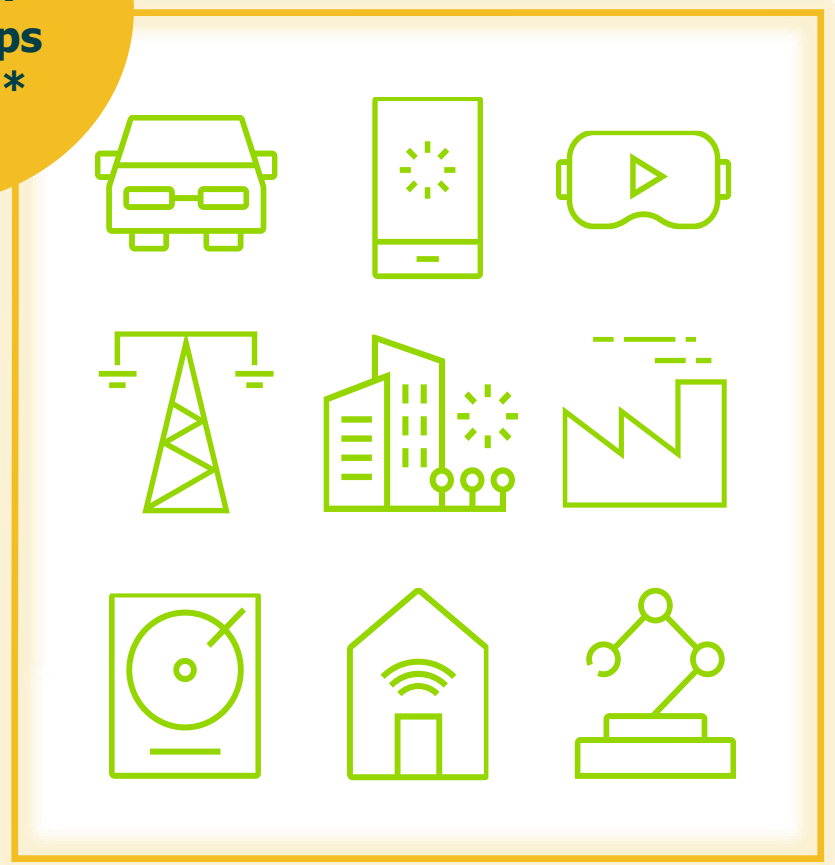
Arm Cortex-M Series Processors Spark a New Era of Use Cases, Enabling Low-Cost, Low-Power Computer Vision and Machine Learning

Stephen Su
Senior Product Manager
Arm Inc.

High Level Overview of Microcontrollers

- Arm Cortex-M processor family is designed and optimized for microcontrollers in cost-sensitive and energy-efficient devices
- Address wide range of markets leveraging ease-of-use of Cortex-M, such as internet of things, industrial and consumer electronics
- Expanding always-on, battery powered, computer vision and machine learning use cases

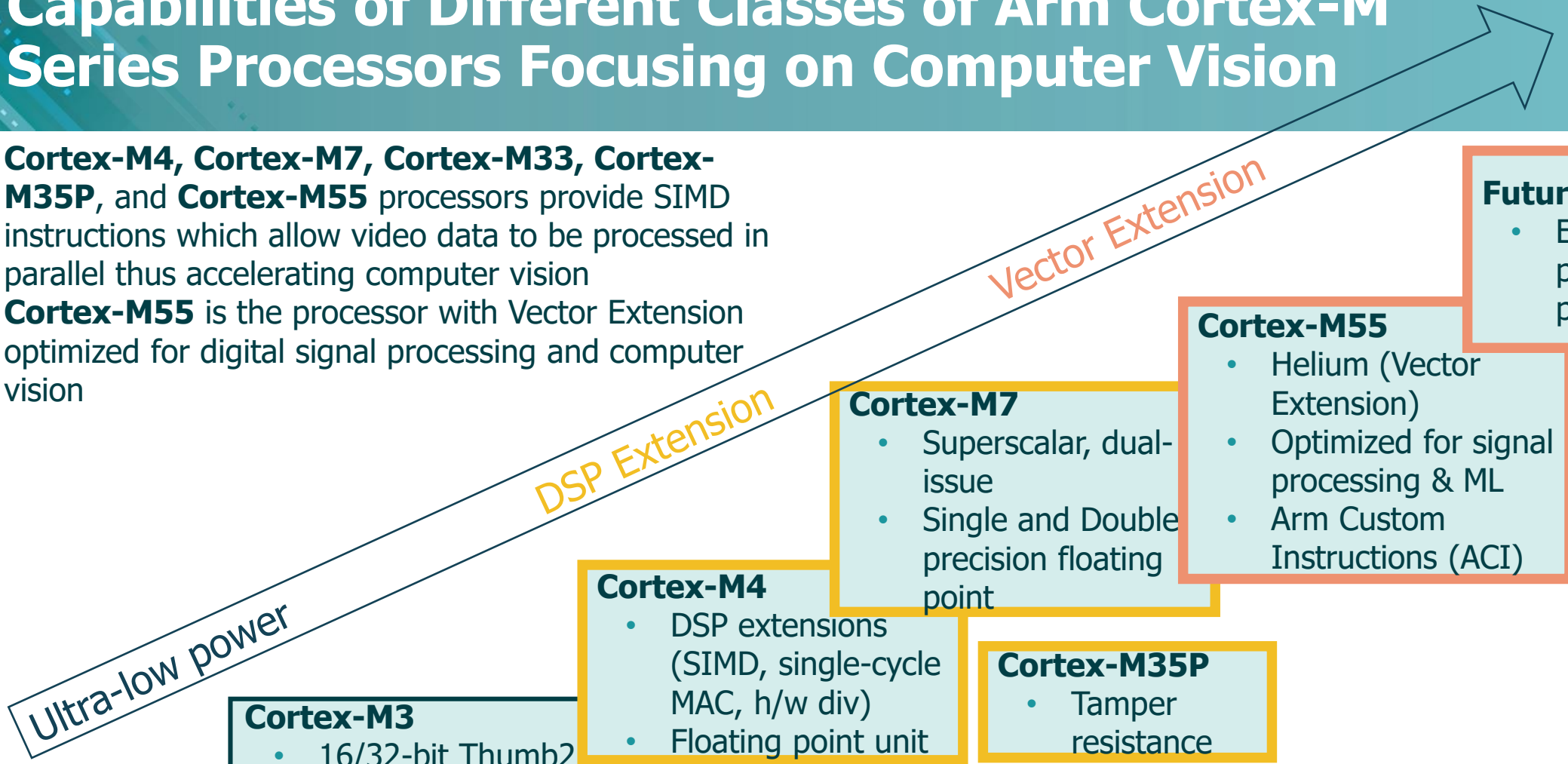
+52 billion Cortex-M based chips shipped**



**Based on Arm data

Capabilities of Different Classes of Arm Cortex-M Series Processors Focusing on Computer Vision

- **Cortex-M4, Cortex-M7, Cortex-M33, Cortex-M35P**, and **Cortex-M55** processors provide SIMD instructions which allow video data to be processed in parallel thus accelerating computer vision
- **Cortex-M55** is the processor with Vector Extension optimized for digital signal processing and computer vision



Cortex-M55 Expediting Computer Vision with Vector Extension

- Cortex-M55 features the new Armv8.1-M architecture, the "M-profile Vector Extension (MVE), also known as Helium technology, with SIMD 128-bit vector processing
- The key algorithms for signal processing to unlock computer vision are:
  - Multiply-accumulate (with various data types)
  - Fast Fourier Transform, and its inverse
  - Neural-Networks (NN) which are convolution based on small integer arithmetic
- And the Cortex-M55 with Vector Extension **is optimized for computer vision algorithms** with performance boost from 3x to 15x*

*The performance boost was estimated by Arm

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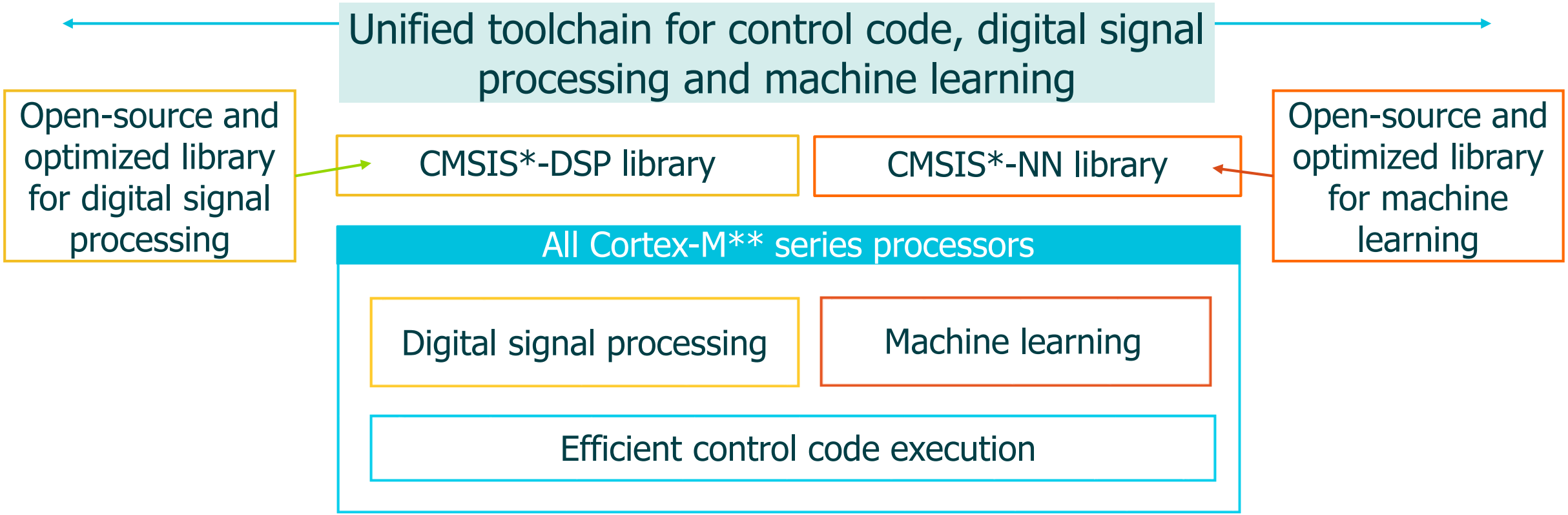
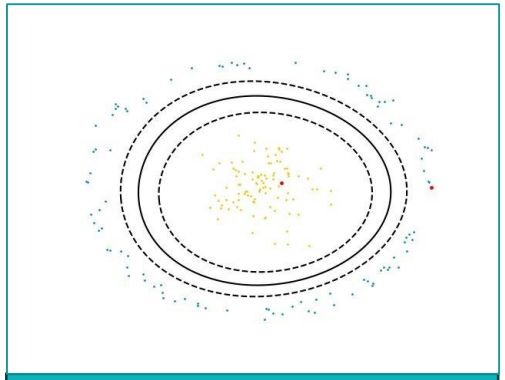
Software Library on Cortex-M



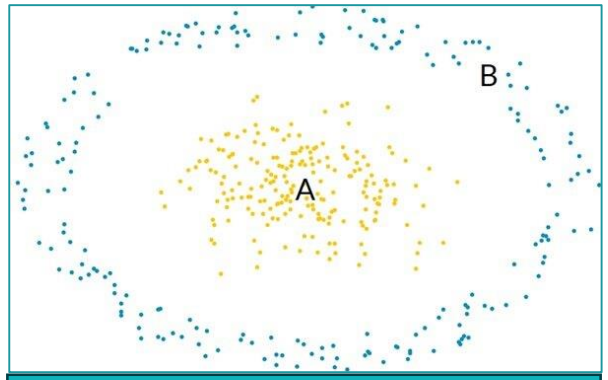
*CMSIS: Common Microcontroller Software Interface Standard, which is open-source and collaboratively developed on GitHub
**Implementations optimized for the SIMD instruction set are available for Cortex-M4/M7/M33/M35P and M55

Unlock Computer Vision in Edge Device with CMSIS-DSP

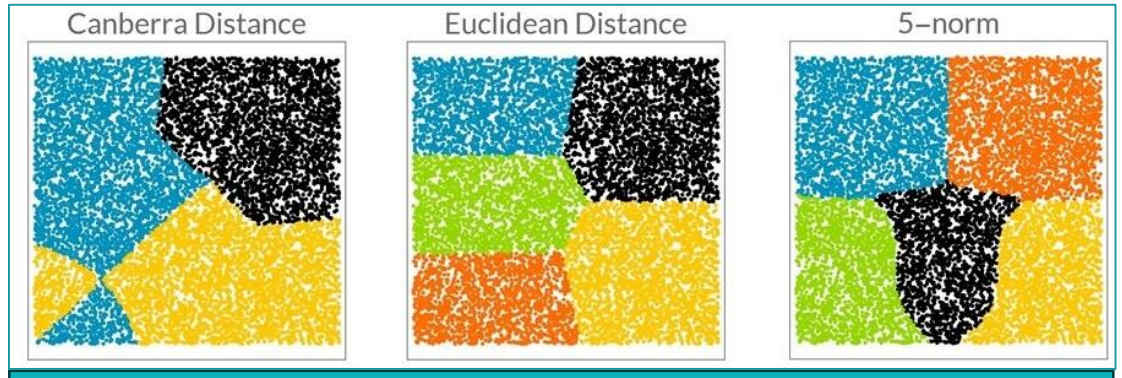
- CMSIS-DSP is an open-source library of DSP algorithms for basic math, filtering, matrix operations, transforms, and other operations optimized for Cortex-M devices
- Example source code available for kick starting development of new computer vision applications on Cortex-M series processors, such as ->



Support Vector Machine (SVM)

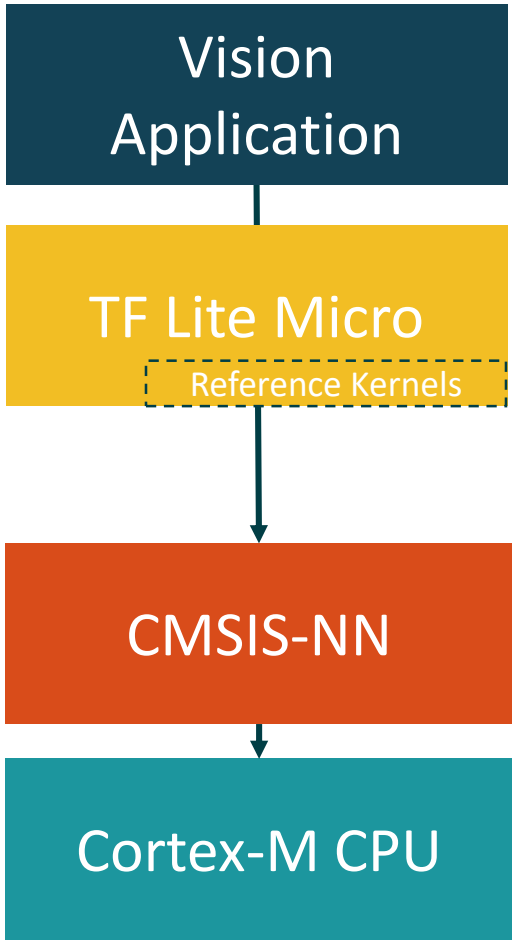


Bayesian estimator



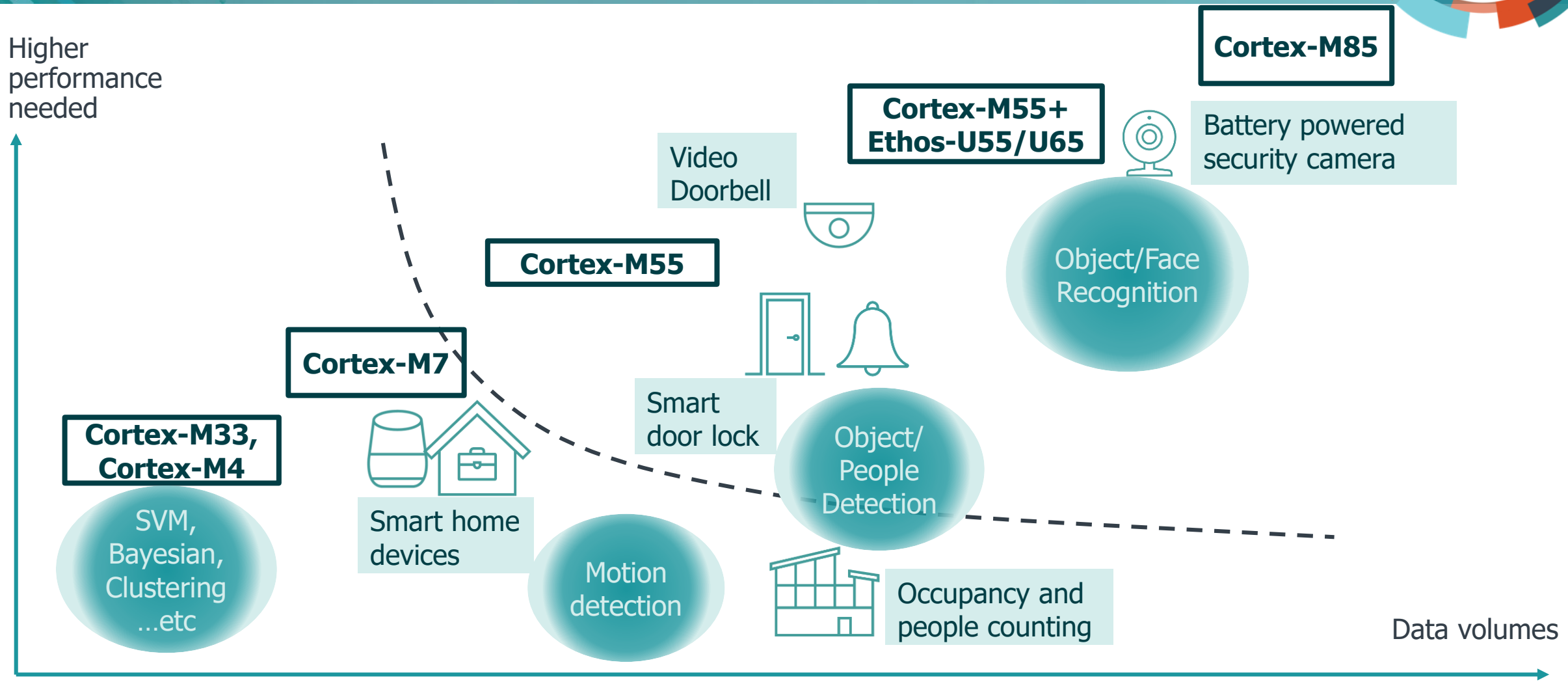
Clustering and other Miscellaneous functions

Enabling Machine Learning on Cortex-M thru CMSIS-NN



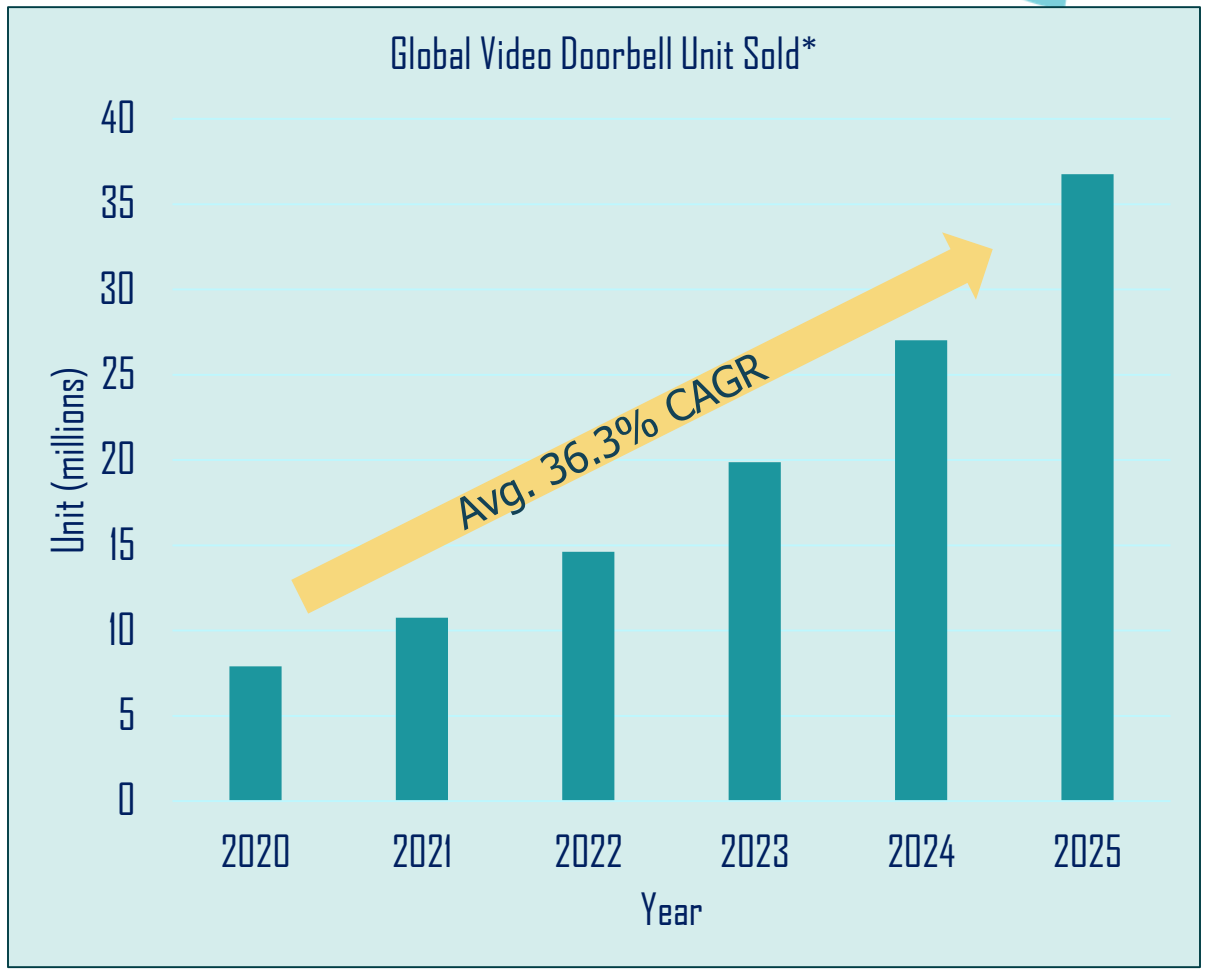
- CMSIS-NN is a software layer between machine learning framework and Cortex-M CPU that provides an optimized kernel library, to enable machine learning neural networks running on Arm Cortex-M
- CMSIS-NN provides efficient implementations of neural network kernels developed to maximize performance and minimize memory footprint
- CMSIS-NN functions can be called from TF Lite Micro or bare metal implementations
- CMSIS-NN is open-source, via Apache 2.0 license (https://arm-software.github.io/CMSIS_5/NN/html/index.html)

How Arm Continues to Invest in Embracing Computer Vision Along with Machine Learning



Market Opportunities for Microcontroller Products with Computer Vision

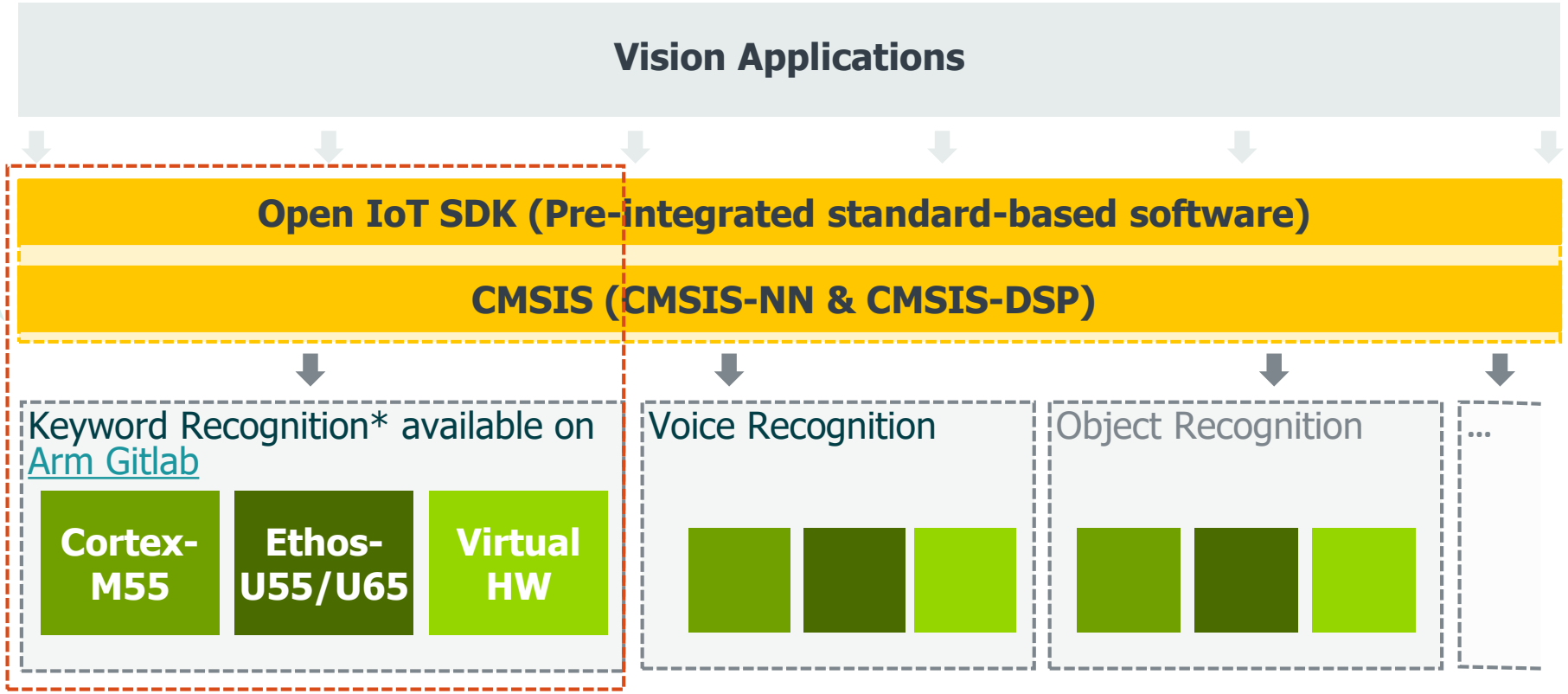
- Video doorbell is a representative product segment which continues to grow rapidly and can take advantage of running computer vision and machine learning locally on the microcontroller
- **Cortex-M product family** can satisfy all these requirements thus creating huge market opportunity for Arm's partners and customers



*: Forecasted by "Strategy Analytics".
Units sold annually, estimate to grow from 7.9 million to 36.9 million through 2025. Average 36.3% CAGR from 2020 to 2025

Arm Total Solutions Enable Computer Vision and Machine Learning with Hardware, Software and Example Applications

Arm Total Solutions, provide everything needed including the advanced tool, Arm Virtual Hardware



*: An example Arm have made available for developers. Not represent the limit on the performance of Cortex-M55+EthosU55/U65

Summary

- Arm Cortex-M series processors with its **DSP and vector extensions**, are ideally suited for computer vision applications at the edge
- Arm continues to invest in **open-source software** through CMSIS-DSP and CMSIS-NN libraries
- Beyond classical computer vision, Arm Cortex-M product family can also run **machine learning algorithms**
- **Arm Total Solutions for IoT** provides a foundation hardware platform along with standards-based reference software

Resources

DSP capabilities of Cortex-M4 and Cortex-M7

https://community.arm.com/arm-community-blogs/b/architectures-and-processors-blog/posts/white-paper-dsp-capabilities-of-cortex-m4-and-cortex-m7?pi353792392=194

CMSIS-NN & CMSIS-DSP

https://arm-software.github.io/CMSIS_5/DSP/html/index.html

https://arm-software.github.io/CMSIS_5/NN/html/index.html

Arm Total Solution

https://www.arm.com/solutions/iot/total-solutions-iot

2022 Embedded Vision Summit

Additional Demos at the Summit:

- "Cloud-native software stack deployment on SystemReady-IR"
- "New generation Arm Mali image signal processor brings advanced imaging to intelligent IoT devices"
- "Machine learning on Arm, showcasing face recognition on DTV and applying PyTorch Mobile with NNAPI on mobile devices"