3D modelization and the industrial heritage

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3D modelization is very well known today in industry and engineering but also in games. Its applications for culture and human sciences are more recent. However, the development of such applications today is quite important in archaeology with amazing results. The proposal of this communication is to show how 3D modelling, and more generally data knowledge, provides new perspectives for approaching industrial archaeology, between knowledge, conservation and valorisation, especially in museums. A new way for us to imagine contemporary archaeology: by the way not only new methodology but actually archaeology of contemporary objects. That is we are trying in Nantes associated laboratories (*Université de Nantes*, *Ecole centrale de Nantes*) in stretch collaborations with museums. This double point of view succeeds necessarily with interdisciplinary questioning between engineering and human sciences approaches for the development of digital humanities. We are trying today to enhance and develop our interdisciplinary methodology for heritage and museology in a new *ANR* resarch project, *RESEED*[1].

Interdisciplinarity for valorization

"When heritage becomes virtual"
Over the past 10 years, our research collaboration has focused on industrial heritage. It is an interdisciplinary approach between the *Centre François Viète*[2], a laboratory of history of science and technology from University of Nantes[3], and the *LS2N*[4], Laboratoire des sciences du numérique de Nantes, a mixt Research unity between *CNRS* , the *University of Nantes* and the *Ecole Centrale de Nantes*, and more precisely inside *LS2N*, the ex *IRCCyN*, a cybernetics laboratory from Centrale Nantes[5].

We are developing our common and interdisciplinary research with bijection between historical archives analysis, on one side, and data management and visualization, on the other side. A such approach allows us to propose for historians, museologists and the whole public multiple and crossed narrations from and about heritage objects

We founded together with our student team an informal resarch group we named *EPOTEC*, *Etude des procédés et des objets techniques* (Study of technical objects and processes). It is possible to see our common production on our website[6]

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[1] « Retro-conception SémantiquE d'objEts patrimoniaux Digitaux »,. http://reseed.ls2n.fr.

[2] http://www.cfv.univ-nantes.fr/.

[3] http://www.univ-nantes.fr.

[4] https://www.ls2n.fr/.

[5] https://www.ec-nantes.fr/.

[6] www.epotec.fr

Of course, we are not the first team to develop research for museology with new technologies and digital considerations. In France it is clearly possible to note some developments about these new preoccupations from the last 90's years. In 1996, an important congress organized by the *Ecole nationale du Patrimoine* held in Paris at *Bibliothèque Nationale de France* and permitted 400 hundred of scientists, museums and heritage specialists to listen forty communications on the subject[7].

Of course, we are not alone too. One of the most notable recent researches about industrial heritage and 3D modelization is the *ANR* program *Usine 3D*[8] supported by Alain-Pierre Michel from the University of Evry. Professor Michel held from years his scientific research about the story of automobile and especially *Renault* Company[9]. 3D modelization allows him to understand and explain the evolutions of the industrialization in the *Renault* factory in Boulogne-Billancourt and how really created and developed line work in the 20's. There are also other examples of automobile history in this project about *Citroën*, *Clement-Bayard* and *Peugeot*, with the collaboration of Paul Smith, Jean-Louis Loubet and others, who embraced different digital methodologies from technical and architectural 3D modelization to GIS (geographical information system).

More generally, 3D modelization is encouraged and supported by CNRS through the *Consortium 3D-SHS*. This group was initiated by Robert Vergnieux, the creator of *Archeovision* in 1993 at Bordeaux, one of the best center in archaeology and 3D modelization in France[10]. *Consortium 3D-SHS* is one of the groups of the *TGIR Huma-Num*, which is dedicated to federate the digital humanities in France in all its diversities[11]. *EPOTEC* at Nantes is an active member of the *Consortium 3D-SHS*[12].

All these researches proceed to develop an original point of view in the different approaches of digital humanities[13]. It is evident for all together digital studies must necessarily increasing in the same time than digital in the whole society, culture, economy and production. Human sciences are obviously for us in a central place. The originality of 3D modelization, not *a priori* a human science methodology, resides to insist on the complex relationship between material and immaterial culture in past and present, beyond the textuality.

"When industrial engineering becomes heritage"

Our projects are developed in a renewed interdisciplinary scientific approach. They are situated in the heart of the contemporary evolutions of the digital technology between

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[7] *Patrimoine et multimédia : le rôle du conservateur*. Colloque Paris, Bibliothèque Nationale de France, 23-25 octobre 1996, Paris : La Documentation française, Ecole nationale du patrimoine, 1997. For a recent example, Bernadette Saou-Dufresne (ed.). *Heritage and Digital Humanities. How should training practices evolve ?*, Zurich, Berlin : LIT, 2014.
[8] www.usines3d.fr/. Alain Michel, Stéphane Pouyllau. *Rapport final du projet " Usines 3D "*. [Rapport de recherche] Centre Alexandre Koyré - CRHST. 2011. <halshs-01592432>, https://halshs.archives-ouvertes.fr/halshs-01592432/document.
[9] Alain Michel, *Travail à la chaîne. Renault (1898-1947)*, Boulogne-Billancourt, ETAI, 2007
[10] http://archeovision.cnrs.fr/.
[11] https://www.huma-num.fr/.
[12] https://shs3d.hypotheses.org/.
[13] Anne Burdick, Johanna Drucker and alii, *Digital Humanities*, Cambridge, Massachusetts : the MIT Press, 2012. In French a short but very good synthesis by Serge Abiteboul and Florence Hachez-Leroy. "Humanités numériques". *Encyclopédie de l'humanisme méditerranéen*, 2015. ⟨hal-01120259⟩

the human and social sciences and the sciences for the engineer. To make a complete study, to establish a model, it is for us the base of research for the documentary and historical point of view and a base for the public too.

Our ambition is to speak about technical objects, machines, factories or port relations in the city and territory, earth, river or sea. It is to speak as long from the point of view of the town planning, of the architecture, of the formal study, that from the point of view of techniques and networks. Objects and scales are multiple: factories, workshops, places of production, but also in a larger way, understanding and explanation of traffic, circulations, and networks, wider point of view of the "territory" and history of the "landscapes".

The *CFV*, the laboratory of history of science and technology, and the *LS2N*, the laboratory of engineering, collaborate for 10 years together. This collaboration baptized *EPOTEC* focused in its beginning on the industrial heritage. This approach was immediately voluntarily interdisciplinary[14], but the separation between every specified domain remains still strong[15]: analyses and historical records on one side; management and valuation of data of the other one.
Highly rated engineering? You have to do specifications and format the data.
Highly rated historian? You have to understand in a double movement of separation / collaboration three bound problems around the very narrative:

    - Within the narrative: the studied subjects (technical, network systems) question the classic linearity of the narrative as the exclusive representation of the history.
    - Between narratives: the capitalization of the historic knowledge is essentially translated by the juxtaposition of autonomous and motionless narratives. When the production of the historian is natively digital technology, the hegemony of the book / article is questioned.
    - After the narrative: the exploitability and the valuation of the "simple" historian narrative are complicated.

The modelization as a scientific approach

"From engineering to heritage"

Our scientific proposition is to reverse the time axis of the design process, using tools and methods of virtual engineering. The beginning of the methodology was clearly an adaptation of the "reverse engineering"[16] used in factories and research and development. This new interdisciplinary, and reflexive, connection between history and

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[14] "La numérisation du patrimoine technique", *Documents pour l'histoire des techniques*, n°18, 2ᵉ semestre 2009. A topical theme of eight scientific propositions, introduction by Michel Cotte: "Les techniques numériques et l'histoire des techniques : le cas des maquettes virtuelles animées », pp.7-21.

[15] Florent Laroche, *Contribution à la sauvegarde des objets techniques anciens par l'archéologie industrielle avancée. Proposition d'un modèle d'information de référence muséologique et d'une méthode interdisciplinaire pour la capitalisation des connaissances du patrimoine technique et industriel*, Thèse, génie mécanique : Ecole Centrale de Nantes , Université de Nantes, 2007. 〈tel-00382703〉. For a first and short reading in English, Florent Laroche. "Advanced Industrial Archaeology and Techno-Museology: A new virtual life for industrial heritage". *TICCIH Bulletin*, 2008, pp.3-4. 〈hal-00422346〉

[16] *Reverse engineering*, also called *back engineering*, is the process by which a man-made object is deconstructed to reveal its designs, architecture, or to extract knowledge from the object, https://en.wikipedia.org/wiki/Reverse_engineering.

archaeology from one side and engineering and manufacturing on the other permits a new way to think the interactions between real object and virtual object[17].

The central problematic is to extend life-cycle comprehension for heritage objects to obtain its specific PLM (product lifecycle management)[18]. It is a KLM methodology, (Knowledge Life-cycle Management), who is extended here possibly far away in the past[19]:

- Past information of a specific object
- Contemporary information of the same object
- Relations between those two pieces of information in the past and present

The case of an heritage object is considered in the same way, from ordinary life to heritage life-cycle extension with its own problematic and scientific proposal, from objectives and constraints to proposition:

- Objectives: Create connections between physical object, digital representation and context information
- Constraints: Take into account temporal, physical and multidisciplinary aspects. Encapsulate complex and multi-scale systems: product, tool, machine, plant, city
- Proposition: Extend ordinary PLM with the long life-cycle of objects to museological PLM (product life-cycle management). Finally, obtain a *Digital Heritage Reference Model*, an operational framework, with process view and product view

The Digital Heritage Reference Model

The difficulty of the historical narrative in space and time is to construct knowledge between the crossed consideration of synchrony and diachrony. The very specificity of heritage scientific consideration is probably to add the question of passed time to present time. If we compare those historian or museologist considerations with engineer considerations, it is in fact possible to ally its own questionings about product and process. It means to bind product view and synchrony explanation, process view and diachronic explanations, during all life since passed creation until our daily presentation or valorisation.

Product view

The DHRM operational framework is overall a consideration about the association of objects and relationships constituting coherent items, exploring them with the exploitation of data and documentations.

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[17] Florent Laroche, Alain Bernard, Michel Cotte. « A new approach for preserving the technical heritage ». *conférence VRIC - salon Laval Virtual*, Mar 2006, Laval, France. 11 p., 2006, ISBN 2-9515730-5-7. ⟨hal-00473008⟩

[18] "*product lifecycle management (PLM)* is the process of managing the entire lifecycle of a product from inception, through engineering design and manufacture, to service and disposal of manufactured products. PLM integrates people, data, processes and business systems" https://en.wikipedia.org/wiki/Product_lifecycle .

[19] Florent Laroche, Alain Bernard, Michel Cotte. « Knowledge management for industrial heritage ». *Methods and Tools for Effective Knowledge Life-Cycle-Management*, Springer, pp.307-330, 2007. ⟨hal-00412066⟩

The object is considered in a large meaning to say process, product, components, Human or events we want to explore and valorise.
We have to consider two generic relationships:
- Direct, between real objects
- Indirect, between real object and abstract concept

The documentation is obviously composed of heterogeneous data, archives, papers, photos, sounds, videos, 3D scans …

Taking into account space and time needs overall explanation and comprehension; that is why the semantic consideration is so important for the meaning. That is a crucial question who engaged not only scientific data consideration in computer ontologies, but in the same time the way we understand the actual meaning of the past creation, use, consideration and conservation or valorisation in the present .

Process view

The process view could be imagined as a simple roadmap in three steps[20]:
- Digitalizing and Knowledge Management: the time to start from the real object, to consider and document its technical and industrial context as well as its socio-economic situation in use during its life cycle.
- Modeling: the time to elaborate the Digital Heritage Reference Model with the 3D modelization and reverse engineering; the object is necessarily contextualized with help of data and documentation.
- Dynamic used situations and virtual reality :the time to show, demonstrate and valorize the model in different possible cases, standalone use at home, standalone use in Museum, immersive System…

Some realizations

A machine: Batz-sur-Mer salt laundry

We first can talk about of the salt laundry of the *Musée des marais salants* of Batz-sur-Mer[21]. At the end of years 2000, the extension of the museum in a closer old workshop and salt warehouse from the beginning of 20th century was the opportunity to discover and study a salt laundry machine, essentially in wood. Its appearance was really a pity and it was just impossible to think to restore it cause of the wood irreversible degradation. Our first idea was to save not the machine itself but to model it and study it for best comprehension and virtual valorization.

But the mechanical re-engineering in CAD was so significant and meaningful for the curators they arrived to conclude a reconstruction was possible in the new museum, at the original place in the warehouse. That one reconstruction is now working since the reopening in august 2013!

It is important to say this not just a material copy of the old and destroyed machine but really the result of the archaeological and mechanical study. Because it is mechanically and dynamically exact, the CAD software use allowed to valid the whole functioning and efficiency not only of the machine but of the general surrounding process too. That

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[20] The 3D modelization methodology has been precised recently by the Consortium 3D-SHS, Violette Abergel, Pascal Benistant, Laurent Bergerot, Jean-François Bernard, Hervé Bohbot, et al.. *Livre blanc du Consortium 3D SHS* : . France. 2017. 〈hal-01683842〉

[21] Florent Laroche, , *Contribution à la sauvegarde des objets techniques…*, op.cit, pp.265-349

constitutes a tremendous difference with video games or simples illustrations. Here we are in a scientific process, able to calculate, verify and transpose.

Batz-sur-Mer Salt Laundry, Cl. Jean-Louis Kerouanton 2004
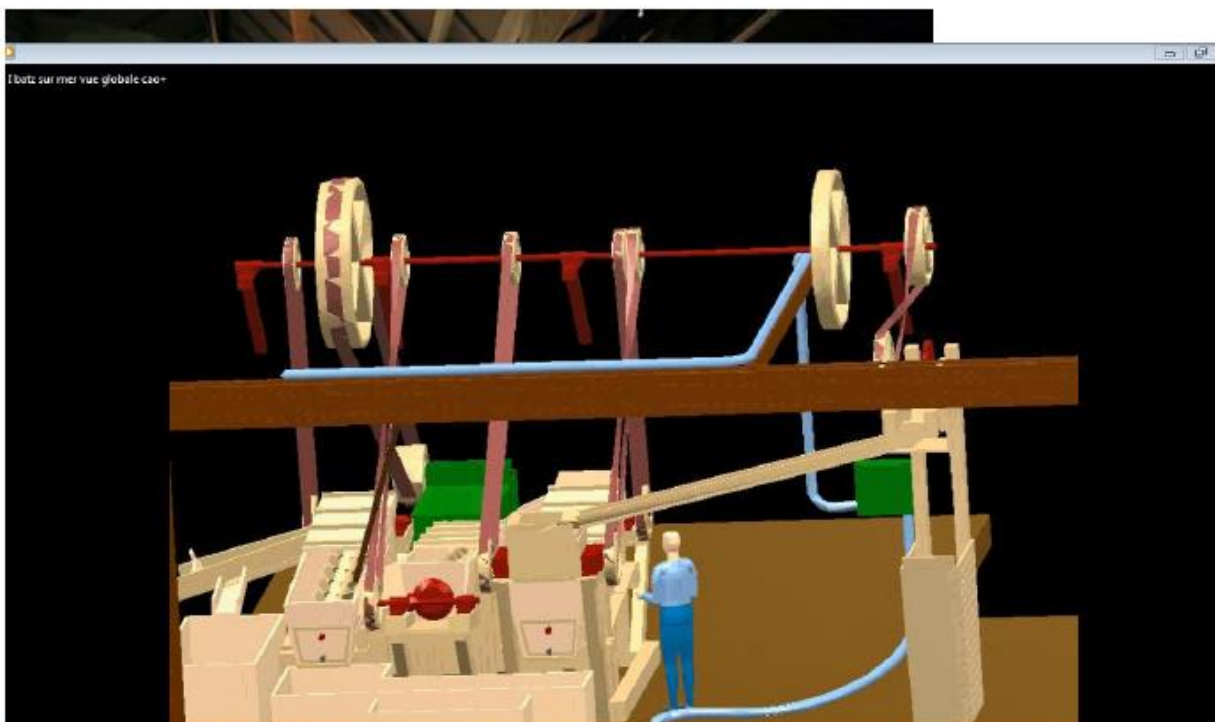
Batz-sur-Mer Salt Laundry, Screen shoot 3D CAD Florent Laroche.

Batz-sur-Mer Salt Laundry, the new museum, Cl. Florent Laroche

A factory : La Ciotat shipyards

Our first visit in the La Ciotat shipyards was in 2007 on the invitation of regional representation of the Ministry of the Culture to make an expertise about the cranes. The question to have the good knowledge of the shipyard's technical installations yet in place was important to indicate a possible proposal for conservation and valorization.

Probably in history the second one in France behind the Saint-Nazaire shipyards, La Ciotat is a very important site reopened in a new economic model since 1995 after the shipyard closing in 1987 and seven years unionized workers occupation. Just interrupted by a short and ephemeral attempt of economic recovery, this movement is quite singular and effective in the work history in France. They actually saved the main functioning machines and overall the Titan and Goliath cranes from destruction and disease. It was just the only condition for a possible reopening and they succeed.

The first study was general[22]; it consisted to inventory all the shipyard cranes, in operation or abandoned, from the smallest to the giant gantry cranes. The site contextualization was evident and the study immediately extended to the industrial landscape and the constructions of the whole factory, administration, workshops, warehouses and obviously maritime infrastructures as quays, dry-docks and slipways. Our proposal, closer to the objects notices, was based on database and GIS to map the

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[22] Jean-Louis Kerouanton, *Les chantiers navals de la Ciotat*, rapport de recherche : Centre François Viète, Université de Nantes, DRAC Provence-Alpes-Côte d'Azur, décembre 2007.

site evolution in time and space, to place the machines, to reference some old maps and plans in their geographical situation. It was our first digital approach[23].

The second digital approach proceeded to the necessity to study before its destruction a bending machine which appeared very original. The *Bennie* machine, with the renewed Ministry of culture support, could be the subject of our methodology. After work in place, 3D scanning, archives documentation, we could propose the mechanical modelling and then a video film for story and valorization[24].

Today, in the large difference of ten years ago where the closure memory was still painful, it is clearly possible to speak in the city about the shipyards past and story[25]. In 2011, a public conference we did showing the video was really a success.


La Ciotat Bennie bending machine, Cl. Jean-Louis Kerouanton 2007

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[23] Jean-Louis Kerouanton, « Pour l'utilisation des SIG (systèmes d'information géographique) en histoire des techniques : entre documentation et analyse spatiale », *Documents d'Histoire des Techniques*, n°18, décembre 2009, pp. 81-94

[24] Jean-Louis Kerouanton, Florent Laroche, Didier Serveille, *La cintreuse à membrures Bennie*, video film, 2010 https://www.youtube.com/watch?v=HvyPULjlRbs.

[25] Sylvie Denante, Jean-Louis Kerouanton, "L'image virtuelle comme source de connaissance pour le patrimoine industriel : les chantiers navals de La Ciotat, espace et représentation technique entre port et architecture du XXe siècle", *RIPAM, Rencontres Internationales du Patrimoine Architectural Méditerranéen*, Marseille : CICRP, octobre 2013, pp.131-133
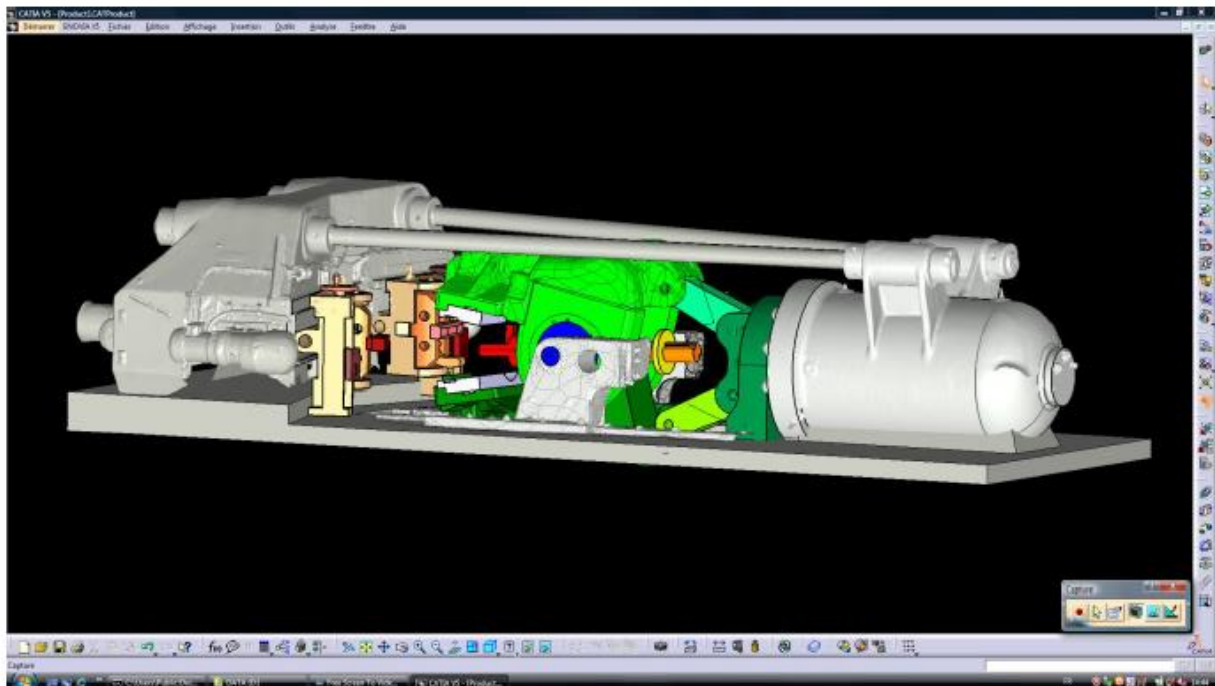
La Ciotat, Bennie Machine, 3D CAD Didier Serveille, 2010

A city industrial harbour : Nantes in 1900

The mock-up of Nantes harbor is one of the most important objects of the Nantes history museum, the *Château des Ducs de Bretagne*. Built by Pierre-Auguste Duchesne in 1899 for the 1900 Paris *Exposition Universelle,* but actualized until 1914, the mock-up is probably one of the best documents for the urban and economic history of Nantes around 1900[26].

The museum curators and the research team had together recognized its interest since a few years[27]. Our common interest for new technologies into museology convinced us to imagine a new common project. We were together thinking to the innovative use of digital technologies to promote cultural heritage. The interactive device was first, and is actually today, a proposition to valorise the object itself.

The first step was to scan the entire mock-up in 3D; then the historical documentation was provided for the database. It was really a work in progress and a real academic experience with approximately one hundred and fifty students during several years, both engineering students and heritage students for the most part, learning from themselves to cross their own academic languages to make common sense.

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[26] COURTIN, Ch. GUILLET, B., KEROUANTON,J-L., LAROCHE, Fl., *Nantes 1900, la maquette du port. Une valorisation scientifique et muséographique innovante.* Nantes : Château des ducs de Bretagne — Musée d'histoire de Nantes, 2015. ⟨hal-01243990⟩

[27] Bertrand Guillet, Laurent Huron, Jean-Louis Kerouanton, « La maquette du Port de Nantes », *Congrès national des Sociétés savantes « Des villes, des ports : la mer, les hommes» (n° 124; 1999; Nantes)*, Paris : CTHS, 2001, pp. 143-155. The scale model is approximatively 1/500 with 9.20m length for 1,85m large.

The scientific objectives were progressively fixed at the same time in permanent discussion with the museum team. They are analysed in the thesis of Benjamin Hervy[28]. Our preoccupations were to develop the DHRM as defined by Florent Laroche in his 2007 thesis, insisting on semantic recognition of 3D elements, time integration (link past/present) in the knowledge database and on the "self-adaptable" meta-model for supporting updates in a sustainable life perspective.

The three interactive multi-touch screens are placed just in front of the mock-up, bounded to precise geo-referenced lightning when notices and thematic links can be read in the same time during navigation. The idea is to help visitor to understand the mock-up as an artistic production, a tri-dimensional town city plan[29], and of course an amazing document for the historians and visitors for the comprehension of the harbour and the city surrounding the river Loire, in its maritime part.

Model is not a simple mock-up !

Of course, this short presentation of our works is not exhaustive. If our research began with industrial heritage objects, it seems to allow some similar considerations on others heritage fields. However, our approach looks probably especially accurate on technical and industrial objects. The 3D modelization, with a real CAD methodology, is obviously operant with technic and past functioning, cause of its precise mechanical and dynamical aspects. But our first reverse engineering methodology drives us to increase the reflexion on data and permanent reflexive links with all their complexity for the historian narrative. We have now to improve it, to anticipate the integration of the outdated phases since the design phase, the reuse phases or recycling phases, to add layers for the present, including heritage life phase.

Our proposal about the *Salons Mauduit*[30], put on some developments in the answering with immersive and interactive situations, augmented reality, serendipity visit or "free but guided" visit. We want to test too the possibility for the visitor to be himself an author, a testimonial contributor *in situ* or on line, in link with the future Nantes City "wiki heritage".

Virtual 3D heritage objects can become a real tool for understanding our history. It is a present question to envisage new representations of the history and to facilitate the valuation by a reflection on the possibilities of the documentary analysis between narrative of the historian and network of knowledge. For the historian, the double crosslinking, within the narrative and between narratives, opens new opportunities of

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[28] Benjamin Hervy. *Contribution à la mise en place d'un PLM muséologique dédié à la conservation et la valorisation du patrimoine : Modélisation et intégration de données hétérogènes sur un cycle de vie produit complexe.* Thèse : Sciences de l'ingénieur : Ecole Centrale de Nantes (ECN), 2014. 〈tel-01102311〉.
[29] As such as the best well-known "plan-reliefs" of the frontier cities since the firsts produced in Louis XIV reign. Eric Deroo, Max Polonovski, *La France en relief: Chefs d'œuvre de la collection des plans-reliefs de Louis XIV à Napoléon III*, Paris : RMN, 2012
[30] Florent Laroche, Jean-Louis Kerouanton. Muséologie, patrimoine, humanités numériques et 3D. *Digital Intelligence*, Apr 2016, Québec, Canada. 2016, Conférence Digital Intelligence. 〈hal-01280767〉. The *Salons Mauduit* is an art-deco well-known place in Nantes, destructed last year but rebuilt this one closer the primary place.

description and understanding. This transfer of the writing and the accesses goes to the sense of the Digital Humanities such as we analyze them from now on.

That is the reason we launched in 2016 our *ReSeed* project[31], financed by the *Agence nationale de la recherche* until 2020, over the Florent Laroche responsibility. Semantic reverse-engineering of digital heritage objects: this present work is clearly the direct following of all the precedents[32]. With its multidisciplinary approach, the Digital Heritage Reference Model contributes to the scalability of knowledge, its interoperability, as well as the re-usability of the framework, independent from the nature of the project. It allows multi-dimensional relationship (belongings, history, geography…), as well as a renewed answering about the interaction between qualitative and quantitative.

Most of the time, 3D use drifts towards creation of perfect models that do not fit with heritage ethics. Because each object is unique, there are no unique methods nor unique tool or general technology to support those approaches. So, managing 3D systematically is a real challenge. Inside the field of the Digital Humanities[33], *ReSeed* project aims to invent a "new use of 3D model". This project meets an interdisciplinary consortium with industrials and universities coming from Human and Engineering Sciences domain. Federated by the Digital area, *ReSeed* put its skills for the cultural society of tomorrow. It will meet the four great challenges of heritage paradigm: knowledge, protection, restoration and enhancement.

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[31] http://reseed.ls2n.fr/fr/le-projet/presentation/

[32] The most recent work, the specific approach on textuality of Matthieu Quantin, *Proposition de chaînage des connaissances historiques et patrimoniales. Approche multi-échelles et multi-critères de corpus textuels*, Thèse : Génie Industriel : Ecole centrale de Nantes, 2018. For a short view, Matthieu Quantin, Florent Laroche et Jean-Louis Kerouanton « Récit historique et objet technique : outil de valorisation mutuelle », *Cahiers d'histoire du CNAM*, vol.5, 2016, pp.93-121, or Matthieu Quantin, Benjamin Hervy, Florent Laroche, Jean-Louis Kerouanton. « Haruspex, Outil de Gestion de Connaissances non Structurées. » *Archéologies numériques*, Openscience, 2017. ⟨hal-01617790⟩

[33] While digital humanities, on that question of history and heritage, are rather turned on texts and archives. Bruno Bachimont. *Patrimoine et numérique. Technique et politique de la mémoire*, Paris : Ina, 2017.