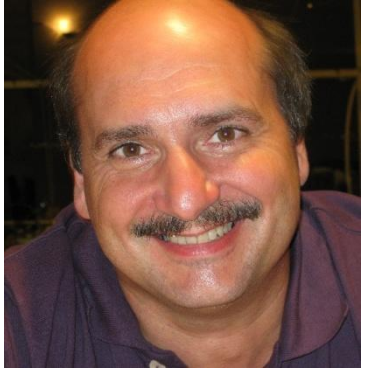


STIC-ASIA ICT-PAMM project meeting

ICT-Asia Program

Guangzhou Meeting

December 7th, 2012, Guangzhou, China

Professor Philippe Martinet

Ecole Centrale de Nantes

Researcher at IRCCyN Nantes

Associated researcher at Pascal Institute (Clermont-Ferrand)

Philippe.Martinet@irccyn.ec-nantes.fr

http://wwww.irccyn.ec-nantes.fr/~martinet

Content

- ✓**IRCCyN**
- ✓**Robotics Team**
- ✓**Recent results**
- ✓**EMARO**

INSIS INS2I INSB

Nantes

350km south-west of Paris

INSIS

INS2I
INSB

Centrale Nantes

LAN (60's)

IRCyN

01/01/2000

22/02/2011

ROBOTEX

2011

IRT
Jules Vernes

INSIS INS2I INSB

Centrale Nantes

l'université nantes angers le mans

PÔLE DE RECHERCHE ET D'ENSEIGNEMENT SUPÉRIEUR

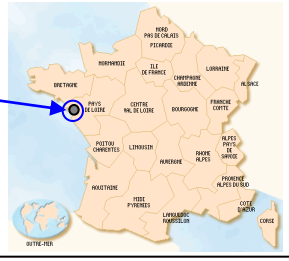
Institut de Recherche en Communications et Cybernétique

Head: Dr Michel Malabre

CNRS Joint Unit of Research

350km south-west of Paris

Nantes



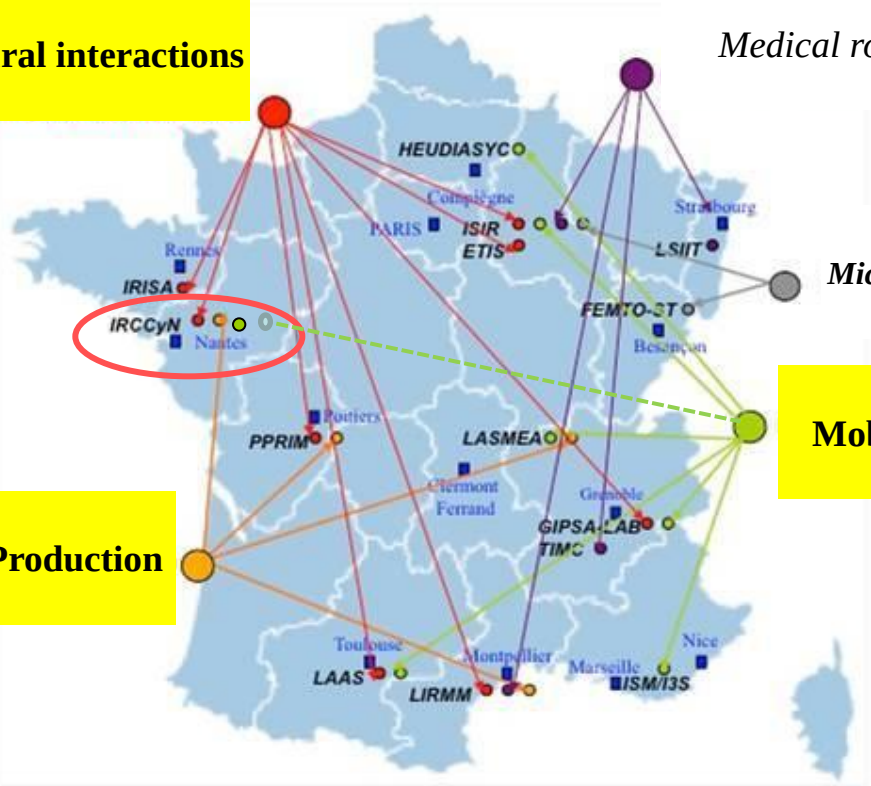
ACSED: *Analyse and Control of Discrete Event Systems*
ADTSI:*Analyse and Decision in Signal and Image Processing*
CONTROL
IS3P: *Systems Engineering, Products, Performances, Perceptions*
IVC: *Image Video Communications*
MÉFORBIO: Formal *Method for Bio--Computer sciences*
MO2P: *Modeling and Optimisation of Production Processes*
PSYCOTEC: *Psychology, Cognition, Technology*
Robotics Group (P. Wenger)
SLP: *Production* Systems and logistics
STR: *Real Time Systems*

Staff : 262 Members (15/01/2010)
17 ITA/IATOS
103 researchers and teachers/researchers
111 Phds
+ …

French Robotic Platform Network

Humanoid Robot and Natural interactions

Medical robotics



Micrio-Nano robotics

Mobile robotics

Robotics for Production

2011

ROBOTEX

Equipment of Excellence

INSIS INS2I INSB

Centrale Nantes

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PÔLE DE RECHERCHE ET D'ENSEIGNEMENT SUPÉRIEUR

2011

Head: S. Cassereau

- **High competitivness industrial area for complex structures production**
- **Design and production of new products using new technologies& processes**
- **Changing the way of design and production using green technologies**

L'UNAM
CNRS
Ecole de Mines Nantes
Ecole Centrale Nantes
Polytech Nantes
Université de Nantes
Université du Maine
ICAM
IFSTTAR
Technocampus EMC²
AIRBUS, ACB, LSTOM,CETIM, DCNS, DAHER, EADS, EUROPE Technologies, FAURECIA, HYROCEAN, PSA, SEGULA, STX
Nantes Metropole,
Région Pays de la Loire

IRT JULES VERNE

INVESTISSEMENTS D'AVENIR

Excellence Technology Research Institute

Content

- ✓IRCCyN
- ✓Robotics Team
- ✓Recent results
- ✓EMARO






ROBOTICS research team

Leader : Philippe Wenger

IRCCYN - CNRS/ECN

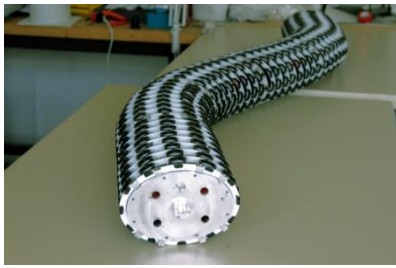
http://www.irccyn.ec-nantes.fr

September 2012

Philippe Martinet





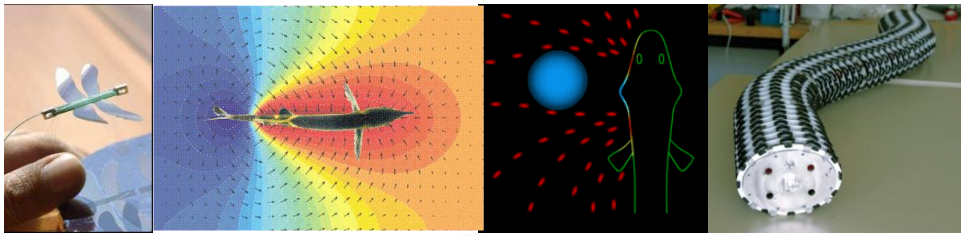



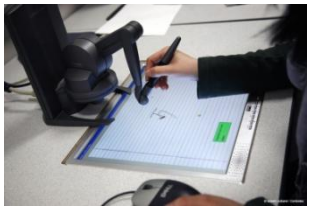
Robotics Team at IRCCYN

Head: P. Wenger

3DR, 2CR, 6PR, 7MCF, 1IR, 21 PhD, 8 post-doc

- **Y. Aoustin, MC (HDR) Nantes University**
- **F. Boyer, PR EMN**
- **S. Briot, CR CNRS**
- **J-C. Cadiou , PR Nantes University**
- **S. Caro, CR CNRS**
- **D. Chablat, DR CNRS**
- **C. Chevallereau, DR CNRS**
- **A. Chriette, MC ECN**
- **C. Dumas, MC EMN (currently in Australia)**
- **M. Gautier, PR Nantes University**
- **W. Khalil, PR ECN**
- **P. Lemoine, IR ECN**
- **G. Levey, MC EMN**
- **P. Martinet, PR ECN**
- **A. Pashkevich, PR EMN**
- **M. Porez, MC EMN**
- **P-P. Robet, MC IUT St Nazaire**
- **S. Sakka, MC Poitiers University**
- **P. Wenger, DR CNRS**



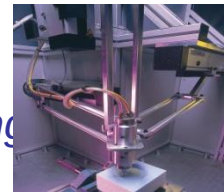


Research topics

- Three methodological axes
  - Modeling, identification and control
  - Design
  - Perception and Interaction
- Three applicative axes
  - Production robotics (*)
  - Bio-inspired robotics and humanoid robotics (*)
  - Mobile robotics (*)

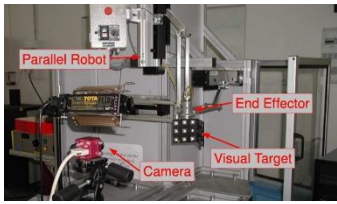
(*) Labeled within ROBOTEX Network

Production robotics: Current Know-How



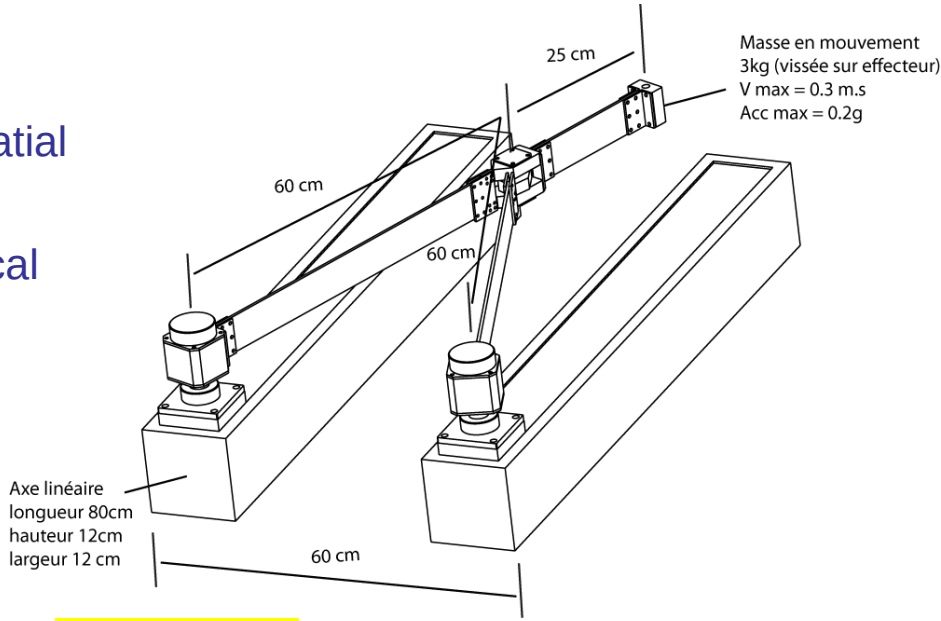
- Optimal Design
  - *Large experience in design of high-speed parallel robot (manipulation, millin*
  - *Optimal design (topology, geometry, kinematics, dynamics, elasticity, …)*
  - *Static and dynamic balancing (cancellation of gravity effects, shaking force and moment vanishing)*
  - *Kinematics and singularity analysis (SIROPA Toolbox, Grassmann-Cayley Algebra, cusp point, etc)*
  - *Modeling for design*
  - *Digital mock-up (CATIA, ADAMS, etc.)*

- Modeling, Identification and control (Kinematics and Dynamics)
  - *Large experience in dynamic modeling*
  - *Identification of dynamic parameters*
  - *Motion planning, task placement optimization*
  - *Control strategy based on dynamic model (computed torque)*
  - *Symoro+ (sofware for geometric, kinematic and dynamic modeling)*
  - *Vision based control*



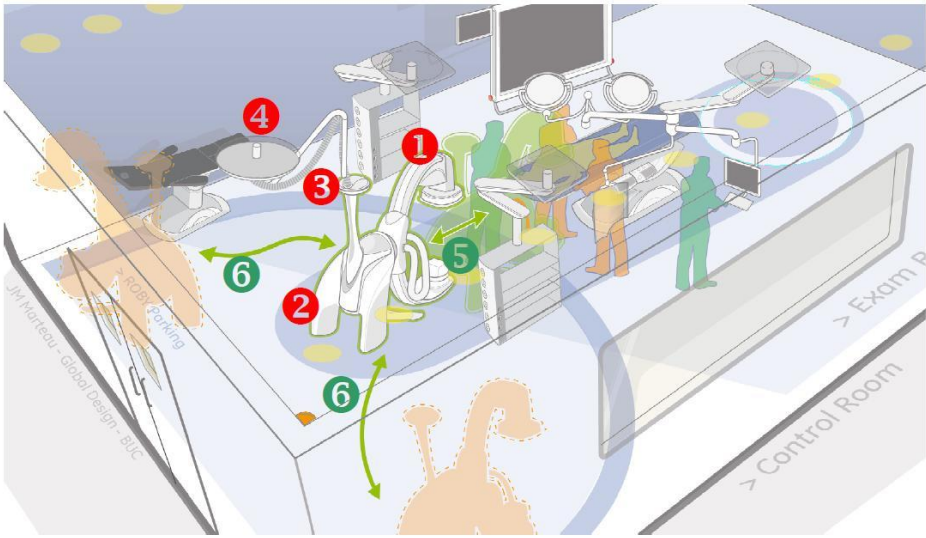
Production robotics: Current research

- Optimal Design
  - Design of new high-speed and accurate robot architectures for assembly
  - Design of reconfigurable parallel robots for workspace enlargement
  - Optimal design taking into account dynamics (rigid and elastic)
  - Process based design (milling, FSW, etc.)
  - “Control oriented” optimal design
  - Model reduction (elastostatic and elastodynamic models)
  - Tolerance synthesis
  - Optimal conceptual design
  - Cusp points analysis (extended to spatial robots)
  - Toolboxes development for geometrical and kinematic analysis



Production robotics: Current research

- Modeling, Identification and Control (Kinematics and Dynamics)
  - Process based modeling and control (milling, FSW, etc.)
  - Reconfigurability (path planning for passing through singularities)
  - Identification of flexibilities
  - Identification of the drive chain properties
  - Reconstruction of interaction efforts
  - Identification of inertial parameters of actuation redundant parallel robots
  - Identification of friction parameters (non linear models)
  - Identification of humans and humanoids inertial parameters
  - Vibrationless control



❶ Arceau
❷ Plateforme robotique omnidirectionnelle
❸ Système de navigation
❹ Système d'accroche et guidage de câbles
❺ Trajectoire positon de travail (imagerie) et retrait temporaire
❻ Trajectoire de/vers la position de parking

Production robotics: Current projects

FUI-**IRIMI** (GE medical robotics) 2010-2012
Mobile robot Control for 3D medical Imaging, Trajectory monitoring, Vibrations

ANR-**ROBOTEX** (CNRS) 2011-2019
AccuFast, DextRob, RoboTool

ANR-**ARROW** (CNRS) 2011-2015
High-speed parallel robot optimal design and advanced control, accuracy vibrations

ANR-**ARMS** (ECN) 2010-2014
Multi arms systems modeling & control, redundancy control, force/vision coupling

ANR-**COROUSSO** (CNRS) 2010-2013
Optimal design and advanced control of robots for milling and FSW, composite materials, integration of robot models with process models

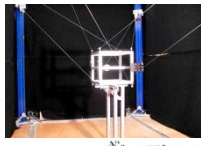
IRT-**ASIMOV***Assistant for Industrial structure and Systems and Manufacturing Optimization Value (EADS, AIRBUS, BA Systemes, CEA, IRCCYN) 2012-2015*
Vision/force/tactile coupling, manipulation, visual servoing

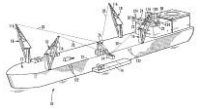
IRT-**DFP** Dry Fiber Placement (ECN) 2012-2015
Fiber placement, critical configuration exploration, trajectory tuning

Production robotics: Future

- Design and Control of Robots
  - Innovative robot architectures
  - With very high accuracy, very high speed and acceleration
  - With very large workspace (cable robots, mobile robots, etc.)
  - Introducing coworkers in Industrial environments

- Cable robots
  - Problem of sagging (forward and inverse kinematics, dynamics, vibrations, etc.)
  - Accuracy in very large workspace
  - Control of cable tensions and vibrations in dynamics
  - Cable inertial and flexible parameters identification





- Green robots
  - Energy saving (optimal design, balancing, process optimization, etc.)
  - Use of green energies (wind turbines, solar panels, accumulators, etc.)
  - Use of green materials (wood, recyclable polymers, etc.) – requires new models

- Safe robots
  - Use of compliance
  - Design of lightweight mechanisms (composite materials, miniaturizing, etc.)
  - Advanced control

Mobile robotics: Current Know-How

- Modeling, Identification and control (Kinematics and Dynamics)
  - *Large experience in dynamic modeling*
  - *Identification of dynamic parameters*
  - *Control strategy based on dynamic model (computed torque)*
  - *Symoro+ (sofware for geometric, kinematic and dynamic modeling)*

- Data fusion for localization
  - *EKF using real kinematic or dynamic mobile robot model*
  - *GPS, Odometry*

- Autonomous Navigation using visual memory
  - *Topological navigation using Visual servoing, multi-sensor based control*
- Platooning using RTK-GPS or visual memory
- Application to many robotic systems
  - *Indoor, Outdoor, Indoor/outdoor, structured and unstructured environment*

Mobile robotics: Current research

- SLAM
  - Binocular SLAM for large environment
- Human/robot control sharing
  - Human/robot control sharing and interaction (PSYCOTECH/Control Teams)
  - Vehicle monitoring (Control Team)
- Platooning and formation
  - *Modeling and control, Visual servoing*
- Unmanned Aerial Vehicles (*UAV*)
  - *Dynamic Modeling and control*
- Autonomous underwater vehicle (*AUV*)
  - *Modeling and control*
- Application to many robotic systems
  - *Indoor, Outdoor, Indoor/outdoor*

Mobile robotics: Current projects

FUI-**IRIMI** (GE medical robotics) 2010-2012

Mobile robot Control for 3D medical Imaging, Trajectory monitoring, Vibrations

ANR-**ROBOTEX** (CNRS) 2011-2019

Safe Autonomous Navigation, Cooperative Navigation

Renault-CIFRE 2010-2012

Tire pressure supervision (Control team)

Human/Robot control sharing (Control/Psycotech Teams)

Pays de la Loire Regional Chair (IRCCYN) 2012-2015

Safe navigation

Autonomous navigation using visual memory

SLAM

*IRT-**ASIMOV** (EADS, AIRBUS, BA Systemes, CEA, IRCCYN) 2012-2015*

Mobile robot Control, Autonomous navigation in encumbered environment

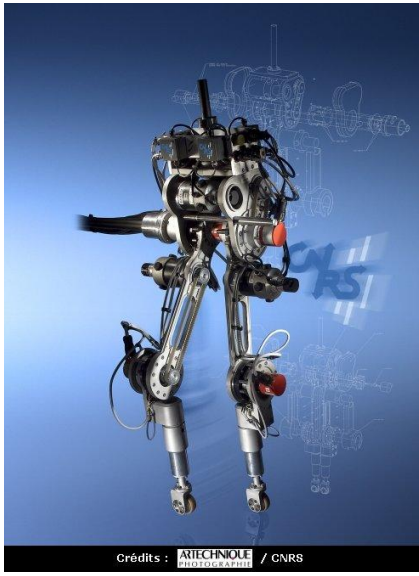
Past projects where P. Martinet have participated at LASMEA: ICT-ASIA (FACT, CITYHOME), ANR (MOBIVIP, CITYVIP, R-DISCOVER), FUI (CRISTAL), ROBEA (BODEGA, OMNIBOT, R2M), RNTL (WACIF), …

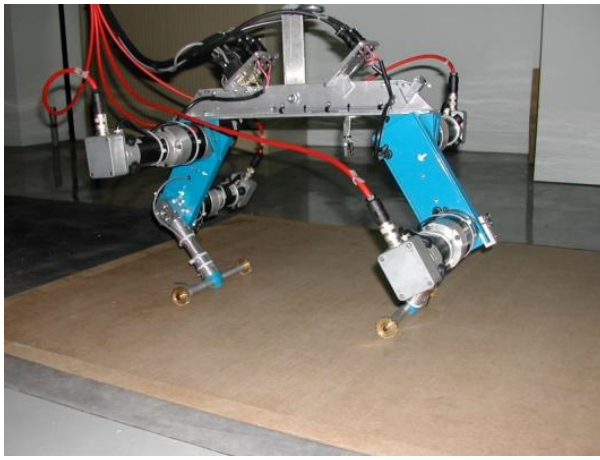
Mobile robotics: Future

- SLAM
  - Monocular SLAM (Scale factor estimation) for large environment
- Safe, Efficient and Cooperative Navigation
  - Navigation in encumbered environment (maneuver, obstacle avoidance, sensor trajectory tracking)
  - Navigation in dynamic environment
  - Multi-sensor based navigation (sensor redundancy, …)
  - Human/robot control sharing and interaction (PSYCOTECH/Control Teams)
  - Driver surveillance and situations awareness
- Platooning and formation
  - *multi-sensor based control*
- *UAV and AUV*
  - *Dynamic modeling and control*
  - *Sensor based control*
- Application to many robotic systems
  - *Indoor, Outdoor, Indoor/outdoor, structured and unstructured environment*

Humanoid Robotics: Current Know-How

- Walking Robots
  - Quadruped and biped
  - From simple mechanism to humanoid
- Dynamic modeling
  - Model of contacts
- Design of optimal walking (optimization)
  - Different gaits : walking, running, trot, amble, curvet, jump
  - Integration of disequilibrium phases as in human walking
- Control
  - Walking and Running
  - Computed torque control
  - Stability analysis (convergence toward periodic motion)
  - Control of the walking direction



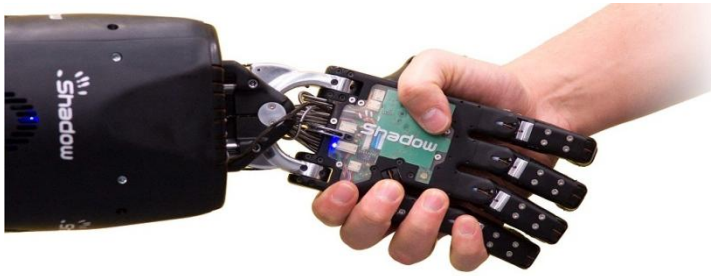


Humanoid Robotics: Current research

- Efficiency of walking
  - Introduction of spring to store/restitute energy
  - Hydraulic actuator
  - Effect of the motion of the arm
- Control
  - Extension to humanoid
  - Rotation of the foot during walking
  - Double support with rotation of the foot
- Design of knee
  - Based on human kinetics
  - Study of energy efficiency
- Whole-body human imitation
  - Human motion capture (IR cameras or kinect)
  - Realtime execution by a robot : effect of dynamic properties

Humanoid Robotics: Current projects

ANR-**PHEMA** (Humanoid Platform) 2006-2009
Design of humanoid robot
hydraulic actuator



ANR-**R2A2** (Humanoid robot) 2009-2012
Reduction of energy cost

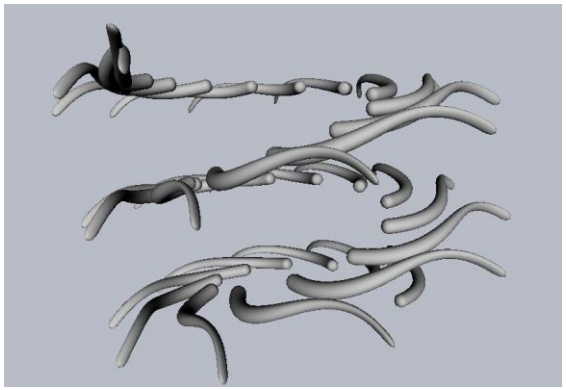
PEPS Control of mechanical hand with
EMG signal 2011-2013

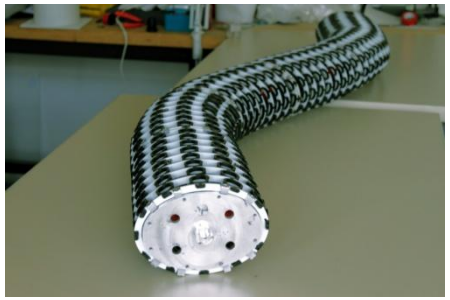
ANR-**ROBOTEX** (CNRS) 2011-2019
Humanoid robot
Equipment: Romeo (1.40m)

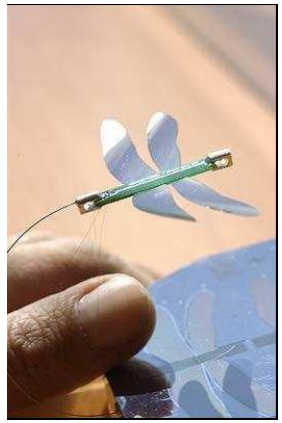
International collaboration : USA, Russia, Japan

Bio-inspired robotics

- In Water : eel-like-robot
  National projects
- On the ground : snake-like-robot
- In air : fly-like-robot
  National project

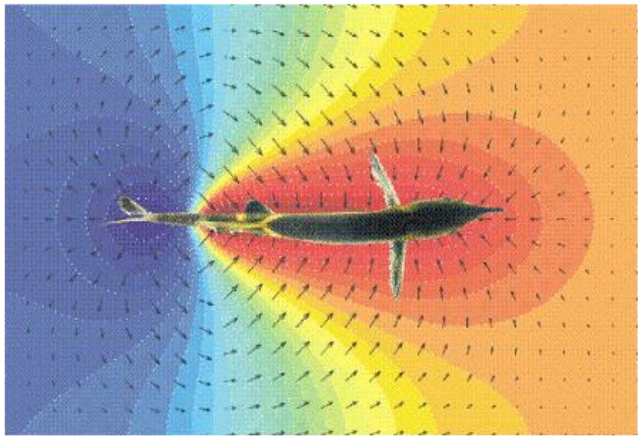


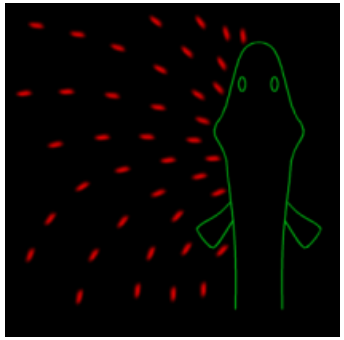


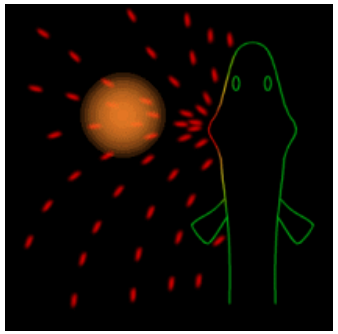


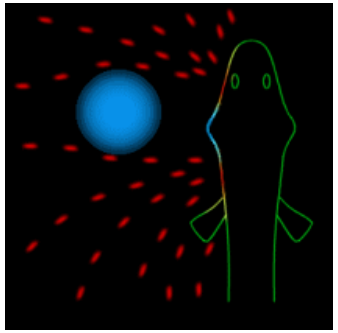
Biomimetic Perception

- Electrolocation of fish
  - National project
  - European project:









Content

- ✓IRCCyN
- ✓Robotics Team
- ✓Recent results
- ✓EMARO

Content

- ✓**IRCCYN**
- ✓**Robotics Team**
- ✓**Recent results and project**
  - ✓**Vision based control (Monocular camera)**
  - ✓**Vision based control (RGBD camera)**
  - ✓**Vision based control PKM**
  - ✓**Vision based control MR**
  - ✓**Multi-Arms modeling and control**
  - ✓**Vision/Force coupling**

Vision Based Control MC (1/3)

A.B. Moughlbay PhD thesis [IROS11, IAS12]

Vision based (MC: monocular camera)

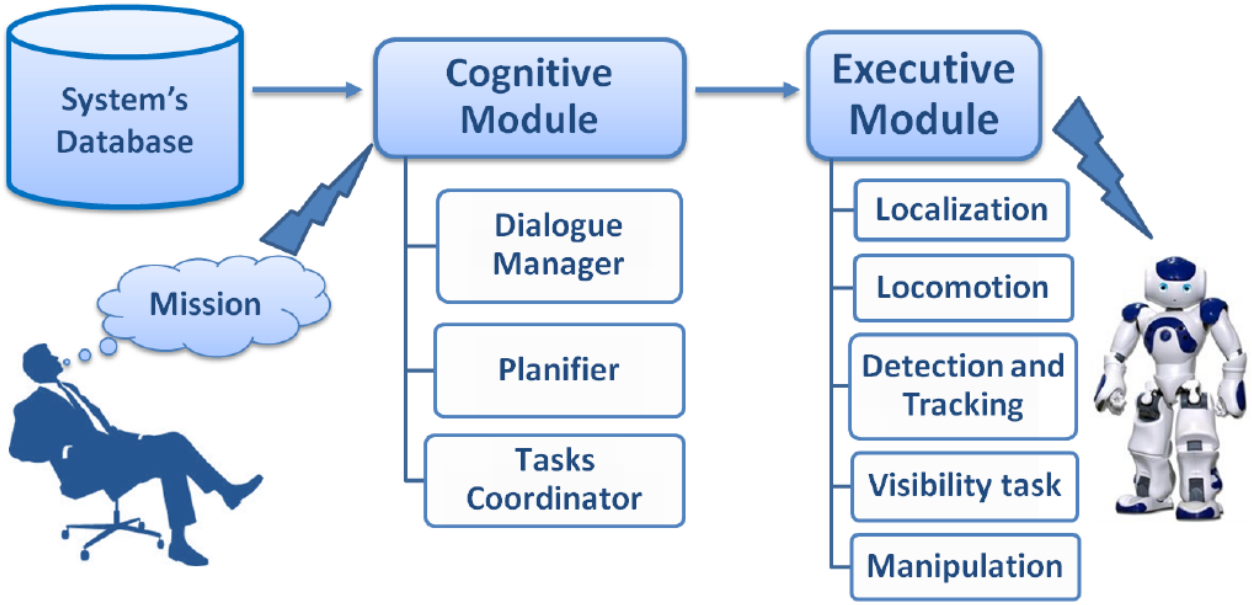
- Localisation and motion control
- Object tracking
- Control of hands and head

Humanoid mobile robot executing different manipulation tasks in an everyday life environment using Sensor-based Control.

Platforms:

- HRP2
- NAO
- ROMEO (coming soon)

System's Architecture



Vision Based Control (2/3)

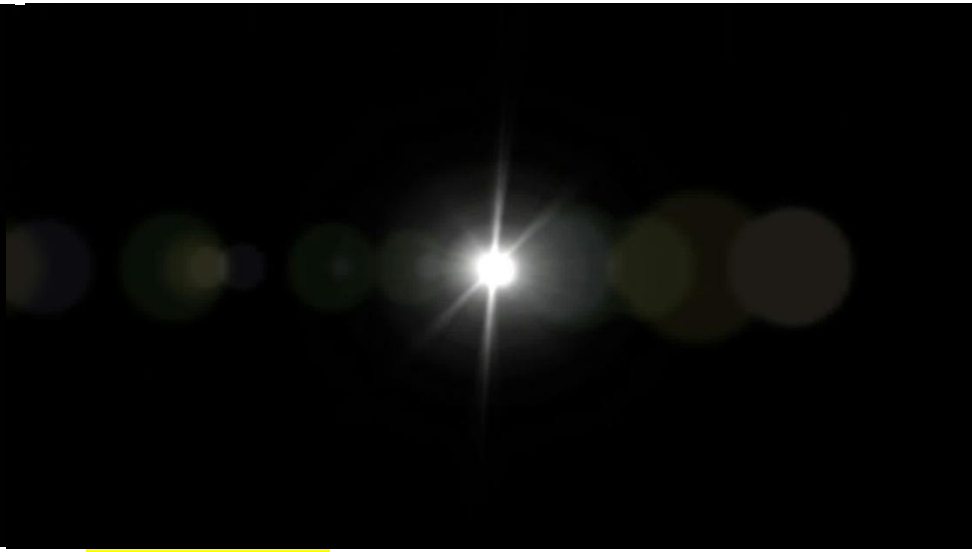
A.B. Moughlbay PhD thesis **[IROS11, IAS12]**

Vision based (MC: monocular camera)

- Localisation and motion control
- Object tracking
- Control of hands and head

Platforms:

- HRP2
- NAO
- ROMEO (coming soon)



Vision Based Control (3/3)

A.B. Moughlbay PhD thesis [ICARCV12]

Vision based (MC: monocular camera)

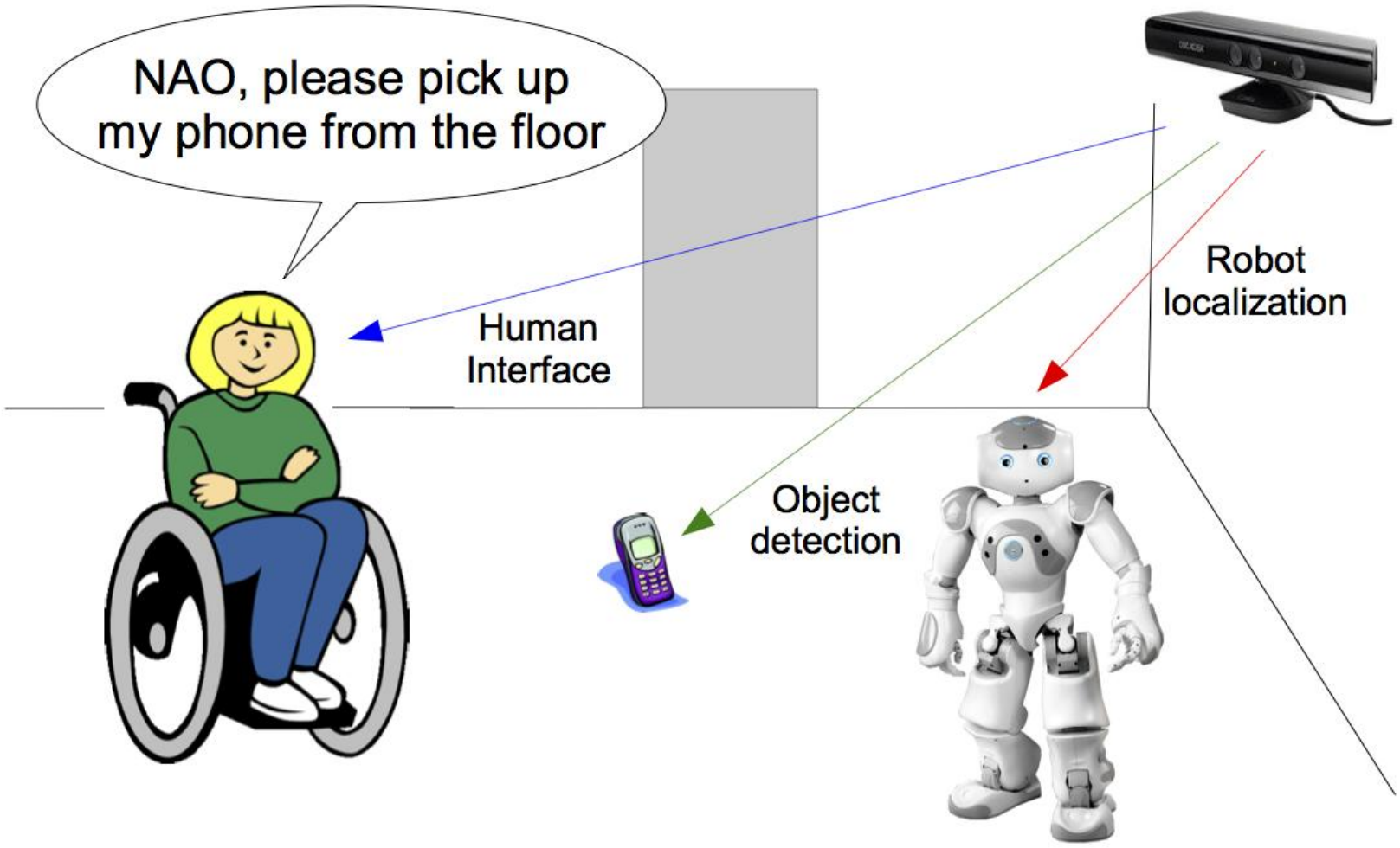
- Object tracking
- Control of hands and head

- Classical exponential decrease
- First error regulation strategy
- Second error regulation strategy

Vision Based Control RGBD (1/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Scenario

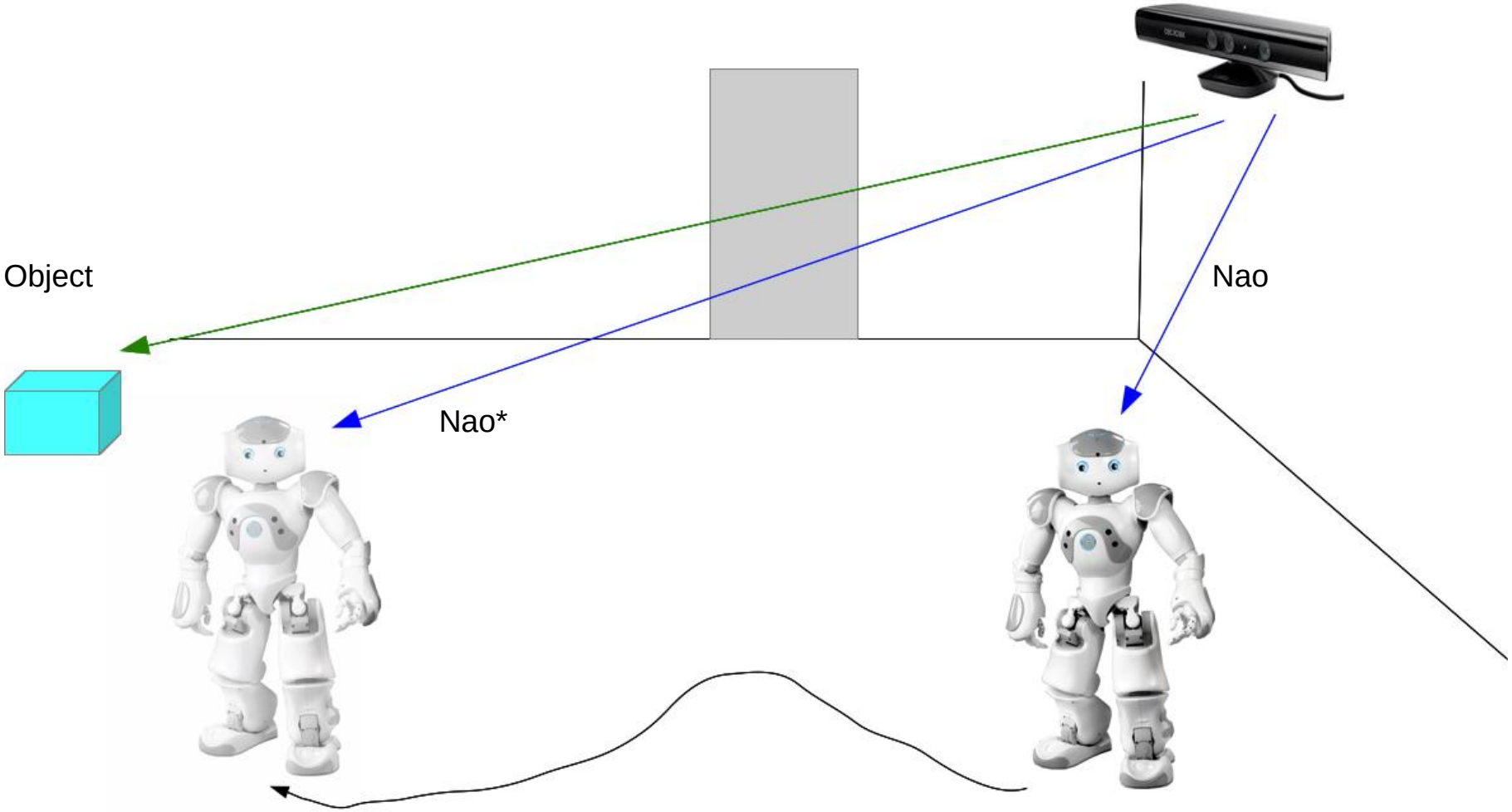


Vision Based Control RGBD (2/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Vision based (RGBD camera)

- Localisation and motion control



Vision based (RGBD camera)
- Localisation and motion control

Humanoid localization

- Indoor environments
- Robust wrt walking

Vision Based Control RGBD (4/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Related work

Vision based (RGBD camera)

- Localisation and motion control

LouLoudi, a. et al. “Integration of the Humanoid Robot Nao inside a Smart Home: A Case Study”, SAIS Workshop 2010.

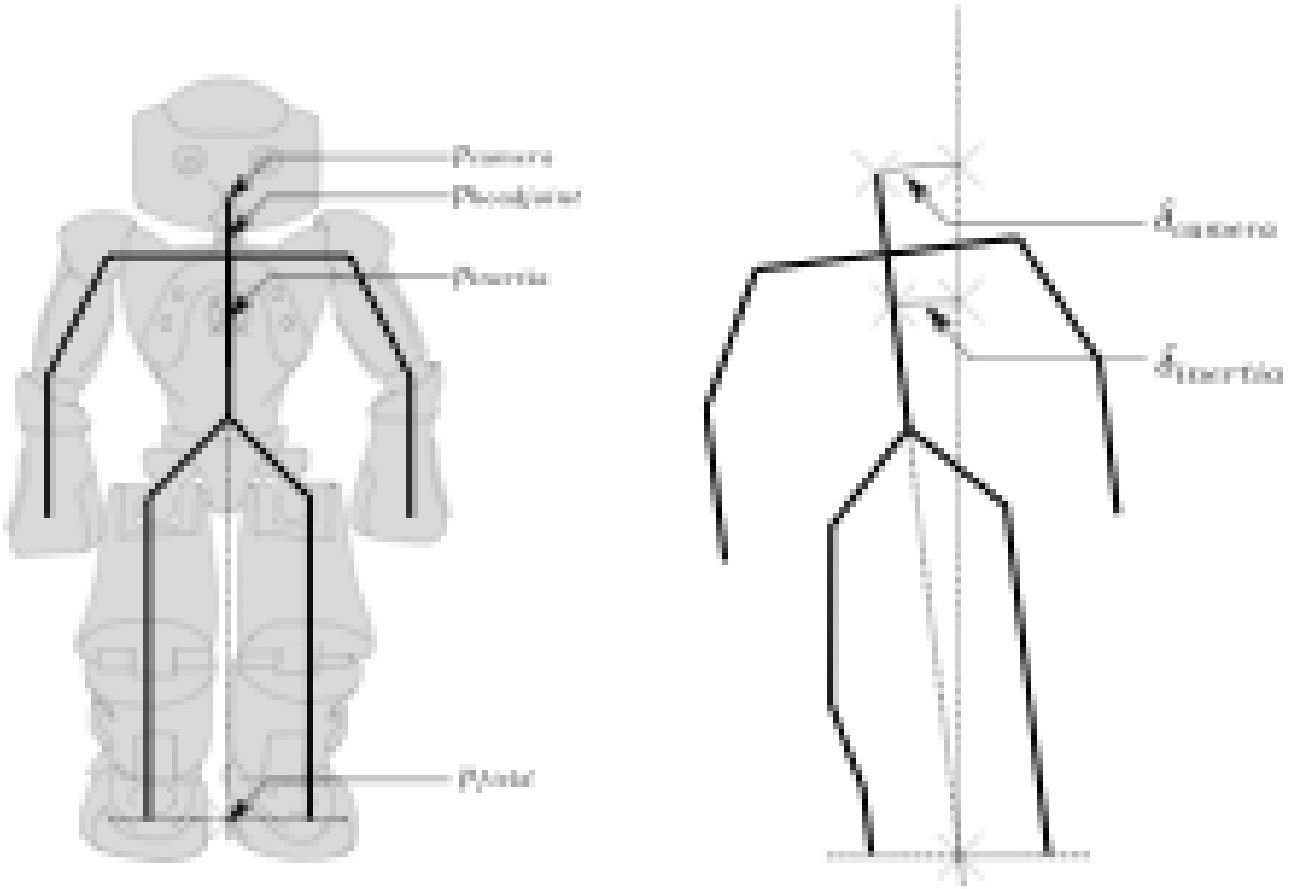
Vision Based Control RGBD (5/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis [IROS12]

Vision based (RGBD camera)

- Localisation and motion control

Related work



Laue, T. et al. “Efficient and Reliable Sensor Models for Humanoid Soccer Robot Self-Localization”, Humanoids 2009.

Vision Based Control RGBD (6/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis [IROS12]

Vision based (RGBD camera)

- Localisation and motion control

Related work

Hornung, A.; Wurm, K. M.; Bennewitz, M. “Humanoid Robot Localization in Complex Indoor Environments”, IROS 2010.

Vision Based Control RGBD (7/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Vision based (RGBD camera)

- Localisation and motion control

RGBD Sensor

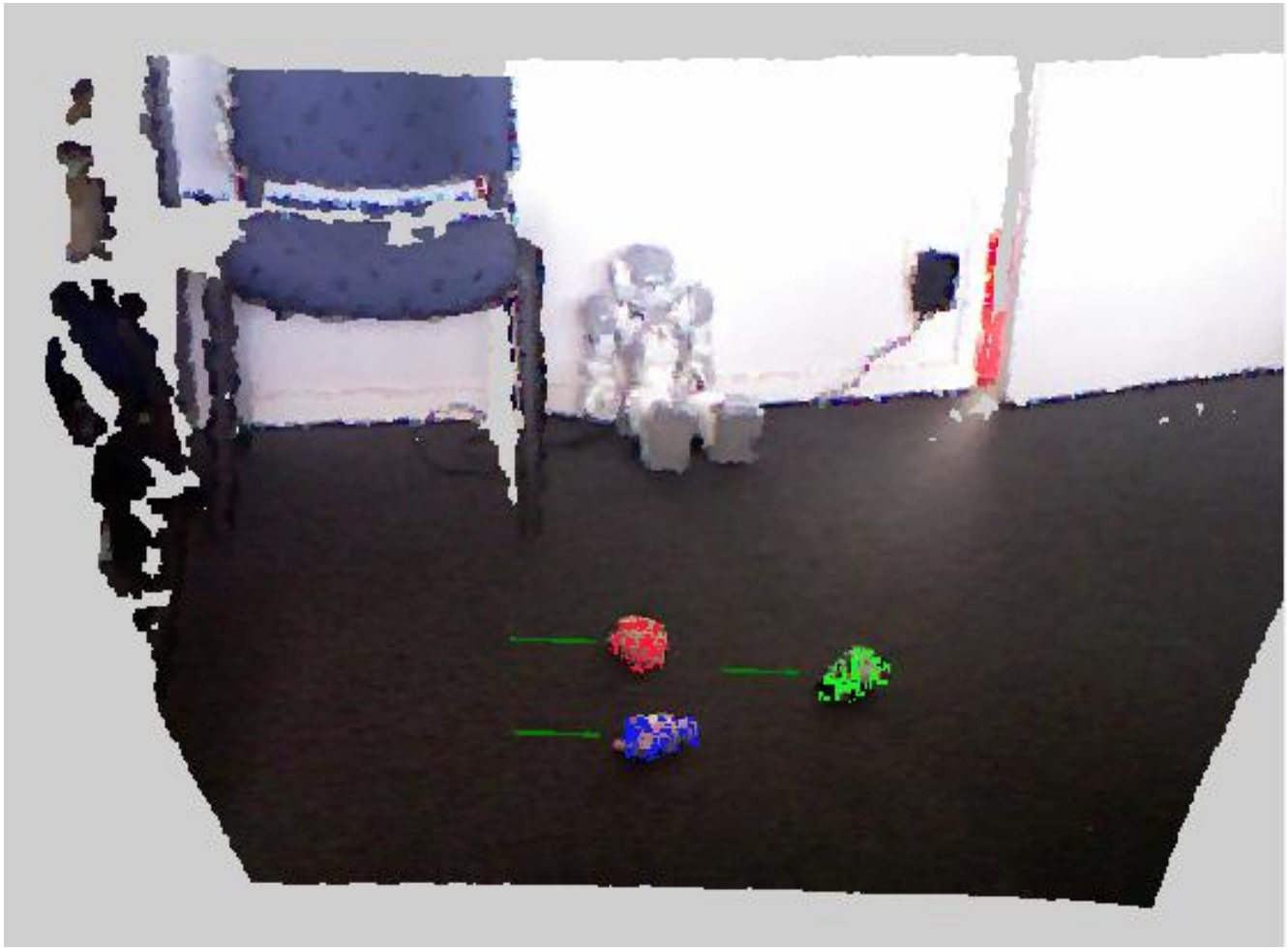
Vision Based Control RGBD (8/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Vision based (RGBD camera)

- Localisation and motion control

Principal plane detection and object clustering



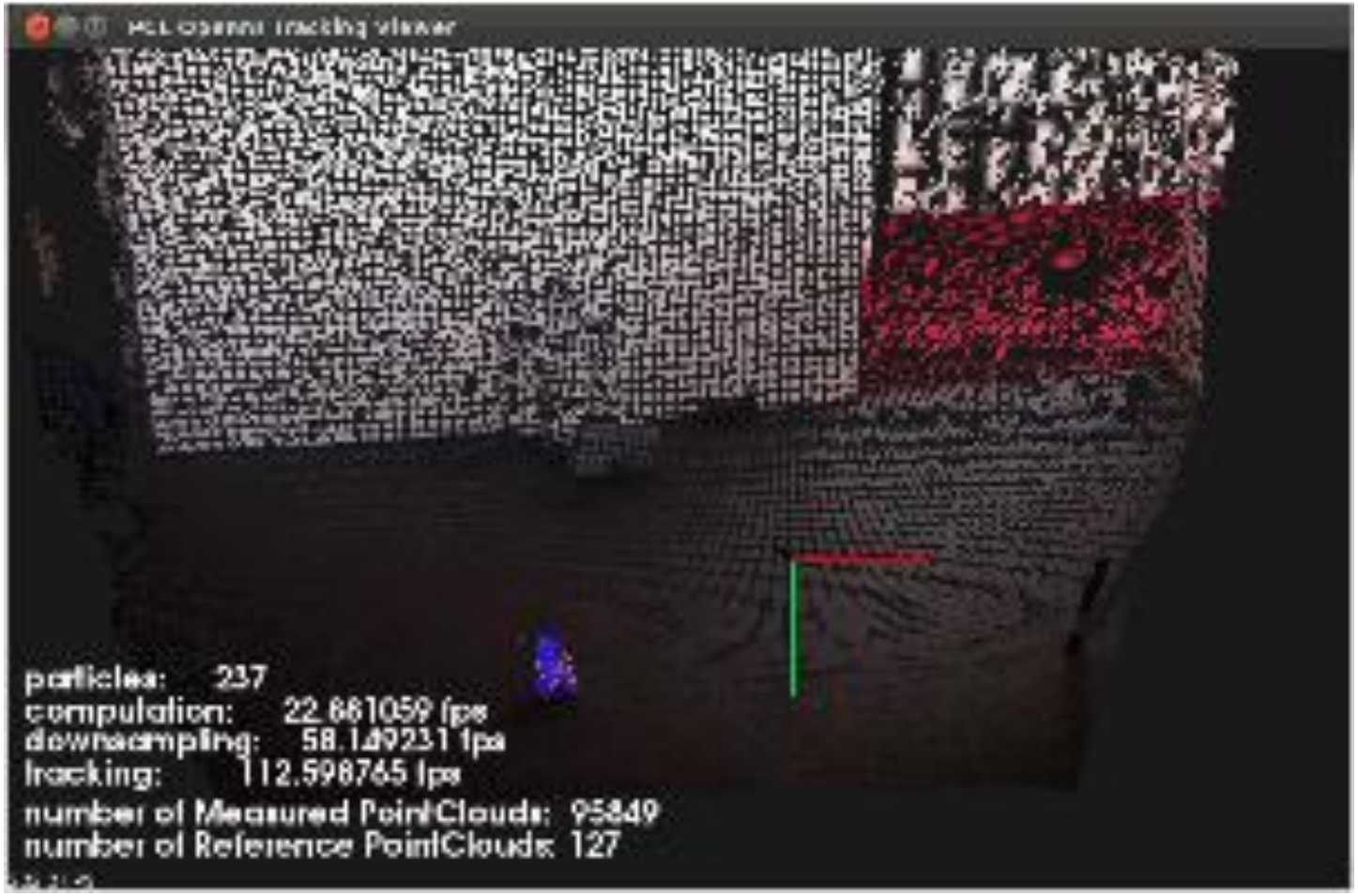
Vision Based Control RGBD (9/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis [IROS12]

Vision based (RGBD camera)

- Localisation and motion control

Object tracking



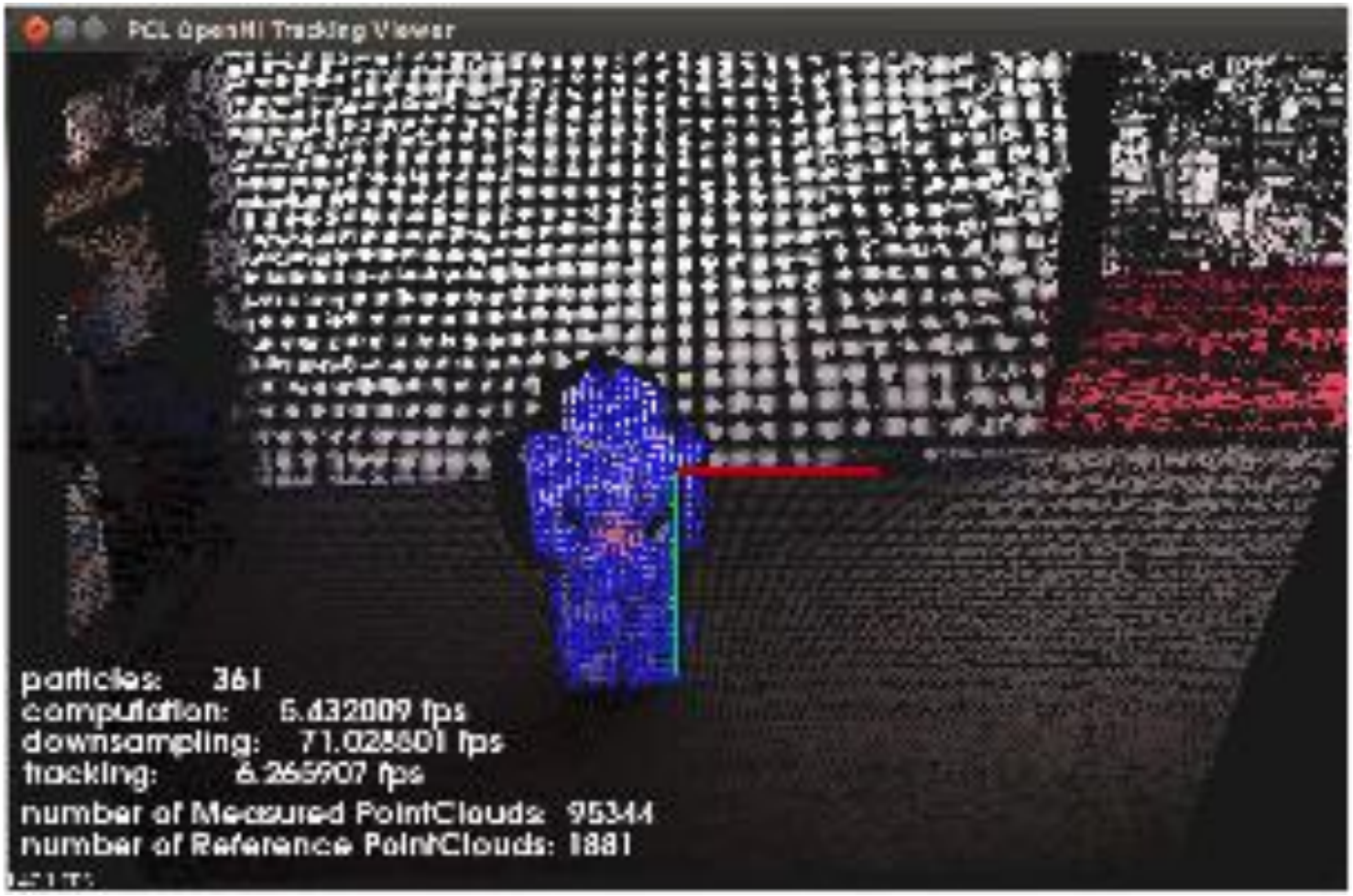
Vision Based Control RGBD (10/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Vision based (RGBD camera)

- Localisation and motion control

Robot tracking



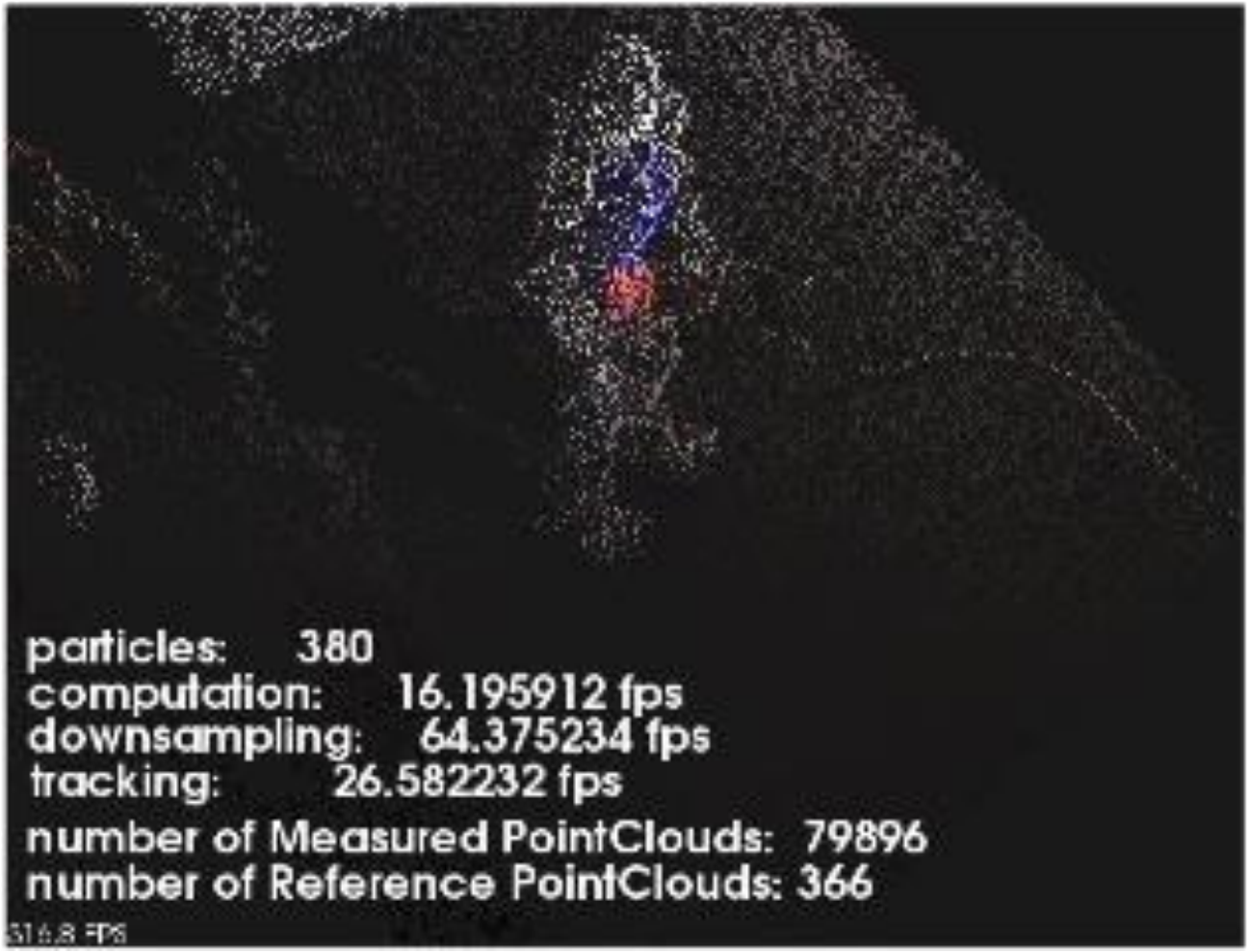
Vision Based Control RGBD (11/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Vision based (RGBD camera)

- Localisation and motion control

Robot tracking



Vision Based Control RGBD (12/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Vision based (RGBD camera)

- Localisation and motion control

3D pose estimation

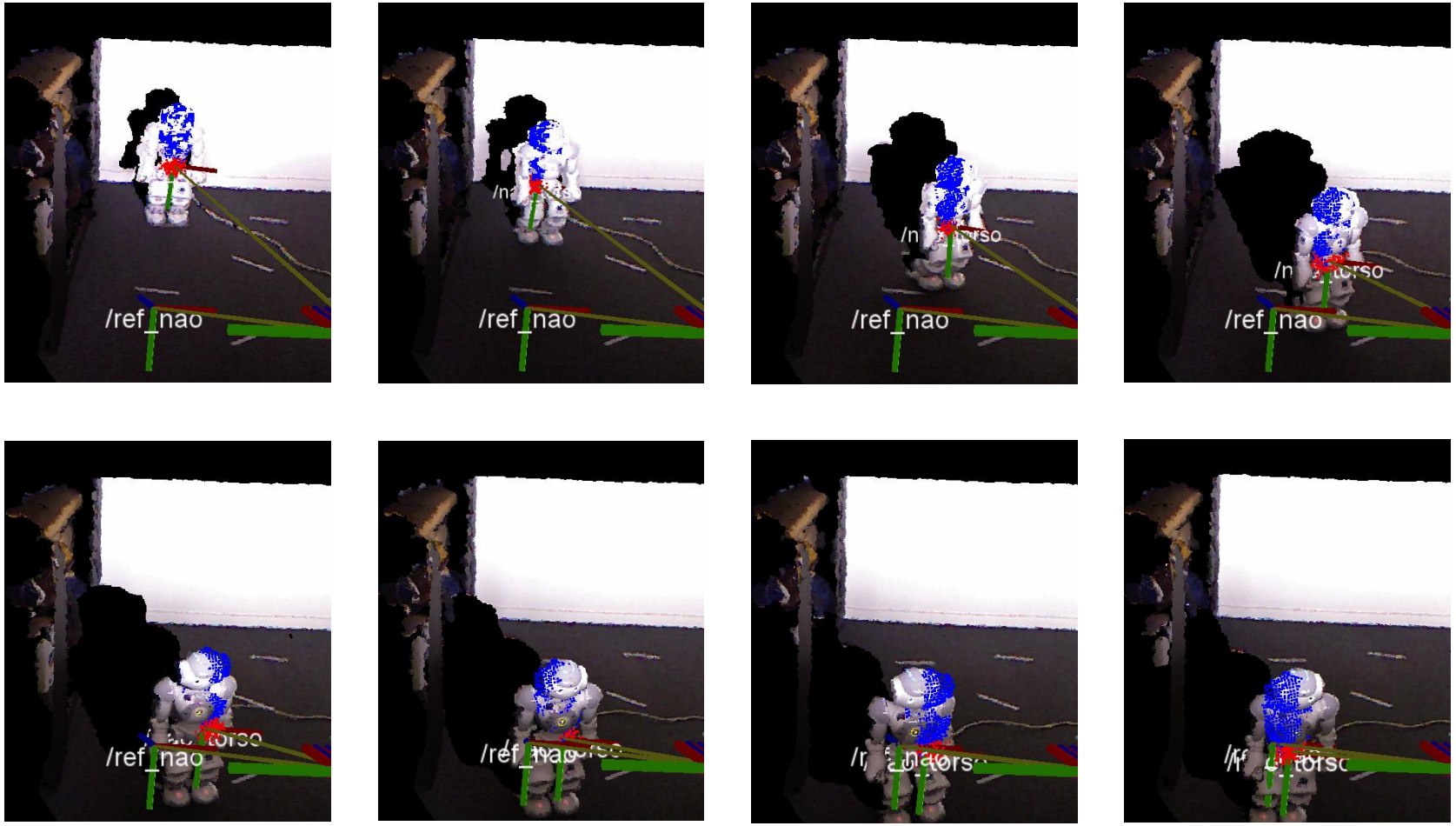
Vision Based Control RGBD (13/16)

E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis [IROS12]

Vision based (RGBD camera)

- Localisation and motion control

3D Closed loop control



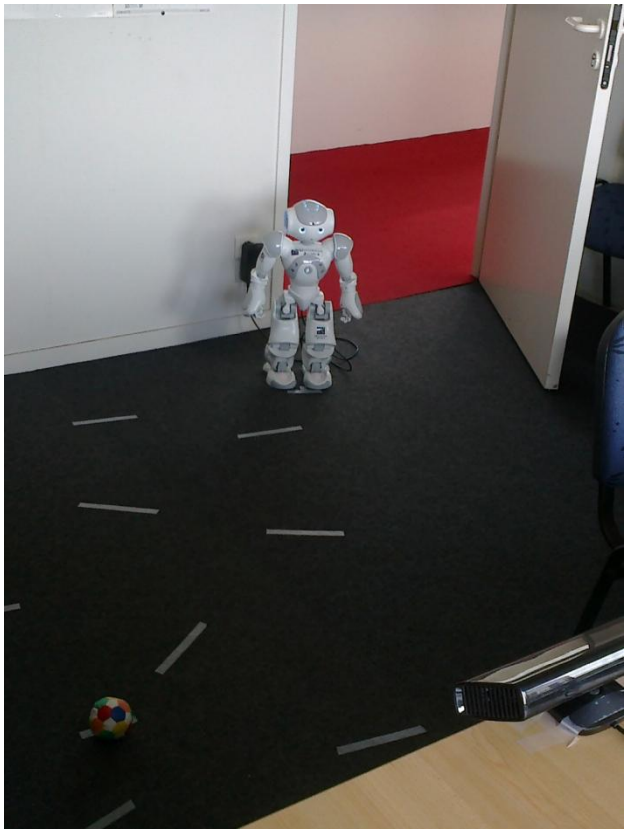
Vision Based Control RGBD (14/16)

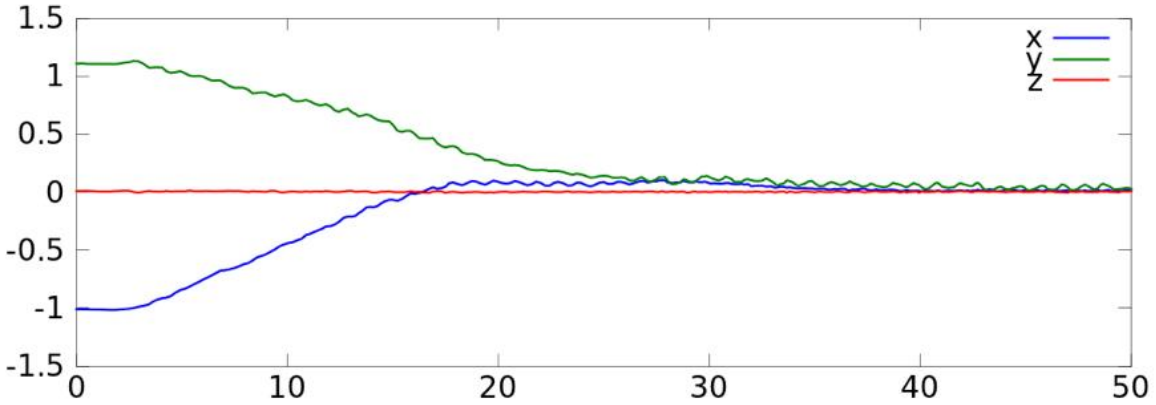
E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis [IROS12]

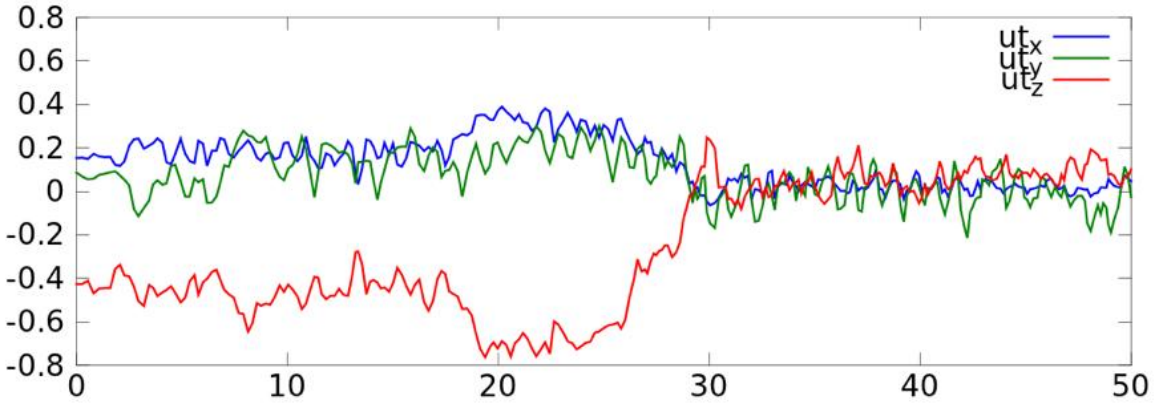
Vision based (RGBD camera)

- Localisation and motion control

Experimental result





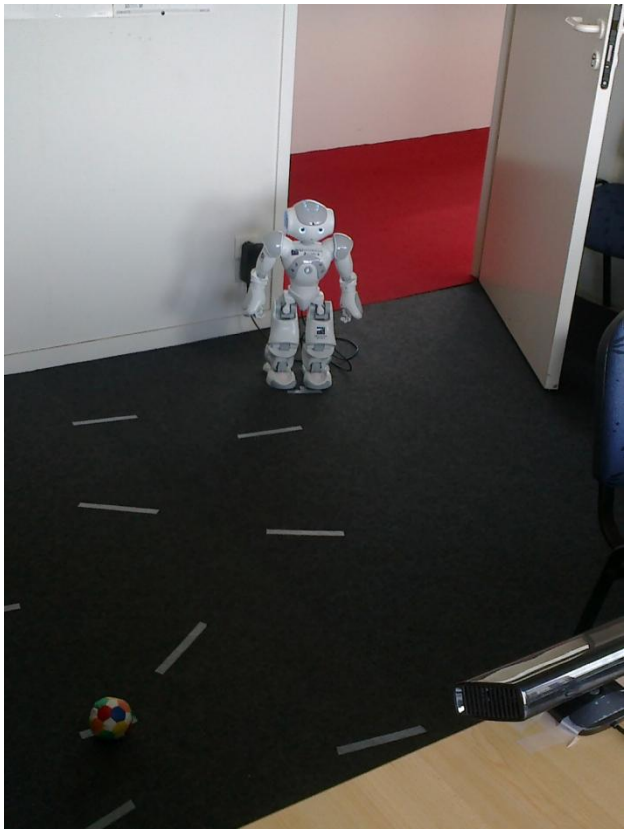


Vision Based Control RGBD (15/16)

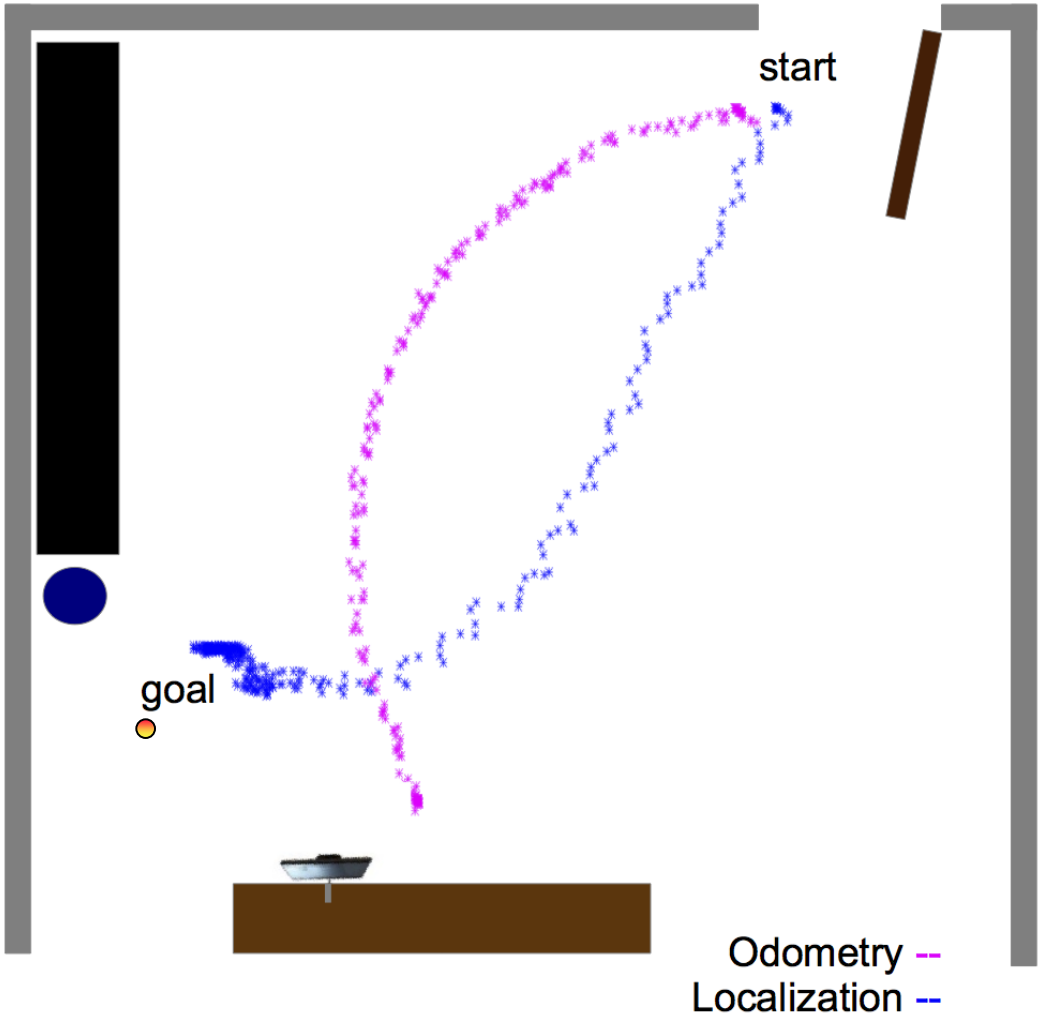
E. Cervera (UJI/IRCCYN) – A.B. Moughlbay PhD Thesis **[IROS12]**

Vision based (RGBD camera)

- Localisation and motion control



Experimental result



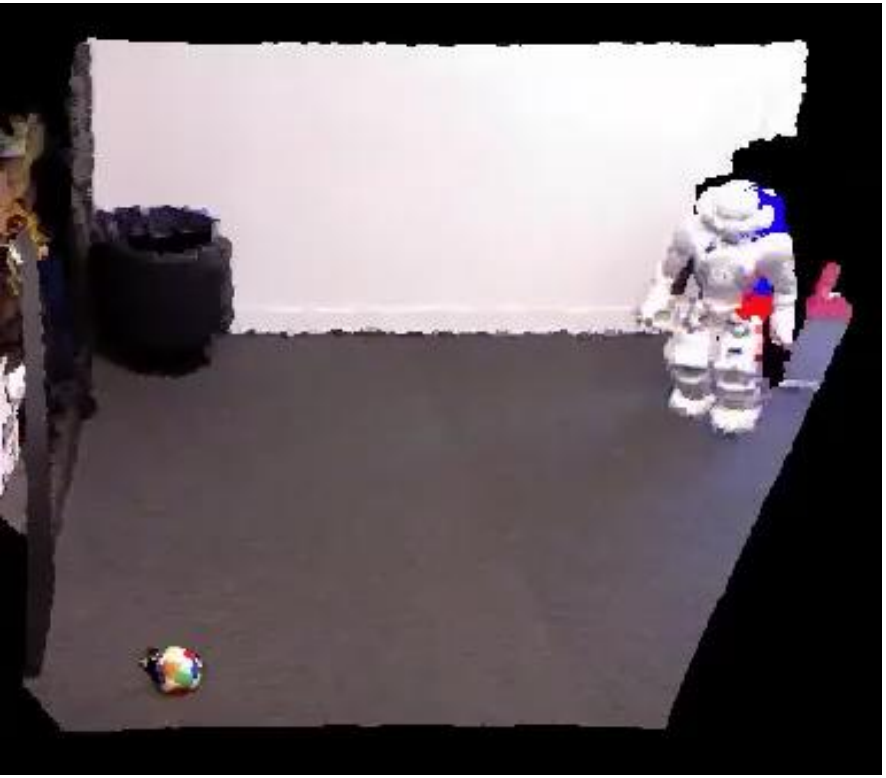
Vision Based Control RGBD (16/16)

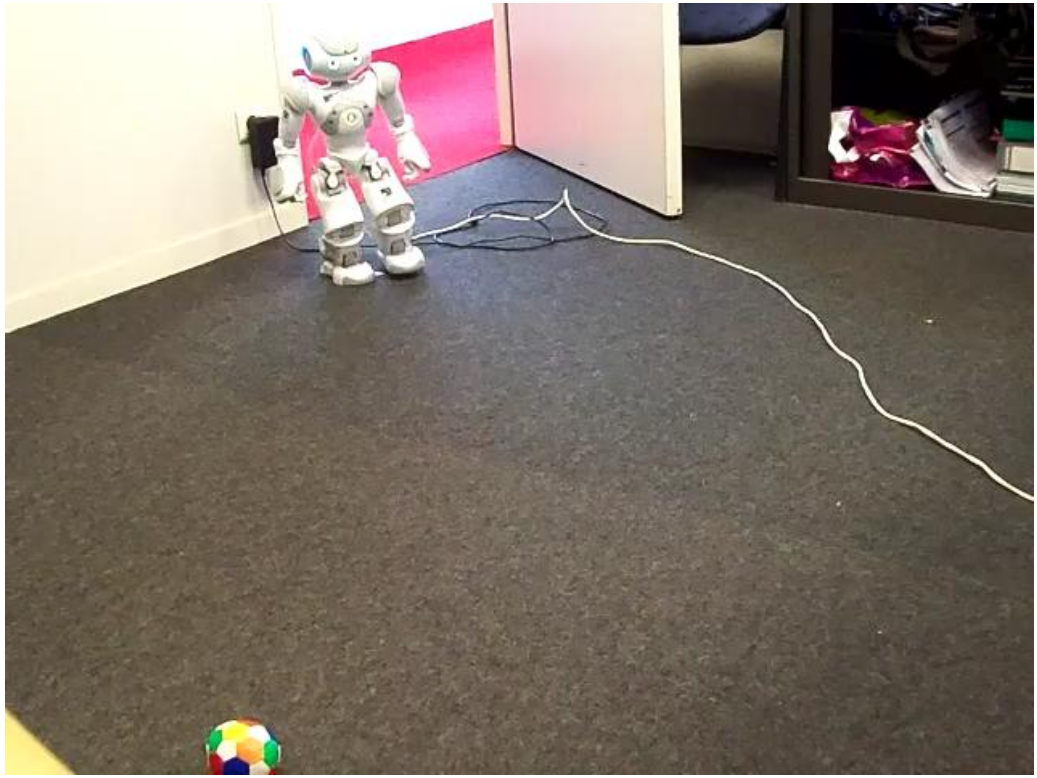
E. Cervera (UJI/IRCCYN) **[IROS12]**

Vision based (Kinect camera)

- Localisation and motion control
- Object tracking
- Control of hands and head

- ROS environment
- PCL library





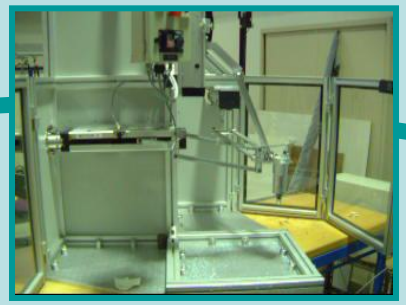
Vision Based Control PKM (1/5)

Kinematics MIC
Dynamics MIC
Cable PKM

Vision based Modeling, Idenfication and control (2001- …)

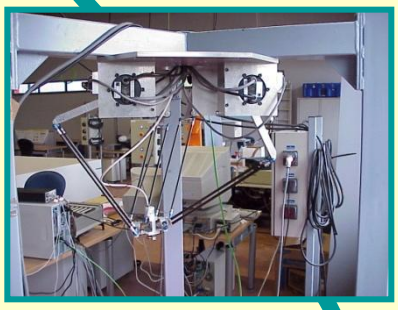
I4R-LIRMM

I4L-LIRMM



Orthoglide-IRCCYN

T3R1



H4-LIRMM

Quattro

Gough-Stewart

Reelaxe8 – LIRMM
Tecnalia

3T3R

3RRR

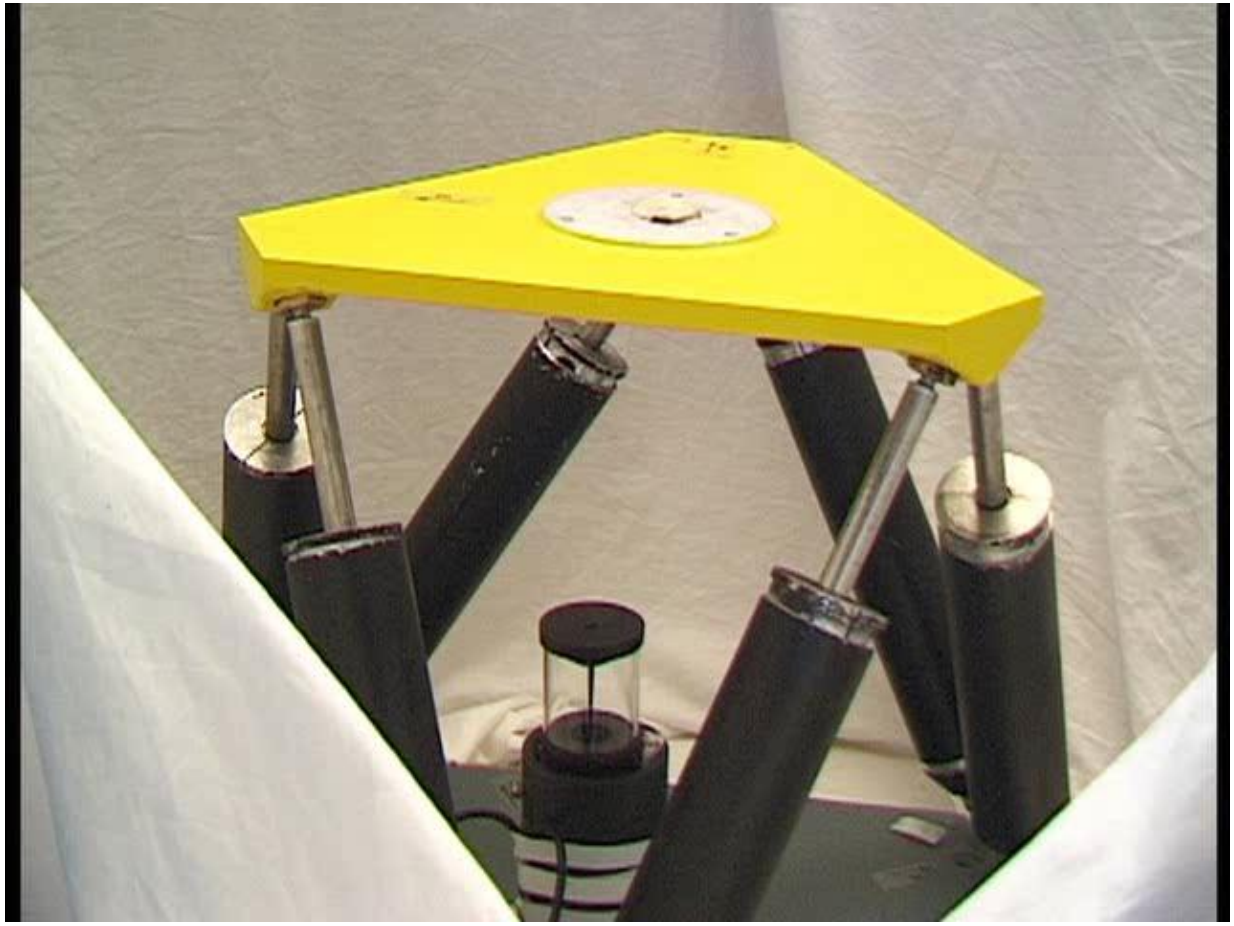
ntes,

Vision Based Control PKM (2/5)

Vision based Modeling, Idenfication and control

- Kinematics control using ominidirectional camera (vision only)

Gough-Stewart platform



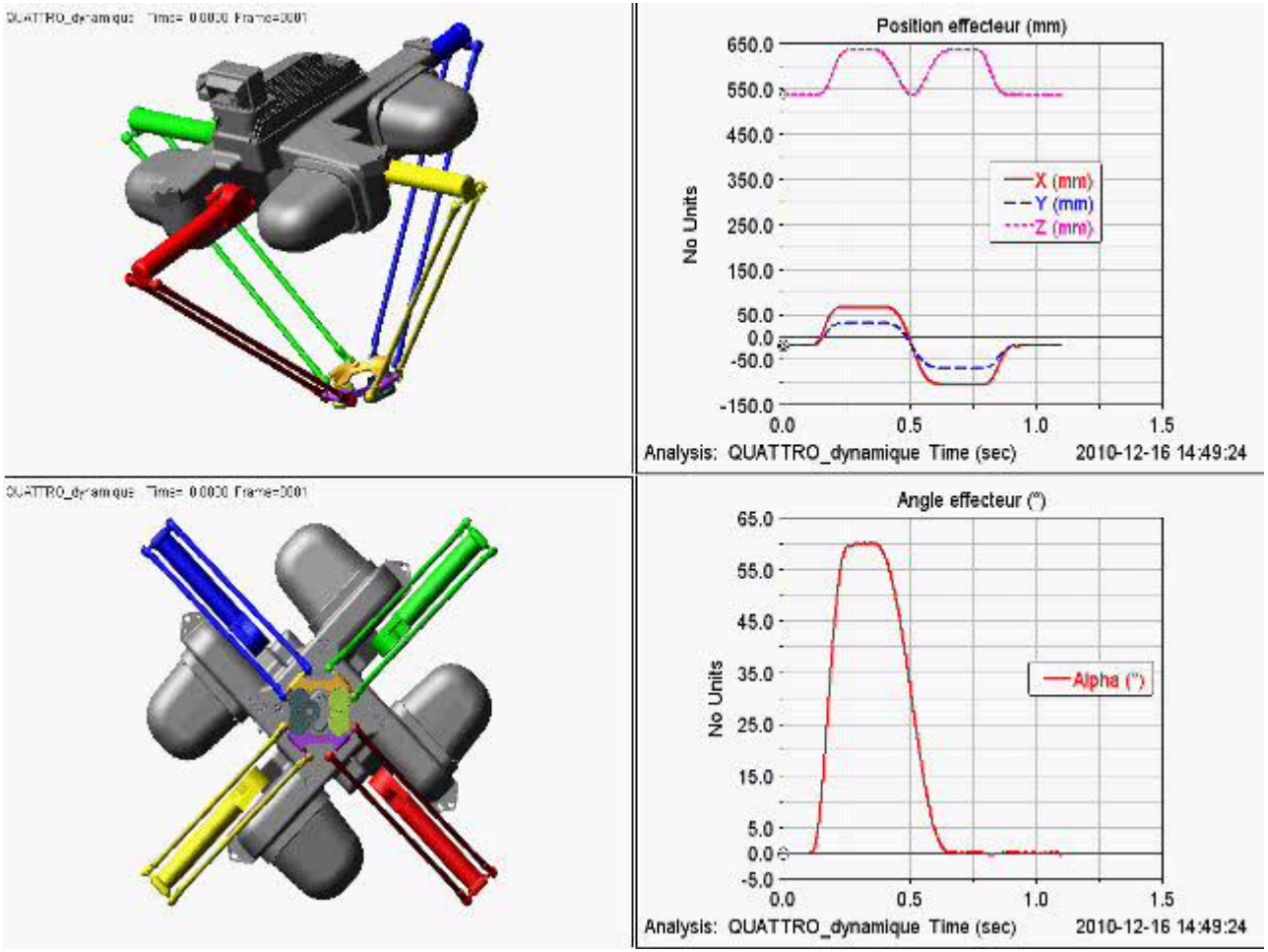
Vision Based Control PKM (3/5)

[Özgür10]

Adept Quattro 560

Vision based Modeling, Idenfication and control

- Dynamic control (using vision only)



Vision Based Control PKM (4/5)

T. Dallej Post Doc

[IROS12]

Vision based (moncular camera)

- End effector tracking
- control

ReelAx8: 3Dpose Vision Based Control

Collaboration with Tecnalia, INRIA and Lirmm

Vision Based Control PKM (5/5)

T. Dallej Post Doc

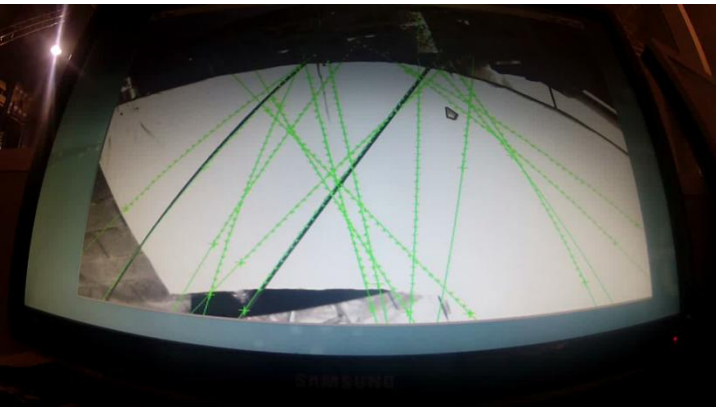
[IROS12]

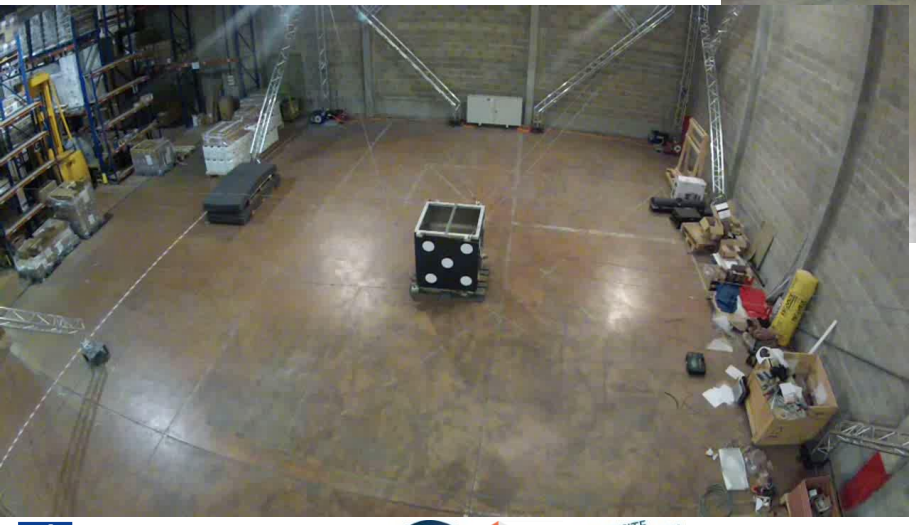
Vision based (multi camera system)

- End effector and cable tracking
- control

COGIRO: 3Dpose Vision Based Control

Collaboration with Tecnalia, Lirmm, INRIA





Vision Based Control PKM (5/5)

T. Dallej Post Doc

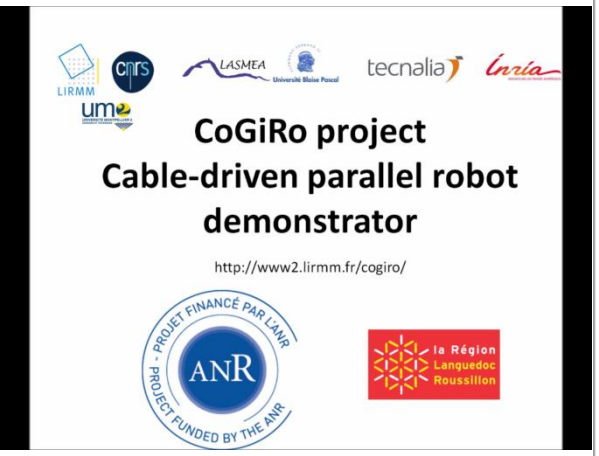
[IROS12]

Vision based (multi camera system)

- End effector and cable tracking
- control

COGIRO: 3Dpose Vision Based Control

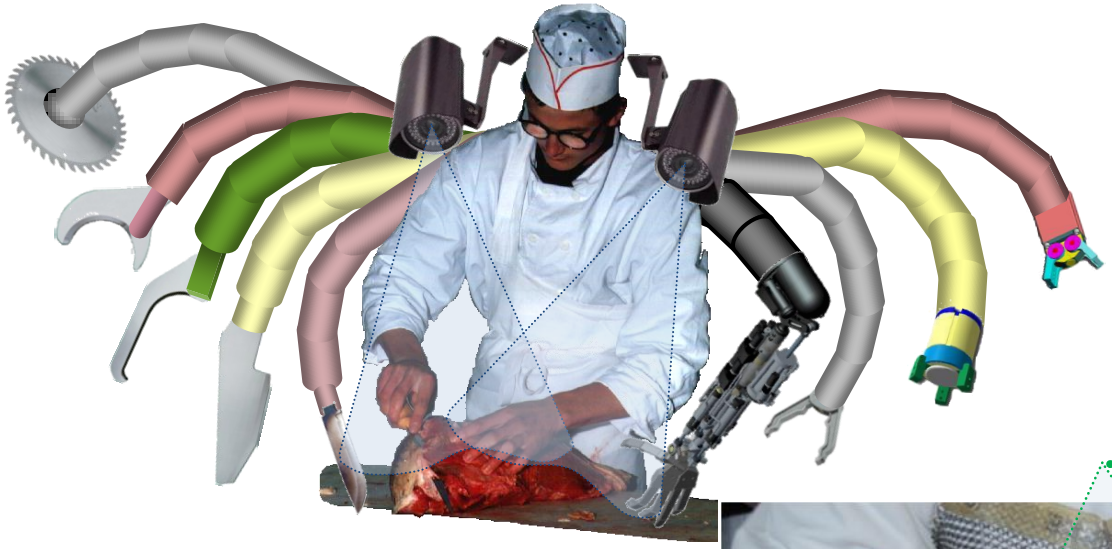
Collaboration with Tecnalia, Lirmm, INRIA

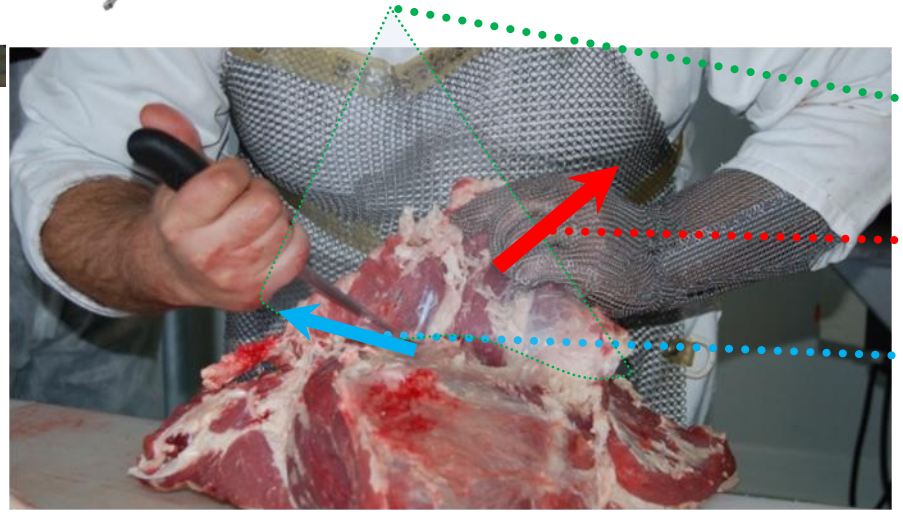


Multi-arms modeling and control

P. Long Master and PhD thesis (ANR ARMS Project) (1/3)

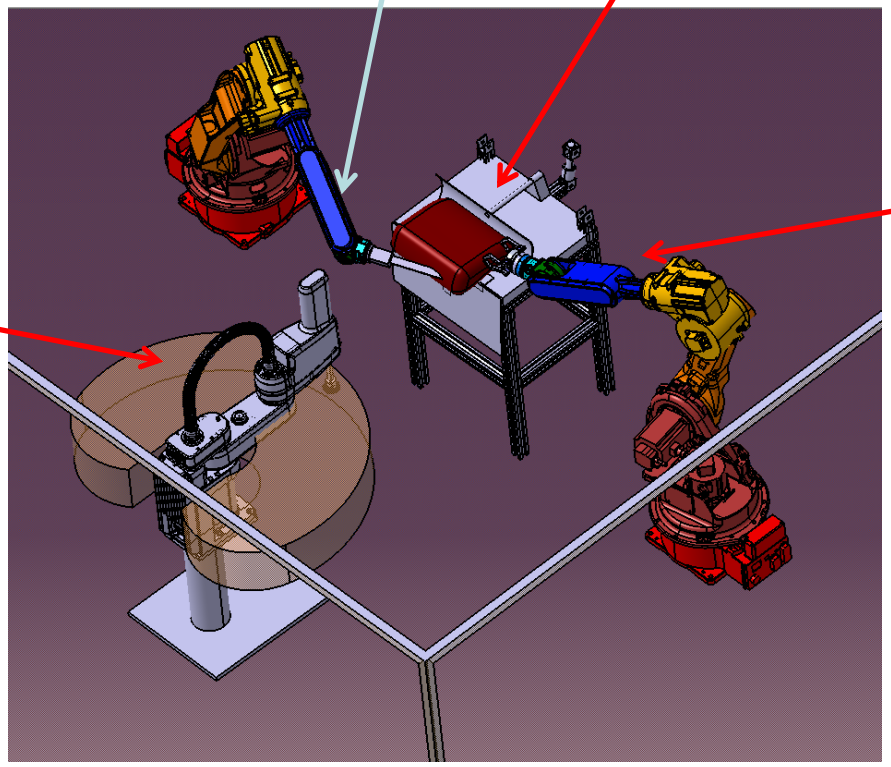
ARMS: Multi Arms System for Muscle Separation





http://arms.irccyn.ec-nantes.fr

ARMS: Multi Arms System for Muscle Separation



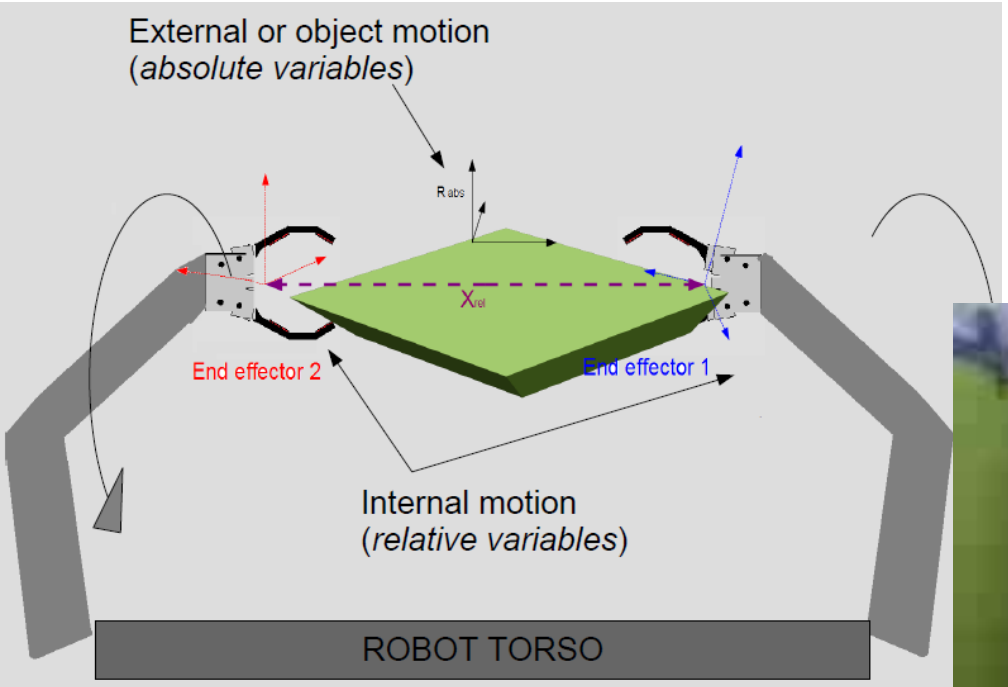
http://arms.irccyn.ec-nantes.fr

Multi-arms modeling and control

P. Long Master and PhD thesis (3/3)

[ICINCO12, SYROCO12]

ARMS: Multi Arms System for Muscle Separation

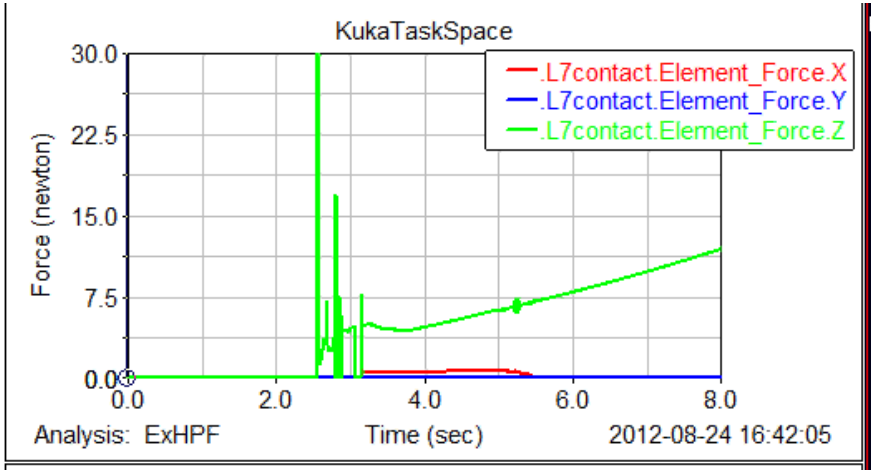


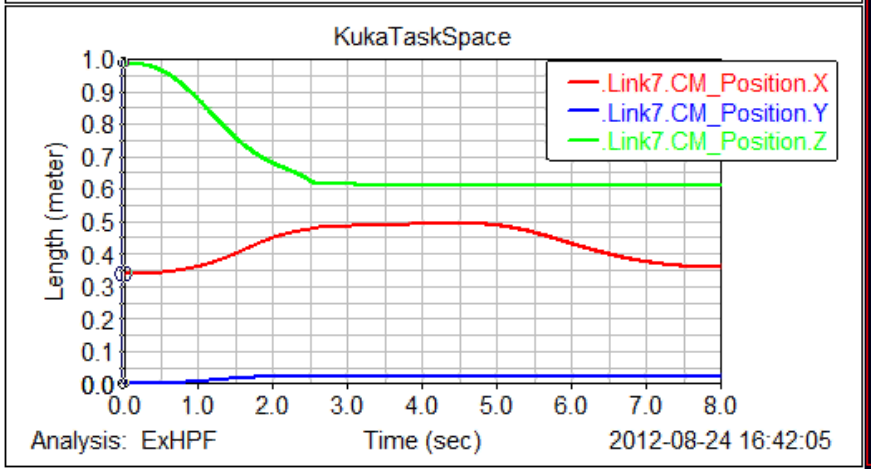
Closed loop formulation of robot arms and object

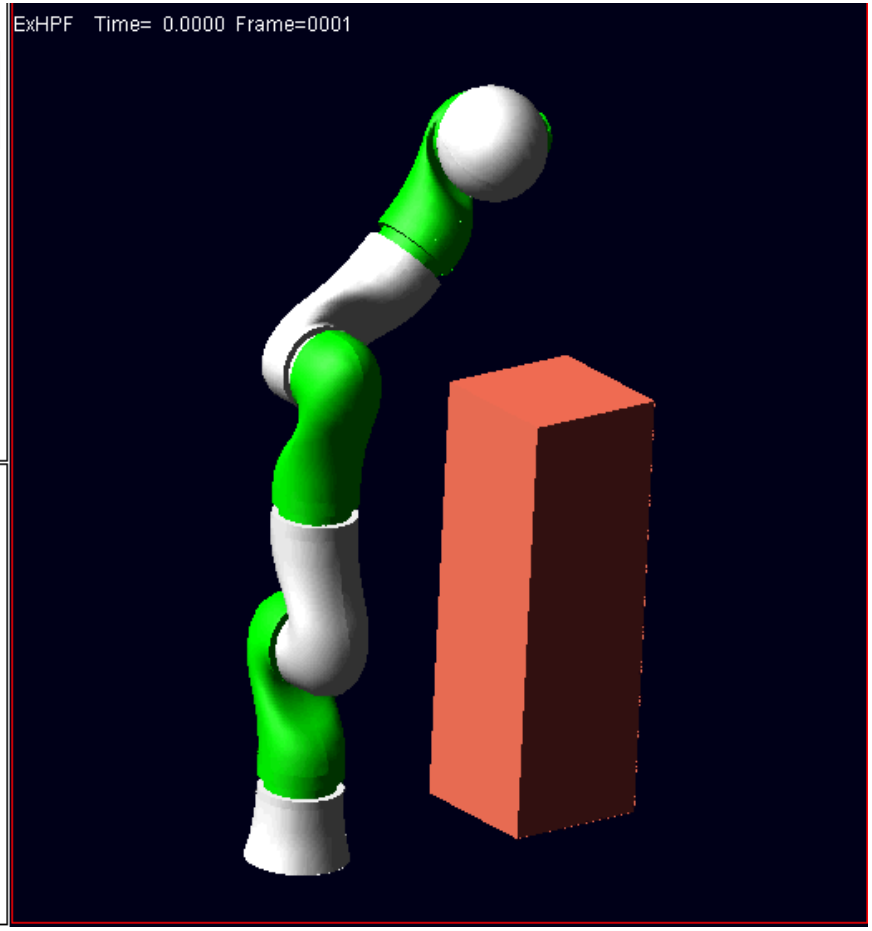
1. Model of robot as closed chain
2. Analysis of the degrees of freedom of the object
3. Analysis of the singularities of the system
4. Derivation of a new Jacobian matrix
5. Derivation of the closed loop direct dynamic model

Vision/Force coupling (1/2)

ARMS: Multi Arms System for Muscle Separation



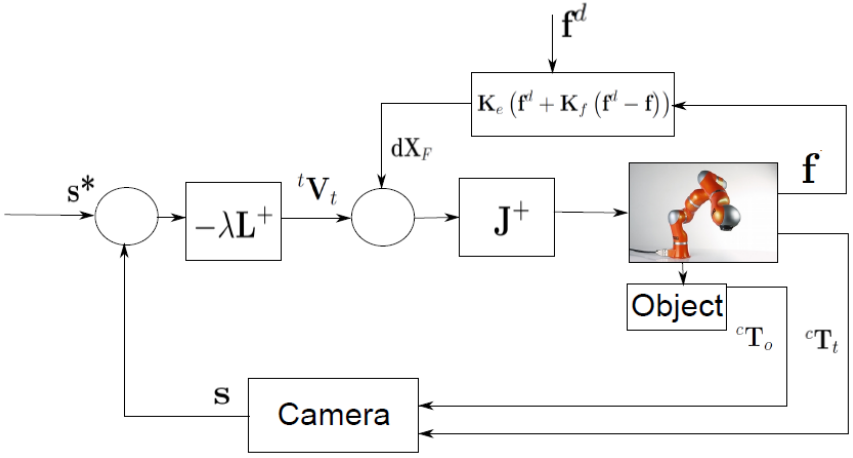




External Hybrid control (Matlab/simulink/ADAMS**)**

Vision/Force coupling (1/2)

ARMS: Multi Arms System for Muscle Separation



External Hybrid control using Kuka ARMS
(Force sensor in wrist, Eye to hand configuration)

Vision/Force coupling (2/2)

S. Vandernotte PhD thesis

ASIMOV: Assistant for Industrial structure and Systems and Manufacturing Optimization Value

EADS, AIRBUS, CEA, BA Systems, IRCCYN

- **Multisensor based navigation in cluttered environment**

- **Vision/force/tactile coupling for precise and adaptive manipulation**

Vision Based Control MB (1/1)

Vision based topological navigation
- using fisheye camera
- using visual memory

Platoon navigation
- using RTK GPS sensor (and Vision)
- online trajectory registering

Vision Based Control MB (1/1)

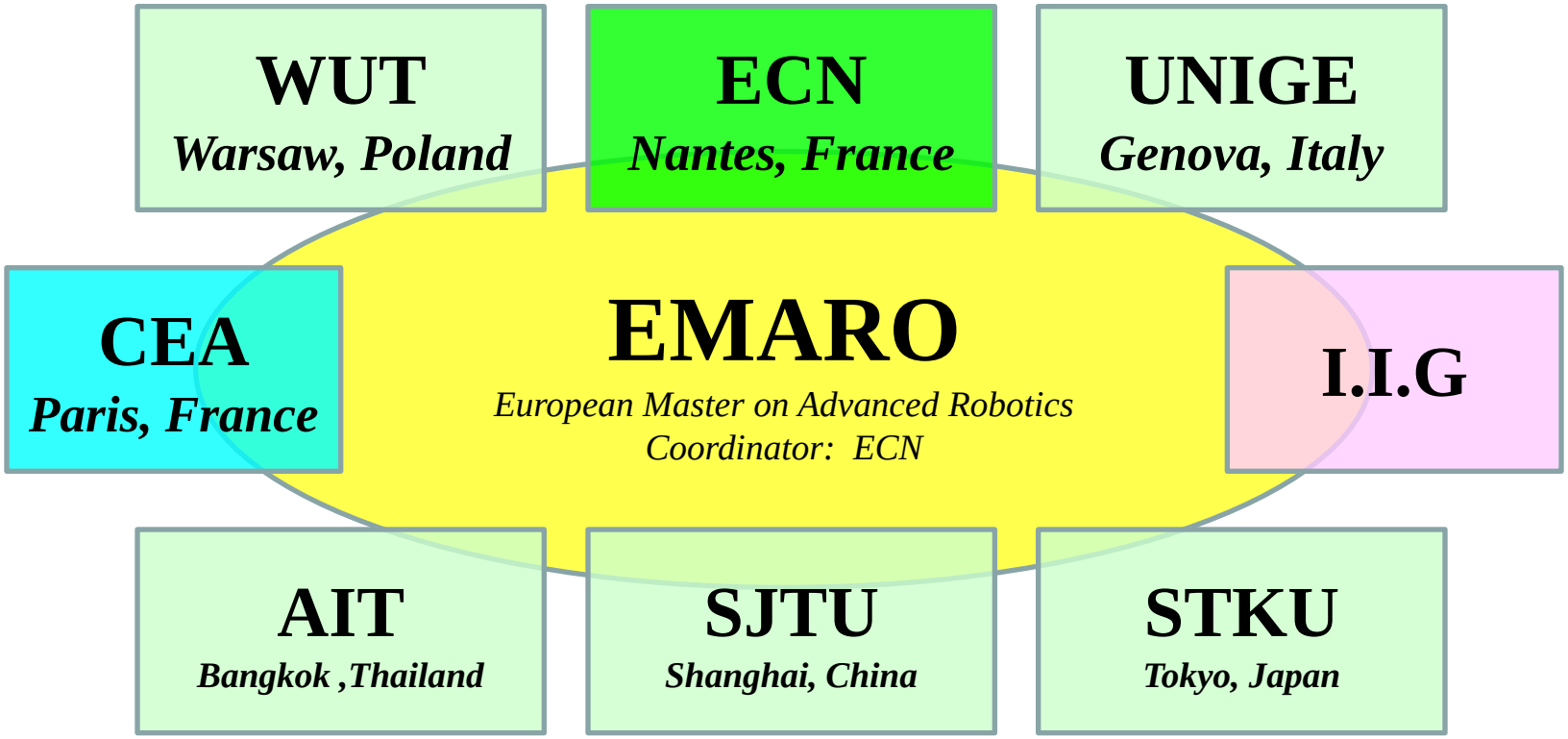
Vision based topological navigation .

- using low cost camera
- using fisheye camera
- using visual memory
- Ground truth using RTK GPS sensor

Content

- ✓IRCCyN
- ✓Robotics Team
- ✓Recent results
- ✓EMARO

Consortium in 2012



http://emaro.irccyn.ec-nantes.fr/

EMARO: International Master on Advanced Robotics

MASTER tracks strategies

Track 1: Typical EMARO Curriculum

M1-E1 → M2-E2 → Master EMARO

S4-ASIA
S4-IIG

M1: 1st year
M2: 2nd year
S4: 4th semester

ASIA
AIT, SJTU, STKU

E1,E2
ECN, UNIGE, WUT

Track 2: Typical local Master Curriculum

M1-E1 → M2-E1 → Master E1

M1: 1st year
M2: 2nd year

Track 3: Double & Joint degree with Asian Partners within EMARO

M1-E1 → M2-SJTU
M1-SJTU → M2-E1
→ ***S5 SJTU or E1*** → Double degree E1-SJTU

M1-E1 → M2-STKU
M1-STKU → M2-E1
→ Joint degree E1-STKU

M1-E1 → M2-AIT
M1-AIT → M2-E1
→ Double degree E1-AIT

E1
ECN, UNIGE, WUT

http://emaro.irccyn.e

Centrale Nantes

Conclusion

Any questions

http://www.irccyn.ec-nantes.fr/~martinet

Philippe.Martinet@irccyn.ec-nantes.fr