The Digital Mechanism and Gear Library – a Modern Knowledge Space

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Abstract

Mechanisms and gears are an essential part of technical products in industry. However, the worldwide existing knowledge about mechanisms in theory and practice is mostly scattered and only fragmentarily accessible for users like students, engineers and scientist. It does not comply with today's requirements concerning a rapid information retrieval. This paper presents the "Digital Mechanism and Gear Library" (DMG-Lib). In this interdisciplinary project of the Technical Universities of Ilmenau, Dresden and the RWTH Aachen a new digital, internet-based library (www.dmg-lib.de) is built to collect, preserve and present the knowledge of mechanism and gear science on a new level of quality. The DMG-Lib contains a wide range of digitalized information resources in very heterogeneous media types. The resources are enriched with various additional information like animations and simulations. Combined with innovative multimedia applications and a semantic information retrieval environment, the DMG-Lib provides an efficient access to this knowledge space of mechanism and gear science.

1. Introduction

In the middle of the 19th century in Germany the systematic research on mechanisms and gears started as a result of the fast growing engine building industry in this time [5]. Especially the theoretical reflections and practical works of the German engineer F. Reuleaux [15] became important. Mechanism and gear technology is today still essential for industry and it will become even more important due to the introduction of new technologies like nanotechnology and corresponding new fields of application.

The existing knowledge about mechanisms in theory and practice is worldwide scattered in hand- and textbooks, photographs, solid functional models, engineering drawings, etc. It is only limited and very fragmentarily accessible and does not comply with today's requirements concerning a rapid information retrieval [5]. However, industrial companies and research institutes demand an efficient access to the whole mechanism and gear theory [7]. Existing activities to pro-

vide such access are promising (e. g. [3]) but by far insufficiently. Today in Germany only 12 university institutes with focus on mechanism and gear science are left. More and more didactical experiences and valuable training material are lost because experts on this field of application retire or through economy measures specialized institutes are closed. Also old and unique literature with only a few numbers left are quite difficult to access like the publications of Reuleaux. They have to be digitized and online presented so that this still important knowledge becomes accessible for the public again.

A solution of these problems is the collection and presentation of all relevant information resources for mechanism and gear science in a centralized worldwide accessible platform [5, 8]. The research and education in various ingenious disciplines would certainly benefit from such a comprehensive library of knowledge.

In 2004 the development of the worldwide accessible "Digital Mechanism and Gear Li-

brary" (DMG-Lib) was started to prevent this sneaking lose of knowledge. The DMG-Lib is an interdisciplinary project of different departments of the Technical Universities of Ilmenau, Dresden and the RWTH Aachen. It is financed by the "German Research Foundation" in the program "Scientific Library Services and Information Systems" (project number: LIS 4-554975).

The aim of this project is the collection, integration, preservation, systematization and adequate presentation of the worldwide knowledge about mechanisms and gears. The gained results and experiences of this project will hopefully help in future other digital libraries in different application domains as well.

The digital library is designed to satisfy the requirements of different user groups like engineers, scientists, teachers, students, librarians, historians and others. To offer users a wide variety of opportunities for retrieval and utilization the digitized resources are extensively post-processed and enriched with various information like animations, meta-data, references and constraint based models. The focus is not only on textual documents, images and animations. Also functional models are digitalized, which exists in thousands of unique models with no or only very limited access for the public.

This huge amount of available heterogeneous information resources in the DMG-Lib implies a key challenge of this project: the implementation of an efficient, uniform and user-satisfying information retrieval [8, 14].

In the following section the concept of the DMG-Lib project is introduced. Afterwards the implementation of the DMG-Lib is presented. Thereby the digitalization and enrichment of the information resources and the DMG-Lib online portal are discussed. Also developed multimedia applications and a semantic information retrieval environment for innovative ways of presentation and retrieval in the knowledge space are described. Finally, the paper concludes with a summary and an evaluation of the project.

2. Concept of the DMG-Lib

The DMG-Lib contains a vast amount of very heterogeneous information resources (see Fig. 1) like books, publications, functional models, gear catalogues, videos, images, technical reports, etc. The original sources are procured, digitized and converted to suitable data formats.
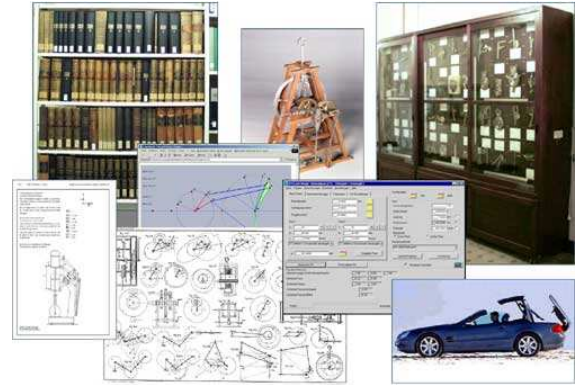

Fig. 1: Examples of information resources in the DMG-Lib

The information resources can be accessed worldwide on the DMG-Lib internet portal. This simplifies the access and distribution of these information resources, but does not directly enhance a goal-oriented usage and retrieval for solutions of technical tasks in research and industry. Furthermore the common storage method for knowledge, mainly in static texts and images, does not comply with requirements concerning an efficient and fast information retrieval. The advantages of functional models for a better understanding of complex construction and function principles are well known. Today the necessary techniques are available to provide an easy access to such helpful demonstration models for a broad public. Computer based methods enable the generation of multimedia documents which describe the function and other relevant attributes of mechanisms and gears. These can easily be distributed and enriched with extensive additional information [7].

Therefore in contrast to other digital libraries projects, which often provide only access to the digital raw data [4], in the DMG-Lib project the digitized resources

are extensively post-processed and enriched with various information like animations, constraint-based models or various verbal descriptions. Also further simulations and analyses are possible, because constraint-based models can be used in external analysis, synthesis and optimization systems. Such approaches are necessary to move from a static to a dynamic problem oriented supply of knowledge for a wide rage of application domains and user requirements.

An overview of the complex production workflow for the identification, digitalization, enrichment, storage and presentation of information resources in the DMG-Lib is displayed in the following figure (see Fig. 2).
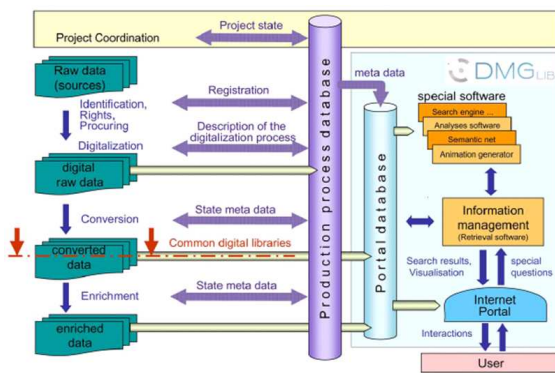

Fig. 2: Production workflow in the DMG-Lib

Based on the vast amount of available heterogeneous information resources in the library and the extensive enrichment, the DMG-Lib is able to provide an efficient retrieval as well as various utilization options for users. Following these considerations several additional aims of the DMG-Lib project can be derived:

- Constraint based modeling of mechanisms and gears as base for generation of further description forms [7]

- Supply of descriptions of mechanism and gear knowledge in various forms to ensure a flexible, adaptive and long term usability (verbal, images, constraint-based descriptions, 2D and 3D animations)

- Cross-platform presentation in the internet for different user-groups and different use-cases like research, product development or self-study

- Development of information retrieval systems, which allow a structural selection and type syntheses of mechanisms and gears

- Support of automated access options for the library content using various applied descriptors or meta-data (e. g. OAI-PMH service)

- Support for researchers and developers during the development of solutions for special synthesis or optimizing problems

3. Implementation of the DMG-Lib

For the implementation of this ambitious concept a consequent cooperation of information, computer and usability scientists as well as engineers, librarians and experts of mechanism and gear science is necessary. This is the only way to collect, enrich and present the complex domain specific heterogeneous information resources according to user requirements.

3.1. Enrichment of the information resources

The following information sources are digitized and integrated in the digital library:

- Literature relevant for mechanism and gear technology (monographs, journal articles, etc.) from different libraries and private collections

- Solid mechanism and gear models of the TU-Ilmenau, the TU-Dresden and the RWTH Aachen

- Images and slides of gears available in the project partners archives

- Technical drawings (outlines, technical blueprints, technical principles and calculation instructions)

- Training materials of the departments involved in the DMG-Lib project

The literature sources are usually scanned with 300 dpi resolution and 256 grayscales and are saved as TIFF files. For the scanned resources meta-data according to the Dublin Core standard are stored in the production database [1]. In addition the documents are classified according to technical aspects.

For further processing of the digital raw data a layout and text analysis is necessary. For the identification of the physical structure (text blocks, images etc.) as well as the individual characters in the documents the commercial software ABBYY-Finereader is used. The software is embedded in a self developed application framework called AnAnAS (**An**alyse-**An**reichungs-**A**ufbereitungs-**S**oftware).

Other applications developed in the DMG-Lib project identify the logical structure (headlines, labels of figures etc.) more and more automatically. The storage of the meta-data in AnAnAS is based on the METS-Standard [2]. Different meta-data are added to the documents like administrative (who scanned the document, document source), descriptive (e. g. Dublin Core) and structural (connection between the content and other meta-data like figure references). The result of the structural and layout analysis is the identified logical structure of the document. This information can be used in further processing steps like the automated generation of links and tables of contents as well as in the ranking of full text search results.

For the enrichment of the scanned documents an animation generator was developed which allows the simulation and the variation of drawings, images and models in an easy and fast way (see Fig. 3).

An export to CAD and special analysis software systems will be available as well. Base for the export and the animation generation is a special XML based file format in which the description of the displayed gear is stored [7]. These abstract model descrip-
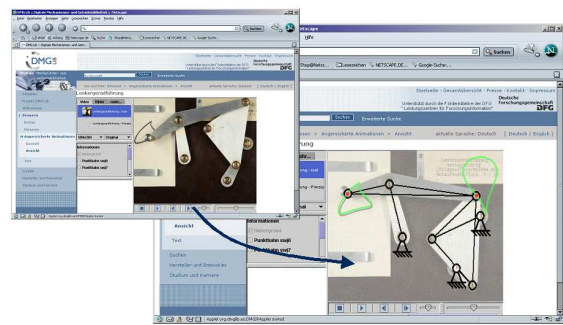

Fig. 3: Enhancement of videos by an overlaid simulation-based animation

tions provide rich information for various search criteria for example the number of elements of the gear. The analysis of the simulation results provides further information describing the function of the gear like the transmission behavior. This functional information is important for the implementation of a problem oriented information retrieval.

To the individual models, animations, images and literature resources experts can attach further meta-data like detailed descriptions, cross-links and other annotations. This information will be edited either in the AnAnAS system during the processing of the digital raw data or in special designed interfaces directly in the production database.

A first version of the production database was developed using MySQL and content is now continually added. In June 2006 the DMG-Lib portal included about 30 books, 700 demonstration models, 45 bibliographic entries and more than 40 enhanced images and videos. However in the production database over 900 documents and 400 persons relevant to the DMG-Lib are listed. In the next years thousands of resources will be provided in the portal.

3.2. DMG-Lib Online Portal

The portal is the internet based communication and presentation interface between the user and the DMG-Lib (see Fig. 4). For an user adequate design and implementation an evaluation of the usability was performed which is oriented on the Usability Engineering Lifecycle developed by Deborah J.

Mayhew [11]. According to this method a requirement analysis and expert interviews have been carried out to develop a conceptual model of the DMG-Lib portal.

In March 2006 the prototypic online portal on www.dmg-lib.org was activated. It currently serves as a platform for usability tests. Beside the interactive search option in the web portal the content of the DMG-Lib can be accessed with an OAI-PMH web service as well.
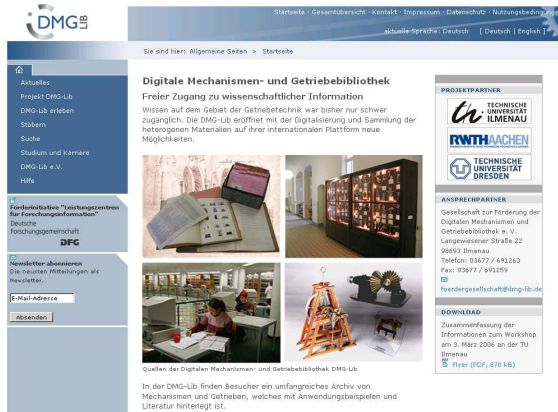

Fig. 4: DMG-Lib portal

3.3. Multimedia Applications of the DMG-Lib

Parallel to the internet portal interface other interactive multimedia applications are developed like the multimedia timeline (see Fig. 5) and the virtual mechanism and gear museum.
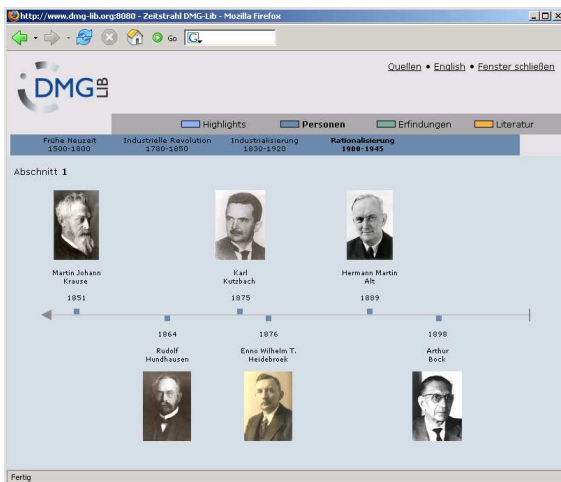

Fig. 5: Timeline of mechanism and gear development

The timeline application gives users a multimedial overview of important persons, inventions and publications in the historical development of mechanism and gear science. Users will be able to directly access corresponding information resources, for example available books of selected persons in the library.

Beside traditional browsing and retrieval methods these applications provide alternative ways to access the knowledge stored in the library. Prototypes of these applications are integrated in the DMG-Lib portal and are currently tested by the user community.

3.4. Semantic Information Retrieval

A further field of research is the retrieval in heterogeneous information resources using different mechanism and gear hierarchies like the structural system of Reuleaux [15] or other classification systems of well-known publications (e. g. [6]).

A visualization and an efficient navigation over these different categories of gears could help users to get a systematic overview over the huge amount of existing mechanism and gear constructions. However, the identification and modeling of these classifications and relations between the different technical terms are quite complicated, because different opinions of experts and authors have to be considered.

To solve this problem semantic web technologies can be used. With the help of Topic Maps, as a special kind of semantic networks, the knowledge of mechanism and gear science can be generalized and explicit modeled in a semantic meta-layer [12, 13]. With the extensive descriptive power of Topic Maps, all relevant concepts and relations between the concepts of this application domain can be modeled. Additionally, valid contexts, alternative names and other relevant semantic information can be included. Furthermore each concept in the semantic meta-layer is linked to all relevant information resources available in the library (see Fig. 6).
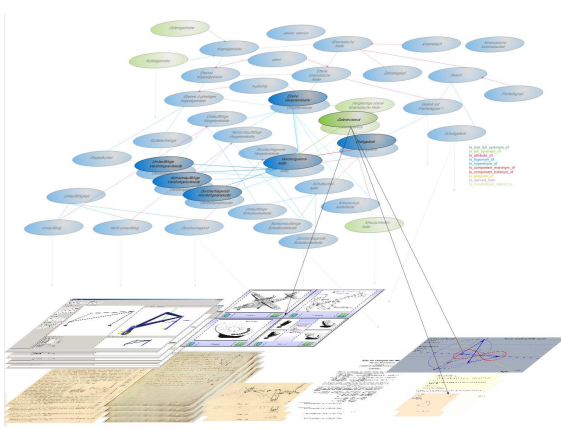
Fig. 6: Semantic meta-layer

With the help of this semantic meta-layer the different hierarchies can modeled and visualized. This enables a user to decide which structuring system he wants to use for navigation.

Currently a Topic Map based "**S**emantic **I**nformation **R**etrieval **EN**vironment for digital libraries" (SIREN) is developed to support the complex development process of the semantic meta-layer and the information retrieval process. SIREN consists of three prototypical systems, which are developed as part of the DMG-Lib:

- **TMwiki** (Topic Map Wiki) [10, 16] enables a collaborative development of semantic meta-layers in a wiki environment.

- **TMV** (Topic Map Visualizer) [10] provides an user-friendly interface for visualization, presentation and navigation in the semantic meta-layer, a graphical topic-based definition of information needs and the presentation of the search results in the semantic context.

- **MERLINO** (Method for extraction and retrieval of links for occurrences) [9, 16] is able to identify relevant information resources for a defined information need automatically. The prototype identifies relevant information resources by querying the database of the digital library based on the knowledge stored in the semantic meta-layer.

Based on the semantic information and with the help of SIREN the structuring and the retrieval in the available heterogeneous information resources of the DMG-Lib can be enhanced.

4. Conclusion

In this paper the DMG-Lib project is presented, a digital and interactive library for mechanism and gear science. Aim of this project is the collection, preservation and suitable presentation of the worldwide existing knowledge about mechanisms and gears. Outstanding features of the digital library are the powerful and user-oriented internet portal and the integration of a high amount of very heterogeneous information resources relevant for this field of application. The extensively post-processing and enrichment of the digital data with various additional information like animations or constraint-based models is also important. Combined with the development of new interactive multimedia applications and a semantic information retrieval environment, the DMG-Lib provides users with an innovative access to the stored knowledge in the library.

The DMG-Lib project is an example for a modern knowledge space, which tries to satisfy the users' needs for an efficient access to required information as one of the key tasks in our today's information society.

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