Surveying of Pharaohs in the 21st Century

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Introduction

- In 1897 two copper statues Pharaoh Pepi I. unearthed in Hierakonpolis (Egypt)
- Made of copper material
- Dated to the 23rd century BC
- Oldest known life size sculptures made of metal
- Restoration between 1996 and 2003
- Presented in Egyptian Museum, Cairo

Introduction

- Geometric documentation carried out as a part of the restoration, conservation and technological investigation
- Joint project between RGZM and i3mainz in co-operation with the DAI (German Archaeological Institute), the Supreme Council of Antiquities and the Egyptian Museum in Cairo

View of the Sculptures before the Restoration
Introduction

View of the Sculptures after the Restoration

Concept

• Demands for the geometrical documentation
  – generation of geometrically correct plans of rivets to document the techniques of fabrication
  – various visualisations
  – virtual reconstruction
  – animations

Concept

• Concept of Recording
  – recording of the shape of the sculptures using laser scanning (not in reproduction accuracy)
  – recording of special features (joints, rivets) using close range photogrammetry
  – using the combination of both recording results as a basis for visualisations

Concept

• Concept of Processing
  – analytical plotting of 3D-vectors from stereo models
  – generation of triangle-based 3D-surface models from point clouds
  – combination of both models

Concept

• Concept of Visualisation
  – visualisation using 3D-visualising software
  – generation of various views
    • parallel projections (plans)
    • perspective view
  – combination of series of images --> animations
  – virtual reconstruction based on comparable objects

Recording

• Cairo, Egyptian Museum
• 11 days
• security controls
• high temperatures
• restricted working time
Recording

Laser Scanning

- **Hardware:**
  - Mensi S25 triangulation scanner
  - Point rate max. 100 / s
  - 46° x 320° field of view
  - Distance for recording: 2 - 10 (25) m
  - Accuracy: ~ 0.6 – 2.0 mm

Using Spheres as connection points between multiple scans

Big Statue:
- 1.8 million points
- 29 positions

Small Statue:
- 0.5 million points
- 10 positions (3 recording through Plexiglas)

Processing of the point clouds:
- registration using spheres
- for (sub-)viewpoints:
  - smoothing
  - elimination of outliers
- global registration using point information
- smoothing, thinning
Laser Scanning

- **Modelling:**
  - software:
    - initially using Mensi 3Dispos
    - later using Raindrop Geomagic Studio
  - processing:
    - triangulation
    - filling of holes, res. cutting
    - adapt resolution / number of triangles
    - export

Photogrammetry

- **Recording:**
  - Rollei 6008 metric medium format camera
  - image format 6 x 6 cm²
  - 11 x 11 Réseau
  - 40 mm lens
  - colour slides

- **Processing:**
  - Analytical Plotter Zeiss P3

- **Preparations:**
  - Big statue:
    - measurement of all reference points in all images
    - calculation of a bundle adjustment to determine the reference point co-ordinates
    - result: point accuracy: 0.3 mm
  - Small Statue:
    - definition of the reference system by the Plexiglas structure
Photogrammetry

- **Processing:**
  - stereo plotting using analytical plotter Zeiss P3
  - data recording into Micro Station
  - processing of all structures of interest as 3D-Polylines
  - further editing using AutoCAD

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Visualisation

- **Using 3D Studio Max® Software**
- **File formats:**
  - Wavefront OBJ (surface models)
  - Autodesk DXF (special structures)

**Combination of the object models with the vector data**

- **Usage of**
  - artificial textures
  - semitransparent surfaces
  - different textures for interior and exterior
  - light sources

- **Generation of parallel projections and perspective views**
- **Generation of animations**
Visualisation

Virtual Reconstruction

- Using 3D Studio Max® Software
- Aim:
  - Impression of the possible original appearance of the sculptures
  - not a photorealistic presentation
- Modelling of the vanished parts using objects of comparison
- Object models from the internet e.g. ears

Virtual Reconstruction

Objects of comparison

Animation of recorded structures and virtually reconstructed objects

Problems

- **Scanner:**
  - accuracy / calibration
  - point rate
- **Software:**
  - modelling software
- **Plexiglas construction of the small statue**
Problem of the Plexiglas construction

- Verification of the approach by control measurements using Leica AXYZ
- Evaluation of different factors:
  - refraction index
  - geometrical configuration
  - thickness of the plate
  - variation of the observation points
- Average offset by Plexiglas in the data: ca. 7mm

Conclusions

- visualisations ease understanding of construction principle
- virtual reconstructions can be created in different versions easily
- caution is advised with specifications on accuracy!!!

Outlook

- combination of different techniques still important
- 3D-scanning will establish in documentation
- standards for documentation?
- expected development:
  - hardware: scanner (possibly combined with other sensors e.g. cameras for texture)
  - software: modelling, registration
Thank you for your attention!