HOTLAB 2013
hosted by Idaho National Laboratory

TELEROBOTIC SYSTEMS
MT200-TAO AND TERMAN TAO

Christophe Selliez-Vandernotte
Scot La Valla
➢ Design and fabrication of standard and customized products aimed at protecting the customer's staff, equipment and facilities from contaminated or radioactive environments
  ➢ Global leader in remote manipulation and in sealed transfer system

➢ Exhaustive capabilities from design to on-site support

➢ World Wide Installed Base

➢ 50 years on the market
TELEROBOTIC SYSTEMS
MT200-TAO AND TERMAN TAO

CONTENTS
1. Introduction
2. TAO concept: principles, advantages
3. TERMAN concept: description, advantages, applications
4. Results of the initial validation phase
5. Next steps

• MT200
  • Master slave telescopic manipulator particularly suitable for large research cells and industrial installations
  • Capacity: 20 daN – 4 m extension
  • Standard weight: 600 kg
  • 800 units in service worldwide
The MT200 remote operating system is a thru-wall mechanical master-slave manipulator (MSM) with telescopic arms.

- Both arms are driven by gears, cables or a combination of both.
- The thru-wall transmission uses rotating shafts to couple the two arms (discontinuous kinematics).

Around 500 MT200 units are used at AREVA La Hague recycling plant, with a total of around 800 worldwide.
MT 200 TAO
Commissioning Feb 2014
Computer Assisted Telemanipulation
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Principles
- “fly by wire” technology now in use in most aircraft-
- breaking the mechanical link between the operator and the top
  end of the slave arm
- replacing human energy by electricity: the movements of the
  slave arm are powered by motors
- integration of a high speed real-time computer in the loop, which
  analyzes the operator orders and transforms them into orders to
  the motors.

TAO = Teleoperation Assistée par Ordinateur = Computer Assisted Teleoperation
THEORETICAL NOTIONS
MASTER-SLAVE COUPLING PRINCIPLE

UNILATERAL COUPLING

Master/Slave are 2 independent mechanisms

BILATERAL COUPLING

Master/Slave are 1 single mechanism

CEA Courtesy
## Theoretical Notions

**Irreversibility versus Backdrivability**

<table>
<thead>
<tr>
<th>Mechanical type (constructive property)</th>
<th>Behaviour</th>
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<tbody>
<tr>
<td>Irreversible</td>
<td>Self-locking</td>
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<tr>
<td></td>
<td>Backdrivable if assisted (force closed loop)</td>
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<tr>
<td>Reversible</td>
<td>Backdrivable (or « bilateral coupling »)</td>
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**TELEOBOTICS RESEARCH AND DEVELOPMENT AT CEA LIST**

P. Garrec and F. Geffard and O. David and F-X Russotto and Y. Measson and Y. Perrot

*ANS EPRRSD - 13th Robotics & remote Systems for Hazardous Environments • 11th Emergency Preparedness & Response - Knoxville, TN, August 7-10, 2011*
THEORETICAL NOTIONS
FORCE TRANSFER LINEARITY & MERIT FACTOR OF A TRANSMISSION

TELEROBOTICS RESEARCH AND DEVELOPMENT AT CEA LIST
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ADVANTAGES OF TAO SYSTEMS

- Exceptional feed back to the operator (no delay, 7 axes)
- Ratio of efforts between slave and master arm is adaptable: we decided on a ratio of 10 in our applications (1 kg at handle gives 10 kg at tong)
- Smart application: filtering of vibrations
- Protection of mechanical and electrical parts against overpassing the demonstrated performances, thus reducing the number of failures

Cartesian control
Coherent and homothetical force feedback
Single “intuitive” indexing push button
Compact master arm without telescope
Indirect vision (camera) with automatic tracking of the gripper

Tool weight compensation
High safety thanks to deadman gripper control
Virtual mechanisms (e.g. 3D guiding functions)
MT200-TAO / TERMANTAO
USER AND OPERATIONNAL ADVANTAGES

- Improvement in HOF, safety, dosimetry, ergonomics, working conditions
- Increase in productivity and efficiency
- Increase of the MTBF of the system, and of the slave arm
- Extension of the working area above the through tube axis
- Capacity to simulate operations
- Capacity to repeat operations
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- Full true mechanical transmission: no more cables
- High responsiveness / rigidity / strength
- No fragile or heavy maintenance components on the hot side
TERMAN TAO SPECIFIC ADVANTAGES

- Increased reliability (MTBF: 1000 h)
- Efficient 20 kg manipulation with Full Area Coverage
- Enhanced Robotised mode (high rigidity)
- Reduced Maintenance Cost
- Interchangeable with MT200 Slave Arm
- 10 inches wall sleeve compatible
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☐ System level Proof of Concept
☐ TERMAN slave arm Proof of Concept
  ➢ Shoulder Feasibility
  ➢ Concentric drive shafts
  ➢ Mechanical friction and rigidity
System level Proof of Concept METHODOLOGY

- Assessment of system with operators
- Integration of initial operator feedback
- Operator training for commissioning,
- Commissioning follow-up by on-site monitoring
  - of operators feedback
  - of the system (via control and command, shift log, etc.)
  - of operation (productivity)

A system designed for and with the user
METHODOLOGY (2)

• OBJECTIVE:
  • Representativity of Real Operation

• METHOD:
  • Use the prototype on a permanent and continuous basis
  • Involve the system in representative (active) stations of work
  • Use all the features of the MT200 TAO system
  • Involve a team of operators, made up of a representative sample of the population of site teleoperators

• KEY FIGURES:
  • Period of operation: over 40 weeks
  • Working time: 500 hours
METHODOLOGY (3)

- Work performed
  - Cleaning melter pieces by chipping
  - Maintaining a frame and inspection window
  - Sorting in activity baskets
  - Small-scale handling
  - Cleaning and storage
  - Installing lighting at a high height

OPERATIONNAL RESULTS

- Users: 90% have appropriated the TAO system
- Operating gain in efficiency (time related to a work)
  - 60 to 65% through increase in operating time (less tiredness)
  - 20% through more accurate movements
- The slave arm has been lasting 5 times more than with a conventional MT200
TERMAN slave arm Proof of Concept
Shoulder Feasibility

- Mechanical couplings realized by conic drive shafts on the articulation axis.
- All the movements must be contained within a space compatible with the future installation.
- All the movements transferred by the shoulder were measured, all the kinematics described, and the shoulder design was proven to allow passage through the standard 10 inch through tube.
TERMAN slave arm Proof of Concept
Concentric drive shafts

Mock up for test

Internal Rod

External Rod

Adjustable bearing

Adjustment area

Fixed bearing
TERMAN slave arm Proof of Concept
Mechanical friction and rigidity

TERMAN MTT model
view with arm in full extension

TERMAN MTT model
view with arm in retracted position
TERMAN slave arm Proof of Concept
Mechanical friction and rigidity

- Oscilloscope
- Electrical Supply
- Torque Sensor
- Motor
- Reducer
- Torque wheel
- Servo-variatior
TERMAN slave arm Proof of Concept
Mechanical friction and rigidity

Law of Z manual direct and indirect friction
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### MASTER SCHEDULE

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- MT200 TAO to be commissioned February 2014, TELMAN TAO December 2014.
- Future benefits: shielded windows avoidance, one room centralized control of manipulators, remote operation
- Future developments: operation from the ceiling of the cell, operation from a mobile gantry inside the cell, heavy manipulator
Thanks for your attention

GRATITUDE
With warmest thanks to AREVA and CEA-LIST for their kind support and valuable contribution.

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