

Mechanisms and Machine Science

Vincenzo Niola  
Alessandro Gasparetto  
Giuseppe Quaglia  
Giuseppe Carbone *Editors*

# Advances in Italian Mechanism Science

Proceedings of the 4th International  
Conference of IFToMM Italy




 Springer

The Springer logo consists of a white chess knight piece on a pedestal, followed by the word 'Springer' in a white serif font.

# Mechanisms and Machine Science

Volume 122

## Series Editor

Marco Ceccarelli , Department of Industrial Engineering, University of Rome Tor Vergata, Roma, Italy

## Advisory Editors


Sunil K. Agrawal, Department of Mechanical Engineering, Columbia University, New York, USA

Burkhard Corves, RWTH Aachen University, Aachen, Germany

Victor Glazunov, Mechanical Engineering Research Institute, Moscow, Russia

Alfonso Hernández, University of the Basque Country, Bilbao, Spain

Tian Huang, Tianjin University, Tianjin, China

Juan Carlos Jauregui Correa , Universidad Autonoma de Queretaro, Queretaro, Mexico

Yukio Takeda, Tokyo Institute of Technology, Tokyo, Japan

This book series establishes a well-defined forum for monographs, edited Books, and proceedings on mechanical engineering with particular emphasis on MMS (Mechanism and Machine Science). The final goal is the publication of research that shows the development of mechanical engineering and particularly MMS in all technical aspects, even in very recent assessments. Published works share an approach by which technical details and formulation are discussed, and discuss modern formalisms with the aim to circulate research and technical achievements for use in professional, research, academic, and teaching activities.

This technical approach is an essential characteristic of the series. By discussing technical details and formulations in terms of modern formalisms, the possibility is created not only to show technical developments but also to explain achievements for technical teaching and research activity today and for the future.

The book series is intended to collect technical views on developments of the broad field of MMS in a unique frame that can be seen in its totality as an Encyclopaedia of MMS but with the additional purpose of archiving and teaching MMS achievements. Therefore, the book series will be of use not only for researchers and teachers in Mechanical Engineering but also for professionals and students for their formation and future work.

The series is promoted under the auspices of International Federation for the Promotion of Mechanism and Machine Science (IFTToMM).

Prospective authors and editors can contact Mr. Pierpaolo Riva (publishing editor, Springer) at: [pierpaolo.riva@springer.com](mailto:pierpaolo.riva@springer.com)

Indexed by SCOPUS and Google Scholar.

More information about this series at <https://link.springer.com/bookseries/8779>

Vincenzo Niola · Alessandro Gasparetto ·  
Giuseppe Quaglia · Giuseppe Carbone  
Editors

# Advances in Italian Mechanism Science

Proceedings of the 4th International  
Conference of IFToMM Italy


 Springer

*Editors*

Vincenzo Niola  
University of Naples Federico II  
Naples, Italy

Alessandro Gasparetto  
University of Udine  
Udine, Italy

Giuseppe Quaglia  
DIMEAS  
Politecnico di Torino  
Turin, Italy

Giuseppe Carbone   
DIMEG  
University of Calabria  
Rende, Italy

ISSN 2211-0984

ISSN 2211-0992 (electronic)

Mechanisms and Machine Science

ISBN 978-3-031-10775-7

ISBN 978-3-031-10776-4 (eBook)

<https://doi.org/10.1007/978-3-031-10776-4>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2022, corrected publication 2022

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

The aim of this proceedings book is to present recent advances in the field of Mechanism and Machine Science (MMS) that originated in the IFToMM Italy community and its international network. The book contains the contributions, ranging from theoretical contributions to experimental and practical applications that have been accepted for presentation at the Fourth International Conference of IFToMM Italy, IFIT 2022.

The Fourth International Conference of the IFToMM ITALY association has been held at the University of Napoli “Federico II,” in Napoli (Italy) on September 7–9, 2022. The conference is under the patronage of IFToMM, the International Federation for the Promotion of Mechanism and Machine Science. IFToMM as the International Federation for the Theory of Mechanisms and Machines (TMM) was founded in 1969 during the Second World Congress on TMM in Zakopane, Poland.

Italy has been one of the founding member organizations of IFToMM, and IFToMM Italy, as a IFToMM Member Organization, was founded in 1970. Therefore, during the IFIT 2022 Conference, a special celebration of the 50th anniversary of IFToMM Italy has been held. Since its establishment, the Italian Member Organization has been very active with many contributions at national and international levels.

The Fourth International Conference of IFToMM Italy continues a series of IFIT conferences that has been started in 2016 by IFToMM Italy with a very successful event in Vicenza. A second event was held in Cassino in 2018, and, then, a third event was held online in 2020 with only a remote tele-meeting mode because of the COVID-19 pandemic circumstances. The IFToMM Italy association board is currently formed by Alessandro Gasparetto (president), Giuseppe Quaglia (vice president), Vincenzo Niola (secretary) and Giuseppe Carbone (treasurer).

The book content includes papers belonging to a broad range of disciplines in the field of MMS: history of mechanism science, biomechanical engineering, robotics, mechanism design, sustainable development goals, tribology, gearing and transmission, vehicle dynamics and control, mechatronics, vibrations, dynamics of machinery, multibody dynamics, computational kinematics and rotor dynamics.

These contributions are provided as a collection of 104 papers that have been accepted after a blind peer-review process. Among them, the best evaluated papers receive award recognition in the three IFToMM categories: research, applications and student. Springer awards in research and student categories are also given since the IFIT proceedings series is planned within the Springer book series on MMS.

We would like to thank all the members of the Scientific and Organizing Committees for their strong contribution toward the success of IFIT 2022:

Honorary Chair: Alessandro Gasparetto (University of Udine)

Conference Chair: Vincenzo Niola (University of Napoli)

Scientific Committee:

- Alessandro Gasparetto (University of Udine, *Chair*)
- Nicola Pio Belfiore (University of Roma Tre)
- Massimo Callegari (Pol. University of Marche)
- Roberto Caracciolo (University of Padova)
- Giuseppe Carbone (University of Calabria)
- Marco Ceccarelli (University of Roma Tor Vergata)
- Enrico Ciulli (University of Pisa)
- Raffaele di Gregorio (University of Ferrara)
- Pietro Fanghella (University of Genova)
- Andrea Manuello (Politecnico di Torino)
- Arcangelo Messina (University of Salento)
- Domenico Mundo (University of Calabria)
- Vincenzo Niola (University of Napoli)
- Paolo Pennacchi (Politecnico di Milano)
- Giuseppe Quaglia (Politecnico di Torino)
- Rosario Sinatra (University of Catania)
- Alberto Trevisani (University of Padova)

Organizing Committee

- Vincenzo Niola (University of Napoli, *Chair*)
- Paolo Boscariol (University of Padova)
- Giovanni Boschetti (University of Padova)
- Giuseppe Carbone (University of Calabria)
- Chiara Cosenza (University of Napoli, *General Secretariat*)
- Flavio Farroni (University of Napoli)
- Riccardo Russo (University of Napoli)
- Aleksandr Sakhnevych (University of Napoli)
- Sergio Savino (University of Napoli)
- Francesco Timpone (University of Napoli)

We wish to express our sincere gratitude to the authors and reviewers for their valuable scientific contributions and useful feedbacks in due time to ensure a high scientific quality of IFIT 2022. We also thank the support of the IFToMM

Permanent Commission for the History of Mechanism and Machine Science, the IFToMM Technical Committee for Sustainable Energy Systems and the IFToMM Technical Committee for Robotics and Mechatronics.

The editors are also grateful to the IFToMM Italy association to coordinate the conference organization as well as the IFToMM federation for its patronage of IFIT 2022.

Finally, we thank all the staff members at Springer for their valuable editorial support.

May 2022

Giuseppe Carbone  
Alessandro Gasparetto  
Vincenzo Niola  
Giuseppe Quaglia



# Contents

## History of Mechanism Science

<b>A Note on 50-Year Anniversary of IFToMM Italy</b> . . . . .	3
Marco Ceccarelli	
<b>Contributions of Italian Jesuits in Machinery Technology Transfer to China in the 16–18 th Centuries</b> . . . . .	7
Marco Ceccarelli and Baichun Zhang	
<b>Evolution of Racing Wheelchair: From Its Origin to the Paralympic Games</b> . . . . .	16
Paride Cavallone, Luigi Tagliavini, Andrea Botta, Giovanni Colucci, Lorenzo Baglieri, and Giuseppe Quaglia	
<b>Earliest Locomotives in Italy and China from the Perspective of Technology Transfer</b> . . . . .	25
Yibing Fang, Marco Ceccarelli, and Yingjie Chu	

## Computational Kinematics

<b>Kinematic Modelling of a High Mobility Tracked Robot</b> . . . . .	37
Angelo Ugenti, Rocco Galati, Giacomo Mantriota, and Giulio Reina	
<b>Motion Profiles with Elliptic Jerk</b> . . . . .	45
Daniele Stretti and Luca Bruzzone	
<b>Kinematic Analysis and Centroides Between Rotating Tool with Reciprocating Motion and Workpiece</b> . . . . .	54
Giorgio Figliolini, Chiara Lanni, and Massimo Sorli	
<b>Kinematic Representation of a Biomimetic Squid Soft Robot’s Arms in a Simulation Environment</b> . . . . .	61
Hazal Emet and M. İ. Can Dede	

<b>Balanced Twin Lip Vane Pumps: A Kinematic Approach to the Design</b> .....	69
Davide Guerra, Mattia Battarra, Emiliano Mucchi, and Giorgio Dalpiaz	
<b>Kinematic Modeling and Design of a Sensorized Cable-Routing System for Cable-Driven Parallel Robots</b> .....	77
Andrea Lucarini and Edoardo Idá	
<b>An Overview on the Kinematic Analysis of the Rocker-Bogie Suspension for Six Wheeled Rovers Approaching an Obstacle</b> .....	86
Armando Nicoletta, Vincenzo Niola, Stefano Pagano, Sergio Savino, and Mario Spirto	
<b>Spring-Loaded Rocker-Bogie Suspension for Six Wheeled Rovers</b> .....	94
Chiara Cosenza, Vincenzo Niola, Stefano Pagano, and Sergio Savino	
<b>Dynamics of Machinery, Rotordynamics, Multibody Dynamics</b>	
<b>Analytical Synthesis of Five-Bar Linkage used for 3D Printer Structure</b> .....	105
Tivadar Demjen, Erwin-Christian Lovasz, Marco Ceccarelli, Carmen Sticlaru, and Antonio-Marius-Flavius Lupuți	
<b>Non-stationary Resonance Transition of the Gyroscopic Rigid Rotor with Nonlinear Damping and Non-ideal Energy Source</b> .....	114
Zharilkassin Iskakov, Nutpulla Jamalov, and Azizbek Abduraimov	
<b>Comparison of PID and PII<sup>1/2</sup>DD<sup>1/2</sup> Position Control of a Rotor with Trapezoidal Velocity Profile: Influence of the Profile Parameters</b> .....	123
Luca Bruzzone	
<b>Visualization Approach of Gaps Between Rotors of an Oil Pump Based on Geometrical Arrangement</b> .....	131
Koji Makino and Hidetsugu Terada	
<b>Multibody Simulation of a Novel Tracked Robot with Innovative Passive Suspension</b> .....	139
Andrea Grazioso, Rocco Galati, Giacomo Mantriota, and Giulio Reina	
<b>Sensitivity Analysis of Flexible Multibody Dynamics with Generalized-<math>\alpha</math> Time Integration and Baumgarte Stabilization</b> .....	147
Veit Gufler, Erich Wehrle, and Renato Vidoni	
<b>Mechanism Design</b>	
<b>Problems and Requirements for Docking Operation in Orbital Stations</b> .....	159
Alexander Titov and Marco Ceccarelli	

**Development of Discontinuous Shaped Roller-Chain Drive Type Wave Motion Reducer** . . . . . 168  
 Hidetsugu Terada, Koji Makino, Xiao Sun, Jin Usami, and Takeshi Saito

**Identification of Key Parameters for Synthesis of Straight-Line Crank Rockers Using Inflection Circle Properties** . . . . . 177  
 P. B. Shiwalkar

**Development of a Hydraulic System for the Mitigation of End-Effector Collisions** . . . . . 185  
 Giulio Cipriani, Domenico Tommasino, Matteo Bottin, Alberto Doria, and Giulio Rosati

**An Analytical Model for Cantilever Layer-Jamming Structures** . . . . . 193  
 Fabio Caruso, Giacomo Mantriota, and Giulio Reina

**Design and Validation of a Novel Pyramidal Cable-Driven Robot** . . . . . 201  
 Mohammed Khadem, Fouad Inel, and Giuseppe Carbone

**Tribology, Gearing and Transmissions**

**Modeling a Magneto-Rheological Fluid-Based Brake via a Neural Network Method** . . . . . 211  
 Sefa Furkan Küçüköğlü, Mehmet İsmet Can Dede, and Marco Ceccarelli

**A Model for the Prediction of Frictional Power Losses in Hypoid Gears** . . . . . 219  
 Eugeniu Grabovic, Enrico Ciulli, Alessio Artoni, and Marco Gabiccini

**A Vision Based Approach to Study Lubrication Conditions in Gearwheels** . . . . . 229  
 Chiara Cosenza, Armando Nicolella, Andrea Genovese, Vincenzo Niola, Sergio Savino, and Mario Spirto

**Determination of Tooth Profile Curve of Helical Pinion and Rack Gears to Achieve Non-constant Transmission Ratio** . . . . . 237  
 Daisuke Matsuura, Yusuke Honjo, Tsune Kobayashi, and Yukio Takeda

**Light Weight Geared Actuator Utilizing the Drive Redundancy** . . . . . 246  
 Takamaru Saito, Kotaro Hoshiba, Yusuke Sugahara, and Yukio Takeda

**A Vibro-Impact Analysis of a Driveline Equipped with a Dual Clutch Transmission System** . . . . . 255  
 Ernesto Rocca and Riccardo Russo

**Vibrations**

**Vibrations of a Rigid Body on Rolling Vibration Bearings in Case of Accidental Kinematic Perturbations** . . . . . 265  
 K. Bissembayev, Zh. Iskakov, and A. Sagadinova

<b>The Effect of Pulleys and Hooks on the Vibrations of Cable Rehabilitation Robots</b> . . . . .	273
Giacomo Zuccon, Lewei Tang, Alberto Doria, Matteo Bottin, Riccardo Minto, and Giulio Rosati	
<b>On the Ride Comfort Effect of Unsprung Mass Reduction Using a Composite Wheel Rim</b> . . . . .	282
Michele Zanchini, Daniel Longhi, Sara Mantovani, and Francesco Puglisi	
<b>Nonlinear Analysis of the Vibrational Behavior of an Internal Combustion Marine Engine</b> . . . . .	290
Vincenzo Niola, Sergio Savino, Chiara Cosenza, Mario Spirto, Armando Nicolella, Vincenzo Maria Arricale, and Giuseppe Quaremba	
<b>Study of Cavitation Phenomenon in a Proportional Spool Valve Through Chaos Theory</b> . . . . .	298
Vincenzo Niola, Sergio Savino, Giuseppe Quaremba, Chiara Cosenza, Mario Spirto, Armando Nicolella, Luca Romagnuolo, and Emma Frosina	
<b>Experiments on a Quasi-zero Stiffness Suspension for Passive Vibration Control</b> . . . . .	306
Giovanni Iarriccio, Moslem Molaie, Antonio Zippo, and Francesco Pellicano	
<b>A Test Rig for Experimental Investigation on a MRE Vibration Isolator</b> . . . . .	313
Renato Brancati, Giandomenico Di Massa, Carlo Motta, Stefano Pagano, Alberto Petrillo, and Stefania Santini	
<b>On the Profitability of Higher Order FE Formulations for Structural Dynamics</b> . . . . .	321
Anna Karpik, Francesco Cosco, Francesco Greco, and Domenico Mundo	
<b>Vehicle Dynamics and Control</b>	
<b>On the Vehicle Stability and Maneuverability Domain Definition for Automated Vehicles</b> . . . . .	331
Aleksandr Sakhnevych, Guido Napolitano dell'Annunziata, and Riccardo Russo	
<b>Problems and Requirements in Impact Analysis from Vehicle Accidents</b> . . . . .	346
María Garrosa, Marco Ceccarelli, and Vicente Díaz	
<b>Development and Validation of a Vehicle Simulation Platform for Driver-in-the-Loop Testing</b> . . . . .	355
Michele Perrelli, Francesco Cosco, Domenico Lo Polito, and Domenico Mundo	

**Active Steering Assistant for Powered Two-Wheelers: Hardware Prototyping and Results** . . . . . 361  
 Stefano Lovato, Matteo Bova, Matteo Massaro, Mauro Andriollo, and Roberto Lot

**A Sliding Mode Course Control for Robust Path Following of a Fixed Wing UAV** . . . . . 370  
 Luca Pugi, Samuele Favilli, Lorenzo Franchi, Giuseppe Mattei, Roberto Fiorenzani, and Armando Casazza

**Virtual 7-Post Rig: A 7 DoF Vehicle Model for Suspensions Parameters Optimization** . . . . . 379  
 Guido Napolitano Dell’Annunziata, Marco Ruffini, Vincenzo Maria Arricale, and Flavio Farroni

**A Nonlinear Estimation Approach for Vehicle and Tire-Road Monitoring with No Interaction Modelling** . . . . . 389  
 Salvatore Strano, Mario Terzo, and Ciro Tordela

**A PID-Based Active Control of Camber Angles for Vehicle Ride Comfort Improvement** . . . . . 397  
 Valentin Ivanov, Raffaele Marotta, Salvatore Strano, Mario Terzo, and Ciro Tordela

**Engineering Education: Exploring Group Projects to Teach Innovative Automotive Topics** . . . . . 405  
 Henrique de Carvalho Pinheiro and Massimiliana Carello

**Modelling and Identification of a Pneumatic Positioning System: A Preliminary Study** . . . . . 414  
 Luigi Lentini, Luigi Mazza, Gianmarco Mossino, and Terenziano Raparelli

**Car-Trailer Dynamics: Modelling for Parametric Study on System Stability** . . . . . 422  
 Luca Zerbato, Enrico Galvagno, Antonio Tota, and Mauro Velardocchia

**Investigation of the Mileage Effects on the Viscoelastic Properties by a Non-destructive Method** . . . . . 430  
 Francesco Timpone, Gianpaolo Contrada, Michele Sanfelice, Vincenzo Arricale, and Guido Napolitano Dell’Annunziata

**Tire Noise Analysis: A Correlation Among Track and Laboratory Measurements** . . . . . 439  
 Vincenzo Maria Arricale, Bruno Borriello, Mario De Martino, Ciro Esposito, Chiara Cosenza, Mario Spirto, Armando Nicolella, Lorenzo Mosconi, and Andrea Genovese

<b>Enhancing ADS and ADAS Under Critical Road Conditions Through Vehicle Sideslip Angle Estimation via Unscented Kalman Filter-Based Interacting Multiple Model Approach . . . . .</b>	<b>450</b>
Simone Battistini, Renato Brancati, Dario Giuseppe Lui, and Francesco Tufano	
<b>Biomechanical Engineering</b>	
<b>A Feasibility Study of ExoPass, a Passive Magnetic-Spring Support Exoskeleton to Reduce Worker’s Physical Strain . . . . .</b>	<b>463</b>
Jhon F. Rodríguez-León, Eduardo Castillo-Castañeda, and Giuseppe Carbone	
<b>Prototype and Testing of a Finger Linkage Exoskeleton . . . . .</b>	<b>471</b>
Adithya Prakash Damarla, Marco Ceccarelli, and Wenshuo Gao	
<b>Design and Testing of RESPIRholter Device for Respiratory Monitoring . . . . .</b>	<b>480</b>
Matteo Aquilini and Marco Ceccarelli	
<b>Design and Testing of a Lab Prototype LARMbot Hand . . . . .</b>	<b>489</b>
Wenshuo Gao and Marco Ceccarelli	
<b>Development of a Serious Game Using the Leap Motion Controller for Virtual Rehabilitation of a Human Upper Limbs . . . . .</b>	<b>497</b>
Rogério Sales Gonçalves, Marcus R. S. B. de Souza, Giuseppe Carbone, and Marco Ceccarelli	
<b>A Passive, Customizable and Kinetically-Accurate Hand Replica for Testing Assistive and Rehabilitative Hand Exoskeleton Systems . . . . .</b>	<b>505</b>
Chiara Brogi, Alice Raggi, Nicola Secciani, Yary Volpe, and Alessandro Ridolfi	
<b>A Novel Design for an Upper-Limb Rehabilitation Assisting Device . . . . .</b>	<b>514</b>
Luis D. Filomeno Amador, Eduardo Castillo Castañeda, and Giuseppe Carbone	
<b>Modelling and Simulation of ADIUTOR Upper Limb Rehabilitation Robot . . . . .</b>	<b>523</b>
Elio M. Curcio, Mariagrazia Quacquarelli, Léa L. H. I. Cariven, Estelle M. C. Pitti, Elena De Momi, Francesco Lago, Stefano Rodino’, and Giuseppe Carbone	
<b>Kinetic Analysis of Lower Limb Power Assist Suits with Biarticulate Muscle Structure . . . . .</b>	<b>532</b>
Yuichi Nakazato, Kitau Takase, Kensuke Takita, and Masaru Higuchi	
<b>Implementation of a Robot Assisted Framework for Rehabilitation Practices . . . . .</b>	<b>541</b>
Giorgia Chiriatti, Luca Carbonari, Daniele Costa, and Giacomo Palmieri	

**Conceptual Design of a Stewart Platform in a Testbed for the Peritoneal Movements** . . . . . 549  
 Sergio Rodrigo Méndez-García, Christopher René Torres-SanMiguel, Juan Alejandro Flores-Campos, Octavio Ramirez, and Marco Ceccarelli

**A Spatial Dynamic Model for the Simulation of Human Upper Limb** . . . . . 560  
 Domenico Dona', Giacomo Zucon, Matteo Bottin, and Giulio Rosati

**Fourier Analysis of Center of Mass Trajectory in Hemiparetic Gait** . . . . . 568  
 Elisa Panero, Dario Anastasio, Giuseppe Massazza, and Laura Gastaldi

**Modeling and Kinematic Optimization of the Human Upper Limb for Collaborative Robotics** . . . . . 577  
 Elisa Digo, Andrea Cereatti, Laura Gastaldi, Stefano Pastorelli, and Marco Caruso

**A Novel Design Method of Four-Bar Linkages Mimicking the Human Knee Joint in the Sagittal Plane** . . . . . 586  
 Luciano Tomassi, Chiara Lanni, and Giorgio Figliolini

**Experimental Characterization of Active Joint for Trunk Exoskeleton** . . . . . 593  
 Mattia Antonelli, Elisa Panero, Michele Polito, Laura Gastaldi, and Stefano Pastorelli

**Robotics**

**Problems and Requirements for Outer Space Astronaut Service Robot** . . . . . 603  
 Jorge E. Araque-Isidro, Daniele Cafolla, and Marco Ceccarelli

**Improving the Efficiency of Closed-Chain Robotic Systems by the Trajectory Energy Index** . . . . . 612  
 Paolo Boscariol, Lorenzo Scalera, and Alessandro Gasparetto

**A Universal Aided Piloting System with NLU Support** . . . . . 621  
 Daniele Cafolla and Betsy D. M. Chaparro-Rico

**A Modal Approach for the Identification of Joint and Link Compliance of an Industrial Manipulator** . . . . . 628  
 Michele Tonan, Matteo Bottin, Alberto Doria, and Giulio Rosati

**Adaptive Real-Time Gesture Recognition in a Dynamic Scenario for Human-Robot Collaborative Applications** . . . . . 637  
 Cecilia Scoccia, Giacomo Menchi, Marianna Ciccarelli, Matteo Forlini, and Alessandra Papetti

<b>End-Effector Collision Avoidance System for Four SCARA Robots Using Buffered Voronoi Cell</b> .....	645
Xiao Sun, Kazuyoshi Ishida, Koji Makino, Kotaro Shibayama, and Hidetsugu Terada	
<b>Partial Contact Loss in Robotic Vacuum Grasping</b> .....	653
Matteo Maggi, Giacomo Mantriota, and Giulio Reina	
<b>Inverse Uncertain-Dynamics of Robot Manipulators Using Interval Arithmetic</b> .....	661
Andrea Giusti and Carlo Nainer	
<b>Realization and Control of a Mecanum Wheeled Robot Based on a Kinematic Model</b> .....	669
Abdelghafour Slimane Tich Tich, Fouad Inel, and Giuseppe Carbone	
<b>Actuation and Control Layout of the Hybrid Locomotion Ground Mobile Robot WheTLHLoc</b> .....	677
Luca Bruzzone, Shahab E. Nodehi, Vittorio Belotti, and Pietro Fanghella	
<b>Performance Evaluation of Mobile Robot Pose Estimation in MARG-Driven EKF</b> .....	685
Akos Odry, Istvan Kecskes, Dominik Csik, Juvenal Rodríguez-Reséndiz, Giuseppe Carbone, and Peter Sarcevic	
<b>Online Planning of Path-Consistent Stop Trajectories for Collaborative Robotics</b> .....	693
Lorenzo Scalera, Andrea Giusti, Renato Vidoni, and Alessandro Gasparetto	
<b>Soft Pneumatic Helical Actuator for Collaborative Robotics</b> .....	702
Michele Gabrio Antonelli and Walter D'Ambrogio	
<b>A Simple but Effective Approach to Generate Energy-Efficient Trajectories of a 2 Degree-of-Freedom Planar Manipulator</b> .....	710
Domenico Dona, Riccardo Minto, Matteo Bottin, and Giulio Rosati	
<b>Design of a Path Planning Method for a Robotized Optimal Trimming</b> .....	718
Matteo Manzardo, Giovanni Carabin, and Renato Vidoni	
<b>Position Control of Lagrangian Robotic Systems via an Affine PID-Based Controller and Using the LMI Approach</b> .....	727
Sahar Jenhani, Hassène Gritli, and Giuseppe Carbone	
<b>Theoretical and Experimental Characterization of a New Robotic gripper's Joint</b> .....	738
Gabriele Maria Achilli, Silvia Logozzo, Maria Cristina Valigi, Mihai Dragusanu, and Monica Malvezzi	



**Dynamic Obstacle Avoidance for Omnidirectional Mobile Manipulators** . . . . . 746  
 Federico Neri, Cecilia Scoccia, Luca Carbonari, Giacomo Palmieri, Massimo Callegari, Luigi Tagliavini, Giovanni Colucci, and Giuseppe Quaglia

**Design of a Service Robot for High-Pressure Cleaning** . . . . . 755  
 Ernesto Christian Orozco-Magdaleno, Eduardo Castillo-Castaneda, and Giuseppe Carbone

**Path Planning of Robot Fleet in Upside-Down Configuration** . . . . . 764  
 Matteo Formigli, Lorenzo Bonin, Paolo Gallina, and Stefano Seriani

**Mechatronics**

**Simple Kinematic Calibration Approach for Eye-In-Hand Depth-Camera** . . . . . 777  
 Lorenzo Baglieri, Luigi Tagliavini, Giovanni Colucci, Andrea Botta, Paride Cavallone, and Giuseppe Quaglia

**Mechatronic Design of an Underwater Multisensor System for Optical Data Acquisition** . . . . . 787  
 Cosimo Fredducci, Gherardo Liverani, Alessandro Bucci, Jonathan Gelli, Lorenzo Bartalucci, Francesco Ruscio, Vincenzo Manzari, Mirko Stifani, Riccardo Costanzi, and Alessandro Ridolfi

**Experimental Evaluation and Comparison of LiDAR SLAM Algorithms for Mobile Robotics** . . . . . 795  
 Diego Tiozzo Fasiolo, Lorenzo Scalera, Eleonora Maset, and Alessandro Gasparetto

**On the Numerical Modelling of Conductive CNT-Polymers: The Electro-mechanical Response** . . . . . 804  
 Giovanni Goldoni, Sara Mantovani, Marzio Grasso, Salvatore Strano, Mario Terzo, and Ciro Tordela

**Mechatronic Design and Experimentation of a Mecanum Four Wheeled Mobile Robot** . . . . . 812  
 Massimo Cavacece, Chiara Lanni, and Giorgio Figliolini

**A Software Application for Fast Liquid-Sloshing Simulation** . . . . . 819  
 Luca Guagliumi, Alessandro Berti, Eros Monti, and Marco Carricato

**Sustainable Development Goals**

**Regenerative Braking Effects on Non-combustion Pollutant Release** . . . 831  
 Giovanni Imberti, Henrique De Carvalho Pinheiro, and Massimiliana Carello

**CHECK TEMPERATURE: Controlling the Heating of Electronic Circuits: A Key-Approach Through Solid-State Elastocaloric-Effect Based Refrigerants** . . . . . 840  
 Adriana Greco, Luca Cirillo, Chiara Cosenza, Suxin Qian, and Claudia Masselli

**Optimization of a Piezoelectric Wind-Excited Cantilever for Energy Harvesting from Facades** . . . . . 848  
 Domenico Tommasino, Federico Moro, Enrique de Pablo Corona, Laura Vandi, Alessia Baietta, Alessandro Pracucci, and Alberto Doria

**Energy Performance and Fluid Leakage in Rotary Volumetric Machines at Off-Design Operating Conditions** . . . . . 857  
 Paolo Iodice, Giuseppe Langella, and Amedeo Amoresano

**A Neural Network Based Approach for the Intake Air Mass Flow Prediction in SI Engines** . . . . . 866  
 Massimo Cardone, Enrico Fornaro, Salvatore Strano, Mario Terzo, and Ciro Tordela

**Non-linear Frequency Domain Modelling of a Wave Energy Harvester** . . . . . 874  
 Mauro Bonfanti and Giovanni Bracco

**Stepping-up Wave Energy Extraction in All Degrees of Freedom by Combining Pendulum and Gyroscopic Effects** . . . . . 882  
 Giuseppe Giorgi, Fabio Carapellese, and Giuliana Mattiazzo

**Experimental Identification of Synthetic Ropes Stiffness for Scaled Mooring Systems** . . . . . 891  
 Sergej A. Sirigu, Marco Fontana, and Bruno Paduano

**Multi-physical Model of a Rainfall Energy Harvester - Sensitivity Analysis** . . . . . 900  
 Ilaria Palomba, Matteo Bottin, Giulio Rosati, and Alberto Doria

**E-scooter Modelling: Battery and Fuel Cell System Integration** . . . . . 909  
 Ettore Bianco, Luca Di Napoli, Elia Grano, and Massimiliana Carello

**Correction to: Tire Noise Analysis: A Correlation Among Track and Laboratory Measurements** . . . . . C1  
 Vincenzo Maria Arricale, Bruno Borriello, Mario De Martino, Ciro Esposito, Chiara Cosenza, Mario Spirto, Armando Nicoletta, Lorenzo Mosconi, and Andrea Genovese

**Author Index** . . . . . 917

# **History of Mechanism Science**



# A Note on 50-Year Anniversary of IFToMM Italy

Marco Ceccarelli<sup>(✉)</sup> 

LARM2, Department of Industrial Engineering, Tor Vergata University, 00133 Rome, Italy

marco.ceccarelli@uniroma2.it

IFToMM as the International Federation for the Theory of Mechanisms and Machines (today for the Promotion of Mechanism and Machine Science) was founded in 1969 with an act on 29 September 1969, during the Second World Congress on TMM in Zakopane, Poland, Fig. 1 a), [1]. Among the IFToMM founding fathers, who signed the foundation act, Prof. Giovanni Bianchi represented the Italian community, Fig. 1 b), being Italy one of the 13 founding communities.

The historical evolution of the Italian community in IFToMM can be recognized in three phases, namely pioneering, aggregating, and associating aspects as formalized over time within different associative forms up to the current legal association IFToMM Italy, Fig. 2, [2, 3].

During the first phase 1969–1971 the community was started as IFToMM Committee of Italy with few members coming from the main Universities only. Soon during the second phase 1972–2003 a Group of study was established within the national Society AIMETA. The activity in the IFToMM disciplines grew with more and more impact also at international levels so that in 1995 the IFToMM Congress was planned in Milan. Consequently, to the growth of the community, a need of proper well-defined aggregation matured into the GMA, Group of Applied Mechanics, within which a section was specifically devoted to IFToMM Italy. At the beginning of the third phase the Italian community referring to IFToMM was widespread in all the Italian universities, even with contacts in industrial and professional frames, requiring a legal identity with independent associative activity that was founded in March 2014, Fig. 3. Today IFToMM Italy as a well-recognized association is organized in working groups running activity in all the topics of MMS in theory, design, formation, practice, and technological transfer and with a biennial conference IFIT with international participation started in 2016, [4]. Figure 4 shows the chairs of the Italian IFToMM community overtime to indicate a continuous activity with individual participation from all the Italian universities as linked to the industrial and professional world with a significant contribution also to the world IFToMM community.

We, the undersigned chief delegates at the Inaugural Assembly of the International Federation for the Theory of Machines and Mechanisms (IFTOMM) here at Zakopane Poland on 27th September 1969, declare that we have founded the above-mentioned Federation and that we have adopted its Constitution which is attached hereto and decided to the following categories (see Article 8.4 of the Constitution).

Territory	Chief delegate	Proposed Category	Signature
Australia	JACK PHILLIPS	<u>II</u> *	<i>Jack Phillips</i>
Bulgaria	Georgi Rusanov	<u>IV</u> *	<i>Georgi Rusanov</i>
German Democratic Republic *	Wolfgang Rössner	<u>III</u> *	<i>Wolfgang Rössner</i>
German Federal Republic *	Nerney Thomas	<u>III</u> *	<i>Nerney Thomas</i>
Hungary *	Leno TERPLAN	<u>IV</u> *	<i>Leno Terplan</i>
India *	J. S. RAO	<u>V</u> *	<i>J. S. Rao</i>
Italy *	GIOVANNI BIANCHI	<u>IV</u> *	<i>Giovanni Bianchi</i>
Poland	Adam Nowicki	<u>IV</u> *	<i>Adam Nowicki</i>
Rumania	Nicolae I. Marelescu	<u>IV</u> *	<i>Nicolae I. Marelescu</i>
United Kingdom *	Douglas Myster	<u>III</u> *	<i>Douglas Myster</i>
U.S.A.	Douglas Myster	<u>I</u>	<i>Douglas Myster</i>
U.S.S.R.	<i>Il'ic Branitski</i>	<u>I</u>	<i>Il'ic Branitski</i>
Yugoslavia	IL'IC BRANITSKI	<u>IV</u> (x)	<i>Il'ic Branitski</i>

(a)



(b)

**Fig. 1.** The foundation of IFTOMM in 1969: a) the foundation act; b) prof. Giovanni Bianchi as Italian representative near right to prof. Erskine Crossley addressing to the audience.

The 50-year anniversary should have been celebrated in 2020 in occasion of the third IFIT, International conference of IFToMM Italy, but due to the COVID-19 restrictions the event was postponed to this year 2022. This is a note to remind the fifty years of activity of the Italian community with the hope and wish of growing success with the new generations preserving and augmenting the original IFToMM spirit for collaboration and improvement in technological fields for the well fare of mankind in peace and prosperity. A commemorative plate, Fig. 5, is planned to be posted at the University of Naples ‘Federico II’ in occasion of IFIT 2022 conference.

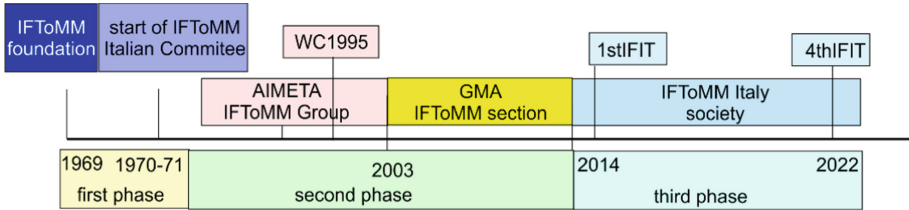


Fig. 2. Historical phases of the Italian IFToMM community



Fig. 3. The logo of IFToMM Italy as a legally recognized association

1969-1986	1987-1995	1996-2002	2003-2008	2009-2013	2014-2017	2017 -pres
Giovanni Bianchi (Milano)	Alberto Rovetta (Milano)	Aldo Rossi (Padova)	Sergio Della Valle (Napoli)	Vincenzo Parenti-Castelli (Bologna)	Cesare Rossi (Napoli)	Alessandro Gasparetto (Udine)

Fig. 4. Chairs of the Italian IFToMM community over time



**Fig. 5.** The commemorative plate for the 50-year anniversary of IFToMM Italy

## References

1. Ceccarelli, M., Huang, T., Zielinska, T., Carretero, J.A., Uhl, T.: Celebrations for the 50-Year Anniversary of IFToMM, *Machines* **7**, 53 (2019). <https://doi.org/10.3390/machines7030053> [www.mdpi.com/journal/machines](http://www.mdpi.com/journal/machines); Journal: Journal of Vibration Engineering & Technologies, Online publication date: 9/9/19. **8**, Number 4, *J. Vib. Eng. Technol.* **8**, 485-488 (2020). <https://doi.org/10.1007/s42417-019-00171-8>
2. Marco, C.: Breve storia della Meccanica Applicata alle macchine in Italia. In: Cuzzolin, N. (ed.) *Atti del Quinto Congresso Italiano di Storia dell'Ingegneria*, pp. 87–102 (2014). ISBN 978-88-87479-80-5
3. Marco, C.: IFToMM Italia: storia e prospettive, *Atti del 3° CONGRESSO NAZIONALE DEL COORDINAMENTO DELLA MECCANICA ITALIANA*, Napoli, 30 Giugno – 1 Luglio (2014). paper ID C08
4. Boschetti, G., Gasparetto, A. (eds.): *Advances in Italian Mechanism Science*, pp. 115–123. Springer International Publishing AG (2017). [https://doi.org/10.1007/978-3-319-48375-7\\_13](https://doi.org/10.1007/978-3-319-48375-7_13)



# Contributions of Italian Jesuits in Machinery Technology Transfer to China in the 16–18 th Centuries

Marco Ceccarelli<sup>1</sup>  and Baichun Zhang<sup>2</sup>

<sup>1</sup> University of Rome Tor Vergata, Rome, Italy  
marco.ceccarelli@uniroma2.it

<sup>2</sup> Institute of the History of Natural Sciences, CAS, Beijing, China  
zhang-office@ihns.ac.cn

**Abstract.** Figures and technical dissemination work of Italian Jesuits are revised it to highlight main aspects that have produced introduction of all machine design with western characters in China. Results are presented from an investigation using illustrations and literature documents with the aim to emphasize the technological transfer in terms of conceptual and cultural aspects. The paper presented review of work activity and influence of early Italian judgment missionary in technological transfer on machine design to China. notes are reported also to explain the white vision of the missionary combining technology and culture in their mission. A specific analysis is reported by referring to main publications and cultural heritage of that pioneer activity.

**Keywords:** History of mechanism design · History of machine technological transfer · Jesuit figures · Mechanisms

## 1 Introduction

The transfer on machine technology from West to East started with Jesuit missionaries in 16th century as part of a cultural means to support the Christian religion diffusion. The Jesuit mission in China has been extensively studied even looking at the science and technology transfer and main figures are identified with their activity as in Michele Ruggieri (1543–1607), Matteo Ricci (1552–1610), Johannes Schreck Terrentius (1576–1630), Giacomo Rho (1592–1638), Adam Schall von Bell (1592–1666), Ferdinand Verbiest (1623–1688) and other Jesuits, [1, 3].

The success of the machine transfer from Europe to China is documented by the latter Chinese literature in machine design with clear reference to the original source of inspiration, as for example in [4–6].

Today a renewed interest is addressed on the Jesuit work with machine transfer both to recognize in modern legacy and full understanding of the contributions and procedures of such an early link at world level frame not only in scientific literature like for example in [3, 7], but even in information communications with public as in newspapers, like for example in [8].



This paper is a contribution to recognize the above characters and legacy in machine technology transfer also within the current Italian mechanical engineering. In particular, the paper presents also minor Jesuits as recorded in the historical cemetery in Beijing [9], whose contribution activity supported the success of the more famous leaders who are known as main contributors for the early machine transfer from western countries to the Chinese word with such education legacy.

## 2 Italian Jesuits in China and Their Activities

The European Catholicism started to open its religious career in the Chinese empire since 16th century. After the Reformation in Europe, the Pope actively sent religious missions everywhere in the world. Portugal suggested the Church sending Christian missions to China in 1540. With the influence of European navigation and trade coming to the east, the European missionaries took business ships and came to Asia one after another. European businessmen were allowed by China to inhabit in Macao after 1557. Jesuits arrived there to open chambers in 1562, but they could not disseminate their religion in the inland of China. Alexandre Valignani (1538–1606), an inspectorate from the Society of Jesus, who was in charge of missionary business in India and the Far East, arrived in Macao before 1578. He planned new missionary strategies, consisting in starting their mission with learning Chinese and adjusting to Chinese customs. In 1579, the Italian Jesuit Michele Ruggieri was invited to Macao by Alexandre Valignani and prepared to go inland by learning Chinese. In order to promote missionary activities, Ruggieri suggested Alexandre Valignani sending another Italian Jesuit Matteo Ricci to China. On August 7th, 1582, Ricci arrived in Macao with a large clock made in Europe from India [10, 11].

Jesuits noticed that Chinese officials and scholars were very interested in European mathematics, astronomy, and technology, so that they carried out a strategy based on the introduction not only of religious contents but on a broader cultural vision in which science and technology play an important role. Actually, European science and technology became missionaries' walking stick for missionary work in China. This character of wide-spectrum cultural transfer can also be recognized by considering the great variety of skills and expertise of the Jesuits, who have contributed to the mission since the first days of their arrival in China. This broad cultural approach had an important aspect in the technology of machines or even better said in the theory of the mechanics of machines with the related applications concerning the design and functionality of machines that have been presented as the fruit of Western culture to Chinese culture for its absorption more than anything else of a cultural nature.

A significant number of Italian Jesuits contributed to this wide-ranging cultural activity with their personalities in various disciplines, even if not always linked to the above-mentioned science and technology of machines. Below we recall Italian Jesuits with their expertise in order to characterize this multidisciplinary framework in which the technological transfer of Western machines and above all of the Italian Renaissance machine culture played an important and even successful role both in attracting the attention of the Chinese cultural community as well as the imperial leadership. Figure 1 shows examples of such an integration at wide cultural level by the Jesuits using Chinese

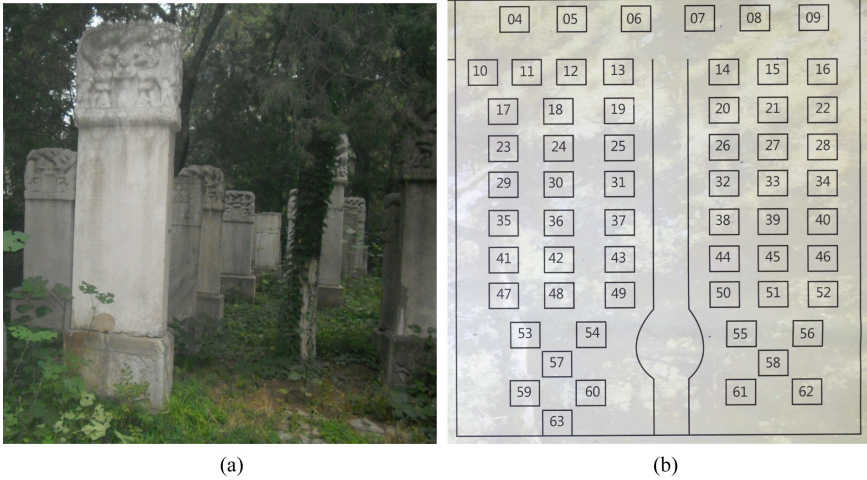
cloths and up to get Chinese names, like for example Matteo Ricci was called as Li Ma-dou.

In addition to Matteo Ricci, whose figure is well known and his activities in in-depth studies under various aspects such as for example in [1, 2], in this paper the attention is addressed to the figures of Italian Jesuits considered of lesser interest in order to characterize the aforementioned broad spectrum culture transfer strategy.



**Fig. 1.** Jesuit Matteo Ricci (1552–1610) in Beijing with Chinese cloths near an imperial dignitary

In particular, with reference to the Italian Jesuit cemetery in Beijing, Fig. 2, [9], considered a place of Cultural Heritage to be preserved, the Italians mentioned in the funerary stones that have been preserved give an indication of a significant presence of Jesuits in the imperial Court but also in Chinese culture during the period of the Jesuit mission. Below are brief biographical notes and information on the activities and expertise of the Jesuits passed away in Beijing who are mentioned in steles n. 4, 7, 12, 15, 25, 35, 45, 54, 54, and 60 in Fig. 2 b), which curiously give sometimes information on the birthplace of each Jesuit, as in Fig. 3. Most of the following data are found from the Jesuit Archives as in [12, 13], and in [14].



**Fig. 2.** The Jesuit historical cemetery in Beijing, [9]: a) the site with funerary stones; b) a plan with stele identifications



**Fig. 3.** Examples of inscriptions in the funerary stones in the Jesuit historical cemetery in Beijing: a) for Giacomo Rho (1593 - 1638); b) Ferdinando Bonaventura Moggi (1684 - 1761)

Giacomo Antonini (no. 4 in cemetery plan) (27 May 1701- 7 November 1739) was born in Venezia and he became Jesuit priest in December 1738 while in Macao. He died in Beijing in 1739.

Ludovico Buglio (no. 45 in cemetery plan) (26 January 1606 – 7 October 1682) was born in Mineo near Catania from an aristocratic family. He studied in Palermo where he became Jesuit priest. In 1636 he arrived in Macao and spent most of his time in Chengdu in the local court with activity on humanistic interests with philosophical and theological studies and analysis of European lifestyles.

Giuseppe Castiglione with Chinese name Lang Shining (no. 60 in cemetery plan) (19 July 1688 – 16 July 1766) was born in Milano and he was a very successful court painter for more than 50 years, particularly appreciated by the Qianlong emperor.

He used his technical knowledge on the use of oil colors, on the principles of geometric perspective, on the use of chiaroscuro and lights to give body and materiality to the figures and objects portrayed not only for artistic works but also to teach to Chinese painters. At the same time, he studied the Chinese techniques in painting absorbing them very successful so that he was well appreciated also with those his works.

Crescenzo Cavalli (no. 7 in cemetery plan) (1754 – 24 December 1791) born in Ivrea, he was Vicar Apostolic of Hukwang, Shansi, and Shensi.

Giovanni Giuseppe Costa with Chinese name Luo Huaizhong (no. 15 in cemetery plan) (6 August 1679 – 28 February 1747) was born in Maglie near Lecce, arrived to Beijing in 1715 where he carried out activity of medicine and surgery also with consultancy at the Imperial court.

Ferdinando Bonaventura Moggi with Chinese name Li Boming (no. 44 in cemetery plan) (14 July 1684 – 27 August 1761) was born in Firenze and before becoming Jesuit priest he was appreciated painter, sculptor, and engraver. Once arrived in Macau in 1721 he was called to Beijing by emperor Kangxi as architect designing and constructing the Saint Joseph church.

Giacomo Rho with Chinese name Luo Yagu (no. 12 in cemetery plan) (1592- 26 April 1638) was born in Milano where he was well formed in Mathematics up to teach the subject also in Rome, being Jesuit priest since 1614. Since 1624 he was involved astronomy with construction of instruments and writing of more than 150 texts even in Chinese in scientific subjects related to his expertise in mathematics.

Angelo da Borgo San Siro (no. 35 in cemetery plan) (1671–1723), Eusebio da Cittadella (no. 54 in cemetery plan) (1700–1785), Francesco Giuseppe della Torre (no. 25 in cemetery plan) 1741–1785) with no information.

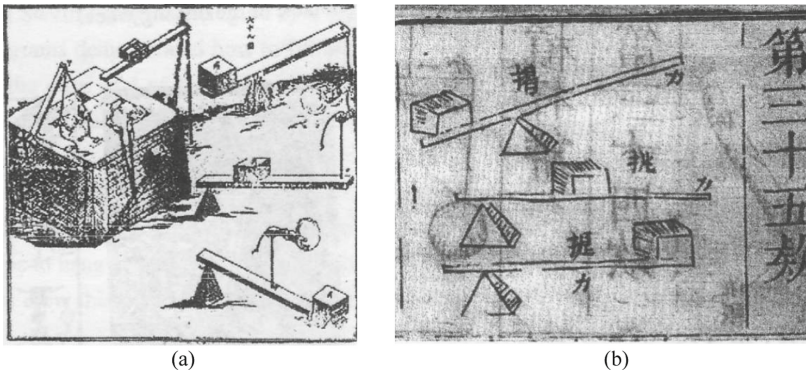
In addition to the Jesuit missionaries mentioned above and remembered in the funeral stones in the historic cemetery of Beijing, there were obviously many others who gave their contributions both in limited periods of stay and in periods that ended with their death still in China by carrying out activities in the fields as varied as the examples mentioned above. The activities related to the technological transfer of the machines are linked mainly to the interest of the Imperial Court in sophisticated machines such as clocks and automata but also in applications especially in astronomy and agriculture. Emblematic is the astronomical cabinet that was developed within the imperial court with a location also inside the forbidden city with a regular attendance of Jesuit missionaries not only for astronomical studies but also for the development of further mechanisms useful both to the calculations and the interpretations of astronomical observation.

### 3 Machinery Technological Transfer

The machine technology with western solutions was introduced from theory up to machine designs by referring to published works mainly up to the end of Renaissance as well-established literature that the Jesuit missionaries could have studied in their formation before coming to China and even brought with them.

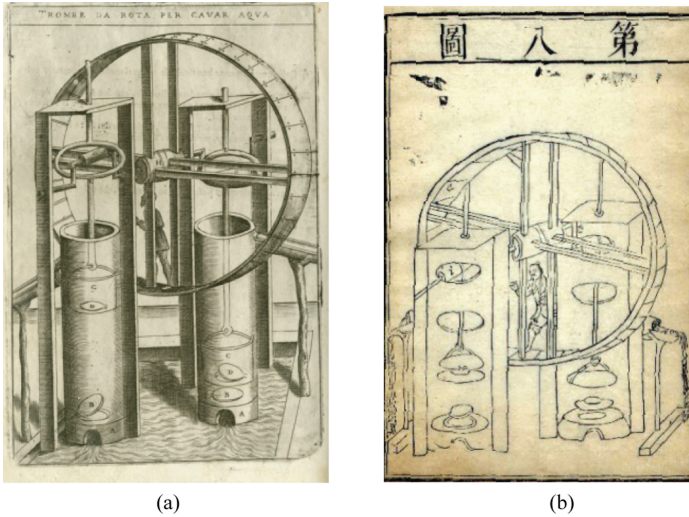
Figures 4 and 5 show examples of the science and technology transfer of western machines into publications in Chinese. Matteo Ricci translated the fundamentals of mechanics of machines referring to Euclid's geometry treatise referring also to the

Archimedes' machine mechanics as in the book by Guidubaldo del Monte. Even the Galilei's *Le Meccaniche* notes were used for those teaching purposes though other European books. In 1627, the German Jesuit Johannes Schreck Terrentius and Wang Zheng (1571–1644) translated the Archimedean fundamentals of mechanics and machines referring to books as Guidubaldo del Monte's *Mechanicorum liber* (1577) and Simon Stevin's *Mathematicorum Hypomnematum* (1605–1608), which includes many illustrations, such as Fig. 4b). In 1674, the Belgian Jesuit Ferdinand Verbiest illustrated some examples of the principle of lever, as Fig. 4 a). The Chinese publications, like in the example of Fig. 4 b), try to keep the western modelling but enriching it with Chinese characters explaining as per the tradition of Chinese publications. It is to note that the western pictorial representation is lost for full attention to the aspects of mechanics only. This approach is more evident in machine presentations, as in Fig. 5 where the Chinese drawings in Fig. 5 b) gives the machine structure with essential parts but somehow not fully clear so that the machine design looks incomplete, if not even wrong, and the operation is difficult to be understood. In fact, in the example of Fig. 5 b) it is not clear the mechanism connections that make the wheel driving the piston of the pump and the pump mechanism is not clearly outlined. Those machines were shown for teaching purposes of the machine culture but also with attempts in practical applications for the aim to improve the Chinese machine technology.



**Fig. 4.** An example of transfer of theory for mechanics of machines: a) from mechanics of lever in Renaissance treatises; b) in a Chinese handbook

Emblematic example is the transfer of mechanics in clock mechanisms from the late 16th century to the early 19th century, since European clocks were imported into China by missionaries and traders, and afterwards imitated by the imperial workshops and private workshops [15]. Matteo Ricci asserted that Chinese clepsydras and water-driven clocks were not so perfect as European timepieces (“they always make errors and can’t tell time accurately”, [16]). In comparison, European mechanical clocks had complicated, packaged and durable metal devices. They were easy to be used and became practical timepieces and artistic furnishings toys in China. Actually, Jesuits realized that their achievements depend on their good relationship with Chinese authorities. They found emperors and other officials all liked clocks and other skillful devices. Matteo Ricci



**Fig. 5.** An example of transfer of machine designs: a) from *Novo teatro di machine et edifici* by *Zonca Vittorio* published in Padova in 1607; b) from Chinese handbook *The Record of the Best Illustrations and Descriptions of Extraordinary Devices of the West* by *Johannes Schreck Terrentius* and *Wang Zheng* published in Beijing in 1628

said, “These things are necessities in social communication. They are like lube filled in gears of the progress of society.”,[16]. In January 1601, Ricci and his team finally had the chance to visit the Wanli emperor, and won the favor of the emperor with two mechanical clocks and other gifts, and obtained the authorization of living in Beijing.

In the reign of emperor Kangxi (1661–1722), the clocks became the important products imported from Europe to China. Emperor Qianlong was extraordinarily interested in clocks and collected many clocks in the imperial court. In the 18th century, clocks became the necessities for many dignitaries’ family. In order to adapt to the Chinese culture and custom, Jesuits and craftsmen made adjustments to the design of clocks and watches. For example, Ruggieri modified a mechanical clock, by adding a clock jar and various decorations. He converted the European 24-h system into the Chinese 12-h system and replaced Arabic numerals with Chinese characters. In the early 17th century, some Chinese tried to imitate European clocks. In the 17-18th centuries, small clock workshops came into being in Guangzhou, Suzhou, Nanjing, Songjiang and other places.

## 4 Today Legacy

The lesson that can be learned from the strategy of the activities of Jesuit missionaries in China can be summarized in the approach of attempting a cultural transfer with educational and social purposes also through scientific-technological issues related to machines. In particular, the legacy of this activity in the field of machine science and technology can still be recognized today in the fact that the theory and design practice of