5

Telesystems

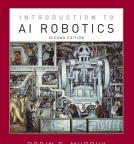
What is a telesystem?

Telesystem– it is a "necessary/temporary evil" or a different style of AI?

What is human supervisory control?

What is semi-autonomy and how it is different?

What types of domains is teleoperation good for?



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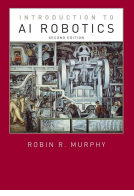
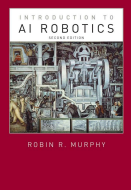
Specific Learning Objectives

- Be able to label the 7 components of a telesystem
- Define telesystem, supervisory control, teleoperation, shared control, traded control, remote control, telepresence, proprioception, exteroception, exproprioception
- If given a description of a supervisory control scheme, classify it as manual, traded, shared, or autonomy
- Give at least 3 characteristics of a domain that is suitable for telesystems
- Describe the out of the loop control (OOTL) problem and why it is a concern for semi-autonomy



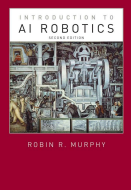
Outline

- Theory
  - What is Teleoperation?
  - 7 Components of a telesystem
  - Types of supervisory control
  - Summary
- Practice
  - Case Studies
  - Human Out Of The Loop Control problem
  - Assessment of where telesystems make sense



Recap: AI

- AI is good at lower level behaviors and skills (reactive layer), and at symbolic reasoning (deliberative layer)
- But not so good at converting sensor data into symbols

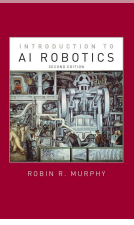


Solution?

- AI is good at lower level behaviors and skills (reactive layer), and at symbolic reasoning (deliberative layer)
- But not so good at converting sensor data into symbols

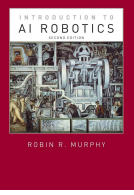
…Telesystems or teleoperation:

- *Where human and robot are physically separated and must interact to accomplish the* task
- Connotation is human must interact with the world **through** the robot and would prefer to delegate tasks to the robot rather than micromanage every movement



Where We're Going…

- Teleoperation is the state of the practice in most DoD and Public Safety mobile robotics
- It is important to consider telesystem as both
  - A legitimate, stand-alone approach to robotics for *remote presence applications* and
  - A transitional path to autonomous *taskable agents*
- It is important to understand why teleoperation is unlikely to be the fail-safe mode for most robotics, even line-of-sight
- Later in the course, discuss Human-Robot Interaction



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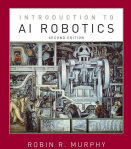
TASKABLE AGENT VERSUS REMOTE PRESENCE



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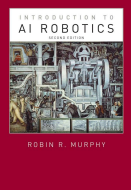
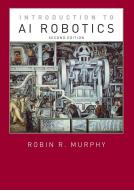
Foci in AI Robotics

Motivation

- Replace
- Project
- Assist
- Amuse



Foci in AI Robotics



Motivation		**Leads to…**
• Replace	→	• **Taskable agent**
• Project	→	• **Remote presence**
• Assist	→	• **Social robots**
• Amuse	↗	

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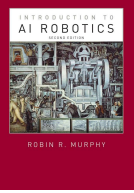
Definitions

- **Taskable agent**
  - Given a task
  - Executes without supervision
  - *Returns (with information)*

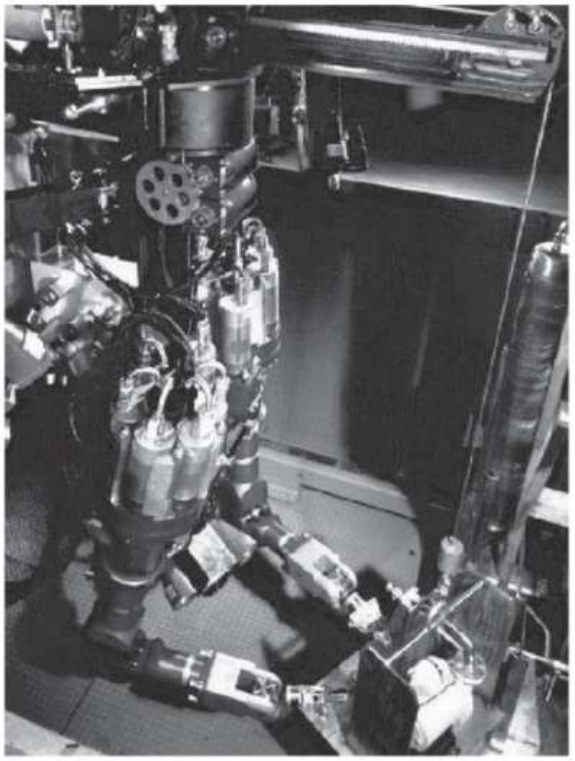
- **Examples**
  - Terminator



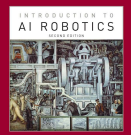
Definitions

- **Remote presence**
  - Human and robot share the task and the role(s)
  - Task execution is blended (joint cognitive system)
- Examples

Master



Slave



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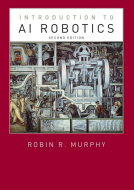
Difference

- **Taskable agent**
  - Given a task
  - Executes without supervision
  - Returns (with information)
  - Designed for replacing human
- **Remote presence**
  - Human and robot share the task and the role(s)
  - Task execution is blended (joint cognitive system)
  - Designed for projecting human into distal environment

The two are not mutually exclusive- could shift from remote presence to taskable agent, "ok, you take it from here," which *is traded control*



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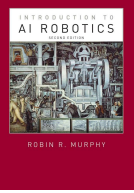
Relevance for Teleoperation

- **Taskable agent**
  - Given a task
  - Executes without supervision
  - Returns (with information)
  - Designed for replacing human
- **Remote presence**
  - Human and robot share the task and the role(s)
  - Task execution is blended (joint cognitive system)
  - Designed for projecting human into distal environment

Teleoperation is a "workaround," especially for perceptual deficiencies

Teleoperation is the desired end-state



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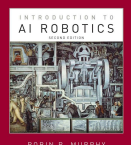
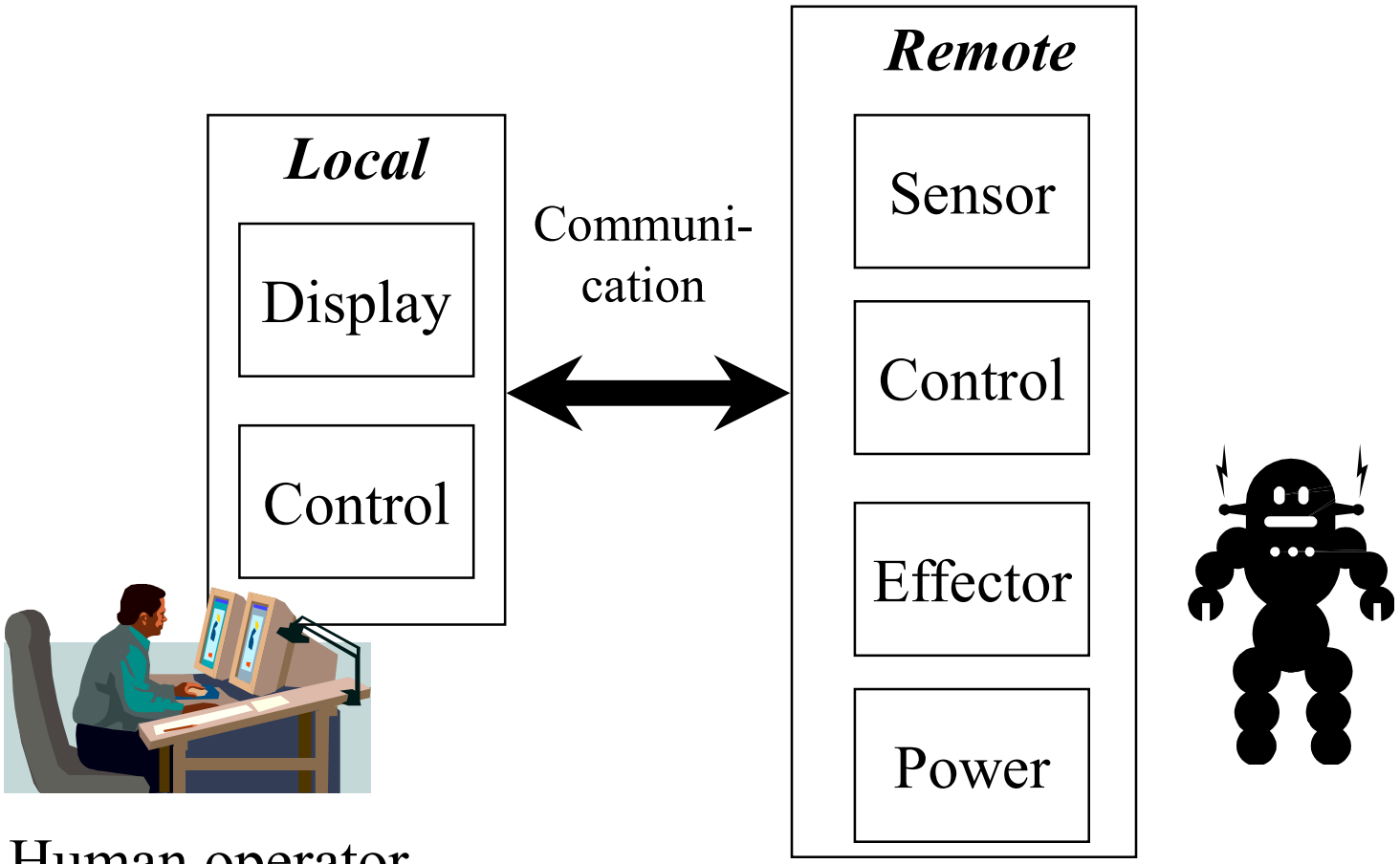
COMPONENTS OF A TELESYSTEM



Components of a Telesystem (after Uttal 89)

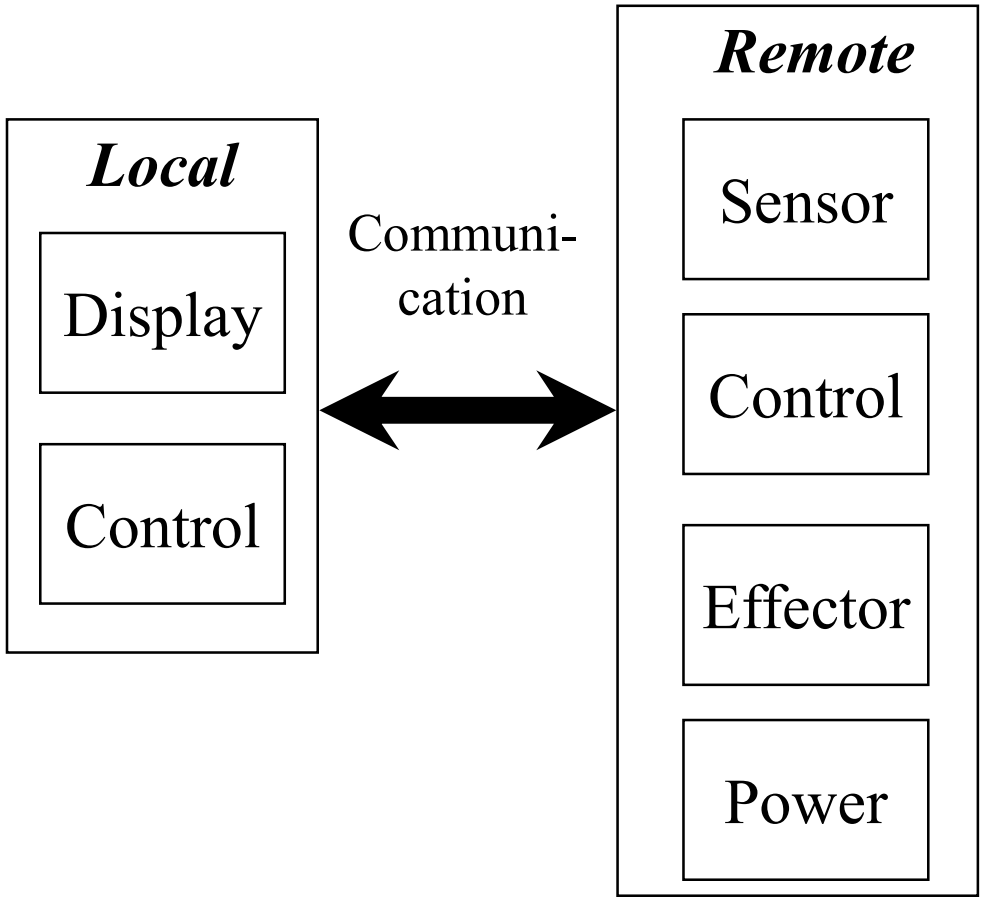


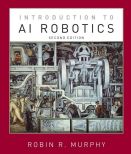
Human operator, or teleoperator

Remote robot, or telefactor

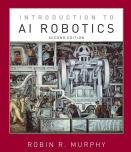
5 7 Components of a Telesystem

- **At Local (2)**
  - *display*
  - *local control device*
- *Communication (1)*
- **At Remote (4)**
  - *remote control device*
  - *sensor*
  - *effector*
  - *power*





5 Hot New Trend in Consumer Robotics



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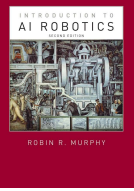
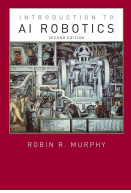
A Bit Harder With Non-Anthropomorphic Systems



5 How Do You Control A Telesystem?

- Referred to as: *Human supervisory control*
  - Term is not limited to unmanned vehicles
    - Airplanes with autopilot and fly-by-wire capabilities
    - Factory automation



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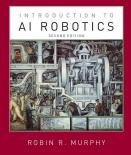
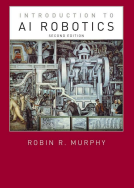
Supervisory Control

- Definition (after Sheridan 92)
  - One or more human operators are intermittently *giving directives* and *continually receiving information from a computer* that itself closes an autonomous control loop through artificial effectors and sensors to the controlled process or task environment
- Ramifications
  - Human is always involved, if only to set objectives
    - Ex. NASA MER
  - Information may be the lack of information (e.g., nothing interesting has happened)
  - Computer is always involved. Ways include:
    - Project effect of actions
    - Compensate for time delays
    - Inner-loop control
    - Safety/self-protection reflexes



5 Types of Human Supervisory Control

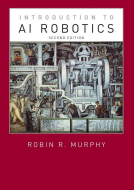
- Two questions that frame human supervisory control
  1. Can you see the robot in its environment?
  2. Where is the major part of the intelligence: the local (operator) or the remote (robot)?



5 Types of Human Supervisory Control

- Can you see the robot in its environment?
- Where is the major part of the intelligence: the local (operator) or the remote (robot)?

Robot Primary controller		
Operator Primary controller		
	Operator Can see robot	Operator Can't see robot



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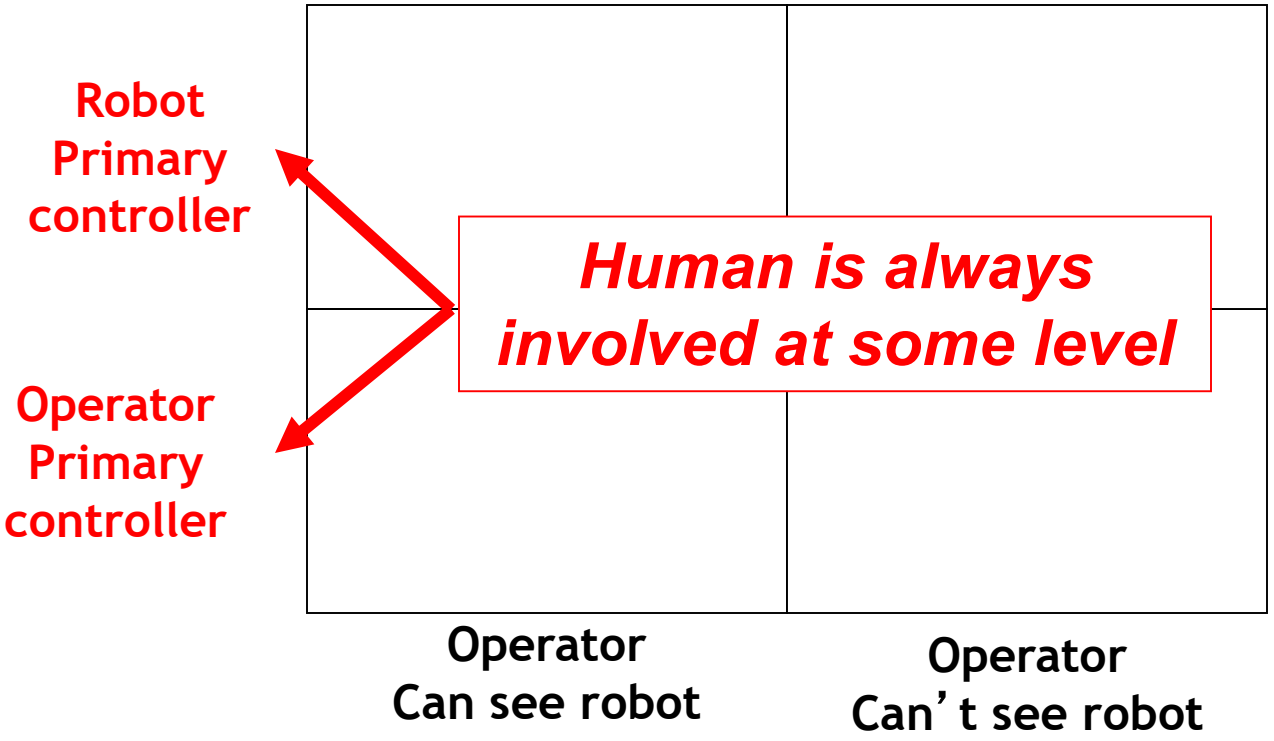
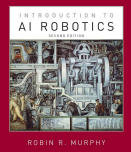
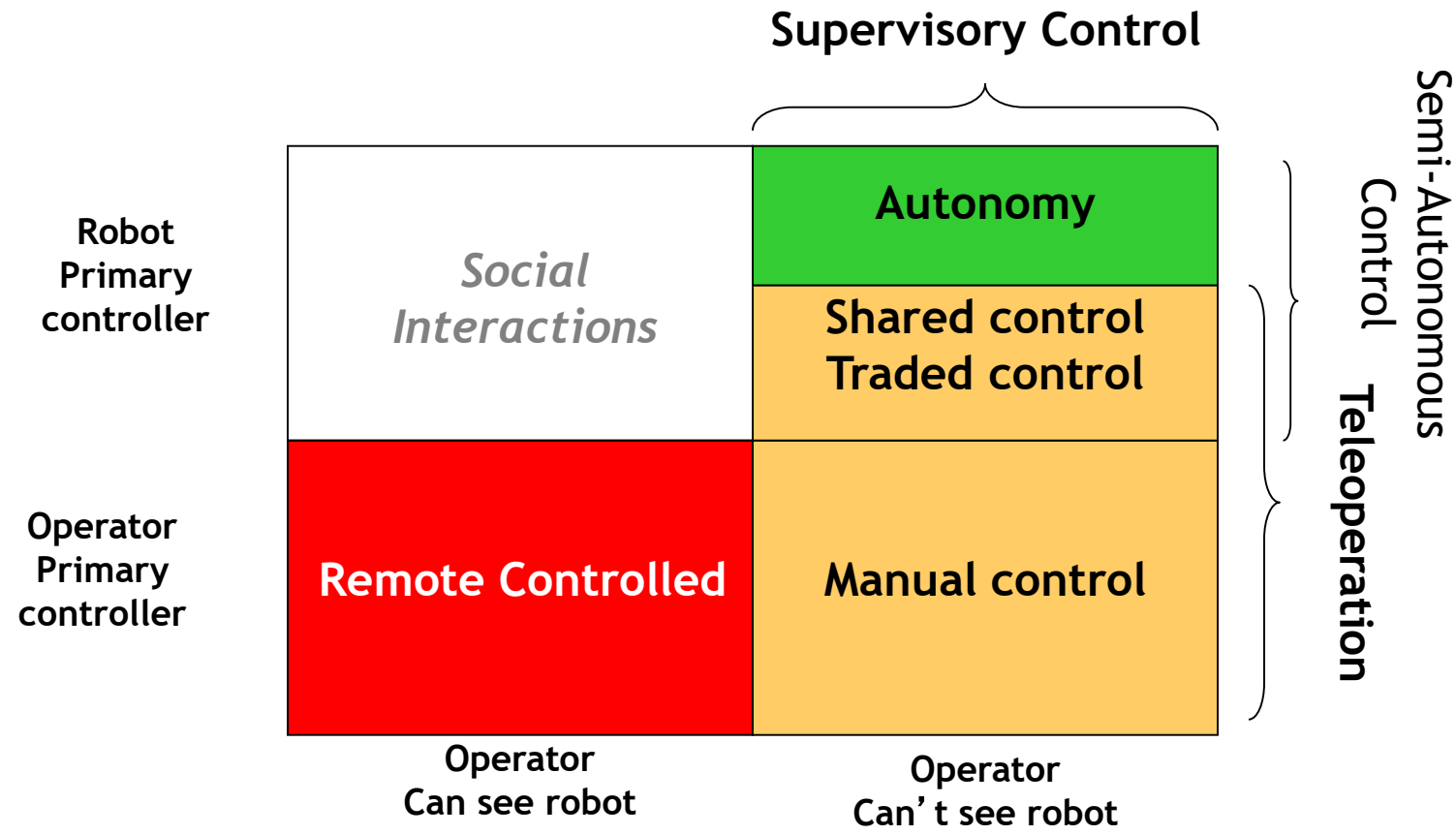
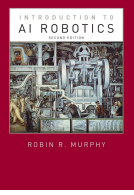




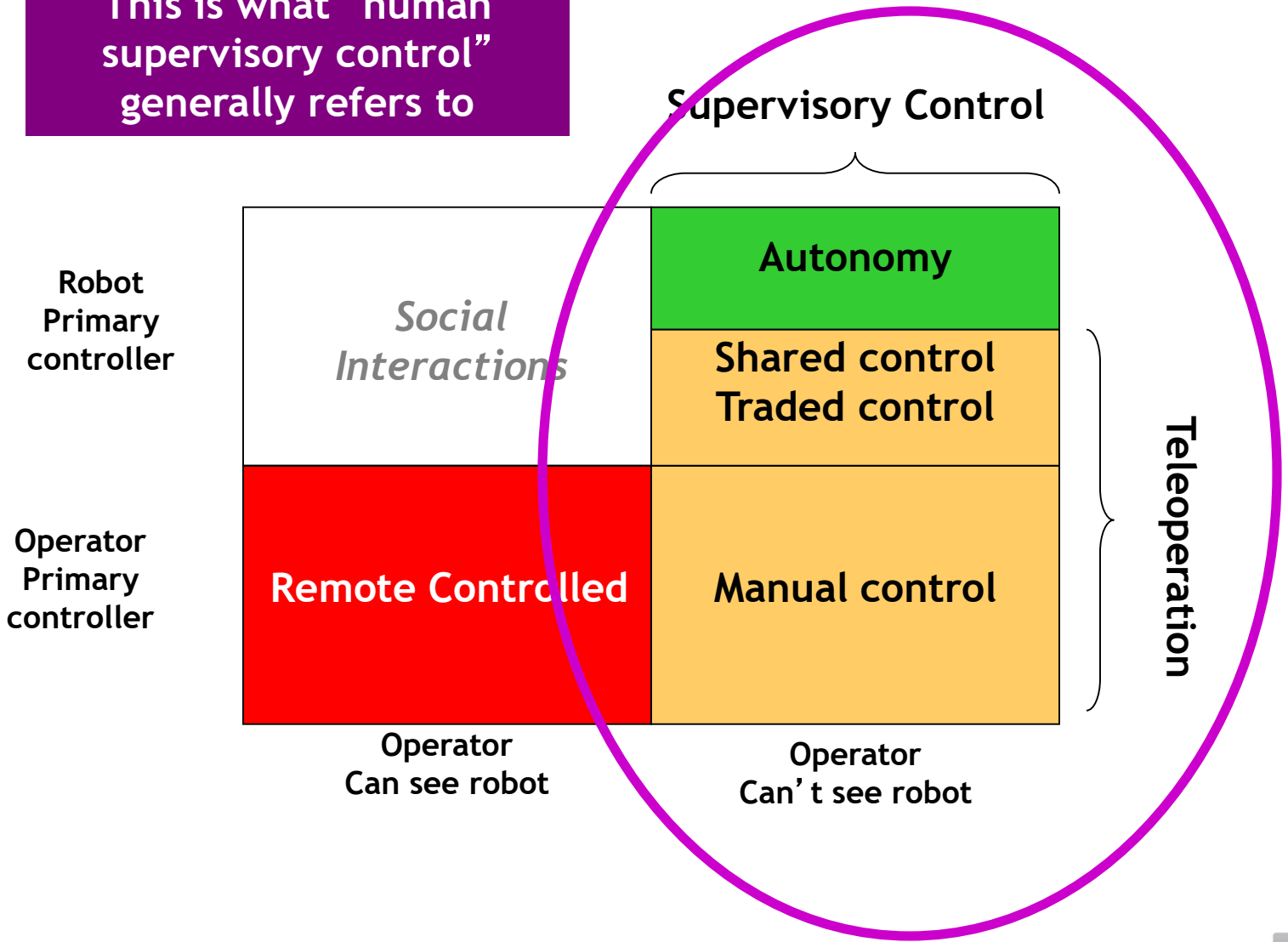
5 Types of Human Supervisory Control

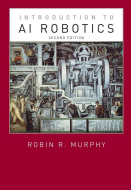




5 Types of Human Supervisory Control

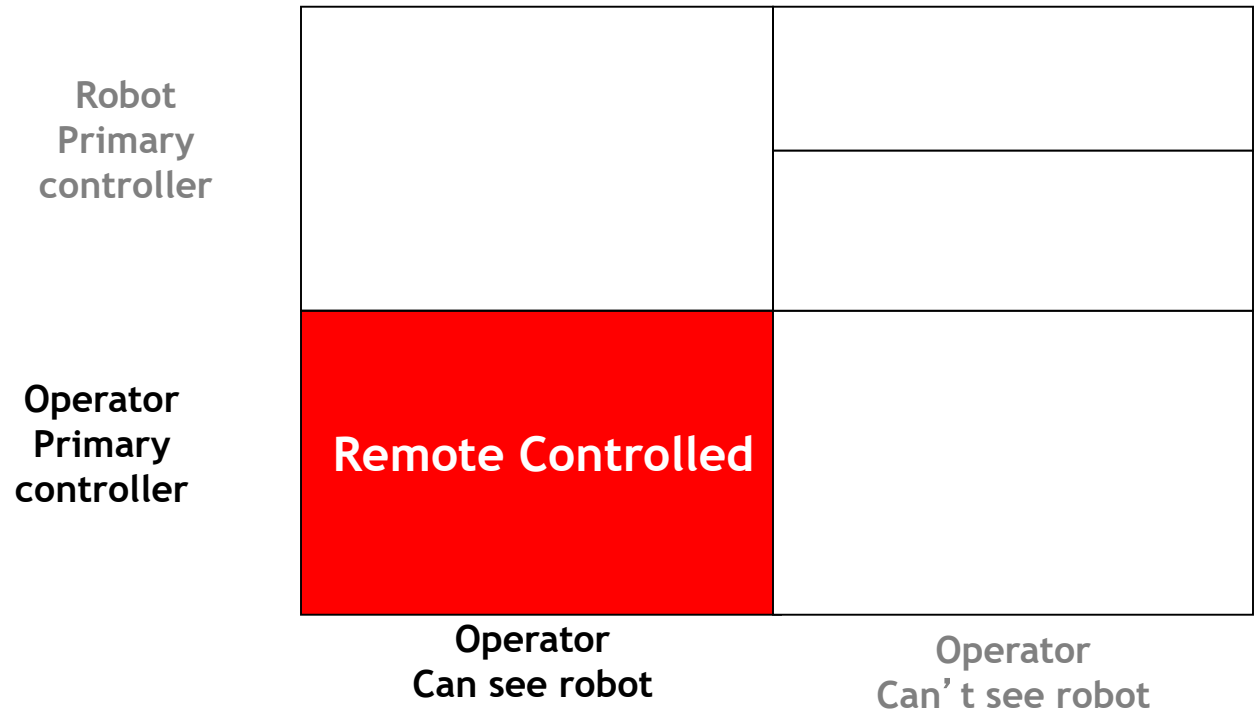
This is what "human supervisory control" generally refers to

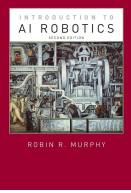




"Radio Controlled" (RC'ing) or "Remote Control"

- Not interesting for AI
  - human does all the work
  - Limited range





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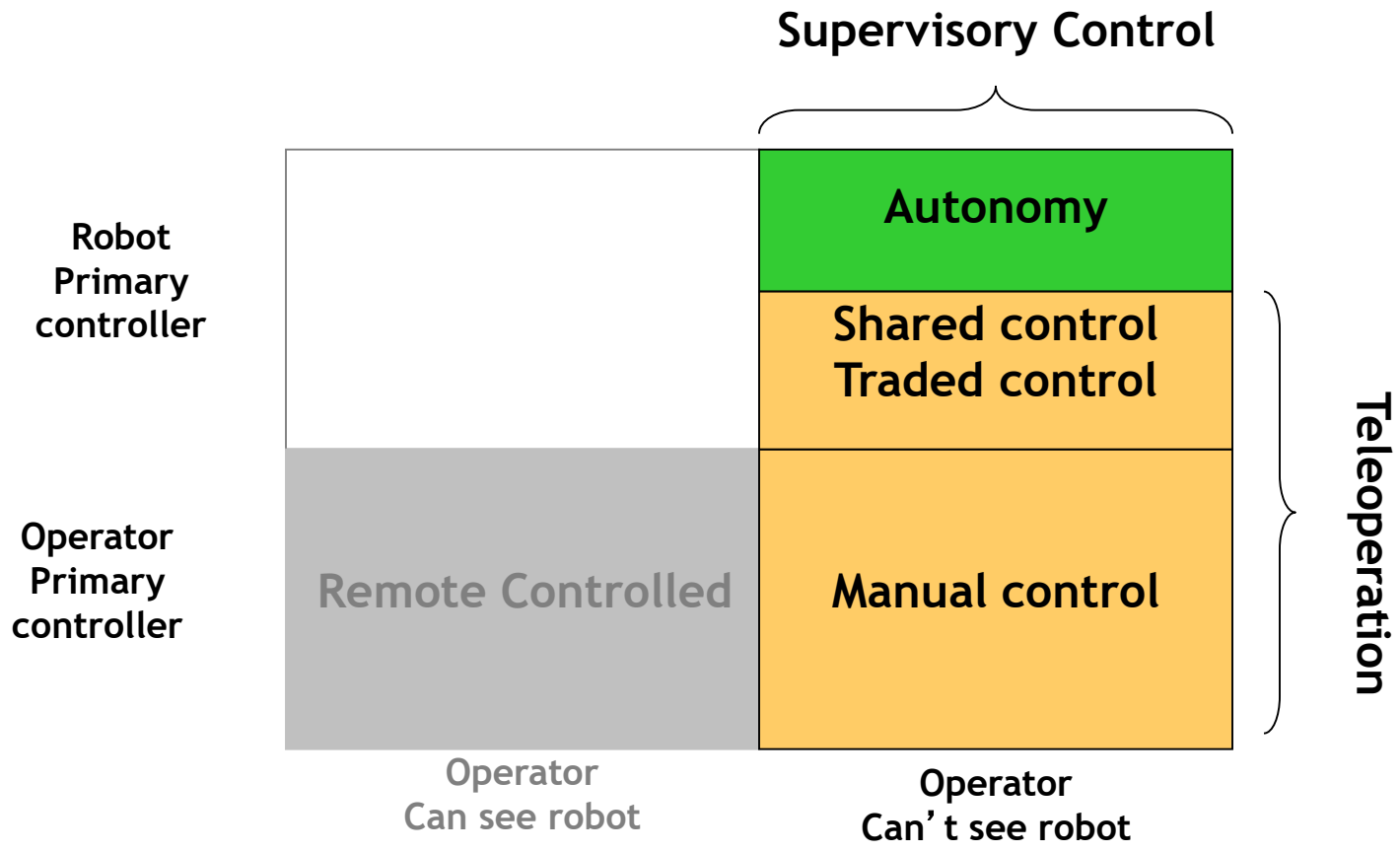
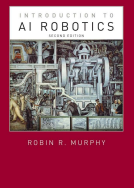
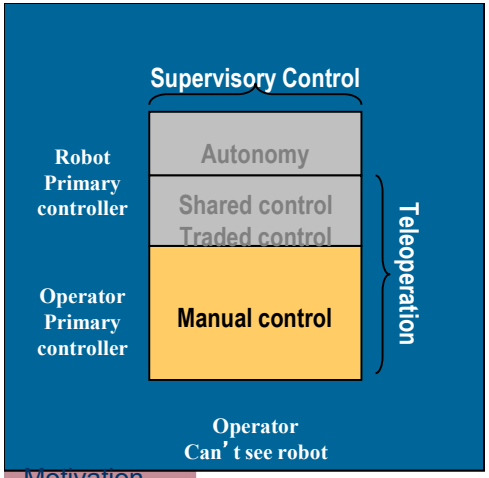
True Supervisory Control

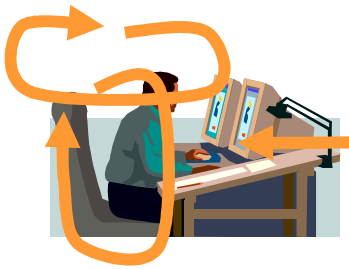
- Connotation is the range of interactive control styles from manual out-of-site control through full autonomy

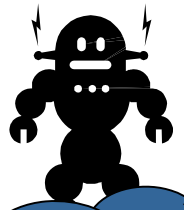




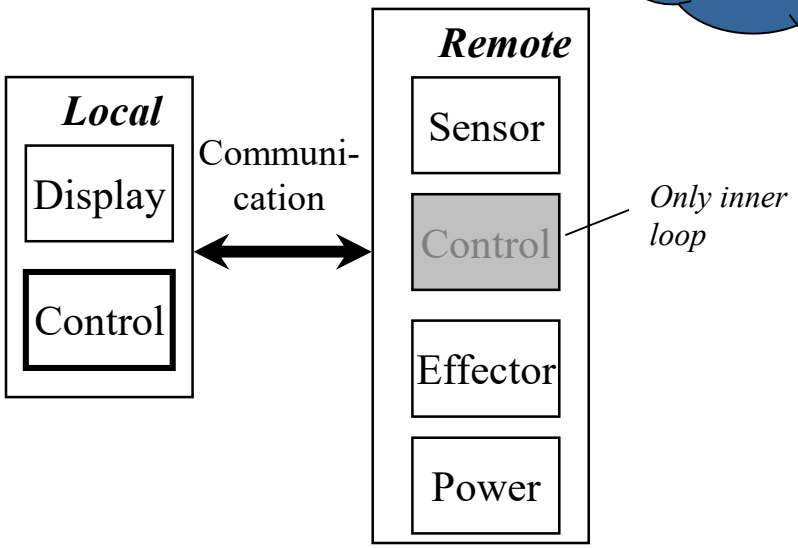


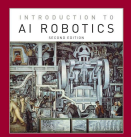
Manual Control



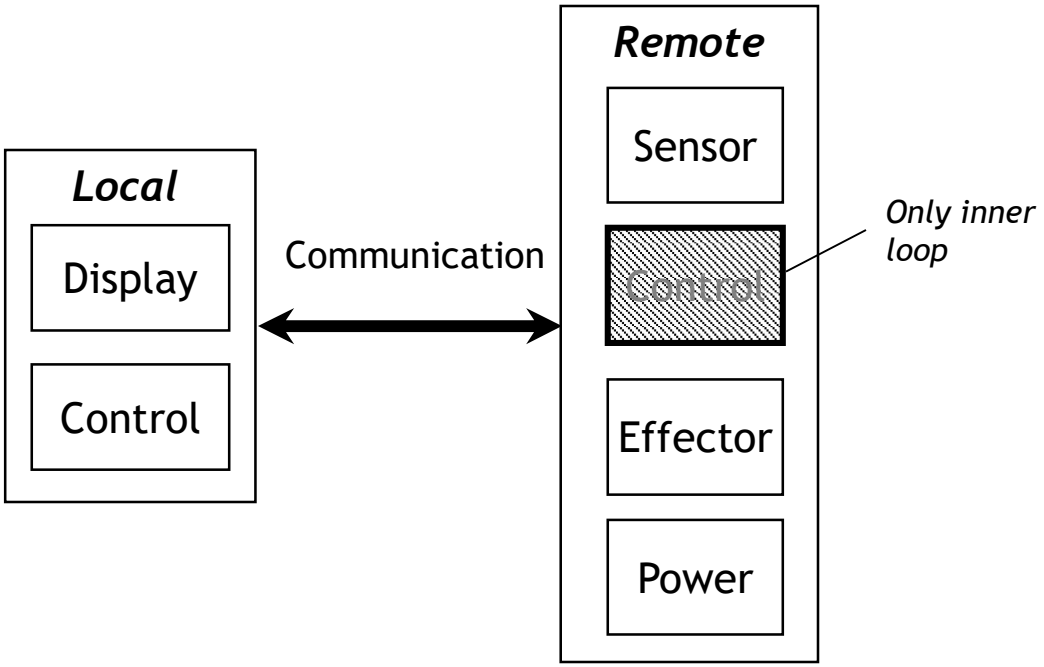


Sometimes called a "telefactor"





Manual Control: The robot has no onboard control component. There may be an inner control loop to stabilize the flight of a UAV.



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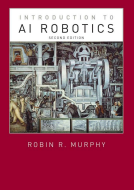
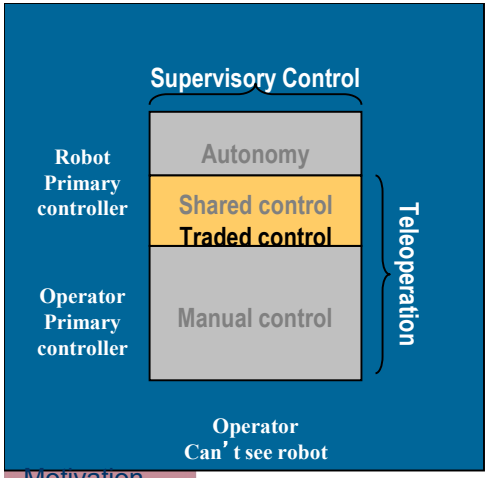
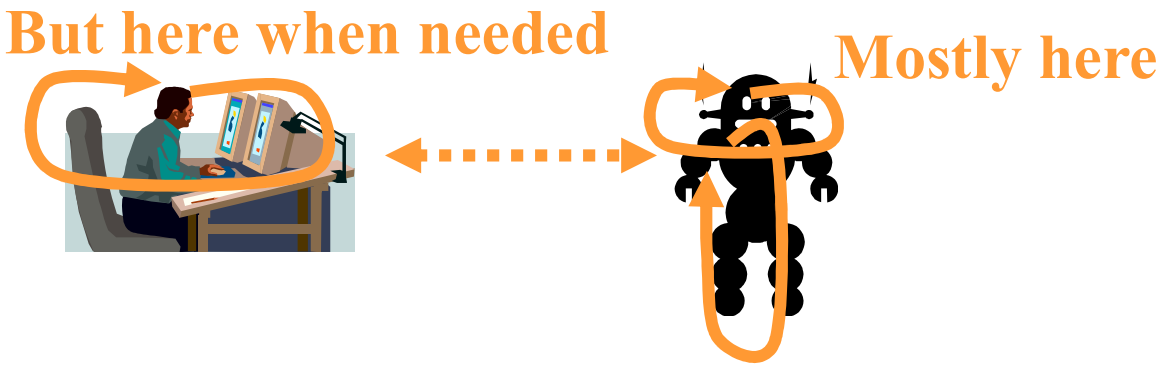
Downside of Manual Control

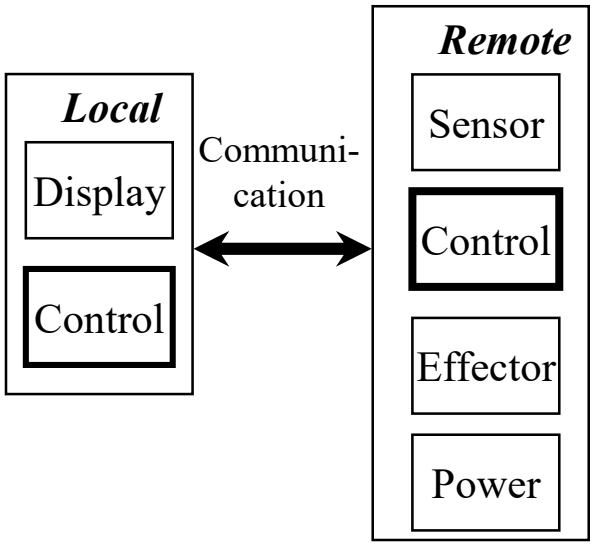
- You can't see the robot but need to control it.
- So, you need information (perception) about robot, its environment, and the relation between them.
- These types of perception are defined as follows:
  - **Proprioception**: measurements of the movements relative to an internal frame of reference
  - **Exteroception:** measurements of the layout of the environment and object relative to the robot's frame of reference
  - **Exproprioception**: measurement of the position of the robot body or parts relative to the layout of the environment.

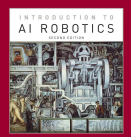




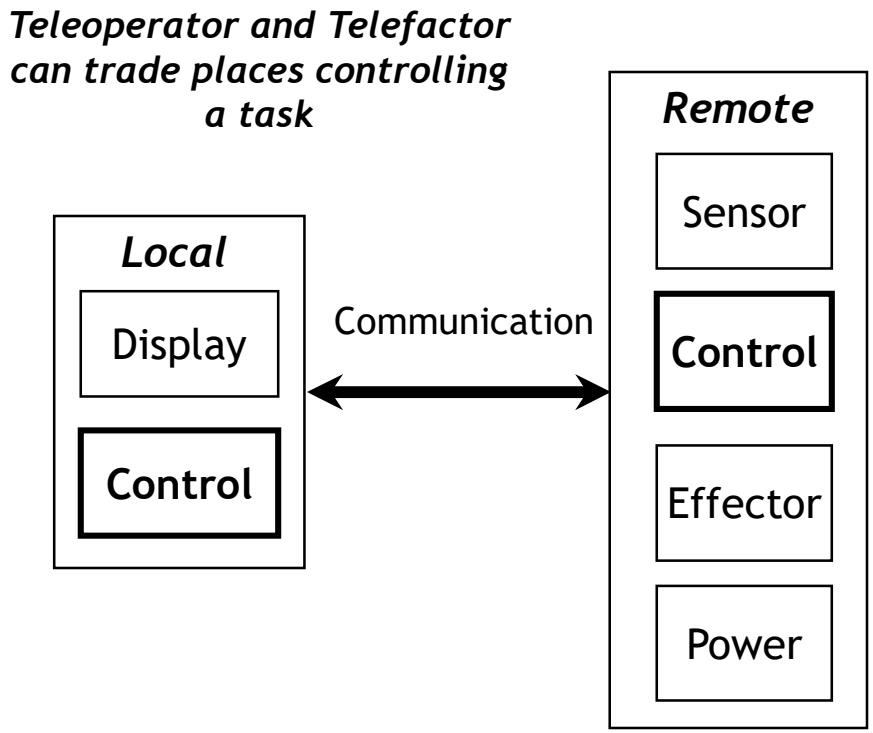
Traded Control

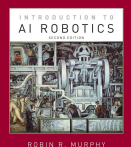


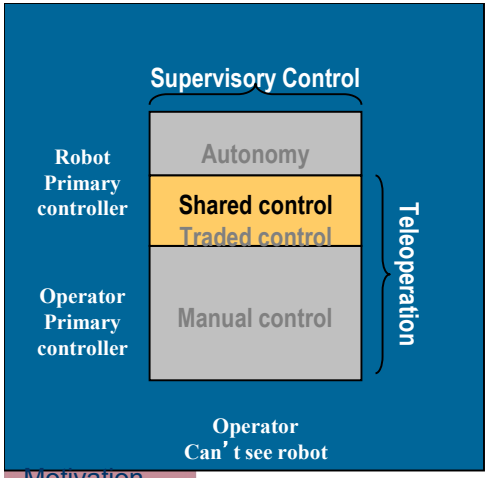




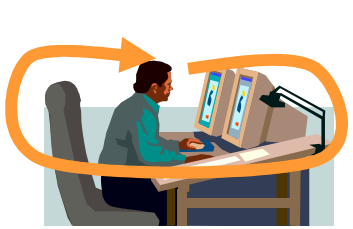
Traded control: the phases of a mission are divided into discrete tasks that the teleoperator will do and those that the telefactor will do.

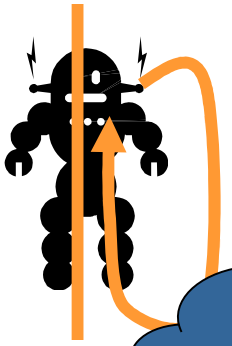






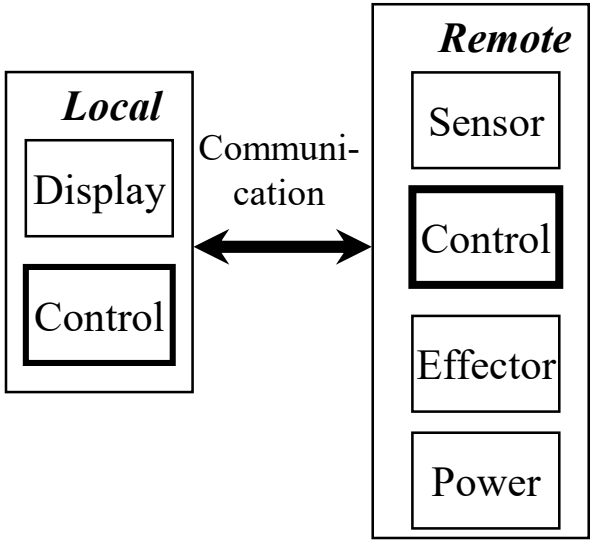
Shared Control

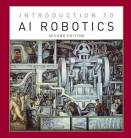




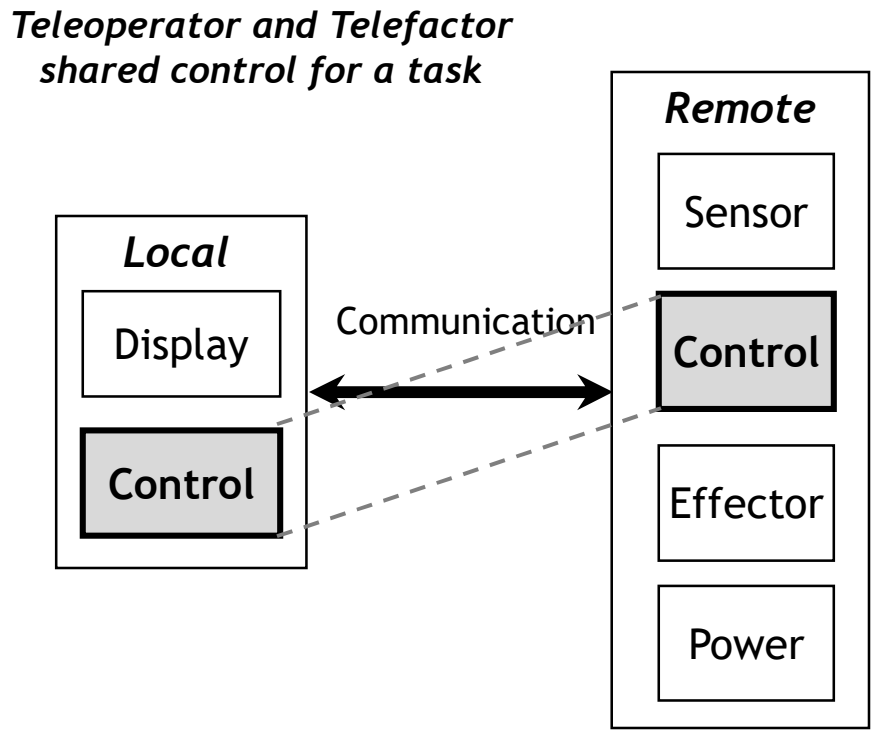
Usually the "deliberative" control

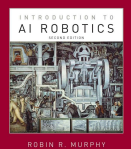
Usually the "reactive" control





Shared Control: Both the teleoperator and the telefactor contribute simultaneously to the control. Typically, the teleoperator provides deliberative inputs and the telefactor provides reactive control



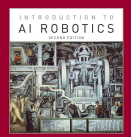


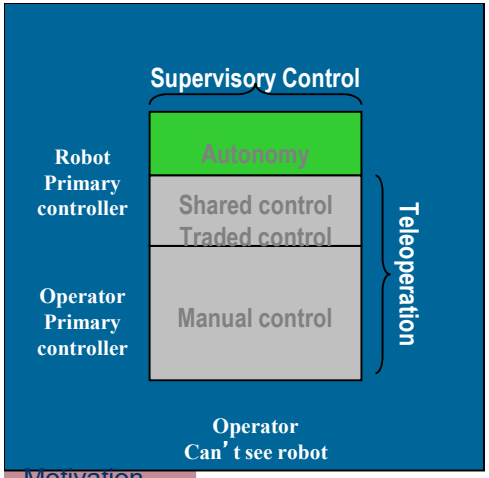
Guarded Motion

A type of human-in-the-loop control, where the robot guards itself from unintended consequences of human directives

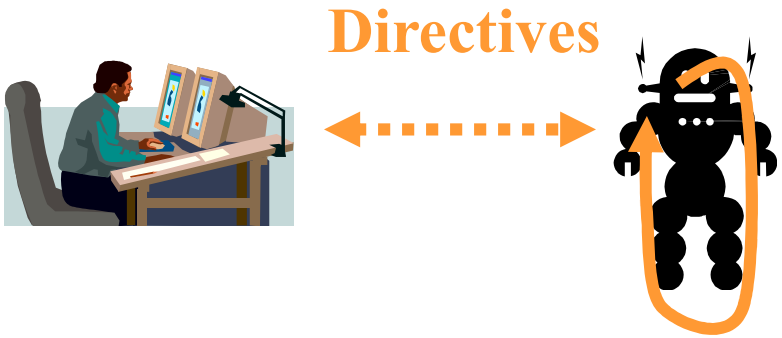
Guarded motion has five components:

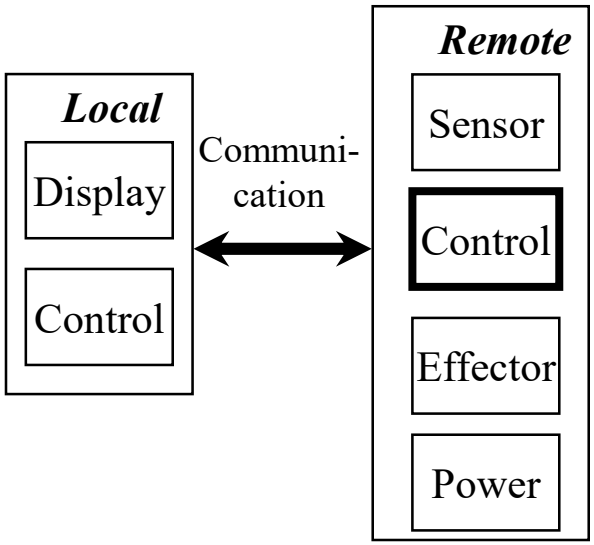
- Autonomy Intervention Criteria
- Command Integration Method
- Monitored Condition
- Interface Modality,
- Display Preprocessing

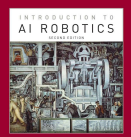




Autonomy

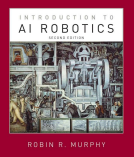






"No Hands Across America"

- 1994
- CMU NavLab
- Pittsburgh to San Diego
  - 2897 miles total
  - 2849 autonomously
- Portions of the trip were traded such as getting on and off the interstate
- Portions were shared
- It is reasonable to classify it as autonomous but not fully autonomous



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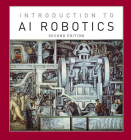
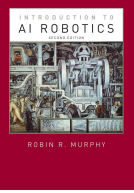
Mini-Summary: Telesystem Theory

- What is teleoperation or telesystems?
- Is it a "temporary evil" or a different style of AI?
  - a popular, immediate alternative to full autonomy in *taskable agents*
  - Telesystems are the "end state" for *remote presence applications;* joint cognitive system
- What is Human supervisory control?
  - how you control a telesystem. The distinctions are not so important because often shift dynamically during a mission.
    - Manual control
    - Traded, Shared
    - Full autonomy



Teleop Problems So Far

- Communications: dropout, bandwidth, lag
- People can't always do the task well due to cognitive fatigue (them) and lack of situation awareness (bad interfaces)
  - Humans not as effective, efficient as should be so start adding manpower
  - Interfaces are poor, manufacturers assume human can make up deficits in design "situation awareness" or "sensemaking"
- Manpower intensive



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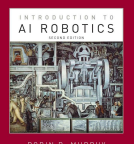
Human Factors

The primary topics in human factors for teleoperation are

- the sources of **cognitive fatigue**,
- the impact of **latency** on the joint cognitive system,
- how **the cognitive limitations** translate into the necessary **manpower** to safely operate, and
- how to prevent the human **out-of-the-loop** (**OOTL**) control problem



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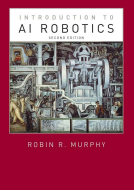
Cognitive Fatigue

- **Cognitive limitations and fatigue** can be introduced by the display and sensor components
- **The keyhole effect**: where a teleoperator is trying to understand the environment by looking through a keyhole in a door or a hole in the wall
- The teleoperator may get **simulator sickness** due to the discordance between the visual system indicating the operator is moving and the inner ear indicating the operator is stationary.



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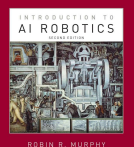
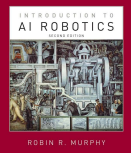
Human Out-of-the-Loop Control Problem

- The human out-of-the-loop (OOTL) control problem
  - the human suddenly has to shift modes from traded or shared control to manual control and to control the remote manually under an unmodeled or unexpected circumstance that the automation could not handle
- There are often significant delays in a human assuming control of an autonomous process
  - In general, the more autonomous the process, the harder it is for the human to quickly and correctly react to a problem

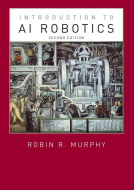


OOTL Control Problem Example: DarkStar UAV got the unofficial nickname DarkSpot after clash



What You Saw

- 7 second communications lag (satellite relay)
- Bad interface to the human pilot
  - Classic post-hoc engineering diagnostic interface
  - Not for real-time flight control
- *"interruption" lag on part of operator*
- In the DarkStar system, it was actually impossible for the experts to shift in time from out-of-the-loop to in-the-loop control.



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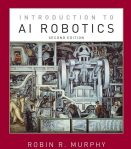
Lessons

- You always want to be able to teleop!
  - Debugging
  - Retrieve

- BUT don't count on it as being "Plan B" if you haven't explicitly designed for a "smooth transfer of control"
  - Autopilot now "warns" pilots when limits are about to be exceeded
  - *in factories it is more profitable to have a lower level of automation and keep human involved so that they could respond more quickly and correctly to problems*



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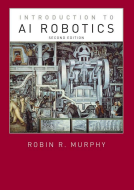
Telesystems are Best Suited For:

- the tasks are *unstructured* and *not repetitive*
- the task workspace *cannot be engineered* to permit the use of industrial manipulators
- key portions of the task require *dexterous manipulation*, especially hand-eye coordination, *but not continuously*
- key portions of the task *require object recognition or situational awareness*
- the needs of the display technology *do not exceed the limitations of the communication link* (bandwidth, time delays)
- the *availability of trained personnel* is not an issue



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Summary

- Telesystems are a popular, immediate alternative to full autonomy
- Human supervisory control is how you control a telesystem
- Supervisory control usually refers to the spectrum from manual control to autonomy
- Problems include: *cognitive fatigue, communications and many:one human to robot ratios*
- Teleoperation or shared control is generally not a reliable "fail safe" or backup plan because of the *OOTL control* problem