Space Robotics Systems

By PERASPERA Consortium
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Outline

• Manipulation systems & robotic arms
  • Large Robot Arms (ERA, CanadaArm)
  • Small (multi)-arm manipulators (Eurobot, EGP, Justin)
  • Sampling and sample transfer arms (Beagle-2 arm)

• Locomotion systems
  • Aerobots/frogbots
  • Rovers (LunoKhods, Exomars, Sojourner, NanoKhod)
  • Advanced motion systems (RIMRES, Space Climber, Hylos)
  • Moles/drills (Exomars, Philae)

• Payload automation systems
Large Robot Arms

In space large robot arms mainly have application in the construction of Orbital infrastructures and specific orbital servicing.

In space, thanks to the lack of gravity, the robot arms can manipulate enormous masses of large space hardware without being massive themselves.

As an example, the International Space Station has been fully assembled by a set of robot arms as the Space Shuttle robotic arm & ISS CanadaArm, both developed by CSA (Canadian Space Agency).
Large Robot Arms: ERA

The European Robot Arm (ERA) is designed & manufactured by Dutch Space and will be launched at the end of 2016 to serve as main manipulator on the Russian segment of the International Space Station (ISS). It is a large as 11m a weight of 630Kg with a design in 7 joints that can handle 8 ton payloads.
ERA Robotic Arm

• The ERA robotic Arm is symmetrical design with 3 DoF wrist and 2 limb connected by motorized hinges; and also general purpose end-effectors on both sides that allow ERA to relocate on the ISS by grappling the specific base-points located at the Station and move to different working location, and providing ERA with a “Walking Arm” capability.

• The ERA robotic arm has the utility of grabbing Space station components for transport or tools for support of EVA activities.

• The grapple mechanism & base point connection is able to Measure Torque/forces, Grapple&guide ERA in the “walking” process, and also transfer power, data & video.
Small (multi)-arm manipulators

The Small robotic arms in space are required for

- Orbital applications: The Manipulators are directed to orbital infrastructure servicing
- Planetary applications: The focus is in sample acquisition and instrument placement/deployment

In orbital applications robot arms works with man-made objects which have manipulation interfaces and masses that require some level of force/torque for handle and also spatial accuracy.

In planetary applications, where the subjects manipulated are natural and of small size, force and torque are not the primary driver. Mass of the robot is main challenge.
Small (multi)-arm manipulators: EUROBOT

EUROBOT goal:
1. Reduce amount of crew time required for ISS external maintenance
2. Reduce EVA duration and number of sorties

Main characteristics:
1. Eurobot is planned to be used for “maintenance work” and fast “EVA” operations in the Space Station
2. Capability \(\sim 150\) kg payload
3. Human-sized and easy to control through haptics interfaces as ESA exoskeleton
The Eurobot arm:

1. Has a modular configuration of at least 6 joints, advanced arms have 7 or more
2. Lightweight structure for low mass, high stiffness (Al, CFRP), that houses the parts of the joint drive system inside
3. Joints made of brushless DC type, specially lubricated gearbox (typical gear ratio: 1600), integrated drive electronics (power and signals) 2 position sensors, motor current sensing, temperature and torque sensors
EGP Rover “Eurobot Ground Prototype”

• The Eurobot system development has evolved in the realization of an EUROBOT Ground Prototype (EGP)
• The Eurobot Ground Prototype is rover in centaur configuration with 2 Eurobots arms used to assist astronauts in the construction and maintenance of a lunar or Martian base station.
• EGP Rover is used to assess operations and their related technology needs.
Sampling and sample transfer arms

The sampling arms are used in planetary missions for deploying instruments to the environment, sampling the soil, and transferring samples to on-board analysis facility or to Earth-return vehicles.

The Beagle-2 robot arm applying the instruments of its end-effector to the soil (credit Airbus)
In space bodies that have an atmosphere it is possible to conceive flying robots. These can be winged (fixed-wing, rotating-wing) or buoyancy based systems.

On Mars the low atmospheric pressure makes difficult the realisation of both types (on Mars wings moving at very high speeds or huge envelopes will be needed for an aerobot mission).

Balloons have already flown on Venus, although they had little of robotics inside.

Possible future destinations may be Titan and a return on Venus.

Also balloons can have intelligent navigation and be “smart” robots.
Other kind of locomotion system for robots is the jumping or frogbots. These robots can “fly” in jumps in space bodies that have little gravity.

Frogbots can propel themselves in jumps using springs (for higher gravities bodies) or unbalancing of rotating masses (for low gravities environments)

Credits P. Fiorini, Caltech Univ. of Verona
Rover classes: (no "standard" terminology !)

1. "large rovers": $\sim 10^3$ kg
2. "mini-rovers": $\sim 10^2$ kg
3. "micro-rovers": $\sim 10^1$ kg
4. "nano-rovers": $\sim 10^0$ kg

5. Range of few tens of kilometers telecom/energy/decision autonomy

*e.g. Lunokhods, Russia 1970*
EGP-Rover

- Rover centaur concept with 2 robotic arms over a mobile platform
- 4 wheels rover platform 2m x 1.5m
- Total mass of 870Kg with payload capability of 400Kg
- High manoeuvrability, Rear-wheels steering and middle free joint
- Successful testing in dedicated Moon-like environment
- Finding specific location on ground using spotlight, finding and following a moving astronaut etc.
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- Range of few kilometres, telecom/energy/decision autonomy

e.g. ExoMars, ESA 2018, 300 kg
ExoMars Rover models

- 3 different models of the ExoMars rover at Astrium EADS
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- Range of few hundreds of metres energy autonomy but telecom and decision dependence on a nearby lander

*e.g. Sojourner NASA/JPL 1997*
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- Range of few tens of metres
  energy, telecom and decision
  dependence on a nearby lander

e.g. Nanokhod (ESA R&D 1999)
Nanokhod Rover

NanoKhod

• The NanoKhod rover objective is to extend the range of scientific measurement from the static landing to a few tens of meters.

• The tether rover (totally dependant of the lander) is acting more as a mobile ‘extended robotic arm’ than an standard “smart” rover.

• The locomotion is performed by means of tracks. The locomotion system is able to position the payload cab with 2 DoF.

• This small rovers control and navigation is semi-autonomous. It exploit a 3D model of the terrain acquired by panoramic camera of the lander.
Space Climber (Developed by DFKI)

Six-legged biologically inspired robot, for climbing steep slopes and rough terrain craters with energy-efficient

- The “Space Climber” will prove that legged systems present a very suitable solution to future missions in difficult terrain, in particular in crater and crevices in the rock. Providing unique terrain adaptive robot mobility through biologically inspired motion patterns
- “Passive dynamic” through intelligent morphology of body shape and specific body patterns a High energy efficiency is obtained

Study period: 2007 – 2010
RIMRES (Developed DFKI)
Reconfigurable integrated multiple-robot exploration system

• RIMRES system is a Combination of Re-configurable robotic agents with varying properties
• is a highly modular system concept – Compilation of a robot team out of robotic agents based on mission objectives and requirements
• RIMRES is composed by the SHERPA rover and the CREX legged robot

Study period: 2009 – 2012c
RIMRES
RIMRES: A Modular Reconfigurable Heterogeneous Multi-Robot Exploration System

- RIMRES is a complex earth-based demonstrator system for a lunar multi-robot exploration scenario that is built up and evaluated with key aspects of modularity and re-configurability.
- A novel approach is pursued in which a wheeled and a legged system can be combined into a single system form by SHERPA & CREX.
- The scenario that is demonstrated within RIMRES envisions a lunar crater exploration where the wheeled system is used to transport the highly mobile six-legged scout system to the crater rim for exploration.
- CREX legged scout can be attached mechanically and electronically to the wheeled rover, constituting a combined system.
HYLOS: Hybrid wheel-legged robot

- Robot with high locomotion performance. Wheel-legged robot with 16 DoF.
- Consist in 4 legs each containing 2 DoF suspension with steering and a driven wheel. Each leg is composed of two 20cm link driven by 2 linear actuators.
- The robot is equipped with 2 inclinometers for roll & pitch measurements and a 3 axes force sensor on each leg.
- Hylos is able to reconfigure the “posture mode” to optimize the locomotion performance.
iStruct (DFKI)
Intelligent structural elements as building blocks for mobile robots

• This project focus in advanced lower limb system for multi-legged robot to demonstrate the advantages of actuated multi-point-contact feet.

• iStruct Develop a biologically inspired standardized elements such as traction-supporting structures or flexible body structures

• The Set-up has being design by integration of basic building blocks and demonstration of intelligent structures

Study period: 2010 - 2013

Quelle: DFKI
LIMES (DFKI)
Learning of intelligent motion for kinematically complex mobile robots

- LIMES (Mantis) is a highly mobile multi-legged walking robot with ability to straighten upper body for manipulate devices & payloads.
- LIMES focus in the development of a multi-functional system for mobile exploration and manipulation in extra-terrestrial environment.
- The objective of LIMES is the optimization of locomotion behavior for different surface environments.

Study period: 2012 – 2016
Moles/drills

In planetary exploration surface science is mainly made by sampling and measuring the underground. Robotic drills/moles are released from the surface and progress in the soil.

They differ as:

• Robotics drills (that maintain a rigid attachment with the surface)
• Robotics moles (that maintain a flexible link with the surface)
ExoMars Drill

- The ExoMars Drill will fly in the Exomars rover in 2018, and is able to acquire soil samples down to a maximum depth of 2 meters.
- The drill is being designed to penetrate in different type of soils on Mars, which include the completion of 7 experiment cycles and at least 2 vertical surveys of 2 meters. This means at least 17 samples shall be delivered for analysis.

Multi stroke technology
- Drill mass: < 15 kg
- Sample size: d= 10 mm, L=25 mm
- Drilling Tool: 700 mm
- Extension Rods: 3 x 500 mm
- Power consumption= 80-100 W
- Sample Preparation & Distribution System (SPDS)
- Position and temperature sensors
- VIS/IR spectrometer PI Experiment (MA_MISS)
MOLES/DRILL

Rosetta Lander: Philae 1/2

MUPUS (Multi purpose sensors for surface and subsurface science)

- The PEN (penetrator) is basically a hollow rod of 35cm which will be deployed at a distance of about 1.5m from the landing module and inserted in commentary soil by a electromagnetic hammering mechanism.
- Progress per stroke is measured to provide data on the mechanical properties of the comet surface.
- Inside the rod 16 titanium temperature sensors will provide a map of temperature depth profile.
MOLES/DRILL

Rosetta Lander: Philae 2/2
SD2 (Sample Drill & Distribution system)

- The Philae Drill is able to acquire soil samples down to a maximum depth of 230 mm
- Designed to penetrate soils with hardness ranging from “fluffy” to basalt

- Drill mass: < 5 kg incl. electronics
- Sample size: 3 mg, 20 mm³
- Drilling Tool diameter: 12 mm
- Extension Rods: 3 x 500 mm
- Power consumption= 4-12 W
- Carousel diameter: 126 mm
- Number of Carousel Ovens : 26

Sample tube: Drill mode (right)
sampling performed (left)

Distribution Carousel (up)
Ovens lay-out(right)
Space Robotics Systems

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