

Building a collaborative network for the digital representation of engineering collections

SUSANA MEDINA, JOÃO PEDRO PÊGO, CÉLIA MACHADO, JOÃO CARLOS AIRES & JOÃO REBELO

Abstract

This paper charts a collaborative experience between university scholars and museum practitioners from two faculties of the University of Porto (Engineering and Humanities). It is based on an historic experimental apparatus with great research potential: namely a single-component aerodynamics balance used to measure drag and lift in bodies. This object is included in the museum collection of the University of Porto's Faculty of Engineering.

The case study concerns a collaborative network built with internal contributions and resources from the two faculties to support the creation of a digital means of communication and teaching using 3D Blender. The team shared the belief that digital technologies offer new opportunities for the discovery, preservation, representation, communication and use of university museum exhibits.

From the university team members' perspective, the different goals, motivations and knowledge creation processes, and the implications for the needs of preservation are examined. Finally, factors contributing to the success of the experience and the obstacles that challenged the collaborative process are discussed.

Foreword

Many university collections emerged through the accumulation of objects that were no longer used in their original teaching or researching contexts. Many university museums originated from the need to preserve research and interpret these collections. Understanding the significance, the new meanings and roles of these collections, both to universities and to contemporary society, has informed changes in the definition of the university museum's mission.

Despite a recent awareness of public interest, many university collections still remain untouchable treasures. Particularly in the engineering field, better understanding of an instrument often requires manual, mechanical or electronic manipulation. As a static display, collections speak little about themselves and the roles they played in teaching and research within the academic community.

Understanding an object means gathering information about it, and documentary research processes embody scientific and technical concepts and use present and past knowledge. Collection research also aims at a better understanding of the connection of objects to concepts and disciplines, and this research and initiative on the part of the museum can often result in renewed scholarly and scientific interest in the collections. The pedagogic potential is rediscovered and access to collections for classroom use is reclaimed.

University museums are also increasingly asked to contribute more significantly to informal education programs as part of their public agenda. In balancing the demands and needs of the academic community and contemporary society, the museum of the Engineering Faculty at the University of Porto has been looking at the most effective ways of telling the stories behind the knowledge produced in Porto's academy.

Faculty of Engineering, University of Porto: Academic context and history

The first Portuguese School of Engineering was founded in Porto, at the Academia Politécnica, and it became the Faculty of Engineering of the University of Porto (FEUP) in 1926. FEUP inherited some of

the teaching and research collections of the mid-18th Century onwards, but records show that its collections have been reorganized, dispersed and, some of them, lost through administrative changes. In 2000, FEUP moved to a new campus situated in northeast Porto. The move from the former premises triggered an internal drive for the creation of a museum at FEUP. This was created in 2003 within the structure of the Documentation and Information Services (SDI) that also comprises other units such as the library, archive, information systems and publishing. Each of these units has a specific mission, resources and personnel, and through integrated work practices, the new creative technologies and the storage, dissemination and communication of information all play a relevant role. The information strategy of SDI is based upon the existence of a repository of digital objects coming from the various units' resources and activities. Within this strategy, SDI offers specific content types in its portal in order to support the information needs of the academic community and external users.

As a formal structure with trained curators, the museum's specific mission for FEUP's collections is to accommodate and study historical teaching and research collections; to create collections with objects that have lost context; to provide access to FEUP collections both to internal and external publics; and to appreciate their significance and potential to the FEUP community, the university and to society (FEUP 2008).

Nowadays, FEUP's heritage comprises 1,300 individual objects organized according to their provenance in teaching collections, by-products of research activity, equipment formerly used for teaching and research and academic memorabilia. The museum's collections remain inaccessible to the general public for a number of reasons. Nevertheless, public access to collections has been possible through exhibitions, publications and digital platforms, which are empowered through research team programs involving the museum staff, tutors, students and technicians from FEUP, as well as students on internship programs from the Porto University Humanities Faculty, all of whom are engaged in collaborative networks.

Building a collaborative network for the digital representation of engineering collections

Since its very beginning, several fortuitous coincidences steered this project towards a collaborative model. The staff of the museum was studying an aerodynamic balance from the aerodynamics collection, an apparatus that consists of a heavy base with vertical rod and adjustable boss on which the balance beam is mounted. Depending on the position the balance beam is mounted, it can be used to measure lift (fig. 1) or drag (fig. 2).¹

¹ An object moving through a gas or fluid (a car in air or a swimmer in water, for example) or an object around which a gas or fluid flows (like the pillar of a bridge or a skyscraper) experiences several forces bearing in different directions relative to motion. The two most important and easily recognised are drag and lift.

Drag is a force that opposes the relative motion of the object and gas or fluid and is integral to the resistance produced by the impact of gas or fluid particles on the surface of the moving object.

The correct measurement and prediction of drag is basic for many everyday applications: Knowing the drag a moving car experiences is necessary to choosing the correct engine; in order to beat records, swimmers use bodysuits that reduce drag; the construction of a skyscraper requires previous knowledge of the wind induced drag for the correct design of the supporting structure in terms of resistance and comfort (vibration of the building).

Drag depends on the velocity, size and shape of the object as well as the gas or fluid properties like density and viscosity, and is commonly presented in the form of the dimensionless drag coefficient C_D . This coefficient, which is scalable with the object size, is defined in equation (1)

$$C_D = \frac{F_D}{\frac{1}{2} \rho v^2 A}, \quad (1)$$

where F_D is the drag force, ρ is the fluid density, v is the object velocity and A is a reference area (normally the frontal area). The higher the value of the drag coefficient, the higher will be the object's resistance to motion. Streamlined objects like aeroplanes have small values of drag coefficients and thus are energetically efficient.

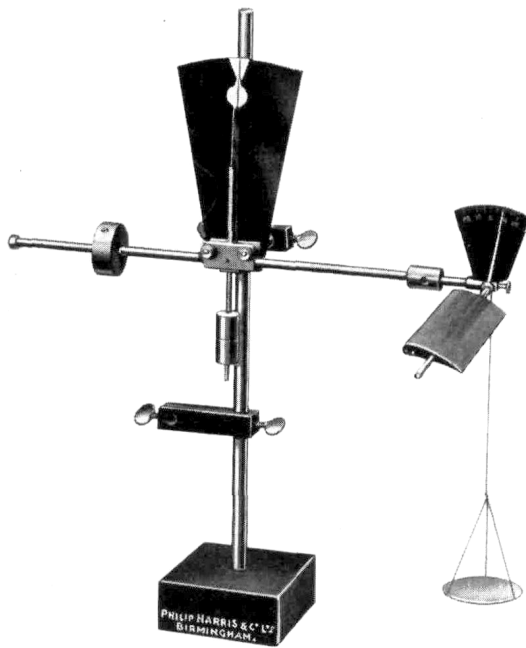


Fig. 1 - Aerodynamic balance fitted for lift measurements: the model facing the wind stream will experience a vertical force that will create a torque imbalance and lift the model. Placing weights on the balance pan until the pointer returns to the original position will balance the generated lift and give its measurement. (Image from a Philip Harris Limited catalogue.)

1. Wing model
2. Sliding weights
3. Zero position indicator
4. Angle of incidence scale
5. Scale pan
6. Heavy base

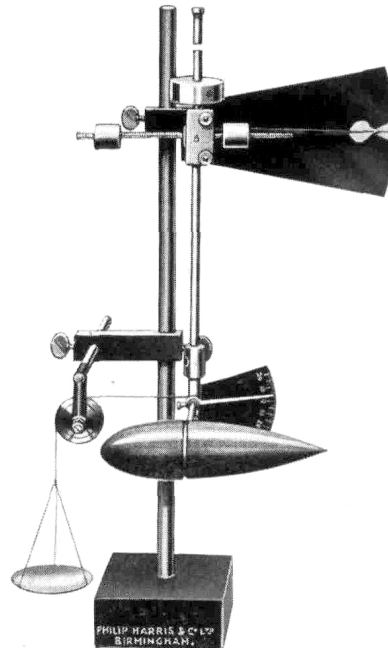


Fig. 2 - Aerodynamic balance fitted for drag measurements: the model facing the wind stream will suffer a force in the direction of motion of the wind that will be balanced by the weights in the balance pan attached to its support. (Image from a Philip Harris Limited catalogue.)

1. Streamlined model
2. Sliding weights
3. Zero position pointer
4. Angle of incidence
5. Scale pan
6. Heavy base

The materials and construction of the aerodynamic balance suggest it was built in the first half of the twentieth century (possibly the late 1930s). A catalogue provided by the manufacturer (Philip Harris Limited, Birmingham) from the 1950s includes this object. FEUP archive documents refer to its acquisition in the 1950s.

The construction of the aerodynamic balance suggests that it was used for demonstration purposes rather than for measurements in scientific experiments. The available study objects (streamlined body, sphere) support this idea since these are classic examples of fluid mechanics bodies. Until the 1970s, students could visualize certain aerodynamic concepts and acquire the knowledge that they would later use in their professional practice. In class, the aerodynamic balance could be used to explain the effect of drag, the influence of velocity, body shape and angle of incidence (angle between the direction of the flow and the axis of the body) in drag value. The balance was positioned in front of a small wind tunnel, with the object of study aligned with the inflow direction. Experiments like this were popular in engineering schools, since they provided direct student interaction with the problems to be solved. In recent decades, the use of this equipment in the classroom decreased due to acquisition

Lift is produced by some streamlined bodies with special shapes like aeroplane wings. It acts in a direction perpendicular to the relative motion between object and gas or fluid, and is the force that makes aeroplanes lift and remain airborne. The correct measurement of lift is also important as it defines how much weight can be sustained without falling.

and maintenance costs associated with mechanical models. The growing number of students in faculties also made demonstrations possible only for small tutorial classes.

The didactic potential of this apparatus and providing classroom access to it were the two main reasons that led to the creation of a digital representation. From the beginning, the physical preservation of the original object was a major concern: there were signs of deterioration such as deflections, scratches, corrosion, loss of bright metal surfaces and fine craquele coating. For this reason, the handling and use of the original object had to be done with care.

The first solution put forward by the research team was to create a replica, but it soon became evident that in the end it would be just a repetition of information. For the staff of the museum, there was also awareness of the multi-communication processes that surrounded this object, and the concepts, principles and ideas embodied in it.

“Besides its function of adequately transmitting information, the museum object is also a ‘thinking device’, a cultural tool for generating meaning. And the driving mechanism of generating meaning is the potential for a given object [...] to support multiple interpretations and activities” (ROWE 2002, 31).

The authors were looking for a medium to communicate the object in the most profound and accessible way and to represent the immaterial and meta-information associated with it. Creating a digital representation of the object in 3D format enabled the SDI digital information systems unit to surround this representation with a set of existing recorded contextual information. The potential of digital objects to become accessible to a diverse range of audiences, and the possibility to contribute to digital communities “across cultures, generations, and geographic boundaries” (FROST 2002, 86) were important factors to consider.

Apart from these qualities, two intrinsic characteristics of this apparatus, namely its aesthetic qualities and its mechanical properties, support the concept of a multimedia product. Finally, the use of collections in teaching and research environments is already common practice at FEUP: some items from FEUP’s Reuleaux Kinematical Collection have already been used in the last three years as study/project cases included in assignments for the Computer Aided Design and Manufacturing courses.

The project started in April 2009 and a temporary committee of experts was formed according to the specific needs of the research opportunity. Common principles of sharing and working together were agreed, as well as common operating rules and the responsibilities of each member:

- a museum curator, with competencies in museum studies and cultural planning, in charge of project design and management, and collection research;
- an assistant conservator, with competencies in conservation of cultural heritage, responsible for preventive and curative conservation;
- a masters student in museum studies, researching the aerodynamics’ collection;
- a professor of civil and environment engineering and researcher at FEUP, with specific competencies in hydraulics and fluid mechanics, responsible for the documentation of fluid mechanics collections;
- a multimedia developer at SDI – FEUP and masters student in multimedia at the same faculty, in charge of 3D modeling and animation.

The production workflow consisted of seven phases:

1. Inventory, preservation and research

a) selection, organization, description, assembling and preservation;

b) research on role of the object, origin and purpose, organization within collections (taxonomic, chronological), users, relationships and connections with other objects and the discipline in formal teaching and research contexts).

2. Analysis and documentation

- a) fluid mechanics analysis for modeling purposes, this was also important as a complement to the object research;
- b) definition and measurement of the components (fig. 3);
- c) assembling and alignment with wind tunnel;
- d) simulation for image capture (photo and video) as reference for modeling and animation processes.



Fig. 3 - Definition of the components

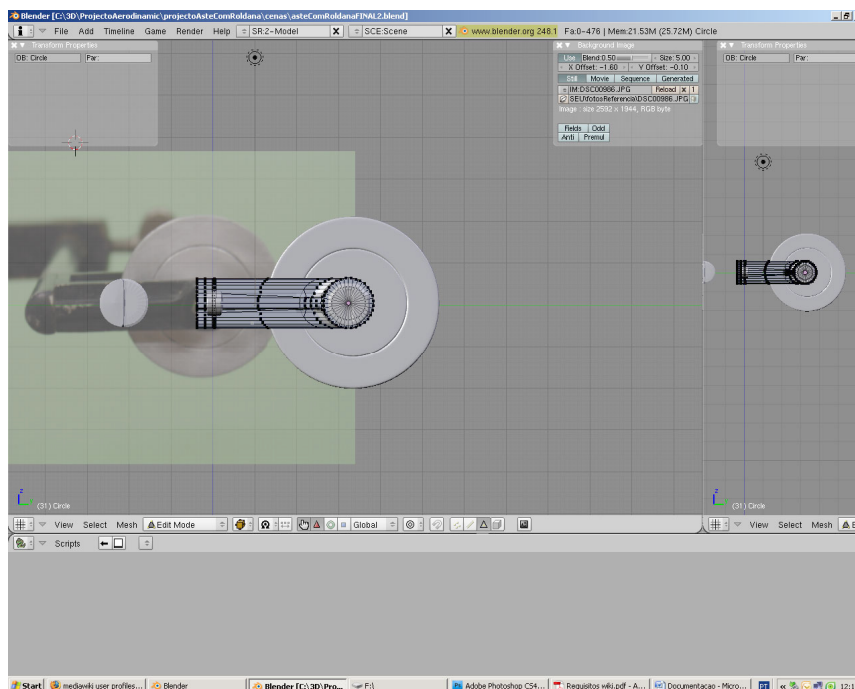


Fig. 4 - Subsurfing modelling of a component using 3D Blender

3. Modeling

- a) selection of 3D Blender as a versatile modeling software in terms of export formats compared to other 3D software packages;
- b) sub surfing modeling of every component using 3D Blender, individually (fig. 4);
- c) computational assembling of the components;
- d) rendering.

4. Rigging and setup for animation

- a) mechanical action-reaction dynamics;
- b) settling animation hierarchies.

5. Animation of the 3D digital model

- a) validation of the created animation;
- b) creation of appropriate key frames in the Blender timeline.

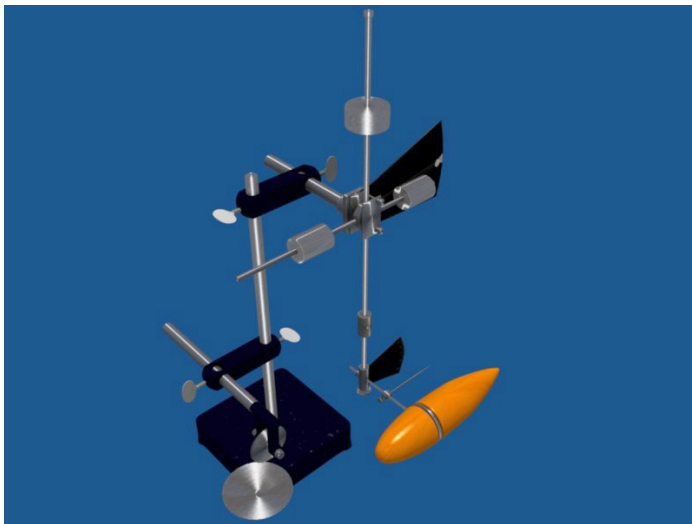


Fig. 5 - Production Pre-Render image

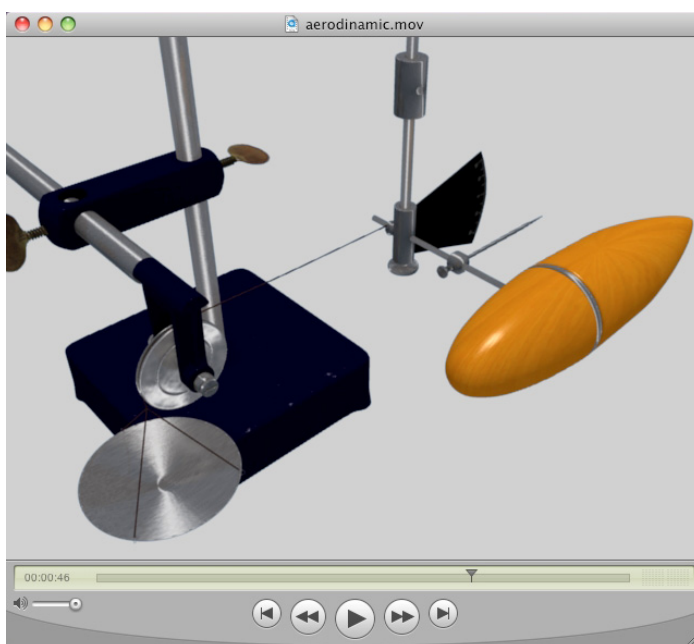


Fig. 6 - Screenshot from final animation rendering movie clip

6. Texturing

- a) identification of materials and detailed photos;
- b) creation of materials and textures in Blender, to insert in 3D modeled object.

7. Rendering

- a) definition of context uses – visual impact;
- b) application of the appropriate 3D rendering settings to produce a final animation with a high level of realism;
- c) animation export for video compositing.

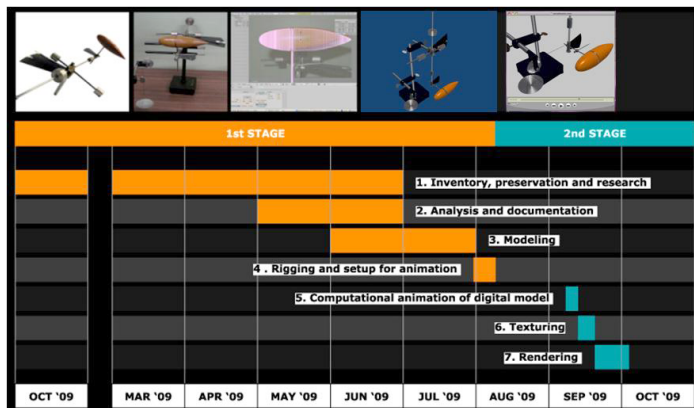


Fig. 7 - Project timeline

Further developments

The 3D model and animation will be stored and published in the SDI repository of digital objects arising from the various units' resources and activities. Contextual information to enable it to be used in different formats is also possible. A 3D model for classroom use, either as a pre-defined film or by allowing students to simulate experiments in a virtual wind tunnel will also be provided. A website describing the meaning and importance of lift and

drag measurement for many everyday applications, together with an explanation of the experiments, will be used to transmit this information to a wider public.

Main conclusions and remarks

Although these digital representations have not been submitted for public use and comment, there are some concluding remarks about the established network and working process as necessary conditions for starting a collaborative process to take into consideration.

These networks depend on resources, but first and foremost rely on a shared vision and an openness to new collection research methods. The success of the project was mainly due to a process based on the right partners with potential and ability (in terms of competencies and capacities), and other factors of a subjective nature such as trust, relevancy of the topic to every member of the team, effective involvement with the object and a shared institutional culture.

This interdisciplinary collaborative practice offered an opportunity for a broader and more profound knowledge of the object. The combination of technical and human approaches provided added value in the interpretation of the object. The project also allowed access to current and innovative knowledge produced in the departments of the university due to the participation of higher degree students and researchers.

However, some difficulties should be noted: projects like this are time consuming and costly in terms of effort and resources, and depend on academic timetables. Careful planning and a common collaborative infrastructure is needed.

In conclusion, the team members share the belief that the goals achieved would not have been possible if attempted individually. It is the authors' belief that the creation of a similar product through outsourcing would face a number of obstacles. On the one hand, there would be the need to create

more detailed guidelines in advance, and foreseeing all the details would be a difficult task for an experimental project such as this one. On the other hand, the time needed for the preparation of the guidelines could be incompatible with the current technological advances that the project required.

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Contact

Susana Medina, MA

Curator, Museum of the Faculty of Engineering of University of Porto

Address: Serviço de Documentação e Informação, Faculdade de Engenharia da Universidade do Porto, Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal

E-mail: [smedina\(at\)fe.up.pt](mailto:smedina(at)fe.up.pt)

biblioteca.fe.up.pt

João Carlos Aires

Multimedia Developer

Serviço de Documentação e Informação, Faculdade de Engenharia da Universidade do Porto, Portugal

E-mail: [jccas\(at\)fe.up.pt](mailto:jccas(at)fe.up.pt)

João Rebelo

Assistant Conservator

Serviço de Documentação e Informação, Faculdade de Engenharia da Universidade do Porto, Portugal

E-mail: [jrebelo\(at\)fe.up.pt](mailto:jrebelo(at)fe.up.pt)

Dr-Ing. João Pedro Pêgo

Assistant Professor

Secção de Hidráulica, Recursos Hídricos e Ambiente, Departamento de Engenharia Civil, Faculdade de Engenharia da Universidade do Porto, Portugal

E-mail: [jppego\(at\)fe.up.pt](mailto:jppego(at)fe.up.pt)

Célia Machado

Museum Studies Student

Curso de Especialização em Museologia, Faculdade de Letras da Universidade do Porto, Portugal

E-mail: [celiagodinhomachado\(at\)gmail.com](mailto:celiagodinhomachado(at)gmail.com)