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The Collection of Mechanisms within the Digital Mechanism and Gear Library (DMG-Lib) – A Knowledge Base for Engineers, Scientists and Students

1 Introduction - The Digital Mechanism and Gear Library (DMG-Lib)

Mechanical motion devices are reliable and fundamental parts of modern technical products. During the period of industrialisation mechanism science was systematized and established as an important discipline in the domain of general machine science by contemporary engineers like Reuleaux, Watt and Evans. The principles of mechanical motion and kinematics were developed and documented in textual form and also in a very demonstrative form of fully functional kinematic models. Modern designs still using advancements of those basic mechanisms which are known since industrial revolution. But the global knowledge about mechanisms in theory and application is mostly scattered and only fragmentarily accessible for users like engineers, scientists or students and it does not comply with today's requirements concerning a quick information retrieval.

The Digital Mechanism and Gear Library (DMG-Lib) can help to resolve this problem and will avoid the sneaking loss of knowledge in this field. In the DMG-Lib heterogeneous sources, which represent a big part of the knowledge about mechanisms, are collected, preserved and provided over an Internet portal (www.dmg-lib.org). The interdisciplinary DMG-Lib workgroup is lined up by staff from the Technical University of Ilmenau, the RWTH Aachen University and the Technical University of Dresden. The DMG-Lib project is supported by the German Research Foundation (DFG).

The variety of the relevant heterogeneous content sources of the DMG-Lib ranges from technical books, journal articles, research reports, mechanism catalogues, technical drawings over physical demonstration models, pictures, movies, interactive animations to software tools. A lot of these sources contain representations of mechanism structures in form of technical drawings, solution principles or images. These mechanism structures, extracted from scanned or digital sources or taken as image sequences from physical models, form together with mechanism-specific metadata so-called mechanism descriptions inside the DMG-Lib.

Enhanced with additional sources such as interactive animations, videos, pictures or hyperlinks to pages in literature, the collection of these mechanism descriptions provides in combination with mechanism-specific search functions a powerful, via Internet accessible knowledge base for design solutions in the field of mechanical motion systems.

The interactive animations or the videos provide a visual impression of the certain motion-characteristic; additional literature offers more background information about engineering methods like analysis and synthesis techniques for example. In this way an engineer for instance can find possible solutions for his unique motion task; students at universities get a better understanding of motion systems and have an easy access to rare literature and to a lot of other helpful content.

With a typical motion task the specific search functions and the presentation of the search results inside the DMG-Lib Internet portal are presented in this article.

Furthermore the collection of mechanism descriptions within the DMG-Lib, the custom workflow for the creation of these descriptions, beginning with discovering or locating of relevant content sources over further processing steps such as digitalization, quality improvement or finding descriptive metadata for mechanisms, are be shown.

2 Solving motion problems by using the DMG-Lib

Solution-catalogues are the state-of-the-art tools for solution determinations in construction methodology [1], [2].

Person in Charge: Kg Page 1 of 1 Date: 01.01.2009	bottle station DMG 001	
		requirement specification

No.	requirement
	… …
10	vertical translation between stations: > 100mm ⇨parallel motion of bottle ⇨dwell period in turning back position for bottle exchange
11	low acceleration of bottle input
12	available space is restricted ⇨frame joints ⇨packaging in factory outlet
13	reliable, low-cost mechanism ⇨robust layout ⇨maintenance

Figure 1. Excerpt of the specification sheet for a conveying system of a bottling station

With a simple, but nevertheless typical engineering design problem (Figure 1), the use of the mechanism collection inside the DMG-Lib during the design process is presented in the following.

A mere mechanical conveying of open bottles in vertical direction inside the bottling station is the main requirement. This kinematic task has to be achieved in the final facility by the demanded mechanism. Those straight kinematic requirements are often constrained by typical secondary tasks, such as:

- Kinematic tasks: constructed and working space, type of operation, maxima of the moving parameters (speed, acceleration).
- Dynamic tasks: maxima of the stress of joints, components, drives; force, output and mass compensation; vibration characteristics.
- Other secondary tasks: accuracy, durability, costs.

To solve the given motion problem by using the DMG-Lib, the mere functional descriptions and the technical requirements must be transformed into a clear search query for the DMG-Lib database, containing the mechanism descriptions. Even if there is still a free formulation of requirements in the specification sheet permitted, the formulation of the motion task in theory must be reverting to an explicit and controlled vocabulary which is realized by the structure of the database and the database search functions.

The search forms inside the DMG-Lib Internet portal provide the user a search with specific descriptive criteria for mechanisms. The structure of these search forms and the selectable features require the metadata concept [3], [4], which was developed for the description of mechanisms in the database. Detailing the motion problem is being realized by using three form sheets (Figure 2), which allows the input of free strings or pre-selected attributes.

At first, the motion task must be classified. Therefore the user can assign his problem to typical subtasks. The ***Structure of mechanism*** form sheet contains the basic functions of the mechanism such as the transformation of motion and the structure. The kind and number of inputs, the type of contained fundamental mechanisms or the maximum number of links are a few possible requirements that can be set here. The form sheets for the sub-tasks ***Guidance function*** and ***Transfer function*** can be selected depending on the intended application of the searched mechanism.

Figure 2. Specific mechanism search forms inside the DMG-Lib portal, (settings for the discussed example are in the guidance function form top right)

In the domain of guidance mechanisms, a defined link or part of the mechanism has to follow a desired path. The main task for transfer mechanisms is to realize the motion of the output according to certain transfer function to accomplish the transmission of power. The above quested mechanism to convey the bottles is according to these sub-tasks a *guidance mechanism*. As a result of the specification sheet, the open bottles have to move along a path from one station to the other and to avoid loosing its content; the motion of each bottle has to be *parallel* and the coupler curve is *closed*.

After setting all known features and parameters in the search forms (Figure 2, top right), the server of the DMG-Lib portal gets a database query and returns a search result.

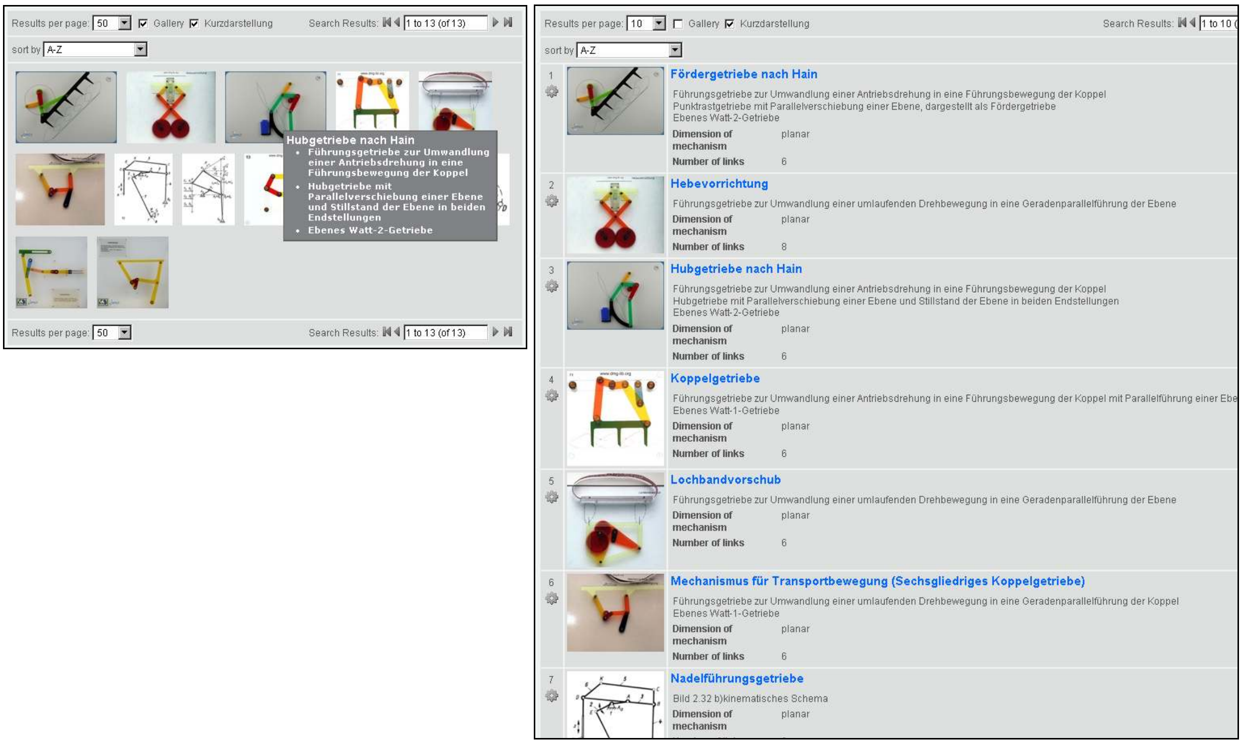

Figure 3. Display of search results: gallery view with "tooltip" or mouse-over text (left) and a list view with short descriptions of mechanisms (right)

In our specific case of finding a proper conveying mechanism, all datasets with matching guidance properties are returned and displayed in the portal website (Figure 3). Using a gallery view with thumbnail images and descriptive mouse-over texts a quick comparison of all possible mechanisms can be done and candidates can be selected for further investigation by using a detailed mechanism description (Figure 4, left side).

According to our mechanism search, a six-bar solution for realizing the desired motion task is chosen. Based on a Watt-2-mechanism a parallel translation of the coupler with additional dwell periods in both turning back positions with revolving input motion is given. At the detail page all available additional digital documents are listed. An interactive animation of the corresponding physical mechanism model (Figure 4, right side) allows a visual impression of motion and completes this early phase of synthesis by finding a suitable principle [5] by assistance of the DMG-Lib. Getting deeper into design process, means to adopt the chosen principle to the bottle station.

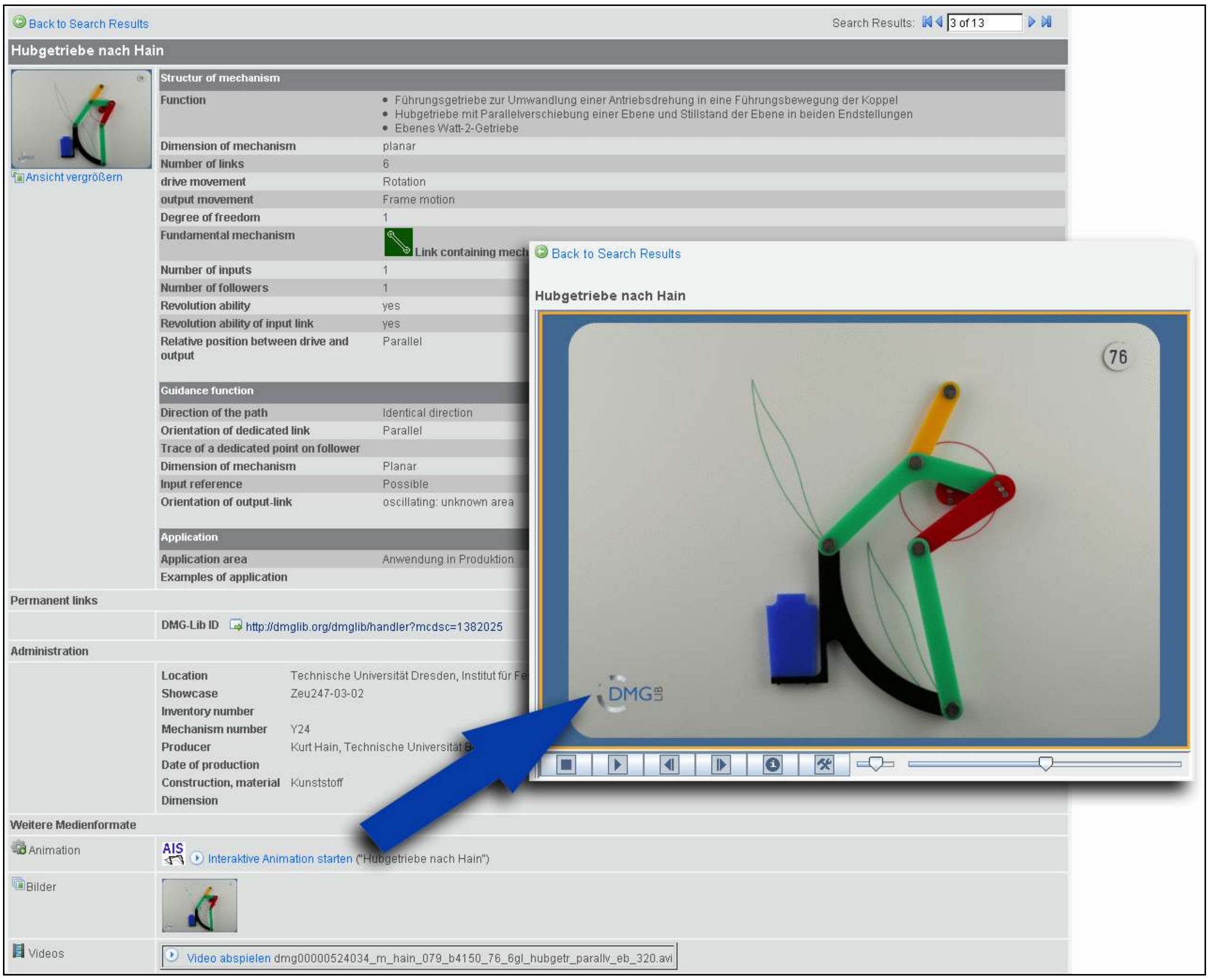

Figure 4. Detail view of mechanism description (left) and started interactive animation (right)

The logical step of scaling kinematic admeasurements often leads to good results, so the design process can advance to the stage of shaping and detailing the design solution. In case of violating constraining secondary tasks, an iterative synthesis step can follow. For this purpose the DMG-Lib provides literature, describing synthesis methods for four-bar mechanisms and gives a lot of additional information in the domain of measurement synthesis. Applying Roberts' / Tschebyscheff's theorem of multiple generation of identical coupler curves will lead to a new design using the same principle and the same kinematic structure as the mechanism found in the database, but with arbitrary joint positions and dimensions. To get more information for this, the full-text search inside the DMG-Lib documents with a to-the-point search result visualization and text highlighting (Figure 5) can be used.

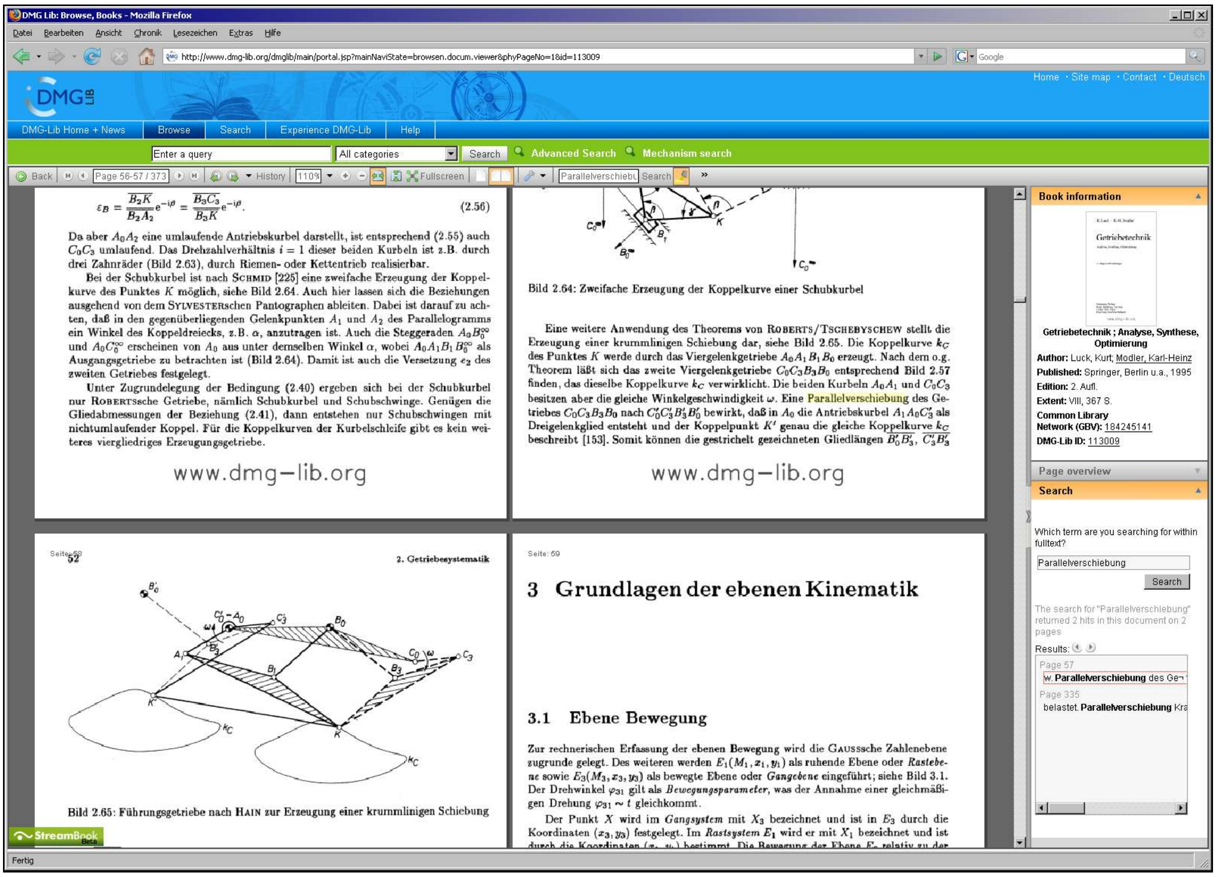

Figure 5. Using full-text search with a to-the-point search result visualization and text highlighting for finding information about synthesis techniques

3 The workflow of creating mechanism descriptions for the DMG-Lib

To allow a reasonable search in the DMG-Lib Internet portal for solving a motion task, as much as possible mechanism descriptions must be collected in the DMG-Lib database. Content sources as the basis for mechanism descriptions are physical models, pictures, movies and animations but also figures in literature such as technical books, journal articles, research reports, patent specifications or mechanism catalogues.

A lot of these sources contain structures of mechanisms in form of technical drawings, solution principles or images. The workflow of creating mechanism description sets from content sources is illustrated in figure 6.

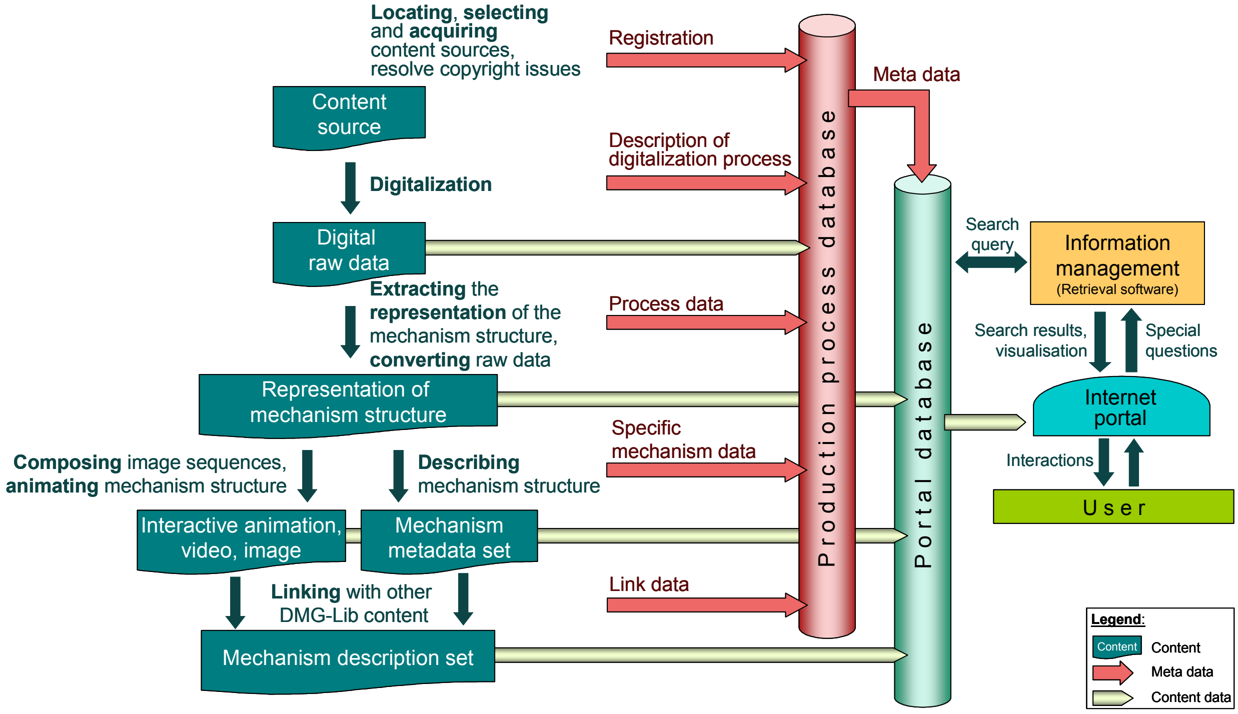

Figure 6. Workflow of creating mechanism descriptions for the DMG-Lib

The first step in this workflow is to discover or to locate the relevant content sources. Institutes for mechanism science at universities support the project by providing physical demonstration models (Figure 7, left side). University libraries and in difficult cases the authors provide literature (Figure 7, right side) for processing in the DMG-Lib project.

Figure 7. Physical demonstration models from the University of Hannover (left) and figures and descriptive texts in books (right) as examples for content sources for mechanism descriptions

After acquiring, or better said borrowing, the content sources are digitized with different technical equipment depending on the kind of the source. Literature and all types of printed media sources are digitized by using a commercial book scanner with a pneumatic driven book holder for a gentle handling (Figure 8).

Figure 8. Workstation with a commercial book scanner for digitalization printed media sources

For the digitalization of physical demonstration models a workstation with a digital (photo) camera, a variable lighting system and a PC-controlled stepper motor was developed (Figure 9). For each series of models an individual adapter between the motor and the model input and an invisible fixing for the model must be designed. A customized lighting position for each series and sometimes for each model is necessary to get contrasty and nearly shadowless images.

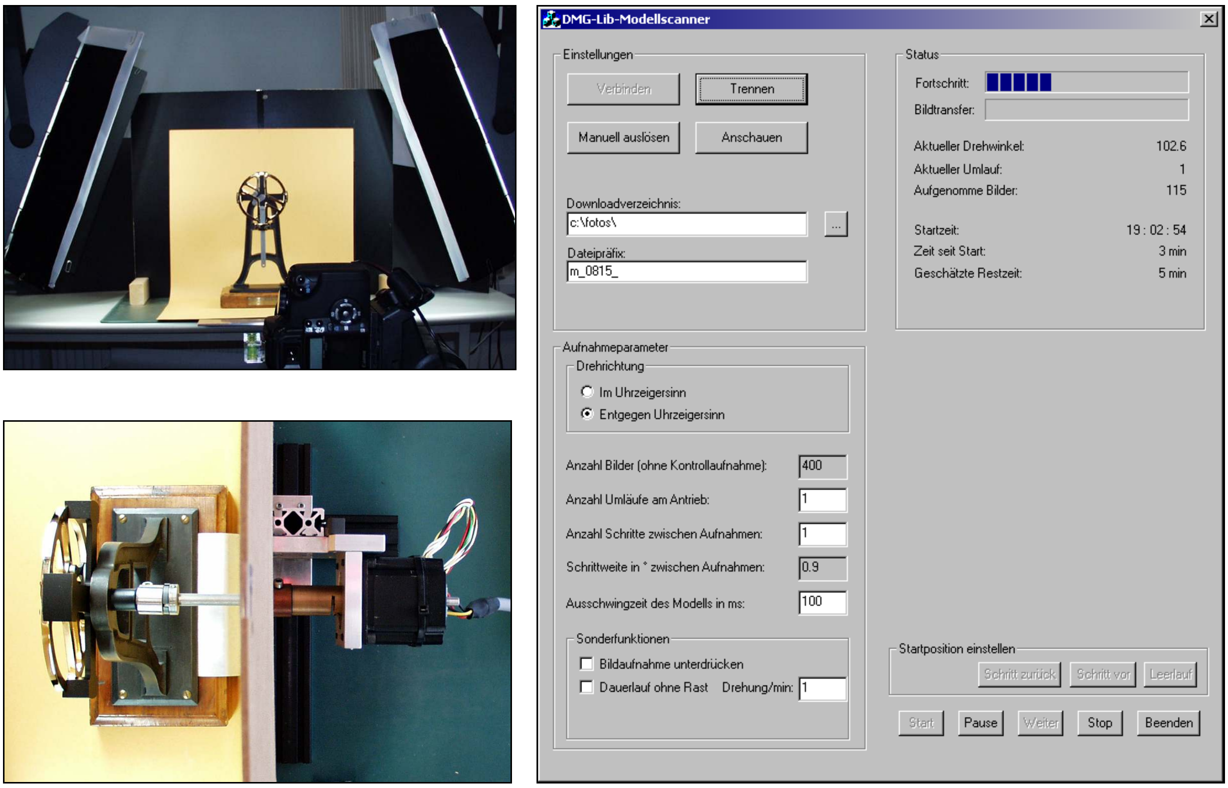

Figure 9. Workstation for digitalization physical demonstration models (top left: front view, down left: top view) and software for controlling stepper motor and camera (right)

The stepper motor drives the model step by step and the camera takes a photo after each step. The stepper motor and the camera are controlled by a PC. The controlling software allows different settings depending on the peculiarities of the models. In this way from each model a sequence of usually 400 images per turn is recorded.

Extracting the representation of the mechanism is the next processing step in the workflow. For the recorded image sequences only cutting and optimizing steps are needed. The scanned book pages or other digital text documents can be processed with a software tool, developed in the DMG-Lib project (Figure 10). By using this tool figures with representations of mechanisms can be extracted, cut and uploaded to the DMG-Lib database as the basis for a new mechanism description sets. The associated figure titles and maybe existing mechanism descriptive text passages can be edited and added with semantics to the new generated mechanism description sets by this tool.

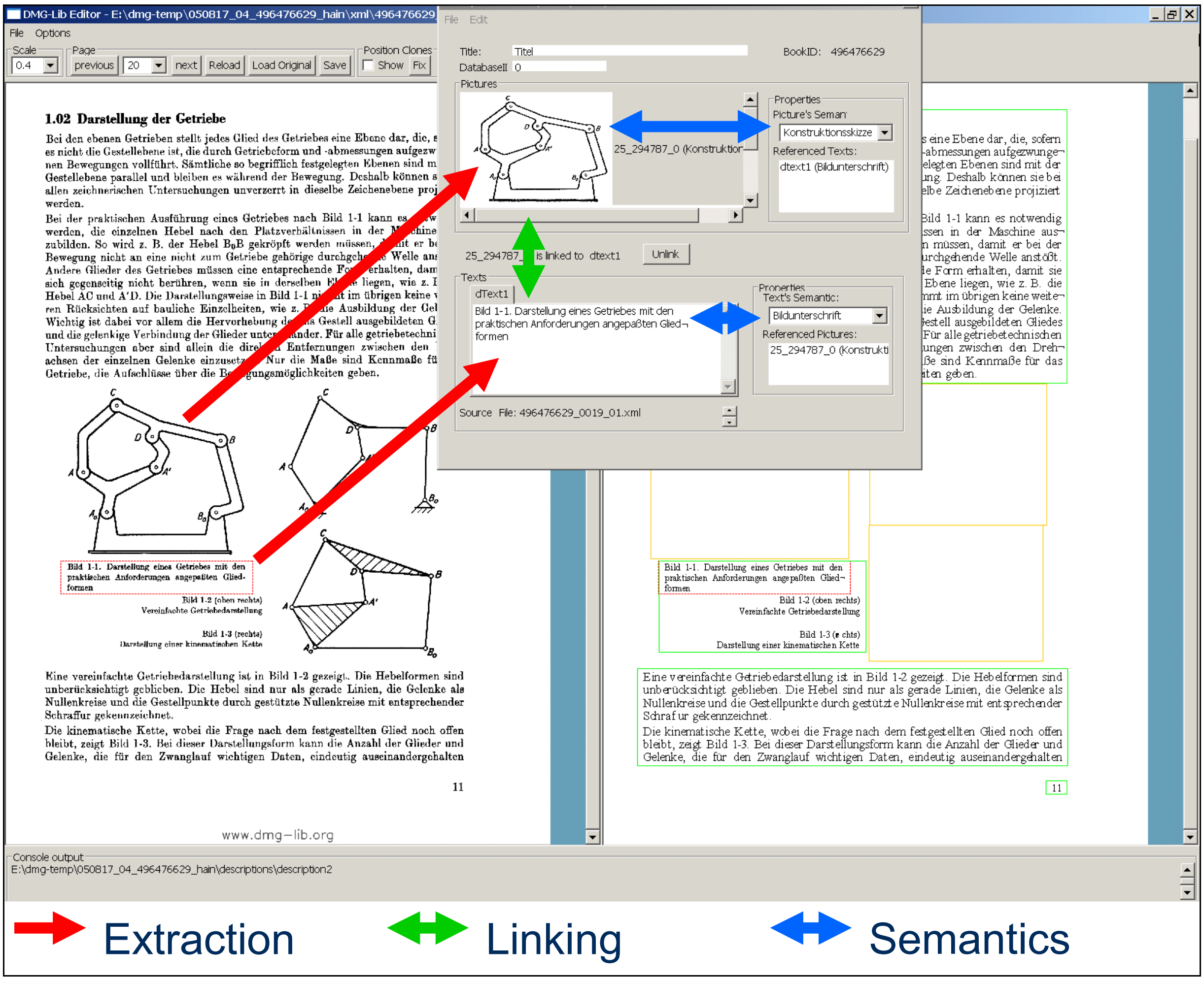

Figure 10. Software tool for extracting representations of mechanisms and associated text passages or figure titles as well as settings of semantic relations (left: scanned book page as pixel image, right: OCR result with recognized text and picture areas)

In the next workflow step, extracted representations of mechanisms which are difficult to understand how they work can be animated by the simulation software MASP (Modelling and Analysis of Solution Principles – free trail version available at DMG-Lib portal). The output of this software is an image sequence of the mechanism motion, similar to the taken image sequences from the physical models, in various possible styles such as solution principle style or original book style. With further handling steps, the image sequences are composed to interactive animations, which can be started inside the DMG-Lib Internet portal (Figure 4) with a special player.
The next important step, which is typically done by experts in mechanism science, is to determine descriptive metadata for each mechanism and to link it to similar or equal mechanisms or to further DMG-Lib content like literature, images, videos or animations. In this way a mechanism description, which is the basis for the mechanism search inside the DMG-Lib portal, is formed by the representations of the mechanism together with the descriptive metadata and the links to other content.
The mechanism descriptions as well as all other relevant information data of the DMG-Lib workflow process are recorded in the production process database (Figure 6). The internal structure of this database was developed in an early project phase and the layout was influenced by former research results [3],[9]. By implementing a relational database system, each mechanism is represented by a single mechanism dataset. All known structural, functional and administrative data for a mechanism are thereby stored as metadata for the related mechanism description dataset. According to the workflow,

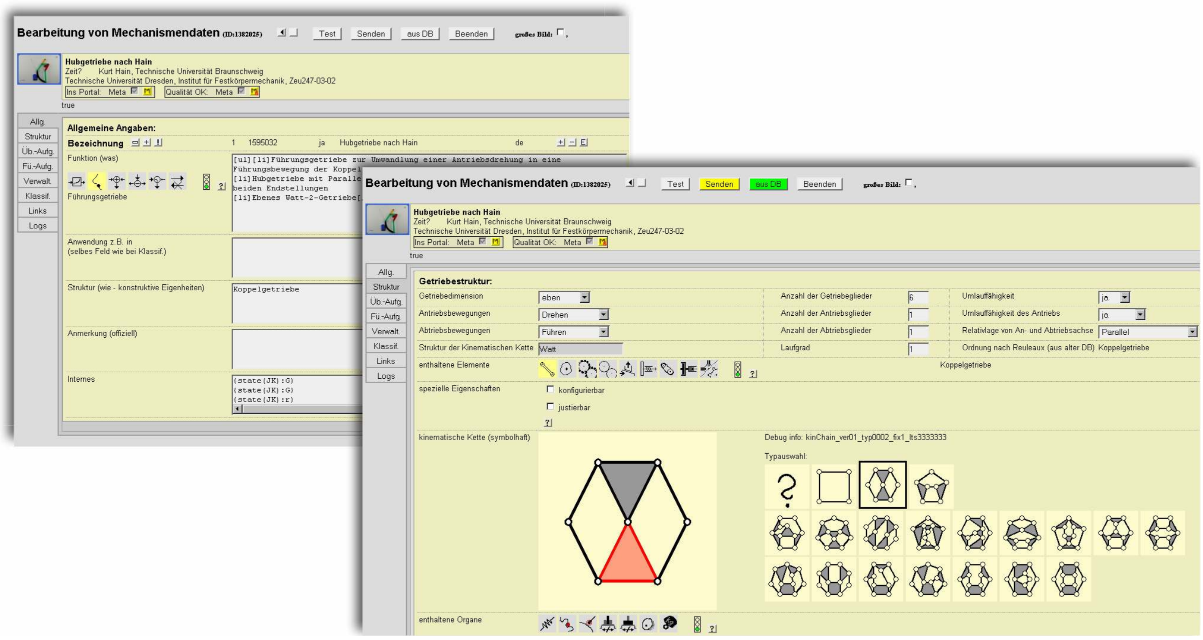

Figure 11. Examples of input masks in the production process database for basic criteria (left) and for structural criteria (right)

each mechanism is registered to the production database by creating its base dataset and adding all obvious characteristics information (e. g. location or origin, owner, creator or creating date).
In the basic section of each dataset a name is given and the motion task is classified and described in a brief form. For this description, itemized and standardized phrases are used to ensure a consistent textual form (Figure 11, left side). Also a further classification can be made here, if typical industrial applications for the mechanism are characteristic. This criterion can be toggled as one additional filter for narrowing and grouping the amount of results at the DMG-Lib portal. The concept of relational dependencies also allows interconnecting mechanism datasets to each other. By specifying the grade of relation, similarities of function or structure can be marked. One of the strongest advantages of the developed database is the possibility of rating the grade of relation and therefore the ability to express the similarity of different mechanisms. This information allows, beyond grouping and arranging search result pages, the identification of mechanisms with similar structures or similar application domains. For this reason structural parameters are used to classify mechanisms by their internal structure and containing internal parts and elements with supporting function (e.g. low friction joints). The kinematic chain is a fundamental visual description medium and can be achieved by an interactive graphical oriented input field, which is currently under development (Figure 11, right side). Properties depending even on structural elements and also on the exact admeasurements like the ability to revolve or the resulting degree of freedom are placed in the structural section of the mechanism dataset, too.
In further input masks the mechanisms can characterized by its transmission or guidance functions such as the form of the transfer function or the provided coupler curve. To allow the application-oriented adoption of a mechanism search as introduced above, every mechanism is described by its characteristic abilities to provide motion.

4 Conclusions

The Digital Mechanism and Gear Library (DMG-Lib) is currently the largest via Internet available digital library in the domain of mechanism and machine science. According to fundamental design methodology, this library can be instrumental in the process of designing motion devices and solving motion tasks by using mechanical solutions. It can be a very helpful tool in the everyday work of engineers, scientists and students. Due to its different approaches in providing information, DMG-Lib is a versatile and a fast accessible information resource to refresh personal knowledge about engineering techniques and specific analysis and synthesis methods. The collection of mechanism descriptions inside the DMG-Lib is one of the most comprehensive repositories in the world, which is providing searchable descriptive metadata, interactive animations of mechanisms and linked additional information. The metadata offer powerful result-oriented search functionality and a well structured and customizable representation of knowledge about mechanisms in contrast to other digital libraries and collections. The future scope of the DMG-Lib project is to increase the amount of available documents by a global orientation, to improve continuously the used technologies or tools and to establish an international community of contributors sharing their knowledge to each other.

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