3D Digitization of the Excavation Site of a Fossil Hominid
(StW 573 / "Little Foot", Sterkfontein, South Africa)

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Jean-Pierre Jessel, IRIT, France
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Ron Clarke, Univ. of Witwatersand, South Africa
Francis Thackeray, Univ. of Witwatersand, South Africa
Sterkfontein is a set of limestone caves of special interest to paleo-anthropologists located near Johannesburg in South Africa. Many *Australopithecus africanus* fossils have been found as STS5.
During more than 10 years of careful excavation, Ron Clarke and his colleagues exposed an almost complete hominid skeleton (Stw 573, nicknamed as “Little Foot”) at Sterkfontein in South Africa, which is estimated to be about 3 Myear old.
The bony remains of this individual are very well fossilized. They lie on a sloped area of around 3×3 meters.
The remains (1)

The bony remains of this individual are very well fossilized. They lie on a sloped area of around 3×3 meters. As the paleo-anthropologists dug out around the different elements in order to reach and identify them, the surface is very irregular with deep and narrow cavities.
The remains (2)

This specimen is exceptional by its completeness. Moreover, it is considered to represent a second species of South-African *Australopithecus* which has been ignored for many years (*Australopithecus Prometheus*, Dart 1948). Most of the elements of the skeleton have been uncovered.
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This skeleton and the associated faunal elements have been considered as accumulated at the site as the result of a natural deathtrap (i.e. by falling into a steep shaft)

A few anatomical parts show refossilization crushing, fragmentation, scattering and disarticulation due to an ancient collapse into a cavity beneath the skeleton.
Objective

This skeleton and the associated faunal elements have been considered as accumulated at the site as the result of a natural deathtrap (i.e. by falling into a steep shaft)

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→ to understand the fossilization of the skeleton:

→ carefully record the 3D orientation and location of the bony elements in their discovery state, before their definitive excavation.
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→ to understand the fossilization of the skeleton:

→ carefully record the 3D orientation and location of the bony elements in their discovery state, before their definitive excavation.

→ use of 3D portable scanners for an as exhaustive and accurate digitization as possible
Some related work

- 3D digitization of caves (in particular wall paintings)


  Laser scanning for conservation and research of African cultural heritage sites: the case study of Wonderwerk Cave, South Africa
  Heinz Büther a, b, Michael Chazan b, Ralph Schroeder c, Rudy Neeser c, Christoph Held d, Steven James Walker e, Ari Matmon f, Liora Koiska Horwitz g

- But very few work on in-situ 3D digitization of artifacts


  Structured light scanning for high-resolution documentation of in situ archaeological finds
  Shannon P. McPherron a, b, c, Tim Gernat b, c, Jean-Jacques Hublin d

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The 3D digitizers

We used two 3D laser scanners:
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- **VIVID 910** (Konica-Minolta): widely used in industrial metrology or in cultural heritage
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3D acquisition by projecting stripe(s), computing depth by triangulation and reconstructing a 3D mesh:
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3D Digitization of the Excavation Site of a Fossil Hominid (StW 573 / "Little Foot", Sterkfontein, South Africa)
Methodology

1. Perform many 3D acquisitions of the site taken from different points of view

Acquisition 1:
132,826 vertices / 259,082 faces

Acquisition 2:
194,056 vertices / 365,792 faces
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2. Align and merge the 3D acquisitions to get a global 3D reconstruction

Aligning & merging 8 acquisitions:
1,510,362 vertices / 2,930,933 faces
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But…

- exhaustive 3D reconstruction
  → find the best points of view to limit as much as possible the occlusions

Acquisition 2;
194,056 vertices / 365,792 faces
Front view
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But...

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Acquisition 2;
194,056 vertices / 365,792 faces
Upper view
Methodology

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But...

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- minimize the scanning cost (time, data size)
  → planning the scanner positions (!!!)
On the ground… overall acquisition
(Minolta)

- FOV ≈ 0.6×0.6 m (middle lens)
- No control of the light → no texture

2-3 m
On the ground… *overall acquisition* (Minolta)

- FOV ≈ 0.6×0.6 m (middle lens)
- No control of the light → no texture
- 1 acquisition = 3D mesh (100-300,000 vertices, 200-600,000 faces)
- 10-16 Mbytes in *obj* format
On the ground... overall acquisition
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23 acquisitions

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12 acquisitions

17 acquisitions

+ 33 acquisitions

+ 7 acquisitions

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Series of acquisitions are pre-aligned by picking manually some landmarks between 2 acquisitions

3 work days by 2 trained people

17 acquisitions +
33 acquisitions +
7 acquisitions

\( \rightarrow \) 2-3 m

12 acquisitions
On the ground... *textured details*  
*(NextEngine HD)*

- FOV ≈ 0.3×0.3 m (wide modes)
- With texture (controlled white light)

- 1 acquisition = 3D mesh (100-300,000 vertices, 200-600,000 faces)
- 10-16 Mbytes in *obj* format

2-3 m

skull: 10 acquisitions

• No need of manual pre-alignment

→ 2 work days by 2 trained people
On the ground... \textit{processing (1)}

- **Selection of 3D views.** To reject useless (redundant or no exploitable information due to occlusion).

- **Automatic global registration** by minimizing the average distance between the overlapping surfaces of two acquisitions.

- **Merging** registered 3D meshes. But, the vertices of the different 3D meshes are not exactly at the same position due to the quantification, the imprecision or the noise. A choice or an average has to be made. How to fuse the colors?

- **Simplification.** Reduce (by deletion or fusion of close points) the number of vertices and faces.

- **Smoothing** to remove visual defects (e.g. spikes).

- **Hole filling** to delete the holes induced by the occlusions. Some algorithms detect the holes in a 3D mesh and infer surface patches which lies on their boundaries. In order to not be too visually detectable, these patches must follow a curvature continuity constraint.

- **Rendering** i.e. displaying the final 3D reconstruction by defining the viewpoint, the lighting and more generally how a triangle of the mesh looks (reflection to the light, color, artificial texture).
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→ many work days by trained computer scientists…

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**On the ground… processing (2)**

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→ comparable results except for rendering which is better with specific (commercial) software…
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<td><strong>Rapidform XOR: ~10,000 $ (?) Zbrush 4.0: 700$ (commercial price)</strong></td>
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Some results *textured details* *(NextEngine HD)*

Photograph of the skull of “Little Foot”
Some results *textured details*

*(NextEngine HD)*

3D reconstruction (1,125,446 vertices / 2,068,848 faces) based on 6 acquisitions, without texture
Some results *textured details*  
*(NextEngine HD)*  

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Some results *textured details*
*(NextEngine HD)*

Photograph of the left arm of “Little Foot”
Some results *textured details*  
*(NextEngine HD)*

3D reconstruction (535,668 vertices / 1,067,723 faces) based on 18 acquisitions with texture
Some results *textured details*

*(NextEngine HD)*

Photograph of the left hand
Some results *textured details* *(NextEngine HD)*

Zoom of the 3D reconstruction (535,668 vertices / 1,067,723 triangles) of the arm with texture
Some results *overall acquisition* (Minolta)

3D reconstruction of the site (1,224,885 vertices / 2,446,034 faces) based on 37 acquisitions
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Parts of the mesh have been manually painted with artificial texture (rock/bone)
Future work

• use the 3D models to **analyze the taphonomic processes**, e.g. how are the arm bones broken, how are positioned the hand bones, how are the different bones dispatched on the floor, etc.?

• **understand the 3D stratigraphy** by observing the geometry of rock layers. Possibility **to come back** to a non-interpretative view of the context.

• 3D scan the fossils at very high resolution (CT, µ-CT) and align these models in the “virtual” site to **combine high accuracy and exact positioning**.

Geometry of the rock layers on the right of the excavation site
The authors thank Nkwane Molefe and Stephen Motsumi for their help and advice during the 3D digitization.

The research is supported by the HOPE (Human Origins and Past Environments) International Program funded by the French Embassy in South Africa and the National Research Foundation (South Africa) and the International PICS INLOO Program funded by CNRS.

Kroomdrai excavation site (2 km E of Sterkfontein)