ICRA'07
2007 IEEE International Conference
on Robotics and Automation
10-14 April 2007, Roma, Italy

Workshop on Roboethics, *Saturday April 14, 2007*

Robots interacting with Humans: confronting the Critical Challenge of Machine Intelligence Dependability

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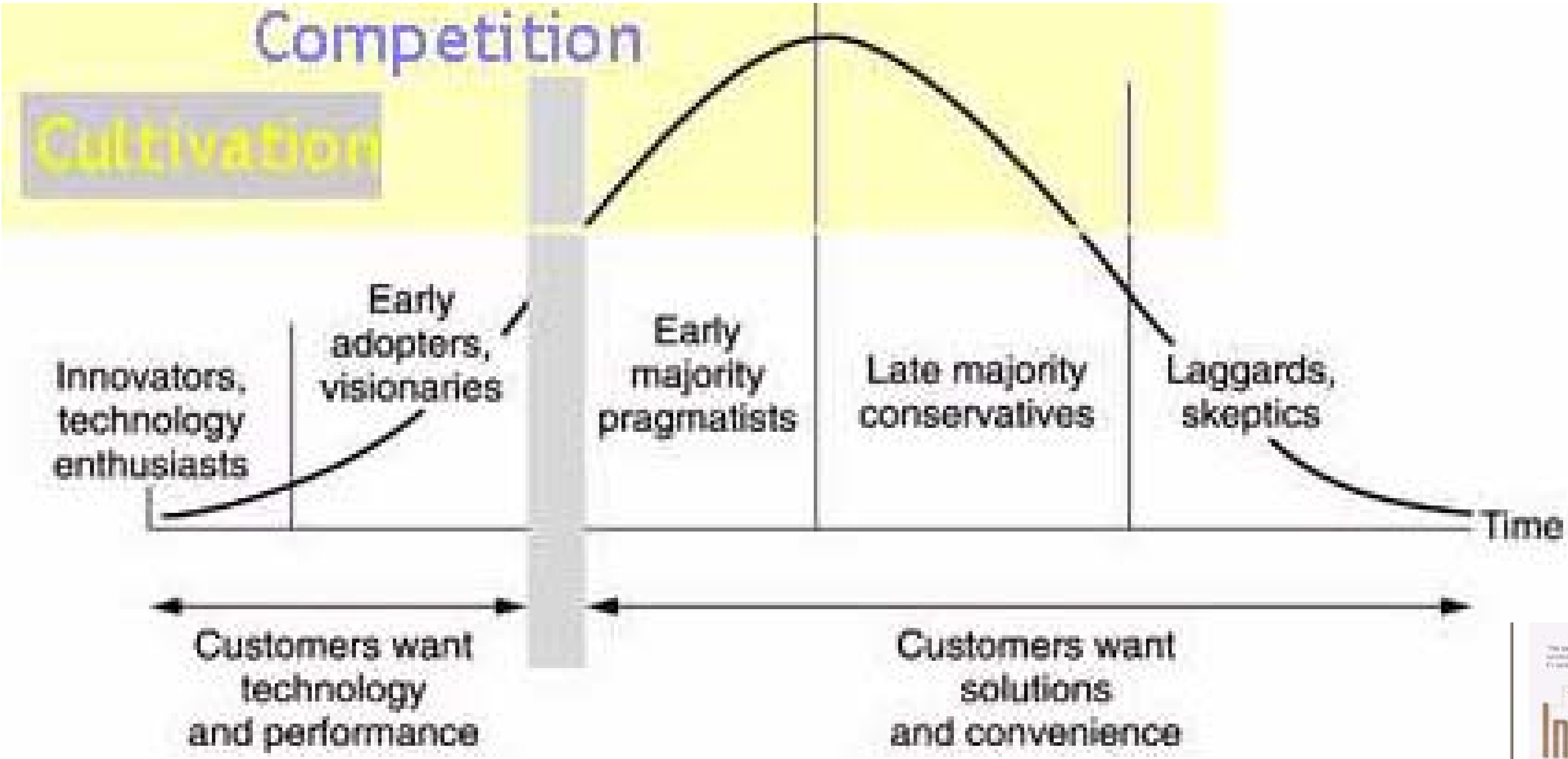
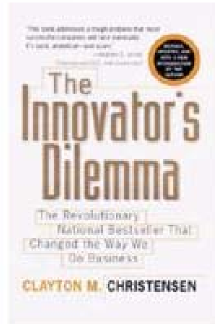
Outline

- What is dependability?
- What is robot dependability?
- Examples of ongoing research efforts
- Robot Dependability Vs. RoboEthics
- The Workshop series on ‘Technical Challenges for Dependable Robots in Human Environments’

Disruptive Innovation





What is dependability?

- ‘Mature’ Technology should be:
  - Useful
  - Appropriate
  - **Dependable**

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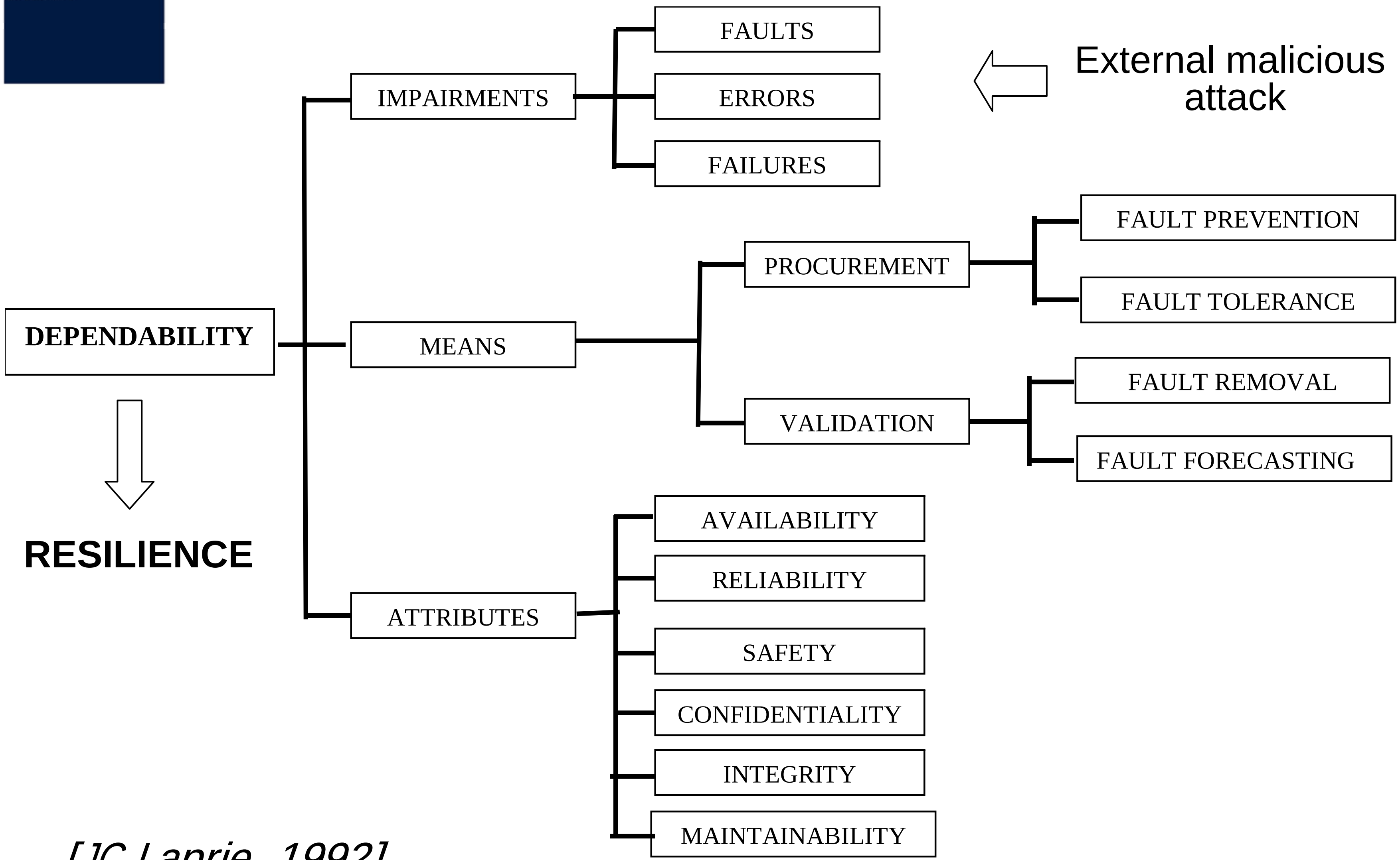
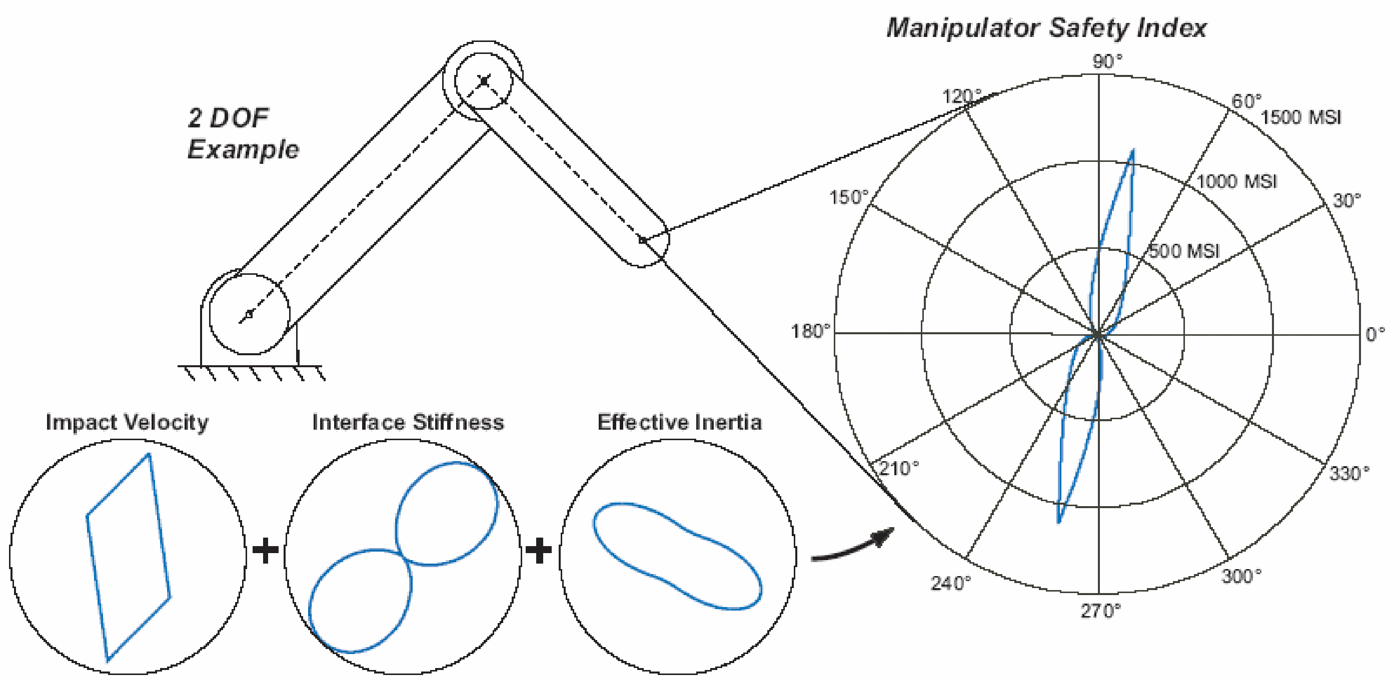
What is dependability?



[JC Laprie, 1992]

What is robot dependability?

- **Levels of dependability**
  - **Hardware Level**



What is robot dependability?

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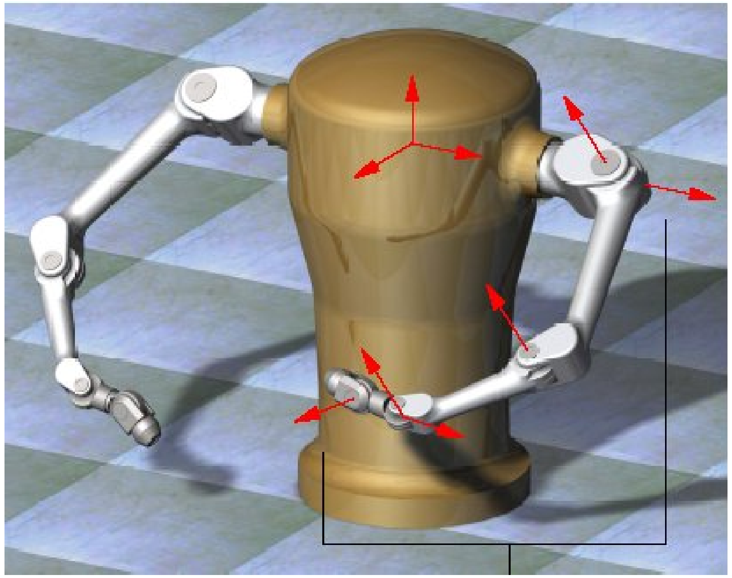
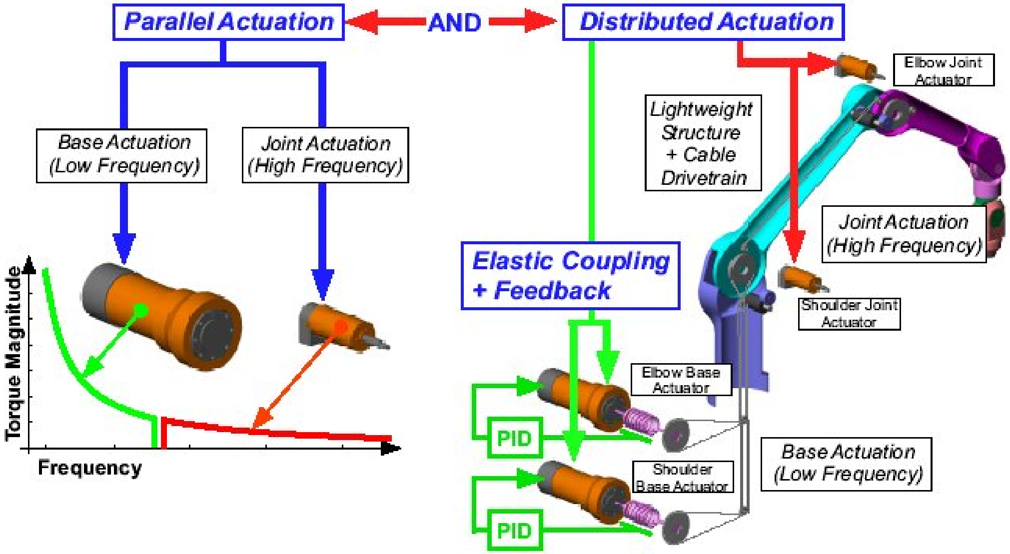
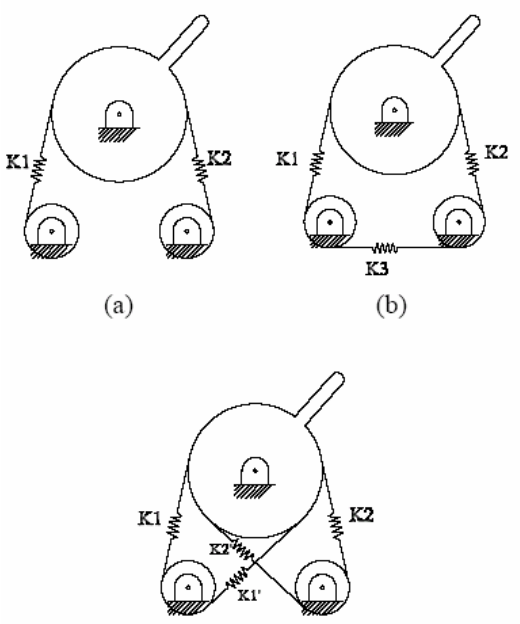




Distributed Macro-Mini Actuation (Khatib et al.)

What is robot dependability?

- **Levels of dependability**
  - ➢ **Hardware Level**



Variable stiffness actuators (Bicchi et al.)

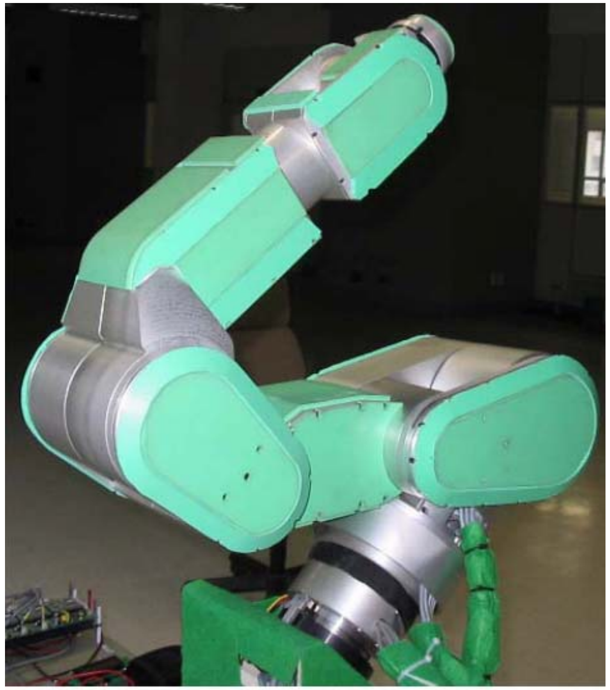


Fig 2. KIST safe arm

Variable stiffness magneto-reologic actuators (Kang et al.)

What is robot dependability?

- **Levels of dependability**
  - **Hardware Level**

Highly back-driveable systems (Hogan et al.)

What is robot dependability?

- **Levels of dependability**
  - Hardware Level
  - **Middle Layer Control Level**

Control of rehabilitation operational machines

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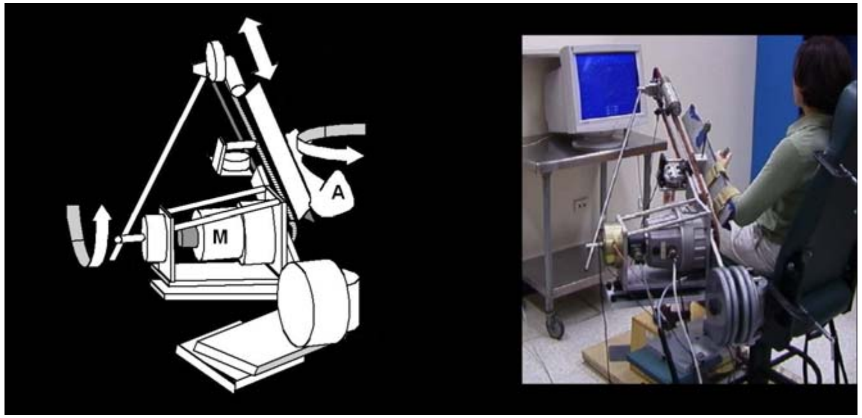
The MIME system:
Compliance control in the Cartesian space

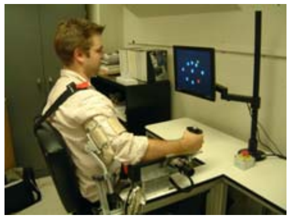
$$\tau = J_A^T K_p e_p - K_d \dot{q} + g(q)$$

$$e_p = x_d - x$$



The ARM Guide:
PID position control

$$V = K_p e_q + K_d \dot{e}_q + K_i \int e_q(t)dt$$



The MIT-MANUS system:
Compliance control in the Cartesian space

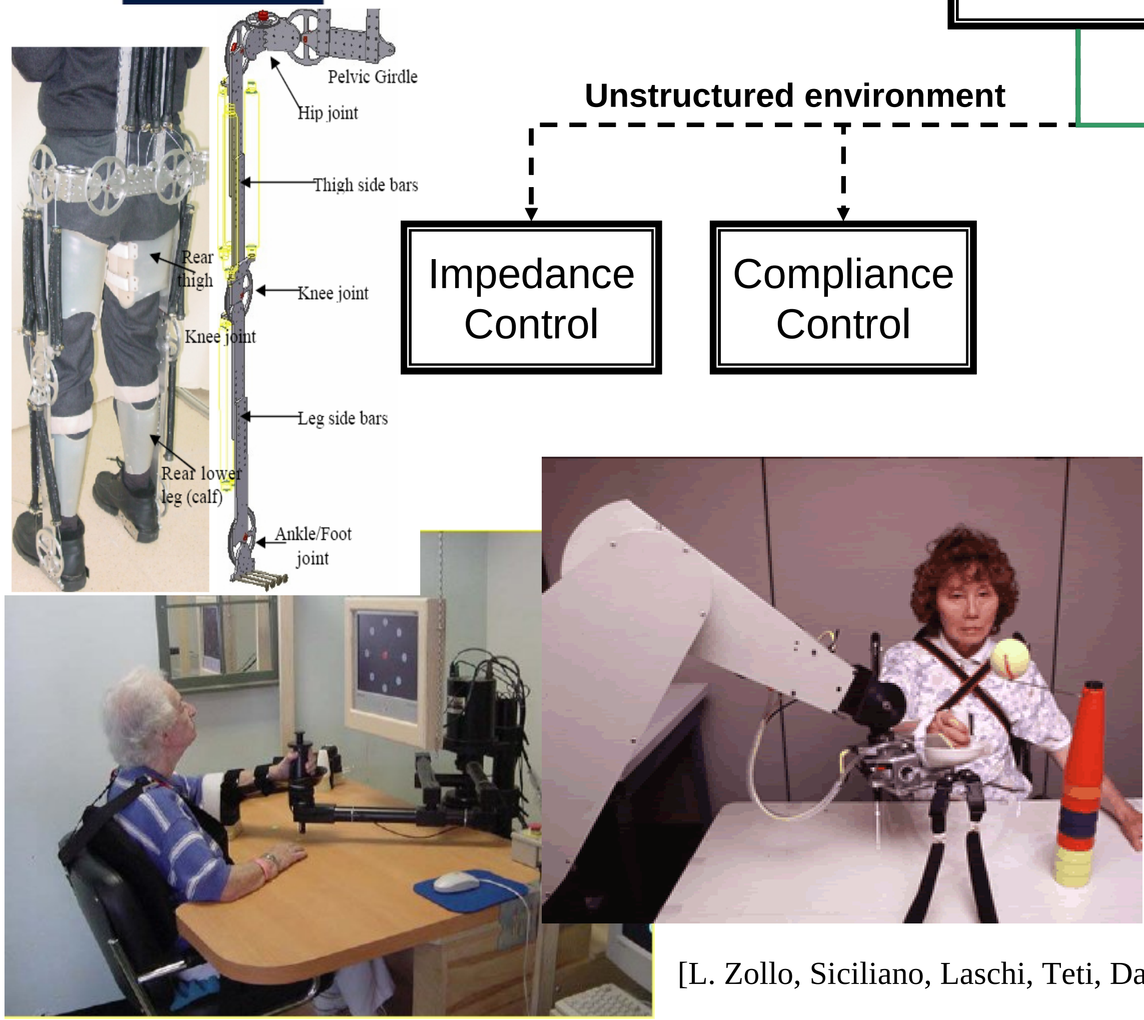
$$\tau = J_A^T K_p e_p - K_d \dot{q} + g(q)$$

$$e_p = x_d - x$$

Control of physical human-robot interaction

Interaction Control

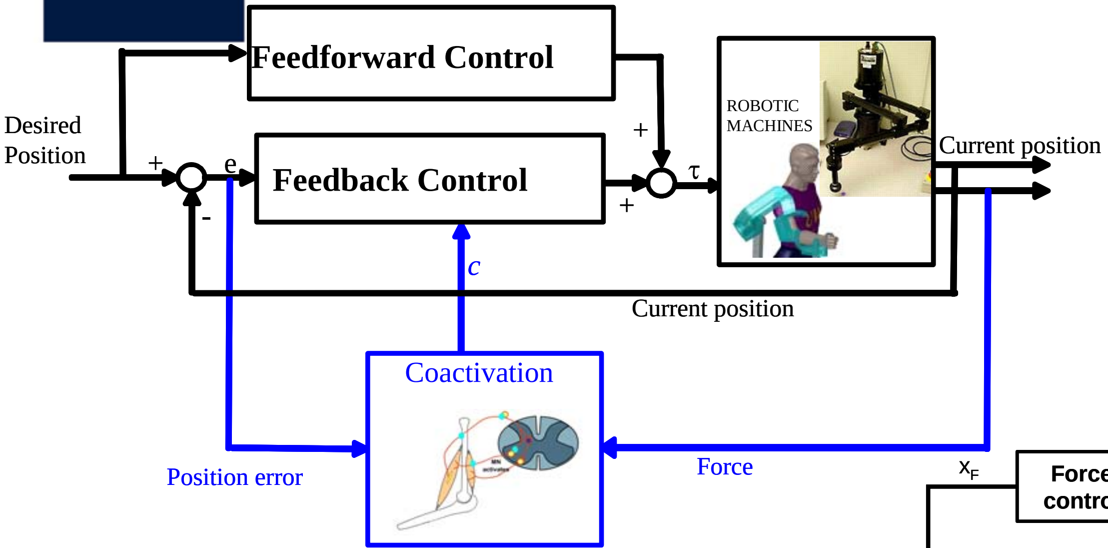
- **Unstructured environment**
  - Impedance Control
  - Compliance Control
- **Structured environment**
  - Force Control
    - with inner position loop
    - with inner velocity loop
    - parallel force/position
  - Hybrid Force/Position Control



[L. Zollo, Siciliano, Laschi, Teti, Dario, Rob. Auton. Syst., vol.44, pp.101-129, 2003.]

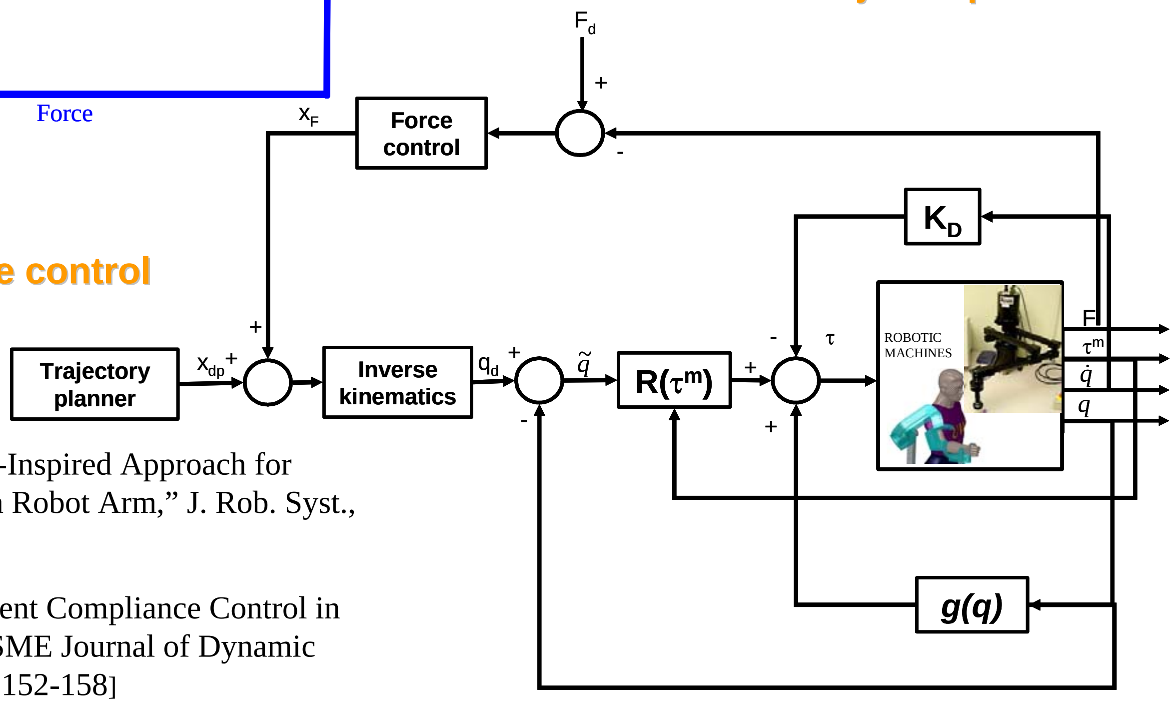
[Zollo, Dipietro, Siciliano, Guglielmelli, Dario. J. Rob. Syst., vol.22(8), pp. 397-419, 2005]

Bio-inspired compliant control schemes



Coactivation-based compliance control in the joint space

Torque-dependent compliance control in the joint spaceì



[Zollo, Dipietro, Siciliano, Guglielmelli, Dario. "A Bio-Inspired Approach for Regulating and Measuring Visco-Elastic Properties of a Robot Arm," J. Rob. Syst., 2005]

[D. Formica, L. Zollo, E. Guglielmelli, Torque-Dependent Compliance Control in the Joint Space for Robot-Mediated Motor Therapy, ASME Journal of Dynamic Systems, Measurement and Control, 2005, Vol.128, pp.152-158]

What is robot dependability?

- **Levels of dependability**
  - Hardware Level
  - Middle Layer Control Level
  - **Supervision and Cognitive Level**

What is robot dependability?

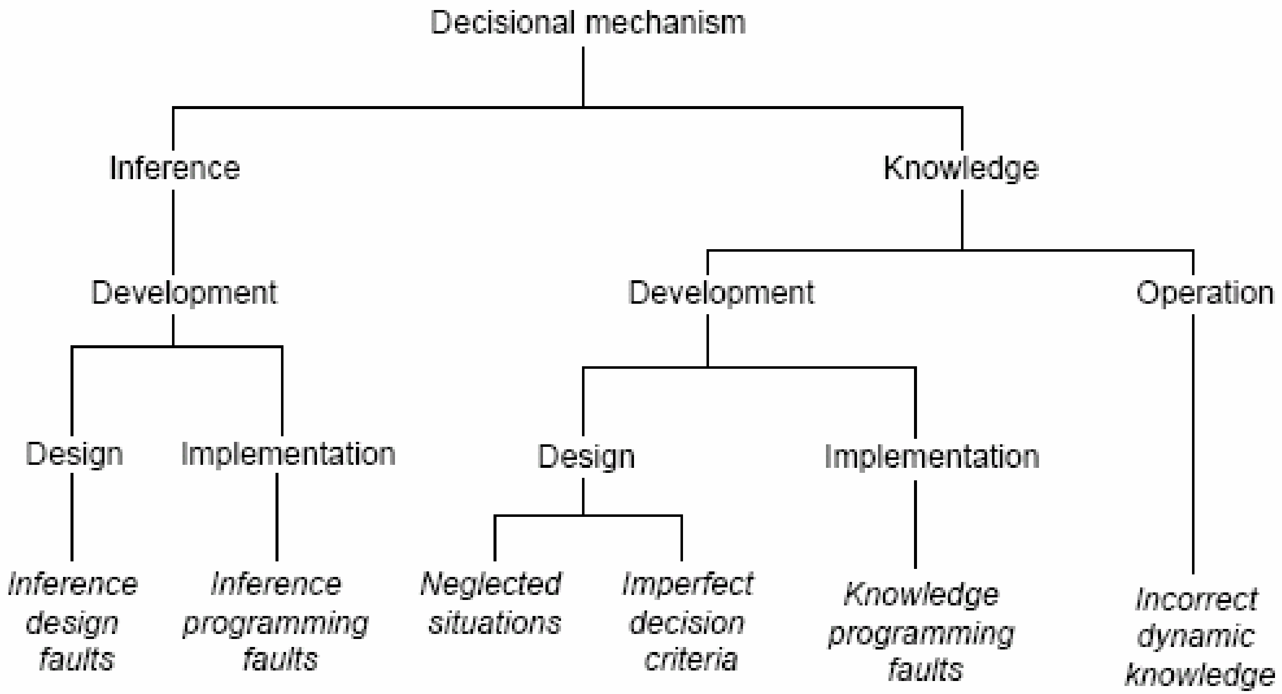
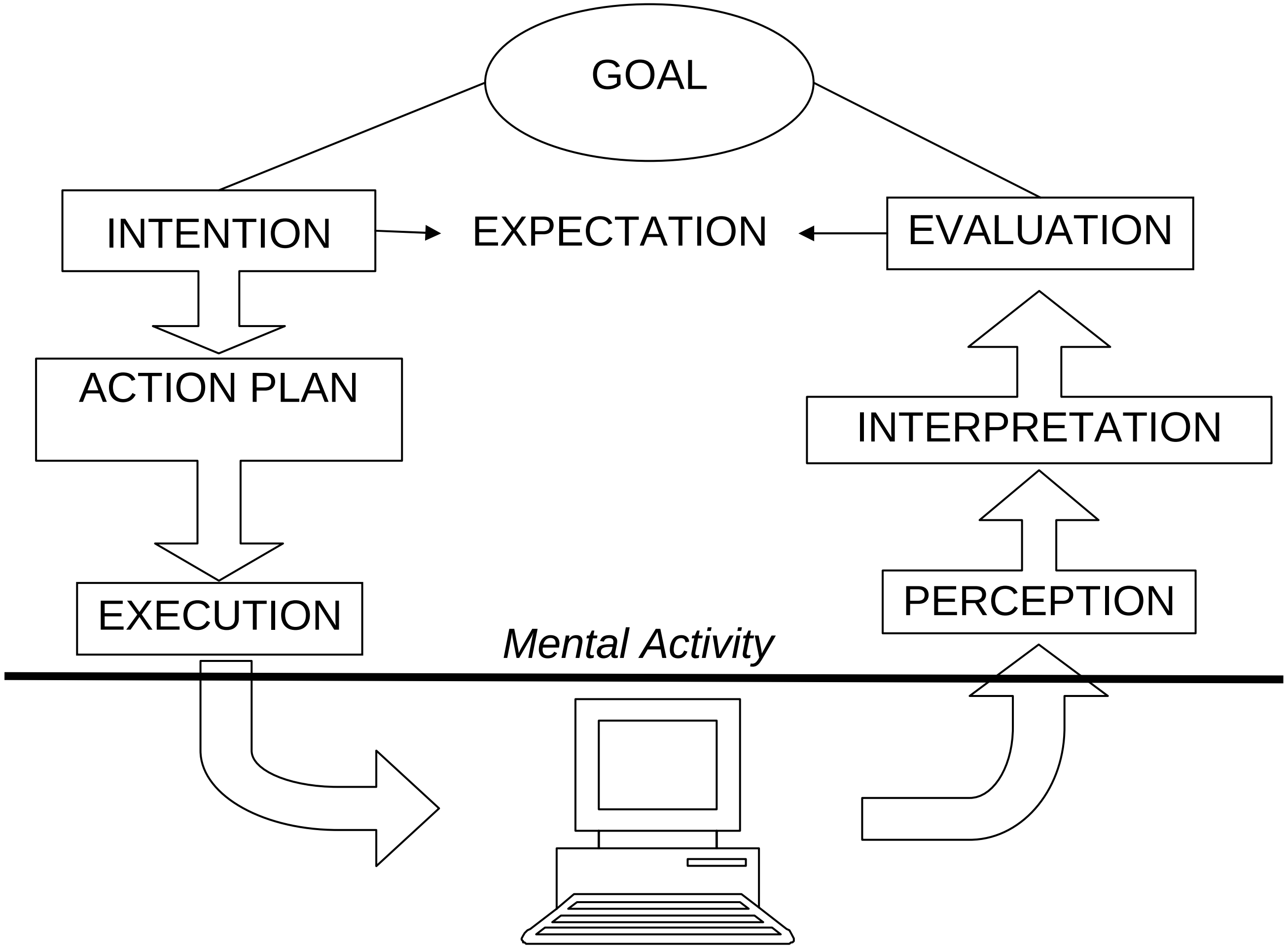


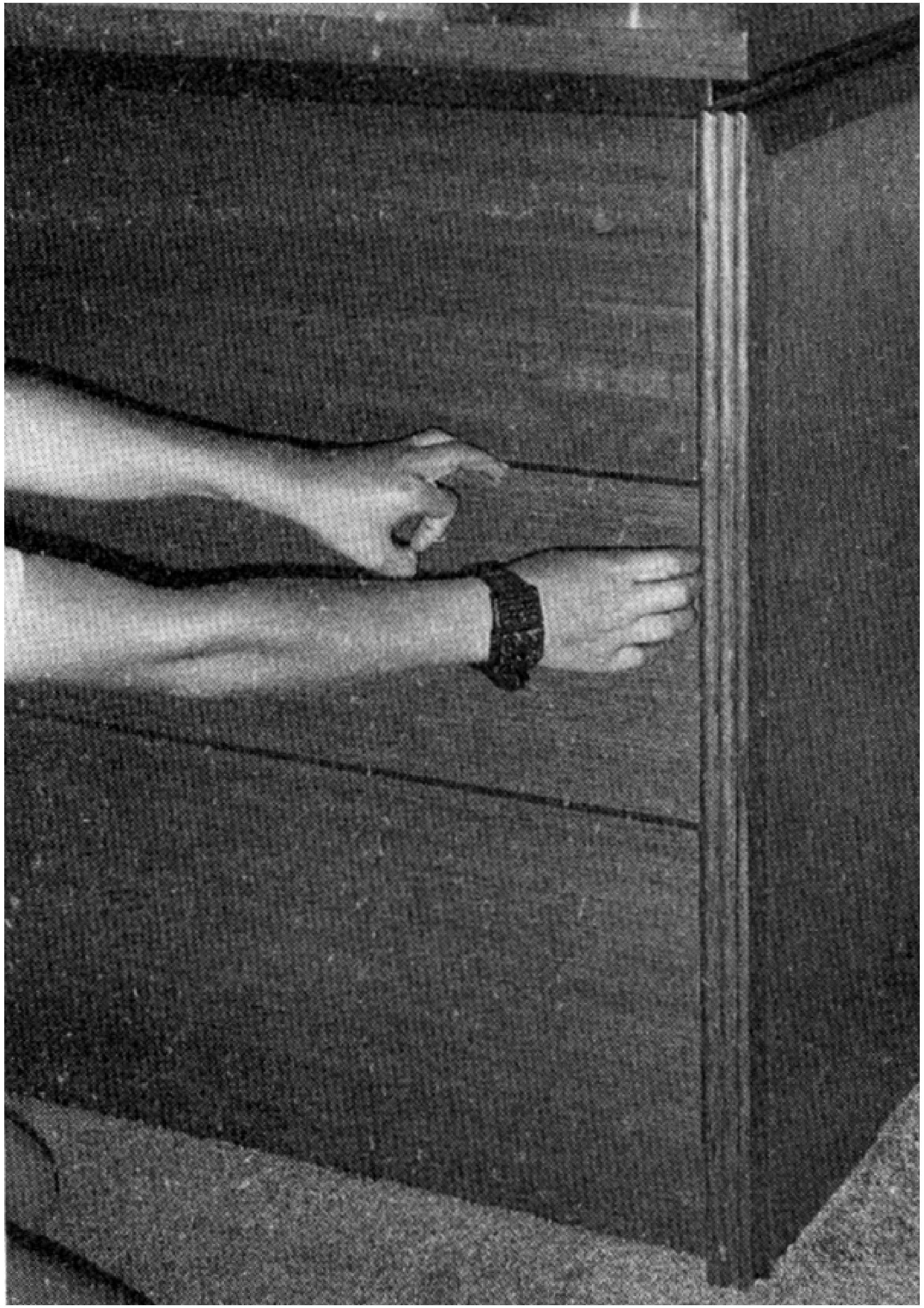
Figure 2: Internal faults in decisional mechanisms

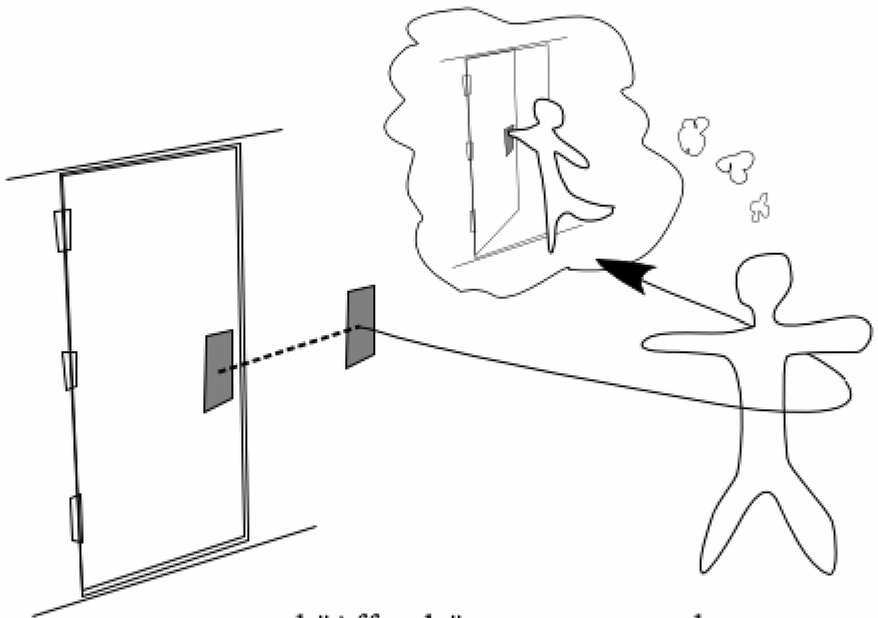
[Lussier et al., Dep WS 2005]

Interaction: a cognitive engineering perspective



D.A. Norman, “Cognitive Engineering”, in *User Centered System Design*, D.A. Norman & S.W. Draper (Ed.s), Hillsdale, NJ, Erlbaum, 1986





panel "Affords" person to push

Affordance (J. Gibson, 1966) is the property of an object, or a feature of the immediate environment, that indicates how that object or feature can be interfaced with.

What is robot dependability?

- **Levels of dependability**
  - ➢**Hardware Level**
  - ➢**Middle Layer Control Level**
  - ➢**Supervision and Cognitive Level**

⇩

SYSTEM LEVEL

Robot Dependability Vs. Roboethics

- Early stage dependability analysis of robotic systems

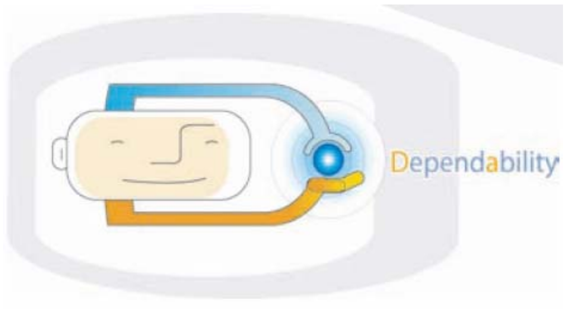
AND

- Early stage ethical evaluation of the application of robotics technology

- **steering research, inputs to ethical committees**
- **enhancing acceptability**
- **significant impact on the development of a successful design!**

The Workshop series on ‘Technical Challenges for Dependable Robots in Human Environments’

Tolouse, Seoul, Manchester, Aichi…Rome



IARP
International Advanced Robotics Programme

European ROBOTICS Research Network EURON

IEEE

INTERNATIONAL WORKSHOP

2007 IARP

Technical Challenges for Dependable Robots in Human Environments

www.robot.brindisi.enea.it/iarp/dep07

April 14 - 15, 2007

Sala Alinari, 5th floor
Associazione Civita
Piazza Venezia 11
Rome, Italy

April 14 : 14.00 - 19.00
April 15: 9.00 - 18.30

Dependability is a key factor for successful introduction of robotic systems in our Society: design paradigms and enabling technologies that could minimize potential risks for end-users, avoid misuse and enhance overall acceptability of robotic artefacts are the main goals of this emerging research area. This International Workshop, for the first time hosted in Italy, continues the successful story of this track of scientific events that gather a restricted group of top experts in Robotics, and in a broad range of other disciplines, to discuss the latest major advances in this field and to identify roadmaps for future development of truly dependable robotic technologies.

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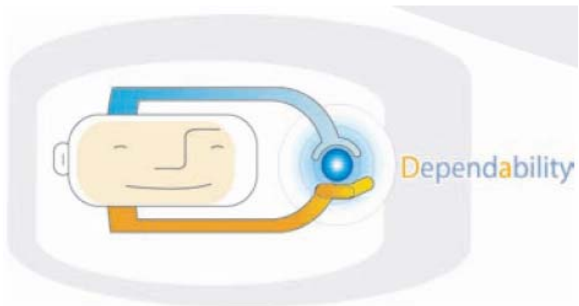
ENEA CIVITA

- Scope
  - Theoretical Foundations of Robot Dependability and Resilience
  - Actuators and sensors for dependable robots
  - Human Factors for Robotics & Human-Centred Robot Design
  - Friendly and Natural Interfaces for Robotic Systems
  - Human-Robot Safe Physical Interaction
  - Supervision Architectures and Control Strategies for enhancing safety, robustness, self-diagnosis, fault-tolerance and exception handling in robotic systems
  - Cognitive robotics & dependability
  - Case-studies on robot dependability in emerging application domains, such as industrial, service, space, military, biomedical, edutainment, humanoid and personal robotics, and others
  - Robot Acceptability
  - Ethical and Social Implications of the Introduction of Robotics Technology in Human Environments

- 9 promoting countries
- 2-day
- Single track
- 1 opening lecture, 26 regular papers
- Follow-up report (for dissemination)



IARP-IEEE/RAS-EURON
International Workshop on
Technical Challenges for
Dependable Robots in Human Environments
Rome - Italy, April 14-15 2007

Opening Lecture, Sat. April 14, 2pm

Human-Friendly Robot Design and Control

Oussama Khatib
Artificial Intelligence Laboratory
Department of Computer Science
Stanford University, USA

IARP-IEEE/RAS-EURON
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Rome - Italy, April 14-15 2007

Session I: Hardware Components and System Design for Dependable Robots

Session II: Middle Layer Control Solutions for Dependable Robots

Session III: Supervision and Cognitive Schemes for Dependable Robots

Session IV: Experimental evaluation of dependability in robotic systems and social implications

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Rome - Italy, April 14-15 2007

Session I: Hardware Components and System Design for Dependable Robots

Co-Chairs: *Oussama Khatib and Eugenio Guglielmelli*

T. Yamamoto, *Toyota Motor Europe, Belgium*
Y. Ota, Toyota Motor Corporation, Japan

R. Filippini, *S. Sen and A. Bicchi, Interdepartmental Research Centre "E.Piaggio", University of Pisa, Italy*

J. Choi, *S. Park, and S. Kang, Korea Institute of Science and Technology, Seoul, Korea*

G. Pegman *& J. O. Gray, National Advanced Robotics Research Centre, Salford , UK*

Y. Yamada, *Safety Intelligence Research Group, Intelligent Systems Research Institute, National Institute of Advanced Industrial and Science Technology (AIST), Tsukuba, Japan.*

K. Abe, *Machinery System Technology Development Dept., New Energy and Industrial Technology Development Organization (NEDO), Japan*

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Session II: Middle Layer Control Solutions for Dependable Robots
***Co-Chairs:** Cecilia Laschi, Yoji Yamada*

***A. M. Dollar**, Harvard/MIT Division of Health Sciences and Technology and the Media Lab, Massachusetts Institute of Technology, Cambridge, MA, USA.*
R. D. Howe, School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA.

***S. Lee**, J. Lee, S.-Min Baek, D. Moon, C. Choi, Intelligent Systems Research Center, School of Information and Communication Engineering, Sungkyunkwan University, Suwon, KOREA*

***C. Laschi**, P. Dario, ARTS (Advanced Robotics Technology and Systems) Lab, Scuola Superiore Sant'Anna, Pisa, Italy.*

*E. Cervera, E. Martinez, **L. Nomdedeu**, A. P. del Pobil, Robotic Intelligence Lab, Jaume-I University, Spain.*

***A. De Santis**, B. Siciliano, PRISMA Lab, Dipartimento di Informatica e Sistemistica, Università degli Studi di Napoli Federico II, Italy.*

*L. Zollo, D. Accoto, D. Formica, **E. Guglielmelli**, Laboratory of Biomedical Robotics & EMC, Università Campus Bio-Medico, Rome, Italy*

Session III: Supervision and Cognitive Schemes for Dependable Robots
Co-chairs: *Felix Ingrand, Roberto Filippini*

S. Bensalem*, VERIMAG - CNRS, Grenoble, France*

B. Lussier, M. Gallien, J. Guiochet, F. Ingrand, M. O. Killijian, ***D. Powell,*** *LAAS-CNRS, Toulouse, France*

R. Alami, ***F. Ingrand****, LAAS – CNRS, Toulouse, France*

IARP-IEEE/RAS-EURON
International Workshop on
Technical Challenges for
Dependable Robots in Human Environments
Rome - Italy, April 14-15 2007

Session IV: **Experimental evaluation of dependability in robotic systems and social implications**

Co-chairs: *Song-Doo Kwon, Jonathan Roberts*

***J. Roberts**, A. Tews and C. Pradalier, CSIRO ICT Centre, Kenmore, Australia.*

***S. Haddadin**, A. Albu-Schäffer, G. Hirzinger, Institute of Robotics and Mechatronics, DLR - German Aerospace Center, Wessling, Germany.*

***G. Veruggio**, CNR, Genoa, Italy – Chair of the RAS Technical Committee on Robo-Ethics*

***A. Casals**, L. M. Muñoz, Manel Frigola, J. Amat, Intelligent Robotic Systems, Department of Automatic Control, Technical University of Catalonia (UPC). Barcelona, Spain.*

***S. Larionova**, F. Mösch, M. Litza, A. El Sayed Auf, B. Javimovski, E. Maehle1, University of Lübeck, Institute of Computer Engineering, Lübeck, Germany.*
W. Brockmann, University of Osnabrück, Institute of Computer Science, Osnabrück, Germany.

*V. Pasqui, **Ph. Bidaud**, Laboratoire de Robotique de Paris, Université Paris 6, France*

***K. Kosuge**, Department of Bioengineering and Robotics, Tohoku University, Sendai, Japan.*

***D.-S. Kwon** et al., Human-Robot Interaction Research Center, KAIST, Daejeon, Korea*

*S. Catini, **R. Setola**, P. Donzelli, Università Campus Bio-Medico, Rome, Italy*

Robot Dependability Vs. RoboEthics

- Not too early for dependability
- Networking with other working groups
  - Computer Systems Dependability Working Group
  - EURON SIGs
  - RAS TCs (Haptics, Rehabilitation, Bio-Robotics..)
  - …
- Personal Robot Challenge (10 years ago, Panel chaired by George Bekey)
- Follow-up report
- Next workshop date & venue