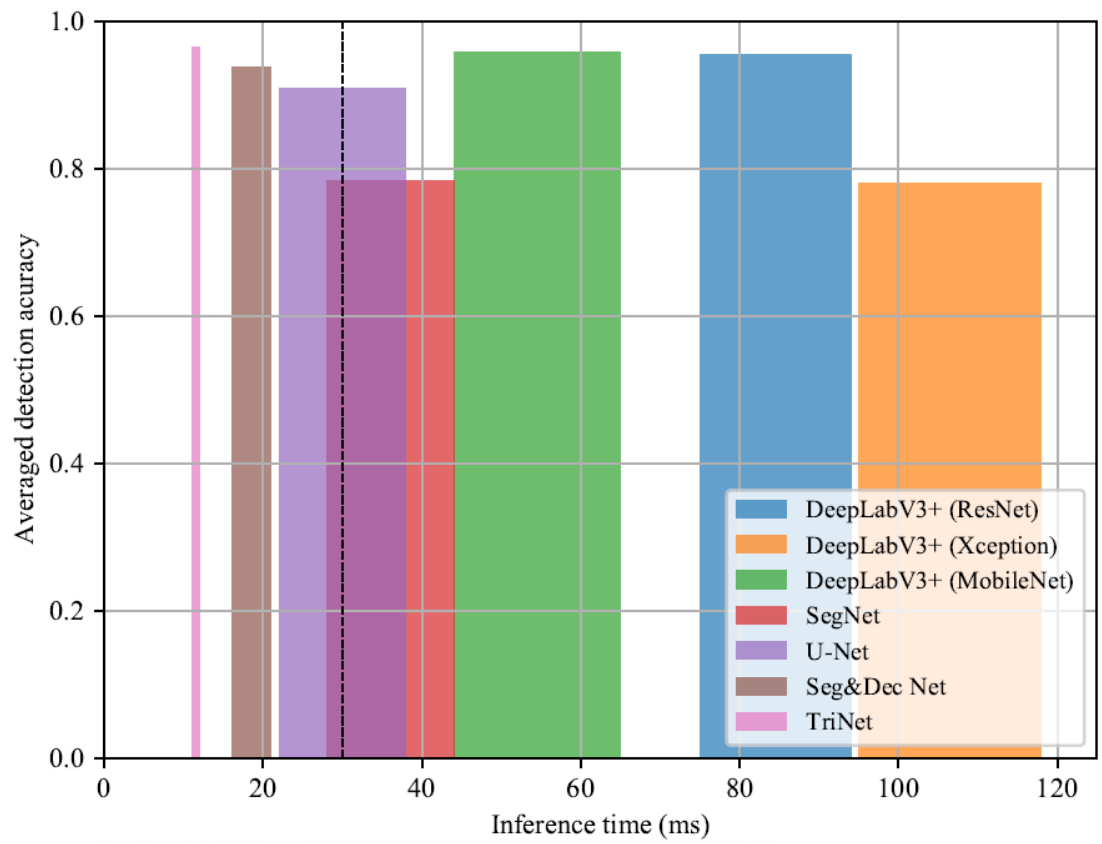
JIM 2020

# Supervised learning

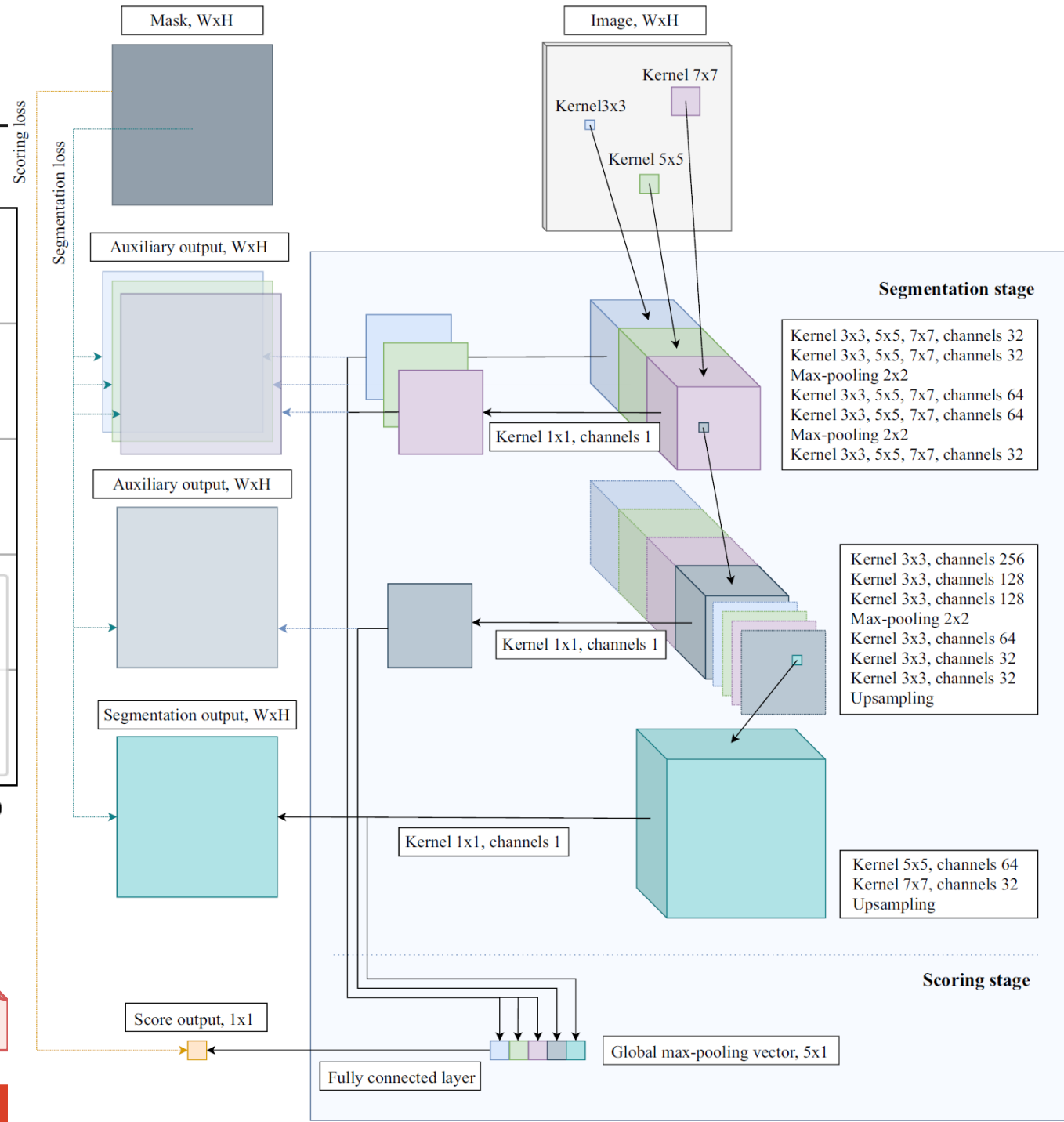


JIM 2020

# Supervised learning

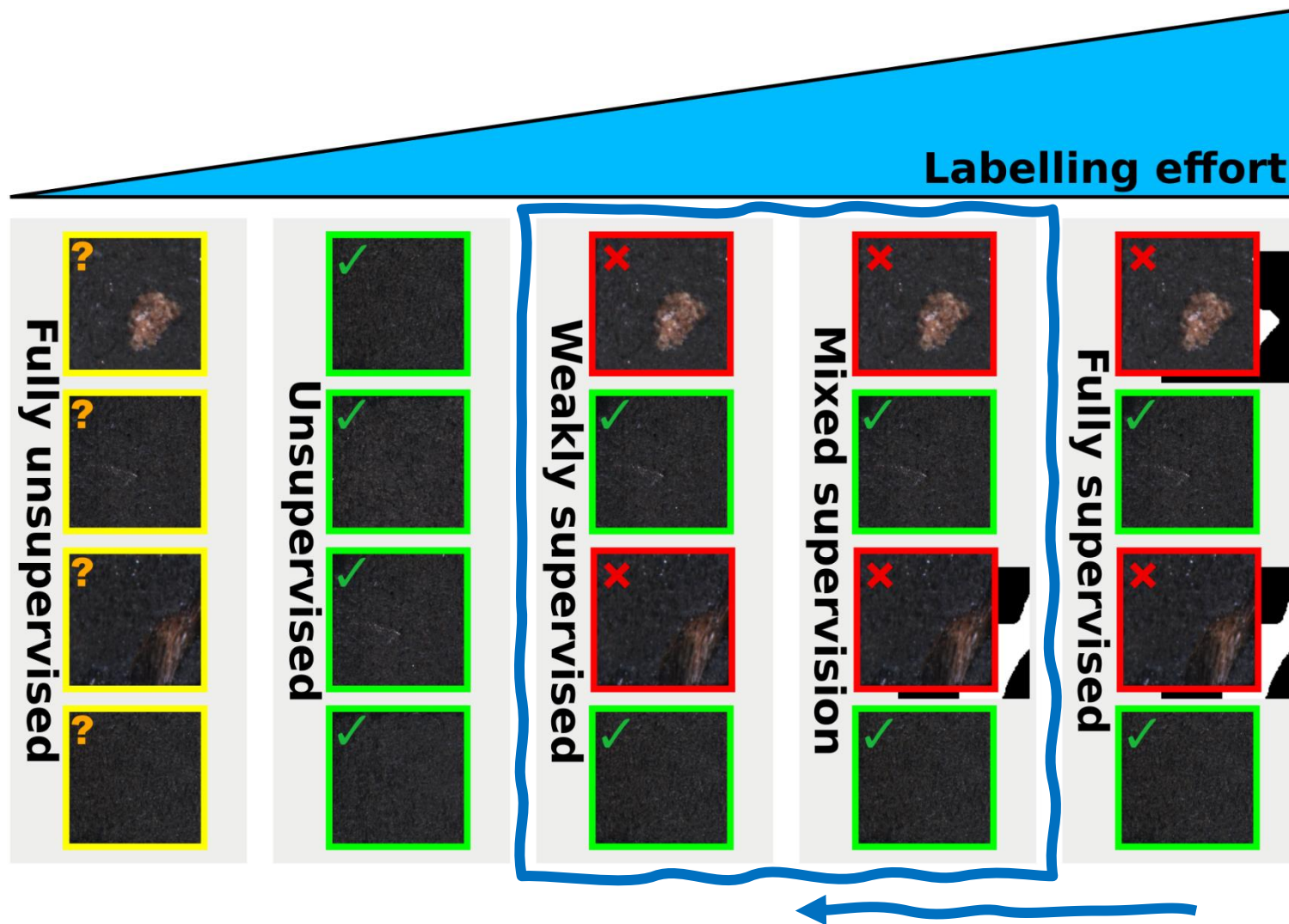


NCAA 2021



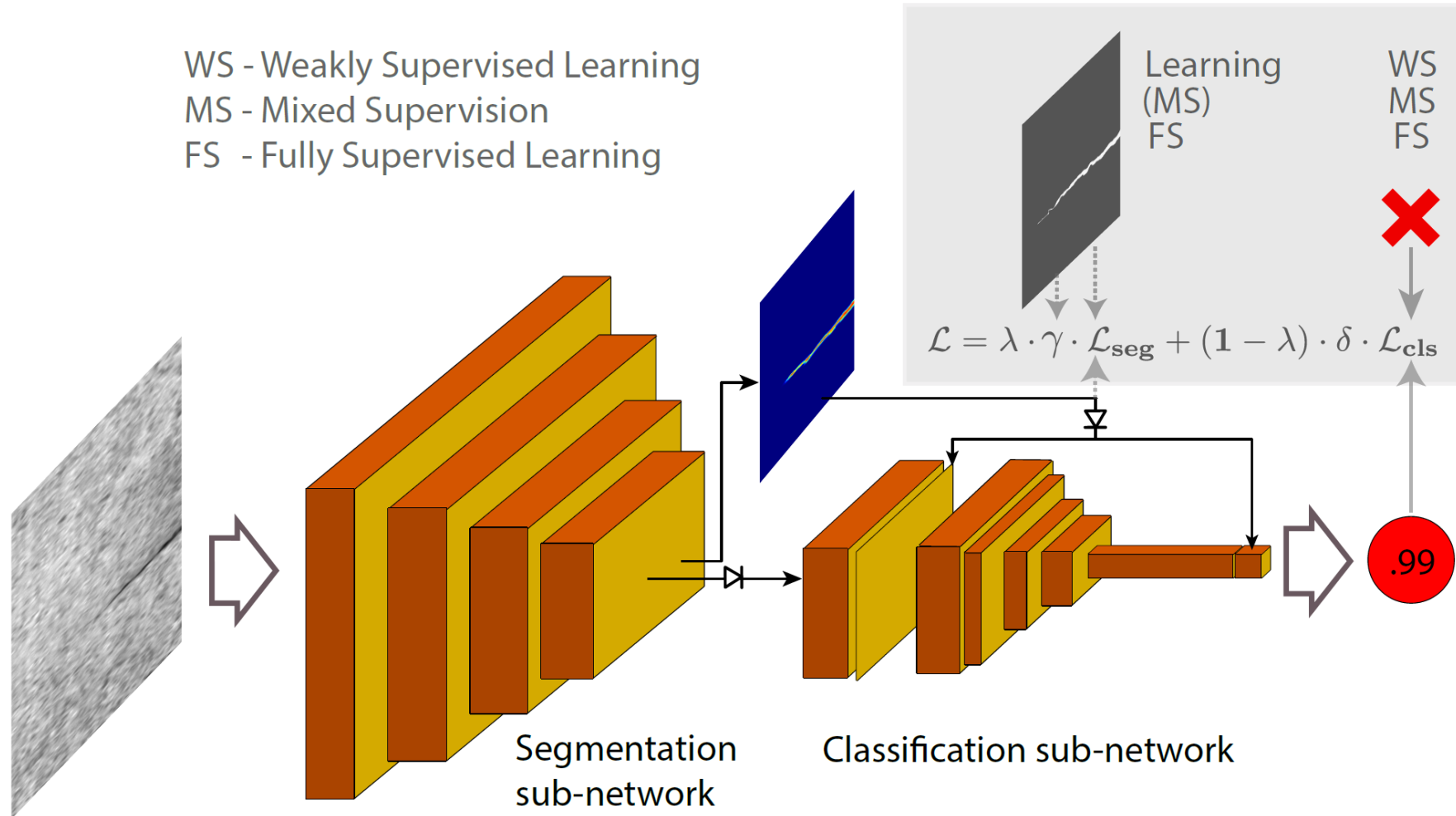


# Learning regimes



# Learning with mixed supervision

WS - Weakly Supervised Learning  
MS - Mixed Supervision  
FS - Fully Supervised Learning

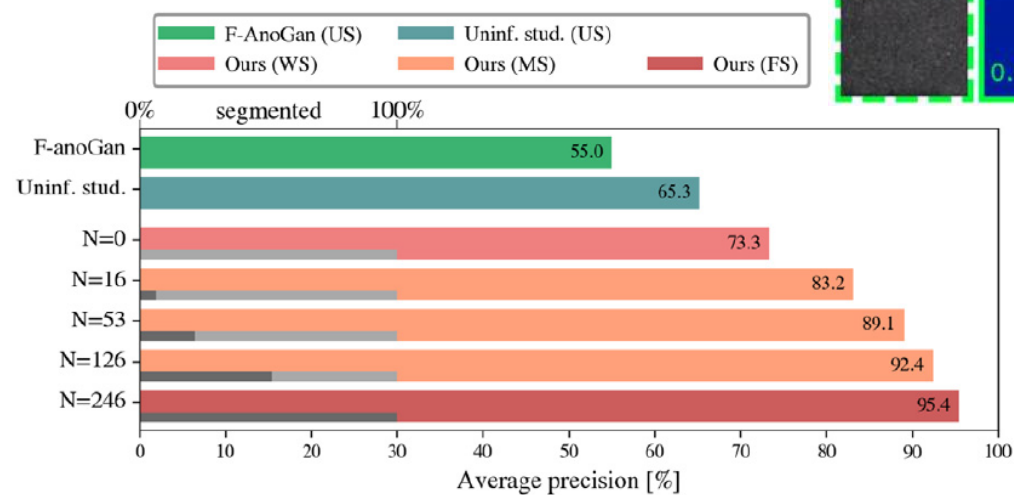
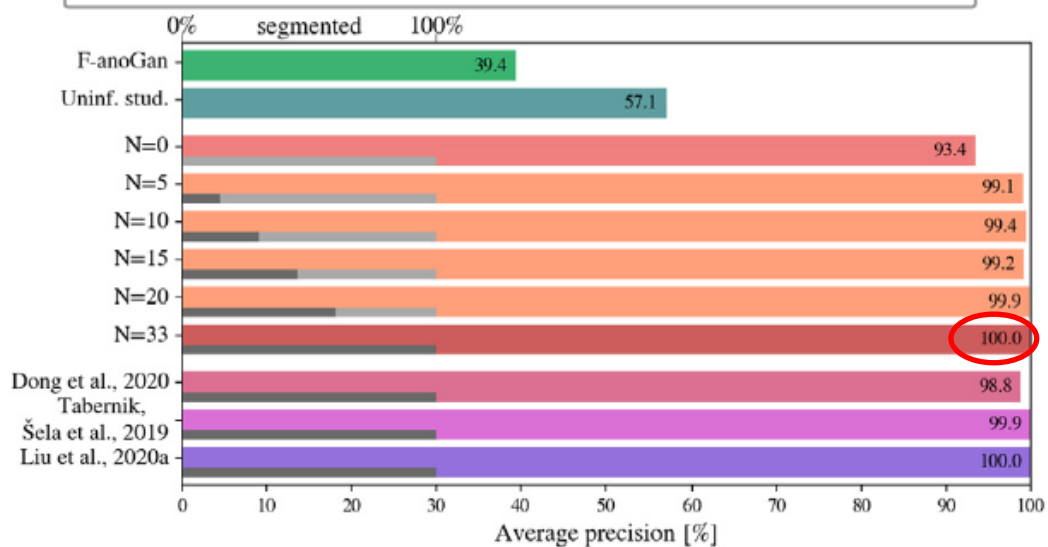
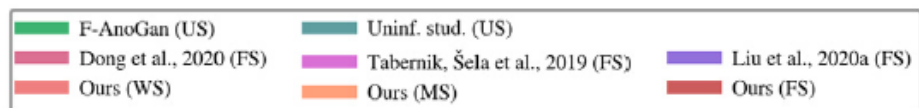
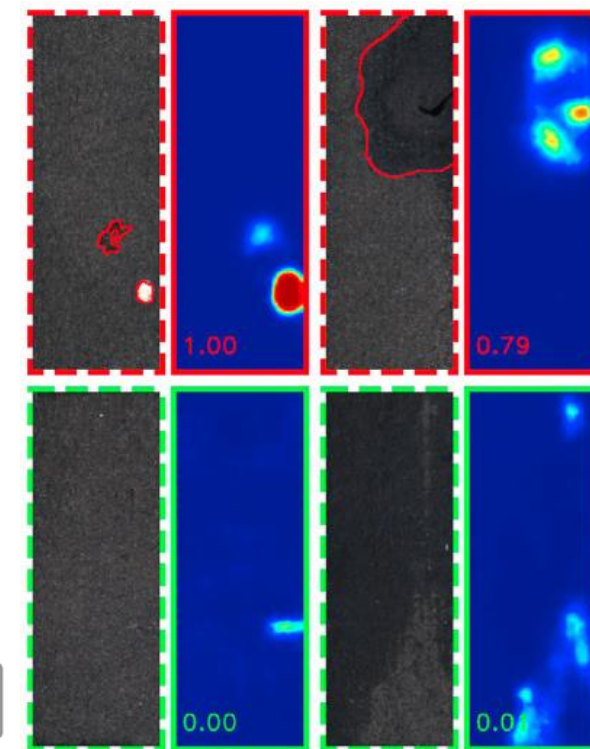
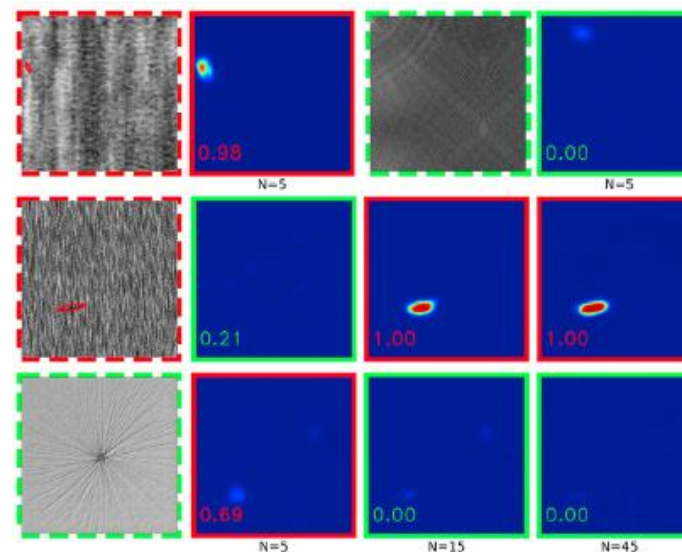
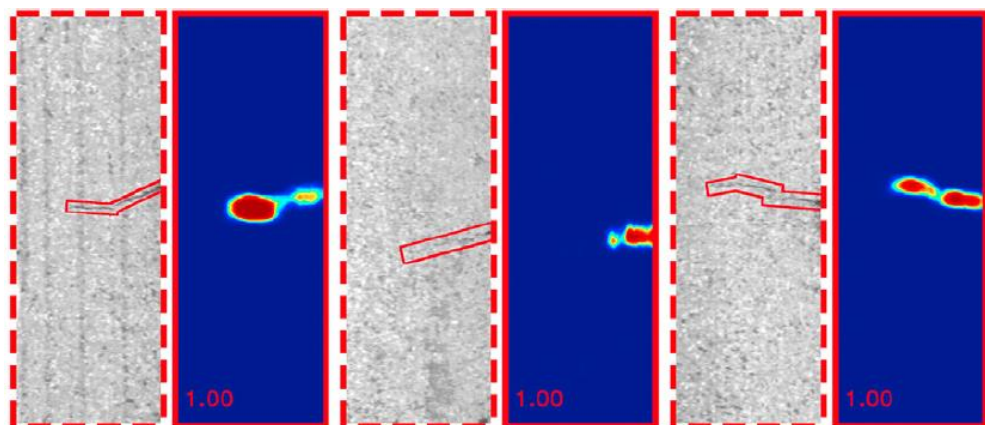


DIVID  
2018-2021

COMIND 2021



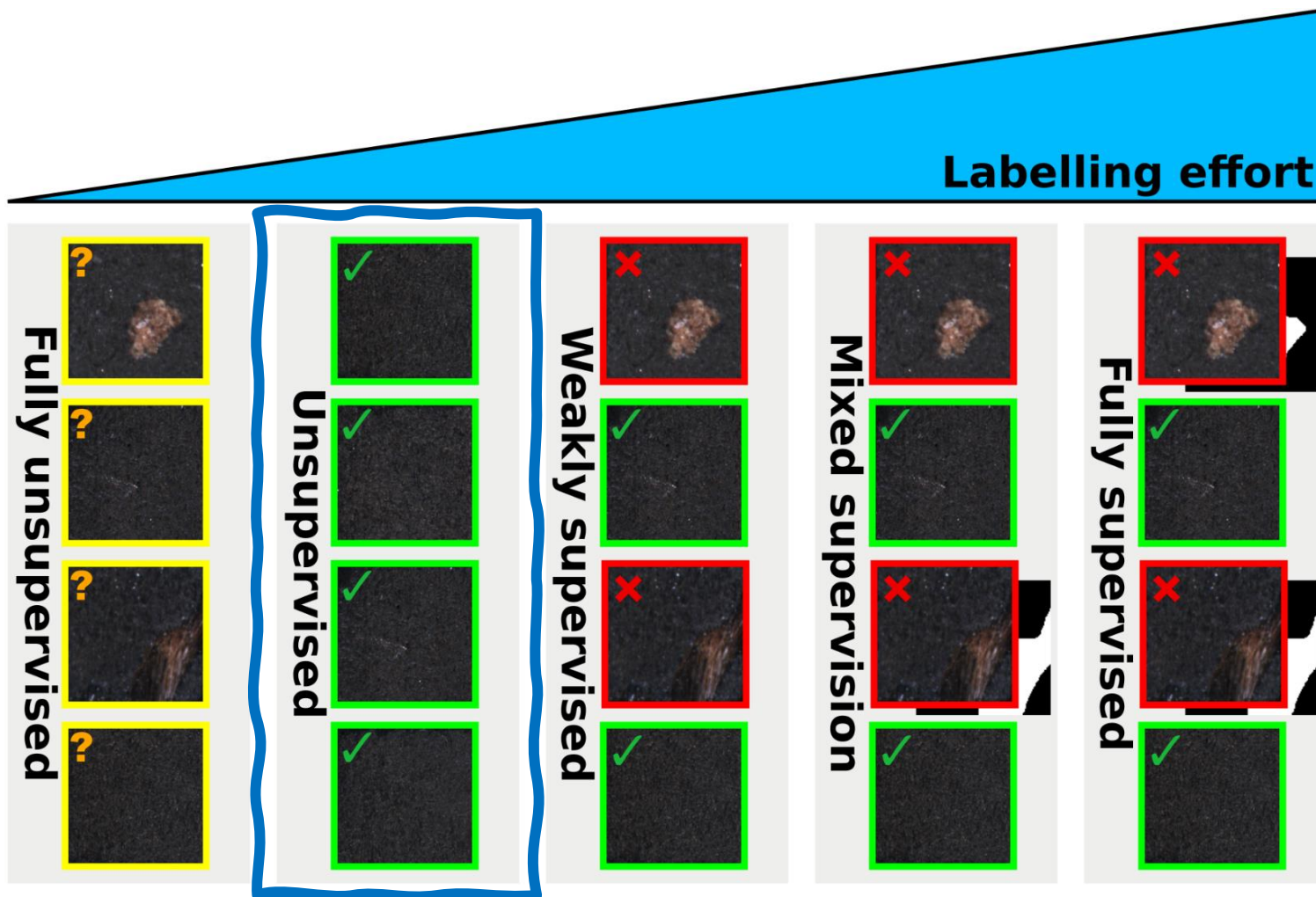
# Learning with mixed supervision



DIVID  
2018-2021

COMIND 2021

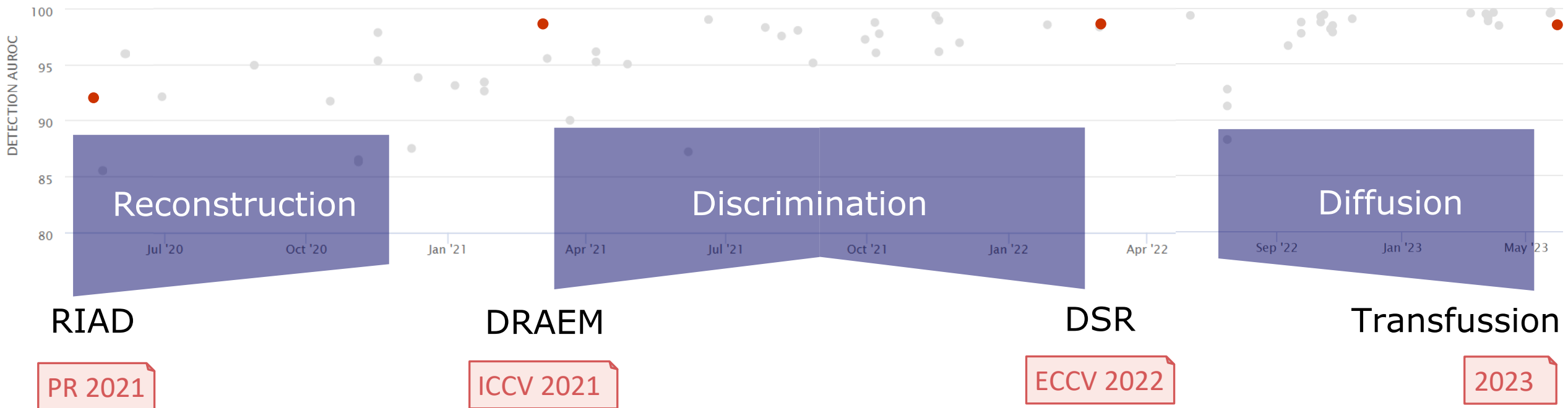
# Learning regimes



# Unsupervised learning

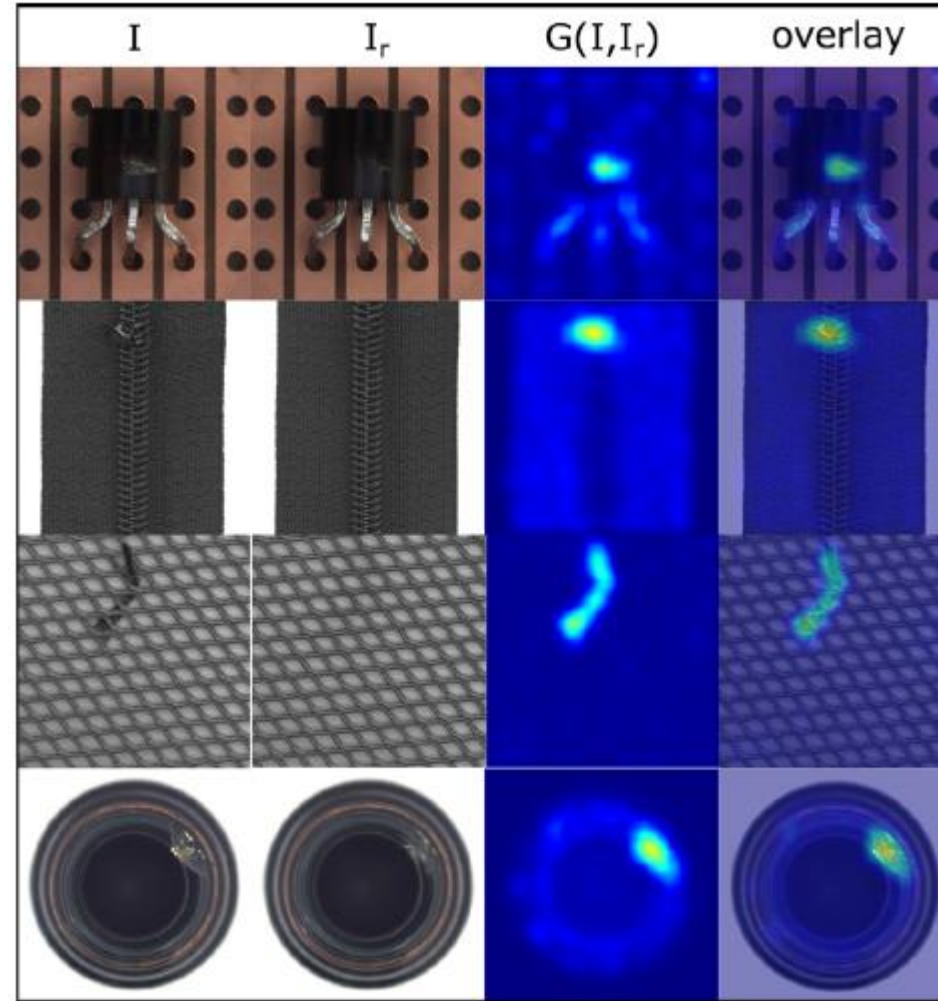
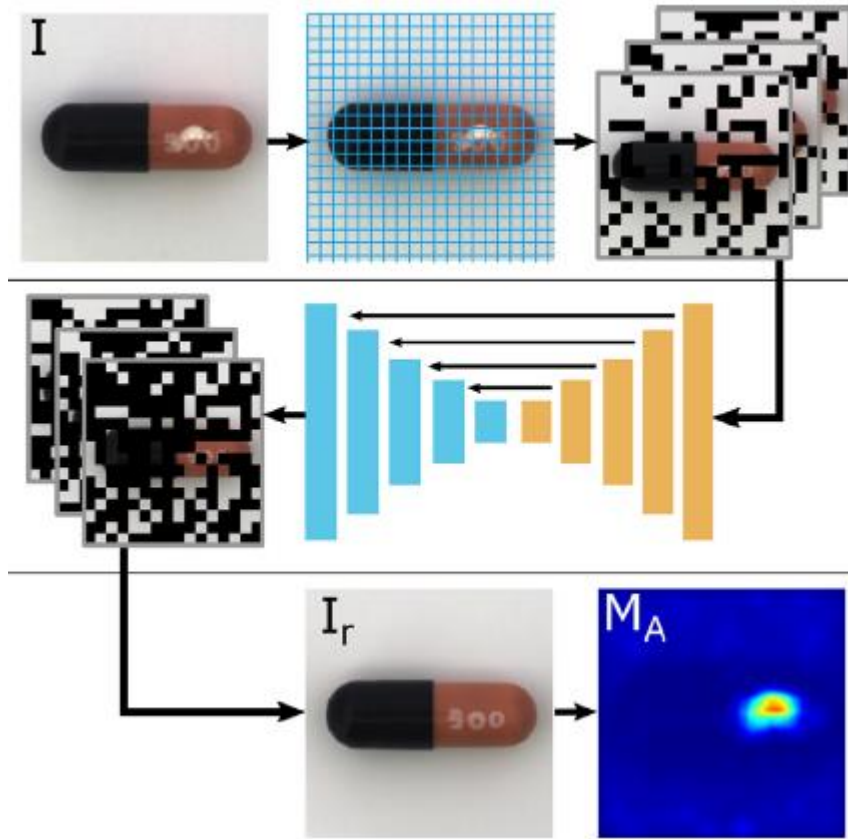
- Only defect-free images required
- Negative-class-only learning
- Detection AUROC on MVTec AD:

[paperswithcode.com]



# Unsupervised learning - RIAD

- Reconstructive approach



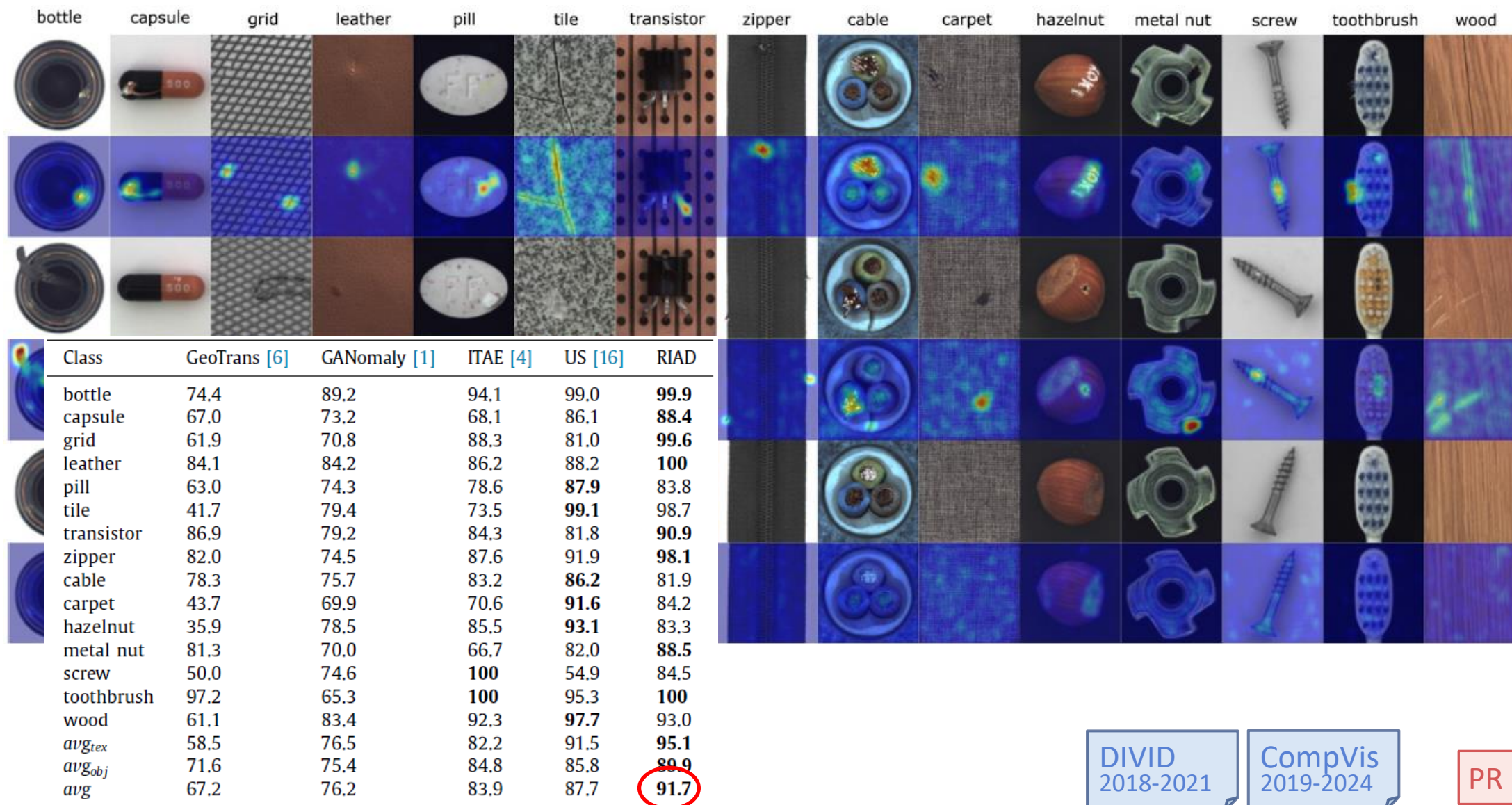
DIVID  
2018-2021

CompVis  
2019-2024

PR 2021



# Unsupervised learning - RIAD



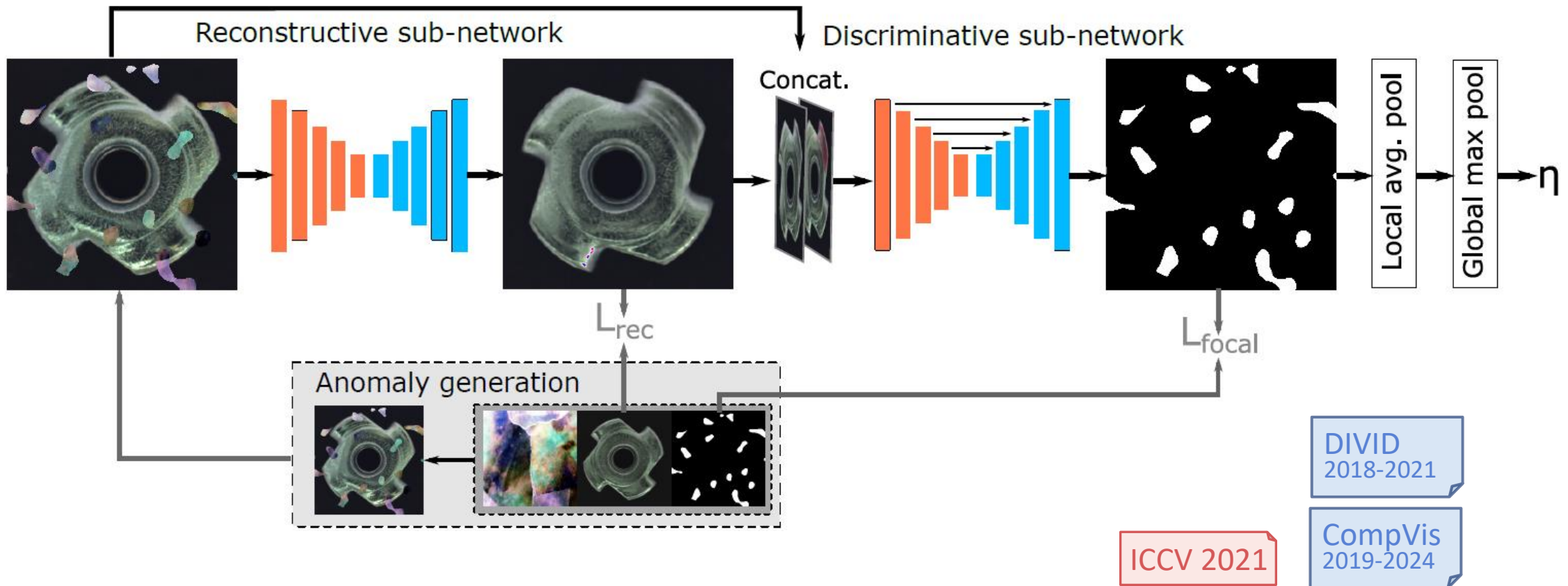
DIVID  
2018-2021

CompVis  
2019-2024

PR 2021

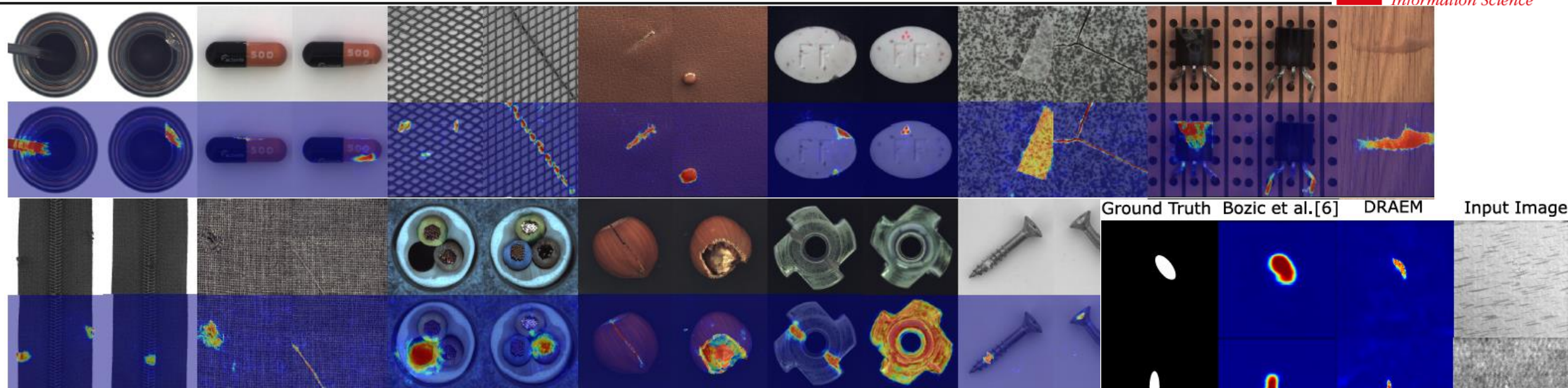
# Unsupervised learning - DRAEM

- Reconstructive and discriminative approach
- Generate synthetic anomalies





# Unsupervised learning - DRAEM



Class	[1]	[26]	[4]	[31]	[20]	[11]	DRAEM
bottle	79.4	98.3	99.0	99.9	<b>100</b>	99.9	99.2
capsule	72.1	68.7	86.1	88.4	92.3	91.3	<b>98.5</b>
grid	74.3	86.7	81.0	99.6	92.9	96.7	<b>99.9</b>
leather	80.8	94.4	88.2	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>
pill	67.1	76.8	87.9	83.8	83.4	93.3	<b>98.9</b>
tile	72.0	96.1	99.1	98.7	97.4	98.1	<b>99.6</b>
transistor	80.8	79.4	81.8	90.9	95.9	<b>97.4</b>	93.1
zipper	74.4	78.1	91.9	98.1	97.9	90.3	<b>100</b>
cable	71.1	66.5	86.2	81.9	<b>94.0</b>	92.7	91.8
carpet	82.1	90.3	91.6	84.2	95.5	<b>99.8</b>	97.0
hazelnut	87.4	100	93.1	83.3	98.7	92.0	<b>100.0</b>
metal nut	69.4	81.5	82.0	88.5	93.1	<b>98.7</b>	<b>98.7</b>
screw	<b>100</b>	<b>100</b>	54.9	84.5	81.2	85.8	93.9
toothbrush	70.0	95.0	95.3	<b>100</b>	95.8	96.1	<b>100</b>
wood	92.0	97.9	97.7	93.0	97.6	<b>99.2</b>	99.1
avg	78.2	87.3	87.7	91.7	94.4	95.5	<b>98.0</b>

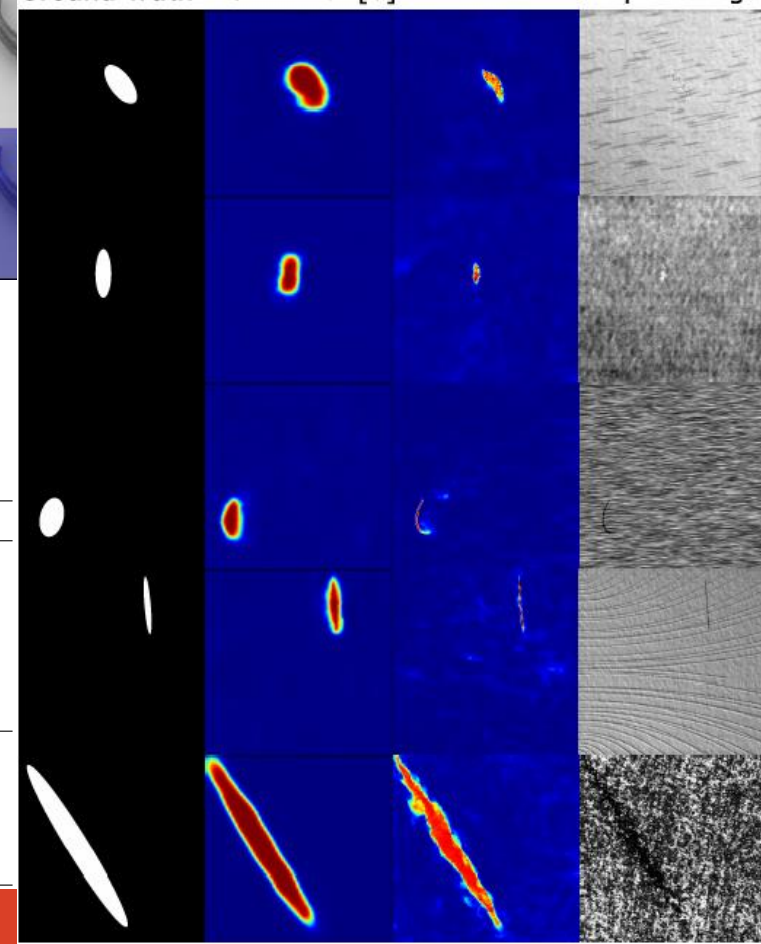
DIVID  
2018-2021

CompVis  
2019-2024

ICCV 2021

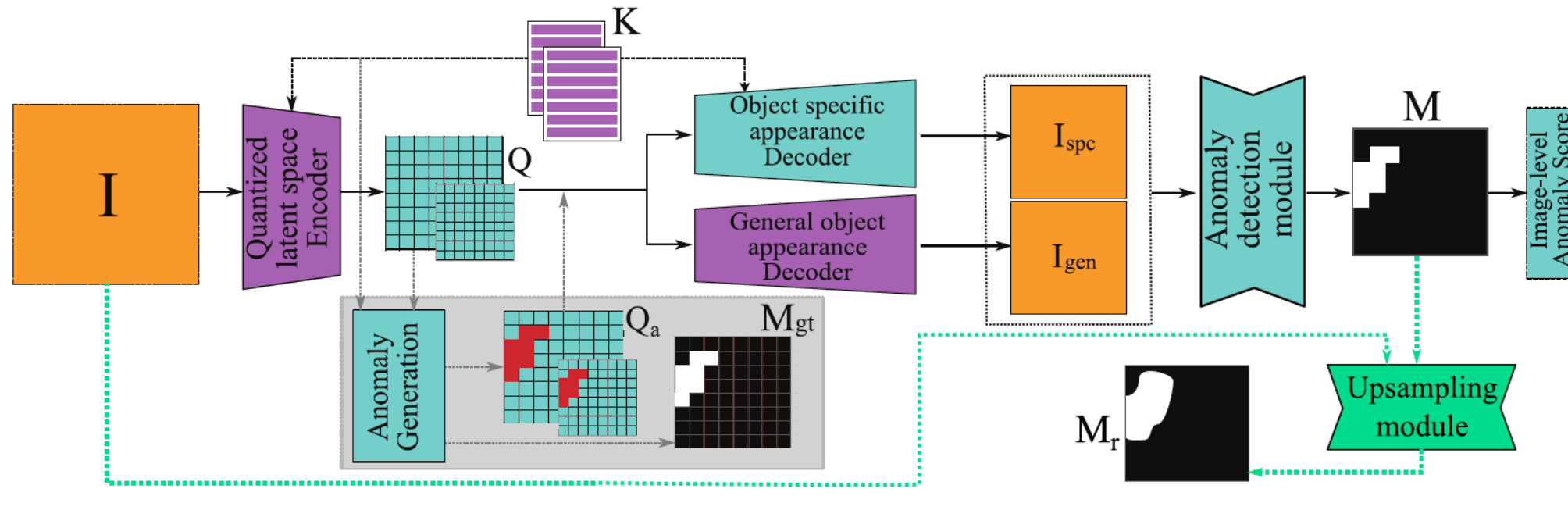
	Methods	AUROC	TPR	TNR	CA
Unsup.	RIAD [31]	78.6	79.2	69.1	70.4
	US [4]	72.5	72.6	65.3	66.2
	MAD [20]	82.4	78.7	85.7	66.2
	PaDim [11]	95.0	83.3	97.5	95.7
	DRAEM	<b>99.0</b>	<b>96.5</b>	<b>99.4</b>	<b>98.5</b>
Sup.	CADN [32]	-	-	-	89.1
	Rački <i>et al.</i> [19]	99.6	99.9	99.5	-
	Lin <i>et al.</i> [15]	99.0	99.4	99.9	-
	Božič <i>et al.</i> [6]	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

Ground Truth Bozic et al. [6] DRAEM Input Image

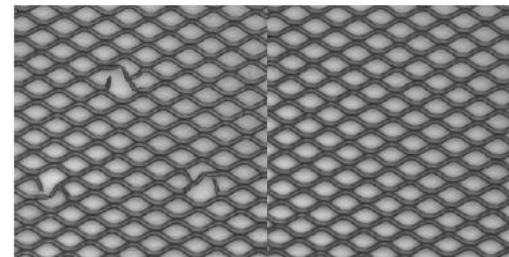




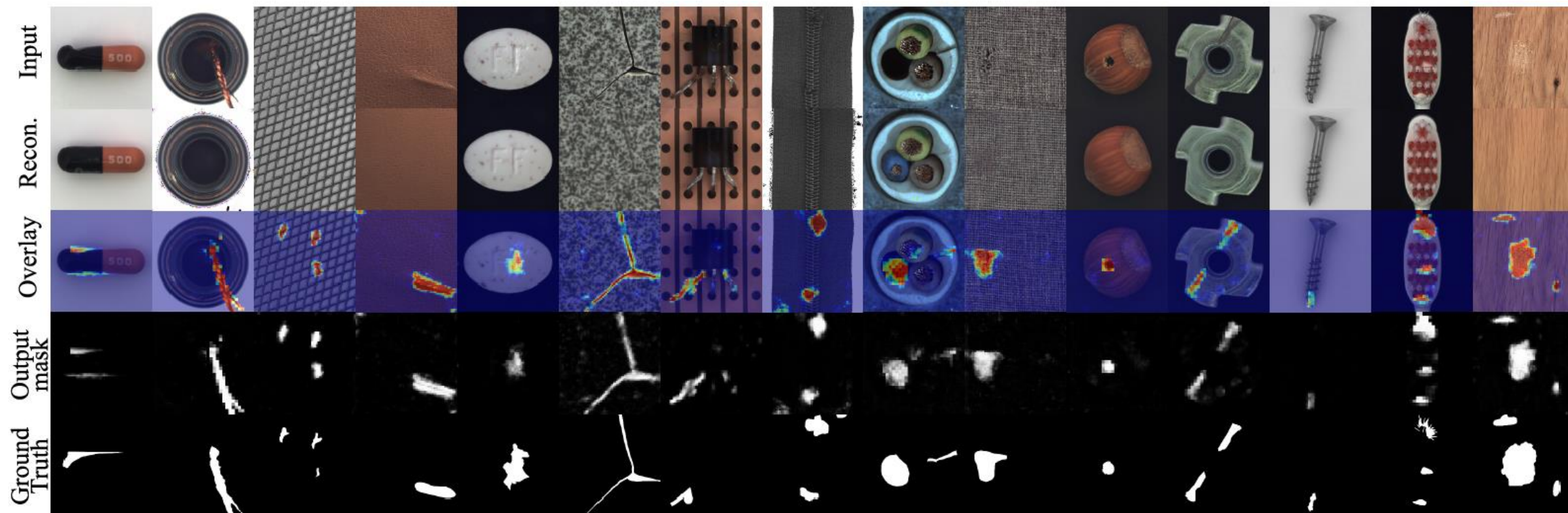
- Generate syntetic anomalies in the quantized feature space



ECCV 2022  
MV4.0  
2021-2024



# Unsupervised learning - DSR

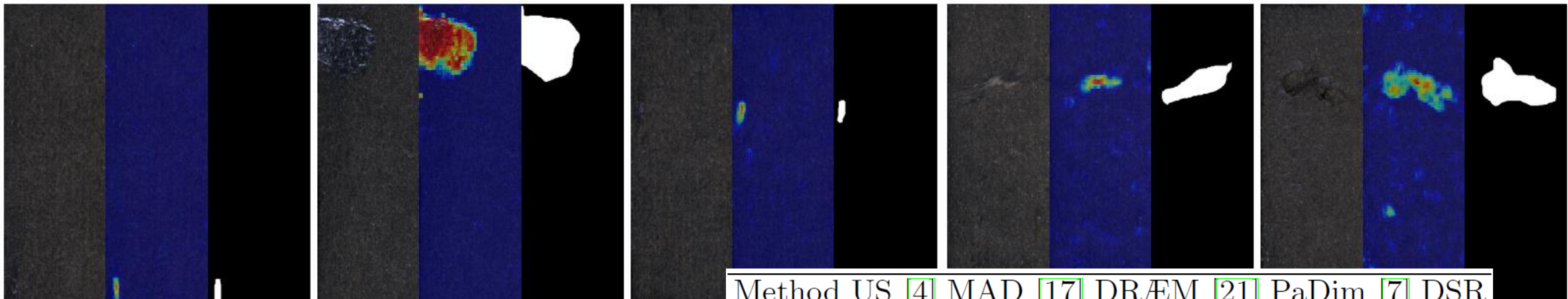
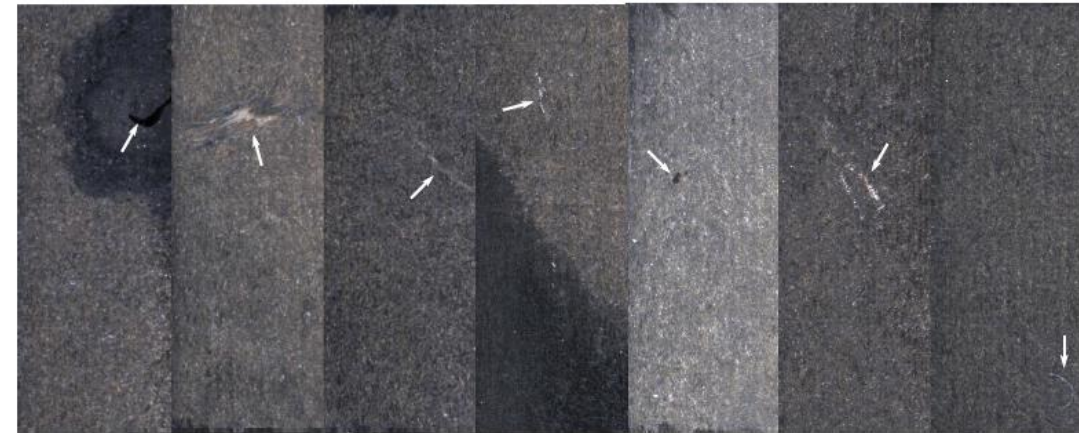


Method	bottle	capsule	grid	leather	pill	tile	trans.	zipper	cable	carpet	hazelnut	m. nut	screw	toothbrush	wood	average
[4]	99.0	86.1	81.0	88.2	87.9	99.1	81.8	91.9	86.2	91.6	93.1	82.0	54.9	95.3	97.7	87.7
[22]	99.9	88.4	99.6	<b>100</b>	83.8	98.7	90.9	98.1	81.9	84.2	83.3	88.5	84.5	<b>100</b>	93.0	91.7
[17]	<b>100</b>	92.3	92.9	<b>100</b>	83.3	97.4	95.9	97.9	<b>94.0</b>	95.5	98.7	93.1	81.2	95.8	97.6	94.4
[7]	99.8	91.5	95.7	<b>100</b>	94.4	97.4	<b>97.8</b>	90.9	92.2	99.9	93.3	99.2	84.4	97.2	98.8	95.5
[11]	98.2	98.2	<b>100</b>	<b>100</b>	94.9	94.6	96.1	99.9	81.2	93.9	98.3	<b>99.9</b>	88.7	99.4	<b>99.1</b>	96.1
[21]	99.2	<b>98.5</b>	99.9	<b>100</b>	<b>98.9</b>	99.6	93.1	<b>100</b>	91.8	97.0	<b>100</b>	98.7	93.9	<b>100</b>	<b>99.1</b>	98.0
<b>DSR</b>	<b>100</b>	98.1	<b>100</b>	<b>100</b>	97.5	<b>100</b>	<b>97.8</b>	<b>100</b>	93.8	<b>100</b>	95.6	98.5	<b>96.2</b>	99.7	96.3	<b>98.2</b>



# Unsupervised learning - DSR

- Results on KSDD2

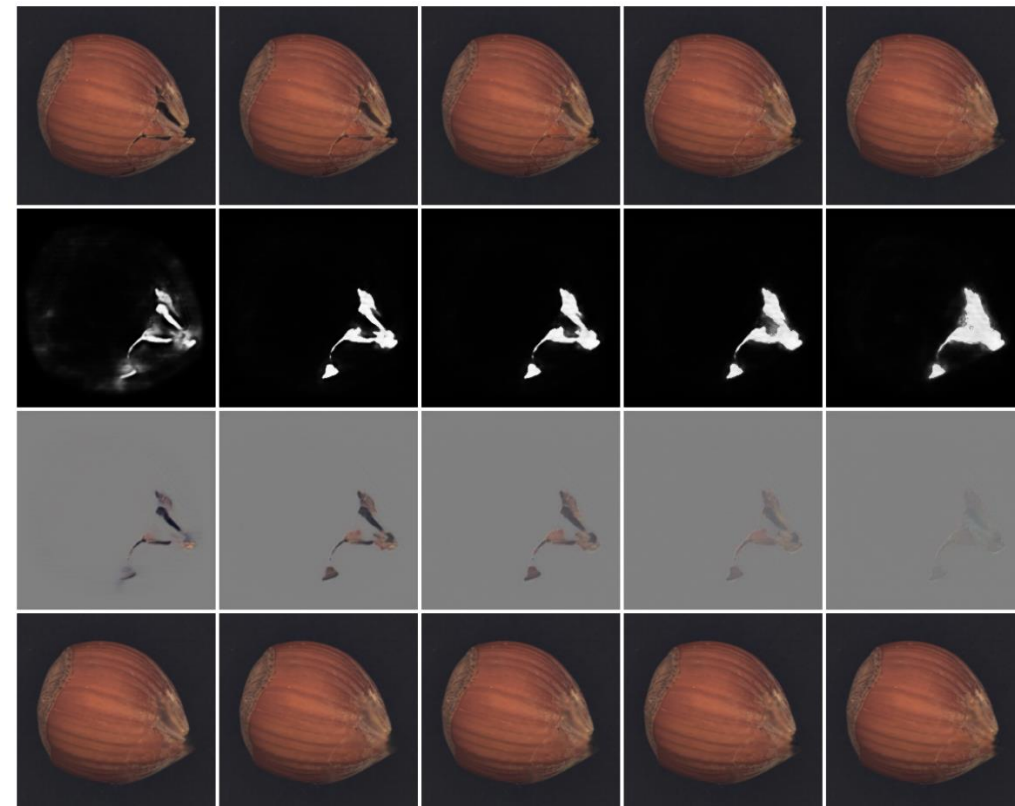


Method	US [4]	MAD [17]	DRÆM [21]	PaDim [7]	DSR
$AP_{det}$	65.3	79.3	77.8	55.6	<b>87.2</b>
$AP_{loc}$	-	-	42.4	45.3	<b>61.4</b>

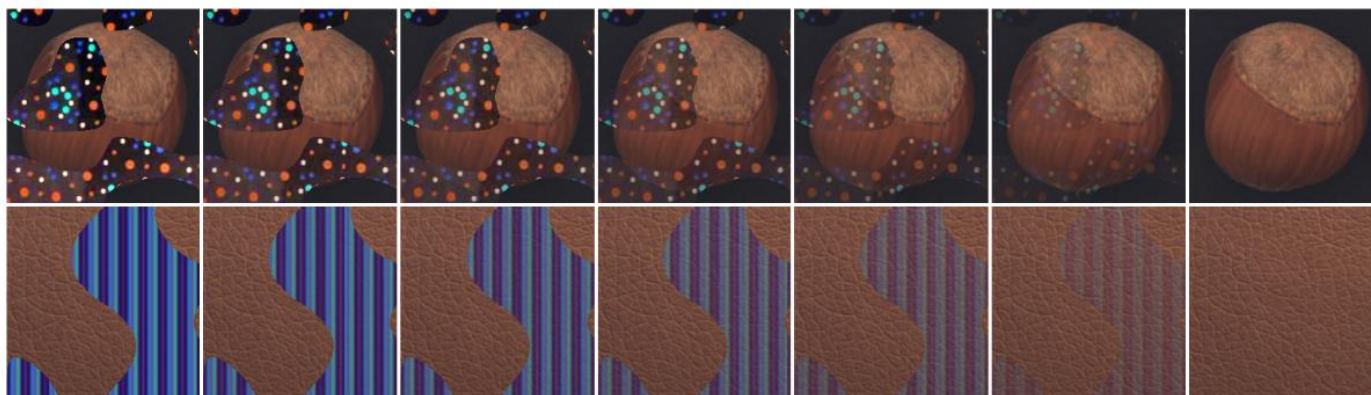
# Unsupervised learning - Transfusion

- TRANSPARENT  
diffUSION
- Using Diffusion  
model estimate
  - Anomaly mask
  - Anomaly
  - Normal image

MV4.0  
2021-2024



Synthetic anomalies

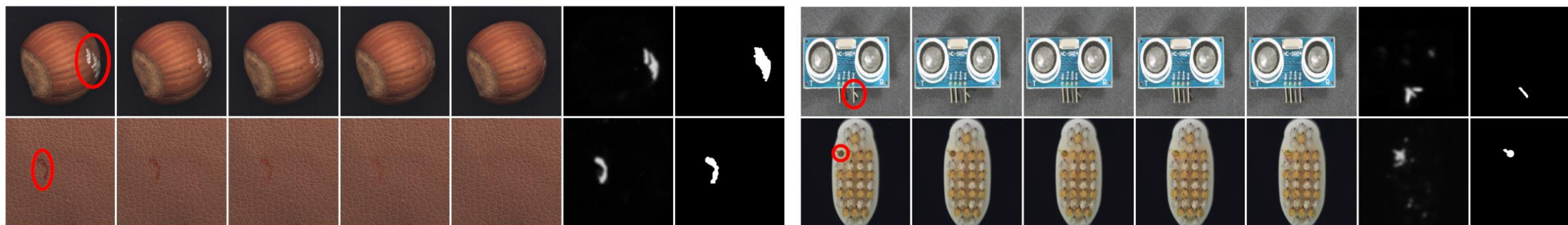
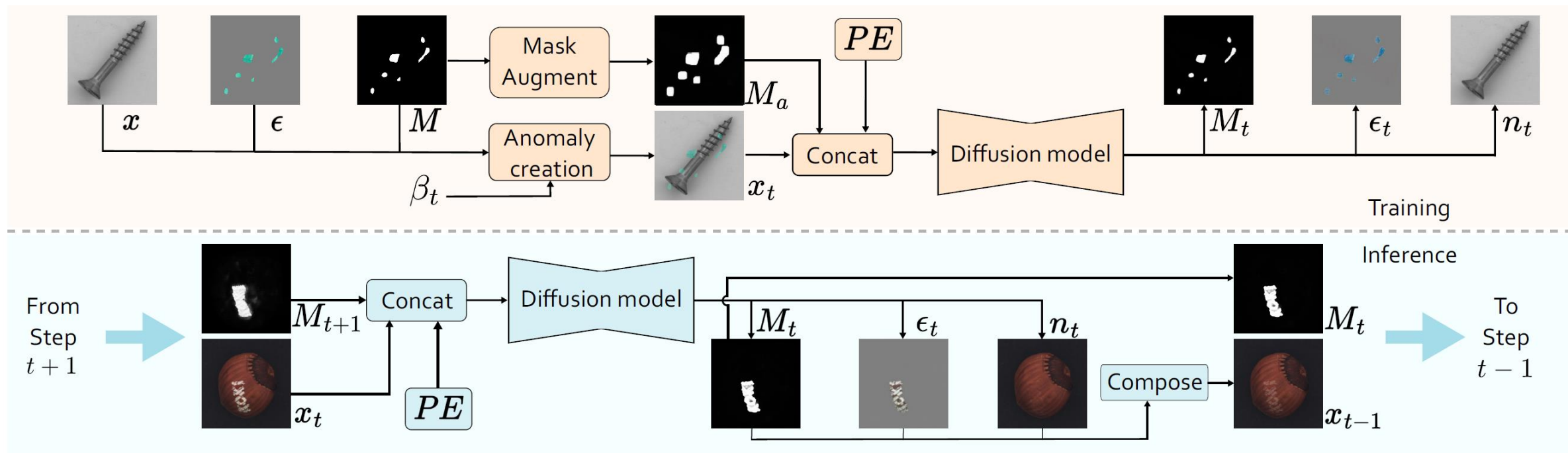


Opaque  Transparent

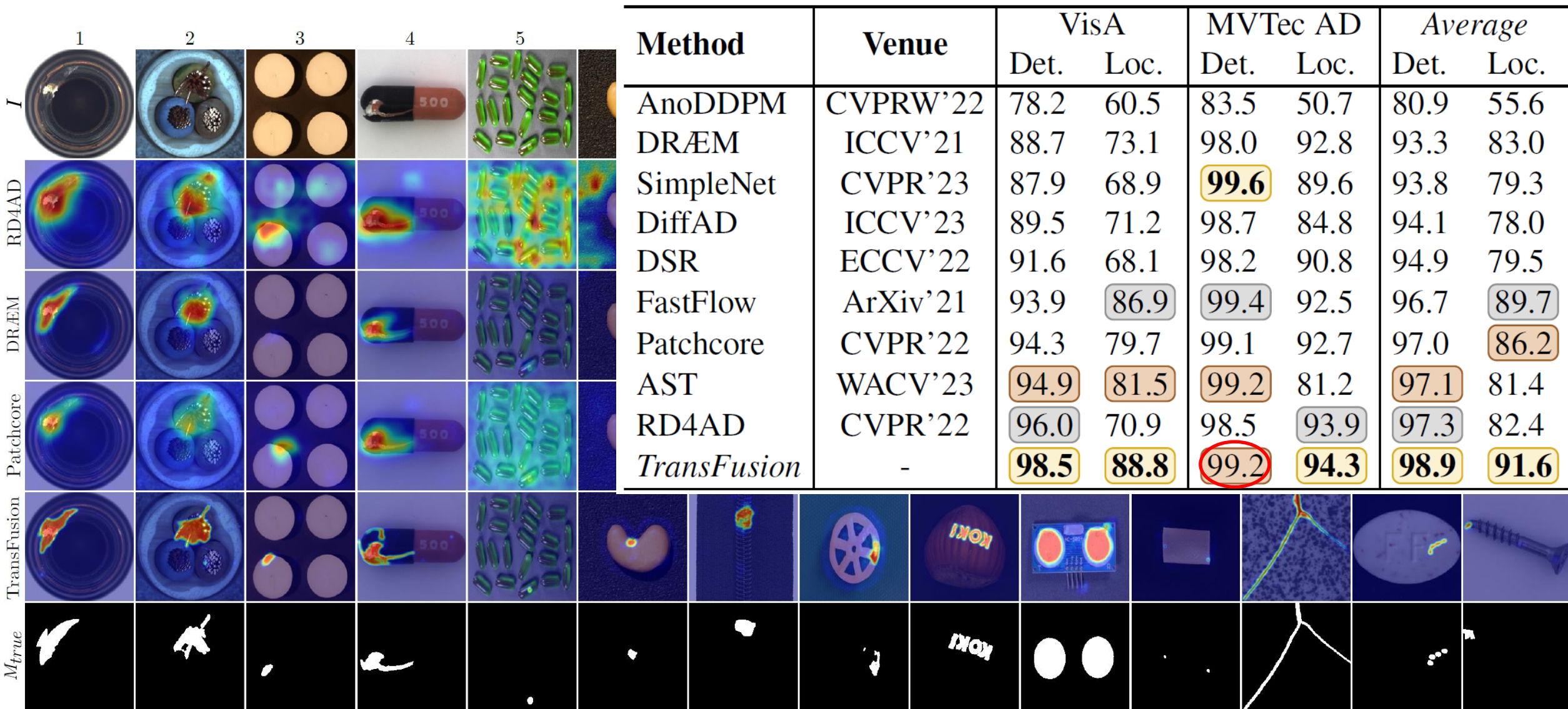
$$x_{t-1} = x_t - (\beta_t - \beta_{t-1})(M_t \odot \epsilon_t) + (\beta_t - \beta_{t-1})(M_t \odot \hat{x}_0^{(t)})$$



# Unsupervised learning - Transfusion

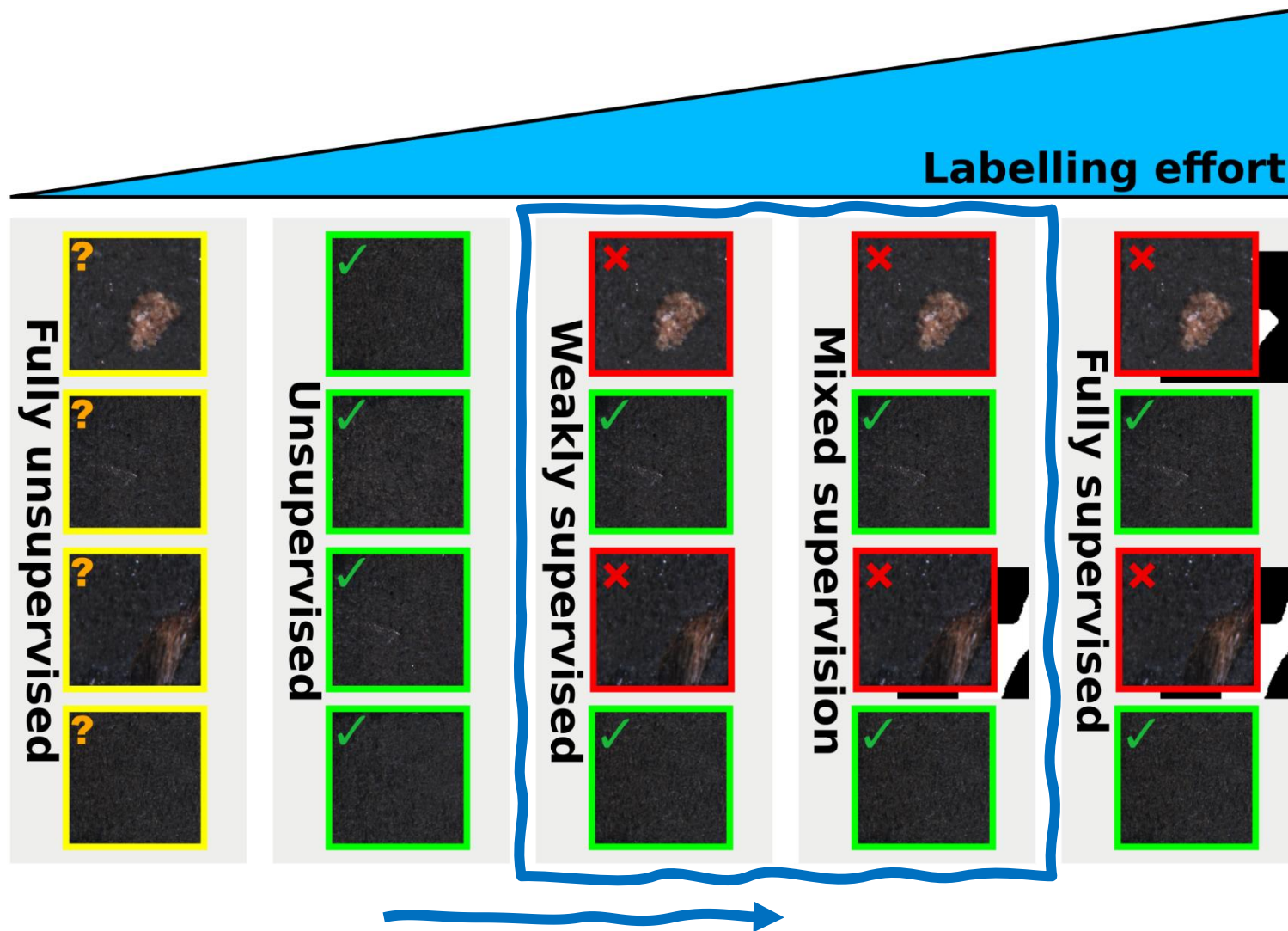


# Unsupervised learning - Transfusion



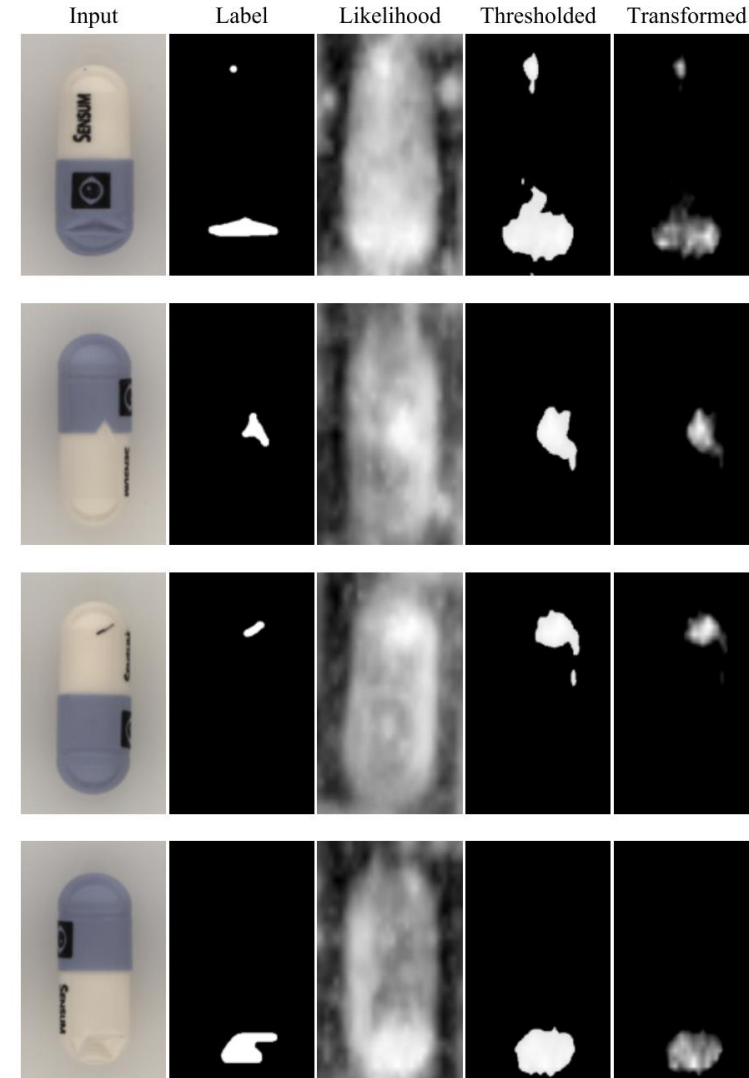
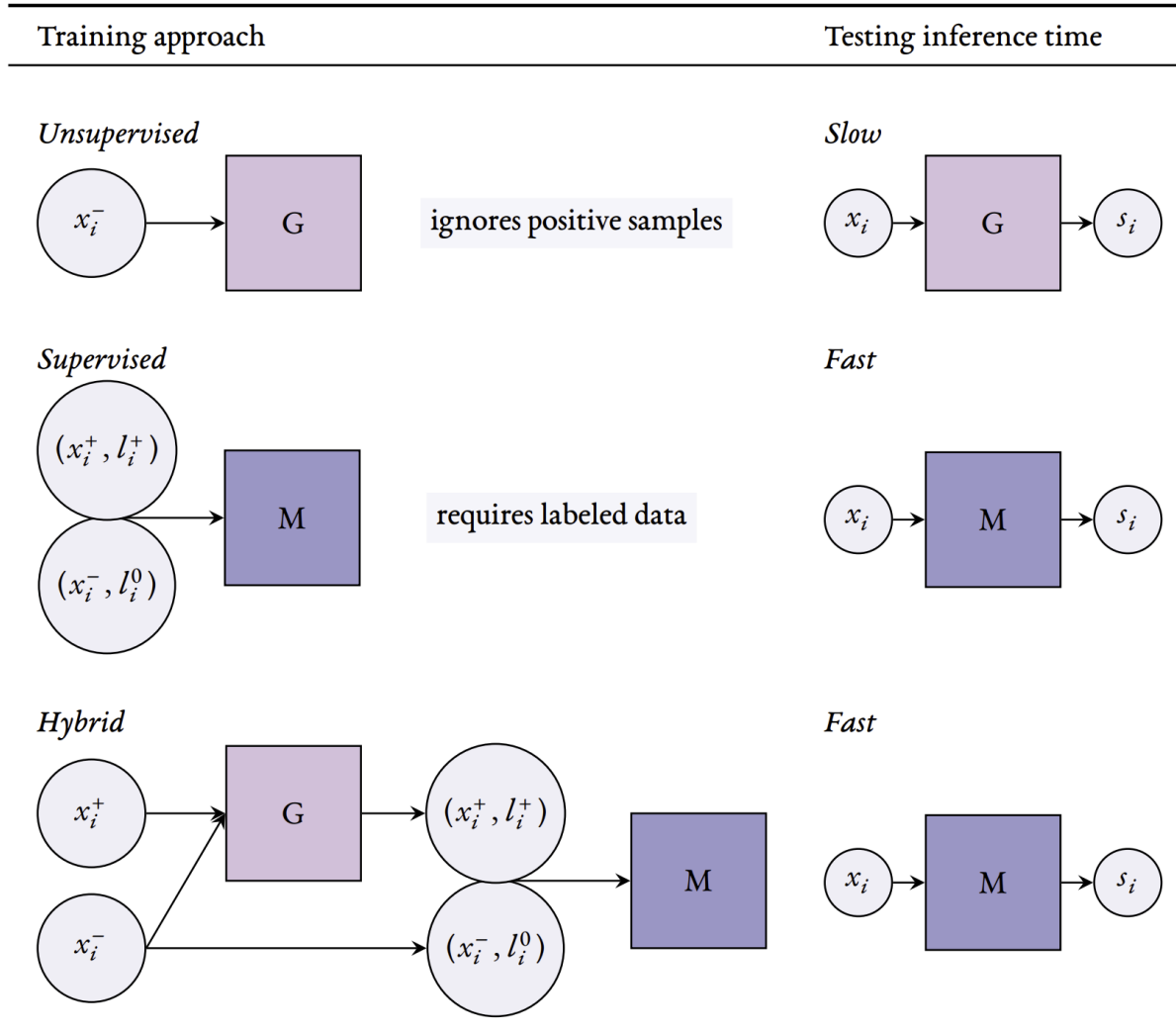


# Learning regimes



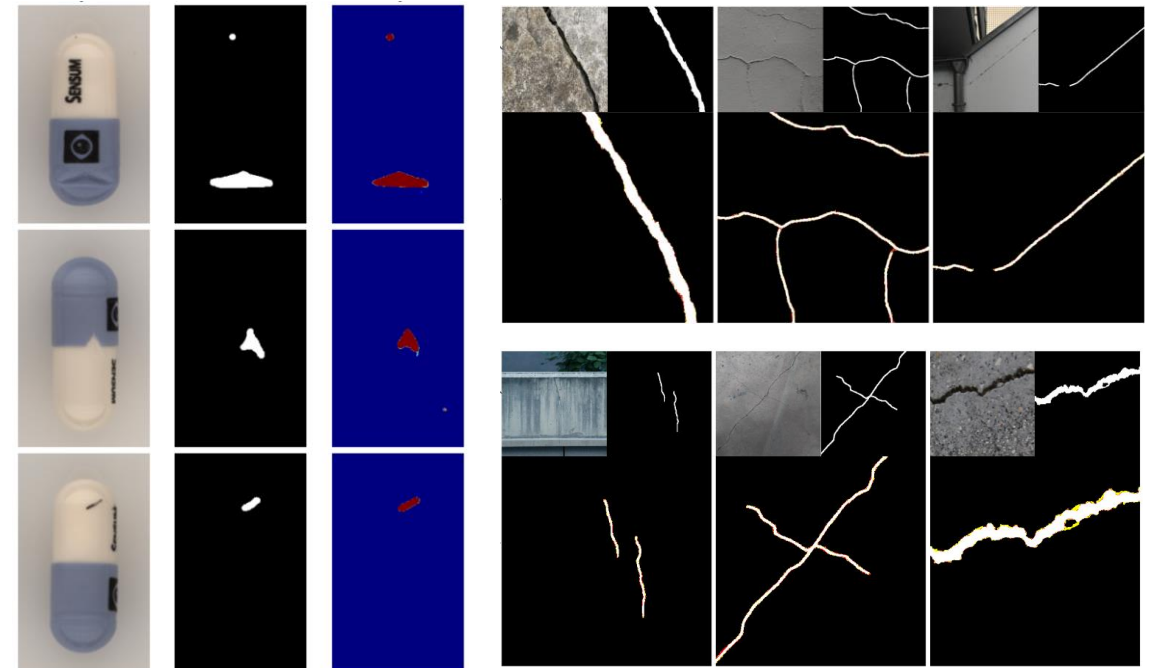
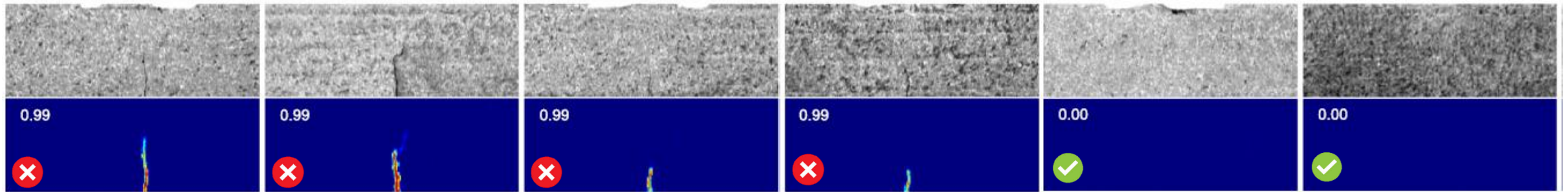


# Learning with mixed supervision



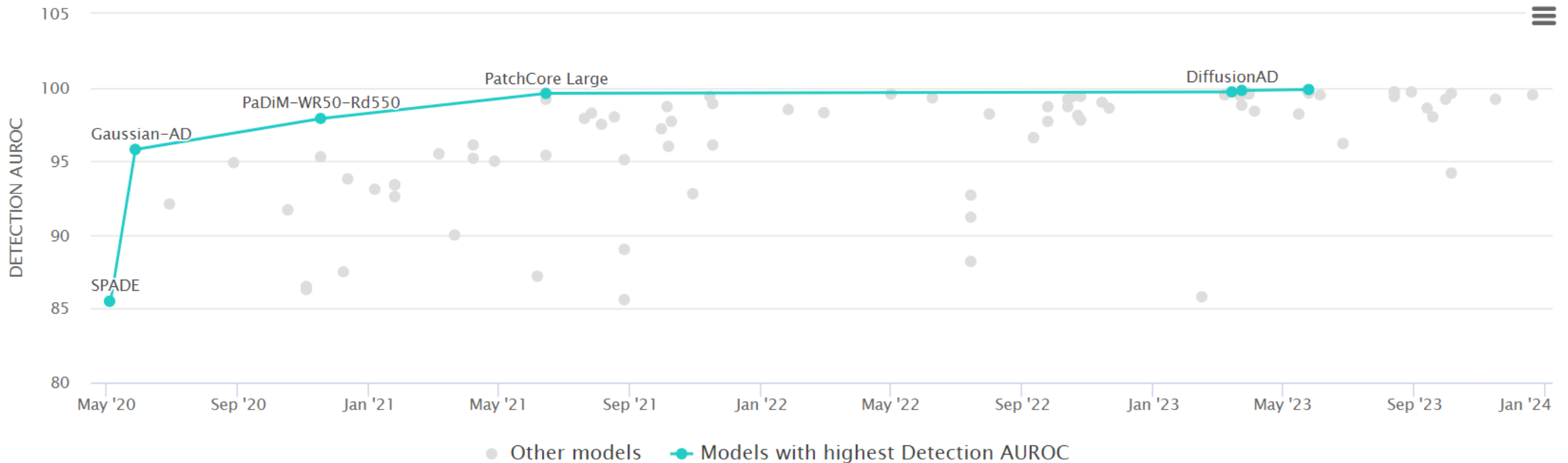
QCAV 2023

- Data-driven deep-learning approach to surface-defect detection



# Anomaly detection methods

- Dozens of methods
- Results on MVTEC AD dataset



- Papers with code:
- <https://paperswithcode.com/sota/anomaly-detection-on-mvtec-ad>