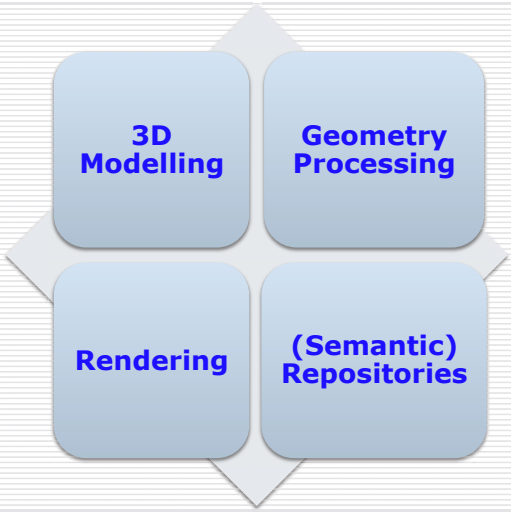
Interactive Visualization for Cultural Heritage: current capabilities and open issues

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

Prologue: enabling technologies

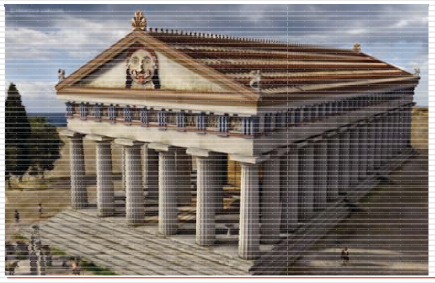


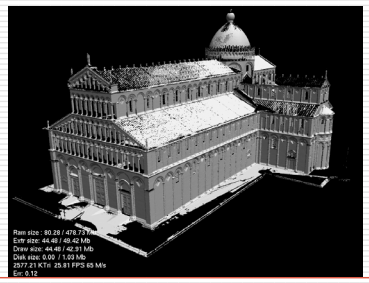
Talk overview

- 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?

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)

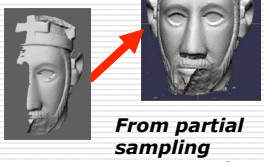




Active 3D scanning technologies

- Devices: many different technologies
  - **Laser or structured light, Triangulation**
    - Small/medium scale artifacts (statues)
    - Very precise, very fast
  - **Laser, Time of flight / Fase 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

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)

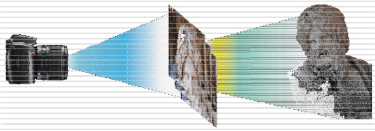


Image by Menci SW

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

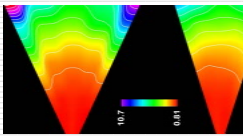
3D Scanning - **Color**

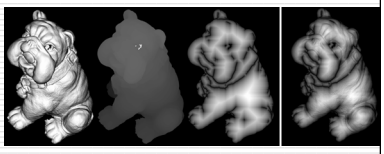
- *No more gray models:* acquiring and mapping **color** (or surface reflection properties) is mandatory for CH apps
- **Issues**:
  - Available methods to acquire surface reflection properties (**BRDF**) work only in lab conditions [***develop more practical solutions***]
  - Geometry is dense (10 samples per sq.mm.), but color can be 10x denser [***huge data***]
  - Color mapping to 3D meshes / point clouds [***guarantee quality & interactive speed***]

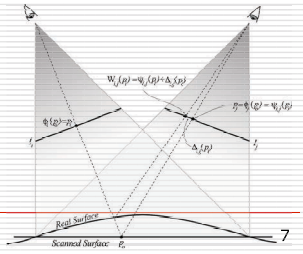
3D Scanning - **Color**

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]





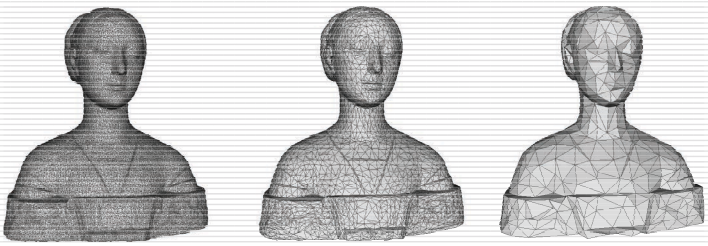


Support **interactive visualization** without sacrifice on quality:

Geometric simplification and multiresolution encoding

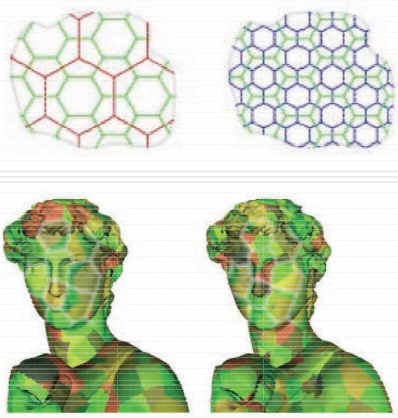
Managing data complexity

- 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

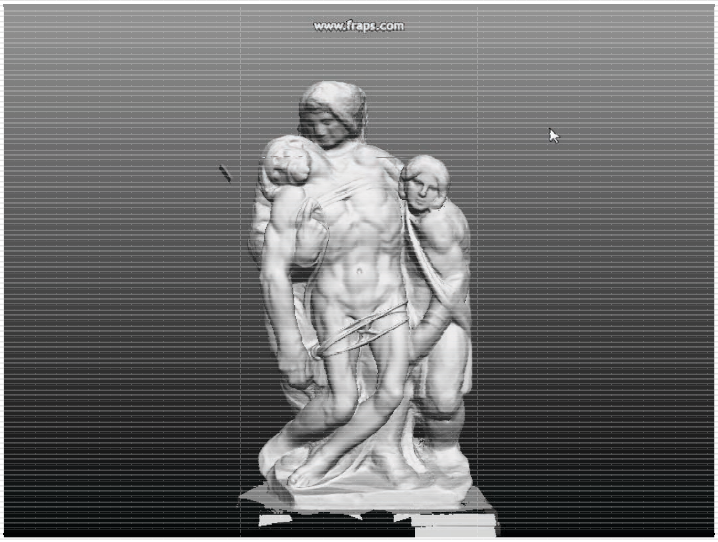
- **Multiresolution encoding** can be build on top of simplification technology
- **Goal:** structure the date to allow to **extract** from the model (**in real time**) an **optimal representation for the current view** ➔ *view-dependent models produced on the fly*
- **Note:** the screen is limited (2M 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]

Managing data complexity



Presentation contexts for CH:

WEB and **mobile platforms**

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

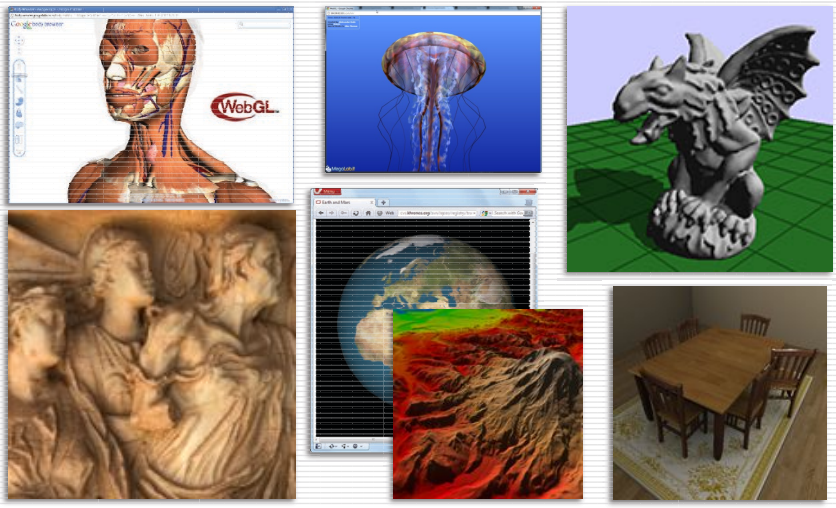
WebGL

Excellent opportunities enabled by WebGL:

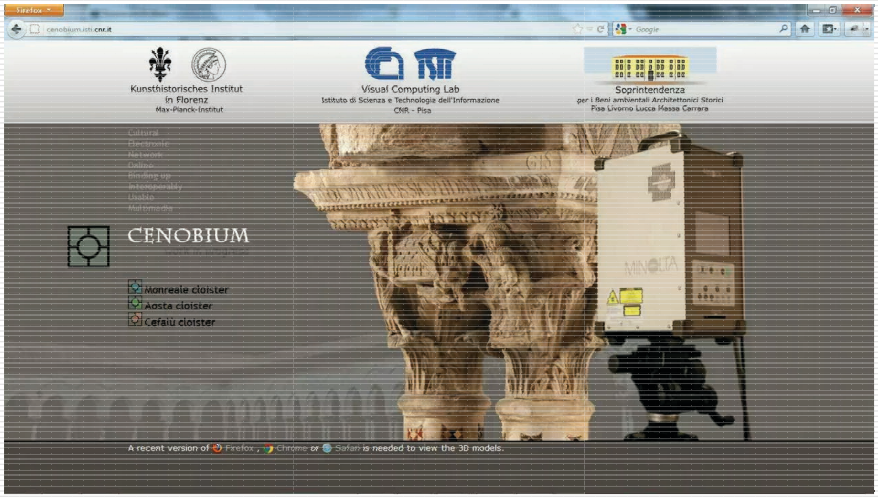
- 3D Graphics technology for JavaScript
- Derives from the high-performace OpenGL|ES 2.0 standard
- Close to the HW (high performance, but not easy to use)
- http://webgl.org

- CNR **SpiderGL** http://spidergl.org
  - Improves easy of implementation, mantains flexibility

WebGL at Work



An example: the **CENOBIUM** system



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/

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…

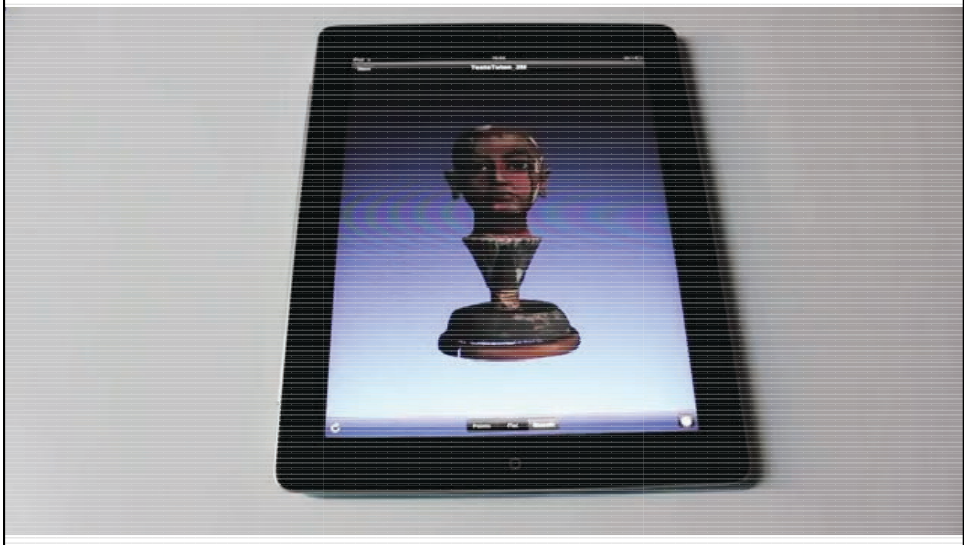
Interaction:

easy manipulation, easy navigation

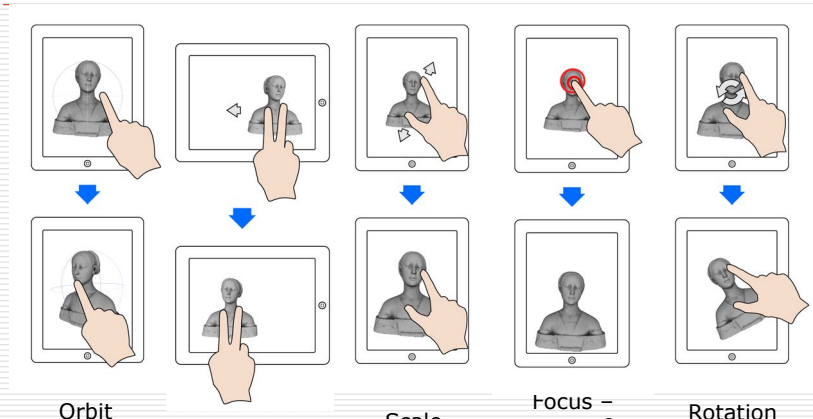
Interaction

- 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**



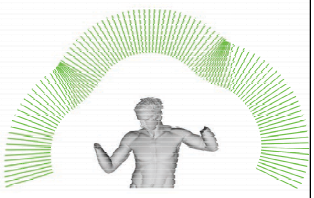
Interaction – **Touch-based**



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

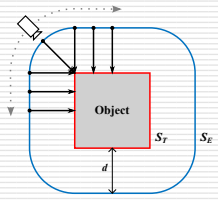
Trackball on complex shapes

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

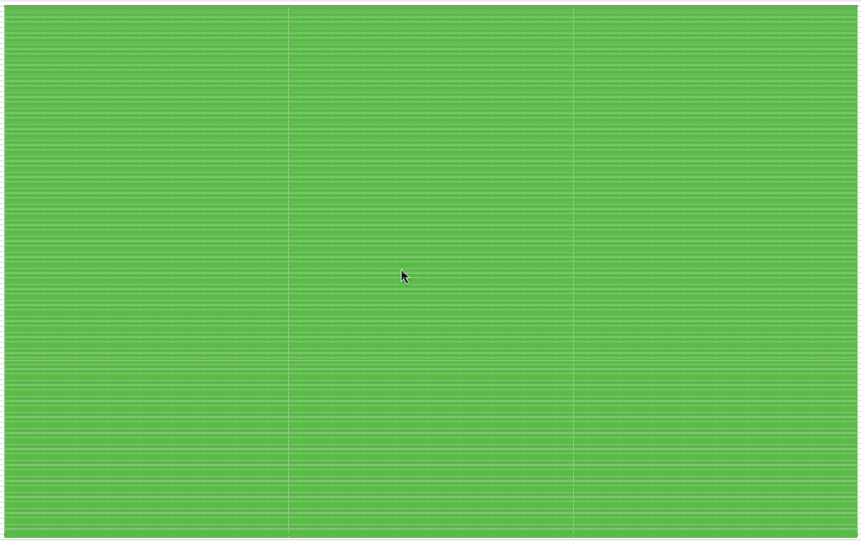


- Detailed **inspection** usually requires **to fly over** the object:
  - Maintaining a **fixed distance** from the surface, irrespective to shape complexity
  - Maintaining smoothness and continuity of the camera path

[paper submitted to CGF, 2013]

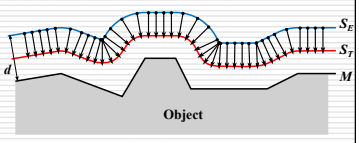


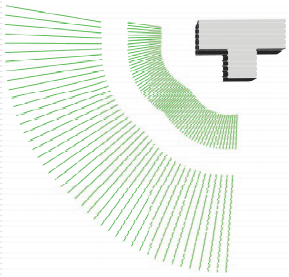
A demo of a generalized trackball



Generalized trackball

- Goal: Define an approach that could be **implemented efficiently** on **mobile platforms** (no heavy run time pre-processing, 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

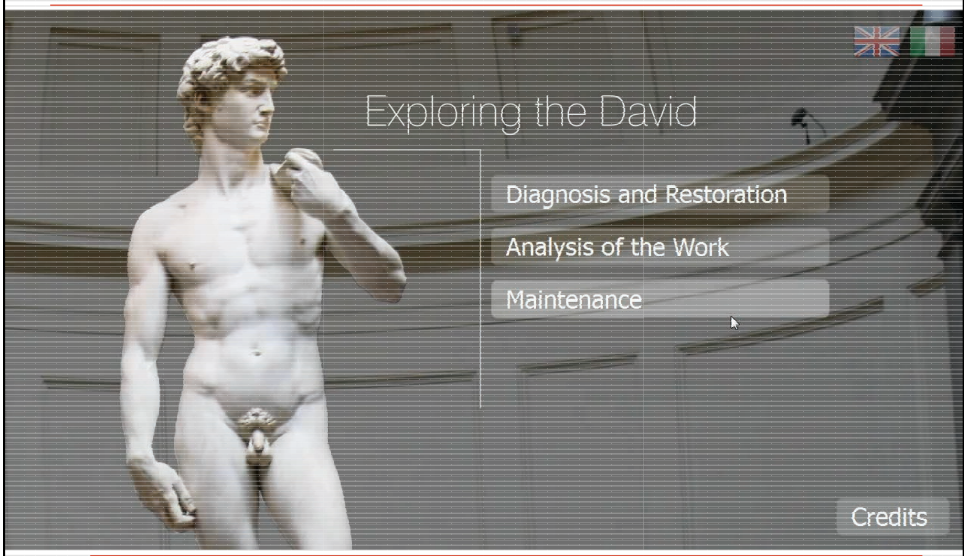
What we would like to archive:

- 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 ➔

Demo – Michelangelo's David



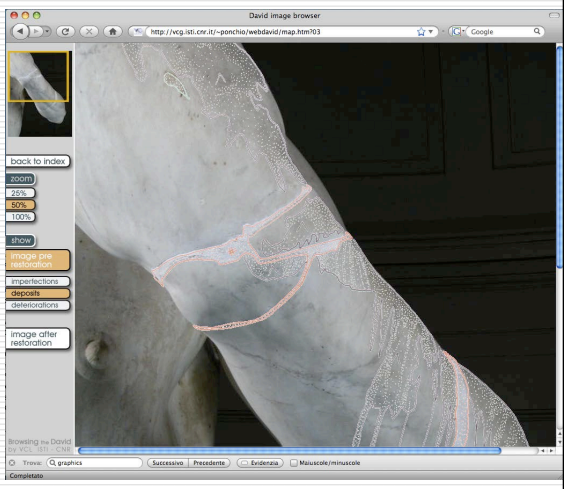
Community Presenter

- 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/

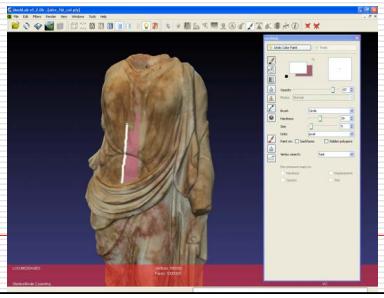
Restoration relieves on 3D

- 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



Mapping color

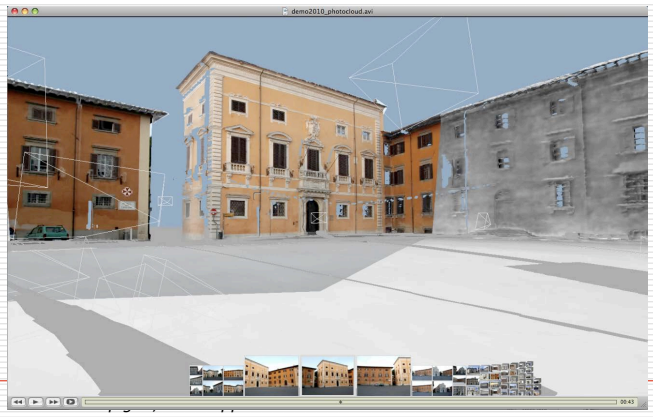
- Color can be real color or our **hypothesis on the original color**
- We need tools for colorizing /editing over 3D meshes
- Some effort done to extend **MeshLab** to painting over meshes

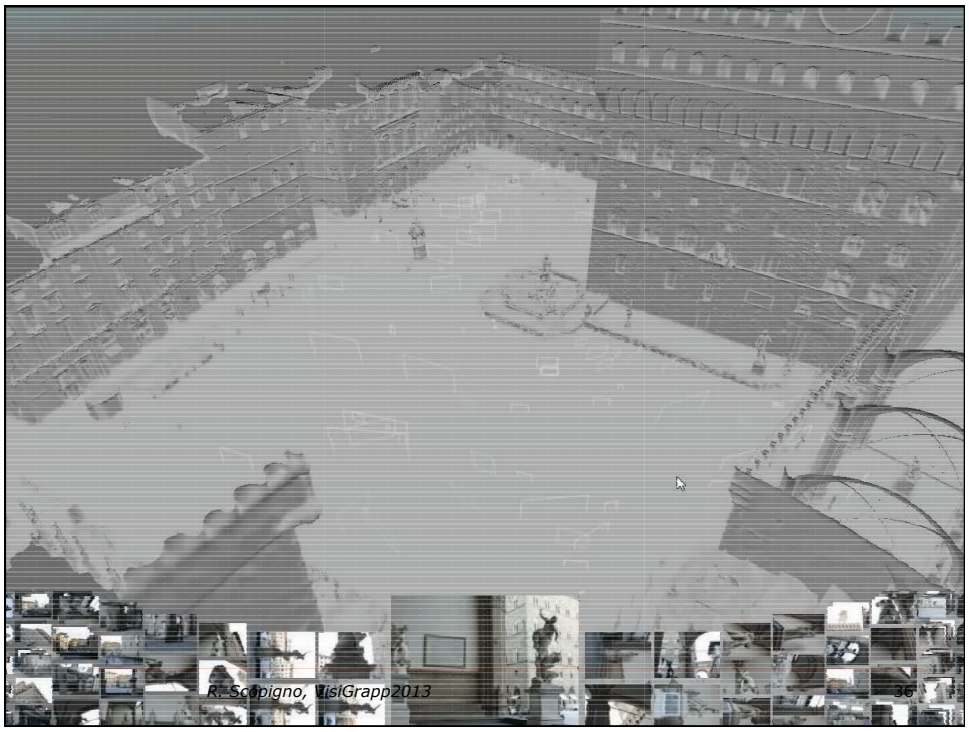


Browsing set of images

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





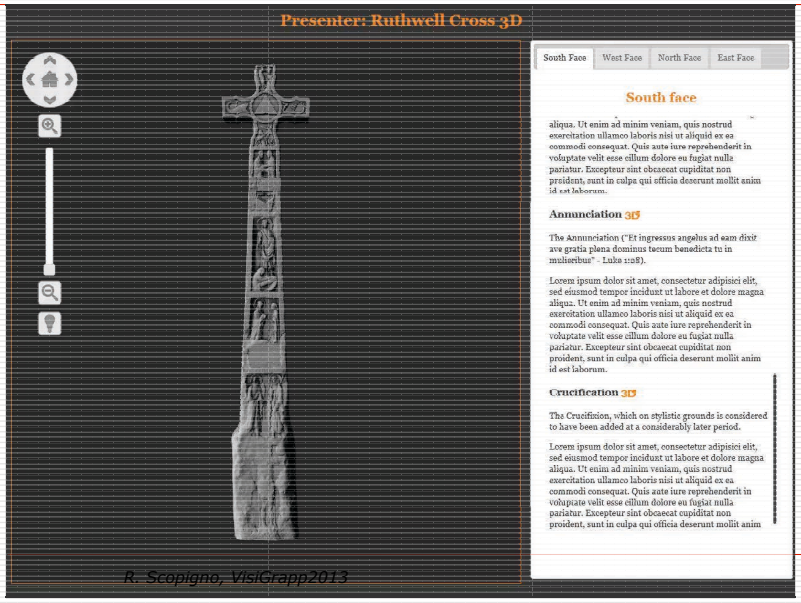
Browsing different media

- **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
    - *Data preparation:* Automatic or semi-automatic alignment of images over 3D model [Corsini et al, International Journal of Computer Vision – 2012; Visapp'13]
    - *Visualization*: nice interfaces, interaction metaphors
- Other media? E.g. **VIDEO**?
  - Tompkin et al, "Videoscapes: Exploring Sparse, Unstructured Video Collections", Siggraph 2012

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)

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`