Robot FRIEND: an innovative approach to space

A. Rovetta **S. Mangiarotti**

Politecnico di Milano, Dipartimento di Meccanica, Laboratorio di Robotica
Piazza Leonardo da Vinci, 32 - 20133 Milano (Italy)
alberto.rovetta@polimi.it

Abstract

This paper deals with a space robot developed for orbiting missions. The robot, called FRIEND, has been designed by the research team of Robotics Laboratory in Milan Politecnico. FRIEND is able to carry out space structure building and maintenance missions.

1. Introduction

Space Missions have seen an intensive use of robotics and automation during the last few years. This fact is due to the need of increasing intelligence on board and reducing the costs. This tendency will come emphasized in the new millennium thanks to new developments in computer science technology and in artificial intelligence. The mechanical technology is becoming adequate to such fast evolutions, pushing the micro mechanics to the new frontiers of robotics. So it is necessary to develop and experiment new robotics technologies for space missions.

2. Robot FRIEND

Aim of robot FRIEND project is to increase the performances of the earth-based robotic technology and to adapt it to the space environment.

The Robotics Laboratory of the Department of Mechanics to Milan Politecnico has developed in the last years the project of a telerobot, called FRIEND (Flying Robot with Intelligently Ended Nursing Dexterity). The project has been commissioned from the Italian Space Agency to Milan Politecnico. The system is the contribution of Italian University, through ASI and ESA to the realization of ISS (International Space Station).

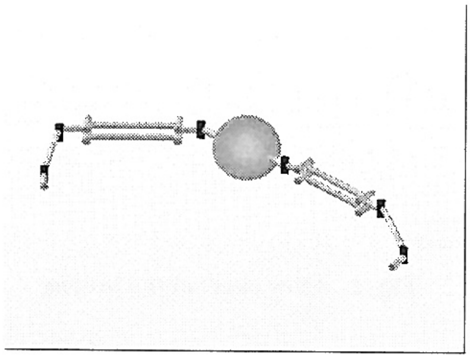

Fig. 1 Robot FRIEND 3

The first plan brought to the realization of robot FRIEND 1 whose working prototype has been built in the Robotics Laboratory, Department of Mechanics of Milan Politecnico. It has been developed in order to catch objects in the space, by means of two robotics and sensorized articulate arms. The two arms can catch a free object and lock it inside the arms, against the spherical body of the robot. The prototype of FRIEND 1 run with c.c. brushless motors and batteries. The control is entrusted to a Galil card inserted in a personal computer. The control software has been developed in Windows environment using Visual Basic language.

Successive design called FRIEND 3 has risen from the idea of building a robot capable of operating an intense extra vehicle activity (EVA) moving in independent way. FRIEND 3 is conceived in order to operate in the International Space Station environment, onto the reticular beam developed by the Department of Aerospace Engineering of Milan Politecnico. The space robots currently in use are, substantially, mounted single arms. FRIEND 3 is built in order to move and operate independently, always under the supervision of the remote operator. The robot is conceived in order to execute assembling and maintenance jobs.

The working characteristics of a space robot introduce particularities that cannot simply be led back to the various environments in which the robot will operate. In fact, the typical problematic of the space atmosphere, like temperature stresses, pressure problems, the exposure

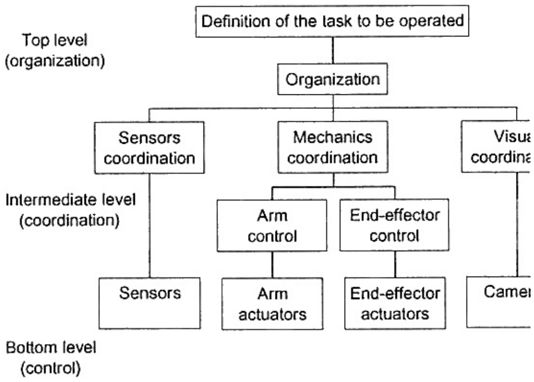

Fig. 2 – Flow chart of the project

to radiations not attenuated from earth atmosphere, the mechanical stresses of the launch, are made much more severe by the typical problematic of the robot system, which are different from those typical of the more conventional earth atmosphere.

In particular the necessity of operating in a structured environment set the focus on the " robustness " of the robot (in terms of redundancy of the critical parts and possibility to reshape the way of operating as a result of possible breakdowns), and on the intelligence that must be used while planning and executing of the scheduled tasks.

We consider the following hierarchy, with considers the information flow going from the top (task to execute) towards the bottom (elementary operations).

The inverse sense information flow corresponds naturally to this hierarchy, from the elementary information supplied by the sensors towards the top levels, with the loops self-closing between each level.

Mobility, degrees of freedom, mission planning, autonomy, modeling, teleoperation, sensors, actuators and reliability must specifically be analyzed depending by the mission to be carried out.

To such typically robotic problematic, more conventional ones must be added. When putting a system on orbit, indeed many aspects of the apparatus must be redesigned. The choice of materials to use, the selection of components and subsystems bring to a modification of the original plan to make it adapt to the new environment.

Last aspect to consider is the interaction between the robot and the environment in which it will operate, with particular reference the necessity of executing a trade-off between conventional end-effectors and special instruments. While conventional end-effectors require a high precision positioning and an exact force control, special instruments may require less precision but the robot must be capable of using them.

3. Originality of space robot FRIEND

The originality of project Friend consists in its independent and particularly flexible robotic system. The robot is indeed remarkably independent and capable of

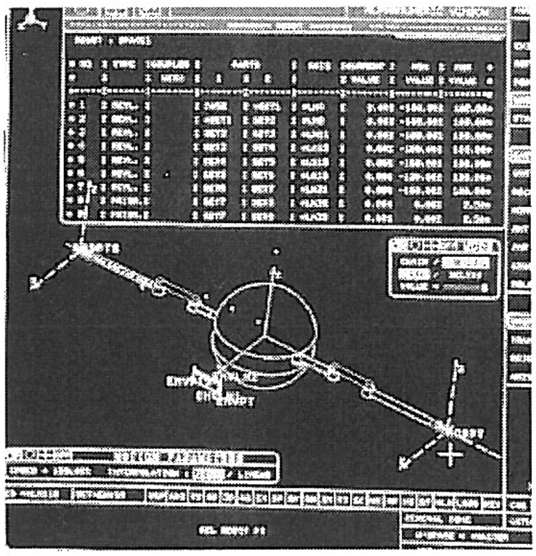

Fig. 3 – CAD design of robot FRIEND

carrying out whichever type of movement on the space structures in complete absence of links. Many current robotic systems are statically bound to the space station structure, or have to follow railroads on the structure.

The robotic system is capable of overtaking any kind of obstacles.

The multi-degrees of freedom kinematic structure is more innovative than the actual solutions in the scientific literature, for the disposition of the degrees of freedom. This structure, allows achieving a great flexibility in the movements.

The use of a robot in space is particularly useful considering the high degree of flexibility that is typical of every robotic structure. The robot can be used for various purposes, and be configured for carrying out different

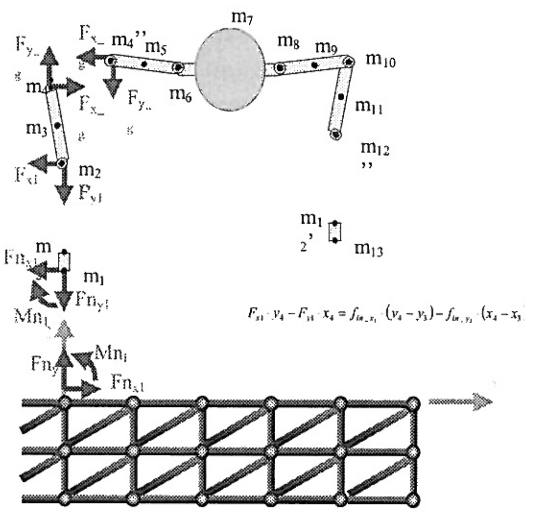

Fig. 4 - Mechanical model for the design of the robot FRIEND structure

tasks from those for which it has been built. The possibility of using interchanging actuators (end-effectors) facilitates this task and makes the machine always capable of answering to the requirements that the space activities demand.

Robot FRIEND is able to carry out automatic assembling tasks such as building space stations or orbiting telescopes. It can also be operated to help astronauts putting together the parts of a space ship for planets exploration, which will be a major activity in the next years.

4. Technical developments

The scientific and technical details may be concentrated in three topics: 1) prototype design and construction; 2) spazialisation; 3) tests and space activities.

For the prototype design and construction, the followed phases have been: 1) conceptual first design; 2) compatibility with mission requirements; 3) redesign of the components and of the system according to space requirements; 4) application to the functionality; 5) design with CAD in 2D and 3D; 6) computerized model; 7) rapid prototyping of the model; 8) laboratory tests for reliability and safety; 9) economic evaluations; 10)

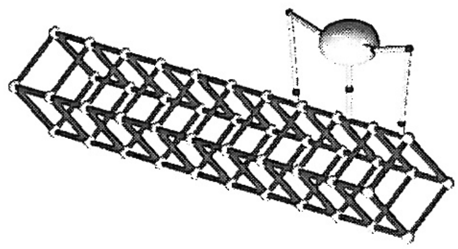

Fig. 5 – Simulation of behavior of the prototype of robot FRIEND

storing of data, technical references, design elements; 11) developments of electric and electronic systems; 12) development of technical analysis and design; 13) control and telecontrol of the robot; 14) software development and testing; 15) redesign of the critical components; 16) validation of the project; 17) acceptance for spazialisation.

For spazialisation, the procedure is standard and must be applied in a methodological way.

Tests and space activities will be consequent.

In Fig. 3 is reported the preliminary design with CAD and dynamic simulation. The whole project was performed with 2D and 3D CAD.

Mechanical model for the design of the robot FRIEND structure is represented in Fig. 4.

The prototype, which is under design spazialisation, is reported in Fig.5. It is able to dock and to operate with its feet / hands.

5. Conclusions

Robot FRIEND joins in itself the characteristics of autonomy and resistance of automatic machines for space and the typical elasticity of earth based robots, obtaining remarkable advantages in all the tasks that may be carried out in obit, because its philosophy of operating is derived from machines that already have proved their flexibility and performances.

Acknowledgments

The Authors thank ASI (Italian Space Agency) for the support and the grant for the development of robot FRIEND.

References

[1] A. Rovetta, P. Cavestro, Redundant Sensorized Arm+Hand System for Space Telerobotized Manipulation, Nasa Conference on Telemanipulation on Space, Pasadena, February 1989

[2] A. Rovetta, S. Vodret, M. Bianchini, Redundancy in Sensors Control and Planning of a Robotic System for Space Telerobotics, Nasa Conference on Telemanipulation on Space, Pasadena, February 1989

[3] A. Rovetta, X. Wen, Integrated robot for space teleoperation, International Symposium on Intelligent Robots, Tsuchiura, July 1990

[4] A. Rovetta, "FRIEND" Robot, space telerobot for rescue and recovery of astronauts in space stations, IEEE/RSJ International Workshop on Intelligent Robots and Systems IROS '91, 3-5 November, 1991

[5] A. Rovetta, X. Wen, Fuzzy Logic in Robot Grasping Control, IEEE/RSJ International Workshop on Intelligent Robots and Systems IROS '91, 3-5 November, 1991

[6] V. Romano, F. Cosmi, D. Nenchev, A. Rovetta, A Grasping Technique for the Friend Dual-Arm Free Flying Space Robot, Icam 1993, Tokyo, August 1993

[7] F. Cosmi, A. Rovetta, Kinematics of Dual-Arm Space Manipulator: Application to a Prototype System, Iros '93, Yokohama, July 1993

[8] F. Cosmi, A. Rovetta, Development of Dynamics for a Space Telerobot, Iros '93, Yokohama, July 1993

[9] P. L. Conley, Space Vehicle Mechanisms. New York, John Wiley & Sons, Inc, 1998

[10] T. P. Sarafin, ed, Spacecraft Structures and Mechanisms: From Concept to Launch, Torrance, CA and Dordrecht, The Netherlands: Microcosm Press and Kluwer Academic Publishers, 1995

[11] D. Nenchev, K. Yoshida, Design of impact optimisation for floating-base manipulator systems, Ninth World Congress on the Theory of Machines and Mechanisms, Vol. 3, Milan, Italy, 1995

[12] D. Nenchev, K. Yoshida, Y. Umetani, Analysis, design and control of free-flying space robots using the fixed-attitude-restricted Jacobian matrix, Prep. 5th Int. Symp. Rob. Research, Tokyo, Japan, 1989

[13] B. Hirzinger, B. Brunner, K. Landzettel, J. Schott, Preparing a new generation of space robots, Preparing for the future, Vol. 7, No. 2, 1997

[14] G. J. Reuter, An intelligent free-flying robot, NASA Conf. on space telerobotics, JPL, Pasadena, Vol. 5, 1989, pp. 373-379

[15] R. Kujath Marek, O. Unyime, Akpan, Stochastic dynamics of a mobile manipulator, Ninth World Congress on the Theory of Machines and Mechanisms, Vol. 3, Milan, Italy, 1995