STIC-ASIA ICT-PAMM Workshop

September 19-20th, 2013, Hanoi, Vietnam

ANNÉE FRANCE VIETNAM 2013 — NĂM VIỆT NAM PHÁP 2014

Control of Redundancy in complex systems from theoretical concepts to applications

Authors ***P. Martinet****, A. Abou Moughlbay, P. Long*

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350km south-west of Paris

Content

- ✓**IRCCyN**
- ✓**Robotics Team**
- ✓**Presentation**
- ✓**EMARO**

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The **IRCCyN**, « Institut de Recherche en Communications et Cybernétique de Nantes » is a **Joint Research Unit, UMR CNRS 6597** (UMR, stands for « Unité Mixte de Recherche ») which has been recognized and granted by the **CNRS (Centre National de la Recherche Scientifique)** for **45 years**.

IRCCyN kept its **A+** notation from the AERES (national agency).

The local administrations of IRCCyN are: « **Ecole Centrale de Nantes** », « **Université de Nantes** » and « **Ecole des Mines de Nantes** », all members of the **PRES L'UNAM** (« Pôle de Recherche et d'Enseignement Supérieur Nantes, Angers, Le Mans »).

The institute presently gathers more than **260 members**: about 100 permanent researchers, 17 permanent administrative and technical staff, more than 100 PhD students, between 5 and 10 Post-Docs, and about 35 researchers or engineers with temporary contracts.

Thanks to various supports, several positions are also regularly opened for welcoming visiting professors, researchers, and students.

IRCCyN is installed, with offices and **technical platforms**, on several campus of the city of Nantes, in close connection with the three local higher education and research institutions. The **main building** is **hosted by Ecole Centrale de Nantes**, with offices for about 160 persons, a large laboratory for experiments, an auditorium and several meeting rooms.




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The **research** performed in IRCCyN is not only of **fundamental** type with main objective to create new knowledge; indeed the institute also keeps a deep involvement in **technological** issues: methods and tools are, and have been for years, developed to bring solutions to **practical** problems raised by industrial or social entities. This nicely covers both “top down” and “bottom up” processes, and offers opportunities for real applications of academic works and for the emergence of hard technical issues which open new and challenging research directions.

The scientific production in those various fields finds its expression in books, journals, and international conferences, as well as in patents, or software licences. In 2009, IRCCyN got the national price “Trophées de l’Innovation” given by INPI (National Institute for Industrial Property). Some researchers also contributed to the creation of several Start-ups.

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The scientific domains which are tackled within our **11 research teams** cover a rather wide thematic spectrum, including:

- **control** of complex systems
- **signal and image processing**
- video **communication** and handwriting recognition
- **robotics** and mechanical systems with joints
- computer aided **mechanical design**
- customer driven design
- modelling and **optimisation of production processes**
- **virtual engineering** for the improvement of industrial performance
- **real time systems**
- modelling and checking for **embedded systems**
- **bio-informatics**
- **logistics and production systems**
- discrete events and **hybrid systems**
- **cognitive psychology and ergonomics**.

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IRCCyN has got a longstanding tradition for industrial partnerships. Contracts are presently active with: AEROFORME, AIRBUS, AKER YARDS, AYRTON, BESNE, CEA, CGE, COURANT, DASSAULT, EDF, FAMAT, FRANCE TELECOM, HALGAND, JALLAIS, KEOSYS, MNM, PSA, RENAULT, SIREHNA, SITIA, SNCF, SYSTEM+, TDF, THALES, THOMSON, TMG, VITEC, …

Through most of its research teams, IRCCyN is member of **several European Consortia and Networks**, as well as **national projects** regularly selected and **granted by ANR** (“Agence Nationale pour la Recherche”). The institute is also involved, as an academic partner, in 10 French **“Pôles de Compétitivité”** (among which «Solutions Communicantes Sécurisées», «System@tic Paris Région», «Images & Réseaux», «Mov’eo», «iDforCAR », and «EMC2».

IRCCyN is involved in national highly competitive projects among which: **ROBOTEX** (Platform for Excellence in Robotics) and **IRT Jules Verne** (Technological Research Institute)

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IRCCyN is also engaged in a large number of international bilateral cooperation actions, in particular with Mexico, Czech Republic, China, Korea, Poland, Italy, South Africa, Malaysia, Unites States of America, Russia, Spain, …

Finally, as concerns research training, IRCCyN welcomes an important number of **Master and PhD students**, most of them registered locally in the partner institutions, university or engineering schools. IRCCyN plays a key role in three doctoral schools, two in Nantes: STIM **in Information Technologies** ("Sciences et Technologies de l'Information et de Mathématique", and SPIGA in **Mechanical Sciences** ("Sciences pour l'Ingénieur, Géosciences, Architecture »", and one in Rennes: SHS in **Human and Social Sciences** ("Sciences Humaines et Sociales").

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

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ROBOTICS research team

Leader : Philippe Wenger

IRCCYN - CNRS/ECN

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

September 2013

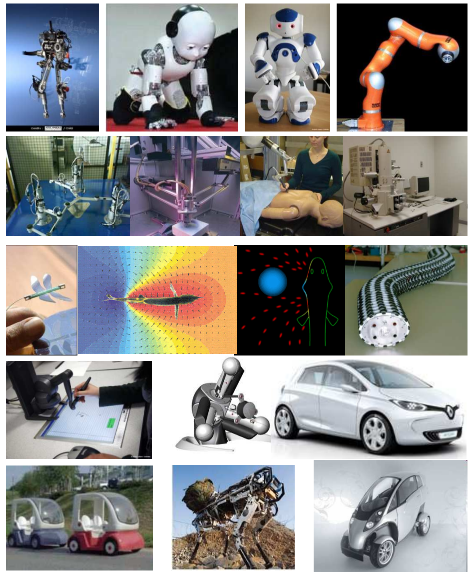
Philippe Martinet

Robotics Team at IRCCYN

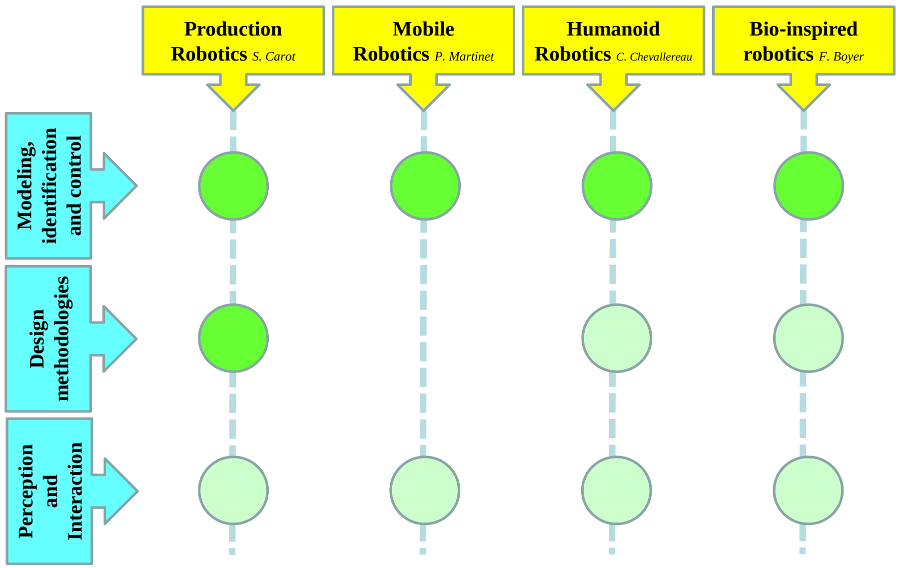
- Head: P. Wenger

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 organization



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Content of presentation

Introduction

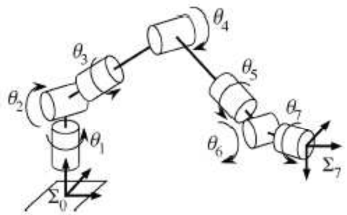
Theoretical concepts

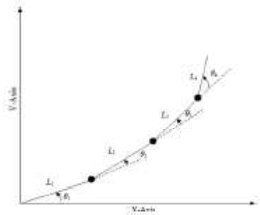
Some applications

Conclusion

Redundancy

1. Robotic System
   - Kinematic Redundancy [Nak90]

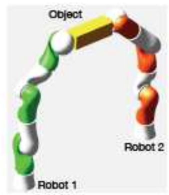


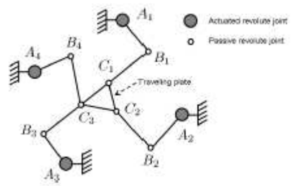


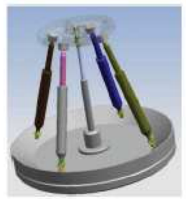
   - Actuation Redundancy
2. Task Redundancy
3. Sensor Redundancy

Redundancy

1. Robotic System
   - Kinematic Redundancy
   - Actuation Redundancy [BH95]



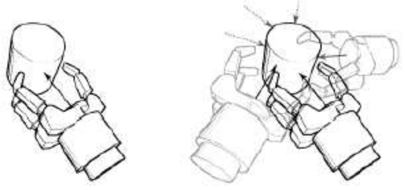


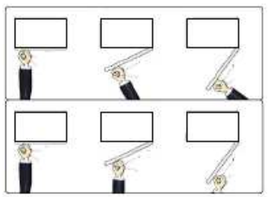


2. Task Redundancy
3. Sensor Redundancy

Redundancy

1. Robotic System
   - Kinematic Redundancy
   - Actuation Redundancy
2. Task Redundancy [PSdP10]

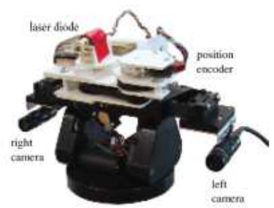


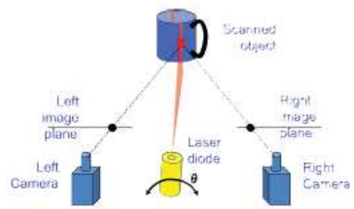


3. Sensor Redundancy

Redundancy

1. Robotic System
   - Kinematic Redundancy
   - Actuation Redundancy
2. Task Redundancy
3. Sensor Redundancy [CKP+10]





Benefit from robotic system's redundancy to execute several service tasks simultaneously

Classic Approaches

- Simple robotic systems to execute well-defined tasks
- Robot's reconfiguration for task sequencing
- Use of optimization to execute simultaneous tasks

Objectives

- Global formalism to control all robotic platforms
- Redundancy identification and resolution
- Development of a global control law for tasks execution

Methodology

Multi Control Points Approach

- Control points definition
- Generic tasks/constraints
- Use of sensors' data
- Global control law
  - Redundancy resolution
  - Task sequencing

Applications

→ Multi-arm, humanoids and single manipulator platforms

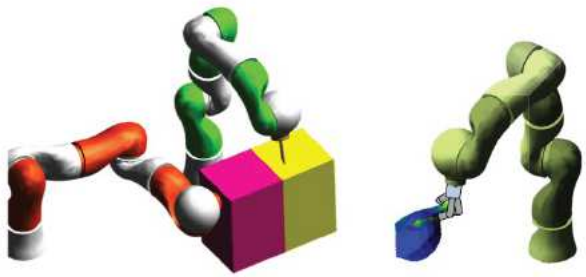
→ Equilibrium, localization, grasping, tracking ...

→ Encoders, vision, odometry, force sensors ...

→ Service and assistive robotic scenarios

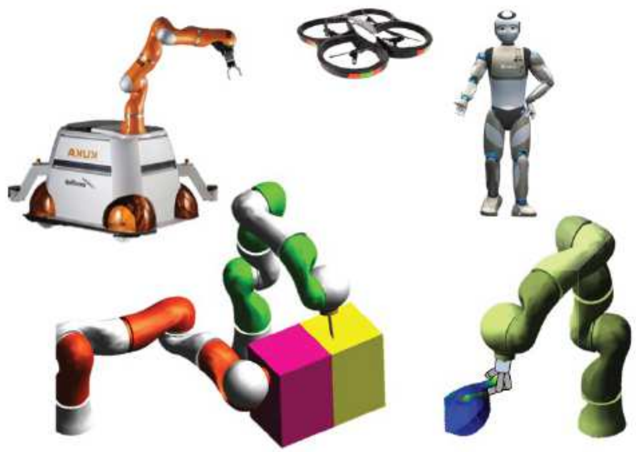
Multi control point approach

1. Generic Approach



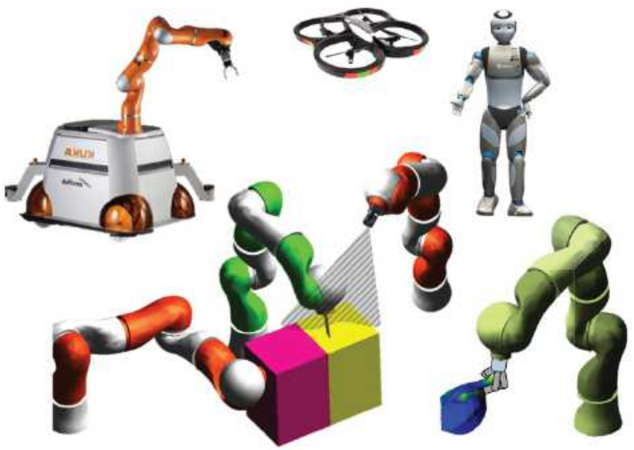
Multi control point approach

1. Generic Approach



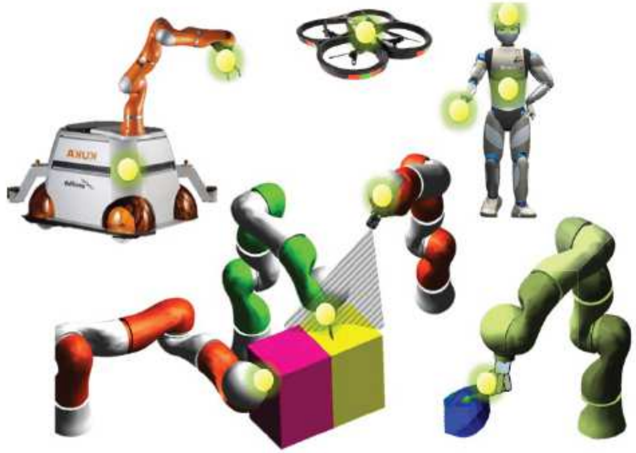
Multi control point approach

1. Generic Approach
2. Embedded and external sensors



Multi control point approach

1. Generic Approach
2. Embedded and external sensors
3. Control points definition



Multi control point approach

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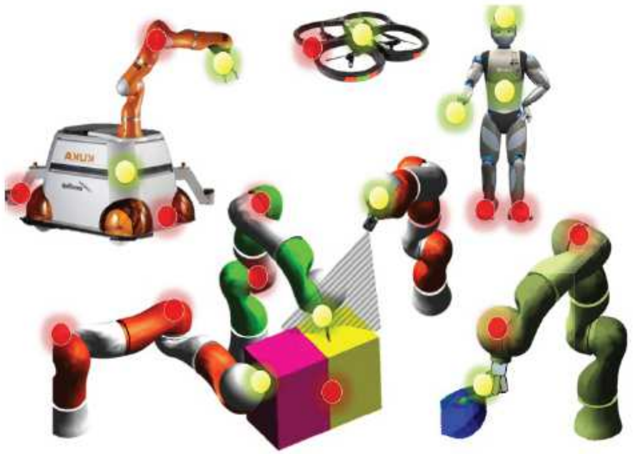
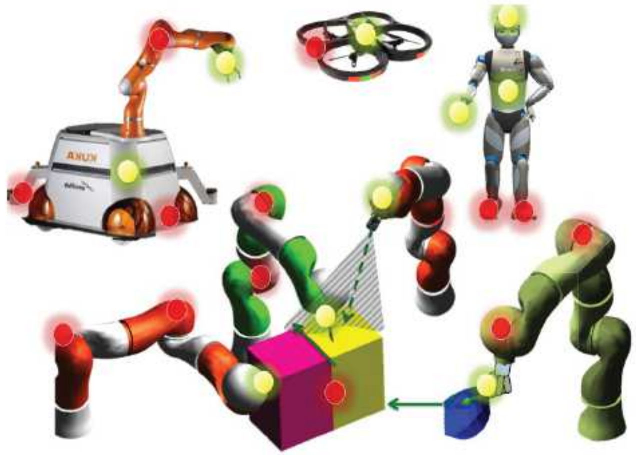


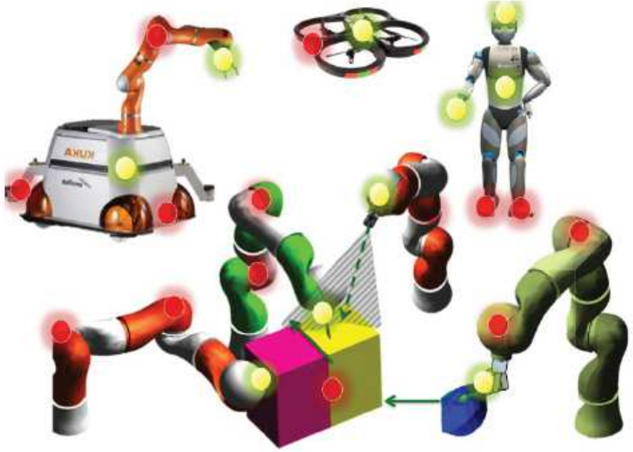
Multi control point approach

1. Generic Approach
2. Embedded and external sensors
3. Control points definition
4. Task definition
5. Constraint definition



Multi control point approach

1. Generic Approach
2. Embedded and external sensors
3. Control points definition
4. Task definition
5. Constraint definition
6. Redundancy identification
7. Global control law



Task/constraint definition

Kinematic Task Definition

$$\dot{\mathbf{q}} = -\lambda \left(\mathbf{L_s}\ {}^{s}\mathbf{W}_{cp}\ {}^{cp}\mathbf{J_q}\right)^{+} (\mathbf{s} - \mathbf{s}^*)$$

- Positioning task
- Target following
- Cooperative task
- Visibility task

- Joint Limits Avoidance

$$\mathbf{H(q)} = \frac{1}{2}\sum_{i=1}^{N}\left(\frac{q_i - q_{i,mid}}{q_{i,max} - q_{i,min}}\right)^2$$

- Collision Avoidance

$$\mathbf{C(q)} = \begin{cases} \sum_{i\in C_p} (\delta_i(q) - a_i)^2 & \text{if } \delta_i(q) < a_i \\ 0 & \text{otherwise} \end{cases}$$

- Occlusion Avoidance

$$g_s = -(L_s W J_q)^{+} \begin{pmatrix} -2\beta d_x e^{-\beta d^2} \\ -2\beta d_y e^{-\beta d^2} \end{pmatrix}$$

- Performance indices

Singularity parameter: $W_{ps} = \sqrt{\frac{1}{\sigma_2 \ldots \sigma_m^2}}$

Kinetic Energy: $E_c = \sum_{i=1}^{n} \frac{1}{2}\, \dot{\mathbf{q}}_i^{\top}\, \dot{\mathbf{q}}_i$

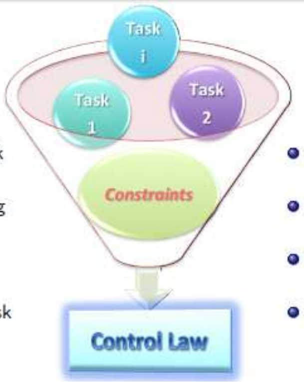
Task sequencing

The Goal

Define a control law and a task sequencing formalism to execute several prioritized tasks by the redundant system

Generic Tasks

- Positioning task
- Target following
- Visibility task
- Cooperative task



Constraints

- Joint Limits Avoidance
- Collision Avoidance
- Occlusion Avoidance
- Optimizing performance indices

Task sequencing and redundancy resolution

The Goal

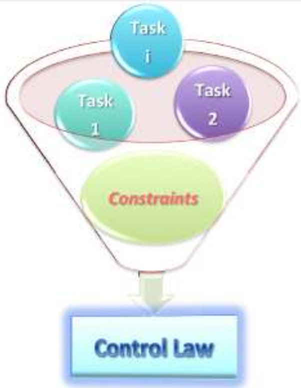
Define a control law and a task sequencing formalism to execute several prioritized tasks by the redundant system

Kinematic Control Law

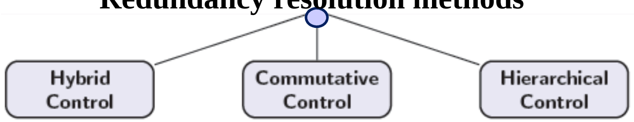
$$\dot{\mathbf{q}} = -\lambda \left(\mathbf{L_s}\ {}^{s}\mathbf{W}_{cp}\ {}^{cp}\mathbf{J_q}\right)^{+} (\mathbf{s} - \mathbf{s}^*)$$

Task Definition:

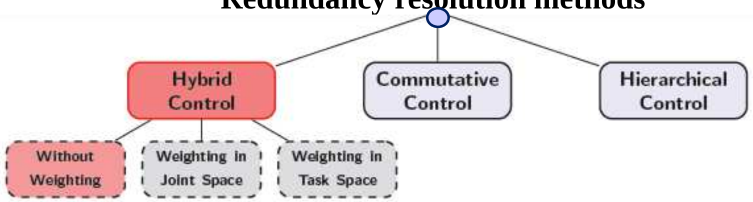
$$\mathbf{e_i} = \mathbf{s_i} - \mathbf{s_i^*} \longrightarrow (\dot{\mathbf{e}}_i,\ \mathbf{J_i})$$



Redundancy resolution methods



Redundancy resolution methods

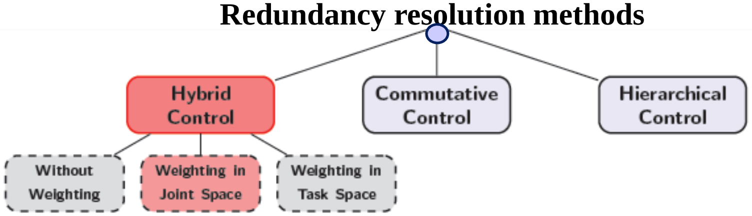


Control Law

$$\dot{\mathbf{q}} = \mathbf{J}_s^+ \,\dot{\mathbf{e}} \quad \text{with} \quad \mathbf{J}_s = \begin{bmatrix} \mathbf{J}_1 \\ \mathbf{J}_2 \\ \vdots \\ \mathbf{J}_k \end{bmatrix}$$

- Use of augmented Jacobian only
- No hierarchy between tasks
- **Application:**
  - Hybrid visual servoing scheme with 2D and 3D data [MLS+00]

Redundancy resolution methods



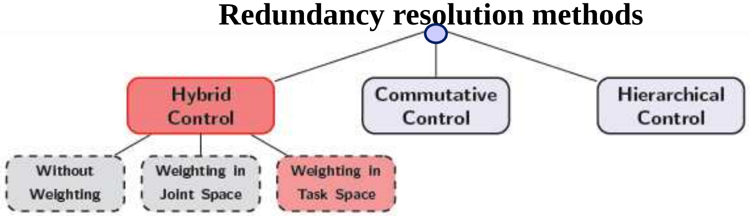
Control Law

$$\dot{\mathbf{q}} = \mathbf{W}\,(\mathbf{J}_s\,\mathbf{W})^+ \dot{\mathbf{e}}$$

Application:

- Performance of an end-effector trajectory, obstacle avoidance and joint limits avoidance [XZW10]

Redundancy resolution methods



Control Law

$$\dot{\mathbf{q}} = (\mathbf{H}\,\mathbf{J}_s)^+\,\mathbf{H}\,\dot{\mathbf{e}}$$

- **Constant** ⟶ Fixed value on each sensor [SG07]
- **Dynamic** ⟶ Use inertia matrix to minimize E_c [Kha87]
- **Experimental** ⟶ Use LQ to minimize some criteria [PNK92]
- **Variable** ⟶ Control tasks/constraints priority [KC11]

Redundancy resolution methods

Hybrid Control | **Commutative Control** | Hierarchical Control

Control Law

$$\dot{\mathbf{q}} = \begin{cases} \dot{\mathbf{q}}_1 & \textit{if} \quad \textit{Condition } 1 \\ \dot{\mathbf{q}}_2 & \textit{if} \quad \textit{Condition } 2 \\ \vdots & \end{cases}$$

- No simultaneous task execution
- No hierarchy or coupling between tasks
- Simple approach but complicated transitions
- **Application:**
  - Switch between visibility & obstacle avoidance [CSC11]
  - Switch between target following & collision avoidance [Ben11]

Redundancy resolution methods

Hybrid Control | Commutative Control | **Hierarchical Control**

Orthogonal Projection | Directional Projection | Norm Projection

Control Law

$$\dot{\mathbf{q}} = \dot{\mathbf{q}}_1 + \mathbf{P}_e\, \mathbf{z}$$

- $\mathbf{P}_e = \left(\mathbf{I} - \mathbf{J}_1^+ \mathbf{J}_1\right)$ [Lie77]
- Lyapunov stability function: $\mathcal{L}_{(\mathbf{P}_e)} = \|\mathbf{e}\|^2$
- Stability condition: $\dot{\mathcal{L}}_{(\mathbf{P}_e)} = -\lambda \|\mathbf{e}\|^2 < 0$

Redundancy resolution methods

Hybrid Control | Commutative Control | **Hierarchical Control**

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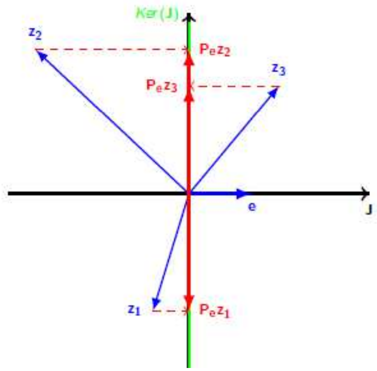

Control Law

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Redundancy resolution methods

Hybrid Control | Commutative Control | **Hierarchical Control**

Orthogonal Projection | **Directional Projection** | Norm Projection

Goal

Enable the secondary task motions that achieve a faster completion of the main task

Control Law

$$\dot{\mathbf{q}} = \dot{\mathbf{q}}_1 + \mathbf{P}_z\, \mathbf{z}$$

- Non-linear projector $\mathbf{P}_z$ to enlarge the projection free space [MC09]
- Lyapunov stability proof: $\dot{\mathcal{L}}_{(\mathbf{P}_z)} < \dot{\mathcal{L}}_{(\mathbf{P}_e)}$

Redundancy resolution methods

Hybrid Control | Commutative Control | **Hierarchical Control**

Orthogonal Projection | **Directional Projection** | Norm Projection

Directional Control Law

$\mathbf{P_z} = \mathbf{V}\tilde{\mathbf{P}}_{\mathbf{z}}\mathbf{V}^T$ such as $\mathbf{J} = \mathbf{U}\mathbf{\Sigma}\mathbf{V}^T$

$$\tilde{\mathbf{P}}_{\tilde{\mathbf{z}}} = \begin{bmatrix} p_1(\tilde{\mathbf{z}}) & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & p_n(\tilde{\mathbf{z}}) \end{bmatrix}$$

$$p_i = \begin{cases} 1 & \text{if} \quad i > m \text{ or } \tilde{z}_i = 0 \\ 1 & \text{if} \quad (\tilde{z}_i) \times (\tilde{v}_i) < 0 \\ 0 & \text{if} \quad (\tilde{z}_i) \times (\tilde{v}_i) > 0 \end{cases}$$

with $m = rank(\mathbf{J})$, $\tilde{\mathbf{z}} = \mathbf{Vz}$ and $\mathbf{\Sigma} = diag(\sigma_i)$

Redundancy resolution methods

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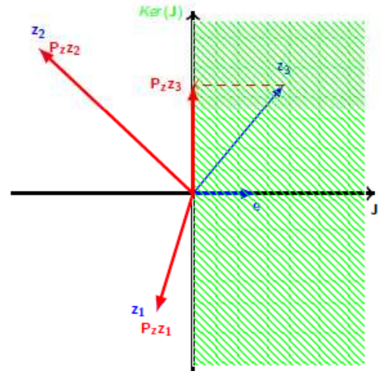

Directional Control Law

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Redundancy resolution methods

Hybrid Control | Commutative Control | **Hierarchical Control**

Orthogonal Projection | Directional Projection | **Norm Projection**

General Idea

Build a projection operator with an exponential decrease of the error: $\dot{\eta} = -\lambda\eta$.

where $\eta = \|\mathbf{e}\|^{\gamma}$ and $\gamma \in \mathbb{R} - \{0\}$

[MC10]

Control Law

$$\dot{\mathbf{q}}_{\eta} = -\lambda\|\mathbf{e}\|^{\gamma}\,\mathbf{J}_{\eta}^{+} + \mathbf{P}_{\eta}\,\mathbf{z}$$

where $\mathbf{P}_{\eta} = \mathbf{I}_{\eta} - \mathbf{J}_{\eta}^{+}\mathbf{J}_{\eta}$

$\mathbf{J}_{\eta} = \gamma\|\mathbf{e}\|^{\gamma-2}\mathbf{e}^T\mathbf{J}_e \in \mathbb{R}^{1\times n}$ at most of rank 1.

$$\mathbf{J}_{\eta}^{+} = \frac{1}{\gamma\|\mathbf{e}\|^{\gamma-2}(\mathbf{e}^T\mathbf{J}_e\mathbf{J}_e^T\mathbf{e})}\mathbf{J}_e^T\mathbf{e}$$

$$\mathbf{P}_{\eta} = \mathbf{P}_{\|\mathbf{e}\|} = \mathbf{I}_n - \frac{1}{\mathbf{e}^T\mathbf{J}_e\mathbf{J}_e^T\mathbf{e}}\mathbf{J}_e^T\mathbf{e}\mathbf{e}^T\mathbf{J}_e$$

Redundancy resolution methods

Hybrid Control | Commutative Control | **Hierarchical Control**

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Stability problem

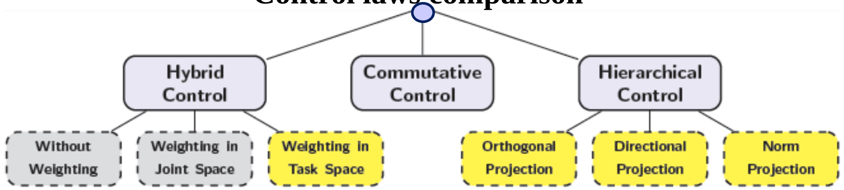
Due to singularity of $\mathbf{J}_{\|\mathbf{e}\|}$ when $\mathbf{e} \to 0$.

Switching between $\mathbf{P}_{\eta}$ and $\mathbf{P}_e$ to ensure convergence

$$\mathbf{P}_{\lambda} = \bar{\lambda}(\|\mathbf{e}\|)\,\mathbf{P}_{\|\mathbf{e}\|} + \left(1 - \bar{\lambda}(\|\mathbf{e}\|)\right)\mathbf{P}_e \quad \text{with } \bar{\lambda} = \begin{cases} 1 & \text{if} \quad e_1 < \|\mathbf{e}\| \\ \frac{\lambda(\|\mathbf{e}\|)-\lambda_0}{\lambda_1-\lambda_0} & \text{if} \quad e_0 \le \|\mathbf{e}\| \le e_1 \\ 0 & \text{if} \quad \|\mathbf{e}\| < e_0 \end{cases}$$

such that $\lambda(\|\mathbf{e}\|) = \frac{1}{1+\exp\left(-12\frac{\|\mathbf{e}\|-e_0}{e_1-e_0}+6\right)}$, $\lambda_0 = \lambda(e_0) \approx 0$ and $\lambda_1 = \lambda(e_1) \approx 1$.

Control laws comparison



Tasks definition:
- $T_1 \rightarrow$ EF's position and orientation
- $T_2 \rightarrow$ Interm. point's position

System-Application relation:
- Indeterminate
- Over-specified

Robot's choice:
- Planar Robots (7R, 5R, 4R)
- LWR Kuka Robot

Comparison Criteria
- Trajectory
- Error variation
- Projector's rank
- Convergence time
- Singularity index
- Kinetic energy
- Parameter tuning
- Unreachable task
- Incompatible tasks

Comparison results

	Orthogonal Projection	Directional Projection	Norm Projection	Hybrid Control
Projector's rank	Fixed	Variable	Variable	Variable
Convergence time	Acceptable	Unacceptable	Acceptable	Acceptable
Parameter tuning	Easy	Hard	Average	Hard
Unreachable task	Bad	Good	Bad	Average
Incompatible tasks	Bad	Good	Bad	Bad
Over-specified case	Good	Best	Good	Average
Joint velocity	Acceptable	Discontinuity	Acceptable	Acceptable

Unified projection operator Pw

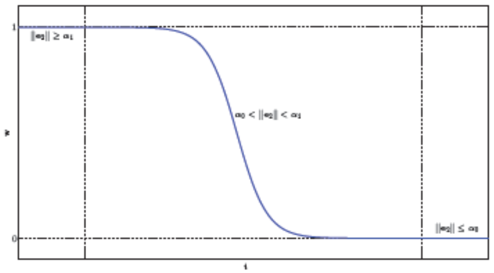
Problem
- Discontinuity in $\dot{\mathbf{q}}$
- No exact convergence of $\mathbf{z}$

Solution
- Benefit from advantages of $\mathbf{P_e}$ and $\mathbf{P_z}$
- Control the direction of the projection

Control Law

$$\dot{\mathbf{q}} = \dot{\mathbf{q}}_1 + \mathbf{P_w}\,\mathbf{z}$$

$$p_i = \begin{cases} 1 & if \quad i > m \text{ or } \tilde{z}_i = 0 \\ w & if \quad (\tilde{z}_i) \times (\tilde{v}_i \sigma_i) < 0 \\ 0 & if \quad (\tilde{z}_i) \times (\tilde{v}_i \sigma_i) > 0 \end{cases}$$



$$w = \begin{cases} 1 & \text{if} \quad \|e_2\| \geq \alpha_1 \\ \frac{1}{1+\exp\left(20\frac{\|e_2\|-\alpha_1}{\alpha_0-\alpha_1}-10\right)} & \text{if} \quad \alpha_0 < \|e_2\| < \alpha_1 \\ 0 & \text{if} \quad \|e_2\| \leq \alpha_0 \end{cases}$$

Unified projection operator P_w

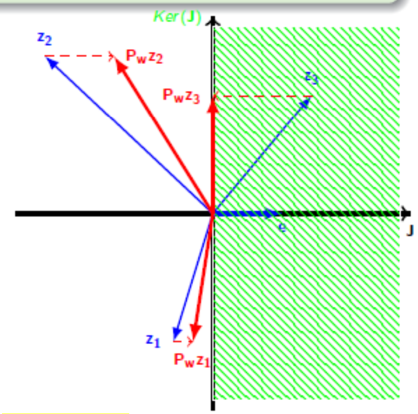
Problem
- Discontinuity in $\dot{\mathbf{q}}$
- No exact convergence of $\mathbf{z}$

Solution
- Benefit from advantages of $\mathbf{P_e}$ and $\mathbf{P_z}$
- Control the direction of the projection

Control Law

$$\dot{\mathbf{q}} = \dot{\mathbf{q}}_1 + \mathbf{P_w}\,\mathbf{z}$$

$$p_i = \begin{cases} 1 & if \quad i > m \text{ or } \tilde{z}_i = 0 \\ w & if \quad (\tilde{z}_i) \times (\tilde{v}_i \sigma_i) < 0 \\ 0 & if \quad (\tilde{z}_i) \times (\tilde{v}_i \sigma_i) > 0 \end{cases}$$



$$w = \begin{cases} 1 & \text{if} \quad \|e_2\| \geq \alpha_1 \\ \frac{1}{1+\exp\left(20\frac{\|e_2\|-\alpha_1}{\alpha_0-\alpha_1}-10\right)} & \text{if} \quad \alpha_0 < \|e_2\| < \alpha_1 \\ 0 & \text{if} \quad \|e_2\| \leq \alpha_0 \end{cases}$$

Generalized projection operator P_β

Problem
- Discontinuity due to SVD
- Discontinuity in $\dot{q}$
- No exact convergence of z

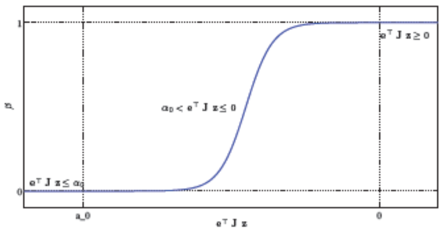
Solution
- Simple projection operator
- Exact regulation of the tasks
- Large stability condition: $\dot{\mathcal{L}}_{(P_\beta)} < \dot{\mathcal{L}}_{(P_e)}$

Control Law

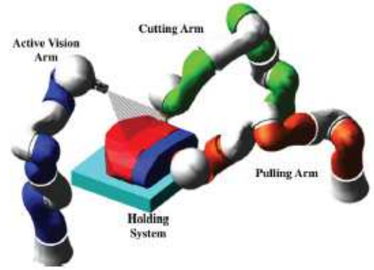
$$\begin{aligned}\dot{q} &= \dot{q}_1 + P_\beta\,\dot{q}_2\\ &= \dot{q}_1 + \left(I - \beta J_1^{+} J_1\right)\dot{q}_2\end{aligned}$$

Stability condition: $(1-\beta)\, e^\top J z \le 0$

$$\beta = \begin{cases} 0 & \text{if} \quad e^\top J z \le \alpha_0 \\ \dfrac{1}{1+\exp\left(-20\frac{\|e_2\|-a}{b-a}+10\right)} & \text{if} \quad \alpha_0 < e^\top J z < 0 \\ 1 & \text{if} \quad e^\top J z \ge 0 \end{cases}$$



Robotic and software platforms

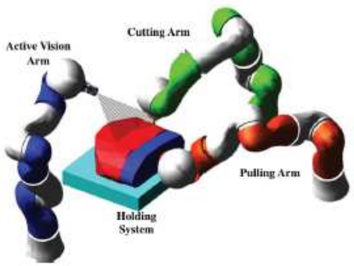


- Multi-arm robot
- 21 DOF
- 10 Control points
- Applied tasks:
  - Cutting/Pulling task
  - Visibility task
  - (Self) Collision avoidance
  - Occlusion avoidance

- HRP-2 Humanoid robot
- 30 DOF
- 6 Control points
- Applied tasks:
  - Equilibrium task
  - Grasping task
  - Head servoing task
  - Object tracking

- NAO Humanoid robot
- 25 DOF
- 3 Control points
- Applied tasks:
  - Localization task
  - Grasping task
  - Robot/Object tracking
  - Visibility task

Robotic and software platforms



External Sensors

Software Enviroments

OpenHRP3 Official Site

NAO DEVELOPER PROGRAM

ROS.org

VISP

ARMS project

ANR · Institut Pascal · ADIV viande performances · CLEMESSY · IRCCyN

Objective
- Conception of a multi-arm platform
- Meat cutting and muscle separation

ARMS project: Application scenario

Robotic Platform:

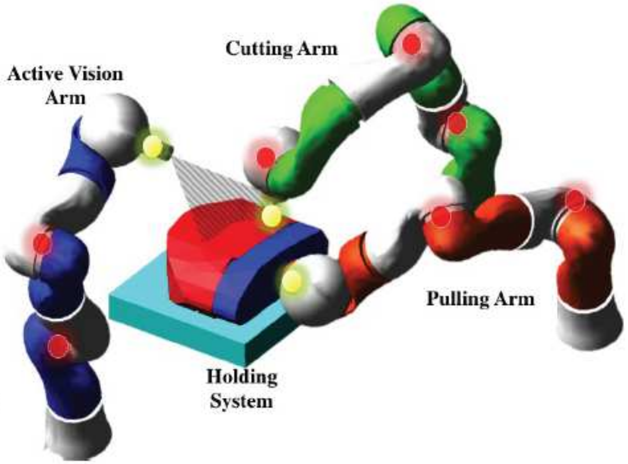
- Holding System
- Cutting arm (7 DOF)
- Pulling arm (7 DOF)
- Vision arm (7 DOF)

Task Definition:

- Cutting task
- Pulling task
- Visibility task

System's Constraints:

- Self collision
- EF and joints collision
- Occlusion avoidance
- Joint limits avoidance



ARMS project: Application scenario

21 DOF Robotic Platform

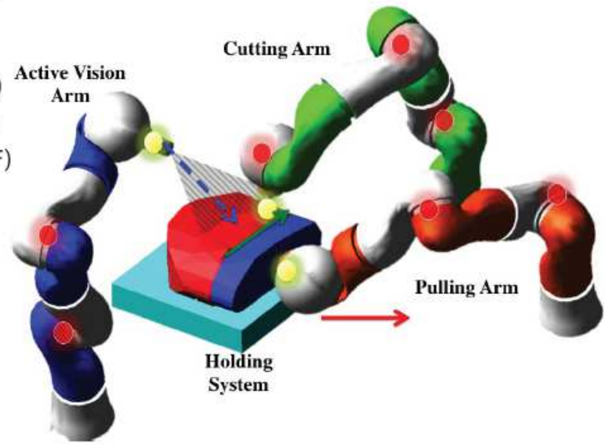
Primary Tasks:

- Cutting task (6 DOF)
- Pulling task (6 DOF)
- Visibility task (4 DOF)

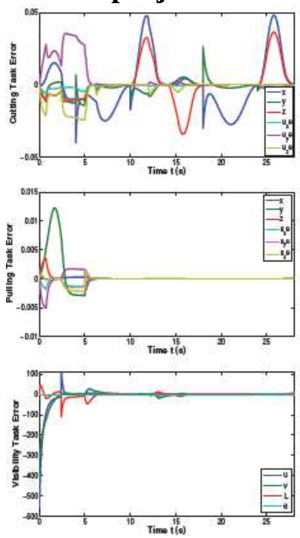
System's Constraints:

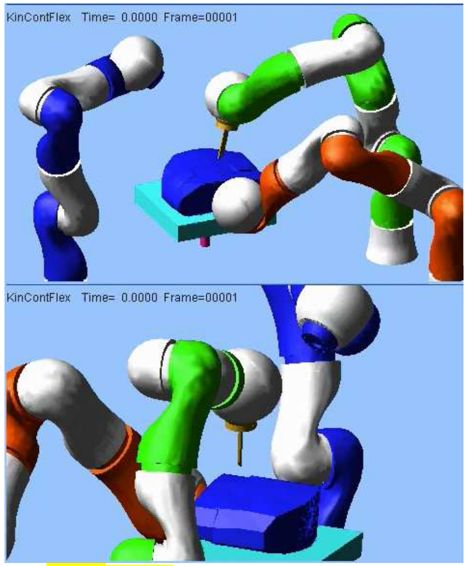
- Self collision (3)
- Robots collision (6)
- Occlusion (1)
- Joint limits (3)

Redundancy Resolution:
Use of the Generalized Projector P_β



ARMS project: results

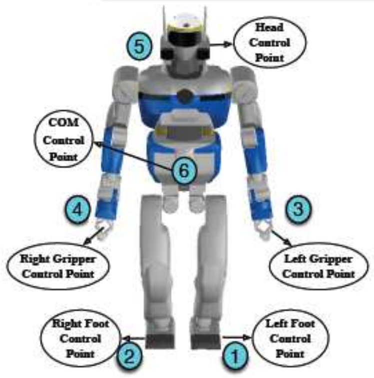




HRP2 : application scenario

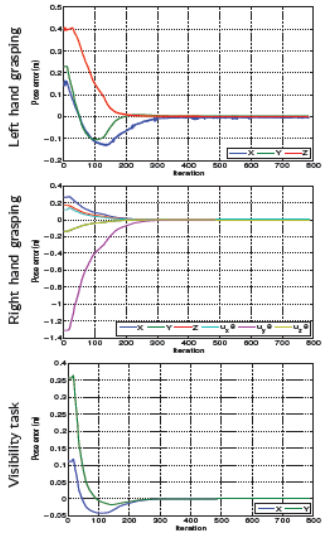
Objective

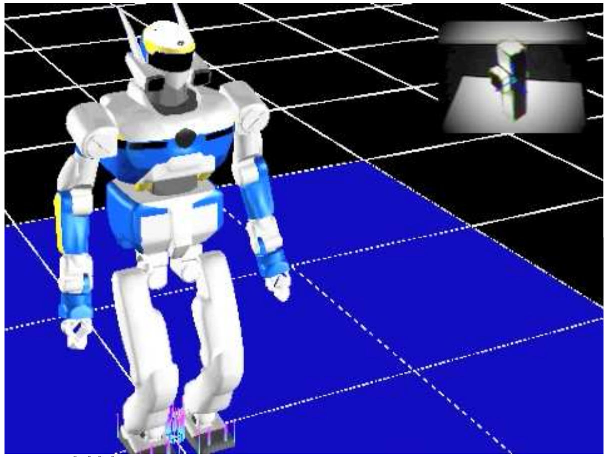
Benefit from the system's redundancy to control the entire robot body in order to execute grasping tasks



Priority	Task name	DOF	Control points
1	Equilibrium	3	6
2	Posture Task	6	1 and 2
3	Grasp Left	3	3
4	Grasp Right	6	4
5	Visibility Task	2	5
6	Gripper Task	2 × 1	3 and 4

HRP2 : results





Initial errors:
- Left Hand Grasping: 490 mm
- Right Hand Grasping: 350 mm, 75°
- Visibility Task: 380 mm

Assistive and service tasks

Objective

Use of embedded and external sensors for localization, navigation, and object manipulation in a smart home environment

Application 1:
Use of external RGBD sensor to navigate towards a detected object

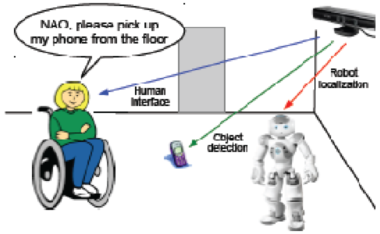
Application 2:
Use of embedded camera to grasp an object with Nao robot

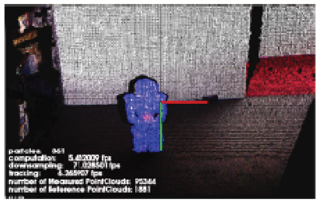
Assistive and service tasks

Goal

Real-time tracking of the robot while walking

- Track 3D objects in continuous point cloud data sequences.
- Control the direction of walking in the plane: (X, Y, θ)

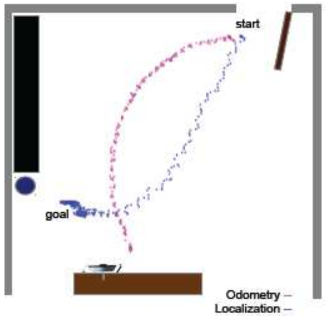


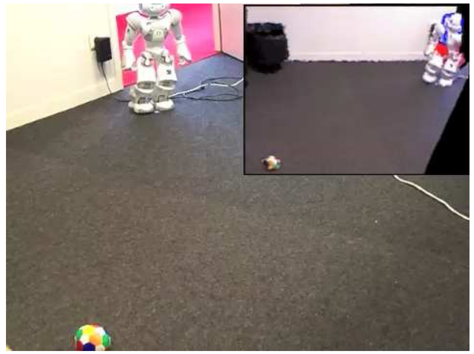


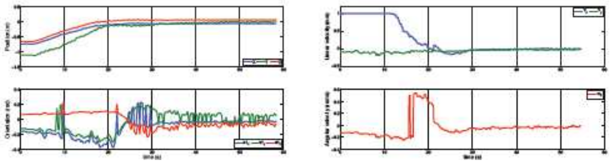
Materials

- 3D scene analysis using Kinect sensor
- Point Cloud Library: open project for 3D point cloud processing.
- Use ROS to create an interface between Kinect, NAO, and PCL

Localization and Assistive tasks







Initial conditions:
1.5 m, 25°

Odometry: 400 mm away from the desired pose.

Final mean position error
$(x, y, \theta) =$
$(12mm, 18mm, 0.07°)$

Manipulation with NAO

Goal

Use robot's camera to track and grasp objects

① Object's Tracking Task

- Use rough model of objects
- Calculate object's 3D pose using MBT technique

② Visibility Task

2 DOF task to control head's Yaw and Pitch

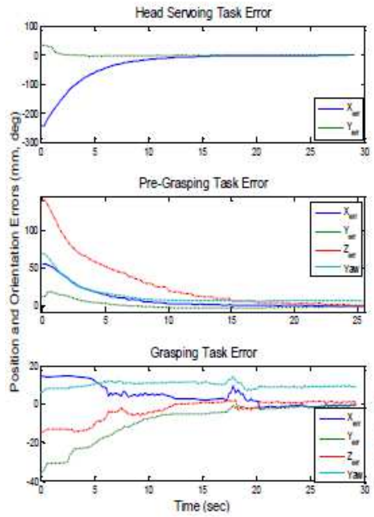
$\mathbf{s} = (x, y)$

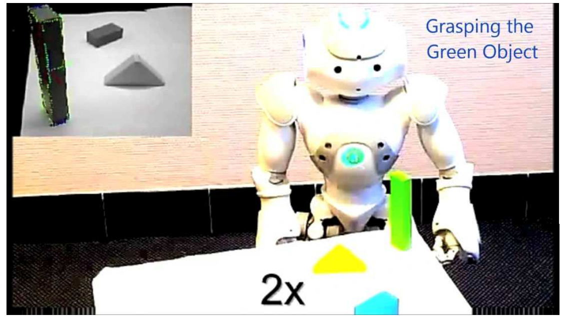
$$\mathbf{L_s} = \begin{bmatrix} -\frac{1}{Z} & 0 & \frac{x}{Z} & xy & -(1+y^2) & y \\ 0 & -\frac{1}{Z} & \frac{y}{Z} & 1+x^2 & -xy & -x \end{bmatrix}$$

③ Grasping Task

- Move the robot's arm to grasp the desired object
- Control of the gripper's pose and Yaw orientation (4 DOF)
- Visual primitive: $\mathbf{s} = (\mathbf{t}, \mathbf{u}\theta)$

Manipulation with NAO





Visibility task:
- Initial error: 300 mm
- Execution time: 18 sec
- Final error: 0.8 mm

Grasping task:
- Initial error: 150 mm, 80°
- Execution time: 30 sec
- Final error: 0.2 mm, 2°

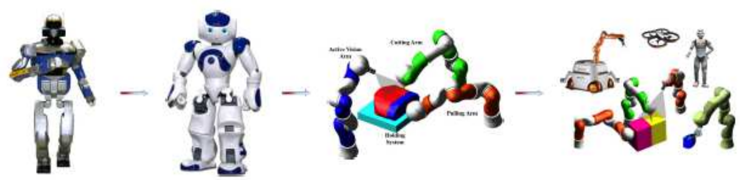
Conclusion

- General control approach for all robotic systems
- Identification of possible sources of redundancy
- Comparison of redundancy resolution methods
- Use of the appropriate method
- Validation of the efficiency of the developed formalism by simulations and experiments

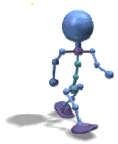
Future works

Redundancy Resolution
- Benefit from the redundancy study
- Extension of redundancy resolution to the dynamic case

Applications
- Application in real time of complete scenarios
- Application to complex systems and robust humanoids



Any questions



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Content

- ✓IRCCyN
- ✓Robotics Team
- ✓Presentation
- ✓**EMARO**

EMARO: International Master on Advanced Robotics

Coordinators: W. Khalil and P. Martinet (2/3)

Consortium in 2013

WUT *Warsaw, Poland*

ECN *Nantes, France*

UNIGE *Genova, Italy*

CEA *Paris, France*

EMARO
European Master on Advanced Robotics
Coordinator: ECN

I.I.G

AIT *Bangkok ,Thailand*

SJTU *Shanghai, China*

STKU *Tokyo, Japan*

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

EMARO: International Master on Advanced Robotics

MASTER tracks strategies

Track 1: Typical EMARO Curriculum

M1-E1 → M2-E2 (S4-ASIA, S4-IIG) → Master EMARO

ASIA — *AIT, SJTU, STKU*

E1,E2 — *ECN, UNIGE, WUT*

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

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*

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