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SPACE ROBOTICS

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ABSTRACT

Space Robotics is a key technology to Japan's space development in the 21st century. Cis-lunar space infrastructure will be developed via advanced artificial intelligence, robotics and automation as well as human astronauts in the next twenty yeas.

1. Space Needs for Space Robotics

Space robotics is an enabling technology to real utilization of space for every people on the Earth. It provides effective tools to humanize the unfriendly environment of airless space. Space robots can be an extension of human body into far remote orbits and the lunar surface. Construction, inspection, equipment exchange, repair and manufacturing in space cannot be performed effectively without full employment of robotic functions. Productivity and economics of space industrialization is largely dependent on the performance of space robotics.

2. Terrestrial Effects of Space Robotics

Space robots should be inevitably intelligent, reliable and robust. Those technologies to realize space robots are directly applicable to terrestrial use. Industrial robots and even home service robots of the next century will be children of space robots. The research of space robots should be on the main stream of the intelligent machine of the future.

3. Generations of Space Robots

We identify three generations of space robots along the degree of autonomy as given below:

FIRST GENERATION : programmed control and/or proximately controlled master-slave robots such as Space Shuttle Remote Manipulator (USA), Space Station/Japanese Experimental Module Remote Manipulator (NASDA) etc.

SECOND GENERATION : teleoperated semi-autonomous robots such as Orbital Servicing Vehicle (NASDA) and Flight Telerobotic Servicer (USA).

THIRD GENERATION : intelligent autonomous robots such as Lunar Working Robot (concept:NASDA).

Our research efforts are concentrated to the second generation space robots for the present and will be on this target in the next four years.

4. JEMRMS

NASDA started the design and manufacturing of Japanese Experimental Module (JEM), which is to be attached to Space Station. JEM Remote Manipulator System (JEMRMS) is a robotic arm installed in JEM as a tool to handle its experimental devices. JEMRMS is 11 meters long, 808 Kg mass, twelve-degree-of-freedom manipulator which can be controlled both by programmed operation and manual operation via a handcontroller inside the pressurized compartment of JEM. JEMRAMS is evidently a first-generation space robot, but it will demonstrate the importance and future possibility of space robots.

5. OSV

Robot Satellite Working Group which was organized in 1982 by NASDA made an intensire study to analyze the utility and the technological feasibility of robotic satellite (RSAT) which could fully or partially substitutes human activities in space.

The concept of Orbital Servicing Vehicle (OSV) is established after those studies to seek a Japanese way to deploy space infrastructure in orbit.

OSV is now a research target of the second generation space robot, to which all our R&D efforts are being materialized. The envisioned OSV is, to some degree, a universal worker in orbit. It deploys spacecraft, platforms, freeflyers and various space vehicles in orbit, catches and tugs them to a space station, supplies fuels, charges their batteries, exchange damaged equipments and devices, offers various logistic support to the whole space infrastructure.

Critical technologies which are required for OSV are also key technologies common to every second generation space robot, as are given below :

(1) teleoperation --- Communication lag, telepresence
(2) artificial intelligence --- natural language, task planning
(3) autonomous rendez-vous docking
(4) free body control --- zero-G kinematics, control
(5) semi-autonomous recognition

6. R&D on Second Generation Space Robot

The main target of R&D efforts on space robotics in NASDA is set to be the materialization of OSV. The next future target will be Lunar Surface Vehicle (LSV), a surface rover version of OSV. The development steps toward OSV/LSV are not definitive, but will be like the following sequence.

(1) Accumulation of experimental data through ground tests and flight experiments of JEMRMS.
(2) Development of unmanned space robots which are teleoperated

from the ground via Data Relay & Tracking Satellite (DRTS).
(3) Development of OSV initial operational capability. (Exchange of Orbital Replacement Units, Recovery, Checkout, Tugging)
(4) Development of advanced OSV which can assemble and repair large space structures. Development of LSV which explore and demonstrate experiments on the lunar surface.

7. Towards the third generation

Development of the third generation space robot will begin around 1995. The concept is presented as a lunar working robot which excavates lunar surface, which could play a central roll in the unmanned lunar activities prior to a manned lunar base.

A good starting point is to build a kinematic simulation model of unmanned lunar surface activities that is as realistic as possible. The model is used as a development tool to study and demonstrate the lunar unmanned activities. It is then reconstructed as the ground slave of human operators who generate commands via master system. The unmanned system on the Moon is operated as the lunar slave. The motion is made identical to that of the ground slave via radio link (see Fig. 1). The problems of signal propagation delay, 1/6 gravity, and vacuum can be technically overcome. This lunar base model gives a very real impression to the people who operate it. Persons with no training can operate the lunar robot working on the Moon.

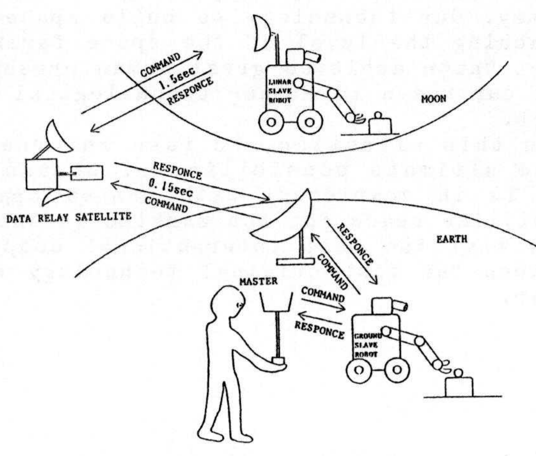

FIG. 1 LUNAR BASE MODEL ON THE EARTH

The main features of the lunar base model on the Earth are given below :

(1) The ground slave responds to the master's motion in real-time, while the lunar slave moves 1.5 seconds later due to the signal propagation delay. The operator sees the lunar situation on TV after another 1.5 seconds.
(2) Size and appearance of the lunar base model on the ground are

identical to the real one on the Moon. The difference of gravity should be rectified by some control inside the ground model. Hence the ground slave moves 3 seconds before the lunar image appears on TV.

(3) The simulated lunar surface made on the Earth has the same shape, color, and physical properties of the lunar counterpart.

(4) The atmosphere around the ground model is variable from high vacuum to 1 atm.

(5) Chemical reaction is simulated by employing various materials and thermal control.

The lunar base model on the Earth is constructed on the flat ground 300 meters in diameter with a dome-shaped ceiling. The surface is covered with simulated 6 meter lunar regolith at the deepest. The shape of the surface is made identical to that of the site on the Moon. Models of landed vehicles are positioned and their attitudes are set exactly.

The operator easily works on the virtual lunar surface. A private company or person can control a lunar robot freely by a lease contract. He might build his house on the Moon out of lunar soil.

8. Conclusions

NASDA's rockets have been achieving the most successful results in the world since the beginning of the space development in this country. Our technology to build spacecraft and rockets is now approaching the level of the space faring nations, while USA and Soviet Union achieved great human presence in space that is far beyond our reach in either technological level or national public support.

We seek in this situation, to take international charge of pursueing the ultimate possibility of unmanned technology in space, which is in complement with manned space technology to explore and utilize space for the mankind in the 21st century.

We believe that the best international cooperation should be constructed when the most original technology of each nation is mixed together.