

XXV FIG International Congress KUALA LUMPUR 2014



Highly Detailed 3D Modelling of Mayan Cultural Heritage using an UAV

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Outline

- Introduction
- Study area
- Data acquisition
 - Imagery
 - Topography
- Data processing
- Model evaluation
- Model presentation
- Work in progress, further work and conclusion

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Introduction

- 3D modeling for archaeology and cultural heritage
- Indispensable tool for:
 - Documentation;
 - Registration;
 - Visualization;
 - Analysis;
 - Restoration;
 - Research;
 - Virtual tourism;
 - ...









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Introduction

- **Objective:** to build a 3D model with high radiometric and geometric accuracy (sub dm) and to establish a 3D GIS and web mapping service of the Mayan site of Edzná, Mexico
- **Prerequisite:** terrestrial camera + flexible & transportable compact UAV (local spare parts, highly manoeuvrable) (helium balloons as spare solution)
- **Timeframe:** two weeks (November 2013)
- **Partners:** UNESCO and INAH Campeche (Mexico)

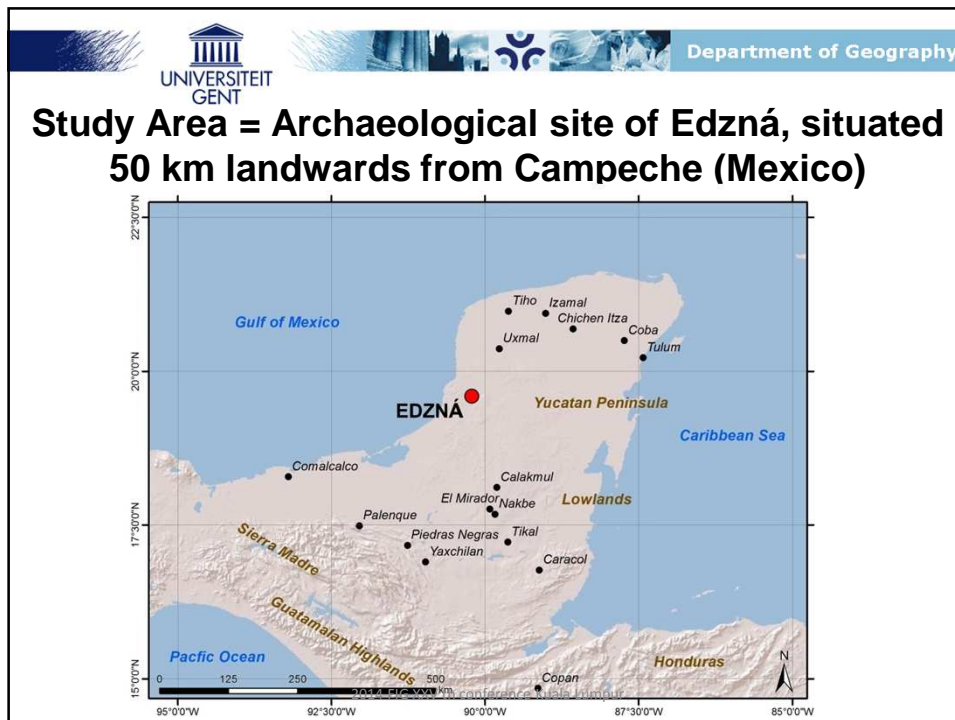


United Nations
Educational, Scientific and
Cultural Organization



Instituto Nacional
de Antropología
e Historia

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Study Area

- Archaeological site of Edzná is a Mayan site
- Habited: 600 BCE – 1450 CE
- Flourished: 600 – 800 CE
 - Over 25,000 inhabitants
 - 16 large structures built in Puuc and Peten style over 18 square km

'Moon temple' 'Temple of the Nohochna' 'North Temple'


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Data acquisition

Imagery: platform → *TSH GAUI 540H* UAV




- Multi-rotor (hexacopter) platform (0,5 kg);
- GNSS antenna and gyroscope for auto-stabilisation (no autopilot, flight planning or geo-tagging yet);
- 7 till 8 minutes autonomy loaded (1,7 kg) with camera and batteries;
- 88 Wh / 700 g LiPo batteries (3 cell = 11 V)

www.gauai.com.tw

www.dji-innovations.com

www.turnigy.com




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Data acquisition

Imagery: platform → *TSH GAUI 540H UAV*



- SONY NEX 5R camera (287 g);
- 16.1 Mp
- APS sized sensor (25.1 x 16.7 mm);
- Video AVCHD 1080/60i HD capacity;
- Lens: 20/2.8 mm or 16-50 mm;
- IR camera trigger;
- Time lapse software
- Two axis stabilising camera gimbal;
- Live video transmission system.

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Data acquisition



- Both terrestrial and airborne (UAV) images (approx. 10000) were taken;
- Flying height of 100 m;
- Angle of view: 55 by 76 degrees;
- Coverage approx. 100 by 150 m;
- Camera mounted vertically or under an angle up to 45 degrees;
- 2 till 4 cm GSD
- very high overlap: 80-90%

<http://www.youtube.com/watch?v=GFZhh7h1MiQ>

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Data acquisition: GCP and geographic framework

- First order topographic network: 9 points, measured with handheld GNSS (Garmin eTrex 30) for absolute geo-referencing (UTM 15N, WGS84) by least square adjustment.
- Second order network: 25 till 90 characteristic (non-materialized) points, measured by Trimble M3 total station, for accurate positioning of GCPs of each temple model and for temple model alignment.
- Of these second order points a subset of approx. 20 points were used as check points for quality control.

GNSS: *Garmin eTrex 30*: 2 meter accuracy in SBAS (WAAS) mode

Total station: *Trimble M3*: Distance accuracy: $\pm (2 \text{ mm} + 2 \text{ ppm})(\text{prism})$, $\pm (3 \text{ mm} + 2 \text{ ppm})$ (reflectorless); Angular accuracy: 2".

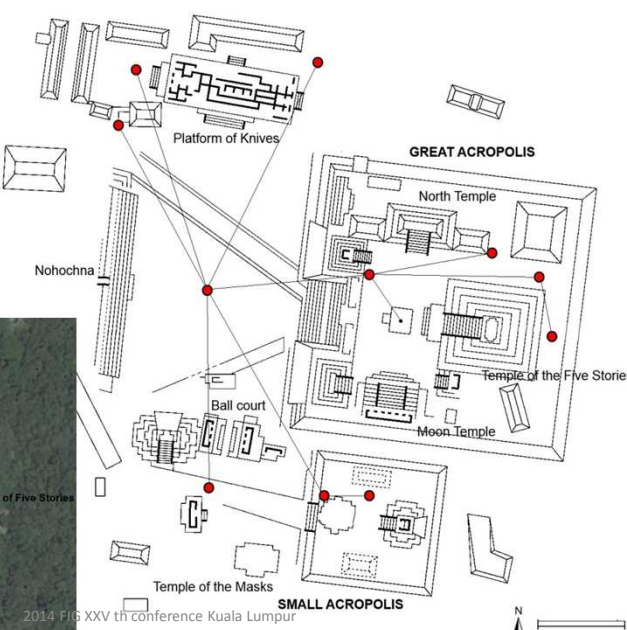




www.trimble.com www.garmin.com

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Topography: GCP and geographic framework





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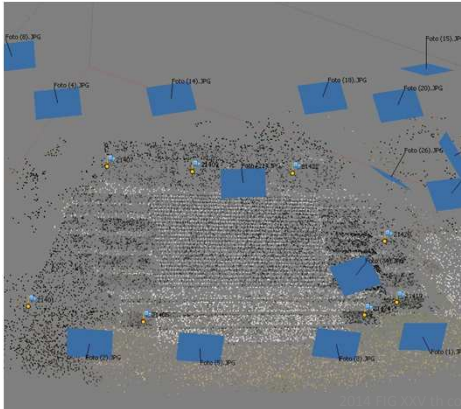
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Data processing

Image based 3D modeling (Agisoft Photoscan software)

Structure from Motion



- Image selection/sorting;
- Feature point detection;
- Feature Matching (multistereo matching);
- Maximum likelihood image alignment;
- Iterative bundle adjustment (sparse point cloud);
- Assigning GCPs to 3D image (3D model alignment).

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Data processing

Image based 3D modeling: SfM-MVS

MultiView Stereo



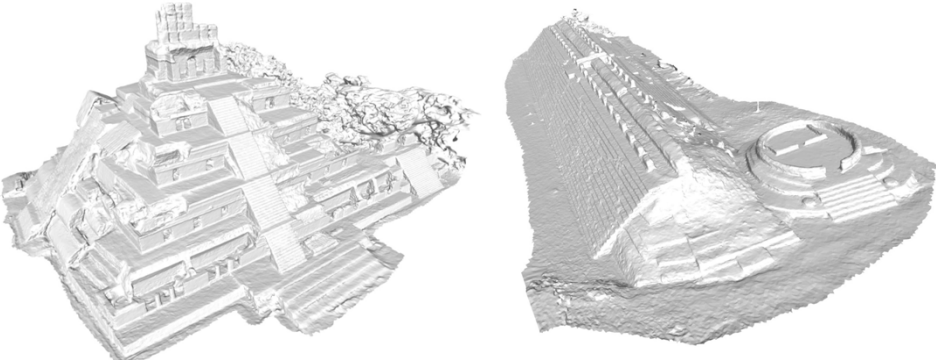
- Projection of pixel rays of dense point cloud of each aligned image in 3D space.
- Using position, orientation and focal length of each image frame, a depth map is calculated, representing the intersections of perspective pixel rays.
- Triangulation of dense point cloud
- Mesh reduction (optional)
- Texture mapping (optional)

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Data processing

Image based 3D modelling: triangulation of dense point cloud and mesh reduction




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Data processing

Image based 3D modelling: texture mapping / image draping



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Model Validation

- Absolute accuracy: related to GNSS measurements
- Relative accuracies (after outlier removal) of second order network (alignment errors using least square adjustment) .

	ΔX		ΔY		ΔZ	
	MAE (m)	RMSE (m)	MAE (m)	RMSE (m)	MAE (m)	RMSE (m)
'Cinco pisos'	0.016	0.020	0.019	0.023	0.016	0.021
'Moon temple'	0.014	0.017	0.014	0.018	0.012	0.014
'North temple'	0.014	0.019	0.019	0.024	0.015	0.019

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Model presentation

Image based 3D modelling:visualization

SOME EXAMPLES

<http://cartogis.ugent.be/edzna/index.html>

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Model presentation

Image based 3D modelling: visualization

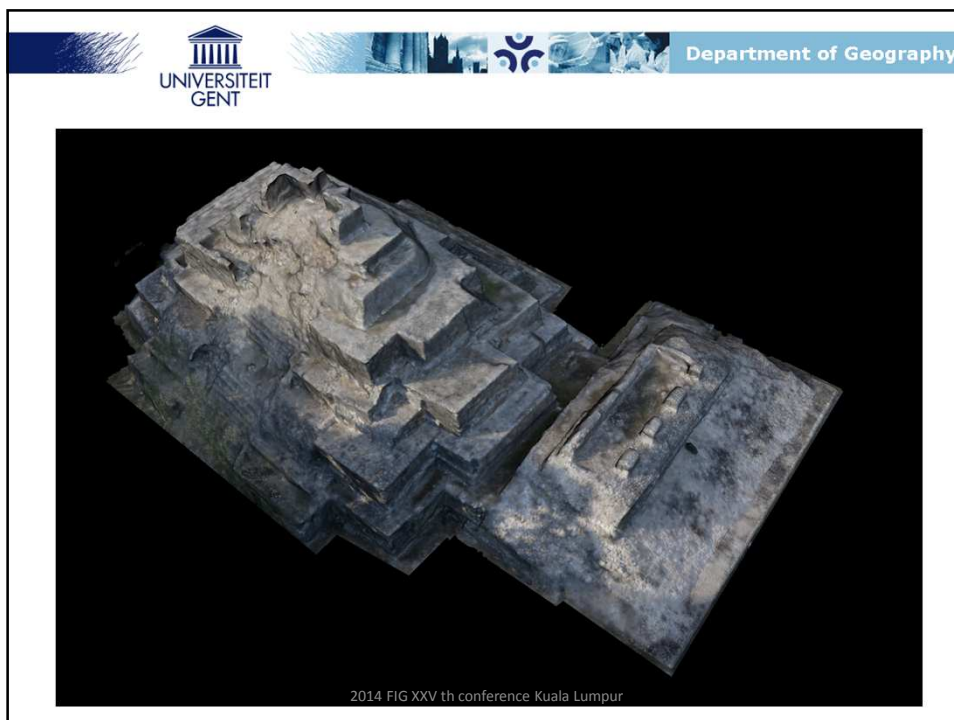
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<http://cartogis.ugent.be/edzna/index.html>

EDZNA 3D Home 3D models
About Contact

3D models

This page contains all generated 3D models. Click on a photo to access the 3D viewer.

All →
Gran acropolis →
Pequeña acropolis →
Other →


Overview → Edificio de los cinco pisos → Moon temple →
North temple → South temple → Ball court →
Nohochna → House → Platform of knives →

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<http://cartogis.ugent.be/edzna/index.html>

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EDIFICIO DE LOS CINCO PISOS [Back to 3D models →](#)

This is the main building. Scroll to zoom and drag to pan.



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Work in progress

Development of a FULL GIS allowing 3D/4D analysis

- Data standardization;
- Feature simplification:
 - Face reduction;
 - Primitive fitting;
 - ...
- Conceptual coherence with archaeological databases;
- Intelligent implementation of Levels of Detail (LoD);
- Decomposition of structures to allow temporal analysis.

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Work in progress

Developing of a Web Mapping Service (WMS) with 3D models visualised in geo-viewers

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Conclusions

3D modeling of archaeological site of Edzná (Mexico) successfully resulted in series of 3D models:

- Compact system configuration was used successfully:
 - UAV for airborne imagery (100 m flying height);
 - Terrestrial images from hand with lowcost camera;
 - First and second order GNSS/total station network for GCP;
- Image-based reconstruction technique (SfM-MVS with Agisoft software) was used for photorealistic models;
- Relative accuracy of 1.0 till 2.5 cm was reached;
- Models available online:
<http://cartogis.ugent.be/edzna/index.html>;
- More work in progress enhancing the 3D/4D GIS component and the Web Mapping Services

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Thank you for your attention



QUESTIONS?

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<http://cartogis.ugent.be/edzna/index.html>

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