3D and virtual reality: standards and methods for acquisition, storage and visualization of digital three-dimensional models for objects or scenes of cultural interest

Index

1. Introduction....2
   1.1 Reasons for governing a major technology evolution phase....2
   1.2 Digital 3D content: a single name for many different data gathering methodologies....2
   1.3 Use of 3D media....2
   1.4 Open challenges....3
Part One: Digital data creation....3
2. Three-dimensional digitization (3D scanning)....3
   2.1 HW and SW technologies for 3D scanning (shape)....3
   2.2 Acquisition of surface color....3
   2.3 HW and SW technologies for data processing (shape and color)....3
   2.4 Coping with the high density of 3D scanned data - Data simplification....4
3. Three-dimensional reconstruction....4
4. Encoding of scanned or reconstructed 3D models....4
   4.1 Data encoding formats (scanned models)....4
   4.2 Data encoding formats (reconstructed models)....4
   4.3 Need for standards (either formal or de facto)....5
5. Metadata creation....5
   5.1 Why adding metadata?....5
   5.2 Documenting the cultural object....5
   5.3 Documenting the acquisition process and data provenance....5
6. Guidelines for 3D acquisition....5
   6.1 Setting the objectives....5
   6.2 Estimating the costs....6
   6.3 The need for specific training....6
Part Two: Data Archival and Management....6
7. Storage and preservation of digital representations....6
   7.1 Storage and management of the digital master material....6
   7.2 Preservation strategies....6
8. Publication and access on web....7
   8.1 Publication on the Web....7
   8.2 Access to 3D web resources....7
9. Intellectual Property Rights (IPR)....7
Part Three: Examples of good practices....7
10. A few examples of digital 3D models acquisition campaigns....7
11. Uses of digital 3D models in CH applications....8

1. Introduction

1.1 Reasons for governing a major technology evolution phase

- Progress of digital 3D graphics tools, including: new HW/SW tools for gathering 3D representations of real objects and for the reconstruction of 3D scenes; inexpensive and pervasive HW devices for real-time 3D visualization.
- Forecasted panorama in the near future: huge effort in digitization of Cultural Heritage (CH) assets, activity widely distributed in the EU at the level of the local authorities, museums, restoration labs, etc.. It will probably be a un-coordinated effort, with major potential problems: different data quality; use of different data encoding formats; lack of interoperability; lack of a common encoding for provenance data; lack of a EU-wide data repository and data retrieval tools (3D data hold by the authors of the digitization, undisclosed to the wider word of experts or public); etc. [list all problematic current approaches to the management of the digitization process]
- Need of a coordinated policy, to be enforced at the level of the single member state or, even better, at the EU level. Important potential leading role for Italy and EU with a word-wide panorama.
- Need for standards (either formal or de facto): Emergence of multimedia solutions which integrate 3D media (e.g. Acrobat)

1.2 Digital 3D content: a single name for many different data gathering methodologies

Two different approaches for the acquisition of digital 3D models:

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- semi-automatic digitization, or 3D scanning, of real objects (at the small, medium or large scale);
- human-driven modeling of digital 3D representations of real or hypothetical structures

In the first case, we have accurate instruments to encode reality in digital formats, while in the second case we produce representations which are mediated by the experience and culture of the human operator.

Mention the corresponding example of photography vs. digital painting/drafting for the production of digital 2D representations.

1.3 Use of 3D media

- Very brief introduction to the many uses of 3D data in CH applications, both current and forecasted (will be described in detail in Sect. 11 - *Uses of digital 3D models in CH applications*)

1.4 Open challenges

- Open challenges for 3D data in the framework of multimedia systems/applications: affordability, accessibility, interoperability, link to metadata, preservation, …

Part One: Digital data creation

2. Three-dimensional digitization (3D scanning)

2.1 HW and SW technologies for 3D scanning (shape)

- Characterization of the different 3D Scanning methodologies:
    - In terms of the supported working volume (i.e. technologies for small/mediun scale artifacts, technologies for large scale artifacts)
    - In terms of the technical approach: active optical vs. passive optical; active optical: laser-based systems, triangulation and time-of-flight; passive optical: silhouette-based systems, multi-stereo matching solutions
- Raw data characterization: present the type of raw data produced, characterize data sampling accuracy

- Technologies for the acquisition of volumetric representation (i.e. encoding both external and internal surfaces, i.e. CAT/TAC devices)

2.2 Acquisition of surface color

- Short introduction on the subtle concept of surface appearance (surface reflectance ad how do we perceive colors).
- Methodologies for sampling the surface reflection characteristics (from simple reflected color acquisition to more complex approaches to sample albedo colors or BRDF's)

2.3 HW and SW technologies for data processing (shape and color)

- Output of scanning devices: usually, a partial representation (range map); need for multiple acquisitions and integration (thus, a subsequent post-processing of raw scanned data is needed)
- Geometric post-processing of 3D scanned data (alignment, editing, merging, simplification)
- methodologies to map 3D color data to a 3D shape/surfaces (inverse projection, texturing, color per vertex)

2.4 Coping with the high density of 3D scanned data - Data simplification

- how to manage the extreme density of 3D scanned data (millions of samples, huge 3D meshes and files)
- methodologies for data simplification and multiresolution management

3. Three-dimensional reconstruction

- Different technologies are available for the human-assisted **reconstruction**, i.e. reconstructing digital 3D models depicting either a real artifact/architecture or the previous hypothetical status (e.g. reconstructions in archeology) by adopting a user-assisted modeling approach (thus, clarify the difference between 3D scanning and modeling-based reconstruction)
- Discuss the importance of starting from a good survey (metric data defining the current situation) and of historical knowledge (e.g. plans depicting the previous status of a building) to build up correct digital representations
- Present the methodologies and tools for the reconstruction of 3D models:
    - commercial modeling systems (Maya, Autodesk 3D studio, etc.);
    - image-based modeling systems (RealViz ImageModeler);
    - …

4. Encoding of scanned or reconstructed 3D models

4.1 Data encoding formats (scanned models)

- describe the different formats available, classify by generality, flexibility, proprietary/open status, diffusion, availability of open source browsers, etc.

4.2 Data encoding formats (reconstructed models)

- describe the different formats available, classify by generality, flexibility, proprietary/open status, diffusion, availability of open source browsers, etc.

4.3 Need for standards (either formal or de facto)

- Emergence of multimedia solutions which integrate 3D media (e.g. Acrobat)

5. Metadata creation

5.1 Why adding metadata?

- Need for coupling the digitized 3D model with metadata
- Scope of metadata for 3D objects, present current approaches (e.g. CIDOC CRM)
- The need for standards
- Assessing and evaluation needs

5.2 Documenting the cultural object

- descriptive metadata
- structural metadata
- administrative metadata
- preservation metadata
- rights management metadata
- terminology standards

5.3 Documenting the acquisition process and data provenance

- Metadata for the description of the 3D content (single object), such as: metadata characterizing the digitization or modeling process; metadata on the further processing steps performed on the geometry data;
- Collection level, metadata for the description of assembly or complex 3D multimedia objects
- Need for making a clear distinction between original data and user edits (and how to encode in the digital files)

6. Guidelines for 3D acquisition

6.1 Setting the objectives

- digital 3D digitization solution versus consolidated solutions (e.g. photography for a 2D medium, photogrammetry for digital 3D medium, calco/molding for a real 3D copy)

- how to model digital 3D replica: modeling vs. scanning (mention in a synthetic way the difference between the two approaches already described in Sect. 2 and 3)
- mention that not all objects can be scanned, specific scanning technologies work well with just a subset of the possible CH artifacts – describe in detail limitations of current technologies
- take into account physical constraints of the different scanning technologies (e.g. empty working space required around the artifact) or alternative modeling solutions

6.2 Estimating the costs

- guidelines to help conservators or CH management body to estimate the cost of a digitization action
- guideline for the definition of the technical content of a sample "capitolato d'opera", to be used while commissioning 3D digitization task to external companies or executors
- production of copies: give some examples of the costs of standard phisical reproduction by calco/molding and by digital solutions (3D scanning + rapid reproduction

6.3 The need for specific training

- need of training at the highly technical level (operators, public and private) and at the medium level (conservators, CH management bodies)

Part Two: Data Archival and Management

7. Storage and preservation of digital representations

7.1 Storage and management of the digital master material

- storage media
- archival formats
- storing basic building blocks (i.e. single scanned models or single reconstructed architecture) or complete MM applications?

7.2 Preservation strategies

- coping with the limited life span of storage media
- coping with the obsolescence of 3D data formats, discuss the quest between open vs. closed formats

8. Publication and access on web

8.1 Publication on the Web

- data formats
- processing for efficient storing, delivery and visualization
- accessibility of 3D objects and scenes
- usability
- security
- authenticity

8.2 Access to 3D web resources

- searching policies (text-based and shape-based)
- metadata harvesting
- web services

9. Intellectual Property Rights (IPR)

- identifying and managing IPR
- safeguarding IPR
- technological protection measures and risks of DRM approaches
- collective licensing models

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Part Three: Examples of good practices

10. A few examples of digital 3D models acquisition campaigns

Movable artworks (e.g. statues):

- Digital Michelangelo (Stanford University, USA)
- Minerva of Arezzo, Museo Archeologico, Florence (ISTI-CNR, SAT)
- Arrigo VII monumental complex, Pisa (ISTI-CNR, SBAAAS)
- Figurated Greek pottery (C2MRF, Musee de Louvre, Paris, France)

- ……
- …….

Architectures - Scanned:

- Parthenon Project (UCSC, USA)
- Pisa Dome (ISTI-CNR, SBAAAS, UniFerrara, UniFi)
- Carved facade of the Ripoll Monastery, (Spain)
- …….
- …….
- chiostro dell'abbazia di Saint-Guilhem-le-Desert, France
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Architectures - Modeled:

- S. Peters, Rome (InfoByte)
- Temple C, Selinunte (IBAM-CNR)
- MAP –Modèles et simulations por l'Architecture, France (www.map.archi.fr/3D-monuments)

11. Uses of digital 3D models in CH applications

- Study and documentation purposes
- Research purposes
- Conservation and Computer-Assisted Restoration
- Communication to the public, popularization of CH
- Teaching and educational purposes
- Entertainment