HRI Definitions, Taxonomy, and Metrics

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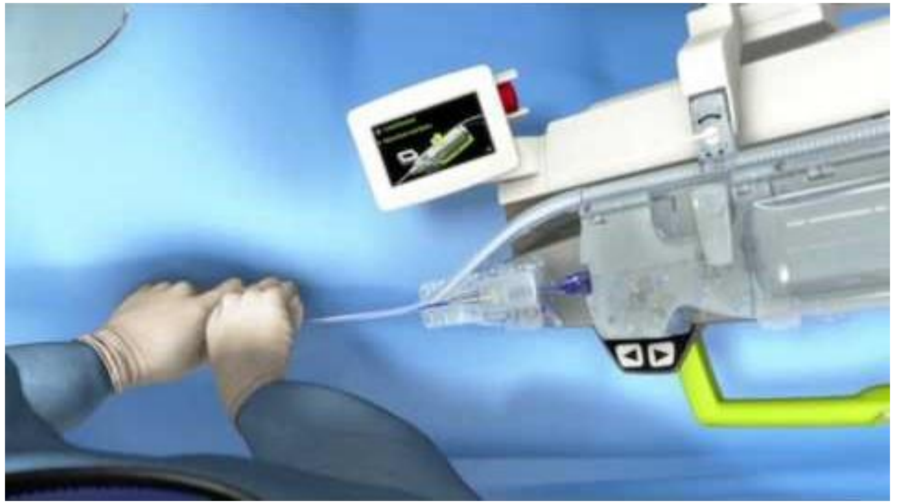
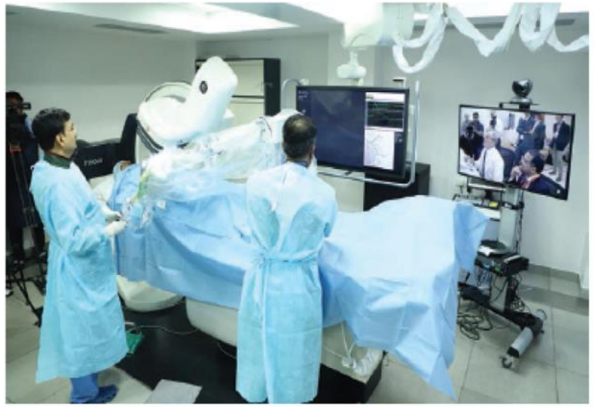
Robotics News Today!

Robot Helps Perform First Long-Distance Heart Surgery

- Surgeons in India performed surgery 20 miles away using the CorPath GRX robot
- Installed stent to open the blood vessels due to plaque build-up
- Two identical stations (one remote and one in-situ) connected via high-speed internet connection. Cameras were also in the room with other surgeons to supervise on site.
- The researchers also set up cameras in the operating room that fed additional footage of the procedure to Dr. Patel, and a pair of surgeons stationed inside the operating room supervised the procedure.
- A total of 5 successful operations were achieved.
- One step closer to for remote and underdeveloped locations!
- What is necessary for this operation?



Robotics News Today!




Defining an HRI Problem

HRI is the problem of understanding and shaping the interactions between one or more humans and one or more robots.

- Whether autonomous or not, robots interact with people
- Designing technology and training to create desirable interactions
- Evaluating robots and humans capabilities
- The field draws from cognitive science, linguistics, psychology, engineering, math, computer science, and human factors
- Designers job is to understand and shape interaction, making the exchange between human and robot mutually beneficial to accomplish a goal

HRI Attributes

- Level and behavior of autonomy
- Nature of information exchange
- Team structure
- Adaptation, learning and training of people and the robot
- Shape of the task
- Human-Interaction Roles
- Physical Proximity
- Morphology

Autonomy

Autonomy refers to how much interaction is required to control the robot and can be defined in several ways:

- An autonomous system which exists in the physical world, can sense its environment and can act on it to achieve some goals

- Autonomy can be characterized by the amount of time it can be neglected.
  - Longer neglect time = higher autonomy
  - Shorter neglect time = lower autonomy

Percentage robot control time + Percentage human control time = 100%

  - Full Teleoperation?
  - Full Autonomy?

Autonomy

- Autonomy is not the end-all be-all to robotics and should only be considered in whether it is beneficial to the interaction between robot and human.
- Physical embodiment and autonomy vary across applications
  - Autonomy may not be desired if you wanted to personally explore an environment
  - Autonomy may be highly desired in dull tasks such as doing homework, folding your laundry, and walking the dog
  - Semi-autonomous systems also exist where humans provide high-level decisions and low-level control tasks are achieved by the robot.
    - Semi-autonomous wheelchair
    - Urban search and rescue (i.e. human-level intelligence for making decisions and low-level decision making and menial, repetitive, and consistent tasks like searching for a human)

Sheridan’s Levels of Autonomy

1. Computer offers no assistance; human does it all.
2. Computer offers a complete set of action alternatives.
3. Computer narrows the selection down to a few choices.
4. Computer suggests a single action.
5. Computer executes that action if human approves.
6. Computer allows the human limited time to veto before automatic execution.
7. Computer executes automatically then necessarily informs the human.
8. Computer informs human after automatic execution only if human asks.
9. Computer informs human after automatic execution only if it decides too.
10. Computer decides everything and acts autonomously, ignoring the human.

Sheridan’s Levels of Autonomy

Limitations of this model:

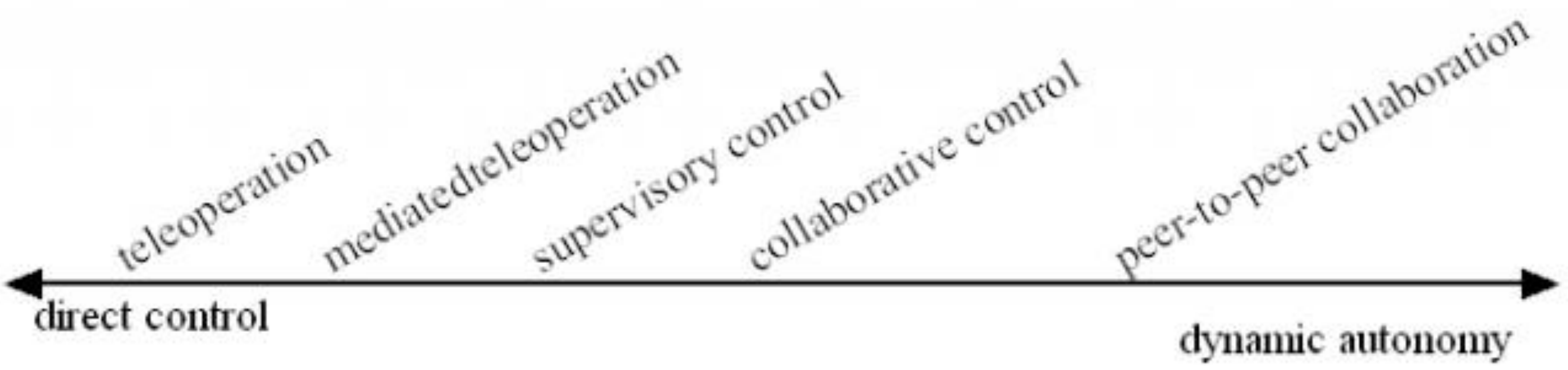
- Requires averaging of robot capabilities over all tasks it completes. The scale would be more useful if you only consider subtasks
  - What would be the level of autonomy for a Tesla Model S from Sheridan’s definition
    - Level 8 while lane keeping is on
    - Level 1 for the human to turn lane keeping on
    - What about other functions in the vehicle?
    - For an autonomatic vehicle, gear shifting could be considered fully autonomous
- What does this tell us about Sheridan’s model?
  - It is technology centric and does not consider when a human takes over

Goodrich’s Levels of Autonomy

- An alternative model which emphasises the level of interaction between human and robot.

- Allows mixed-initiative strategies where robot or human only contribute to what is best at the time based on their capabilities

- Example: A human and multiple robots searching for a victim in an USAR environment. The human would supervise all the robots as they go to search for victims while the human is responsible for verifying found robots and high-level decisions like where approximately robots should look.



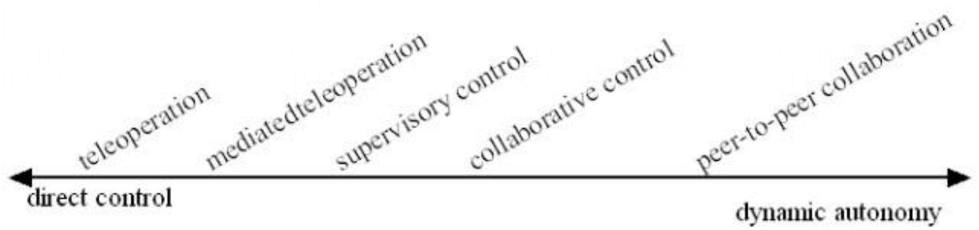
Goodrich’s Levels of Autonomy

Challenges that need to be addressed along this scale:

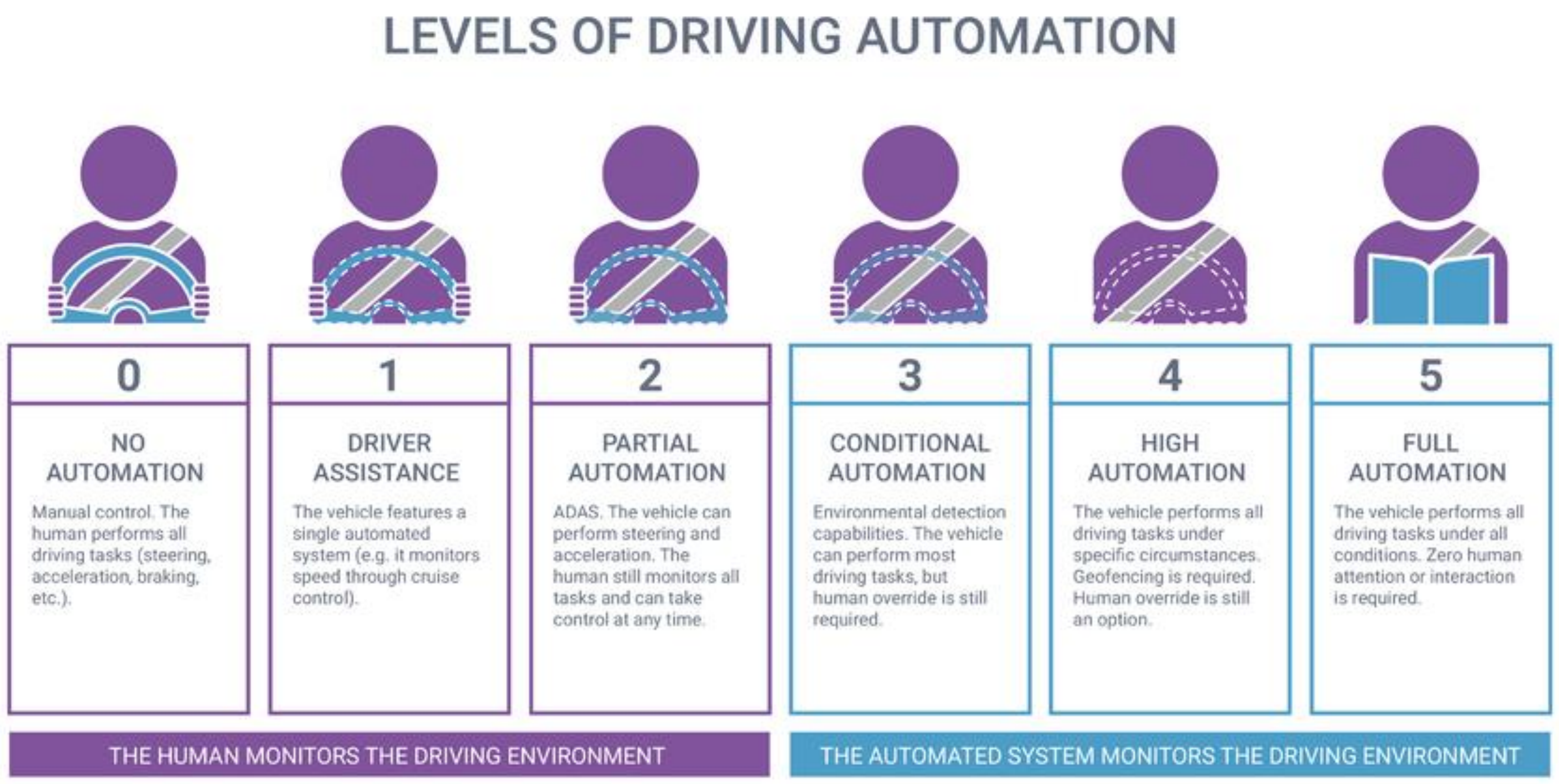
- On the direct control side the user interface needs to minimize the cognitive load of the operator while maximizing useful information retention.

- On the peer-to-peer collaboration side you will need a robot which can interact naturally and efficiently alongside a human

- Peer-to-peer is probably hardest because it needs not only full autonomy at times but also be capable of socially interacting with people
  - Example would be a manufacturing robot that needs to work with a person. It needs to be able to not only conduct pick and place but it needs to know how to adjust itself according to a persons need



Levels of Autonomous Vehicles



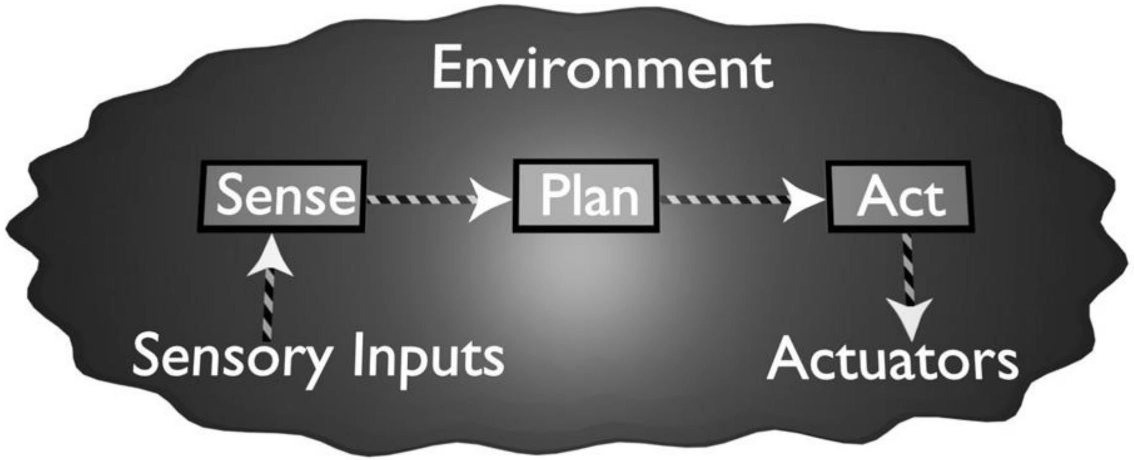
Autonomy

- Autonomy requires techniques from control theory, AI, signal processing, cognitive science, and linguistics

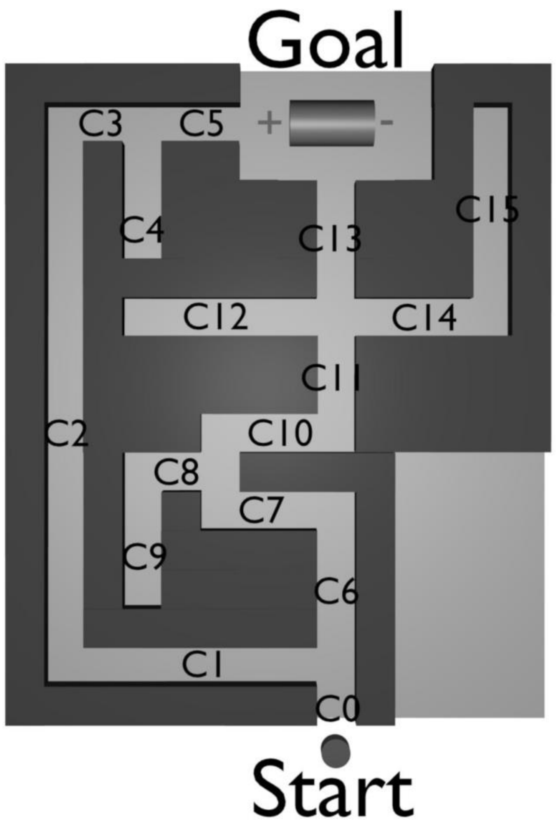
- Numerous autonomous robot control paradigms have been developed but they can be categorized into:
  - Sense-Plan-Act/Deliberative (1967-1990)
  - Behavior-Based/Reactive (1988-1992)
  - Hybrid

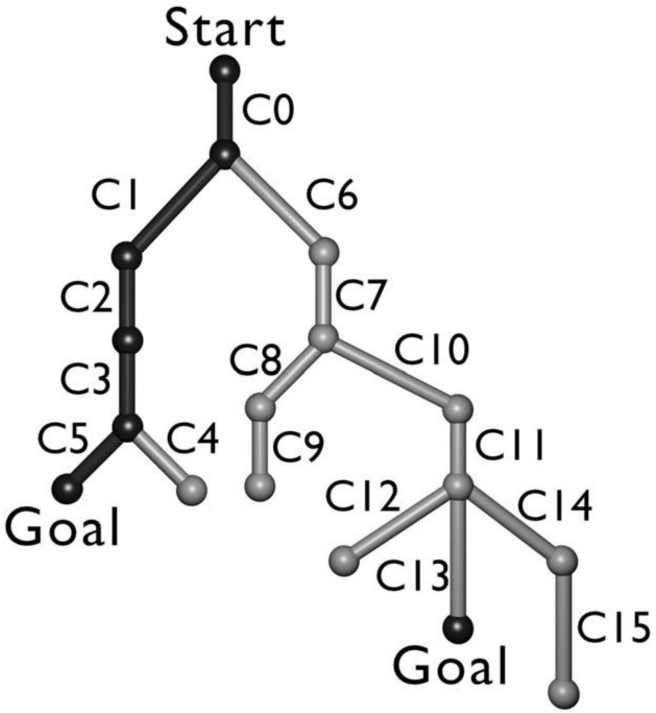
Paradigm: Sense-Plan-Act (Deliberative Control)

- Robot senses the world, plans the next action, and then acts
- Sensing data gathered into one global world model, a single representation that the planner can use and can be routed to the actions
- Generic global world models are hard



Paradigm: Sense-Plan-Act (Deliberative Control)





Paradigm: Sense-Plan-Act (Deliberative Control)

Paradigm: Sense-Plan-Act (Deliberative Control)

Use Cases:

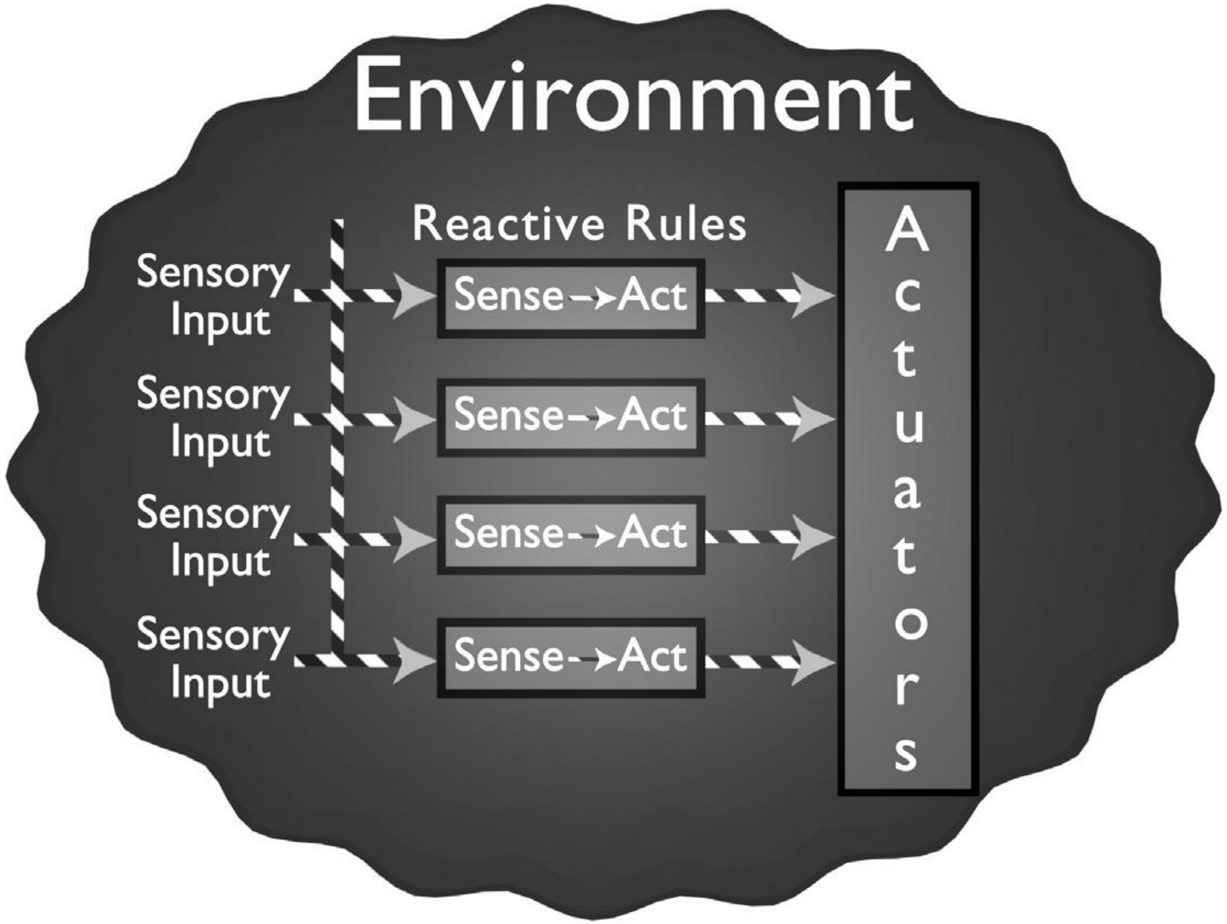
- The environment does not change during the execution of the plan in a way that affects the plan
- The robot knows what state of the world and of the plan it is in at all times
- The robot's effectors are accurate enough to execute each step of the plan in order to make the next step possible.
- In general, whenever the world is static, there is enough time to plan, and there is no state uncertainty, it is a good thing to do.

Limitations:

- Can be slow
- Can be memory-intensive in a real environment
- Requires updating the world model, which takes time.

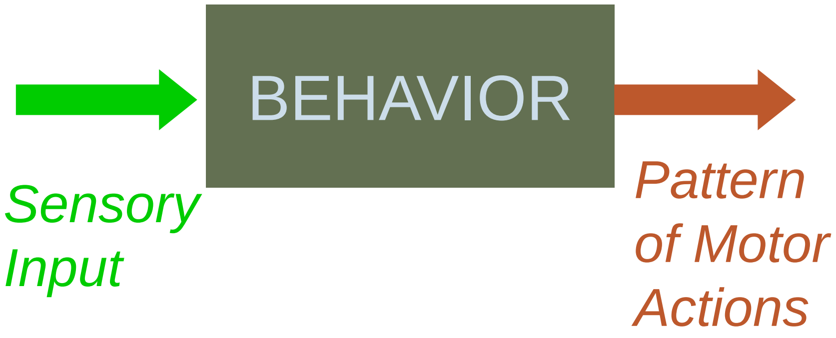
Paradigm: Behavior-Based (Reactive Control)

1) do not use any internal representations of the environment
2) do not look ahead at the possible outcomes of their actions
3) They operate on a short time-scale and react to the current sensory information.
4) complex computation is removed in favor of fast, stored precomputed responses.
5) The best way to keep a reactive system simple and straightforward is to have each unique situation (state) that can be detected by the robot's sensors



Paradigm: Behavior-Based

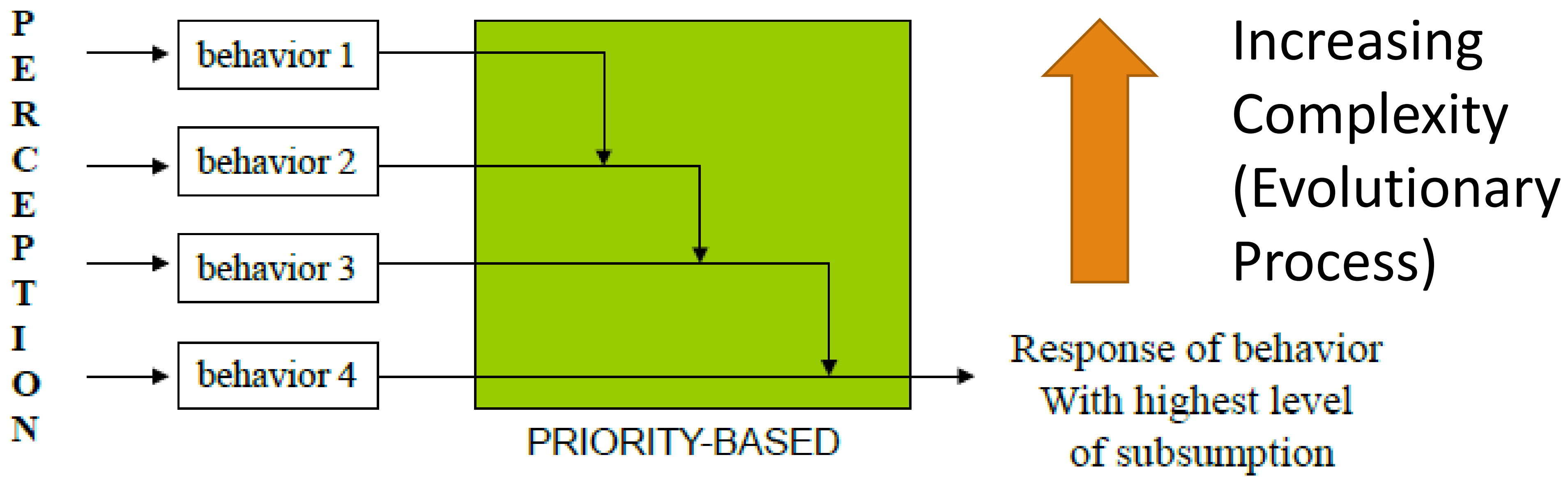
- Behavior-based approach states that intelligence is the result of the interaction among an asynchronous set of behaviours and the environment
- A behavior is a reaction to a stimulus



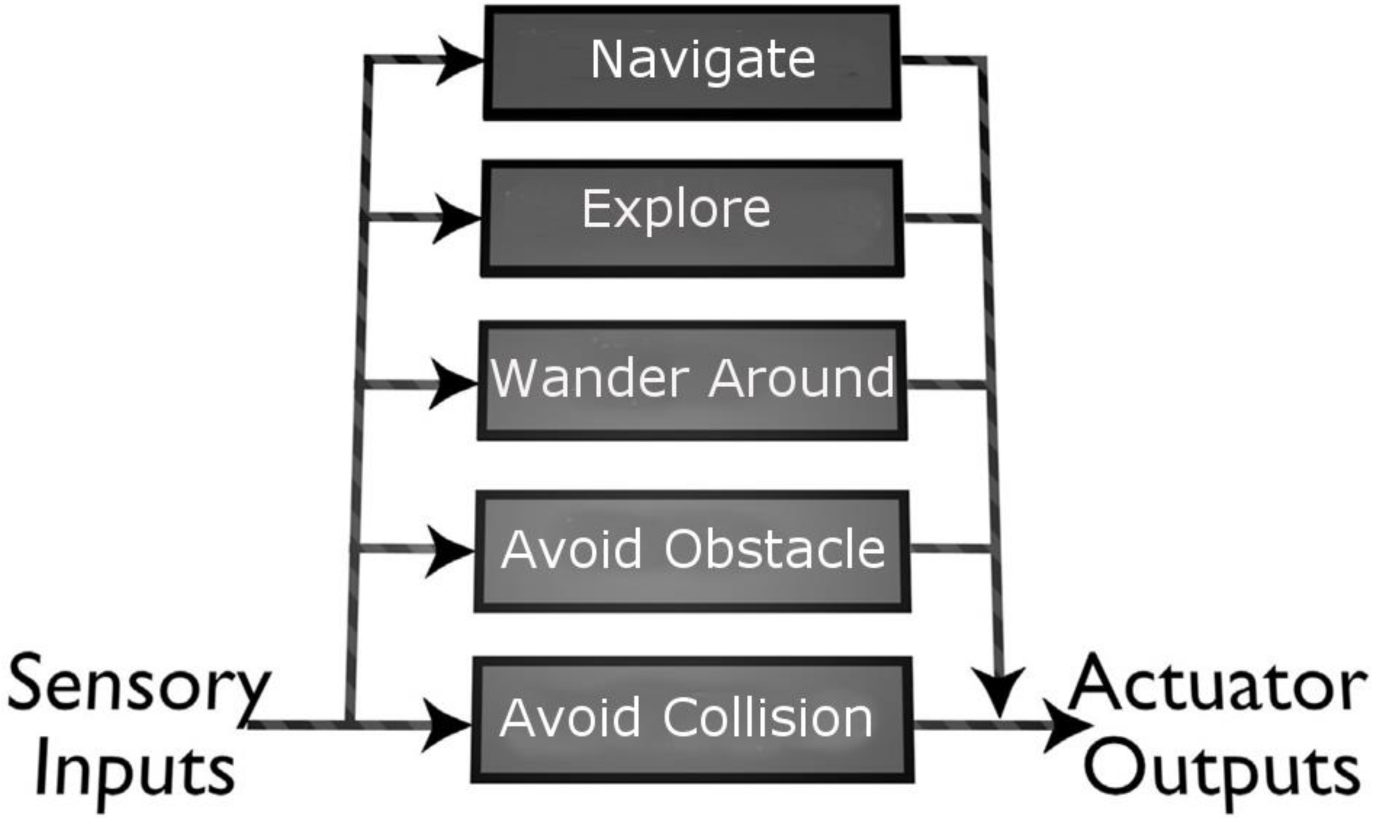
Rules for a Behavior

- Maintain or achieve a particular goal
- Are time-extended and not instantaneous
- Can communicate with other behaviours, take inputs from sensors, and send outputs to effectors
- Are more complex then actions
- Essentially provide a level of abstraction

Priority Based (Subsumption)



Subsumption Architecture



Subsumption Architecture

Guiding Principles:

- Systems are built from the bottom up.
- Components are task-achieving actions/behaviors (avoid obstacle, find doors, visit rooms).
- Components can be executed in parallel (multitasking).
- Components are organized in layers.
- Lowest layers handle the most basic tasks.
- Newly added components and layers exploit the existing ones.

Subsumption Architecture

Guiding Principles (Continued):

- There is no use of internal models; "the world is its own best model.
- The use of layers is meant to modularize the reactive system, so it is bad design to put a lot of behaviors within a single layer
- Also, it is bad design to put a large number of connections between the layers, so that they are strongly coupled

When is it useful?

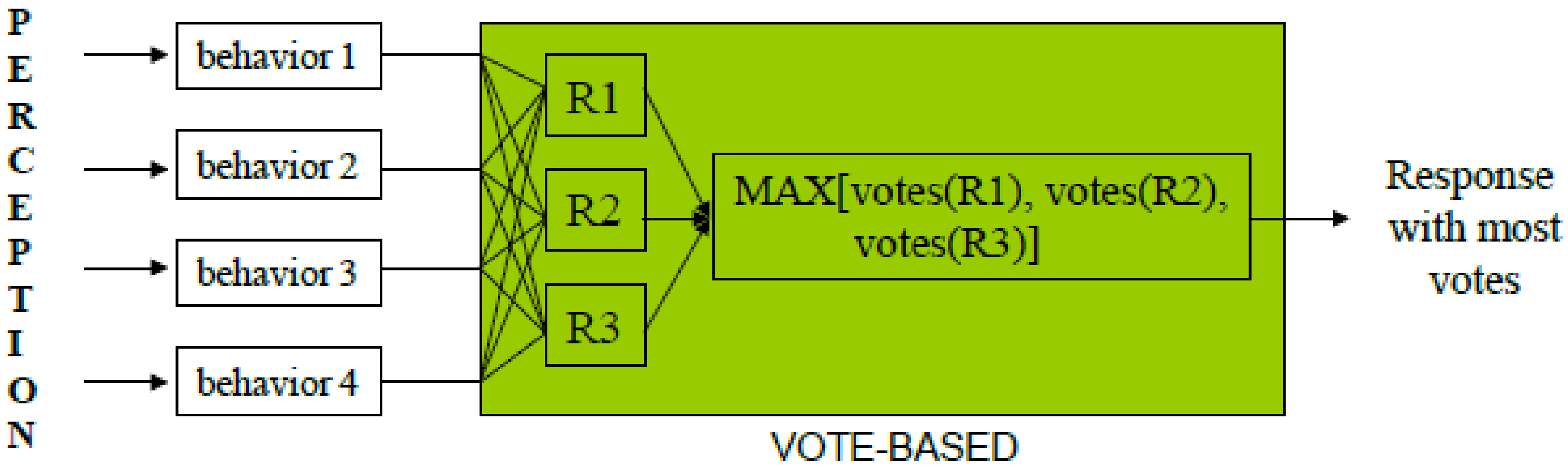
When tasks need to be completed quickly

Good when the environment is dynamic and unstructured

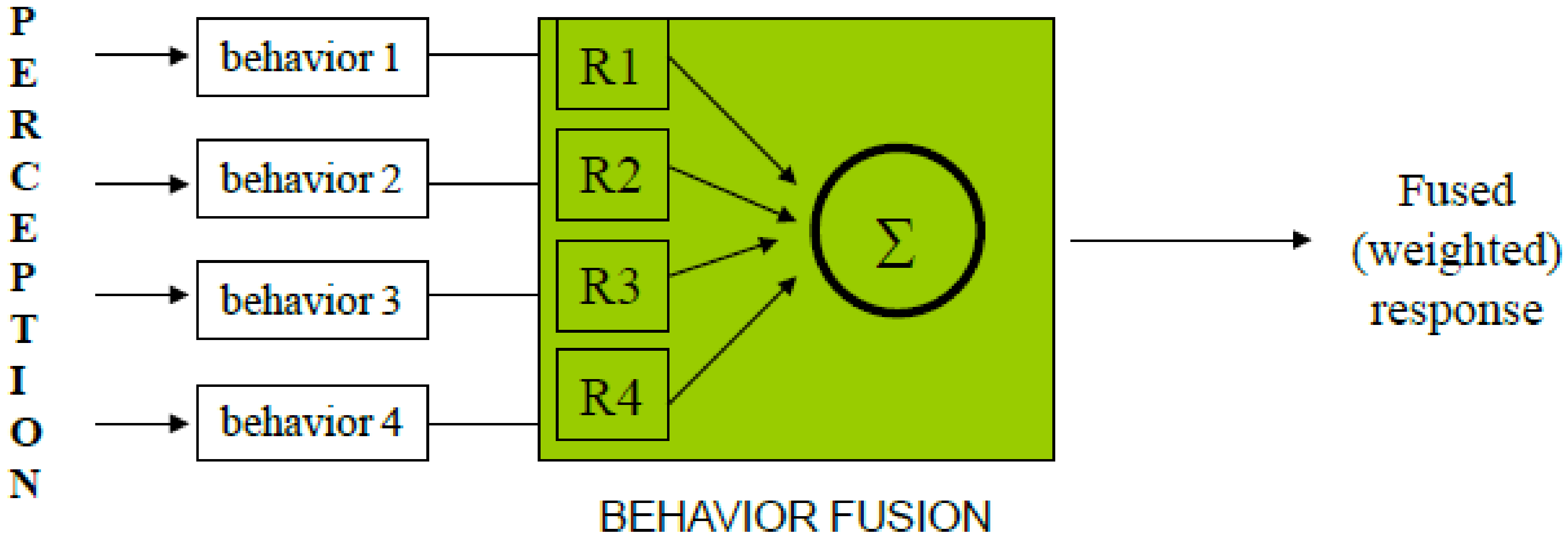
Modules are independent and decoupled so failures in one layer do not affect another (Robust)

Easy to debug subsumption architecture because layers are built bottom up

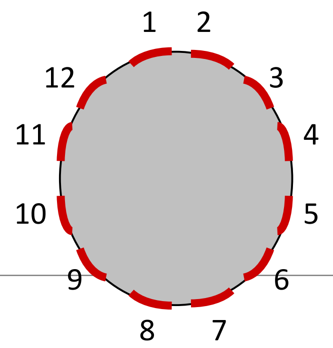
Vote Based


PERCEPTION
behavior 1
behavior 2
behavior 3
behavior 4
R1
R2
R3
MAX[votes(R1), votes(R2), votes(R3)]
Response with most votes
VOTE-BASED

Behavioral Fusion



Example – Safe Navigation



A robot with 12 sonar sensors, all around the robot

Divide the sonar range into two zones

- Danger zone: things too close
- Safe zone: reasonable distance to objects

if minimum sonars 1, 2, 3, 12 < danger-zone **and** not-stopped

then stop

if minimum sonars 1, 2, 3, 12 < danger-zone **and** stopped

then move backward

otherwise

move forward

This controller does not look at the side sonars

Example – Safe Navigation

For dynamic environments, add another layer

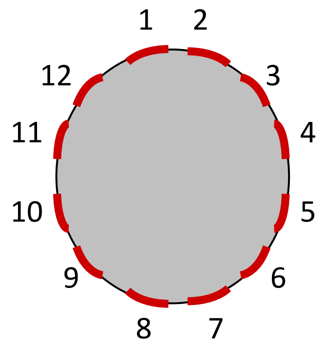
if sonar 11 or 12 < safe-zone **and**

sonar 1 or 2 < safe-zone

then turn right

if sonar 3 or 4 < safe-zone

then turn left



The robot turns away from the obstacles before getting too close

The combinations of the two controllers above $\Rightarrow$ collision-free wandering behavior

Above we had mutually-exclusive conditions

Advantages

1. The ability to react in real-time

2. The ability to use a uniform structure and representation throughout the system (with no intermediate layer(s)).

3. Networks of behaviors can store states and construct world models and look into the future

Limitations

- Often requires parallel processing to monitor and execute multiple rules at once
  - Without such capabilities events may be missed or fail to react in time
- Does not have a memory
- Does not learn from previous experiences (no adaptability)
- Does not have an internal model of the world
- Inflexible (rules are set in stone)
- Does not look ahead when performing actions
- Must make sure to account for all possibilities

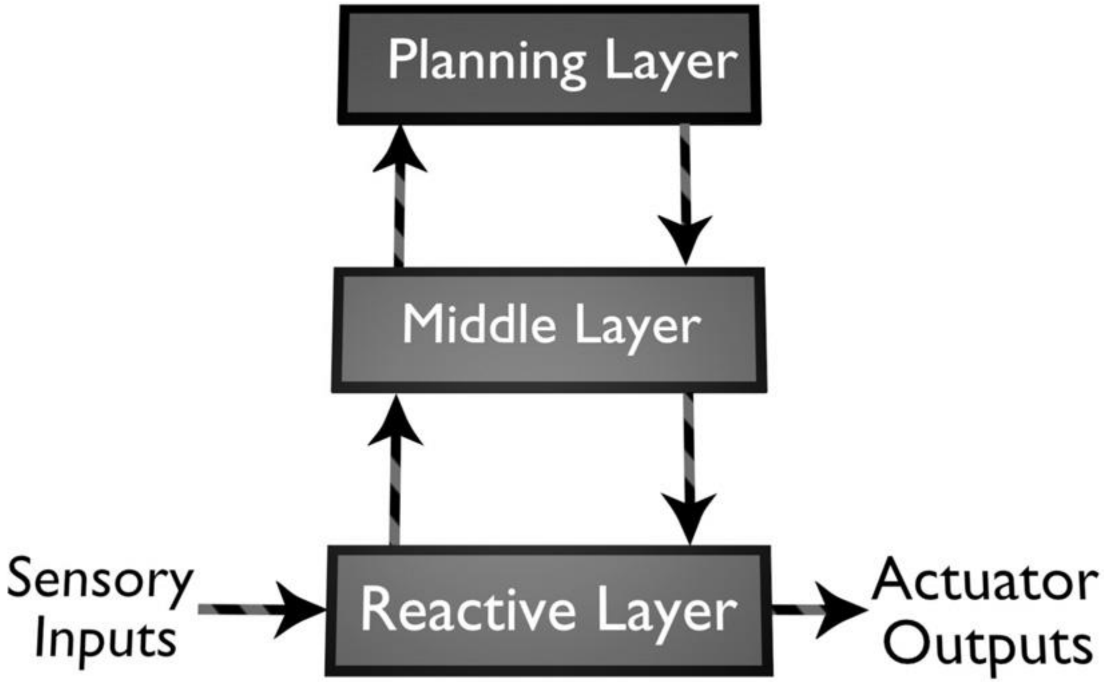
Example

Herbert collected empty soda cans and took them home

Herbert’s capabilities:

- Move around without running into obstacles
- Detect soda cans using a camera and a laser
- An arm that could: extend, sense if there is a can in the gripper, close the gripper, tuck the arm in
- Look for soda cans, when seeing one approach it
- When close, extend the arm toward the soda can
- If the gripper sensors detect something close the gripper
- If can is heavy, put it down, otherwise pick it up
- If gripper was closed tuck the arm in and head home

Hybrid Control



Hybrid Control

- Sensor data gets routed to each behavior that needs that sensor, but is also available to the planner for constructing a task oriented global model
- Compensate for the limitations of both the planner and the reactive system
- Reconcile their different time-scales
- Deal with their different representations
- Reconcile any contradictory commands they may send to the robot.

Future of Autonomy

- Sensing, sensor-processing, and reasoning algorithms have also been advancing the state of the art autonomy.
- A great example of this is probabilistic robotics which enables robot localization and mapping.
- This has all been made possible but increasing computational power and speed
- Representing knowledge and performing reasoning in teams has also grown.
- New architectures such as belief-desire-intention architectures, joint intention theory, affect -based computing, and temporal logics.

Information exchange

- A secondary component of making interaction beneficial between humans and robots is exchanging of information
- Ways of measuring the efficiency of an interaction includes:
  - Time required for intent or instructions to be communicated to the robot
  - Number of commands required to achieve a desired goal
  - Cognitive and/or mental workload
  - Amount Situational awareness provided by the interactions
  - Amount of shared understanding between robot and human
- Two dimensions of communication/information exchange:
  1) communication medium or modality
  2) the format of the communication

Information Exchange -Medium

The primary modes of interaction with a human-robot interaction are seeing, hearing, and touch. The other two senses such as taste and smell have rarely been explored in robotics for interactions. These media are manifested as:

Visual displays – GUI, augmented reality, virtual reality

Body Language – hand gestures, facial expressions, body orientation, movement, proximity

Speech and natural language – auditory speech or text

Non speech audio – alerting sounds or prosody (e.g. intonation, rate of speech)

Physical interaction – haptics for telemanipulation (aka augmented reality)

More recently, people are working with multi-modal systems to reduce workload according to wicken's multiple resource theory which aims to make interactions natural or easier to learn

Information Exchange - Format

The format of information exchange can greatly vary across domains

- For natural language they could use a limited vocabulary or scripted based on formal languages. Considerations should not only be made of the content of the information exchange follow Gricean Maxims of understanding how truthful, relevant, clear, and informative is the information being exchanged.

- Haptic information could be warnings via vibrations, feelings of presence, provide spatial awareness via vests, or communicate specific information via icons.

Information Exchange - Format

- Audio information can include alerts, speech exchanges, and 3D awareness (closer sounds are louder and further sounds less loud)
- Social Information include attentional cues, gestures, shared physical space imitation, facial expressions, speech and natural language
- Visual could be ecological displays, virtual reality, or windows-type interactions

Teams

Human-robot interactions can come in the form of teams.

- This could be for search and rescue where two or more people may manage a group of robots to find victims.

- 2013 DARPA grand challenge was a great example of this. DRC-HUBO (32 DOF humanoid) was teleoperated by 3 people for navigation and manipulation capabilities. One operator focused on stability and avoiding collisions. One generated trajectories by key framing (trajectory designed). One executed and monitored trajectories in real time (Execution manager). One gathered images and point cloud data for others to perform their tasks (perception manager). (Ref: A General-purpose System for Teleoperation of the DRC-HUBO Humanoid Robot)

Teams

- Lots of discussion over this topic and it remains an open challenge but Robin Murphy a pioneer in USAR suggests that at least two operators are required based on the demands of the task, form factor, and need to protect the robot operators from fatigue.

- In military domains it has been suggested that one person can control multiple robots

- However, it should be considered that the question is not how many robots a person can manage but how many humans does it require to manage a fixed number of robots with the help of adaptable autonomy and dynamic handoffs

Teams: How Many Robots?

One key challenge or research question for Human-robot interaction in teams is how many robots can a single human control?

- Depends on level of autonomy
- Depends on task type
- Defines type and quantity of info provided to human
- Depends on modes of communication

Teams: Organization and Structure

A second challenge is how the team is organized or structured.

- Who makes decisions (robot, human, software)
- Who issues commands to a robot and at what level (strategic, tactical, operational)
- How are conflicts resolved especially in peer-like relationships with multiple humans
  - Is a person a better driver than a car? Or is the car a better driver than a person? In what conditions is this true? What if someone just woke up after autonomous mode, should they gain control? What if the weather is poor or sensors or broken?
- Is the structure dynamic or static? Are responsibilities, authorities, or roles changing within the team ?

Teams: Organization and Structure

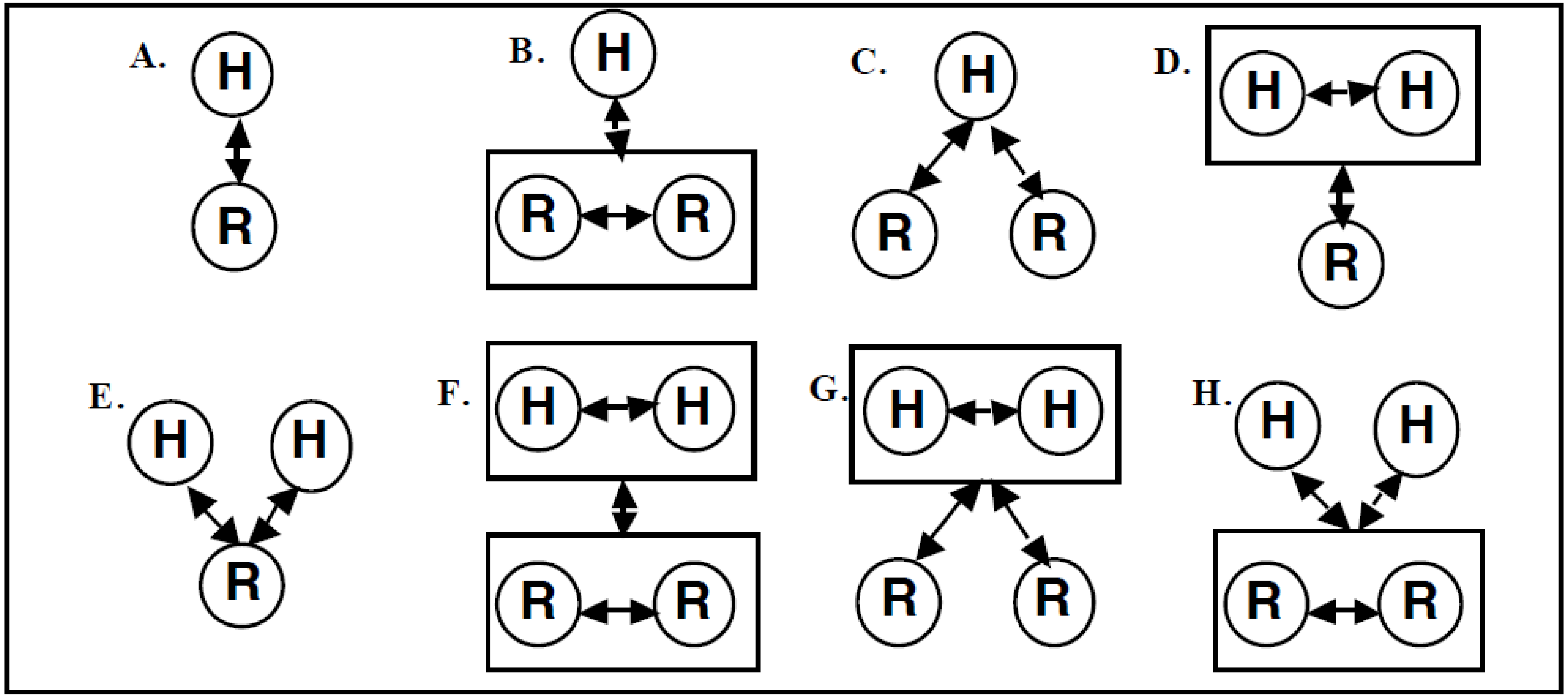
Multi-Robot Questions

- Are commands acted on independently?
- Are all robots receiving commands and coordinating amongst themselves?

Multi-Human Questions

- Are commands being issued independently?
- Do robots prioritize and deconflict on their own?

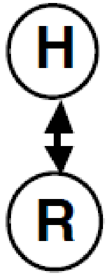
Teams: Organization and Structure



The possible combinations of single or multiple humans and robots, acting as individuals or in teams.

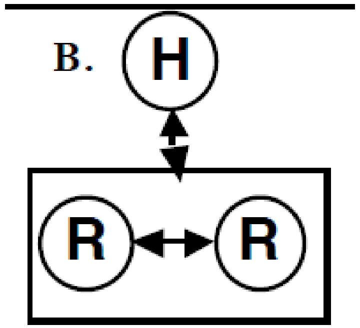
Teams: Organization and Structure

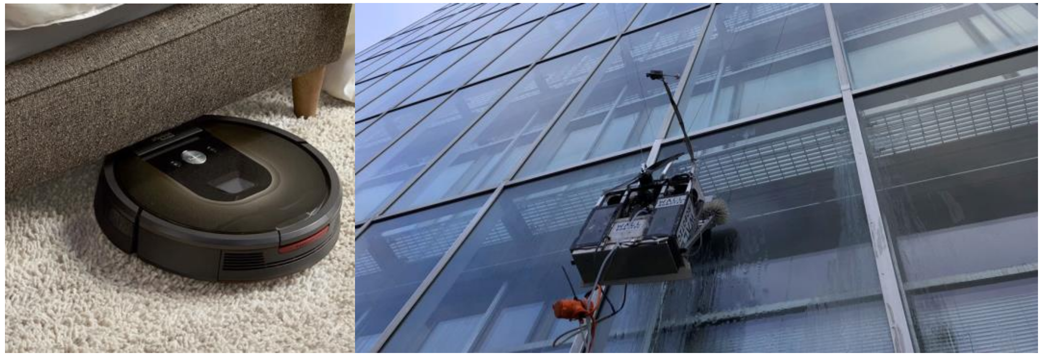
One Human Controls
One Robot



Teams: Organization and Structure

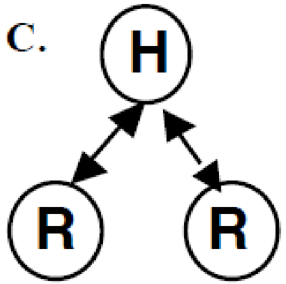
One Human Controls
Robot Group





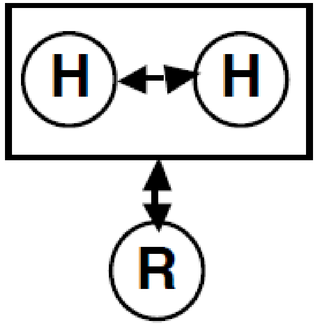
Teams: Organization and Structure

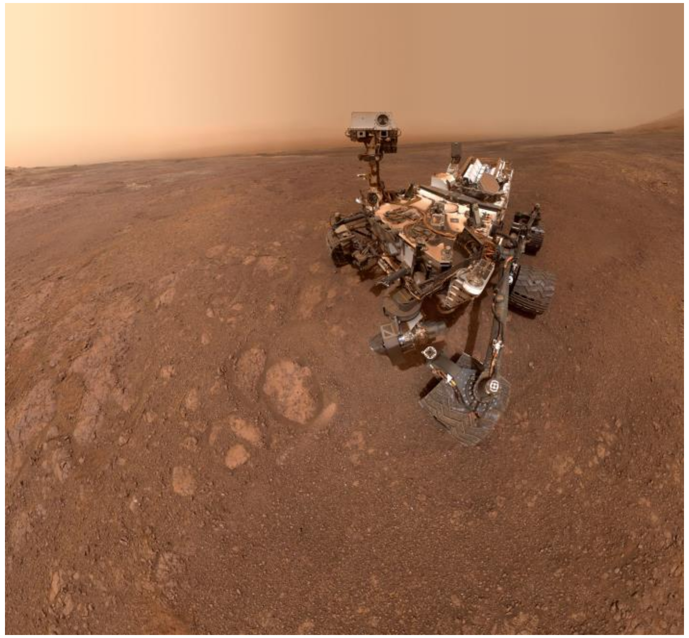
One Human Commands
Each Robot Individually



Teams: Organization and Structure

Human Team Controls
One Robot

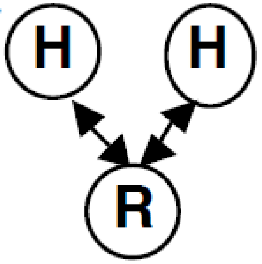


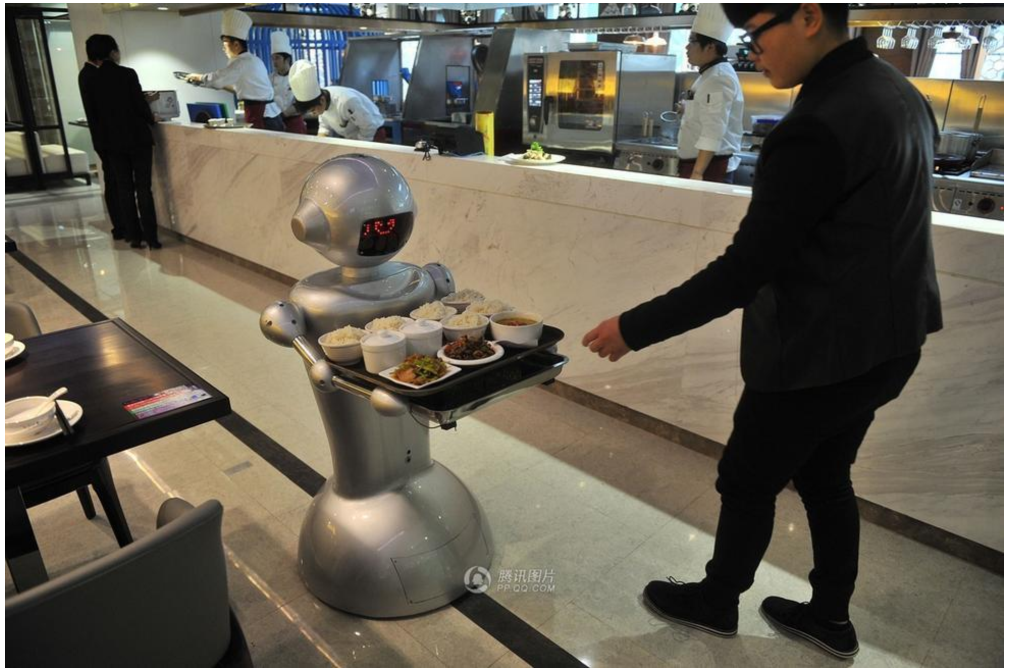


Teams: Organization and Structure

Multiple Humans Send Independent Commands to a Single Robot

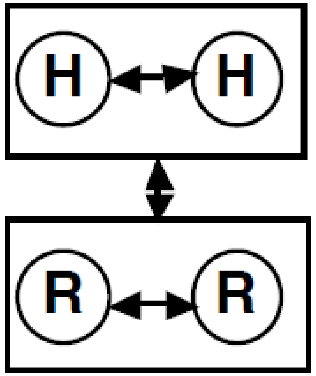
E.

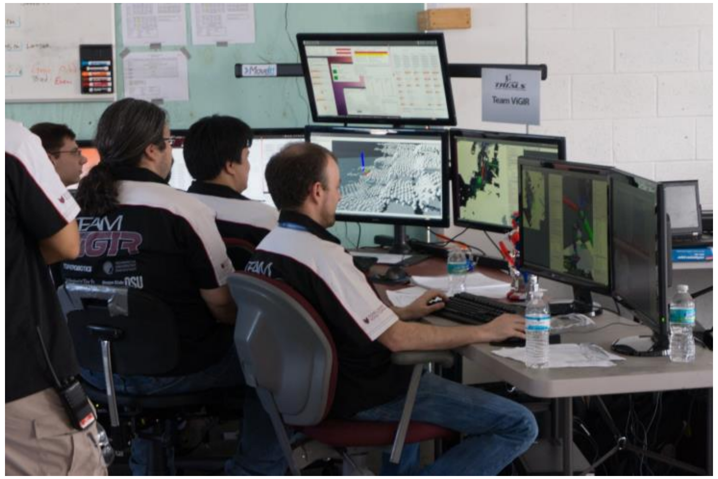




Teams: Organization and Structure

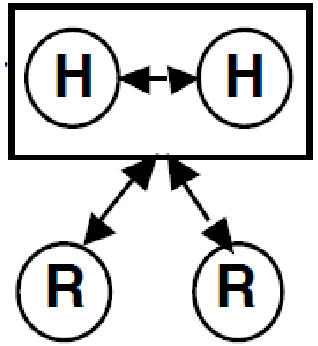
Multiple Human Team Commands Multi-Robot Team

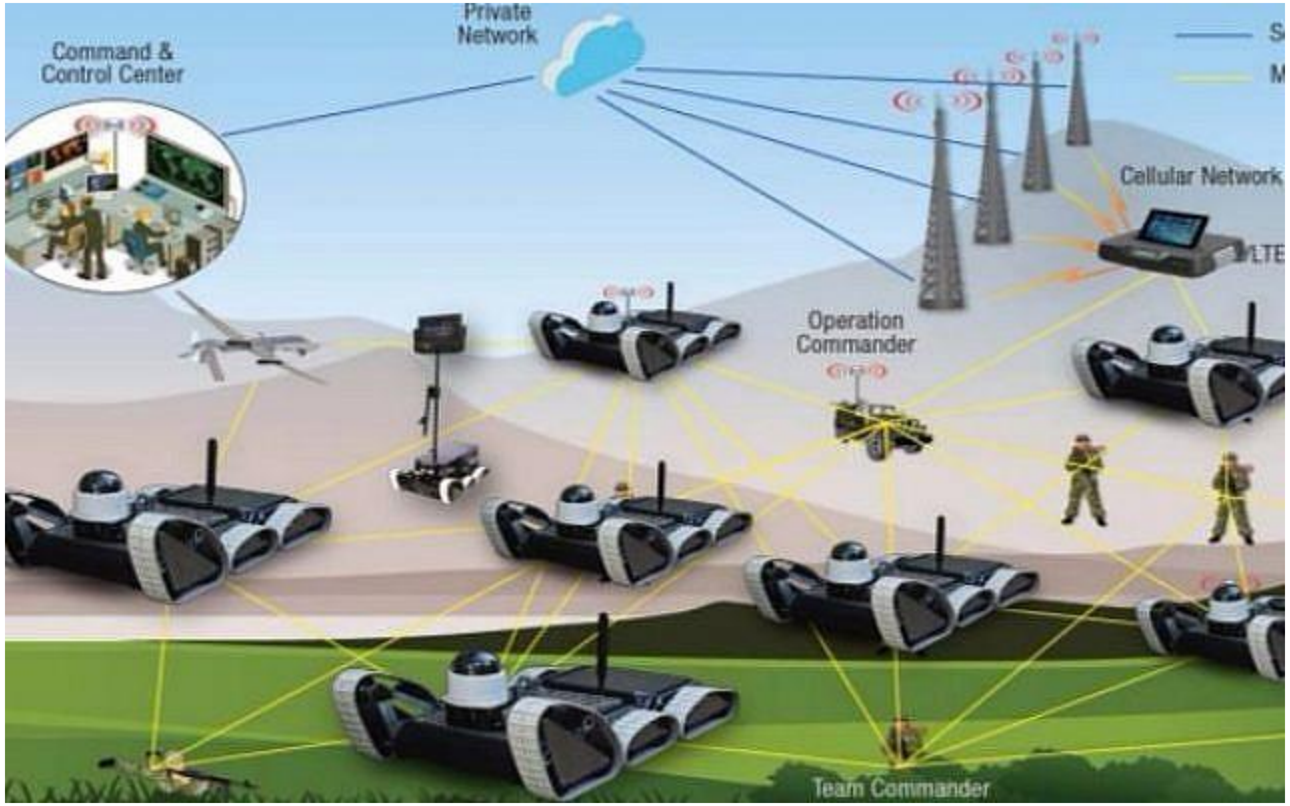




Teams: Organization and Structure

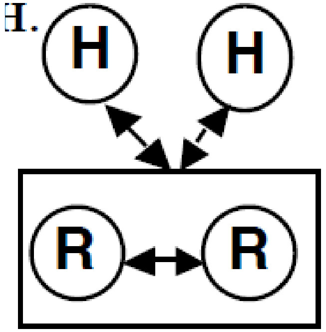
Multiple Human Team Commands Individual Robots





Teams: Organization and Structure

Individual Humans Send Commands to a Robot Team



Teams: Organization and Structure

- Several example works of this can be found below:
  - J. Wang, M. Lewis, and P. Scerri “Cooperating Robots for Search and Rescue”, Proceedings of the AAMAS 1st International Workshop on Agent Technology for Disaster Management, 2006.
  - B. Sellner, F. W. Heger, L. M. Hiatt, R. Simmons, and S. Singh “Coordinated Multiagent Teams and Sliding Autonomy for Large-Scale Assembly”, Proceedings of the IEEE, vol. 94, no. 7, pp. 1425–1444, 2006.
  - G. A. Kaminka and Y. Elmaliach “Experiments with an ecological interface for monitoring tightly-coordinated robot teams”, IEEE International Conference on Robotics and Automation, 2006
    - Explicit coordination has been also shown to reduce failures and improve consistency
  - M. Skubic, D. Anderson, S. Blisard, D. Perzanowski, and A. Schultz, "Using a qualitative sketch to control a team of robots“, IEEE International Conference on Robotics and Automation, pp. 3595-3601, 2006.
    - Others have also explored different drawing interfaces to control a team of robots (“using a qualitative sketch to control a team of robots”)

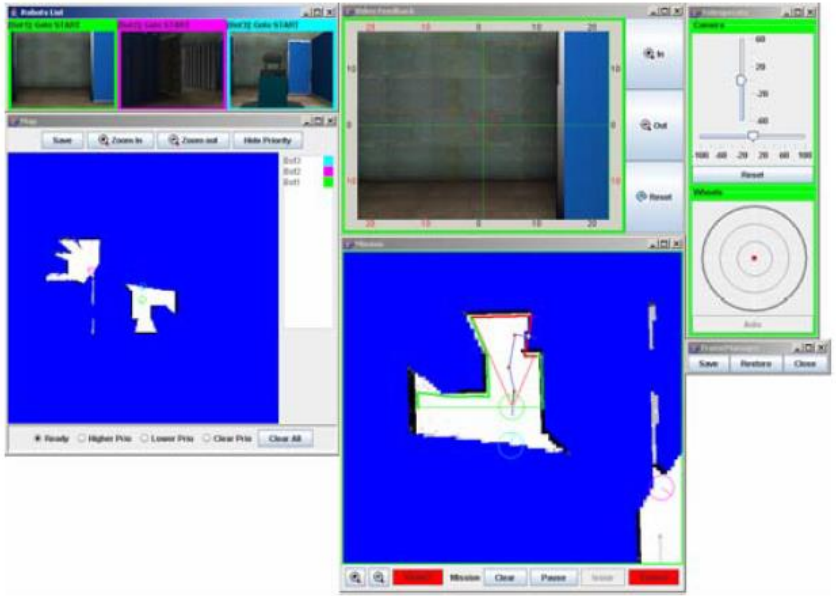
Teams: Organization and Structure

Paper: J. Wang, M. Lewis, and P. Scerri “Cooperating Robots for Search and Rescue”, Proceedings of the AAMAS 1st International Workshop on Agent Technology for Disaster Management, 2006.

Primary Focus: Comparing USAR performance of operators while using a robot in autonomous vs. manual mode

Methods:

- Manual mode has human have full control of the robot and all autonomy eliminated
- Autonomy mode has robots autonomously coordinate where to search/explore and how to reach those locations. Human can issue waypoints, control robot cameras, teleoperate, and observe all camera data



Teams: Organization and Structure

Experiments: Search for victims in office environment created in USARsim

Subjective Measures – Ratings of how the robot helped and trust

Objective Measures - # victims found and time spent switching robots

Results:

- Autonomy perceived to be more helpful.
- More victims found in autonomy.
- More areas explored.
- No difference in time spent with different robots but switched robots more frequently. More frequent switching led to more victims found.
- Only half people trusted the robots

Limitations:

- Not real world implementation (e.g. no sensor noise, what about latency of communication with robots, unrealistic environment)

Teams: Organization and Structure

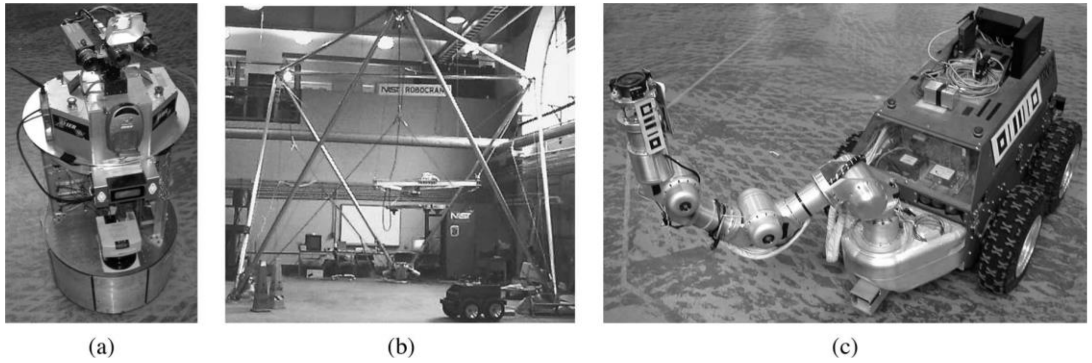
Paper: B. Sellner, F. W. Heger, L. M. Hiatt, R. Simmons, and S. Singh "Coordinated Multiagent Teams and Sliding Autonomy for Large-Scale Assembly", Proceedings of the IEEE, vol. 94, no. 7, pp. 1425–1444, 2006.

Primary Focus: Four autonomy configurations were compared in construction task with multiple robots that have differing capabilities

Methods:

Four Modes of Autonomy Compared were:

1) System – Initiative – Robot asks for assistance but human can't interrupt the robot (Robots determine what human would be most suited for)
2) Mixed-initiative – Robots can ask for help and human can interrupt system to perform task, subtask , or monitoring (can intervene before a robot makes a final error)
3) Fully autonomous
4) Teleoperated



The three robots used to build the square structure: (a) Roving Eye, (b) Crane, and (c) Mobile Manipulator.

Teams: Organization and Structure

Experiments: Assemble four beam structure

Objective Measures - time for task to be completed and how well the task was complete

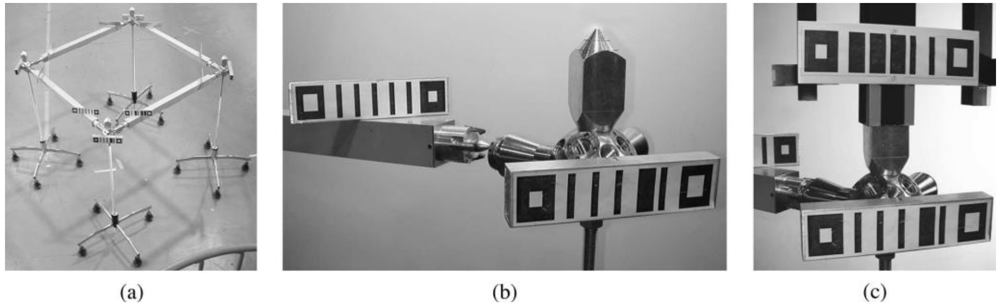
Subjective Measures – Workload as measured by NASA-TLX

Results:

- Teleop took longest
- Task success increased with human involvement with autonomy worst
- Teleop had highest workload
- Trade off of speed and robustness. Sliding autonomy attempts to get best of both world

Limitations:

- No consideration of more than one human
- They suggested to use this for space construction. Latency would be really high for such operations. Also the bandwidth limitations make the sensory information available and number of commands a human teleoperator can provide unrealistic.



(a) Fully assembled four-beam structure. (b) View of beam being inserted into node. (c) Close-up of node being braced by the Crane.

Teams: Future?

- Robots, humans, and software agents for a team.
  - A simple version would be where the software agent monitors and categorizes human behavior as well as monitor and detect robot problems. The software agent then provides assistance to the human to account for workload, environmental conditions, and robot capabilities.
  - NASA has a more complicated version of this with distributed humans interacting with robots and software agents to coordinate mission plans, human activities, and system resources.
- More recently there is a focus on the role of the human especially when humans are not expecting to work with a robot.
  - Urban search and rescue robot comes across a human
  - Military robots interacting with civilians
  - Health assistant robot helping patients or visitors
- Human-Robot teams for healthcare delivery
  - One nurse and multiple robots to help

Adaptation, Learning, and Training

- What's the difference between adaptation, learning, and training?

Adaptation – Adjusting current capabilities to a given situation

Learning – Generating new knowledge by generalizing, reorganizing, acquiring, or reusing information.

Training – Acquiring new experiences or information

Adaptation, Learning, and Training

- Most current HRI has focused on learning and adaption of robots because the current aims in research are to:
  - minimize the training to utilize robots
  - designed for specific domains and used for short periods of time
- Robot learning and adaptation are treated as useful for design of behaviors, tasks, and long-term interactions
- Although not yet addressed, training humans users will be vital in the future

Adaptation, Learning, and Training

- Minimizing the need for humans to adapt or trained is important in certain interactions such as those with older adults with dementia or prophesises for physical impairments

- In other cases is may be better for the human to adapt or learn in the HRI such as for handling hazardous materials, therapy, or education.

- We will discuss scenarios requiring careful training and minimal operator training

Adaptation, Learning, and Training: Minimizing Operator training

- Minimizing operator training has been a primary focus for robots used in the classroom, museums, entertainment, or home

- Training has included instruction manuals or robot instructions via speech

- A Roomba is the best example of this as they had to guide users of expectations of use and alert for possible dangers
  - You’ve seen the videos of dogs and roombas
  - Similarly, the robot can’t climb stairs and can’t be use for other tasks

Adaptation, Learning, and Training: Minimizing Operator training

Studies have investigated:

- how children use educational robots in the class
- how children with ASD interact with a robot in social settings
- how robots can support humans in the house
- interaction patterns with museum guide robot

Adaptation, Learning, and Training: Minimizing Operator training

There are then studies that focus on common or intuitive (archetype) patterns of behaviors to trigger correct mental models of operation

- For example, “gamers” will be better at interacting with mobile robots than people with no experience
- People with video conferencing, instant messaging, and other computer-mediated communication will be better at communicating with robots
- Some studies have shown that anthropomorphic robots enable people to use commonly held mental models because they can exploit their experience with cognitive, social, and emotional processes (“Mental models of robotic assistants”) (“Toward sociable robots”). However this can lead to the uncanny valley where robot behavior falls short of actual human behavior. (“Design spaces and niche spaces of believable social robot”) (M.Mori “uncanny valley”) (K. MacDorman, “subjective ratings of robot video clips for human likeness, familiarity, and eeriness: an exploration of the uncanny valley)

Adaptation, Learning, and Training: Efforts to train humans

Efforts have also focused on training humans in high-risk and high-workload situations such as military (human packable robots), police (bomb squad), space (telemanipulation), and S&R applications

- Training has focused on using the interface, interpreting video, controlling the robot, coordinating with other members of the team, and staying safe while operating the robot in a hostile environment.
- In space, military, and police domains people are hand selected by determining if they are the best at managing the robot (mostly focuses on air robots)
- These trainings have primarily been with remote robots but for proximate robots they often focus on produce human learning or behavioral responses. For example, therapeutic and social robots change, educate, or train humans.
- People also adapt to service robots over long-term and in some cases require mutual adaptation from the robot and human bystanders
- Culture has also been factor for long-term and short-term acceptance of a robot.

Adaptation, Learning, and Training: Training Robots

Learning should not only be restricted to humans. Current robots also learn to interact with their human partners both offline as a part of the design process or online as a part of the interaction (especially true for long-term interactions).

- Improving perceptual capabilities through communication between humans and robots
- Improving reasoning and planning based on interactions (past or present)
- Improving autonomy
- Robots could also learn via:
  - programming and learning from human demonstrations
  - Biologically inspired models of learning have also been explored for learning and teaching and training a robot
  - Exploration of human learning is also being conducted because the brain learns in so few trials.
  - Task learning
  - Skill learning such as social, cognitive, and imitation skills

Task Shaping

Robots are introduced to do two things:

1) enable a human to do a task they couldn't do before

2) make it easier for the human to accomplish a task

Hence, when introducing a robot this influences and changes the way the task is done by the human.

Task Shaping

- Task shaping considers how the task should be done or how the task will be done when technology is introduced
- There are formal ways to understand how a task should be done and currently done as well as unintended consequences:
  - Goal-direct task analyses
  - Cognitive work analyses
  - Ethnographic studies
- This is an often overlooked area because designers are often creating technology and interactions to accomplish a task.

Task Shaping

- Essentially we are hypothesizing how the technology will improve a process but conversely we should also consider how a task could be modified to improve the interaction
  - Examples of this could be explicitly designing space or underwater equipment so it can be manipulated by a robot arm (e.g. door handles or connectors)
  - Pre cleaning a room so a vacuum can do better (e.g. Picking up clutter)
  - Performing pre-inspection tasks to form maps and plans

Human-Interaction Roles

- Supervisory
- Operator
- Teammate
- mechanic
- Programmer
- Bystander

Physical Proximity

Interpersonal interaction distances with the robot:

- Avoiding
- Passing
- Following
- Approaching
- Touching

Task Type

- Sets the tone for system use and design
- Should be described at a high-level:
  - USAR
  - Walking Aid
  - Toy
  - Delivery

Morphology

- Robots can have many forms and people can reach to robots differently based on appearance
  - Social Expectations
  - Prior Expectations
- Three types of Morphology:
  - Zoomorphic: Animal-Like
  - Anthropomorphic: Human-like
  - Functional: Related to the robots function



Time/Space

		Time	
		Synchronous	**Asynchronous**
Space	**Proxemic**	Wheelchair	Manufacturing
	Remote	USAR	Mars Rover