Digitization and 3D Modeling of Movable Books

Pierre Cubaud, Jérôme Dupire, Alexandre Topol
{cubaud, dupire, topol}@cnam.fr
Centre d'Etudes et de Recherche en Informatique (CEDRIC)
Conservatoire National des Arts et Métiers (CNAM)
292 rue Saint-Martin, 75003 Paris, France

Abstract
Movable books provide interesting challenges for digitization and user interfaces design. We report in this paper some preliminary results in the building of a 3D visualization workbench for such books.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**] : User Interfaces - *Interaction styles, Prototyping.*

General Terms
Design, Experimentation.

Keywords
Digital Library, 3D Interaction, Virtual Reality.

Motivation and background
Movable books have a long and fascinating history that can be traced back to the middle ages [1]. They were at first designed for didactic purposes or as paper-based computational tools. Since the 19th century, movable books are mostly produced for children recreation and use a never-ending variety of animation techniques. In this paper, we focus on the former category for an on-going experiment on the digitization of scientific antiquarian collections: the *Conservatoire Numérique des Arts et Métiers* project (http://cnum.cnam.fr).
The virtualization of movable books has several advantages since, most of the time, the damage caused by repeated handling of the animated parts prohibit their public access. On the other hand, it is understandable that their proper digitization is difficult and that specific interfaces have to be created.
3D interfaces for book reading and collections browsing have been studied in [2, 3, 4]. None of these interfaces can handle the complex interactions required for the handling of movable books. Animated pages are built using several types of movable parts, such as volvelles, wheels or flaps. More complex animations can be provided by linking movable parts together (pull-tabs, pop-up). We shall use as an example a work of the Renaissance engineer Salomon de Caus on the building of solar clocks. Figure 1 shows a page which includes a paper model of a gnomon. It is composed of two flaps which are initially overlapped. The final 3D model is obtained when both flaps are lifted. The reader is asked to properly place the model in front of the sun in order to read the current solar time. We discuss in the following sections the building process of a digital reconstruction of this page.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
Conference'04, Month 1–2, 2004, City, State, Country.

Digitization
Capturing the volumetric (3D) structure of warped documents has been pioneered in [5] using a structured light 3D scanner. It can be complemented using photogrammetry in order to obtain absolute metrics for the 3D triangulation [6]. However, these methods can't detect thin perpendicular edges and occlusions such as those shown in fig. 1. We then relied on conventional digital camera, capturing both faces of each movable part and the main page (5 images for our example). The model building rules must first be understood and all the faces of the moving parts have to be reachable without destruction.

Modelisation
The main goal of our work consists in describing in a formal way the organization of the systems we want to digitize. The movable parts can be described with the following attributes: a *Name* and a *Type* (flap, wheel, volvelle, pull-tabs, gatefold, harlequinade, etc.). For a given *Type*, specific geometric attributes (e.g. axis position and orientation, motion direction and amplitude, initial state) must be provided. Each part also owns front and back images. In the case of complex systems where many objects are connected together, we can consider the 3D model as a tree where

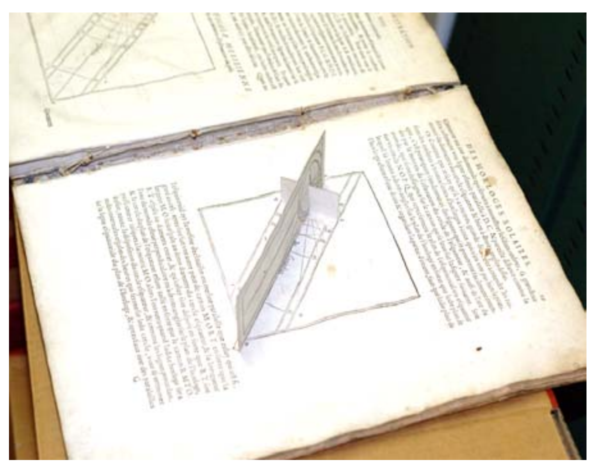

Figure 1. Salomon de Caus. *La pratique et démonstration des horloges solaires.* Paris, Drouart, 1624.

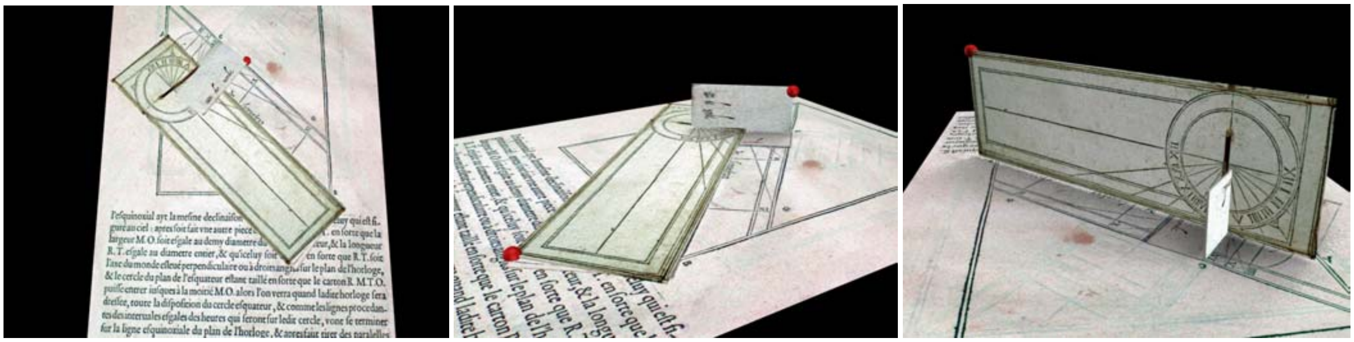

Figure 2. 3D reconstruction of the gnomon model.

the root is the current page. *Parent* gives the position of a specific part within the model's hierarchy. *Actions* characterize the type of interaction which the part enables and defines the parts affected by this action. Usual books can also be described using this hierarchical model where pages (and folded plates) are considered as large flaps linked by the binding. Table 1 shows the description of the movable parts of the gnomon model. The scheduling of lifting is important: the small flap (F1) must be raised before the large one (F2).

Table 1. Model's hierarchy

Part's Name	Type	Parent	Actions
Page	Root	(none)	(none)
F1	Flap	Page	Lift:self Block:F2
F2	Flap	F1	Lift:self

Interaction

The 3D rendering of the model in its initial state can be derived automatically from the hierarchy description. The visualization software must also provide to the reader handles for acting upon the movable parts. The handles appear in a sequence that respects the hierarchy of actions constraints.

Figure 2 shows screenshots of some 3D visualizations of the gnomon model. The (red) spheres located in the corner of the movable parts depict the handles. Fig. 2 (left) shows the model in his initial state. The user can only lift F1. When F1 rotation angle has reached its maximum value (fig. 2 middle), the user has then two choices for action (represented by the two spheres): either he moves back F1, or he moves F2 (fig. 2 right).

The screenshots were created with 3DstudioMax. They compare favourably with the original model on Fig. 1. The visualization workbench under development will use a library for simulating rigid body dynamics (ODE), in order to ease the motion constraints managing. The workbench should also provide to the user the free choice of his point of view. This feature is currently lacking in the environments described in [2, 3, 4].

Future work

We shall continue our study of the three aspects described in this report: digitization techniques, modelling and user interface. The animation of the movable book is only a part of a general reading activity and we shall next study how to integrate the visualization functions described in [2]. Many ergonomic issues are still open: more feedbacks should be provided to the user. For instance, adding a synthetic light to the 3D scene would produce a shadow for the gnomon and a better understanding of its use. More experiments with existing movable books are necessary in order to gain confidence in the hierarchical model. It could then evolve into a standardized metadata model for the physical structure of antique books.

References

[1] P. Haining. *Movable books, an illustrated history*. New English Library, 1979.

[2] P. Cubaud, P. Stokowski, A. Topol. Mixing Browsing and Reading Activities in a 3D Digitalized Library. *Proc. of ACM-IEEE JCDL'02*, Portland, USA, June 2002.

[3] S. K. Card, L. Hong, J. D. Mackinlay, E. H. Chi. 3Book: A Scalable 3D Virtual Book. *Proc. of ACM CHI'04*. Vienna, Austria, April 2004.

[4] Y.C. Chu, D. Bainbridge Jones, I. Witten. Realistic books: a bizarre hommage to an obsolete medium ? *Proc. of ACM-IEEE JCDL'04*, Tucson, USA, June 2004

[5] M.S. Brown, W.B. Seales. Beyond 2D images: effective 3D imaging for library materials. *Proc. of ACM DL'00*. San Antonio, USA, June 2000.

[6] P. Cubaud, J.F. Haas, A. Topol. Numérisation 3D de documents par photogrammétrie. *Proc. 8ème conf. francophone sur l'écrit et le document* (CIFED'04). La Rochelle, France, June 2004