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Keynote Lecture:

Evolution of TMM (Theory of Machines and Mechanisms) to MMS (Machine and Mechanism Science): An Illustration Survey

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Abstract – In this lecture paper the main past works on TMM are reviewed through an illustration survey by giving information on the main technical achievements and even brief notes on the personality of the authors. The historical overview is started from early works at the Ecole Polytechnique in Paris that was established in 1794, which can be considered a fundamental date for modern TMM. Main works in XIX-th century are reviewed to identify the Golden Age of the Theory of Mechanisms. Continuous evolution and success of the field brought during the Industrial Revolution Mechanism Design to be recognized as a fundamental engineering discipline also in the XX-th century. Another important period can be identified in the 1960's when TMM evolved further and finally in 1990's it has been assumed the character of an Engineering Science, named as MMS. The significance of MMS (TMM) in modern Technology is stated also by the teaching of TMM in Mechanical Engineering curricula all around the world. The international community has been identified in 1969 with the foundation of IFToMM (The International Federation of TMM) that has been renamed as IFToMM, the International Federation for the Promotion of MMS in 2000.

Keywords: TMM**,** History of Mechanisms, Past people, Past Works, History of IFToMM, History of MMS.

Introduction

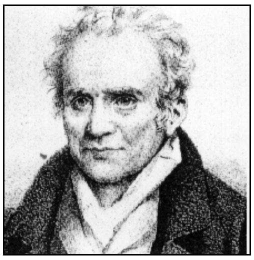
The identity of a person or even a Community can be indicated by a name giving a synthetic description of personality and main capability or characteristics.
The names of IFToMM, TMM (Theory of Machines and Mechanisms), and MMS (Machine and Mechanism Science) identify IFToMM Community. The names of IFToMM, TMM, and MMS are related to fields of Mechanical Engineering concerning with Mechanisms in broad sense.
TMM (Theory of Machines and Mechanisms) is often misunderstood even in the IFToMM Community, although it is recognized as the specific discipline of Mechanical Engineering related with mechanisms and machines. The meaning of TMM can be clarified by looking at the meaning of the topic over time through few definitions by significant Authors as in the following short list:
by Marco Pollione Vitruvius (he lived in 1st century B.C.) in De Architectura- liber X, translated and discussed by Fra Giocondo in (1151): "A machine is a combination of materials and components that have the capability of moving weights";
by Galileo Galilei in (1593): "A machine is a means by which a given weight will be transported to a given location by using a given force";
by Jacob Leupold in (1724): He treated the description of machines and mechanisms referring to "their aim of modifying motion rather than just the construction of machinery";
by Josè Maria de Lanz and Augustin de Betancourt in (1808): "In agreement with Mr. Monge, we consider as elements of machines the devices than can change the direction of the movements… the most complicated machines are only combinations of those capable of single movements";
by Robert Willis in (1841): "I have employed the term Mechanisms as applying to combinations of machinery solely when considered as governing the relations of motion. Machinery as modifier of force";
by Franz Reuleaux in (1875): "A machine is a combination of bodies capable of withstanding deformation, so arranged as to constrain the (mechanical) forces of nature to produce prescribed effect in response to prescribed input motions".
by Francesco Masi in (1897): "Hence we name: as mechanism a kinematic chain that has been fixed on one of its components; as machine a mechanism whose components make mechanical work";
by Richard S. Hartenberg and Jacques Denavit in (1964): "The term machine is associated with the use and transformation of force, and although motion is varying degree is encountered in a machine, the idea of force dominates. Mechanism, on the other hand, definitely conjures up the idea of motion, and while forces do exist, they are relatively small and unimportant compared with the exploitation of motion".
In addition, IFToMM terminology (IFToMM 1991) gives:
- Machine: mechanical system that performs a specific task, such as the forming of material, and the transference and transformation of motion and force.
- Mechanism: system of bodies designed to convert motions of, and forces on, one or several bodies into constrained motions of, and forces on, other bodies.
The meaning for word "Theory" needs further explanation. The Greek word for Theory comes from the corresponding verb, whose main semantic meaning is related both with examination and observation of existing phenomena. But, even the Classic language the word theory includes practical aspects of observation as experiencing the reality of the phenomena, so that theory

means also practice of analysis results. In fact, this last meaning aspect is what was included in the discipline of modern TMM as Gaspard Monge (1746-1818) established it in the Ecole Polytechnique, (Chasles 1886), at the beginning of XIXth century (see for example the book by Lanz and Betancourt (1808), whose text include early synthesis procedures).
In conclusion since the modern assessment, TMM has been considered as a discipline, which treats analysis, design and practice of mechanisms and machines. This will be also in the future, since we shall always have mechanical devices related with life and working of human beings. These mechanical devices need to be designed and enhanced with approaches from mechanical engineering because of the mechanical reality of the environment where the human beings will always live, although new technology will substitute some components or facilitate the operation of mechanical devices.
The term MMS has been adopted within the IFToMM Community since the year 2000 (IFToMM Constitution 2000) after a long discussion (see (Ceccarelli 1999) in the IFToMM Bulletin), with the aim to give a better identification of the enlarged technical content and broader view of Mechanism knowledge and practice.
Indeed, the use of the term MMS has also stimulated an in-depth revision in the IFToMM terminology so that in a current proposal one can find the definition of MMS as (IFToMM PC for Terminology 2002):
- Mechanism and Machine Science: Branch of science, which deals with the theory and practice of the geometry, motion, dynamics, and control of machines, mechanisms, and elements and systems thereof, together with their application in industry and other contexts, e.g. in Biomechanics and the environment. Related processes, such as the conversion and transfer of energy and information, also pertain to this field.
The evolution of the name from TMM to MMS, that has brought also a change in the denomination of the IFToMM Federation from "IFToMM International Federation of TMM" to "IFToMM, the International Federation for the Promotion of MMS", can be considered as due both to an enlargement of technical fields to an Engineering Science but even to a great success in research and practice of TMM.
In this lecture paper, an overview is attempted to outline the evolution of TMM to MMS with a particular attention to the activity of the IFToMM Community.
Historical overviews of the fields of TMM and MMS have been proposed since the beginning of TMM and over the time, and even nowadays as specific papers like for example (Koetsier 2000) or preliminary chapters in textbooks and research reviews on Mechanisms like for example (Erdman A.G. Ed. 1993). Many other authors have attached the problem of outlining the History of MMS at different level of content, in the past as for example Chasles (1837) and Reuleaux (1875), and recently as for example De Jonge (1943), Hartenberg and Denavit (1956 and 1964), Ferguson (1962), Hain (1967), Nolle (1974), Crossley (1988), Dimarogonas (1993), Marchis (1994), Angeles (1997), Roth (2000) Ceccarelli (1998 and 2001). Indeed, very rich reference lists can be found also in some historical overviews, as for example in (Hain 1967), (Nolle 1974), (Marchis 1994).
This lecture paper has a complementary view since it is addressed to the IFToMM Community and his future activity as guided from past experience and history.

The Beginning of TMM

Mechanisms and Machines have addressed attention since the beginning of Engineering Technology and they have been studied and designed with successful activity and specific results. But TMM have reached a maturity as independent discipline only in XIXth century.
It is usually said that TMM activity has been started with the foundation of the Ecole Polytechnique in Paris (Fig.1a) in 1794, at which the formation of industrial engineers was a specific goal with a specific teaching. The need for a Technical University was required by a need of properly educated engineers for the developing Industrial Revolution. Thus, the previous curricula at Universities or at Military Schools were not considered satisfactorily oriented to form engineers for growing industrial environments. This new teaching vision was felt at different level but everywhere in the world as documented in many acts of Universities, like for example in Brazil as outlined in (Oliveira 1999).
Indeed this need of formation of engineers for civil activity was felt since the early Renaissance, when those design experts were formed at the "bottega" of a "mastro", as explained for example in (Ceccarelli 1998). But even then, there were attempt to establish school environments, like for example in Spain where the King Chief Engineer Juan de Herrera proposed and Academy for engineers at the end of XVI-th century, (Vicente 2000)).
However, J.M. Lanz and A. Betancourt in the milestone work (1808), Fig.2, which was developed also under the supervision of Hachette, collected the ideas of Monge on mechanisms. In (1811) Hachette published his own work, Fig.3, which is directed mainly to teaching class on Mechanisms. Those two works were the first modern successful attempts for mechanism classification and mechanism analysis.

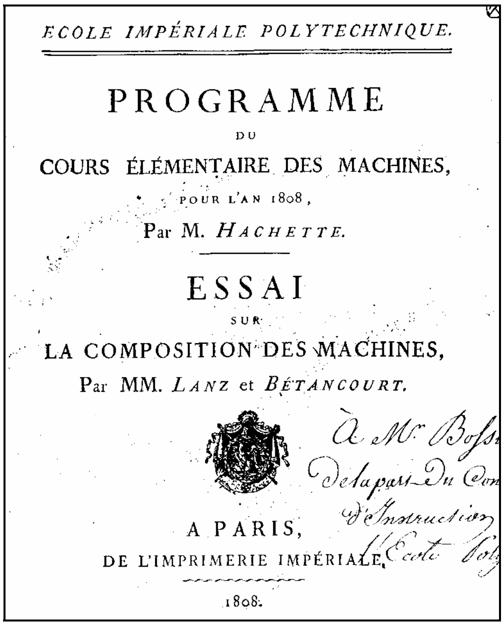
a)



b)

c)

Fig.1: The beginning of TMM with foundation of Ecole Polytechnique in 1794: a) the building today; b) Gaspard Monge (1746-1818); c) Jean Nicolas Pierre Hachette (1769-1834).



ECOLE IMPÉRIALE POLYTECHNIQUE.

PROGRAMME

DU

COURS ÉLÉMENTAIRE DES MACHINES,

POUR L'AN 1808,

Par M. HACHETTE.

ESSAI

SUR

LA COMPOSITION DES MACHINES,

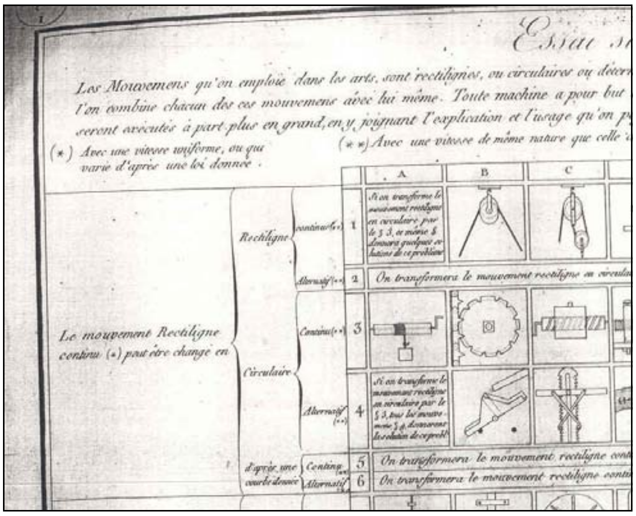
Par MM. LANZ et BÉTANCOURT.

A PARIS,

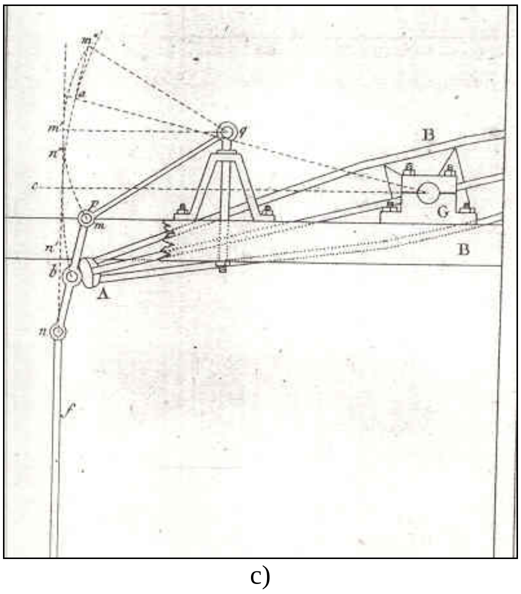
DE L'IMPRIMERIE IMPÉRIALE.

1808.

a)



b)



c)

Fig.2: The "Essai sur la composition des machines" by Josè Maria Lanz and Agustin Betancourt in 1808: a) title page; b) classification of mechanisms; c) an analyzed mechanism with design purposes.

TRAITÉ ÉLÉMENTAIRE

DES MACHINES,

PAR M. HACHETTE,

INSTITUTEUR DE L'ÉCOLE IMPÉRIALE POLYTECHNIQUE.

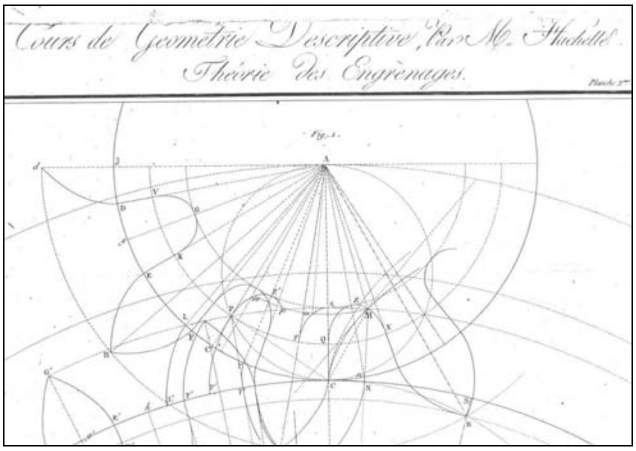
PARIS,

J. KLOSTERMANN fils, libraire de l'École Impériale Polytechnique, rue du Jardinet, n°. 13, quartier St.-André-des-Arts;

SAINT-PÉTERSBOURG,

KLOSTERMANN père et fils, libraires.

a)



b)

Fig.3: The "Traitè elementaire des machines" by J.N.P. Hachette in 1811: a) title page; b) a study of gear for mathematical formulation.

Figure 2b) shows the table of Monge mechanism classification as function of motion types; Fig. 2c) and 3b) show examples of first kinematic models for analysis of mechanisms and gears.

The successful beginning of TMM at the Ecole Polytechnique was achieved with the work of many others, who were inspired by Monge's activity. Among the many, relevant is the work in 9 volumes published in (1818-21) as an a technical Encyclopaedia of mechanisms and machines by G.A. Borgnis, who was pupil at the Ecole and then professor in Pavia (Italy). Many Ecole pupils started a successful activity around the world, and first modern TMM engineers can be considered J.M. Lanz and A. Betancourt yet, who were scientists, engineers, and managers as outlined in (Lopez-Cajun et al. 2003).

TMM has found its independent position within Engineering Science, when Gaspard Monge (1746- 1818, Fig.1b), proposed to teach specific classes on Mechanisms, although within the course on Descriptive Geometry. This proposal was submitted since the beginning of the Ecole Polytechnique, but the teaching could start only in 1806 by Jean Nicolas Pierre Hachette

(1769-1834), Fig.1.c), since Monge was participating at Napoleon’s trip to Egypt as expert both in engineering and civilizations. Hachette was pupil and strict collaborator of Monge. In fact, he was the successor of Monge and made reality the Monge's plans in the Theory of Mechanisms but with additional relevant personal views and contributions.

The Golden Age of TMM

The maturity of TMM can be recognized when the teaching of TMM has been recognized as fundamental in the Engineering Academic curricula. We can fix the start of the Golden Age for TMM in the year 1831, when TMM discipline was considered as fundamental also at Sorbonne University in Paris. Just after, many other Universities in Europe have started courses on TMM, that were named on Kinematics (word coined by Ampere in (1834)), as regular fundamental courses. At the same time, professional skill on Mechanism Design has enhanced machinery and industrial process over the XIXth century during the Industrial Revolution.

Thus, the successful activity increase was carried out at Universities both in teaching and research on TMM. The first approach by Monge was enlarged and criticized but was the inspiration to deepen Mechanism Analysis and Design through a mathematization that gave mainly graphical procedures and first analytical algorithms.

After Monge’s classification there were several attempts to have a unified view of mechanisms. Those mechanism classifications were proposed with a descriptive approach, like in (Giulio 1846); with an enlarged analysis of mechanism connections, like in (Willis 1841), Fig.5; by using the kinematic chain concept, like in (Reuleaux 1875), Fig.6; and even with practical view and formulation, like in (Masi 1883).


c)

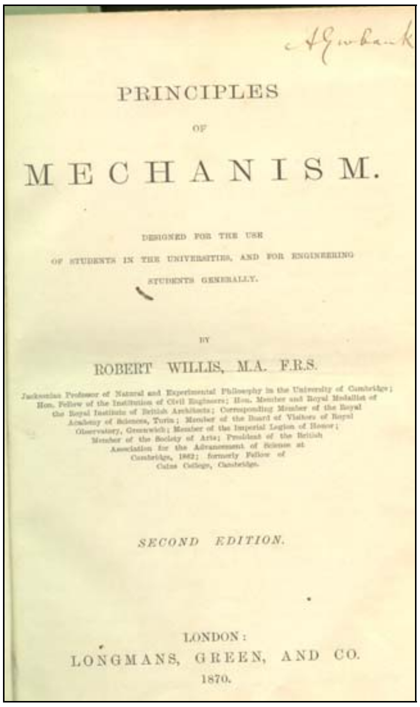

b)


c)


d)

Fig.4: Portrait of: a) Robert Willis (1800-1875); b) Franz Reuleaux (1829-1905); c) Pafnutii Livovich Chebyshev (1821-1894); d) Francesco Masi (1852-1944).

The analysis of mechanism was mathematized with suitable formulation even through closed-form expressions by using suitable kinetic models, like in (Chebyshev 1899), Fig.7. The above-mentioned personalities are shown in Fig.4 with the aim to recognize those who contributed considerably to the development and evolution of TMM during its Golden Age. But their activity are the relevant expression of the activity of a multitude of pupils, investigators, and professionals who have stimulated, used and enhanced TMM as a fundamental means of knowledge in Engineering fields.


PRINCIPLES

OF

MECHANISM.

DESIGNED FOR THE USE
OF STUDENTS IN THE UNIVERSITIES, AND FOR ENGINEERING
STUDENTS GENERALLY.

BY

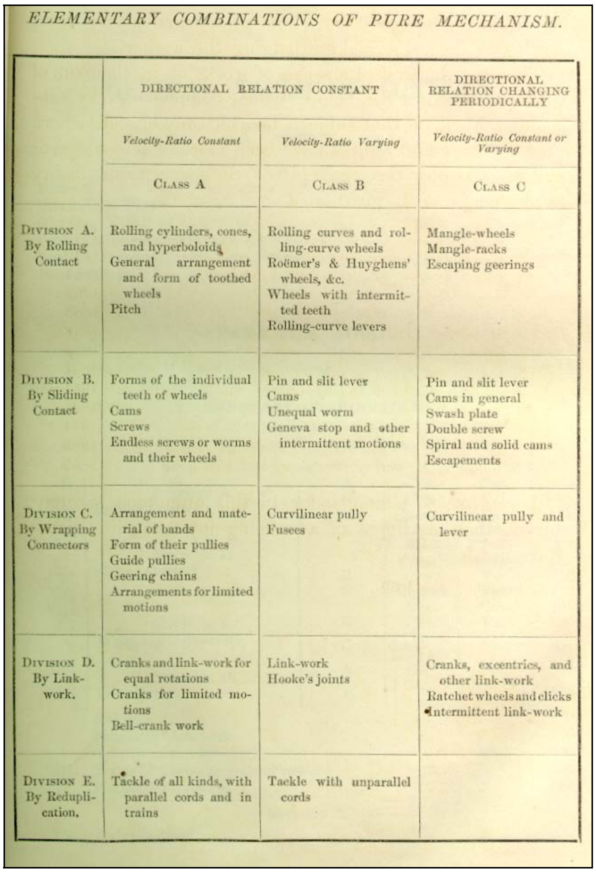
ROBERT WILLIS, M.A. F.R.S.

Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge; Hon. Fellow of the Institution of Civil Engineers; Hon. Member and Royal Medallist of the Royal Institute of British Architects; Corresponding Member of the Royal Academy of Sciences, Turin; Member of the Board of Visitors of Royal Observatory, Greenwich; Member of the Imperial Legion of Honor; Member of the Society of Arts; President of the British Association for the Advancement of Science at Cambridge, 1862; formerly Fellow of Caius College, Cambridge.

SECOND EDITION.

LONDON:
LONGMANS, GREEN, AND CO.
1870.

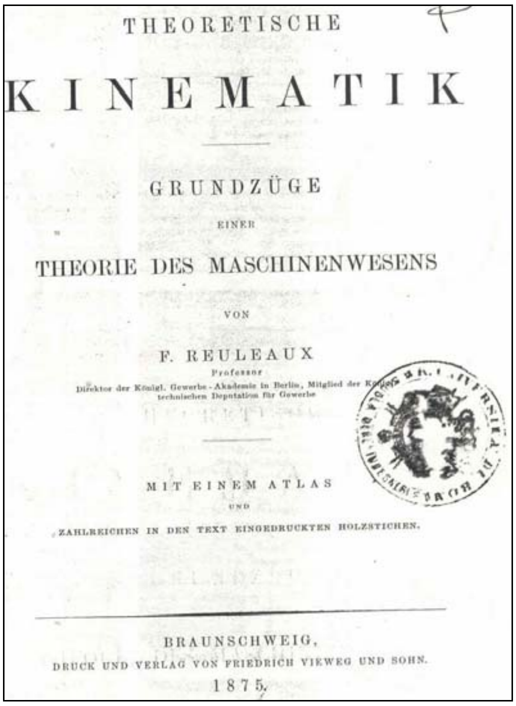
a)


ELEMENTARY COMBINATIONS OF PURE MECHANISM.

	DIRECTIONAL RELATION CONSTANT		DIRECTIONAL RELATION CHANGING PERIODICALLY
	Velocity-Ratio Constant	*Velocity-Ratio Varying*	*Velocity-Ratio Constant or Varying*
	CLASS A	CLASS B	CLASS C
DIVISION A. By Rolling Contact	Rolling cylinders, cones, and hyperboloids General arrangement and form of toothed wheels Pitch	Rolling curves and rolling-curve wheels Roëmer's & Huyghens' wheels, &c. Wheels with intermitted teeth Rolling-curve levers	Mangle-wheels Mangle-racks Escaping geerings
DIVISION B. By Sliding Contact	Forms of the individual teeth of wheels Cams Screws Endless screws or worms and their wheels	Pin and slit lever Cams Unequal worm Geneva stop and other intermittent motions	Pin and slit lever Cams in general Swash plate Double screw Spiral and solid cams Escapements
DIVISION C. By Wrapping Connectors	Arrangement and material of bands Form of their pullies Guide pullies Geering chains Arrangements for limited motions	Curvilinear pully Fusees	Curvilinear pully and lever
DIVISION D. By Link-work.	Cranks and link-work for equal rotations Cranks for limited motions Bell-crank work	Link-work Hooke's joints	Cranks, excentrics, and other link-work Ratchet wheels and clicks Intermittent link-work
DIVISION E. By Reduplication.	Tackle of all kinds, with parallel cords and in trains	Tackle with unparallel cords	

b)

Fig.5: The “Principles of Mechanism” by R. Willis in 1841: a) title page; b) classification of mechanisms.



THEORETISCHE

KINEMATIK

GRUNDZÜGE

EINER

THEORIE DES MASCHINENWESENS

VON

F. REULEAUX

Professor

Direktor der Königl. Gewerbe-Akademie in Berlin, Mitglied der Königl. technischen Deputation für Gewerbe

MIT EINEM ATLAS

UND

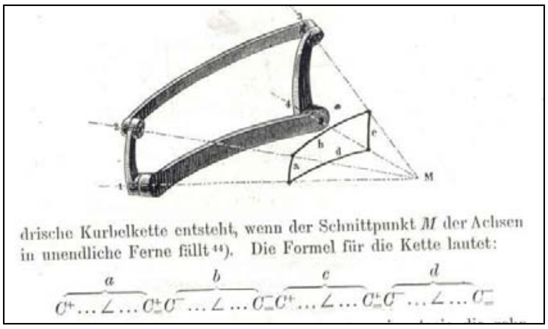
ZAHLREICHEN IN DEN TEXT EINGEDRUCKTEN HOLZSTICHEN.

BRAUNSCHWEIG,

DRUCK UND VERLAG VON FRIEDRICH VIEWEG UND SOHN.

1875.

a)



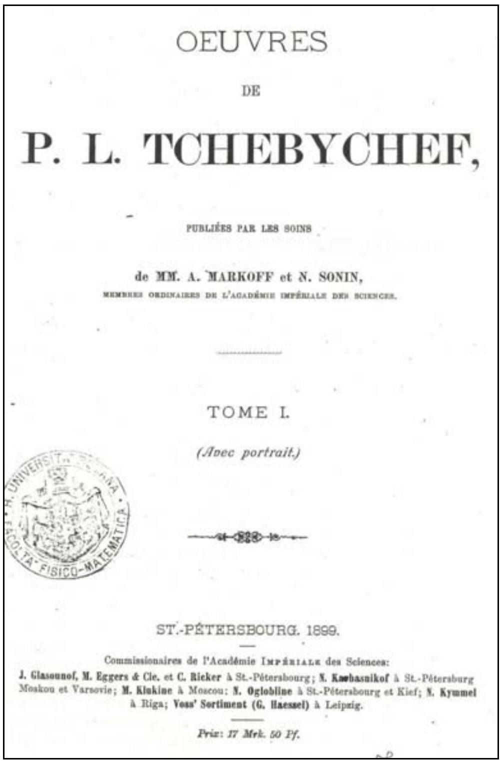
b)

Fig.6: The “Theoretische Kinematik” by F. Reuleaux in 1875: a) title page; b) notation for mechanism classification as based on connections types.

In particular, the analytical approach of Chebyshev can be considered as fundamental in the modern mathematization process of mechanism analysis and design not only from historical viewpoint but still yet from practical engineering viewpoint for development of algorithms for design purposes.

Discovering and formulating basic kinematic and dynamic properties for practical procedures enhanced the analysis of mechanisms. Significant is the analysis of velocity and acceleration of mechanisms through the application of the relative motion in the form of vector sum, as shown in Fig.8. This analysis was well established at the end of the XIX-th century and it has been so widely applied that it is still a successful taught in courses on MMS.

In addition, the growing knowledge on mechanisms and their variety has stimulated an intense teaching activity, which produced different views and approaches in several textbooks. Those books, sometimes forgotten today, can be considered still of current interest not only for the discussions on kinematical and dynamical concepts, like for example (Burmester 1888), but even for the proposed formulation applied in practical analysis and design algorithms, like for example (Allievi 1895) referring to Burmester’s work.



OEUVRES

DE

P. L. TCHEBYCHEF,

PUBLIÉES PAR LES SOINS

de MM. A. MARKOFF et N. SONIN,

MEMBRES ORDINAIRES DE L'ACADÉMIE IMPÉRIALE DES SCIENCES.

TOME I.

(Avec portrait.)

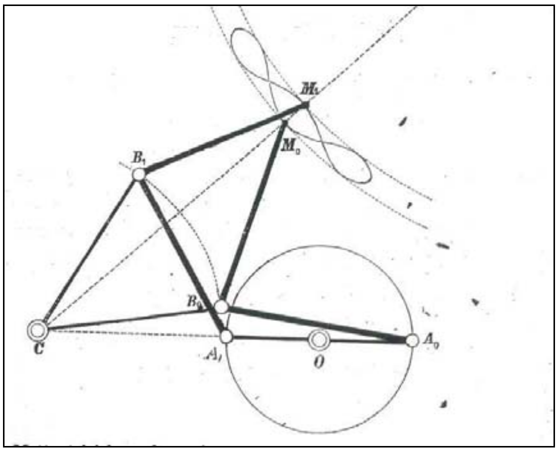
ST.-PÉTERSBOURG. 1899.

Commissionnaires de l'Académie Impériale des Sciences:

J. Glasounof, M. Eggers & Cie. et C. Ricker à St.-Pétersbourg; N. Kymmel à Riga; Voss' Sortiment (G. Haessel) à Leipzig.

Prix: 17 Mrk. 50 Pf.

a)



b)

Fig.7: The mathematization of mechanism analysis by Chebyshev in (1899): a) title page of paper collection; b) an example of graphical representation for mathematical formulation.

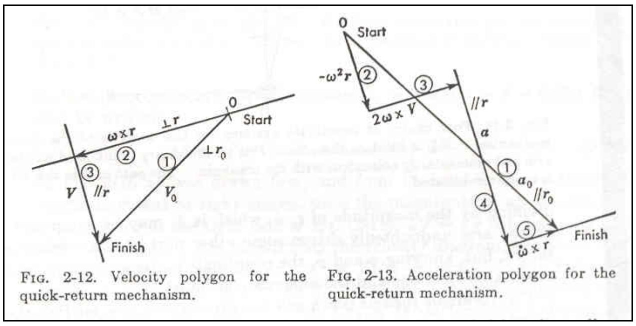
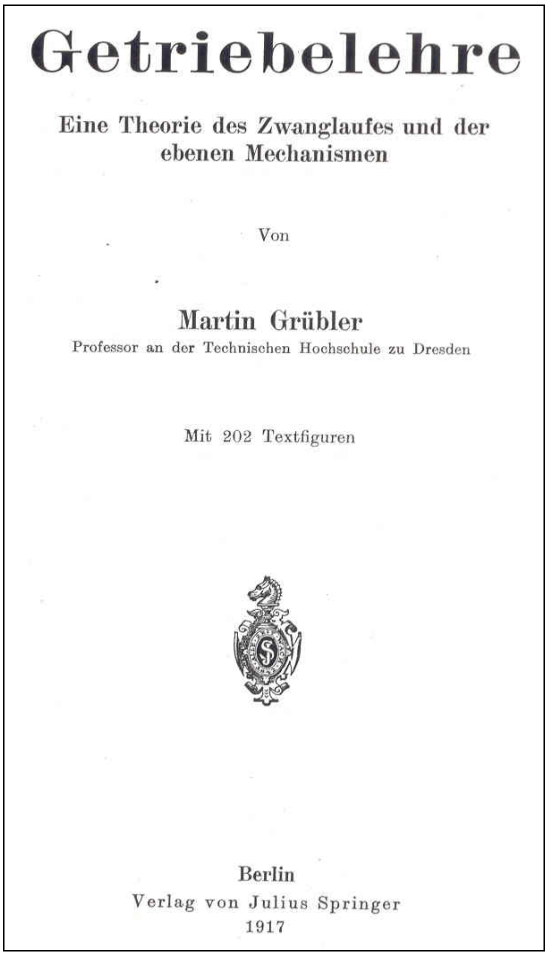


Fig.8: An example of the velocity and acceleration analysis for graphical and numerical evaluation developed at the end of XIX-th century as presented in (Beggs1955).

Thus, the Golden Age of TMM can be considered in the second half of the XIX-th century when intense activity in

teaching, research and practice on TMM was well established by giving as main results enhancements in machinery and automation in industrial processes.
At the beginning of the XXth century TMM has been further assessed with great design activity and for example the works by Bricard (1926), and Grubler (1917), can be considered of modern significance.
Mechanism designs achieved high complexity, never seen before, and they required further enhancements of analysis procedures, mainly for modeling and numerical aspects, as shown for example in Fig.9b). At the same time 3D motion was attached not only from pure academic interest and was studied also to give first practical procedures, as in the example of Fig.10b).


Getriebelehre

Eine Theorie des Zwanglaufes und der ebenen Mechanismen

Von

Martin Grübler

Professor an der Technischen Hochschule zu Dresden

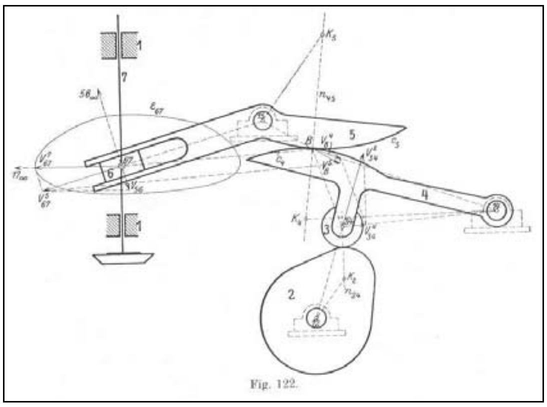
Mit 202 Textfiguren

Berlin

Verlag von Julius Springer

1917

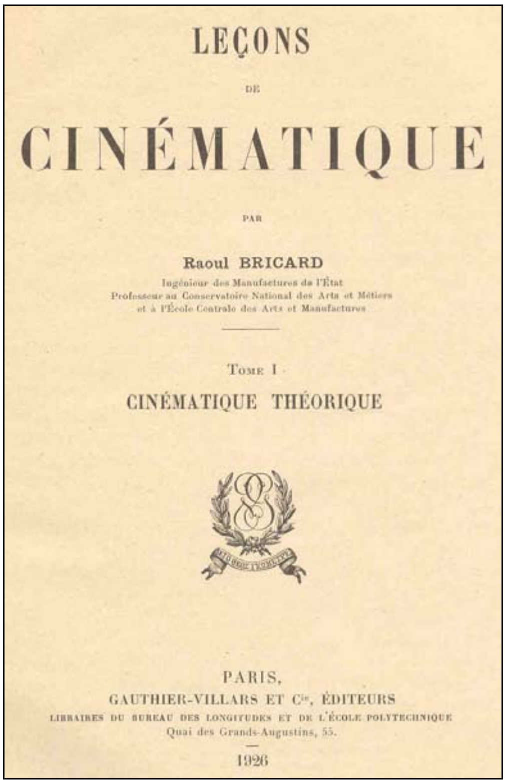
a)



b)

Fig.9: The “Getriebelehre” by Martin Grubler in 1917: a) title page; b) a study of a multibody mechanism.

Then, between the two World Wars it seems that almost nothing was done since very few publications are available. But one can consider the war secrecy that did not permit circulation of results. However, the acquired knowledge and expertise was a stimulus for a renewed interest on TMM since the 1950’s.
After a certain decrease of success, the mechanism science has got renewed interest starting from the late 1950’s with the works by Rossenaur and Willis (1953), Hartenberg and Denavit (1964), Hall jr (1961), and Hain (1967), only to cite some.
The increased needs of industrial applications stimulated re-consideration of TMM with a modern view that is directed mainly to more efficient numerical calculations, yet on graphical basis, for optimized solutions. Thus, even new kinematic properties were re-discovered and newly formulated, like for the illustrative case of Fig.11. New approaches were attempted as the successful case of matrix representation of mechanisms in Fig.12. In this period a great success of TMM can be recognized as due to demands of Industry for machinery and automatic systems with higher and higher speed and efficiency.


LEÇONS

DE

CINÉMATIQUE

PAR

Raoul BRICARD

Ingénieur des Manufactures de l'État
Professeur au Conservatoire National des Arts et Métiers
et à l'École Centrale des Arts et Manufactures

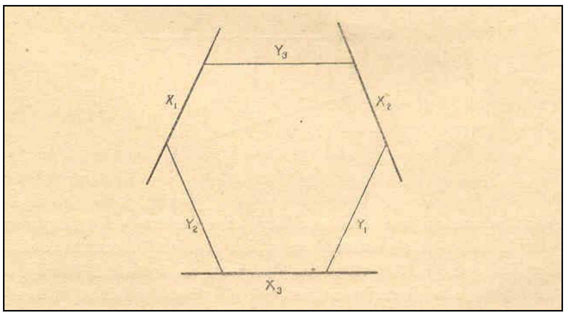
Tome I

CINÉMATIQUE THÉORIQUE

PARIS,
GAUTHIER-VILLARS ET C^ie, ÉDITEURS
LIBRAIRES DU BUREAU DES LONGITUDES ET DE L'ÉCOLE POLYTECHNIQUE
Quai des Grands-Augustins, 55.

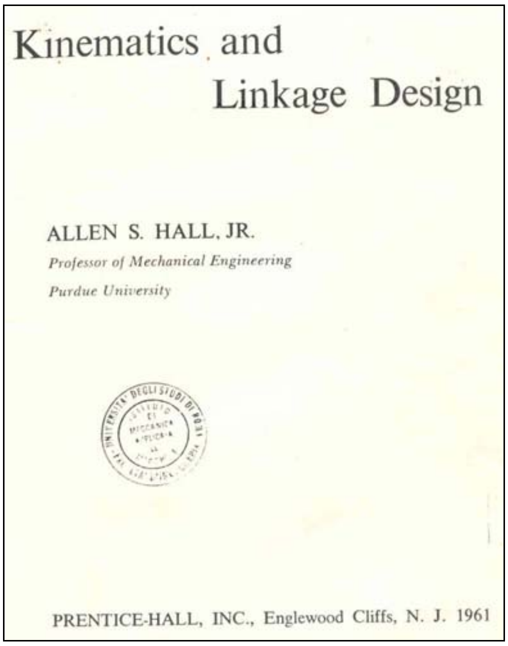
1926

a)



b)

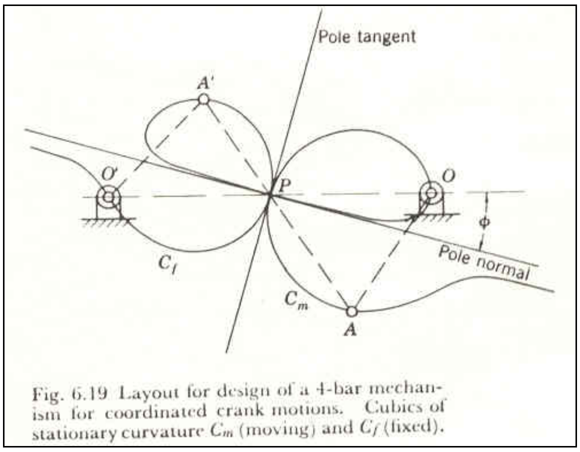
Fig.10: The “Lecons de Cinematique" by Raoul Bricard in 1926: a) title page; b) a screw triangle scheme for the analysis of screw motion.


Kinematics and
Linkage Design

ALLEN S. HALL, JR.
Professor of Mechanical Engineering
Purdue University

PRENTICE-HALL, INC., Englewood Cliffs, N. J. 1961

a)



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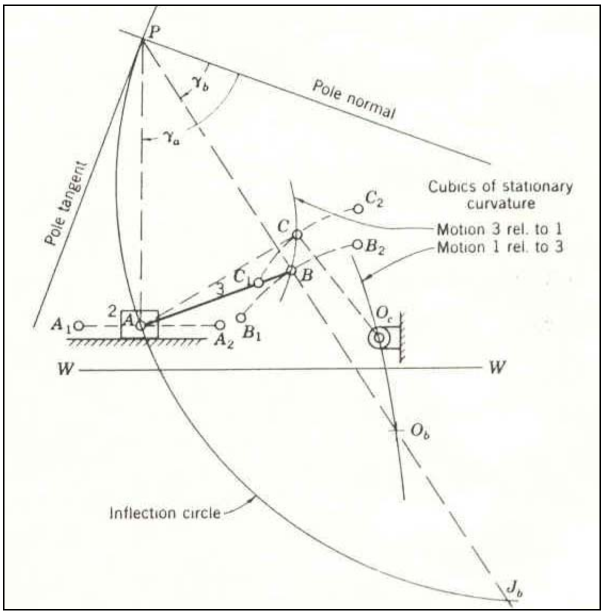
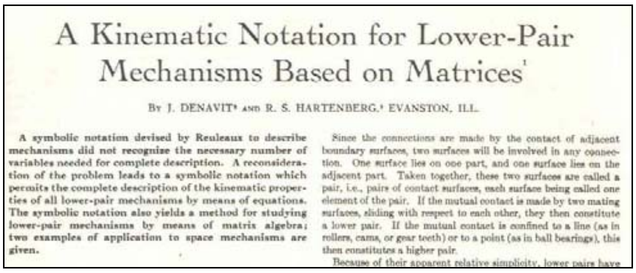


c)

Fig.11: The “Kinematics and Linkage Design” by Allen S. Hall in 1961: a) title page; b) the cubic of stationary curvature; c) a design scheme based on the cubic of stationary curvature.


A Kinematic Notation for Lower-Pair Mechanisms Based on Matrices[1]

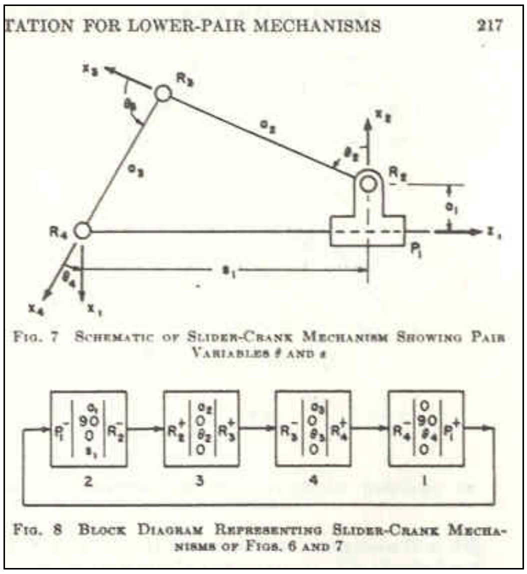
By J. DENAVIT[2] and R. S. HARTENBERG,[2] EVANSTON, ILL.

A symbolic notation devised by Reuleaux to describe mechanisms did not recognize the necessary number of variables needed for complete description. A reconsideration of the problem leads to a symbolic notation which permits the complete description of the kinematic properties of all lower-pair mechanisms by means of equations. The symbolic notation also yields a method for studying lower-pair mechanisms by means of matrix algebra; two examples of application to space mechanisms are given.

Since the connections are made by the contact of adjacent boundary surfaces, two surfaces will be involved in any connection. One surface lies on one part, and one surface lies on the adjacent part. Taken together, these two surfaces are called a pair, i.e., pairs of contact surfaces, each surface being called one element of the pair. If the mutual contact is made by two mating surfaces, sliding with respect to each other, they then constitute a lower pair. If the mutual contact is confined to a line (as in rollers, cams, or gear teeth) or to a point (as in ball bearings), this then constitutes a higher pair.

Because of their apparent relative simplicity, lower pairs have

a)



b)

Fig.12: The matrix representation of mechanisms as proposed by J. Denavit and R.S. Hartenberg in (1955): a) title and abstract of the paper; b) example.

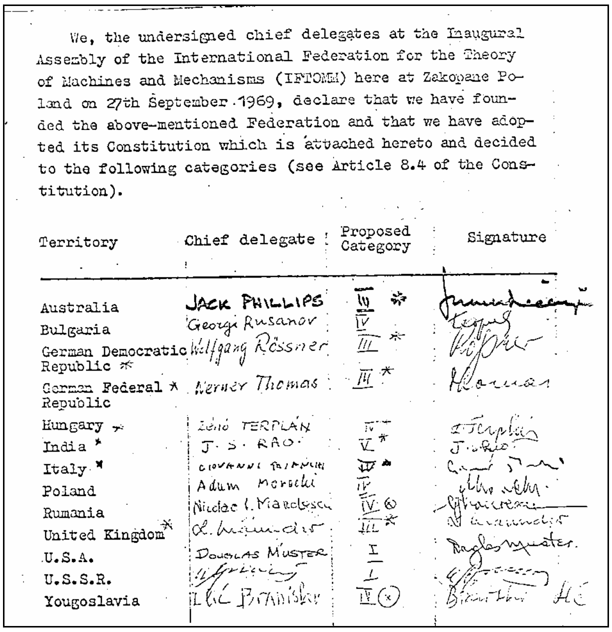
Modern TMM towards the Foundation of IFToMM

We can consider the period of modern TMM as starting with the study of three dimensional motions and mechanisms for practical applications, just after the first World War. Modern TMM has approached the multi-dofs motions and 3D mechanisms. These subjects have requested further enhancement of knowledge and use of new means for developing and operating new solutions. The developments for industrial machinery have stimulated cooperation all around the world at any level. One of the most relevant results has been the foundation of IFToMM in 1969, Figs.13 and 14.

IFToMM was founded as a Federation but as based on the activity of individuals within a family frame with the aim to facilitate co-operation and exchange of opinions and research results in all the fields of TMM. Many individuals have contributed and still contribute to the success of IFToMM and related activity, (see IFToMM webpage 2002) under the vision coordination of IFToMM Presidents, Fig.15.

The modernity and relevance of IFToMM activity can be recognized in the common frame of views and results on TMM, although in many different technical fields.

A fundamental historical event can be advised in the paper (Freudenstein and Sandor 1959) in which for the first time results of mechanism design were obtained by computer calculations that gave the possibility of very precise computations, as shown in Fig.16. This event can be also considered a first act in the evolution of TMM to a wider discipline having the character of an Engineering Science.


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

Territory	Chief delegate	Proposed Category	Signature
Australia	JACK PHILLIPS	III *	[illegible]
Bulgaria	Georgi Rusanov	IV	[illegible]
German Democratic Republic *	Wolfgang Rössner	III *	[illegible]
German Federal * Republic	Werner Thomas	III *	[illegible]
Hungary *	Zénó TERPLÁN	IV *	[illegible]
India *	J. S. RAO	V *	J. S. Rao
Italy *	GIOVANNI BIANCHI	IV *	[illegible]
Poland	Adam Morecki	IV	[illegible]
Rumania	Nicolae I. Manolescu	IV ⊗	[illegible]
United Kingdom *	L. Maunder	III *	[illegible]
U.S.A.	DOUGLAS MUSTER	I	Douglas Muster
U.S.S.R.	[illegible]	I	[illegible]
Yougoslavia	Ilić Branislav	IV ⊗	[illegible]

a)

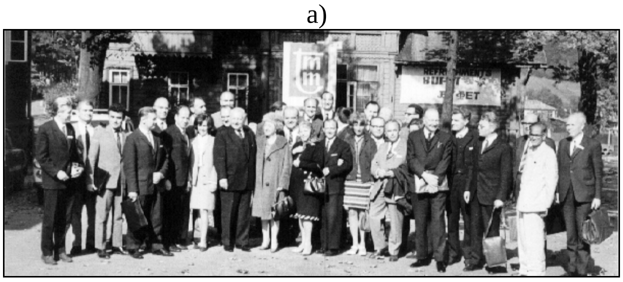

b)

Fig.13: The foundation of IFToMM in 1969: a) the signed act; b) participants at the founding Assembly.


b)


c)

Fig.14: Founding fathers of IFToMM: at the founding act on September 29, 1969 in Zakopane, Poland; b) the main founders prof. A.A. Artobolevski (USSR) and prof E.J. Crossley (USA) at the 1975 IFToMM World Congress in NewCaslte upon Tyne, UK.


Fig.15: IFToMM Presidents at HMM2000 (from left to right): Giovanni Bianchi (1984-'87 and 1988-'91), Arcady Bessonov in substitution of Ivan I. Artobolevsky (1969-71 and 1972-'75), Bernard Roth (1980-'83), Jorge Angeles (1996-2000), Kenneth J. Waldron (2000-'03), Leonard Maunder (1976-'79), Adam Morecki (1992-'95), and Marco Ceccarelli (Chairman of HMM200 Symposium). (the years in the brackets indicate the term of President mandate)

IFToMM Activity evolved TMM to MMS

Since the beginning of IFToMM, IFToMM Community has been very active in deepening and applying TMM, but even in enlarging TMM areas of interest. The evolution of TMM took over the time slowly (but quickly if compared with technical evolutions of the past!) and only in the year 1999 TMM was recognized formally as evolved to MMS in the IFToMM Community.

Technically, MMS can be seen as an evolution of TMM as having a broad content and view of a Science, including new disciplines.

Historically, TMM has included as main disciplines: Mechanism Analysis and Synthesis; Mechanics of Rigid Bodies, Mechanics of Machinery; Machine Design; Experimental Mechanics; Teaching of TMM; Mechanical Systems for Automation; Control and Regulation of Mechanical Systems; RotorDynamics; Human-Machine Interfaces; BioMechanics.

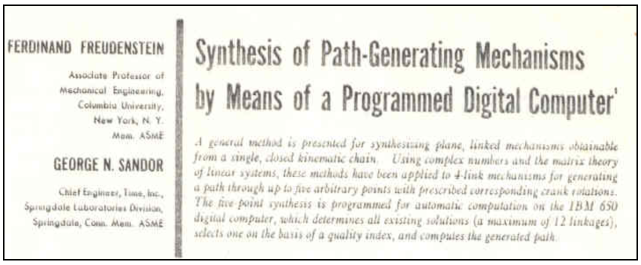
The modernity of MMS has augmented TMM with new vision and means but with many new disciplines, whose the most significant can be recognized in: Robotics; Mechatronics; Computational Kinematics; Computer Graphics; Computer Simulation; CAD/CAM for TMM.

Thus, the new Science vision of TMM can be recognized in an interest and integration of other aspects/disciplines for the study and design of modern current mechanical systems.

Emblematic is the establishment of RoManSy Symposium series that has been started within IFToMM in 1973, Fig.17a), at the early starting of Robotics. Already in the first event, significant results were presented and they are milestones in History of Robotics, like the example of Fig.17b) and c).

Mechatronics is the last new established field of MMS in which the multidisciplinary character is represented in the example in Fig.18 referring to a recent celebratory event for Manfred Hiller, one of the first "Mechatronic people".

The Science character of MMS (the current TMM) is also started by the renewed and well-established interest also on the History of MMS and IFToMM. Although IFToMM gave attention to History of TMM since the beginning with the appointment of a Commission for History of MMS, only recently the field has reached a maturity that is expressed by the HMM Symposium series, Fig.19.

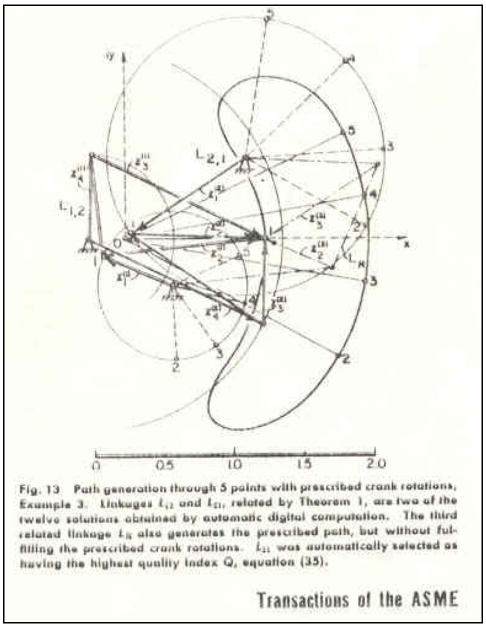

FERDINAND FREUDENSTEIN
Associate Professor of Mechanical Engineering, Columbia University, New York, N. Y. Mem. ASME

GEORGE N. SANDOR
Chief Engineer, Time, Inc., Springdale Laboratories Division, Springdale, Conn. Mem. ASME

Synthesis of Path-Generating Mechanisms by Means of a Programmed Digital Computer[1]

A general method is presented for synthesizing plane, linked mechanisms obtainable from a single, closed kinematic chain. Using complex numbers and the matrix theory of linear systems, these methods have been applied to 4-link mechanisms for generating a path through up to five arbitrary points with prescribed corresponding crank rotations. The five-point synthesis is programmed for automatic computation on the IBM 650 digital computer, which determines all existing solutions (a maximum of 12 linkages), selects one on the basis of a quality index, and computes the generated path.

a)



b)

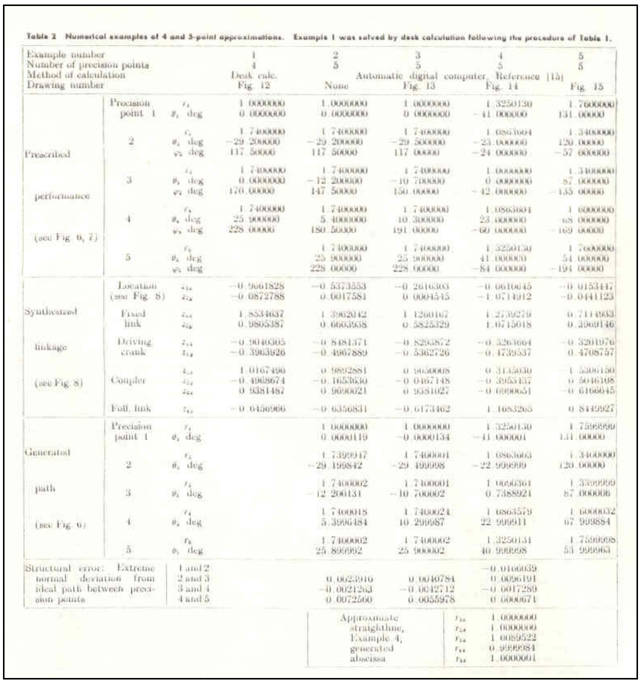
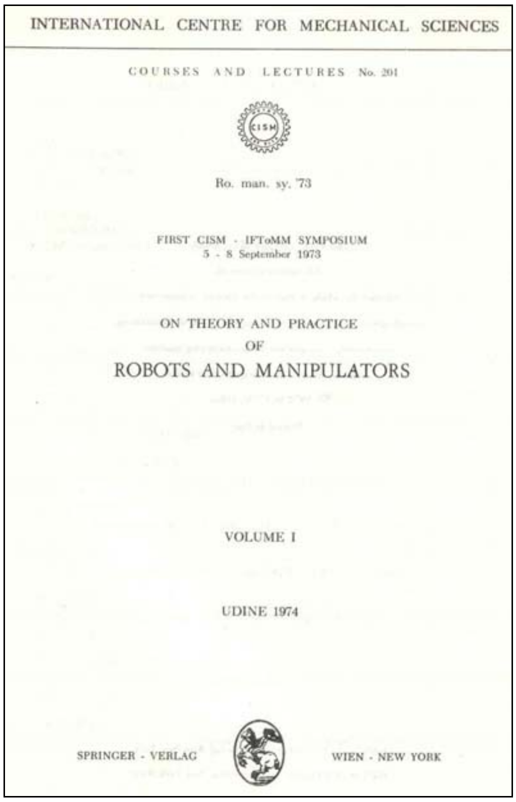


Table 2 Numerical examples of 4 and 5-point approximations. Example 1 was solved by desk calculation following the procedure of Table 1.

Example number			1	2	3	4	5
Number of precision points			4	5	5	5	5
Method of calculation			Desk calc.	Automatic digital computer, Reference [15]			
Drawing number			Fig. 12	None	Fig. 13	Fig. 14	Fig. 15
Prescribed performance (see Fig. 6, 7)	Precision point 1	r_1	1.0000000	1.0000000	1.0000000	1.3250130	1.7600000
		θ_1 deg	0.0000000	0.0000000	0.0000000	-41.000000	131.00000
	2	r_2	1.7400000	1.7400000	1.7400000	1.0863604	1.3400000
		θ_2 deg	-29.200000	-29.200000	-29.500000	-23.000000	120.00000
		φ_2 deg	117.50000	117.50000	117.00000	-24.000000	-57.000000
	3	r_3	1.7400000	1.7400000	1.7400000	1.0000000	1.3400000
		θ_3 deg	0.0000000	-12.200000	-10.700000	0.0000000	87.000000
		φ_3 deg	170.00000	147.50000	150.00000	-42.000000	-135.00000
	4	r_4	1.7400000	1.7400000	1.7400000	1.0863604	1.6000000
		θ_4 deg	25.900000	5.4000000	10.300000	23.000000	68.000000
		φ_4 deg	228.00000	180.50000	191.00000	-60.000000	-169.00000
	5	r_5		1.7400000	1.7400000	1.3250130	1.7600000
		θ_5 deg		25.900000	25.900000	41.000000	54.000000
		φ_5 deg		228.00000	228.00000	-84.000000	-194.00000
Synthesized linkage (see Fig. 8)	Location (see Fig. 8)	z_{1x}	-0.9661828	-0.5373553	-0.2616303	-0.0610645	-0.0153447
		z_{1y}	-0.0872788	0.0017581	0.0004545	-1.0714912	-0.0441123
	Fixed link	z_{2x}	1.8534637	1.3962042	1.1260167	1.2739279	0.7114933
		z_{2y}	0.9805387	0.6603938	0.5825329	1.0715018	0.3969146
	Driving crank	z_{3x}	-0.9040365	-0.8481371	-0.8293872	-0.5263664	-0.3201976
		z_{3y}	-0.3963926	-0.4967889	-0.5362726	-0.4739537	0.4708757
	Coupler	z_{4x}	1.0167496	0.9892881	0.9650008	0.3135030	-1.5306150
		z_{4y}	-0.4968674	-0.1653630	-0.0467148	-0.3953437	0.5046108
		z_{4z}	0.9381487	0.9690021	0.9381027	-0.0990651	-0.6166645
	Foll. link	z_5	-0.0456966	-0.6356831	-0.6173462	1.1683265	0.8449927
Generated path (see Fig. 6)	Precision point 1	r_1		1.0000000	1.0000000	1.3250130	1.7599999
		θ_1 deg		0.0000119	-0.0000134	-41.000001	131.00000
	2	r_2		1.7399947	1.7400001	1.0863603	1.3400000
		θ_2 deg		-29.199842	-29.499998	-22.999999	120.00000
	3	r_3		1.7400002	1.7400001	1.0050361	1.3399999
		θ_3 deg		-12.200131	-10.700002	0.7388921	87.000006
	4	r_4		1.7400018	1.7400024	1.0863579	1.6000032
		θ_4 deg		5.3996484	10.299987	22.999911	67.999884
	5	r_5		1.7400002	1.7400002	1.3250131	1.7599998
		θ_5 deg		25.899992	25.900002	40.999998	53.999963
Structural error: Extreme normal deviation from ideal path between precision points	1 and 2					-0.0166039	
	2 and 3			0.0023910	0.0040784	0.0096191	
	3 and 4			-0.0021263	-0.0042712	-0.0017289	
	4 and 5			0.0072560	0.0055978	0.0000671	
Approximate straightline, Example 4, generated abscissa		r_{1x}				1.0000000	
		r_{2x}				1.0000000	
		r_{3x}				1.0089522	
		r_{4x}				0.9999984	
		r_{5x}				1.0000001	

c)

Fig.16: The first application of computer calculation for mechanism design by Ferdinand Freudenstein and George N. Sandor in (1959): a) title and abstract of the paper; b) a model for mechanism design computation; c) the table of numerical results.


INTERNATIONAL CENTRE FOR MECHANICAL SCIENCES

COURSES AND LECTURES No. 201

Ro. man. sy. '73

FIRST CISM - IFToMM SYMPOSIUM
5 - 8 September 1973

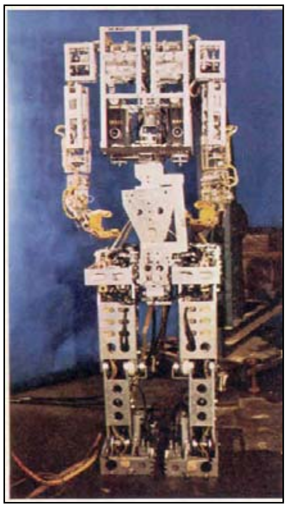
ON THEORY AND PRACTICE OF ROBOTS AND MANIPULATORS

VOLUME I

UDINE 1974

SPRINGER - VERLAG WIEN - NEW YORK

a)



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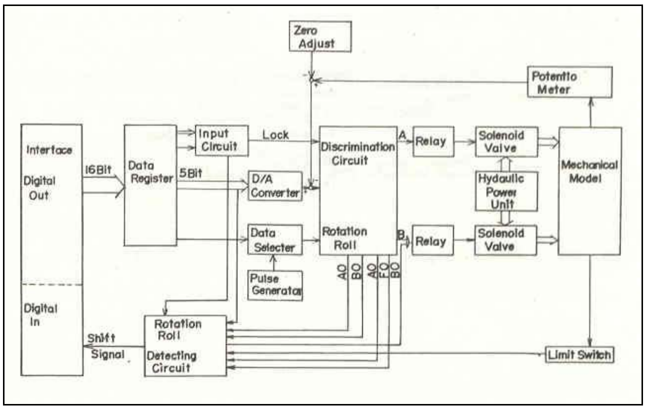
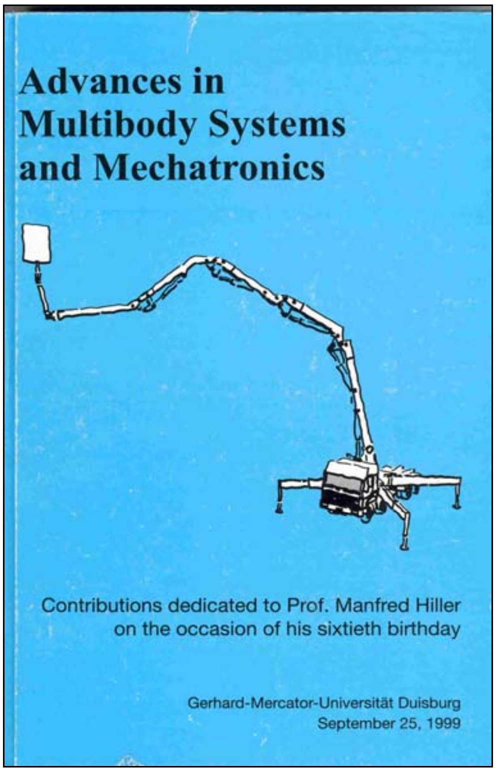
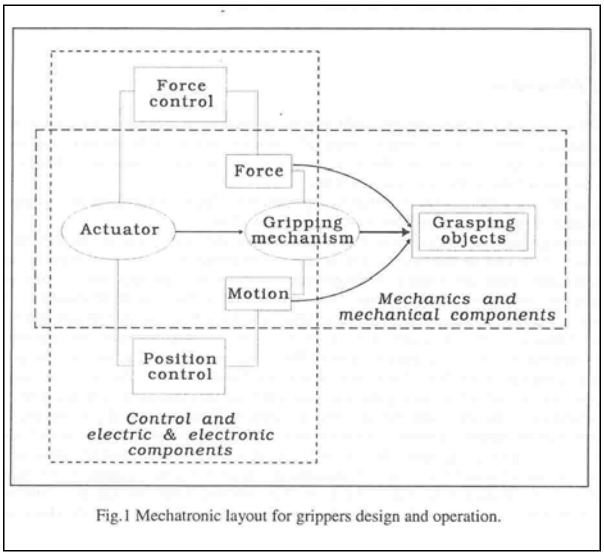


c)

Fig.17: Ro.Man.Sy'73, the first IFToMM Conference on Robotics in 1973: a) title page of Proceedings; b) the WABOT-1 robot presented by Ichiro Kato; c) a scheme for the control system of Wabot L5.



a)



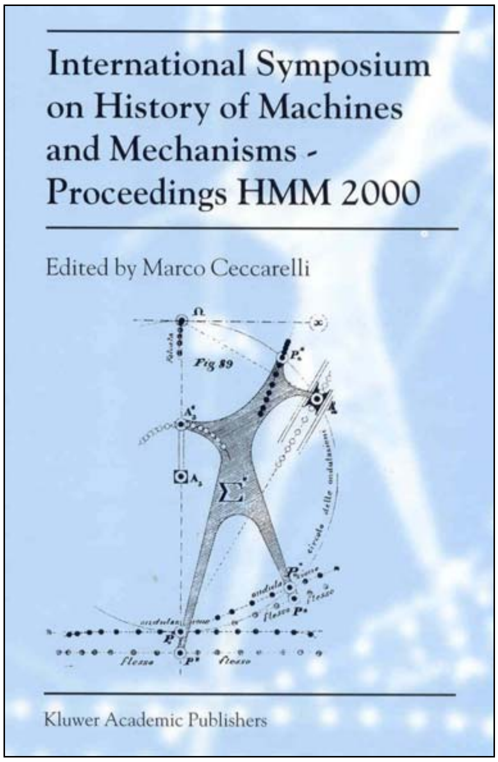
b)

Fig.18: Advances in Multibody Systems and Mechatronics in (1999): a) title page; b) a scheme for the mechatronic design of grippers.

The historical interest from IFToMM viewpoint is explained by the example in Fig.19 b) and c) in which a past mechanism design is reviewed and reinterpreted with a modern representation and formulation, respectively, in order to understand the historical achievements but to get stimulus and ideas for future work. The interest on History of MMS is fundamental to complete the Science view of MMS.

The Science character of MMS is expressed also in the IFToMM World Congress that in 2003 will be a forum for presentation of ideas and results in all the field of MMS as outlined in Call for Papers list of Fig.20.

Thus, MMS and IFToMM are directed from past experiences and achievements to future goals and success.



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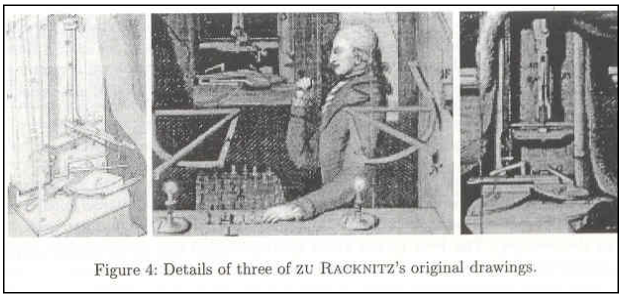

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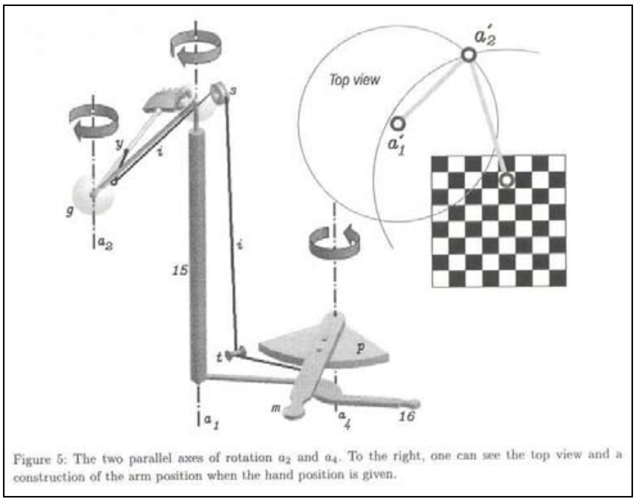

c)

Fig.19: Proceedings of the first IFToMM International Symposium on History of Machines and Mechanisms in 2000: a) title page; b) the automatic chess player by Racknitz; b) a sketch for modern reinterpretation.

Conclusive Vision

In this paper the evolution of TMM to MMS is outlined briefly by looking at few main aspects and personalities. The overview is incomplete but it gives us the opportunity to look optimistically at the future of IFToMM activity in MMS as oriented by past directions. Main aspects of past and future activity can be considered in teaching, practice, research, and cooperation in MMS and integrating it more and more with other engineering disciplines. Although the future Technology seems to be directed mainly to Informatics and Electronics means, mechanical systems will be always needed since the mechanical nature of human beings -environment interaction. Therefore, mechanism and mechanical devices will be always needed but they will be asked with enhanced designs and performances and the IFToMM community will make efforts and successful results for the Society improvements like in the past.

(1) Computational kinematics
(2) Gearing and transmissions
(3) Human-machine systems
(4) Linkages and cams
(5) Mechatronics
(6) Micromechanisms
(7) Nonlinear oscillations
(8) Robotics
(9) Rotor dynamics
(10) Transportation machinery
(11) Reliability of machines and mechanisms
(12) Education
(13) History
(14) Biomechanics
(15) Design methodology
(16) Dynamics of machinery
(17) Tribology

Fig.20: Main Topics at the 11-th IFToMM World Congress in Tianjin, China, in 2003 from the Call for Papers.

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