UNDERWATER COOPERATIVE MANIPULATION AND TRANSPORTATION

Giuseppe Casalino

http://www.isme.unige.it

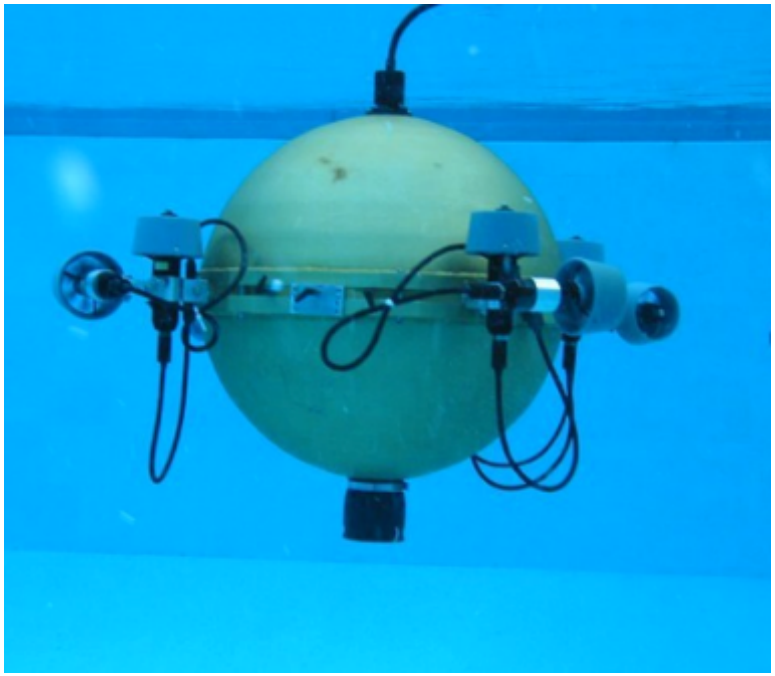
After the development of some pioneering projects during the nineties, the topic of underwater manipulation, and in particular cooperative manipulation and transportation, to be performed under floating conditions and within different types of cooperative forms, is now receiving an increasing attention by part of the research community, in the perspective of transferring the relevant technologies toward different underwater intervention applications, of both civil and commercial types. In this perspective the talk will provide an overview of the control and coordination problem which as been afforded by ISME (within different collaborative projects of both international and national type). Now available control and coordination results, near to be transferred toward practical applications, will be outlined; then followed by a presentation the on-going research activities, addressing the extension of cooperative control methodologies to more complex underwater intervention scenarios foreseeable for the near future.

Autonomy in UW-Intervention Robotics

Past History

University of Hawaii at Manoa

ODIN (1994 -)



ISME
Integrated System for Marine Environment

Autonomy in UW Intervention Robotics

Past History

Stanford University
Aerospace and Robotic Lab.

OTTER (1995 -)

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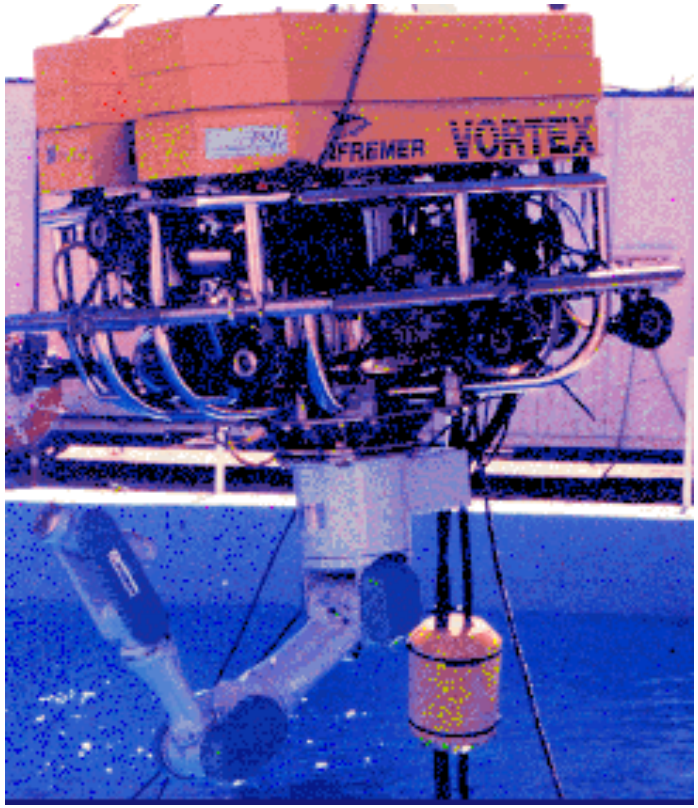
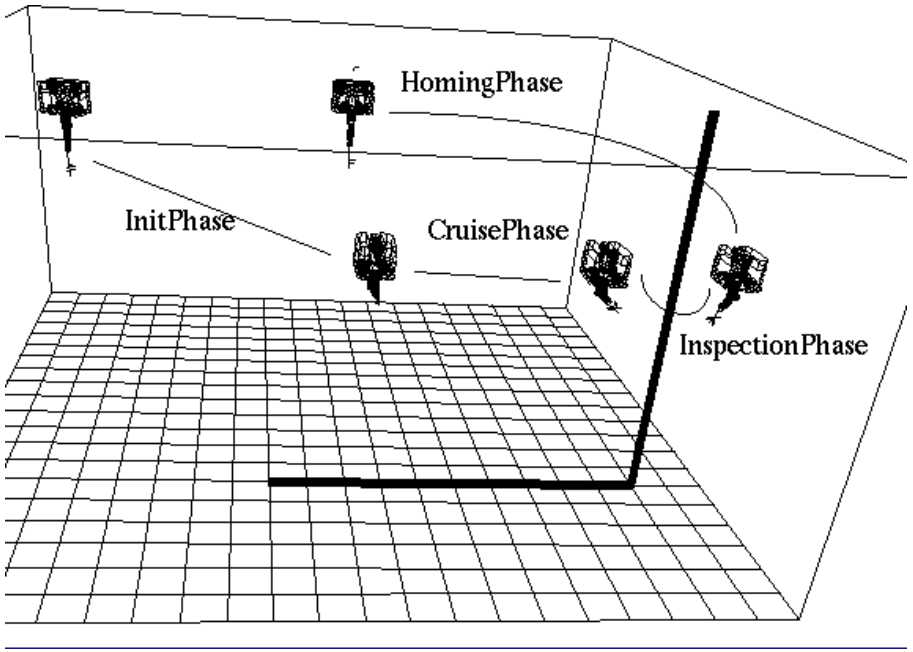
Autonomy in UW Intervention Robotics

Past History

UNION (1995-)

Ifremere, Toulon

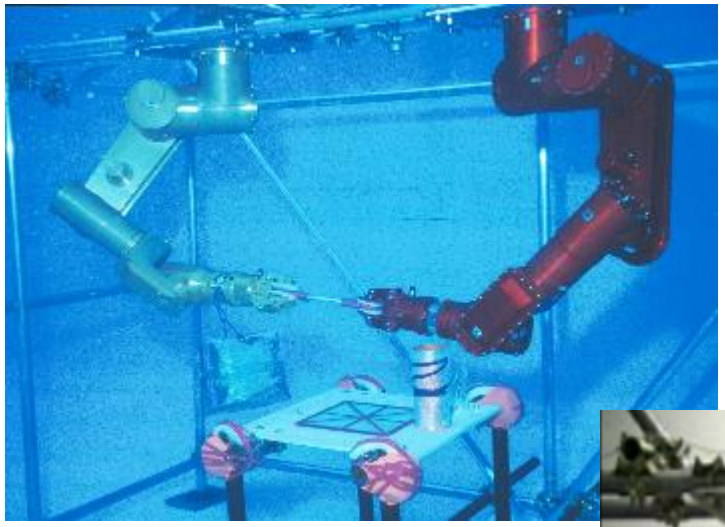




Autonomy in UW Intervention Robotics

Past History

AMADEUS (1997-1999)



University of Genova – DIST
Graal-lab

IAN CNR, Genova
Robotic-Lab

Heriot Watt University
Edinburg
Ocean System-lab

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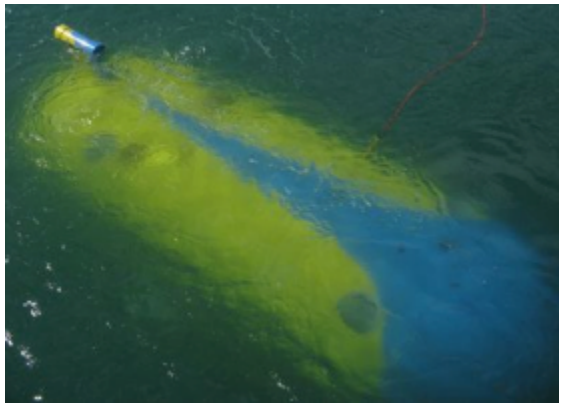
Recent History

University of Hawaii at Manoa

SAUVIM (1997-2009)



1-Undock from the pier to reach the center of the harbour

2-Search for the submerged item

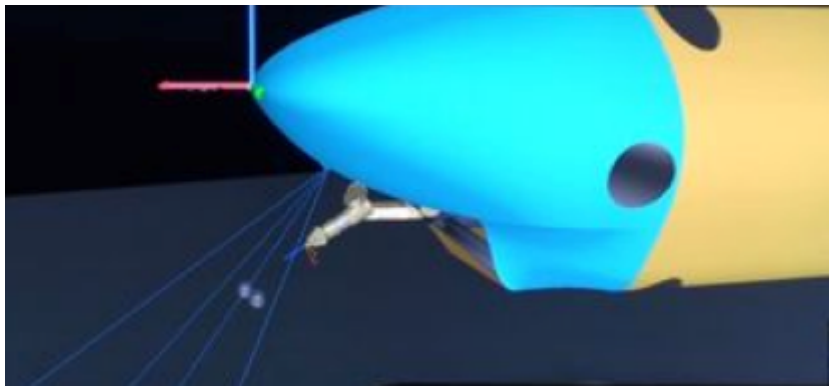
3- Navigate and dive toward the item

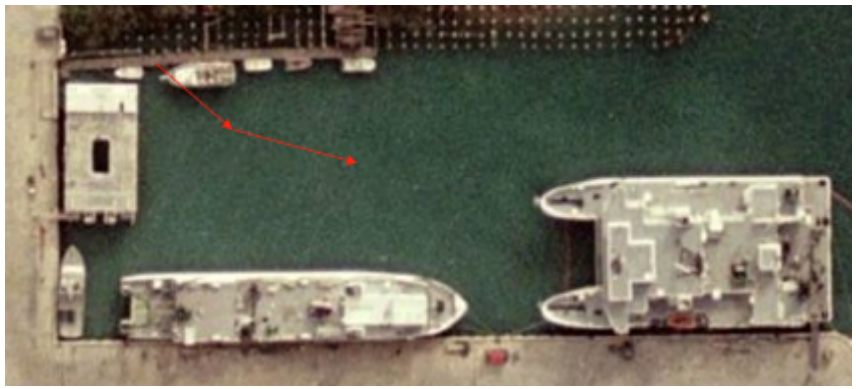
4- Hover in the proximity of the detected item

5- Start the autonomous manipulation
(hook a recovery tool to the target, cut a rope)

6- Otimize the workspace during manipulation

7- Dock the arm and back for re-docking the pier





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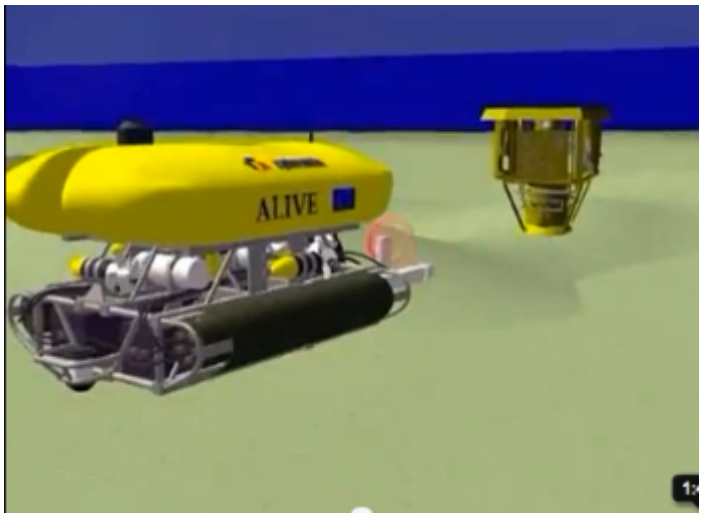
Autonomy in UW Intervention Robotics

Recent History

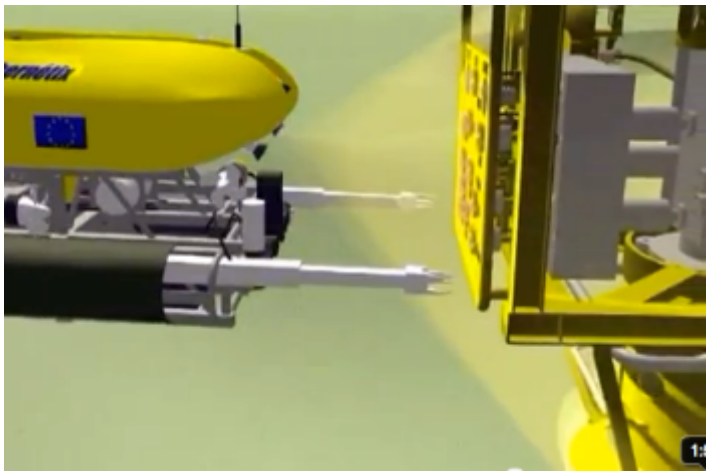
ALIVE (2001-2003)

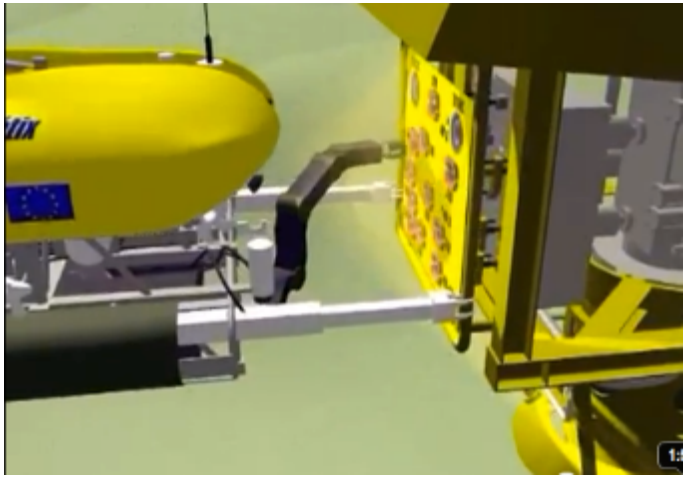


Cyberbernetix Company
Marseille

Ifremere, Toulon

HW University, Edinburg
Ocean System lab





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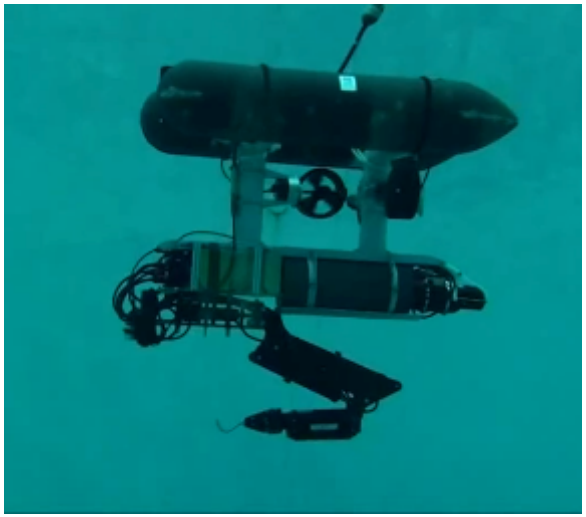
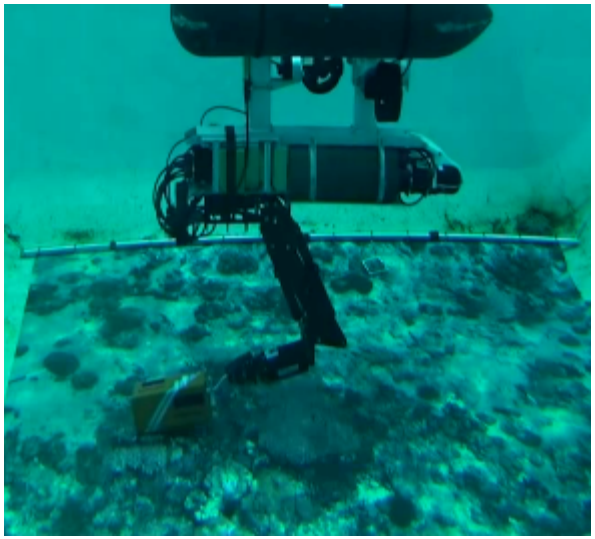
Autonomy in UW Intervention Robotics

Nowdays

RAUVI (2009-2012)





Universitat Jaume Primero

Universitat De Illes Balears

University of Girona

- *Directly Inspired from SAUVIM*
- *Much Lighter mechanical assembly*
- *Consequently prone for "Agility" (concurrent coordinated Vehicle-arm motions)*
- *Sequential motions were however used*

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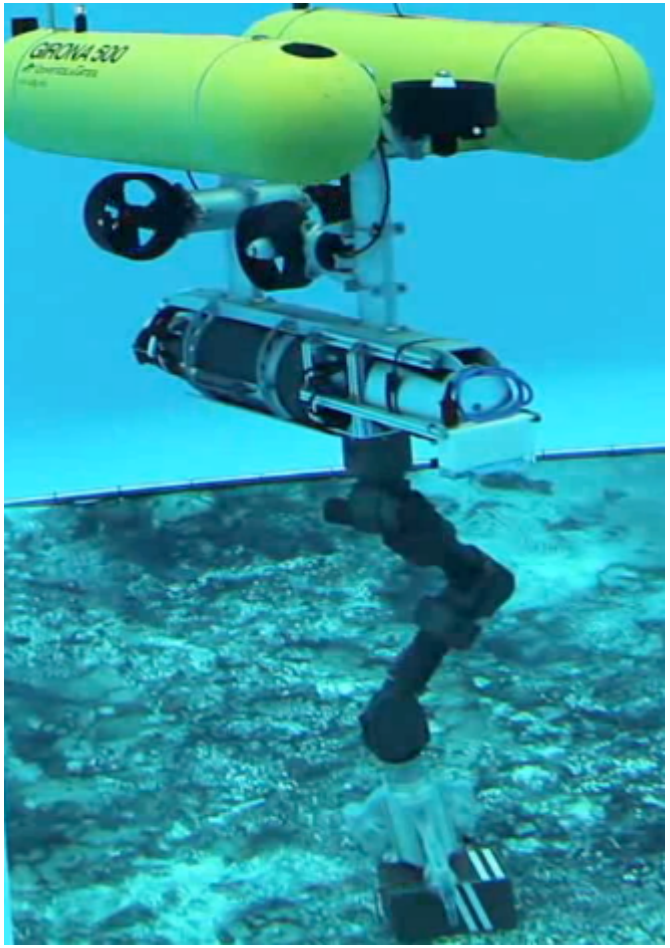
Autonomy in UW Intervention Robotics

Nowdays

TRIDENT (2010-2013)



Universitat Jaume Primero

Heriot Watt University

Universitat De Illes Balears

University of Genova

University of Girona

University of *Bologna*

Istituto Superiore tecnico

Graaltech s.r.l. Genova

- *Directly Inspired from SAUVIM*
- *Much Lighter mechanical assembly*
- *Consequently prone for "Agility" (concurrent coordinated Vehicle-arm motions)*
- *"Agilty" achieved v ia Multi-task Priority Dynamic Programming Based approach*
- *Unified scalable distributed control architecure*
- *Allows tasks to be added-subtracted, even "on-fly", wit invariant algorithmic structure*

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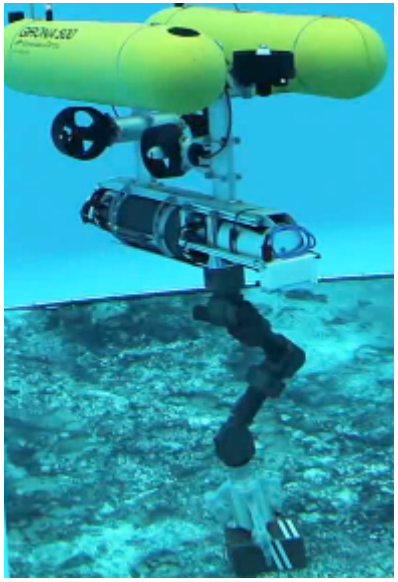
TRIDENT Project

Simulations and field trials

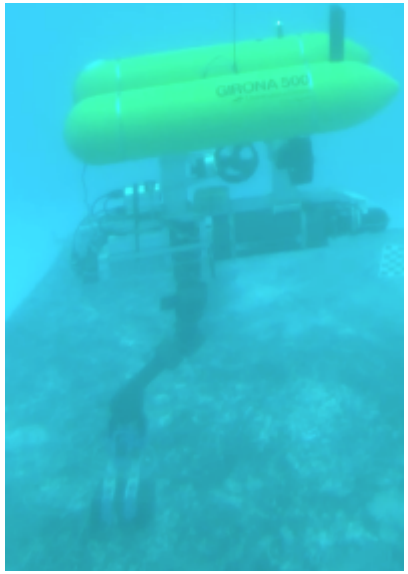
x

2 *Simulation*

Including vehicle & arm dynamic control layer



3 *Teleoperated in the pool*



4 *Autonomous in the pool*

5 *Autonomous in the sea*

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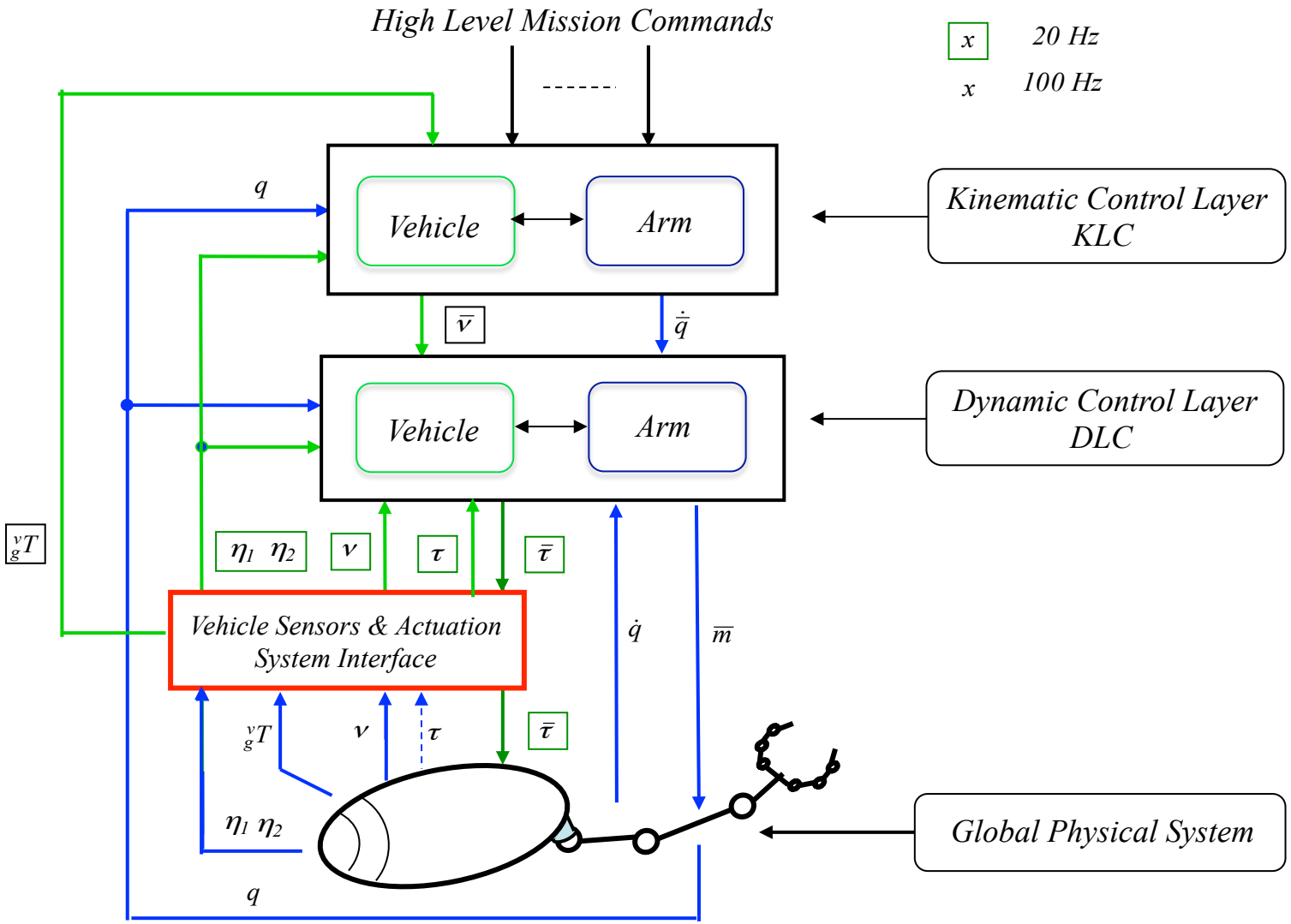
TRIDENT Project

Functional Control Architecture



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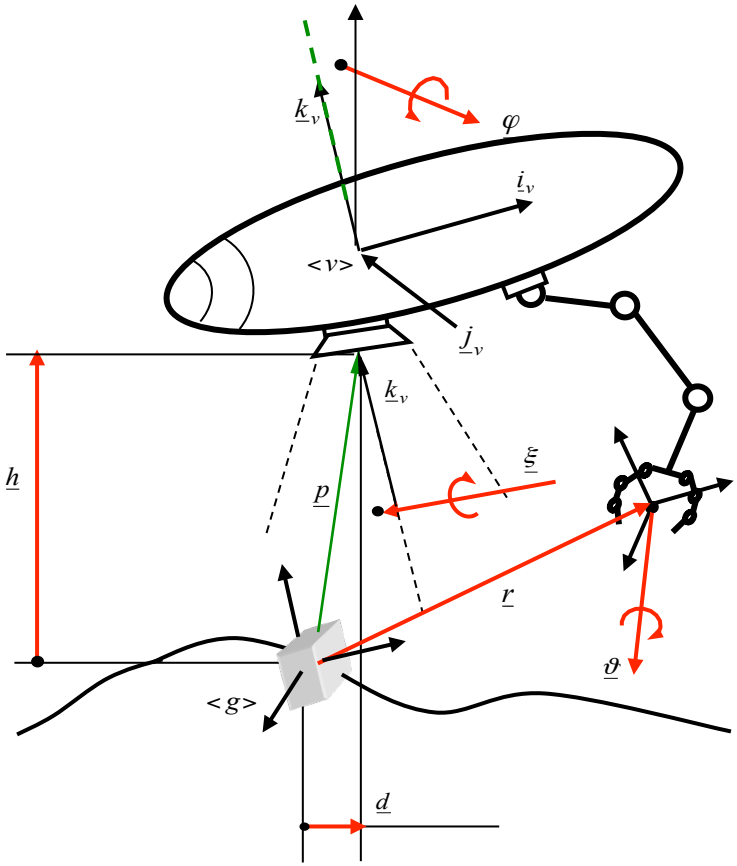
TRIDENT Project

Objective-priority-based Control Technique



Macro priorities ***Micro Priorities***

1 Inequality objectives

- *1 Camera centering*
- *1 Camera distance*
- *1 Camera height*
- *3 Joint limits*
- *4 Manipulability*
- *5 Horizontal attitude*

2 Equality objectives

- *1 End-effector approach (distance)*
- *2 End-effector approach (orientation)*

3 Sub-system motions

- *1 Arm*
- *2 Vehicle*

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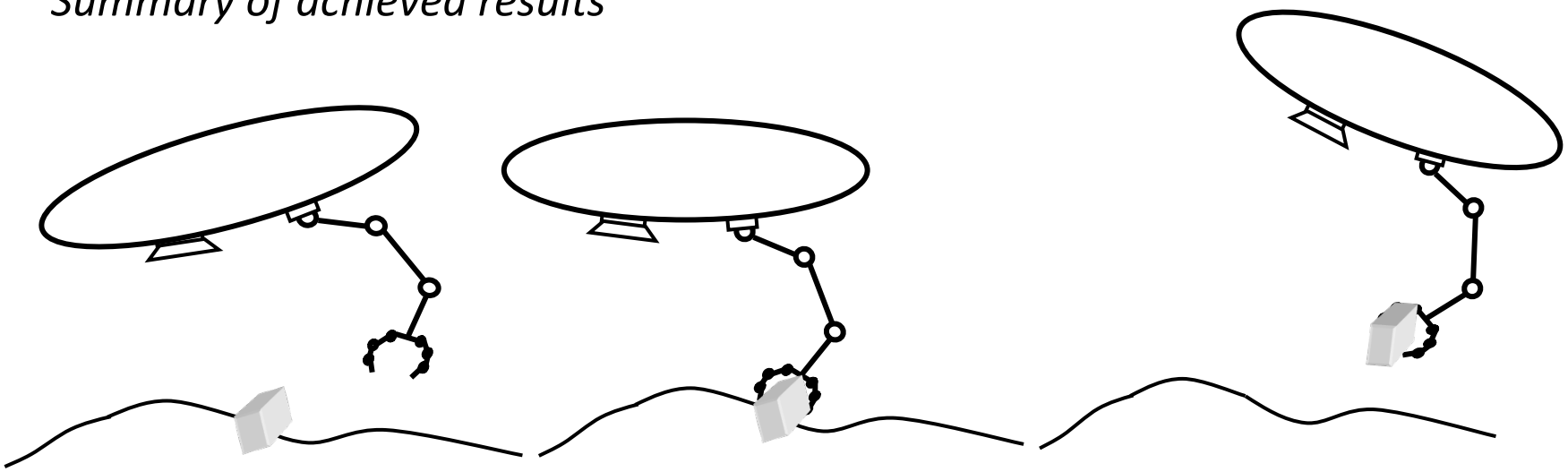
Single-Arm Floating Manipulators

Summary of achieved results



1- A unified algorithmic control framework has been assessed

2- Simulation experiments have been successfull

3- Control architecture and related R Talgorithmic Sw has been implemented

4- Field trials at pool successfull

5- Field trials at sea successfull

6- Refinements related with discontinuity-avoidance in reference syestem velocities have been recently produced

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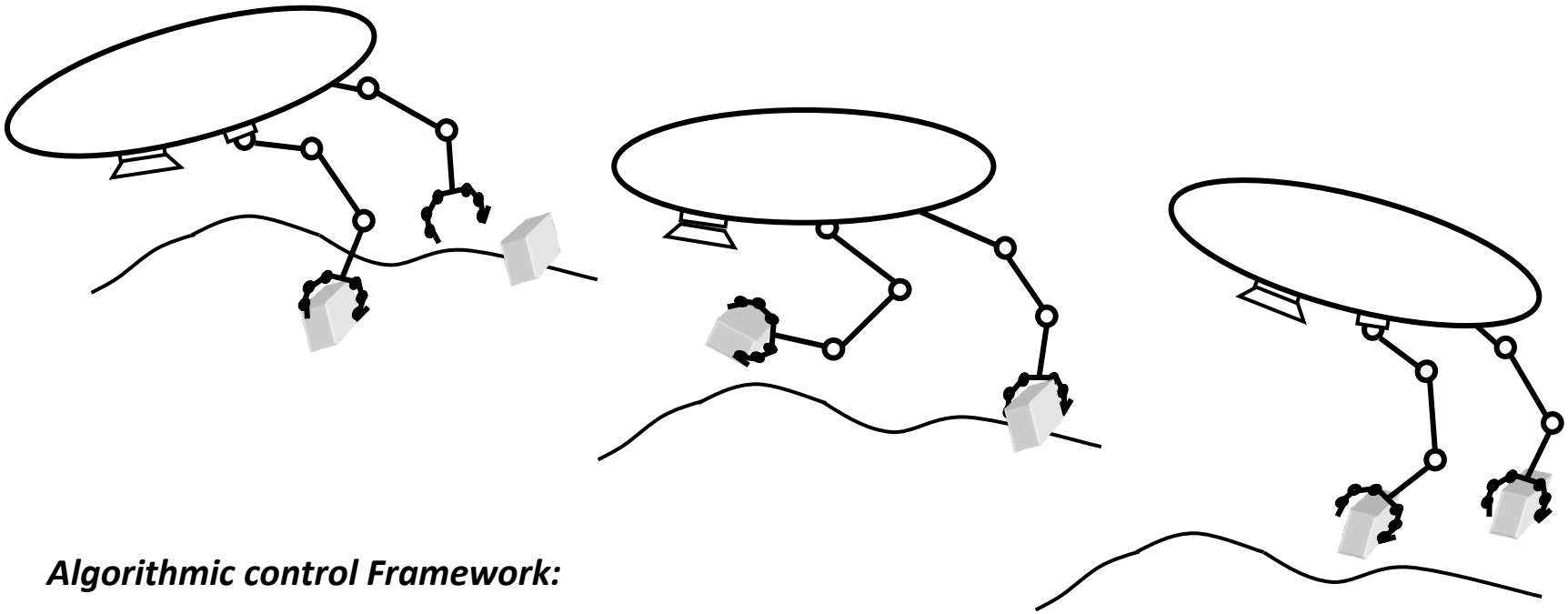
Dual Arm Extension-1



Algorithmic control Framework:

- *Direct extension from the Single arm case*
- *Embedding Single Arm case a as special one*

Additional aspects:

- *The vehicle velocity must now be assigned in order to suitably contribute the motions of* ***both*** *arms*

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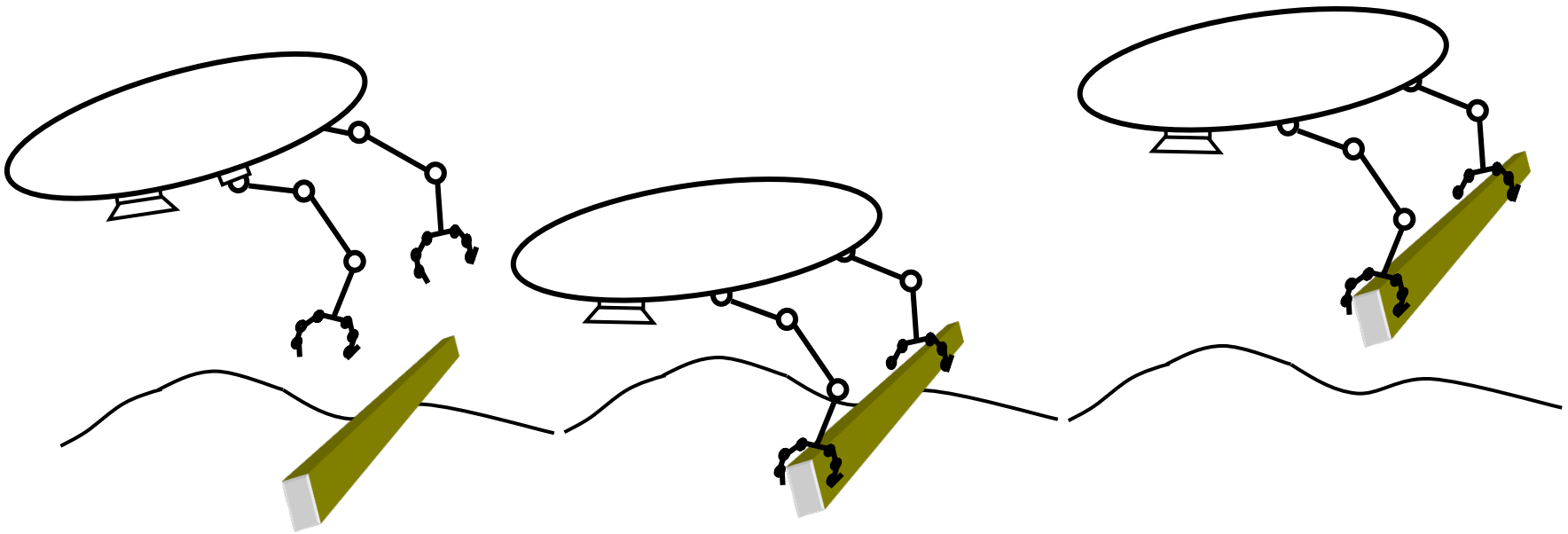
Dual-arm Extension-2



Algorithmic control Framework:

- *Direct extension from Extension-1*
- *Embedding Singel- arm and extension-1 as special cases*

Additional aspects:

- *The **grasping constraints** must be guaranteed fulfileld all times*
- ***Object stresses** shpould be avoided or minimized*
- *The vehicle velocity must again be assigned in order to suitably contribute the motions of **both** arms, in turn consrained by the grasped object*

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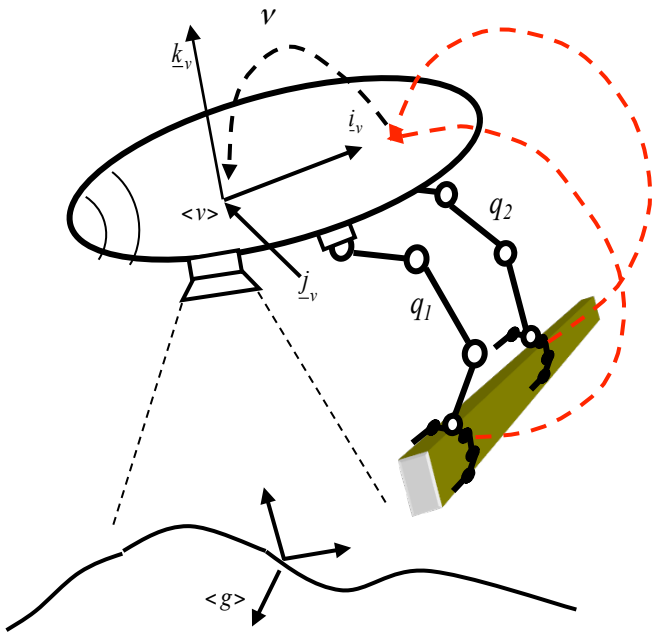
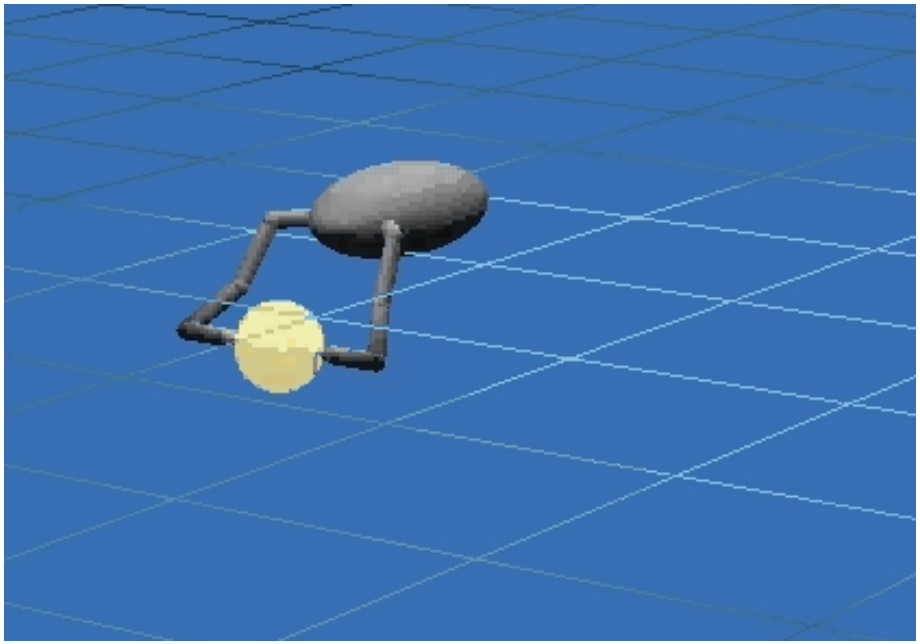
Dual-arm Extension-2

Preliminary *simulation of a purely kinematic model*





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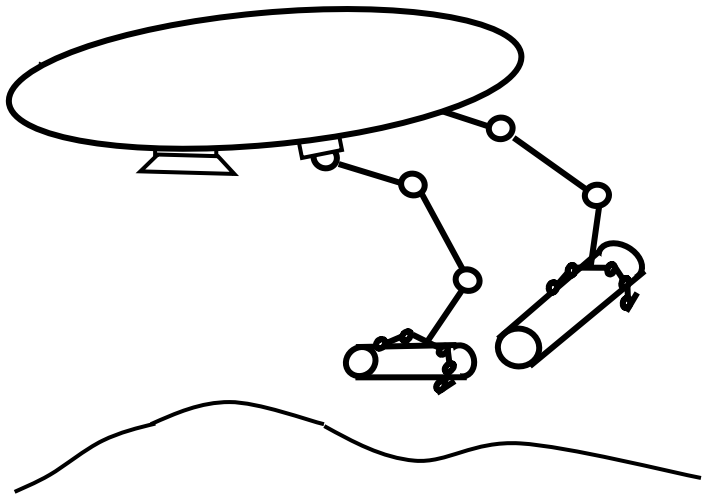
Dual-arm extension-3

Dual-arm floating assembly



Algorithmic control Framework:

- *Direct extension from dual-arm previous ones*
- *But largely independent from base motion (assembly during transportastion? **Why not?**)*

Additional aspects:

- *More extensive use of vision (for relativel localization of the mating parts)*
- *More extensive use of force-feedback (for driving the mating once the contacts have been established*

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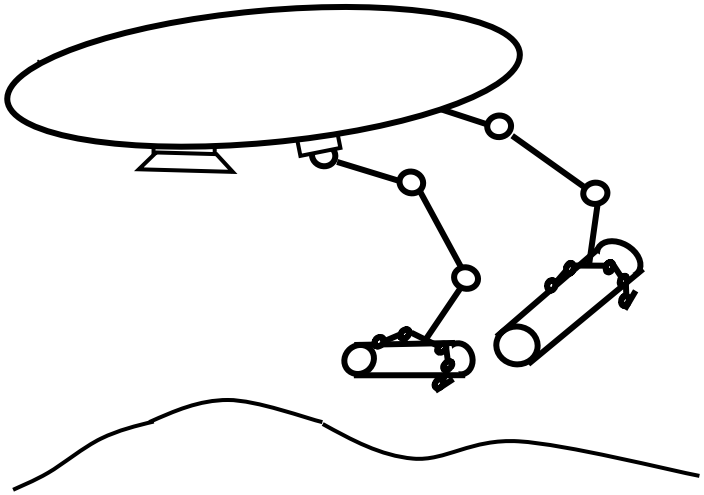
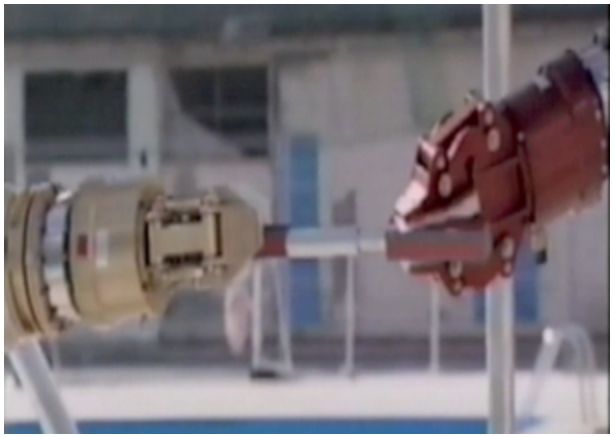
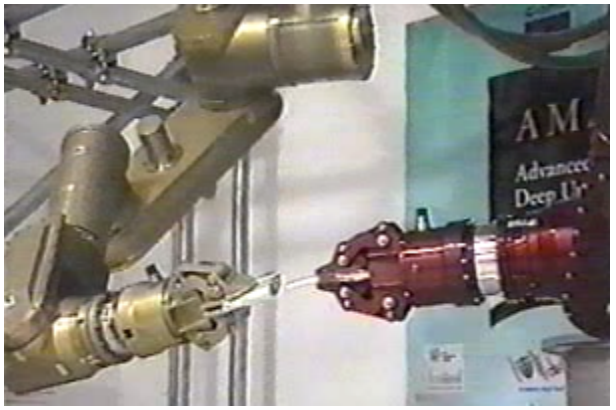
Dual-arm extension-3

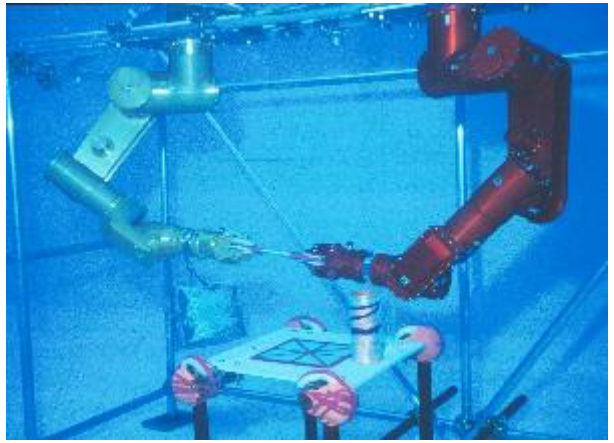
Non-floating dual arm Peg-in-hole

Early AMADEUS Project Experiments (1997-1999)









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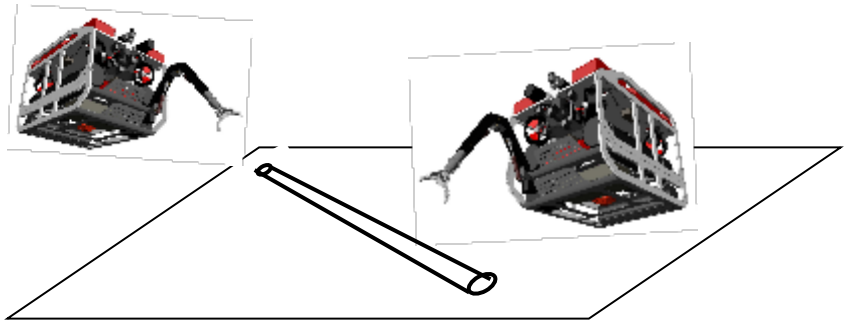
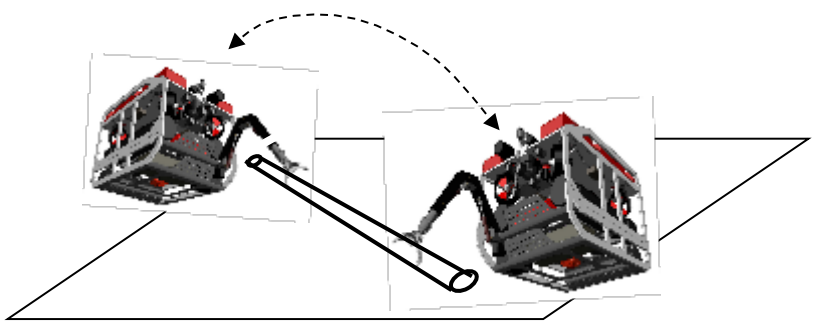
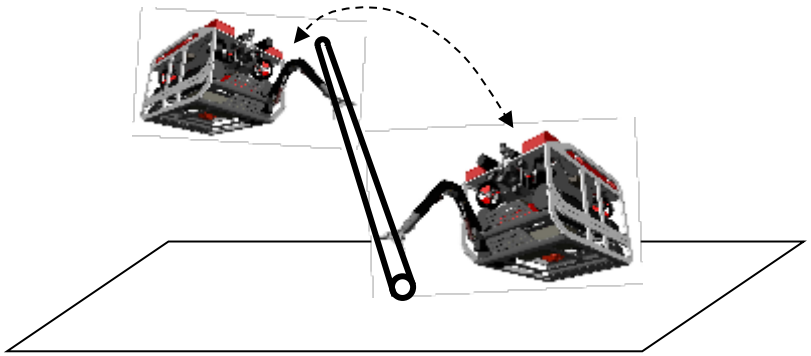
Cooperative Extension







Algorithmic control Framework:

- *Stll a direct extension of the previous*
- *Embedding the previous as special cases*

Additional aspects:

- ***Grasping constraints*** *must be guaranteed fulfilleld all times*
- ***Object stresses*** *to be avoided or minimized*
- ***Mutual Localization*** *is needed (at least for avoiding vehicles collision)*
- *Some control parameters have to be shared* $\Longrightarrow$ ***Communication***

$\Longrightarrow$ **MCIS**
Min. Common Info Set

- *Control performances to be tuned with the MCIS communication bandwidt (lower bandwidth-slower responces)*
- *An optimized* ***MCIS Management System (****MCIS-MS), maximally guaranteting coordinated cooperative control performances, needs to be developed*

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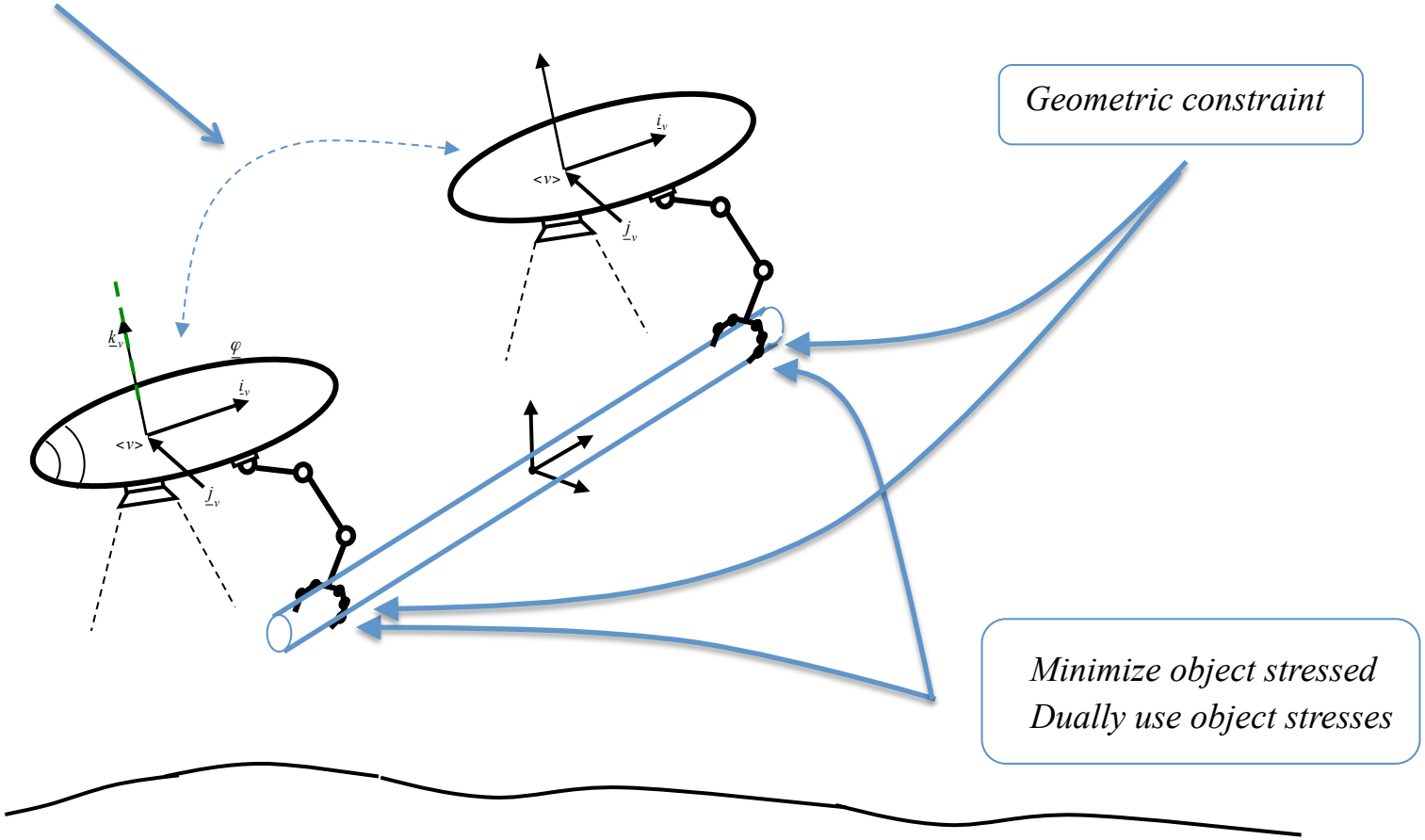
Cooperative Extension

Very scarce communication allowed ⇒ *Fully Centralized approaches* ***NOT*** *feasible* ⇒ ***Minimize explicit*** *comm.* ***Maximize Implicit*** *comm. expl.on*



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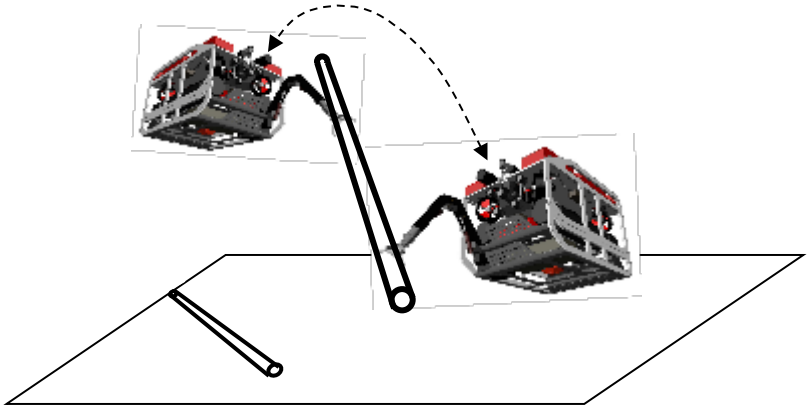
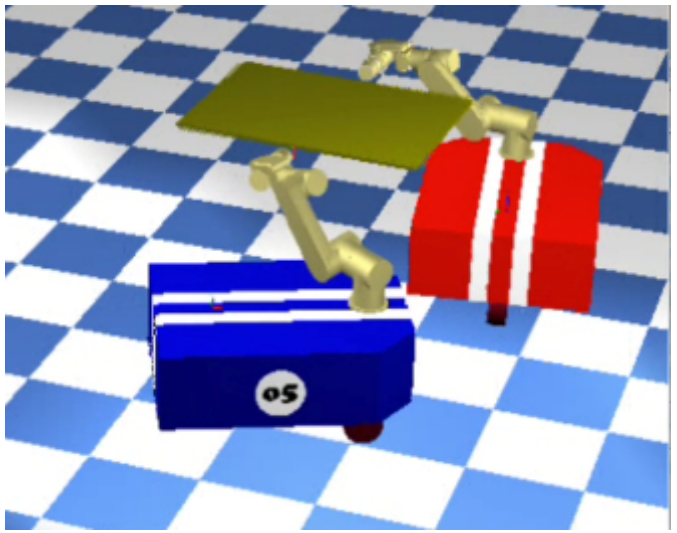
Cooperative extension

***Preliminary** simulation and experiments of purely kinematic grounded models*
(Total communication allowed)





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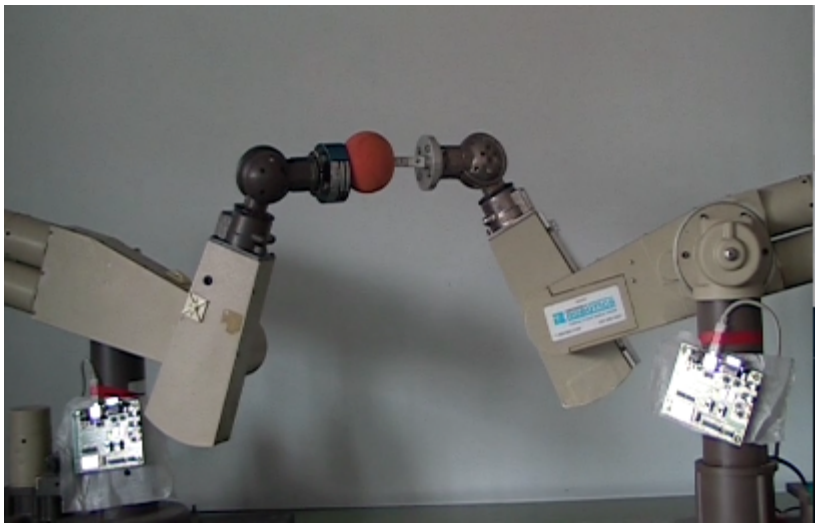

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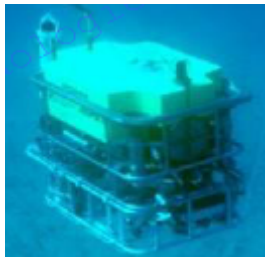
Autonomy in UW Intervention Robotics

Nowdays

MARIS (20013-2016)



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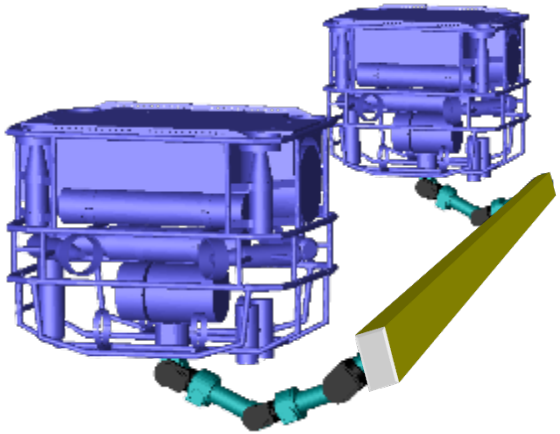


GENOVA
Cooperative Control

PISA
Communications

CASSINO
Dynamic Control

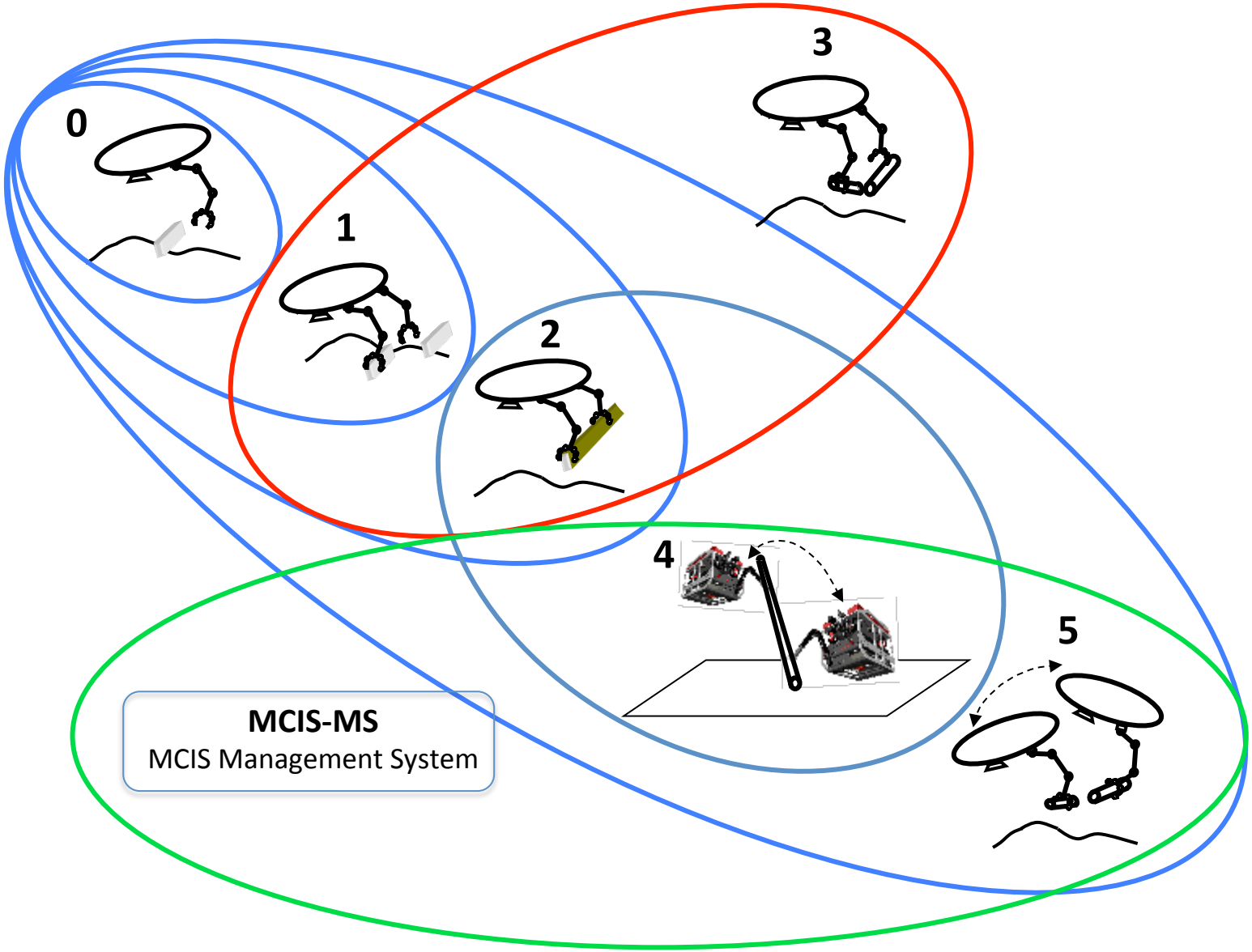
LECCE
Navigation

GENOVA
Integration
Mission planning

BOLOGNA
Grippers F/T sensing

PARMA
Vision

A Foreseable Road-MAP



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