i 3 mainz

Institut für Raumbezogene Informations- und Messtechnik

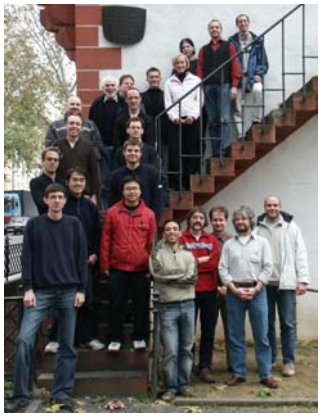
Fachhochschule Mainz

Römisch-Germanisches Zentralmuseum Mainz
Forschungsinstitut für Vor- und Frühgeschichte

Surveying of Pharaohs in the 21st Century

Hartmut Müller

FIG Working Week 2005 and GSDI-8
From Pharaohs to Geoinformatics
Intercontinental Semiramis, Cairo, Egypt, 16–21 April 2005
TS22 - New Measurement Technology and Its Application to Archaeological and Engineering Surveys, Number TS22.5



i3mainz - staff

Contents of the presentation

- **Introduction**
- **Concept**
- **Recording**
- **Processing**
- **Visualisation**
- **Problems**
- **Conclusions / Outlook**

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**

Introduction

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

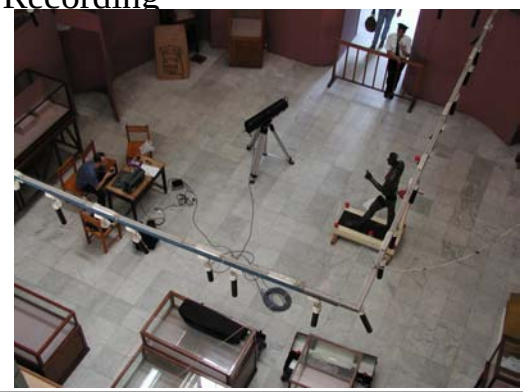
Concept

- **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

Laser Scanning

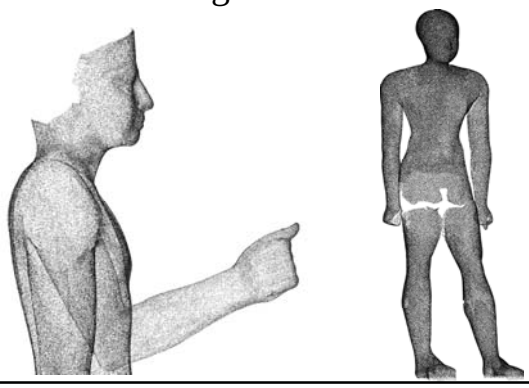
- **Using Spheres as connection points between multiple scans**
- **Big Statue:**
  - 1,8 million points
  - 29 positions
- **Small Statue:**
  - 0,5 million points
  - 10 positions (3 recording through Plexiglas)

Laser Scanning

Laser Scanning

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

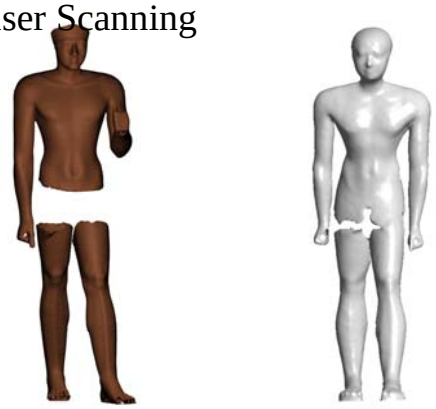
Laser Scanning



Laser Scanning

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

Laser Scanning



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

Photogrammetry

- **shootings with two exposure times**
- **illumination with additional lamp**
- **big statue:**
  - 16 convergent images for triangulation
  - 10 stereo models
  - reference points with targets
- **small statue:**
  - 12 stereo models (5 recording through Plexiglas)
  - given reference points at the Plexiglas structure

Photogrammetry

Photogrammetry

- **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

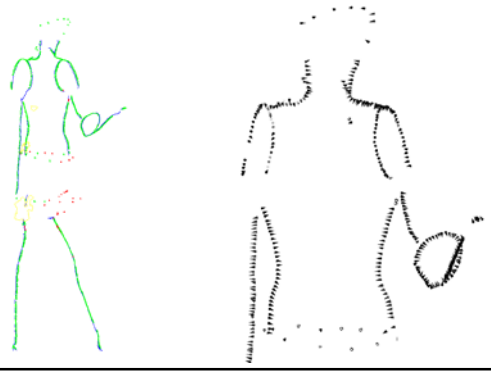
Photogrammetry

- **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

Photogrammetry

- **Processing :**
  - combination of the plots from different directions
  - coding of various tools using AutoLISP
  - generation of cones and tori for the representation of rivets and holes

Photogrammetry



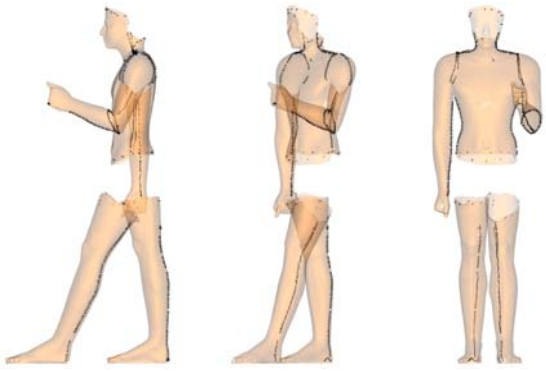
Visualisation

- **Using 3D Studio Max® Software**
- **File formats:**
  - Wavefront OBJ (surface models)
  - Autodesk DXF (special structures)
- **Combination of the object models with the vector data**

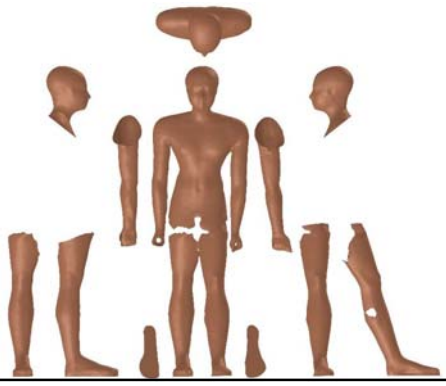
Visualisation

- **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



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

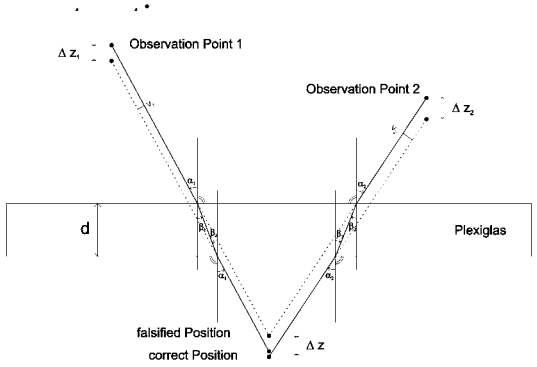
Virtual Reconstruction

Animation of recorded structures and virtually reconstructe d objects

Problems

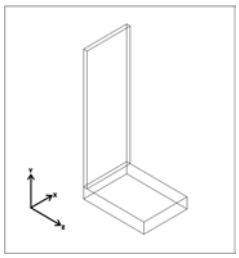
- **Scanner:**
  - accuracy / calibration
  - point rate
- **Software:**
  - modelling software
- **Plexiglas construction of the small statue**

Problem of the Plexiglas



Problem of the Plexiglas construction

- **identical approach for Photogrammetry and Laser Scanner**
- **modelling correction values**
- **coding of a tool to correct the incorrectly measured data**



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

- **approach combines advantages of both methods**
- **accuracy of the surface models allows visualisations and measurements, but not reconstructions**
- **combination of the data allows illustrations with higher information content as compared to single data sets**

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!