LARM2:
Laboratory of Robot Mechatronics
http://larmlaboratory.net
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Challenges for Mechanism Design in Robotics

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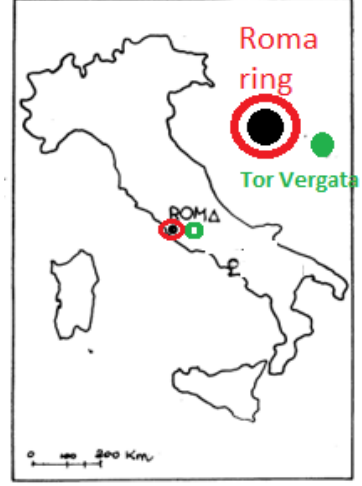
- **Robots are based on mechanical structures**
  with mechanisms that play an important role
  on functionality and performance characteristics **with a variety of solutions.**

- **Everywhere is asked for innovation in technological developments.**
- **But what does innovation mean?**
- **community identity and role in challenges in technological developments**



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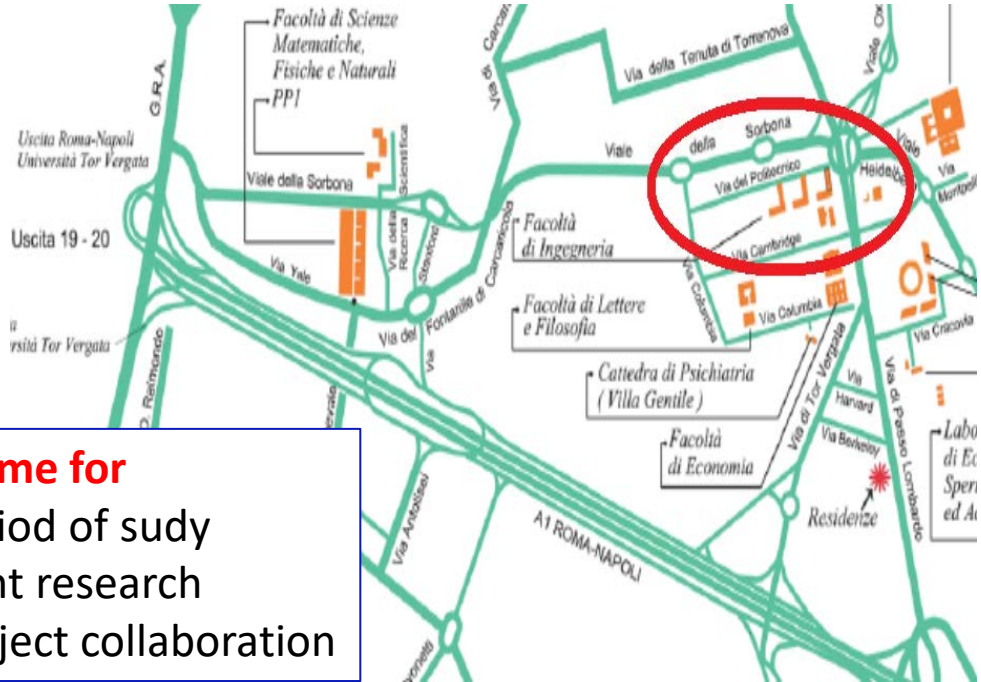
- The Laboratory of Robotics and Mechatronics (LARM) was founded in 1990 in Cassino
- Since March 2019 it is in Rome University Torvergata
- The aim of LARM2 is to develop experience, teaching, and research in the fields of Automation, Robotics and Mechatronics with main focus on aspects of Mechanical Engineering.



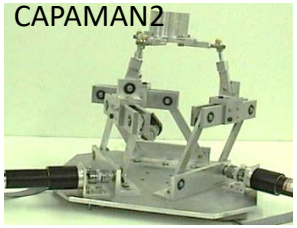
Welcome for

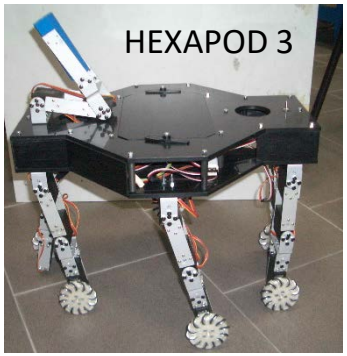
- Period of sudy
- Joint research
- Project collaboration

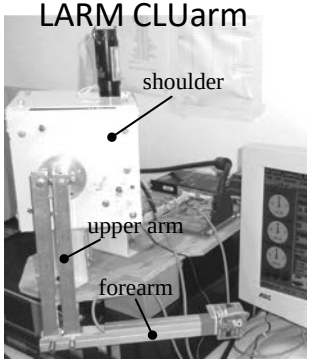
Attività di ricerca – prototipi

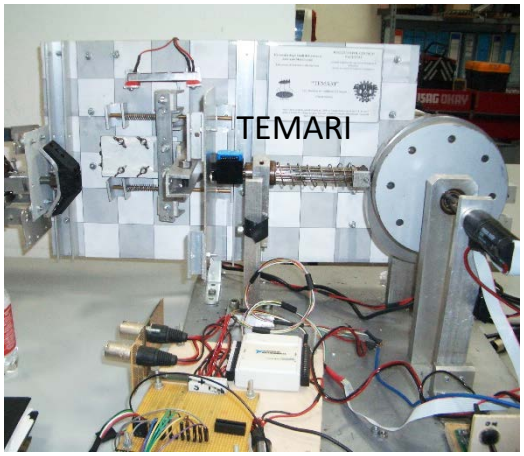
Mechanism Design, Robotics, History of MMS

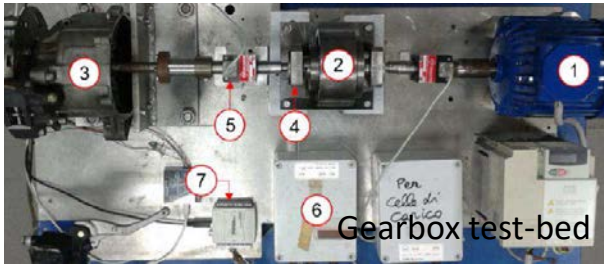
teach2017

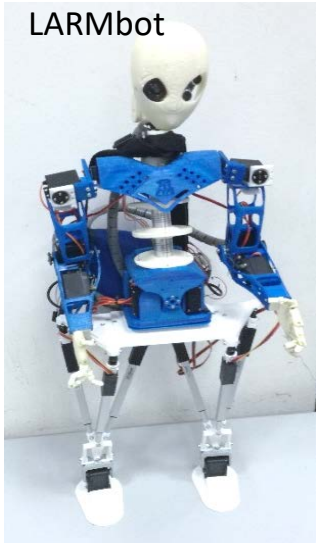


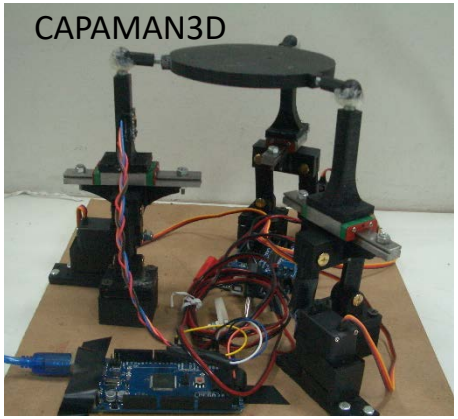






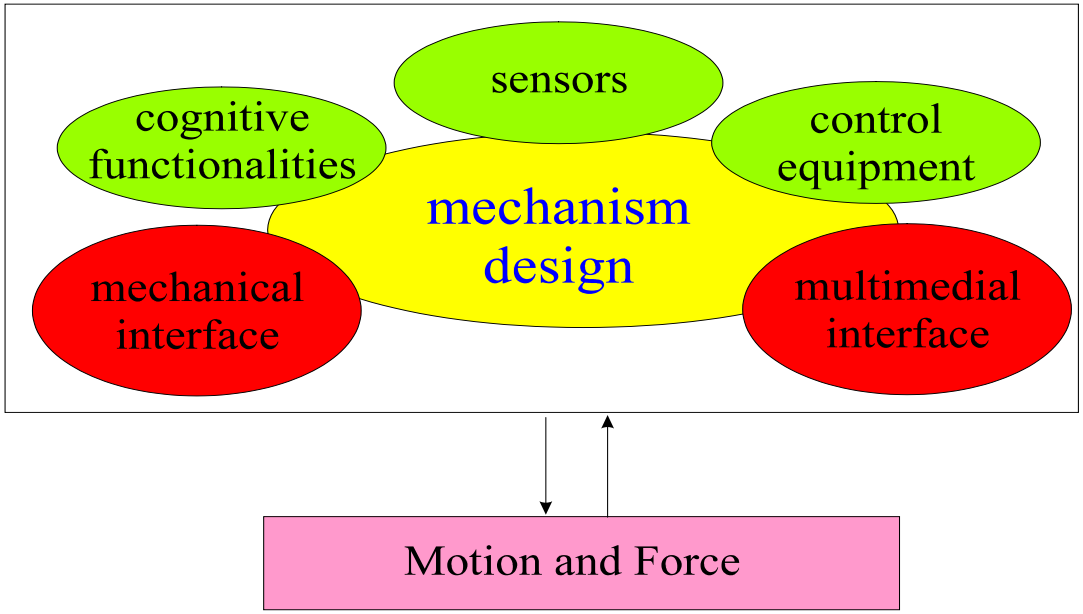


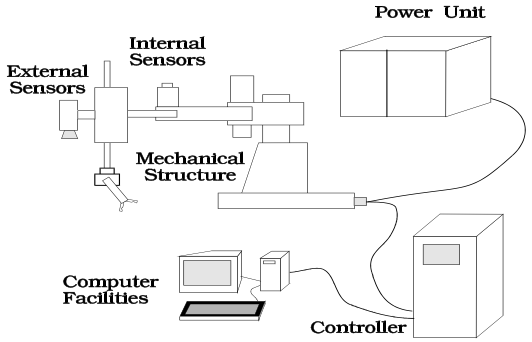




and much more ….

with students and international collaboration





Mechanism: system of bodies designed to convert motions of, and forces on, one or several bodies into constrained motions of, and forces on, other bodies.

Fig. 1. General structure of modern mechatronic system

the today machines with such a mechatronic design and operation that it is often believed that their performance do not depend of mechanical aspects.

It is indeed true that

- **mechanical components can be less and less**
- **and even with reduced influence on the overall design of mechatronic systems.**

Why innovation & why Mechanics with key role

Enhancements in knowledge and Technology needs for human life and industrial production have changed and evolved over time, also because of the evolution of systems, requiring innovation that have brought to Mechatronic design and operation of modern systems

- **Whatever Electronics, Informatics, Telecommunications and so on, will be enhanced and expanded in Mechatronics Technology, Mechanical Design will be always needed**
- **since a woman/man will always live and interact with the environment on the basis of mechanical phenomena of the human nature.**

Innovation meaning

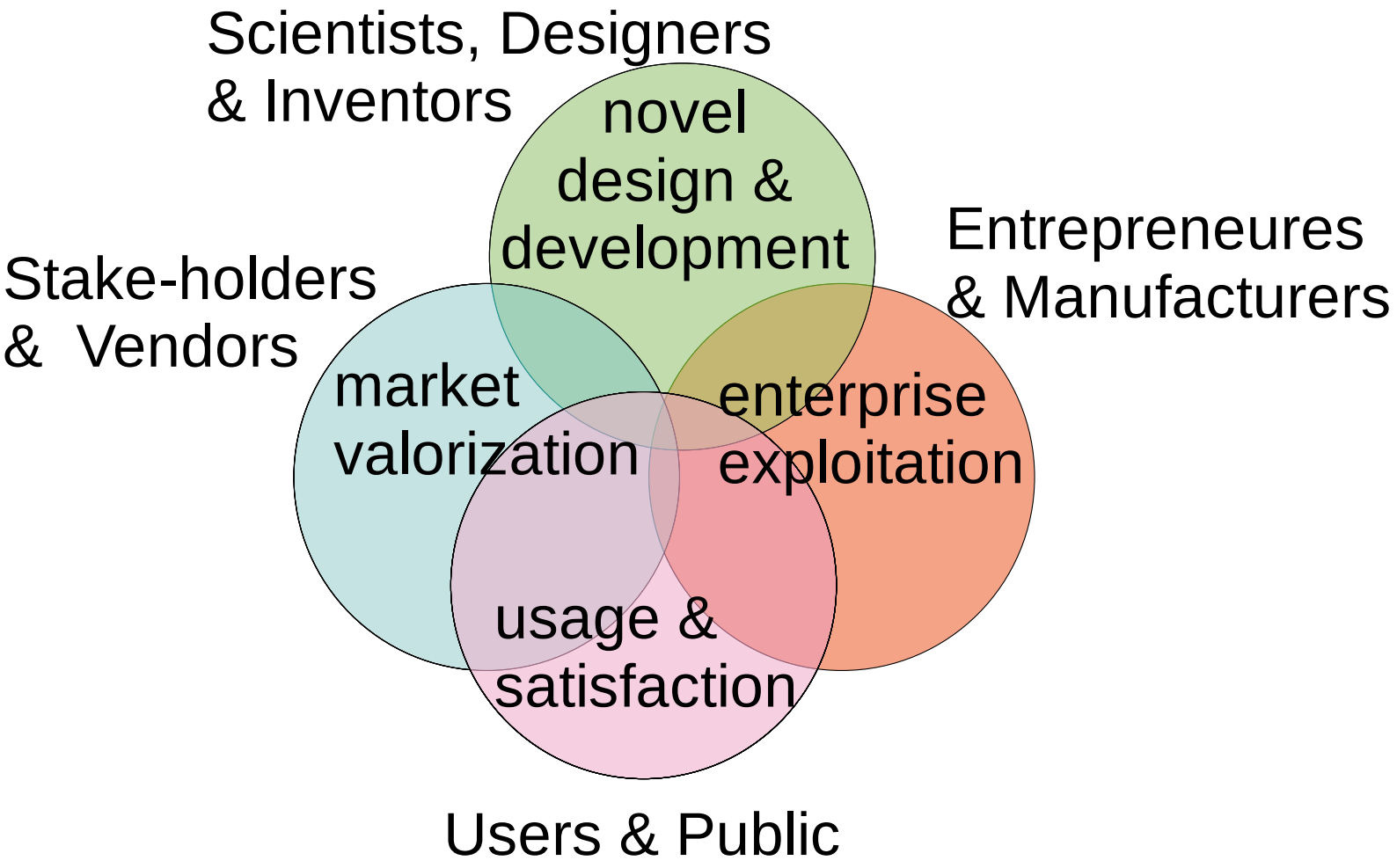


Fig. 1 Conceptual scheme for innovation for a general understanding;

•Innovation can be started when a **technical idea or solution has potential** contents.

- initiators of innovation are designers or scientists with engineering skills,
- main exploiters are business experts or enterprise leaders, for market valorisation and users' acceptance.

> •**novel ideas** but mainly when the knowledge transfer **reaches successfully the real world with users' acceptance**.

•**a sequence of skills:** when just one is weak or fails, the whole transfer process will fail.

Thus, **not only new solutions** make innovation, but very often is **the exploitation plan** that produce innovation, like for example when a product reaches the market sales with no other competitors.

•Science and Technology are the fundamentals,

•but Economics and Administration are the motors

•and Education and Publicity are final tools of Innovation.

•University frames can be involved in fundamentals and final tools

Education and Formation are essential areas both for conceiving new ideas and preparing users to the acceptance of those new ideas.

Mechanism Design for mechatronic systems

Robotics has shown Innovation challenges and potentialities since the early days and nowadays is well recognized the impact that any further achievement in Robotics can have on the society improvements both in production aspects and in diary life quality.

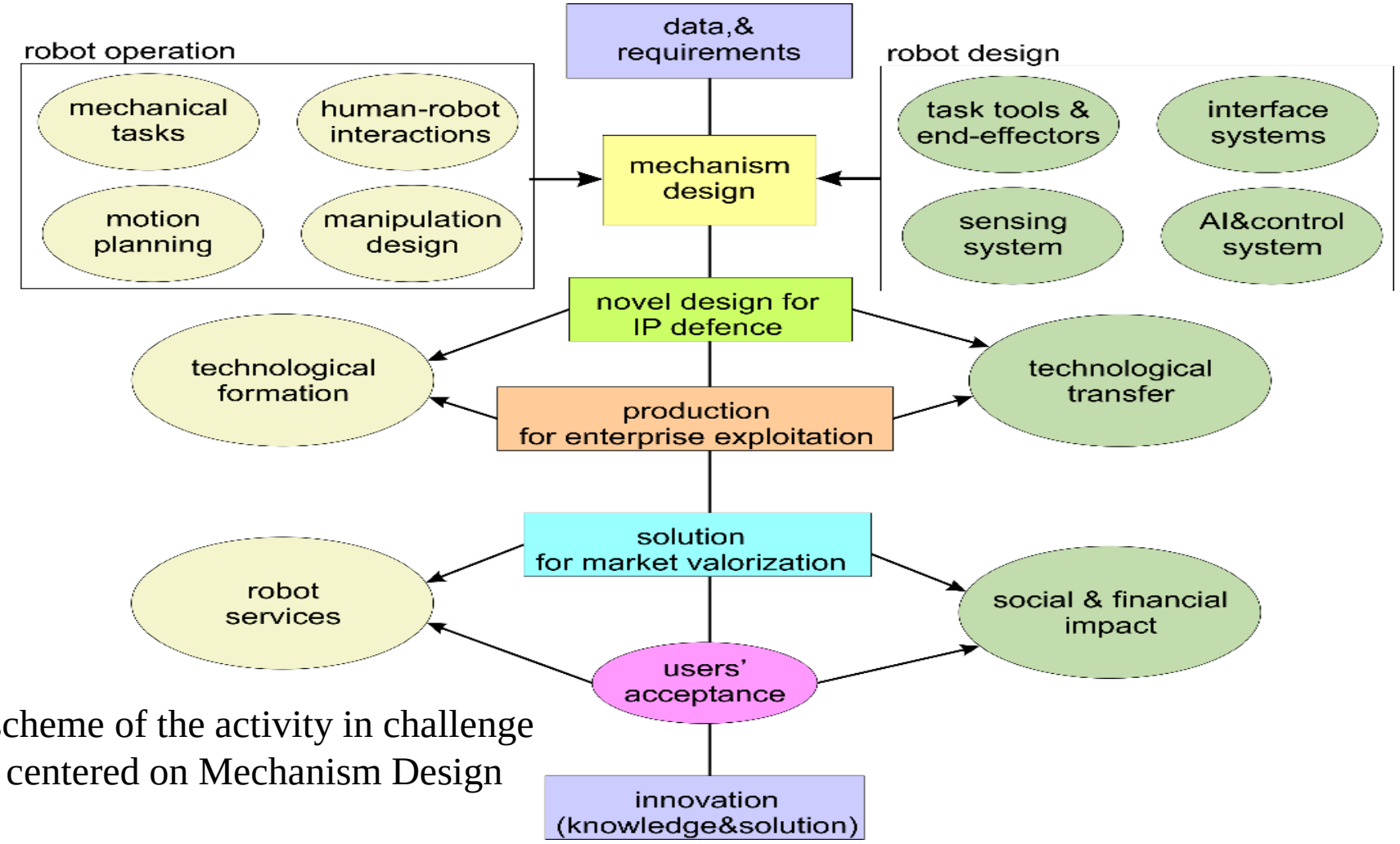
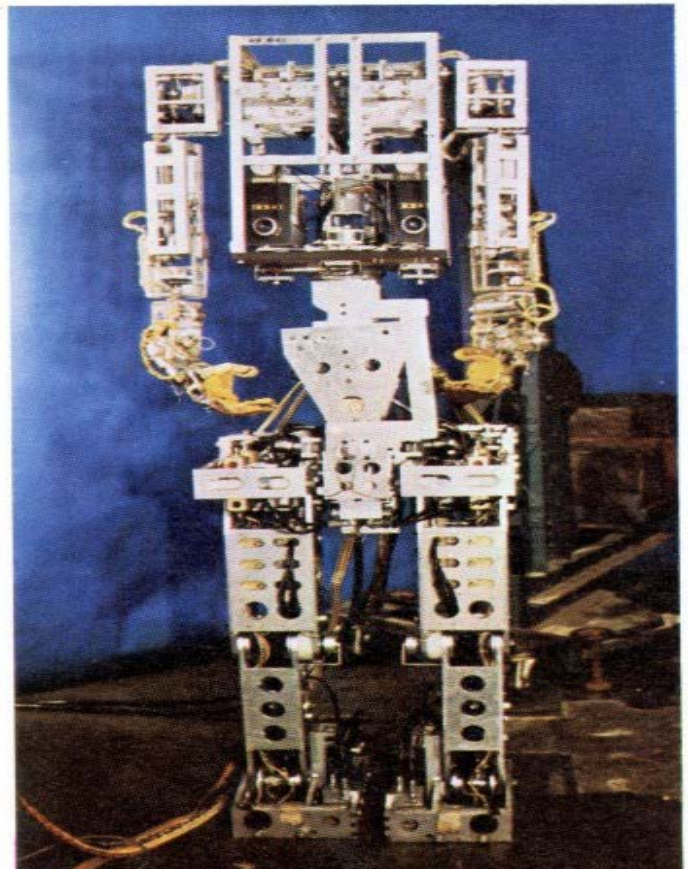
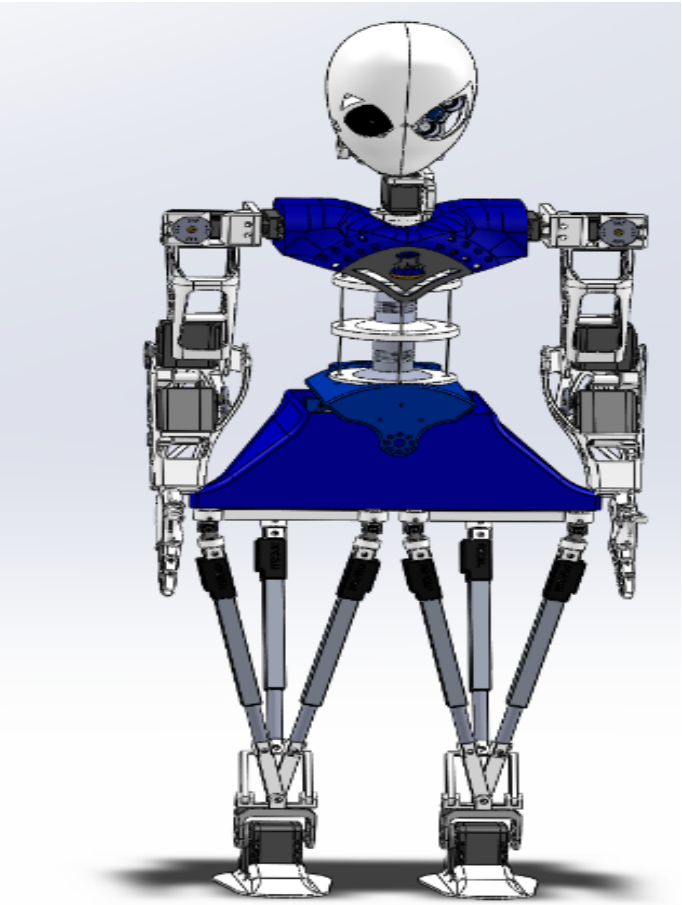


Fig. 2 A scheme of the activity in challenge activity centered on Mechanism Design

Examples:

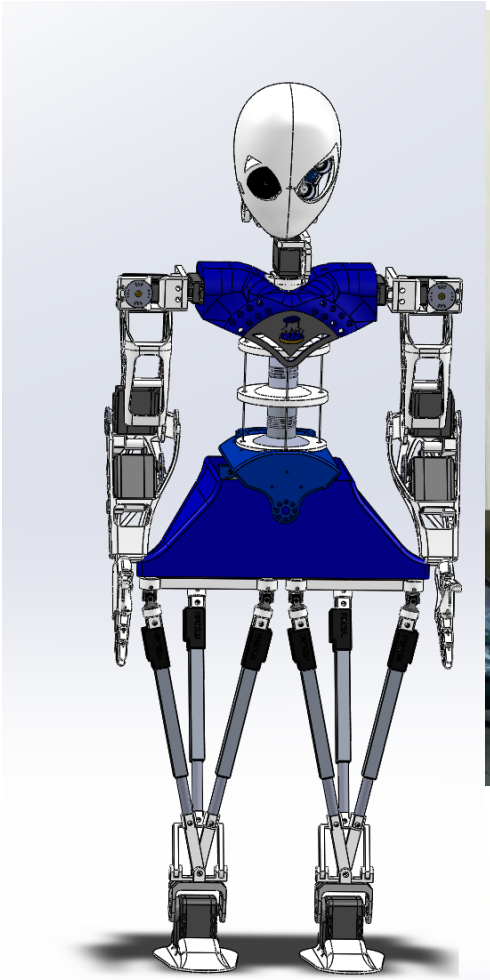
humanoid robots as based on mechanism design

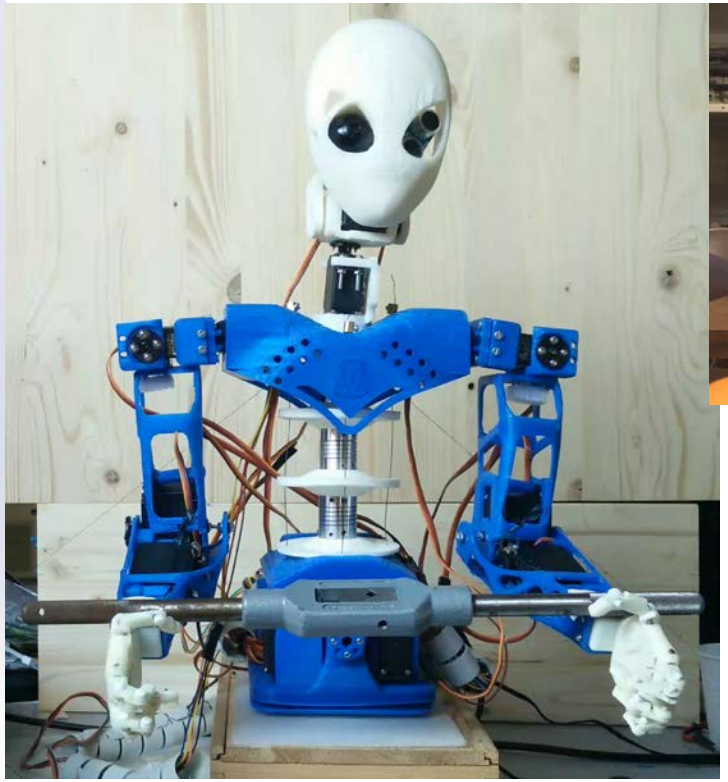


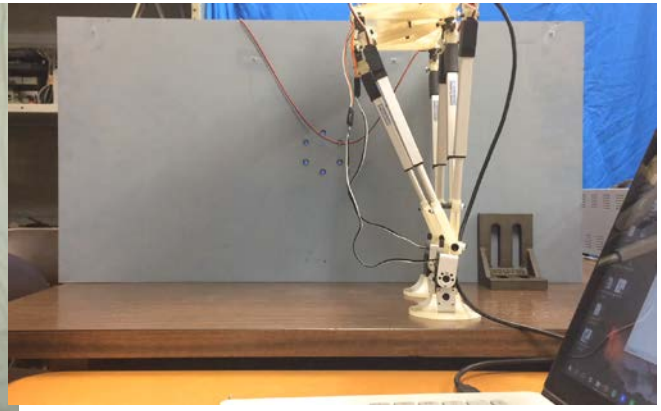


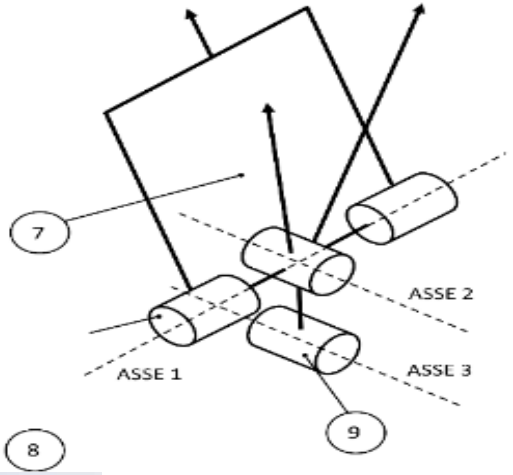
a) Wabot 1 humanoid in 1973, [4]; b) LARM bot design in 2017, [5]

LARMbot Humanoid – 2008-2017 (patent pending)





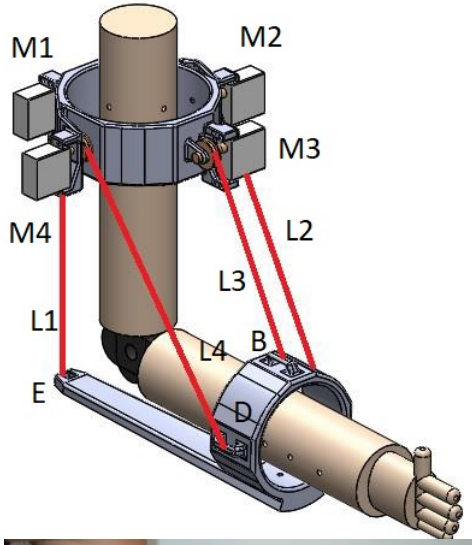


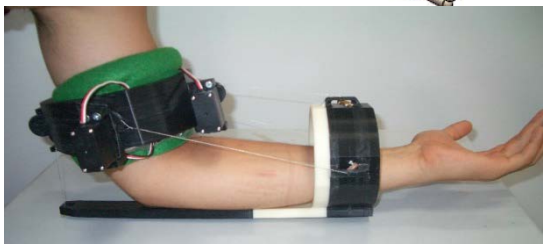


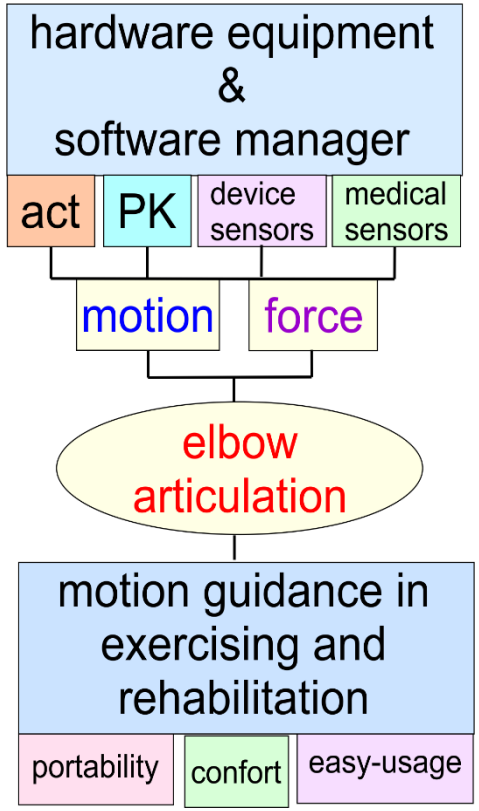
CADEL design for elbow motion assistance

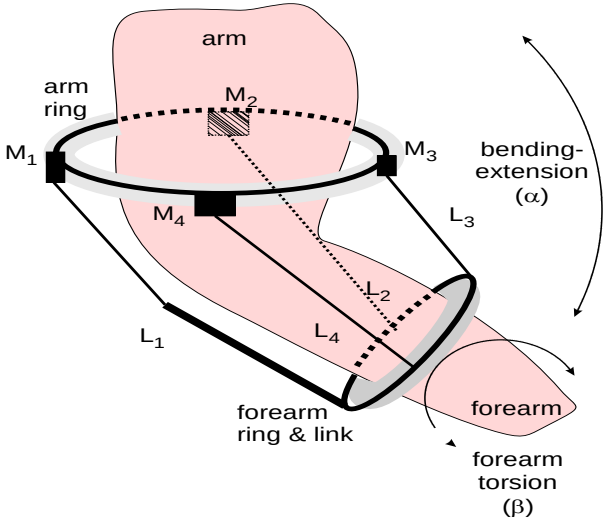
low-cost, easy wearable, low power consumption, user-orented operation…

Original design in 2017



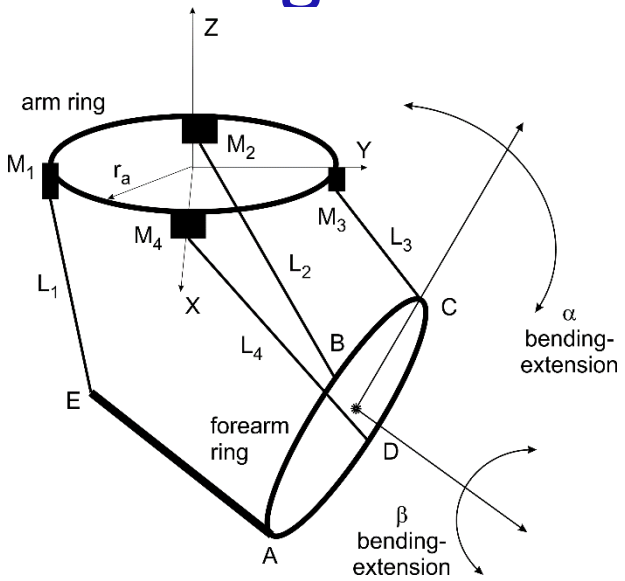






Marco Ceccarelli, Lucia Ferrara and Victor Petuya, Design of a cable-driven device for elbow rehabilitation and exercise,)In: Interdisciplinary Applications of Kinematics, pp. 61-68, Springer AG 2019, Cham 2019, https://doi.org/10.1007/978-3-030-16423-2_6

Modelling and computations - for motion planning



The cable length L_1 is given by the norm of vector $\mathbf{M_1E}$ as

$$\mathbf{M_1E} = \mathbf{M_1O} + \mathbf{OE}$$

$$\mathbf{M_1E} = \begin{bmatrix} \mathbf{0} \\ -r_a \\ h_a \end{bmatrix} + \mathbf{R}(\alpha, \mathbf{x})\mathbf{R}(\beta, \mathbf{y}) \begin{bmatrix} \mathbf{0} \\ -r_a \\ -r_b \end{bmatrix}$$

where, $\mathbf{R}(\alpha, \mathbf{x}) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix}$ and $\mathbf{R}(\beta, \mathbf{y}) = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\alpha \end{bmatrix}$ are the rotation matrices around $\mathbf{x}$ and $\mathbf{y}$ axes, respectively.

$$L_1 = \sqrt{(r_a + r_a\cos\alpha - r_b\sin\alpha)^2 + (r_b\cos\alpha - h_a + r_a\sin\alpha)^2}$$

$$L_2 = \sqrt{(h_a + h_f\sin\alpha - r_a\sin\alpha)^2 + (\cos\alpha)^2(h_f - r_a)^2 + (r_a + r_b)^2}$$

$$L_3 = \sqrt{(h_a + r_b\cos\alpha + h_f\sin\alpha - r_a\sin\alpha)^2 + (r_a + h_f\cos\alpha - r_a\cos\alpha - r_b\sin\alpha)^2}$$

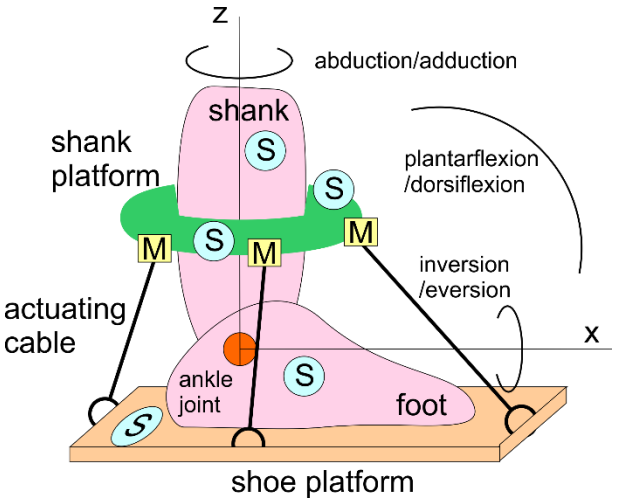
$$L_4 = \sqrt{(h_a + h_f\sin\alpha - r_a\sin\alpha)^2 + (\cos\alpha)^2(h_f - r_a)^2 + (r_a + r_b)^2}$$

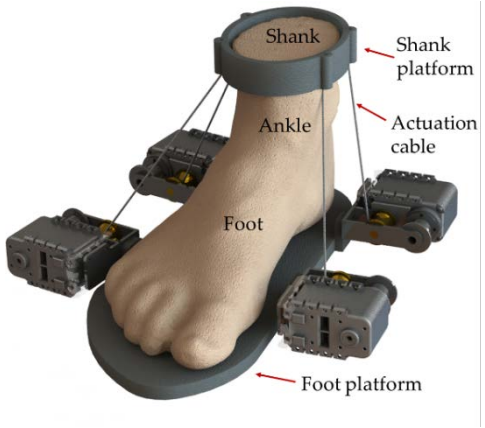
- for cable tension

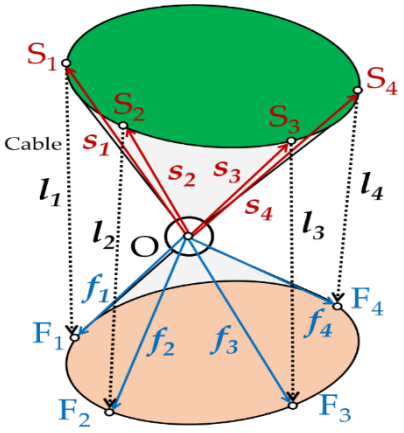
$$\mathbf{w}_e = \mathbf{J}^T\mathbf{T}$$

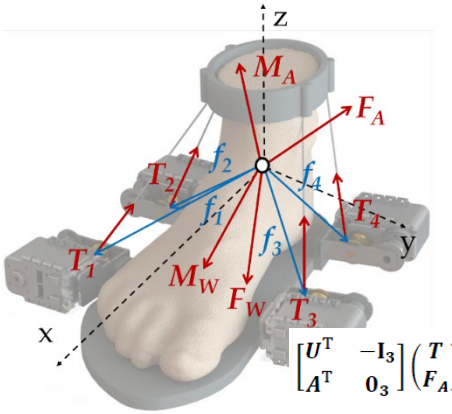
$$\mathbf{J}^T = \begin{bmatrix} \mathbf{u}_1 & \mathbf{u}_2 & \mathbf{u}_3 & \mathbf{u}_4 \\ \mathbf{R}_O \cdot \mathbf{O}_b\mathbf{E} \times \mathbf{u}_1 & \mathbf{R}_o \cdot \mathbf{O}_b\mathbf{B} \times \mathbf{u}_2 & \mathbf{R}_o \cdot \mathbf{O}_b\mathbf{C} \times \mathbf{u}_3 & \mathbf{R}_o \cdot \mathbf{O}_b\mathbf{D} \times \mathbf{u}_4 \end{bmatrix}$$

CADELankle- 2020





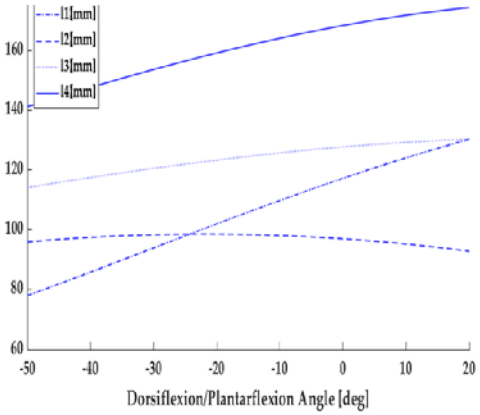


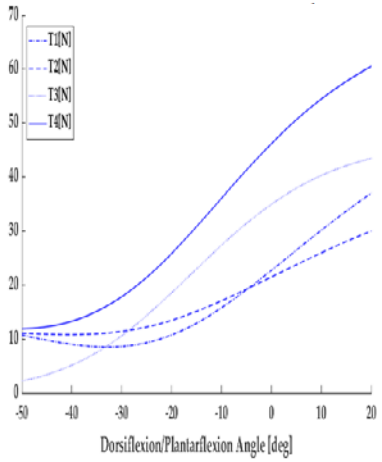


$$\begin{bmatrix} U^{\mathrm{T}} & -\mathbf{I}_3 \\ A^{\mathrm{T}} & \mathbf{0}_3 \end{bmatrix} \begin{pmatrix} T \\ F_A \end{pmatrix} = \begin{pmatrix} F_W \\ M_W \end{pmatrix}$$

$$A^{\mathrm{T}} = [\boldsymbol{f}_1 \times \boldsymbol{u}_1 \quad \cdots \quad \boldsymbol{f}_4 \times \boldsymbol{u}_4].$$

$$l_i = \sqrt{{}^{S}\boldsymbol{s}_i^{T}\,{}^{S}\boldsymbol{s}_i + {}^{F}\boldsymbol{f}_i^{T}\,{}^{F}\boldsymbol{f}_i - 2\,{}^{S}\boldsymbol{s}_i^{T}\,{}^{SF}\boldsymbol{R}\,{}^{F}\boldsymbol{f}_i}$$





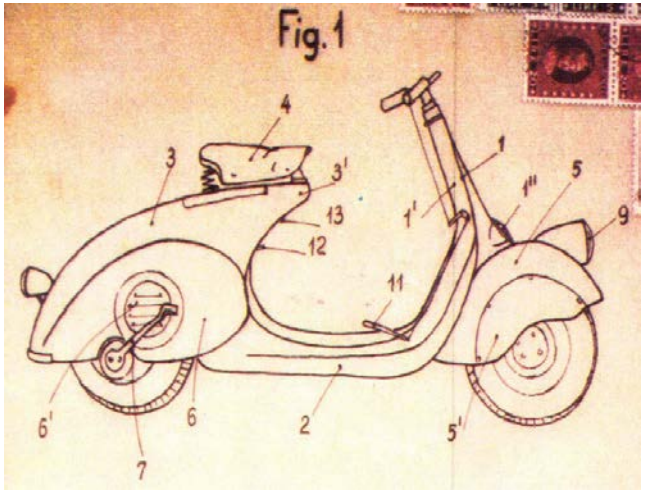
Russo M., Ceccarelli, M. Analysis of a Wearable Robotic System for Ankle Rehabilitation. Machines 2020, 8(3), 48; https://doi.org/10.3390/machines8030048.https://www.mdpi.com/2075-1702/8/3/48

Historical-techncal analysis of landmarks

Scooter Vespa: documenti storici, contesto storico, inventore, dettagli tecnici, analisi prestazioni, …

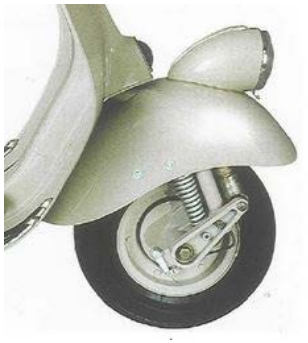
Corradino D'Ascanio (1891-1981)

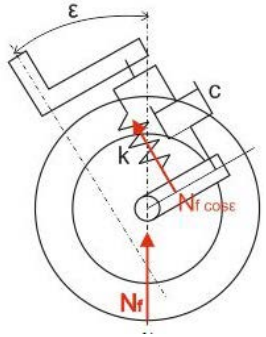
1914 laurea in ingegneria meccanica
1925 primo elicottero, DAT1
1929 primo elicottero a volare, DAT3
1932 inizia collaborazione con Piaggio
1945 progetta la Vespa
1951 elicottero PD4
1970 aereo per uso agricolo



Brevetto della Vespa 98 : 23 aprile 1946

TELAIO: a guscio a forma aperta e carenata.
SOSPENSIONE: ant. elastica, post. di gomma
TRASMISSIONE: diretta sulla ruota posteriore
CAMBIO DI MARCIA: disposto sul manubrio
MESSA IN MOTO: a pedale
RUOTE: 3,50 x 8; intercambiabili
CONSUMO: 50 km/l





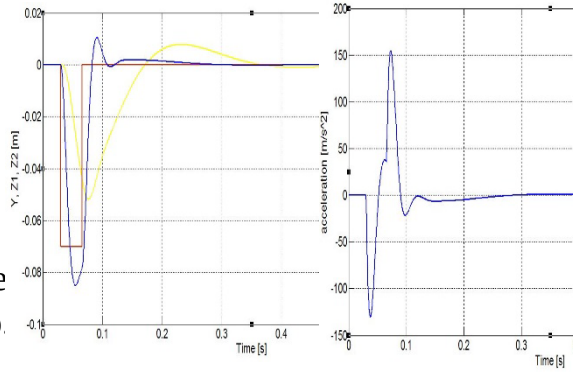
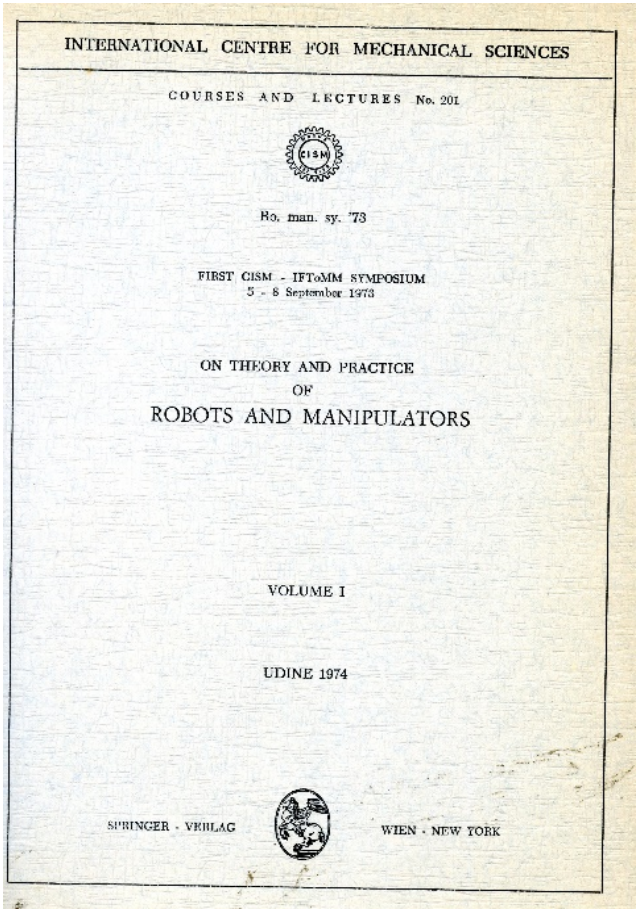
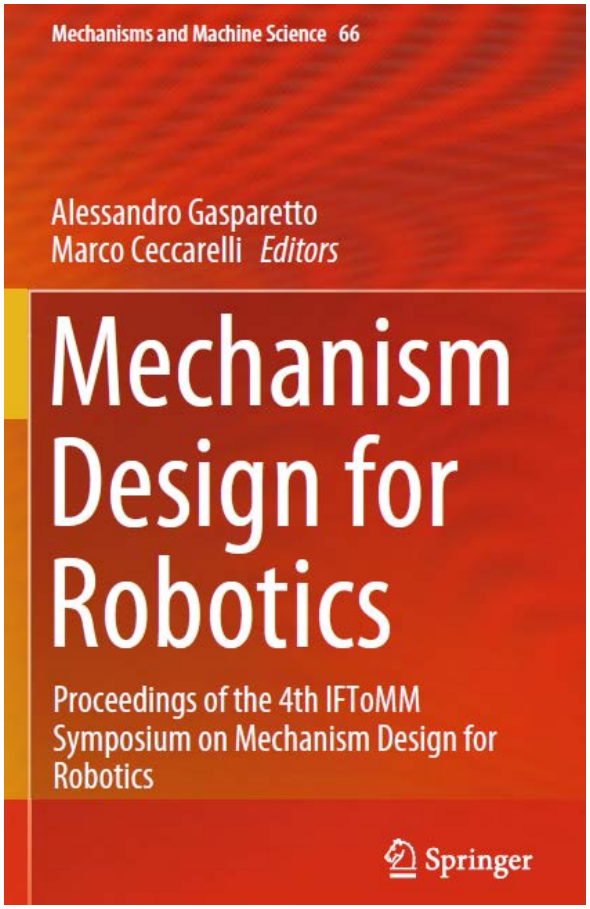


Fig. 11 Numerical results of performance evaluation for model in Fig.9 when running at 30 Km/h in a road hole of 7 cm high and 20 cm wide: a) displacements of masses (in blue for road profile; in yellow for mass m_1 and in red for mass m_2); b) acceleration for mass m_1 of a driver.

example of innovation from community viewpoints





Community acticities:

Conference initiatives & publication frames:

- To disseminate
- To discuss
- To generate innovation

with Science & Technological transfer

Title page of proceedings of:
a) Romansy in 1973, [4];

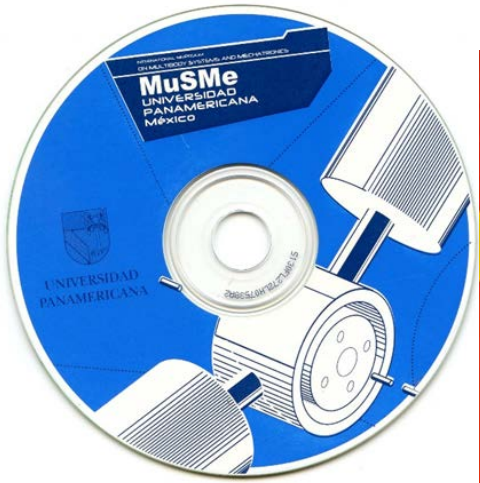
b) MEDER in 2018,

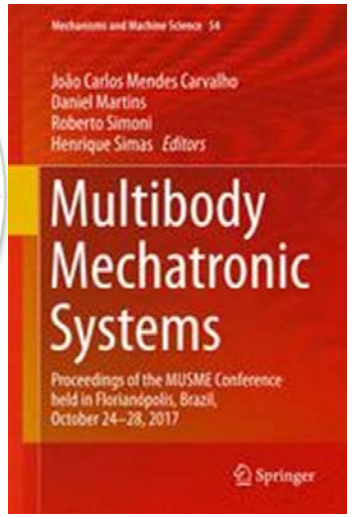
IFToMM- FeIbIM Symposium on Multibody and Mechatronics MUSME

A conference stimulating integration
between the disciplines of Mechatronics and Multibody System Dynamics
A forum for facilitating contacts among research people and students
A match conference **for IFToMM and FeIbIM communities**
preferable to have MUSME Symposium in Latin-America every three years.

MUMSE 2002: Mexico city, Mexico, foundation
MSUME 2005: Uberlandia, Brazil
MUSME 2008: San Juan, Argentina

MUSME 2011: Valencia, Spain
MUSME 2014: Huatulco, Mexico
MUSME 2017: Florianópolis, Brazil
MUSME 2020-21: Online - Cordoba, Argentina





Best Paper Awards
in Research, Applications, & Student
Started in 2014
- by an Award Committee (AC)
- by consider the reviews
- 3 levels Gold, Silver, Bronze.

Community role in MMS Innovation

- Innovations is produced by inventors coming **from a community** and producing new figures in the community.
- Significance of innovation is produced and supported by the **corresponding community**
- particularly significant **the history and role of IFToMM**

in Robotics and MMS at large

The mission of IFToMM is

to promote research, development, and education in the field of Machines and Mechanisms by using theoretical and experimental methods, along with their practical application.

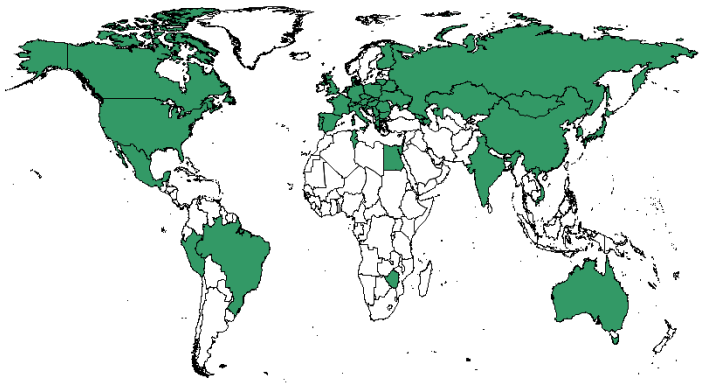
Main activities can be summarized in:

- conference initiatives
- meetings of the IFToMM
- publications
- knowledge transfer and science development
- collaborations

next World Congress will be held in 2023 in Tokyo, Japan

IFToMM

the International Federation for the Promotion of Mechanism and Machine Science



IFToMM

GA with Mos
General Assembly with Memebr Organizations

GACs

President with Executive Council

PCs
Permanent Commssions

TCs
Technical Committees

activities for the promotion of Mechanism and Machine Science

WC
world congress

SIOMMS
student Olympiad

Executive Council

GA

TC

TC Chair

IFToMM Member Organizations

TC members

TC observers

other communities in regions and disciplines

collaboration

individuals

conferences, meetings, tutorials

formation, research, design, search of new directions

technological transfer, publications, editorial works, practice

The IFToMM generations:

- 1950s-1975 – **First generation: founding fathers** and their friend colleagues up to the 4th IFToMM World Congress in New Castle upon Tyne in 1975 with Prof. Leonard Maunder as Congress Chair.
- 1976-1995 – **Second Generation: pupils and people, who were educated in TMM** by founding fathers and their friend colleagues; up to the 9th World Congress in Milan in 1995 with Prof. Alberto Rovetta (Bianchi's pupil) as Congress Chair.
- 1996-2011 – **Third Generation: educated people with MMS activity** in the frames of IFToMM and within IFToMM activity with 48 national organizations as IFToMM members, up to the 13th World Congress in 2011 in Guanajuato, Mexico with Prof. Carlos Lopez-Cajùn as Congress Chair.
- 2011 – **Today – Fourth Generation:** educated people working in frames that are linked to IFToMM and within IFToMM activity with 47 organizations as IFToMM members.

IFToMM officers are:

- the Chairs of IFToMM Member Organizations,
- the Chairs of TCs and PCs, the members of the Executive Council

Main activities (conferences, meetings, publications, knowledge transfer, collaborations)

47 IFToMM members of territory and national Associations

13 Technical Committees (Biomedical Engineering, Computational Kinematics, Multibody Dynamics, Gearing and Transmissions, Linkages and Mechanical Controls, Micromachines, Reliability, Robotics and Mechatronics, Rotordynamics, Sustainable Energy Systems, Transportation Machinery, Tribology, Vibrations)

3 Permanent Commissions (Comms-Publication-Archive, Educations, History, Terminology)

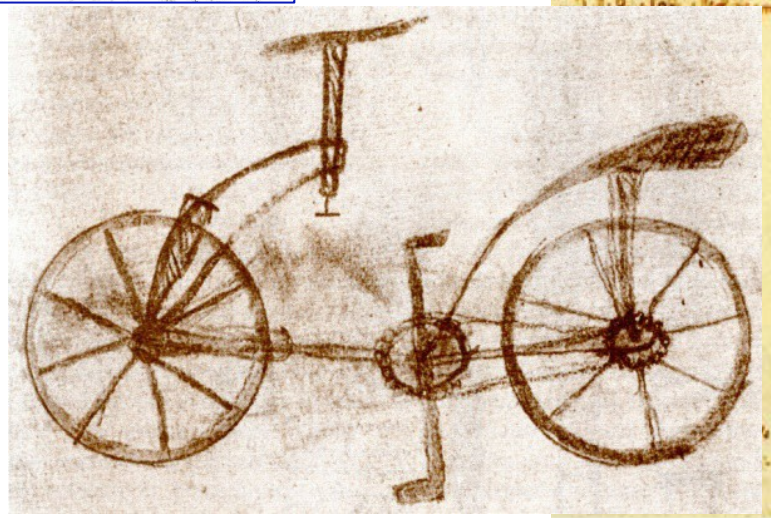
5 Journals (Mechanism and Machine Theory, Chinese Jnl of Mechanical Engineering, open-access Mechanical Sciences, Advances in Vibration Engineering, Mechanics Based Design of Structures and Machines)

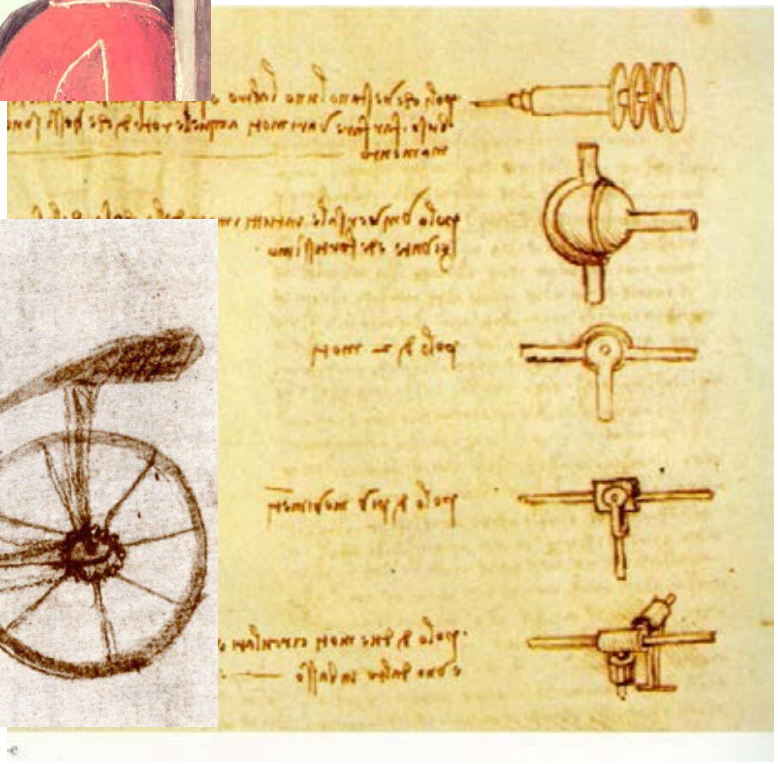
IFToMM events: conferences, summer schools, tutorials, meetings; **editorial works- World Congress in 4 years**

Examples of machines and their inventors

Mariano di Jacopo (il Taccola)
(1381? - 1458)

Francesco di Giorgio
(1439-1501)



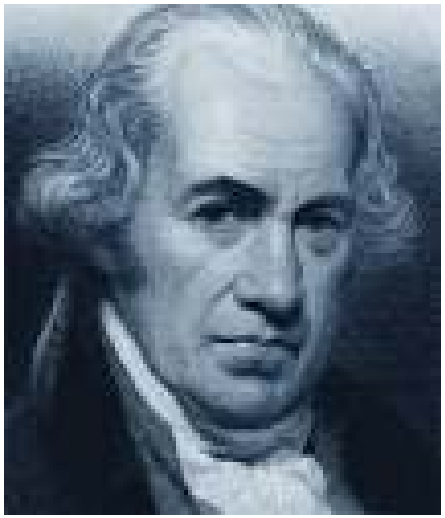


Leonardo da Vinci
(1452-1519)

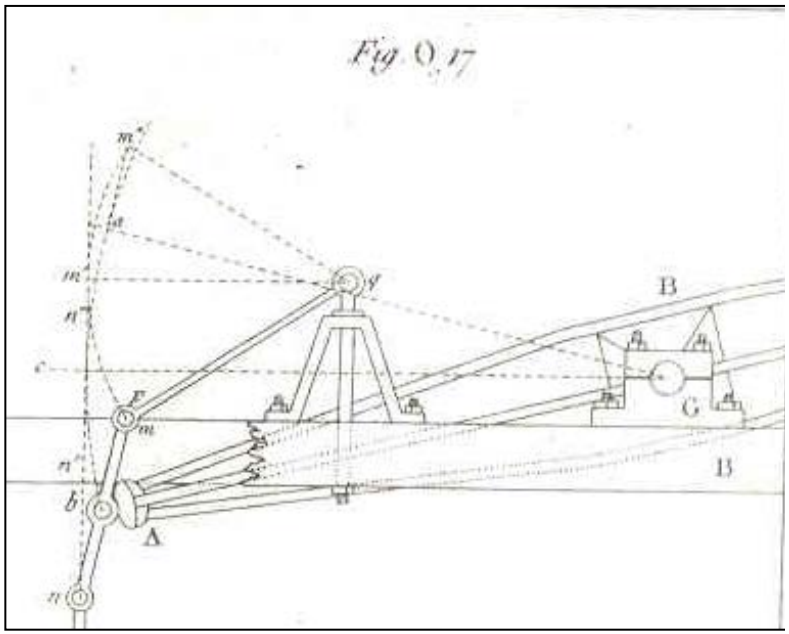
prominent Renaissance figures

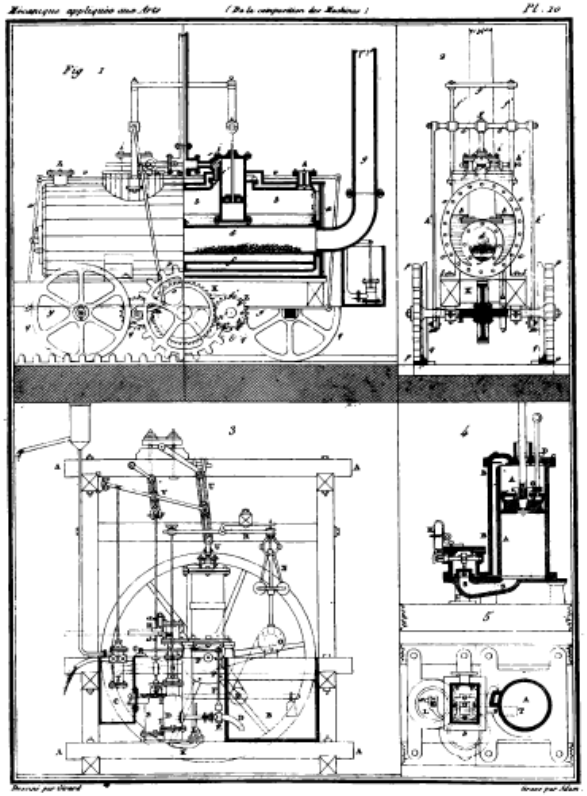
- for polyhedral activity
- showing a modern character of scientist
- **n accumulating experience and dissemination knowledge**.

Examples of machines and their inventors



James Watt

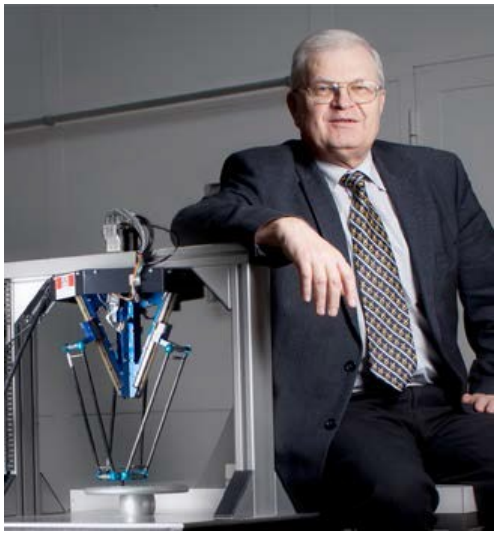


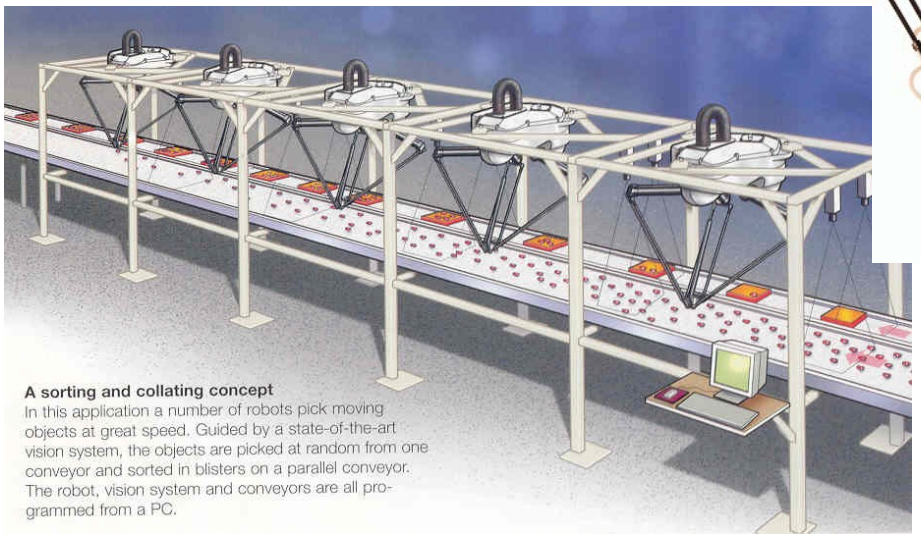


First efficient application of Thermodynamics with its circuits , but thanks mechanisms

Fig. 2 Past innovation with Watt mechanism: a) early kinematic study of kinematic properties in the book by Lanz and Betancourt in 1808; b) applications for locomotives (top) and industrial plants (bottom) in the book on Composition of Machines by G.A. Borgnis in 1818.

Robots in applications... **for new areas** .....





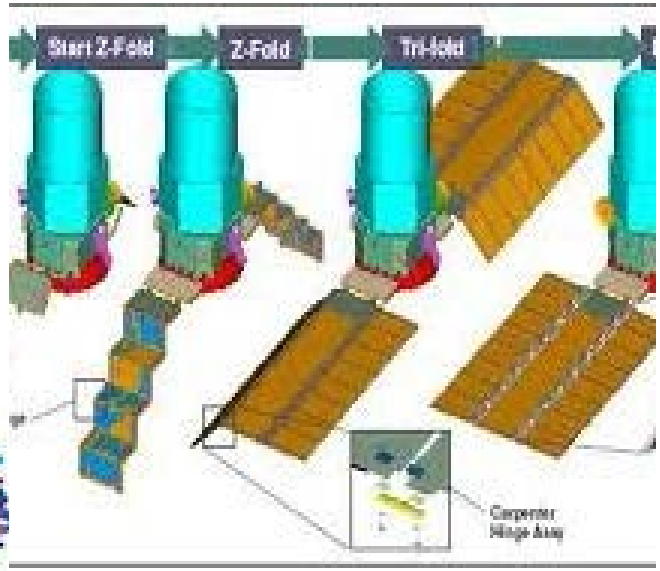
A sorting and collating concept
In this application a number of robots pick moving objects at great speed. Guided by a state-of-the-art vision system, the objects are picked at random from one conveyor and sorted in blisters on a parallel conveyor. The robot, vision system and conveyors are all programmed from a PC.

Delta parallel manipulator:

a) the ABB commercialized version; b) industrial application for fast pick & place packaging

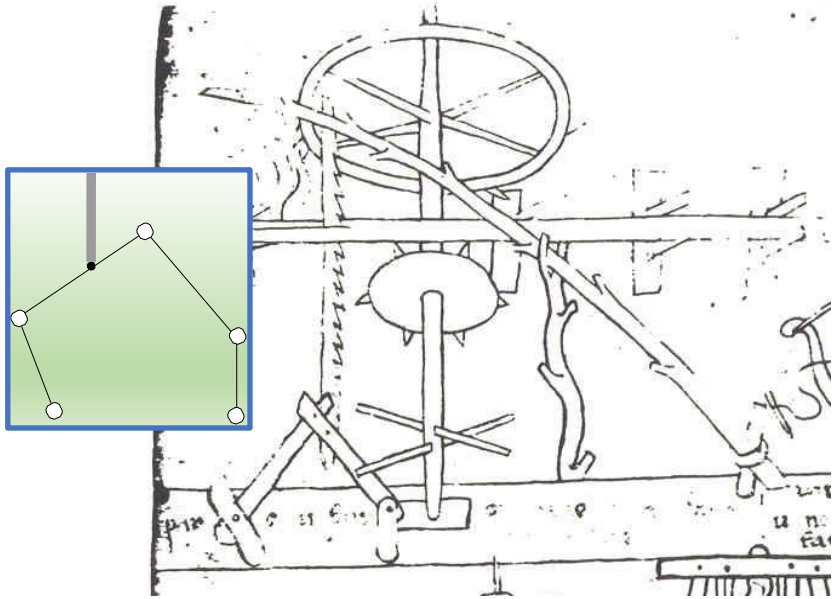
Fig shows the ABB delta robot whose parallel manipulator architecture is the core of the success in pick & place operations at high speed in manufacturing and assembling operations for industrial and non-industrial applications. In the first case knowledge was acquired with first experiences in industrial object transfer and then it was applied in further developments also in other industrial applications. In the second case theoretical works accumulated experience that has permitted the conceptions of this machine structure in new application areas (see also Fig.b). In both case the technical values was exalted by business plans and enterprise exploitations.

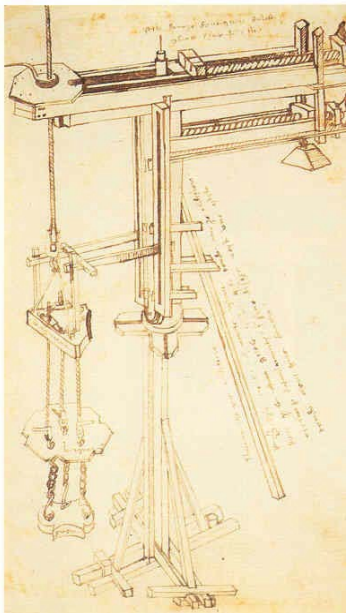
New technical solutions in exploitations in different areas

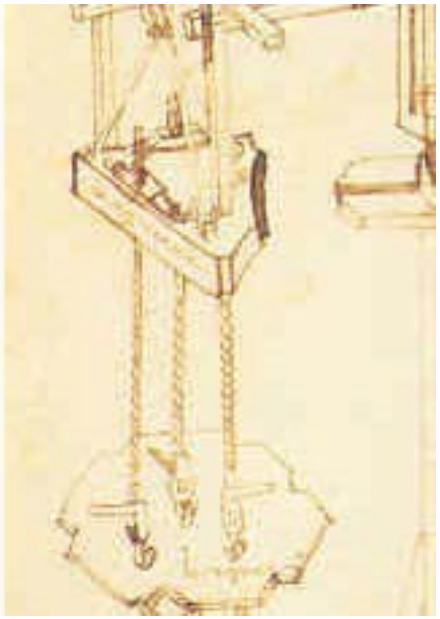


Deployable mechanisms in innovative applications:
a) in toy design; b) for space antenna structures; c) in load lifters for civil engineering

What we develop today …. Is really innovative solution?







Early modern mechanisms:

*a) 2dof linkage with coupler guiding point by **Villard de Honnecourt** in13th century;*

*b) cable-based parallel manipulator by **Filippo Brunelleschi** (1377-1446).*

Impact and fame of inventors - engineers

Who got & gets better reputation?

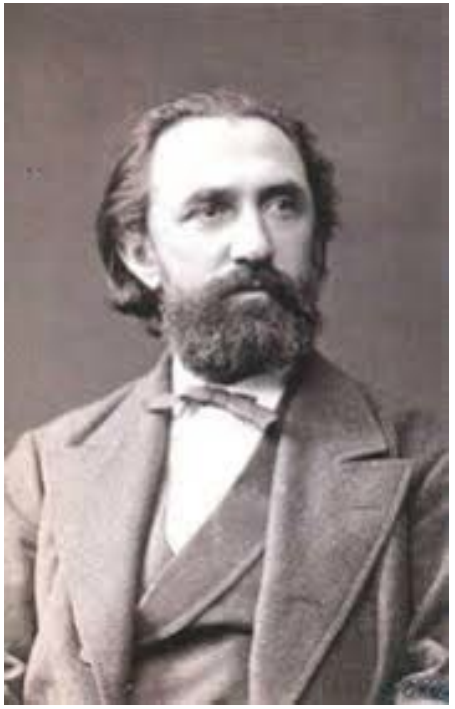
Dorando Petri- marathon of first Olympiad

In the past

scientists and engineers

Were better considered than other professions

…. although ……



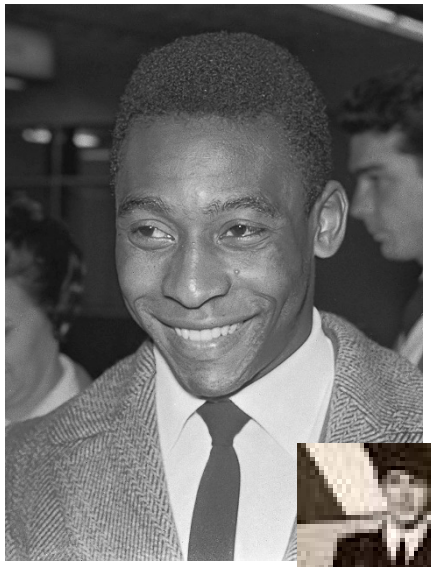
Franz Reuleaux

Impact and fame of roboticists - engineers

Who got & gets better reputation?...

Reason to work on history!

Properly sized for the impact on society improvements



Pelè

Gianni Rivera

Ikiro Kato

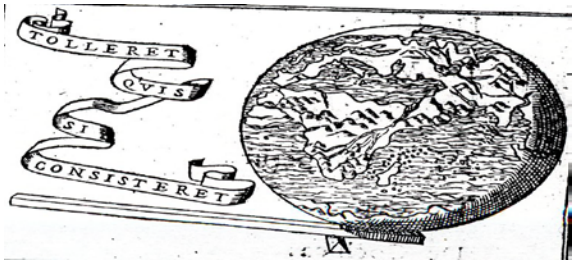
Joseph Engelberg

Beatles

Alberto Rovetta

How to regain Primary consideration? ...and funding???

Conclusions



Innovation is a result of knowledge and creativity (**which comes first?**)
With success of products and people

today **commercial exploitation** reduces the merit of technical valorization.

achievements and solutions in Mechanism Dseign as well the corresponding community can be considered **important bases for innovation**
as technical content and background,
without which no innovation is possible in machine area
and even in more other fields.

But **a full modern innovation**
requires a community with more multi-disciplinary skills

IFToMM community can work such a role as established with vision of international frames a for collaboration purposes with impact and application in technological developments **for the benefits of the society.**

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