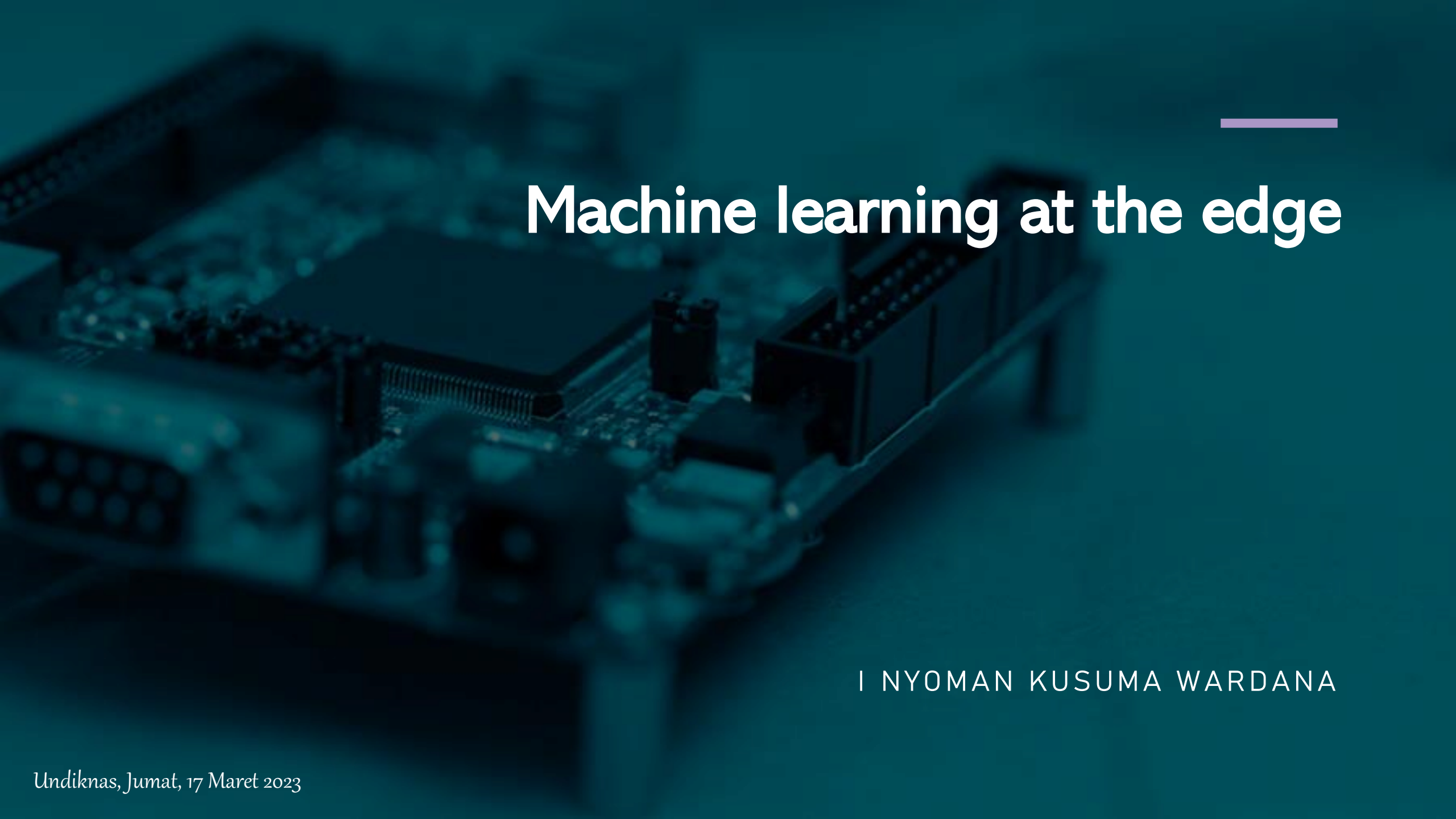
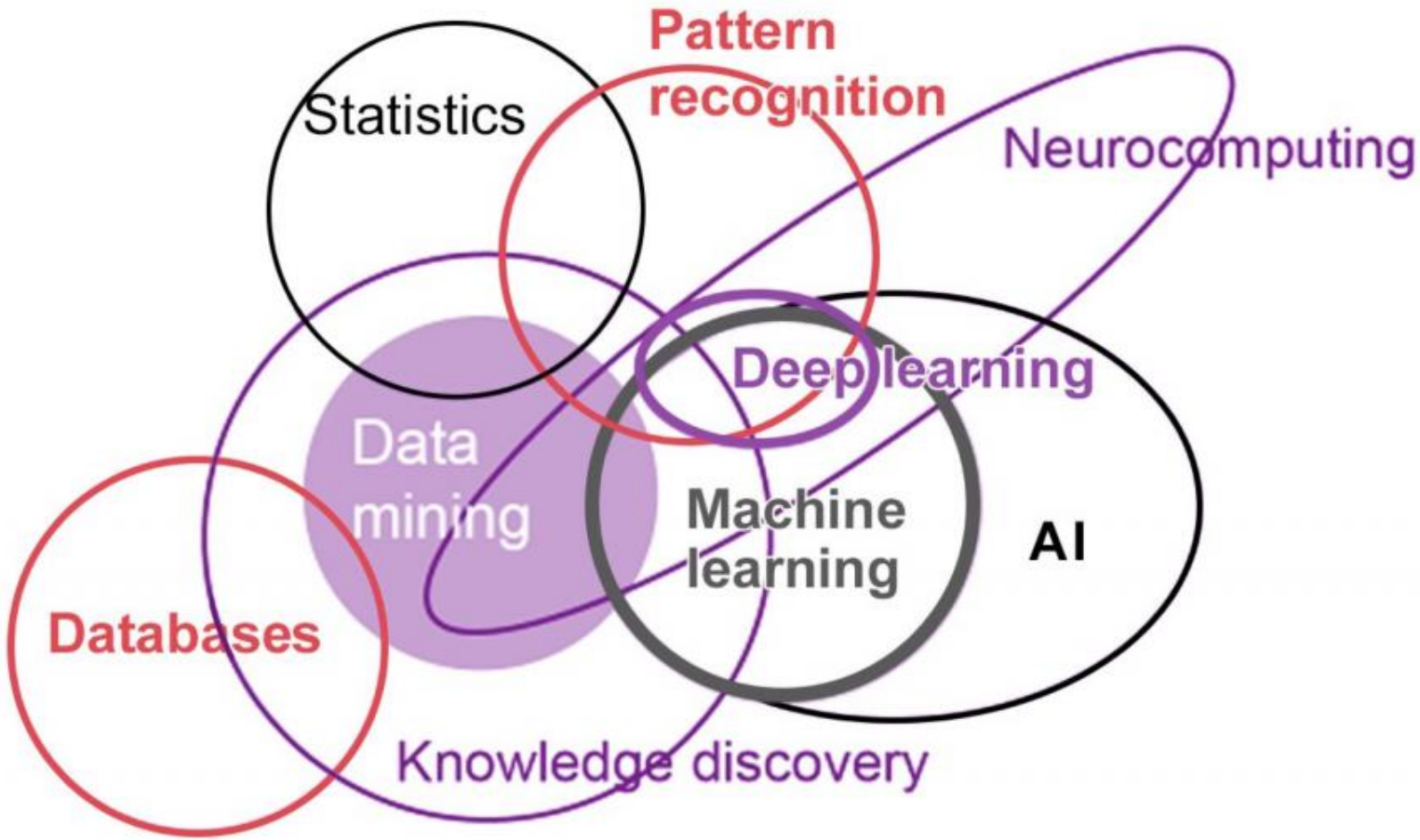


Machine learning at the edge

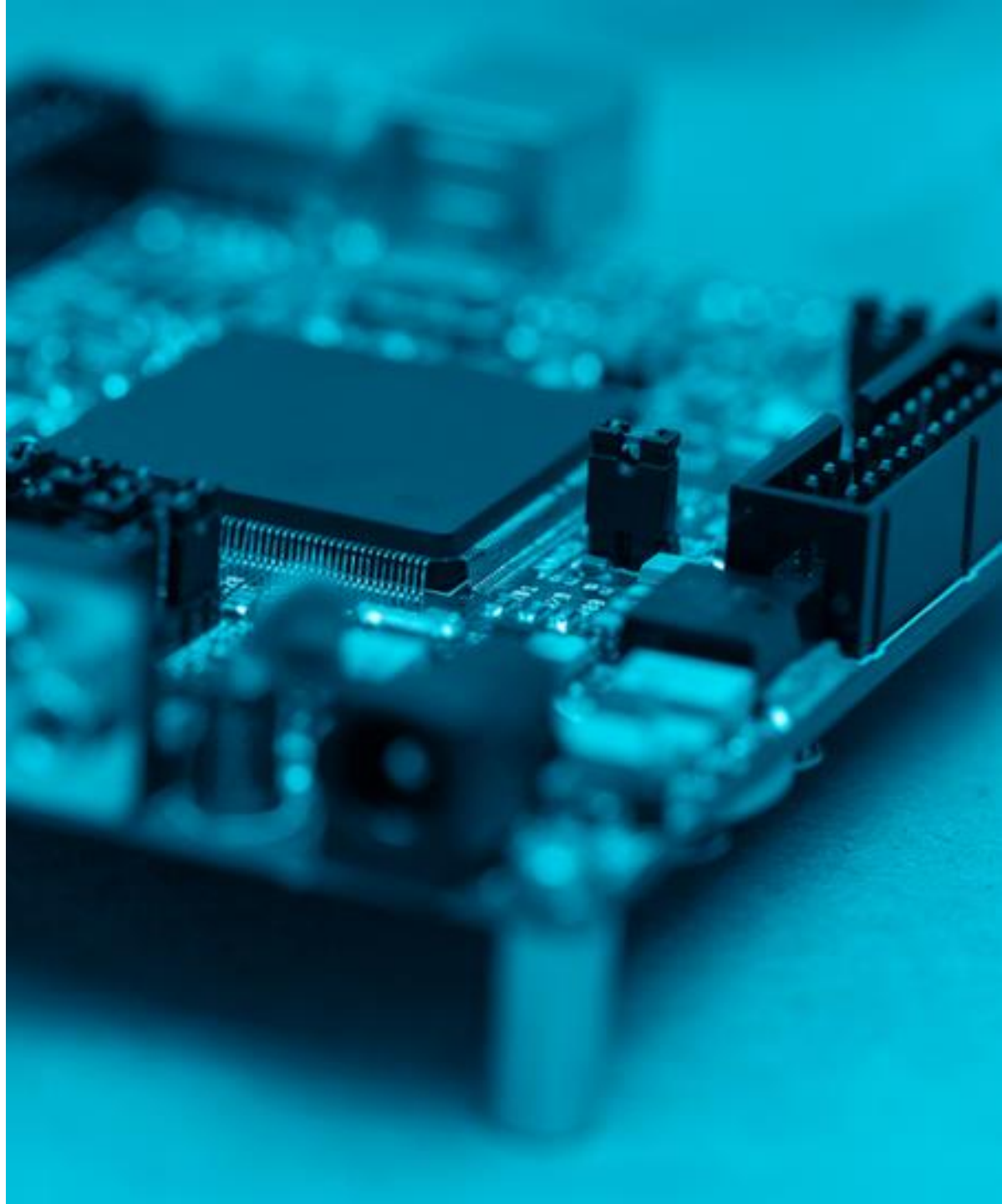
I NYOMAN KUSUMA WARDANA

Undiknas, Jumat, 17 Maret 2023



***Referensi**:*
https://jaylatta.net/history-of-ai-from-winter-to-winter/

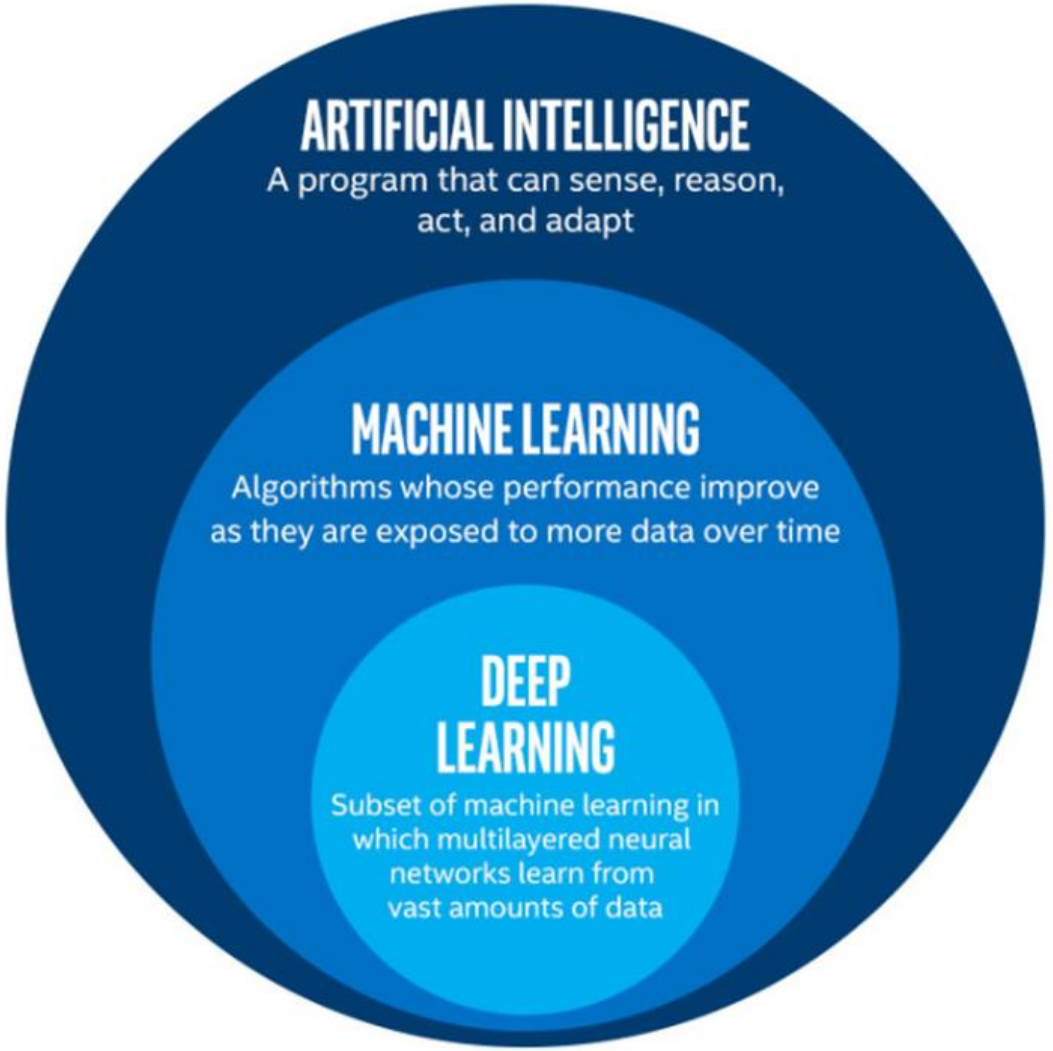
Perkenalkan saya dengan beberapa terminologi terkait ML ...



Machine learning adalah bagian dr artificial intelligence (AI) yang secara umum didefinisikan sebagai kemampuan mesin untuk meniru perilaku mansusia.

Machine learning adalah salah satu cara untuk mewujudkan AI. Istilah ML dipopulerkan oleh **Arthur Samuel** pada akhir tahun 1950-an, yg mendefinisikan ML sebagai "bidang studi yang memberi komputer kemampuan untuk belajar tanpa diprogram secara eksplisit"

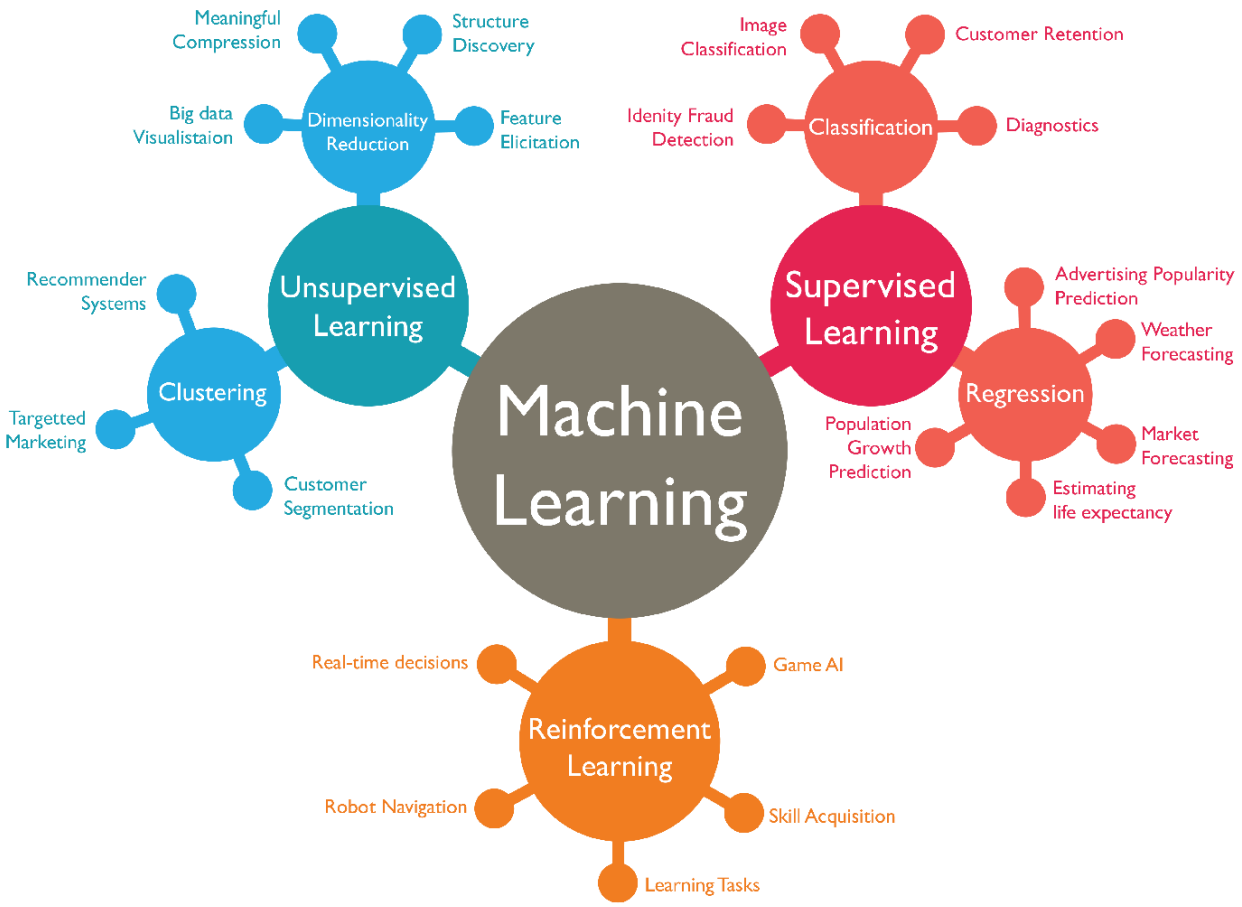
Machine learning dari **data** — angka, gambar, teks, dsb.



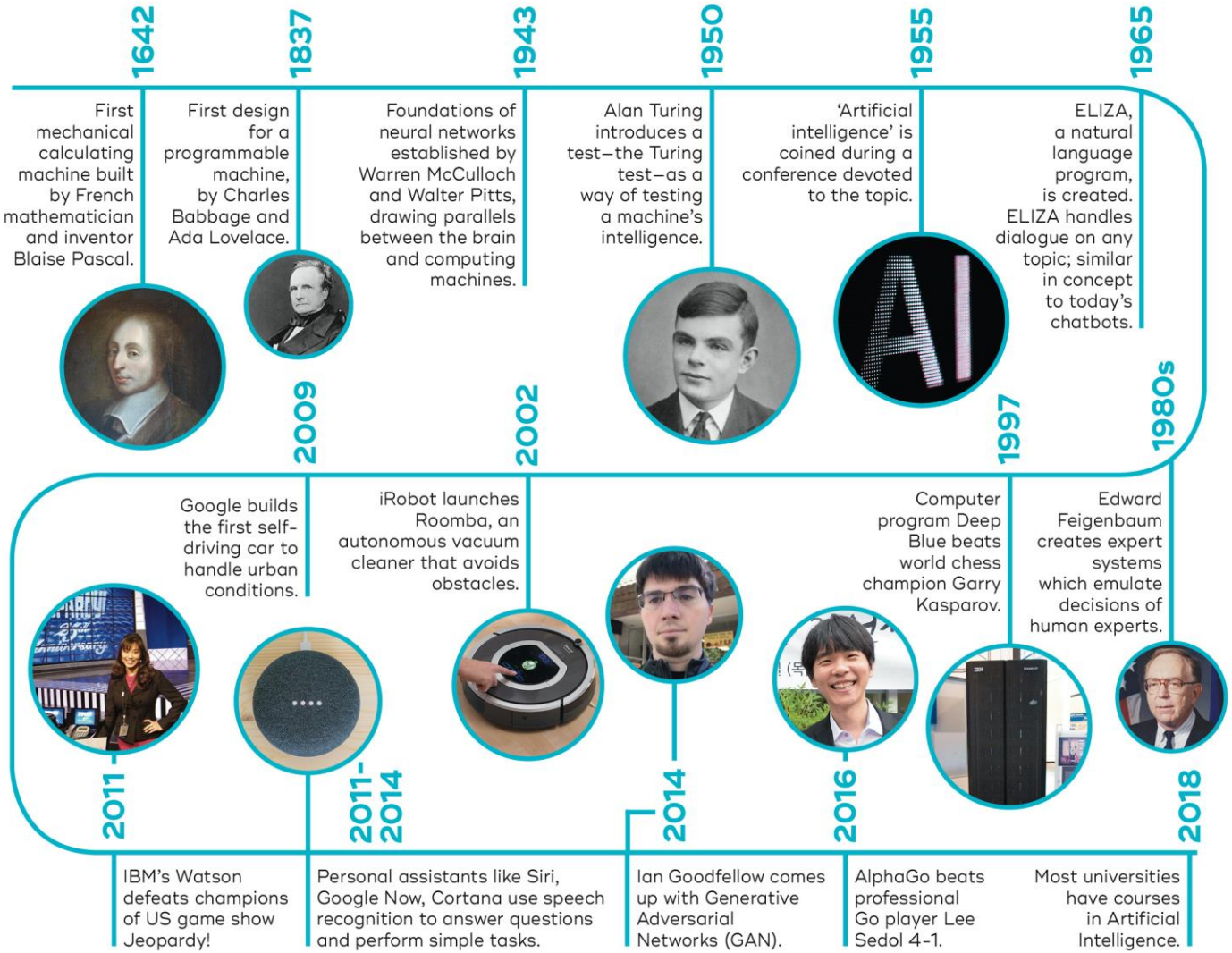
***Referensi**:*
https://mitsloan.mit.edu/ideas-made-to-matter/machine-learning-explained

Penerapan Sistem Berbasis Machine Learning:

- **Descriptive** – sistem menggunakan data untuk menjelaskan apa yang telah terjadi
- **Predictive** – sistem menggunakan data untuk memprediksi apa yang akan terjadi
- **Prescriptive** – sistem akan menggunakan data untuk membuat saran tentang apa yang akan dilakukan

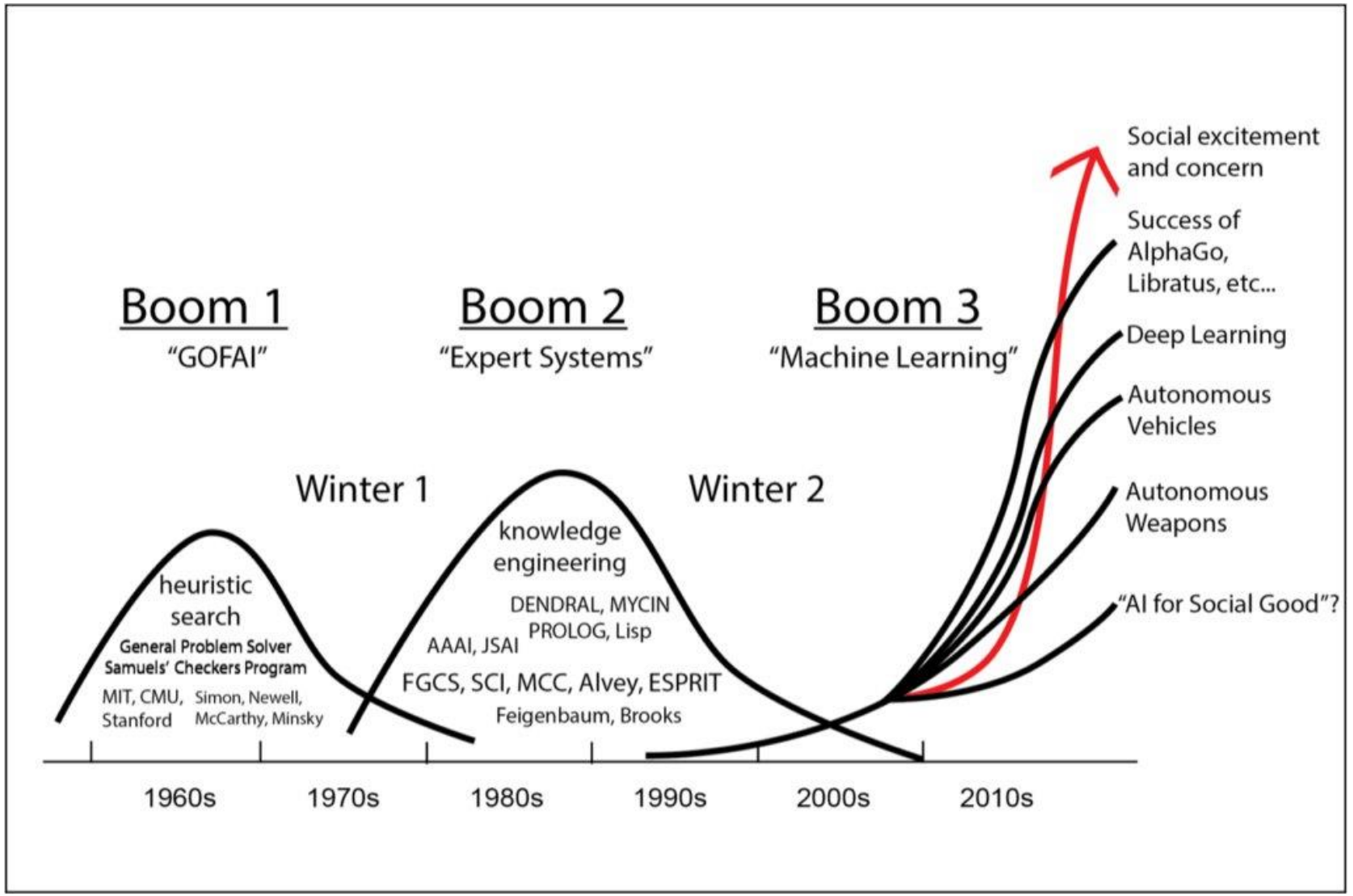


Sejarah AI



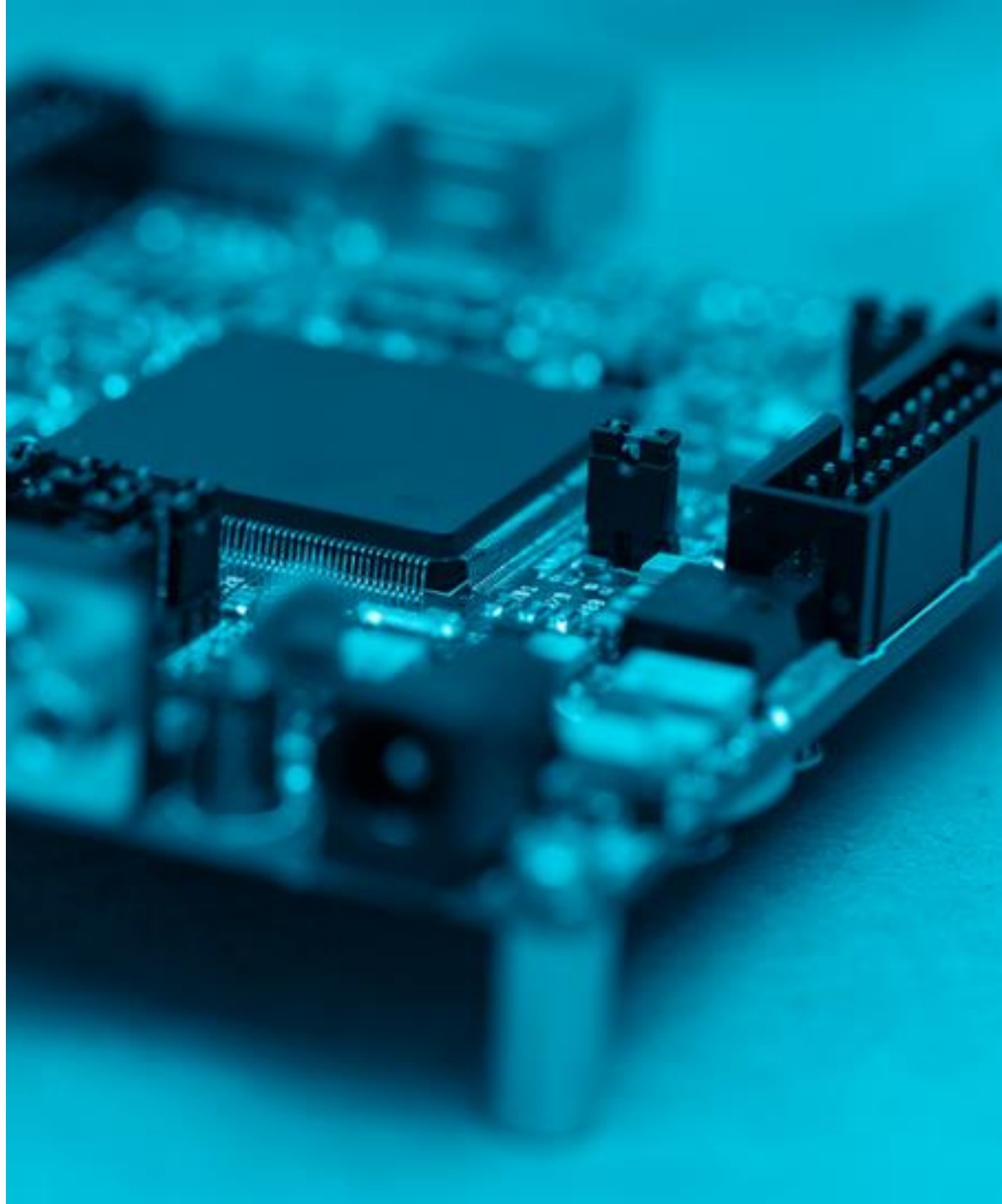
***Referensi**:*
https://qbi.uq.edu.au/brain/intelligent-machines/history-artificial-intelligence

AI: Winter ke Winter



***Referensi**:*
https://jaylatta.net/history-of-ai-from-winter-to-winter/

Apa yang membuat ML menjadi begitu popular saat ini?

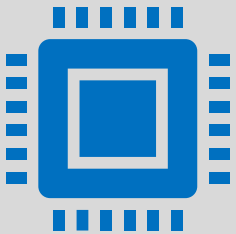


Faktor pendorong berkembangnya ML

1

Ketersediaan Data

2



Kemampuan Komputasi

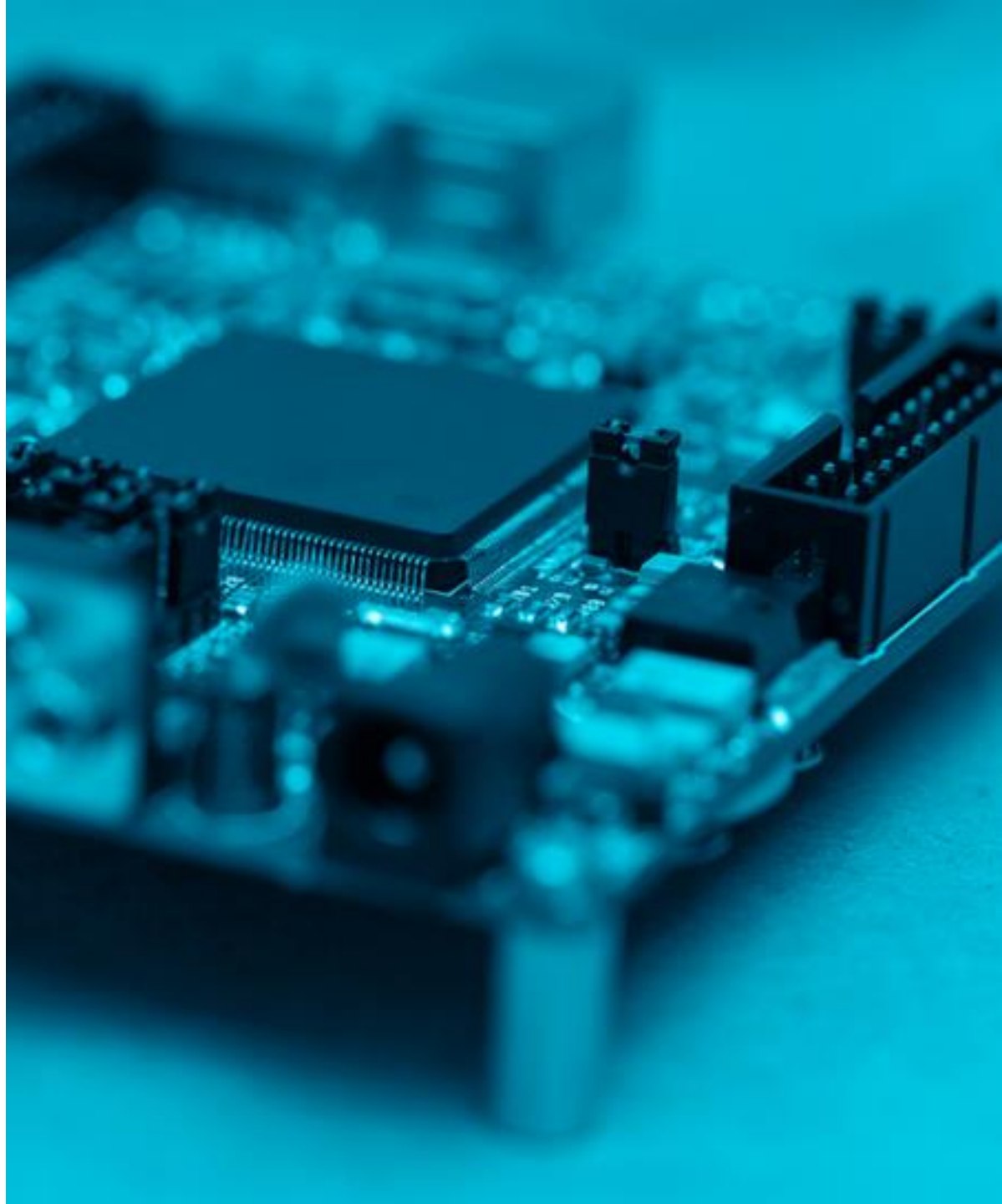
3

Perkembangan Algoritma

4

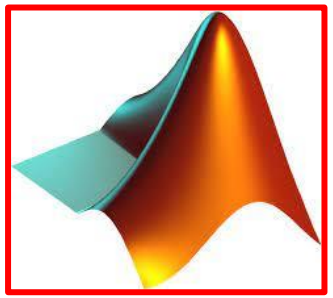
Kepentingan Publik

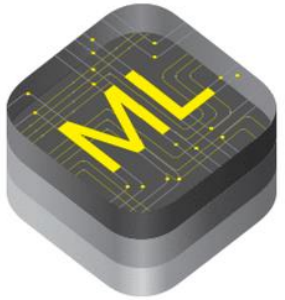
Trus… saya bisa mulai belajar ML dari mana?



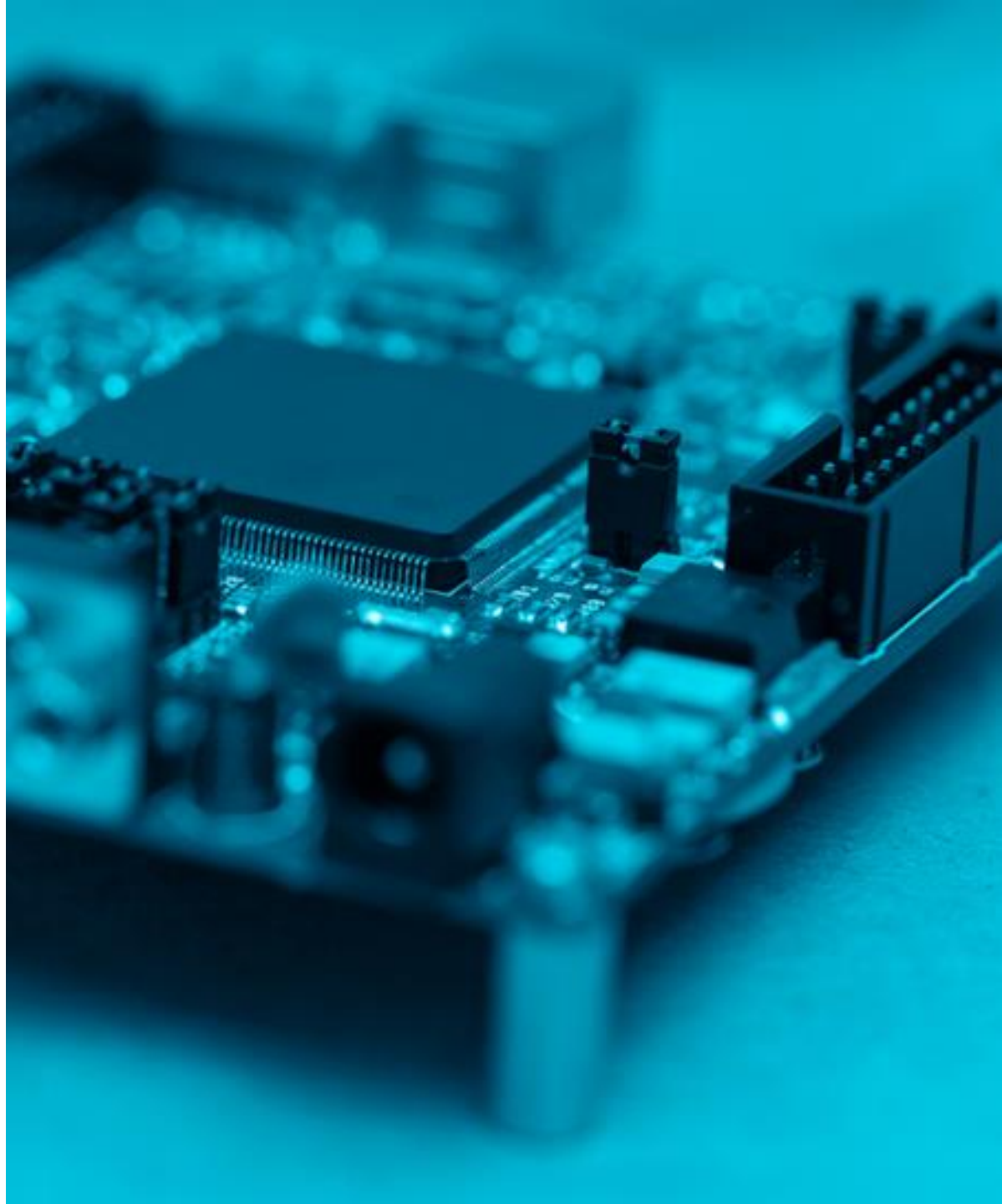
Popular Machine Learning Frameworks

Anda bisa memulai dari ini:

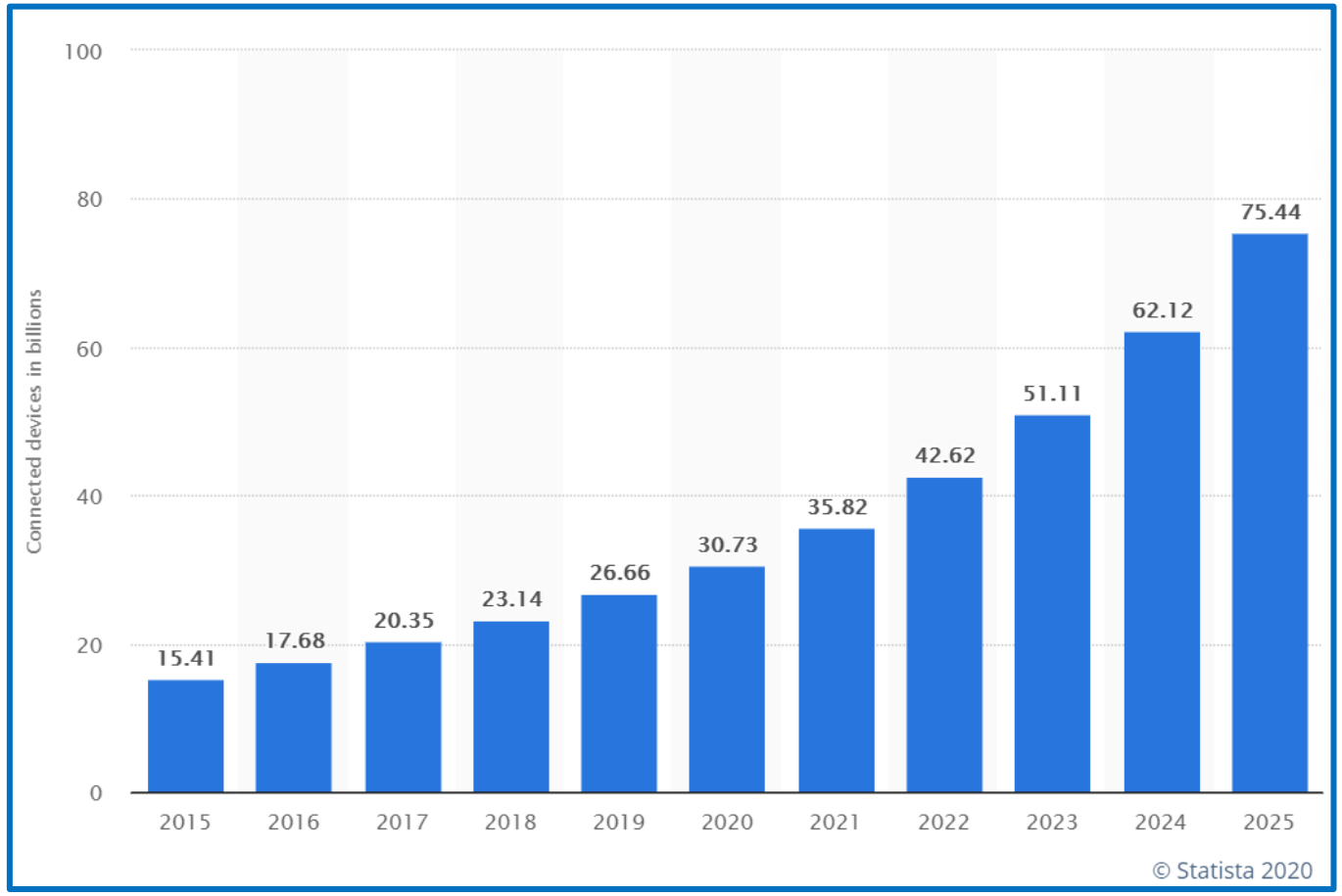


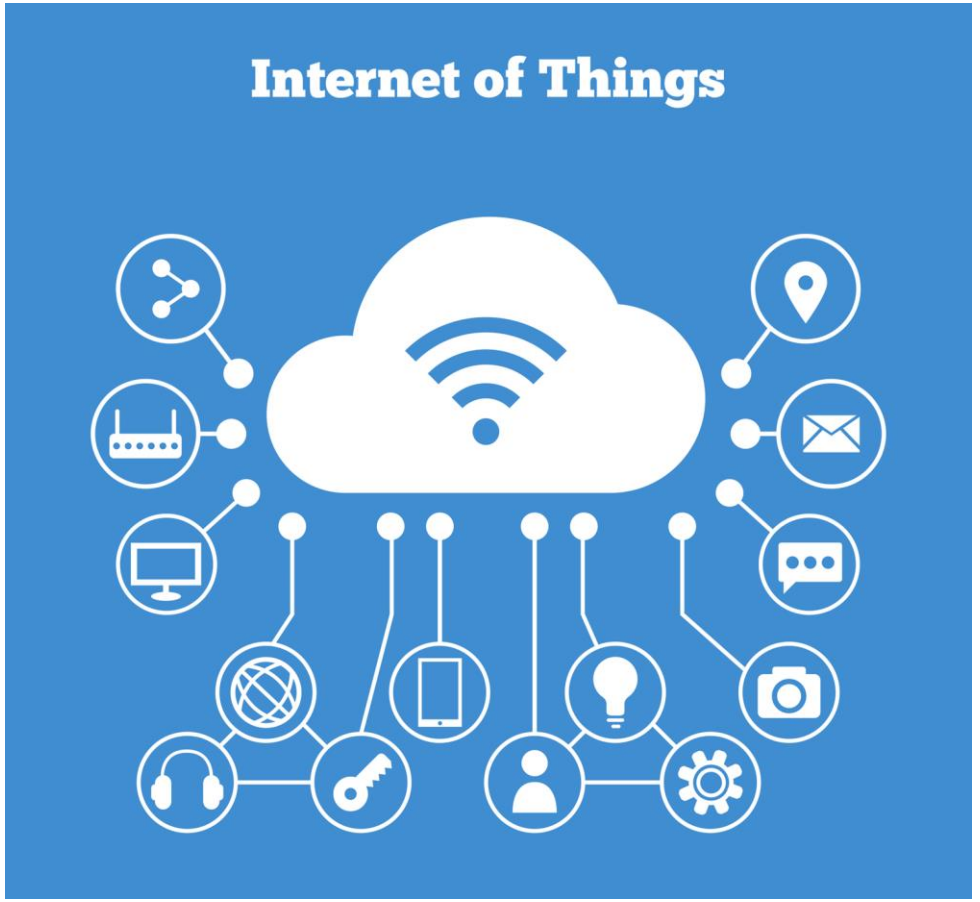


Apa itu Cloud Computing dan Edge Computing?



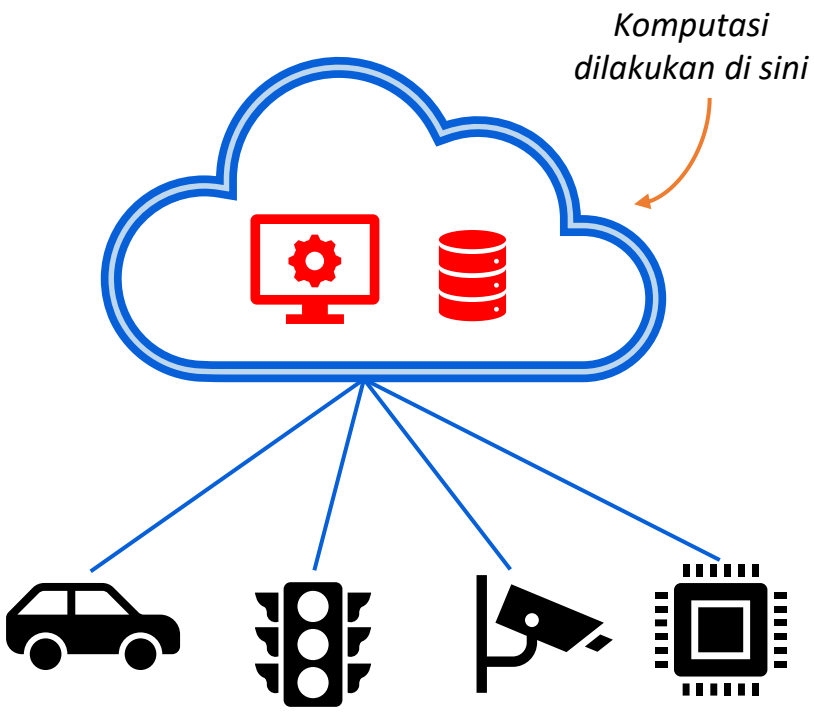
Prediksi Jumlah Alat yang Terkoneksi Internet of Things (IoT) dari thn. 2015 - 2025



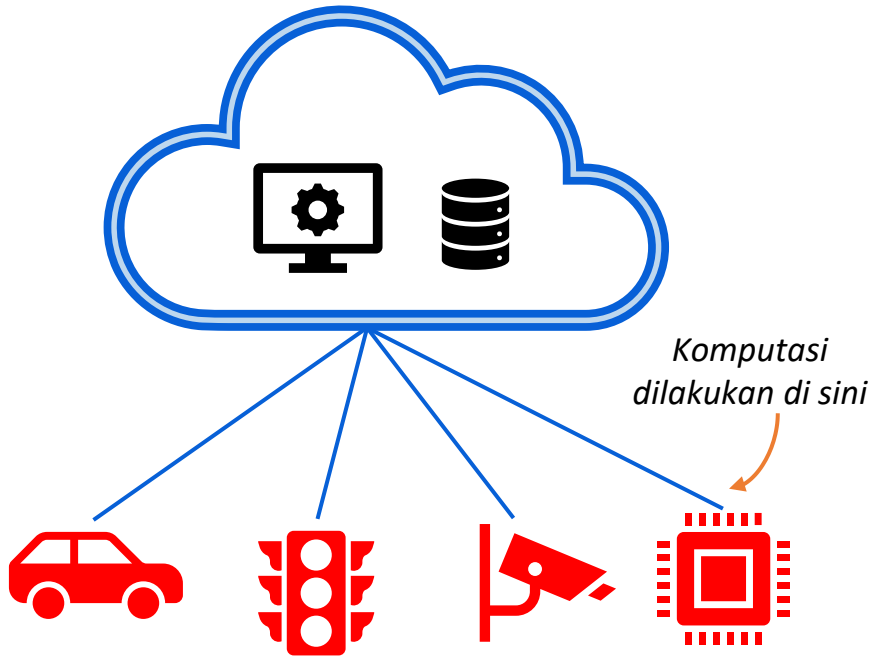


The total installed base of Internet of Things (IoT) connected devices is projected to amount to 75.44 billion worldwide by 2025, a fivefold increase in ten years. The IoT, enabled by the already ubiquitous Internet technology, is the next major step in delivering Internet's promise of making the world a connected place. (statistica.com)

Edge computing vs. cloud computing



Cloud Computing

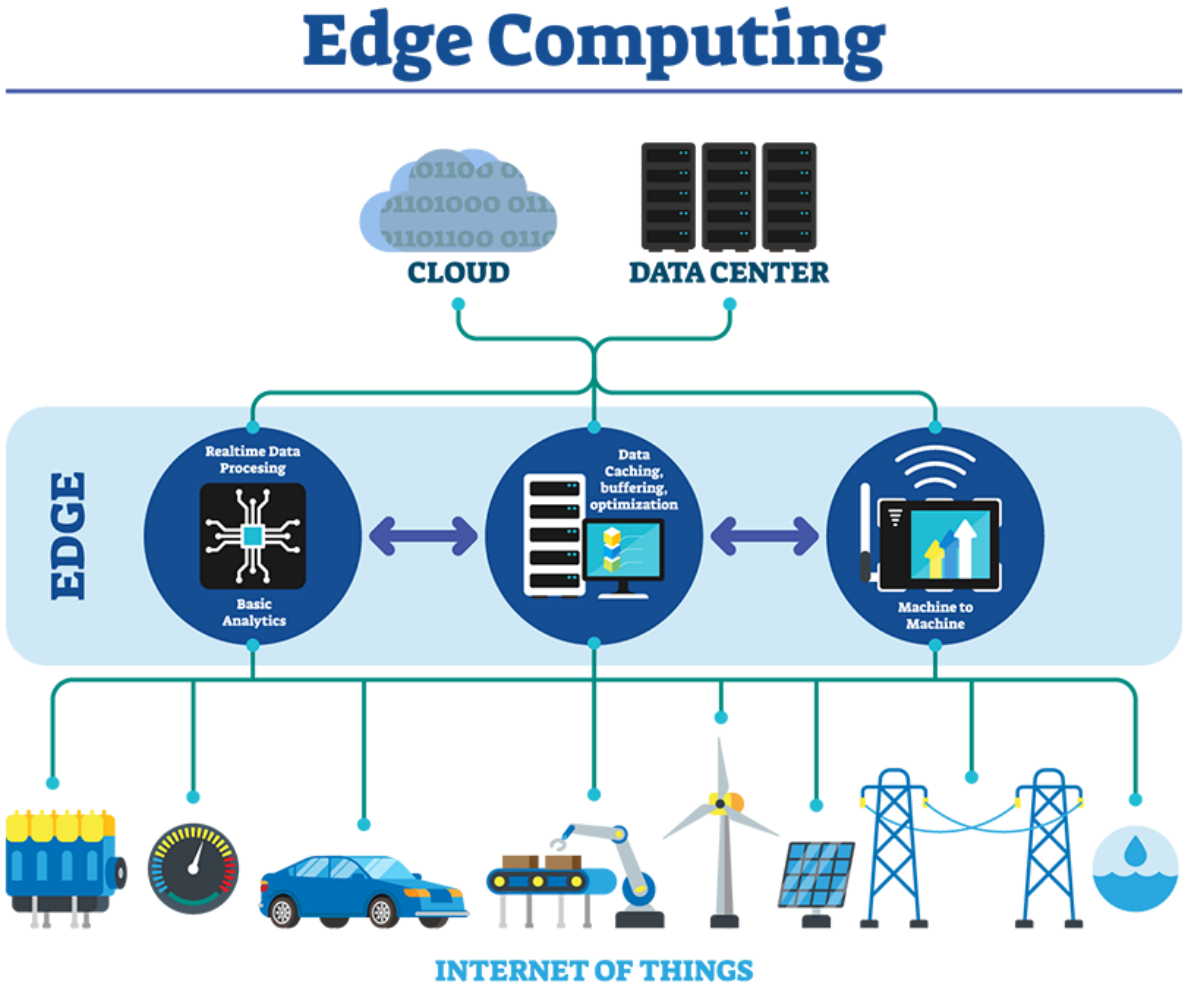


Edge Computing

- **Tantangan Cloud Computing:**
  - Isu keamanan data
  - Masalah performa
  - Biaya operasional

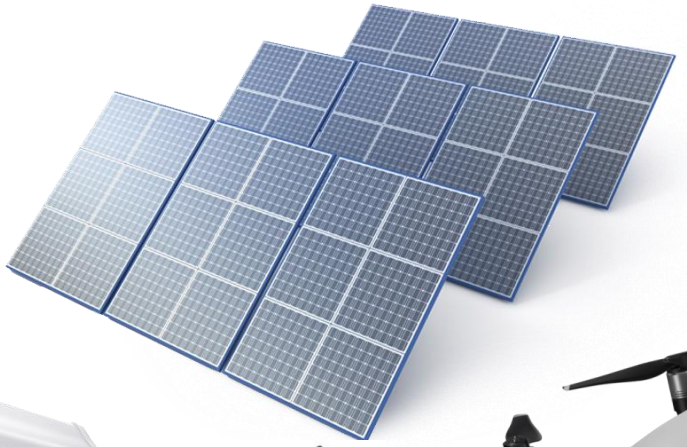
Keuntungan Edge Computing:

- Meningkatkan privasi dan keamanan data
- Performa lebih responsif dan tangguh
- Mengurangi biaya operasional
- Meningkatkan reliability dan efisiensi bisnis
- Unlimited scalability
- Mengurangi latensi



***Referensi**:*
https://innovationatwork.ieee.org/real-life-edge-computing-use-cases/

Edge Devices

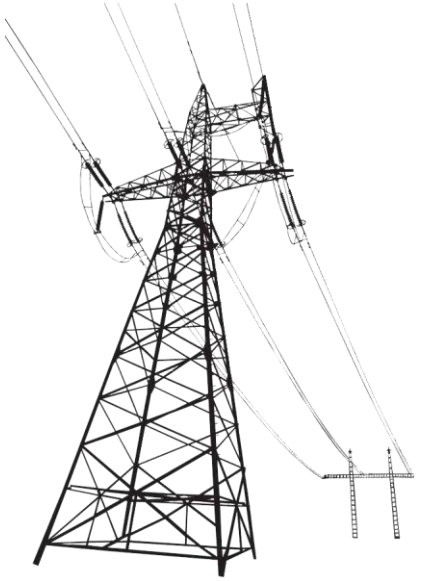





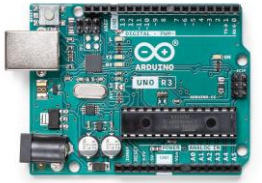




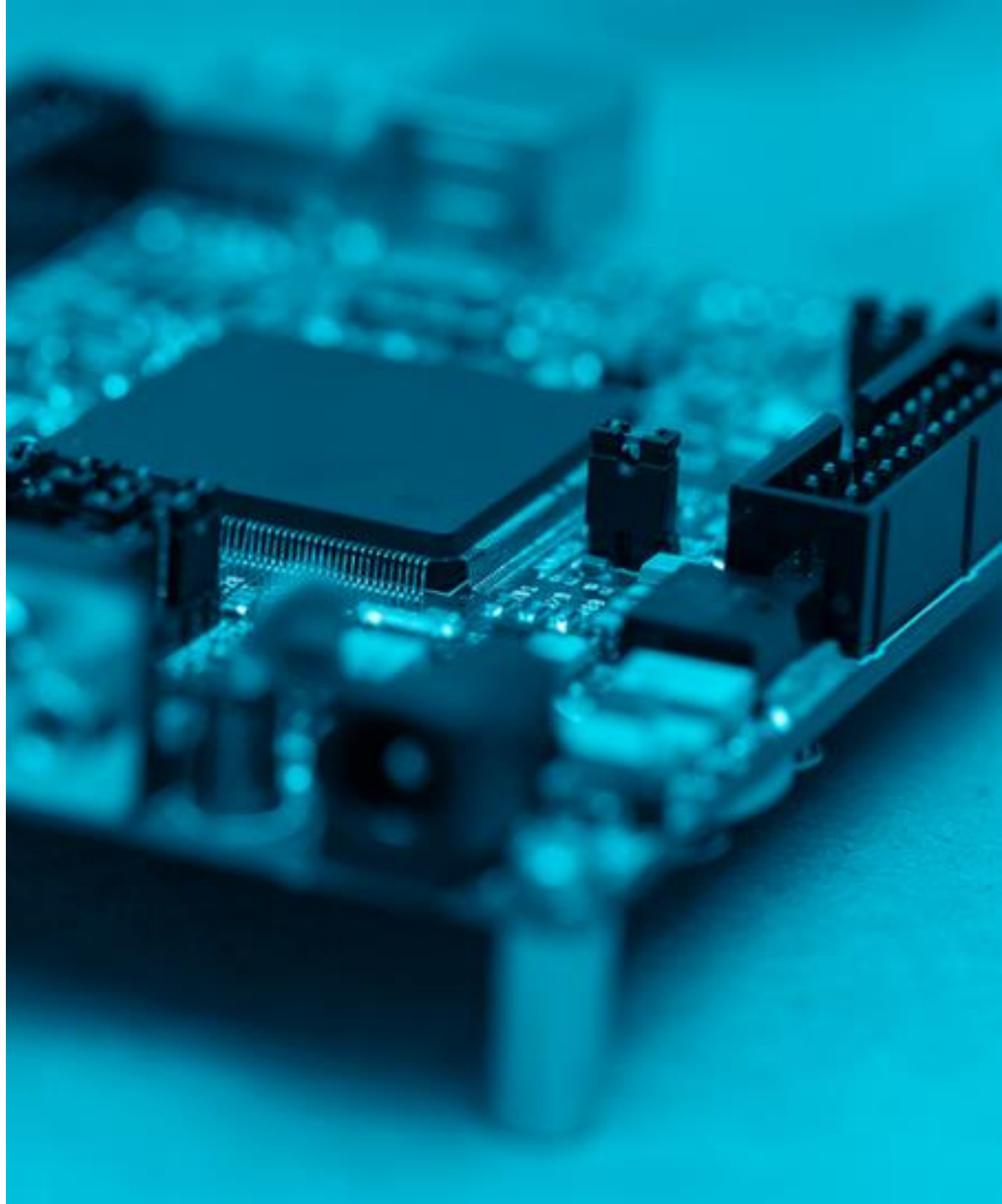






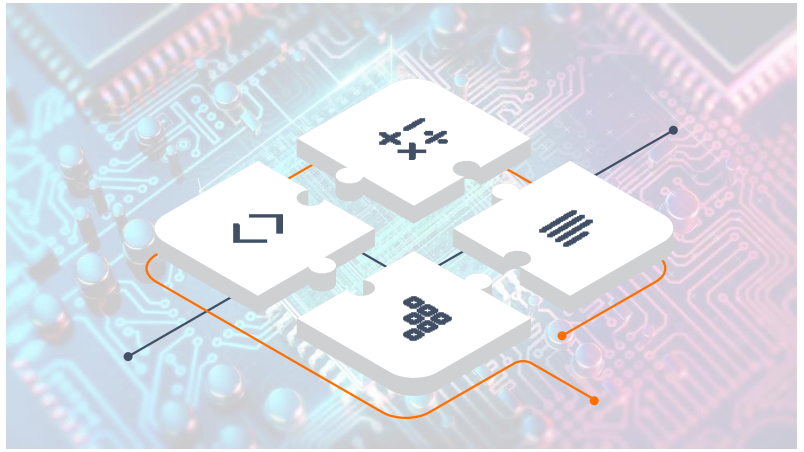




Apa itu embedded systems?

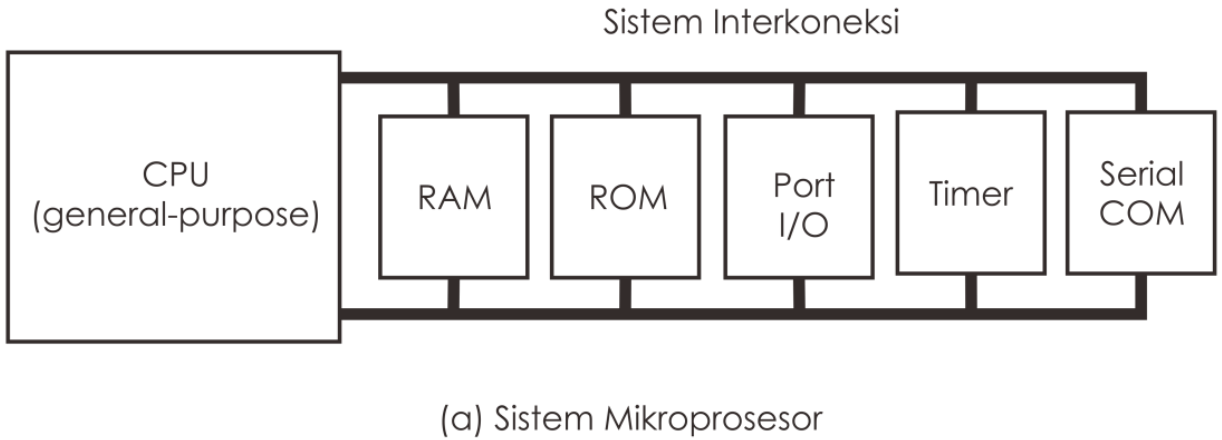


Embedded Systems

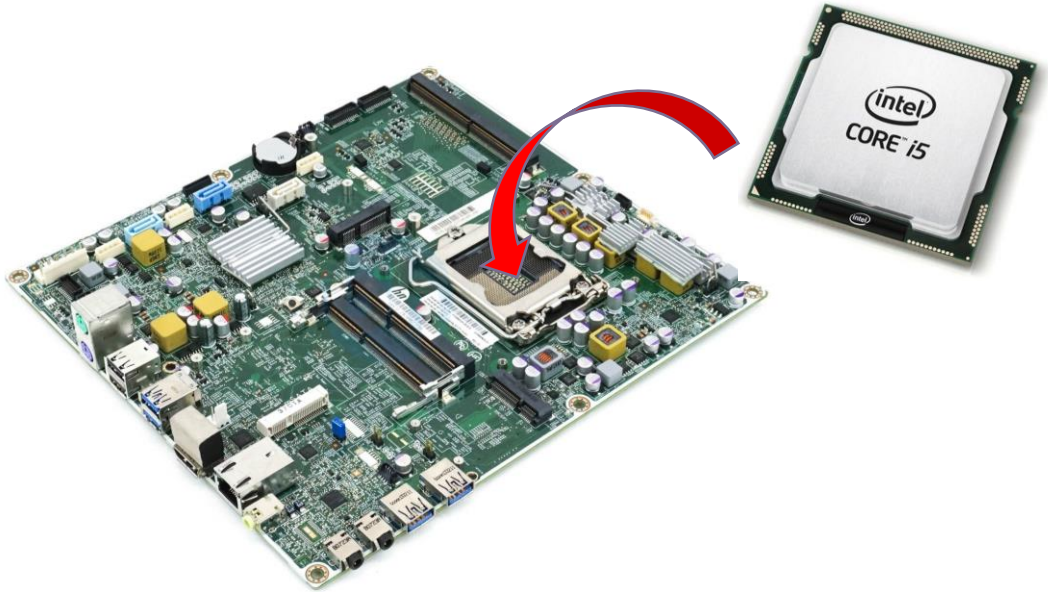
- **System** → A system is an arrangement in which all its unit **assemble work together** according to a set of rules. It can also be defined as **a way of working, organizing or doing one or many tasks** according to a fixed plan.
- **Embedded System** → Embedded means something that is **attached to another thing**. An embedded system can be thought of as a computer hardware system having software embedded in it. An embedded system is a microcontroller or microprocessor-based system which is designed to **perform a specific task**.
- **Characteristics** of an Embedded System:
  - Single-functioned
  - Tightly constrained
  - Reactive and Real time
  - Microprocessors based
  - Memory
  - Connected
  - HW-SW systems

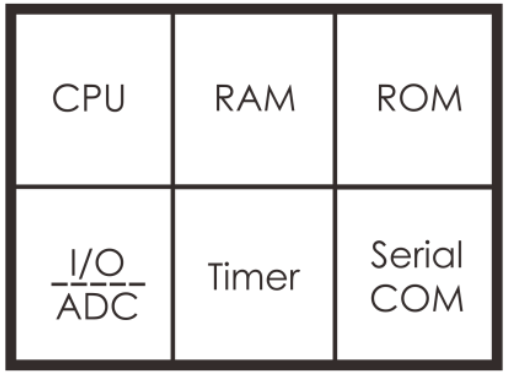


General purpose processor vs Microcontroller



(a) Sistem Mikroprosesor

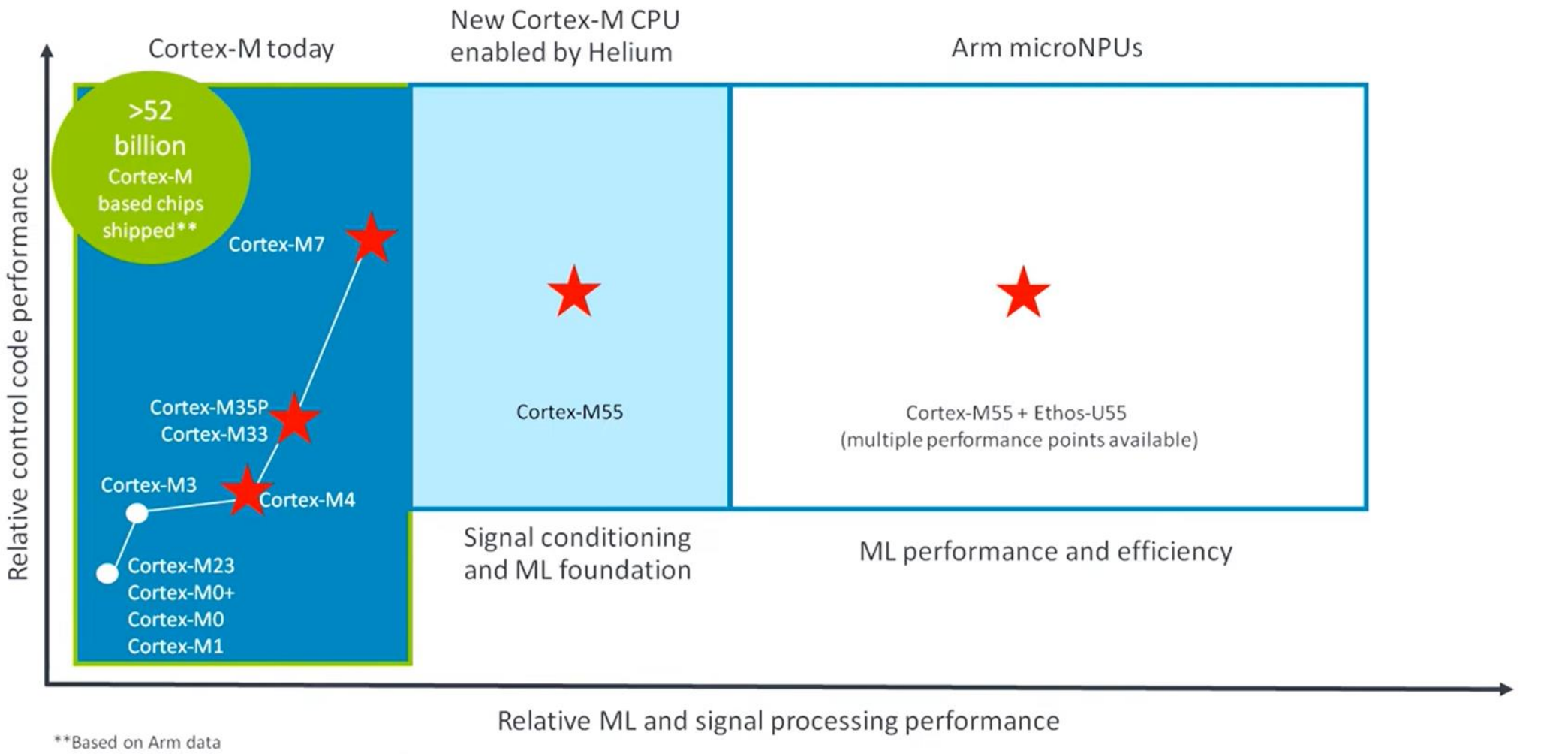




(b) Sistem Mikrokontroler

Banyak digunakan di penerapan embedded

Pushing the Boundaries for Real-time On-device Processing

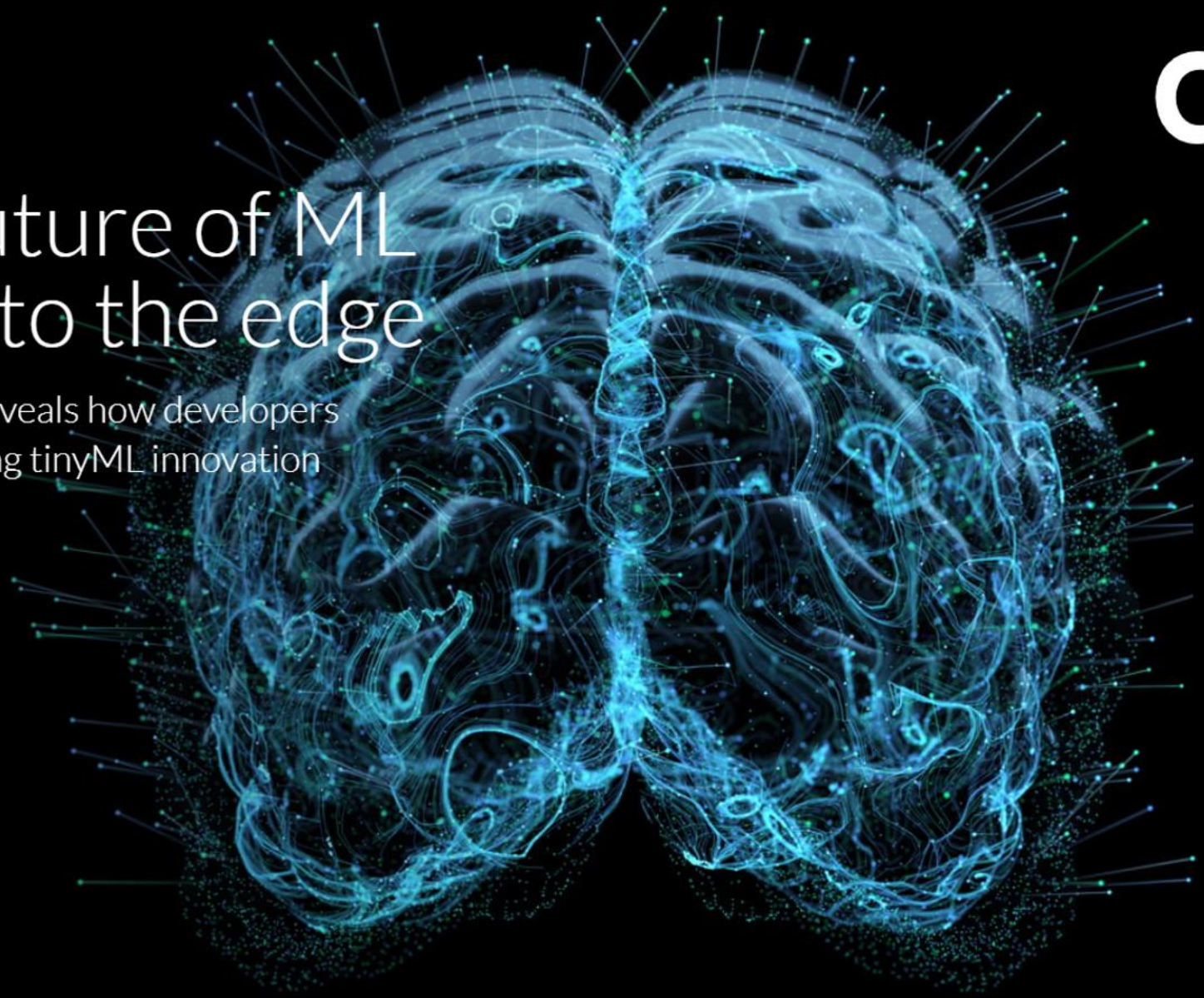


***Referensi**:*
https://www.youtube.com/watch?v=RDGCGho5oaQ&list=PL7VEa1KauMQqZFj_nWRfsCZNXaBbkuurG&index=3&ab_channel=EdgeImpulse

arm

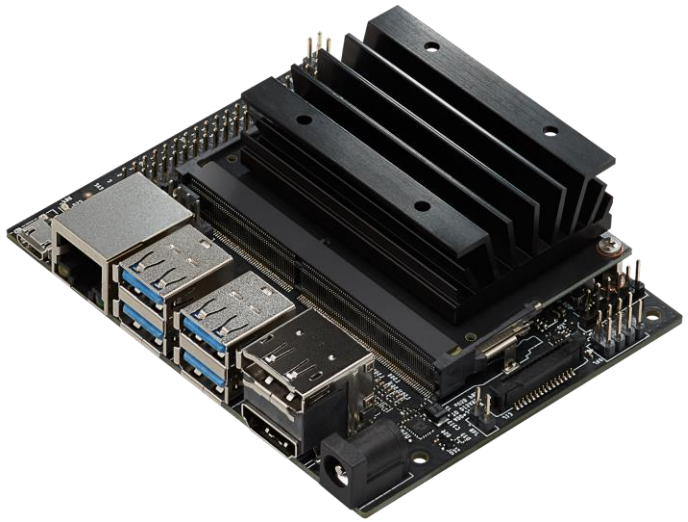
The future of ML shifts to the edge

New survey reveals how developers are accelerating tinyML innovation



Bagaimana dengan SBC?

Raspberry Pi

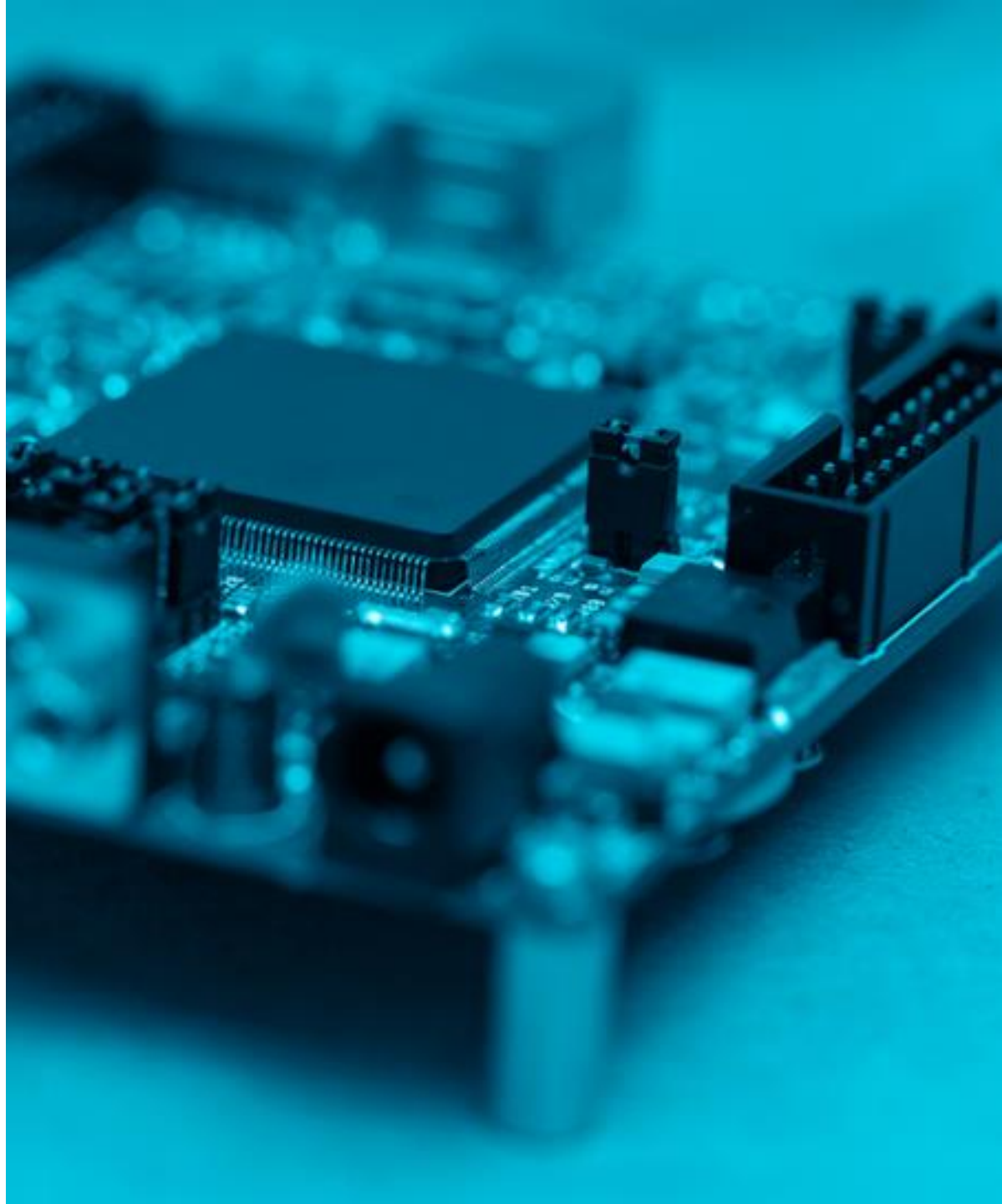


NVIDIA

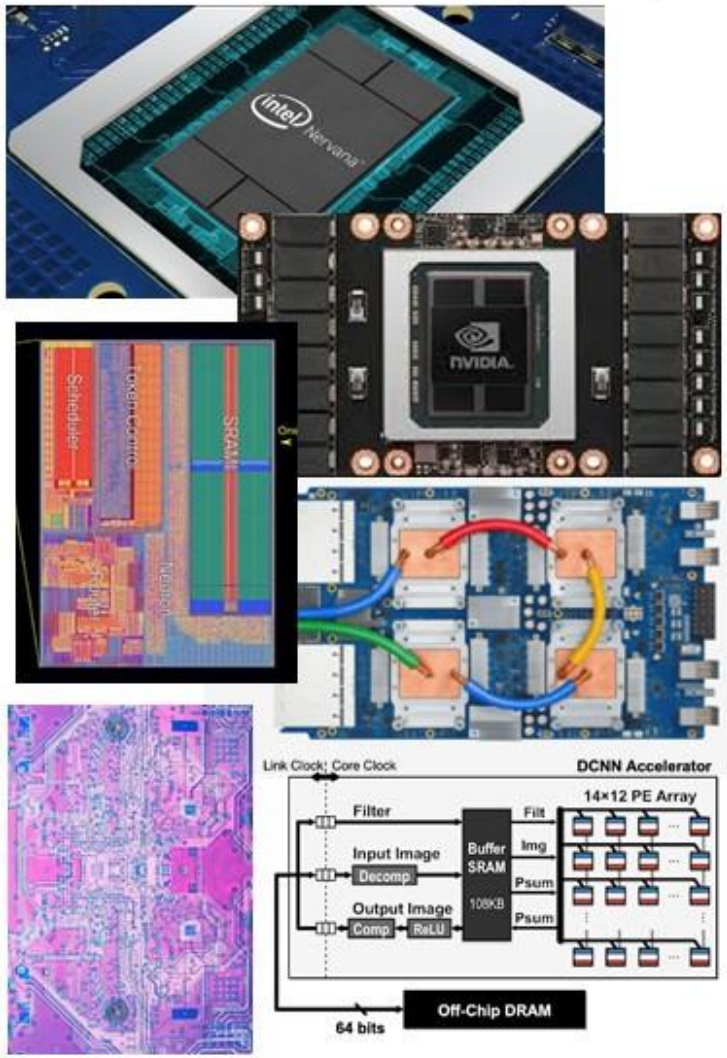
Bagaimana dengan SBC?

Embedded Devices

Apa itu embedded machine learning?

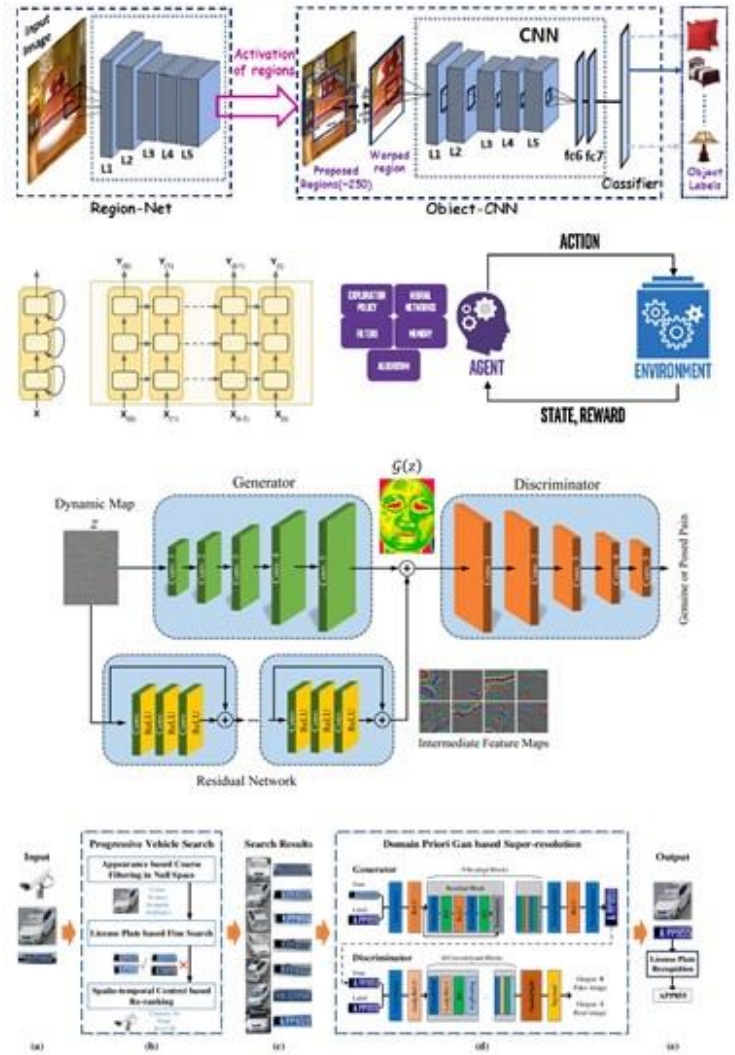


Hardware Accelerators



Embedded and IoT Systems

Deep Learning Software



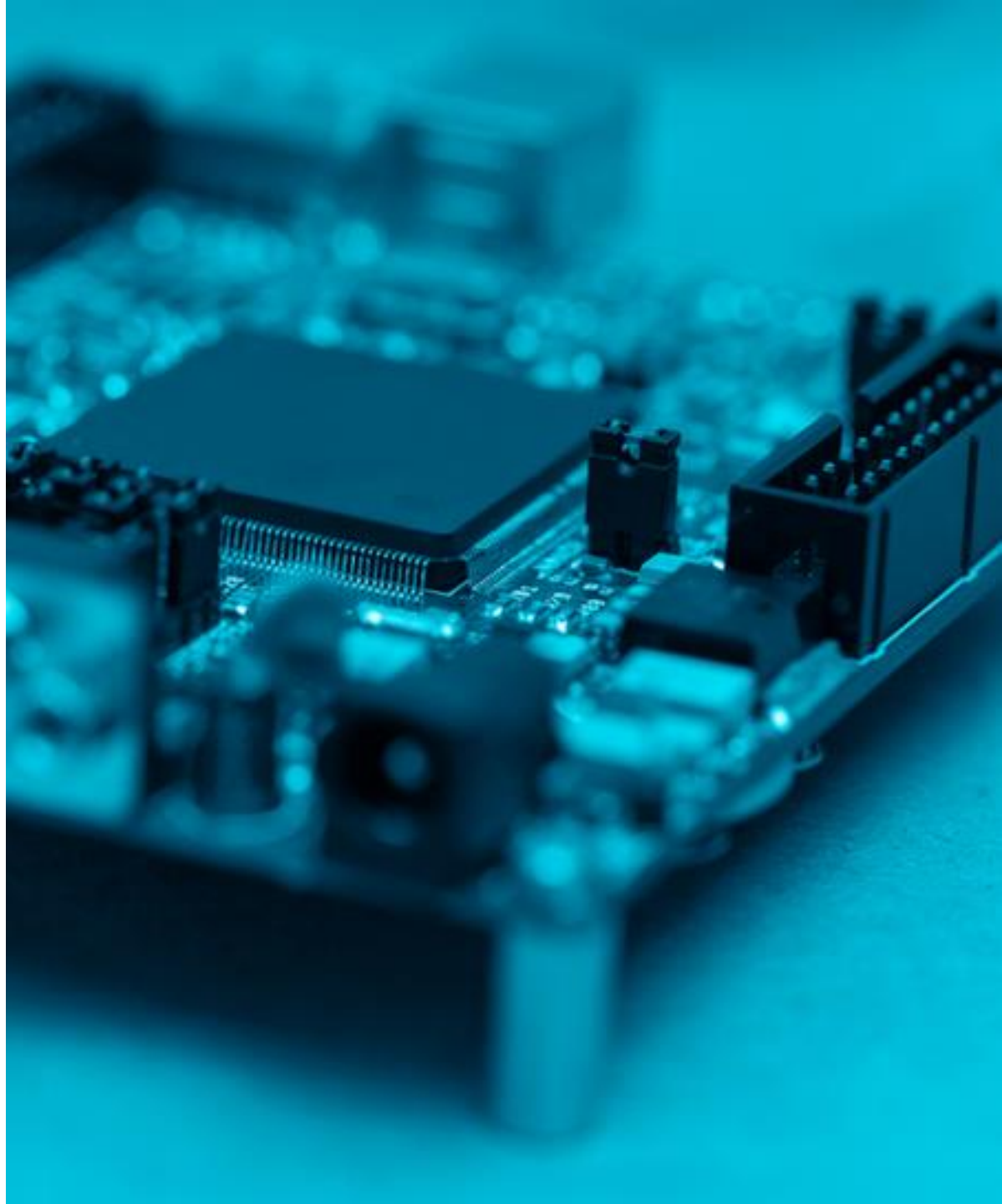
***Referensi**:*
https://www.engr.colostate.edu/~sudeep/embedded-machine-learning/

Keuntungan ML pada embedded device

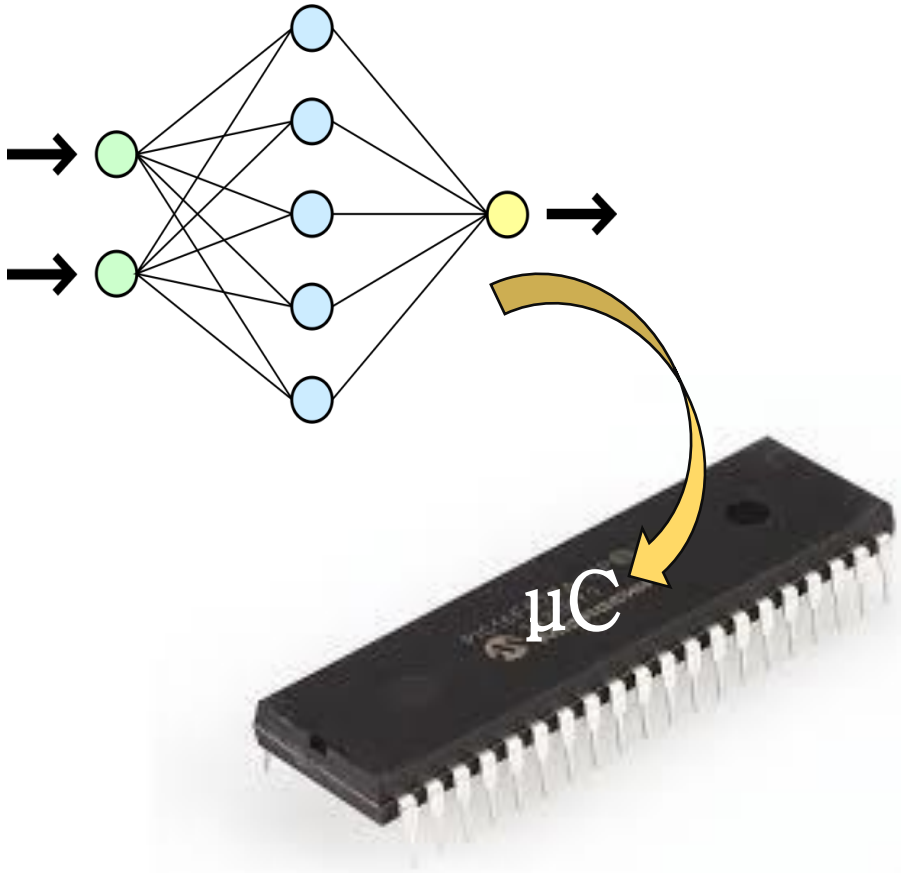
- **Bandwidth**—ML algorithms on edge devices can extract meaningful information from data that would otherwise be inaccessible due to bandwidth constraints.
- **Latency**—On-device ML models can respond in real-time to inputs, enabling applications such as autonomous vehicles, which would not be viable if dependent on network latency.
- **Economics**—By processing data on-device, embedded ML systems avoid the costs of transmitting data over a network and processing it in the cloud.
- **Reliability**—Systems controlled by on-device models are inherently more reliable than those which depend on a connection to the cloud.
- **Privacy**—When data is processed on an embedded system and is never transmitted to the cloud, user privacy is protected and there is less chance of abuse.

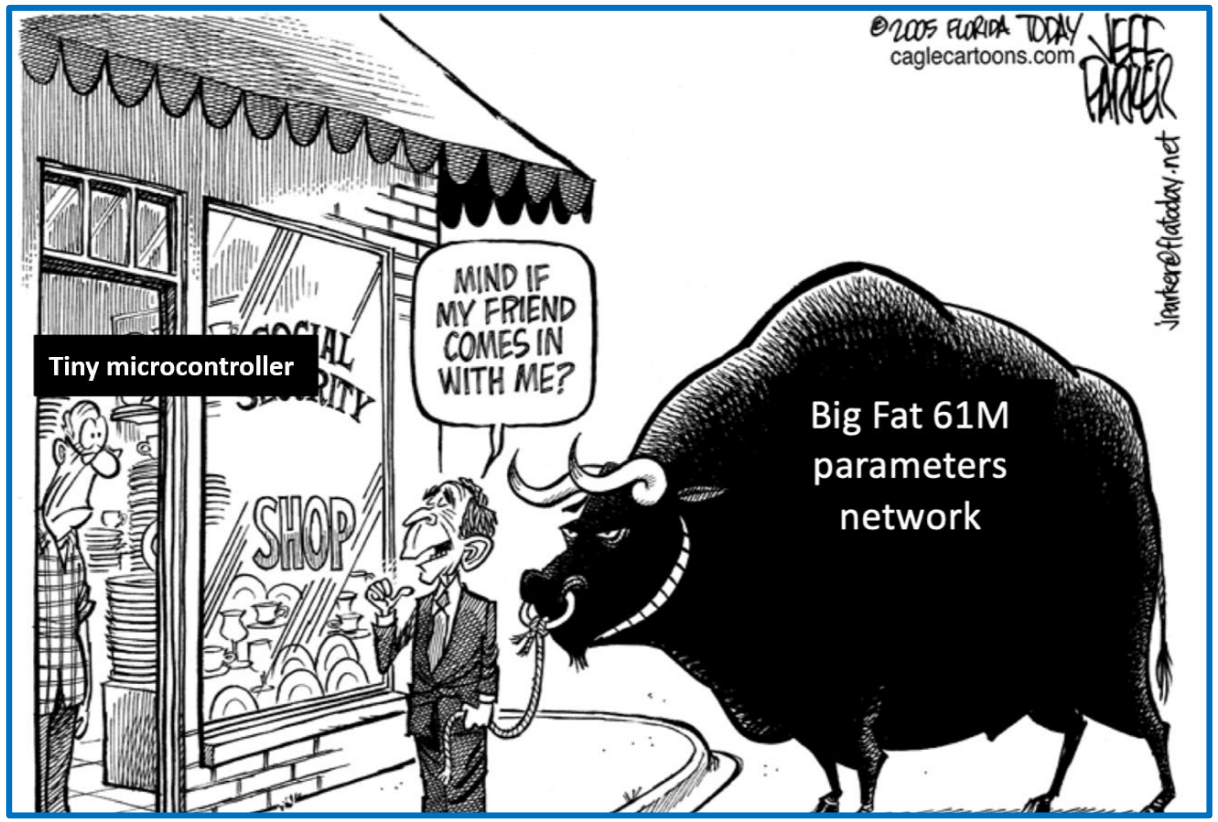
***Referensi**:*
https://docs.edgeimpulse.com/docs/what-is-embedded-machine-learning-anyway

Pernah mendengar tinyML?



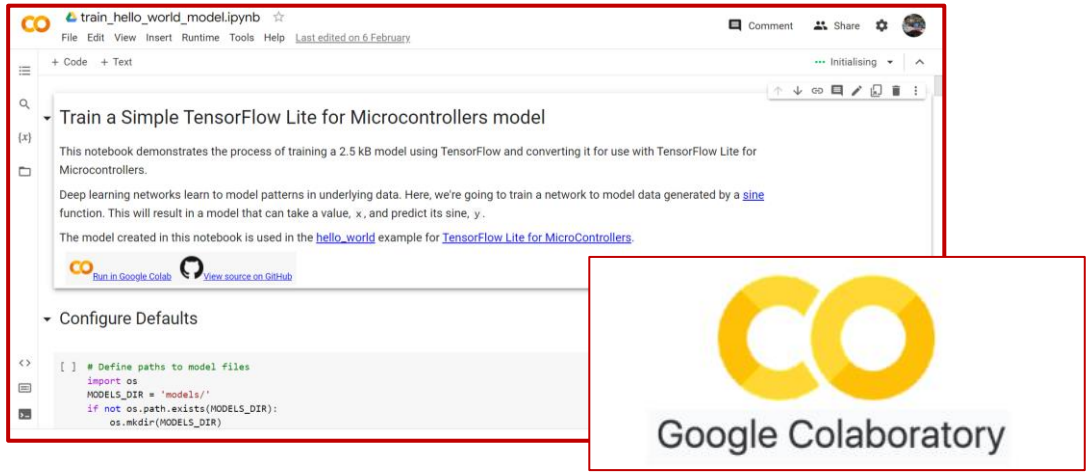
TinyML


µC


©2005 FLORIDA TODAY
caglecartoons.com
JEFF PARKER
jparker@flatoday.net
MIND IF MY FRIEND COMES IN WITH ME?
SHOP
Tiny microcontroller
Big Fat 61M parameters network

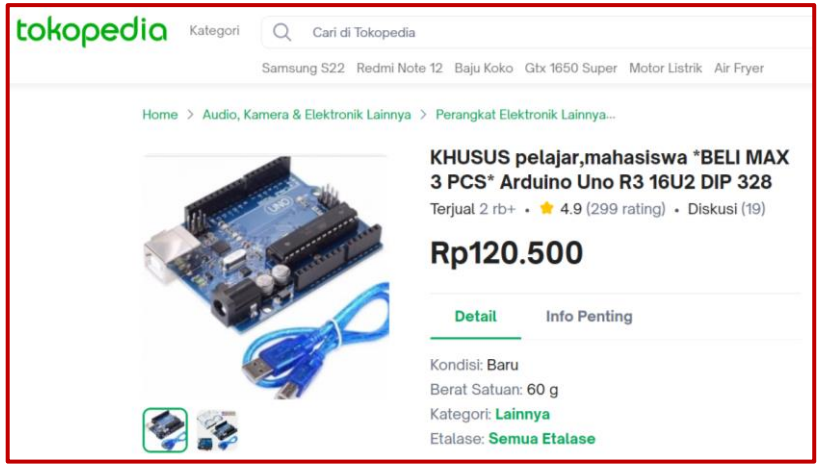
Machine Learning:

- ❑ Arsitektur neural network semakin canggih
  - Gratis, open-source, framework mudah digunakan
- ❑ End-to-end Tools → membuat desain ML semakin sederhana
- ❑ ML tidak hanya untuk para ahli!



Mikrokontroler:

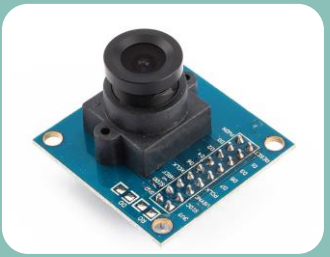
- ❑ Dapat diprogram dengan mudah
  - Lingkungan pengembangan (IDE) yang menawarkan plug-and-play
  - Dengan sedikit baris koding kita dapat membaca sensor, menyalakan LED, memutat motor, dsb
  - Koding kompatibel dgn berbagai platform
- ❑ Terdapat banyak sensor dan papan pengembangan mikrokontroler dengan biaya terjangkau



Penerapan TinyML: 3V

Vibration

- Accelerometer
- Suhu, kelembapan, dsb



Vision

- Image
- Video

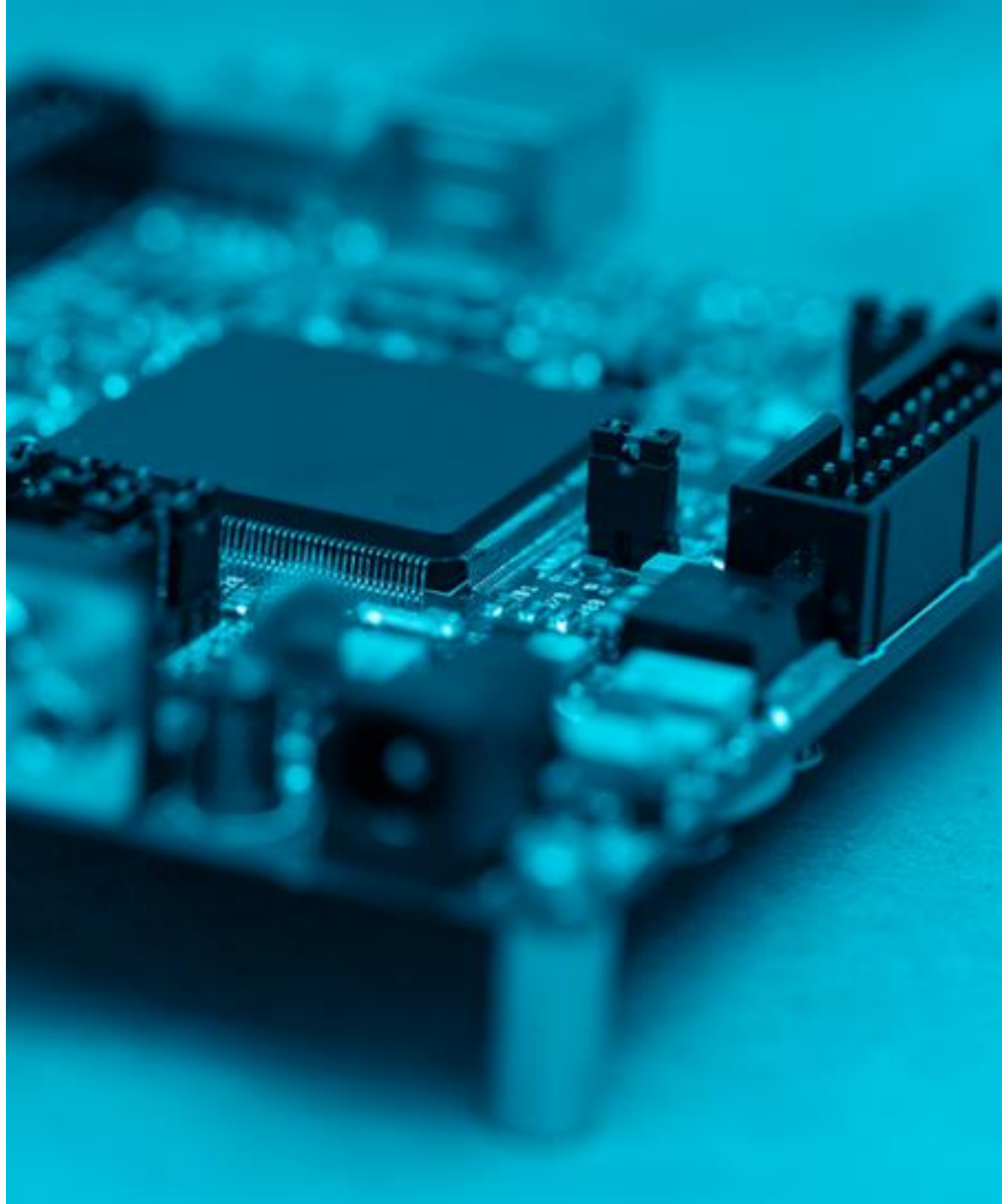
Voice

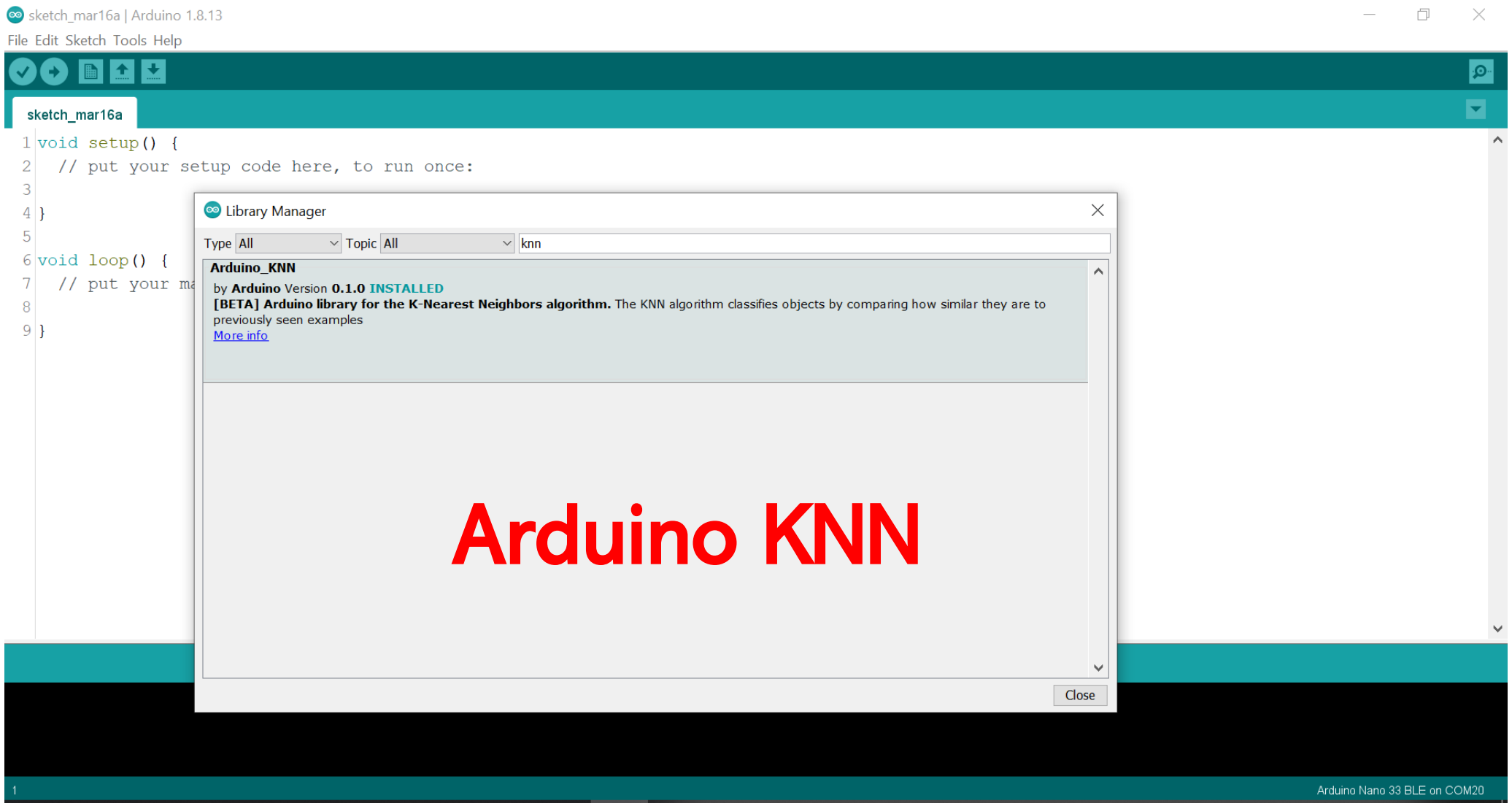
- Pengenalan suara/bunyi
- NLP

Perusahaan besar di balik pengembangan tinyML

***Referensi**:*
https://www.tinyml.org/

Oke, saya tertarik (sedikit) tentang tinyML. Dari mana saya memulai?





https://blog.arduino.cc/2020/06/18/simple-machine-learning-with-arduino-knn/

AIfES (Artificial Intelligence for Embedded Systems) → https://github.com/Fraunhofer-IMS/AIfES_for_Arduino

TensorFlow Lite

- **TF Lite** → open-source deep learning framework untuk menjalankan model TensorFlow pada alat/device
- **Target** : mobile, embedded & IoT devices
- Memungkinkan menjalankan **on-device machine learning** → low latency & small binary size.
- **Penerapan**: Mulai dari mikrokontroler sampai pada perangkat bergerak

TF Lite Developer workflow

Buat TensorFlow Model

- Ukuran model harus cukup kecil
- Gunakan operasi yang mendukung

Konversi ke TensorFlow Lite

- Lakukan kuantisasi jika diperlukan
- Perhatikan akurasi

Konversi ke C byte array

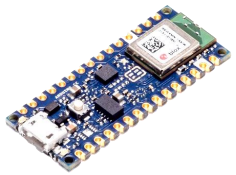
- Model → Read-only program memory
- Tersedia dlm bentuk file C

Integrasikan ke Pustaka C++

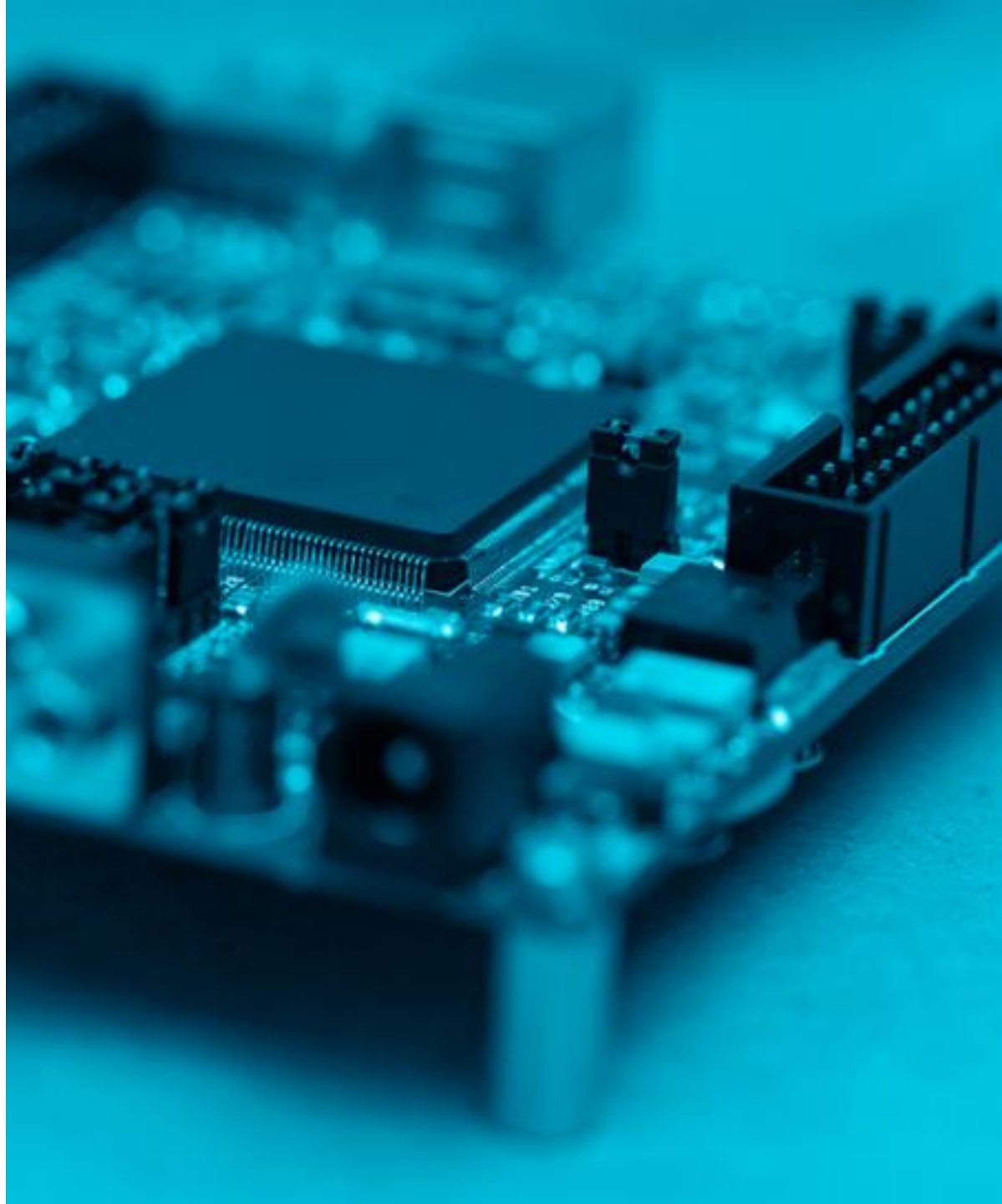
- Gunakan pustaka TensorFlow Lite
- Lakukan pemrograman mikrokontroler

Deploy ke mikrokontroler

- Upload program ke mikrokontroler
- Lakukan validasi hasil akhir

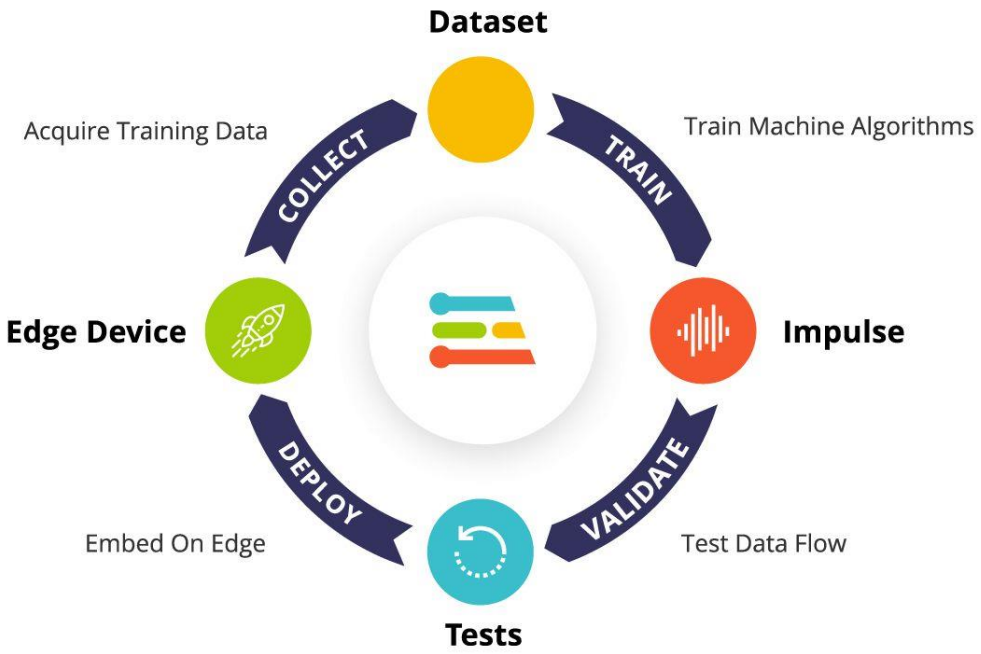


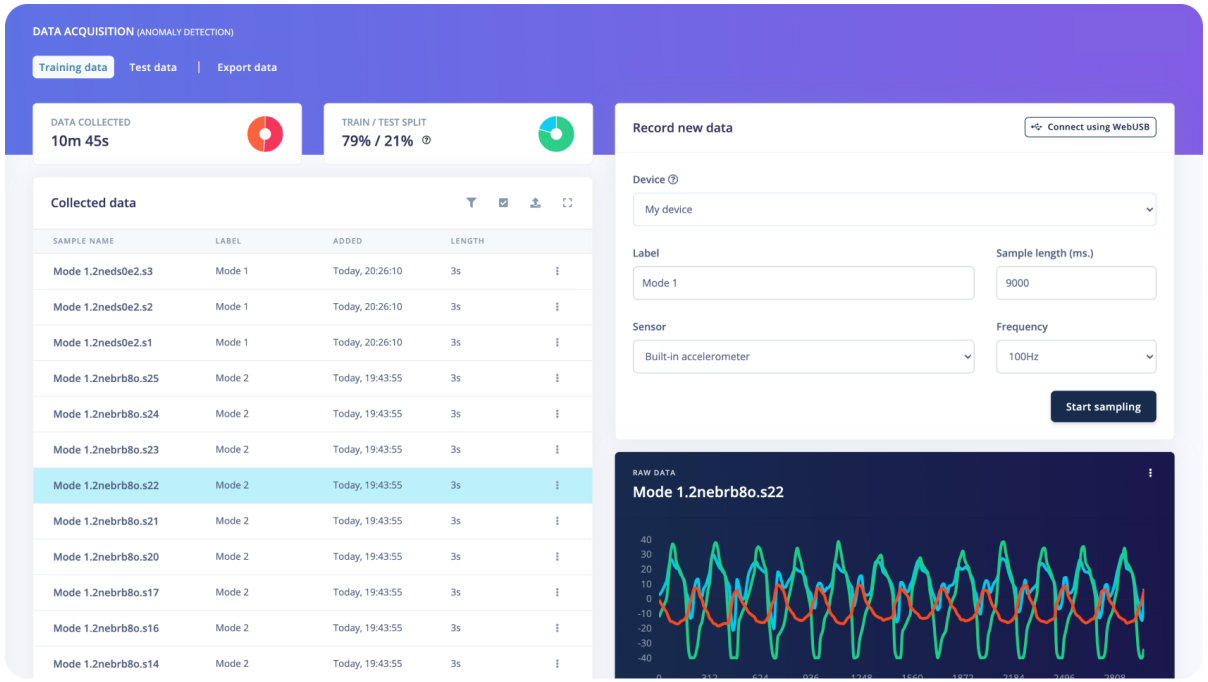
Saya tidak ingin ribet. Bisa kasih saya platform yang lebih sederhana?



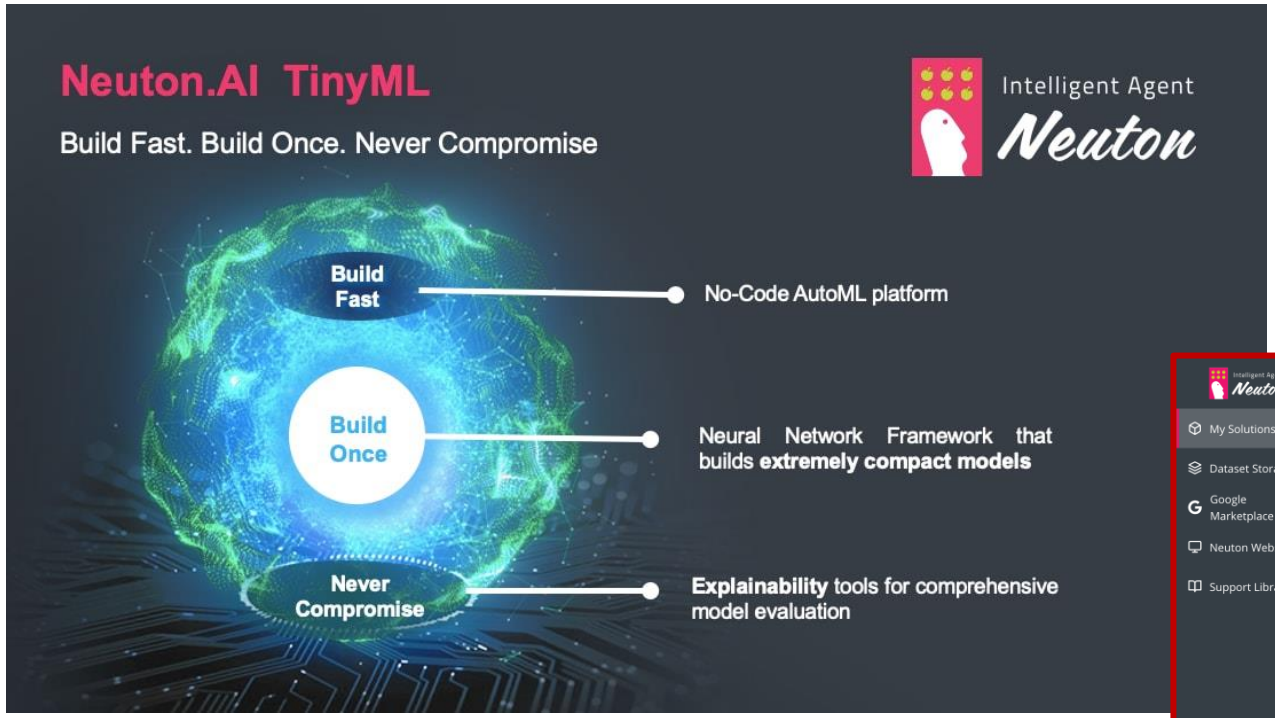
Gunakan Auto(tiny)ML

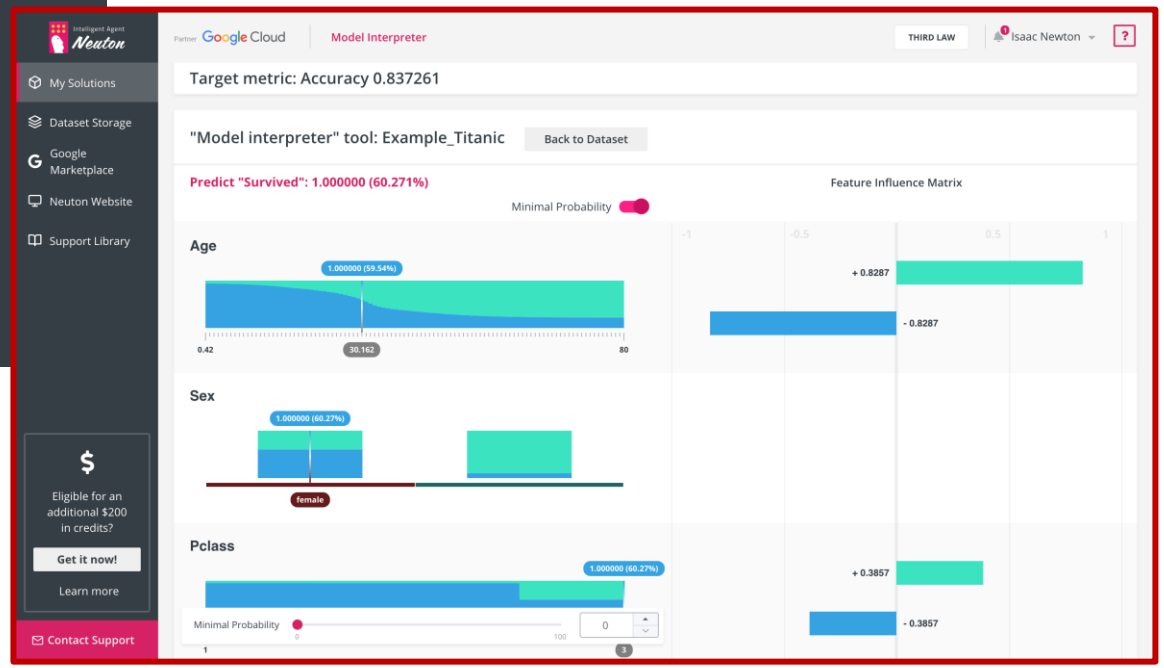
EDGE IMPULSE



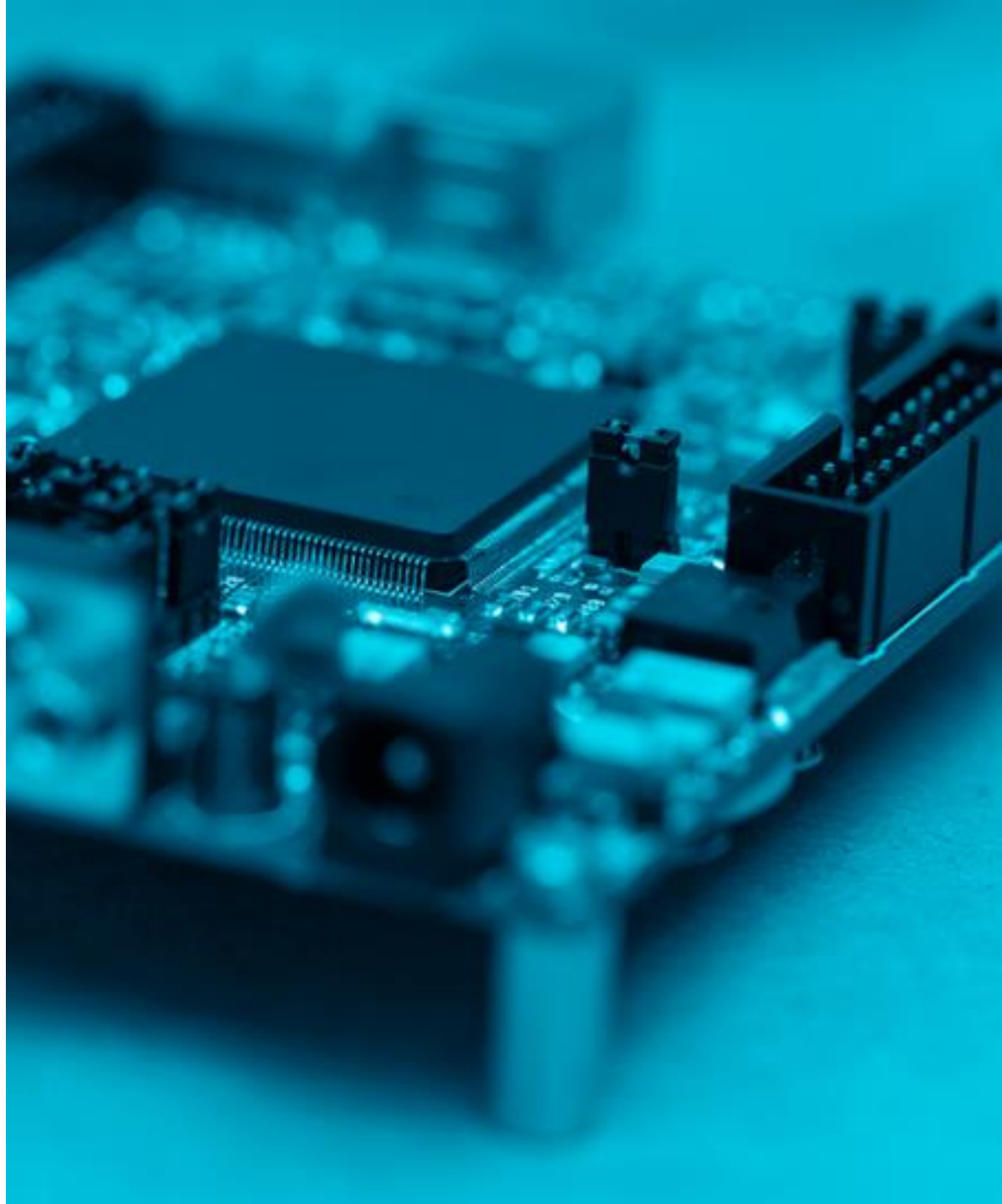


Gunakan Auto(tiny)ML



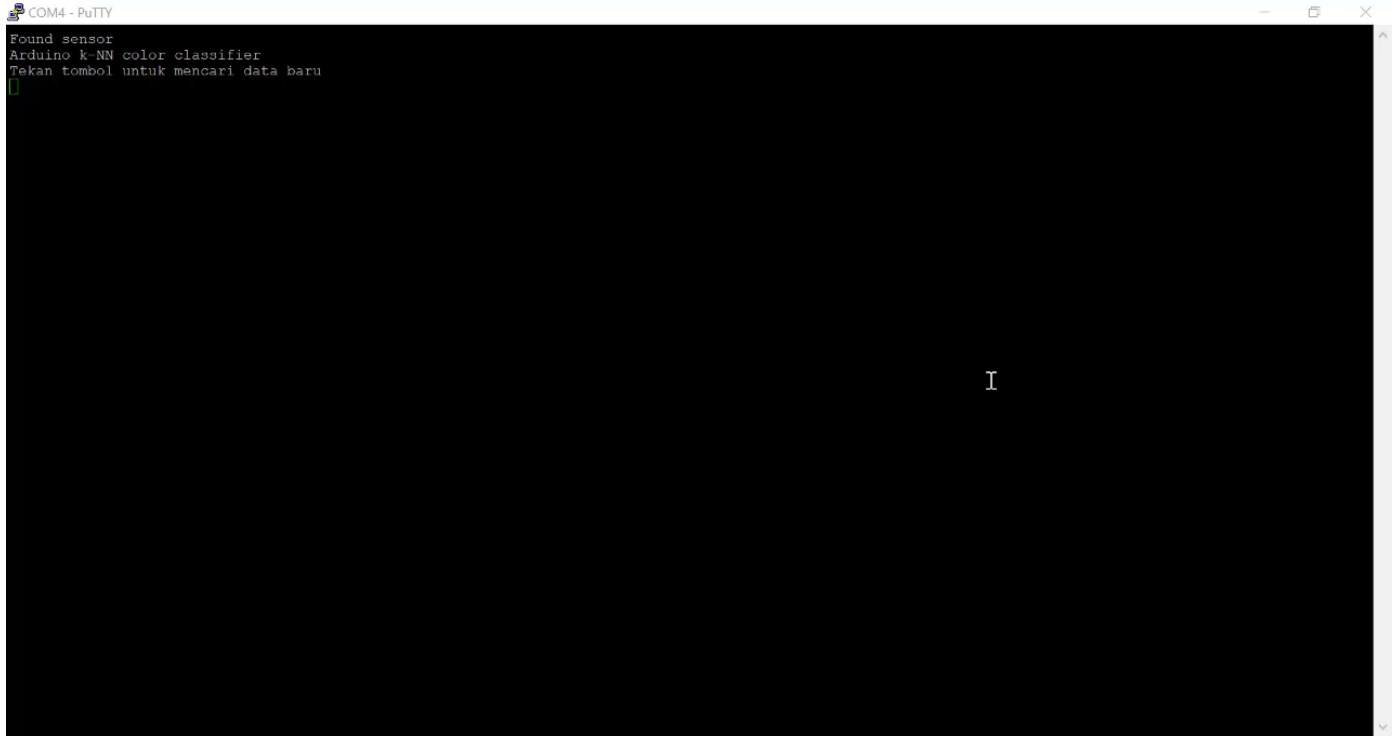


Bisa kasih saya sedikit demo mengenai penerapan AI?



Penerapan TinyML

Klasifikasi Buah Menggunakan KNN - Arduino



Video Link:
https://github.com/Narin-Laboratory/SeminarUndiknas/blob/main/colour_classification_fruits.mp4

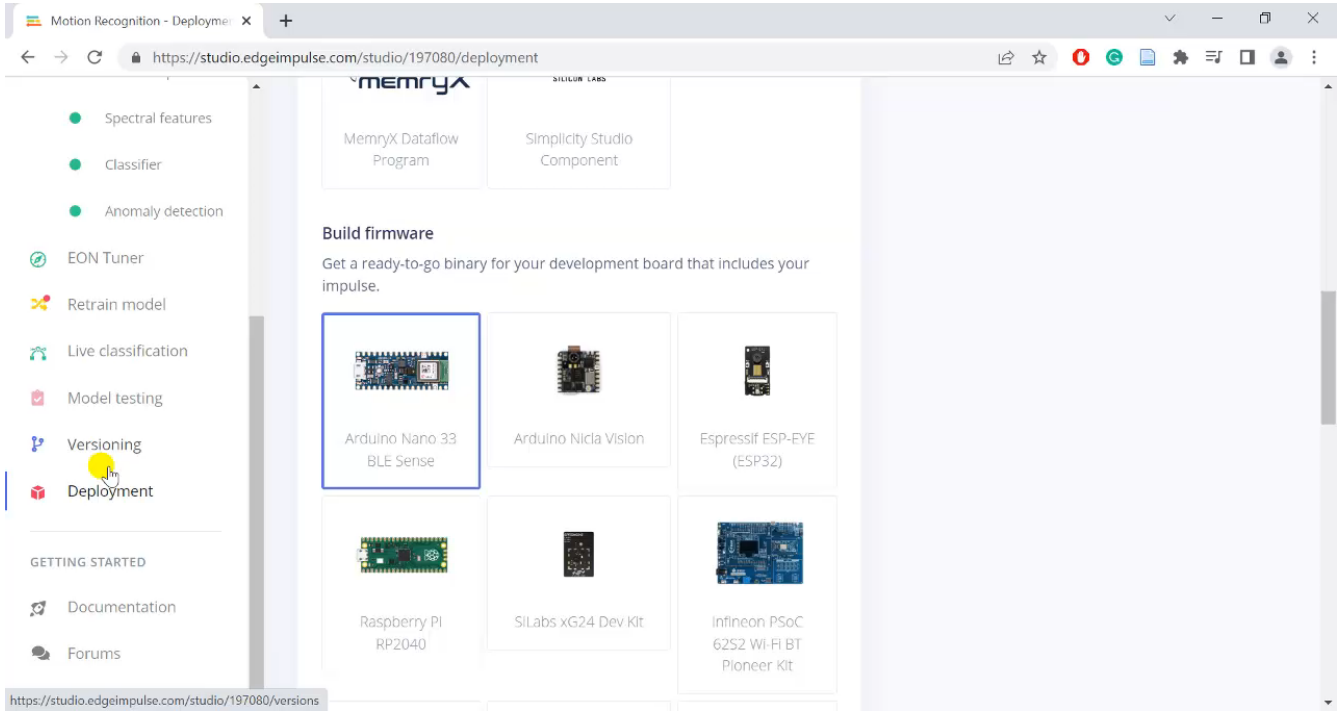
Penerapan TinyML
Motion Recognition Menggunakan Edge Impulse

- Pengambilan Data

Video Link:
https://github.com/Narin-Laboratory/SeminarUndiknas/blob/main/ambil_data_gesture.mp4

Penerapan TinyML: Edge Impulse

- Deployment ke Alat



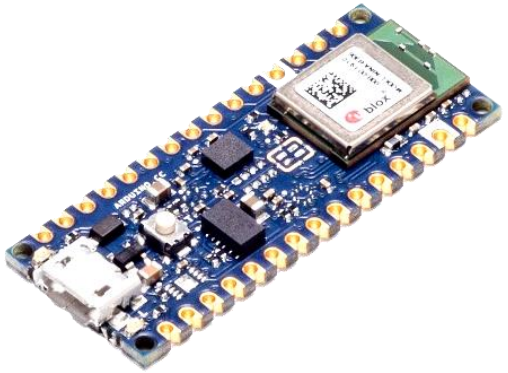
Video Link:
https://github.com/Narin-Laboratory/SeminarUndiknas/blob/main/deployment.mp4

Contoh menggunakan TensorFlow: Pengenalan Hand Gesture Sederhana

- Demo resources:

  https://github.com/Narin-Laboratory/Webinar/tree/master/HandGesture

Hardware



Software

TensorFlow

ARDUINO

matplotlib

TensorFlow Lite

pandas

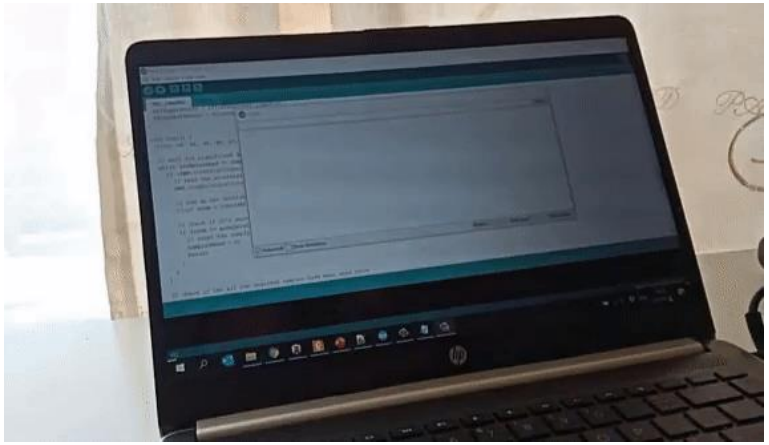
NumPy

Definisi Project

- Membedakan dua jenis gesture sederhana:

  Kepalan tangan **telungkup**

  Kepalan tangan **tengadah**

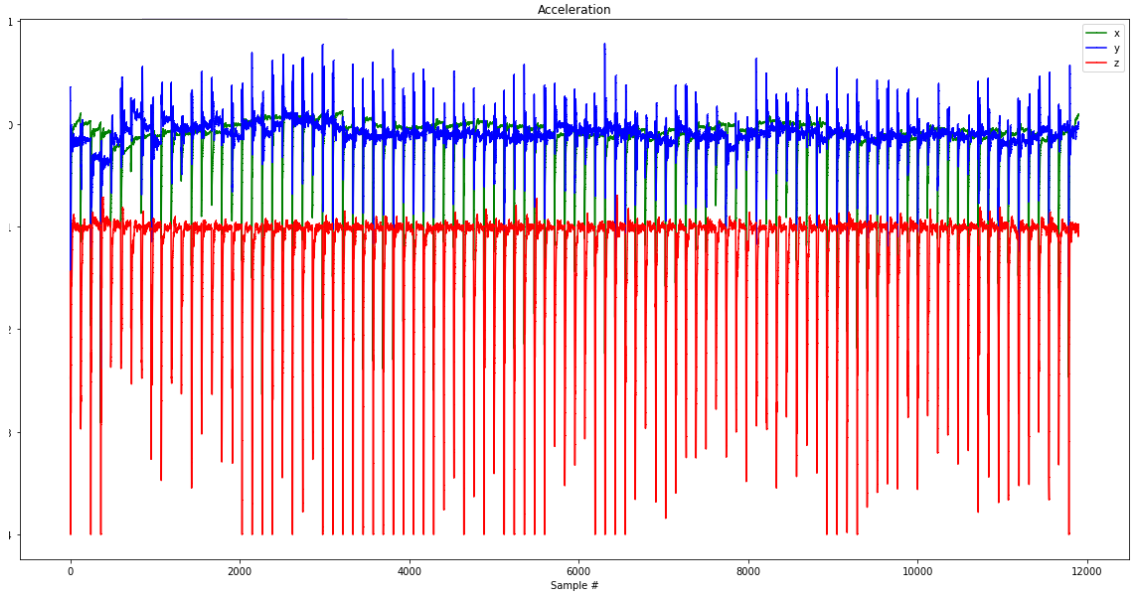


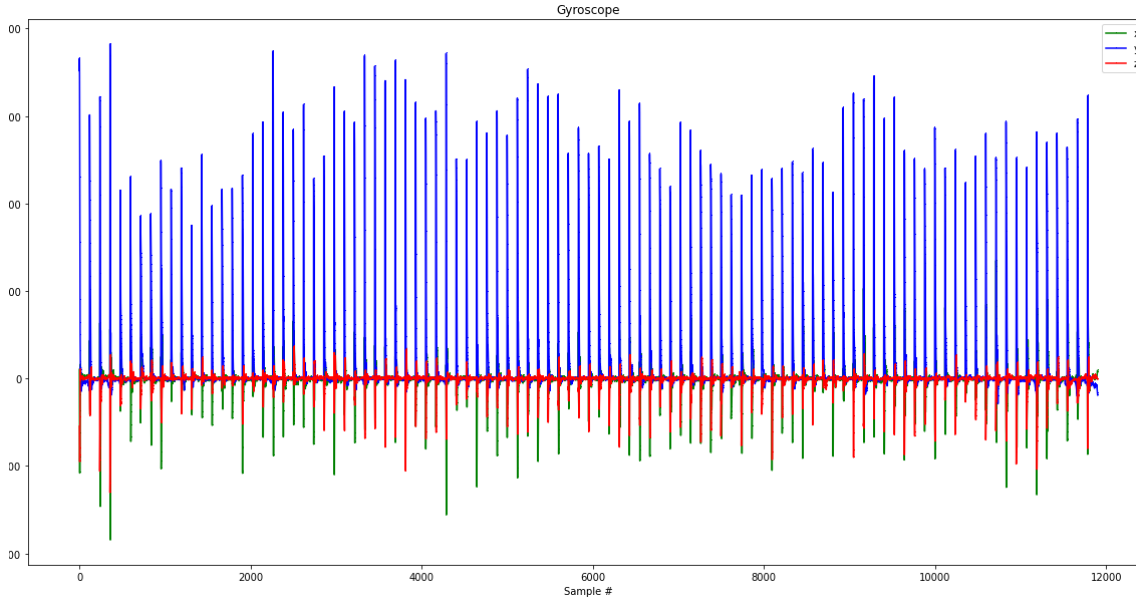
- Data:

  Output dari sensor IMU → **accelerometer** & **gyroscope**

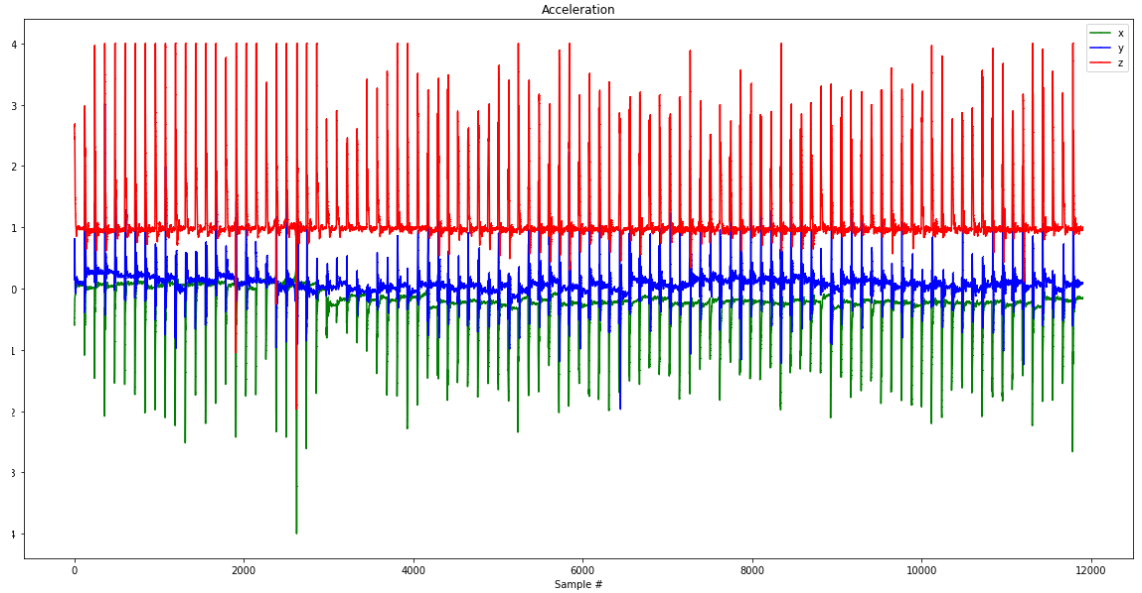
Model arsitektur: **Fully connected layer**

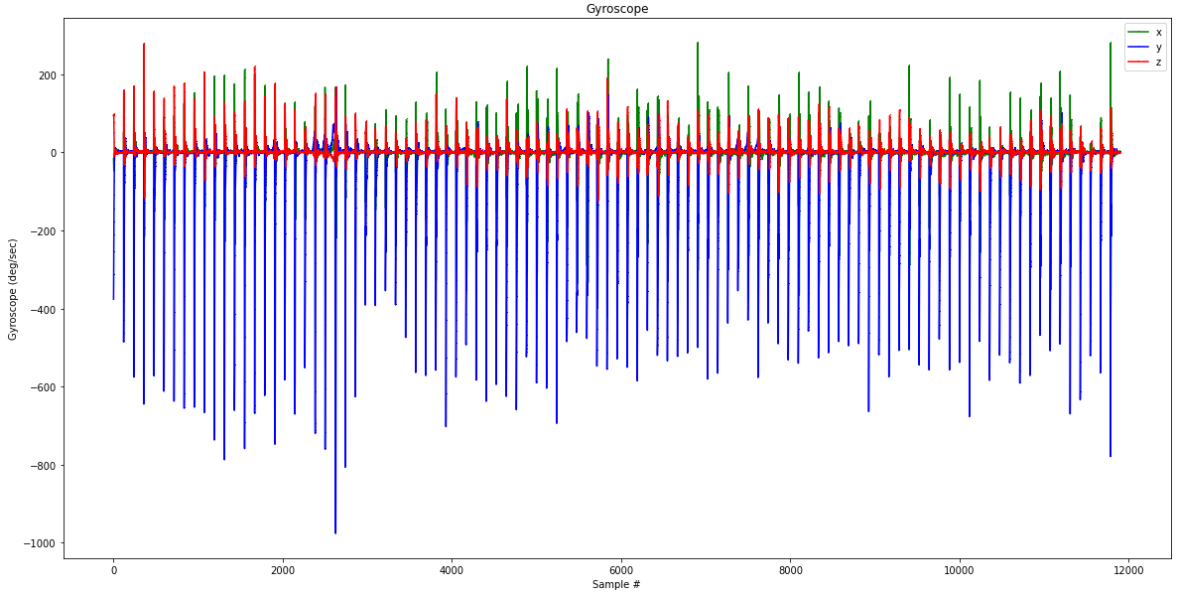
Telungkup



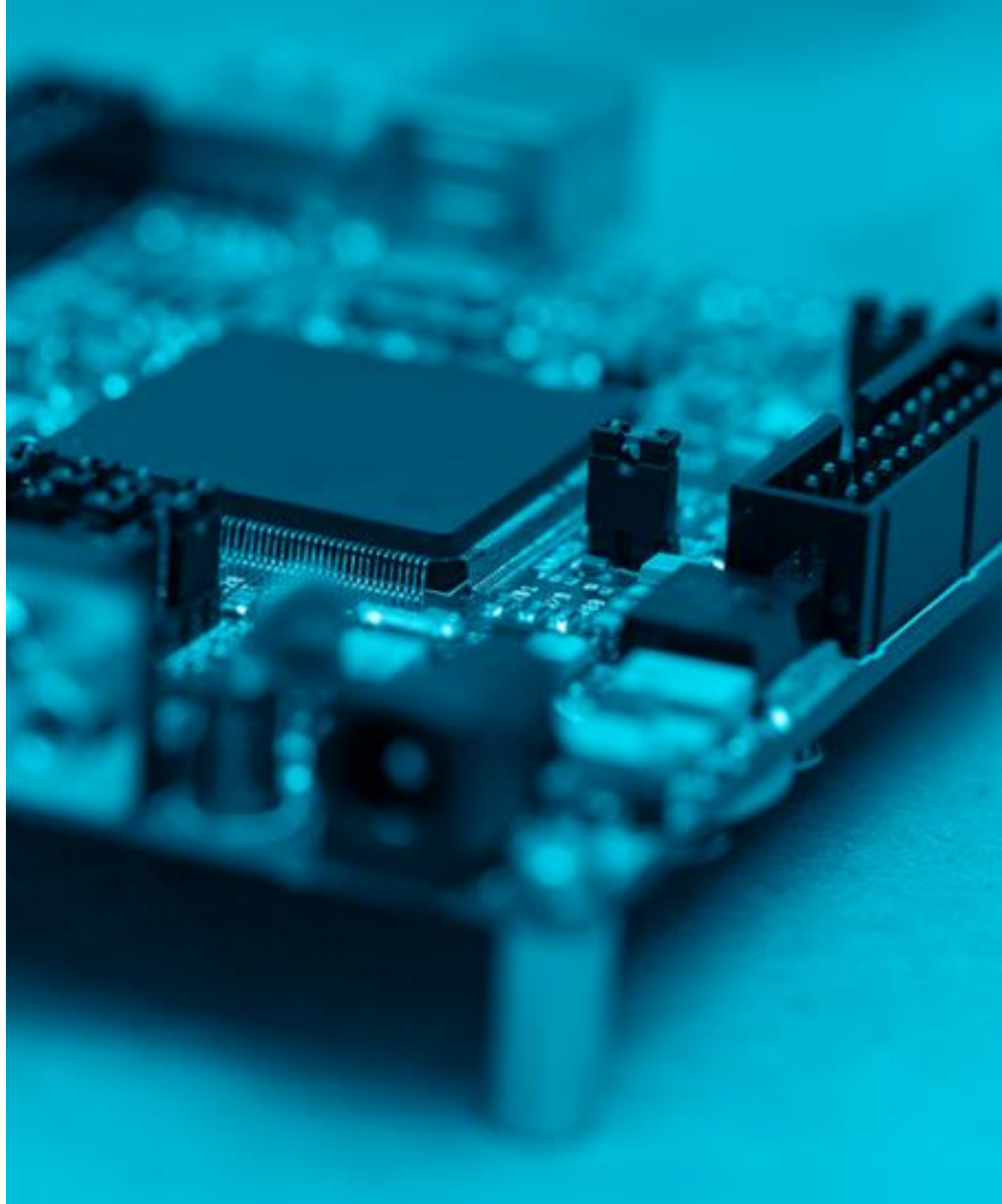


Tengadah

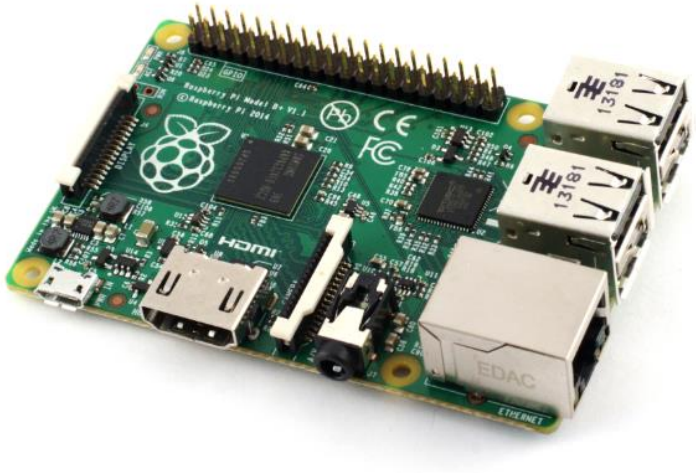




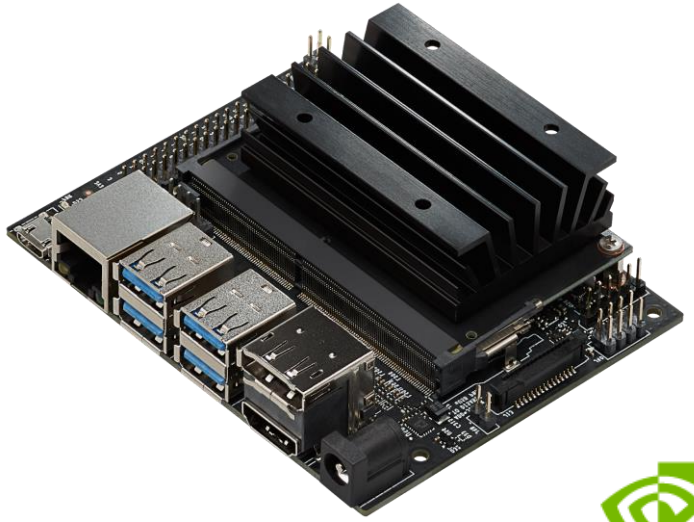
Saya tidak mau menggunakan mikrokontroler, tapi saya suka koding.
Ada saran agar bisa menggunakan ML untuk bidang embedded?



Gunakan Raspberry Pi atau SBC yang lain



Raspberry Pi



NVIDIA

Contoh: Prediksi Energi Listrik di Rumah Hunian

- Demo resources:

https://github.com/Narin-Laboratory/Webinar/tree/master/EnergyPrediction

- Reference resources:

https://github.com/LuisM78/Appliances-energy-prediction-data

https://archive.ics.uci.edu/ml/datasets/Appliances+energy+prediction

Hardware

Raspberry Pi3

Software

TensorFlow

TensorFlow Lite

scikit learn

matplotlib

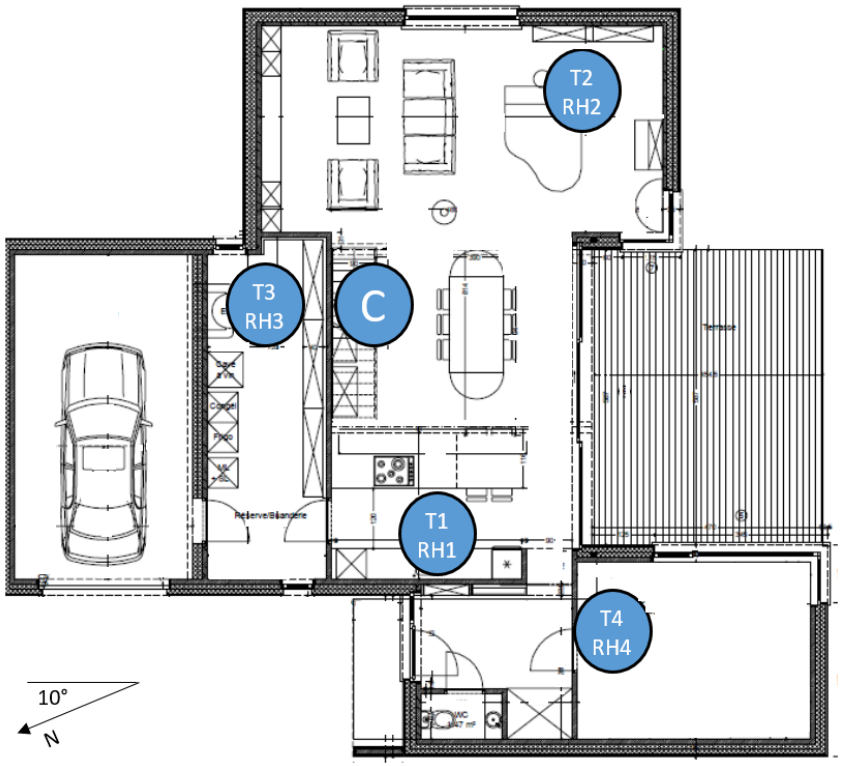
Seaborn

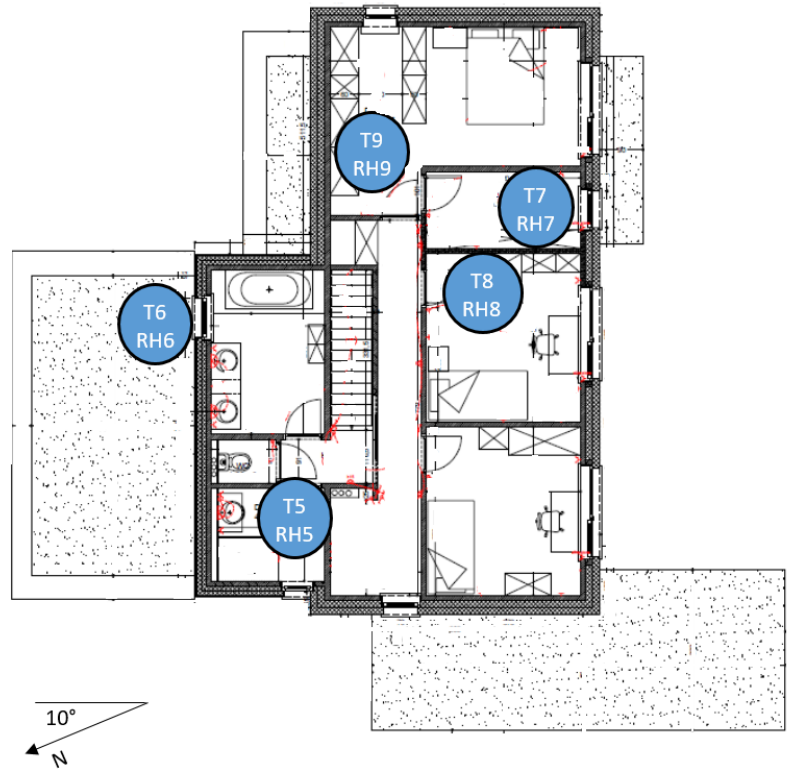
NumPy

pandas

Contoh Penerapan: Prediksi Energi Listri di Rumah Hunian

Data Driven Prediction Model

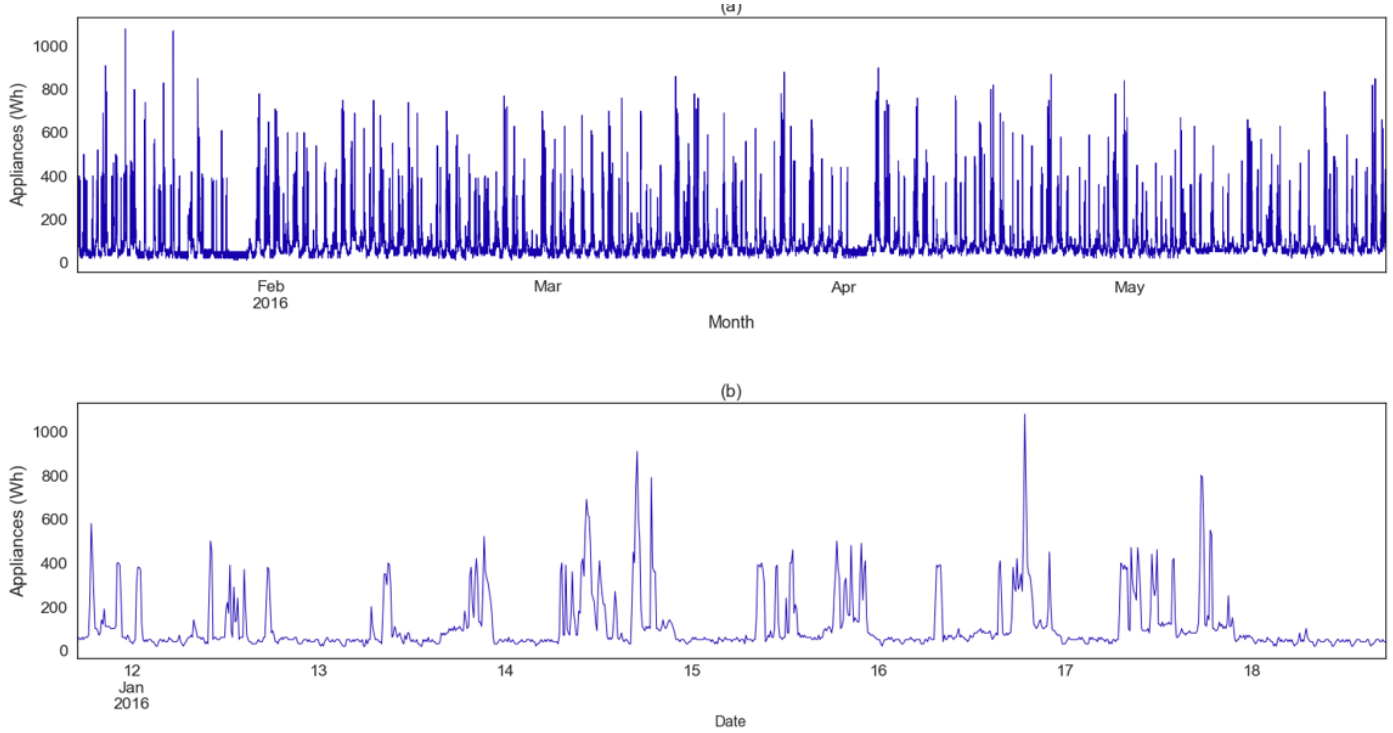




L. M. Candanedo, V. Feldheim, and D. Deramaix, “Data driven prediction models of energy use of appliances in a low-energy house,” Energy Build., vol. 140, pp. 81–97, Apr. 2017, doi: 10.1016/j.enbuild.2017.01.083.

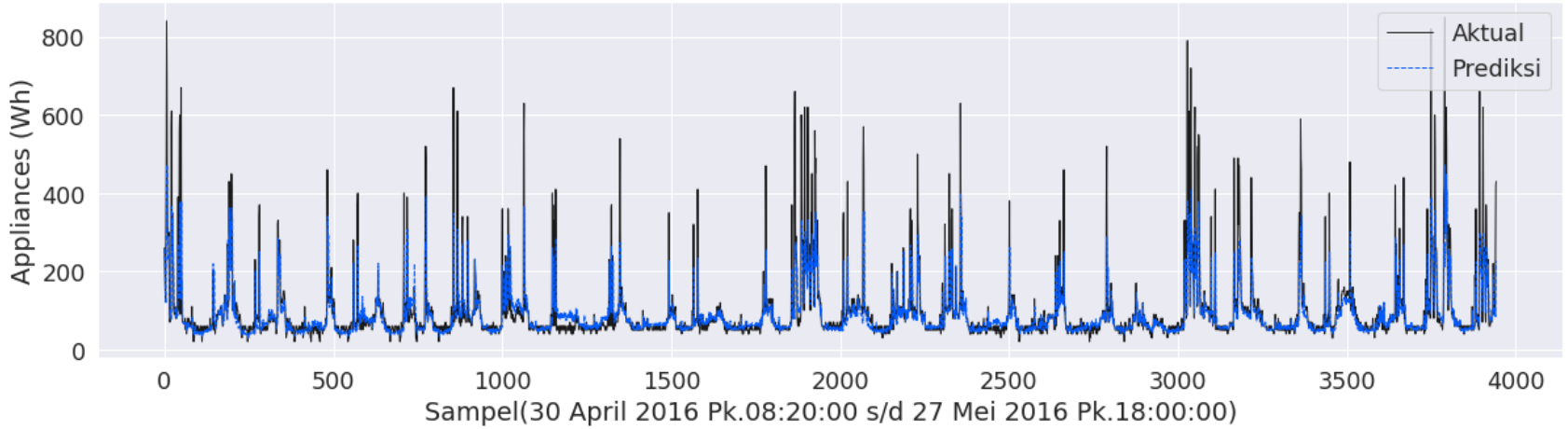
Studi Kasus 2: Prediksi Energi Listri di Rumah Hunian

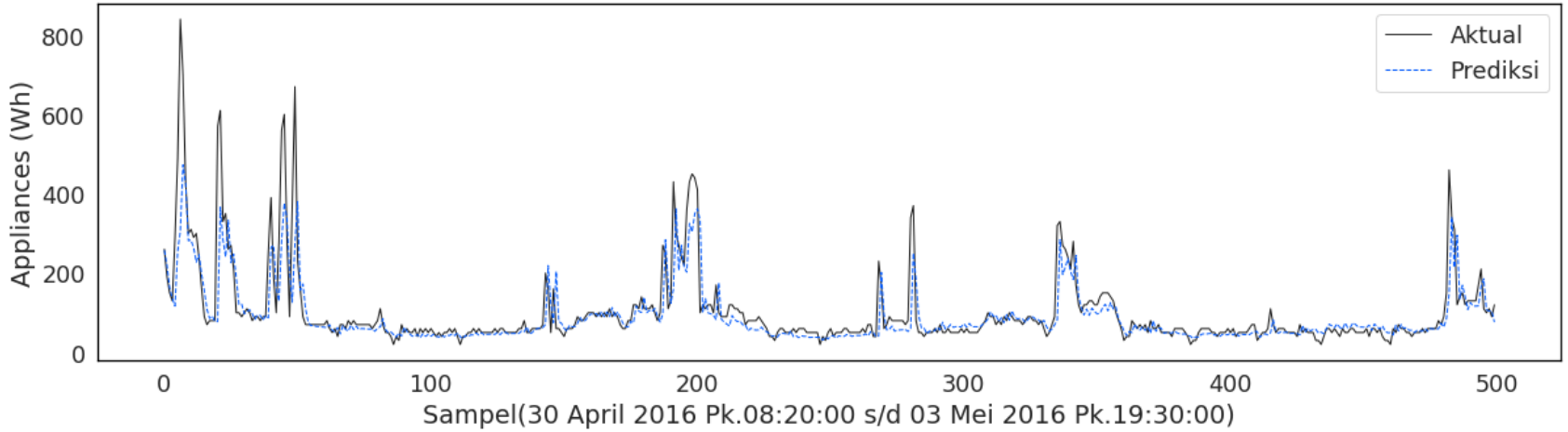
- **Tipe** : Regresi
- **Model arsitektur**: LSTM
- **Input**: lighting, suhu, kelembaban, kecepatan angin, dsb
- **Target**: memprediksi kebutuhan energi listrik
- Jumlah data: **19.735** baris data
- Pembagian data:
  - ✓ 60% sebagai data latih (11.841 baris)
  - ✓ 20% sebagai data validasi (3.947 baris)
  - ✓ 20% sebagai data uji (3.947 baris)

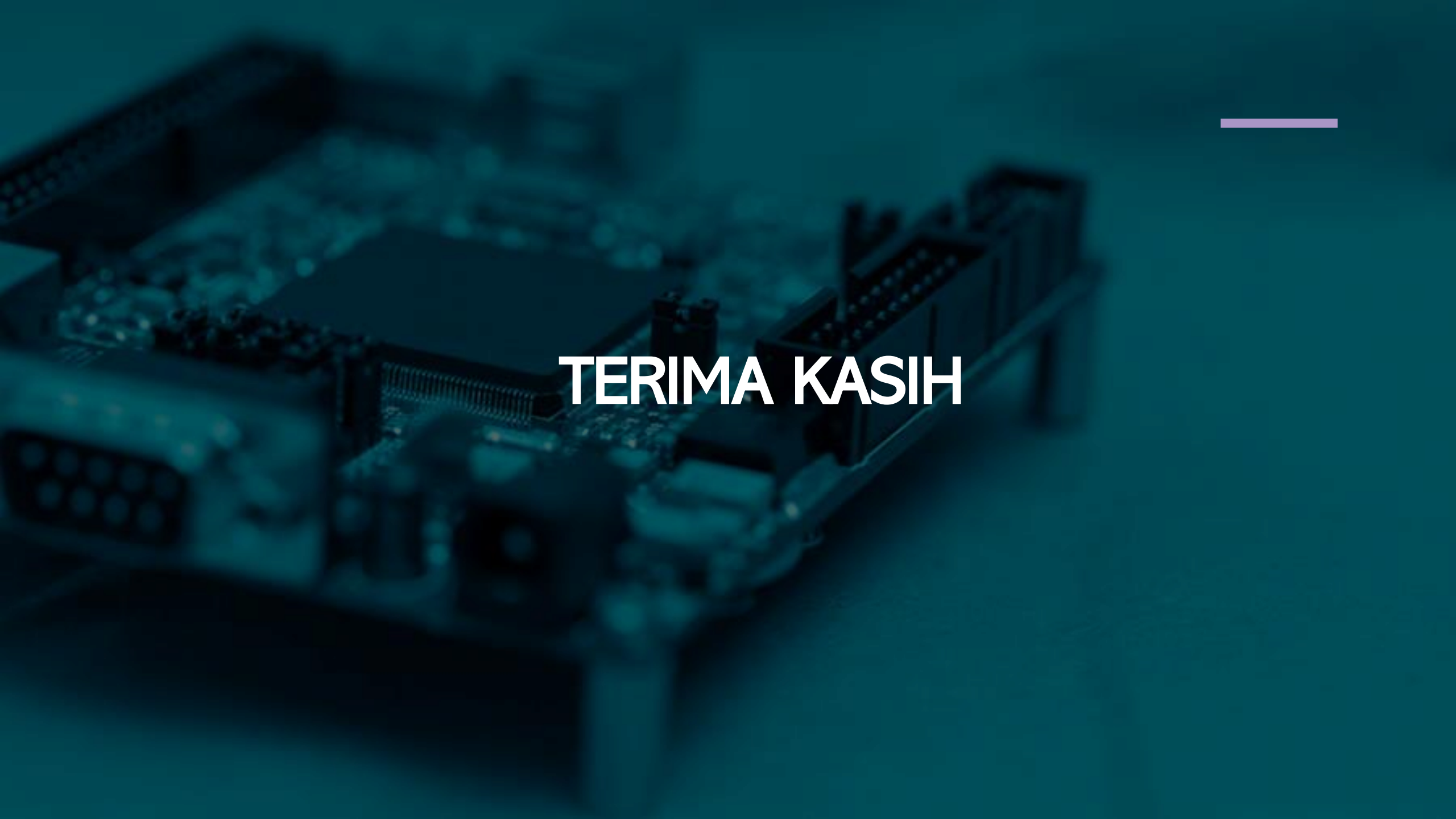


Gambar 1. (a) Pola konsumsi energi listrik selama periode penuh, (b) Tinjauan lebih detail untuk pola konsumsi energi selama satu minggu pertama

Hasil Prediksi







TERIMA KASIH