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Italian Creativity in Mechanism Design

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Abstract

Creativity is a complex of skills in technical fields that produce innovation at theoretical, design, and technology transfer levels with specific aspects which in general are also of a broader cultural nature. These implications and properties of creativity in the design of mechanisms are clarified by referring to results obtained within the Italian community in order to emphasize a cultural background that is often ignored as a fundamental basis for creativity in the technical-design field of mechanical and mechatronic systems. The skills and cultural aspects that contribute to defining and determining creativity skills in the field of mechanism design are analyzed and clarified. The reported examples are intended to be illustrative of this synergy of even non-technical aspects with those that are based on knowledge and technical expertise in the sector of the invention when combined with an innovative vision in solving problems and needs.

Keywords

History Mechanism Design, Creativity, Innovation, History of Mechanisms

1. Introduction

In general, creativity is associated with innovation as per new/novel results, and new solutions, even without attaching or solving a problem.

In Mechanism Design, creativity is also associated to procedures to design or identify mechanism topologies with theoretical structures and performance, as for example presented in Yan's book (Yan, 1998).

But creativity can be better understood as capacity and activity by which novel results, both for new inventions and problem solutions, can be achieved as based on very personal attitudes. Thus, at large creativity can be considered a complex of personal skills including aspects such as technical expertise, scientific vision, general cultures, history knowledge, problem understanding in different contexts and open-minded attitude in order to overpass and exploit previous experiences as outlined for example in the recent books by Roth (2015) and Nieto (2012).

Since it is understood as a very personal attitude it is also believed that although those above-mentioned knowledge-based aspects, creativity is a personal capability that has components that cannot be not completely learnt (Trevelyan, 2014). This is because they are based on personal feelings and vision very often even with no reasonable backgrounds.

Achievements of creativity/innovation in Mechanism Design are obtained in theoretical, numerical, and design aspects that once implemented in engineering practice or in science applications are recognized as innovation (Ceccarelli, 2014a, 2015, 2017, 2019; Chondros, 2007). In this paper a synthetic presentation is attempted to clarify innovation mainly as related to technical aspects that are linked to Mechanism Design with special reference to Italian examples in the period from 14th to 20th centuries (Ceccarelli, 2014b). Italian creativity in many fields, even not in technological areas, looks to be determined by a mixture of the above-mentioned aspects with a culture in life developments that has been forged with creative experiences in hundred years. This is to say that creativity generates creativity although it cannot be formally taught.

2. Concepts and Activity for Creativity

A proper analysis of the concepts involved in the innovation process makes clear what are the sills and activity necessary to have successful results in conceiving and developing innovative products (Osterwalder et al., 2014) either in theory or practice of system productions.

Today's innovation is experienced as a multidisciplinary activity that is expected with results in terms of technological achievements with successful implementations for benefits of producers and users. In the last decades Science developments have made possible design achievements (and vice versa!) in many fields with an evolution that have been faster than ever in the past. This continuous expectation has also produced a certain obsession for innovation sometimes with no clear views in solutions with characters that are not so instrumental to satisfy novel and past needs as well to propose new advances in the welfare of users. Experiences and trends of the innovation with multidisciplinary activity are discussed and solicited in a rich literature from the many viewpoints of the multidisciplinary content of Innovation. References from a rich literature in the several frames for innovation activity are not included in this paper as per its character aim to introduce a different perspective of the Innovation concepts and to refer to the Italian creativity in the mechanism design frames with the mechanism central role in modern system conceptions.

In general, activity for innovation is understood as a product of knowledge with corresponding solutions into market products for large public fruition. **Figure 1** summarizes the concept of innovation as referring to those multi-disciplinary activities by several performers from different disciplines and

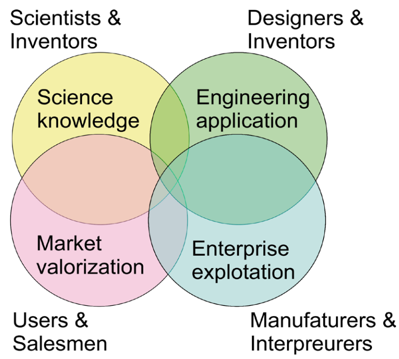


Figure 1. A scheme for frames and performers of Innovation.

frames. Innovation is based on novel ideas, but it is achieved only when the product transfer successfully reaches a large usage with users' acceptance. The complex of activities as indicated in the scheme in Figure 1 includes a large variety of skills and when just one is weak or fails, the whole transfer process will not reach the public usage and thus fails. Innovation starts when a technical idea or solution shows novel aspects with potential contents of practical implementation in the society to satisfy new and past needs or problems. Thus, initiators of innovation can be identified in designers or scientists with engineering skills as inventors, but in general main exploiters are business operators and enterprise leaders, who can further develop an innovative idea to a product with proper features for market valorization and users' acceptance. Worthful to note is that new solutions can be considered innovation basis for new products but are exploitations plans that realize true innovation with new sale offers, like for example when a product successfully reaches market sales even with no other competitors. Therefore, a successful innovation is determined by a full understanding of what can be transferred into market with enterprise perspectives with features attractive to solicited / identified users. Thus, Science and Technology can be considered the fundamentals, but Economics and Administration are the motors. In addition, Education and Publicity are necessary final tools for Innovation fully success. Education, likewise, Publicity, help potential users to understand the novelties and to accept them for practical usages. Thus, even University frames as centers of knowledge aggregation and formation, can be involved in those activities not only referring to technical contents. Indeed, Education and Formation can be considered instrumental both for conceiving new ideas and preparing users to the acceptance of new innovative products.

Activities for innovation can be planned from different perspectives but requiring the following main features as still referring to the spheres of activity and performers in Figure 1:

- Technical novelty, which is the source of innovation as coming from new ideas and solutions in solving problems or needs;
- Production feasibility, which refers to the product construction of the novelty at proper levels of manufacturing;

- Operation efficiency, which expresses the practical usability as user-oriented products;
- Market exploitation, which is a successful offer to a large public for large implementation and usage;
- Users' acceptance, which refers to a real success with acceptance and usage by potential users.

Technical aspects are often the core of innovation as due to design creativity and ingenuity, and the intellectual property, not only in terms of patent release, is considered one of the main innovation values to be defended and highlighted in all the above steps of an innovation procedure.

All the above considerations on innovation concepts and features can be specifically applied to modern systems with mechatronic architectures as in the scheme of Figure 2(a) with a procedure in Figure 2(b).

Figure 2(a) summarizes the multidisciplinarity of modern systems with mechatronic architecture referring to a synergy of components of different nature and operation in which the role of the mechanism structure can be considered central due to the fact that in general these systems perform their functionality in movements and actions to help or replace human operators who act on mechanical bases, meaning what in movement and force. Therefore, the innovation of new systems can be based on an architecture with innovative components and mainly in the structure for the transmission of movement and force in the functionality of the system for the purpose of obtaining even more efficient systems for the required tasks. The synergy of the components can be already ensured in the early stages of design procedures as indicated in the diagram of Figure 2(b) where the contribution and constraints deriving from the other spheres of competence and activity are emphasized through the side boxes and the definitive ones for the success of the procedure

In Figure 2(b) a traditional engineering process is indicated in the block "system design" of the diagram since it is the core design activity with procedures up to validation of prototypes after considering data and requirements at early stages. The Innovation multidisciplinary aspects can be very influential for the design development such those involving the enterprise exploitation and market valorization as it is indicated in general terms by two corresponding lateral blocks in Figure 2(b). Market issues as well as Production constraints may suggest alternative or different solutions for the innovative designs and their performance by influencing the final product solution. Therefore, those many aspects that are necessary to have a machine design as an innovation proposal will require the collaboration of experts from many other disciplines than engineering, such as those that can be not even directly linked to design procedures, like for example psychology and general education of users.

The activity for "IP protection" (defense of Intellectual Property) in general is aimed at the explicit protection of Intellectual Property of the innovation through patents and legal acts. It can be also influential on how the design is

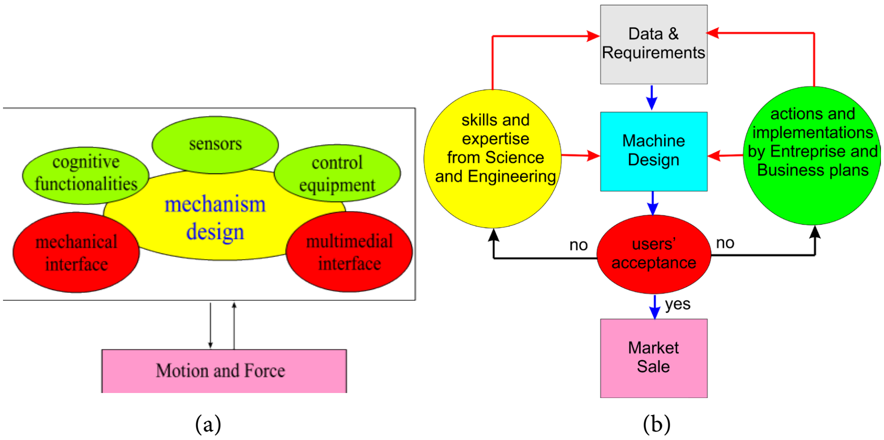


Figure 2. A scheme for design procedure for Innovation in mechanical/mechatronics systems: (a) role of mechanism design; (b) overall procedure.

produced in clear explanation of the novelties and for its exploitation considering the aspects of technology transfer with dissemination of the innovation with clear paternity by publication and publicity toward a large public. This activity will again require collaboration from different disciplines, such as for example a legal expertise and a financial analysis.

The "production" activity refers to manufacturing processes of a product from an innovation idea and system design up to successful manufacturing results and market values so that it can be ready for practical exploitation by the innovators and for fruition by a large public of users. Fundamentals are also aspects from business areas and commercialization so that the innovation can be a reality when a product is available with proper features for commercialization.

The final steps in Figure 2(b) refer to users' acceptance and then the real market success. Users' acceptance is a first proof that the innovation product has been well targeted since it is really appreciated as product. This step is often the most unpredictable one of the Innovation processes since it depends on aleatory aspects and large diversity of potential users. But the final proof is the market success that states the exploration of the innovative product in practical usage by a large public of users.

The challenges of Mechanism Design in terms of Innovation can be recognized in those above aspects for providing new solutions for new problems as well as to update or improve existing solutions of mechanical systems or mechanical parts of the mechatronic systems for new or updated requirements and tasks. Thus, a main request can be identified in design solutions that require ingenuity for new ideas but also improvements of design procedures with better computation algorithms. Within Mechanism Design literature, this has suggested different approaches based on theoretical design aspects to search for new mechanisms even independently from a specific design problem or task. Challenges in Mechanism Design can be also understood in the ability to identify all the possible solutions among which a designer/inventor or even a user can select the one for a proper solution of the need or problem under consideration. As linked to the design problem also the analysis approaches can be asked to provide proper new evaluations of the new expected performance even in already existing solutions.

The ingenuity is recognized able to give solutions and ideas even without a knowledge background or technical expertise, at least at a level of a first proposal of innovation and in such a case it is also addressed as creativity. In Oxford Dictionary creativity is defined as "the use of skill and imagination to produce something new or to produce art". Thus, it is more prolific and successful an innovation activity that is based on creativity as combination of proper expertise and ingenuity.

Figure 3 aims to summarize and emphasize the role and the fundamental aspects of the main components of innovation activities in creativity and background knowledge for the identification of the fundamental performers who can be identified in the figures of designer, inventor, and innovator. In Figure 3(a) the innovation is indicated as the most evident part in the form of a roof of a building which intends to represent the complex activity which leads to clearly visible innovative solutions. The scheme intends to emphasize the role of foundation of knowledge and technical ability on which ingenuity and creativity find strong nourishment for the creation and conception of new ideas. Those new ideas are then made concrete with the complex activity of all the roles already indicated in the diagram in Figure 1. In particular, in Figure 3(a), creativity is represented by pillars which, despite being slender, carry the heavy building of innovation to high levels starting from technical skills to precisely indicate a role of cultural background and high performance for innovation. In Figure 3(b) the characteristics of the innovator have been separated into three aspects that are clearly distinguishable today. They are the designer, who carries out all the procedures for identifying and sizing the idea produced by the creative activity of an inventor, who does not necessarily have to be an expert in area but (as already mentioned) she/he must have a wide culture, and finally the figure of the innovator who wants to summarize all the roles and indeed the coordination of the complex activities that lead to the innovative product.

In the field of Mechanism Design, the roles indicated in Figure 3 are of particular importance and are easily identifiable in the performers who are the major contributors to the development of new mechanical system and in modern mechatronic systems. The basic experience and technical expertise can be understood in those theoretical and design aspects referring to the kinematics and design of mechanisms which can already produce innovative solutions both in procedures and in mechanism architectures. Creativity as in the conception and design of new mechanisms can be thought of as linked to the ability to see perspectives of further developments of architectures of mechanisms and even to identify new configurations. The innovation that completes cutting-edge aspects can be recognized in the actual design of a mechanism with all its functional and structural characteristics, also and not only in new and possible fields of application.

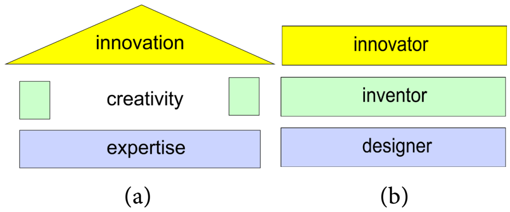


Figure 3. A scheme for Innovation activity: (a) main aspects; (b) acting figures.

In **Figure 4** we want to summarize the essential characteristics of what is meant by creativity from a technical-design point of view which still includes those personal cultural aspects that make creative actions peculiar. At the basis of creative abilities, with reference to the first block in **Figure 4**, it is possible to recognize aspects of general culture. They can strengthen a specific culture in the areas of interest of the innovative problem in the sense that a broader vision can allow understandings and perspectives even from different points of view. This includes and is projected into one's own personal vision of the problems and characteristics of the area of interest for the development of an innovative solution.

As previously mentioned, these personal characteristics must certainly be considered combined with the aspects referring to specific technical competence and therefore to personal experiences in the field of interest for the innovation under study. In the next box in **Figure 4**, more specifically technical aspects are noted referring to an appropriate understanding of the problems and requirements to which innovation must respond with the ability to conceive conceptual solutions that can be evaluated with a view to expected results. The combination of these two areas of ability of the innovator with prerogatives of designer and inventor combine with intuition and imagination which are undoubtedly fundamental components for the conception of ideas containing innovation. Intuition and imagination in innovation activities are undoubtedly to be considered personal aptitude skills that are difficult to learn with the usual training processes. But they can also be considered the result of a personal background coming from previous experiences and skills, and even coming from the community of reference that over time may have accumulated and transferred this perception and attitudes towards innovation. In conclusion, **Figure 4** wants to emphasize again that an innovative solution, be it at a theoretical or practical level, with products that can be accepted by the community to which they are directed, is a result of activities and skills in a complex process that combines educated aptitudes and personal skills of own culture.

3. Italian Creativity: An Historical Outline

The central role of Mechanism Design in modern systems can be highlighted by noting that human beings operate tasks and interact with environments with or without systems on the basis of actions of their mechanical nature and therefore a mechanical component even in modern systems, is an essential part. In addition, today a continuous attention is asked to update problems and solutions in Technology since Society continuously evolves with new and updated needs and requirements in looking at new or better products for a better welfare and life. Therefore, even mechanical systems are expected to evolve for new and updated problems that require a continuous innovation with new or updated solutions of the mechanical components of modern systems.

The following examples in Figures 5-9 clarify the above aspects of innovation meaning and values in Mechanism Design for system developments with an illustrated approach by referring to Italian community in its historical evolution on how an expertise in Mechanism Design can be a source of successful solutions. The references are limited to the direct experience and work of the author, although a huge bibliography can be available for each of the discussed below figures, even from different viewpoints.

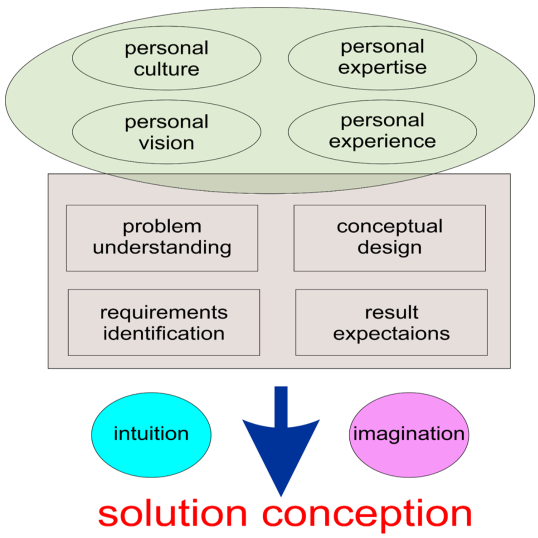
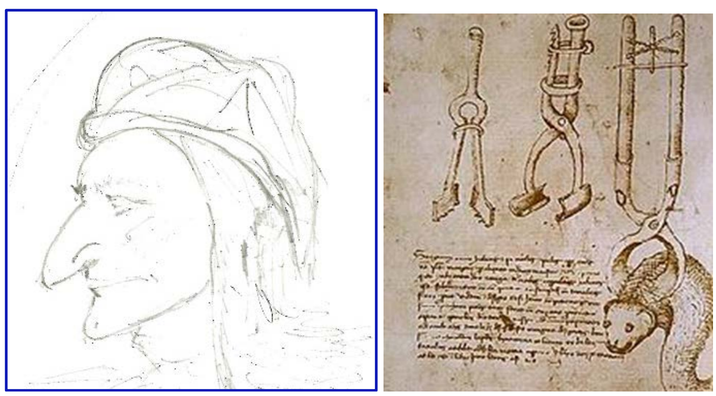


Figure 4. A scheme for skills and capacities in Innovation activity.



(a) (b)

Figure 5. An example: (a) supposed portrait of Mariano di Jacopo, Il Taccola (1381?-1458); (b) his design of gripping devices for living fishes (Scaglia et al., 1984; Scaglia, 1971).

The Italian Creativity can be recognized in the field of mechanism design since ancient times with solutions of considerable impact both in technological and social frames with those above-commented aspects in combination of ingenuity and specific and general cultural background. In ancient times we can refer to the emblematic examples of Archimedes (Rossi et al., 2009), who with his talents not only determined a substantial progress in mechanical engineering but also had a decisive impact in the applications of his innovative solutions such as for example in the resistance of the city of Syracuse to the aggression of the nascent Roman empire (Ceccarelli, 2023). During the Roman Empire there were numerous engineers in the Legion corps with the figure of Faber (Barbaro, 1584), Cigola and Ceccarelli (2014), who contributed to military technology but also to civil engineering for the construction of successful infrastructures and machinery with an accumulation of experience and knowledge in documentary references. In this regard we can cite the work of Vitruvius (Singer et al., 2013; Capocaccia, 1977), in which the tenth chapter pays particular attention to the ingenuity of the structures of mechanisms and their functionality in the most varied functions. In the following sections, emblematic cases referring to modern and contemporary times from 14th to 20th century are reported with reference to personalities and innovative solutions of mechanisms that demonstrate the high ingenuity and creativity of their authors with a cultural background and experiences as well as the evident impact of such innovative solutions in the evolution of technology and in the impact on the development of society. Indeed, the history of mechanism and machines can be represented looking at the achievements and solution from theoretical and practical solutions over time as for example outlined in (Bautista Paz et al., 2010; Ceccarelli, 2008; Galluzzi, 2001).

Italian creativity in the mechanism design during all the times can be characterized by a blend of skills and attitudes in terms of cultural background with knowledge and experience accumulated over time and capacity for intuition and imagination for innovative solutions (Ceccarelli, 2015), that have been transferred into approach training combining theory and experimental practice still persistent in current academic programs (Ceccarelli, 2014a).

3.1. Examples from Renaissance Time

During Renaissance, studies and designs of new mechanism and machines were developed by two approaches, namely practical experience and experimentation by practitioners, and theoretical studies and investigation of literature and previous works by Academic/cultured people (Galluzzi, 1991, 2001; Ceccarelli, 2008). At the end, the two approaches came to a fusion in well recognized discipline and activity as in Mechanics of machinery that gave further achievement up to contribute substantially to the Industrial Revolution. In this historical development we may indicate representative figures like Leonardo da Vinci and Galileo Galilei and several others who contribute significantly to the Theory and

Technique of Mechanisms. In the next few examples, the most important characters are discussed by stressing the evolution of Mechanism Design by means of few distinguished figures and significant innovative ideas among the many personalities and the many contributions in the evolution of mechanism designs and identification of specific scientific and professional expertise through the innovation.

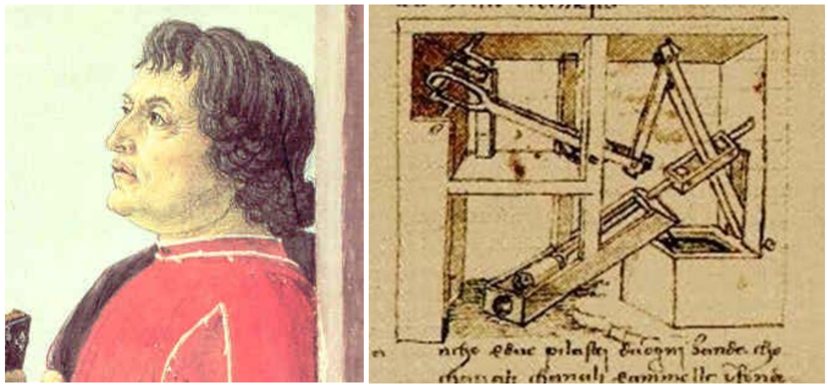
Mariano Danniello Vanni, known as Mariano di Jacopo (Il Tacccola), (Marcolongo, 1934; Shelby, 1975; Ceccarelli, 2021) (**Figure 5(a)**), (the imaginary portrait is made by the author) was born in Siena on 4 February 1381 where he died between 1453 and 1458. The nickname Taccola from Tuscany language with which he was and still is also known, is due probably to the fact that he was used that to adjust the machine constructions with wedge (the English word for the Tuscany word taccola) or very likely because he had an eagle-like nose (as still today it is nicknamed those people in Tuscany). It is not much known of his life expect to his activity as engineer and well reputed person in Siena where he was known also as "Archimedes da Siena" because of his may inventions for the design and practice of machines. He was one of the first, who gave dignity to the machine design activity thanks both of the achievements and reputation that he reached and used also as a culture within social and political frames. His multifaceted activity is very likely due a formation in a bottega (a sort of laboratory and class frame) where he learned artistic skill that can be still recognized in his very clear drawings of machines. His humanistic formation included Latin so that later he could directly study rediscovered works on machine design by Vitruvius and other classic authors as well as later he wrote his treatises De Ingeneis (Scaglia et al., 1984), and De Machinis (Scaglia, 1971), in Latin yet, although they can be considered personal hand notes since mainly made of drawings. After an initial activity as artist, he worked on machines for hydraulic systems to provide solutions and means for water supply in Siena by contributing significantly to the design and construction of the Siena water network of underground aqueduct, that still in operation is recognized as historical architectural heritage. Mariano di Jacopo conceived and designed several solutions new at the time as he reported his treatises De Ingeniis and De Machinis, with somehow dissemination purposes. He was used also to work design activity for conception of new solutions with discussions within cultural frames, as for example during his leader position (Camerlengo) at the Domus Sapientiae institute of Siena during the period from 1424 up 1433. There he met Filippo Brunelleschi (1377-1446) with whom he had a long successful collaboration very likely also in the conception of the machines used for the construction of Florence cathedral. They shared the first needs of an intellectual protection of machine designs that is documented by the fact some of the devices in his treatises are not completely explained in a note indicating for "avoiding risks to be stolen of the machine design".

The manuscipts of De Ingeneis (Scaglia et al., 1984), and De Machinis (Scaglia, 1971), by Mariano di Jacopo are milestone hand-written treatises, as a sort of first machine handbooks, coming from his direct experiences and expertise: De Ingeneis written from 1419 to 1450 in four volumes containing solutions for civil and military machines, and De Machinis written from 1430 until 1449 in ten volumes as a more wide collection of machine designs for hydraulic systems, machines for war, construction machines (civil engineering to lift weights), transport machines, machines for mills, and instruments for measuring distances and heights. Solutions are often recognizable even as inspired by classic authors such as Philon, Vegezius, Frontinus, and Vitruvius whose works Mariano di Jacopo was able to read and study thanks to his humanistic training. Of new significant conception for the time are the machines for the exploitation of automated fishing with structures for barriers and artificial lakes as well as devices for fishing in fish farms. Professional ability of Mariano di Jacopo as a machine inventor and designer is also demonstrated by the fact that he used and improved existing machines with both updated and innovative solutions. In his works one recognizes the practice that later became habitual during the Renaissance to draw sketches and write short comments on the designs and usages of the reported machines. These drawings can be considered yet as personal notes but with those explanatory notes could be useful also for the potential users and as indications for collaborators, in the construction and use of the designed machines. A significant contribution of Mariano di Jacopo in mechanism design can be recognized in the several innovative design solutions and updates of the machines of the time even with a modern-like vision of the importance and influence of technological systems in the development of society and well-being in general, and also for political purposes and peace between peoples.

Figure 7(a) shows a study for grasping of a fish to design proper grippers with different solutions both in the structure and in the grasp configuration with alternative modes of fixing the grasp. In those design drawings special attention is addressed to a careful grip against the body of the fish to avoid its damage. They are solutions conceived or better adapted to a well identified problem focusing the attention and the solution not only to the specific subject of grasping. The figure which is enriched by notes is indicative of a deepen analysis of the problem of grasping delicate objects with two-finger grippers. The different shapes of the fingertips of the grippers can be recognized as coming of a wide experience in the problems related to the grasp of objects.

Francesco Maurizio di Giorgio Martini (named as Francesco di Giorgio), (Vasari, 1550; Promis, 1841; Fiore & Cieri Via, 1997; Ceccarelli & Molari, 2020) (**Figure 6(a)**), was born in Siena (Italy) in 1439 where he died on 29 November 1501.

He was one of the most representative figures of the Renaissance (Ceccarelli, 2008; Galluzzi, 2001), for his wide activity with large variety of interests, knowledge, while servicing in the many prominent states (cities and kingdoms) of the time, although with a preference to his homeland city Siena. He started the activity as painter with very successful results but later his activity as architect in designing buildings, fortresses, king houses all around Italy gave him a



(a) (b)

Figure 6. An example: (a) portrait of Francesco di Giorgio (1439-1501); (b) his design of a hydraulic pump with inverted slider-crank mechanism (Di Giorgio Martini, 1465-70; Di Giorgio Martini, 1475).

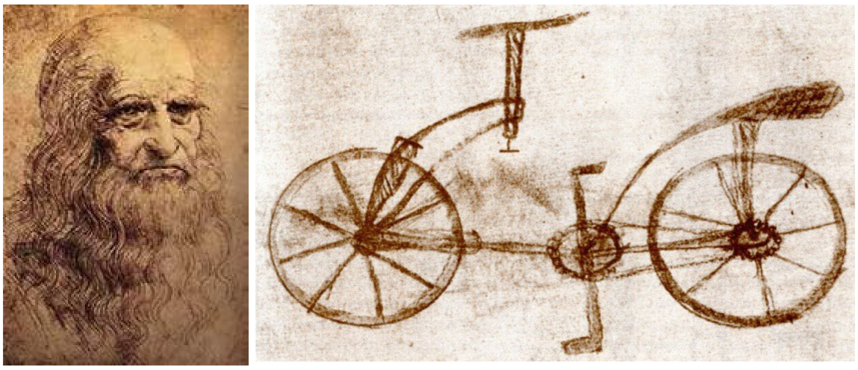
great reputation so that his hometown Siena appointed him as city architect in order to ensure his genius and expertise for the city growth. Indeed, his activity was unusual for the time as for the frequent travelling around Italy in order to get knowledge/expertise accumulation and working on commitments/consulting in several cities. He can be recognized as early Renaissance "humanist actor" with a figure of a first modern scientist with the need to meet other experts and to make new experiences while producing new solution and knowledge mainly in machine design. In particular, beside Siena, he dedicated most of his activity since 1477 at the service of the duke of Montefeltro in Urbino where he strongly contributed to the magnificence of Palazzo Ducale (the Duke's king house) among many other works for fortress designs. Of great originality and impressive sign of a celebration of machine technology with a reach both to a large public understanding and cultural values is the unique use of machine designs in sculpture representations (made by the sculptor Ambrogio Barocci under supervision and conception by Francesco di Giorgio) as artistic frames in the seating areas around the entrance of the Duke palace in Urbino. Francesco di Giorgio worked at the most as an architect by designing and directing construction of new buildings and fortresses, by inventing, design and constructing machines useful for those architectural jobs as it was typical of the time. In addition, his activity as inventor and designer of machines brought him also to study and to develop theoretical aspects of the machine developments that is repeated in the first treaties on mechanism design (Di Giorgio Martini, 1465-70; Di Giorgio Martini, 1475; Maltese, 1967). He started his engineer activity in Siena working at the maintenance and operation of the hydraulic system for to the city. He kept this job along all his life looking at the pumping systems and the structures of hydraulic networks. He experienced and worked several water pumping systems and developed also new designs.

An example of this design innovation applied to hydraulic systems is shown in **Figure 6(b)** (Di Giorgio Martini, 1465-70; Di Giorgio Martini, 1475), where the pumping system can be recognized working by the piston of a slider-crank mechanism with inverted kinematics. The kinematic solution combined with a transmission mechanism to a crankshaft power shaft is undoubtedly of great innovative impact for the times with surprisingly modern contents considering that the concept of kinematic inversion of the mechanisms was formulated and applied to the design of machines only starting from the mid-nineteenth century. In the drawing of **Figure 6(b)** it can be noted the considerable competence in the design of mechanisms to bring out the novelty of the inverted slider-crank mechanism as an essential element in the functionality and efficiency of the proposed machine.

Francesco di Giorgio conceived several other innovative machine designs mainly to solve practical problems in defining solutions to needs and requirements for the functionality of machines serving the most varied tasks from hydraulic engineering, as indicated above, to civil engineering and even war engineering by also making use of what was previously designed by other Siena engineers such as with particular reference to the mechanisms of Mariano di Jacopo. In this last observation we can recognize the aptitude and perhaps even the already present tradition in the inventors and machine designers of the Renaissance to refer and consider the existing cultural background as a source of inspiration for updated and new solutions with improvements and new ideas of greater design and functional effectiveness.

Leonardo da Vinci was born in Vinci, a small village not far from Florence, on 15 April 1452 (Treccani Enciclopedia, 2023; Pedretti, 1999; Ceccarelli, 2016), **Figure 7(a)** and he died on 2 May 1519 in Amboise, France. He got formation in artistic frames at the bottega of Verrocchio, and soon he made his own paintings with great success. In 1482 he moved to Milan at the Court of Ludovico il Moro where, while working as machine designer and artist, with science interests he met many other important figures of Renaissance. In 1499 he left Milan and went to Mantova, Venice, and then Florence. In 1502 Leonardo served under Cesare Borgia as architect and military engineer but soon he came back to Florence, where he remained until 1508. After that he went again to Milan. But in 1513 he moved to Rome under the protection of Giuliano de' Medici. Finally in 1517 Leonardo moved because invited to Amboise, France, under the protection and service of the king Francis I. Along his life he dedicated interests to wide range of subjects in art, science and technology gaining a reputation of architect and scientist, although he was well reputed also as machine designer.

As it is well known because of a huge literature on Leonardo, as an example within Italian frames in (Cianchi, 1984; Pedretti and Cianchi, 1995; Pedretti, 1999; Starnazzi, 2005; Ceccarelli, 2016; Suterna, 2001), most of the machine drawings by Leonardo are personal notes for his study of machine designs with aims of understanding/improving existing designs and investigating innovative solutions. Leonardo got inspiration by machine designs by others within a well-established community of machine designers at the time. But Leonardo was also able to conceive completely new solution for machines and any other devices bot for practical applications and for investigation of mechanism possibilities.



(a) (b)

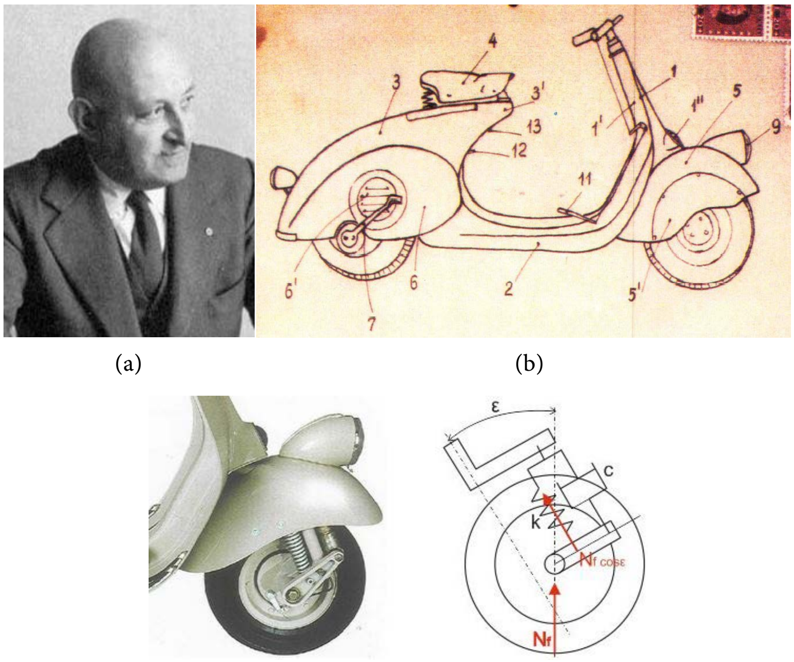
Figure 7. An example: (a) portrait of Leonardo da Vinci (1452-1519); (b) his design of a bicycle (Cianchi, 1984; Pedretti & Cianchi, 1995; Pedretti, 1999; Starnazzi, 2005).

This last field was much better a kind of research area that sometimes was used also as to produce systems for exhibitions or to show the potentiality of his design skill for new machines. Emblematic of the creativity of Leonardo in mechanism design is the examples in **Figure 7(b)** referring to the invention of an early bicycle. This design can be considered also a result of his expertise in machine designs and theoretical studies on mechanisms. The bicycle design of **Figure 7(b)** can be considered a brilliant new conception of a transportation vehicle with innovation contents that never reached the full innovation character since it was never build or used until the modern invention in the second half of 19 the century. But the idea can be recognized of cutting-edge novelty as referring to wheeled vehicles and the cultural background and previous expertise can be recognized in using chain transmissions and human machine powering that Leonardo investigated and designed in many other machines following a sort of Renaissance tradition for autonomous chariots/cars. Thus, the creativity of Leonardo in conceiving and exploring new solutions, even for not identified practical needs, is of emblematic value a vision towards the future, within a science interest.

3.2. Examples for Contemporary Times

In contemporary times, creativity on mechanism design has been experienced with innovative solutions based not only on individual ingenuity skills but also on those general and specific cultural characteristics with a background of experience if not in the specific field in the next engineering cultural sphere. In the rich Italian tradition of such creativity in the design of mechanisms, two illustrative examples are reported referring to a case of creativity based on individual professionalism as per Corradino D'Ascanio and a case based on academic research activity with particular foundations in collaboration and technological transfer at an educational level as per Professor Alberto Rovetta.

Corradino D'Ascanio, (**Figure 8(a)**) (Fondazione Piaggio, 2001; Regional Archive, 1986; Ceccarelli & Teoli, 2014), was born 1 February 1891 in Popoli (Pescara), and died on 5 August 1981 in Pisa.



(a) (b)

(c)

Figure 8. An example: (a) portrait of Corradino D'Ascanio (1891-1981); (b) his design of Vespa scouter (Piaggio, 1946); (c) his design and model of front wheel suspension) (Ceccarelli & Teoli, 2014).

He got a degree in mechanical engineering in 1914 at the Royal school of Engineering in Turin. He was enrolled in the military aviation during the First World War as engineer with an activity in solving accidents by innovative solutions. After the war he worked at Pomilio small company for which he went to USA in 1917 to get better experiences in aeronautic fields. Once back to Italy in 1919 he worked on solutions for vertical flight that gave him the possibility in 1925 to start a company for building his first helicopter DAT 1. Only in 1929 he designed and built the DAT 3 that was able to successful fly achieving several international records without giving him a financial success. In 1932 he patented a variable pitch propeller, and he started a collaboration with Piaggio company during which he developed the new helicopter prototypes PD1, PD2 and PD3, although no one went into production (D'lncecco, 1986). After the Second World War Piaggio company was forced to convert the war production in a civil production quitting helicopter design program. D'Ascanio was asked to design of a new motorcycle considering the traditional motorcycle uncomfortable and difficult to drive. D'Ascanio conceived a new innovative design also with challenging technical features of a new scooter as even a family vehicle (D'lncecco, 1986; Frisinghelli et al., 1998; Mondini, 1995; Ceccarelli & Teoli, 2014). In 1946 Piaggio started the production of Vespa scooter (**Figure 8(b)**) (Piaggio, 1946), that immediately got a great market success and still todays it is a very successful product with its updated versions. However, D'Ascanio reputation was recognized for his results in vertical flight designs by receiving honors and awards worldwide like the one in 1948 by the American Helicopter Society. In 1951 he designed his last helicopter PD4 for Piaggio company, but even PD4 design was not so successful to reach a market production.

D'Ascanio activity was characterized by efforts in new innovative solution though his creativity as based on technical knowledge and visionary ideas. His great ingenuity is documented by several patents and new designs for several different systems, among which the Vespa scooter and helicopter designs are the most relevant.

On April 23, 1946 at Florence's Patent Office, Piaggio submitted the patent for a scooter as "Motorcycle to rational complex of organs and elements combined frame with fenders and hood, covering the whole mechanical part" (**Figure 8(b)** and **Figure 8(c)**) (Piaggio, 1946). The original prototype design of "motor scooter 98cc" (named asVespa 98) was presented at Piaggio on August 10, 1945, with the drawing of the patent submission that very quickly went into massive productions. The innovative idea of the scooter design is recognizable in a comfortable riding since a user will be in a seated configuration with all the commanding units on front handlebars.

An additional innovative characteristic for the time is the chassis that, beside the comfort shape, is also the structure connecting the front and back wheels with all the mechanical parts in a single block that was placed under the saddle so that the engine is fully covered to avoid dirt against to the driver as the previous motorcycles. Even the transmission had new feature by acting directly on the rear wheel without any belt. The front wheel is designed for an aside installation with a properly new set up of elastic suspension and damper that is very efficient in reducing any disturb due to the road conditions. D'ascanio used his long expertise in mechanical design applied to helicopters combining his visionary idea to have a scooter riding in a seated comfortable configuration for potential users who should not necessarily have knowledge or expertise in motorcycles. In his case the creativity was strongly supported by a valuable technical background from his expertise.

The main innovation features of the Vespa 98, beside and in combination with the shape design for a new concept of scooter riding, can be summarized in:

- elastic suspensions with spiral steel spring for the front wheel and with rubber pads to the rear wheel and engine;
- single engine with two-stroke horizontal cylinder made of cast light alloy with 98 cm^3;
- direct transmission on the rear wheel via shift gears and coupling;
- 3-speed gear with clutch combined command on the left side of the handlebar;
- expansion brakes activated by hand on the right side of the handlebar for the front wheel, and by foot on the platform for the right rear wheel;
- wheels of 3.50 × 8 inches that are removable with nuts (like in cars) ;
- dimension for an easy handling by a user, being total weight of 60 Kg.

Alberto Rovetta, (**Figure 9(a)**) (Rovetta, 2019; Kedzior, 2010; Ceccarelli & Rovetta, 2023), was born in Brescia, Italy, on 19 June 1940, but he lived in Milan where he died on 25 November 2020.

He graduated in Electronic Engineering at the Politecnico di Milano on 14 March 1964 and there he worked his long academic career covering all the positions up to full professor of Machine applied Mechanics with teaching activity mainly on Robot Mechanics and on Design of Machine Elements. Prof. Rovetta activity was centered on research with important attention in teaching as a transfer of his investigation with scientific-technical achievements for the development of Technology and welfare of the society. During his long academic career, he dedicated the teaching activity to engineering and architecture students within a large variety of topics such as Mechanism Design, Robot Mechanics, Industrial Design, Visual Communication, Foundations and Methods of Industrial Design, Modelling and Simulation of Mechanical systems, Design of Intelligent Robots, and Space Robotics with pioneering tele-teaching to student worldwide. Prof. Rovetta activity was also directed and combined with international collaborations with leadership position in projects and initiatives with strong human relationship.

Prof. Alberto Rovetta has been a prestigious figure with his unique attitude to combine friendships and rigorous scientific activity in working out innovation solutions by collaboration, sharing, and improving the technology for the benefit of the society in the welfare of human beings.

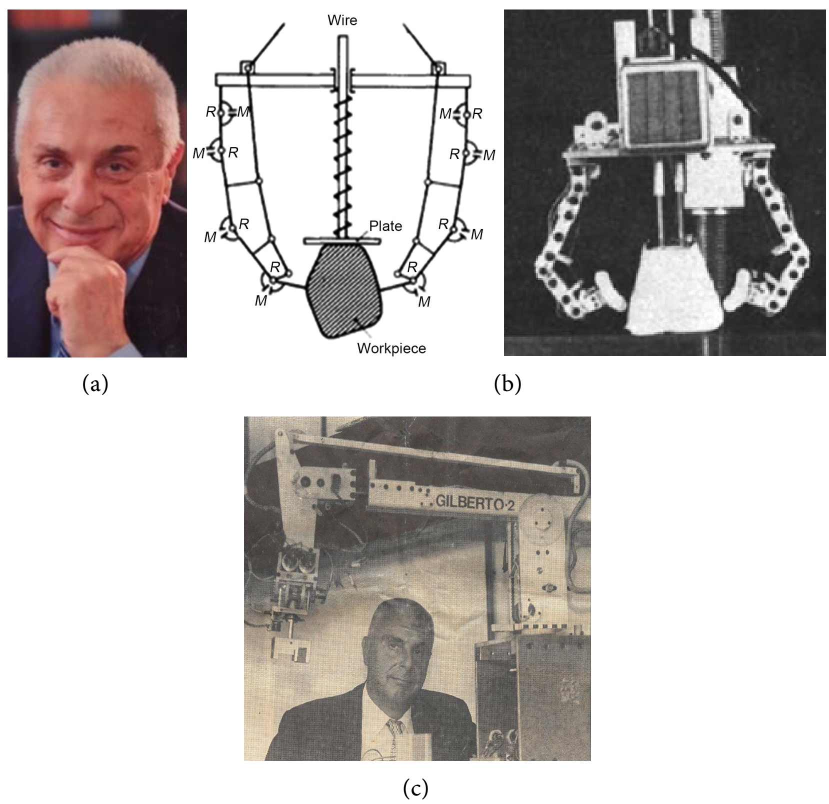


Figure 9. An example: (a) portrait of Alberto Rovetta (1940-2020); (b) his design and prototype of a first versatile robot hand (Rovetta, 1979, 1981); (c) his robot manipulator for tele-operation (Rovetta, 1977).

One of the most significant innovative contributions of prof. Rovetta, both for pioneering aspects and valuable design results, can be considered the development of the Rovetta-Bianchi hand (**Figure 9(b)**) (Rovetta, 1979, 1981). He studied the human grasping to understand why human fingers are five, and how they grasp objects combining with expertise on kinematic design of mechanism and mechanical trasmssion of belt systems. This motivated the design of a multi-scope human-like hand with innovative solutions as in the schemes in **Figure 9(b)**. The hand is designed to grasp objects of different shape with a self-adaptative grasping configuration. The Rovetta-Bianchi hand design was built as a mechanical hand prototype with a human-like functionality in grasping of a large variety of shapes and dimensions. Its innovative peculiarities can be summarized in a grasping configuration with redundant multiple contacts producing grasping forces converging in a point; in a mechanical design with elastic elements ensuring actions towards the center of the hand, while the rigid palm pushes to increase elastic energy of the finger action, due to the spring inserted in the finger joints and below the palm. The mechanical solution was designed with three phalanges moved by a cable tendon acting on the phalanx extremities, and with springs in the joints of the phalanx links. The mechanical palm resented represented an innovative active element for a stable grasping action. The creativity of the design solution can be recognized in the combination of well-known elements assembled in a new assembly for a new successful task as per grasping system well suited for an installation on robot arms.

Another innovative design by Prof. Rovetta is the Gilberto robot (**Figure 9(c)**) (Rovetta, 1977), that after its mechanical constructions in 1977, he adjusted for a first voice-controlled robot in a prototype in 1982 with a collaboration with Alfa Romeo company since its application whose planned for automated factory work. This states the great interest of Prof. Rovetta in synergy of mechanical structures of robots with communications and tele communications, up to attempt successfully much later an application of telerobotic surgery with transatlantic remote control of surgical machines, in a first experiment in the world in 1993 in collaboration with Prof. G. Bekey of University of Southern California, (Ceccarelli & Rovetta, 2023).

Those pioneering activities of Professor Rovetta gave results of undoubted historical impact in the development of Robotics with research approaches and solutions still of reference today. The cultural legacy consists of how the knowledge of the theory of mechanisms can be a valid tool and support for the development of innovative solutions in the field of Robotics, even with its mechatronic structure.

From a historical point of view, both the design and the prototyping of the Rovetta-Bianchi hand are obviously of a technical-scientific cultural heritage. It can therefore be considered an example of cultural value of how a mechanical structure, despite its long history, can be the object and source for research and inspiration in innovation.

The current innovation activities are recognized and based on the aspects of creativity and ingenuity as well as professional skills and specific competences which in the field of mechanism design takes the form of more often theoretical solutions in terms of mechanism topology which then have to be implemented for achieve the true value of an innovative product as discussed since **Figure 1**. Italian creativity in mechanism design sector is still prolific with a historical background of both patented and non-patented solutions and of inventors' personalities in the role of professionals or academic researchers, which however remains not fully exploited both from a historical point of view and a professional perspective in an education to innovation of the new generations of engineers. This paper therefore also has the purpose of being an attempt to shed appropriate light on these aspects and above all to create a greater interest in recognizing merits and characteristics of inventions and innovators as well as to encourage creativity in the new generations based on appropriate cultural background and experience.

4. Conclusion

Innovation with successful products is fundamentally based on the creativity that generates novel solutions that solve problems and needs for a large population of potential users. Creativity is explained in this paper as based by multiple aspects among which some are usually downplayed such as those related to an appropriate competence and skill combined with even a general culture and a broad knowledge of the topic related to the application area. The Italian creativity in the design of mechanisms is a peculiar example and it is explained by referring to illustrative examples in a historical excursus which aims to clarify the peculiarities of the Italian design of innovative solutions as based on personal attitudes and structured knowledge as well as intuition and pioneering vision.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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