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CAN COMPUTER AIDED TELEOPERATION REALLY HELP NUCLEAR CELL OPERATION?

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Abstract

The risk of radiation and contamination made remote operation necessary from the beginning on of the nuclear industry. In fact many concepts still in use today even for other applications than the nuclear ones, such as the force reflection master slave manipulator for instance, find their roots in the pioneers days of the forties. The manipulators were basically mechanical devices where master and slave are closely linked together. They are still in wide use today in cell operation. Although they benefit from a long experience, good training and mature equipments, they have basic limitations, such as limited volumic range, low payload, need of direct sight, physical stress when used for long times and relatively low MTBF.

High power manipulators were then developed with electrical connections between master and slave. This allowed for higher payloads, longer ranges (for instance when coupled to a gantry system or positioned on a mobile platform), but were still completely manually controlled devices. The basic limitations of operator skill, with respect to reaction time, remote perception, multiprocess control, makes the use of such equipment quite complex and demanding.

On the other hand, the industrial world saw a parallel development of automated machines, of robots for manufacturing purposes, pre-programmed and repeating defined tasks in well structured environment. The applications of robots to the nuclear types of work was far from straightforward, except in some fuel fabrication operation, or reprocessing lines. For most nuclear tasks, the environment cannot be structured, and is even often unpredictable. A classical robotic approach is doomed to fail in such cases.

But robotic research goes on. After the teach and repeat robots, already well established for large series manufacturing, the need to automize small series productions, to obtain flexible workshops, to get to real computer integrated manufacturing, pushed research in enhancing the robots autonomy and adaptability.

Intelligent autonomous robots are however still a long way ahead. But a more pragmatic approach is to integrate both computer and manual superviser in the control strategy and to distribute the responsabilities according to the particular skills. The operator is particularly good at qualitative reasoning on incomplete or noisy data at low bandwidth, whereas the computer is better at calculation intensive subtasks, repetitive combersome actions at high bandwidth. This is the start of the so called telerobotics, a merge of robotics and teleoperation.

On the other hand, nuclear teleoperation progressively tries to integrate some of these advanced features in master/slave relationship. Computer layers of control are superposed or put in parallel to the direct human link. Computer aided teleoperation (CAT) is actually aiming at the same goal as telerobotics, but starts from the other side.

CAT can be seens at different levels. The first immediate one is the help of the operator, keeping him however still in full control of the machine. Advanced man-machine interfaces, with good ergonomic input devices, good synthesis of monitoring data, are a first step towards real telepresence features where 3D cameras, force and tactile feedback, realistic sound return enhance the operator's remote perception.

A second level is the use of automated sequences to relieve the operator from tedious repetitive tasks, complex start-up or close-down procedures, storage rack or tool rack management, etc. The machine sees always one defined superviser, either the operator or the computer, in sequential order, in a so-called traded control scheme.

A third approach is a real share of responsabilities, in parallel, bewteen computer and operator. Examples of such shared control strategies are collision avoidance systems (sensor or model based), subsystem control (cameras, tools, etc), share in degrees of freedom control (orientation keeping, surface following, etc), automatic task schedule check or log-book filling in.

Examples of applications of such features are emerging, mainly in new installations, for instance for dismantling purposes, reprocessing plants or in the fusion research.

Although CAT can help the operator in reducing the stress, in lowering the human error risks, in checking for sequence and movement correctness, and can help reducing the costs due to higher efficiency, less down times and better ergonomy (less labour cost), it is still a challenge. New technologies must still prove their long term reliability, mainly when failures can have important consequences and could impede all foreseen benefits. They need new training schemes for the operators, and new standards to be set.

CAT
(Computer Aided Teleoperation)

# Can CAT *really* help nuclear cell operation?

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Computer Aided Teleoperation

- Nuclear
- Deep sea and Offshore
- Space
- Security
- Military

Nuclear Teleoperation

- As old as the nuclear age
- Still mainly mechanical transmission
- Limited working volume
- Limited lifting power
- Anthropomorphic kinematics
- Mainly direct sight applications
- Good remote "feeling" (telepresence!)
- Long experience and good training

master

direct mechanical or
electrical link

operator

slave
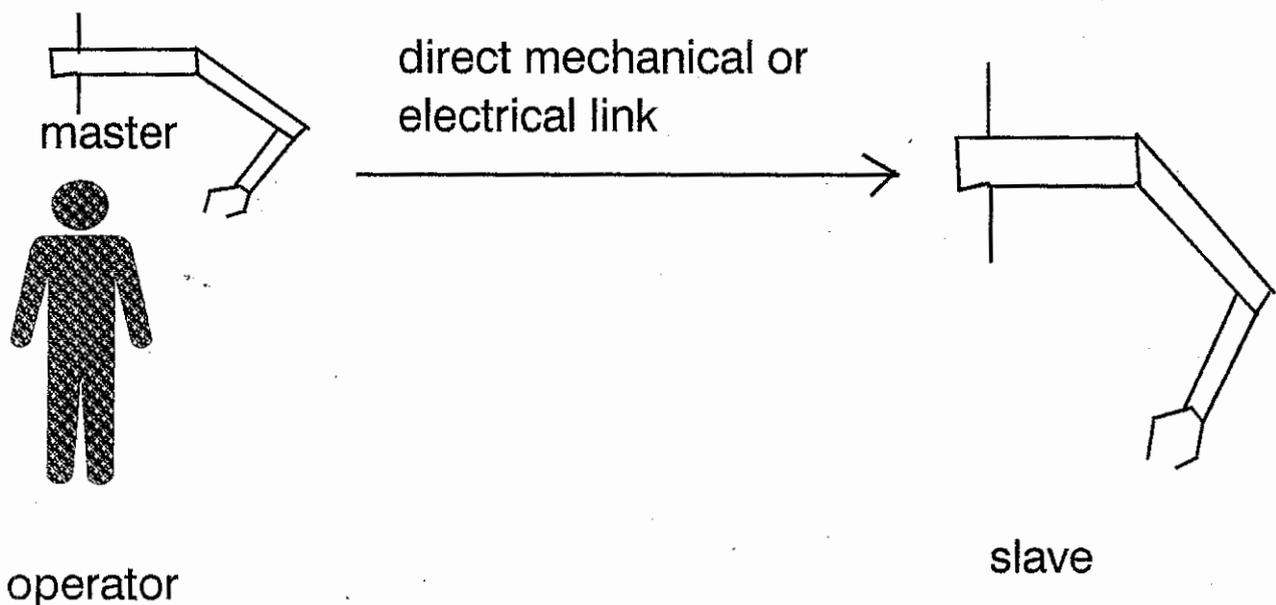
Robotics

- Mainly teach and repeat operations
- No man-in-the-loop operations
- Structured environment (built around the robot)
- Good position accuracy and repeatability
- Good MTBF figures (industrial series)

Telerobotics

- Smaller series
- Adaptability
- Good level of sensing
- No structured environment
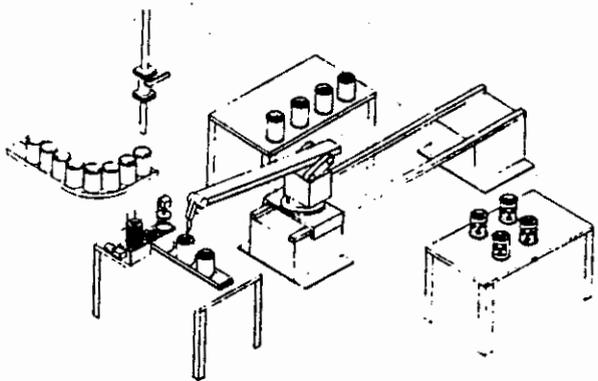- Man-in-the-loop
- Non manufacturing applications
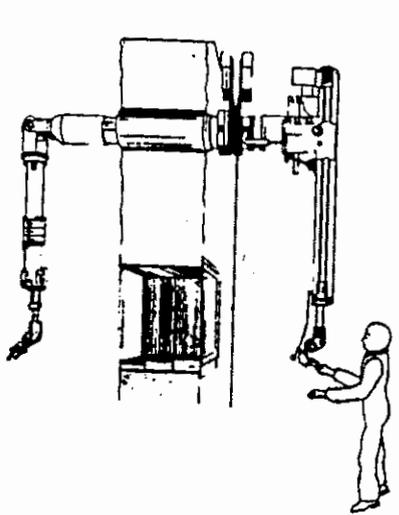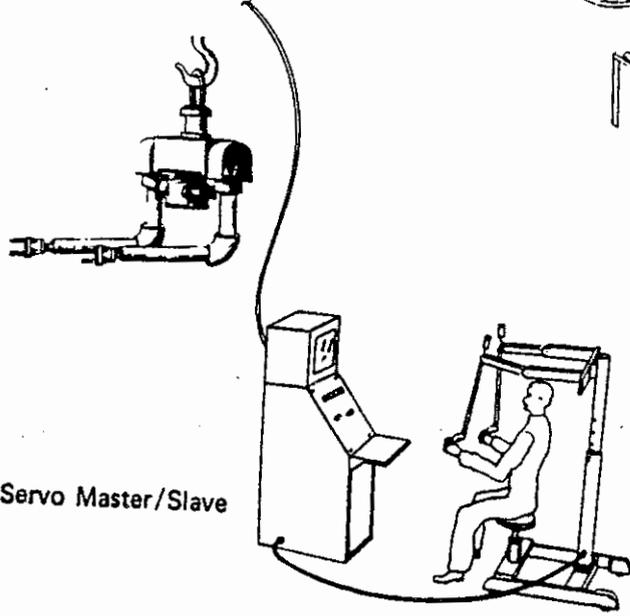
Mechanical Master/Slave
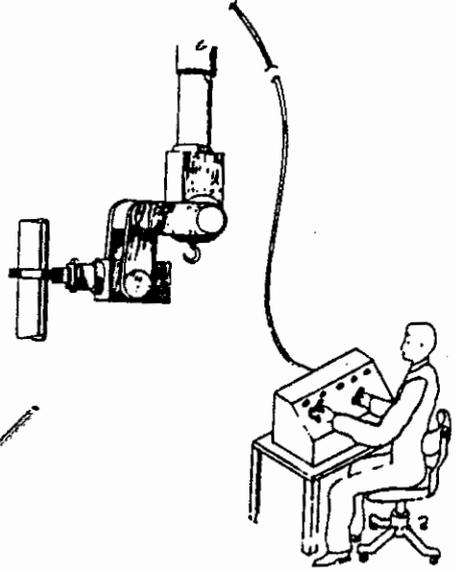
Power Manipulator

CAT

Robotic System

Servo Master/Slave

TELE-ROBOTICS

Computer aided Teleoperation

- Help operator in avoiding problems
- Lower the operator stress
- Take care of secundary systems
- Give more information
- Monitoring and log-book functions

Control concepts

- **Telepresence** (using sensors, synthetic images)
  - operator still in control of all details
- **Traded control**
  - computer replaces operator during some tasks
- **Shared control**
  - computer takes care of some concurrent subtasks
- **Guarded mode**
  - computer and operator in charge
- **Delegated mode**
  - computer takes over when needed

computer link

master

advanced MMI
telepresence
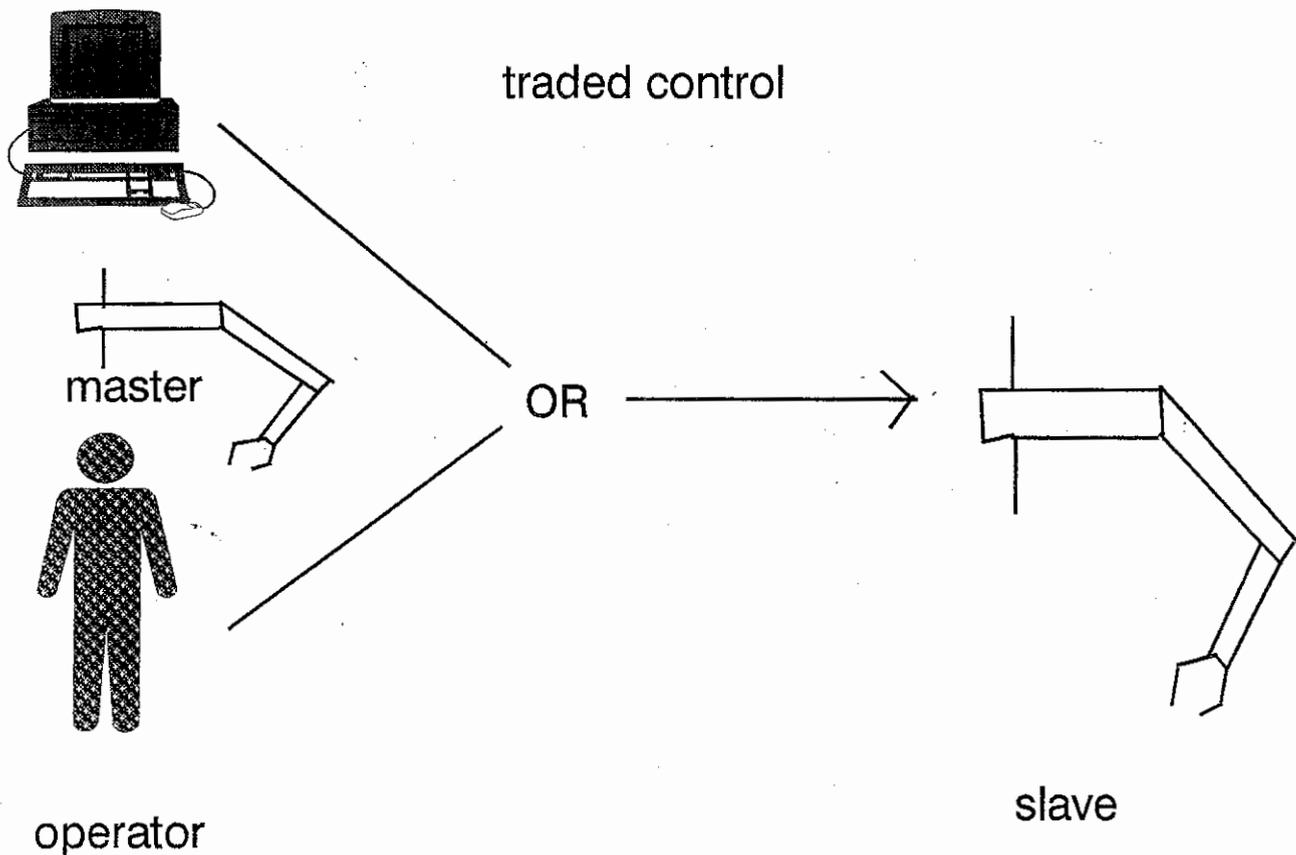
operator

slave
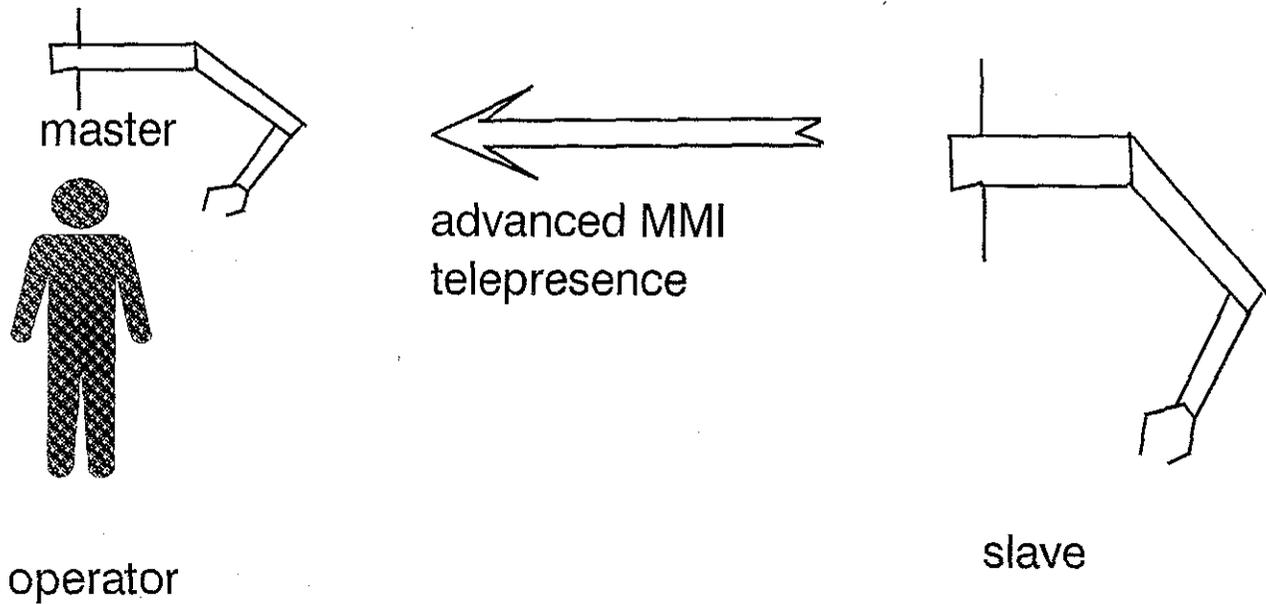
Man-machine interface

- Central control of all subsystems
- "Better" master configurations (ergonomy)
  - multiple function (e.g. force/position)
  - indirect (goal driven)
- Synthesis of information (image, sound, sensors, process)
- Alarm information
- Voice input

Telepresence

- **Force reflection**
  - direct mechanical link
  - sensor driven (e.g. MA23, NEATER)
  - synthetic forces (obstacles avoidance)
- **Synthetic images**
  - model based and even sensor based
  - superposition of real images
- **Sound return**
  - real sound
  - synthetic sound (motor or tool functions)
- **3D cameras**

Traded control

- Sequential control computer/operator
- Teach and repeat operations
- Automatic insertion
- Automatic tool operation (e.g. bolt, unbolt)
- Surface covering (e.g. in decontamination)
- Automatic set-ups or close-downs (tool changers)
- Automatic storage control

traded control

master

OR $\longrightarrow$

slave

operator

Shared control

- Concurrent computer and operator tasks
- Degrees of freedom (orientation keeping, surface following, etc)
- Possibility to depart from anthropomorphism
- Control of subsystems (cameras, tools, hoist, etc)
- Collision avoidance (model or sensor based)
- Procedure sequence check
- Automatic log book

shared control

master

AND

operator

slave
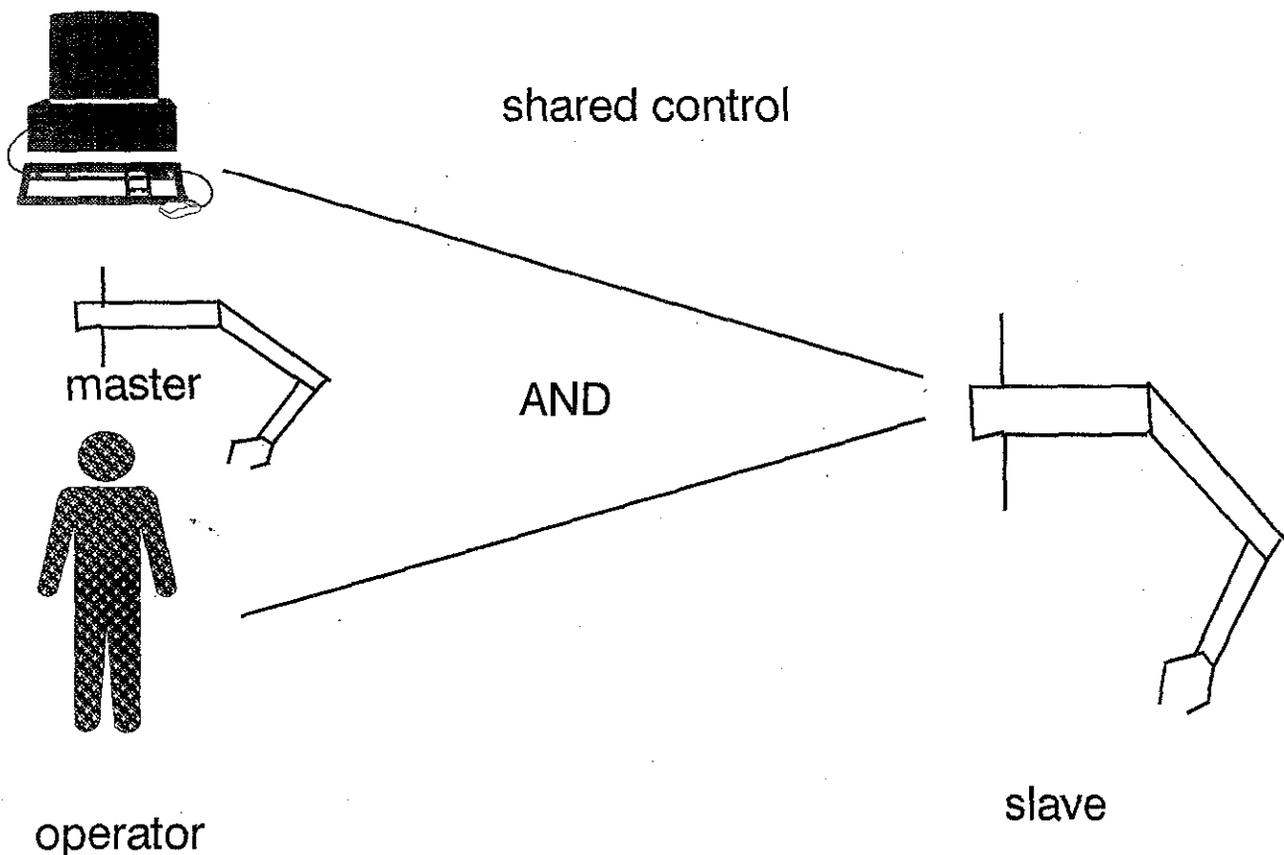
When can CAT really help?

- when extending *reach* and direct sight is lost
- when extending *payload* and safety becomes critical
- when extending *degrees of freedom*
- when extending *concurrent subsystems*
- when extending to complex and *precision tasks* (industrial robots)

CAT : a help

- Safety (reduce human errors)
    - collision avoidance
    - sequence correctness
    - less stress (less concurrent actions)
- Cost
    - higher efficiency
    - less down times
    - better ergonomy (less labour cost)

CAT : a challenge

- new technologies (reliability?)
- consequences of failure can impede benefits
- training of operators
- need for standards
- advanced technologies must be environmental resistant
- investment costs (progressive?)