SUPPORTING THE REUSE OF HISTORICAL SOLUTIONS IN THE FIELD OF MOTION SYSTEMS

Ulf Döring, ulf.doering@tu-ilmenau.de
Torsten Brix, torsten.brix@tu-ilmenau.de
Ilmenau University of Technology, Ilmenau, Germany

Abstract. *In historical literature various depictions of technical solutions in the field of motion systems can be found. The form of the stored knowledge may be different. For example it may be represented as textual description, image or diagram. Those sources of knowledge are spread all over the world in libraries, museums, companies, universities and other institutions. Today it is at least in general possible to have fast access to some of these sources, because a lot of digitization projects present their results online. Some of the projects concern common (possibly technical) literature and patents whereas other projects are focused on the special field of motion systems (e. g. DMG-Lib or KMODDL). The main problem is, that the solutions described in the different sources can not be found efficiently by the engineering designers because usual search techniques supplied in the Internet are text-based and the textual descriptions have a certain language which is in the older literature often not English. But even if the key words are entered in the correct language a lot of solutions will not be found, because the author uses terms according to his personal context (e. g. determined by time, region and community). Furthermore solutions described in images and diagrams will only be found, if an attached text can be found. Thats why new approaches are needed. Projects like DMG-Lib and KMODDL try to develop such approaches which reactivate the rich cultural heritage in mechanism and machine science. Combined with modern materials, manufacturing processes and areas of application the old solution principles can lead to new innovative products. Because of the world wide demand as well as the world wide location of the sources international cooperation is needed. A network of interested persons, institutions and companies must be build up, which collects the different sources, extracts the solutions and makes them accessible. The presented paper deals with a concept, the possible realization and necessary tools for such a network. The emphasis lies on meta data, handling of multilingualism, extraction of solution principles, representation of solution principles and search techniques.*

Keywords: *motion systems, digital libraries, solution principle, search techniques, meta data*

1. INTRODUCTION

The design of more or less complex motion systems for the solution of kinematic as well as dynamic problems is one of the basic tasks for design engineers in mechanical engineering and tool building. In this field mechanical solutions are still adequate. Even in future mechanical solutions will often be used, probably in conjunction with new materials and technologies or in new fields of application.

Even though the knowledge concerning motion systems is not only important for mechanical engineering and tool building, according students are provided only with the basics of mechanism structures, analysis and synthesis. The growing lack of experts in mechanism and machine science leads to the need for a fast access to the knowledge which is relevant for motion system development. A modern possibility for such an access is the use of a digital library in which the digitized knowledge is stored. One of those digital libraries is the "Digital Mechanism and Gear Library" (DMG-Lib, see Brix *et al.* 2007). The DMG-Lib is continuously growing and contains very different sources like books, articles, drawings, images of machines and physical models, biographies, interactive objects etc. The different sources are collected, linked and indexed for a fast retrieval. To allow more than finding the words supplied by the authors of the sources, some of the described mechanisms are handled in a special way. They are analyzed and enriched with the gathered meta data. This way in the last years a set of over 1400 mechanism descriptions was collected. The set of mechanism descriptions will be enlarged because a uniform description of a large set of such descriptions is the basis of a solution repository which can supply design engineers with various solutions for their problems. Figure 1 shows several mechanisms collected in the DMG-Lib.

2. PROBLEM

2.1. Differences between digital mechanism collections

Besides DMG-Lib there are only a few other specialized digital libraries dealing with knowledge about motion systems in a more or less detailed way, e. g. KMODDL, TAMTM, DMD, LEONARDO, DELFT, BMSTU. We expect that in the near future the number as well the quality and the quantity of such digital collections will grow, because there is a need in industry as well as in teaching. Furthermore there is the intention of authors or institutions to present content in the world wide web because this leads to a better public perception which e. g. causes more citations or attracts clients with development tasks. Another growth indicator is the rising budget for the development of digital libraries which is supplied by institutions like the European Commission or the Deutsche Forschungsgemeinschaft.

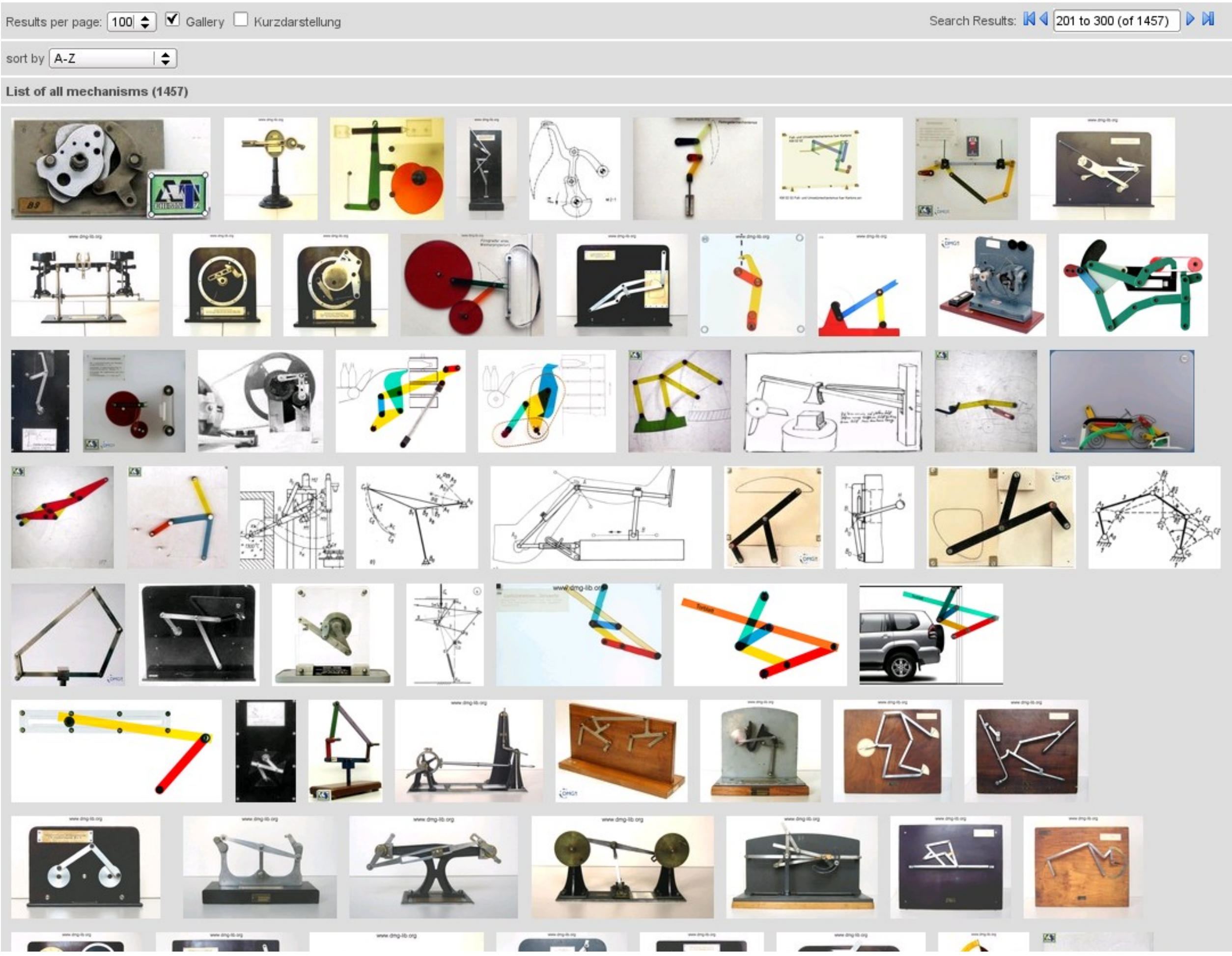


Figure 1. Preview of selected mechanisms in the DMG-Lib portal

Nevertheless, the worth of digital repositories for design engineers depends strongly on their ability to provide solutions for movement tasks in an effective way.

Problems concerning the retrieval of solutions from a repository will probably arise from:

- heterogeneous types of sources (text, image, interactive object, etc) and different level of abstraction within one source type (images could be e. g. solution principles, technical drawings or photographs) which can make it hard to understand and compare different solutions,
- different terms in the describing texts (this depends on language, time, profession / research field, etc) which lead to problems in text based search,
- insufficient meta data (then the solutions can not be distinguished in a problem oriented way),
- small amount of solutions and narrow range of solutions (only special types) cause gaps in the solution space,
- a lack of suitable search tools (text based as well as non-text based search is needed, it should be easy for users to describe the problems) and
- last but not least, insufficient support of a solution export into analysis or design programs.

Current days libraries show a very heterogeneous description of included technical solutions. That depends on the used meta data set (should fit the needs of the audience which shall be provided with the information), the scientific background of the persons which were responsible for the gathering of the meta data and the analysis effort. A first impression of the variety which can be found in the world wide web is shown in Fig. 2 … Fig. 5.

The shown mechanisms come from projects with different background. There are nowadays solutions enriched with information from the design engineers point of view as well as historical solutions usually described by historians. Thats why the historical solutions have usually a great lack of information in the context of motion problem solving. But the old solutions are still interesting for the engineers and may be the base for further inventions. For instance Neumann (2005) shows examples for the reuse of old inventions.

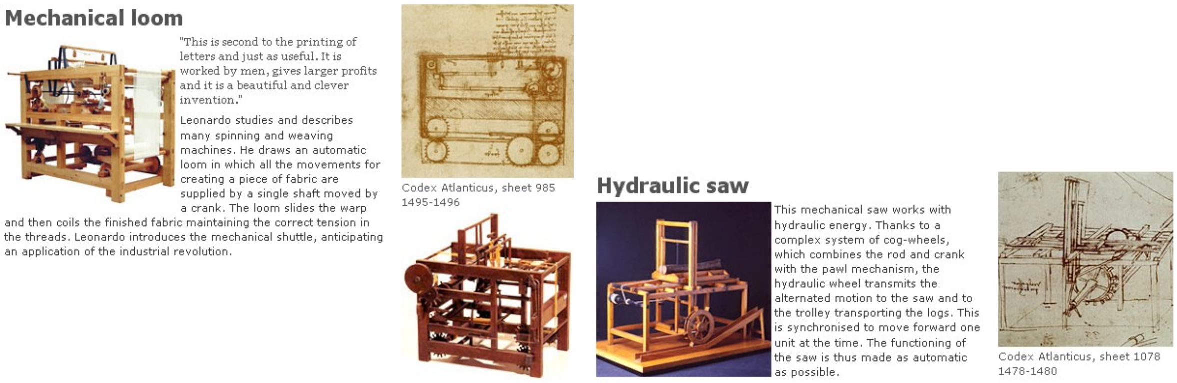


Figure 2. Examples for the description of movement systems in the virtual model collection "The Leonardo Gallery" of the Museo Nazionale della Scienza e della Tecnologia, see MUSEOSCIENZA

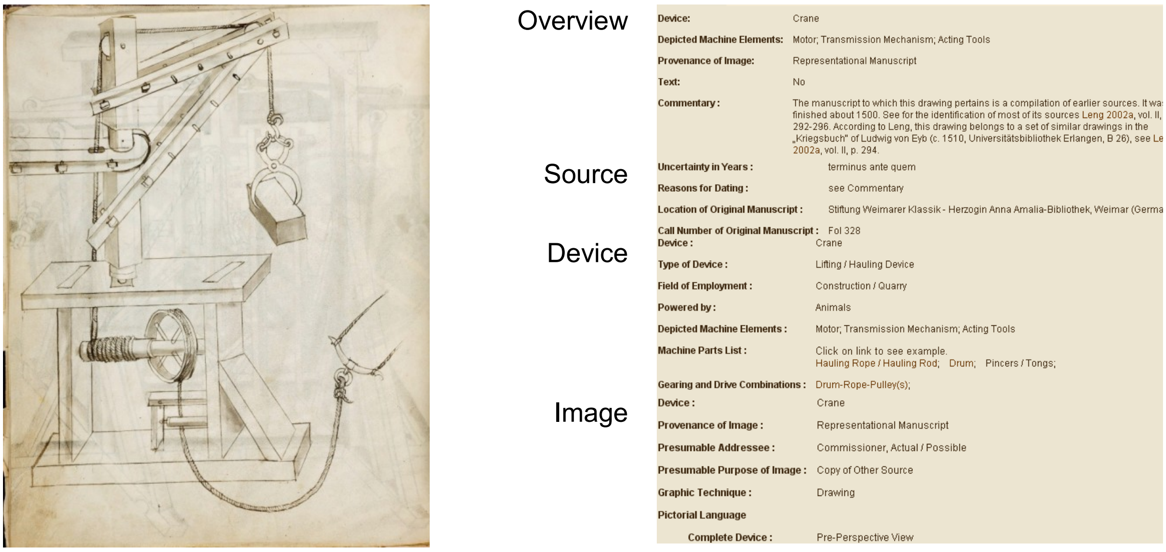


Figure 3. Example for the description of a crane shown in DMD

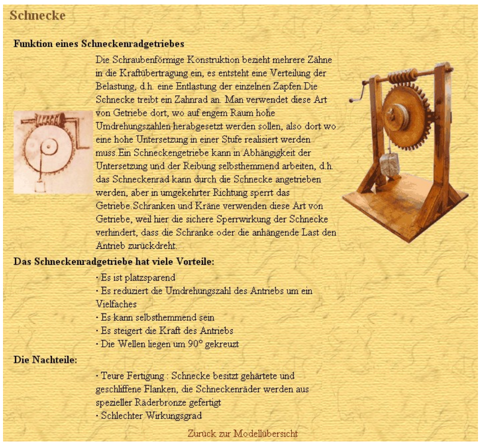
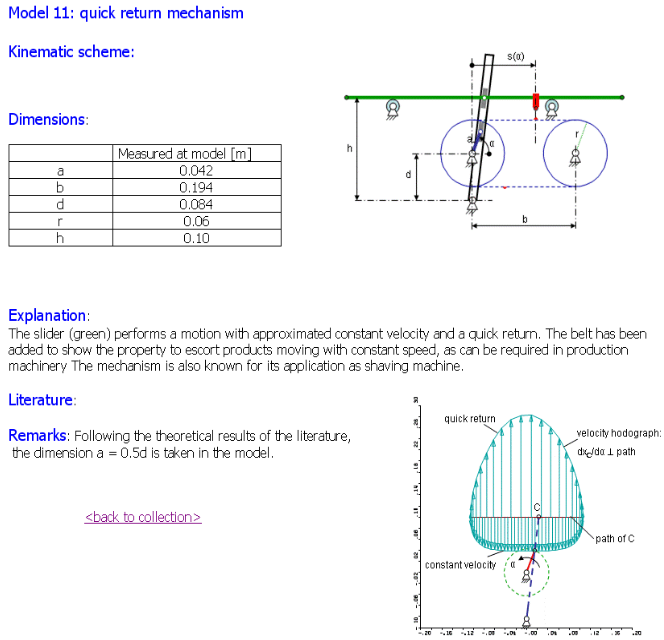


Figure 4. Example for the description of a worm gear in LEONARDO

The description of the models in Fig. 2 explains function and structure of the shown models in a quite simple way. This matches the intension to attract visitors to the museum. In Fig. 3 a more detailed description is shown. On the according DMD web pages search masks can be used to find certain categories of mechanisms. But the provided meta data fits mainly the needs of historians. A design engineer may find interesting insights into the knowledge of former times, but during a problem-oriented search he will rarely find a fitting solution. Figure 4 shows how some interesting facts about worm gears are provided on the web page of the project group "Leonardo da Vinci" (LEONARDO). The description may be useful for students in the first semesters (given that they can understand German) but solving a certain motion design task is not directly supported.



Model 11: quick return mechanism

Kinematic scheme:

Dimensions:

	Measured at model [m]
a	0.042
b	0.194
d	0.084
r	0.06
h	0.10

Explanation:
The slider (green) performs a motion with approximated constant velocity and a quick return. The belt has been added to show the property to escort products moving with constant speed, as can be required in production machinery The mechanism is also known for its application as shaving machine.

Literature:

Remarks: Following the theoretical results of the literature, the dimension a = 0.5d is taken in the model.

<back to collection>

Figure 5. Description of a quick return mechanism as shown in DELFT

The information shown in Fig. 5. from the web pages of the mechanism collection at the TU Delft seems to fit the needs more than the other examples did. But fast problem-oriented search for a solution is here also not possible.

The examples have shown, that spread over the world wide web information about interesting solutions can be found. But that information is usually not sufficient for design engineers tasks to efficiently find a solution for a certain motion system problem.

2.2. Special problems in gathering meta data from historical solutions

Besides the fact that a deeper analysis of mechanisms is in general a cost intensive work which must be done by experts, the analysis of historical mechanisms may lead to special problems. These problems arise mainly from the historical development of scientific standards. Especially the formerly used drawing styles with ambiguities, inconsistent proportions and errors in the perspective can make it hard to find a fitting (3D-) model with a behavior as described by the author of the historical document. Figure 6 shows such a problematic drawing. Often it is not clear if such a model even exists, because it may be that the drawing is only a sketch of an idea which was never realized as a or in a working machine.

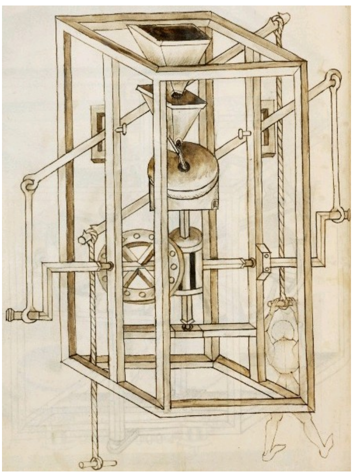


Figure 6. A mechanism shown in DMD. The drawing style causes problems if a matching 3D-model is searched.

3. SOLUTION

3.1. META DATA

A standardized set of meta data seems to play the most important role for an adequate solution. Meta data is the basis for the problem-oriented search. Approved meta data sets from different web based projects as well as the sets of attributes described in printed mechanism collections can be sources for the development of a common meta data format. Figures 7 and 8 show meta data provided for an inversor mechanism in the DMG-Lib. Parts of the meta data set stem from Niemeyer (2003). Figure 7 is a snapshot of a web based form for the meta data from the maintainers point of view. In this case he enters the data using an interface in German language. Nevertheless, as shown in Fig. 8 it is possible to provide the same information in an other language too. Here English is used to describe the mechanism in the public areas of the DMG-Lib portal. The generation of both HTML-pages (Fig, 7 and 8) is based on the same database entries.

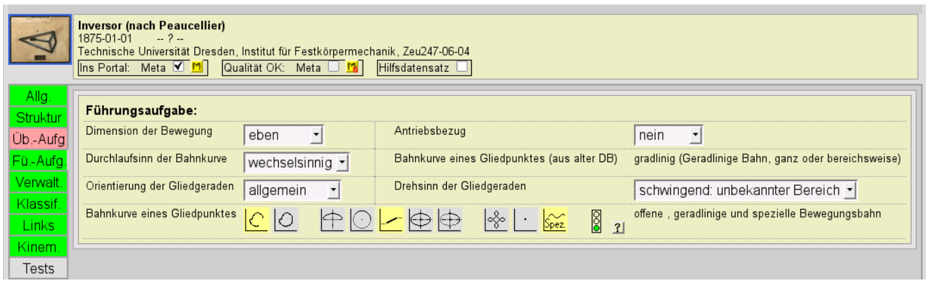


Figure 7. Web based form (German) for a database maintainer with the meta data for an inversor mechanism.

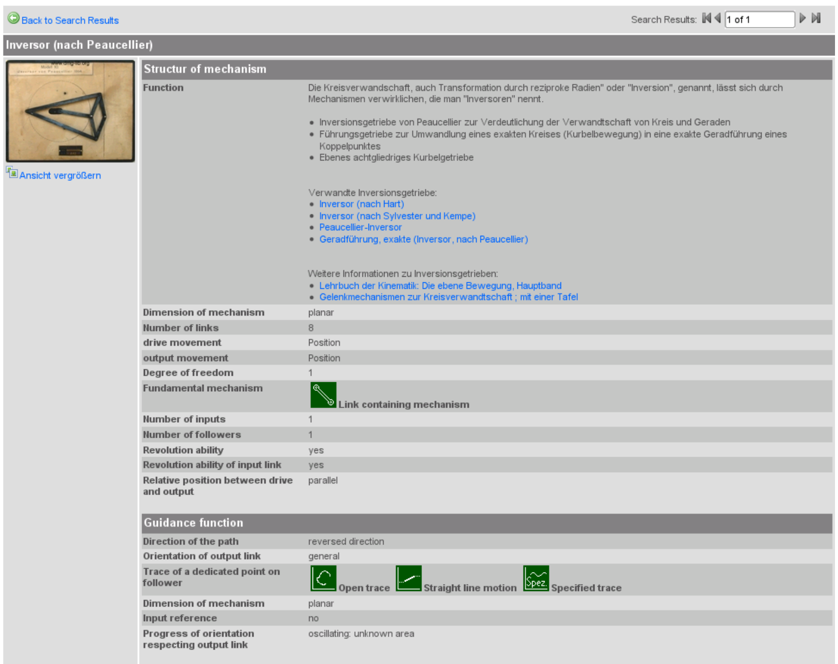


Figure 8. Meta data of the mechanism from Fig. 7, now shown to the DMG-Lib users in English

Figures 7 and 8 show an example how language independent storage of meta data helps to make information available for users all over the world. But Fig. 8 shows in its upper part also the problem of an appropriate translation of free text. In the example only the German text describing the function can be shown on the English page, because the text was entered only in German. May be that in the next years automatic translation of scientific texts improves, but from the today's point of view the use of standardized text blocks will be a good solution for the multilingual presentation of meta data as well as for language independent search.

The meta data description used in the DMG-Lib project and meta data sets from other projects like KMODDL, DMD etc as well as approaches described in the literature can be starting points in the development of a standardized meta data format. But as shown below, a set of single describing properties may not be enough. Beside the database like point of view (describing properties like the number of elements, the existence of straight line parts in the path of certain points, ...) an other kind of information should be part of the meta data format too: a more detailed description of the mechanism structure and of its single elements. This will allow the use of simulation/analysis software, the generation of animations/videos/interactive objects, the export into CAD formats and reparametrization/optimization etc. The DMG-Lib uses an XML-based format to describe the solution principles of mechanisms as well as shapes of parts and simulation results (see Döring e*t al*, 2006). For instance the generation of interactive animations from a single image (e. g. a figure in a book) is based on this XML-format.

3.2. WORKFLOW

Because entering/gathering high quality meta data for a certain mechanism causes a quite large effort, different aspects should be taken into account:

- If more or less abstract models of the mechanisms are available, then appropriate analysis tools could automatically calculate meta data. That would decrease the overall effort if the model generation costs are not too high and the quality of the analysis tools results is sufficient.
- Automatic analysis could be useful to avoid interpretation problems or errors (e. g. if humans have to decide if a certain section of a movement path is a straight line or not).
- Data entered by hand and / or data derived using tools should be compared to detect inconsistencies and to improve the quality.
- As shown above meta data should be as language independent as possible. This is quite easy for properties if they can only have one or more values which come from a predefined set of allowed values.
- Different kinds of search should be supported. Furthermore it should be possible to combine (free-)text-based, property-based and sketch-based approaches (see section 3.3).
- In the meta data format it should be possible to keep redundant data representations in parallel, because that makes it easier to fit the needs of different tools. In such cases the quality of the whole meta data set depends on the equality of the alternative descriptions too.
- There should be one or more minimal sets of meta data as well as a kind of basic representation for certain parts of the data, e. g. triangle meshes could be the basic representations for the description of single elements whereas analytical descriptions are optional alternatives.
- Tools may be used to generate alternative meta data, derive new meta data, perform consistency checks etc. If on a local system certain needed tools are not available, then web services could be started, e. g. to generate the paths of selected points based on a solution principle.
- The interpretation problems described in section 2.2 can only be solved with expert knowledge.

Nevertheless, even if a meta data set is defined and according tools for model generation, analysis, transformation and consistency checks are available, there is still a lot of work to do. This should be done in a network of interested persons, institutions and companies. The partners have to collect the different sources, extract the solutions and make them accessible in solution repositories. Here also tools are needed to coordinate the work and to synchronize the single collections. Coordination of the work will help that the collected mechanisms in the repositories span a larger solution space. Of course there will be always multiple descriptions of quasi the same mechanisms but coordination should avoid the x-thousandth four-bar linkage in the repositories as long as other types of mechanisms have only view representatives. Furthermore coordination should reach a balance between historical solutions from different times and present-day solutions, whereby it seems to be obvious that the number of representatives will be on average higher for newer mechanisms. A general survey about useful types of tools is given in Tab. 1. Such tools can be for instance existing CAX-software, specially developed programs or parts of a web based applications.

Table 1. Types of tools which should be used in the workflow

Type/purpose of the tools	Comment
generation of solution principles	With an appropriate tool planar mechanisms can often be processed in less than a minute. Even fast generation of special shapes or constraints and coloring may be supported by such tools.
generation of models (esp. shapes) for single elements	This will allow dynamics analysis with collision detection or more realistic animations. A higher degree of abstraction may be used to save modeling effort/time. Triangle lists could be the most basic format.
degree of freedom analysis	Based on solution principles abstract (graph based) degree of freedom analysis can be done.
kinematic analysis	Path of selected points should be calculated and stored in the format too. The analysis of the paths can generate meta data describing the shape of the path or the existence of dwells. Also the space needed by the moving parts seems to be worth to be analyzed and stored explicitly.

import/export interfaces	An SDK (software development kit) can reduce the effort of developing import and export interfaces or converters for useful tools.
animation generators	Often the understanding of certain solutions can be improved if (possibly interactive) animations or videos are provided. From a deeper understanding of existing solutions, e. g. those which nearly fit to a certain design problem, new solutions can be inspired.
statistics about mechanisms described in the repositories and search queries	Mechanisms can be categorized according to very different meta data (properties). An active search for mechanisms with certain properties or even property combinations which are underrepresented in the repository will be important for a continuously enlarged solution space. Besides the more theoretical database point of view the user needs should be also taken into account when the next mechanisms are selected for deeper analysis.
quality management	Consistency checks between data entered by experts and / or data derived by tools are important for a high quality of the stored data. After detecting deficiencies tasks must be assigned to responsible persons. Quality management may be local for one repository or global covering different repositories.
clustering / cross linking support	Common digital libraries often offer “similar objects” or “these objects may be interesting too”. Tools calculating similarity are in mechanism repositories important too. They provide the basis for statistics tools and allow to show alternatives to users (e. g. to inspire new/adapted solutions)
translation support	It is desirable to support a number of interface languages in a portal, because this increases the user acceptance. Changes of portal texts as well as changes / introduction of new items in the standardized set of meta data terms must be propagated to translators. The contemporary translation should be supervised.
other	A lot of other tools could be used to derive additional meta data, e. g. tools for dynamic analysis, assembly analysis etc.

3.3. SEARCH AND FURTHER USAGE

At this point the origin of a solution (e. g. historical or not) will only play a secondary role for design engineers. Of course the according meta data could be used to retrieve solutions from a certain time, e. g. those which allow patent free designs, but in general the problem-oriented search should be supported with equal quality (should not depend on the time a solution stems from).

If repositories use the standardized meta data format, it is possible to combine the solution spaces from different repositories. Software or web portals can then use the solution space spanned by the used repositories in different ways. The search interfaces presented to the users may be in general very different. They may be for instance:

- text based search, possibly improved by the use of a semantic network (describing synonyms, translations etc.)
- meta data based search, e. g. as provided in DMG-Lib (see Fig. 9) or
- sketch based search for mechanisms with e. g. certain paths of points or transfer functions, see Döring *et al* (2006) for examples.

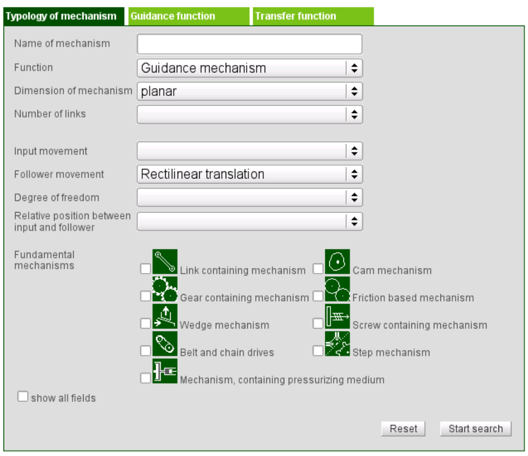


Figure 9. Meta data based mechanism search in the DMG-Lib Portal (English)

An other useful feature would be the coupling with optimization tools which could fit the retrieved solutions to a given motion problem.

Furthermore the integration of the search functionality into the tools used by design engineers would be good for a more effective work. According to the problem a design engineer deals with, the CAX tool could automatically generate search queries for the mechanism repositories. Matching mechanisms retrieved from the repositories could be converted automatically into the internal model of the tool (as good as it is possible) and then serve as basis for further modeling interaction of the design engineer.

4. CONCLUSIONS

The importance of digital solution repositories is undoubted. Historical solution should be part of such repositories equal to present-day solutions. The upcoming digital libraries describing motion systems differ in quality and quantity as well as in the target groups. To support the reuse of historical and present-day solutions a standardized meta data format is needed. Such a standard promotes the quality and exchangeability of meta data. This avoids problems with the search in narrow or too small collections, because networked search becomes possible. The meta data description used in the DMG-Lib project can be one starting point in the development of a standardized meta data format. Because the analysis of mechanisms and the gathering of high quality meta data is usually cost intensive a network of partners from the mechanism and machine science community as well as historians should fill the repositories with mechanism descriptions. A set of tools using import and export interfaces for the format can reduce the effort in model generation, analysis, transformation and consistency checks. In future the mechanism repositories can play a role in mechanical engineering and tool building which is similar to the present-day role of open access repositories which provide meta data and content concerning literature, works of art etc. to a broad public. Historical solutions will be an integral part of these mechanism repositories.

5. REFERENCES

BMSTU, August 2009, Mechanism Model Collection of the Bauman Moscow State Technical University, <http://tmm-umk.bmstu.ru/index_3.htm>.

Brix, T., Corves, B., Döring, U. and Modler K.H., June 2007, “DMG-Lib: the Digital Mechanism and Gear Library - Project”, Proceedings of the 12th World Congress in Mechanism and Machine Science, Besançon, France, <http://www.dmg-lib.org/dmglib/main/download/A127.pdf>.

DELFT, August 2009, Mechanism Collection of the TU Delft, Netherlands, <http://wbmttt.tudelft.nl/cadom/Models/Index.htm>.

DMD, August 2009, Database Machine Drawings, <http://dmd.mpiwg-berlin.mpg.de/home>.

Döring, U., Brix, T., Reeßing, M., August 2006, “Application of Computational Kinematics in the Digital Mechanism and Gear Library DMG-Lib”, Mechanism and Machine Theory, Special issue on CK 2005, International Workshop on Computational Kinematics, Volume 41, Issue 8, Pages 1003-1015.

KMODDL, August 2009, Kinematic Models for the Design, <http://kmoddl.library.cornell.edu>.

LEONARDO, August 2009, Homepage of the project group “Leonardo da Vinci”, FH Bielefeld, Germany, <http://lrh10.fh-bielefeld.de/Projekte/Leonardo>.

MUSEOSCIENZA, August 2009, Museo Nazionale della Scienza e della Tecnologia, Milano, Italy, <http://www.museoscienza.org>.

Neumann, R., May 2005, “Old inventions in up-to-date applications”, Third International Workshop on History of Machines and Mechanisms, Moscow, Russia, <http://www.techno.edu.ru:16001/db/msg/28305.html>.

Niemeyer, J., 2003, “Methodische Entwicklung von Prinziplösungen bei der Auslegung ungleichmäßig übersetzender Getriebe unter Verwendung eines praxisorientierten interaktiven Wissensspeichers”, PhD thesis, RWTH Aachen, Germany.

TAMTM, August 2009, Taiwans Antique Mechanism Teaching Models, <http://www.acmcf.org.tw/model/index.htm>.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.