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Italian Mechanism Models from Blotto Catalogue in Late XIX Century

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Abstract

In the late 19th century, the teaching of mechanics and mechanical engineering at Italian engineering schools was based on physical models that were used as a teaching tool to show practical applications to students even in theoretical courses. A similar approach was applied in the European academic world (later worldwide) until the end of the 20th century with the use of computers and computer-aided design, which led to a digitalisation of teaching tools, including mechanical models as CAD models for simulation. The objective of this paper is to illustrate the relationship between the mechanical models available in Italy and the classification of mechanisms developed at this time by notable Italian figures working in teaching Theory of Machines and Mechanisms (TMM). In particular, the catalogue of mechanism models made by Giovanni Blotto in the early mid-19th century is discussed as linked to the mechanism classification that was originally proposed in 1845 by Carlo Ignazio Giulio, at the Royal School of Applications for Engineers of Turin, Italy (today the Politecnico of Turin), some before the famous Voigt-Releaux models. Mechanism models from the main collections of the engineering schools at Italian universities are discussed, not only coming from Blotto production, to show the fascination that these models still produce so that they can still be considered from both educational and museum perspectives.

Keywords

History of Mechanical Engineering, Mechanism Models, Mechanism Classifications

1. Introduction

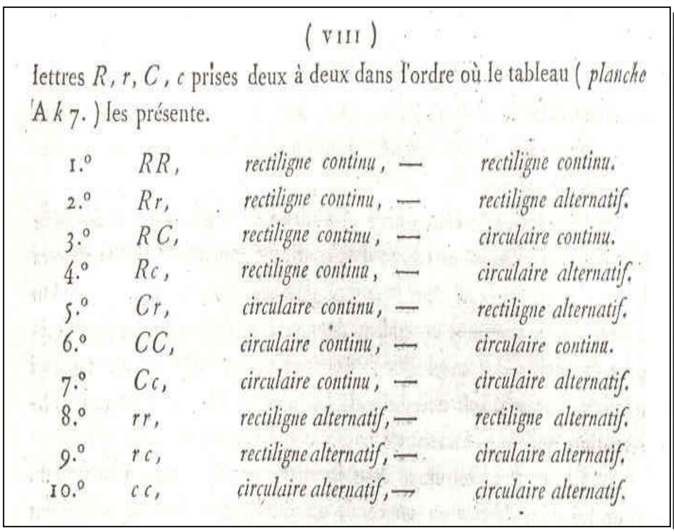
Modelling is a widely used teaching tool, especially in fields related to the development and analysis of systems. Today, these models are essentially in digital forms, but there is also a renewed interest in physical models that can help in learning concepts and functions with direct physical experience and can facilitate and complete the introduction and explanation of their related problems and solutions, even with historical perspectives (Ceccarelli & Cocconcelli, 2022a). In particular, since the early days of modern time mechanical engineering have been interested in physical models of mechanisms, both for educational purposes as well as for research activities in the field of classification and cataloguing of the structural possibilities of mechanisms (Kerle, Mauersberger, & Ceccarelli, 2011; Ceccarelli, 2004; Ceccarelli, 2020), such as, for example, in the pioneering works (Lanz & Betancourt, 1808; Borgnis, 1818-1821; Willis, 1841; Giulio, 1846; Reuleaux, 1875). The study of physical models of mechanisms and their re-evaluation, both at historical and educational levels, has attracted recent interest primarily for museum purposes, as reported in (Ceccarelli & Cocconcelli, 2022b; Franco, Trivella, & Quaglia, 2020; Shiroshita, 2009; Kerle, Mauersberger, & Ceccarelli, 2011). Recently, the use of mechanism models is re-evaluated also for modern educational purposes in combination with digital models that can be developed with CAD simulation procedures (Ceccarelli, 2020).

In this work, we present specific aspects of the development and production of mechanisms' physical models in the Italian context with a tradition started mainly from the early second half of the 19th century and continued until the 1960s, with their use for educational purposes (Ceccarelli, 2021; Ceccarelli & Cocconcelli, 2022). Today many of these models that were forgotten for a long time, are rediscovered and re-evaluated mainly for technical-historical valorization which still requires attention and research to properly define their characteristics and their history. This paper focuses also on the specific experience of Giovanni Blotto, an Italian manufacturer (Blotto, 1879), who was very successful in the production of mechanism models since the early mid of the 19th century, as proved by the presence of his wooden mechanism models in many universities in Italy. The successful dissemination of the Blotto models seems to have anticipated the German mechanism models as in (Schroder, 1899) that were successfully disseminated by the Voigt company with catalogue (Voigt, 1907), that is linked to the works of Franz Reuleaux (Reuleaux, 1875).

A preliminary version of this paper was presented at HMM2024, the 8th International Symposium on History of Machines and Mechanisms in Ankara, Turkey, 18-20 April 2024 (Cocconcelli & Ceccarelli, 2024). In this extended revised version, mechanism models from most of the Italian universities of the time are shown and discussed. A special attention is addressed by referring to a comparison between the first (1869) and second (1879) edition of the Blotto's catalogue. The proposed examination is an attempt to provide an overview of this experience with mechanism models in Italian frames as well as to suggest a stimulus for more in-depth research and valorisation of historical-technical aspects on mechanism models also at Italian local frames.

2. Italian Classification of Mechanisms

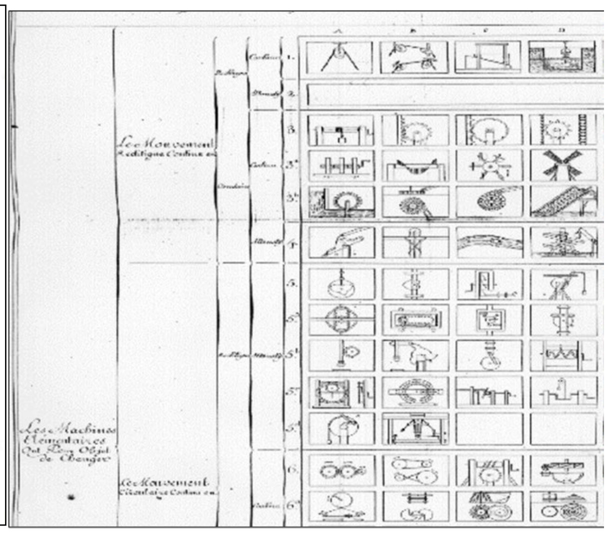
Models of mechanism were developed in two ways, namely by drawing schemes and physical models (Ceccarelli, 2020; Traetta & Ceccarelli, 2022). The first type was used since the early day of the mechanism technologies for several aims, such as primarily to explain and formulate design solutions and but even to teach. Within this activity investigations were carried out to summarize the mechanism possibilities with catalogues. Catalogues were a first attempt of classification of mechanism's that become a theoretical problem to search for unification principle of the large variety of mechanism designs. Indeed, classifications of mechanisms were developed also for practical purposes of cataloguing of the variety of mechanisms available under different viewpoints for design or applications attempting also to find new solutions as pointed out for example (Ceccarelli, 2004). In the modern era, a first classification with those aims is due to Gaspard Monge, who was a co-founder of the Ecole Polytechnique in Paris teaching a first modern academic course on Mechanism Design. Following those lectures his collaborators-students Augustin Betancourt and Josè Maria Lanz published in the pioneering 'Essai sur la composition des machines' (Lanz & Betancourt, 1808), a treatise for analysing and designing the input-output movement relations depending on the structure of the mechanism categories, **Figure 1(a)**. Monge's successor, Jean Nicole Hachette made such an approach a textbook in (Hachette, 1811) **Figure 1(b)**.


(VIII)

lettres *R*, *r*, *C*, *c* prises deux à deux dans l'ordre où le tableau (*planche* A *k* 7.) les présente.

1.°	*RR*,	*rectiligne continu*, —	*rectiligne continu.*
2.°	*Rr*,	*rectiligne continu*, —	*rectiligne alternatif.*
3.°	*RC*,	*rectiligne continu*, —	*circulaire continu.*
4.°	*Rc*,	*rectiligne continu*, —	*circulaire alternatif.*
5.°	*Cr*,	*circulaire continu*, —	*rectiligne alternatif.*
6.°	*CC*,	*circulaire continu*, —	*circulaire continu.*
7.°	*Cc*,	*circulaire continu*, —	*circulaire alternatif.*
8.°	*rr*,	*rectiligne alternatif*, —	*rectiligne alternatif.*
9.°	*rc*,	*rectiligne alternatif*, —	*circulaire alternatif.*
10.°	*cc*,	*circulaire alternatif*, —	*circulaire alternatif.*

(a)

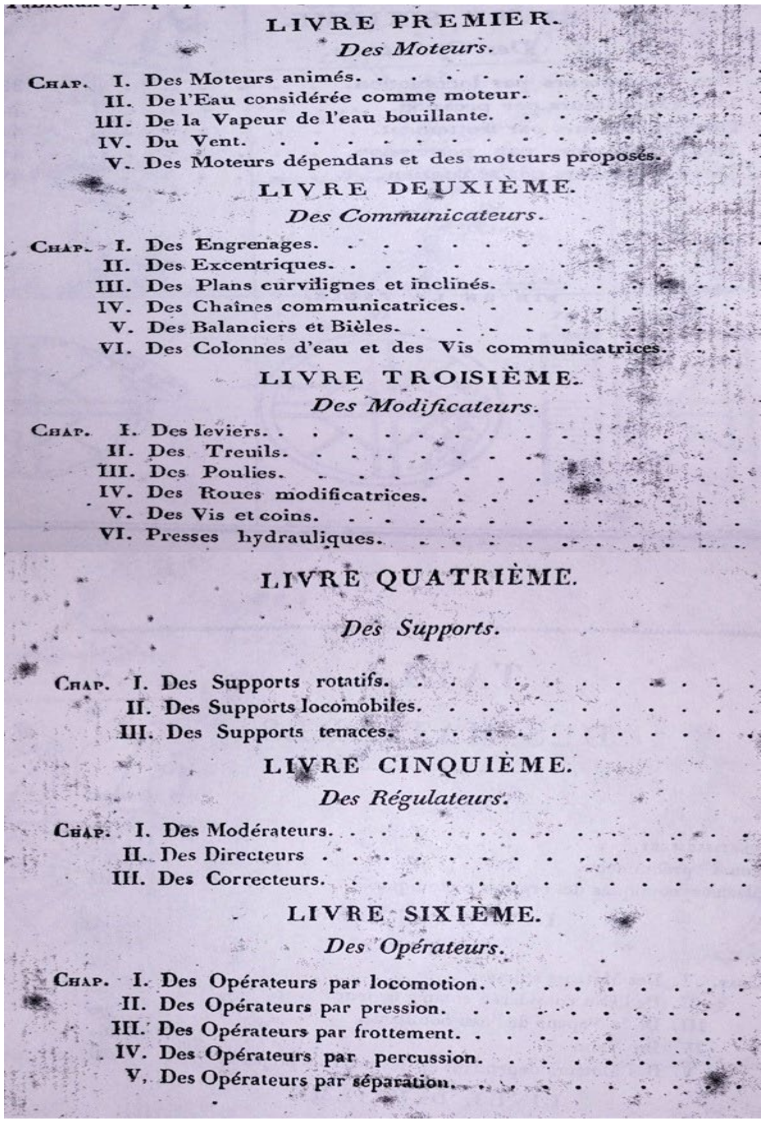


(b)

Figure 1. Monge classification of mechanisms in: (a) Essai sur la composition des machines (Lanz & Betancourt, 1808); (b) Traite elementaire des Machines of 1811 (Hachette, 1811).

This treatise was considered a reference for long time as per the later proposals of classifications and catalogues of mechanisms when searching for generality and topological possibilities of mechanisms, even those not yet invented or designed. In these catalogues, the models of the mechanisms were represented by drawings or schemes that were also used to produce physical examples of the structures of mechanisms, by starting to the teaching tradition with the use of models (Ceccarelli, 1998).

Giuseppe Antonio Borgnis, (Ceccarelli, 2014), extended Monge classification in his milestone work (Borgnis, 1818-1821) by including a description of machine components in terms of "receptors, modificators, frames, regulators, and operators", as summarized in the textbook index in **Figure 2**.



LIVRE PREMIER.

Des Moteurs.

CHAP. I. Des Moteurs animés.
II. De l'Eau considérée comme moteur.
III. De la Vapeur de l'eau bouillante.
IV. Du Vent.
V. Des Moteurs dépendans et des moteurs proposés.

LIVRE DEUXIÈME.

Des Communicateurs.

CHAP. I. Des Engrenages.
II. Des Excentriques.
III. Des Plans curvilignes et inclinés.
IV. Des Chaînes communicatrices.
V. Des Balanciers et Bièles.
VI. Des Colonnes d'eau et des Vis communicatrices.

LIVRE TROISIÈME.

Des Modificateurs.

CHAP. I. Des leviers.
II. Des Treuils.
III. Des Poulies.
IV. Des Roues modificatrices.
V. Des Vis et coins.
VI. Presses hydrauliques.

LIVRE QUATRIÈME.

Des Supports.

CHAP. I. Des Supports rotatifs.
II. Des Supports locomobiles.
III. Des Supports tenaces.

LIVRE CINQUIÈME.

Des Régulateurs.

CHAP. I. Des Modérateurs.
II. Des Directeurs
III. Des Correcteurs.

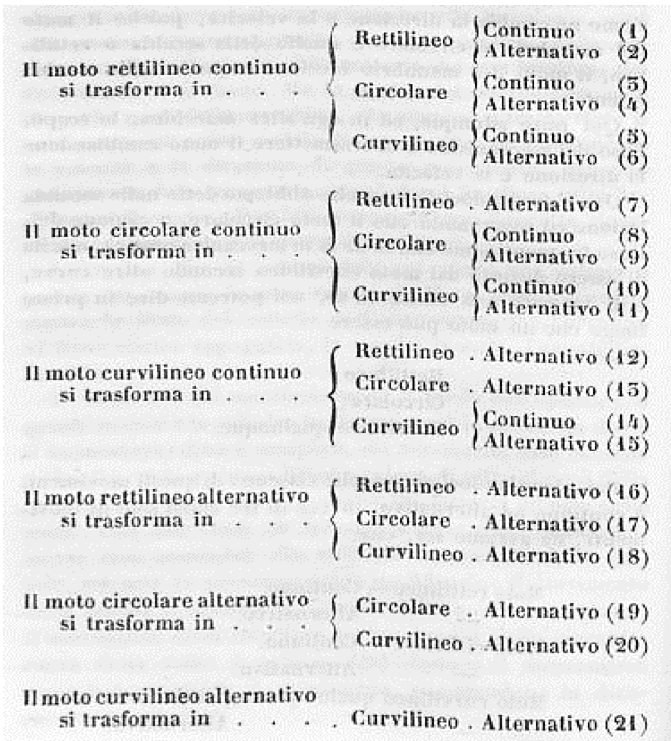
LIVRE SIXIÈME.

Des Opérateurs.

CHAP. I. Des Opérateurs par locomotion.
II. Des Opérateurs par pression.
III. Des Opérateurs par frottement.
IV. Des Opérateurs par percussion.
V. Des Opérateurs par séparation.

Figure 2. Borgnis' classification of mechanisms in his Essai sur la composition des machines (Borgnis, 1818-1821).

Then he catalogued the existing machines by referring to practical applications up to include 1200 mechanical devices with drawing schemes in his encyclopaedic mechanism handbook of 9 volumes (Borgnis, 1818-1821). This milestone work was of practical reference during the whole 19th century and was also source of further developments, whose the most significative ones can be considered those by Robert Willis (1841) and Carlo Ignazio Giulio (1846). In 1841, Willis classified mechanisms as function of the transmission ratio (constant as constant or varying with constant or changing direction of the motion) in five divisions depending on the type of contacts among basic components as "rolling contact, sliding contact, wrapping connectors, linkwork, reduplication". In the same time Carlo Ignazio Giulio (1803-1859), who was professor of Pure and Applied Mathematics as co-founder of the School of Engineering in Turin, in 1846 published a textbook (Giulio, 1846) from lectures started in 1841 for the students at the Royal School od Application for Engineers in Turin. In his textbook (Giulio, 1846), he included a classification of mechanisms based on the motion of the input and output elements that he classified according to three characteristics, namely the shape (rectilinear, circular or curvilinear motion), the type (continuous or alternative), the direction (input and output of the mechanism can be input exchanged with each other). Based on these characteristics the possible 21 categories are identified as summarized in **Figure 3**. Each mechanism category is discussed with mechanism examples that are analysed in detail with drawing models in tables at the end of the book. This started the Italian modern tradition on Mechanism Design.



Il moto rettilineo continuo si trasforma in . . .	Rettilineo	Continuo	(1)
		Alternativo	(2)
	Circolare	Continuo	(3)
		Alternativo	(4)
	Curvilineo	Continuo	(5)
		Alternativo	(6)
Il moto circolare continuo si trasforma in . . .	Rettilineo	. Alternativo	(7)
	Circolare	Continuo	(8)
		Alternativo	(9)
	Curvilineo	Continuo	(10)
		Alternativo	(11)
Il moto curvilineo continuo si trasforma in . . .	Rettilineo	. Alternativo	(12)
	Circolare	. Alternativo	(13)
	Curvilineo	Continuo	(14)
		Alternativo	(15)
Il moto rettilineo alternativo si trasforma in . . .	Rettilineo	. Alternativo	(16)
	Circolare	. Alternativo	(17)
	Curvilineo	. Alternativo	(18)
Il moto circolare alternativo si trasforma in . . .	Circolare	. Alternativo	(19)
	Curvilineo	. Alternativo	(20)
Il moto curvilineo alternativo si trasforma in	Curvilineo	. Alternativo	(21)

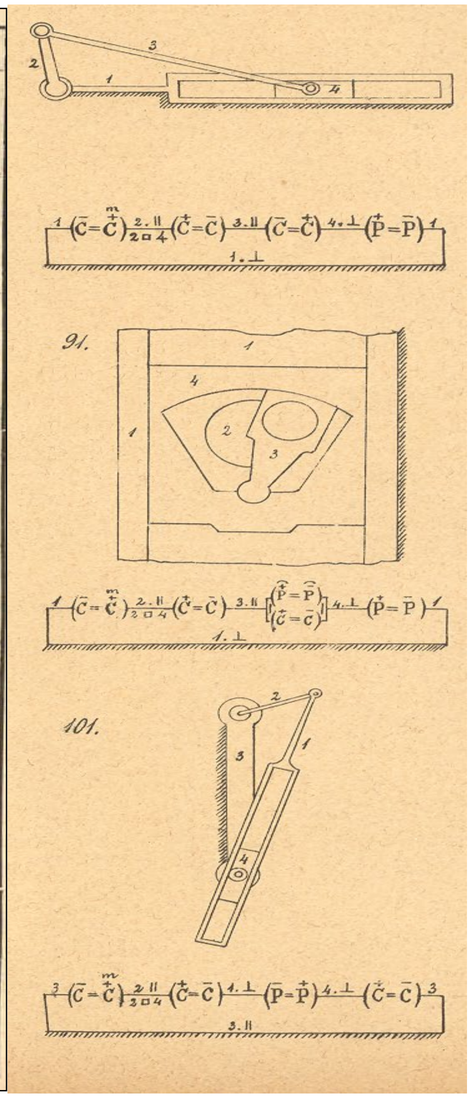
Figure 3. Giulio classification of mechanisms in his textbook (Giulio, 1846).

The specific interest on mechanism classification attracted Francesco Masi, (Ceccarelli, 2010) at the University of Bologna. With his works he extended the previous mechanisms analyses and proposed a classification procedure using the mechanism modelling of Reuleaux up to elaborate his own algorithm in (Masi, 1883), which classifies up to 10,362,600 mechanisms including quaternary ones (composed of quaternary links) (**Figure 4**).

MECCANISMI SEMPLICI		
Categorie	**Numero delle classi per categoria**	**Classi descritte**
Omogenei	8	Sistemi articolati
Binari	28	Cunei ed eccentrici - Bocciuoli - Viti - Ruote di frizione - Ruote dentate - Arpionismi semplici Meccanismi ad organi di trazione e compressione.
Terniari	56	Ruote dentate con bocciuoli - Arpionismi con ruote dentate.
Quadernari . .	70	
Quinquenari .	56	
Sessenari . . .	28	
Settenari . . .	8	
Ottenari	1	

MECCANISMI COMPOSTI		
Categorie	**Numero delle classi per categoria**	**Classi descritte**
Omogenei	225	Sistemi articolati composti - Viti composte - Rotismi di frizione composti - Rotismi dentati composti - Arpionismi composti - Meccanismi ad organi di trazione e compressione.
Binari	25200	Rotismi e sistemi articolati - Bocciuoli ed organi di trazione - Rotismi ed arpioni - Arpionismi e sistemi articolati - Sistemi articolati con organi di pressione.
Ternerari . . .	1873200	»
Quadernari . .	10362600	»
Quinquenari .		»
Duecentocinquenari	1	»

(a)



(b)

Figure 4. Classification with numbering of mechanisms by Francesco Masi (Masi, 1883): (a) the summary table; (b) examples of graphical models of catalogued mechanisms.

Also, in this classification graphical models of mechanisms are used to explain the mechanism catalogue and to prove the algorithm efficiency in describing design and operation features of each type of mechanisms. These graphical models are treated as mechanism models in combination with those physical models that started to circulate for teaching purposes. Masi work well established an Italian tradition up nowadays in teaching Mechanism Design by looking at the variety of mechanisms combined with experiencing models (graphical, physical, or virtual ones) (Ceccarelli, 2020; Ceccarelli & Cocconcelli, 2022), with practical details in design and applications.

Figure 5 shows the Italian figures who were pioneers mainly but not only, in Italian frames in developing approaches in design and teaching Mechanism Design both with theoretical (graphical) and practical models.

(a) (b) (c)

Figure 5. Founders of the Italian modern school on Mechanism Design: (a) Giuseppe Antonio Borgnis (1781-1863); (b) Carlo Ignazio Giulio (1803-1859); (c) Francesco Masi (1852-1944).

The value of mechanism classifications can be recognized in teaching purposes to give the students a methodology to approach the design of mechanisms or machines considering the variety of available solutions. Once a student has a clear understanding of the input-output motion relationship (as a constraint of a problem or not), she/he can select a topological solution among available mechanisms by applying further design and performance criteria. The mechanism models, either in graphical representations or physical products, can clearly explain the design and operation that are formulated by equations and discussions in a textbook or handbook, helping students with practical examples. Physical models can represent a further step even in today computer-based teaching activity, since they permit the students to touch what today we call 3D-model of a mechanism.

3. Models of Mechanisms

In the early days of 19th century, both theoretical and practical courses in engineering schools in Italy and Europe were included as important parts of the teaching activities for engineering formation. This was emphasised also by the name of the schools, like in Italy where the engineering schools were named "School of Application for Engineers" (Scuola di Applicazione per Ingegneri). The laboratory activity was planned for students to manage objects and tools for a direct experience on what a professor explained in classrooms, for a better understanding of the theoretical subjects. Mechanism models were widely used for teaching purposes in university engineering curricula throughout the 19th century (Ceccarelli & Cocconcelli, 2022b). The main advantage of mechanisms models consists in the fact they can provide a three-dimensional representation of mechanisms and machines, which cannot be fully represented by two-dimensional drawings in textbooks and in research design results. The diffusion of teaching mechanism models was so successful that the most important schools were organized with their own official workshops, and their models were often sold to other research centres and universities through commercial sales supported by catalogues. Two emblematic examples of the 19th-century market activity of mechanism models can be indicated in Gustav Voigt in Germany (Voigt, 1907) and Giovanni Blotto (1842-1932) in Italy (Blotto, 1879).

3.1. Mechanism Models of Gustav Voigt

The workshop Gustav Voigt Werkstatt in Berlin manufactured and exported educational models mainly referring to machine mechanisms all around the world, as it is documented for example in (Shiroshita, 2009) with a collection still preserved at the University of Kyoto. The factory was managed by the Voigt family from 1879 to 1933, but the name of the factory varied slightly (Moon, 2007). The Voigt educational models were produced referring to the modelling and the classification of Reuleaux (Reuleaux, 1875). Most models were made of steel with wooden bases and markers to indicate relative displacements of parts. In same case a model was provided of mechanical stops to block the motor or the running crank in a specific position. The models were designed with limited size to be easy to transport in classrooms, and in a proper open shape to clearly show the movements of the different parts.

In several universities they keep Voigt models, but the most consistent collection is today at Cornell University, USA, that is preserved as Reuleaux Kinematic Mechanisms Collection (RKMC) (Moon, 1999). It lists more than 300 Reuleaux Voigt models as the most comprehensive remaining mechanism model collection by Gustav Voigt. Since 2005 as per a renewed interest of mechanism models both for historical heritage and technical value (Ceccarelli & Cocconcelli, 2022b), those models were made available also in digitalized format (Moon, 2004), as an open multimedia resource for learning and teaching about kinematics and machine history, within the computer-based current engineering formation.

3.2. Models of Giovanni Blotto

In the same period, as indicated by the reference (Blotto, 1879), Giovanni Blotto was an official model manufacturer of the Royal School of Applications for Engineers in Turin. He worked on wooden models of machines and mechanisms, as well as crystallographic models, building models and design models supporting teaching in different fields such as steam machines, civil engineering, and naval construction. Unfortunately, there is no information or recorded documents about Blotto's commercial activities that permitted to sell his models, except a mention to a prize received in 1884 at the Italian General Exhibition (Camera di Commercio ed Arti di Torino, 1884) and the catalogue listing available models and their prices in (Blotto, 1869; Blotto, 1879). More information on the catalogue can be found in the following sections. Examples of these models are still available at the schools of engineering of the universities active at that time, such in Bologna, Milan, Turin, Padova, Rome, Pisa and Palermo, as evidence of their large dissemination in Italy up to the beginning of the 20th century. The Blotto models were mainly made of wood, and their cost was probably lower than the metal ones, like the Voigt metal models. In general, they can be easily differentiated by the

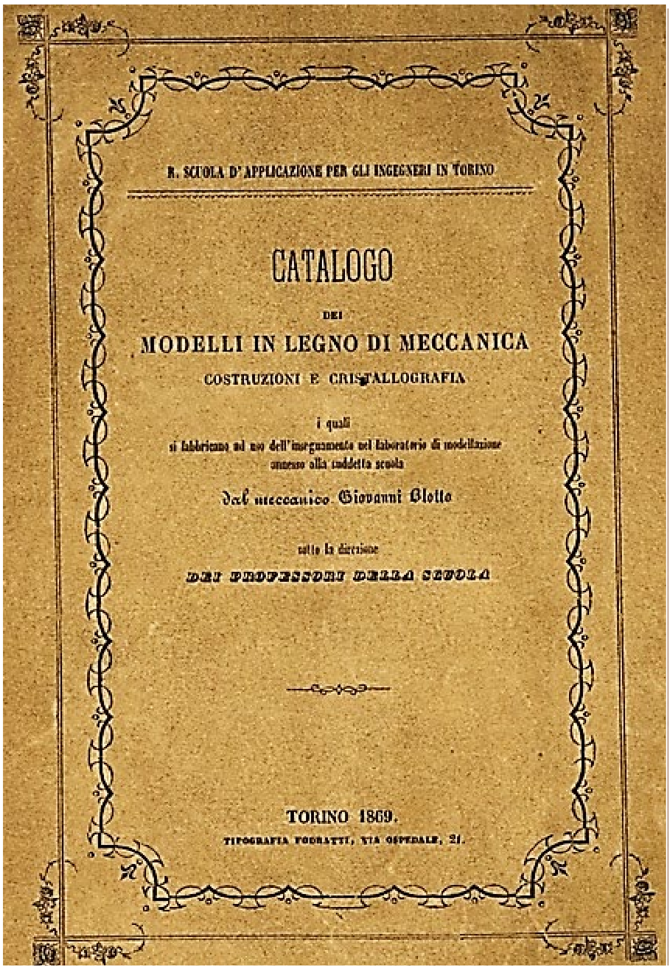
Voigt ones by the base frame, even if in wood, since it is dark in the Voight models with the main mechanism in bright metal to focus the attention on the mechanism structure, while Blotto models are only wooden made, with the moving part in bright wood (light brown) and with markers to show relative movement.

4. Blotto Catalogue

Little is known about Giovanni Blotto's life and his company. Born in Biella, Giovanni Blotto was employed at the Royal School of Application for Engineers (Reale Scuola di Applicazione per Ingegneri) of Turin since 1860. During works at Valentino in 1863-1864, among the 13 workers the name of Giovanni Blotto appears in the economic books, indicating that he was hired the following year as a trainer. With this job he was responsible for developing the collections of mechanics, constructions, geometry and crystallography with wooden objects coloured in oil and paint in imitation of real products, in the frame of a laboratory-workshop within the Royal School of Application for Engineers under the direction of Professor Curioni, teacher of Machine Design. He collaborated in the preparation of collections of solid geometry, models for elementary mechanics, construction of mechanical and steam machines, with a large sector dedicated to wood, iron and stone constructions for civil works and infrastructures. Since 1865 Blotto, as head of that laboratory-workshop at the Royal School of Application of Engineers of Turin, became the teachers' point of reference for the development of teaching models for courses and for scientific experiments. Vittorio Canepa appeared later as his close collaborator with whom he will also share the direction of the laboratory. Already in 1861 Blotto participated with an exhibition of models of machines and mechanisms at the Italian Exhibition held in Florence with a citation in Volume 2 of the Proceedings. He was awarded a silver medal in 1884 for section VIII - INSTITUTES, BOOKS AND LIBRARIES of the Academy of Sciences of Turin. On 14 February 1876 he was appointed Knight of the Order of the Crown of Italy (Cavaliere dell'ordine della corona d'Italia) for technical-scientific merits linked to his activity as a trainer with the construction of teaching models, also exported to other training institutes in the Italian kingdom. Giovanni Blotto died in 1887 in Turin.

Today, few mechanisms models of Blotto productions remain. The main reference source is the catalogue of models, whose a copy of the second edition (1879), **Figure 6(b)**, is preserved in the Bologna University Historical Archive, while a digitalized version of the first edition in 1869 is available on Google Books (Blotto, 1869) (**Figure 6(a)**). The catalogue of 1869 is a result of activity that was started since the early 1860s' very likely following a tradition of the school with laboratory practices, by indicating the original activity against the later German activity with metal models.

The Blotto catalogue contains the list of all models for sale at a given price to other institutions. **Figure 6** shows the title page of the first and second editions of the catalogues, which consist of 30 and 36 pages respectively. Unfortunately, the


R. SCUOLA D' APPLICAZIONE PER GLI INGEGNERI IN TORINO

CATALOGO

DEI

MODELLI IN LEGNO DI MECCANICA

COSTRUZIONI E CRISTALLOGRAFIA

i quali
si fabbricano ad uso dell'insegnamento nel laboratorio di modellazione
annesso alla suddetta scuola

dal meccanico Giovanni Blotto

sotto la direzione

DEI PROFESSORI DELLA SCUOLA

TORINO 1869.

TIPOGRAFIA FODRATTI, VIA OSPEDALE, 21.

(a)


R. SCUOLA D'APPLICAZIONE PER GLI INGEGNERI IN TORINO

CATALOGO

DEI

MODELLI IN LEGNO DI MECCANICA

COSTRUZIONI E CRISTALLOGRAFIA

i quali si fabbricano
ad uso dell'insegnamento nel laboratorio annesso alla suddetta scuola

dal Cav. GIOVANNI BLOTTO

MECCANICO MODELLATORE

SECONDA EDIZIONE CORRETTA ED AMPLIATA

TORINO
Tipografia FODRATTI, Via Gaudenzio Ferrari, 3.

1879

(b)

Figure 6. Front pages of the Blotto catalogues: (a) 1st edition published in (Blotto, 1869); (b) 2nd edition published in (Blotto, 1879).

catalogue does not contain any figure of the models, but only the name of the model and the corresponding price in Italian pound (**Figure 8**). The second edition of the Blotto catalogue consists of 871 increasing the 682 models of the first edition. The model offer is divided into three main categories: 345 (281 in the first edition) mechanical models, 326 (201) construction models, 200 (200) Crystallography models. Mechanical models are further divided into eight sub-categories: 4 (0) solid geometry models, 20 (17) elementary mechanics, 100 (80) kinematics, 85 (56) machine design, 62 (64) steam engines, 40 (36) Railways, 34 (28) Hydraulics. In addition, the catalogues include 200 crystallographic models, and 312 construction models divided into unions between woods (80), different wooden structures (54), iron constructions (40), masonry constructions and different vaults (30), common and hydraulic foundations (22), devices for the transport of earth and materials with appropriate hardware (14), retaining walls (22).

In 1879 Blotto's new collection included 895 wooden models, among which Quintino Sella's crystallographic models also appear as composed of geometric shapes combined with colours (e.g. yellow for primitive shape, white for octahedron, dark green for rhombododecahedron, etc.) to simplify the recognition of minerals.

Table 1 summarizes the list of items in the catalogues in the two editions.

The specific complete list of the mechanism models is reported in the Appendix. The mechanism models can be classified into 6 categories, namely cams, screws, friction devices, pulleys, gears, and cranks. The number in the table in Appendix refers to the sequential code number in the Blotto's catalogue. Engraved on each wooden model there is the stamp of the manufacturer with the name and the city (Figure 7), but unfortunately it is not indicated any date of the manufacturing nor the corresponding name of the catalogue nor the code of the mechanism. The catalogue books are the only documents available of the Blotto productions of models that very likely were purchased by many Italian universities at that time.

Table 1. Number of models in the catalogue in the first (Blotto, 1869) and second (Blotto, 1879) edition of the catalogue, Figure 6.

Section	Subsections	1st Ed. (1869)	2nd Ed. (1879)
Mechanical models	Solid mechanics	0	4
	Elementary mechanics	17	20
	Kinematics	80	100
	Machine design	56	85
	Steam engines	64	62
	Railways	36	40
	Hydraulics	28	34
	Total	***281***	***345***
Construction models		201	326
Crystallography models		200	200
Total		***682***	***871***

Figure 7. Example of the stamp "BLOTTO GIOVANNI MECCANICO" of the Blotto mechanism production in wood models.

Recently we discovered similar wood models of mechanisms with the indication of "Costa - Grugliasco" and "G. Costa - E. Giraudo modellatori Torino" referring to a model production yet in Turin in a period after 1910. These workshops look to be the continuation of the Blotto activity, still linked to the Turin Royal School of Application for Engineer but located outside of it. This can indeed indicate a well-established production of mechanism models with a dissemination in the le territory of Italian Kingdom.

6

3.	Due manovelle conducenti due eccentrici a gruccia rettilinea e circolare . . . . L.	25
4.	Eccentrico a scanalatura foggiata secondo due spirali d'Archimede di verso contrario e di egual passo, con stanghetta e sostegno relativo . . . . »	16
5.	Meccanismo per la trasformazione del movimento circolare continuo in circolare alternativo . . . . »	12
6.	Ruota a sega con arpione a leva e nottolino . . . »	16
7.	Bocciuolo a sviluppante di circolo che solleva un pestello . . . . »	14
8.	Bocciuolo a sviluppante di circolo per trasformare il moto circolare continuo in rettilineo d'andivieni . »	16
9.	Bocciuolo a tre foglie, a sviluppante di circolo, per trasformare il moto circolare continuo in rettilineo alternativo . . . . »	16
10.	Quattro eccentrici diversi cioè: 1° circolare; 2° a cuore; 3° variabile; 4° triangolare . . . . »	60
11.	Bocciuolo cilindrico con stanghetta . . . . »	14
12.	Bocciuolo conico con stanghetta . . . . »	16
13.	Macchinetta per segnare eliche di passo dato . . . »	32
14.	Cilindro con scanalatura ad elica e stanghetta . . »	15
15.	Cilindro con vite a pane triangolare conducente una asticciuola dentata . . . . »	12
16.	Cilindro con due scanalature ad elica destra e sinistra e con stanghetta . . . . »	20
17.	Vite a pane triangolare con chiocciola . . . . . . »	8
18.	Due viti a pane rettangolare: 18_a a un pane; 18_b a due pani . . . . »	12
19.	Torchio a vite fissa e madrevite mobile . . . . . »	30
20.	Torchio a vite mobile e madrevite fissa . . . . . »	30
21.	Vite perpetua a pane rettangolare . . . . »	20
22.	Cono con scanalatura ad elica e stanghetta . . . . »	15

Figure 8. Example of an inner page of the 1st edition of the Blotto catalogue with cost of models in Italian Lire (L).

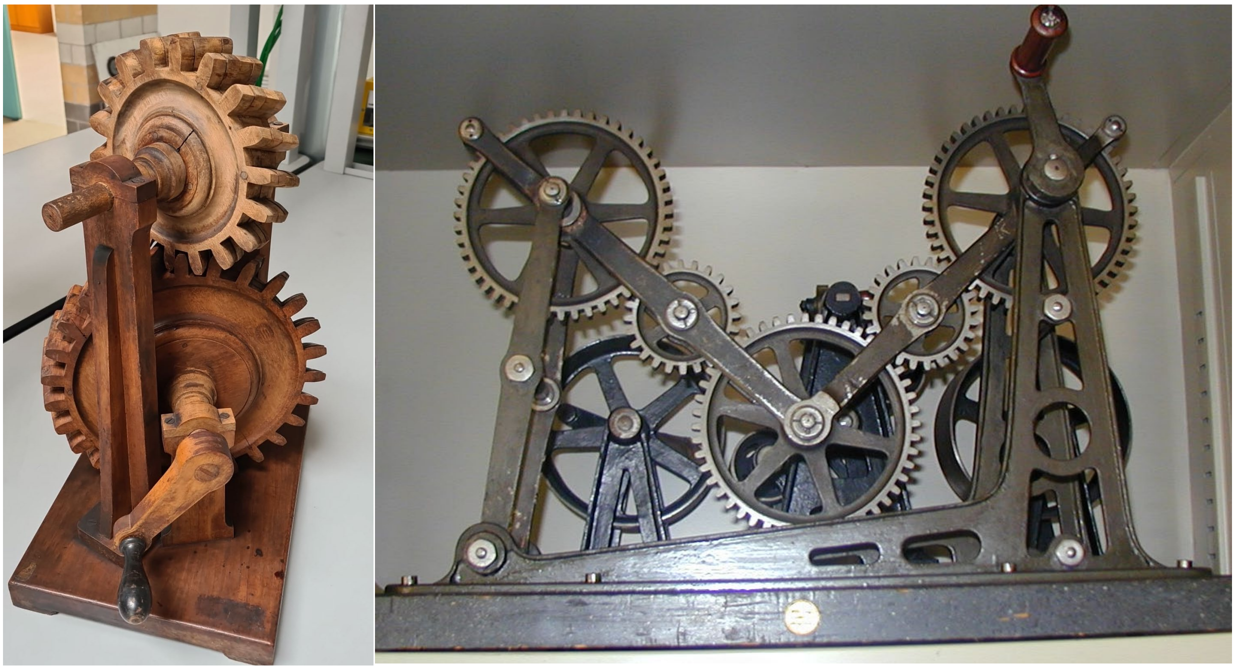
5. Mechanism Models in Italian Universities

Mechanism models are still available today in several Italian universities, as outlined in (Ceccarelli & Cocconcelli, 2022b; Ceccarelli, 2021). They can be found in teachers offices, archives, and museums of the oldest universities active with school of engineering in 19th century, such as Bologna, Milan, Padua, Palermo, Pisa, Rome, Naples, and Turin. In the following, examples from each of these universities are proposed with short discussion also referring to different model producers and testifying the diffusion of mechanism models in education. It should be noted that most of these mechanisms' models were inspired, if not even designed, referring to the graphical models in these treaties and manuals, such as (Borgnis, 1818) Giulio (Giulio, 1846) and Masi (Masi, 1883), which contain a classification of mechanisms with catalogues and examples of mechanisms. The models of the mechanisms that remain in some Italian academic institutions where a group in the field of Theory of Machines and Mechanisms (TMM) (today Mechanisms and Machine Science (MMS)) is still active, have been preserved against dispersion and destruction in recent years due to a depreciation following activities based on the use of the computer, thanks to mainly individual interest of some colleagues who recognized historical and educational values. In some cases, it was possible to preserve a conspicuous collection with a dimension valid even for a museum exhibition as today can be appreciated at the Politecnico of Turin (in the Department of Mechanics) (Franco, Trivella, & Quaglia, 2020), and the University of Palermo (at the museum University of Engines and Mechanisms) (Genchi, 2024). Furthermore, it should be noted that in addition to what is described above in relation to the production of Italian models, the existence of wooden and metallic models can be found which were probably produced locally both in the academic laboratories and by a specially appointed craftsman. However, there is no information on many of these models which also remain of unknown dating. In the following overview with a few examples of these models, this variety of models and their manufacturing can be highlighted although there is evident a significant representation of the commercial ones made by Voigt and Blotto which seem to have also been an inspiration for these local productions. Another worthy observation is the originality of the Italian models of mechanisms, especially wooden ones, which were produced even before the marketing mentioned above. In the end, the modern models appear to have originated from these simple but functional designs, which were converted into real mechanisms by different manufacturers almost without any modifications, as educational tools within teaching courses in engineering schools. It is worth noting that the practice of final tables that collected all mechanical drawings in textbooks at the end of the 19th century was later quite common, and that remarkably similar tables are present in different books of this period and later.

5.1. Politecnico of Turin

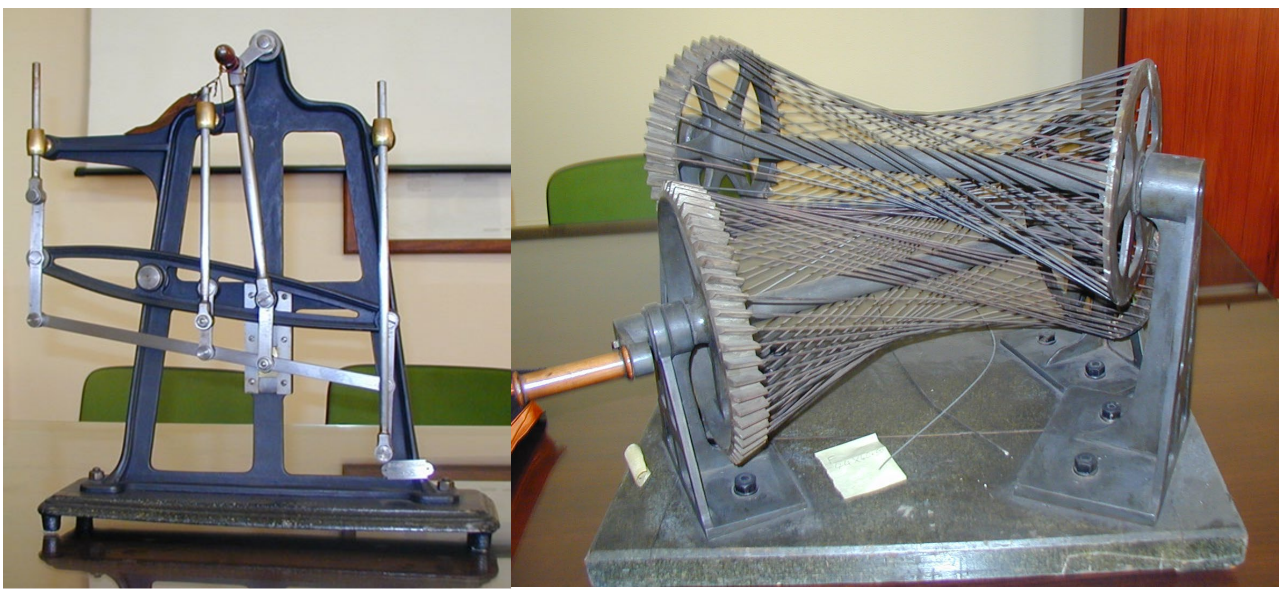
The Department of Mechanical and Aerospace Engineering of the Politecnico of Turin preserves a collection of about 85 models, that are built in iron coming as purchased by the company J. Schröder of Darmstadt (Franco, Trivella, & Quaglia, 2020). Some are also made by Blotto and some other look to be produced later with no indication of manufacturer. The examples in **Figure 9** and **Figure10** show such a variety that is characteristic indeed of such collections of the mechanism models at the time from mid-end 19th century up around the mid of 20th century.

Figure 9 shows gear transmission models which, among other things, were the main part of these collections of physical models which aimed to represent and teach mainly the mechanical transmission with the characteristics related to gear trains. **Figure 9(a)** shows a beautiful example of the wooden production by Giovanni Blotto, probably coming from the second catalogue of 1879. Considering the age of the model, one can appreciate the solidity as well as the precision in the reproduction of the tooth profiles and the solution with skew axes which still remains operationally efficient. Figure 9(b) shows a planetary gear system with a solid metal construction which still represents a solution of interest not only for educational but also design purposes. In the collection there are many other geared models that want to show the versatility and multiplicity of solutions that



(a) (b)

Figure 9. Model of geared models from the collection of the Politecnico of Turin: (a) Blotto wooden model; (b) an iron model of planetary geared systems.



(a) (b)

Figure 10. Models from the collection of the Politecnico of Turin: (a) Watt mechanism; (b) conceptual design of hypoid gear wheels.

can be obtained with the design of gear trains and planetary systems even with non-circular wheels of the elliptical type or of various geometry.

Figure 10 shows two examples that refer to didactic fundamental topics in terms of articulated mechanisms and conceptual modelling for the motion of mechanical systems. In particular, Figure 10(a) shows a metal model still from the Schorder collection which represents the Watt mechanism with its original configuration due to Watt's design for the steam engine. In Figure 10(b) an original model of the ruled surfaces is shown to explain the movement in the hypoid gear wheels with the same configuration that can be found in many texts and manuals for the design of gears useful for transmission in the space between axles differently skewed. In this case, in that model built with surprising details in a robust metal solution, there is no indication of the manufacturer nor of the time of production, probably indicating its creation in a period somewhat after the First World War.

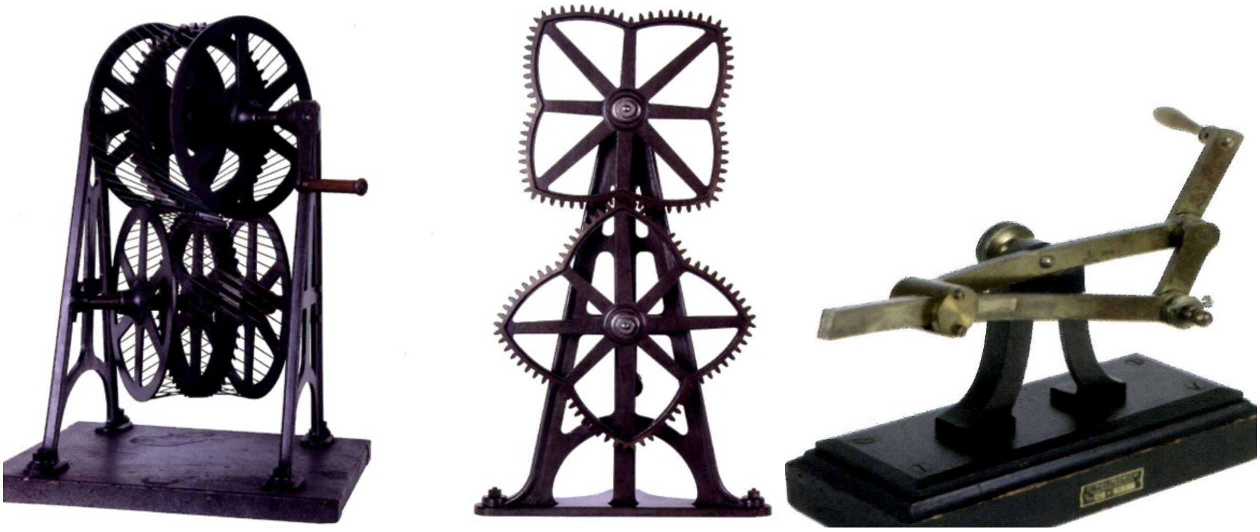
The models represented in Figure 9 and Figure10 are still functional and can be considered of high historical museum value but still of interest for teaching in the design of mechanisms and gears as well as in laboratory practices.

5.2. Politecnico of Milan

At the Politecnico di Milano, a few examples of mechanical models have been preserved which are now exhibited at museum level with reference to the Department of Mechanical Engineering. Figure 11 shows representative examples of the collection which must have numerous models and today unfortunately is limited to a few examples of metal manufactured ones that are not clearly declared in terms of manufacturers and date. The examples in Figure 1(a) and Figure 1(b) refer to models probably from the beginning of the twentieth century. In particular, in Figure 11(a) a metal model similar to that of Figure 10(b) is shown to represent the design and functionality of the hypoid wheels, also equipping the model with a crank for a practical exercise by the students of the time. Figure 11(b) shows an unusual design of geared wheels with a quadrangular section which was part of the same collection as the model in Figure 11(a) since showing the same metal manufacture. Figure 11(c) shows a slider-crank mechanism with a metal structure probably built in the 1930s at the laboratories of the same Politecnico di Milano.

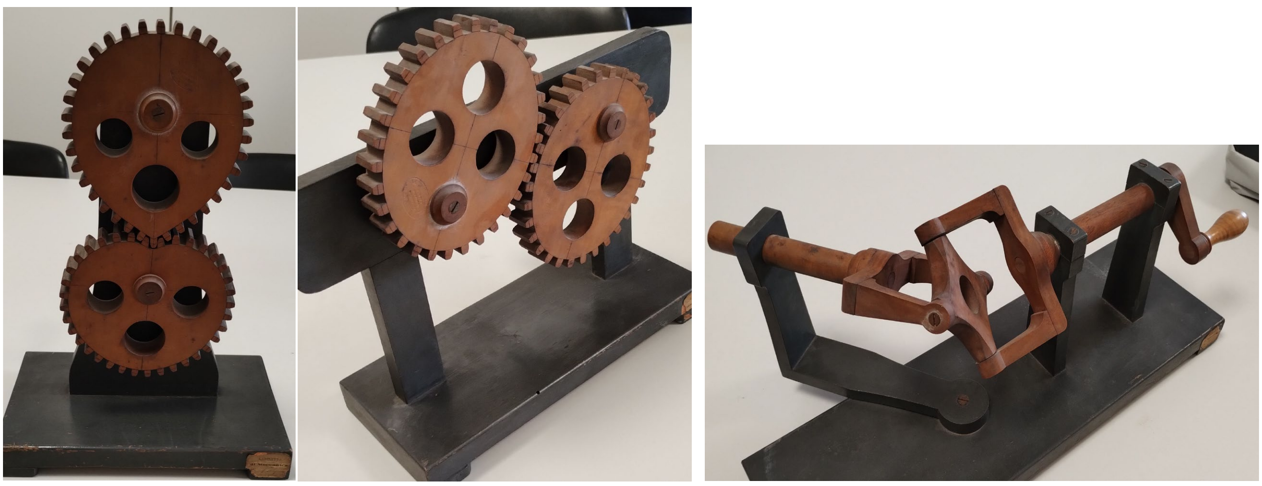
5.3. University of Padua

Of the rich collection of both wooden and metallic mechanism models at the University of Padua, only a very few remained, recently saved by a professor while the administration was definitively getting rid of them. Figure 12 illustrates some of these few wooden models which appear to be produced by Blotto, however without indication of the production date. This collection shows examples of mechanism models for the transmission of motion and one can appreciate the good preservation of the models with the characteristic configuration of the Blotto



(a) (b) (c)

Figure 11. Models from the collection of the Politecnico of Milan: (a) conceptual design of hypoid gear wheels; (b) a square gear transmission; (c) a slide-crank mechanism



(a) (b) (c)

Figure 12. Wooden Blotto models at the University of Padua. From left to right: (a) noncircular gears; (b) elliptical gears; (c) Cardan joint.

production with the transmission elements in light wood while the support is painted dark to highlight the transmission elements. The gear wheels, both elliptical and with different geometric shapes, are manufactured with lightening through holes, likewise they are generally produced in industrial applications, so that they are noteworthy and of high-quality manufacturing. The cardanic transmission is represented with its essential structure and equipped with a crank to allow direct experience of the mechanism. As in all Blotto productions, these specimens also have small dimensions with a very limited weight which ensures easy use both in laboratory environments and in temporary exhibitions during a classroom lecture. The quality of the woods used has ensured flawless preservation which still allows it to be used without problems today.

5.4. University of Bologna

At University of Bologna remains a collection of 34 mechanism models only from Blotto production since all of them show the Blotto stamp of **Figure 7** on the main wood elements. **Figure 13** shows several mechanical transmissions with belt and chain solutions for different configurations of the axes for relative movements with the same layout as proposed in Masi book (Masi, 1897) for classification. While the wheels are in the usual robust wood, the belt elements are made of simple manufacture with different materials such raw fabric for the planar belt, lever for the cable, and iron for the metallic chain, respectively, with the aim of also indicating different material options in the industrial applications of the time.

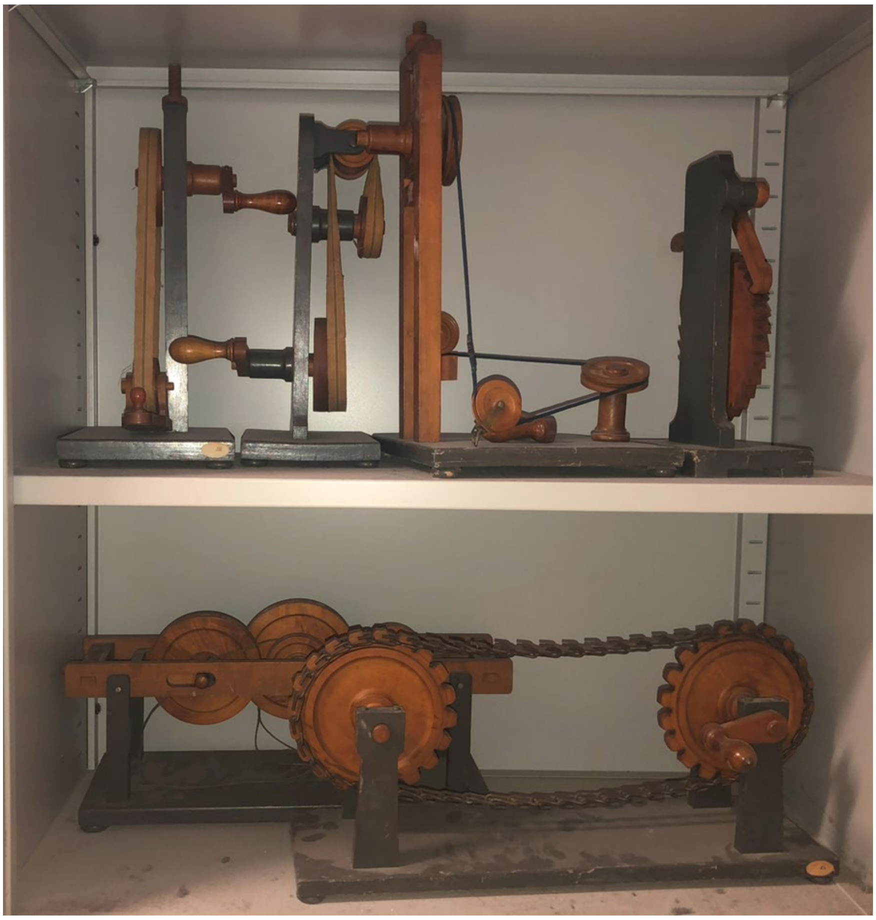
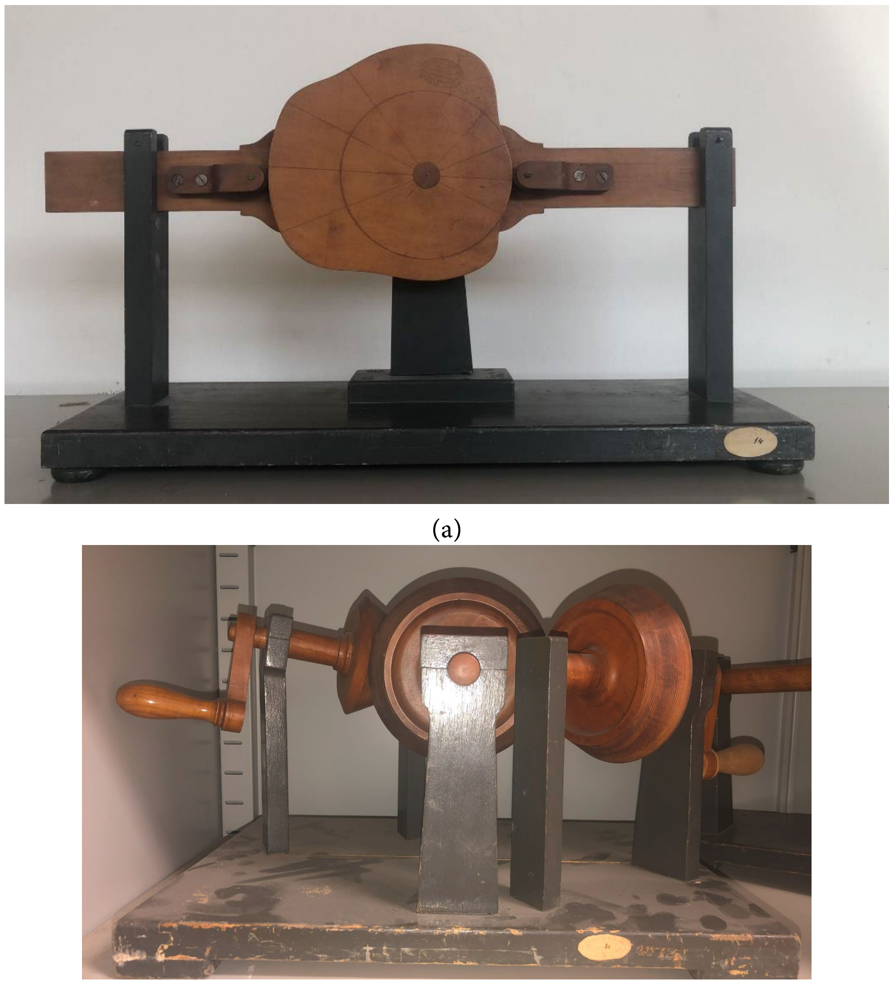


Figure 13. Models from the collection of Bologna University referring to belt and chain transmissions for different axis configurations according to the examples in (Masi, 1897).

Although the collection includes also gear models and gear train transmissions typical of the Blotto catalogue like the ones in **Figure 9(a)** and **Figure 12**, the examples in **Figure 13** refer to cam transmissions, **Figure 13(a)**, and bevel gears, **Figure 13(b)**. In **Figure 13(a)** a three-leaf-shaped cam moves the bar in an alternative way as referring to the basic concepts for the construction and functioning cam profiles as it is represented in most of textbooks and manuals for cam transmissions as the planar cam transmission. On the cam body there are the signs for the cam base circle and the lines for the cam output displacement indicating the rest angle ranges and the ramp angular arcs. On the back, there is a crank that the student uses to rotate the cam. The desmodromic connection with the bar allows to convert a continuous circular movement into an alternative rectilinear movement, as one of the basic configurations for motion transmission that is reported in the classifications of reference. The mechanism model with bevel friction wheels in Figure 13(b) shows a transmission among skew axes by using three believe friction gear wheels with a high-quality wood design whose functioning is still efficient in giving the possibility to give input motion in one of the extremity wheels.



(a)

(b)

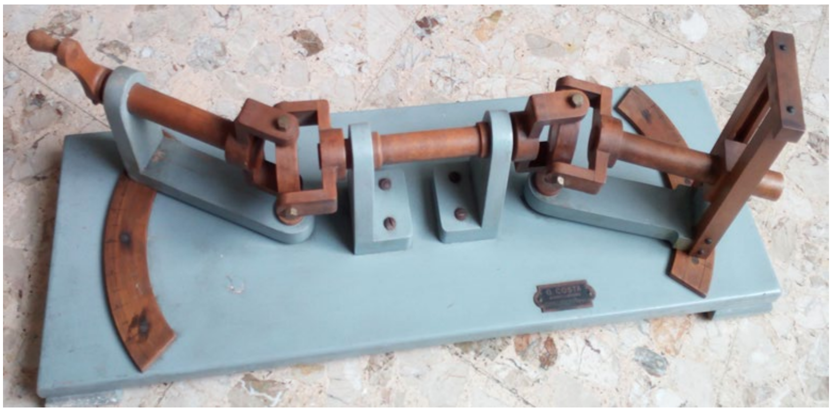
Figure 14. Wooden models of from the University of Bologna: (a) Blotto three-leaf shaped cam moving a bar alternatively; (b) bevel gear transmission

5.5. University of Pisa

The remained mechanism models preserved at the University of Pisa were by "G.

Costa - Grugliasco, Turin" as indicated in the small labels on each frame as in examples in Figure 15(a).

(a)



(b)

Figure 15. Wooden model made by G. Costa from the collection of the University of Pisa: (a) worm spur gear transmission; (b) axis transmission with Cardan joints.

The Costa manufacturer worked in Grugliasco, a small city near Turin, with a model production that looks very similar to Blotto (see both the wood robust essence for the main elements and the grey base frames) so that, although no information is available, it looks that they continued the activity of Blotto after 1912, still linked to Turin school of engineering but with a more independent product sales. It is interesting to note the similarity with the Blotto model, but with small design differences such as the use of screws instead of glue to fix the bases. Figure 15(a) shows a worm spur gear transmission with a very detailed manufacture of the gear profiles for a well assembled robust transmission. In Figure 15(b) a very interesting model for axle transmission is shown with two Cardan joints to connect two skew axes that can be eve rotated to get different configurations with different angles of deviation. The input is given only from one size with the usual crank provided of a handle for manual operation, even to give sensitivity of the transmission to as user.

5.6. University of Rome

Of the rich collection of mainly wooden models that were used at the University of Rome "La Sapienza" until the 1960s in combination with large posters in classroom lectures, unfortunately very few and poorly preserved remain. In this collection, many examples of Blotto production could be recognized, such as the one in Figure 16(a) together with many others that were produced over time on behalf of the teachers of mechanisms design. Figure 16(a) represents a typical wooden model of Blotto production without however having a dating due to the lack of archival data. The model for the gear transmission of straight toothed cogwheels is represented with the transmission elements made of light wood of robust essence with the coloured support of a dark grey which appears to be characteristic of the Blotto production. Figure 16(b) shows a model of the mechanism referring to a scaled-down fixed crane structure of approximately 50 cm in height with the mechanical transmission elements for moving the trolley on the load-bearing axle and the transmission elements for lifting weights with metal gear solutions. The model appears to be a validation model for experimental activities referring to a lightened fixed crane solution probably between the 1950s and 1960s, demonstrating that the mechanism models were produced and used not only for teaching activities but also for research and design.

(a)

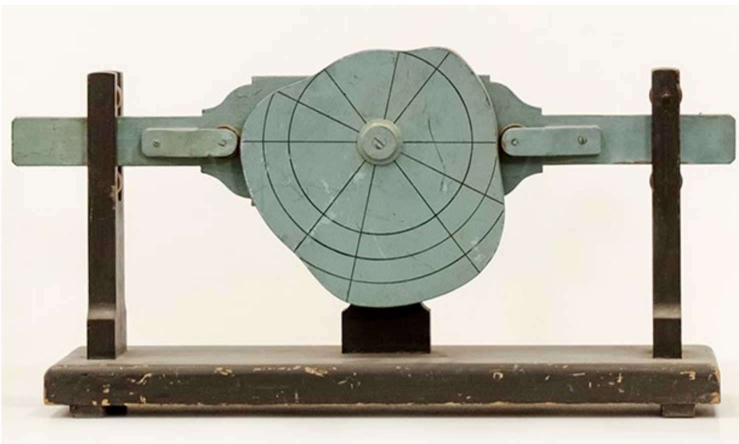
(b)

Figure 16. Models from the collection of the University of Rome: (a) Blotto wood cylindrical gear transmission; (b) a chain—base crane model.

5.7. University of Palermo

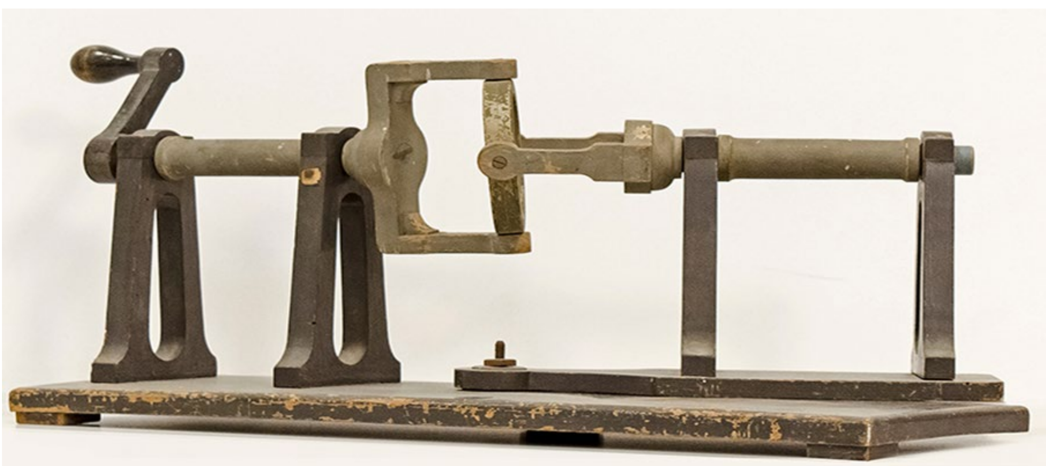
University of Palermo hosts the Historical Museum of Engines and Mechanisms (Genchi, 2024) with an important collection also of physical models for teaching that includes a considerable portion of mechanism models, which can be considered the most significant one. For the significance of its scientific-technical heritage value, the Museum received, first in Italy, the ASME landmark award that is a prestigious international award for Mechanical Engineering Heritage Collections from the American Society of Mechanical Engineers (ASME).

Among the several models available, **Figure 17(a)** shows a three-leaf-shaped cam that moves the bar in an alternative way that is like the same proposed for the University of Bologna as in **Figure 14(a)** demonstrating also the common usage of model of the same type but built by different producers. In fact, the models in Palermo does not look to have been purchased by Blotto, although the size and shape in several models show great similarities being very likely of the end of 19th century. The model in **Figure 17(b)** shows below the painting-coloured



(a)

(b)



(c)

Figure 17. Wooden models from the collection of the University of Palermo: (a) three-leaf shaped cam moving a bar alternatively; (b) racks against a geared wheel; (c) a Cardan joint.

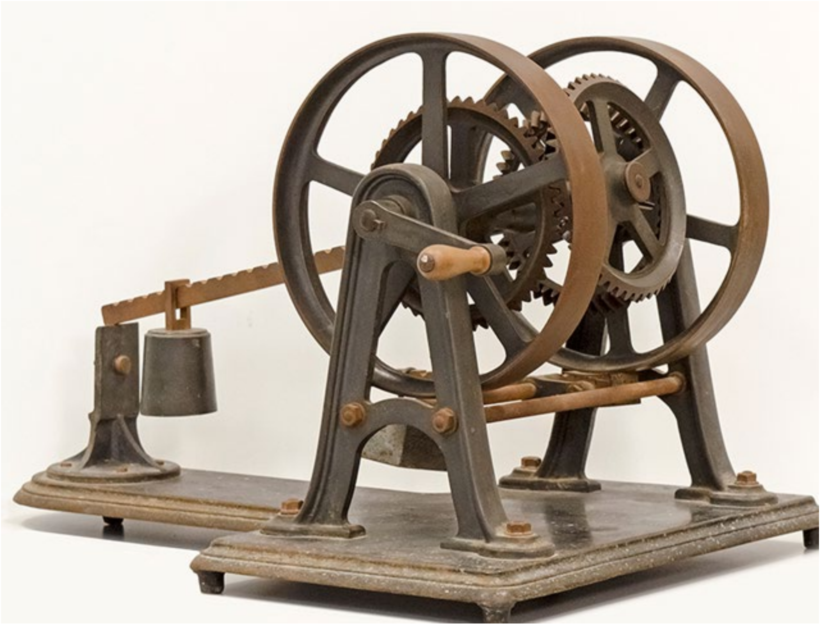
surface a wood essence that looks similar to the one used in Blotto models. This mechanism model shows the design and function of racks against a geared wheel with only wood elements.

Figure 17(c) shows a clear model for the cardan joint in a typical configuration, like the one in **Figure 12**, in which the output axis can be oriented at different angles by rotating its wood base frame. This can be understood either as a copy of the Blotto product or much more reasonably a common model coming by the textbooks of reference, such as (Masi, 1897) at the end of 19th century.

Figure 18 shows metal models from Schröder production indicating how the collections of mechanism models were usually integrated with different solutions by different producers.

(a)

(b)



(c)

Figure 18. Metallic models for teaching from the collection of the University of Palermo: (a) Watt mechanism; (b) articulated mechanism for regulation of internal combustion engine; (c) differential gearbox with variable load.

In **Figure 18(a)** it is shown the Watt mechanism similar to the Voigt one preserved in Turin, **Figure 10(a)** but with the link essential structure made of bronze bars to show the linkage design and functioning with emphasis to the coupler curve approximate straight lines of the bars that are constrained in prismatic joint on the frame. **Figure 10(b)** shows articulated mechanism for regulation of internal combustion engine with a double-effect piston. It is designed as a planar mechanism to clarify the kinematics. **Figure 10(c)** shows a differential gearbox with a symmetrical design showing the high-power possibility with variable weights in the output bar with a handle that gives the possibility to feel the motion and force transmission.

6. Conclusion

Wooden and metal model of mechanisms has been developed in the modern era together with teaching on the analysis and design of mechanisms with particular reference to the proposals for classification and cataloguing of mechanisms since the beginning of the 16th century in an Italian tradition well developed both with the start of engineering schools and with the work of classification and cataloguing of mechanisms by Italians such as Borgnis, Giulio, and Masi. This activity also determined an important teaching line for the training of engineers which is still persistent today. The production of mechanism models in Italy is characterized by two aspects, namely the creation of models based on local needs in local laboratories and the production of models corresponding to catalogues and classifications available from corporate entities also for sale to other educational institutions. The second category corresponds to the case of Giovanni Blotto who at the Turin school developed models of mechanisms that were spread throughout the Italian territory, first and then in competition with the more famous German manufacturer Voigt of educational models. Unfortunately, many of these models have been lost due to the modern teaching concept based on the use of computers which has diminished their usefulness even at the level of practical exercises. Recently, a new interest from a historical and technical point of view has seen these models of mechanisms being re-evaluated to the point of recognizing their museum value as well as considering their re-evaluation at an educational and training levels. The overview offered on what remains in many Italian locations allows us to clarify both the historical and technical-scientific values of these mechanism models, with the aim also of promoting greater attention and research into what could still be preserved in the archives and the warehouses of universities.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Table A1 lists the mechanism models that are proposed by Blotto in his catalogue. The first column shows the description of a mechanism as provided by Blotto, and the second and third columns list the corresponding enumeration in the first (Blotto, 1869) and second (Blotto, 1879) editions of the catalogue. The second edition differs from the first one by twenty new entries: some of them are completely new (e.g. the Oldham's coupling (82)), some other are a revised version of previous mechanisms (e.g. circular (10), heart (11), triangular (12) and variable (13) cams with ring and rotational shaft were originally proposed as a unique model (10) in the first edition of the catalogue). Sometimes there are few changes (e.g. "four wheels with live axles moving by belts" (32) in 2nd edition was "six wheels with live axles moving by belts" (25) in the 1st edition.

Table A1. List of mechanism models proposed by Blotto in the 1st (Blotto, 1869) and 2nd (Blotto, 1879) edition of the catalogue. The numbers refer to the enumeration in the catalogue.

Blotto Catalogue	1st Ed.	2nd Ed.
Eight different wedges with bars and support	1	1
Ten different cams with shafts, bars and moving device	2	2
Crank-handle moving a straight bar	3	3
Crank-handle moving a curved or circular bar	3	4
Cam with right and left Archimedes spirals with the same pitch and a moving device	4	5
Transformation from continuous to alternative circular motion	5	6
Circle involute cam lifting a pestle	7	7
Circle involute cam moving a bar alternatively	8	8
Three-leaf shaped cam moving a bar alternatively	9	9
Circular cam with ring and rotational shaft	10	10
Heart cam with ring and rotational shaft	10	11
Triangular cam with ring and rotational shaft	10	12
Variable cam with ring and rotational shaft	10	13
Cylindrical cam disc with bar	11	14
Conical cam disc with bar	12	15
Mechanism to draw fixed pitch propeller	13	16
Cylinder with helicoidal groove moving a bar	14	17
Cylinder with right and left helicoidal grooves moving a bar	16	18
Cylindrical screw with triangular thread moving a toothed bar	15	19
Rack wheel with pawl	6	20
Triangular-thread screw with lock nut	17	21

Continued

Squared-thread screw	18	22
Double squared-thread screw	18	23
Triangular-thread worm gear with driven wheel	–	24
Squared-thread worm gear with driven wheel	21	25
Fixed screw press and movable nut	19	26
Movable screw press and fixed nut	20	27
Cone with helicoidal groove and a bar	22	28
Cone rotating on its axis, linked to a variable-speed wheel sliding along its generatrix	26	29
Discs rotating on orthogonal axes, engaging with variable-speed	23	30
Inclined disc rotating along vertical axis, moving a bar	24	31
Four wheels with live axles, moving by belts	25 (six wheels…)	32
Pulley transmission with parallel axes and open or cross belt	–	33
Pulley transmission with variable angle axes	–	34
Pulley transmission with parallel axes by means of two idler-pulleys	41 (of one idler…)	35
Pulley transmission with any axes (neither parallel nor concurrent) by means of two idler-pulleys	–	36
Four pulleys with different shapes with shafts	37	37
Double pulley transmission	42	38
Cylinder transmission by a fixed rope	40	39
Truncated cone transmission by a fixed rope	39	40
Toothed pulley transmission by continuous chain	36	41
Pulley transmission with different teeth	–	42
Cone transmission by contact (crown wheel)	27	43
Truncated cone transmission by contact (crown wheel)	28	44
Cone and circular disc transmission by contact	29	45
Motion transmission between two axes by means of four truncated cones	30	46
Crown gears coupling	55	47
Hyperboloid transmission by contact	31	48
Hyperboloidal gears coupling	–	49
Hyperboloidal gears coupling (version 2)	–	50
Alternative motion mechanism driven by a gear	38	51
Eccentric plate wheel driven by a drum with orthogonal axis	35	52

Continued

Elliptical gears coupling (half teeth/half contact)	32 (full contact)	53
Elliptical gears coupling	33	54
Eccentric gears coupling	34	55
Heart gears coupling	–	56
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