The Batsheva de Rothschild Workshop on Robotics for Nano-Structure Delivery in Agriculture

From Industrial to Agricultural Co-Robotics: The Nano Dimensions and Challenges

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ABSTRACT

Realizing the theme of this Workshop, Robotics for Nano-Structure Delivery in Agriculture, we focus on how we can benefit in the future from lessons learned in robotic delivery, Nano manufacturing, and Nano Medicine. Challenges and conclusions are presented in the context of relevant Nano Dimensions:

- Nanotechnology and agricultural intelligence (AI)
- Nano-ag robots and cyber-physical systems
- Nanofertilizers, Nanopesticides, Nanovaccines …

that can enable and improve Ag productivity with Precision Ag goals.

Scope and broader vision

1. Collaborative automation and robotics
2. Key learning from robotic delivery and Nano- Mfg./Med.
3. Challenges and conclusions

In the context of relevant Nano Dimensions:

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Robotic delivery & Relevance to Nano-Ag

Deliver what?

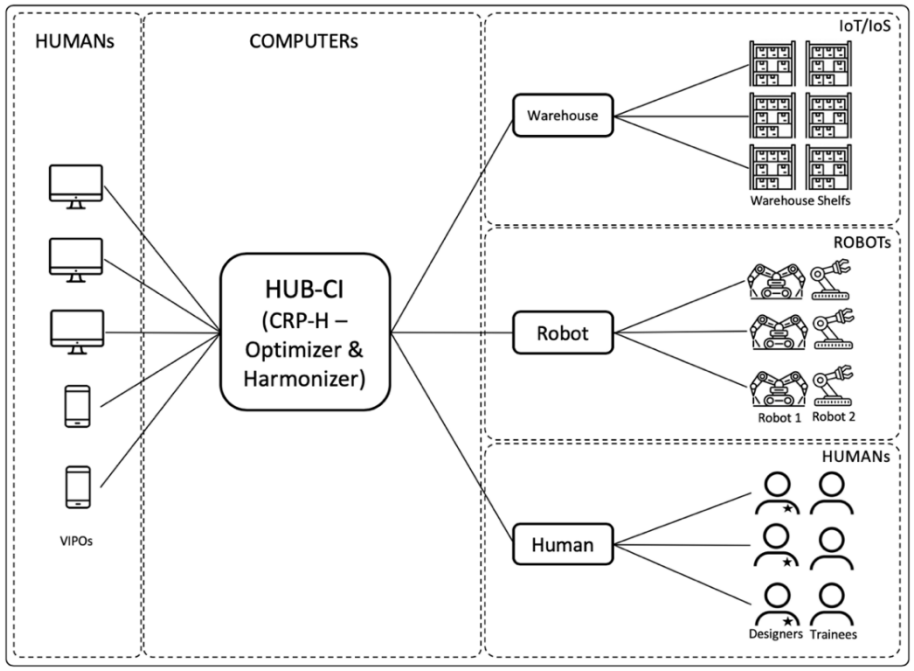
- **Commodities** (water, gas, energy); **Supplies** (food, drugs, goods, information; Nano-fertilizers? Nano-pesticides? Nano-therapies?); **Knowledge** (learning; healthcare)

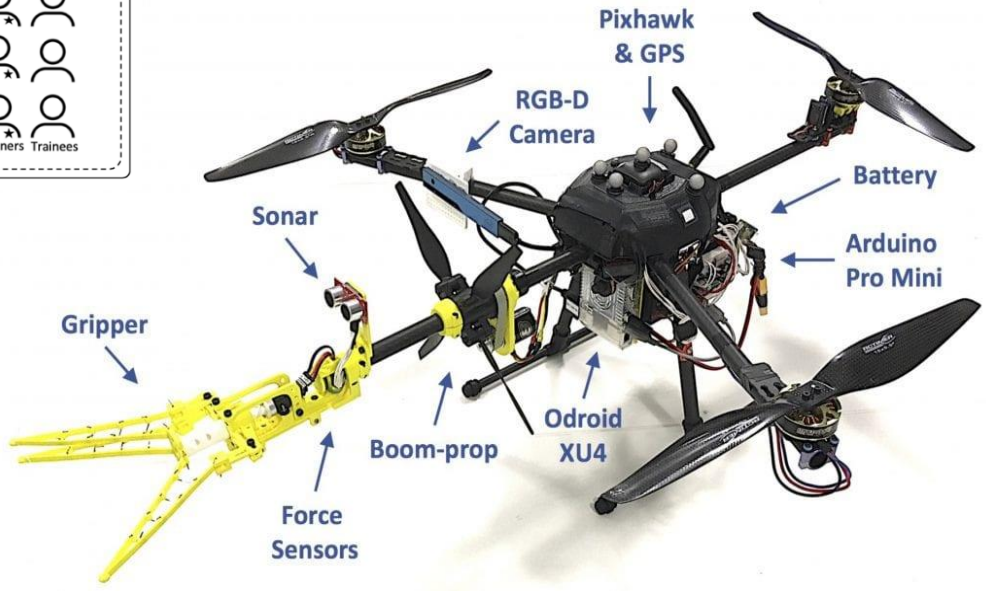
By which delivery carrier?

- **Solo robots**: mobile, autonomous car/truck, drone, sprinkler, sprayer
- **Multi robots**: drones, swarms, robotic insects
- **Robotic networks**: smart grid; cyber physical infrastructure (pipelines); sensor arrays; IoT

Multi-robot teams deliver in cyber physical warehouse

[Dusadeerungsikul et al., IJPR, 2022]



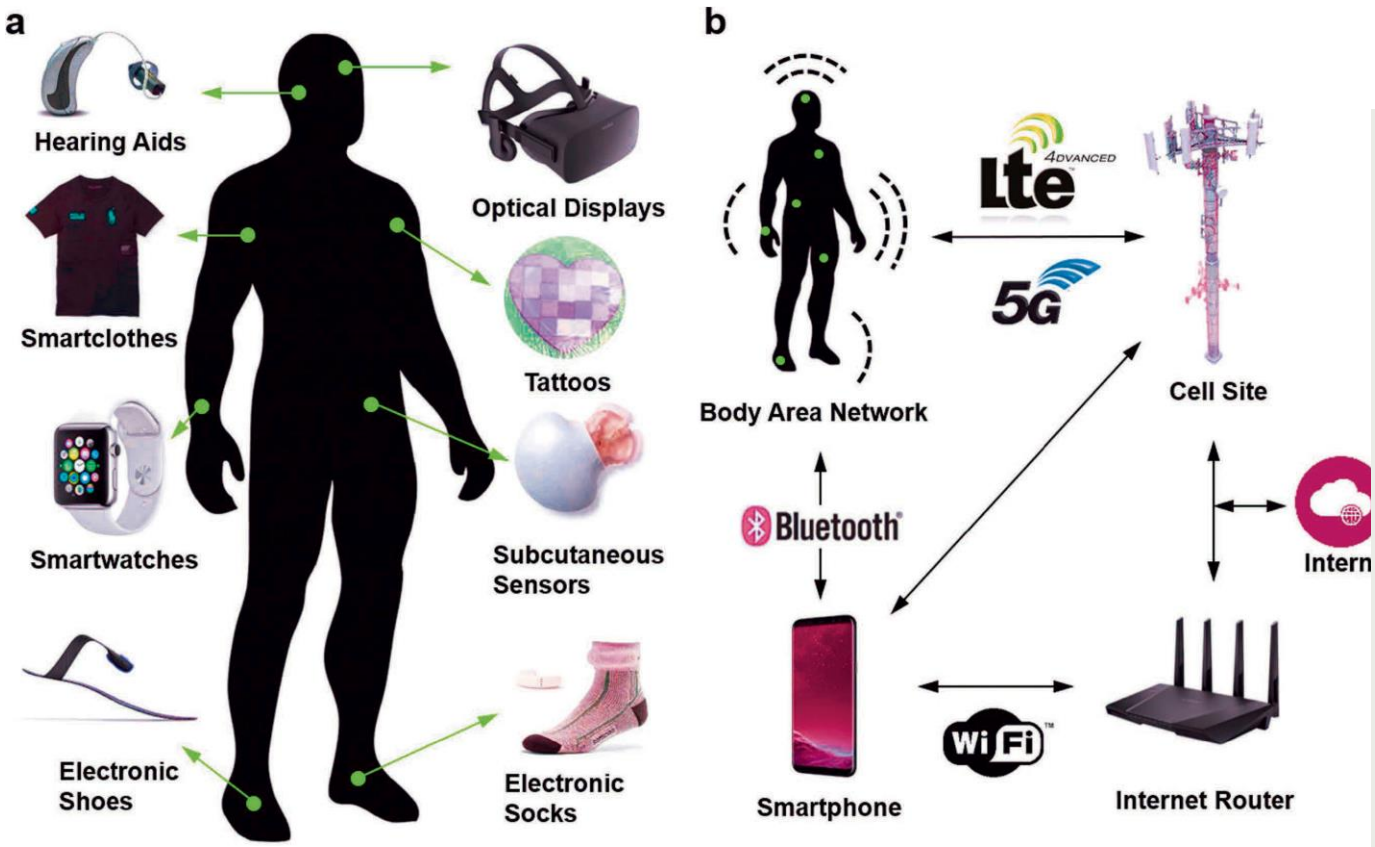


Micro-drone for ag

[D. Cappelleri, Multi-Scale Robotics and Automation Lab, Purdue University]

Wearables, e-Textiles, and Soft Robotics for Personalized Medicine

[Martinez, *Springer Handbook of Automation 2nd Ed.*, 2022; Yetisen et al., *Adv. Materials*, 2018]



a) Wearables collect data;

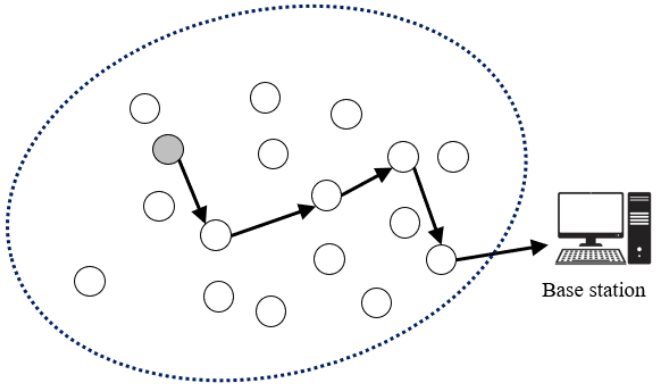
b) Data analyzed locally/sent to analysis

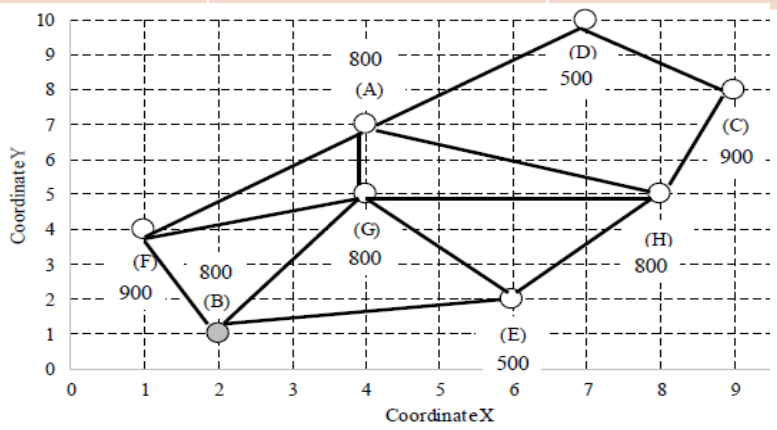
c) **Monitor and deliver:**

- Smart bandages
- Smart stickers
- Wearable bio-electronics
- Implantable soft robotics to monitor and to deliver drug, therapy, nutrition

Lessons Learned about Robotic Delivery

Attributes?	What to deliver? When?	Source • Single •Multiple	Route • Direct • Indirect	Address: where to deliver?	To a point, surface, area, or volume?
How?	Value-added on route	Continuous	Periodic	Just-In-Time	Just-In-Need





Lessons Learned about Nano-scale

1. Can improve structure and properties of materials and surfaces, e.g., ▪ Molecular beam & Atomic deposition of thin films; ▪ AFM dip-pen writes on a surface with chemical fluid; ▪ Self assembly (additive) of components/materials to form a designed Nano-structure; ▪ Laser/photonic mfg.
2. Nano sensors enable and can improve at the Nano scale where sensors can reach, and what they can sense
3. A robotic/programmable automation program is used to enable it
4. Nano systems require non-Nano systems (Hybrid) to plan and control their activities and delivery. Ex. Microscopes/cameras for human/computer vision.

Challenges and Conclusions

1. From Integration and Interactions our goal is Precision Collaboration for optimized Precision Ag.

2. Optimize collaborative robotic delivery by cyber and AI, to eliminate errors, avoid conflicts, overcome disruptions, deliver the best results

3. Nano risks from inhaling, and toxic risks; can we develop secure delivery to eliminate them?

Acknowledgements

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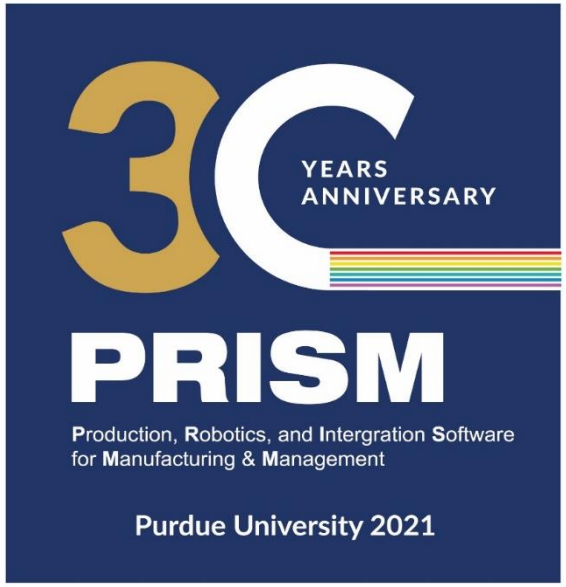
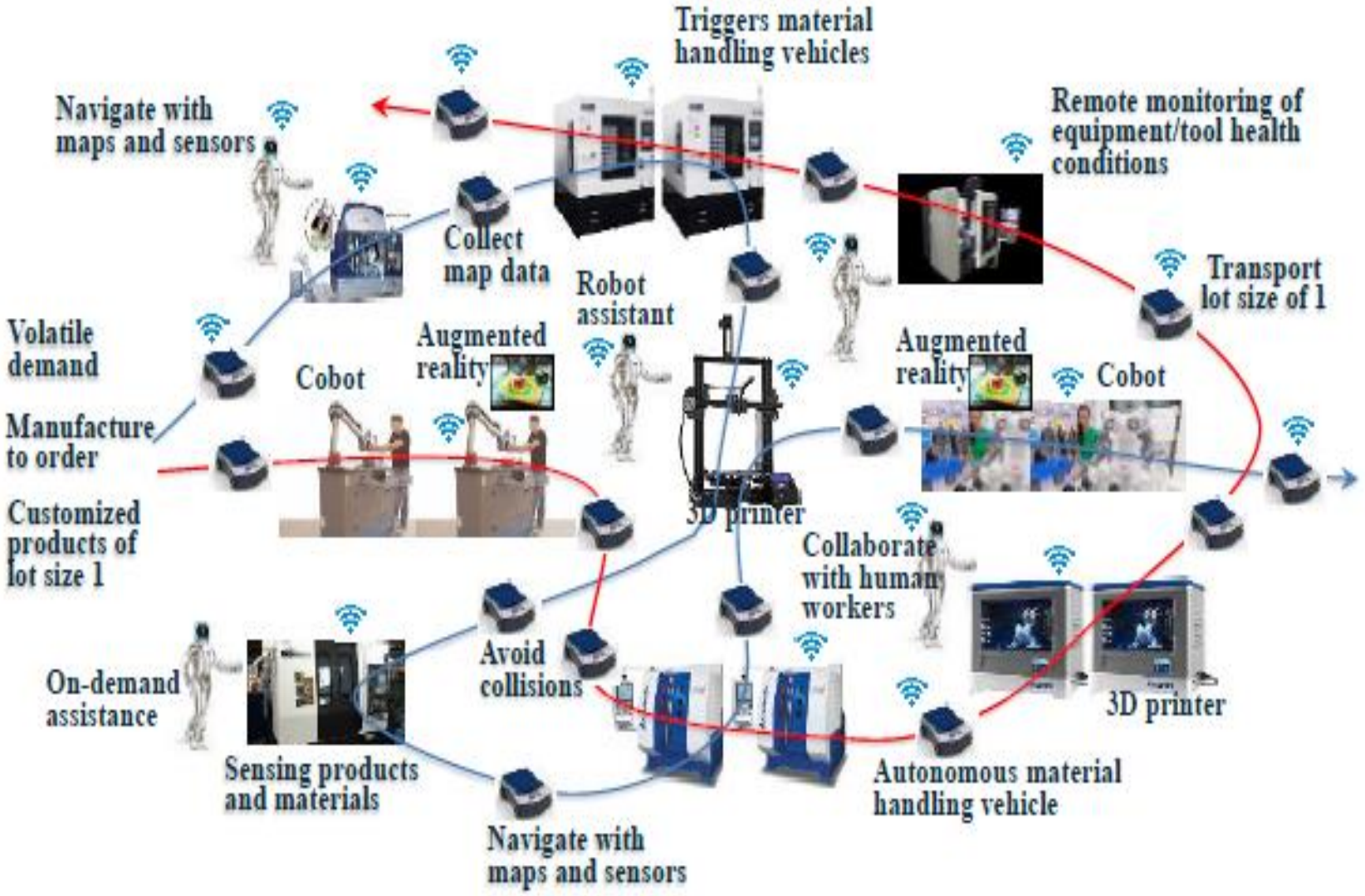
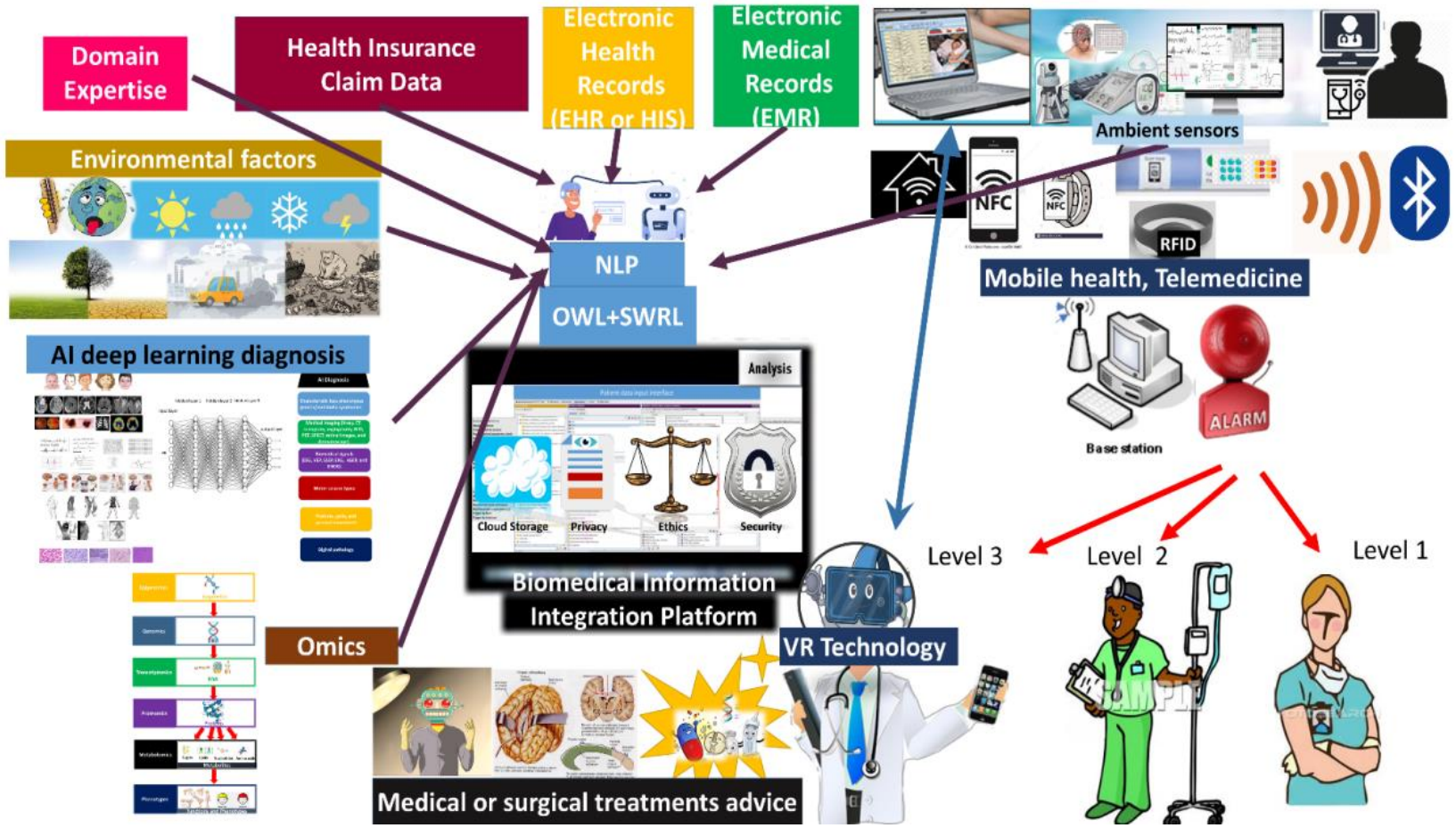


Robotic Delivery in Production/ Nano structure



[Munoz, et al. (2022) *Engineering Applications of Social Welfare Functions,* Springer ACES Series]

Emerging Telemedicine for Healthcare Delivery



Illustrated telemedicine and tele-critical care model for the future

[Chiang and Huang, in *Springer Handbook of Automation 2nd Ed.*, 2022]