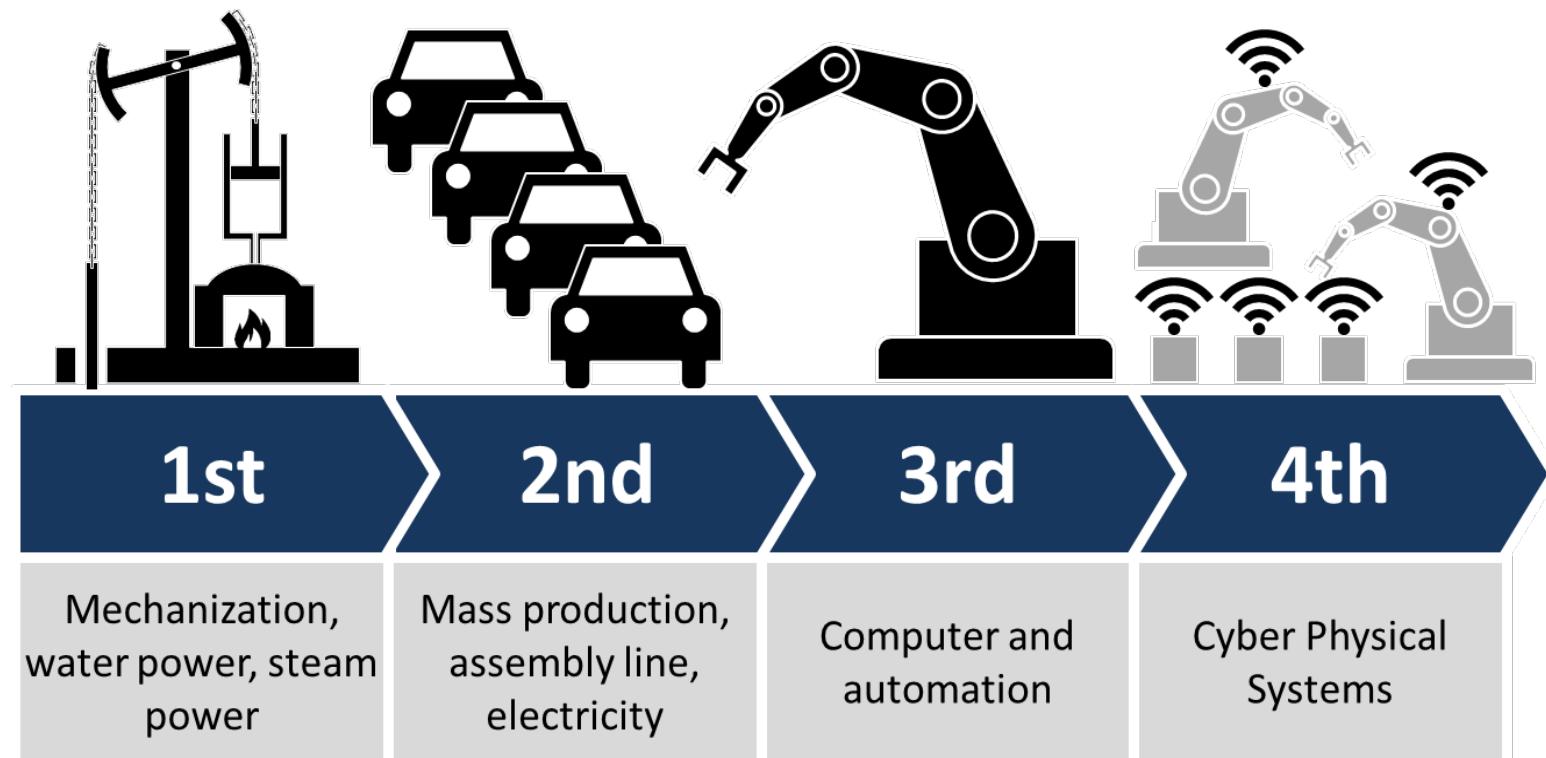


Cloud Robotics

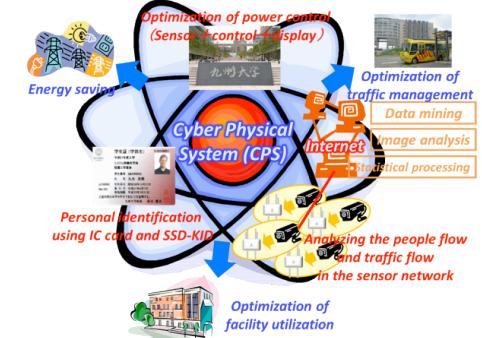
Intelligent Robots as Cyberphysical Systems



Industrial Revolutions



Cyber Physical Systems



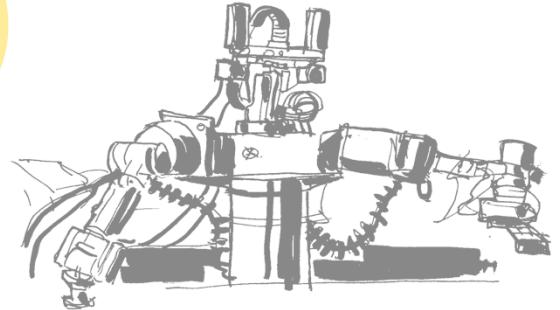
Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components. (NSF, 2017)

CPS are smart networked systems with embedded sensors, processors and actuators that are designed to sense and interact with the physical world (including the human users), and support real-time, guaranteed performance in safety-critical applications.

(Vision statement, NITRD CPS Interagency Working Group).

CPS technology will transform the way people interact with engineered systems -- just as the Internet has transformed the way people interact with information. (NFS 2017)

What is a Robot?



Robots are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components.

Robots are smart networked systems with embedded sensors, processors and actuators that are designed to sense and interact with the physical world (including the human users), and support real-time, guaranteed performance in safety-critical applications.

Robotics technology will transform the way people interact with **robotic** systems -- just as the Internet has transformed the way people interact with information.

A Robot is a CPS, but not all CPS are robots

- Applications of CPS:

Vehicular systems and transportation (Public transport, Road monitoring...)

Medical and health-care systems (Robot-assisted operation)

Smart homes and buildings (Healthcare in smart homes)

Social network and gaming

Power/Thermal management

Cloud computing and data centers

Power Grid or Power Systems

Networking systems

Surveillance

Industrial process control

Aerospace and air-traffic management

Water-distribution

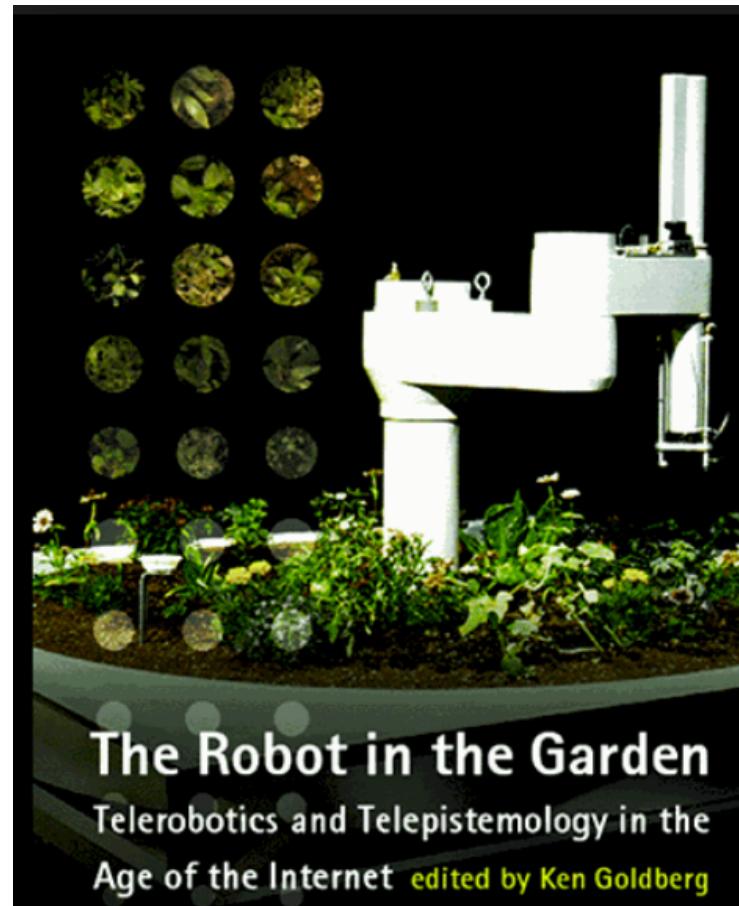
Robotics

From: Khaitan, S. K. & McCalley, J. D. (2014). Design techniques and applications of cyber physical systems: a survey. IEEE Systems Journal, 9 (2), 350-365.

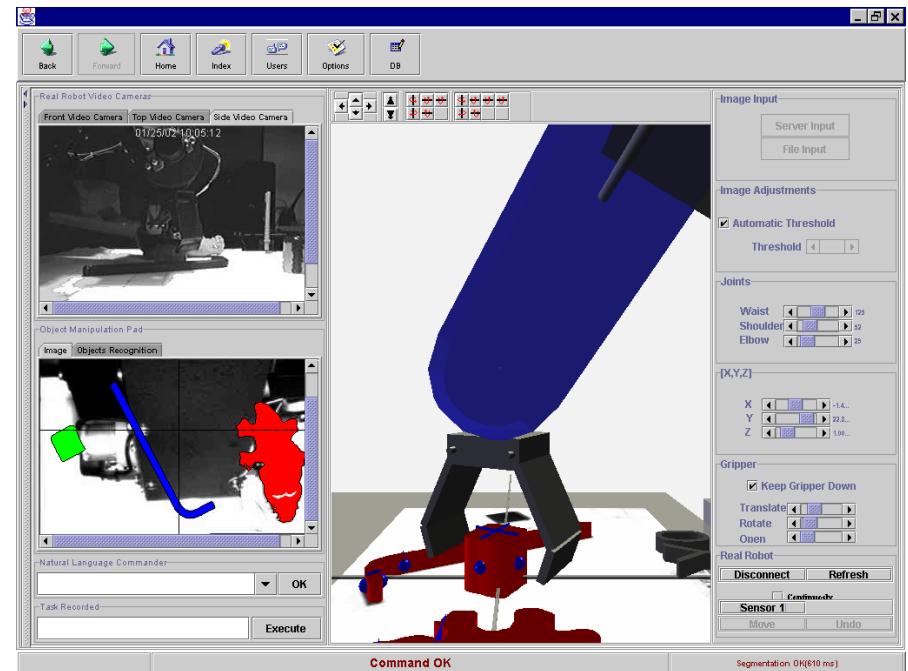
Where is the Internet?

Robots/CPS are smart **networked** systems with embedded sensors, processors and actuators that are designed to sense and interact with the physical world (including the human users), and support real-time, guaranteed performance in safety-critical applications.

From On-line Robots to *Cloud Robotics*

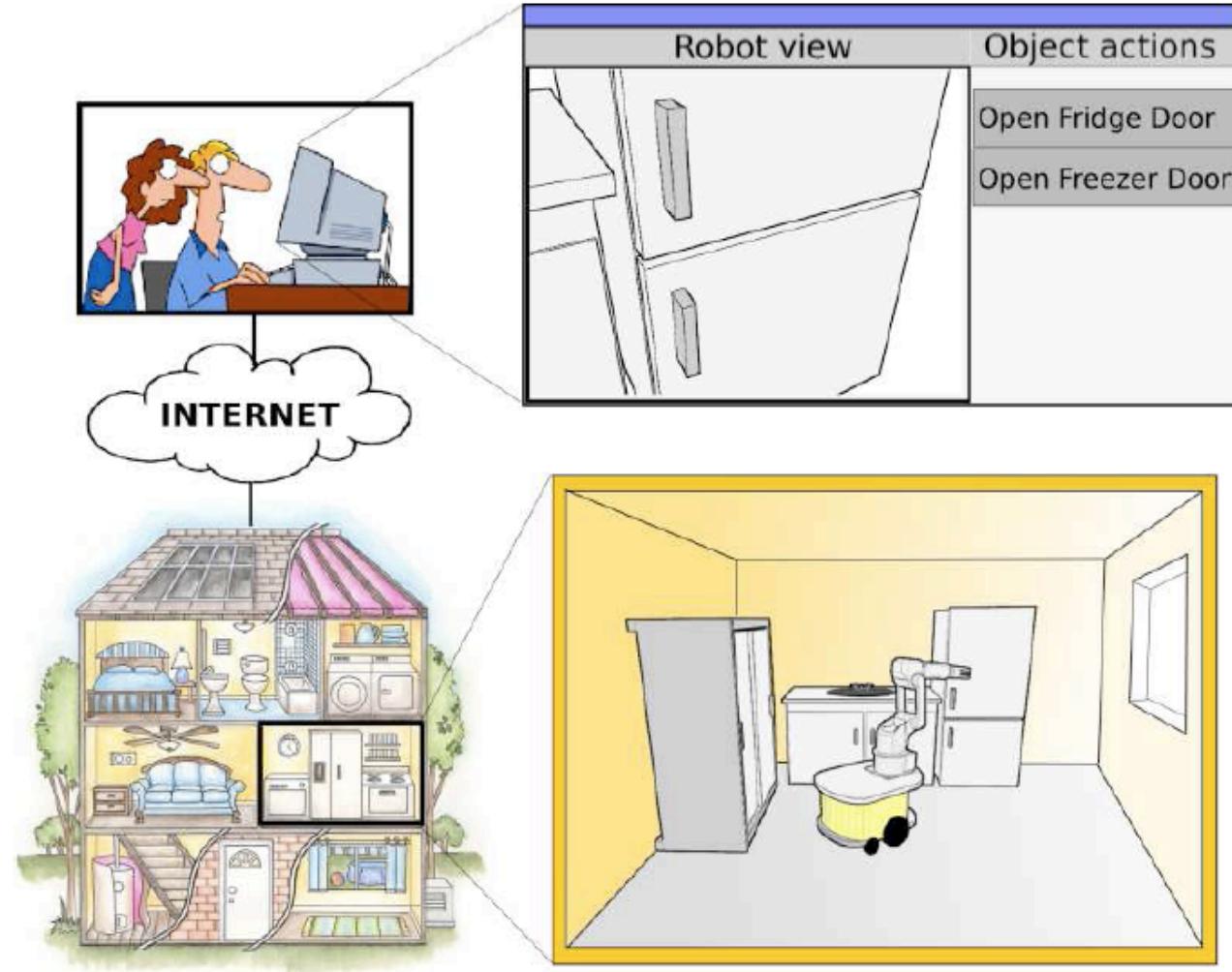


The UJI Online Robot



Marín, R., Sanz, P.J., del Pobil, A.P., 2003,"The UJI Online Robot: An Educational and Training Experience",
Autonomous Robots, Vol. 15, No. 3, pp. 283-297

Telepresence paradigm



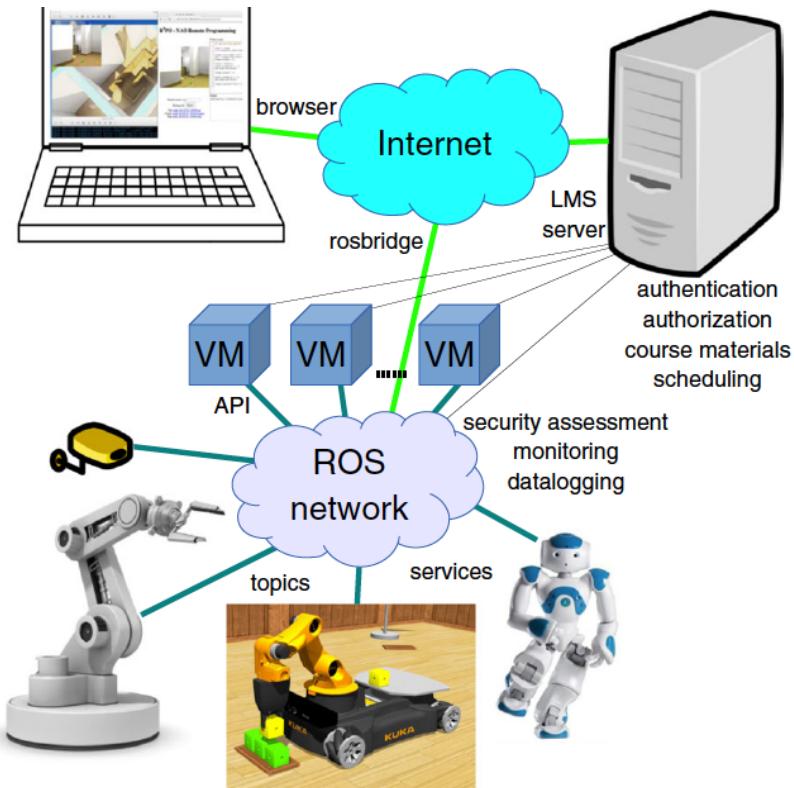
The Night Robot Guide

- Custom-made guide robot at Tate Britain museum
- Any Internet surfer can explore the masterpieces inside the museum
- At night by live-streaming the robot's vision with commentary



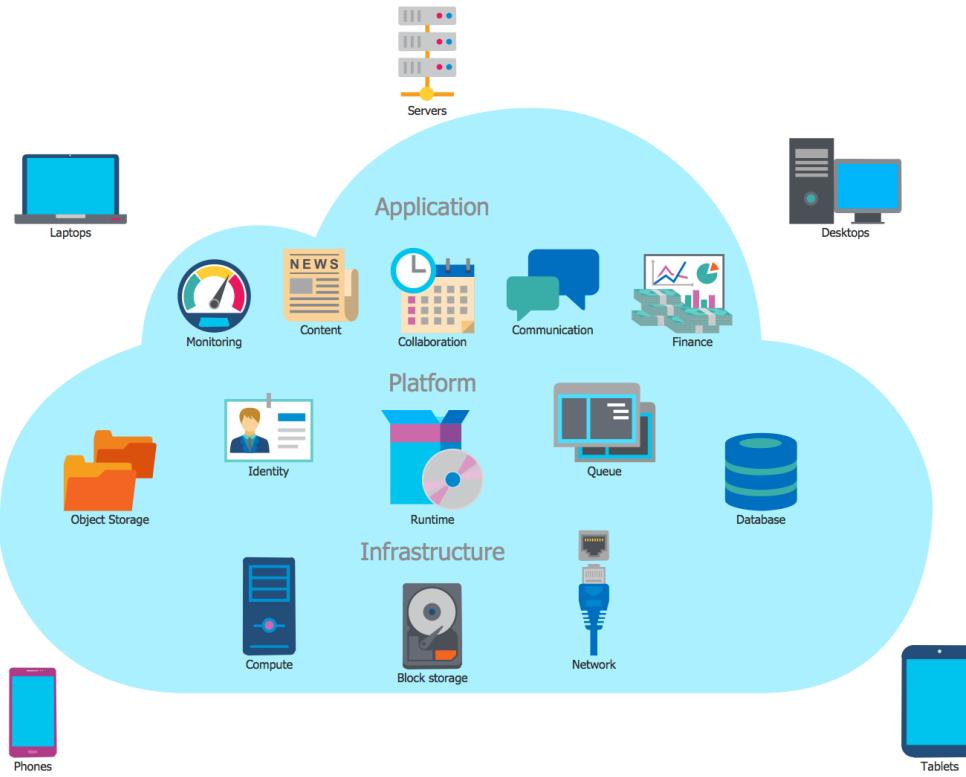
The Robot Programming Network

- The user is connected to Internet via a browser
- He is granted access to the LMS server
- The user's code is run on a Virtual Machine
- A secure API for interacting with the ROS modules of the network



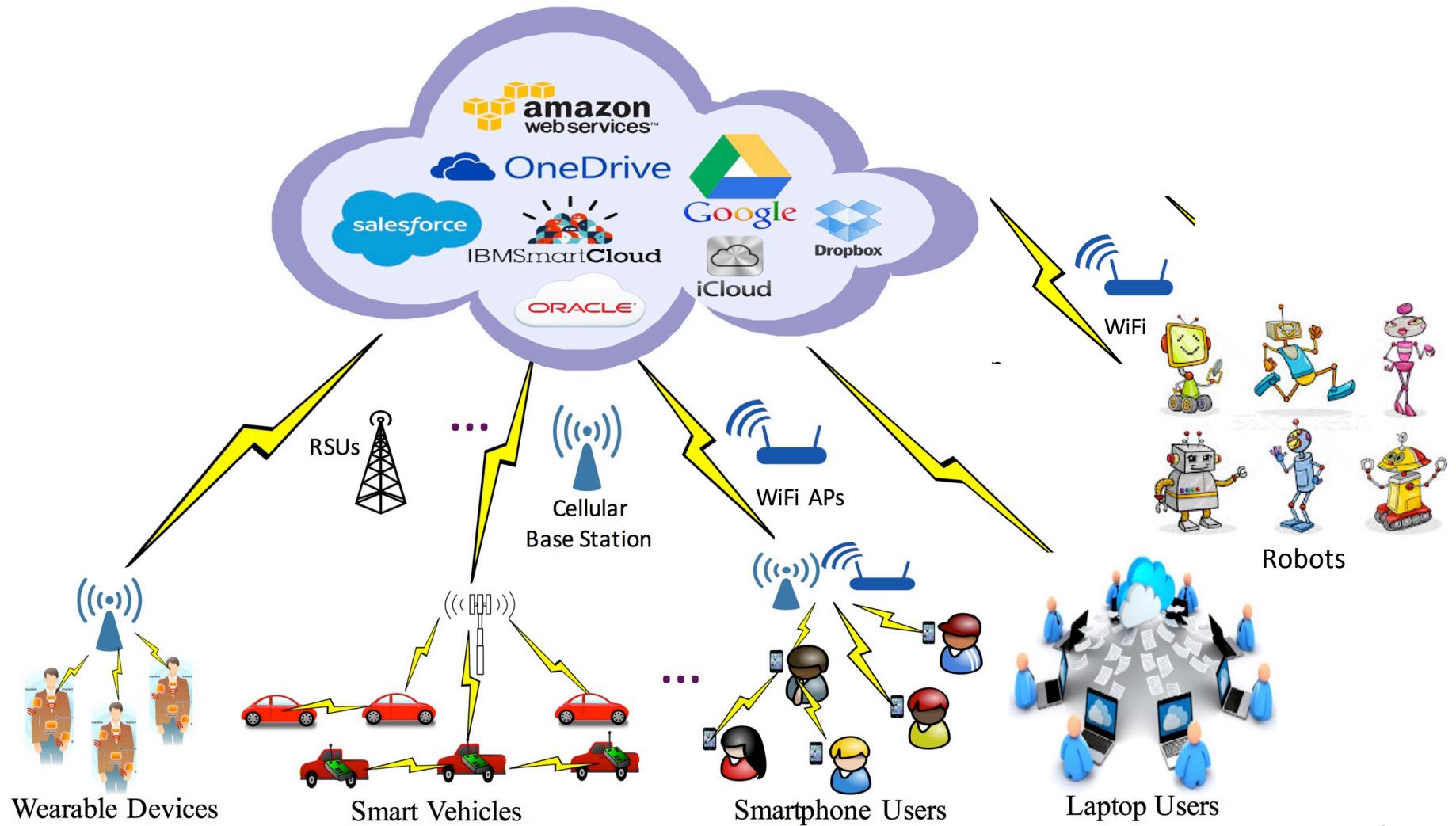
Cervera, E., Martinet, P., Marin, R., Moughlbay, A.A., del Pobil, et al., 2016, "The Robot Programming Network", *Journal of Intelligent & Robotic Systems*, Vol. 81, pp. 77-95

Cloud Robotics?



Cloud computing: ubiquitous, convenient, on-demand network access to a shared pool of configurable resources and services: servers, storage, networks, applications..., provisioned by cloud service providers.

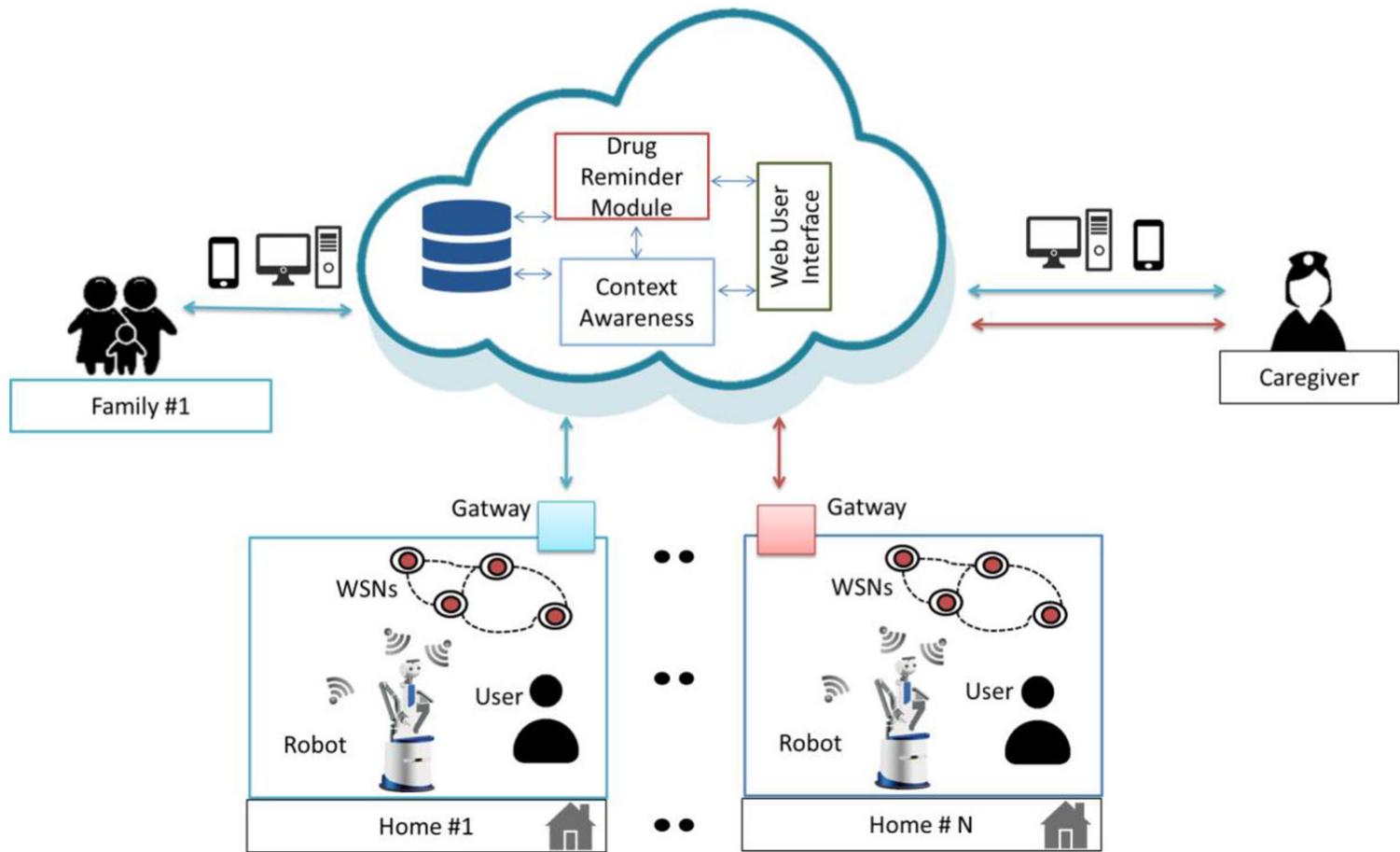
Cloud Robotics



Cloud Robotics

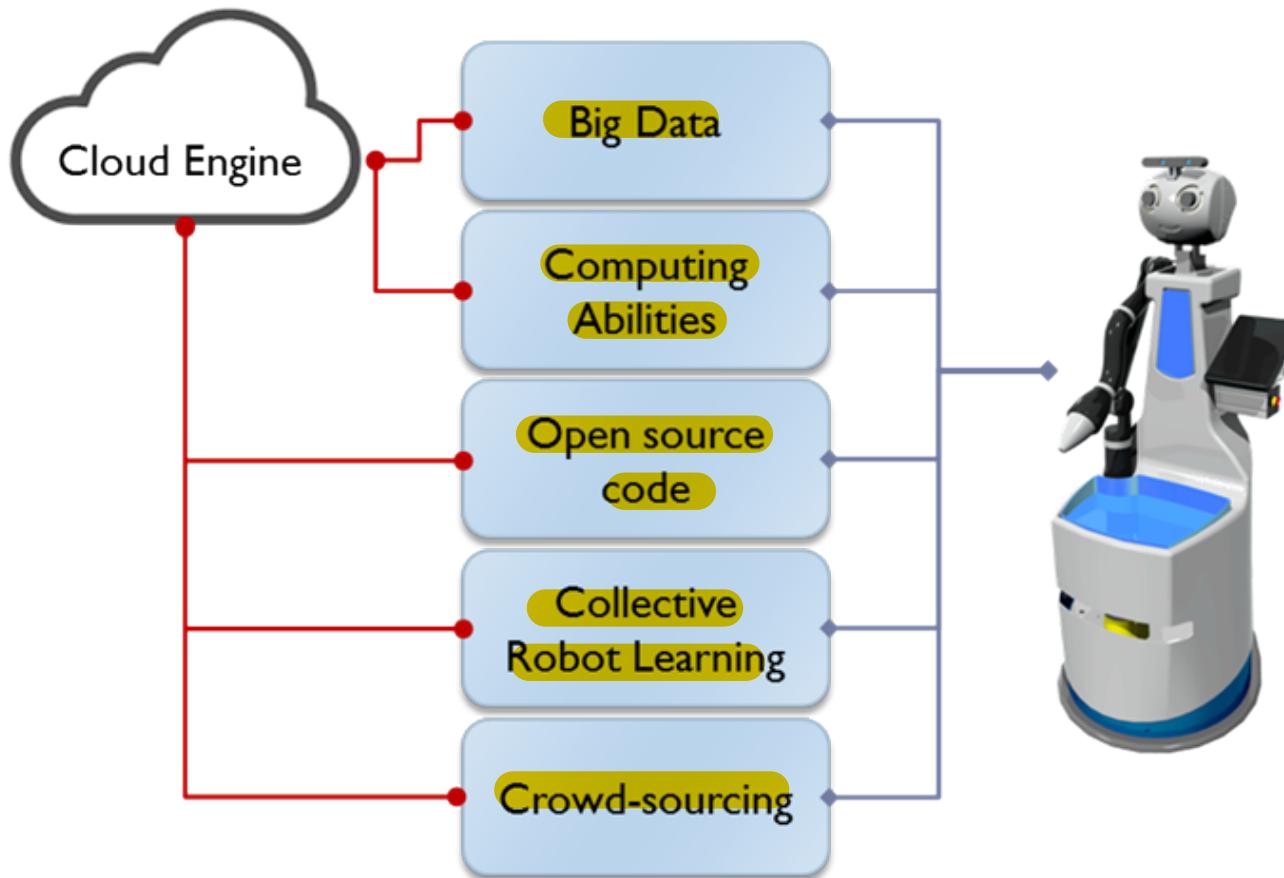


Cloud Service Robotics for Assisted Living Applications



From L. Fiorini et al., "Enabling personalized medical support for chronic disease management through a hybrid robot-cloud approach", Autonomous Robots · July 2016

The Five Elements of Cloud Robotics



Kehoe, B., Patil, S., Abbeel, P., & Goldberg, K. (2015). A survey of research on cloud robotics and automation. *IEEE Transactions on Automation Science and Engineering*, 12(2), 398-409.

The Five Elements of Cloud Robotics

1. **Big data.** Access to a vast amount of data: indexing a global library of images, maps and object data.
2. **Cloud computing.** Grid computing on demand for statistical optimization, machine learning, and motion planning in high dimensions
3. **Open source.** Humans sharing robot code, data, algorithms, and hardware designs
4. **Collective robot learning.** Robots sharing trajectories, control policies, and outcomes to collectively improve their performance with statistical machine learning
5. **Crowdsourcing and call centers.** online and on-demand human guidance for evaluation, learning, and error recovery.

