Are Theory and Procedures for Mechanism Designs Suitable as Goods of Cultural Heritage?

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1. Introduction

It is well understood that a memory of the past helps for a sure identity of subjects, communities, and persons. Such a good memory is today identified as Cultural Heritage mainly but not only for preservation of past developments and achievements in the broad sense of humanity experience, (UNESCO 2010).

In technical fields such an attention to memory of the past is addressed as History of Science and Technology, including History of Engineering in its specific expertises. History of MMS (in the past TMM) is the historiographical area dealing with history and evolution of MMS (Mechanism and Machine Science), and it is related to technical insights on MMS thanks to the activity of a community mainly referring to the IFToMM PC (Permanent Commission) for History of MMS, (Koetsier 2000).

Works on History of MMS with engineering viewpoints have been published in Proceedings of HMM Symposium series in the years 2000-2012, (Ceccarelli 2000 and 2004, Ceccarelli and Yang 2008, Koetsier and Ceccarelli 2012) and in books of a series that has been recently started by Springer on History of MMS (available at http://www.springer.com/series/7481).

Even in the past, and since the beginning of a well-recognized discipline on TMM (Theory of Machines and Mechanisms) (now MMS) attention has been devoted to History of TMM to track and record technical past of MMS developments, like for example in (Chasles 1837, Reuleaux 1875, De Jonge 1943, Dimarogonas, 1993, Ferguson 1962, Hartenberg and Jacques Denavit 1956, Nolle 1974, Roth 2000), just to cite few significant literature sources.

Only recently History of MMS is recognized with technical contents not only for memory purposes (to give credits to inventors and scientists, and to track evolution of engineering procedures and theories), but even for orienting future developments along well-identified directions of MMS development. But this approach cannot be yet recognized as a technical Cultural Heritage of MMS achievements, since this historical awareness is still restricted to a small well identified technical community and is not available to a wide public of the society for a general understanding and appreciation.

In general, Cultural Heritage is defined as the legacy of products of human ingenuity in the form of physical artifacts and intangible attributes of a group or community that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations, as indicated in (UNESCO 2010).

Physical or tangible Cultural Heritage products are understood as buildings and historic places, monuments, artifacts, etc., that are considered worthy of preservation for the future. These include objects significant to the Archaeology, Architecture, Science or Technology of a specific culture. Nature aspects are also important parts of a culture, encompassing the territory and natural environment, including what is scientifically known as biodiversity. The significance of physical artifacts can be interpreted against the backdrop of socioeconomic, political, ethnic, religious and philosophical values of a particular group of people. Of course, intangible Cultural Heritage is more difficult to preserve than physical objects.

Rules and laws have been developed in a recent past in order to clarify the values of Heritage items and to establish criteria and procedures for identifying and assigning credits of cultural products. Significant is the Convention Concerning the Protection of World Cultural and Natural Heritage that was adopted by the General Conference of UNESCO in 1972, (UNESCO: 2010). Then, many other standards and agreements have been elaborated at national and international levels, but mainly within the frames of architectonic goods.

Tangible MMS products can be recognized in machines that have been built and operated successfully, but even unsuccessfully, in the past as a contribution to the evolution of Technology and Society at local and worldwide levels. Even plans, drawings, and patents are recognized as MMS products with value of Cultural Heritage and in fact, they are often stored and used in museums and exhibitions of History of Science and Technology. Intangible MMS products can be also considered as referring to acquired knowledge that has been expressed in theories, algorithms, and reasoning for design and operation of machines. In general, those intangible MMS products are difficult to be identified and stored when they have been not reported in specific reports or books on corresponding tangible MMS products. In addition, even when reported in written documents or books those intangible MMS products are not considered worth full of consideration for Cultural Heritage since their technical contents make very often difficult the understanding and fruition from non-expert public. Thus, the true contribution remains hidden or even forgotten in old books or manuscripts in libraries and personal archives.

This paper is an attempt to address attention to intangible products of MMS activities, with a novel attention referring to a technical content that can be understandable even to a large public and can be useful to current professionals. Indeed, the paper is aimed at illustrating the values of intangible MMS products with few significant examples. The analysis of tangible MMS products as whole masterpieces or mechanism components is extrapolated in a similar approach to evaluate intangible MMS products such as conceptual designs, theories, and algorithms. Summarizing, this paper is an attempt in the direction of illustrating how History of MMS in its many different aspects but with technical contents can be interpreted and made available as part of Cultural Heritage for Humanity, both for memory preservation and future use of acquired knowledge in MMS expertise.

2. History of mms for cultural heritage

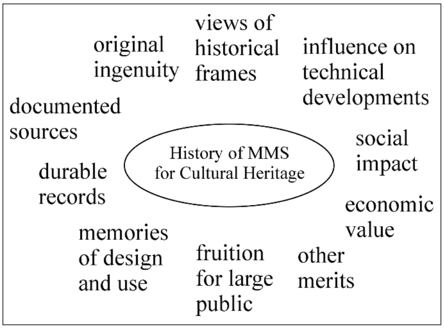

Fig. 1 Main aspects for evaluating mechanism designs as products for Cultural Heritage

In Fig. 1 a summary of main aspects that can contribute to an evaluation of a product in History of MMS as Cultural Heritage good is represented by stressing the multidisciplinary of such an evaluation with the above-mentioned considerations. The scheme has not the aim to be exhaustive and indeed a complementary view is needed as contributed by historians of Cultural Heritage. The concept and corresponding list of necessary steps in Fig. 1 are indicated to stress that the achievements in MD can be treated as any other products of Cultural Heritage in Technology. Thus, this overview is thought convenient to show the feasibility of such a consideration and not to propose new procedures.

Evaluation and identification of a mechanism design for Cultural Heritage with characters in Fig. 1 can be outlined similarly to traditional Cultural Heritage procedures with the following steps:

- get general information, as a first screening activity of matter of interest in multidisciplinary contexts
- search for original documents and source of information, as regarding an investigation of historical sources with multidisciplinary views
- validate the documents and sources by means of a historiographical work, even with help of historians
- analyze the document for technical soundness as related to its time
- understand the technical influence and effects on technical developments of the time and subsequent periods
- consider the social impact in society developments
- evaluate other aspects for quoting the document as valuable as product of Cultural Heritage with fruition for a large public
- submit the document interpretation to the community for validating the value as product of Cultural Heritage.

The above procedure summarizes a complex activity that will require a multidisciplinary approach with cooperation of experts also in areas other than in Cultural Heritage. An existing approach can be considered that one that has brought and brings pieces of technical achievements in terms of built machines and textbooks in Science museums. But most of the time those exhibitions are aimed only at surprising visitors with past solutions, which have some modern appearance or content. Significant examples with aspects for large public fruition can be indicated in the Smithsonian Museum in Washington, British Museum in London, and Science Museum in Milan. The fails of MMS exhibits in the cited museums can be understood in the fact that those exhibits show just some products but they do not give the possibility to have an overview of their MMS characters with even the corresponding theoretical backgrounds. A complete fruition of a mechanism design as product for Cultural Heritage will require a more wide understanding and explanation both in a mechanical design and theoretical aspects. Since a preliminary stage of such awareness it would be convenient to convince technical experts and historians that even mechanism designs both in constructions and procedures, are worth full to be considered as product for Cultural Heritage in a broad sense and not only as a show of the past expertise.

Attempts in direction of building collections of mechanism designs are experienced in a recent past, but mainly in the form of products (models, books, machine scaled reconstructions) for museum exhibitions or just in archives but with a limited access to a large public. Significant examples can be indicated in the mechanism collections in Bauman Technical University in Moscow (Russia), Cornell University in Cornell (USA), Dresden Technical University (Germany), and Turin Technical University (Italy), just to cite few significant ones. The cited University collections are not available to a general public and they are mainly focused on technical issues. A very recent focused plan towards Cultural Heritage of mechanism designs can be considered in the European project 'Thinkmotion' (7FP EU project: CIP-ICT-PSP.2009.2.3 for years 2010-2013), whose aim is to make the History of MMS available to a large public through a digital library in the Europeana webpage of the European Community.

3. A short outline of MMS developments

Over the time changes of needs and task requirements in Society and Technology have required continuous evolution of mechanisms (the term is used as mechanical system) and their uses, with or without a rational technical consciousness. In past evolution, technical knowledge has made possible to propose more and more solutions enhancing mechanisms and their uses in order to satisfy demands with updated aspects for Technology and Society.

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 (Theory of Machines and Mechanisms) has reached a maturity as independent discipline only in the 19-th century. Today we refer to TMM as MMS because of a more wide engineering area of interest and application of mechanism concept.

The historical developments of mechanisms and machines can be divided into periods with specific technical developments that, according to author's personal opinion, can be identified and characterized by referring to significant starting events such as:

- Utensils in Prehistory
- Antiquity: 5-th cent. B.C. (Mechanos in Greek theatre plays)
- Middle Ages: 275 (sack of the School of Alexandria and destroy of Library and Academy)
- Early design of machines: 1420 (the book Zibaldone with designs by Filippo Brunelleschi)
- Early discipline of mechanisms: 1577 (the book Mechanicorum Liber by Guidobaldo Del Monte)
- Early Kinematics of mechanisms: 1706 (the book Traitè des Roulettes by Philippe De La Hire)
- Beginning of TMM: 1794 (Foundation of Ecole Polytechnique)
- Golden Age of TMM: 1841 (the book Principles of Mechanism by Robert Willis)
- World War Period: 1917 (the book Getriebelehre by Martin Gruebler)
- Modern TMM: 1959 (the journal paper Synthesis of Mechanisms by means of a Programmable Digital Computer by Ferdinand Freudenstein and Gabor N. Sandor)
- MMS Age: 2000 (re-denomination of TMM by IFToMM)

The historical evolution to the current MMS can be shortly outlined by looking at developments that occurred since the Renaissance. Mechanisms and machines were used and designed as means to achieve and improve solutions in other fields. Specific fields of mechanisms grew in results and awareness so that first personalities were recognized as brilliant experts, like for example Francesco Di Giorgio Martini and Leonardo Da Vinci among many others, as emphasized in (Ceccarelli 2008). At the end of Renaissance Mechanics of Machinery addressed a great attention also in Academic world, starting from the first classes given by Galileo Galilei in 1593-98 (Ceccarelli 2006). The designer figure evolved to a professional status with strong theoretical bases finalizing a long process only in 18-th century. In Renaissance prominent was the activity of closed small communities of pupils/coworkers after 'mastros' and 'maestros', (Ceccarelli 2001 and 2008). Academic activity increased basic knowledge for rational design and operation of mechanisms. First mathematizations were attempted and fundamentals on mechanism kinematics were proposed by first investigators, who were specifically dedicated to mechanism issues, like for example Philippe De la Hire among many others. The successful practice of mechanisms was fundamental for relevant developments in Industrial Revolution during which many practitioners and researchers implemented the evolving theoretical knowledge in practical applications and new powered machines. The 19-th century can be considered the Golden Age of TMM since relevant novelties were proposed both in theoretical and practical fields. Mechanisms were the core of any machinery and any technological advance. A community of professionals was identified and specific academic formation was established worldwide. TMM gained an important role in the development of Technology and Society. Several personalities expressed the fecundity of the field with their activity, like for example Franz Reuleaux among many others. The first half of 20-th century saw the prominence of TMM in mechanical (industrial) engineering but with more and more integration with other technologies. A great evolution was experienced when with the advent of Electronics, it was possible to handle contemporaneously several motors in multi-d.o.f. applications of mechanisms and to operate 3D tasks with spatial mechanisms. The increase of performance (not only in terms of speed and accuracy) required more sophisticated and accurate calculations that have been possible with the advent of Informatics means (computers and programming strategies). Technically, MMS can be seen as an evolution of TMM as having a broad content and view of a Science, including new disciplines, even with multidiscipline contents.

Systems, inventions, theories, algorithms, applications and general technical events are part of this evolution that can be considered forming a Cultural Heritage of MMS developments. Those achievements have been developed by a community and in particular by individuals, whose efforts and activities are also interesting and indeed worth full of consideration for Cultural Heritage value, as pointed out with technical emphasis in the book series, and particularly in its Volumes 1 and 7, in which biographical notes are combined with memories and modern interpretation of those achievements.

4. Examples of theories and algorithms

Intangible goods for a Cultural Heritage of MMS can be considered intellectual activities and results such as for example theories, algorithms for analysis and synthesis, formulation of design criteria and performance indices, machine operation strategies, modeling of structures, kinematic concepts.

Although the above intangible products can be stored in publications that can be themselves tangible goods, those products of MMS achievements in terms of acquired knowledge require specific attention for preservation both in understanding and interpreting original value for the future, also for a suitable fruition by a large public.

In the following, few examples of those MMS heritage products are reported with a short discussion both to show samples from different historical periods and to illustrate peculiarities of their evaluations as well as their values for Cultural Heritage with the above-mentioned aspects.

In Fig. 2 a page of handwritten treatise by Francesco di Giorgio in (Galluzzi 1991) is shown as a record of an early classification of machines referring to pumping systems. Likewise the case of disk records of songs, the product itself is a piece of Cultural Heritage (as in fact it is considered as a very valuable document in a

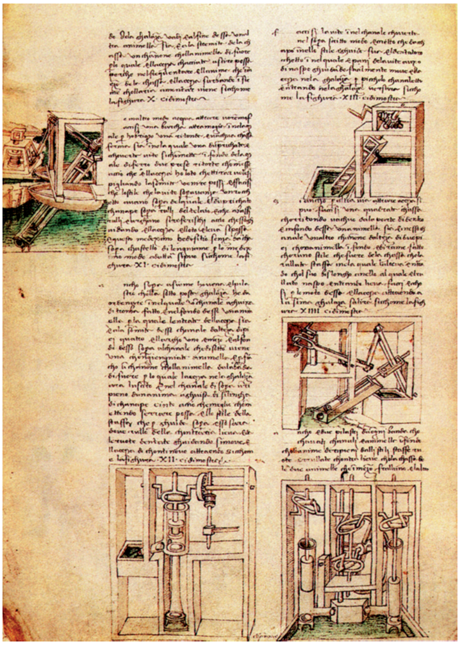

Fig. 2. Hand written manual for pumping systems by Francesco Di Giorgio (1439-1501), (Galluzzi 1991)

science museum). But its great value for Cultural Heritage can be better recognized in the conceptual achievement of considering different mechanical designs of machines as referring to a unique topology, even with a very early concept of kinematic inversion (as in the middle right figure) in which an inverted crank-slider mechanism can be identified. This is an example of early theoretical works that can be appreciated without formulation but with relevant MMS achievements that deserve preservation and consideration in future generations.

Fig. 3 shows schemes by Guidobaldo Del Monte in his book (Del Monte 1577) as very early kinematic models to study the motion capability of basic machines. They can be considered fundamental in tracking the historical evolution of abstraction of machine structures and operation that has a fundamental role in computational engineering both for design and operation of systems.

Another example is the notation proposed by Charles Babbage in 1826 for mechanism catalogue (Babbage 1826). This notation was not considered efficient in his time and it was very quickly forgotten. But the attempt is well recorded and even

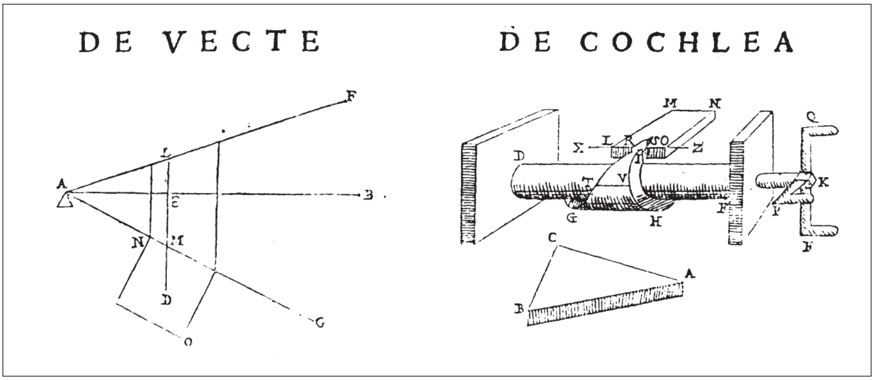

Fig. 3. Schemes of basic elementary machines/mechanisms as studied by Guidobaldo Del Monte in 1577

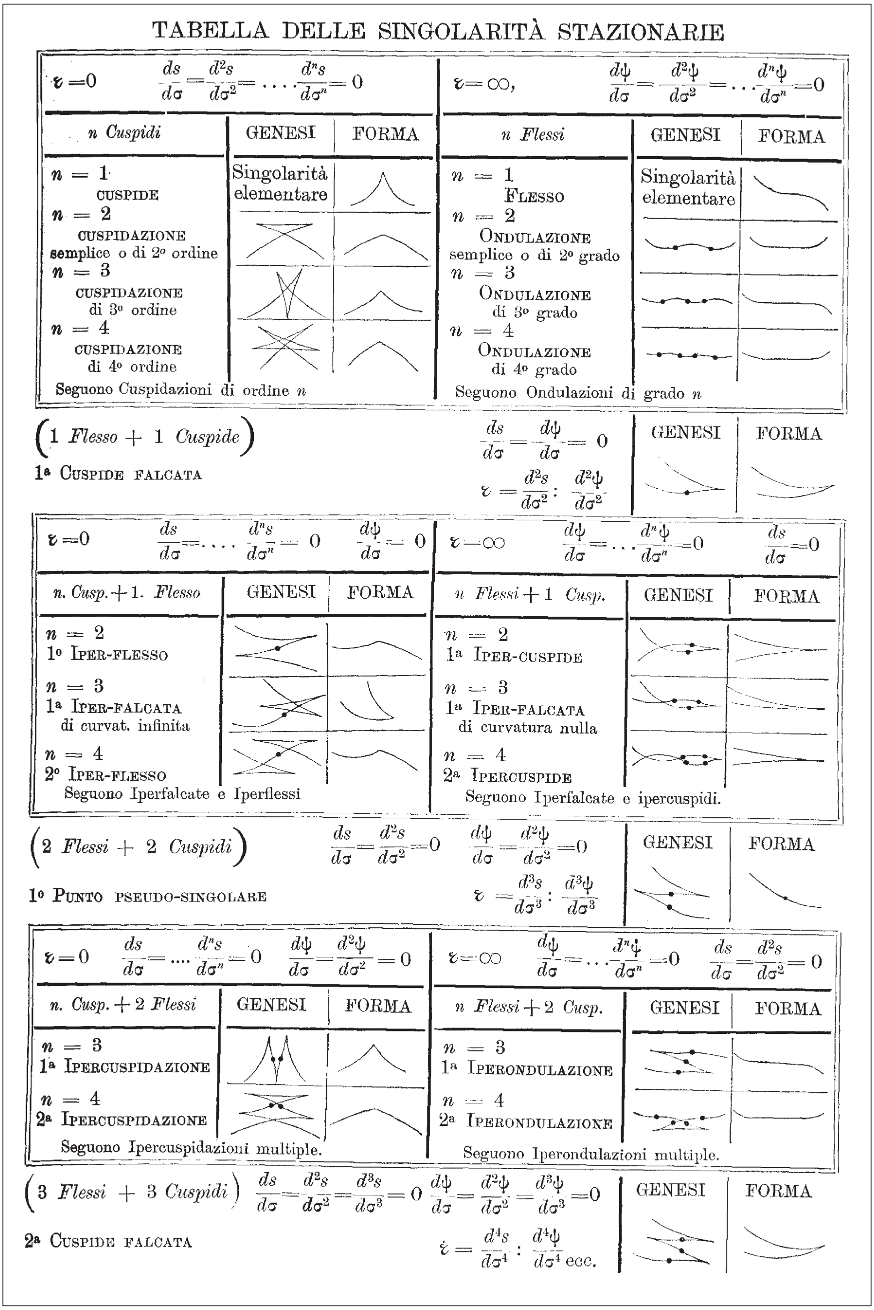

Fig. 4. A classification of coupler curves by Lorenzo Allievi published in (1895)

mentioned in other proposals for a language of mechanism catalogue (Ceccarelli 2000). This can motivate the need of preservation of its formulation and logics as an intermediary step of the evolution to a successful modelling that is used today.

There are many of those classifications that are based on logics and rules that can be understood as intangible products that deserve to be preserved in their original state, although nowadays they are not anymore used. This is a specific chapter of the history of MMS and its consideration will require specific attention and new evaluation as concerning a value for Cultural Heritage.

An example is illustrated in Fig. 4, (Allievi 1895), in which planar mechanisms are classified by using theoretical properties in tracing special loci in coupler curves as defined and understood by using kinematic properties and formulation. In such an evaluation significant are not only kinematic concepts but even aspects of mathematics and mechanical engineering at the same time. It is a heritage product since it is even representative of a reasoning that was under development at the end of 19-th century.

Similarly, in modern time it is significant the encyclopaedic classification by Artobolevski (1975-1980), also for the social implication and general influence in more large area than only research and mechanical engineering. In this case the work can be understood as a tool for facilitating the understanding of machines and mechanisms even to a public with only basic knowledge on mechanisms since the classification is worked out with an illustration-based approach. The rich approach and the exhaustive collection can be considered itself a masterpiece for preservation of mechanisms in current practice, but in the history of mechanism design.

Fig. 5 is an example that even very modern achievements of theories and algorithms can be considered suitable for preservation. This is the case of the modeling and formulation in terms of a mathematics-oriented outputs for development of expert systems as applied to mechanism design in (Tsai 2001).

Other examples of theories and algorithms that deserve consideration as products for Cultural Heritage can be considered the graphical techniques that the advent of Informatics and computer calculations have made obsolete, although they are still of great interest from conceptual viewpoints. Those techniques are outlined and indeed stored in several publications during the 19-th century but a unique frame is not yet available and indeed sometimes differences are given from one author to another.

Other theories can be considered as those that brought to modern mathematizations and computer-oriented algorithms, whose background is often underestimated, like for example first developments of Screw Theory or algebraic approaches for mechanism analysis and synthesis. Emblematic is the case of the deduction of the sixth order formula for the coupler curve of a four-bar linkage that in modern texts is not even mentioned. Another past algorithm with modern yet interest is the analysis procedure through vector polygons, that was developed in 19-th century.

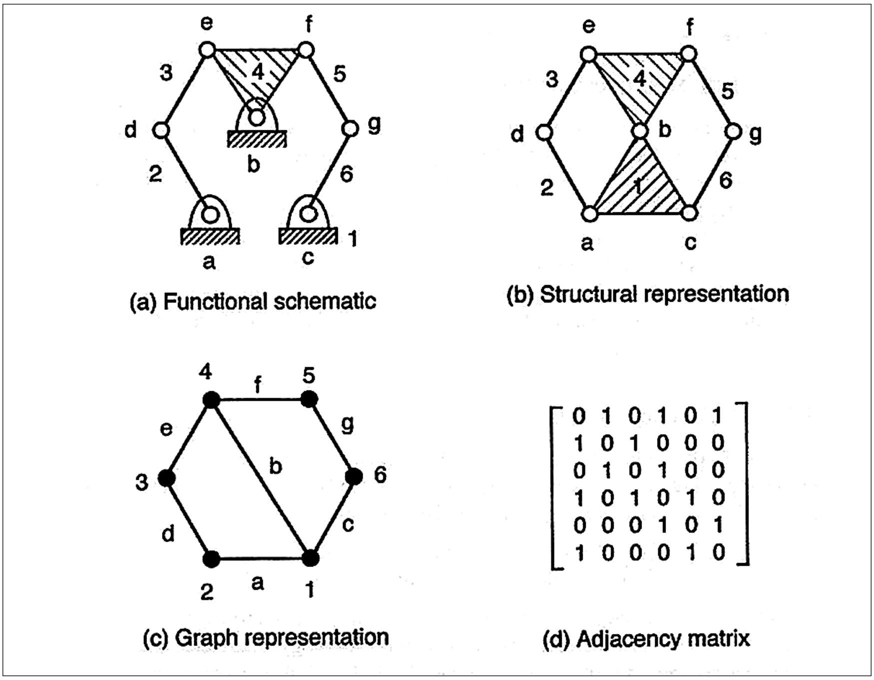

Fig. 5. A mathematization of mechanism models by using graphs by Tsai L.W. in 2001

The above examples can give both samples of what could be considered intangible products of Cultural Heritage from MMS achievements but also they show the problems and peculiarities for identifying them and indeed what and how preserving their heritage values. The abstraction and even formulation behind and after acquired knowledge are what can be considered valuable aspects for Cultural Heritage. But they are complex and difficult to store with those contents of Cultural Heritage that are so far considered for the traditional heritage from mankind developments, mainly with aspects for fruition by large public that makes significant a preservation.

Main difficulty with preservation of theories and algorithms can be understood in providing suitable fruition frames for a large public so that they can fully understand and appreciate such heritage products. Up to now only expert historians with significant technical backgrounds can fully appreciate and indeed use those past algorithms and procedures so that easily they are lost.

5. Conclusions

Cultural Heritage has the aim to identify and preserve significant achievements of humanity developments in durable records and memories that can be useful to future generations, not depending of the fashion of the time. This paper is an attempt to present achievements from MMS in term of products based on acquired knowledge as worth full to be considered intangible goods of Cultural Heritage for a wide public that can recognize ultimately the significance and contribution of MMS in humanity developments. The proposed examples are chosen to show both the wide range of time and place , and the variety of achievements in MMS as products of Cultural Heritage value. Each of these examples will need indeed a specific study and consequent evaluation as relevant product of Cultural Heritage. The purposes of those examples is also to show a continuity of those MMS achievements both in time and contents during the MMS history.

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