Human Behavior and Context Sensing

It takes many good deeds to build a good reputation, and only one bad one to lose it.

Benjamin Franklin

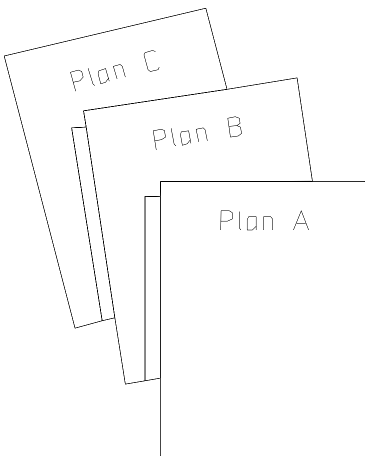
SEOUL NATIONAL UNIVERSITY

Human-Centered Computer Systems Lab

Overview

- Objective
  - ✓ To understand the computational aspect of life-immersive computing

- Content
  - ✓ Human behavior and context sensing
  - ✓ Computational challenges of context sensing



- After this module, you should be able to
  - ✓ Have a high-level understanding of human behavior and context sensing and their computational challenges

Notes on Project

- We have 9 amazing project teams!

- Think about how to work smoothly through various communication channels.

- Create a GitHub repo and share it with Kyungjin.
    - ✓ GitHub ID: kyungjin-lee

Life-Immersive Mobile Computing

Sense real-world situations and human behavior

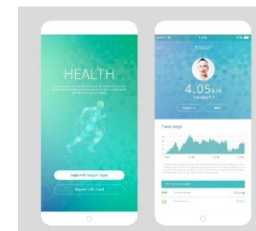
Extract and infer useful insights and Knowledge

Provide what people need right on time & place

Sleep Quality Monitoring

Pothole Monitoring

Location-aware Alarms



Physical Activity Diary

Bus Stop Queue Estimation

Proactive Advertisement

Life-Immersive Mobile Computing

- The first step toward realizing Mark Weser's vision for ubiquitous computing

The Computer
for the 21st Century

Mark Weiser

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.

Key Building Block:
Behavior and Context Sensing

Research Trends

Comprehensive/ detailed behavior

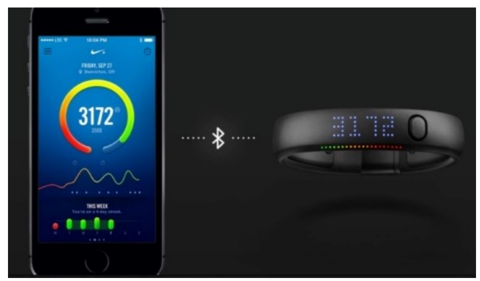
- ✓ Centimeter-level indoor localization

- ✓ Eating
- ✓ Smoking
- ✓ Shopping
- ✓ Dancing
- ✓ Drumming

- ✓ Turn-takings
- ✓ Linguistic contents
- ✓ Emotional expressions

External Behavior

Location



Physical Activity

Conversation

Internal States

- ✓ Heartrate
- ✓ Stress
- ✓ Mood
- ✓ Sleep quality
- ✓ Distractibility
- ✓ Intention
- ✓ Engagement
- ✓ Attention
- ✓ Mindfulness
- ✓ Emotion
- ✓ Anxiety
- ✓ Depression
- ✓ Boredom
- ✓ Fatigue
- ✓ …

Smartphone Sensors

Sensor-rich Environments

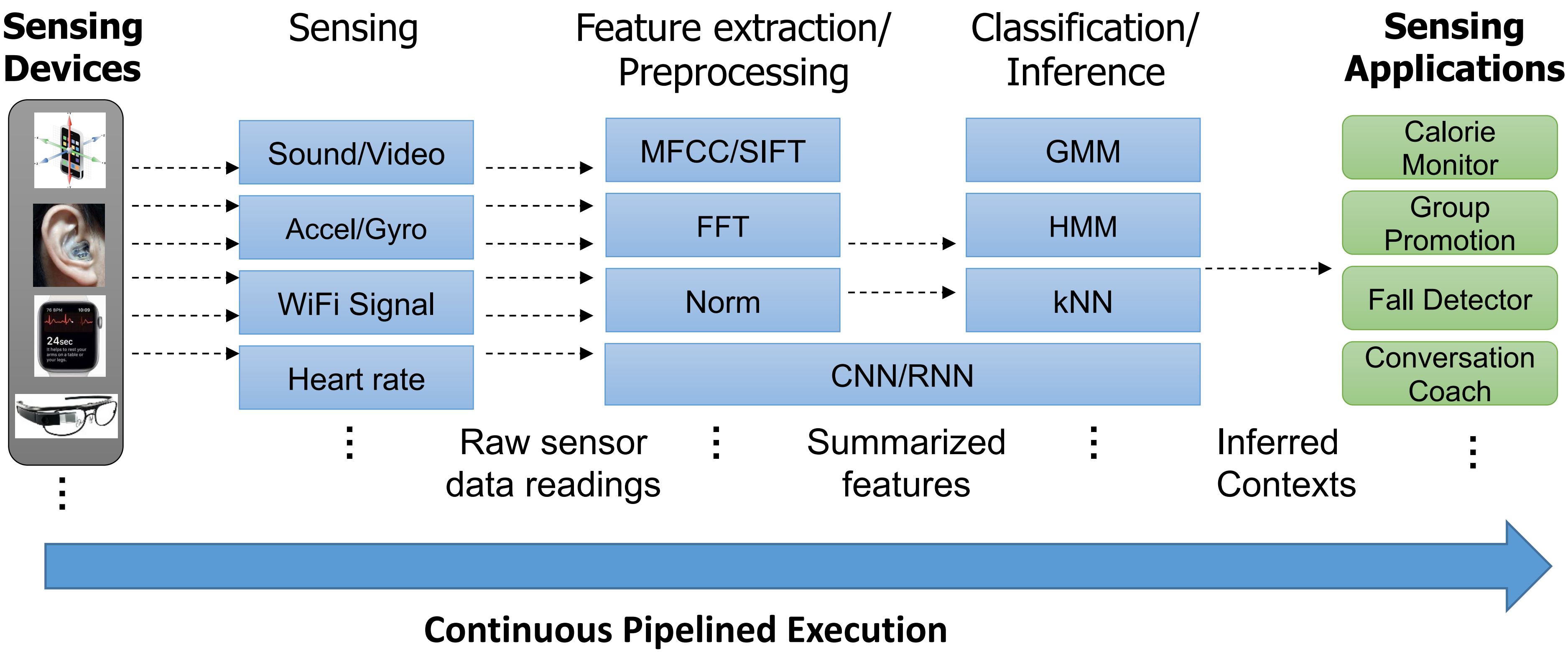
Wearable sensors

Phone-embedded sensors

☼ Space/object-embedded IoT sensors

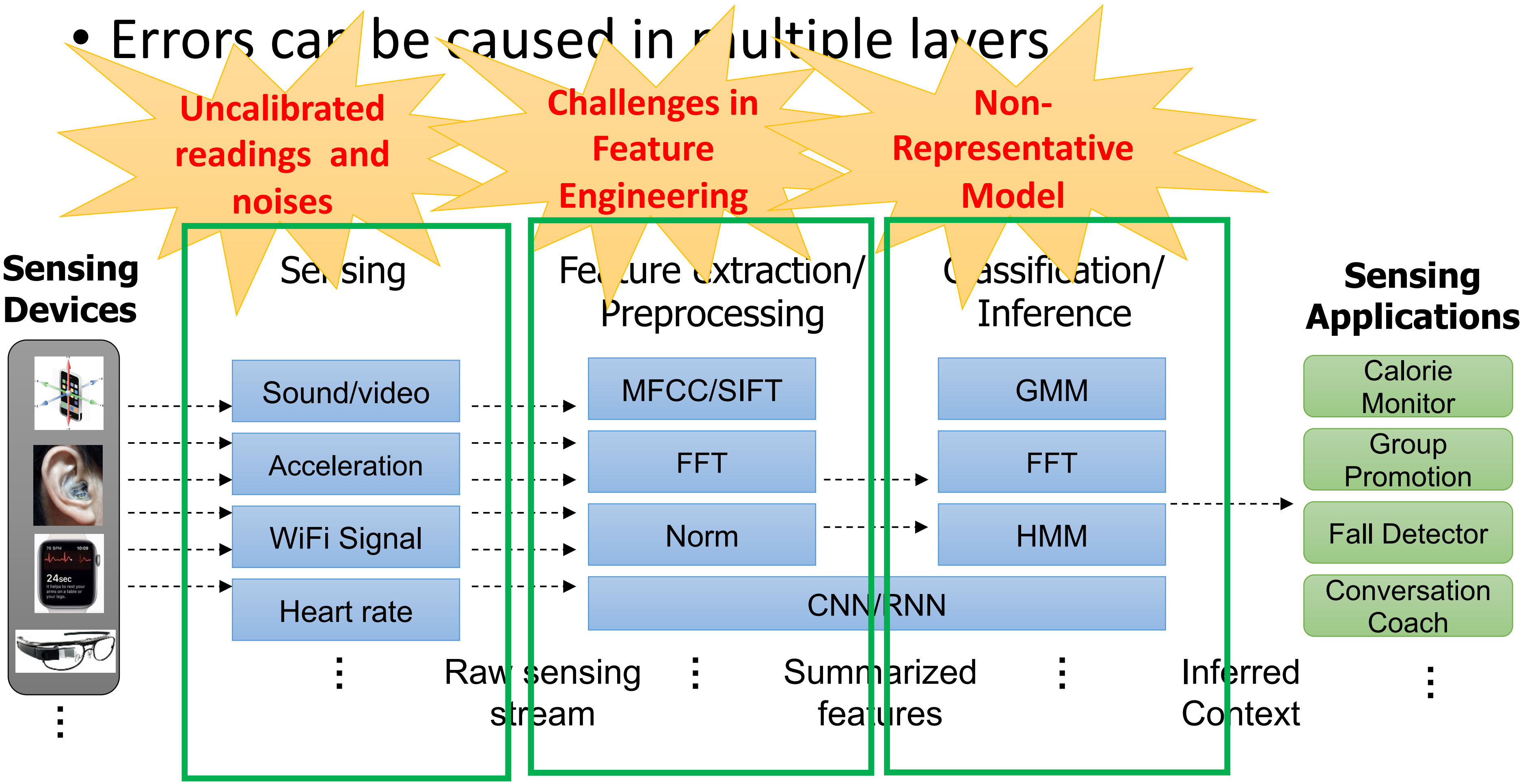
Common Computational Flow

1. **Continuous sensing of various low-level signals.**
2. **Extraction of user behavior and contexts using machine learning.**



Challenge 1: Inference Accuracy

- > 90% accuracy is extremely challenging.
- Errors can be caused in multiple layers

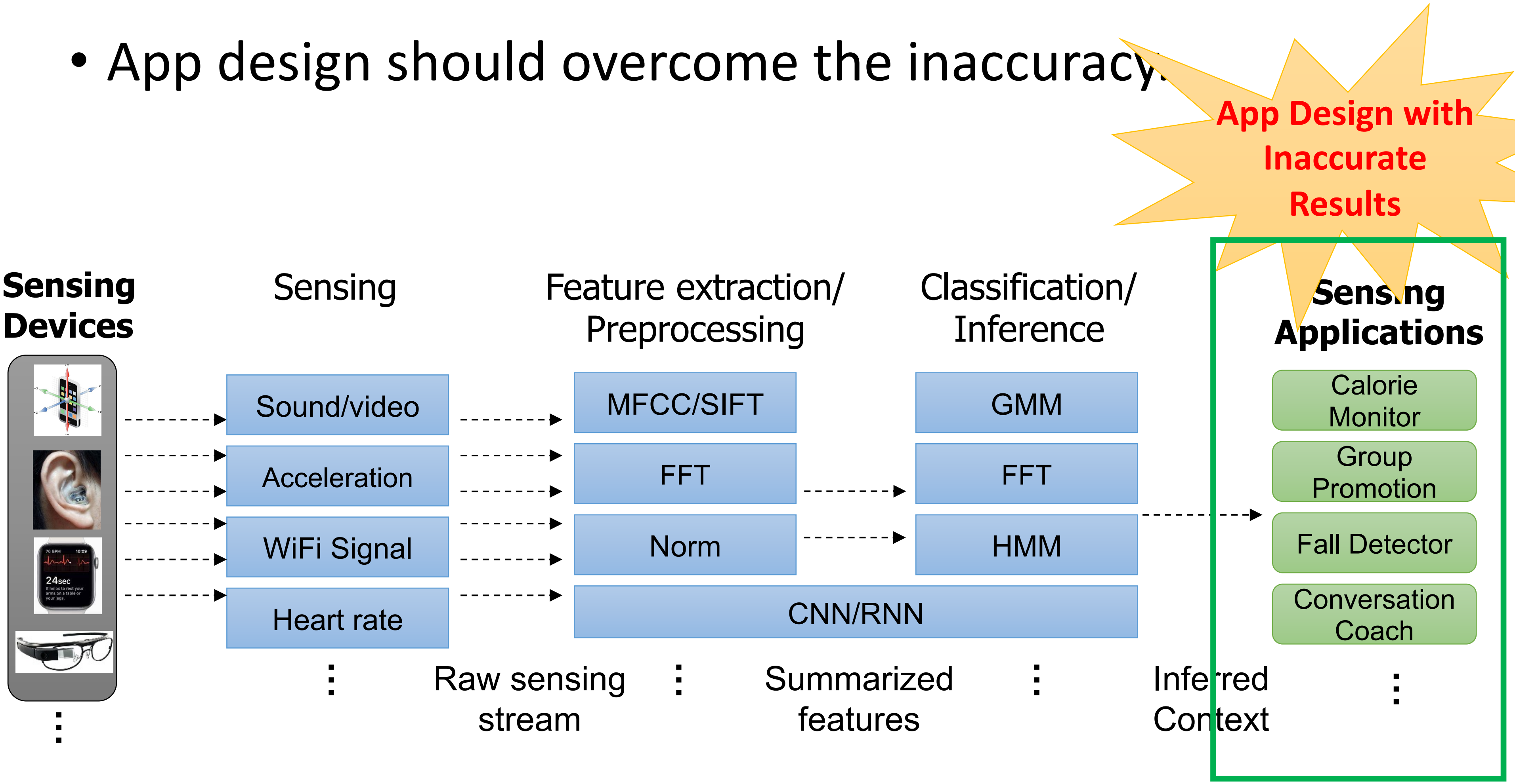


ML View vs. Mobile Computing View

Vision and text data	**Vs.**	Multi-modal sensory data from mobile/wearable/IoT devices
Clean and organized data from controlled environment	**Vs.**	Noisy and un-organized data from real worlds
Pre-collected, static set of data (no control on data and users)	**Vs.**	On-the-fly, dynamic set of data (control on data and users)

Challenge 2: Application Usability

- The inference results are not 100% correct.
- App design should overcome the inaccuracy.



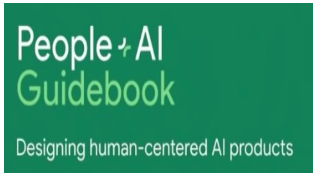
Human-AI Interaction (1/2)

Microsoft **Project Name : Guidelines for Human-AI Interaction**

- **Goal** : Recommend best practices for how AI systems should behave upon initial interaction, during regular interaction, when they are inevitably wrong, and over time – total 4 steps.
- *Guidelines for Human-AI Interaction* (CHI 2019)
  - The paper collected 150 AI-related design recommendations and synthesized them into 18 guideline sets, helping practitioners to design better human-centric AI-infused systems through this guidelines.
  - A user study was conducted with 49 HCI practitioners to evaluate the effectiveness of applying these guidelines to various existing products and whether the guideline is clear.

Human-AI Interaction (2/2)

Google **Project Name : [People + AI guidebook]**



- The guidebook is designed to introduce the entire development process of AI-driven services, beyond developing machine learning or deep learning models.
- It was introduced in 2019 Google I/O, and more details are available at this presentation.

Developer **WWDC 2019 Human Interface Guidelines for Machine Learning**

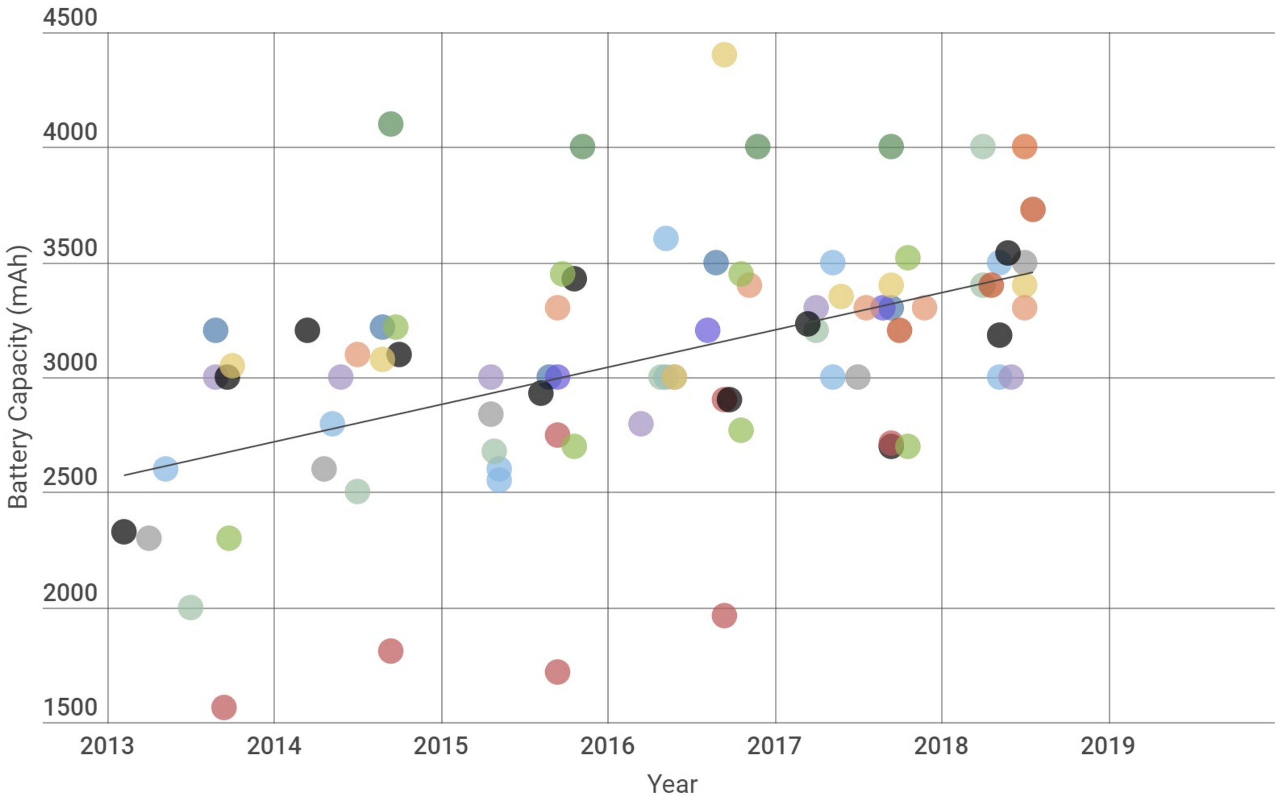
- Apple also suggests their own Apple's Guidelines, which is a much simpler set of advices on the practical app implementation.

Another good article to read:

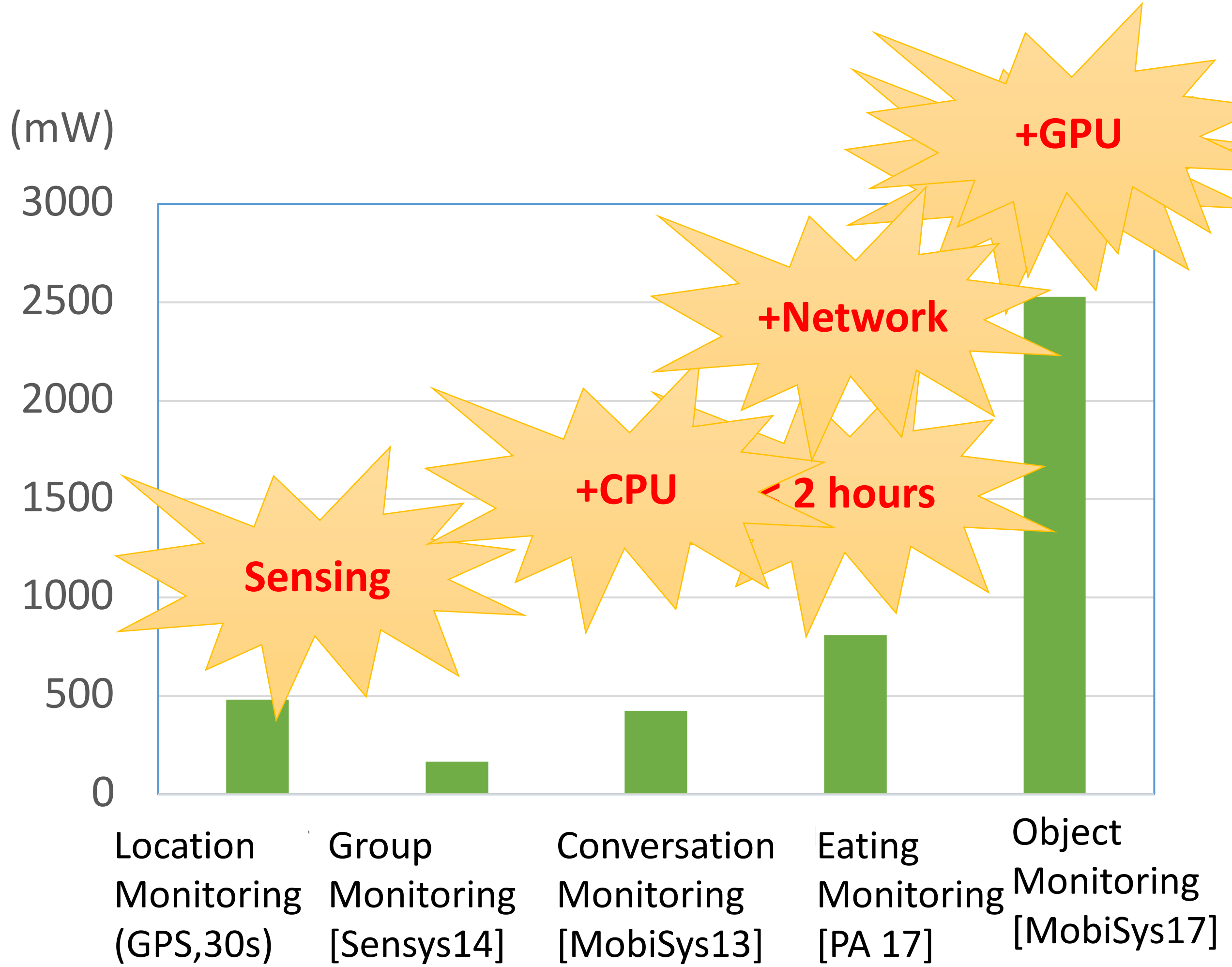
- Re-examining Whether, Why, and How Human-AI Interaction Is Uniquely Difficult to Design (CHI 2020, focuses more on UX design than on system design)

Challenge 3: Power Scarcity (1/2)

- Battery capacity hardly increases over time.
- It is much harder to improve 'performance per watt' compared to 'performance' for mobile devices.



Challenge 3: Power Scarcity (2/2)



- Measured with Samsung Note 4 (3220mAh battery)
- Used Samsung Gear (315 mAh battery) for Anapruna (eating detection)

Challenge 4: New Operational Mode

Vs.

A single user-interactive application

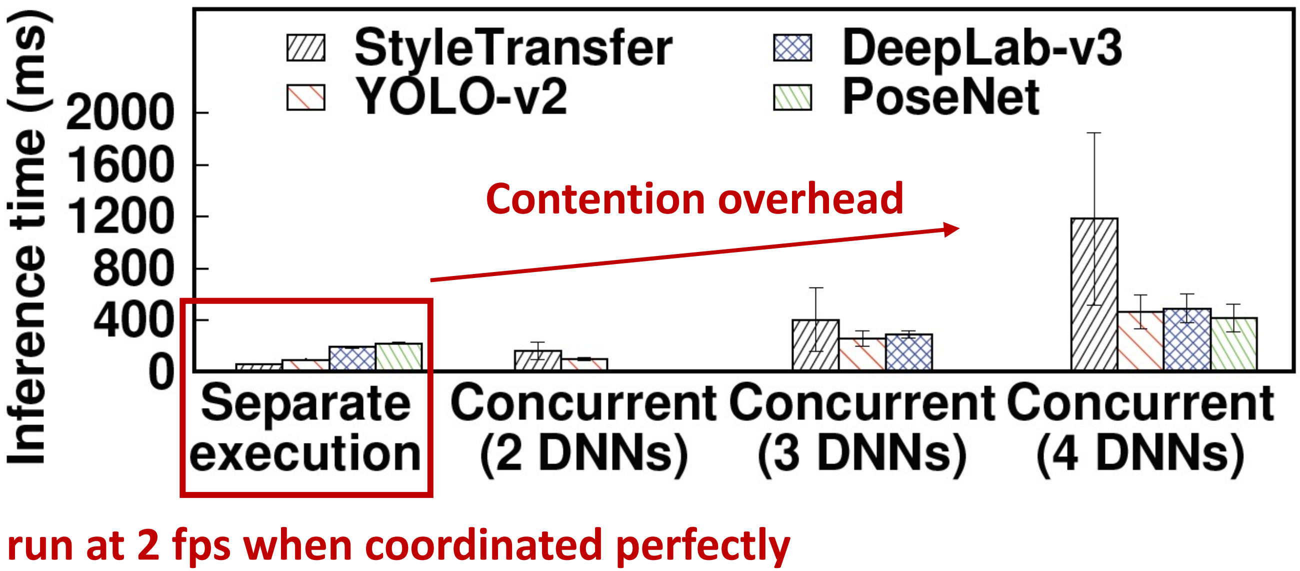
- Requiring continuous user attention
- Assumes limited interaction capabilities (e.g., small screen, touch interface)

Concurrent background-running applications

- Intermittent user interaction
- *Autonomous*, *situation-aware* services

Challenge 5: Resource Contention (1/2)

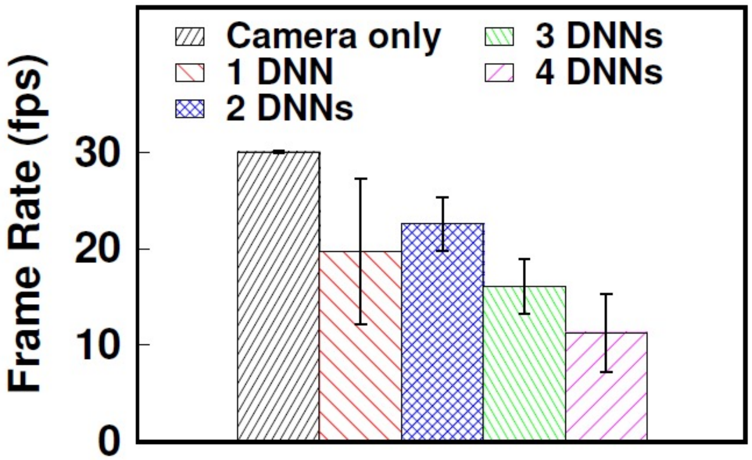
- Multi-DNN GPU contention degrades inference speed



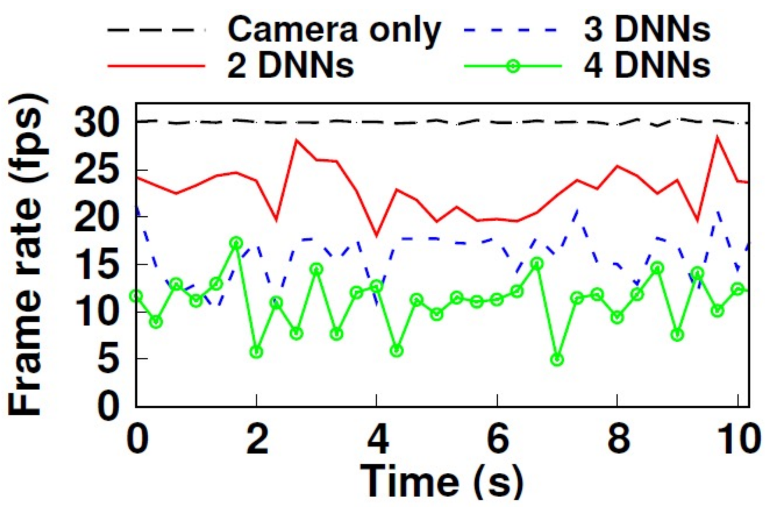
- Measurements on Xiaomi MACE over LG V50 (Qualcomm Adreno 640 GPU)

Challenge 5: Resource Contention (2/2)

- Rendering-DNN GPU contention degrades frame rate.



Average frame rate

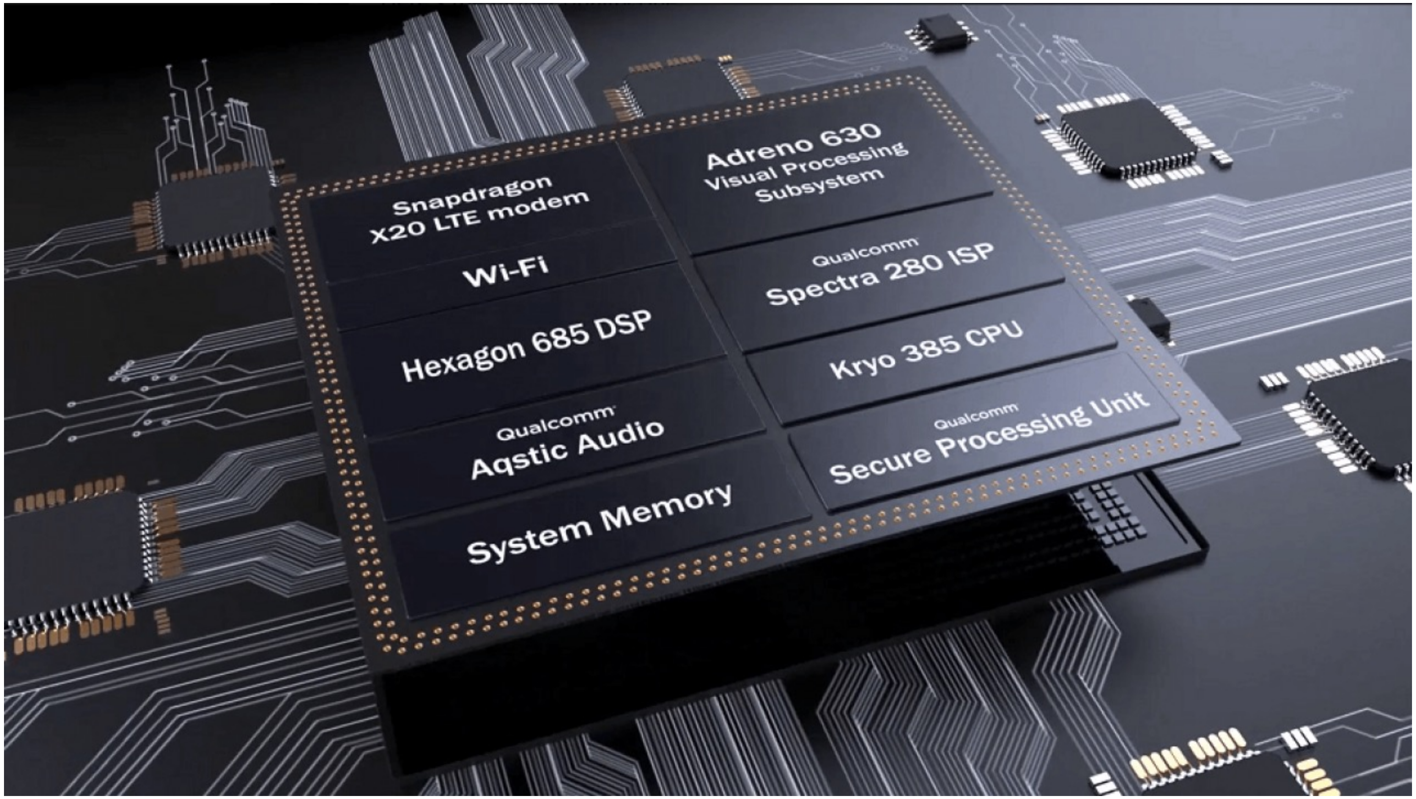


Frame rate over time

- Measurements on Xiaomi MACE over LG V50 (Qualcomm Adreno 640 GPU)

Mobile Processors and Architecture

- Many heterogeneous processors
- Single system-on-chip design with integrated architecture



Challenge 6: Poor Scalability

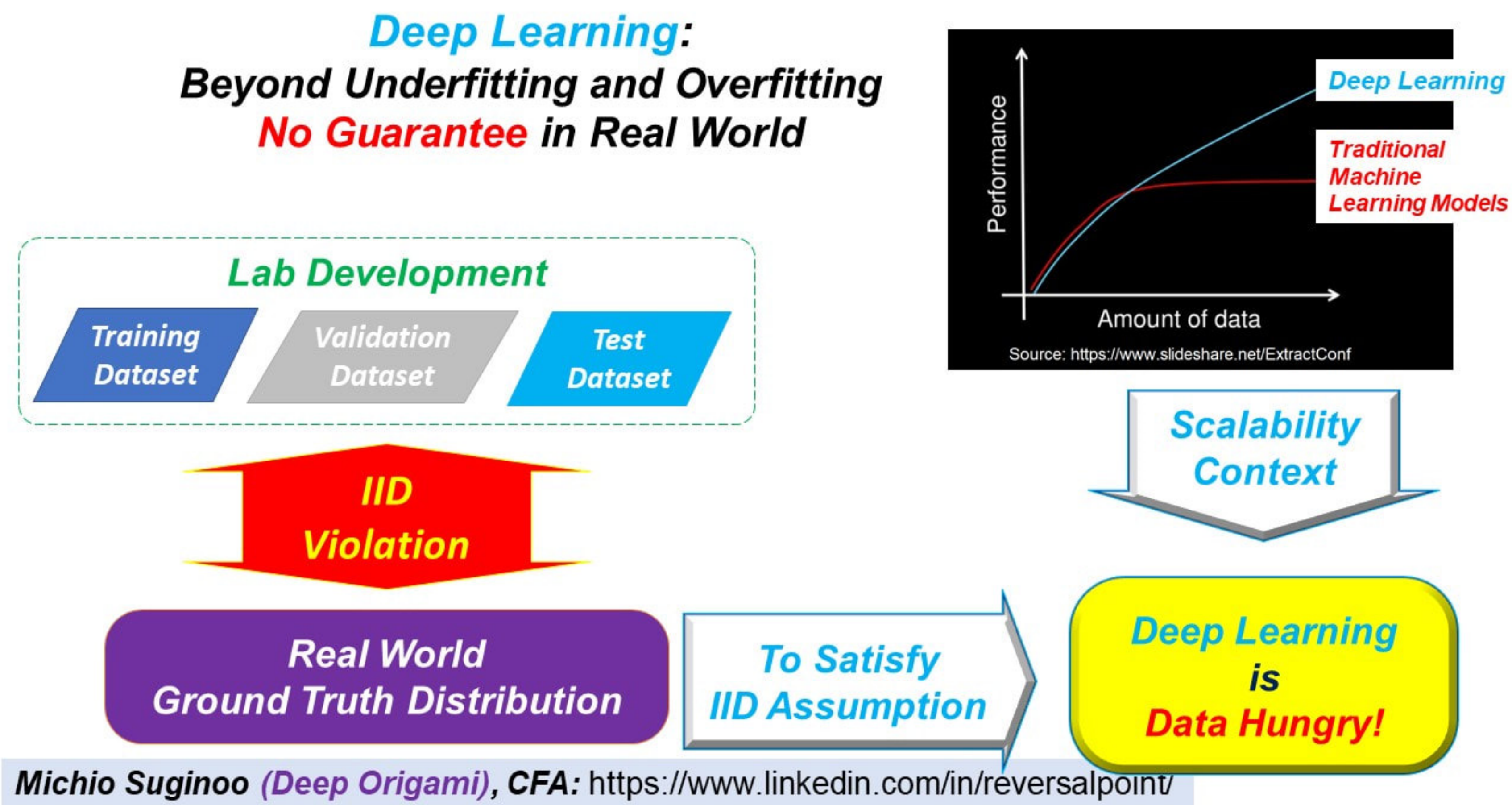
Amazing mobile s
How to test with

Lets test it with lab users and
a small number of real users and
consider it "real-world".

Wow! It does not work!
Need access to real venues
With real users on real devices
HOW???

IID Assumption in Machine Learning

- It is difficult to know if “Independent and Identical Distribution Assumption” (IID assumption) holds or not.



Individual Applications Solve All These?

Complexity to implement **accurate** inference logics and handling inaccuracy in app design

Serious **optimization** in battery and resource usage

Scalable deployment and testing with a large pool of real users in real-life situations