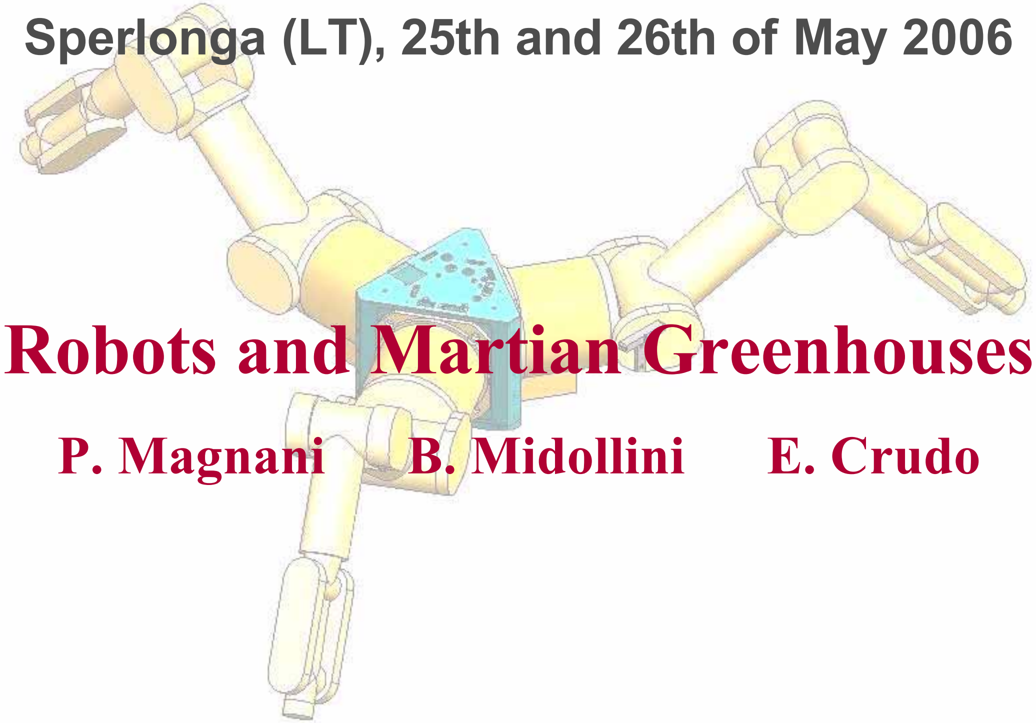
Galileo Avionica

2nd International Workshop “Agrospazio: Ricerca e Territorio”

Sperlonga (LT), 25th and 26th of May 2006



Robots and Martian Greenhouses

P. Magnani B. Midollini E. Crudo

SELEX
Sensors and Airborne Systems

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1. Introduction

The assembly and running of a greenhouse on Mars is a very ambitious task which, depending on the final requirements to comply with, will necessitate an adequate robotic infrastructure in order to keep the system as autonomous as possible.

Starting from the cultivation needs (e.g. recommended types of crops, possible greenhouse layouts, operations needed to run the facility, etc.) the robotic systems which can be foreseen in support to the greenhouse internal management are presented.

2. Robotics and Automation needs for Greenhouses Internal Operations

According to [1] humans can survive on a selection of only three crops: wheat, rice, and beans since they provide almost all of the 50 basic nutrients humans need.

System	Primary	Secondary
Plant selection	Wheat, dwarf rice, potatoes, pinto bean, strawberries, lettuce, tomatoes, broccoli, spinach, amaranthus, arabidopsis thaliana.	Herbs: parsley, basil, thyme, garlic, oregano Microorganisms: algae, cyanobacteris

Preliminary list for plant selection, extracted from [1]

Potatos Regular [1]

Dwarf Rice Crop [1]

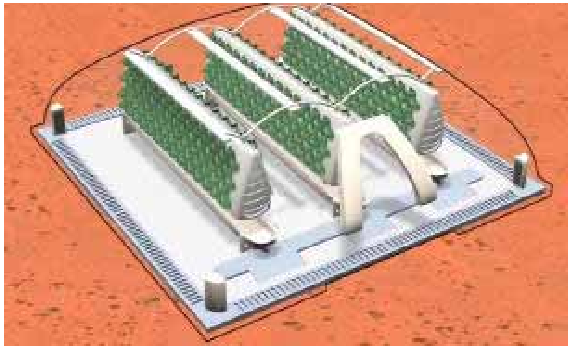
Pinto Bean Plant [1]

[1] Mars Deployable Greenhouse – University of Central Florida / Florida Space Institute 2002

2. Robotics and Automation needs for Greenhouses Internal Operations (cont.)

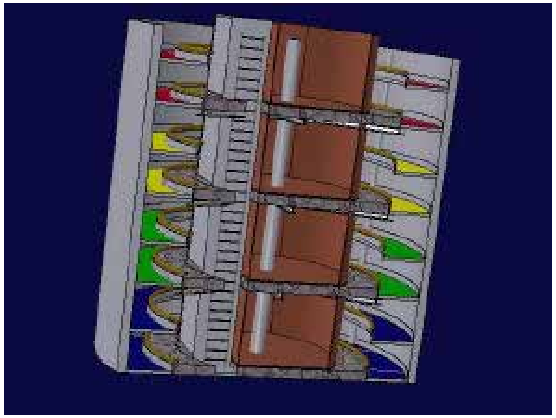
Several internal layouts have been considered in the different studies for mars greenhouses with different solutions in terms of:

- ✓ trays disposition (inclined, flat circular, rectangular, …);
- ✓ volume for pipe/cabling/feeds;
- ✓ access paths/corridors for human/machine servicing.



Pictorial of internal green house layout
Aerosekur Mars study - 2004

Ligurian Basil Coltivation - Source [1]



Pictorial of green house
Internal layout [2]

[1] Mobile Robots in Greenhouse Cultivation: Inspection and Treatment of Plants – Acaccia et Al. - University of Genova

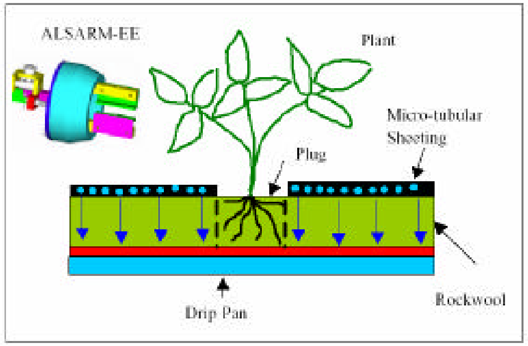
[2] Mars Deployable Greenhouse – Cornell University 2002

2. Robotics and Automation needs for Greenhouses Internal Operations (cont.)

Typical operations to be carried out inside the greenhouse:

- surveillance and detailed inspection;
- cutting of leaves and weeds;
- replacement of plants/herbs from nursery and detachment of replaced;
- progressive harvesting of crops;
- transport of crops to storage/’freezing’ site;
- transport of parts and maintenance operations

The operations to perform on the environment need particular care due to the non deterministic shape and consistency of the objects on which operate.



Schematic of servicing [1]

Lettuce Crop [1]

[1] Mars Deployable Greenhouse – University of Central Florida / Florida Space Institute 2002

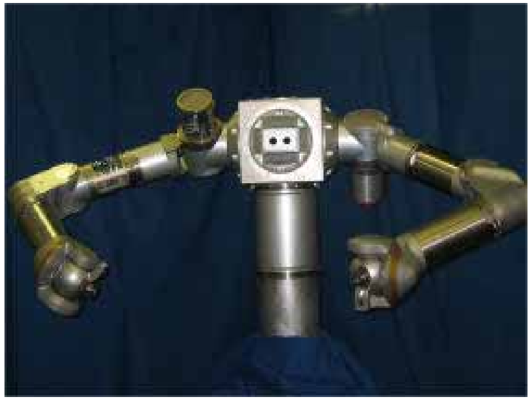
3. Typology of Farmer Robots

Farmer Robots can be devised with different configurations also to better exploit the internal layout of the greenhouse. Three major categories:

- wheeled robots;
- legged robots;
- climbing/crawling robots

Hybrid combinations can always be considered. Fixed and Gantry/Railing based solutions are here not addressed due to important constraints they likely pose to guarantee servicing.

In general the robots need be equipped with a robotic front end encompassing manipulation capability, high sensoriality, high autonomy.



RANGER Robot (University of Maryland)

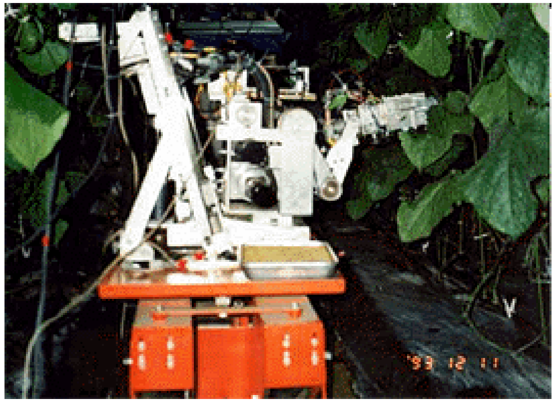
SPIDER Manipulator Arm
Galileo Avionica
(contract ASI)

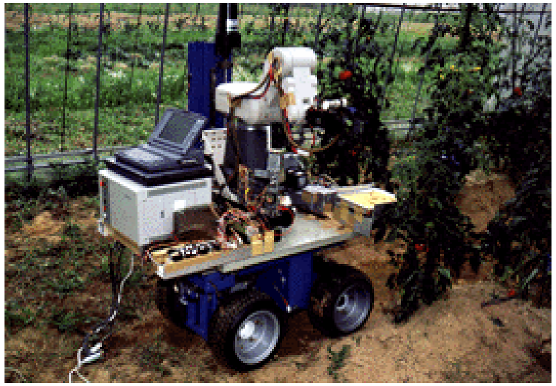
3. Typology of Farmer Robots (cont.)

Wheeled Robots

They are charactrized by a wheeled platform carring a robotic and sensorised front end. This is likely the most 'easy' approach and examples/prototype exists.

Mars Science Laboratory (by JPL/NASA)





Pictorial of wheeled robot concepts [1]

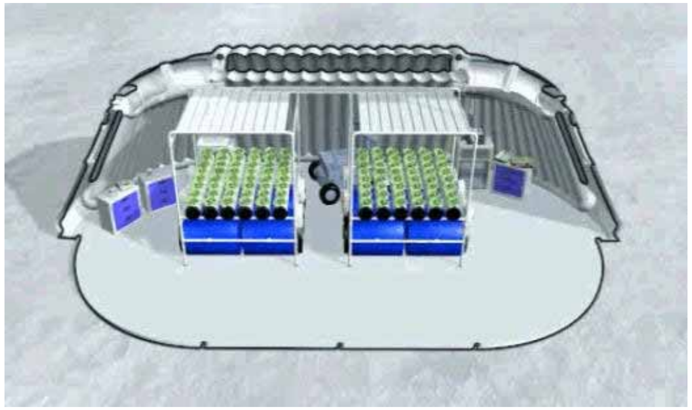
[1] Laboratory of agricoltural system engineering, Kondo et al.(Okayama)

3. Typology of Farmer Robots (cont.)

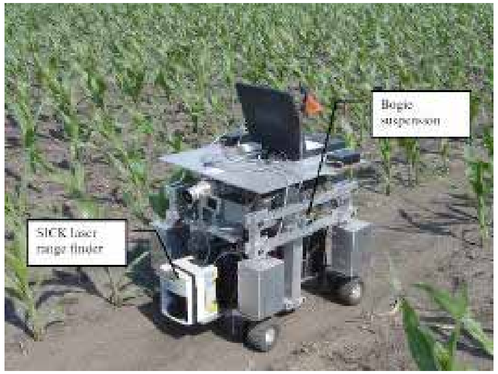
Wheeled Robots

Design Impacts

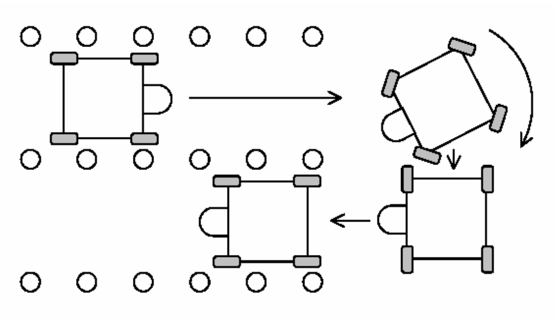
- Appropriately sized corridors and service areas to be foreseen in the layout;
- spacing between corridors shall allow reaching capability by the robotic front end to the whole cultivated surfaces;
- forces reacted by wheels type interface so size and leaning of the arm/s need be duly sized.



Pictorial of internal green house layout
Aerosekur Mars study - 2004



AgBo Robot (University of Illinois)



Schematic of End of Row Turning [1]

[1] 'Devepopment of Aut. Robots for Sgricoltural Applications' Grift et Al. (IAESTE and University of Illinois)

3. Typology of Farmer Robots (cont.)

Legged Robots

They are charactrized by a legged platform carring a robotic and sensorised front end/torso.

Design Impacts

- Motion dexterity and control complexity quite depending on type of articulation/motion (very dextrous and complex for walking robots).
- service areas and corridors need may be less demanding than with respect to wheeled robots;
- the forces are reacted by 'feet'/soil type interface and in complex solutions posture coordination is important during interaction with environment.

ASIMO Robot (by Honda)

Walkie Robot tested on Mountain Etna (by Politecnico di Torino)

3. Typology of Farmer Robots (cont.)

Climbing/Crawling Robots

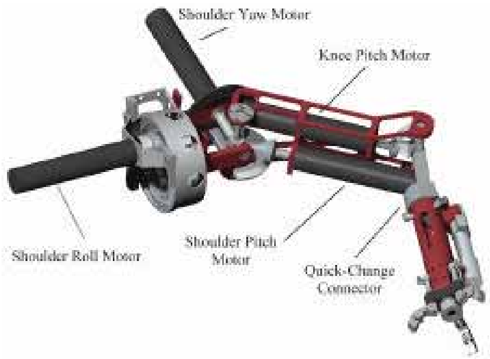
Their design can be based on an integrated 'robotized platform' where the movement's actions can be supported by elements of the robotic front end.

Design Impacts

- Limited impacts in terms greenhouse corridors and service areas layout;
- needed forces/torques are reacted by local 'grasping type' interfaces;
- multiple arms approaches would allow sufficient dexterity and operativity;
- control is within state of the art technology.

Pictorial of climbing/crawling robot (by JPL/NASA and AIAA)

Sixl egged LEMUR robot (by JPL/NASA)

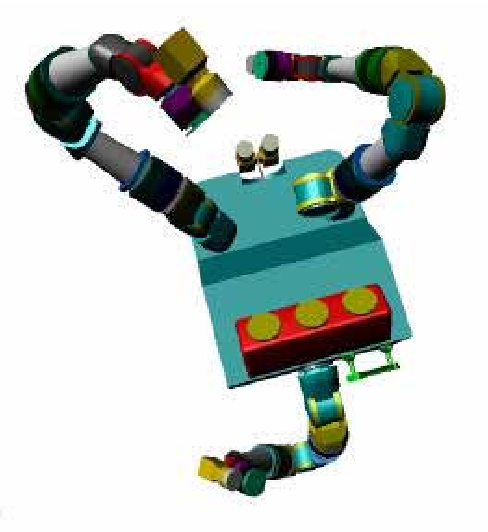


Articulation of LEMUR robot (by JPL/NASA)

3. Typology of Farmer Robots (cont.)

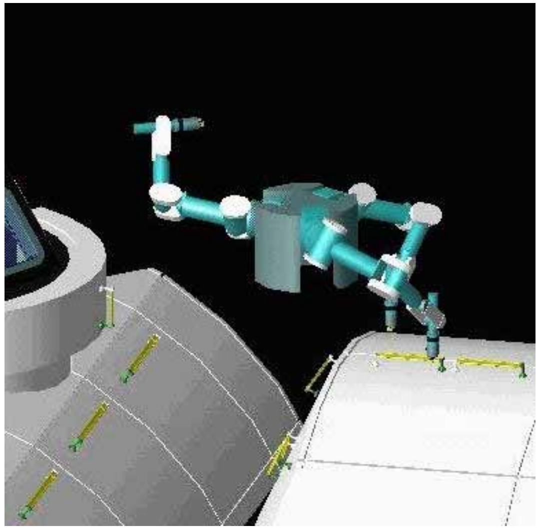
Climbing/Crawling Robots

Examples of on going studies in EUROPE in the frame of ISS



EUROBOT Schematics
(ESA Study Contract)

EUROBOT Test Bed in ESTEC

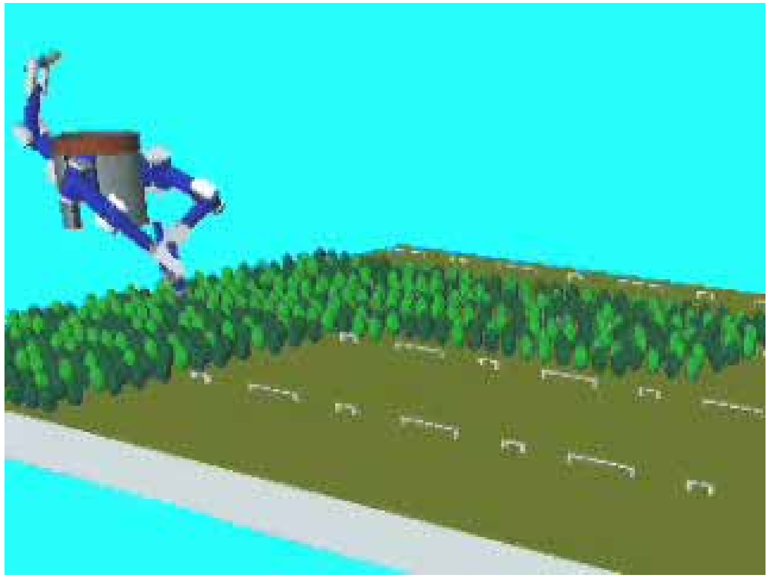


Crawling action on Space Station
CONTEXT Study
(Galileo Avinica - contract ESA)

3. Typology of Farmer Robots (cont.)

Climbing/Crawling Robots

Simulation Example with a three articulation robot (suited to microcgravity)

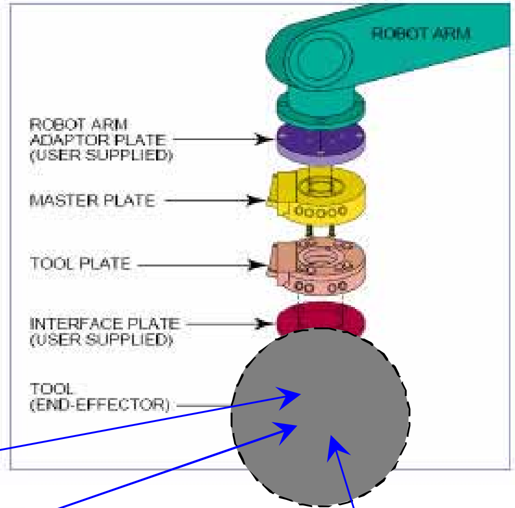


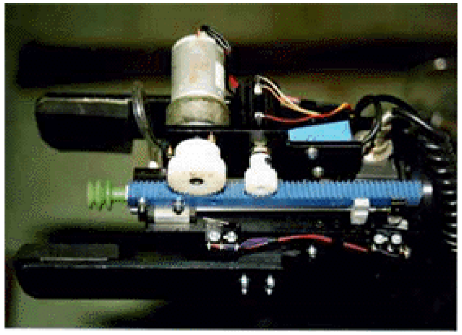
For Mars gravity application a four leg/arm approach can be appropriate

4. End Effector Issues

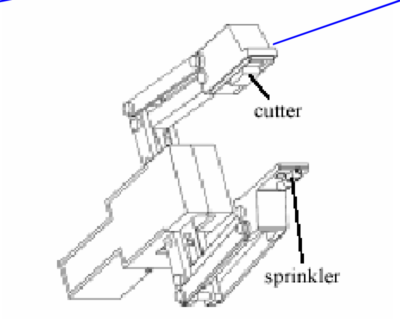
End Effectors/Grippers

- ⇒ EE/Grippers are key elements to perform the operations on plants, herbs, vegetables;
- ⇒ The operations are delicate due to the non fixed shape of the objects on which operate;
- ⇒ Arm/EE automatic exchange device needed to operate multiple specialized End Effectors.





Schematic of a tomato harvesting EE [1]



Multiple Grasping Element [2]

Schematic of a grapevine harvesting EE [1]

[1] Laboratory of agricultoral system engineering, Kondo et al.(Okayama)

[2] Mobile Robots in Greenhouse Cultivation:Inspection and Treatment of Plants – Acaccia et Al. - University of Genova

5 Conclusions

The internal management of greenhouse plants on Mars environment can take important advantages from robotics and automation techniques.

To achieve this goal it is very important to implement a technology enabling activity tuned with an overall mission schedule.

In particular this relates to the basic components of the earliest scenarios like medium size robotic arms (1-2 m class) for manipulation, compact actuators for mobility (wheels/legs/grasps), effectors for greens handling, autonomous techniques and safe control.