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The Use of Deep Learning for Sticker Detection During Continuous Casting

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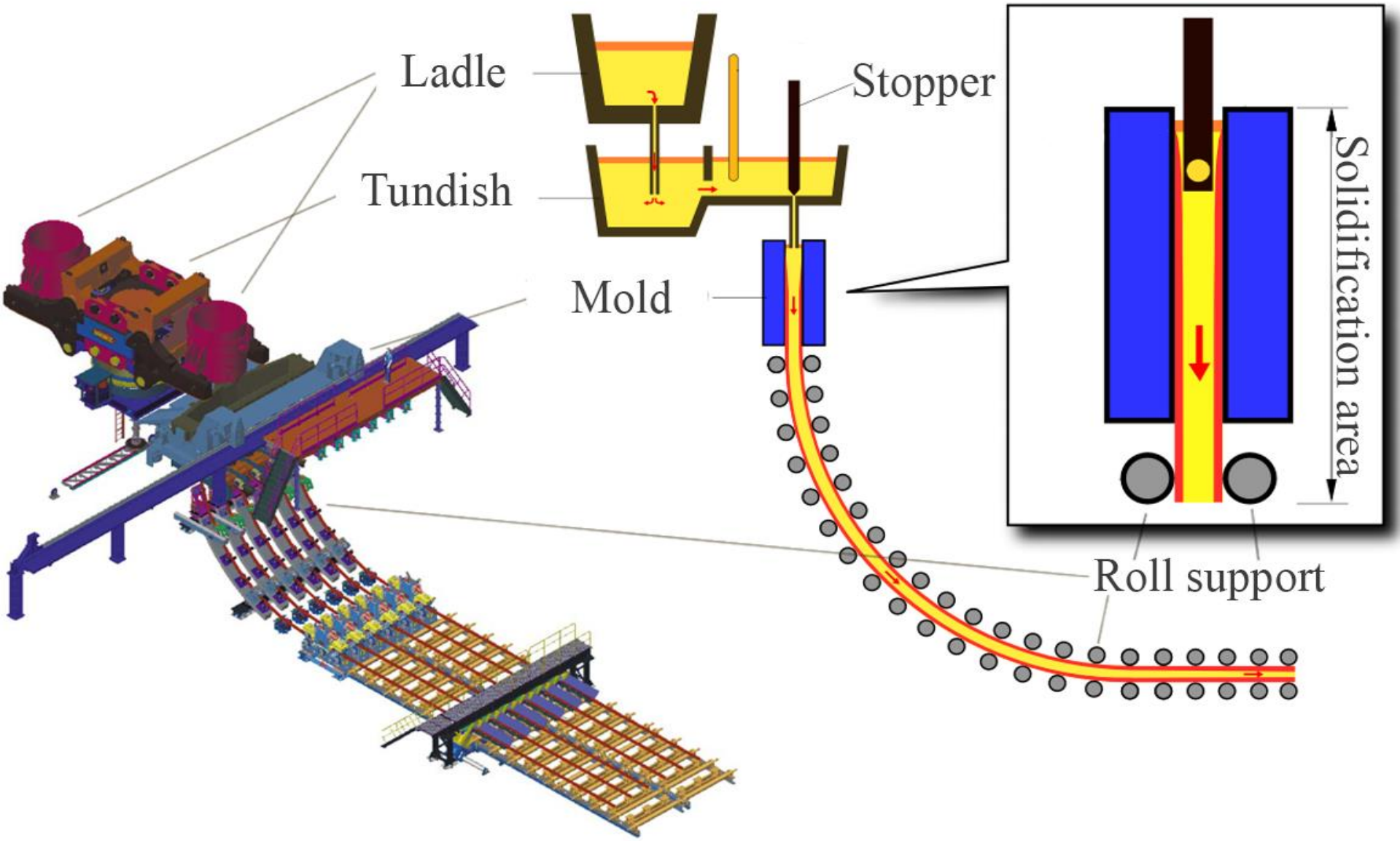
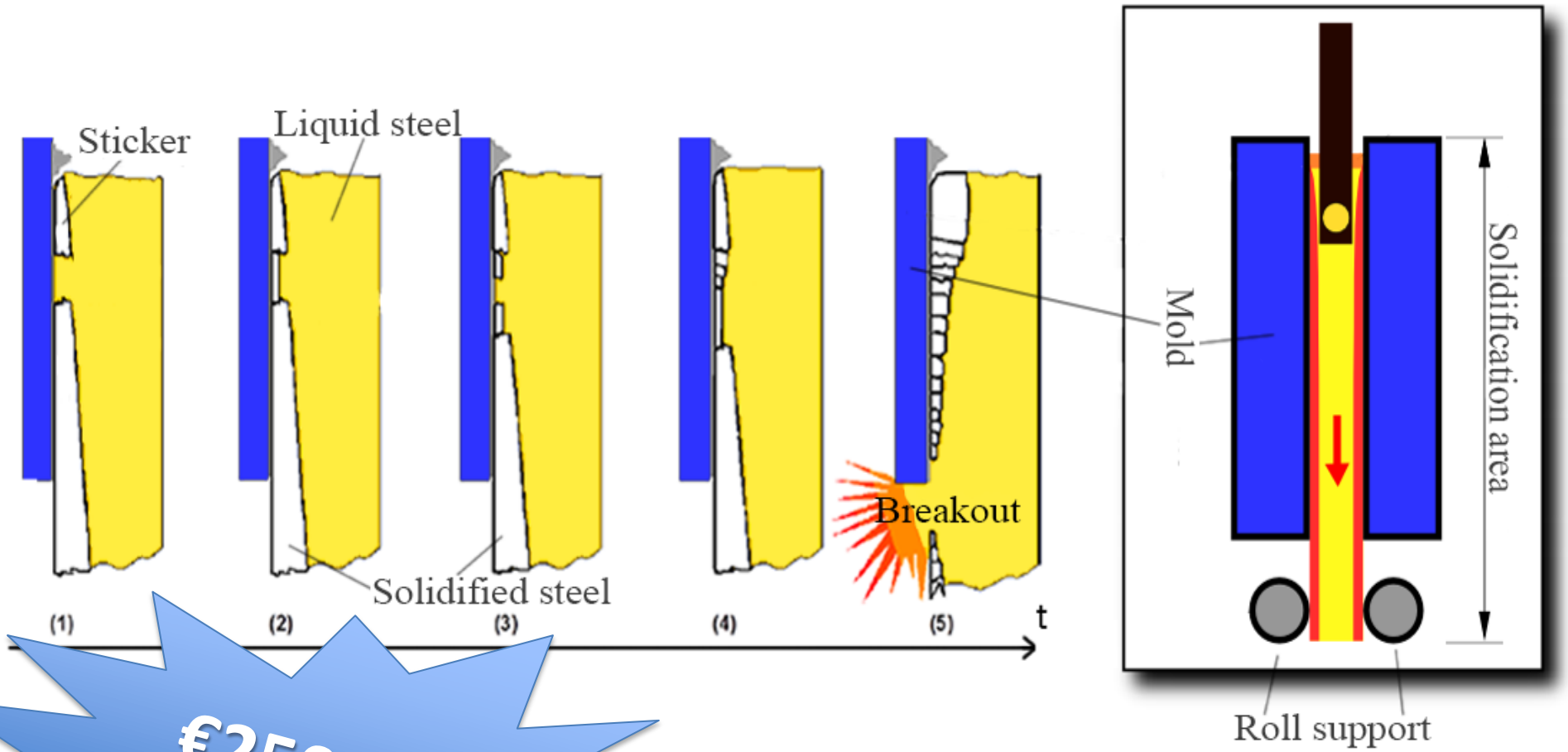
Continuous casting



Breakout



€250 000

The HD mold monitoring system

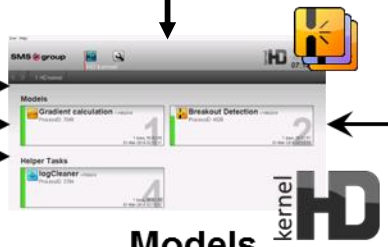
HMI with OPC-Client

Sticker Detection System

Application Server

Process Data Archiving (iba PDA) with OPC-Client

SMS.FlexOPC Server



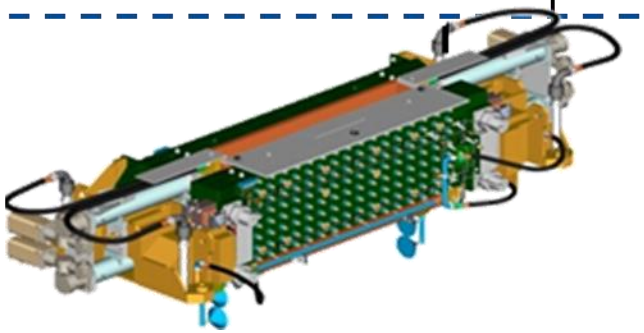
Models with OPC-Client

Level1 Interface with OPC-Server

OpcCopy

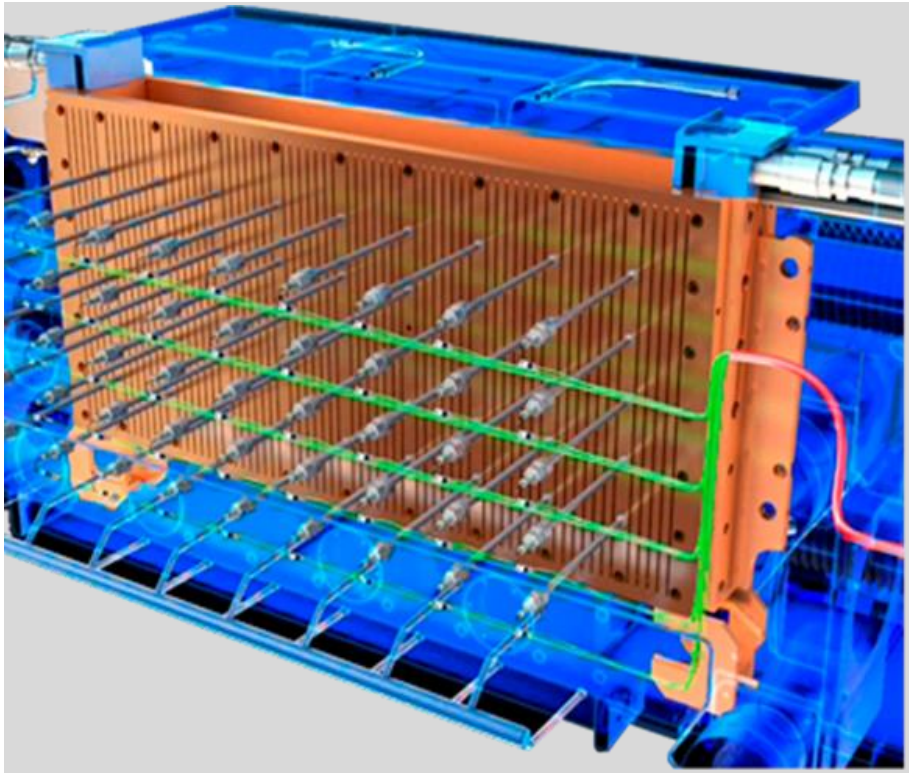
Interrogator

Drive PLC

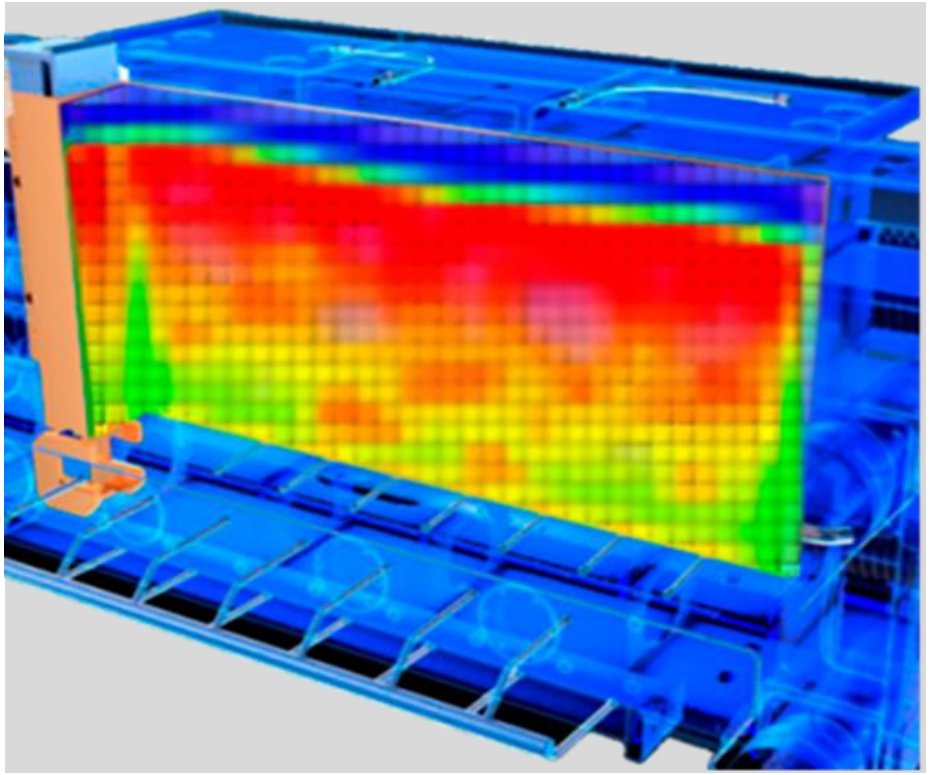


Mold

Casting mold

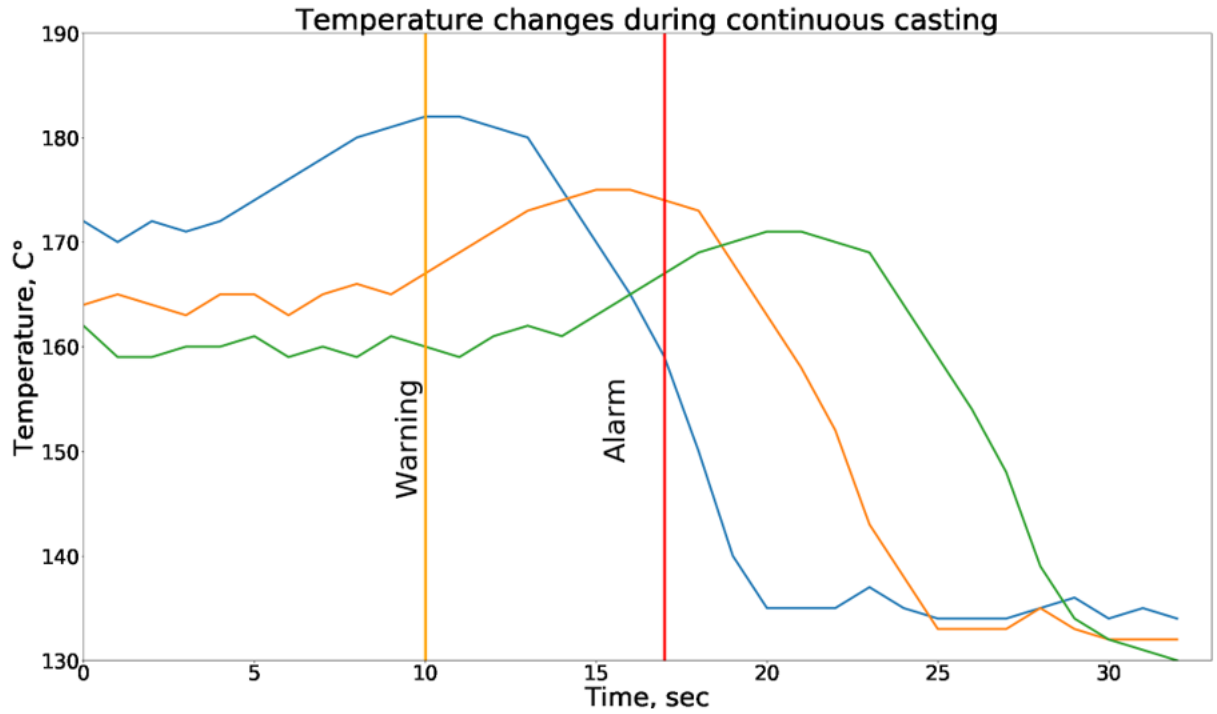


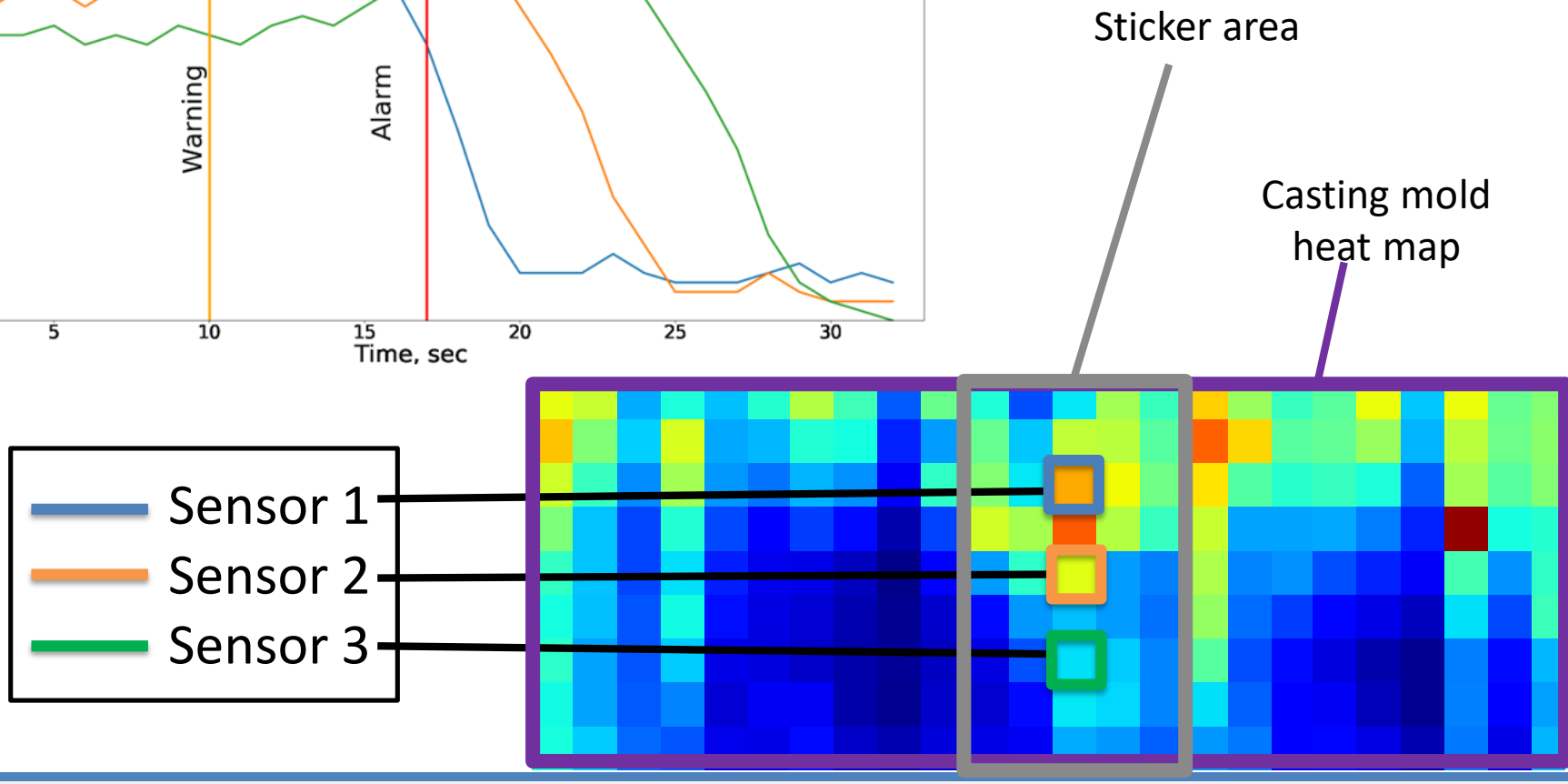
576 fiber optic sensors



Heat map

Sticker


Temperature changes during continuous casting
Temperature, C°
Time, sec
Warning
Alarm
190
180
170
160
150
140
130
0
5
10
15
20
25
30

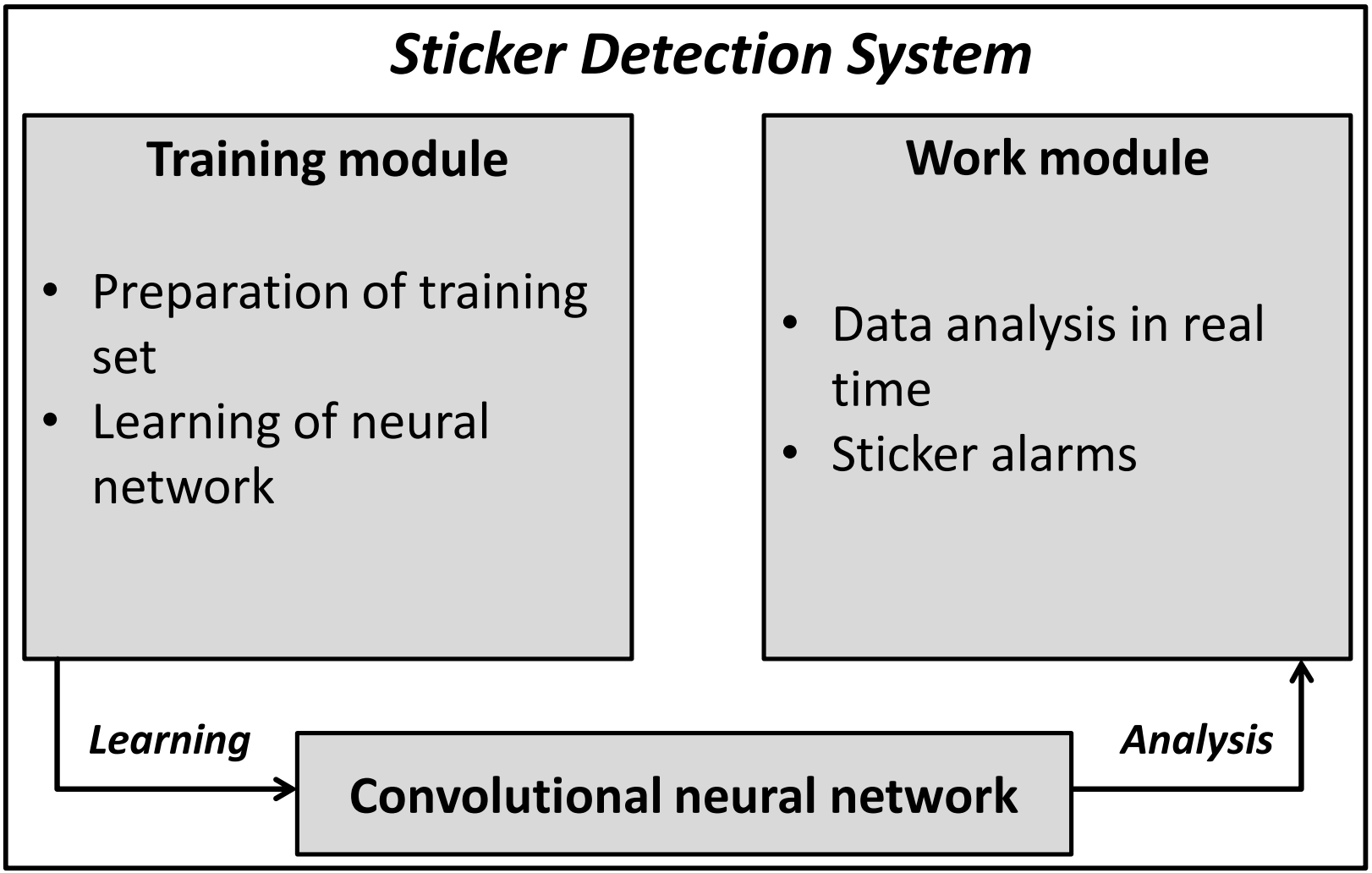

Sticker area
Casting mold heat map
Sensor 1
Sensor 2
Sensor 3

An example of false alarm

Each false alarm is assessed by an expert

Damage €1000+

Sticker detection system



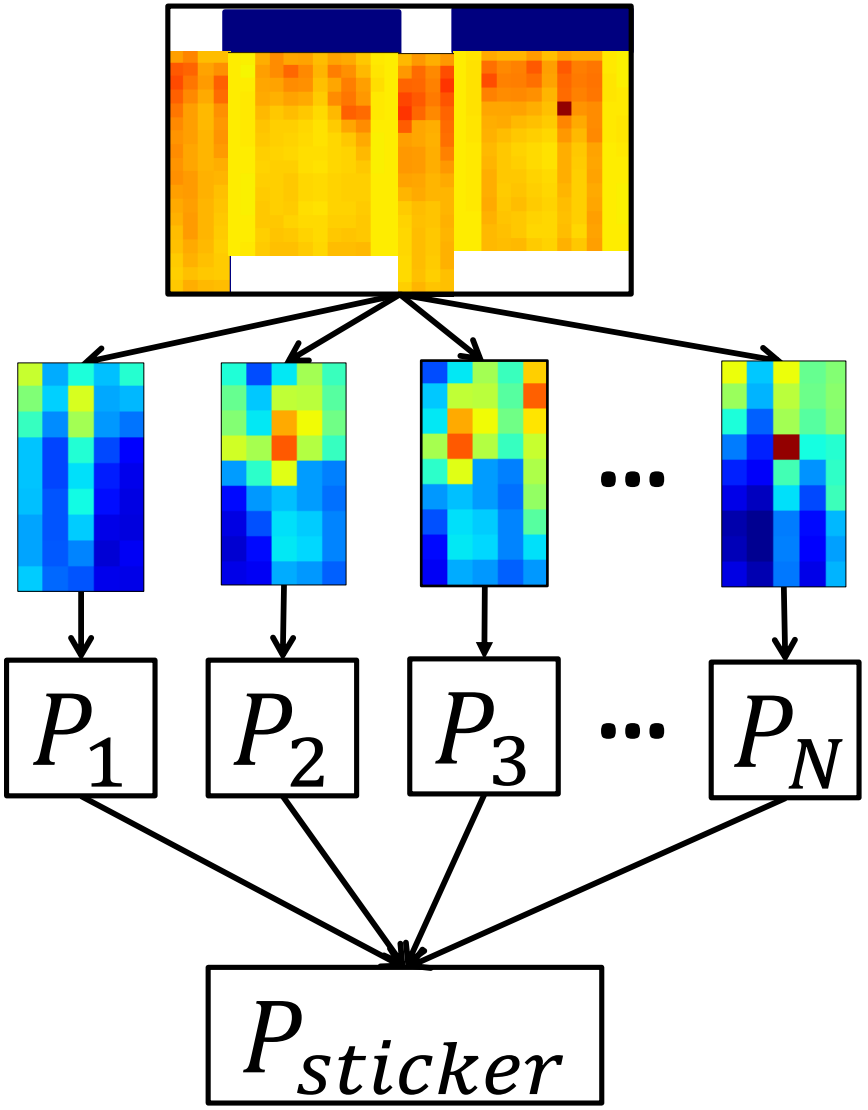
Data analysis

Data reading
(in real time)

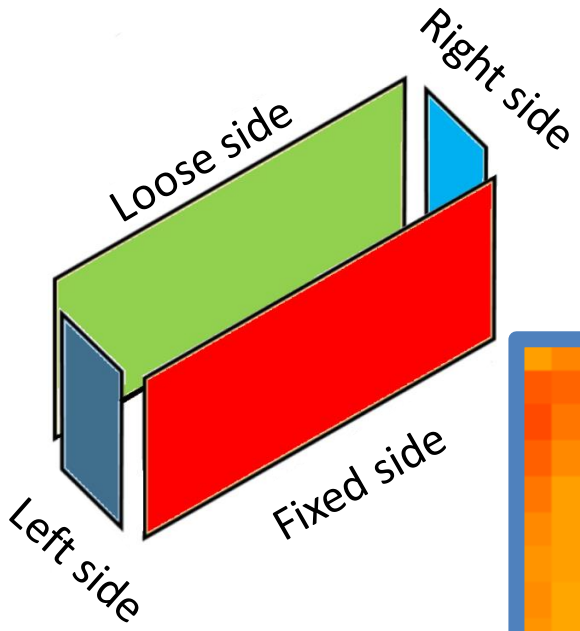
Data preprocessing

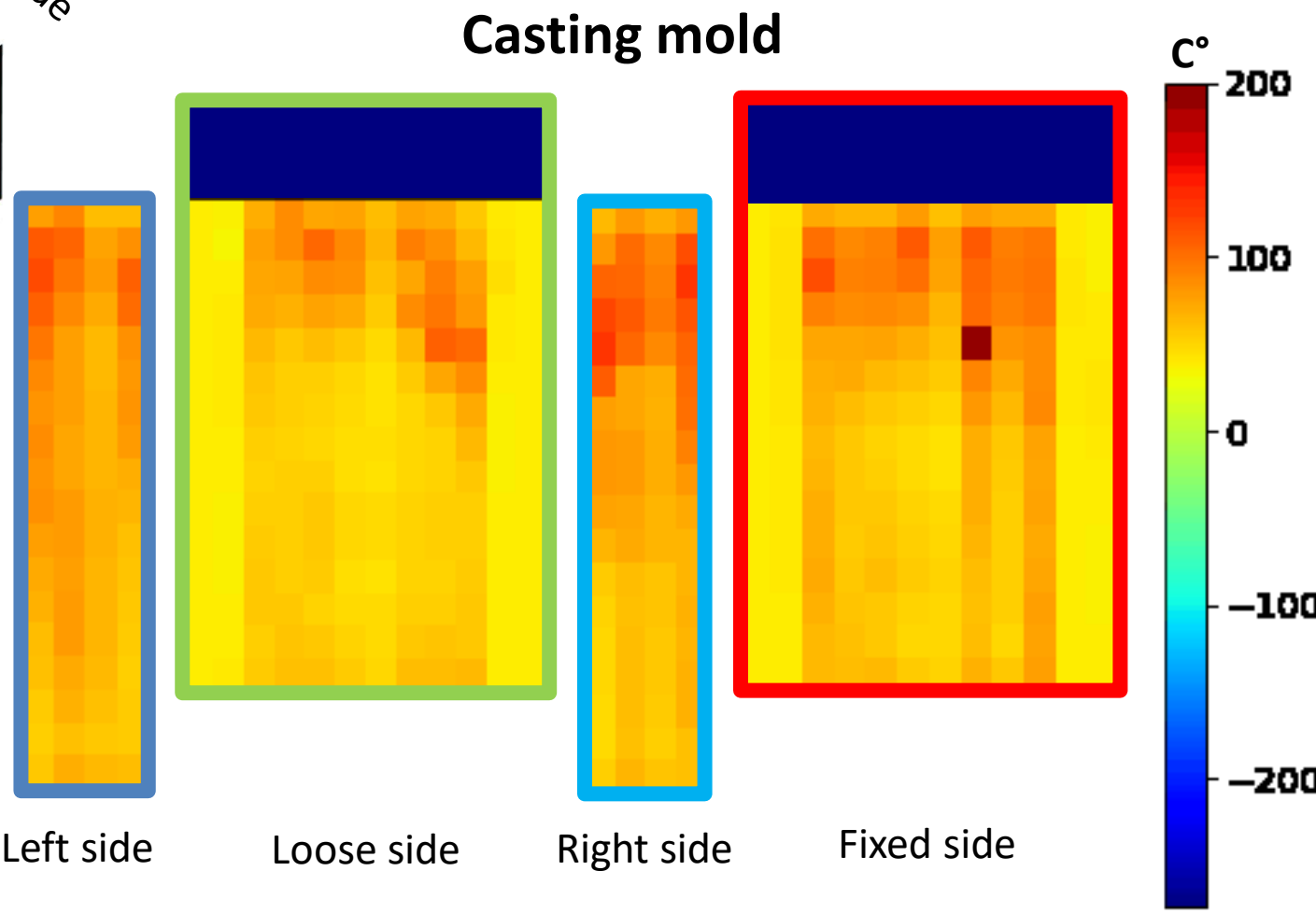
Data analysis
(Neural Network)

Data postprocessing

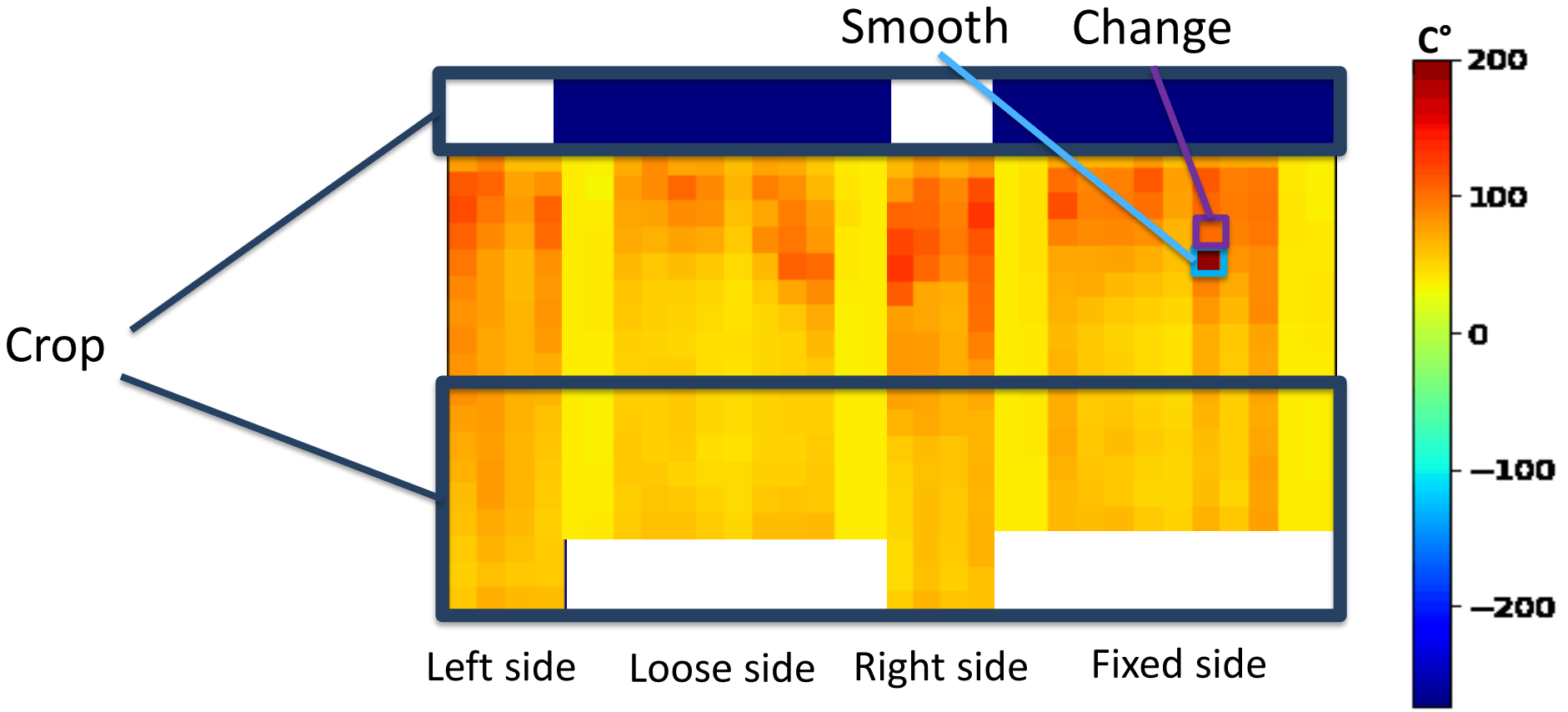


Data reading (in real time)





Preprocessing: data cleaning

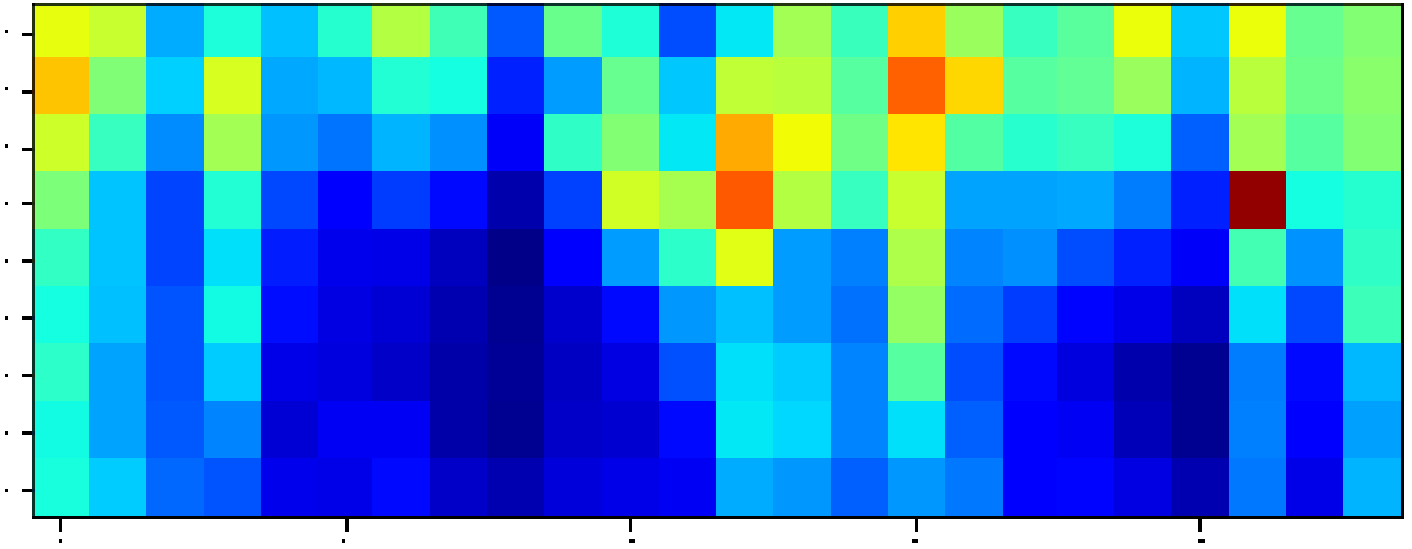


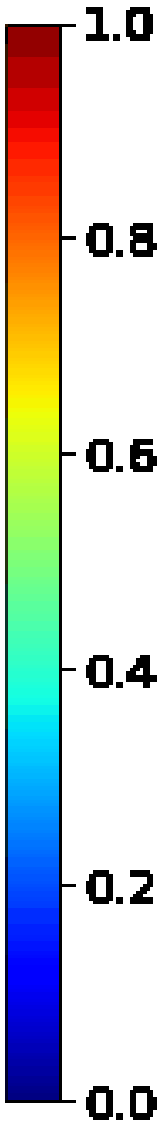
Smooth:

$$T = min(max(T, T_{avg} - \delta), T_{avg} + \delta)$$

Preprocessing: normalization

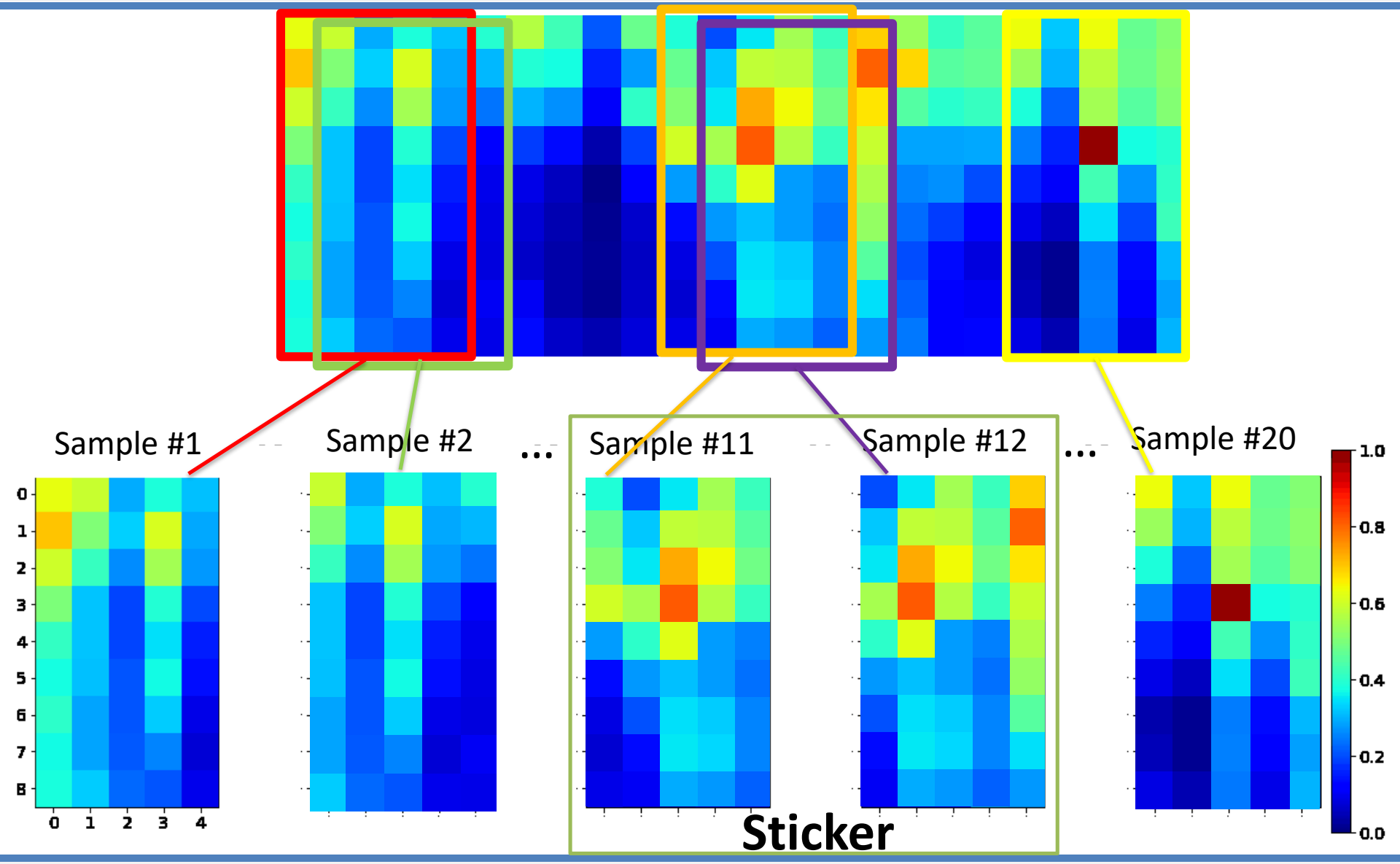
Normalized data





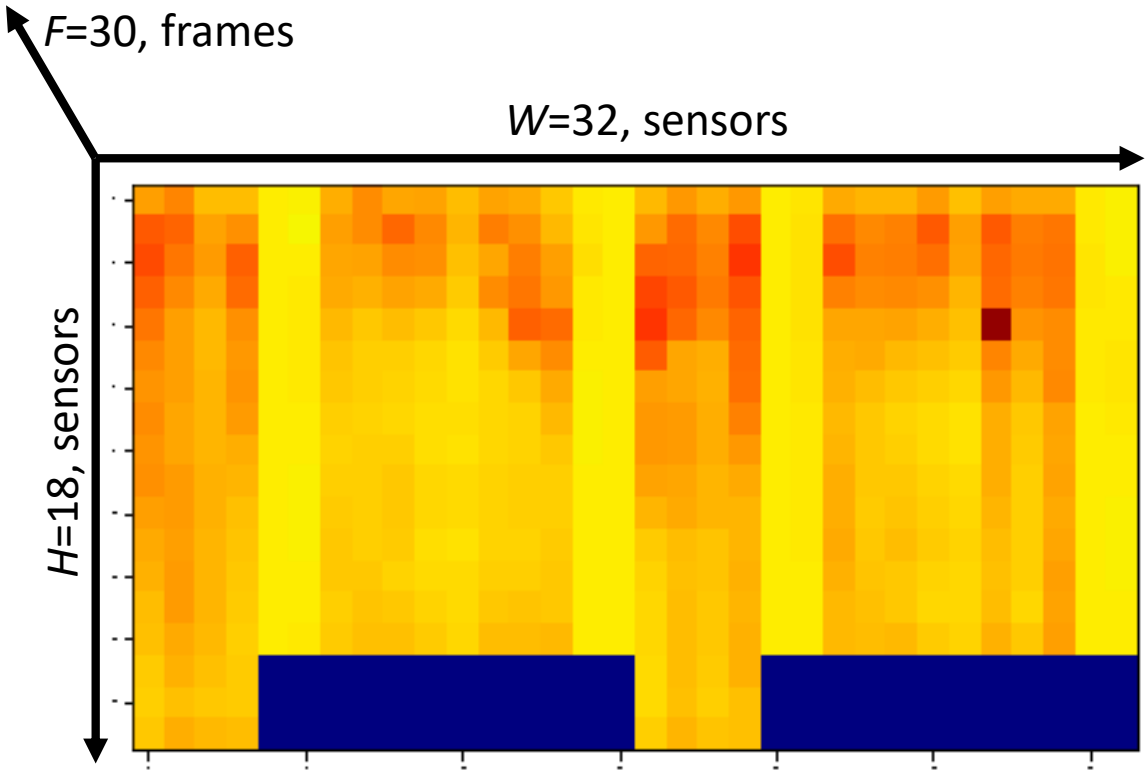
$$T_{norm} = \frac{T - T_{min}}{T_{max} - T_{min}}$$

Preprocessing: slicing

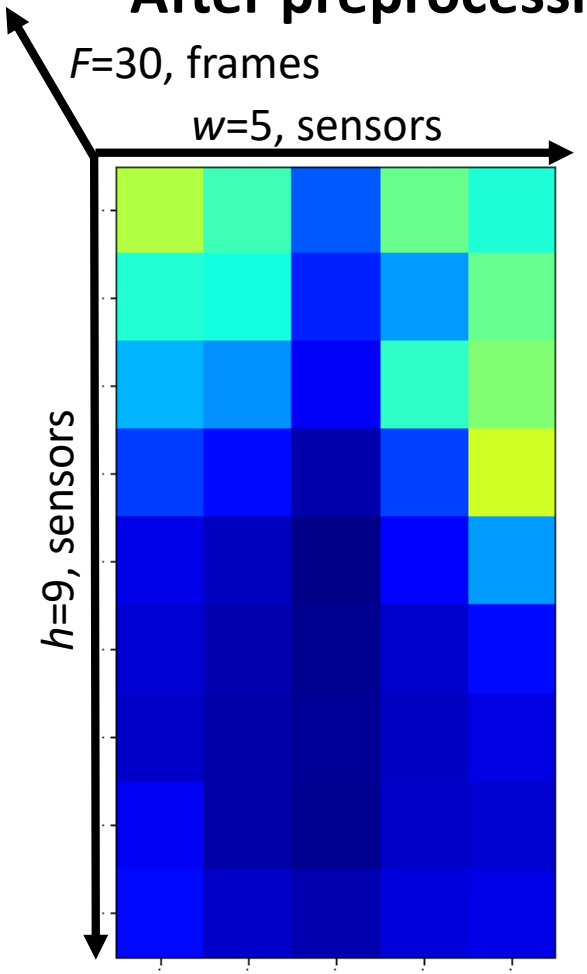


Data sample as an input for CNN

Before preprocessing

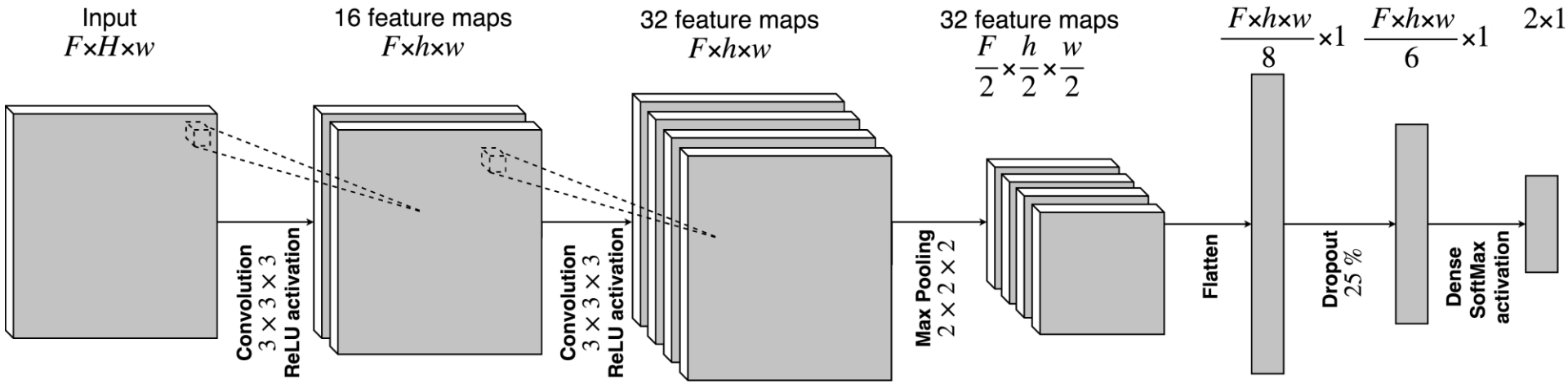


After preprocessing



F=30 – number of frames where gap between frames is 0.25 sec

Structure of CNN

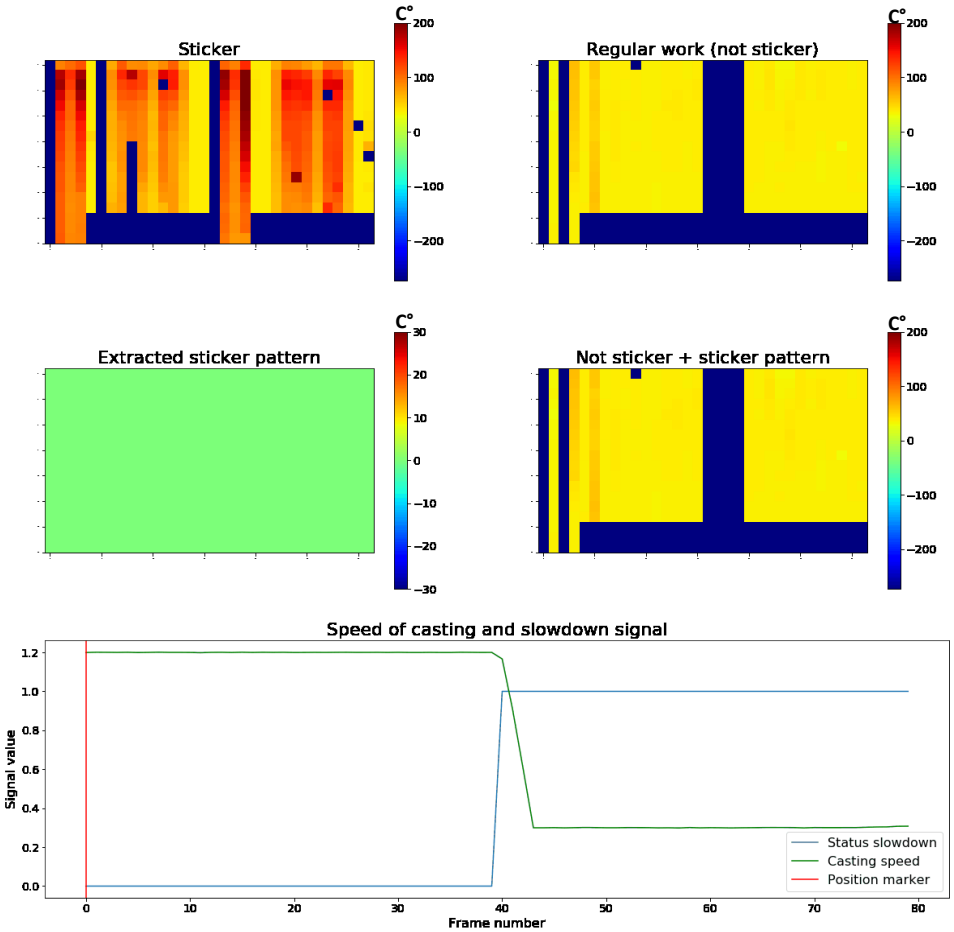


- ***Input data*** are preprocessed samples of 7.5 sec
- ***Output data*** are probabilities of “sticker” and “not sticker” events

Training set (Archive of SMS group)

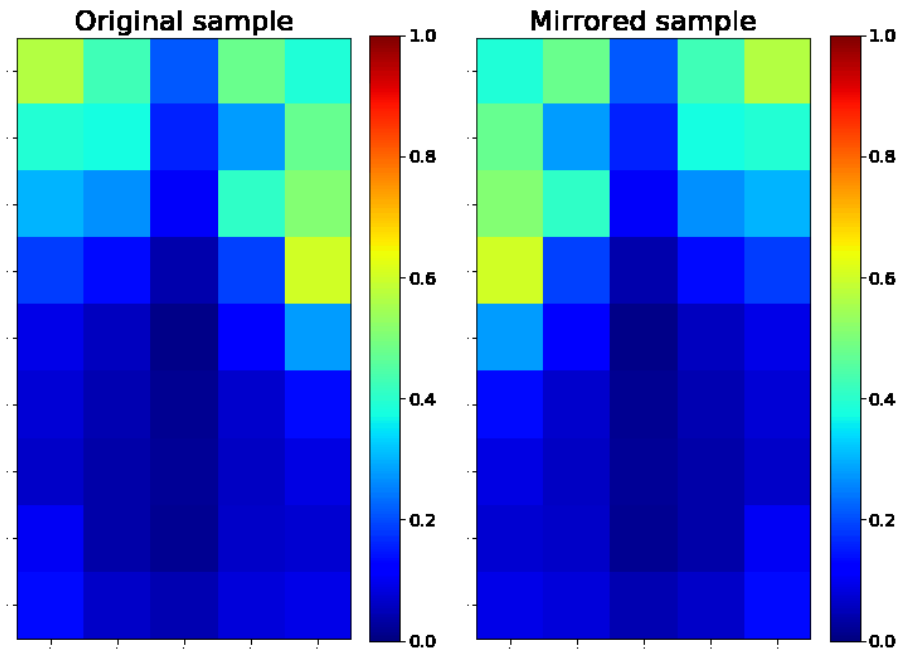
- **14** sticker cases
- **103** false alarm cases
- **∞** regular work cases

Data augmentation



Transferring

+ 6 307 samples *W×H*



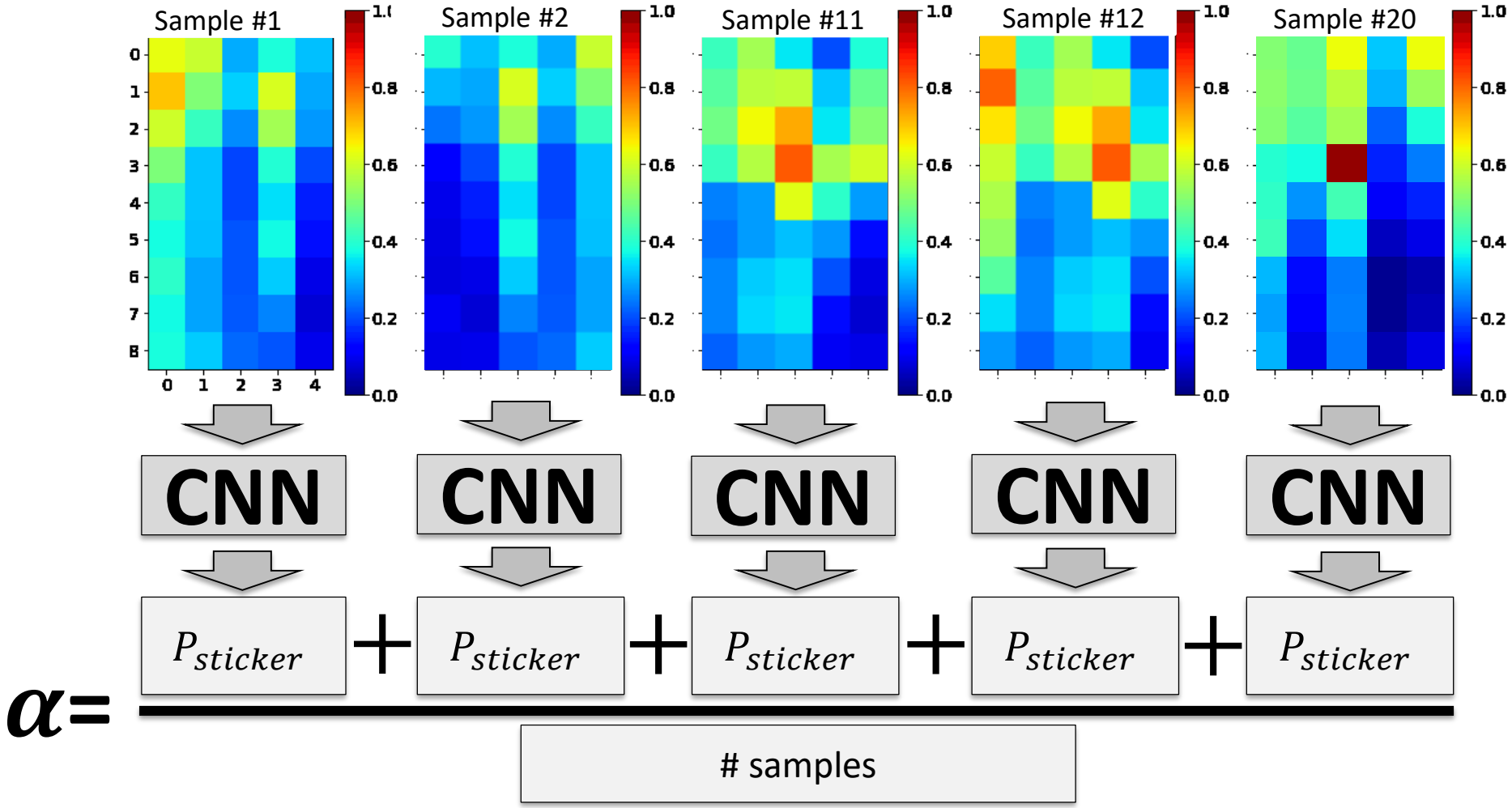
Mirroring

×2 samples *w×h*

Augmented training set

Case	Cases		Samples for CNN	Class
	Real	Synthetic		
Sticker	11	6,307	~25,000	Sticker
False alarm	88	2,384	~7,000	Not sticker
Regular work	11,701	0	~30,000	Not sticker

Data postprocessing



If α is greater than (empirically found) threshold then sticker is detected

Results

Test set:

- 3 real sticker cases
- 15 false alarm cases
- 9,567 regular work cases

Characteristics	BPS	BPS+SDS
Stickers detected	3	3
Stickers missed	0	0
False alarms signaled	15	8