CITECDx
CONGRESO DE INGENIERÍA

Engineering of cyber-collaborative robotics and agentics in agriculture and manufacturing

Shimon Y. Nof

Purdue PRISM Center, PGRN, & Edwardson School of Industrial Engineering

Purdue University, W. Lafayette, Indiana, USA

PURDUE UNIVERSITY

CITEC colegio ingenieros tecnólogos

PRISM Global Research Network

Our purpose:

- Understand and explore recent advances and emerging opportunities for engineers, managers, and students

- How can cyber-collaborative agentics & robotics
  - enable successful solutions in Costa Rica and worldwide with resilience and sustainability?
  - Overcome disruptions and sustain our quality of life?

+ The future of factories, work, and the workforce
  + The cyber-physical automation of food supply and security
    + Costa Rica – Purdue University Semiconductor partnership

What is Robotics? Agentics? Collaborative?

- **Robotics:** Designing, building, and applying robots, computer-controlled mechanical devices
- **Agentics:** Designing, building, and applying automation systems with intelligent agents, software-hardware systems
- **Collaborative automation:** Designing, integrating, building, and applying automation systems and devices that collaborate effectively

Why collaborate? Systems collaborate to facilitate integration

What is Cyber? Cyber-Collaborative?

- **Cyber:** → Cyber-Physical Systems (CPS)
  1. Computing
  2. Communication (incl. Internet, IoT)
  3. Real-Time Control
  4. Digital brain models (cybernetics, AI, learning, IoS)

- **Cyber-Collaborative** Automation: → Works with people & agents
  1. Cyber
  2. Physical items & systems
  3. Networked
  4. cc-Work & cc-Management

Why do we engineer with higher levels of intelligence?

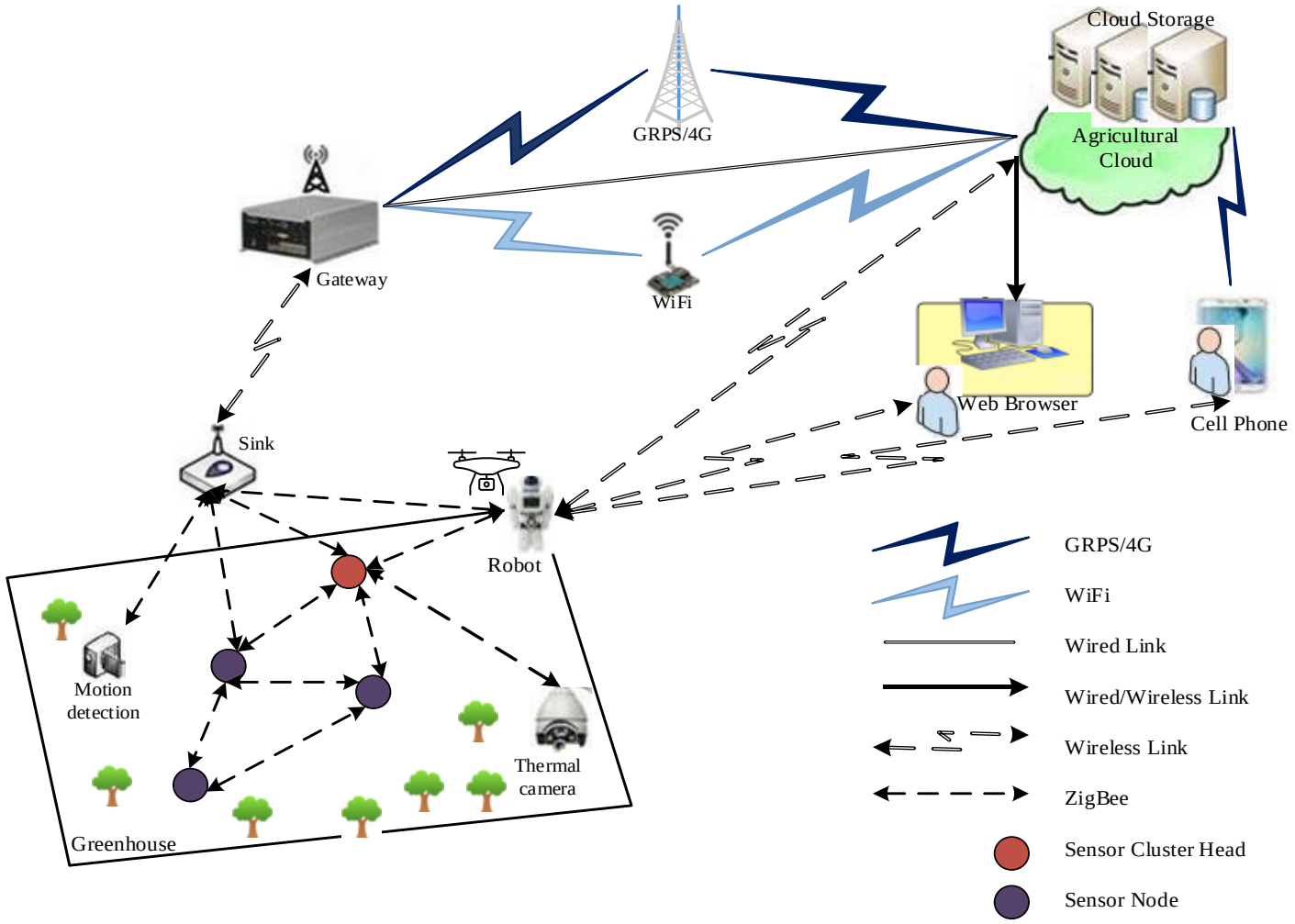
- **Changes** and **disturbances** interrupt normal operations, process optimality, reducing resilience and sustainability

  1. Understand their characteristic; predict, diagnose, prevent, and recover from them
  2. Prepare the workforce of the present and the future

- Massive data to collect, analyze, and learn from
- Must share intelligence, knowledge, skills, and tasks
- Develop cyber-collaborative logic and augmentation to do that

  → **Cyber-collaborative control theory (C3T)** [1]

Cyber-collaborative agricultural CPS [2]



Cyber:

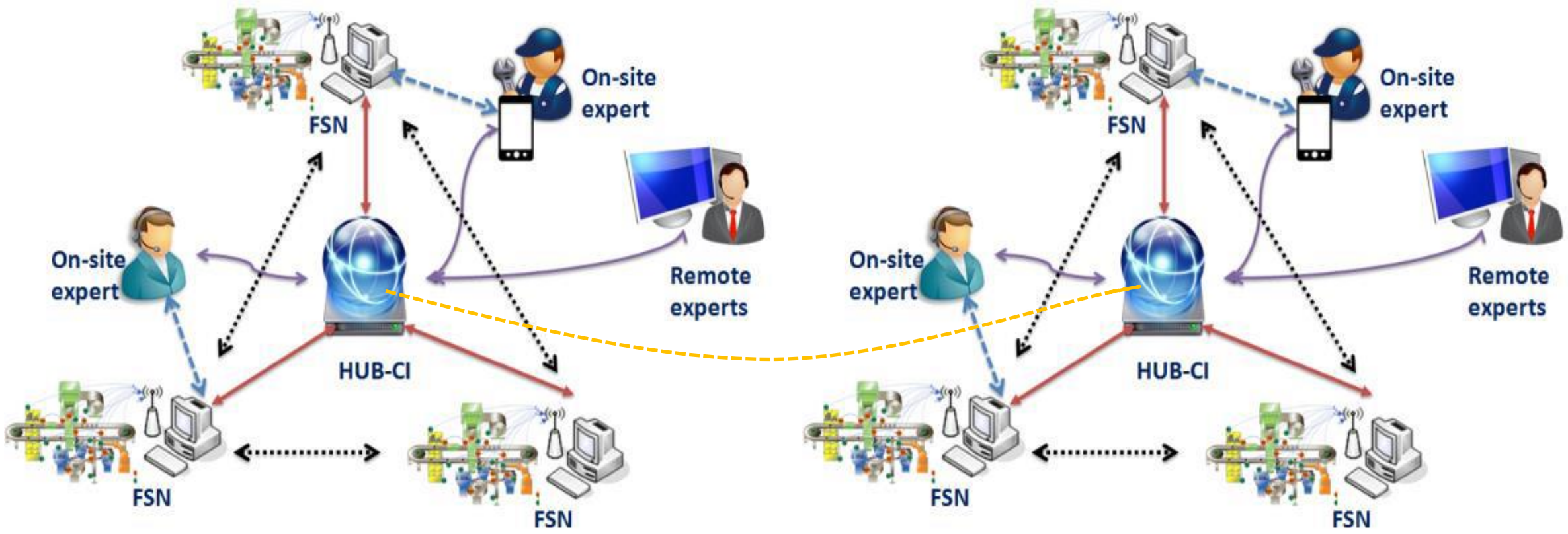
- Computers
- Communication
- Real-time control
- Brain models

Physical:

- Crops, livestock
- Agents:
  - Farmers
  - Robots
  - Drones
  - Sensors

Hubs of collaborative intelligence (HUB-CI/multi-brain) [1]

Harmonize, **U**nite, **B**uild **C**ollaborative, **I**ntegrated **I**ntelligence

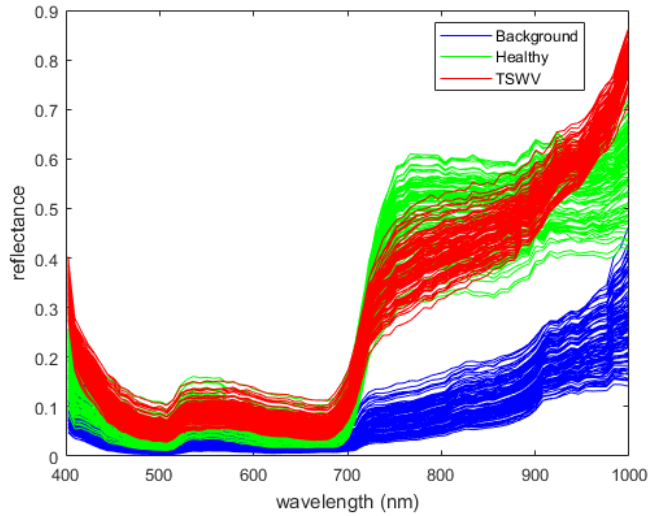


Cyber-Collaborative Control Theory (C3T) for systems collaboration

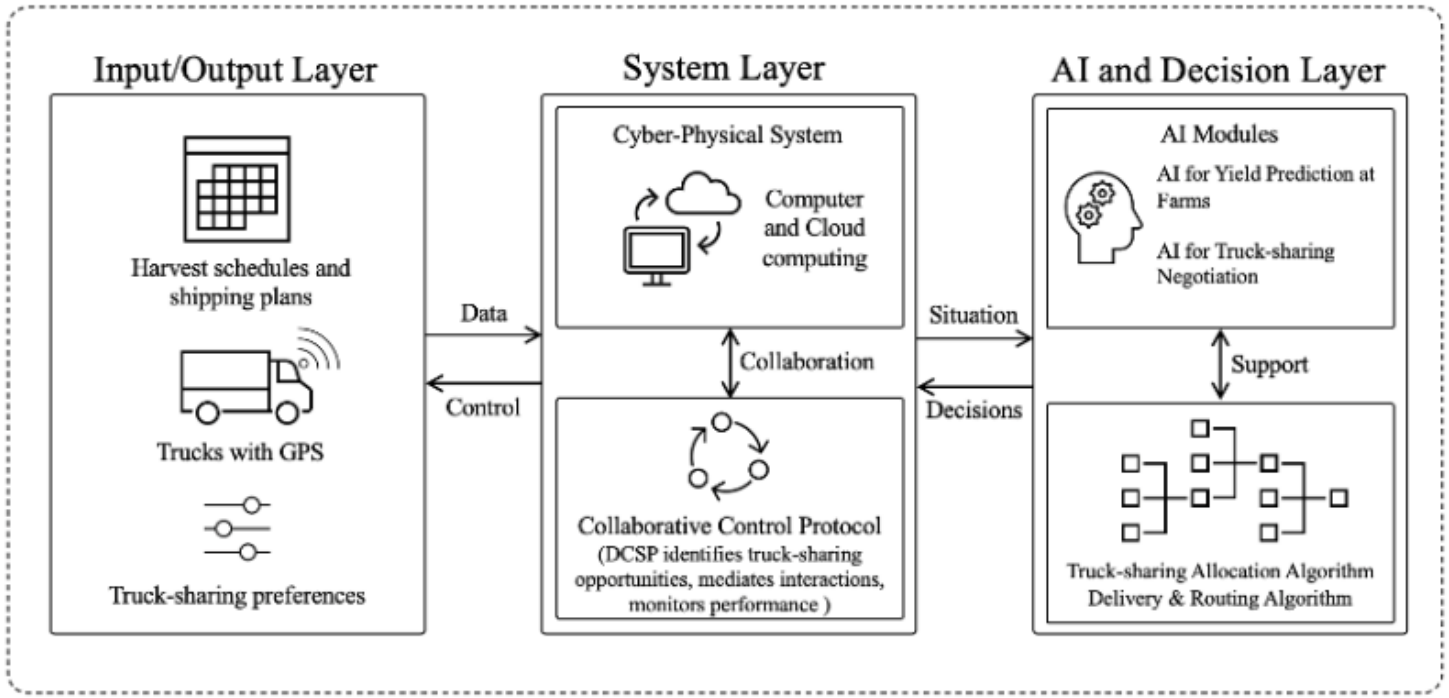
C3T principle	C3T augmentation by protocols, algorithms, and agents
1) MA-ML	Multiagents and multilayer collaboration architectures
2) CCP	Collaborative control protocols
3) HUB-CI	Hubs of collaborative intelligence and sharing
4) CIU	Collaborative insights and understanding
5) NCA	Negotiation, compromise, and agreement
6) CRP	Collaboration requirements planning
7) EWP	E-work parallelism
8) ECDPR	Error and conflict detection, prevention, prediction, and recovery
9) FTT-RBT	Fault tolerance and resilience by teaming
10) AD/N	Associating with or dissociating from a collaborative network
11) DLOC	Dynamic lines of collaboration
12) BMP	Best-matching protocols
13) DCSP	Demand-and-capacity sharing principle
14) KISS!	Keep it simple, system!

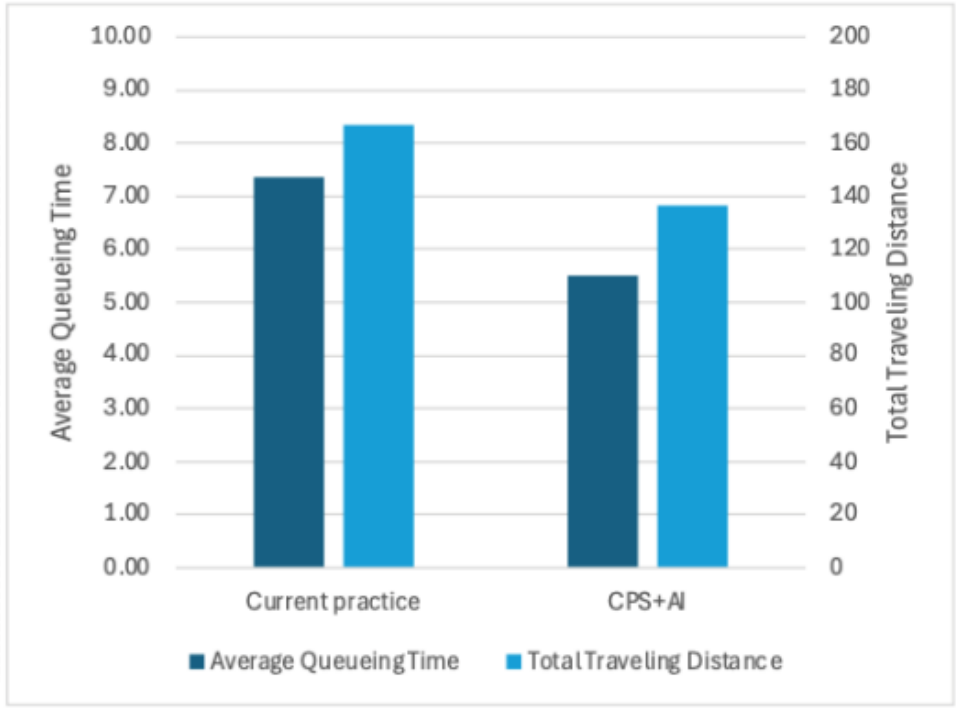
[1, 3]

Cyber-collaborative autonomous mobile cart + robot + vision system + HUB-CIs for early detection & treatment [4]

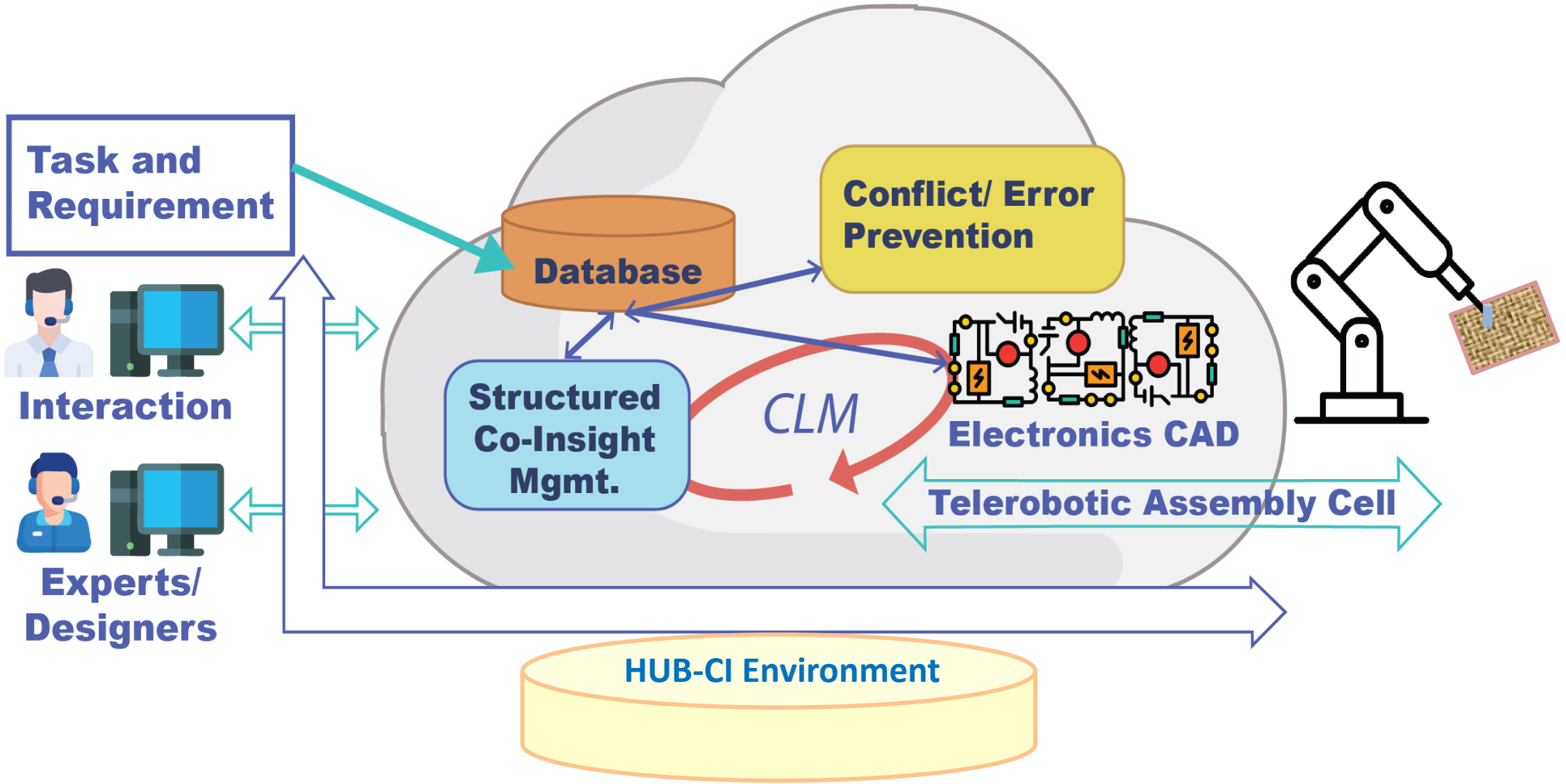


Agentic GPS + AI system for collaborative truck sharing of post-harvest shipping [5]

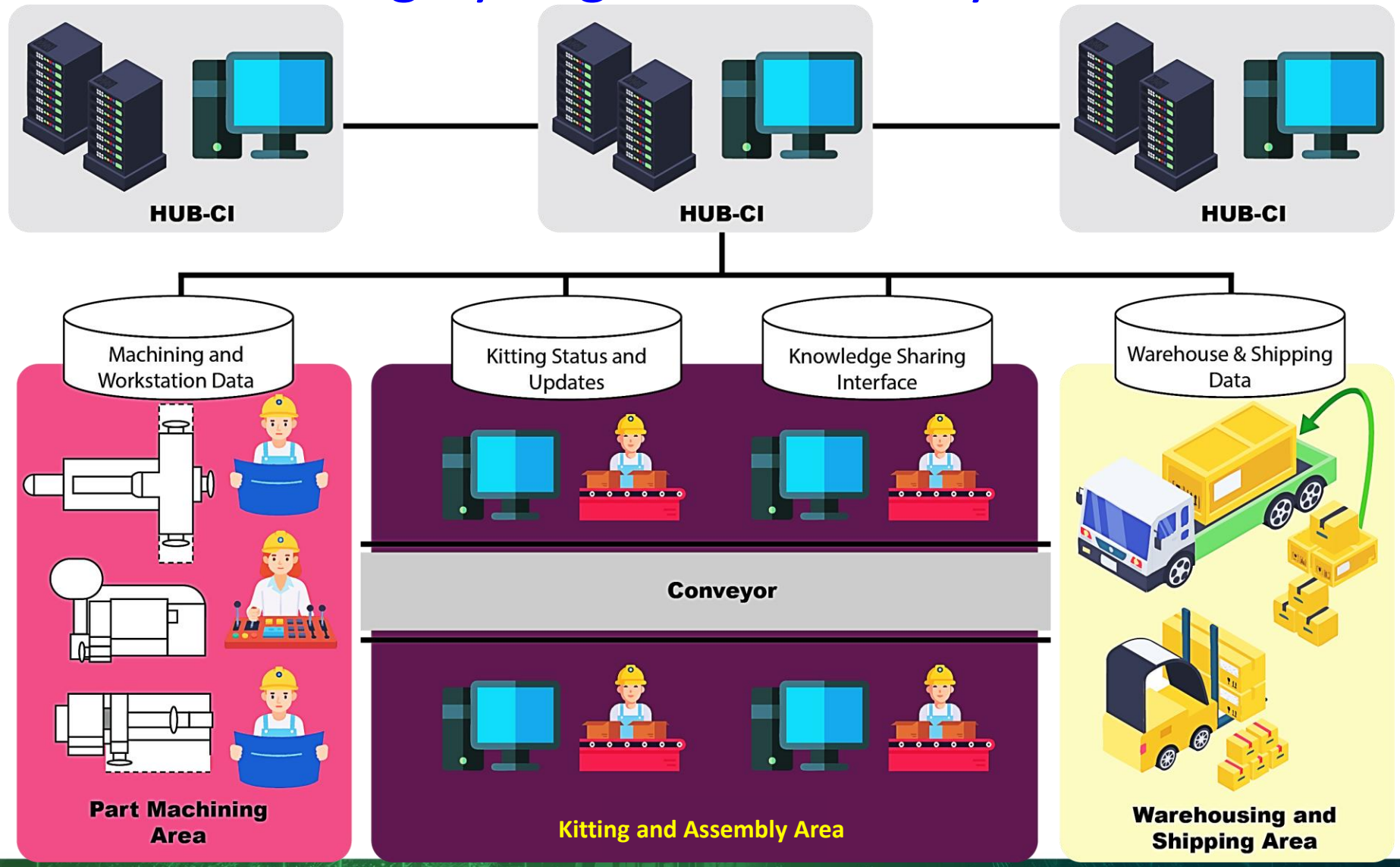




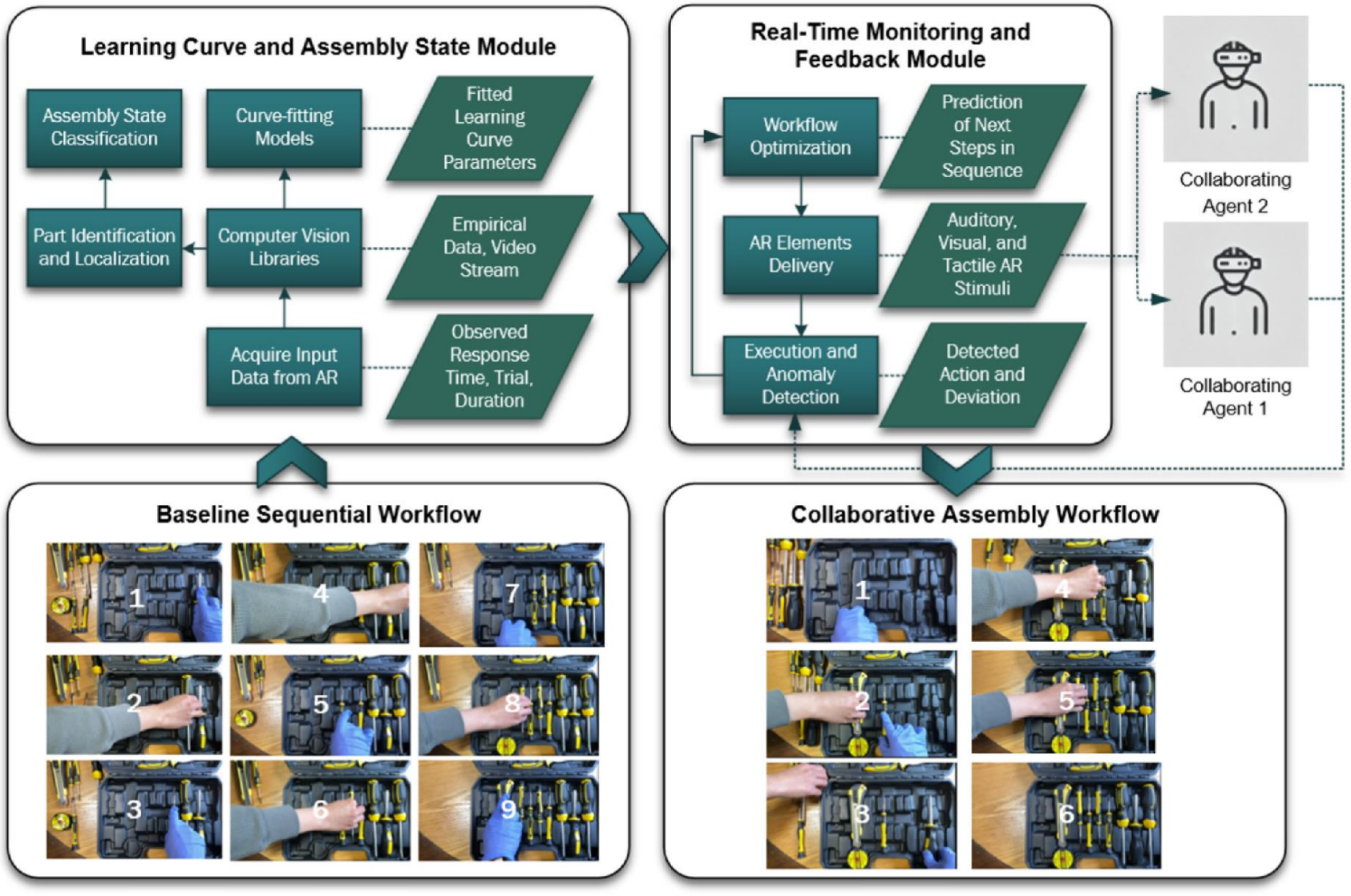
Cyber-collaborative telerobotic design and assembly [1]



Cyber-collaborative manufacturing with skill and knowledge sharing by augmented reality wearables [6]



Cyber-collaborative assembly workflow with HUB-CI [6]



Summary: Digital & Cyber-Collaborative Automation:

Augment the abilities of workers, robots, systems, and organizations

Increasing levels of **cyber mobility, computational intelligence, and Cyber-Collaborative Control Theory** (C3P)

- Higher levels of automation intelligence
- operational optimality
- resilience to internal and external changes & disruptions
- sustainability

Emerging challenges: Human changing roles, trust, awareness, quantum transformation

Digital & Cyber Augmentation	
1970	Computerized
1980	Computer Integrated
1990	Internetworked + Mobile
2000	Cloud-Based + Machine Learning
2010	Cyber-Physical + Cybernetics
2020	Quantum { computing & AI }


COSTA RICA


Costa Rica
Exotic wood collection
Ron-Ron (Ironwood) Astronium graveolens
Corteza (Cortez) Tabebuia Chrysantha
Guayacán Real (Ironwood) Guaiacum sanctum
Gravilia (Lacewood) Cardwellia sublimis


COSTA RICA
COSTA RICA


COSTA RICA

Hughes, L., et al. (2025). AI agents and agentic systems: A multi-expert analysis. J Computer Infor Syst, 1-29.

[1] Nof, SY (2026). *How collaborations succeed*. Springer Nature ACES Series

[2] Guo, P. et al. (2018). Agricultural cyber-physical system collaboration for greenhouse stress management, *Comp Electr Agric* 150, 439-454

[3] Nof, SY (2007). *Collaborative control theory for e-work, e-production, and e-service*. *Annual Reviews in Control*, 31(2), 281-92

[4] Dusadeerungsikul, PO, Nof, SY (2024). *Cyber-collaborative algorithms and protocols: Optimizing agricultural robotics*. Springer Nature ACES Series

[5] Dusadeerungsikul, PO, et al. (2025). Cyber-Physical Systems and AI in Smart Agriculture: Case Studies in Crop Management and Distribution. *Proc. of ICPR* Chia, Colombia

[6] Ajidarma, P, Nof, SY (2025). Skill-and-Knowledge Sharing HUB-CI Model for Resilient Production Systems. *Int J Prod Econ* 287

Acknowledgement

Partial support from Purdue PRISM Center (Production, Robotics, and Integration Software for Manufacturing and Management), NSF, and BARD grants, and collaborations with PGRN, PRISM Global Research Network researchers.

Muchas gracias

Preguntas?

nof@purdue.edu

CITECDx CONGRESO DE INGENIERÍA

CITEC colegio ingenieros tecnólogos