. Robots perform certain tasks to improve the human efficiency and reduce human errors.

Robots co-exist, and augment humans to enhance their capability in performing certain tasks.
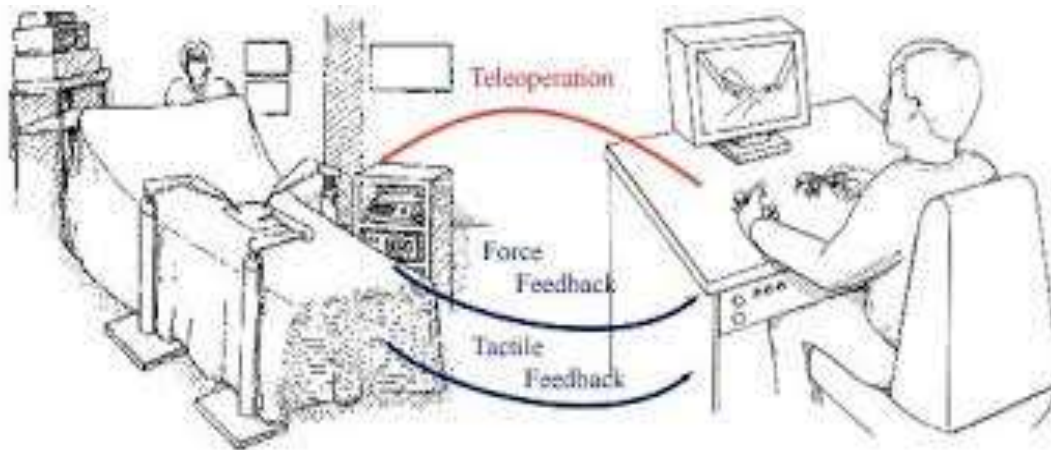
Robots are able to infer their environment and take their autonomous decisions.

- Robots providing tele-health services in remote areas.

- Robots collaborating in Manufacturing and Assembly Line.

- Perform a specific task based on static instruction and supervision by humans !

- Robots and Humans are lifting a ladder together.

- Robot is assisting human in executing repairing task.

- Robots and humans need to understand and interact with each other!

Requirements & Challenges

- Knowledge Representation
  - Unified representation of learning, emotions, senses is essential.
  - Unambiguous sharing of information and interoperability
  - among robots and robot to human is critical !
- Safety and Trust
  - The operating environment must be safe for humans.
  - For human-robot collaboration, the robotic system must be utmost trustworthy.

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Affective Model to represent emotional state

Effective language for Communication
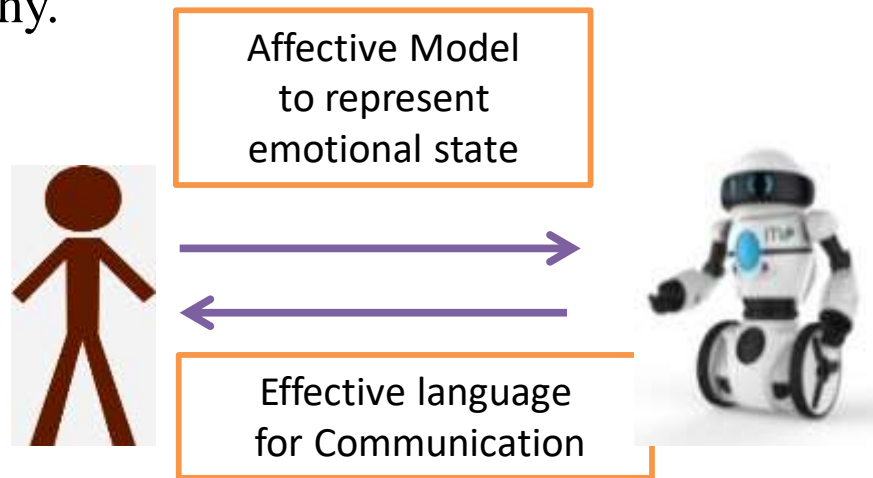
Requirements & Challenges

Networking & Communication

- Different types of data with different QoS
- requirements – e.g. Telematics, Control, Perception.
- Co-existence and interoperability of multiple
- heterogeneous devices and communication technologies.
- Should be able to provide all of above using public infrastructure !

Cloud

Inter Robot Communication
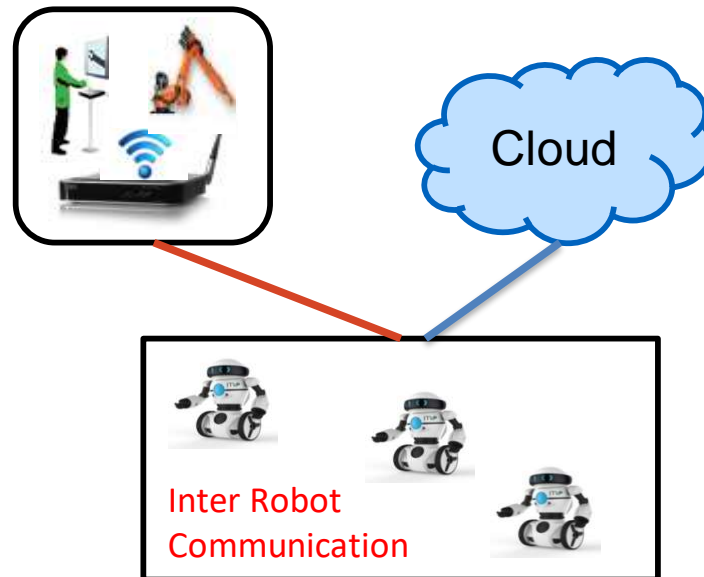
- Robots and Humans need to understand each other
- Semantically connected Knowledge Representation
  - Robots must **autonomously** learn, represent and adapt to the knowledge **in real time**.
  - Requires semantic link between knowledge items.
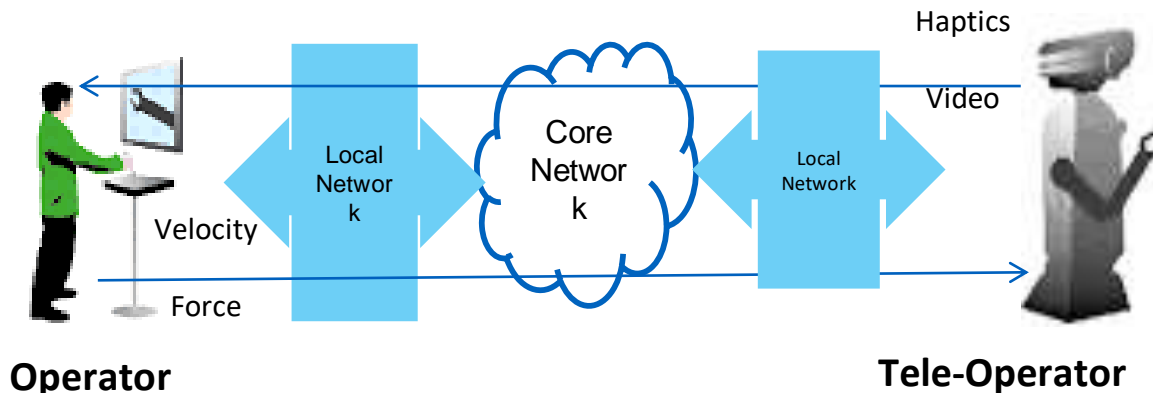 - Must be able to share this knowledge with peers.

I know it! I saw you cleaning !!

Knowledge Representation should be able to address the aspects of

- Knowledge about environment and planning for the same
- Understanding of human colleagues and other co-workers based upon their capabilities
- Must be able to represent gestures, signs and expressions of human colleague

AuR Standardization – Networking

Deterministic Networking

- Time synchronization of 1 µs, Packet Error Rate ($<10^{-8}$).
- Guaranteed end-to-end latency and bounded jitter.
- Dynamic reliability and resource reservation based upon the application context !

- 3GPP/TSDSI – AuR use-cases for 5G and beyond

    .

    - Frugal 5G has been proposed to connect remote areas
        - Requires high bandwidth (several Gbps), Low latency (<5ms), Low PER ($<10^{-7}$) and ultra high reliability (<3.5 sec of outage per year).

Expert/Doctor

Core Network

Robotic Edge at Patients End

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