Industrial Engineering: From Optimization by Interaction & Integration to Augmentation & Collaborative Control

Our Frontiers for Future Work and Factories

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PRISM Center

Production, Robotics, and Integration Software for Manufacturing and Management

"Knowledge through information; Wisdom through collaboration"

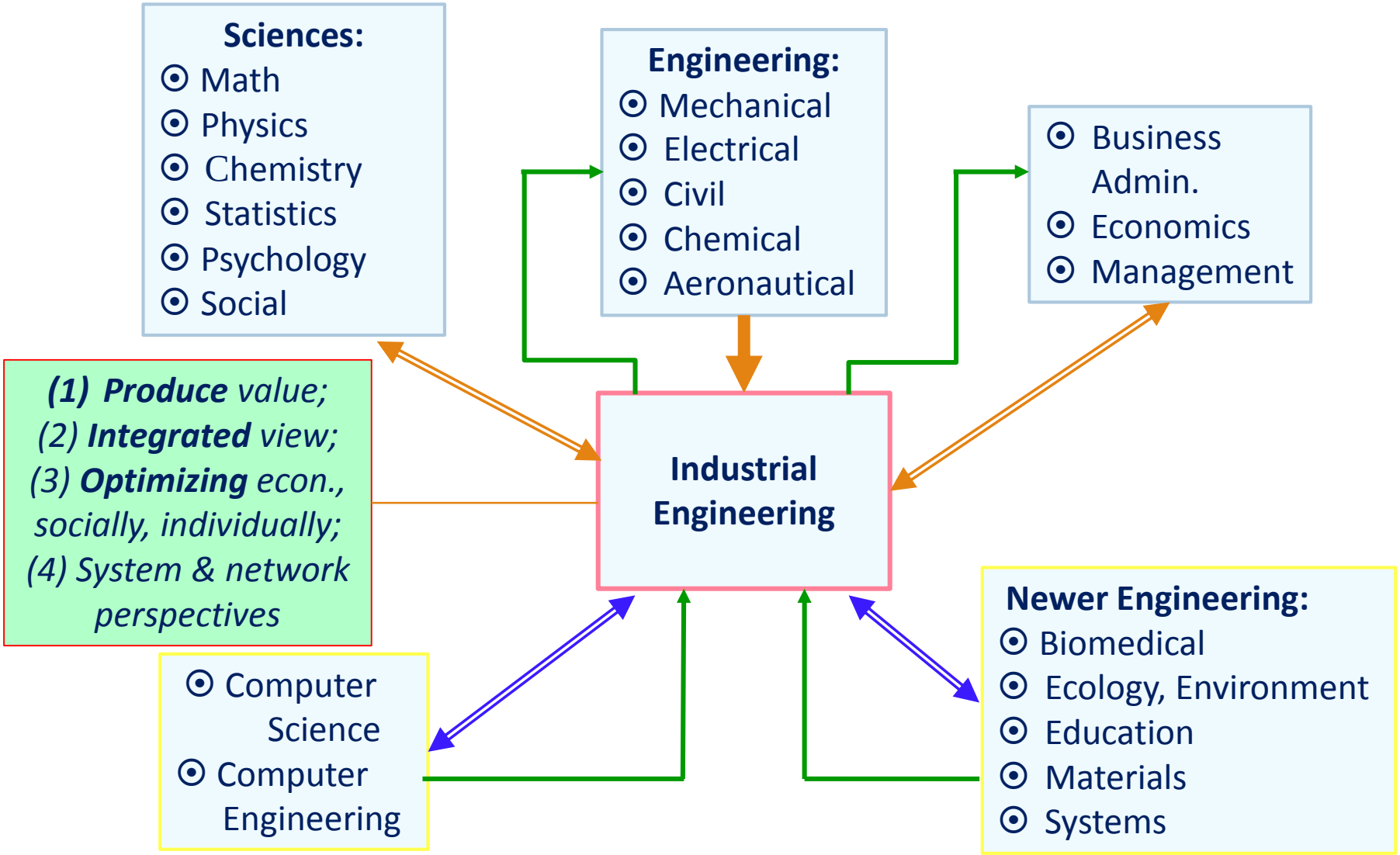
In a Nut Shell

1. Why would one become an IE? What is the unique role of Industrial Engineering in our life? [3]

2. Cyber augmentation of e-Work & Robotics – What? Why? How does it influence IE now and in the future? [4, 5]
3. Role of emerging cyber augmented collaborative automation: Cyber-optimize work interactions [6]
4. How does cyber-augmented collaborative control augment automation, quality, and resilience? [7]
5. Challenges and exciting opportunities; Relevancy to COVID [8, 9]

Historical Perspectives on IE Progress & Success

(1) Suppliers; (2) Adopters; (3) Successors



Industry & Management Disruptions, Transformations
Collaborative e-Work and its transformative influence

v - Design v-Enterprise	e- Business e-Production	a-Robotics c-Robotics	v - Factory e - Mfg.	e- Logistics e- Service	Collaborative Cyber Physical Systems	. . .

e-W o r k → **c-Work** → **cc-Work** → **???**

electronic / digital work -- **c**ollaborative work -- **c**yber-**c**ollaborative work

- **Power fields** (magnetic fields; gravitation) influence bodies to organize and stabilize
- **Cyber fields** (IT, communication, AI / brains, robotics) envelop us and influence us to *organize our e-Work systems* in a different, better (optimal) way → *Integrate*
  - Purposefully, *stabilize e-Work* to effectively produce desired and sustainable outcomes

We realize: World "big" data growing exponentially, while individuals' cognitive abilities evolve slowly → ***Augment !***

Cyber in e-Work Automation: Better work & product

Augments abilities of workers, machines, sensors, robots, and organizations

Increasing levels of computing, communication, mobility, and computational intelligence increase levels of automation collaborative intelligence (CI), of quality, and of resilience to internal and external disruptions, through cyber collaborative e-Work (cc-Work)

BE-- Before Electricity

BC – Before Computers

BI – Before Internet

BCP – Before Cyber Physical

B?? – We are young…
- Brain augment. (CI);
- Cyber materials …

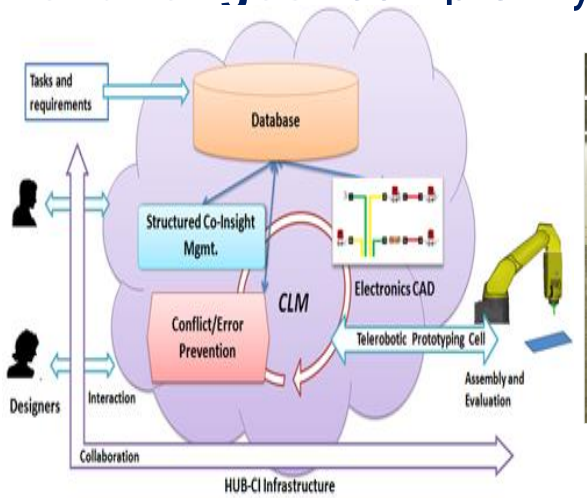
Cyber Augmentation of Work and Factories	
1.0	Computerized
2.0	Computer Integrated
3.0	Internetworked + Mobile
4.0	Cloud-Based + Machine Learning
5.0	Cyber-Physical + Cybernetics

Emerging Cyber Collaborative Physical Work

Highly distributed work: Interactive • networked • autonomous • local/global

→ Must augment and optimize their collaborative interaction

Design challenges: complexity • dynamicity • uncertainty • human role • trust



Human-Robot cc-Design, cc-Work, cc-Assembly

Smart Warehouse

Drones in logistics

Autonomous vehicles

Monitoring and smart repair by cc-Robots

CCPS: Cyber-Augmented Collaborative Physical Systems

Cyber:

1. Computing
2. Communication
3. Real Time Control
4. AI/Brain models (cybernetics)

IoS / IoT / Industrial Internet:

1. Physical Internet 3.0
2. Services/Industrial systems
3. Connected

"Industry 4.0":

1. Sensors – "Data driven"
2. Cloud
3. Big data analytics
4. Integration (Interoperability)

CCPS:

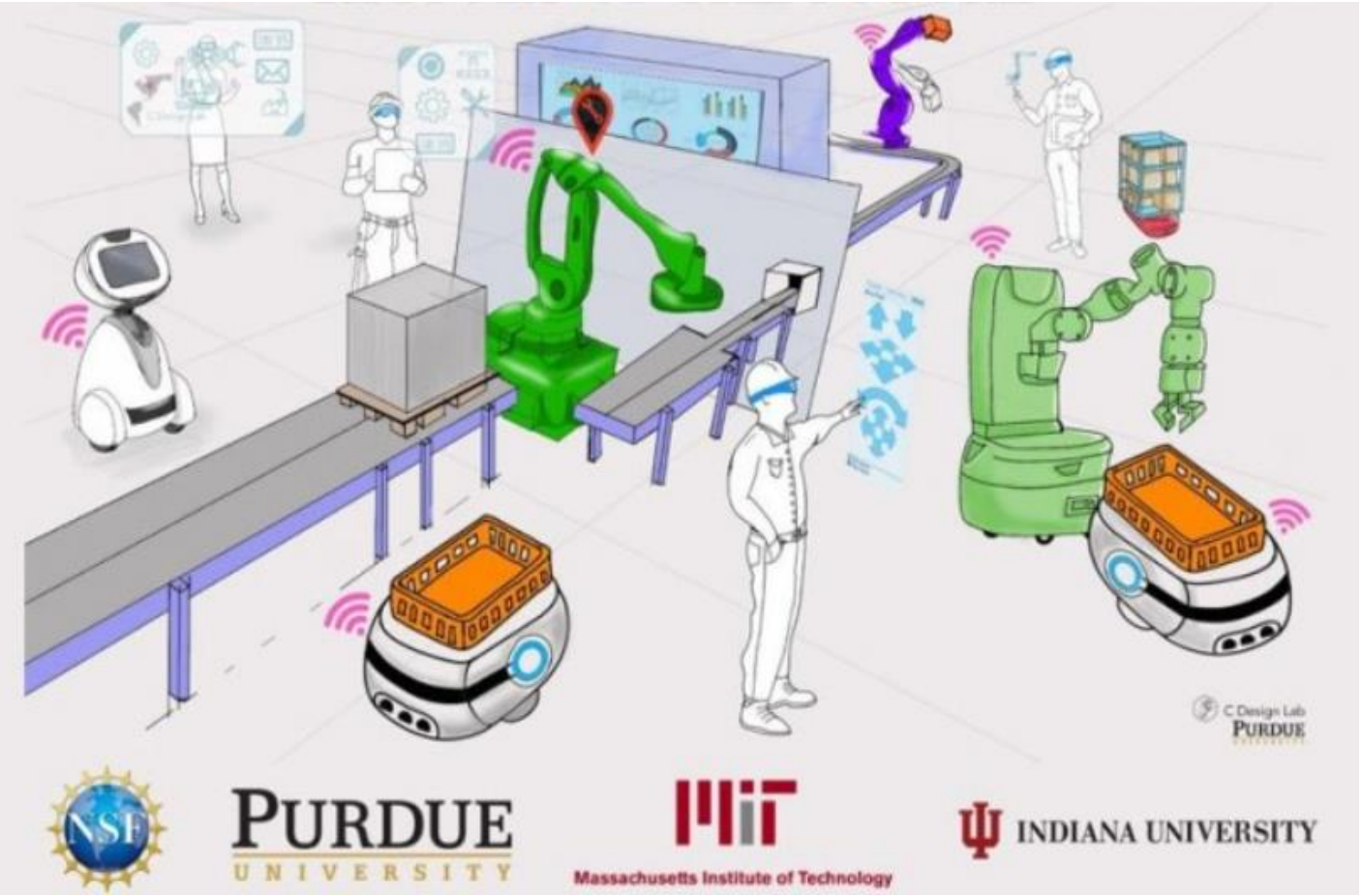
1. Cyber
2. Physical items & systems
3. Networked
4. cc-Work & cc-Management

Automation 5.0:

- Cyber-supported, smart, augmented collaboration in Work, Robotics, Production, Service, Management
- CI, collaborative intelligence for better (optimal) results

Prepare Society, Manufacturers, Workers, Managers for the "Work/Factory of the Future" [NSF project 2018-22]

Humans must always be in the loop, but differently; Joy, resilience, Economics and Management issues / challenges



1. Workers' attention, safety, awareness: Who will know to alert us?
2. Can machines instruct us?
3. Prevent errors/ conflicts/ crashes?
4. Overcome disruptions?
5. **CI** and control for JIT, JIN knowledge & skills?
6. Pre-skilling, skill sharing?
7. Trust in automation?

Collaborative Control Theory (CCT)
View of Cyber Augmented Automation

- *CCT Motto:* ***Collaborate or Collapse;***
  Collaborate & Conquer

CCT enables collaborative automation intelligence and resilience

By CCT agents, algorithms, and protocols that

a. *Augment people* – individuals, teams, organizations, by cyber support for Collaborative Intelligence;

b. *Enable better results* with physical tools and infrastructure by applying cyber intelligence

Nof, Ceroni, Jeong, Moghaddam, *Revolutionizing Collaboration through e-Work, e-Business, and e-Service*, Springer ACES Series, 2015

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