# Detecting Shape Similarities in 3D Pottery Repositories

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## 3D graphics technologies in the cultural heritage domain

- 3D digitisation is a common practice in the cultural heritage domain

- But how can we take advantage of the content richness provided by 3D replicas of artefacts in order to support the archaeological research?

  - A solution might be given by using *3D Content Based Retrieval Mechanisms (3DCBR)*
  - Archaeological research is based on perception and comparisons
    → Thus, the need to identify similar artefacts is INEVITABLE

*3DCBR enables us to*

→ Discover similarities & coherences by an automated exploitation of morphological features
→ Overcome the multi-language text-based annotation barriers
→ To search in a database by using an artefact as the actual query

## 3D Content Based Retrieval for complete or nearly complete

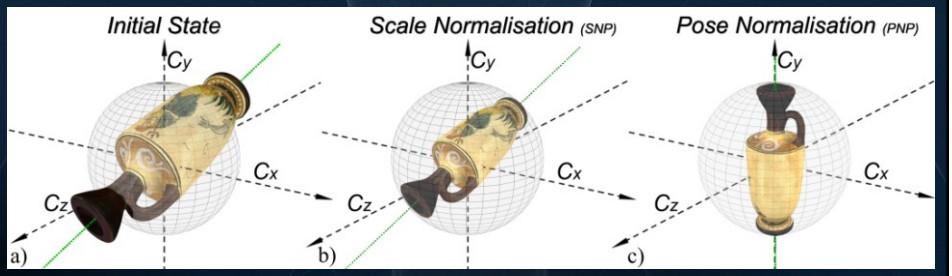
- 3DCBR is based on the extraction and the compact encoding of morphological features
- The extracted features should be invariant in terms of:
  →Translation, Rotation and Scaling
- This is achieved in many cases (as found in literature) with a data pre-processing stage
- We developed a scale & pose normalisation algorithm for complete and nearly complete vessels
- The pre-processing stage → Extraction of comparable morphological features





## A 3D Pottery Scale & Pose Normalisation Algorithm

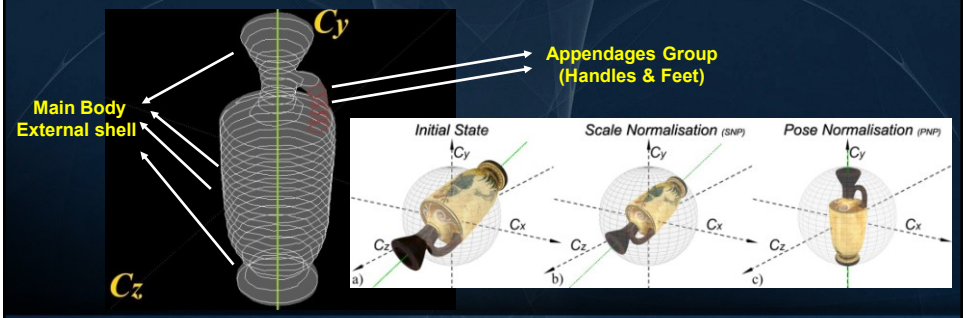
- **Scale Normalisation (SNP)**
  1. Calculate the Minimum Bounding Sphere (*MBS*) [B. Gärtner '99]
  2. Resize the object so that the *MBS radius = Unit Sphere radius (0.5 units)*
  3. Translate the object so that the *MBS centre lies on origin of Cartesian*



## A 3D Pottery Scale & Pose Normalisation Algorithm

### • Pose Normalisation (PNP) – General Description

- A recursive algorithm based on contouring the triangulated mesh
  - → Group curves at each contouring level (Main body internal and external shells, appendages)
  - → Estimate the real axis of symmetry (*Va*)
  - → Rotate the vessel so that *Va* || *Cy*
- But as real vessels are far from perfect (*noisy surfaces of revolution*)
  - → The algorithm attempts to converge to an optimum *Va*



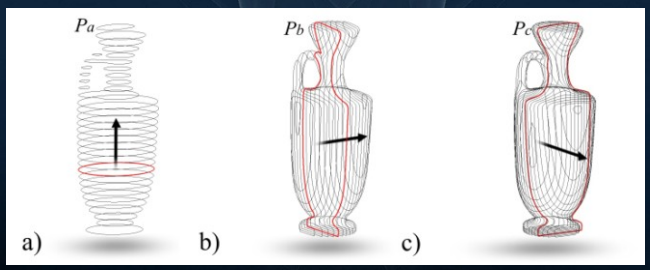





## A 3D Pottery Scale & Pose Normalisation Algorithm

### • Pose Normalisation (PNP)…continued

- Initialisation Phase – Compute Principal Component Analysis
  - Scope → Detect which of the three principal axes approximates the real axis of symmetry
  - EXPLOIT THE ROTATIONAL SYMMETRY OF VESSELS
  - Perform 3D mesh contouring along each principal axes
  - Perform circular regression for all curves at each contouring level
  - Calculate average circle fitting error (variance) for each axis
  - Rotate the vessel so that the principal axis with the lowest variance is parallel to Cartesian Y



## A 3D Pottery Scale & Pose Normalisation Algorithm

### • Pose Normalisation (PNP)…continued

• Then the algorithm attempts to converge in getting Va || Cy

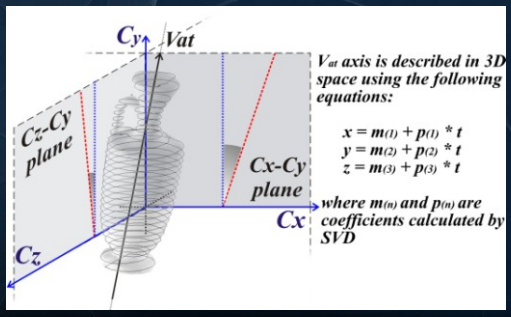
- This is done by repeating the following steps:
  1. Mesh contouring along the temporary axis of symmetry (*Vat*)
  2. Object grouping
  3. Estimation of *Vat* using the centres of gravity of the main body external shell
  4. Rotate the vessel so that new Vat || Cy

**Until**

The resulted rotations angle is below a given threshold

**or**

Reached the maximum number of iterations → Algorithm oscillation





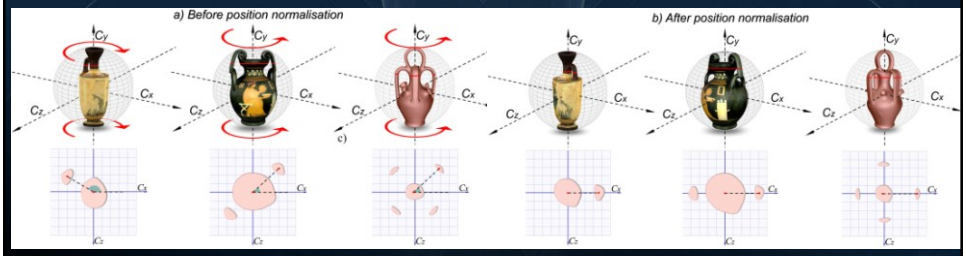



## A 3D Pottery Scale & Pose Normalisation Algorithm

### • Pose Normalisation (PNP)…continued

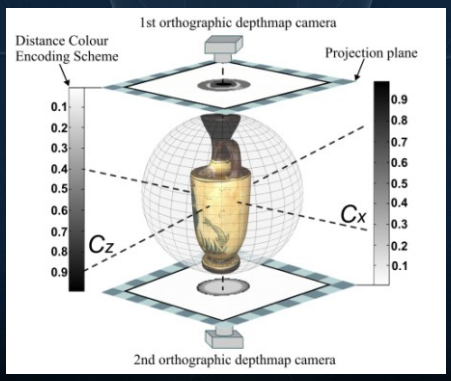
• Normalise appendages position

- Detect most distant to *Va* curve that belongs to the appendages group
- Rotate vessel around *Va* so that the curve's centre of gravity lies on the positive side of *Cx*
- In case of
  - Two handles → They are positioned along *Cx (negative and positive sides of Cx)*
  - All other cases → Most distant to *Va* curve is considered as the dominant



## A 3D Pottery Scale & Pose Normalisation Algorithm

- **Pose Normalisation (PNP)…continued**
- Detect the top of the vessel
  - Use of two virtual orthographic cameras and render the depth map of their viewpoint
  - Summation of pixel values of circular area around the axis of symmetry (Va)
  - Lowest value indicates top of vessel

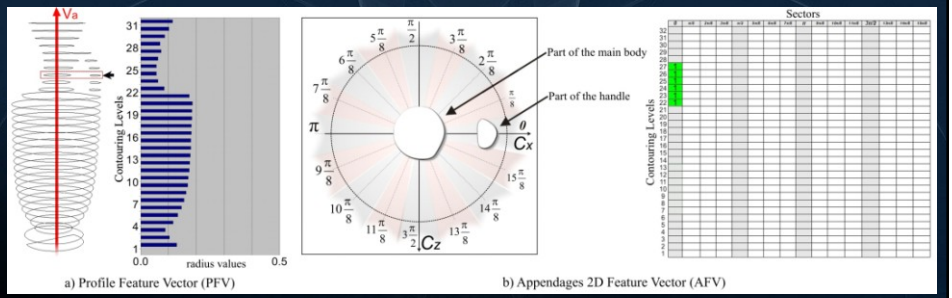







## 3D Pottery Shape Descriptors

- **Axial Symmetry Based Shape Descriptor (ASB)**
- Profile Feature Vector → Carries the radiuses of the best fitted circle of the exterior shell curves
- Appendages 2D Feature Vector → The position of the best fitted circle of each curve is quantized into a predefined area-sector around the unit circle
- Euclidean distance for the profile feature vector
- Hamming distance for the Appendages Feature Vector

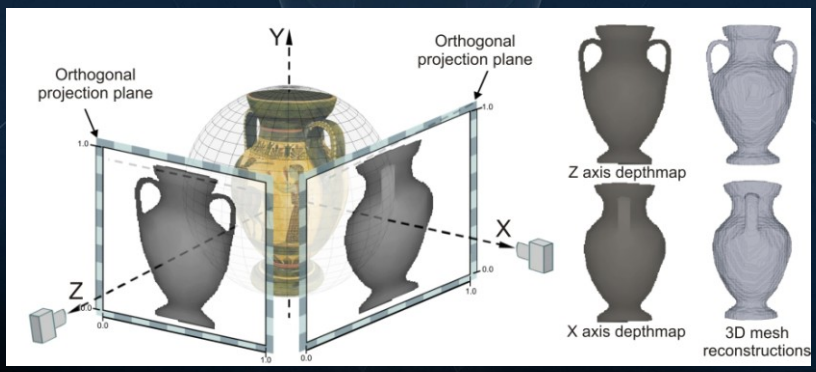



a) Profile Feature Vector (PFV) b) Appendages 2D Feature Vector (AFV)

## 3D Pottery Shape Descriptors

### • Depth Map Image Based Descriptor (DBD)

- Based on the assumption that the main morphological features of a vessel can be captured using a pair of depth map images
- A set of two orthographic projection virtual cameras are positioned on the positive sides of the X and Z axes of a 3D Cartesian coordinates system



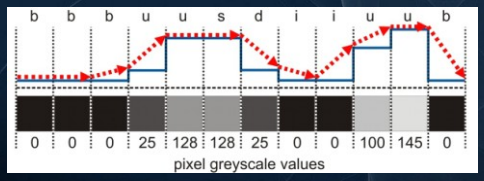


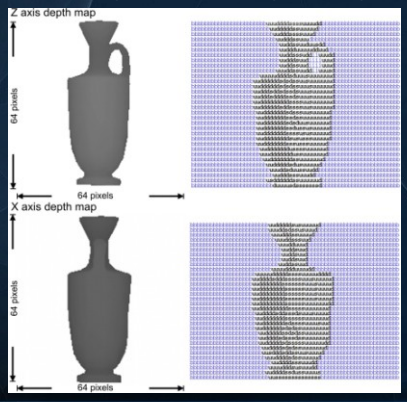



## 3D Pottery Shape Descriptors

### • Depth Map Image Based Descriptor (DBD)

- A Chaouch et al. 2007 descriptor variant
- The vessel's surface relief is encoded using characters that represent the curvature
- Different characters discriminate between the vessel's surface region and the background region
- Needleman-Wunsch comparison metric



## 3D Pottery Shape Descriptors Performance Evaluation

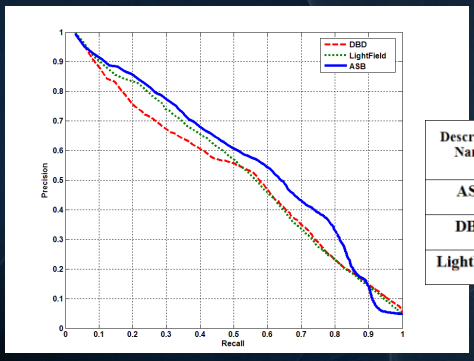
- Perform multiple queries-by-example in a repository of 3D vessels (1012 vessels in total)
- We have selected 5 different ancient Greek shape categories due to their relatively high population within the database
  - Alabastron, Amphora, Hydria, Lekythos, Psykter
- Evaluate the performance of the two proposed descriptor in relation with a generic descriptor
  - LightField descriptor Chen et al. 2003
- Use each 3D object as a query
- Calculate average Precision-Recall performance over all vessel shape categories
- Calculate average values of performance scalars proposed in 3D Shape Retrieval Contest (SCHREC)





## 3D Pottery Shape Descriptors Performance Evaluation

Averaged Precision-Recall graph for all five vessel shape categories

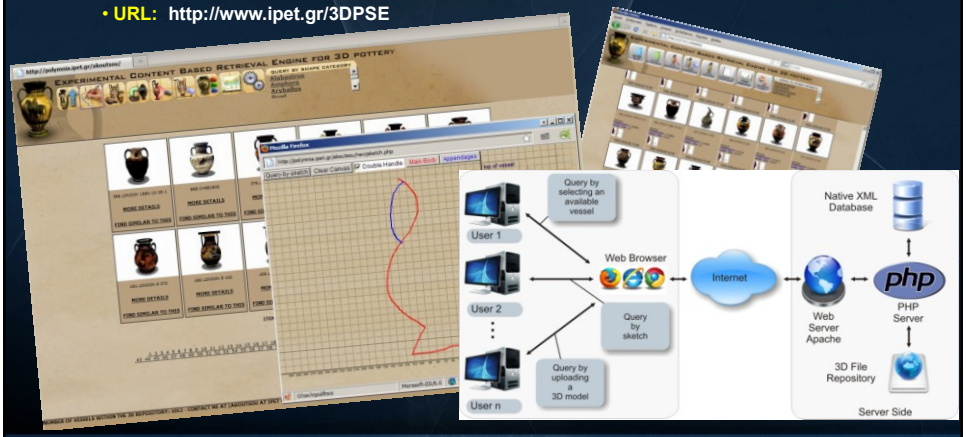



Performance Scalars for all five vessel shape categories

| Descriptor Name | 1st Tier | 2nd Tier | Averaged Mean Precision | E-Measure[64] | NN |
|---|---|---|---|---|---|
| ASB | 63.20 | 37.60 | 0.57 | 0.48 | 0.9 |
| DBD | 53.55 | 33 | 0.49 | 0.52 | 0.9 |
| LightField | 53.56 | 33.31 | 0.49 | 0.52 | 0.92 |

## Experimental 3D Pottery Search Engines

- A web based content based retrieval 3D pottery search has been developed
- Open source technologies
  - Apache HTTP server, PHP, eXist Native XML Database System & Java (applets)
  - URL: http://www.ipet.gr/3DPSE

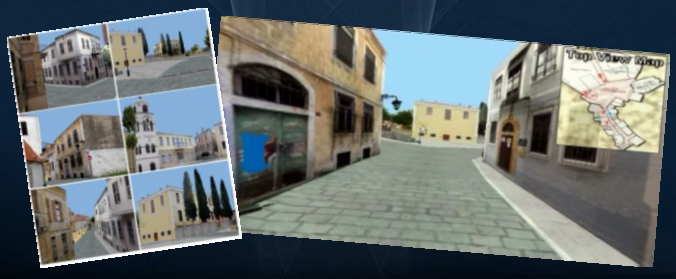







## Experimental 3D Pottery Search Engines

- Integrating a content based retrieval system in an interactive real time 3D VR system
- Enhances the virtual visitors' experience by allowing the system to reply to queries such as
  - *Where else in this scene can I find objects similar to this?*
- Open source technologies combined with commercial VR software
  - Apache HTTP server, PHP, eXist Native XML Database System, Java (applets) & Quest 3D
  - URL: http://polymnia.ipet.gr/akoutsou/xanthi
  - A case study: A virtual tour in the old city of Xanthi



# Thank you