SPACE ROBOTIC OPERATIONS NETWORK:

CHALLENGES AND INITIATIVES

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Abstract. Nowadays space robotics as a science and technology becomes important part of human exploration of extreme environment. There are two main fields of applied researches: interplanetary missions and operations with orbital spacecrafts. Both fields have much in common because basic means of operation are based on remote informational-mechanical interaction between different parts of robotics systems. The space robotics are the basic means for lowering of complexity and risks at on-orbit satellite reconfiguration, installation of flexible spacecraft constructions or orbital manoeuvres. Space robots have the perspectives of usage at repair spacecraft, upgrade constructions, replacements of blocks and prolongation of subsystems. This paper describes experience of Robotics and Technical Cybernetics Institute in space robotics research and initiatives in implementation of new approach in design of such systems.

1. Introduction. Space technology (ST) has significant impact on all socio-economic and life aspects of the global society and space environment represents one of the most challenging applications of robotics as a key factor of technologies evolution. Therefore many efforts from research groups, academia, industry and governments were applied to merge space and robotics technologies within space robotics concept (SR). A desirable feature for space robotics machines includes intellectual control, mobility, reconfigurable techniques, and recognition. These features require radical innovations in computer science, mechatronics and control technologies. The new opportunities of robotics systems in cosmic environment are considered as hi-tech priority which requires non-trivial and constructive approaches and innovative architectures. Obviously many important aspects ST such as specific novel communication techniques, effect of weightlessness or autonomic behavior of SR systems cannot be verified on-ground condition. That is why all innovative decisions need to be tested and demonstrated in open space

condition within realistic scenarios. Starting points for Robotics and Technical Cybernetics Institute (R&TCI) research in SR were stimulated by mission of Moon rover “Lunachod” and creation of the multifunctional onboard manipulator for the Russian shuttle “Buran”. In both cases basic aspects which were taking into account are the following:

1) cosmic micro gravitation conditions radically changes engineering requirements for robotics components and possible applications,

2) computer has big potential to extend intelligent and adaptable features of cosmic appliances and apparatus,

Now after the years of experience new aspect should be added to the previous list:

3) computer network concepts (in TCP|/IP or DTN interpretation) can fundamentally improves robotics design and functionality.

Therefore the impact of computers and telecommunication capabilities prepared qualitative leap in robotics including architecture, behavior models and control operations. Space robotics systems intelligent and functionality are increased due to new level of performance in information processing at local at remote locations. New operation opportunities can overcome previous functional restrictions but need to be supported by adequate means and information resources. This new opportunities can overcome previous functional restrictions but they need support by adequate means and information resources. To clarify R&TCI background and innovation initiatives we present some historical facts, discuss several ideas and define problems important to improve service features of robotics systems. In the Part 2 we consider basic aspects of space robotic design and the ways how to control remote intelligent machines. In the Part 3 we survey the space robotics background with emphasis on applications, modular architecture and the ways how artificial machine investigates the external environment and provide adaptation functionality. In the Part 4 we describe idea of adaptation via reconfiguration

(automatically or manually) of robot structure. Reconfiguration is a best way to fit robot structure to the terrain on which robot has move or has to manipulate. Adaptation idea in polymorphic interpretation has huge potential impact for many robotics applications, resources virtualization and routing protocols. Therefore proposed approach is a part of space robotics research within framework of Russian space experiment “Kontur” which has been launched by R&TCI together with DLR Institute of Robotics and Mechatronics (DLR IRM).

2. Robotics operation network testbad. Field of space robotics as an engineering discipline has largely been developed within the computer science and AI communities. However, many open issues of great practical significance still remains and requires fresh ideas, modern mathematical and computational tools as well as conceptual judgment. In 1995 R&TCI launched robotic operations network project together with partners from EU's ACTS research program. Basic project’s idea was to arrange trans-European point-to-point ATM PVP (Permanent Virtual Path) transport service with the CBR (Constant Bit Rate) service class up to 6 Mbit/s between Russian shuttle “Buran” space manipulator in R&TCI, Telematics Department, Saint Petersburg, and Alenia Aerospazio, Divisione spazio in Totino. This first research operation network was being carried out in the TEN-34 Phase 1, Test Program over the JAMES ATM network. Scientific approbation of this experiment was at JENC8, annual Joint European Networking Conference, Edinburgh, Scotland, May, 1997 [1]. This experiment was the first step and starting point to new research in modification TCP/IP communication suite that should be robust enough to delays, disruptions, and unauthorized access. Within this research “store-and-forward” method of packets processing was replaced to more robust “store-processing-forward” mode [2]. We find several obstacles to use TCP/IP networks within robotics application which stem from internal nature of packets traffic which demonstrate long-range dependence, statistical self-similarity and fractal properties. Constructive decision to solved underlying theoretical problems came from mathematicians and engineers of Polytechnic University,

Saint-Petersburg. This decision was based on p-adic formalism, fractional derivatives equations and active queuing management algorithm. New robot operation segment has two types of network appliances - firewalls and gateways. The first appliances run in specific “stealth” mode in which network interfaces have no physical (MAC) and logical (IP) addresses altogether, the second - shape TCP flows and provied proxy services including wireless high speed access to supercomputers for on-line modeling or model-based control.

3. Robotics challenges. Robots in new operations network have many possibilities to improve robot's features by copying principles of information processing and the organization of the movements existing in the nature. The most important challenges in the such robotics environment are: 1. formal models and requirement for performance guarantees; 2. dynamic control algorithms; 3. methods to characterize the power requirement and matching robot system structure to different environment conditions. Using experience of control and reconfiguration in virtual network infrastructure new solution how to improve robot’s features was offered in 2003. This solution is grounded on usage of a principle of self-similarity with reference to mechanical constructions. The new mobile robot played back typical snake locomotion or "wheel model" of transportation. This appliance was the first prototype of robot platform for robotics space experiment “Kontur” that started in 2008 in cooperation with DLR IRM. At the first phase of this space experiment in 2008-2009 years ROKVIS terrestrial operations network was extend and now includes segments in R&TCI (www.rtc.ru) and RSS “Energia” (www.energia.ru).

4. New initiatives. New segment of robotics operation network acts like “cloud computers” and therefore can be used for integration of different components and services. Thanks to advances in tele-robotics machines features new phase of space experiment “Konture-2” has the realistic goal to arrange reconfiguration in information plane or “inverse” direction of manipulation if compare to first

“Kontur” phase - control of mobile and reconfigurable robots on Earth surface from ISS.

In 2011-2012 years R&TCI and DLR IRM team which have innovation vision how to encourage challenges in different areas of space robotics such as DTN topology, control or engineering practice will provides space experiment that can improve robotics theory, verify specific techniques for navigation and telecommunication. In this research space experiment “Kontur-2” will be test-bad providing in-orbit demonstration of potential future exploration scenarios involving robots and astronauts.

References

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