The statement of the problem I investigated

General problems - The required motion trajectory may be impossible to follow if the ability of the robot to translate and rotate objects is limited to anything less than six degrees of freedom. Robots can be less efficient if the trajectory of movement is not optimized. Accuracy may suffer if the minimim measurable unit is too large for the task. Payload placement or orientatoin may be incorrect if the net accuracy of the robot does not match its resolution. Placement or orientation may be incorrect if the robot cannot repeatedly move to the same position and orientaton in time. Unintended motion could result in collisions with objects near the intended trajectory of motion. Slowly damped oscillations will waste time while the operator waits for a stable arm before conducting the next move, or worse, an operator may attempt a motion under the misguided impression that a robot apendage is at a specific poition in space and cause a collesion. If the robot is dynamically unstable, it could destroy itself as well as objects withing its reach. If the robot does not respond as its controller intended, unintended collisions could occur.

Teleoperation problems - Observation difficulty

Telecommunication problems - Time delay

My research questions

What methods or systems will mitigate or eliminate the disadvantages of teleoperated robots?

The purpose of my study

The purpose of this study was to develop the logical basis for the practical operation of robots in space by operators on earth, and propose methods of eliminating or mitigating the problems inherent in teleoperated robots.

Operational definitions of variables used in my study

[If the word “variables” were not part of this sentence, then the following definitions would be appropriate. As it is, the mathematical variables would be more appropriate, but that makes little sense given the lack of an opportunity to present the equations that use the variables. Get clarification.]

Automation: The automatically controlled operation of an apparatus, a process or a system by mechanical or electronic devices that substitute for human organs of observation, decision, and affect.

Robot: A programmable multi-functional manipulator designed to move material, parts, tools, or specialized devices through variable motions for the performance of a variety of tasks. It may be automated to the extent that it performs functions ordinarily ascribed to human beings or operates with what appears to be almost human intelligence.

Pick-and-place robots: These robots perform the operation of grasping individual parts in a known location and placing them in a known location. Typically no reorientation of parts is required.

Assembly robots: These robots adapt to part position and orientation variations, significantly change the position and orientation of parts as they are assembled, and may include accessories to fix the part in place using multiple end effectors (screw drivers, riveters, adhesives, arc welder).

Adaptive robots: These robots are able to sense their environment and modify their actions in response to the information sensed.

Manipulator system: Typically a mechanical arm mechanism, consisting of a series of links and joints that perform the motion by moving the end-effector through space. It closely resembles a human arm and consists of a base, shoulder, elbow, and wrist. Each joint couples two links in one motion plane. Multiple joints at the same location increase the degrees of freedom of the associate link (simultaneous angular motion in all three spatial coordinates, linear motion along any angle, rotational motion at any angle or linear position).

End-effector: Typically a device that can grasp various end-effector tools as needed for various tasks (hand),

Actuator power drive: Provides electric, hydraulic or pneumatic energy to move the manipulator arm and end-effector.

End-effector tool: Anything from a screw or nut driver to a welder or another robot that makes it possible for the robot to perform a specific task.

Fixtures: The fixed jigs and other tooling that facilitate or make more accurate the activities of the end-effector.

Controller: Converts simple motion commands into device driver commands for all the robot components involved in the movement.

Sensor: Provides pressure (contact, force, torque), photon (visual) acoustic (proximity or process) or thermal (proximity, process) feedback to the controller so it can iterate movement as a function of the sensed information.

Interface: Allows external systems to communicate gross or specific commands to the controller.

Teleoperator: A machine that extends a person's sensing and/or manipulating capability to a location remote from that person.

Teleoperation: The direct and continuous control of the teleoperator.

Telerobot: An advanced form of teleoperator, the behavior of which a human operator supervises through a computer intermediary.

Telerobotics: The supervisory control of a teleoperator.

Limitations to my study

This study was primarily a broad literature search and detailed review of the literature. The results derived from that review are limited to requirements for the viable teleoperation of robots in space.

A description of the references that were most influential

[Pick a few.]

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A summary of my research design and results

The secondary problems of accuracy and repeatability that are common to locally operated robots as well as teleoperated robots, but amplified by teleoperation are mitigated by various design solutions like six degrees of freedom, movement macros that optimize often repeated moves, fully modeling the robot and its environment and payload to provide multiple views of the operation to the operator, and colorizing the simulated robot structure and payload to indicate stress levels.

The primary problem of Ground Operated Telerobotics (GOT) is the communication time delay. Modeling the operating space in three-dimensions and operating the robots by why of simulators eliminates this problem. GOT controllers input commands to the ground-based simulators that are sent to peer simulators on the space system. While waiting for validating feedback from the space-based simulators, the ground simulators provide feedback to the GOT controllers according to what is expected to occur as a result of their control input. As feedback is received by the space-based simulators of the actual movements, and relayed to the ground-based simulators, the ground-based simulators adjust their simulation to insure that the GOT controllers see and feel the reality of what is occurring in space.

Video images of that space-based activity overlaid on the computer monitors displaying the three-dimensional model of the simulation provide an additional and confirming sense of reality.

Furthermore, if the crew operates their local space-based robots by way of the space-based simulator used by ground operators, the space-based operators can benefit from the simulation by being able to see views of the operation not available from their crew cabin windows or video cameras. The robot activity would not be limited to what can be seen from windows. The windows could be eliminated, saving weight and cost, and eliminating the safety hazard of windows.

The implications of my work

The designers of manned space systems like the International Space Station (ISS) myopically decide that robots on those systems will be operated by the crew of those systems, even if it means that those robotic resources will be idle while the crew sleeps or are too busy with other tasks to operate the robots, and even after simulations prove that the quantity of robotic work exceeds the crew time available for the corresponding robot operation tasks. The concept of having people on the ground operating the space-based robots is never seriously considered, even to operate the robots only when members of the crew are unable to do so.

Those involved with space systems design decisions may conclude from this work that the operation of space-based robots by ground-based operators is practical for work in Earth orbit and beyond. Ground-based operation of space-based robots would more fully utilize expensive equipment, relieve astronauts of excessive and unnecessary workload, and in many cases, eliminate the need for astronauts, which are pound for pound the most expensive payload to lift from the surface of Earth and sustain in space. Furthermore, human payloads must be returned to earth, which is another exceedingly expensive proposition, while other payloads can be discarded.

Suggestions for future research

Validate the conclusions with simulated telecommunication time delays between the simulators of terrestrial robots and their operators on Earth. Gradually increase the time delays to challenge the system, motivate improvements, and determine the maximum practical operating range of teleoperated robots.

My plans to implement or apply my results or findings

Send proposals for the suggested future research to space system design decision-makers, who are not politically disposed to justify astronauts in space, soliciting funding for system development and terrestrial tests to be followed by space-based validation.