Interactive Visualization for Cultural Heritage: current capabilities and open issues

Roberto Scopigno
Visual Computing Lab, CNR-ISTI, Pisa, Italy

Prologue: enabling technologies

- 3D Modelling
- Geometry Processing
- Rendering
- (Semantic) Repositories
Talk overview

☐ CH: where do 3D models come from?

☐ Interactive visualization - Issues:
  ▪ Reach **interactivity** without sacrifice on quality – Simplification and multiresolution
  ▪ **Web & Mobile** - the domains to focus on
  ▪ **Interaction**: easy manipulation, easy navigation
  ▪ Not just a 3D model: integration of other media
  ▪ Which future?

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Modelling vs. Scanning

☐ **Modelling**
  ▪ Manual process ["redraw"]
  ▪ Accuracy is unknown
  ▪ 3D model is usually **complete**

☐ **Scanning**
  ▪ Semi-automatic process ["photography"]
  ▪ Accuracy is known
  ▪ 3D model is usually **uncomplete** (many unsampled regions)
Active 3D scanning technologies

- Devices: many different technologies
  - Laser or structured light, Triangulation
    - Small/medium scale artifacts (statues)
    - Very precise, very fast
  - Laser, Time of flight / Phase shift
    - Large scale (architectures)
    - Less precise, but allow sampling of large surfaces

- Geometry processing:
  - Mostly automatic
  - Nearly consolidated

- Color data acquisition & processing:
  - Still manual, not consolidated
  - Lot of activity in EC IP “3DCOFORM”
  - See last MeshLab version

From partial sampling To a complete model

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3D scan without a scanner

FROM Stereo-Photogrammetry TO Multi-Stereo-Matching: geometry from a set of images

- Photo pairs from calibrated positions (automatic stereo-matching)
  - Menci’s ZScan (digital photo camera + calibration bar + SW)

- Stream of images from uncalibrated positions (automatic multi-stereo-matching)
  - Arc 3D (http://www.arc3d.be/), Autodesk 123D Catch, + many others

Image by Menci SW

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3D Scanning - Color

- No more gray models: acquiring and mapping **color** (or surface reflection properties) is mandatory for CH apps

- **Issues:**
  - Available methods to acquire surface reflection properties (**BRDF**) work only in lab conditions [*develop more practical solutions*]
  - Geometry is dense (10 samples per sq.mm.), but color can be 10x denser [*huge data*]
  - Color mapping to 3D meshes / point clouds [*guarantee quality & interactive speed*]

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Some recent results:

- Simplified acquisition of color via **flash-based photography** [*LNCS’09, VAST’09, ACM JOCCH’10*]

- [Semi-] **Automatic alignment** of photos to 3D meshes [*CGF’09, IJCV’12, Visapp’13*]

- Improved mapping to 3D meshes via **weighted interpolation** [*C&G’08*]

- **Improving alignment** & mapping by comparing **pixel flow** and distorting locally the images [*TVCG ‘12*]
Support **interactive visualization** without sacrifice on quality:

**Geometric simplification and multiresolution encoding**

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**Managing data complexity**

- 3D scanning tools produce **huge meshes** (from 5M faces up to Giga faces)
- Data **simplification** is a must for managing these data on common computers (PC, internet)
- Standard simplification approach: **edge collapse** with quadric-based error control (QEM) [GarHecSig97]
Managing data complexity

- **Multiresolution encoding** can be built on top of simplification technology.

- **Goal:** structure the data to allow to extract from the model *(in real time)* an optimal representation for the current view → view-dependent models produced on the fly.

- **Note:** the screen is limited (2M pixels), take this into account to reduce data representation complexity.

CNR’s Nexus [vcg.isti.cnr.it/nexus/]["Batched Multi Triangulation", P. Cignoni et al, IEEE Visualization 2005 + newer ideas]
Presentation contexts for CH:

**WEB and mobile platforms**

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**3D – Which dissemination?**

- Originally, 3D content used only inside PC & specialized software - 3D was not part of the “multi” in *multimedia*
- The (drastically more *multi*-medial) nature of web applications led developers to create software for visualizing 3D data on the web
- First approaches:
  - Proprietary implementations (*plug-in*), 3D “external” to the web page
  - An history of failures... (user perception)
- Need of a **standard**, 3D should be one of the media, not a exotic component
WebGL

Excellent opportunities enabled by WebGL:

- 3D Graphics technology for JavaScript
- Derives from the high-performance OpenGL|ES 2.0 standard
- Close to the HW (high performance, but not easy to use)
- [http://webgl.org](http://webgl.org)

- CNR SpiderGL [http://spidergl.org](http://spidergl.org)
  - Improves ease of implementation, maintains flexibility

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WebGL at Work
An example: the **CENOBium** system

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CNR’s **Nexus**

**Supports:**

- **Construction** of Multiresolution repr.:
  - Based on iterative edge collapse
  - Atomic element: patch of triangles
  - Encodes MRes graph, with compression of geometry and topology

- **View-dependent** extraction and **rendering**:
  - http streaming
  - de-compression
  - color per vertex (soon also textures)
  - Efficient, can be ported to Java and mobile platforms

- Available on [http://vcg.isti.cnr.it/nexus/](http://vcg.isti.cnr.it/nexus/)
World is now **Mobile**

- Move 3D systems on the **mobile platforms** (smartphones, tablets)
- **Issues:**
  - Efficient transmission of complex data
  - Efficient rendering (multiresolution)
  - Specific interfaces for manipulation/viz
  - Design nice apps

- **MeshLab on IOS / Android** → presented in the “Interfaces” section...

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**Interaction:**

easy manipulation, easy navigation
Interaction

- A very wide context:
  - Approaches for efficient and easy **manipulation** (single object in focus)
  - Approaches for efficient and easy **navigation** (large scenes)
  - Natural or **disappearing interfaces** (gesture-based, tracking via Kinect-like devices, etc.)

Interaction – **Touch-based**
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- Orbit
- Pan
- Scale
- Focus – center & zoom
- Rotation on Z axe

- **Usability**: excellent results from tests with CH users!
  Better than usual mouse/PC

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**Trackball on complex shapes**

- The touch-based interpretation of the classical trackball approach works very well on simple shapes (sphere-like)

- Detailed **inspection** usually requires **to fly over** the object:
  - Maintaining a **fixed distance** from the surface, irrespective to shape complexity
  - Maintaining smoothness and continuity of the camera path

[Paper submitted to CGF, 2013]
A demo of a generalized trackball

Generalized trackball

- Goal: Define an approach that could be implemented efficiently on mobile platforms (no heavy run time preprocessing, no complex data structures)
- Main ingredient: define an offset surface at distance \( d \), manage singular points to produce smooth camera paths and smooth view direction changes
- Should also work at different distances ➔ multiresolution approach, build multiple offset distances
- Data structure: Kd-tree of normal field (approximation of gradient of distance function)
Not just a 3D model: integration of other media

Data management

- In CH applications, the 3D models are major assets to:
  - Document an artwork
  - Assess the conservation status
  - Present the status before and after a restoration
- Complex pool of data associated to / interlinked with the 3D model
- Data ideally should be open and available to all scholars/students/amateur
Data management

Need for comprehensive MM repositories:

- Should be able to **archive** different media and data formats
- Should allow to **encode relations** between different items
- Should be **distributed** and **accessible** on web
  - Controlled **basic data sharing** is a key factor to reduce the cost of the implementation of Virtual Museums or VR/interactive installations
  - Avoid to **redesign the wheel** multiple times! (virtual spaces need to be populated by artefacts!)

3D repositories

What we would like to archive:

- The digital representation – **MM content**
- **Metadata**: info characterizing the represented artefact
  - Name, author, museum, inventory no., …
- **Provenance Data**: info on the digitization process
  - Sampling device used, acquisition specs, processing tasks, SW used, person in charge of processing, simplification/smoothing, …
Presenting multimedia data

- The 3D model can be the **spatial index** and the **supporting media** to present other information
  - Document a restoration or a conservation project
  - Support the study of artworks (scholars, students)
  - Presentation of artwork to the public in museums or on the web

- Required features:
  - Interactive visualization / navigation
  - 3D model enriched by hotspots to link other multimedia assets (images, text, graphics, video, audio, …)

- An example ➔

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Demo – Michelangelo’s David

Exploring the David

Diagnosis and Restoration
Analysis of the Work
Maintenance

Credits

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Community Presenter

- Collection of tools and templates for the creation of multimedia interactive presentations
  - Easy visualization in HTML pages or QML applications of different media (3D models, high-res images, RTI, video, audio)
  - Support streaming of multiresolution 3D meshes over HTTP (using the Nexus format), allowing for exploration of very large models
  - Mobile applications and museum kiosks can be created using Presenter, a tool based on QML, Qt declarative language
  - Web presentations make use of WebGL technology through the SpiderGL library

See at: http://vcg.isti.cnr.it/presenter/

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Restoration relieves on 3D

- Restoration: preliminary investigations encoded by graphic relives
- David restoration (2003-2004): relives done on digital 2D images
- Current goal: draw restoration relieves directly on the skin of the digital 3D model

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Mapping color

- Color can be real color or our hypothesis on the original color
- We need tools for colorizing /editing over 3D meshes
- Some effort done to extend MeshLab to painting over meshes

Browsing set of images

PhotoCloud (ISTI-CNR) [IEEE CG&A'13]
- Allows to browse jointly a sampled 3D model (obtained from a set of photos) AND the set of photos
- Follows PhotoSynth, proposed by Microsoft and Univ. of Washington
Browsing different media

- **PhotoCloud**: integration & viz of 2D and 3D data
  - More flexible than previous approaches (any 2D and 3D data; no limitations over data size or provenance)
  - Data size and transmission time are critical
  - **Integration of media**: An algorithmic effort
    - *Visualization*: nice interfaces, interaction metaphors

- Other media? E.g. **VIDEO**?
Linking 3D and text

- Hot spots: from 3D ➔ text
- **Why not from text ➔ 3D?**
  - Allow the connection to be **bi-directional**
  - Support construction of presentations where we have text on one side and the 3D model on the other side, interconnected by a large number of links
- **Goal:** be able to tell the story of complex and decorated objects by providing to the reader easy links from the textual channel to the visual channel (and vice-versa)

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Demo of parallel text/3D
A glimpse to the future?

Interactive 3D and CH

- Impressive capabilities for museums and didactical tools (schools & univ), technologies:
  - Large screens & disappearing/natural interfaces [Museums]
  - Apps on mobile devices [Museums & didactic]
  - Augmented reality on mobile devices (using location & orientation based on CV)

- A niche market: support computer-aided restoration and CH study (Geometry Processing)
  - CG might become the XXI c. tool for CH scholars/restorers
Questions?

This presentation is the contribution of many colleagues of:

Visual Computing Laboratory
ISTI-CNR (Pisa, Italy)

http://vcg.isti.cnr.it
roberto.scopigno@isti.cnr.it