



Enhanced IoT Edge by Smart Sensors

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Shenzhen Dec 2019

Enhanced IoT Edge by Smart Sensors

Driving innovation and cooperation: building sensor solutions

► Overcoming the challenge of **TECHNOLOGY**

- Leverage CORE MEMS- and system know-how
- Size, power, performance, embedded intelligence

► Overcoming the challenge of **FRAGMENTATION**

- Platform solution with hardware and software
- APPLICATION know-how in the Bosch Group
- Application-specific software, e.g. AR/VR/PDR

► Overcoming the challenge of **COMPLEXITY**

- From components to systems and solutions
- Simple design and TURN-KEY solution
- COOPERATION with third parties, reference designs



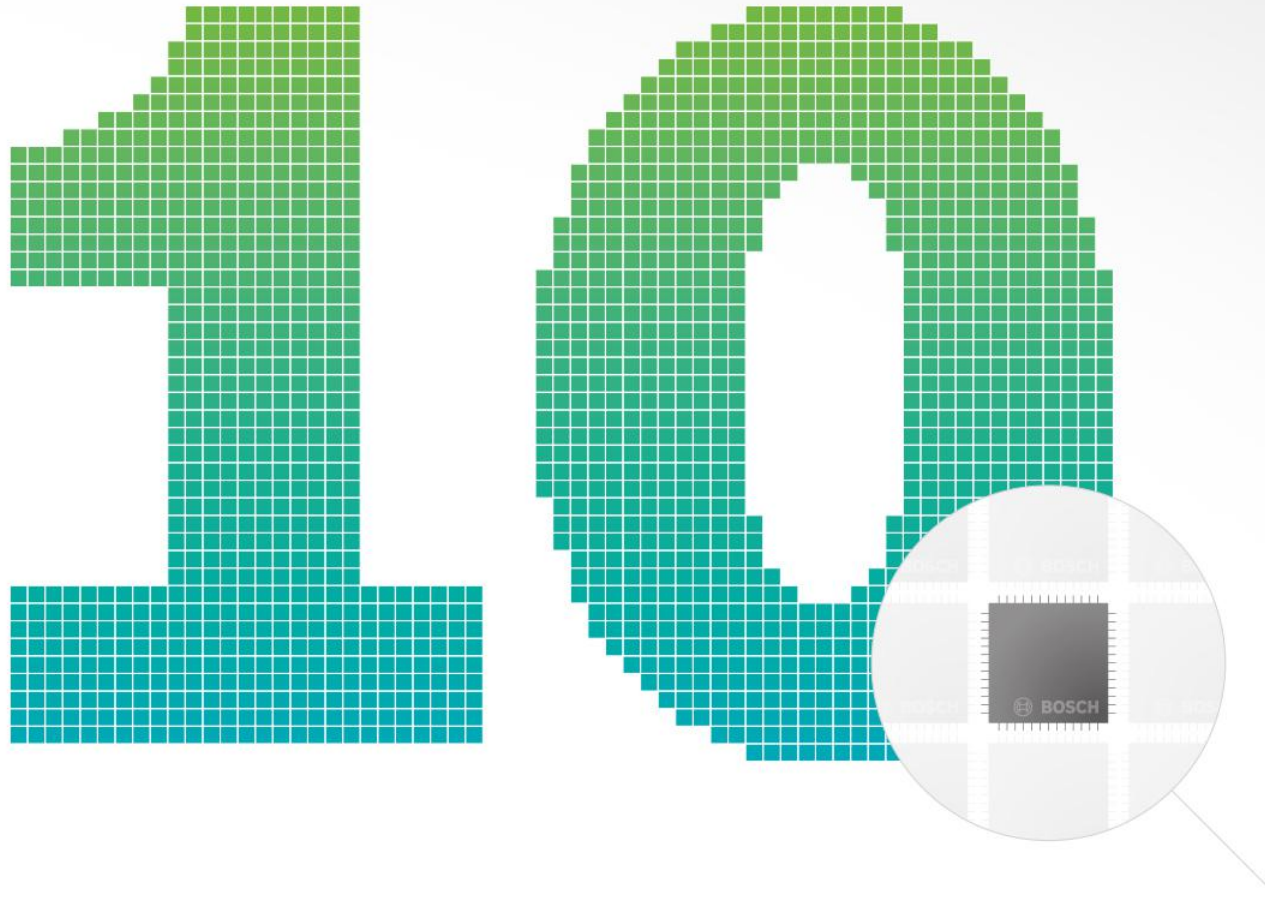
Role of smart sensors

Smart sensors are sensing our world in multiple and complex environments, allow things to be “Simply.Connected.” and act as the enablers of the IoT.



BOSCH

Invented for life



Ten billion
superheroes
in chip format

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Bosch Group: highlights of the 2018 business year

Sales

€77.9bn¹



EBIT from operations

€5.3bn¹

Research and development

69,500

associates worldwide
+5,200



€47bn¹

Mobility Solutions
sales revenue



+37%

52m web-enabled
products sold



Headcount rises to

410,000

+7,800

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Artificial intelligence: core area of expertise for Bosch



4,000

AI experts at Bosch by 2021 –
4x more than in 2018

150

projects in the Bosch Center
for Artificial Intelligence

52m

web-enabled products sold in 2018 +37%



8.5m

sensors and devices
connected over the
internet of things

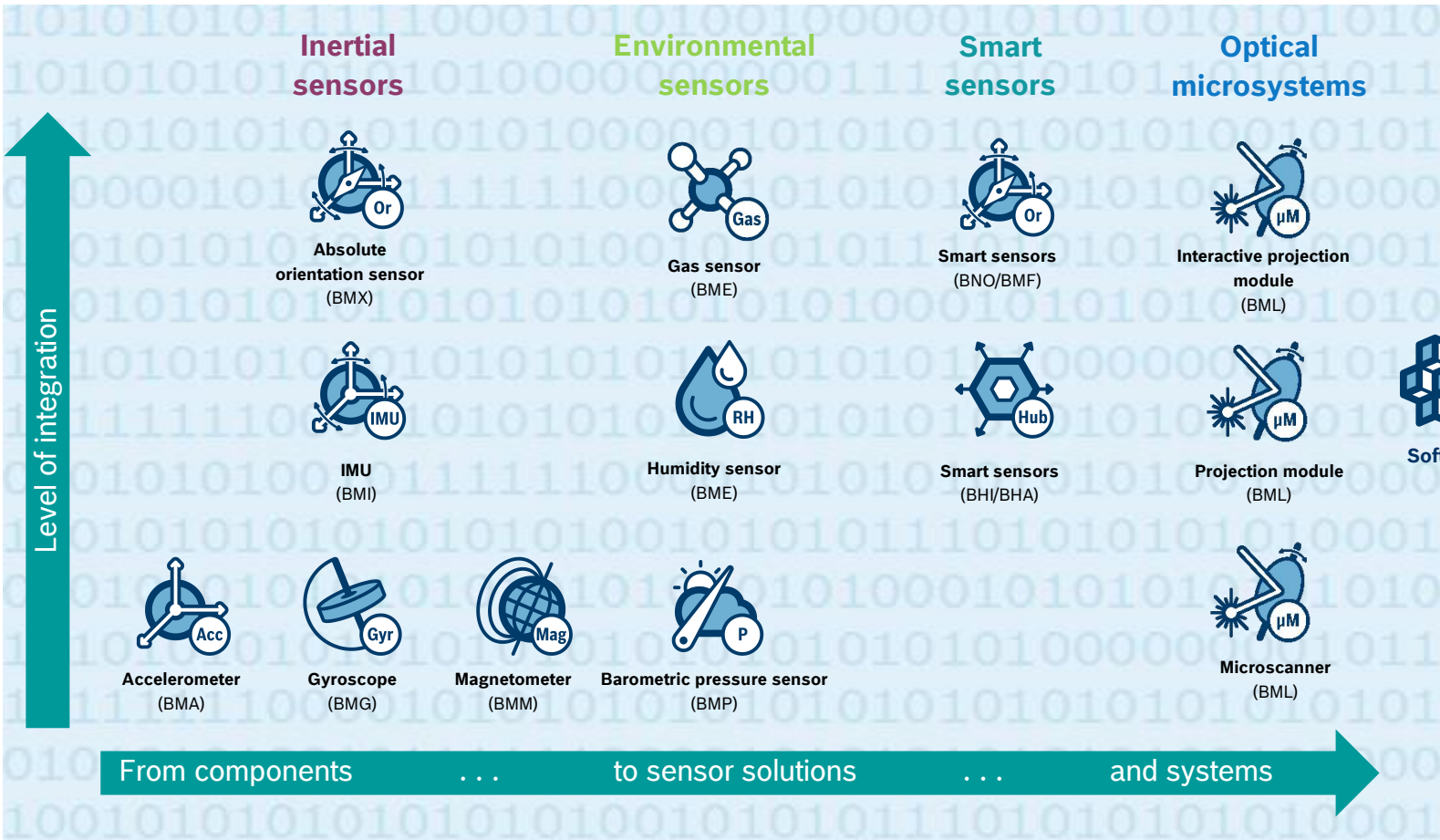
100%

of Bosch products will feature AI
by the middle of the next decade,
or AI will have been used to
develop or manufacture them



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Internet of sensing things



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What do IoT architects expect from sensor providers?

Maximize charging intervals



**Ultra-low power
consumption**

Compact design



**Small package & high level
of integration**

**Automatic adaptation to
individual behavior**



Embedded intelligence

Always-on



**Ultra-low power
consumption**

High accuracy



**Optimized sensor and
algorithm systems**

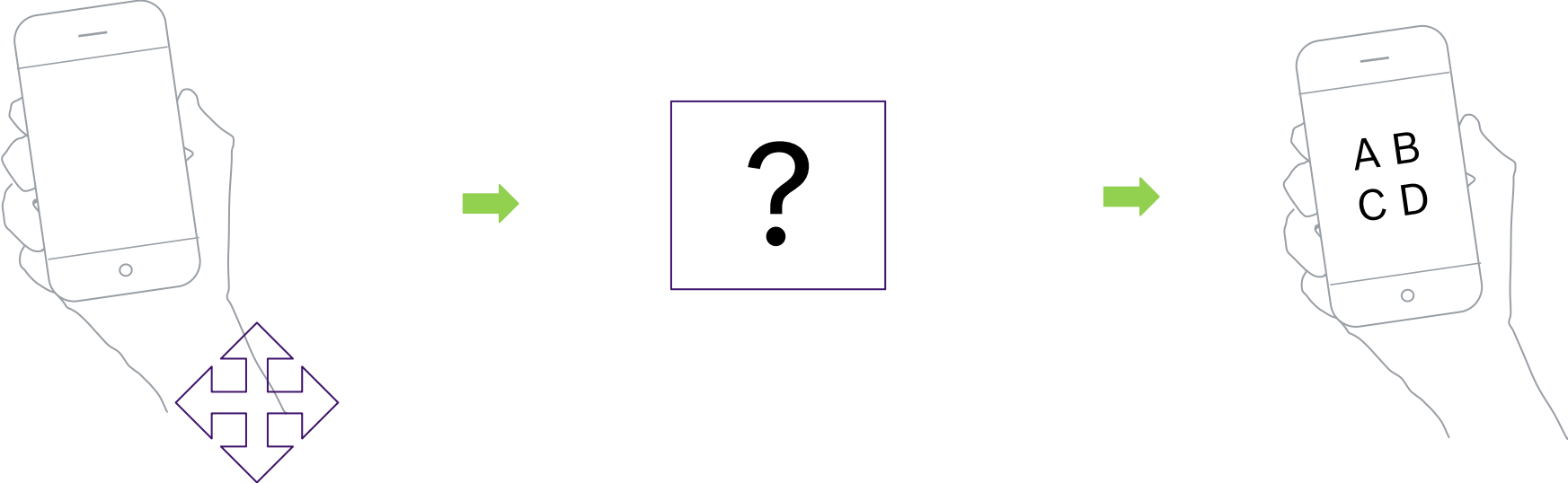
Multi-functionality



**Flexible and broad feature
spectrum**

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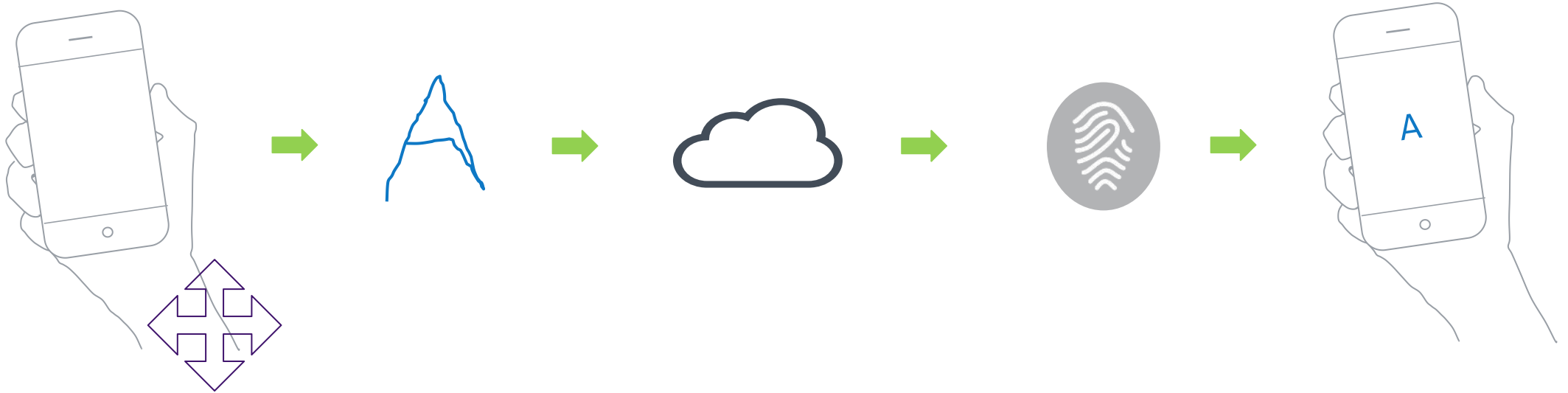
Gesture Recognition: The Challenge



Challenge: develop algorithm to recognize characters from user gesture

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Gesture Recognition: The AI solution

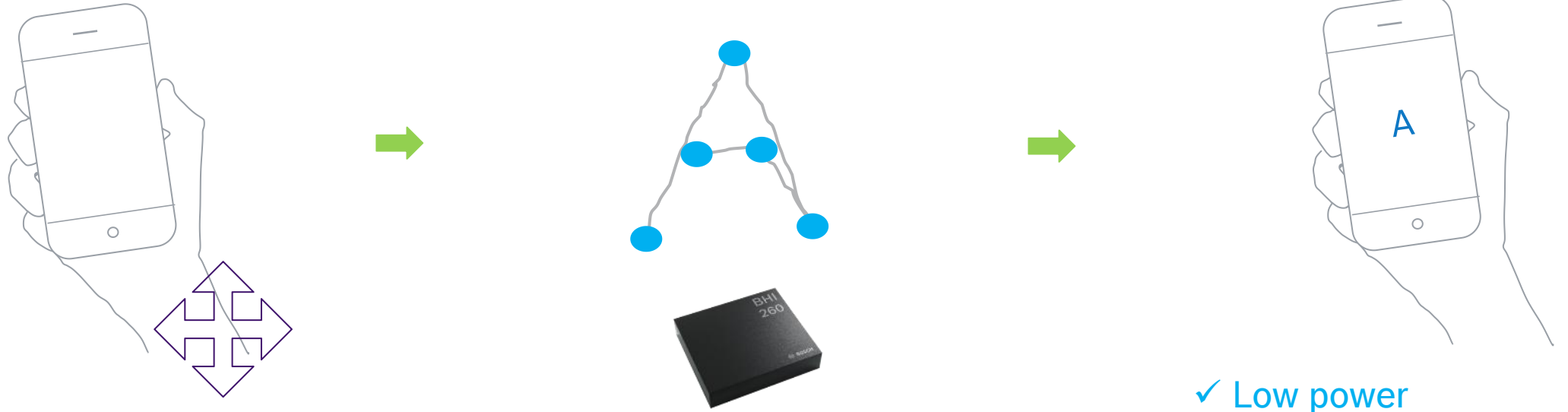


- ✓ High accuracy
- ✓ Adaptable

AI Solution: Generate image -> upload to cloud -> image recognition -> return character

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Gesture Recognition: The Smart Sensor solution

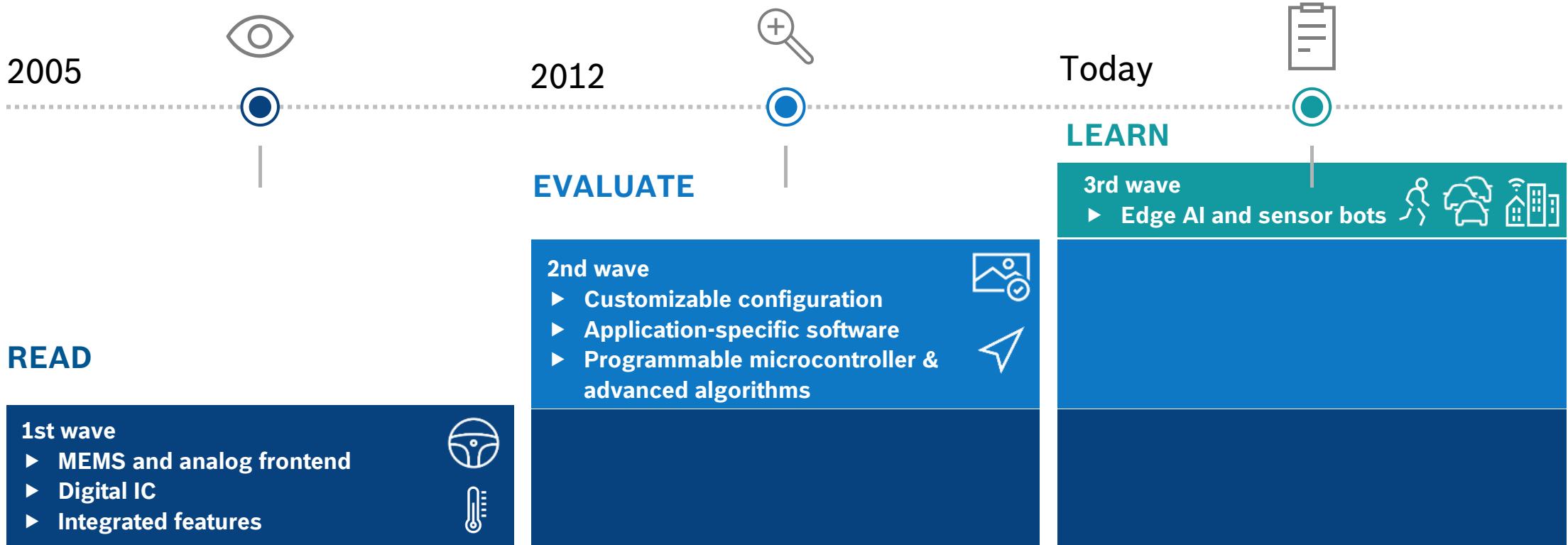


- ✓ Low power
- ✓ Low Latency
- ✓ Low data traffic cost

Smart Sensor Solution: Extract data points from motion -> Return character

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Three waves of software evolution



- ▶ Software adds value not only to the sensor but also to the entire system.
- ▶ Software is becoming increasingly intelligent, enabling AI inside the sensor itself.

THIRD WAVE: EDGE AI

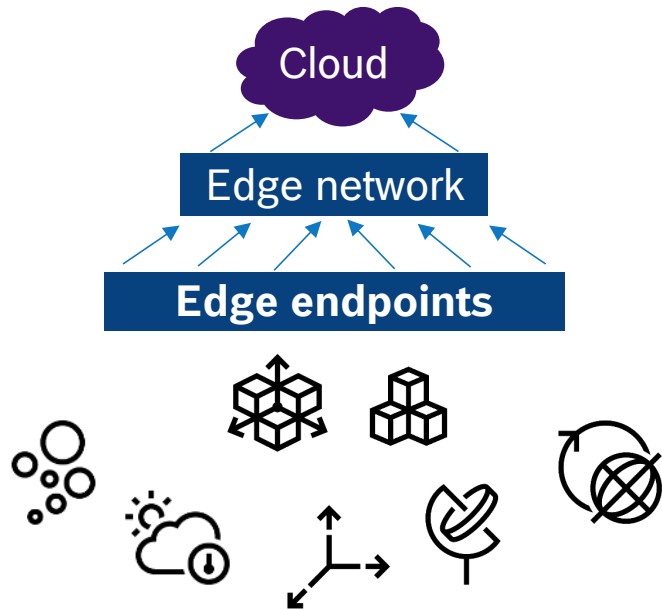
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Definition and benefits of edge AI



What is edge AI?

Edge AI is artificial intelligence inside the MEMS sensor system.



What are the benefits of edge AI?

User benefits

Benefits of edge AI

Personalization

More accurate data adapted to user due to accumulating data of individual user only

Privacy of user data

Data is kept private due to edge data processing without cloud involvement

Real time feedback

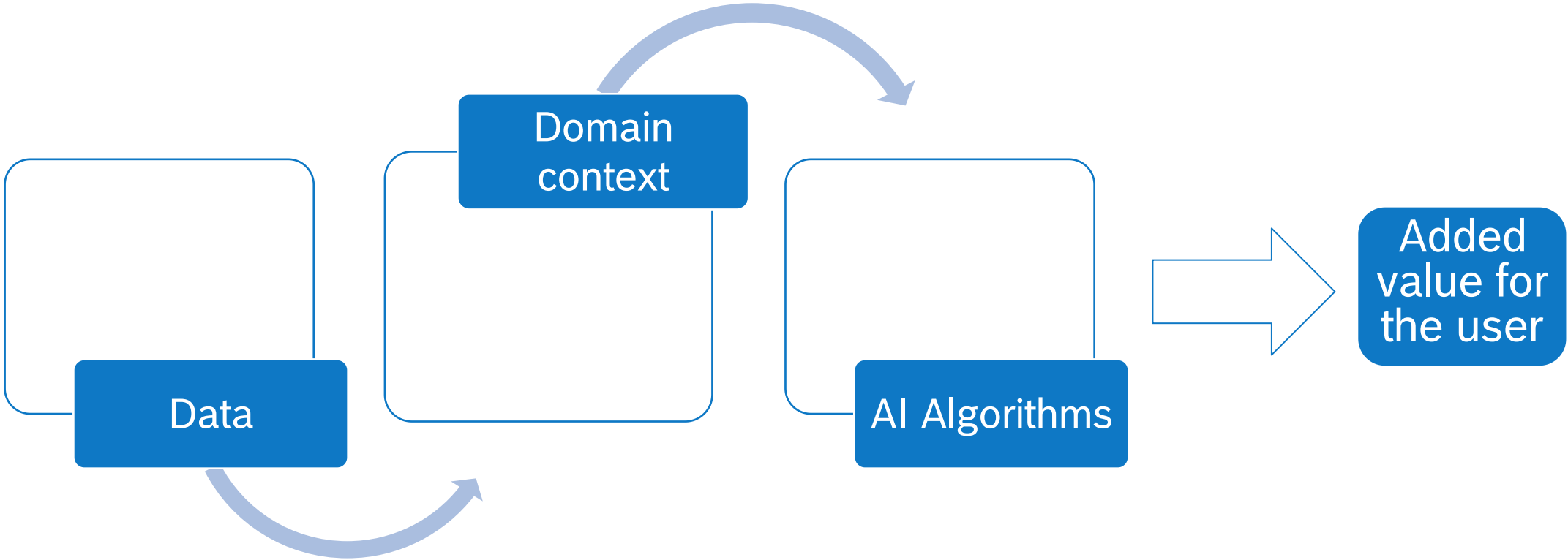
Low latency due to avoidance of data transfer

Improved battery life

Lower power consumption due to occasional connectivity & data transfers

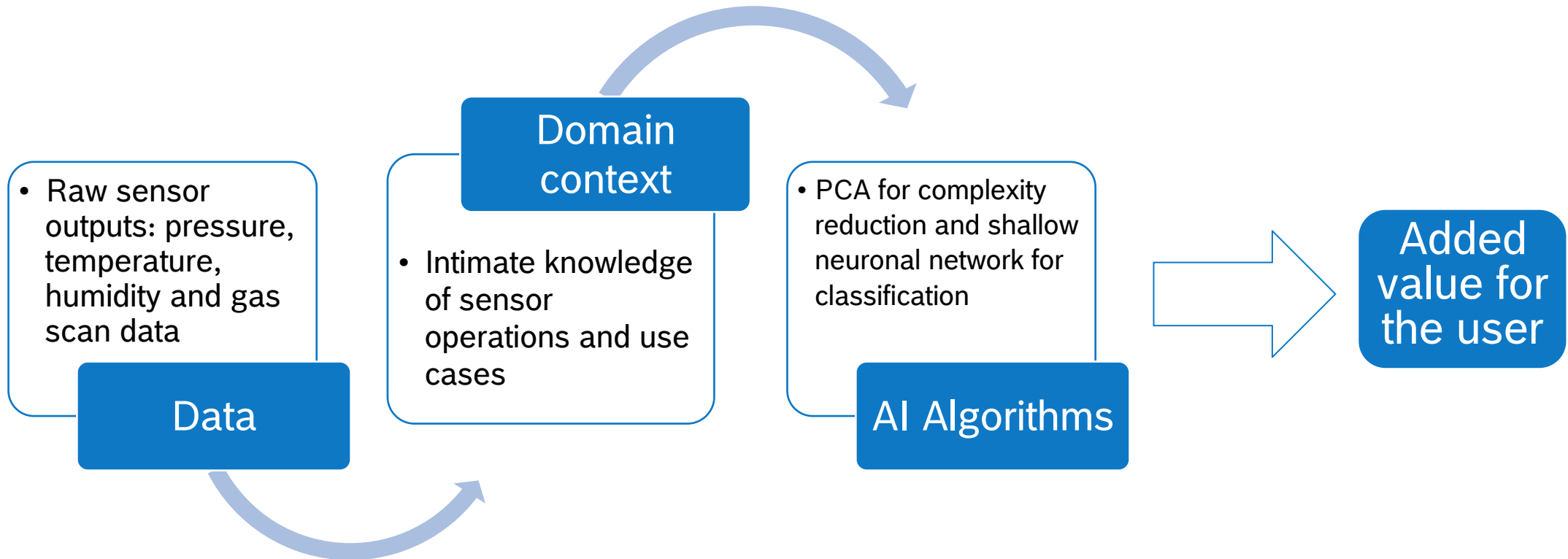
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Critical success factors



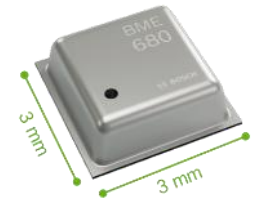
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Critical success factors – example gas sensor

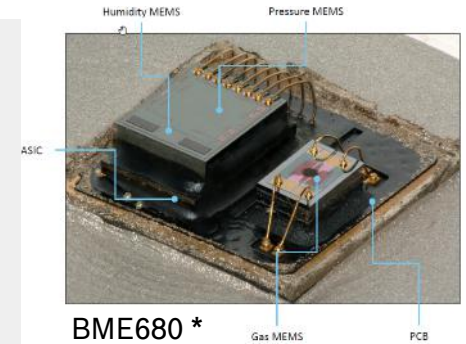
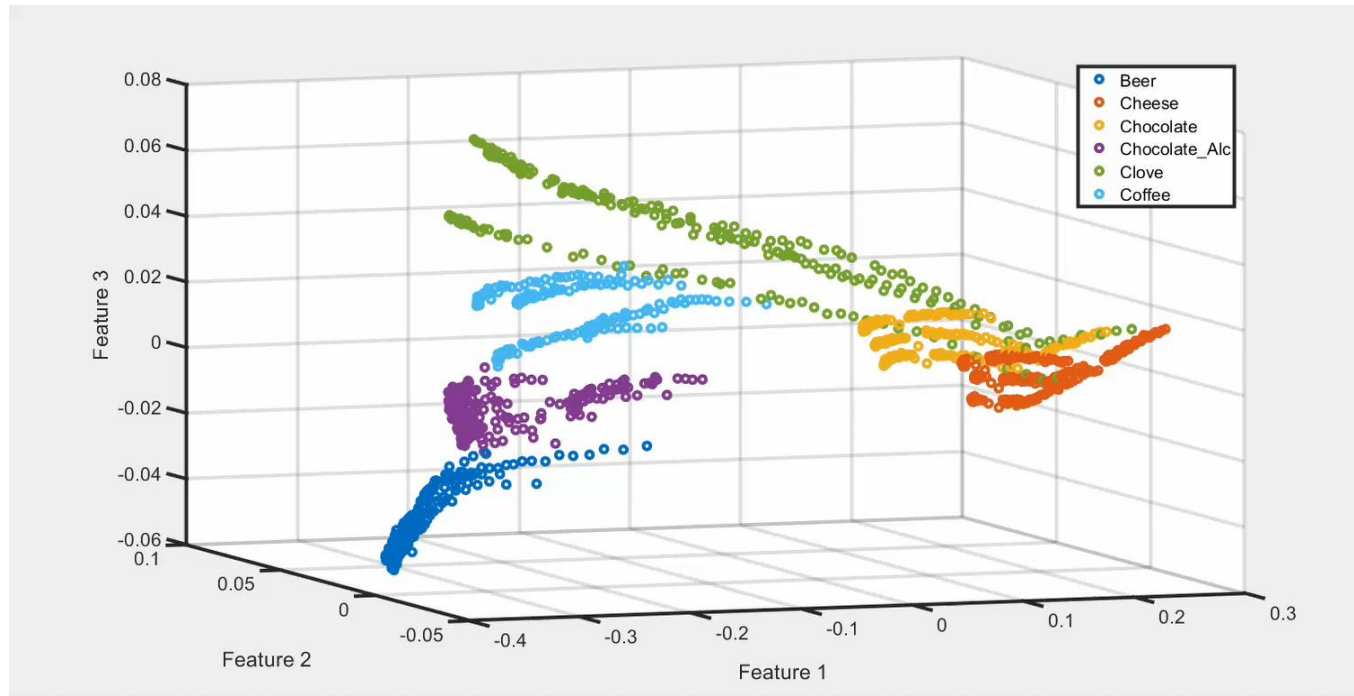


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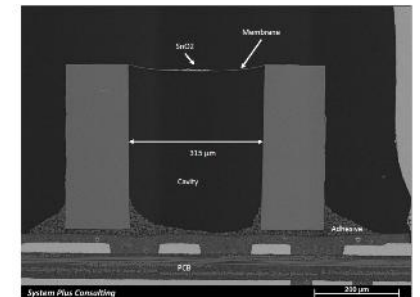
Example: environmental sensing with BME680



By temperature-cycled operation of the BME680's gas MEMS, different gas mixtures can be recognized and classified.



BME680 *



Cross-section of gas MEMS *

Environmental MEMS sensors and AI-based software enable new solutions.

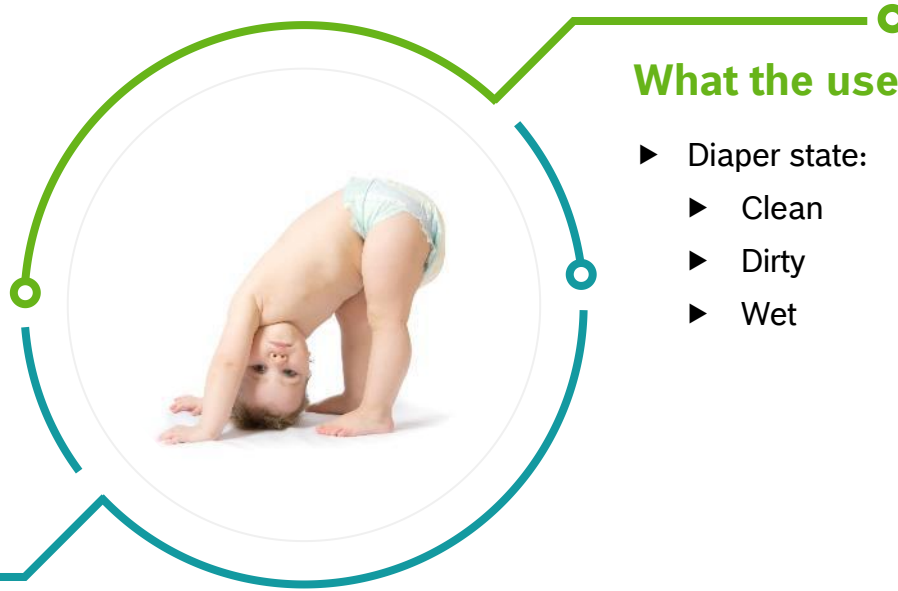
* Source: Bosch BME680 Environmental Sensor, MEMS report by A. Lahrach, System Plus Consulting, July 2017

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AI can bridge the gap between sensor data and user's needs

What environmental sensor hardware in a diaper delivers

- ▶ Raw temperature
- ▶ Raw pressure
- ▶ Raw humidity
- ▶ Raw gas sensor signals



What the user wants

- ▶ Diaper state:
 - ▶ Clean
 - ▶ Dirty
 - ▶ Wet

Solution

1. **By machine learning:** mathematical model based on sensor raw data predicts 3 possible states: clean, dirty, wet
2. **By edge AI:** final device fine-tunes the model to the individual user

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AI can bridge the gap between sensor data and user's needs

What small sensor nodes can provide

- ▶ Temperature, pressure, humidity, air flow,...
- ▶ Gas sensor signals (from air quality up to smell patterns)
- ▶ Present devices (people!)



What the user wants

- ▶ Forest climate model
- ▶ Risk evaluation
- ▶ Early fire detection

Solution

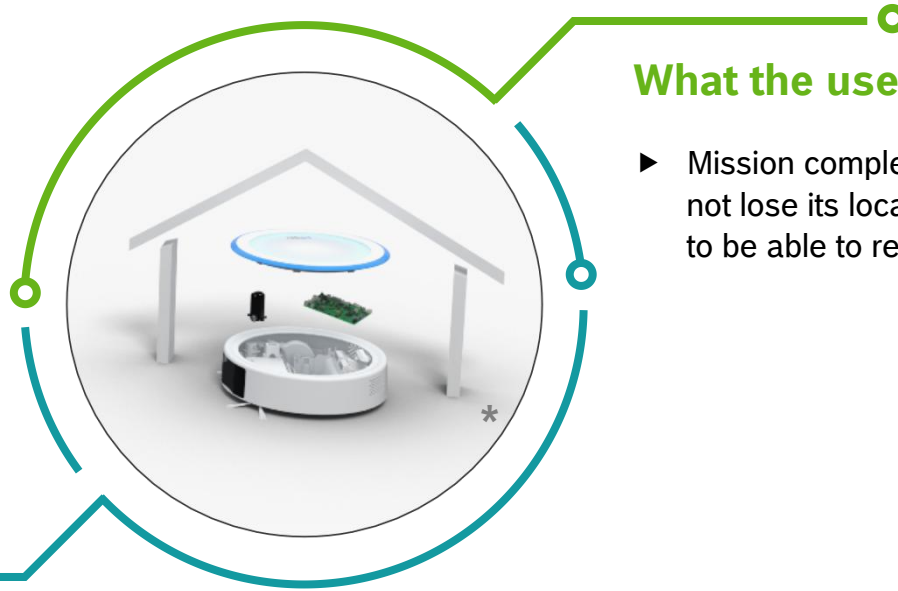
1. **By sensor network:** climate map for whole area w/ life view of activities
2. **By machine learning:** a model which classifies different situations and rates risks
3. **By edge AI:** adaptation on area-specific conditions and low-power solution

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Example: Robart's solution using an IMU

What the sensor delivers in a cleaning robot

- ▶ Wheel speed
- ▶ 6D inertial measurements



What the user wants

- ▶ Mission completion - robot must not lose its location within the map to be able to return to home base

Solution

1. Monitor wheel speed vs. inertial measurements
2. **Machine learning:** detect discrepancy patterns as traction loss on tough obstacles
3. **Edge AI:** Learn location of „dangerous zones“ and avoid them in future

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Example: Robart's solution using an IMU

What the sensor delivers in a cleaning robot

- ▶ Wheel speed
- ▶ 6D inertial measurements
- ▶ „Local“ low-cost Lidar (< 5 m)



What the user wants

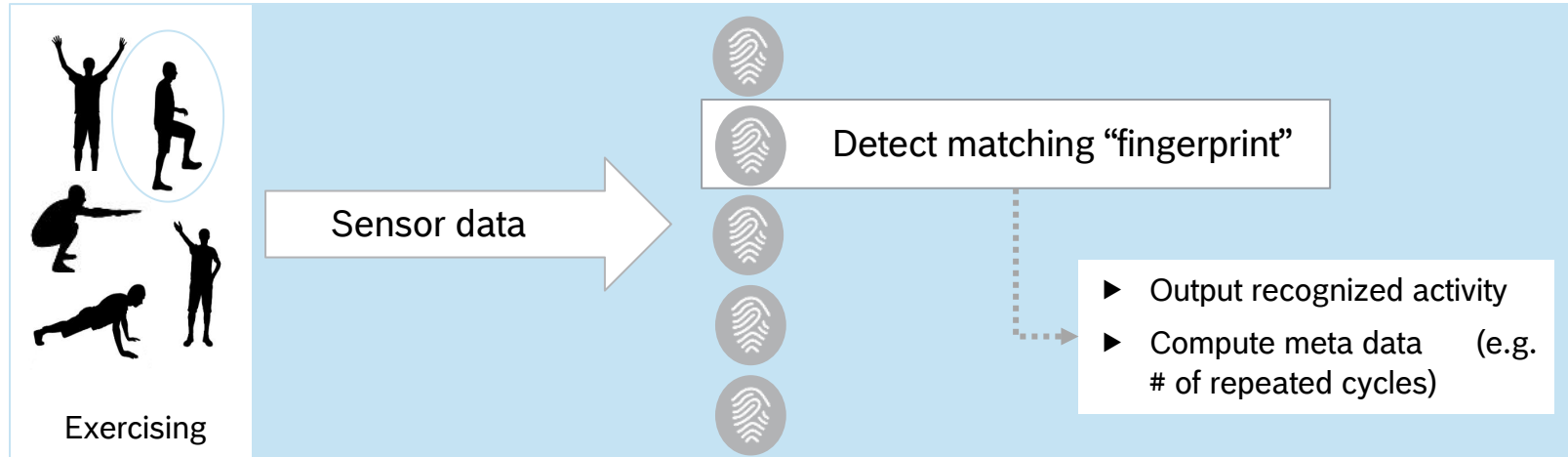
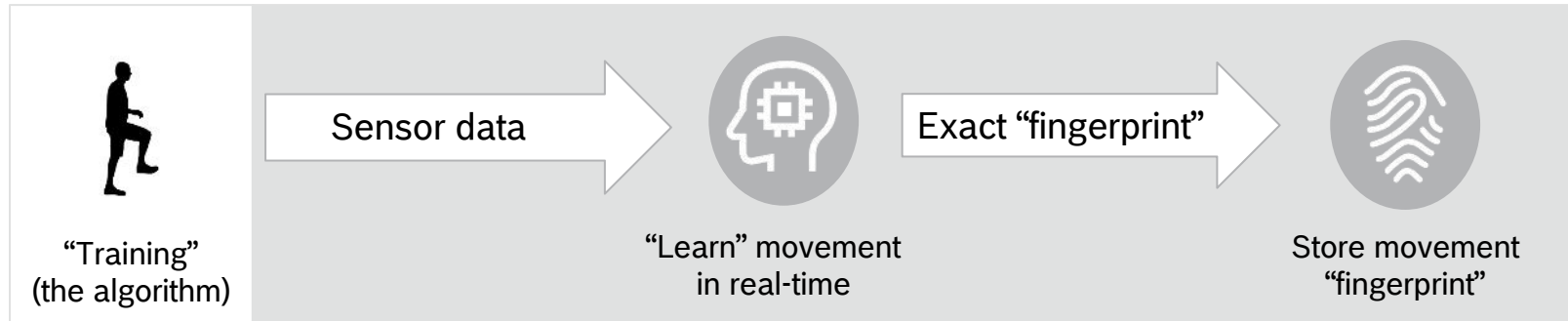
- ▶ Easy interaction based on maps or voice commands

Solution

1. Learn the users home using LSLAM (logical input SLAM)
2. Edge AI: interpret floor-plan and adapt to individual user's home

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Real-time learning on the edge for adaptation to individual user



What's next?

... less **A**rtificial, more **I**ntelligent ...

THANK YOU!



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