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tinyML EMEA Technical Forum 2021 Proceedings

June 7 – 10, 2021

Virtual Event

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June 7-10, 2021

Squeeze-and-Threshold based quantization for Low-Precision Neural Networks

Presented by: Binyi Wu, PhD student, Infineon, Germany

June 7, 2021

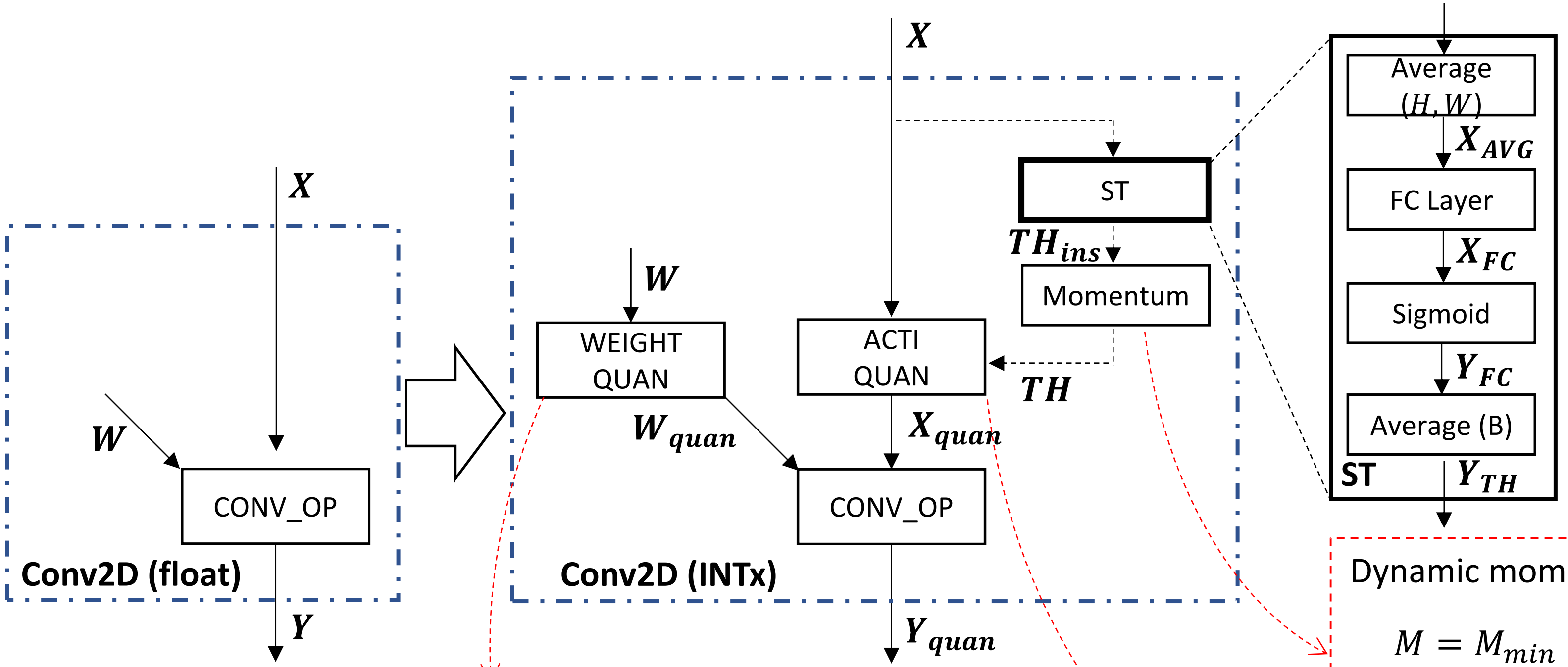
Introduction:

- Convolution neural networks quantization
- low-quality black-and-white photos are well enough to recognize. → Different features should be adjusted to different ranges, and a threshold should be should be learned to distinguish (quantized) them.

Contributions:

- A novel quantization method based on attention mechanism
- A unified 1-bit and multi-bit activation quantization method

Activation Quantization: Squeeze-and-Threshold (ST) quantization



$$\boldsymbol{X_{AVG}} = \frac{1}{HW}\sum_{i=0}^{H}\sum_{j=0}^{W}\boldsymbol{X}[:,:i,j]$$

$$\boldsymbol{X_{FC}} = MatMul(\boldsymbol{X_{AVG}}, \boldsymbol{W})$$

$$\boldsymbol{Y_{FC}} = sigmoid(\boldsymbol{X_{FC}})$$

$$\boldsymbol{Y_{TH}} = \frac{1}{B}\sum_{i=0}^{B}\boldsymbol{Y_{FC}}[i]$$

Dynamic momentum

$$M = M_{min} + (M_{init} - M_{min}) * \cos\left(\frac{E_{cur}}{E_{tol}}\right)$$

$$\boldsymbol{TH} = (1 - M) * \boldsymbol{TH_{last}} + M * \boldsymbol{Y_{TH}}$$

$$\boldsymbol{X_{int}} = clip\left(round\left(\frac{\boldsymbol{X}}{\boldsymbol{TH}}\right), 0, 2^b - 1\right)$$

$$\boldsymbol{X_{quan}} = \boldsymbol{X_{int}} * mean(\boldsymbol{TH})$$

Weight quantization

1-bit weight binarization uses the scheme from BNN+[1].

Multi-bit weight quantization uses the scheme from LSQ[2].

[1] *Sajad Darabi, Mouloud Belbahri, Matthieu Courbariaux, andVahid Partovi Nia. BNN+: improved binary network training*

[2] *Steven K Esser, Jeffrey L McKinstry, Deepika Bablani, Rathinakumar Appuswamy, and Dharmendra S Modha. Learned step size quantization. In 8th International Conference on Learning Representations (ICLR), 2020, Addis Ababa, Ethiopia, April 26-30, 2020*

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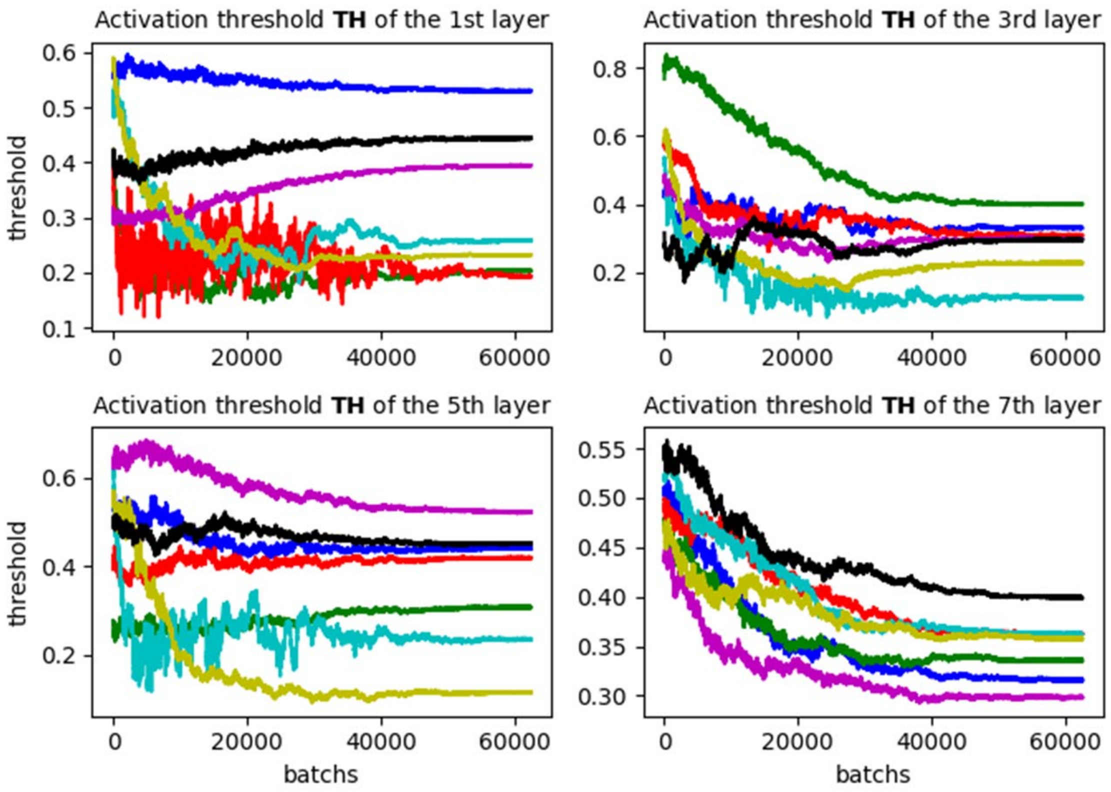
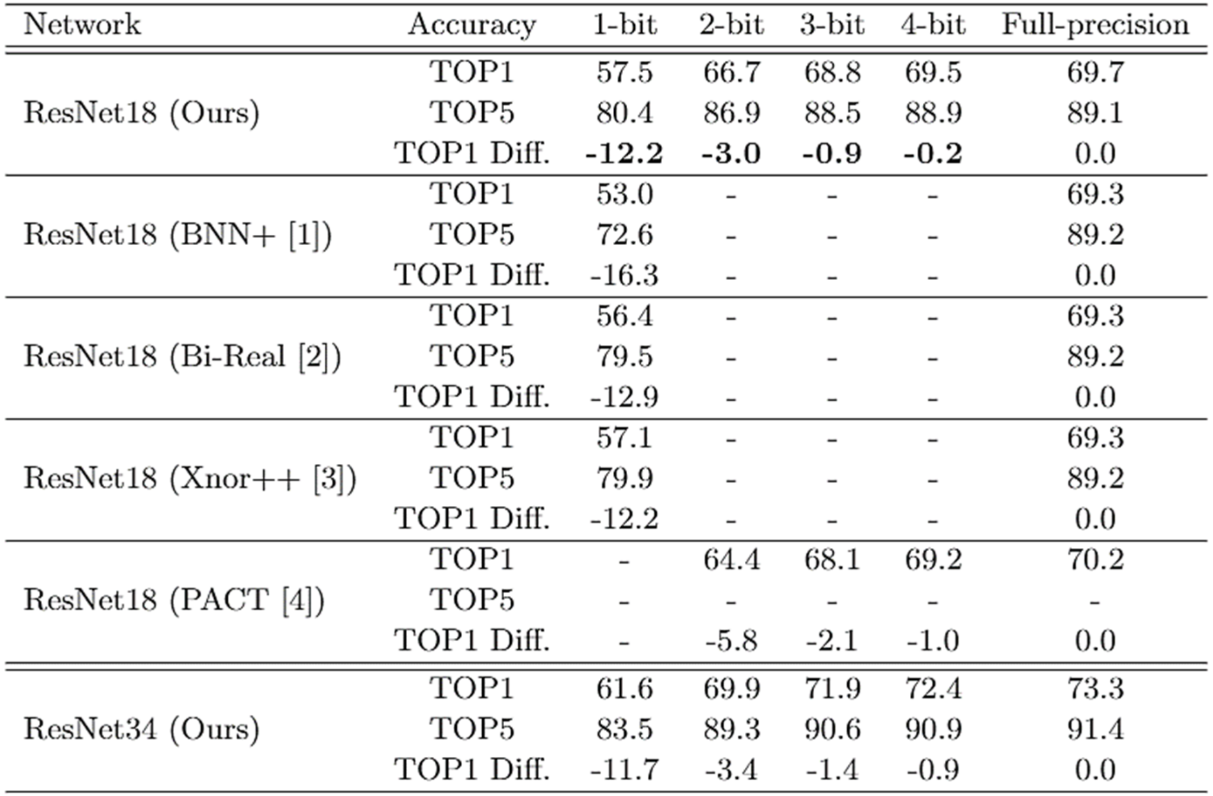


Figure 1. Activation thresholds on the different layers during training



Network	Accuracy	1-bit	2-bit	3-bit	4-bit	Full-precision
ResNet18 (Ours)	TOP1	57.5	66.7	68.8	69.5	69.7
	TOP5	80.4	86.9	88.5	88.9	89.1
	TOP1 Diff.	**-12.2**	**-3.0**	**-0.9**	**-0.2**	0.0
ResNet18 (BNN+ [1])	TOP1	53.0	-	-	-	69.3
	TOP5	72.6	-	-	-	89.2
	TOP1 Diff.	-16.3	-	-	-	0.0
ResNet18 (Bi-Real [2])	TOP1	56.4	-	-	-	69.3
	TOP5	79.5	-	-	-	89.2
	TOP1 Diff.	-12.9	-	-	-	0.0
ResNet18 (Xnor++ [3])	TOP1	57.1	-	-	-	69.3
	TOP5	79.9	-	-	-	89.2
	TOP1 Diff.	-12.2	-	-	-	0.0
ResNet18 (PACT [4])	TOP1	-	64.4	68.1	69.2	70.2
	TOP5	-	-	-	-	-
	TOP1 Diff.	-	-5.8	-2.1	-1.0	0.0
ResNet34 (Ours)	TOP1	61.6	69.9	71.9	72.4	73.3
	TOP5	83.5	89.3	90.6	90.9	91.4
	TOP1 Diff.	-11.7	-3.4	-1.4	-0.9	0.0

Table 1. Top-1 and top-5 accuracy (in percentage) of our quantization scheme and prior state-of-the-art quantization methods on ImageNet dataset

[1] Sajad Darabi, Mouloud Belbahri, Matthieu Courbariaux, andVahid Partovi Nia. BNN+: improved binary network training

[2] Zechun Liu, Baoyuan Wu, Wenhan Luo, Xin Yand, Wei Liu, and Kwang-TingCheng. Bi-real net: Enhancing the performance of 1-bit cnns with improved rep-resentational capability and advanced training algorithm

[3] Adrian Bulat and Georgios Tzimiropoulos. Xnor-net++: Improved binary neuralnetworks

[4] Jungwook Choi, Zhuo Wang, Swagath Venkataramani, Pierce IJen Chuang, Vijay-alakshmi Srinivasan, and Kailash Gopalakrishnan. PACT: parameterized clippingactivationfor quantized neural networks

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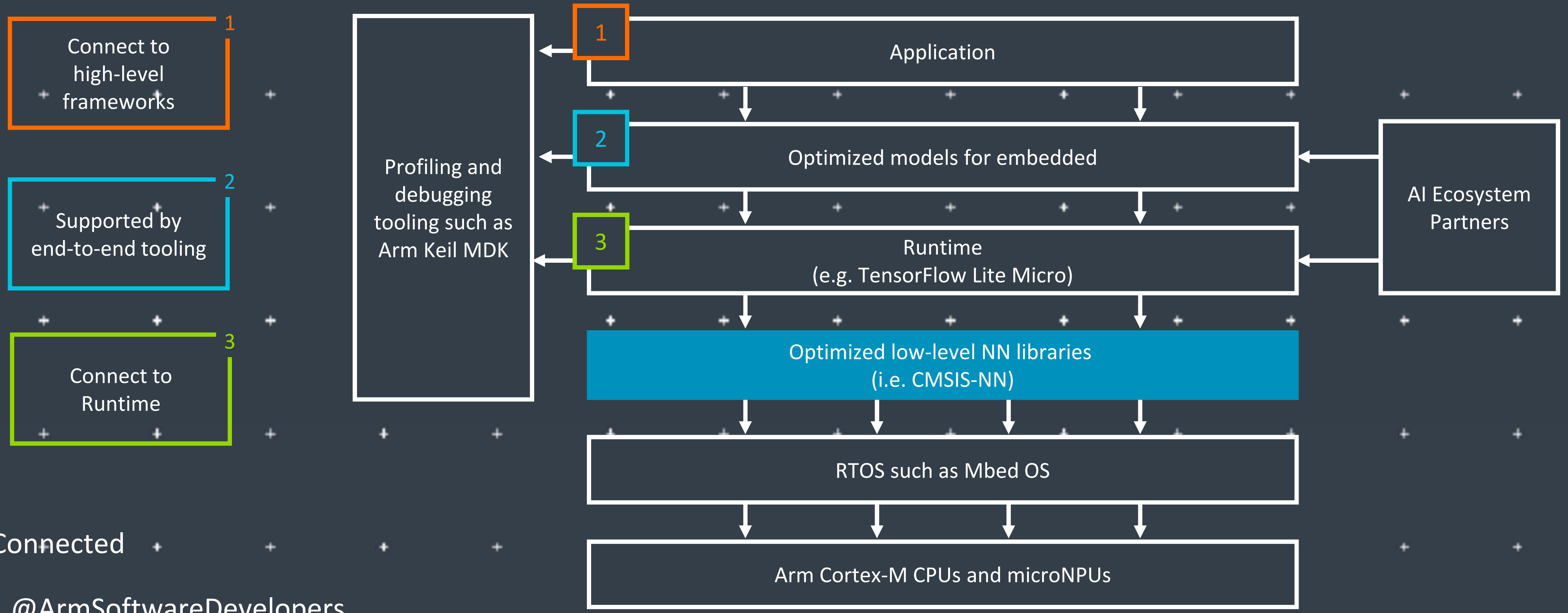
1
Connect to high-level frameworks
2
Supported by end-to-end tooling
3
Connect to Runtime
Profiling and debugging tooling such as Arm Keil MDK
1
Application
2
Optimized models for embedded
3
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TinyML for all developers

C++ library

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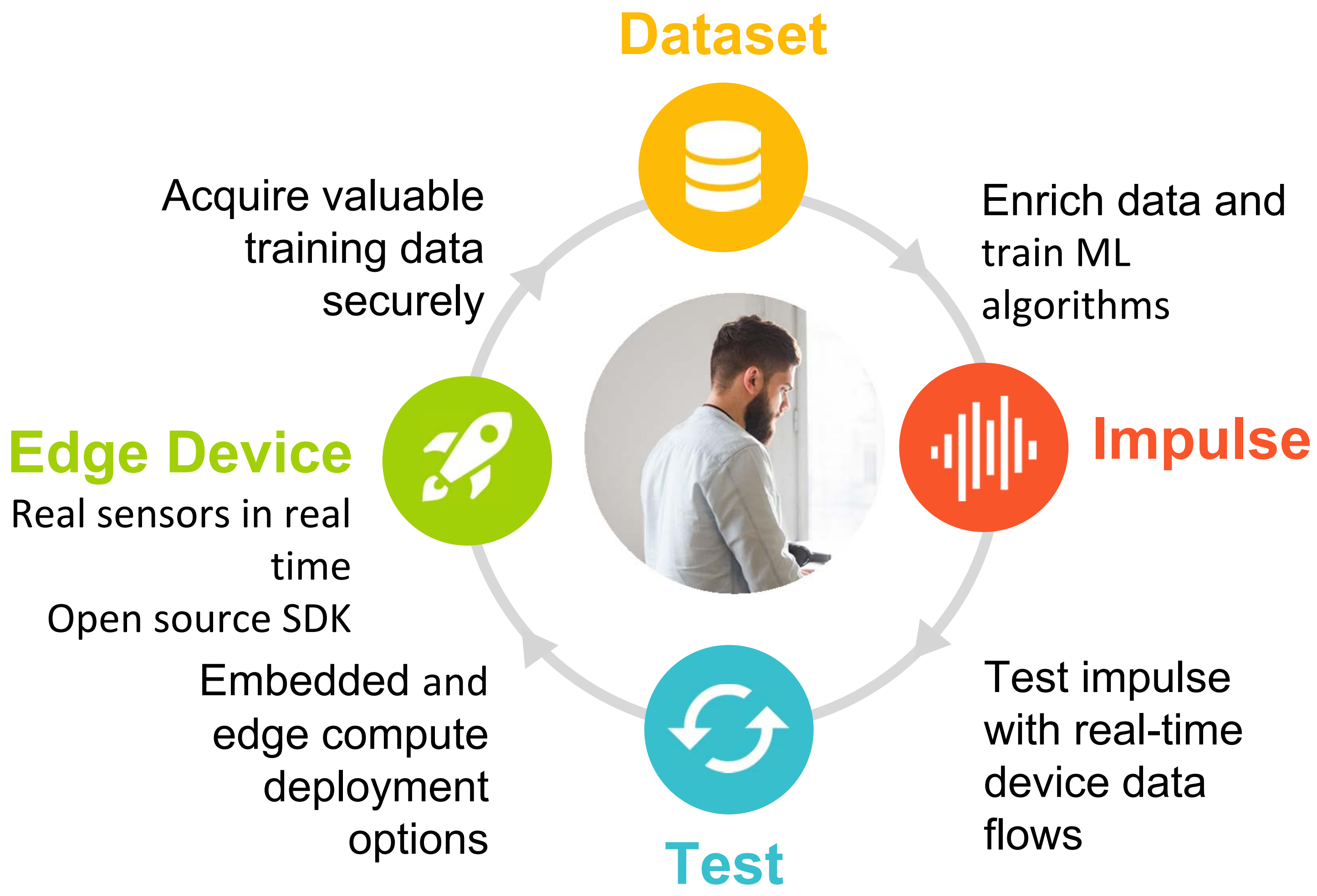
WebAssembly



Dataset

Acquire valuable training data securely

Enrich data and train ML algorithms

Impulse

Test impulse with real-time device data flows

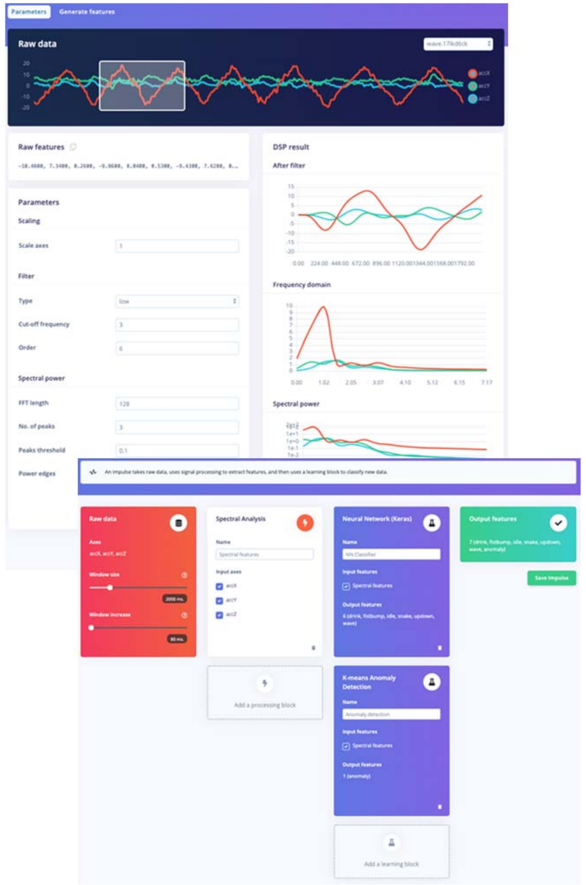
Test

Embedded and edge compute deployment options

Edge Device

Real sensors in real time

Open source SDK



Raw features

-10.4000, 7.3400, 0.2600, -0.0600, 0.0400, 0.5300, -5.4300, 7.6200, 0..

Parameters

Scaling

Scale axes 1

Filter

Type low

Cut-off frequency 3

Order 6

Spectral power

FFT length 128

No. of peaks 3

Peaks threshold 0.1

Power edges

An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

Raw data

Axes

accX, accY, accZ

Window size

2000 ms.

Window increase

80 ms.

Spectral Analysis

Name

Spectral features

Input axes

☑ accX

☑ accY

☑ accZ

Add a processing block

Neural Network (Keras)

Name

NN Classifier

Input features

☑ Spectral features

Output features

6 (drink, fistbump, idle, snake, updown, wave)

K-means Anomaly Detection

Name

Anomaly detection

Input features

☑ Spectral features

Output features

1 (anomaly)

Add a learning block

Output features

7 (drink, fistbump, idle, snake, updown, wave, anomaly)

Save impulse

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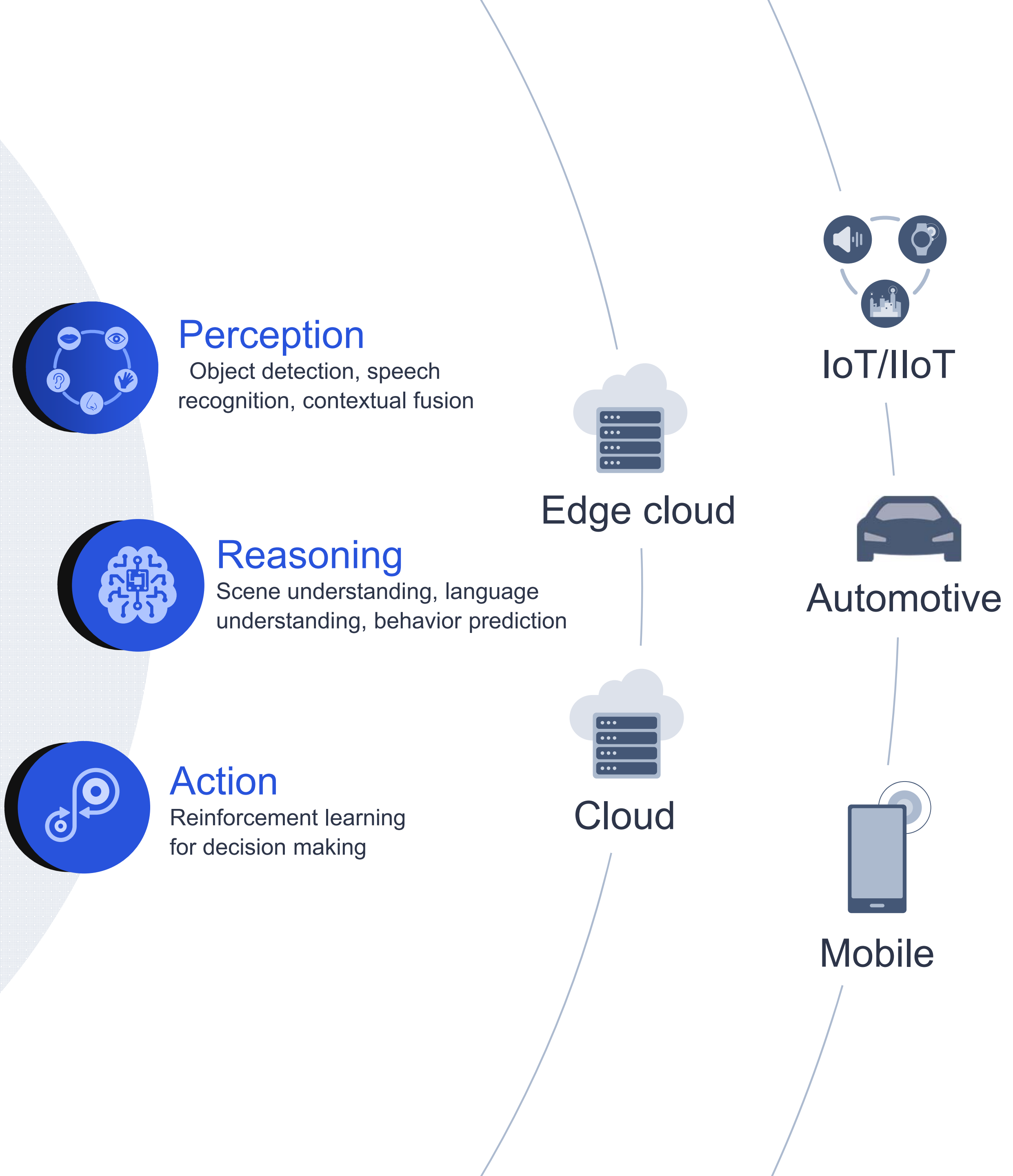

Perception
Object detection, speech recognition, contextual fusion

Reasoning
Scene understanding, language understanding, behavior prediction

Action
Reinforcement learning for decision making

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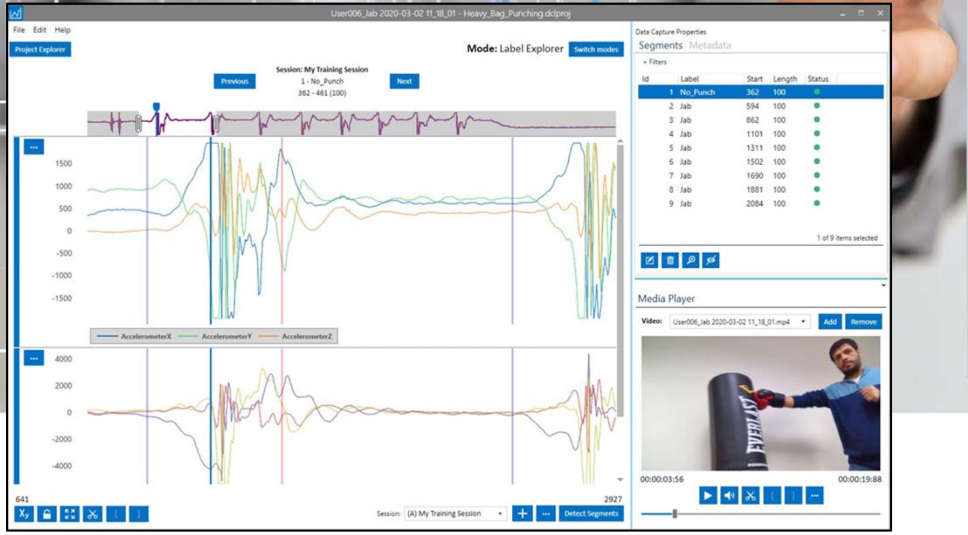

Session: My Training Session
1 - No_Punch
362 - 461 (100)

Session: (A) My Training Session

Id	Label	Start	Length	Status
1	No_Punch	362	100	●
2	Jab	594	100	●
3	Jab	862	100	●
4	Jab	1101	100	●
5	Jab	1311	100	●
6	Jab	1502	100	●
7	Jab	1690	100	●
8	Jab	1881	100	●
9	Jab	2084	100	●

1 of 9 items selected

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