Mindful AI for Adaptive, Resilient CyberPhysical Human Systems (CHPS)

Nikil Dutt
Dutt Research Group
UC Irvine

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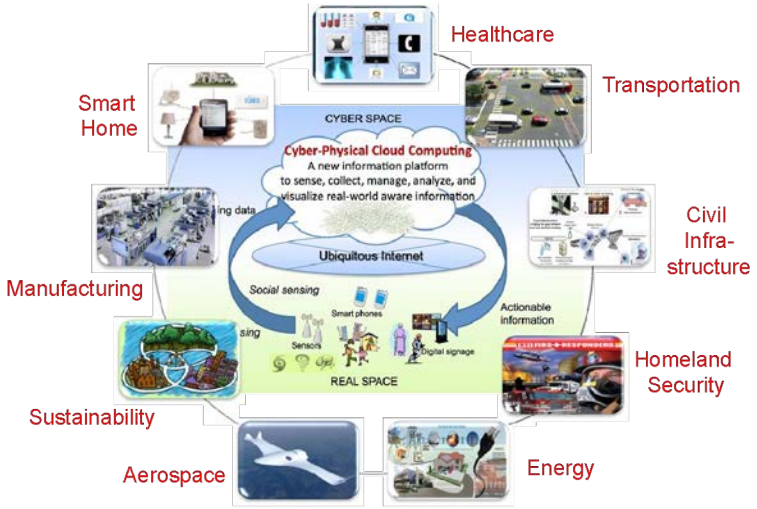
Cyber-Physical Human Systems and Omni-Layer Intelligence

Cyber-Physical Human Systems (CPHS):

- Small-scale IoT to large system-of-systems
  - Diverse verticals with varying goals and constraints
  - Humans interacting with CPS



[Courtesy Fadi Kurdahi]

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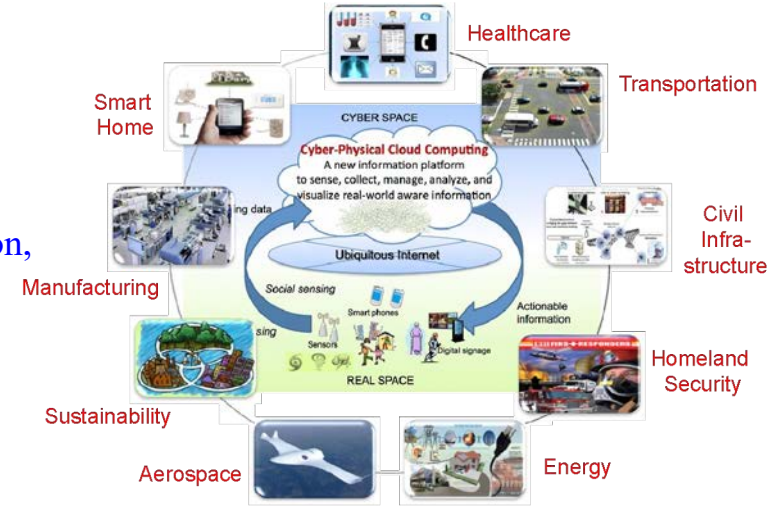

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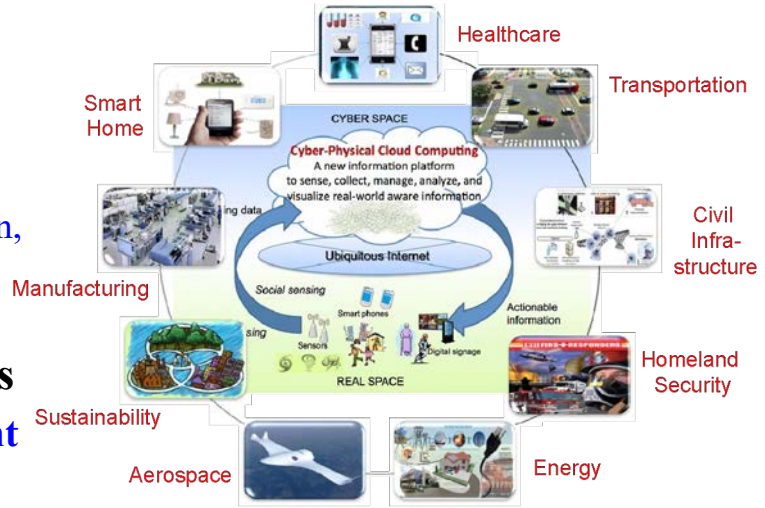
- **New Challenge: Intelligence embedded across layers**
  - **unpredictable AI, unpredictable/unforeseen/emergent behaviors, unpredictable human intervention….**
- **Inherently Dynamic: Need adaptive, run-time mechanisms, online learning, safeguards,...**



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Another Challenge: Diversity in Systems & Applications

Abstraction Layers

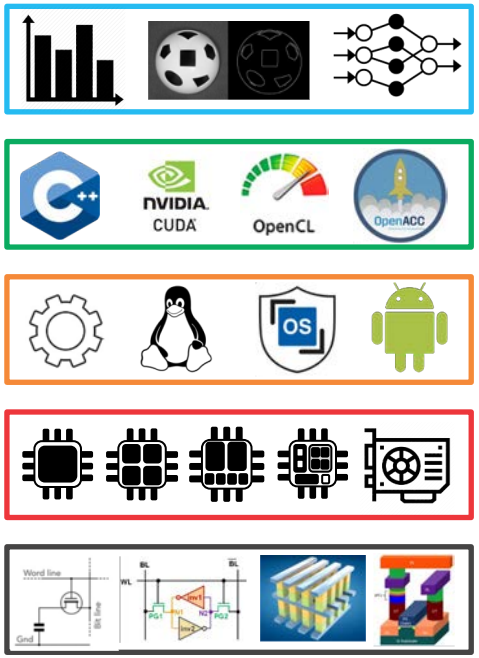
Applications

Vendor Libraries

Kernel

Architecture

Device Tech



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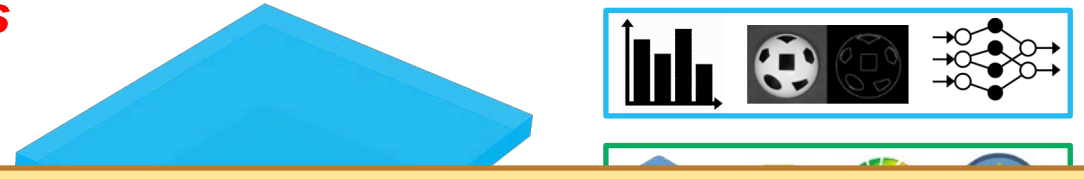

- **"Triple Whammy" of changes:**
  1. Platforms (e.g., process variability, aging, ..)
  2. Environment (e.g., temperature, radiation, …)
  3. Application dynamics (e.g., processing, memory, unpredictable AI..)
- Static design techniques can't cope with changes
- Increasing need for runtime adaptivity
- Cross-layer Computational Cognitive Intelligence (CCI) to the rescue?

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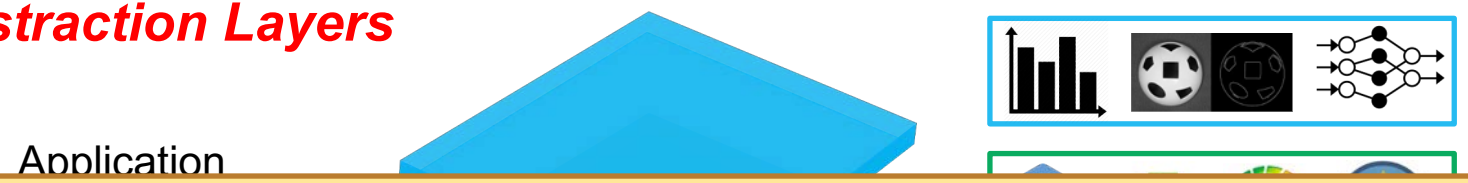

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- **Mindful AI to the rescue?**

What is Mindfulness?

Mindfulness

From APA (American Psychological Association)

The capacity to maintain awareness of both internal and external states in a deliberative, adaptive manner.

Mindfulness enhances Cognitive Intelligence

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Three Related Questions for CHPS:

1. **What is Cognitive Intelligence?**
2. **How does Mindfulness enhance Cognitive Intelligence?**
3. **What is Mindful AI for CHPS?**

1. What is Cognitive Intelligence?

The mental processes your brain uses to acquire, store, transform, and use information.
It's how we perceive the world, make sense of it, and act on that understanding.

The mind's capacity to learn, understand, and use knowledge to
think, reason, solve problems, and adapt to new situations.

From APA, GPT-5, Claude Sonnet 4, Gemini 2.5

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Core Cognitive Processes

From APA, GPT-5, Claude Sonnet 4, Gemini 2.5

- **Perception** - How we interpret sensory information
- **Attention** - Focusing on specific stimuli while filtering out others
- **Memory** - Encoding, storing, and retrieving information
- **Learning** - Acquiring new knowledge and skills
- **Language** - Understanding and producing communication
- **Thinking** - Mental manipulation of information
- **Problem-solving** - Finding solutions to challenges
- **Decision-making** - Choosing between alternatives

2. How does Mindfulness enhance Cognitive Intelligence?

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2. How does Mindfulness enhance Cognitive Intelligence?

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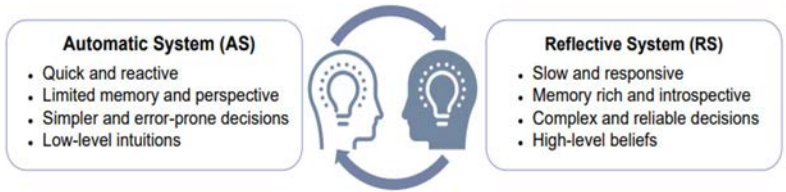
Mindfulness enhances Core Cognitive Skills

From GPT-5, Claude Sonnet 4, Gemini 2.5

- Perception
- Attention
- Memory
- Learning
- Language
- Thinking
- Problem-solving
- Decision-making
- **Metacognition: thinking about one's own thinking (self-awareness, strategies)**
- **Executive functions - Planning, organizing, and controlling behavior**



3. What is Mindful AI for CPHS?

Use computational abstractions of mindful biological cognition

Computational Cognitive Intelligence (CCI): biologically inspired, but adapted for computing systems

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- ❑ Explicit models of ***self***, ***environment***, and ***context*** for adaptivity/autonomy
- ❑ **Computational abstraction of mindful biological cognition**: self- and environmental-models; goal management; understanding & reasoning; contextualization; and history
- ❑ Use **CCI reference architecture** for driving adaptive system design

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What is Self-Awareness?

Self-awareness

From Wikipedia

From Wikipedia, the free encyclopedia

Not to be confused with Self-concept, Self-consciousness, Self-perception, or Self image.

This article has multiple issues. Please help improve [hide] it or discuss these issues on the talk page.

- This article **may require cleanup to meet Wikipedia's quality standards.** *(March 2009)*
- This article **needs attention from an expert on the subject.** *(May 2009)*

Self-awareness is the capacity for introspection and the ability to recognize oneself as an individual separate from the environment and other individuals.

Contents [hide]

1 In philosophy
2 In biology
  2.1 Animals
  2.2 Evolution
  2.3 Neurological basis

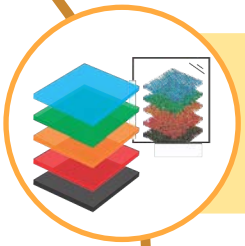
The mirror test is a simple measure of self-awareness.

From GPT-5, Claude Sonnet 4, Gemini 2.5

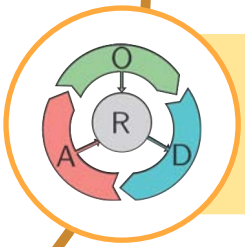
Self-awareness is the ability to see yourself clearly and objectively through **reflection and introspection**. It involves monitoring your own internal state, including your thoughts, emotions, and beliefs, as well as understanding how you are perceived by others.

Computational Self-Awareness

Computing systems that.. [Kounev 2015]



learn models capturing knowledge about themselves and their environment on an ongoing basis



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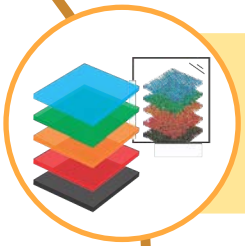

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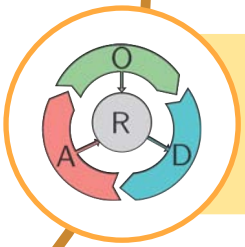

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Computational self-awareness enables

- **Adaptive autonomy** for runtime decisions
- Capability to **reason about** and **manage autonomy at runtime**

Computational Self-Awareness: A Hierarchical View Self-*

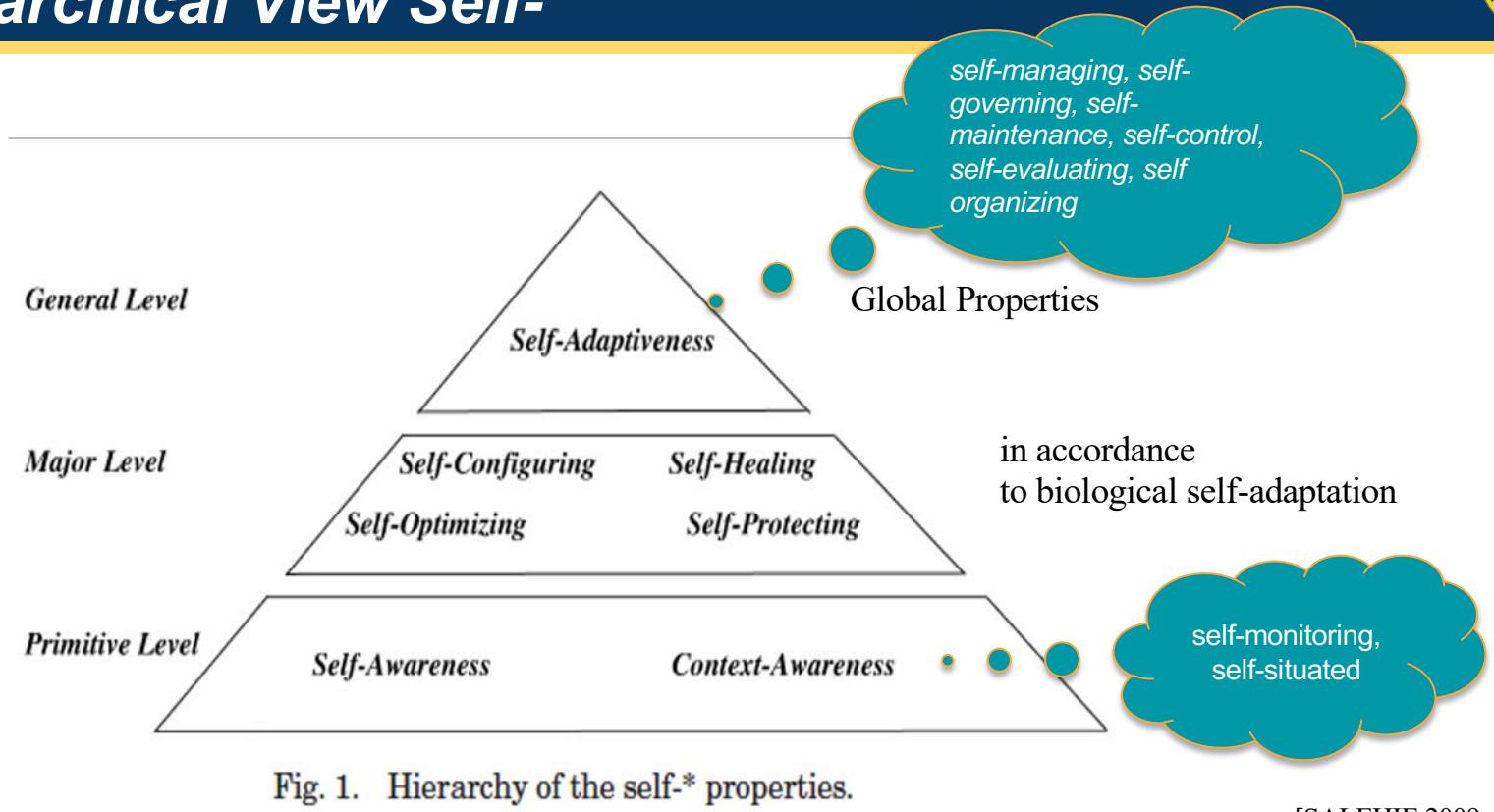

Fig. 1. Hierarchy of the self-* properties.

[SALEHIE 2009, TAAS]

Self-* Computing: Related Efforts

- Self-test, Self-diagnosis, Self-Repair for chips and computing platforms (several decades)

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- **Missing pieces for CHPS:**
  - **Cross-layer sensing/actuation**
  - **Self-modeling and introspection**
  - **Modeling environment and context**
  - **Control/coordination of emergent behaviors**

Building Computationally Self-Aware Systems

- Self-Aware Systems
  - ***Construct model*** of behaviors and environment using sensor data
  - Achieve ***self-awareness*** through cross-layer sensors and monitors
    - Experience phenomena
    - Aware of state and behavior
  - The ability to ***introspect***
  - ***Adapt behavior*** based on model of external and internal environment

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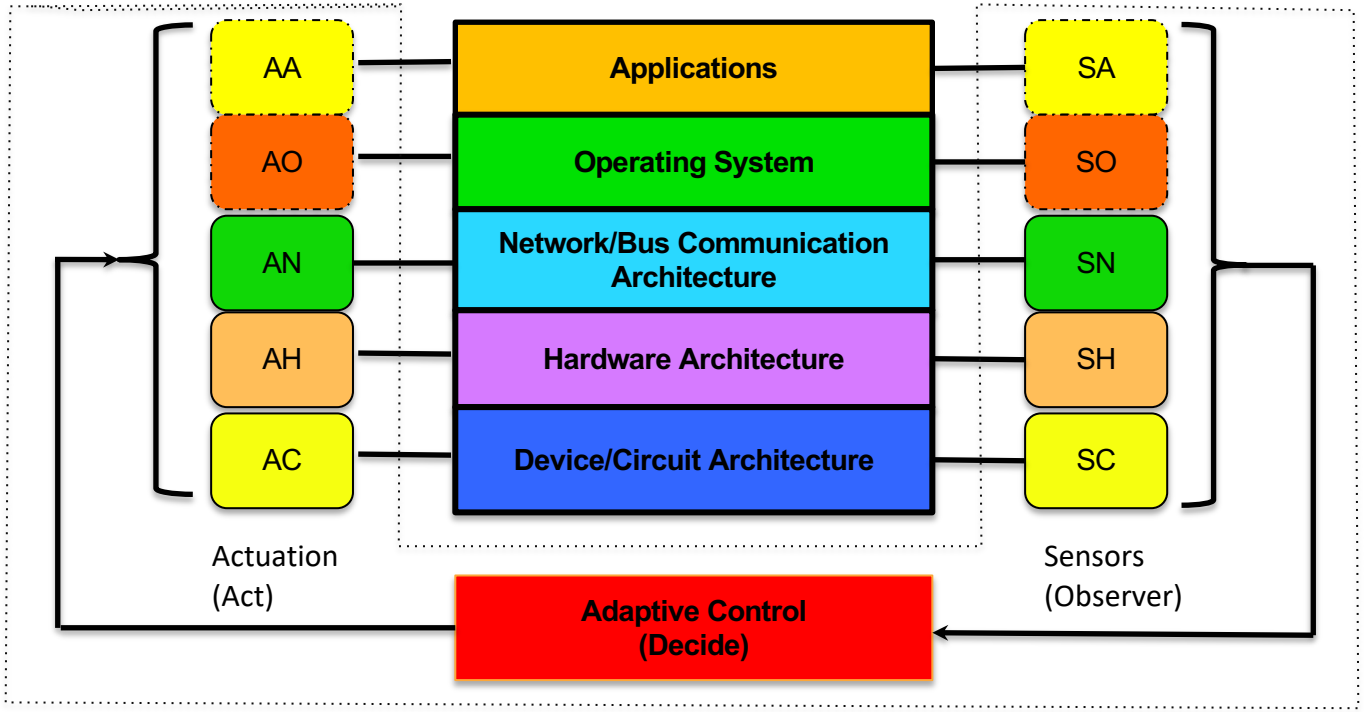
Cross-Layer Physical/Virtual Sensing & Actuation



Cross-Layer Physical/Virtual Sensing & Actuation: Examples

Layers	Virtual/Physical Sensors	Virtual/Physical Actuators
Application	Execution Time, Workload Power, Energy,	Loop perforation Algorithmic Choice
Operating System	System Utilization Peripheral States	Task Allocation, Scheduling, Migration, Duty Cycling
Network/Bus Communication	Bandwidth; Packet/Flit status; Channel Status, Congestion, Latency	Adaptive Routing Dynamic Bandwidth Allocation Ch. no and direction
Hardware Architecture	Cache misses, Miss rate; access rate; IPC, Throughput, ILP/MLP, Core asymmetry	Cache Sizing; Reconfiguration, Resource Provision Static/Dynamic Redundancy
Circuit/Device	Circuit Delay, Aging, leakage Temperature, oxide breakdown	DVFS, DFS, DVS ABB, Clock and Power-gating

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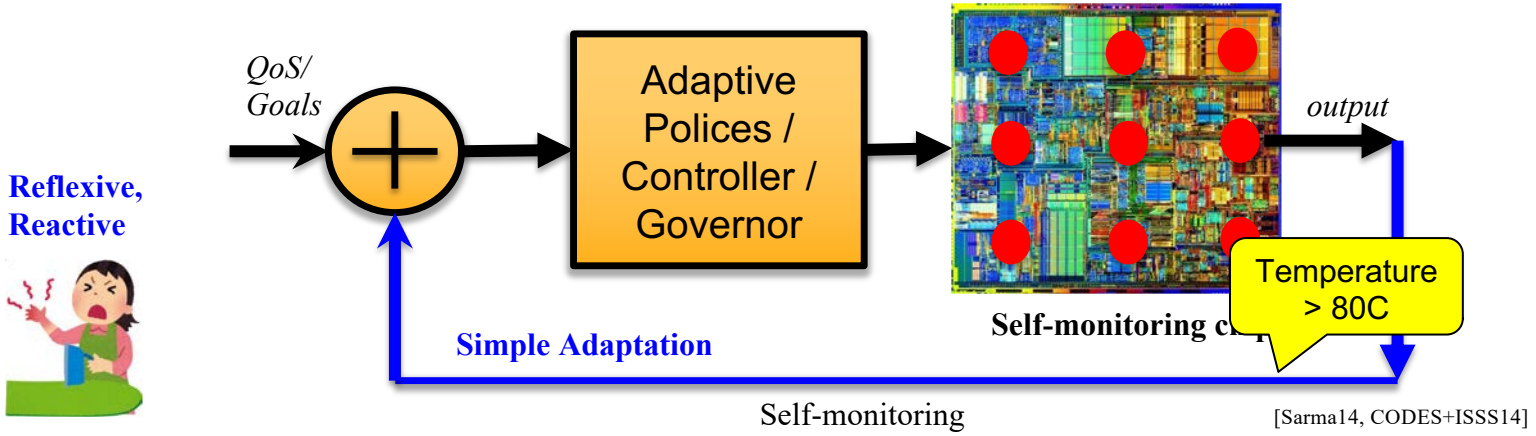
Reflex

Reflexive, Event-driven, Reactive

- **Actions driven solely on external feedback**
  - **E.g., our autonomic nervous systems**

Towards Self-Aware Systems: What we do now



[Sarma14, CODES+ISSS14]

Reflex vs Reflect

Reflexive, Event-driven, Reactive

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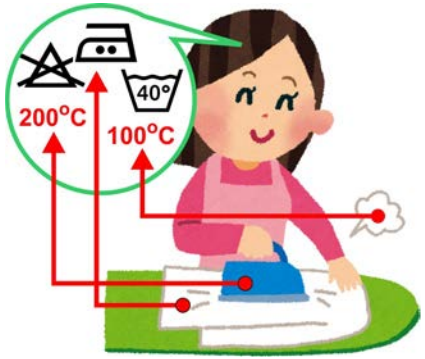
Reflection, Introspection, Proactive

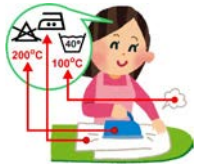


- Consider past and future outcomes
  - E.g., planning, strategies, policies, …

Towards Self-aware Systems

Beyond simple reactive models

Reflection, Introspection



Reflexive, Reactive

There is unusual activity in Core 27

System Behavior (Model Building)

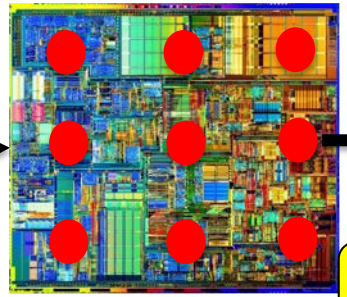
measurement

input

Self-Aware Adaptation

QoS/ Goals

Adaptive Polices / Controller / Governor



output

Temperature > 80C

Self-monitoring chip

Simple Adaptation

Self-monitoring and **Self-modeling**

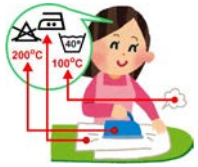
[Sarma14, CODES+ISSS14]

Towards Self-aware Systems

Beyond simple reactive models

Observe-Reflect-Decide-Act

Reflection, Introspection



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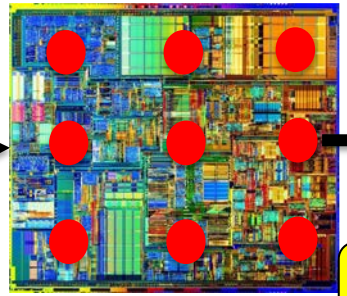

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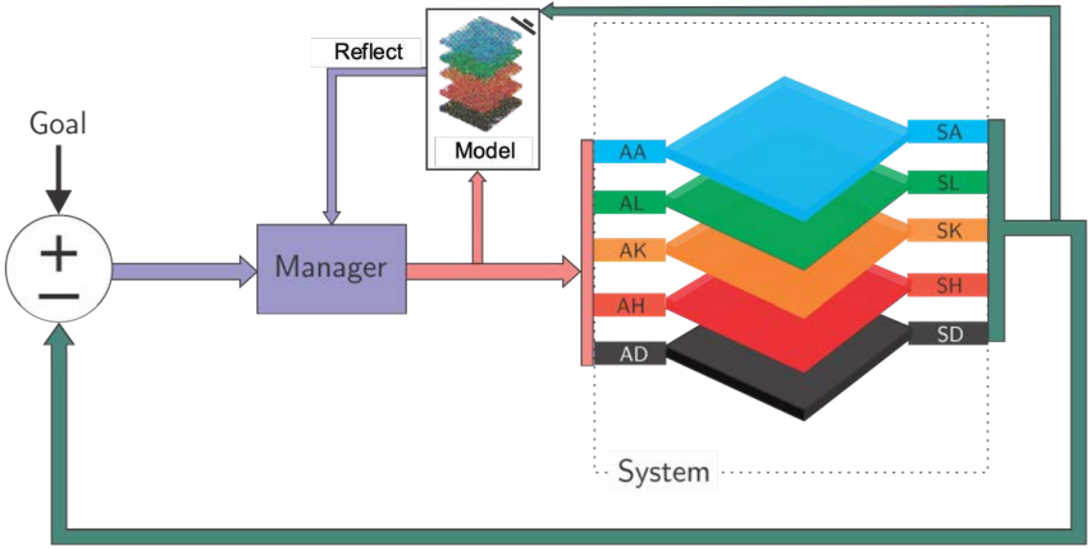

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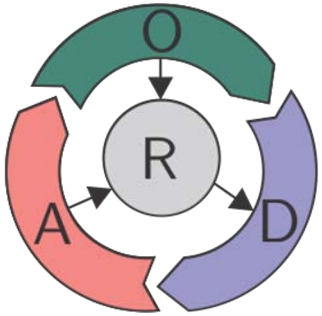

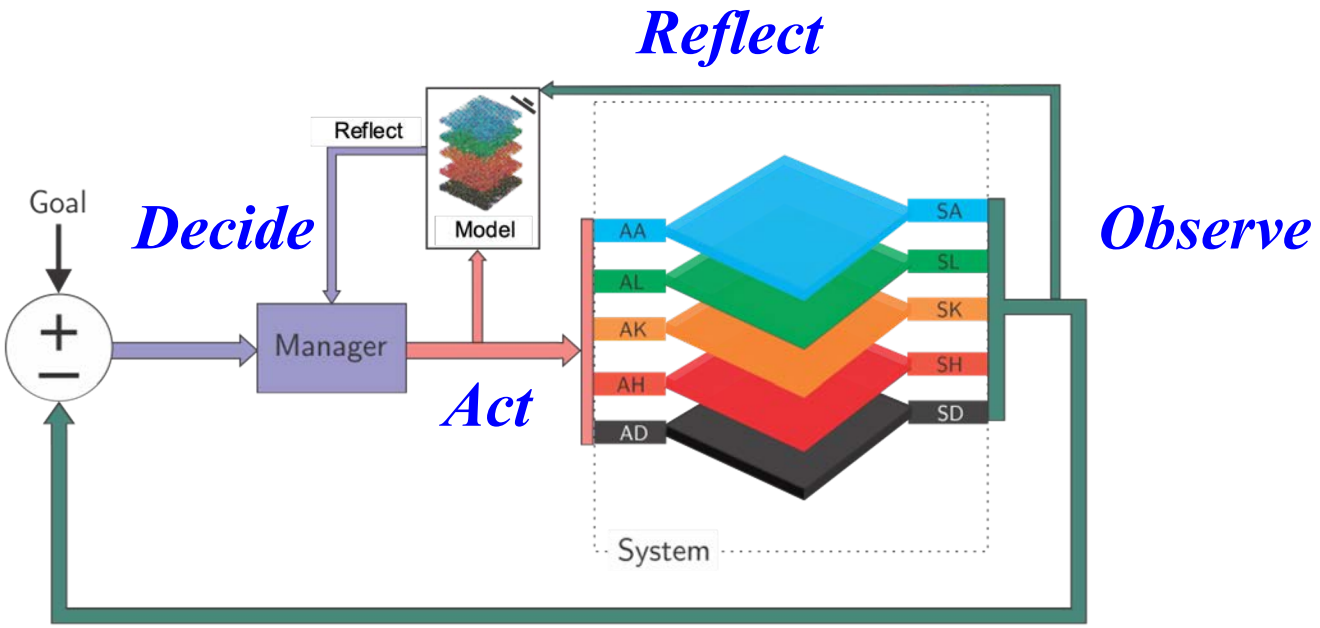

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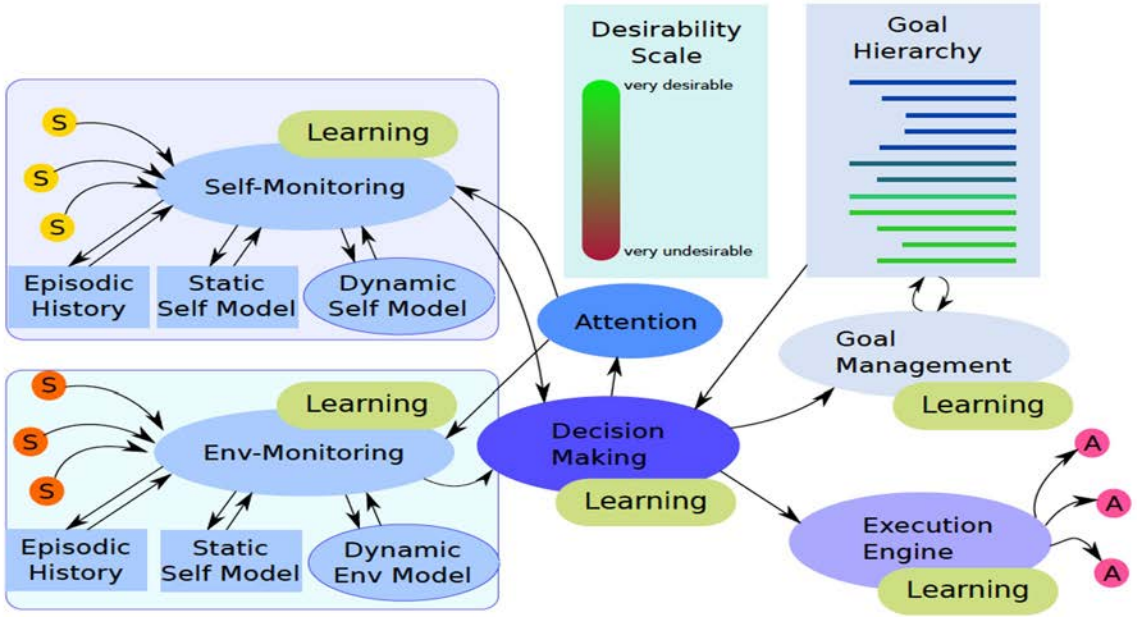
Exemplar CCI Reference Architecture



[Jantsch & Dutt 2017]

Exemplar CCI Reference Architecture

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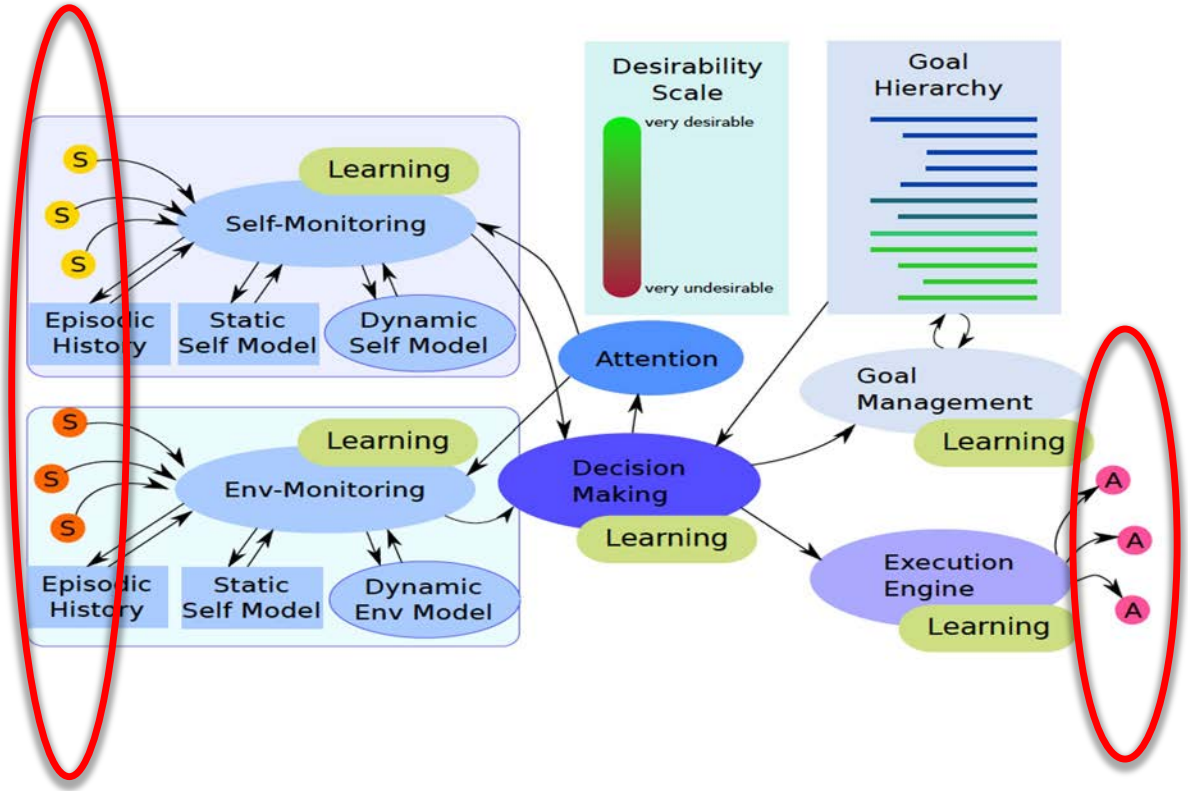


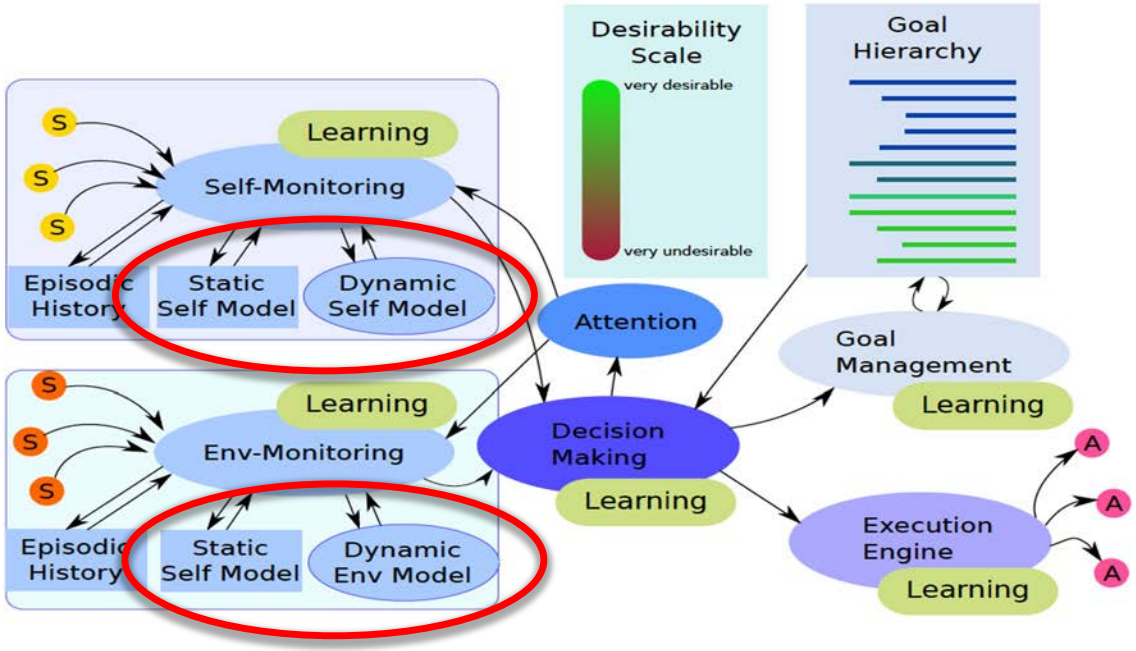
Actuators

[Jantsch & Dutt 2017]

Exemplar CCI Reference Architecture

Self-Models

Env-Models



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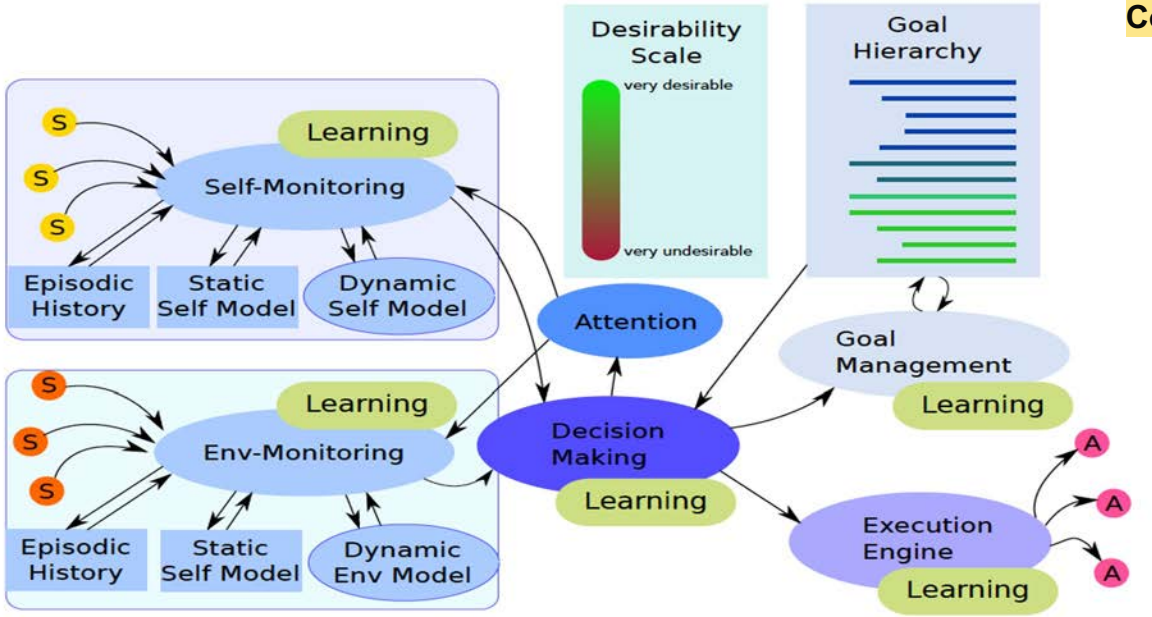

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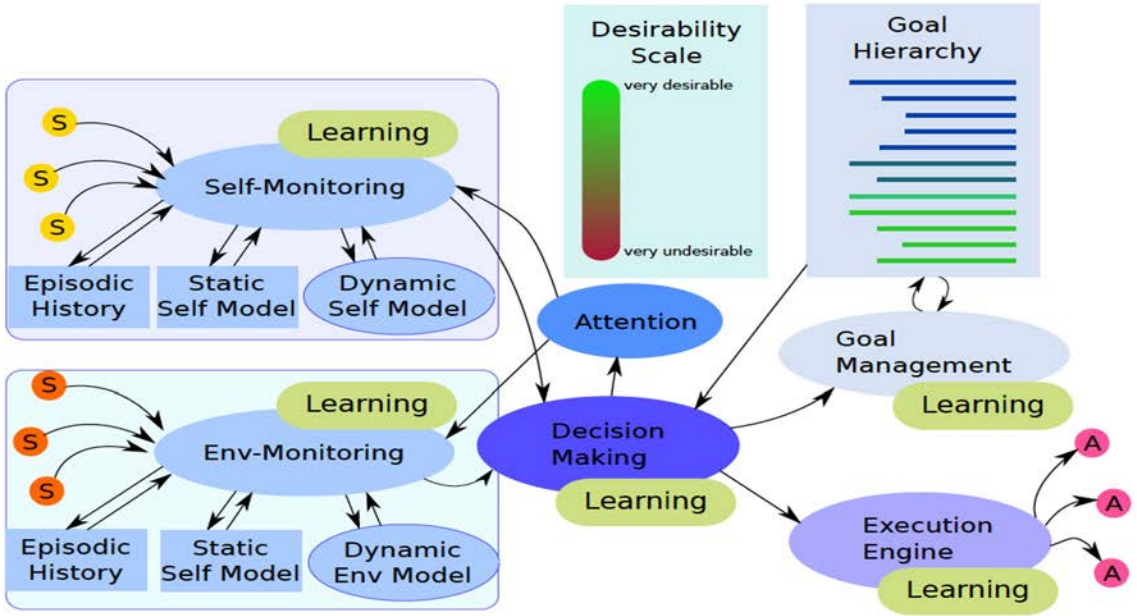
Exemplar CCI Reference Architecture

Sensors



Actuators

Observe->Reflect->Decide->Act

[Jantsch & Dutt 2017]

Computational Cognitive Intelligence (CCI)

CCI: biologically inspired, but adapted for computing systems

- ❑ Explicit models of ***self***, ***environment***, and ***context*** for adaptivity/autonomy
- ❑ **Computational abstraction of biological cognition**: self- and environmental-models; goal management; understanding & reasoning; contextualization; and history
- ❑ Use **CCI reference architecture** for driving adaptive system design
- ❑ Demonstrated utility of CCI in several CPHS use-cases

Computational Cogni

CCI: biolog

- Explicit m
- Comput
  goal ma
- Use **C**
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Exemplar Cross-Layer CCI Projects (2012-)

CPHS: **C**yber-**P**hysical **H**uman **S**ystems

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Chips

CPSoC – adapting to process variability for nanoscale SoCs (2012-2017)

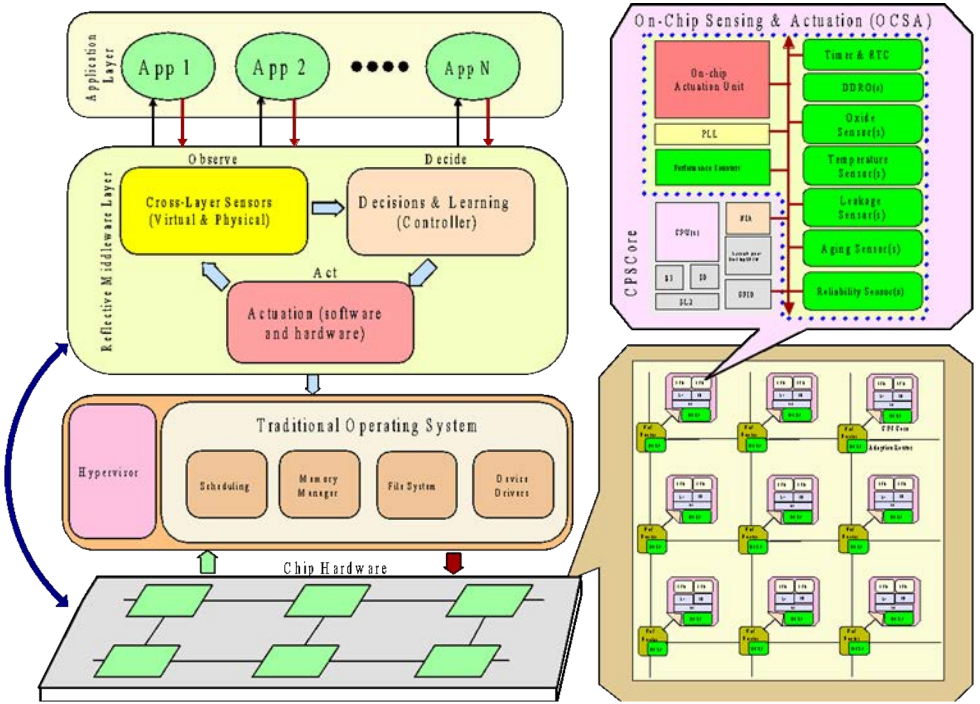
- *Adaptive Resource Management – for microarchitectures*
- *Adaptive Memory Hierarchy Management*
- *Adaptive datacenter resource management*

- *Healthcare IoT: Sensor-Edge-Cloud Adaptivity*
- *Mindful AI for Personal Health and Wellbeing (PHW)*

- *AV Systems: adaptivity for end-to-end pipelines*
- *Coordinated distributed autonomy: truck platooning*
- *Runtime verification: proactive detection of failures*

CPSoC: Variability-Aware CyberPhysical SoC* (2012-2017)

- Sensor/Actuator-rich SoC fabric
  - **OCSA: On-Chip Sensing and Actuation unit**
- NoC overlay (or separate network)
- SW enabled sensors & actuators
- Adaptive control of platform resources



* Joint work with Santanu Sarma

Research Partially Supported by the NSF Variability Expedition Project

CPSoC Use Cases (2012-2017)

- **Energy Efficiency (Throughput/Power)**
  - Dynamic Workloads
  - Opportunistic Load balancing
  - Adaptive Scheduler
  - Evolutionary Approach

S.Sarma, T. Muck, Luis. A.D. Bathen, N. Dutt, and A. Nicolau, "SmartBalance: A Sensing-Driven Linux Load Balancer for Energy Efficiency of Heterogeneous MPSoCs," **DAC 2015**.

T. Muck, S. Sarma, and N. Dutt, "Run-DMC: Runtime Dynamic Heterogeneous MultiCore Performance and Power Estimation for Energy Efficiency", **CODES+ISSS 2015**.

B. Donyanavard, T. Muck, S. Sarma, and N. Dutt, "SPARTA: Runtime Task Allocation for Energy Efficient Heterogeneous Many-cores," **CODES+ISSS 2016**.

- **Thermal-Aware Performance**
  - Dynamic/Adaptive Parallelization
  - Heterogeneous Architecture
  - Adaptive Scheduling

S. Sarma, T. Muck, M. Shoushtari, A. BanaiyanMofrad, and N. Dutt, "Cross-layer Virtual Physical Sensing and Actuation for Resilient Heterogeneous Many-core SoCs **ASPDAC-2016**.

S. Sarma and N. Dutt, "Minimal Sparse Observability of Complex Networks: Application to MPSoC Sensor Placement and Run-time Thermal Estimation & Tracking," **DATE 2014**.

- **Aging and Resilience**
  - Opportunistic Allocation
  - Duty cycling: Active & Resting periods

M. Namaki-Shoushtari, A. Rahimi, N. Dutt, P. Gupta, and R. Gupta, "ARGO: Aging-aware GPGPU Register File Allocation," **CODES+ISSS 2013**.

T. Muck, Z. Ghaderi, E. Bozorgzadeh, and N. Dutt, "Exploiting Heterogeneity for Aging-aware Load Balancing in Mobile Platforms," **IEEE TMSC 2017**.

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CPHS: **C**hips **P**latforms **H**umans **S**ystem-of-Systems

Platforms

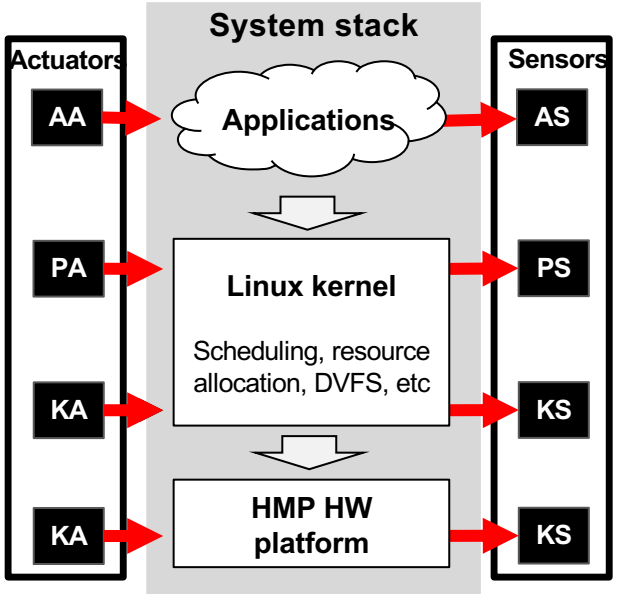
- *CPS: … adapting to process variability for nanoscale SoCs*
- ***Adaptive Resource Management – for microarchitectures***
- ***Adaptive Memory Hierarchy Management***
- ***Adaptive datacenter resource management***

(2017-2024)

- *Healthcare IoT: Sensor-Edge-Cloud Adaptivity*
- *Mindful AI for Personal Health and Wellbeing (PHW)*

- *AV Systems: adaptivity for end-to-end pipelines*
- *Coordinated distributed autonomy: truck platooning*
- *Runtime verification: proactive detection of failures*

MARS middleware for reflective resource management



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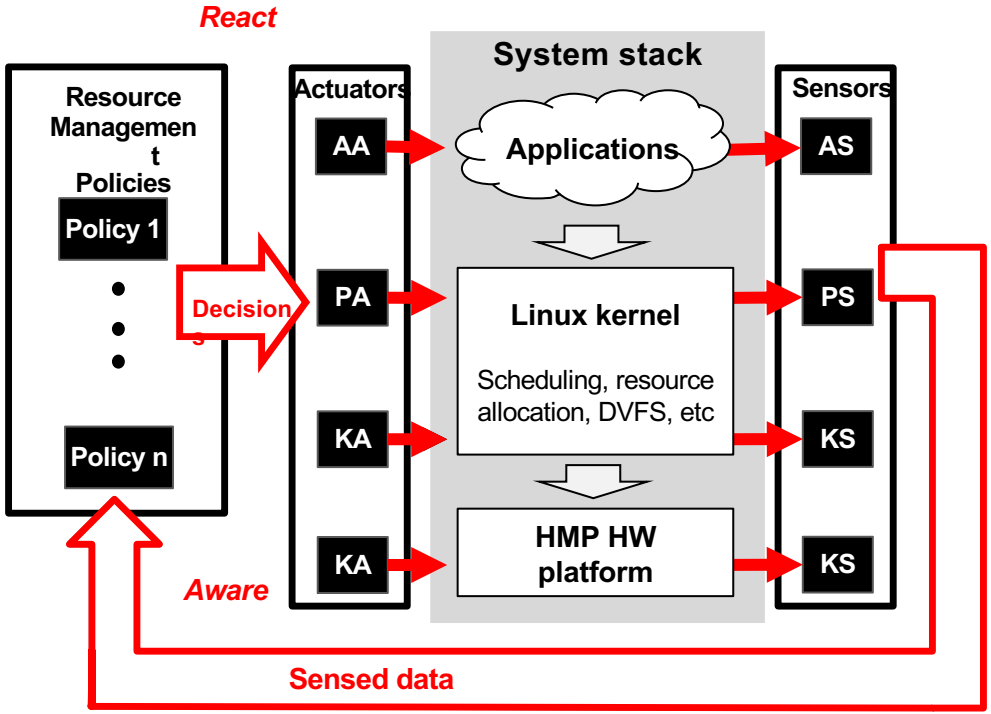

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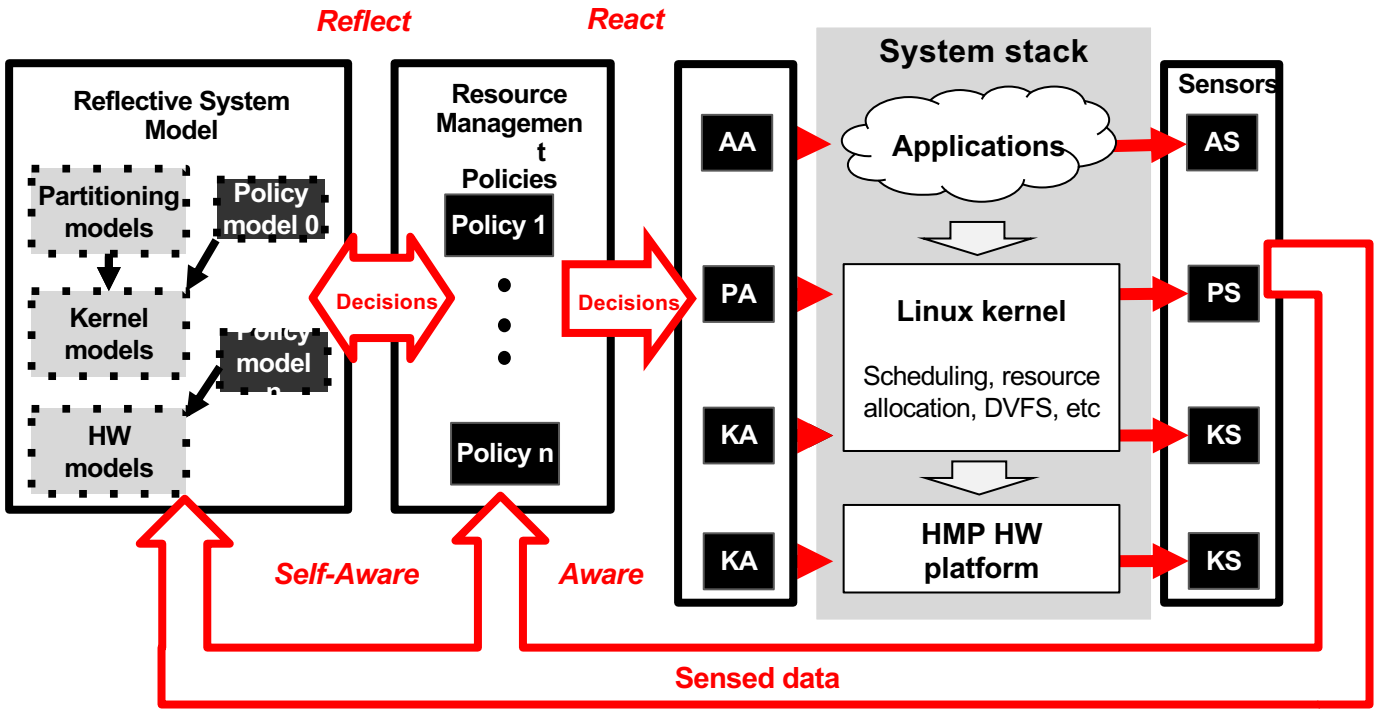

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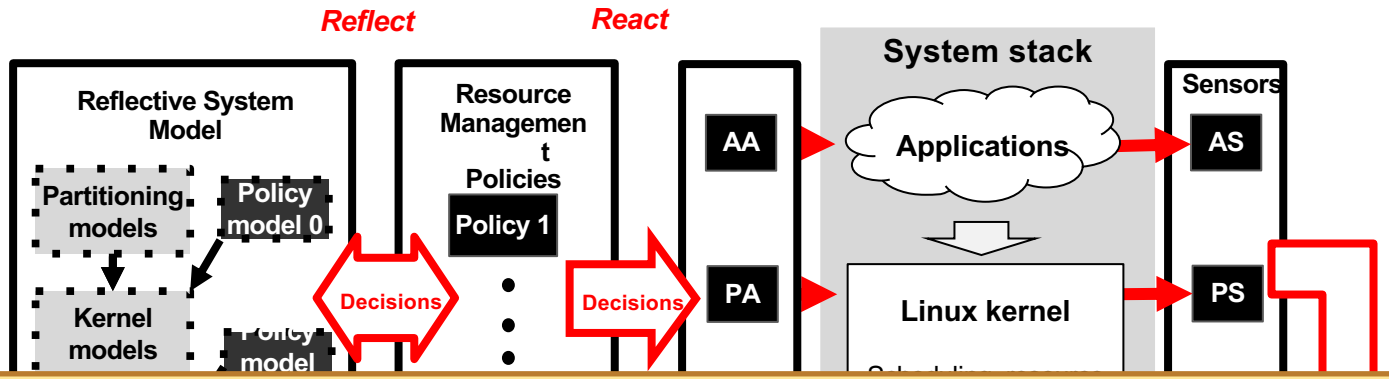

- **Cross-layer Self-Awareness**
  - Self-Models across different abstraction levels
  - Enables CCI principles to be applied *across the hierarchy*

Computational Cognitiv

CCI: biologic

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Exemplar Cross-Layer CCI Projects (2012-)

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Humans

- ***Healthcare IoT: Sensor-Edge-Cloud Adaptivity (2017-2024)***
- *Mindful AI for Personal Health and Wellbeing (PHW) (2020-)*
- *AV Systems: adaptivity for end-to-end pipelines*
- *Coordinated distributed autonomy: truck platooning*
- *Runtime verification: proactive detection of failures*

Sample Healthcare CPHS Projects*

- **NSF WiFiUS**: *IoCT-CARE: Internet of Cognitive Things for Personalized Healthcare* (2017-2020)
  - *IoT-based Early Warning Score Everyday Settings*
  - *Smart Pain Assessment*

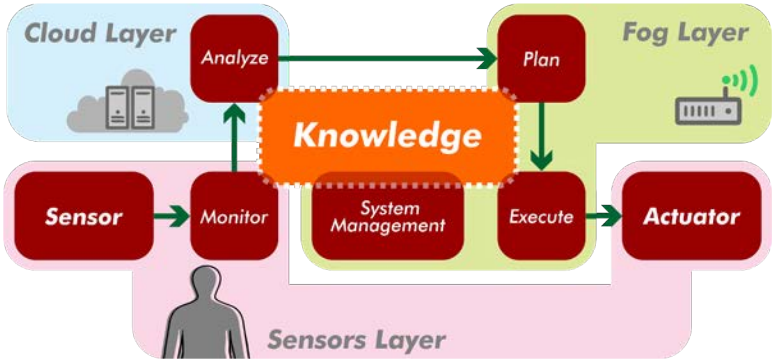
- **NSF SCC Program**: *UNITE: Smart, Connected, and Coordinated Maternal Care for Underserved Communities* (2018-2022)
  - *Improving maternal health: personalized models via lifelogging, health monitoring and recommendations*

- **Susan Samueli Integrative Health Institute:** *Harnessing the Power of Positive Connections to Reduce Loneliness in College Students (2021-2022)*
  - *Stress and loneliness in college students during pandemic*

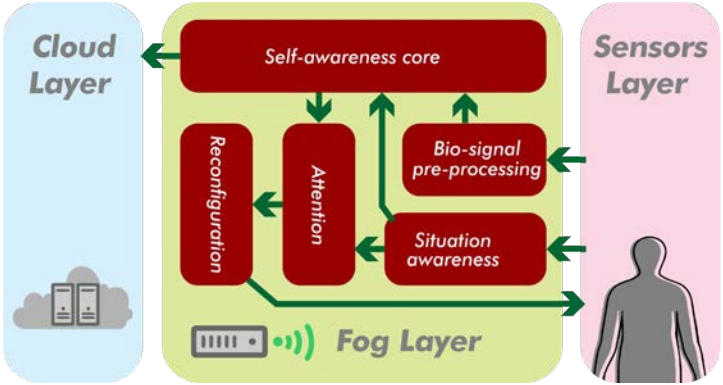
*** Joint work with Amir Rahmani**

IoCT-CARE CPHS Architectures

HiCH: a hierarchical computing architecture for healthcare IoT



Self-Awareness in Remote Health Monitoring Systems using Wearable Electronics



Goals: availability and timeliness

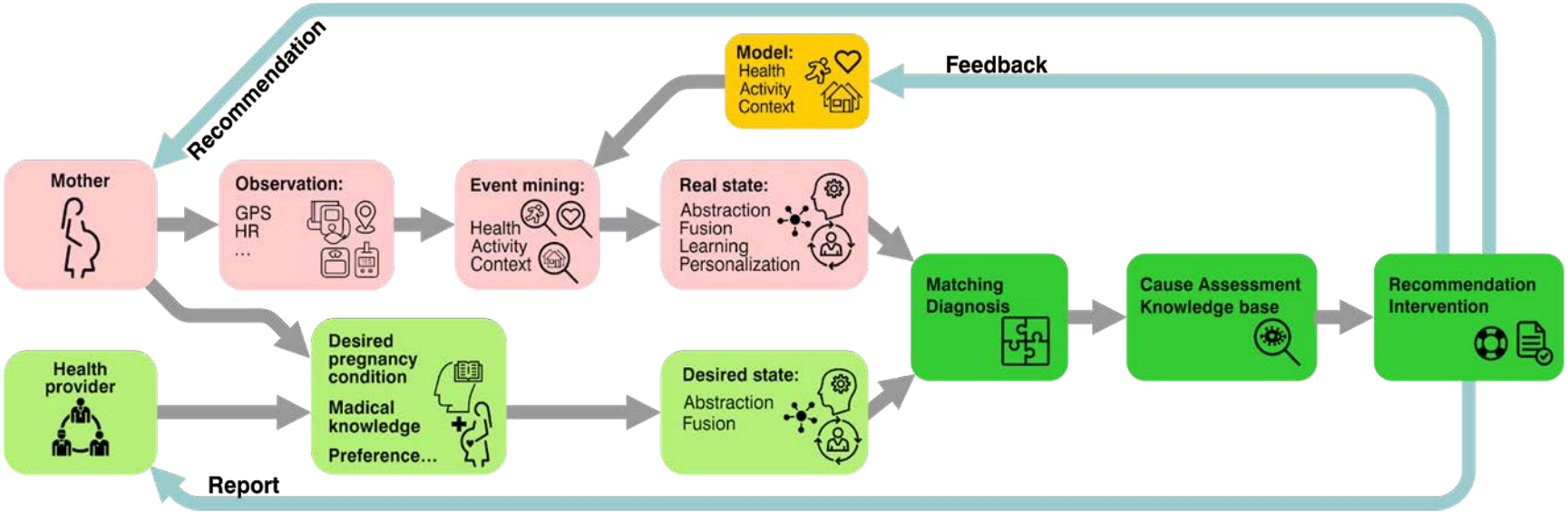
I. Azimi, A. Anzanpour, A.. Rahmani, T. Pahikkala, M. Levorato, P. Liljeberg, and N. Dutt, ***EMSOFT/ ESWEEK 2017***

Goals: intelligent decision making and energy efficiency

A. Anzanpour, I. Azimi, M. Götzinger, A.Rahmani, N. TaheriNejad, P. Liljeberg, A. Jantsch, and N. Dutt, ***DATE, 2017***

UNITE Technology Platform: AI-Powered, Personalized Services

*Closed-loop system for lifelogging, health monitoring and recommendation leveraging **personalized models***



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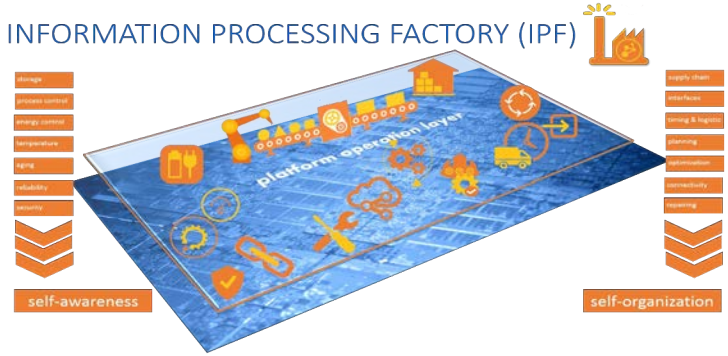
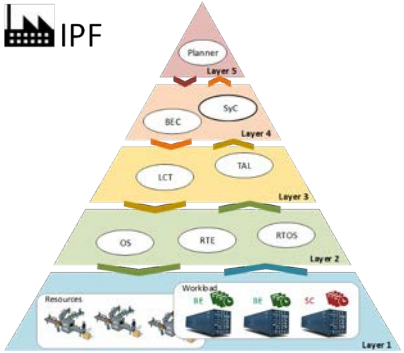
- ***Runtime verification: proactive detection of failures***
- ***(2017-)***

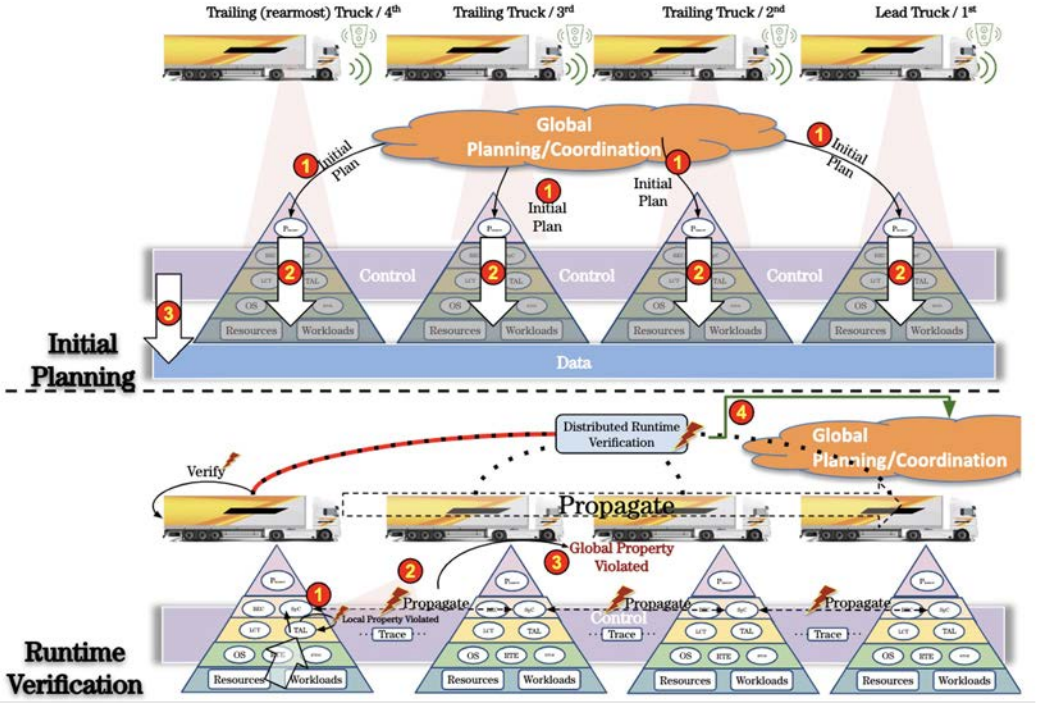
The Information Processing Factory (IPF)

- DFG-NSF project (2018 –2021)
  - UC Irvine, TU Munich, TU Braunschweig
- Objectives
  - Growing IC material effects, parameter variation, aging, degradation, defects, …
  - Growing load changes in autonomous applications
  - Longer lifetimes - system autonomy
- Vision
  - Operate future MPSoC like a factory
  - Rich sensor system, physical adaptation
  - Enable online optimization
    - Keep updated system model on chip – self-reflection
    - Optimize own state and operation – self-organization
  - Autonomous planning with networked ICs





Information Processing Factory 2.0 (IPF 2.0): Self-Awareness for Autonomous, Collaborative Systems



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Mindful AI for Personal Health and Wellbeing (PHW)

- **PHW Challenge**:
  - Increasing use of wearables for mHealth

Mindful AI for Personal Health and Wellbeing (PHW)

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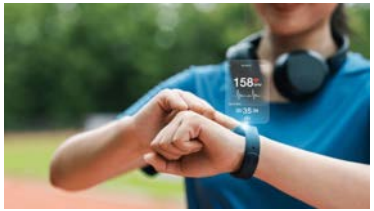
Mindful AI for Personal Health and Wellbeing (PHW)

- **PHW Challenge**:
  - Increasing use of wearables for mHealth tasks: *pain/emotion recognition, sleep monitoring*

Mindful AI for Personal Health and Wellbeing (PHW)

- **PHW Challenge**:
  - Increasing use of wearables for mHealth tasks: *pain/emotion recognition, sleep monitoring, activity tracking, stress, ...*



Mindful AI for Personal Health and Wellbeing (PHW)

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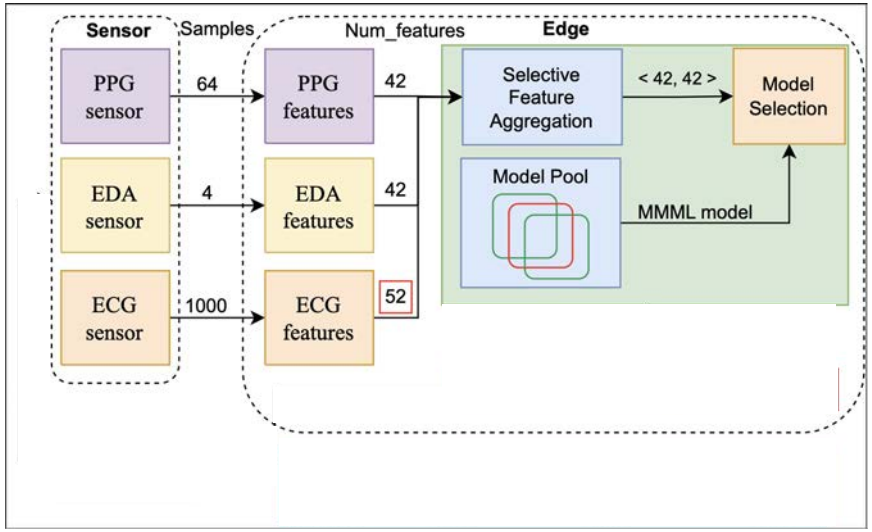

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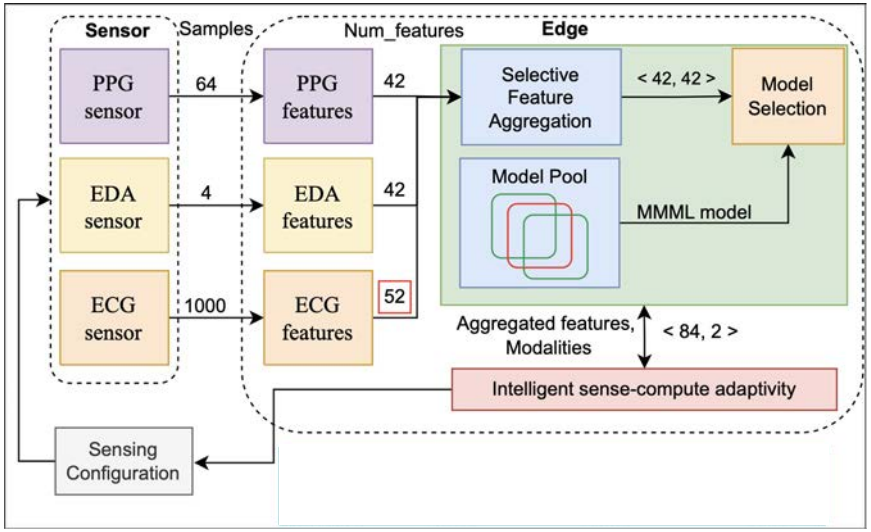
- **Approach**:
  - **Mindful AI for PHW** through adaptive sense-compute co-optimization



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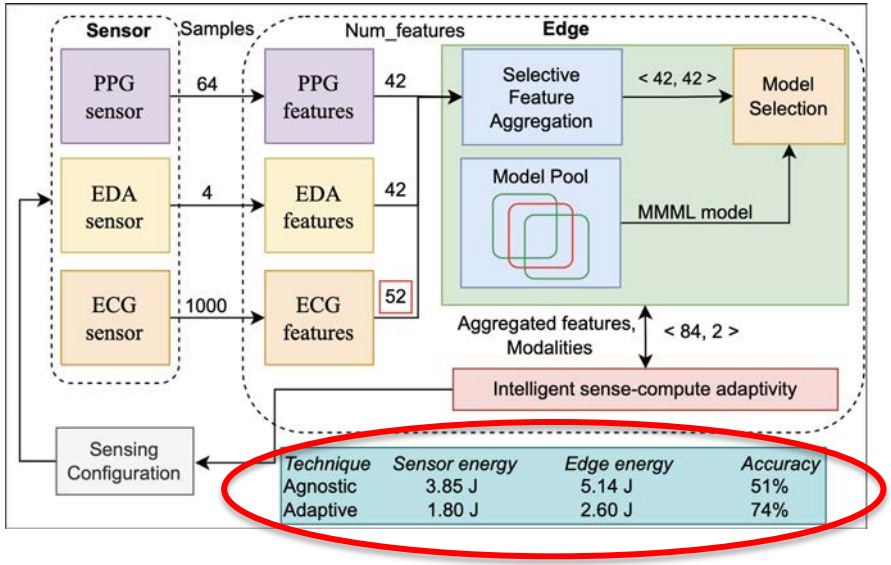
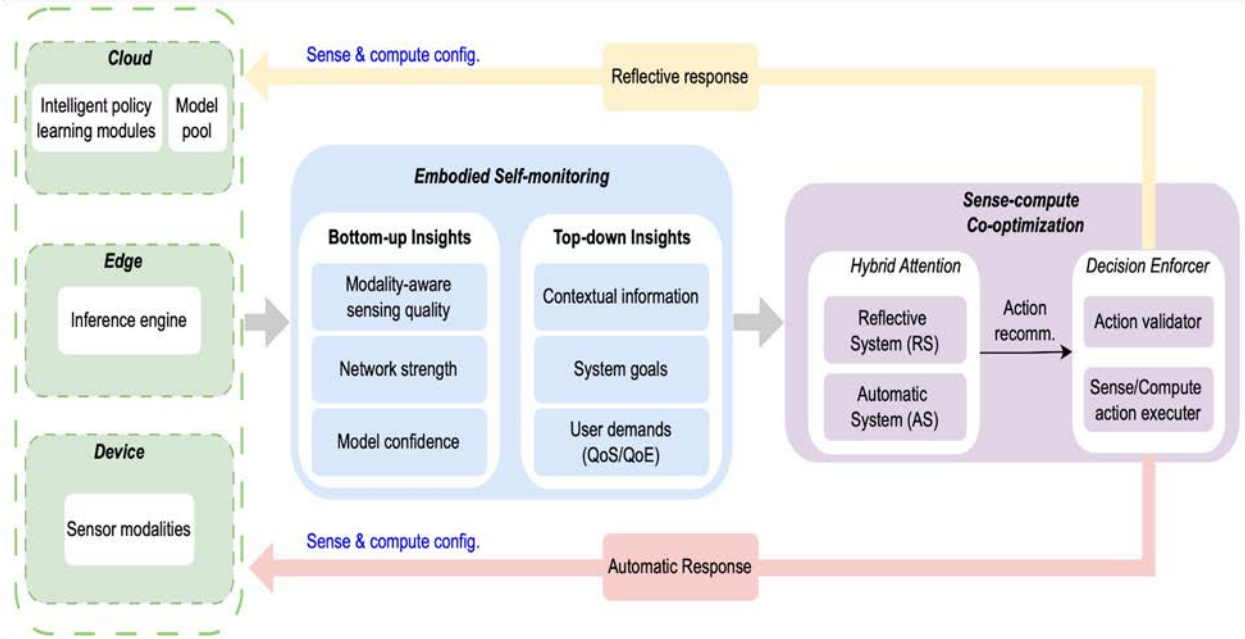


Mindful AI for Personal Health and Wellbeing (PHW)

Mindful AI for PHW

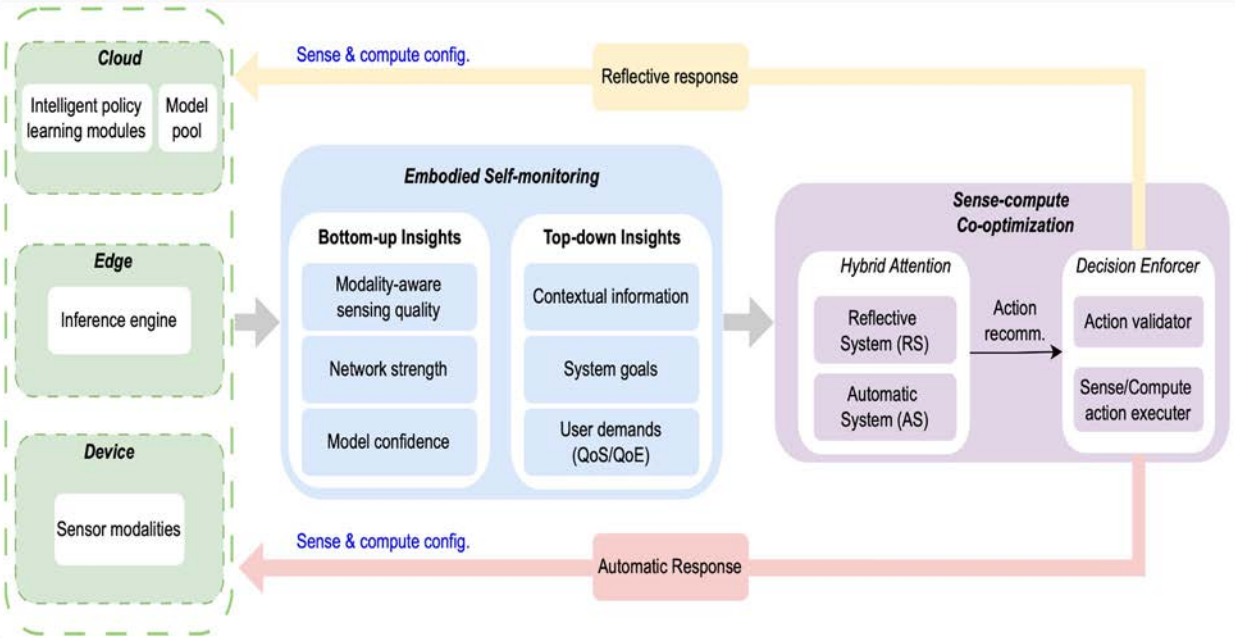
- End-to-end pipeline across **Device → Edge → Cloud**



Mindful AI for Personal Health and Wellbeing (PHW)

Mindful AI for PHW

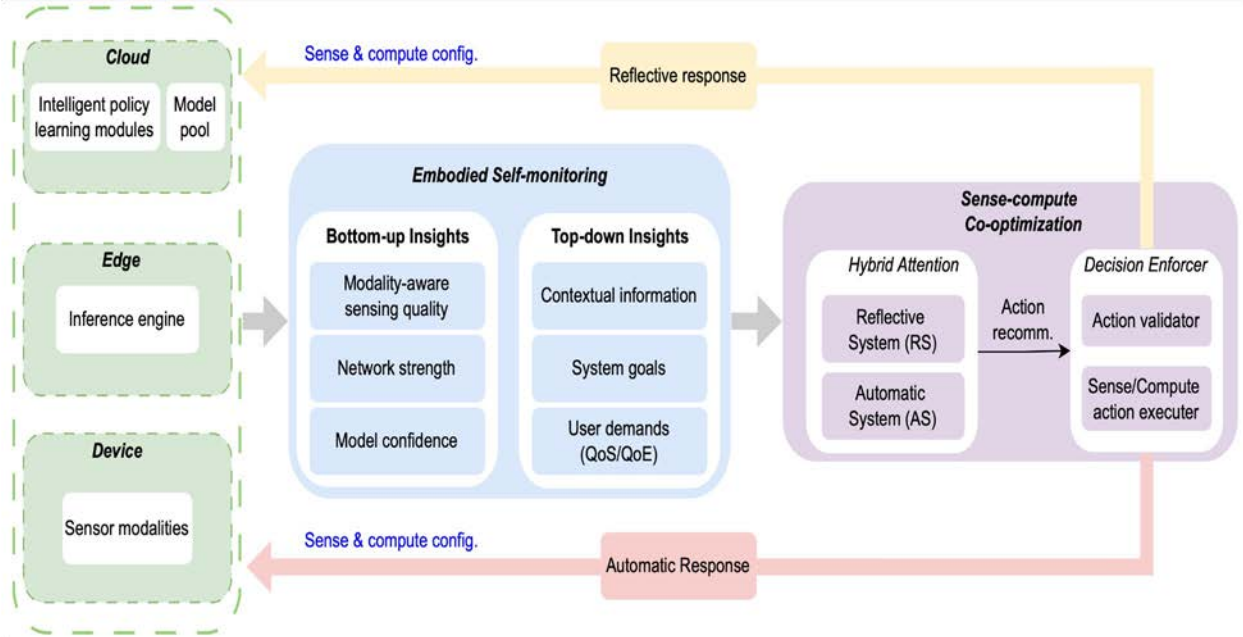
- End-to-end pipeline across **Device → Edge → Cloud**
- Sensor modalities activate **model pool + policy learning modules**



Mindful AI for Personal Health and Wellbeing (PHW)

Mindful AI for PHW

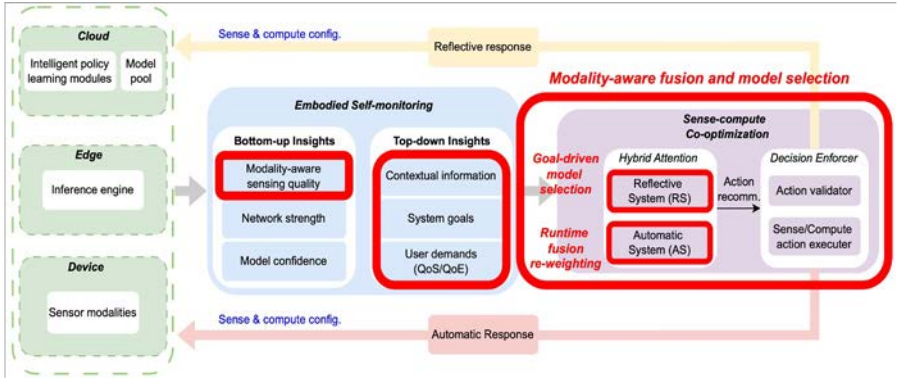
- End-to-end pipeline across **Device → Edge → Cloud**
- Sensor modalities activate **model pool + policy learning modules**
- **Bottom-up (data-driven)** and **Top-down (goal-driven)** insights guide adaptation



Mindful AI for PHW Use Cases: DynaFuse for Human Activity Recognition (HAR)

ESWEEK/CODES+ISSS 2023

DynaFuse: Efficient inference for Human Activity Recognition (HAR)



Human Activity Recognition (HAR)

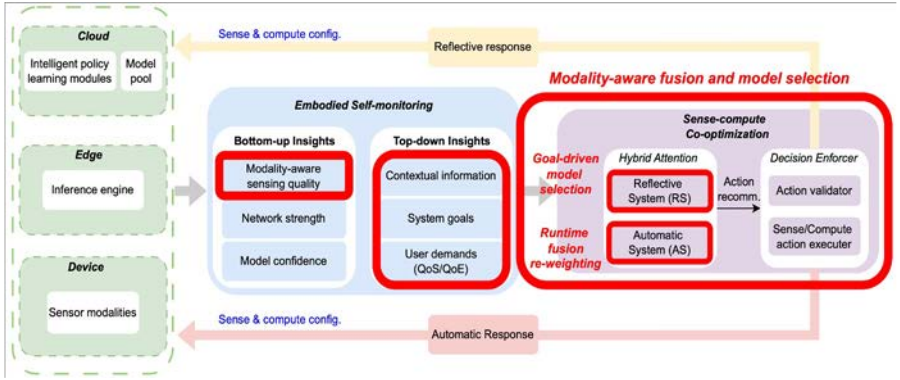
- Accel & gyro sensors attached to foot, shin, and thigh; EMG sensor attached to front thighs

Mindful AI for PHW Use Cases: DynaFuse for Human Activity Recognition (HAR)

ESWEEK/CODES+ISSS 2023

DynaFuse: Efficient inference for Human Activity Recognition (HAR)

- **Automatic System (AS):**
  - *Runtime fusion reweighting* → **Hybrid Attention** in AS
- **Reflective System (RS):**
  - *Goal-driven model selection* → **Reflective response** path
- **Sense-Compute Co-optimization:**
  - *Modality-aware fusion and model switching* → **Model confidence** + **System goals** + **Contextual information**
- **Main Adaptation:**
  - *Resource & sensing-aware fusion for efficient edge inference*



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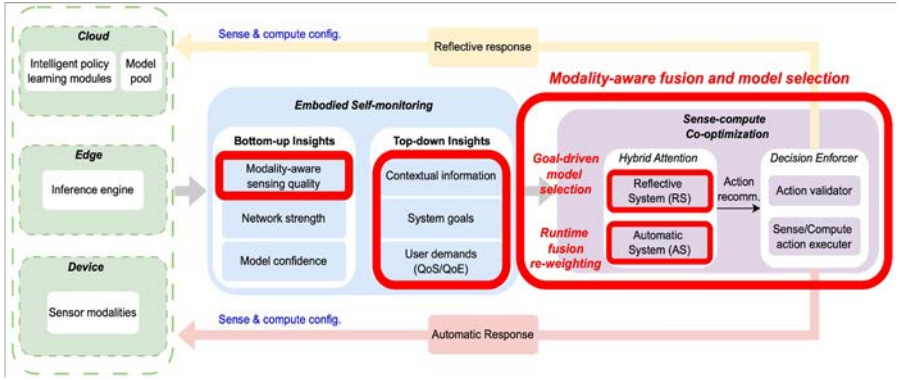


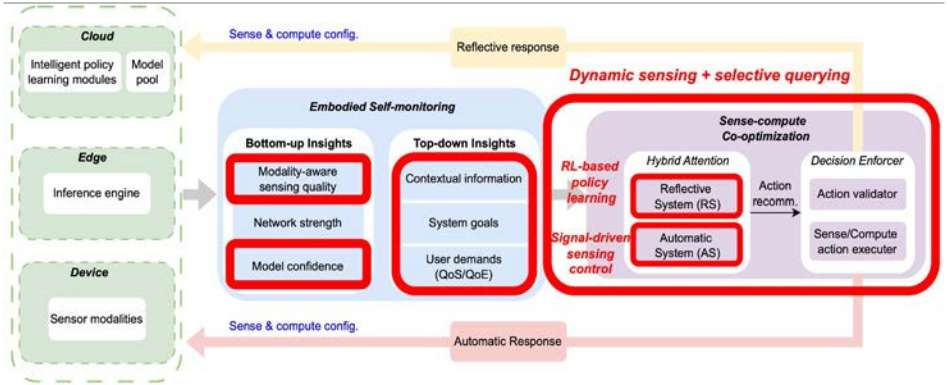
Human Activity Recognition (HAR) Results

- Accel & gyro sensors attached to foot, shin, and thigh; EMG sensor attached to front thighs
- Average **22% accuracy gain** with **34% energy saving** compared to baseline

Mindful AI for PHW Use Case: EA² for stress monitoring

ISPLED 2024

EA²: Active learning on wearables for personalized stress monitoring



Personalized stress monitoring

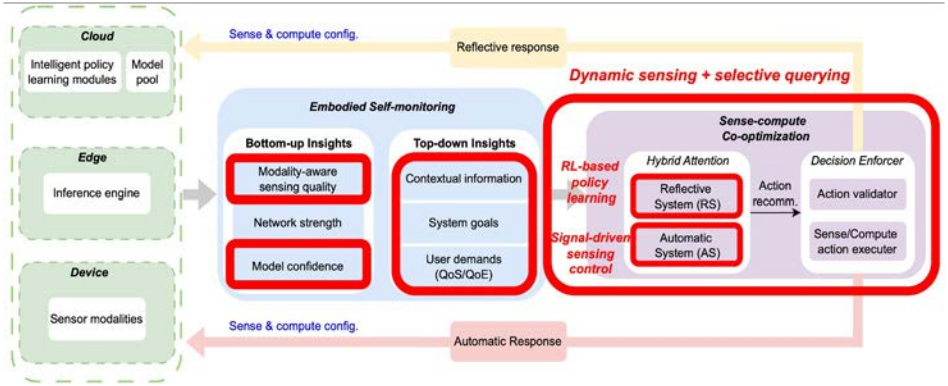
- Context-aware sensing and labeling

Mindful AI for PHW Use Case: EA² for stress monitoring

ISPLED 2024

EA²: Active learning on wearables for personalized stress monitoring

- **Automatic System (AS):**
  - *Signal-driven sensing control* → **Modality-aware sensing quality** + **Automatic Response**
- **Reflective System (RS):**
  - *RL-based policy learning* → **Intelligent policy learning modules**
- **Sense-Compute Co-optimization:**
  - *Dynamic sensing* + *selective querying* → **Sense & compute config.** (Device ↔ Edge ↔ Cloud)
- **Main Adaptation:**
  - *Energy-aware active learning across device-edge-cloud*



Personalized stress monitoring

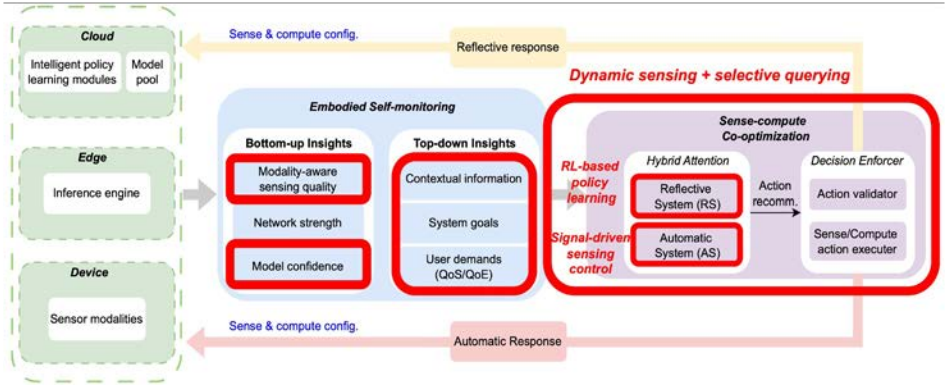
- Context-aware sensing and labeling

Mindful AI for PHW Use Case: EA² for stress monitoring

ISPLED 2024

EA²: Active learning on wearables for personalized stress monitoring

- **Automatic System (AS):**
  - *Signal-driven sensing control* → **Modality-aware sensing quality** + **Automatic Response**
- **Reflective System (RS):**
  - *RL-based policy learning* → **Intelligent policy learning modules**
- **Sense-Compute Co-optimization:**
  - *Dynamic sensing + selective querying* → **Sense & compute config.** (Device ↔ Edge ↔ Cloud)
- **Main Adaptation:**
  - *Energy-aware active learning across device-edge-cloud*



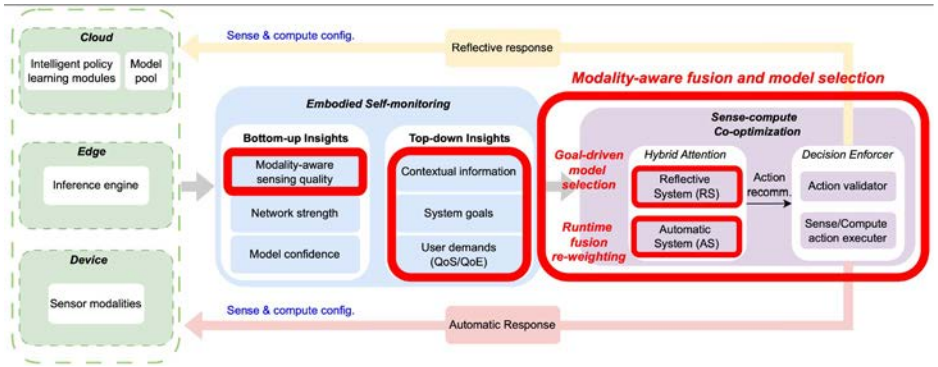
Personalized stress monitoring Results

- Context-aware sensing and labeling
- **76% reduction in sensing events** vs. continuous sensing
- **88% higher labeled samples** vs. selective sensing & querying

Mindful AI for PHW Use Cases: ISCA: Wearable healthcare for pain assessment

IEEE Design & Test 2025

ISCA: Wearable healthcare for pain assessment



Pain Assessment

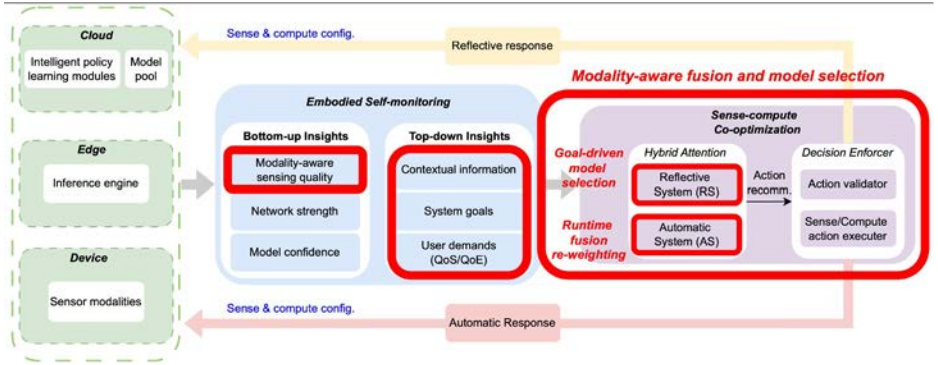
- Pain monitoring using ECG, EMG, and EDA signals, tested across WiFi, 4G, 3G networks with varying noise levels (0–50%).

Mindful AI for PHW Use Cases: ISCA: Wearable healthcare for pain assessment

IEEE Design & Test 2025

ISCA: Wearable healthcare for pain assessment

- **Automatic System (AS):**
  - *Kernel/feature switching* → **Sense/Compute action executer**
- **Reflective System (RS):**
  - *History-based performance modeling* → **Embodied self-monitoring + System goals**
- **Sense-Compute Co-optimization:**
  - *Adaptive kernel + feature scaling* → **Sense & compute config.**
- **Main Adaptation:**
  - **Resilient mobile health inference via lightweight runtime adaptation**



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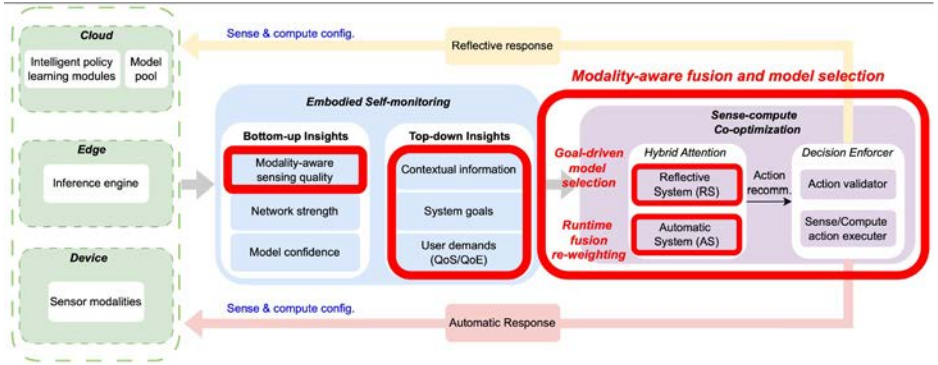


Pain Assessment Results

- Pain monitoring using ECG, EMG, and EDA signals, tested across WiFi, 4G, 3G networks with varying noise levels (0–50%).
- **23% increased accuracy** over noisy baseline
- **42% energy saved** over SOTA

Computational Cogni

CCI: biolog

- ❑ Explicit m
- ❑ Comput
  goal ma
- ❑ Use C
- ❑

Exemplar Cross-Layer CCI Projects (2012-)

CPHS: **C**yber-**P**hysical **H**uman **S**ystems

CPHS: **C**hips **P**latforms **H**umans **S**ystem-of-Systems

- ***CPSoC – adapting to process variability for nanoscale SoCs***
- ***Adaptive Resource Management – for microarchitectures***
- ***Adaptive Memory Hierarchy Management***
- ***Adaptive datacenter resource management***
- ***Healthcare IoT: Sensor-Edge-Cloud Adaptivity***
- ***Mindful AI for Personal Health and Wellbeing (PHW)***
- ***AV Systems: adaptivity for end-to-end pipelines***
- ***Coordinated distributed autonomy: truck platooning***
- ***Runtime verification: proactive detection of failures***

Exemplar Cross-Layer CCI Projects (2012-)

CPHS: **C**yber-**P**hysical **H**uman **S**ystems

- **Cross-layer Self-Awareness with Mindful AI**
  - Self-Models across different abstraction levels
  - Enables CCI principles to be applied *across the hierarchy*
  - ***Mindful AI:*** *Combine reflection (long horizon planning) with fast reactive decision loops*

Key Takeaway 1: CCI for CPHS

Cyber-Physical Human Systems (CPHS):

- Small-scale IoT to large system-of-systems
  - Diverse verticals with varying goals and constraints
- Impossible to capture behavioral design space
  - State space explosion via cross-product of behaviors
  - Unforseen/emergent behaviors from over/under specification, bugs, failures,..

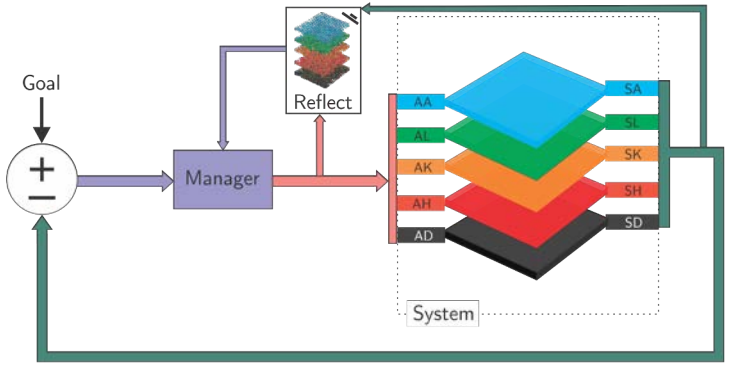
Can we exploit Computational Cognitive Intelligence (CCI) Principles for Adaptivity and Resilience?

- Apriori design-time models insufficient for dynamism

[Courtesy Fadi Kurdahi]

Key Takeaway 2: Mindful AI and Cross-layer CCI

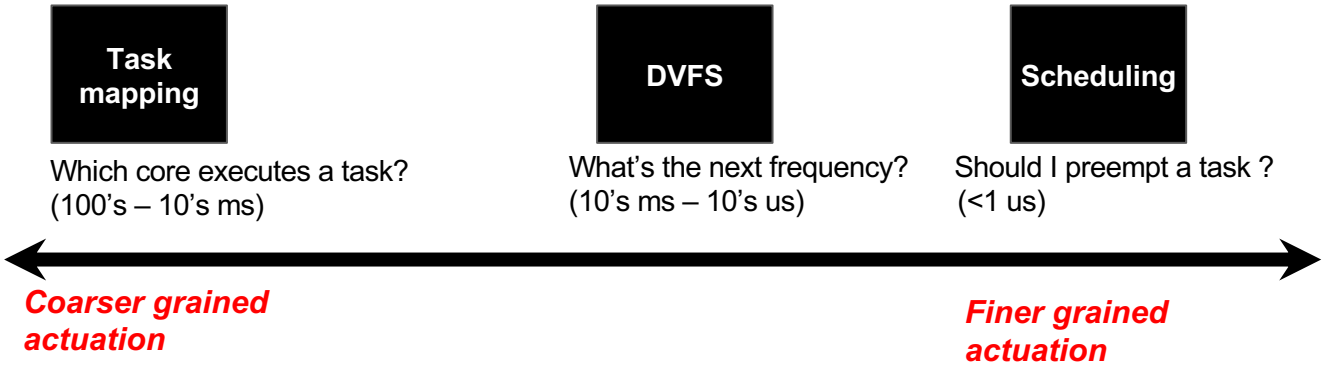
Cross-layer sensing/actuation
Self-modeling and introspection
Control/coordination of emergent behaviors



Computational SA: Observe-Reflect-Decide-Act

Self-awareness: Do we have room for reflection?

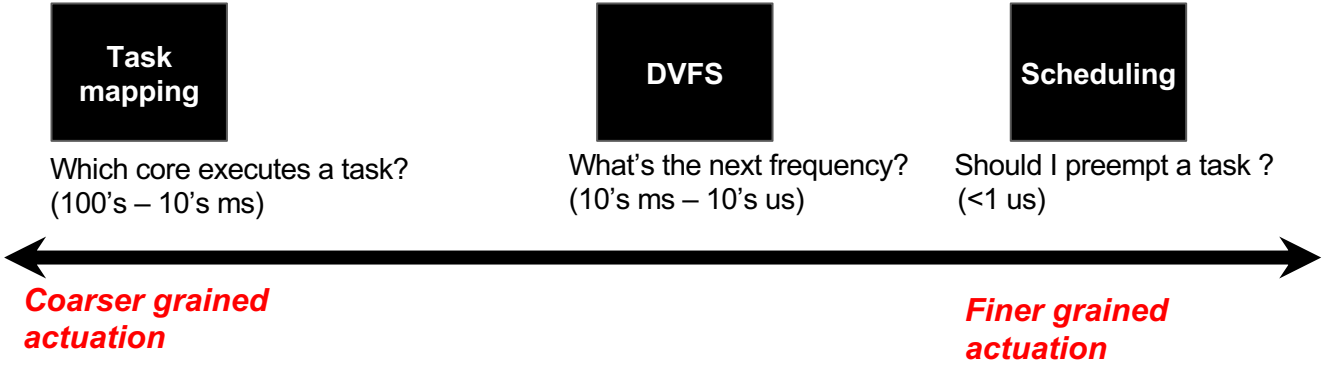
Systems actuations happen at different timescales



- Some actuations happen quickly with little room for reasoning
- Other actuations can occur on larger timescales
  - ***Task mapping, Wear-leveling (for aging)….***

Self-awareness: Do we have room for reflection?

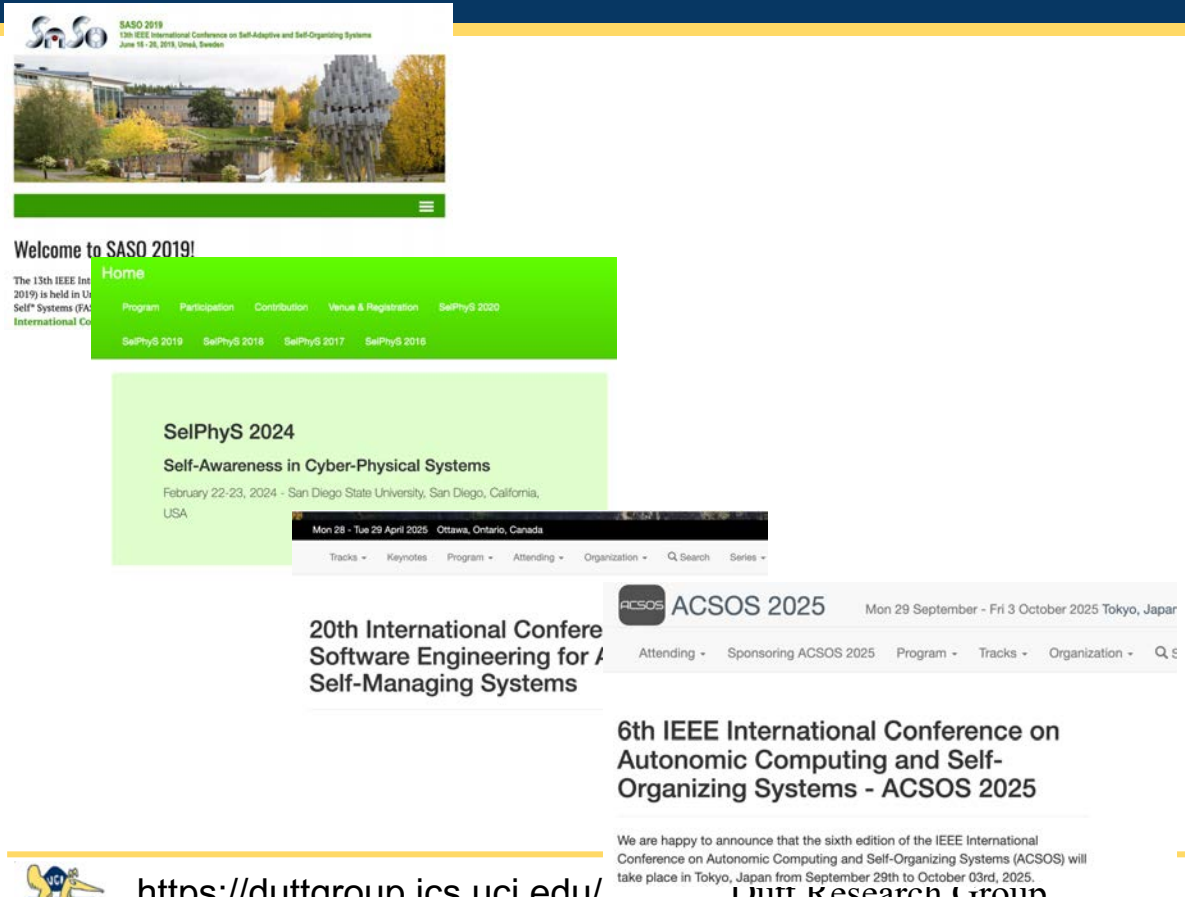
Systems actuations happen at different timescales



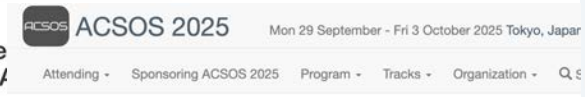
- Some actuations happen quickly with little room for reasoning
- Other actuations can occur on larger timescales

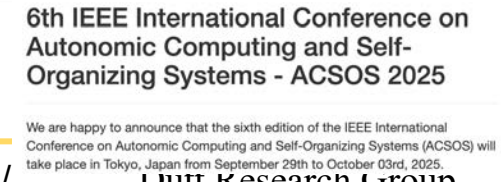
Use Reflection Judiciously!

Growing use of Mindful AI



Growing use of Mindful AI





Mindful AI & Cross-Layer CCI: Challenges/Opportunities

- **Security and Privacy for Highly Dynamic/Adaptive CPHS**
  - System models learn and evolve: moving targets!
  - Can we exploit principled CCI concepts?

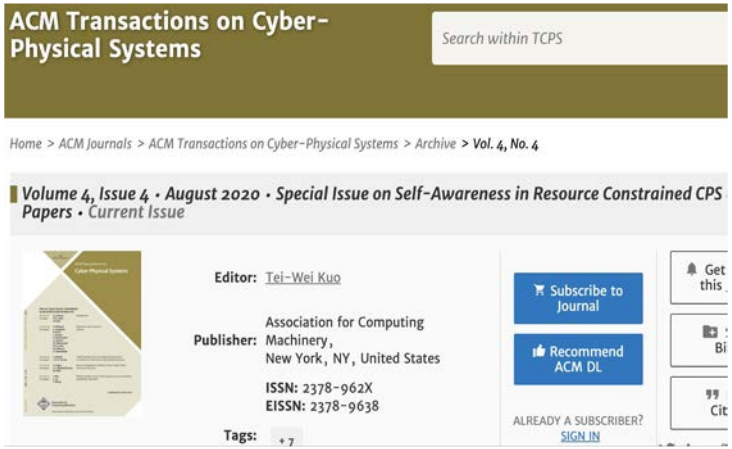
- **Safety & Predictability**
  - Can RV help? Monitor/detect/bound emergent behaviors?
  - Safety engineering meets ML!

- **Trustworthy AI for CHPS**
  - GenAI in digital twins?
  - Predictable, supervisory layer? Contain deployment? Overheads?

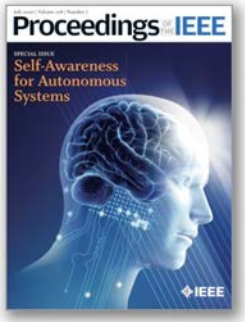
Towards "Mindful AI"

Computational Self-Awareness: References

ACM TCPS Special Issue on Self-Awareness in CPS
Guest Editors: *Axel Jantsch, Nikil Dutt, Peter Lewis*
August 2020



Proceedings of the IEEE Special Issue on Self-Awareness for Autonomous Systems
Guest Editors: *Nikil Dutt, Carlo Regazzoni, Bernhard Rinner, Xin Yao*
July 2020



Self-Awareness for Autonomous Systems

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- Guest Editors
- Special Issue Papers

Guest Editors:

Nikil Dutt
Carlo S. Regazzoni
Bernhard Rinner
Xin Yao

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