ETH Eidgenössische Technische Hochschule Zürich

DARCH
Institute of Conservation
and Building Research

UAV-based very high-resolution 3D city modeling

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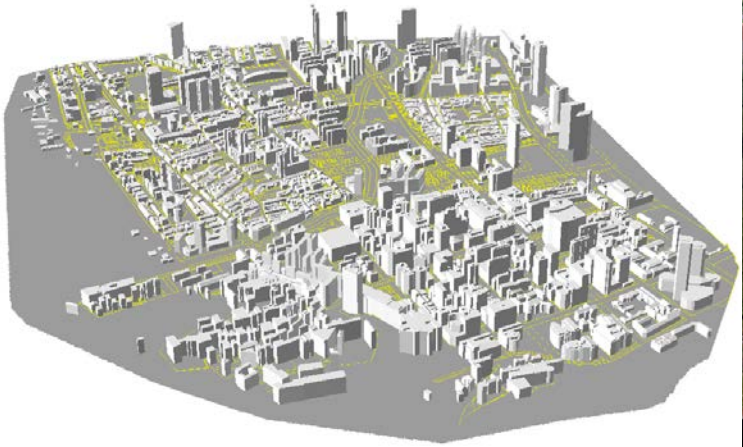


Measuring and Modeling *(to combine !!!)*

Modeling

- Generic (synthetic)
- Reality-based
- Combinations

Object modeling

+ Geometrical	⟶	• Pointcloud
+ Topological		• Line model
+ Semantic		• Surface model
+ Texture		• Volume model

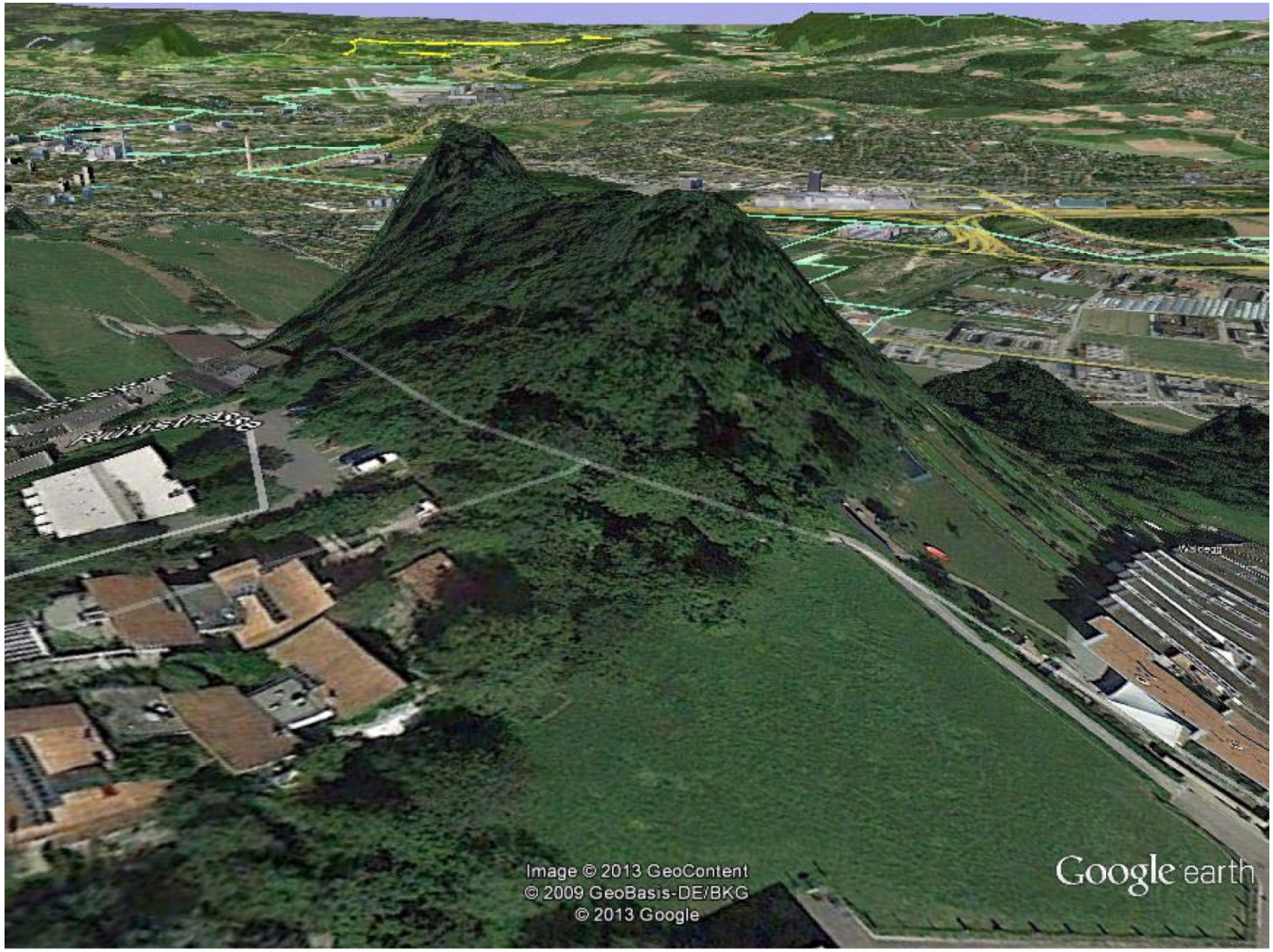
Data processing

- Measurement
- Modeling
(- Combination, simultaneous)

+ manually
+ semi-automatically
+ automatically

Trends: Multi-sensor approaches
- more efficient recording
- to ease automation

Taipei – reality based modeling on Google Earth

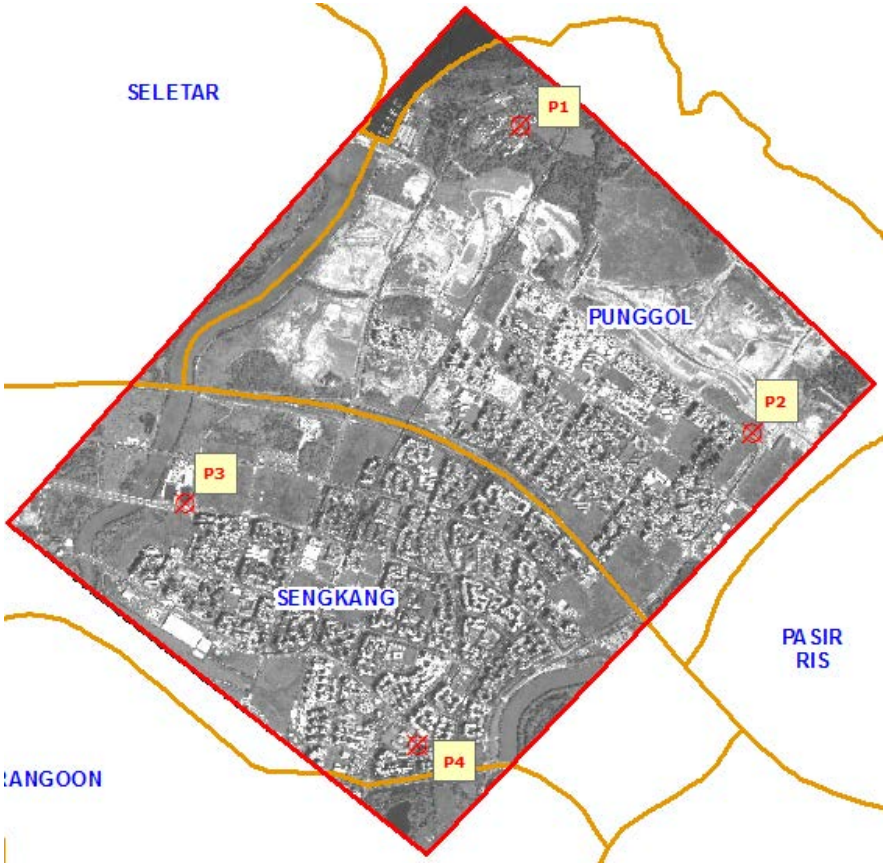


Zurich Gockhausen
in Google Earth

Singapore – 3D city models from satellite images

IKONOS, WV-2 stereos

WV-2 Punggol



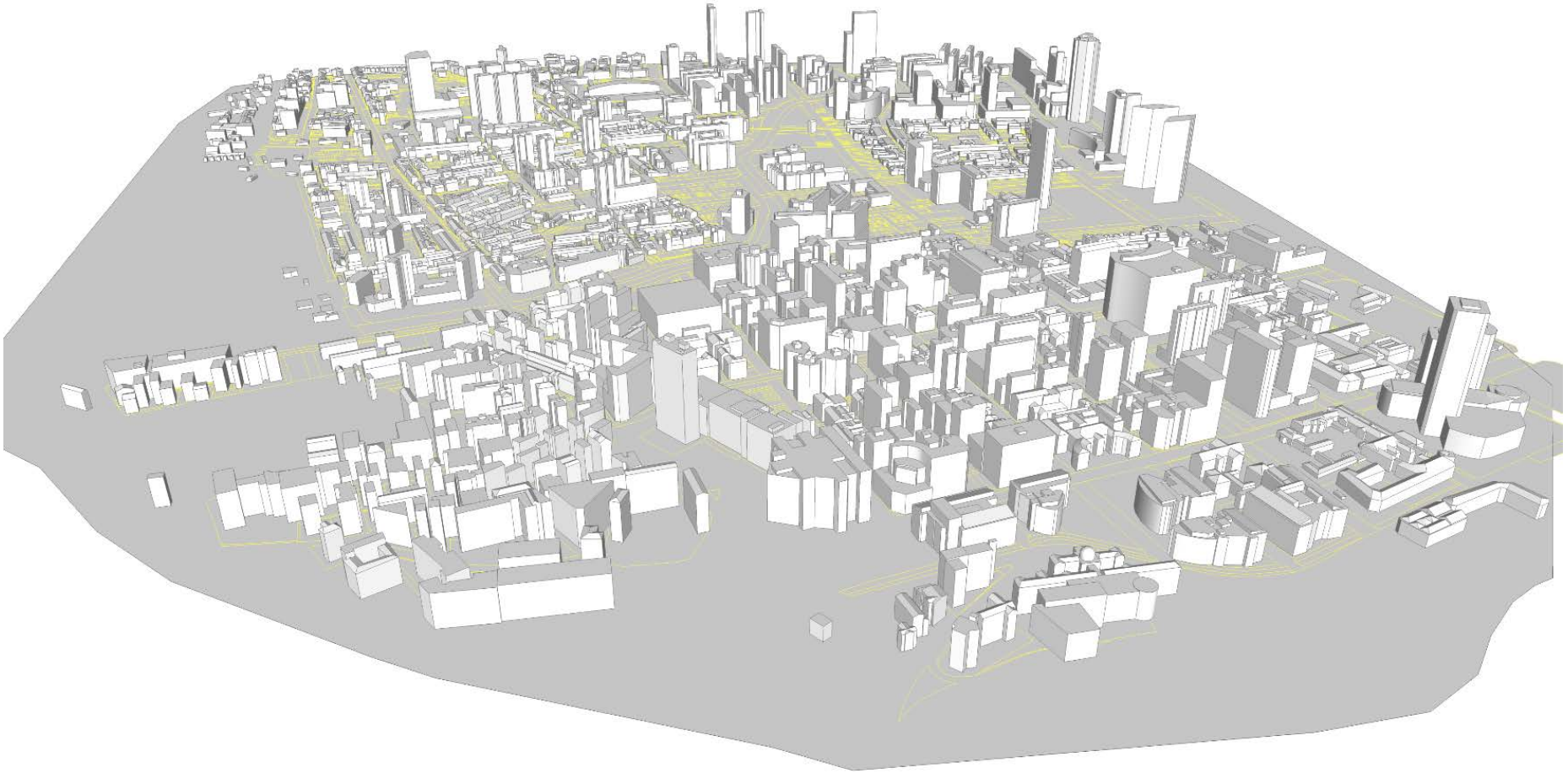
IKONOS Little India, Geelong

Building and Terrain Model – Little India

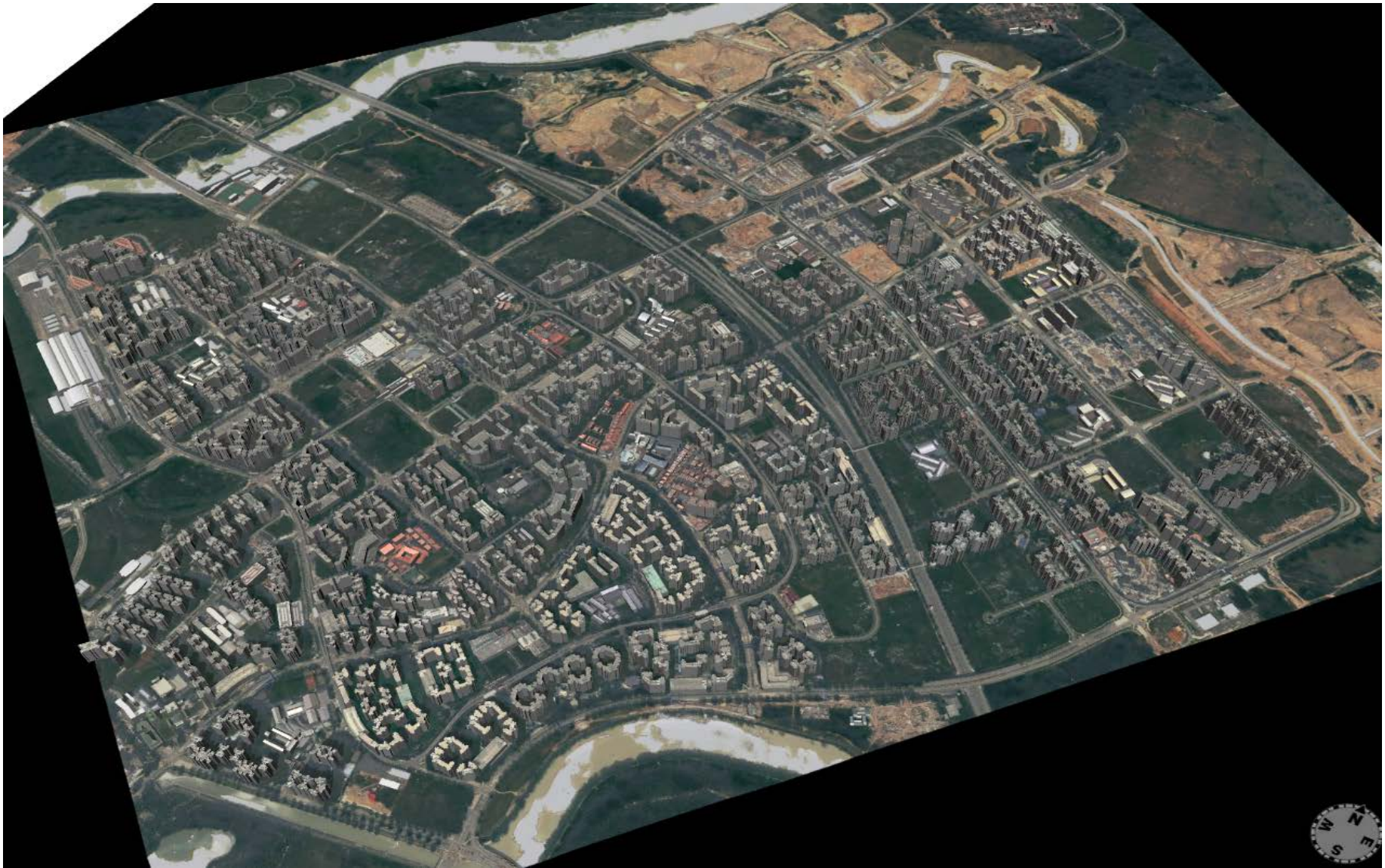
Overlay cadastral map

Rochor

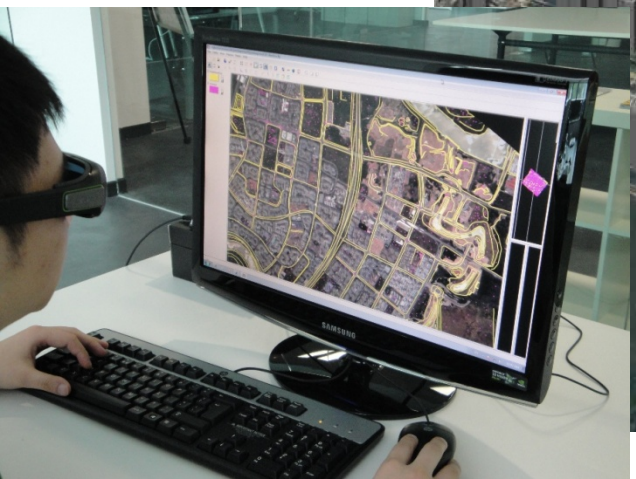
3 clips



Punggol 3D



Punggol 3D



Aerial Cameras

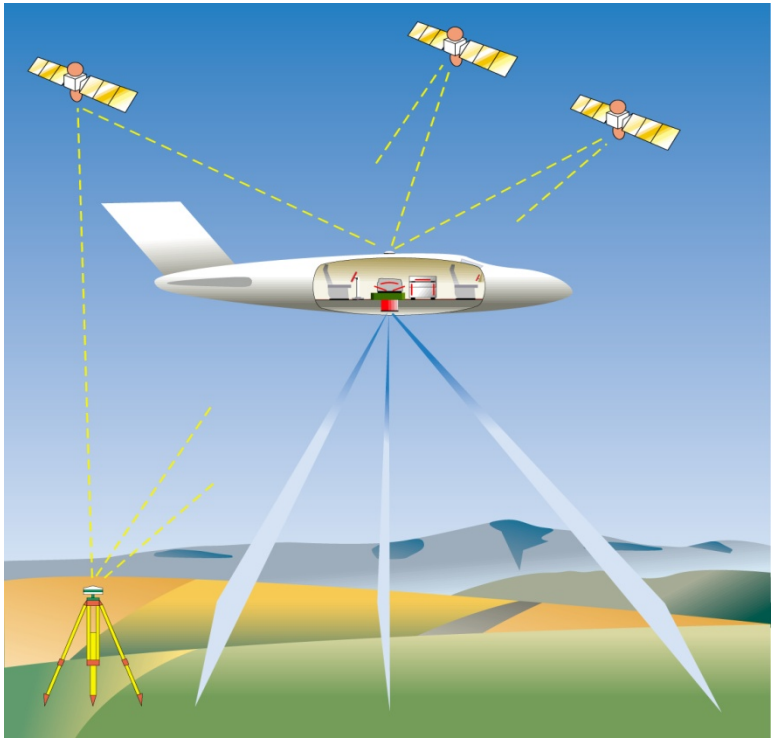
Digital cameras:

6 commercial large format systems

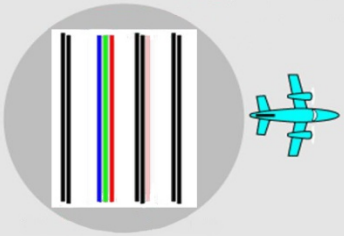
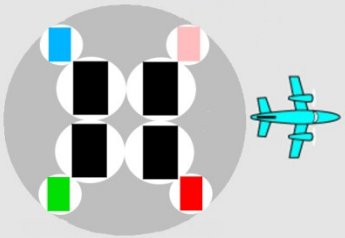
Many new medium format cameras

Multi-camera oblique systems

UAVs with amateur cameras



Das Produktion Model
mit einer Optik und einer Focalebene

ADS40 von LGGM	DMCS von Z/I
	
3 Zeilen panchromatisch gestaggert für Stereo 3 bis n Zeilen multispektral	4 Matrix panchromatisch schräg 4 Matrix multispektral
1 Optik + 1 Fokalebene	8 Optiken + 8 Focalebenen

CC-Modeler: ETH Zurich, Main Campus

Planning

flyover

Student project: Castle Landenberg

Symbol of Obwalden in the

Landenberg: Flight planning

- Circle with a radius of 25 meters
- 24 images; every 15°
- Images oblique
- Simulation

Student project: Castle Landenberg

Terrestrial Techniques

Development of sensors

- Low cost cameras
- Panoramic cameras
- Laserscanners, structured light
- 3D CCD/CMOS chips
- Hybrid systems (e.g. Mobile Mapping Systems)

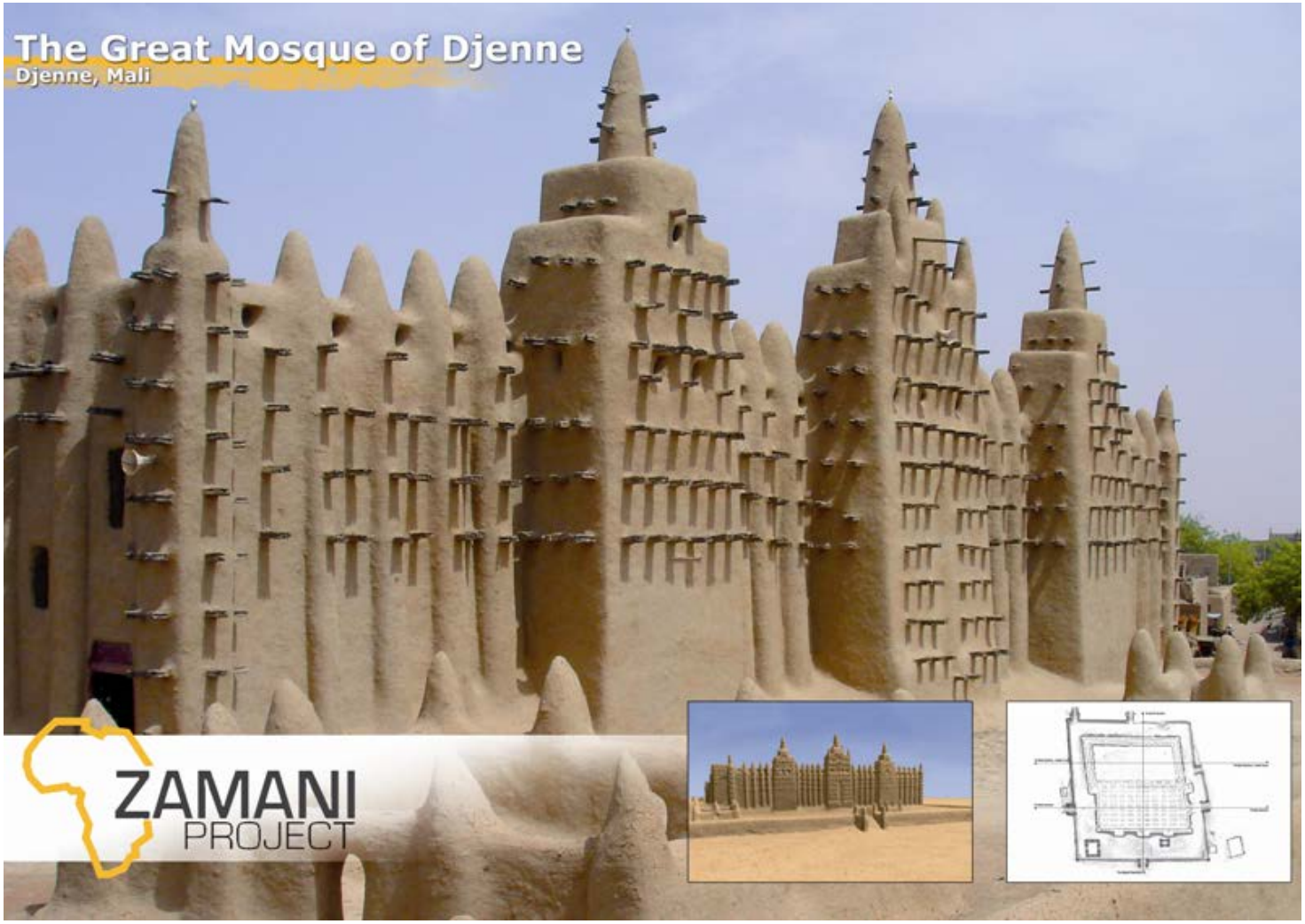
Large format cameras:

Hasselblad&Phase One:
39 Mpi, 2 sec/image, ca. SFr 40 000

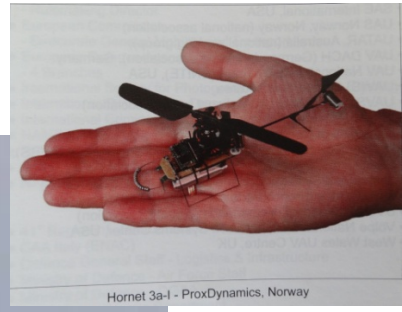
Mobile (Ubiquitous) Photogrammetry

Example: Galaxy S3, 13Mpi camera, full HD video, 3GB RAM, 32/64 GB, GPS/GLONASS, bluetooth, WIFI, UBS, etc.

Zamani project (courtesy H. Ruether): **Djenne mosque (2008)**



Various UAVs

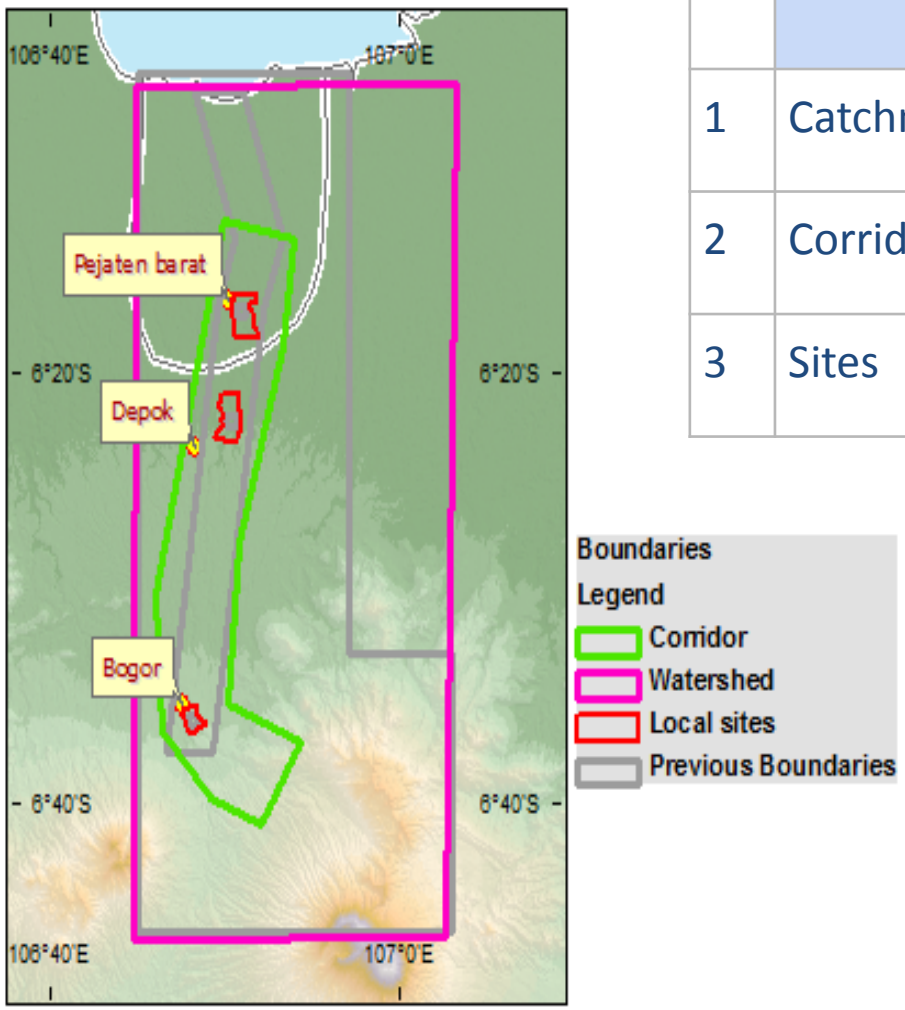


SEC-FCL project – UAV over NUS campus

Prime Minister of Singapore Lee Hsien Loong, National Day Rally 2012, UAVs as a key breakthrough technology for the next 20 years: **”UAVs will have many uses in the future – civilian and military”.**

AscTec Falcon 8
500 g load
max 20 min flight time
max 10 m/s wind speed
redundancy through 8 rotors
GPS, height sensor, compass, IMU
max. Total weight 1,8 kg

Required Chiliwong DTM data



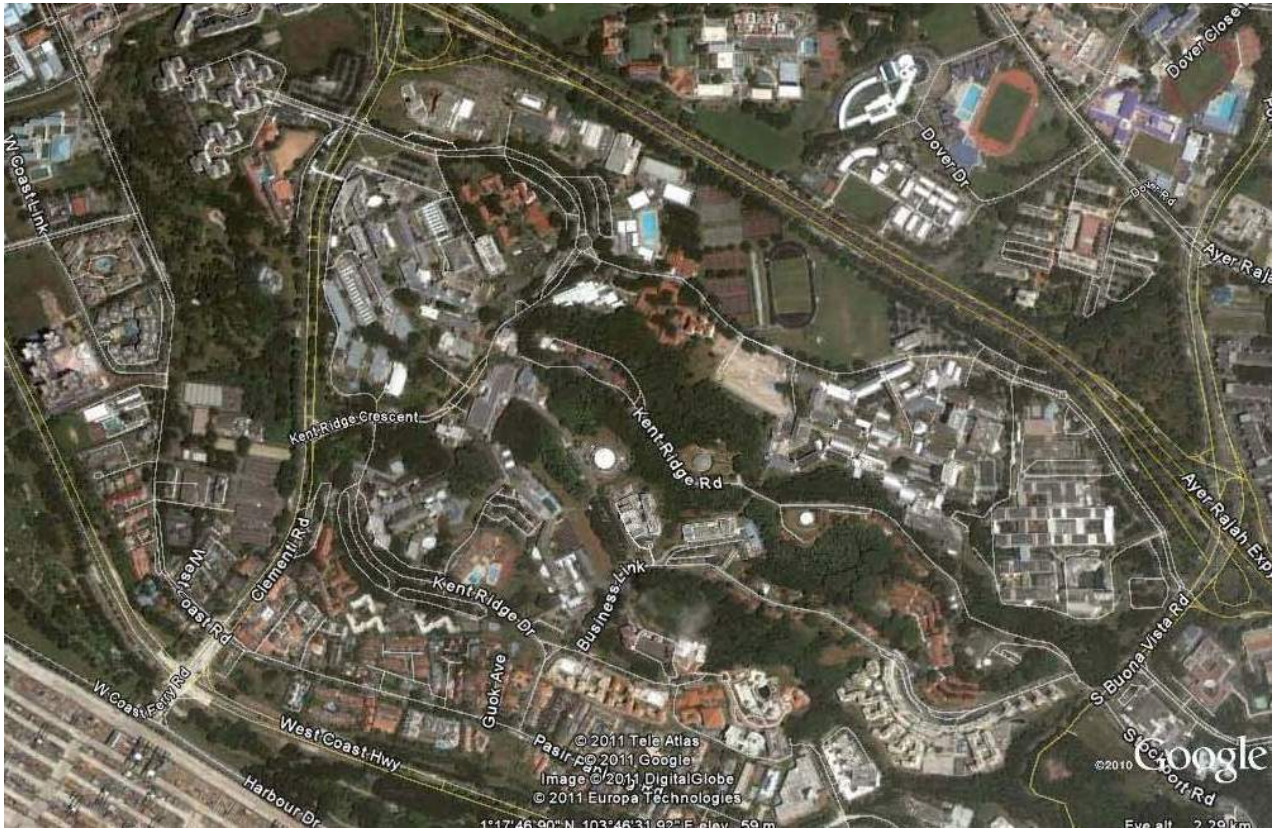
N	Level	Area (ca. sqkm)	Resolution (m)	Vertical accuracy (m)
1	Catchment	2443	100	5.0
2	Corridor	425	5	1.0
3	Sites	18	1	0.1

High-res sites:
Urban: Kampung Melayu
Sub-urban: Serengsen Sanat
Rural: Ciawi

Ciawi model

SEC-FCL project – UAV over NUS campus

Singapore – **E**TH **C**entre for Global Environmental Sustainability
Future **C**ities **L**aboratory (Simulation Platform)



Difficulties in UAV urban data acquisition

- Permission application, various flight restrictions
- Radio interference in urban areas
- Limited take-off/landing spaces
- Short flying times
- NUS Campus: Steep terrain, high buildings, tropical vegetation

SEC-FCL UAV NUS campus flight
Take-off and landing stations

CREATE take-off

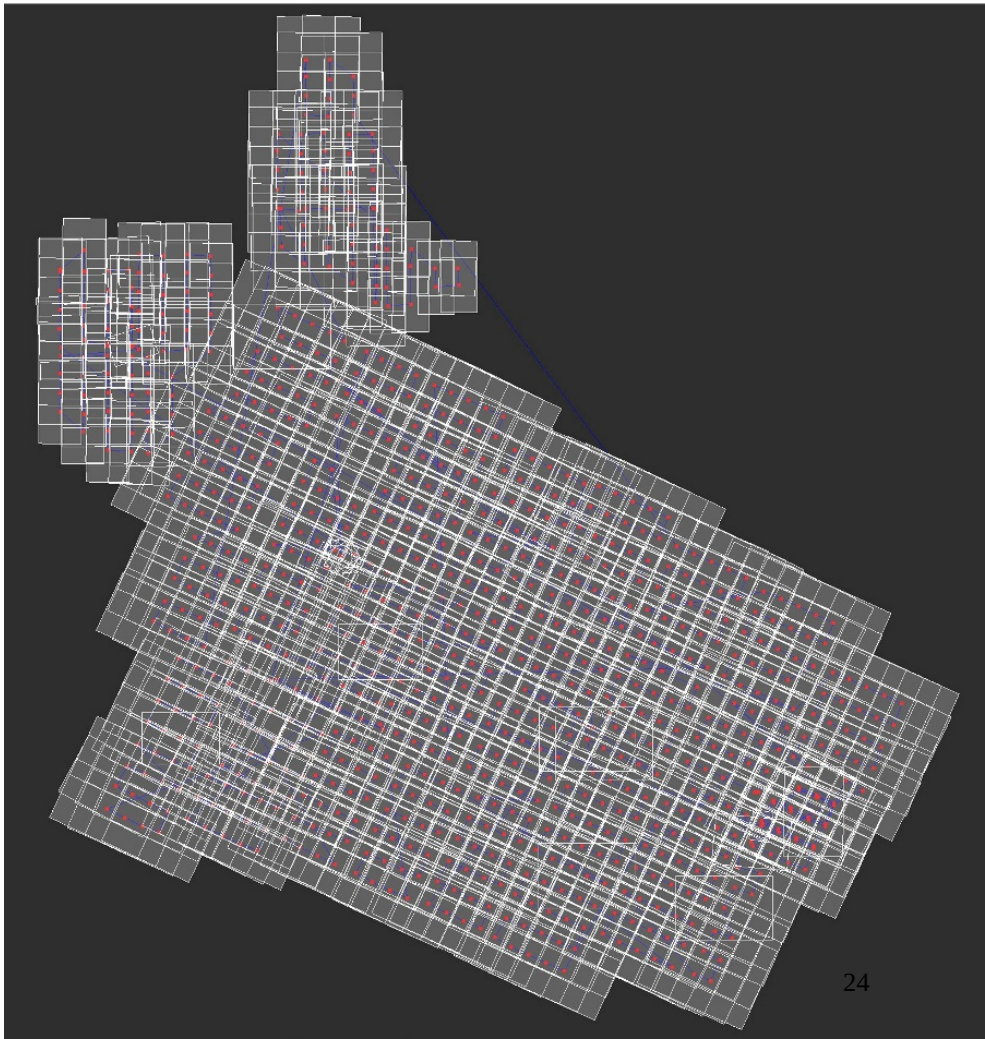
Falcon roof landing

Education Resource Centre

CREATE Tower

SEC-FCL project – UAV over NUS campus

Singapore – **E**TH **C**entre for Global Environmental Sustainability
Future **C**ities **L**aboratory (Simulation Platform)

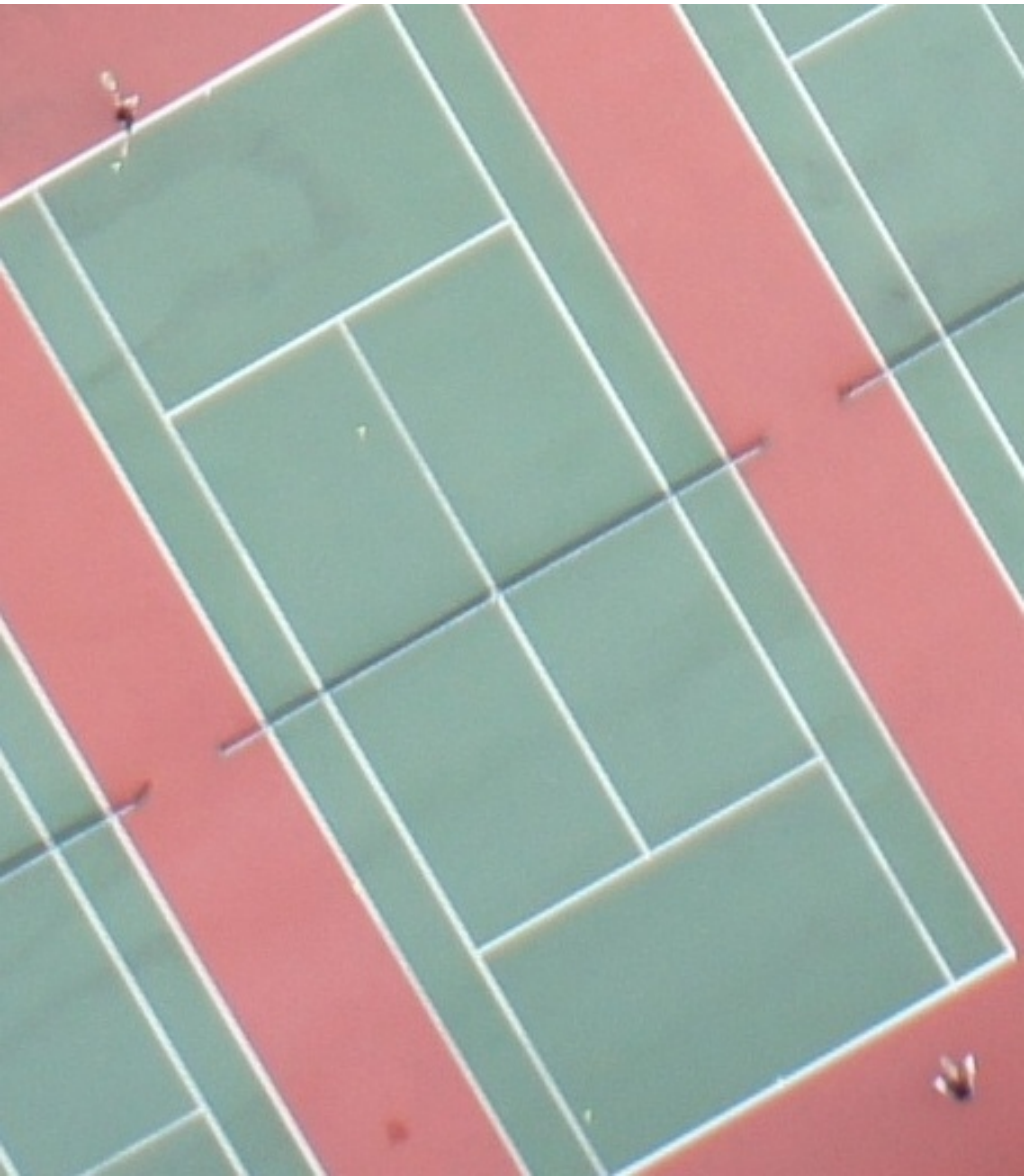


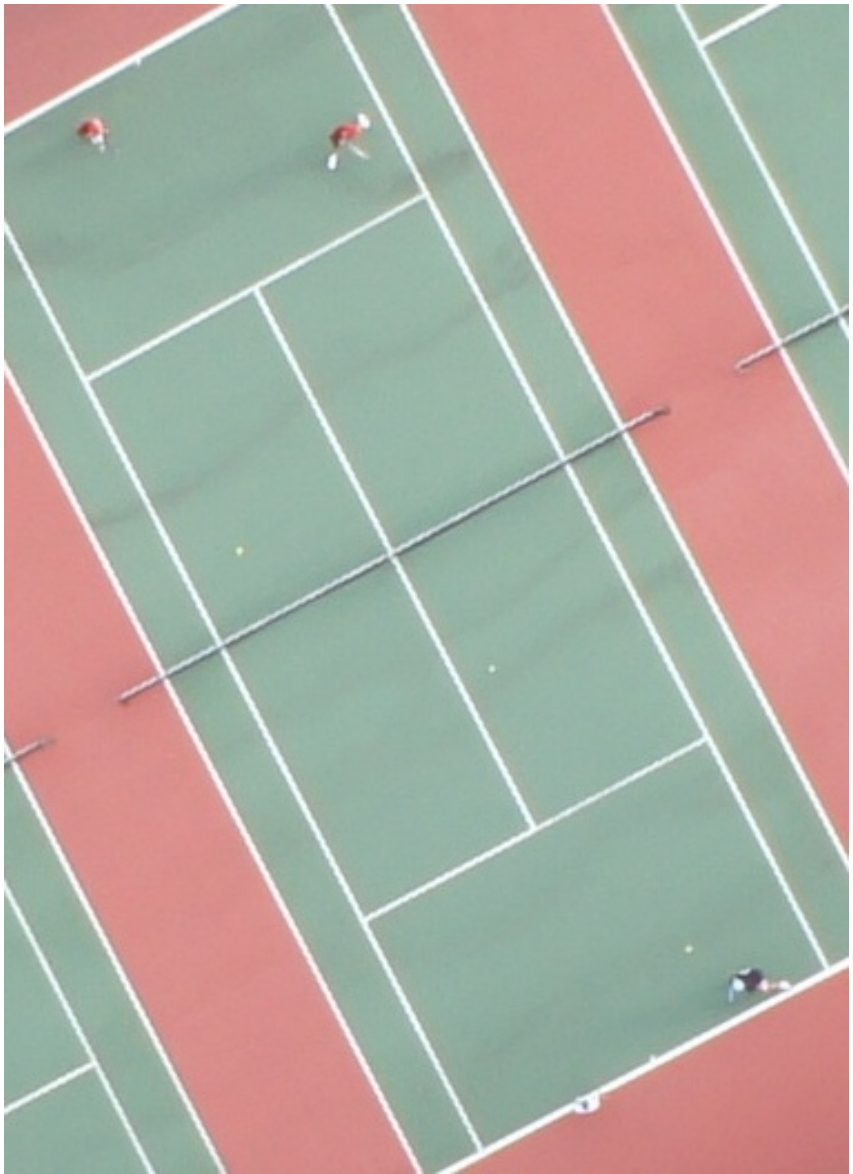
4x4 image block University Hall

4x4 block

P-Centres total block

NUS tennis courts, tennis balls





Data Processing

- Georeferencing: GCPs by GPS (datum)
  Image triangulation/bundle adjustment
- Model generation: DTM, man-made objects, natural features (trees, etc.)
  Photo texture: Roofs, terrain

Tree models

Geo-referencing – with LPS

LPS failed in tie point generation.

Image 505

Self – developed tie point generator:

Sift + Ransac algorithm in relative orientation for blunder detection.

Triangulation results with LPS

Check Pt No.	Max ImRes x(pixel)	Max ImRes y(pixel)	ResX(meter)	ResY(meter)	ResZ(meter)
6	0.76	0.29	0.198	0.176	-0.910
9	1.28	1.19	-0.081	0.142	2.074
10	0.68	0.35	0.303	0.113	4.351
15	0.26	1.03	0.005	0.074	0.347
21	1.74	0.25	-0.040	-0.071	0.202
22	3.27	1.96	-0.193	0.120	1.742
29	0.61	0.88	0.136	0.137	-0.346
30	1.48	1.22	-0.099	-0.089	0.189
31	0.38	1.22	-0.076	-0.071	-0.173
33	1.04	1.22	0.104	-0.116	0.113
39	1.09	0.98	0.125	0.109	0.999
Mean			0.035	0.048	0.781
Std			0.143	0.105	1.406
RMSE			0.147	0.115	1.608

Software Packages for Trial

high automation, easy to use, less customized settings. The mean projection error is 0.11 pixels, gcp residuals are provided but without image point residual of gcp

high automation. Mean projection error in free-network bundle adjustment is 2 pixels. Maximal around 2 meters in check point residual

Customized software from University of Graz[1]

Oriented 600 images

[1]Towards Fully Automatic Photogrammetric Reconstruction Using Digital Images Taken From UAVs Arnold Irschara, Viktor Kaufmann, Manfred Klopschitz, Horst Bischof, Franz Leberl. Proceedings International Society for Photogrammetry and Remote Sensing Symposium, 100 Years ISPRS - Advancing Remote Sensing Science, 2010

Software Packages for Trial

Support only traditional aerial mapping, but hard to configure our block into strips. Not applicable for our dataset.

Inpho	MATCH-AT	Failed

Apero Linux open source software developed by IGN, France. Successful in free-network triangulation, obtained RMSE of 8cm, 6cm,6cm in x,y,z directions. Coordinates of object points are not accessible. Covariance matrix not available.

Triangulation results of Apero

Check Pt No.	Max ImRes x (pixel)	Max ImRes y (pixel)	ResX(meter)	ResY(meter)	ResZ(meter)
6	1.89	0.87	0.102	0.066	0.016
9	1.53	0.64	0.004	0.04	0.08
10	1.93	1.46	0.142	0.005	-0.099
15	1.4	1.06	0.142	0.134	-0.014
21	0.74	0.43	-0.009	-0.007	0.006
22	1.98	1.25	0.038	0.057	-0.148
29	1.1	0.53	-0.005	0.039	0.026
30	1.57	0.77	-0.012	-0.024	0.016
31	1.57	0.94	0.05	0.027	-0.026
33	1.6	0.82	0.057	0.052	-0.044
39	2.39	0.79	-0.108	0.122	-0.061
Mean			0.061	0.052	0.049
Std			0.057	0.036	0.048
RMSE			0.080	0.066	0.065

Multi-sensor data

(1) Vertical aerial UAV images at 5 cm footprint

(2) Oblique UAV images (in planning)

(3) Raw point clouds from MMS

(4) Terrestrial images from off-the-shelf cameras

(5) Ground Control Points (GCPs)

(6) Existing data (maps)

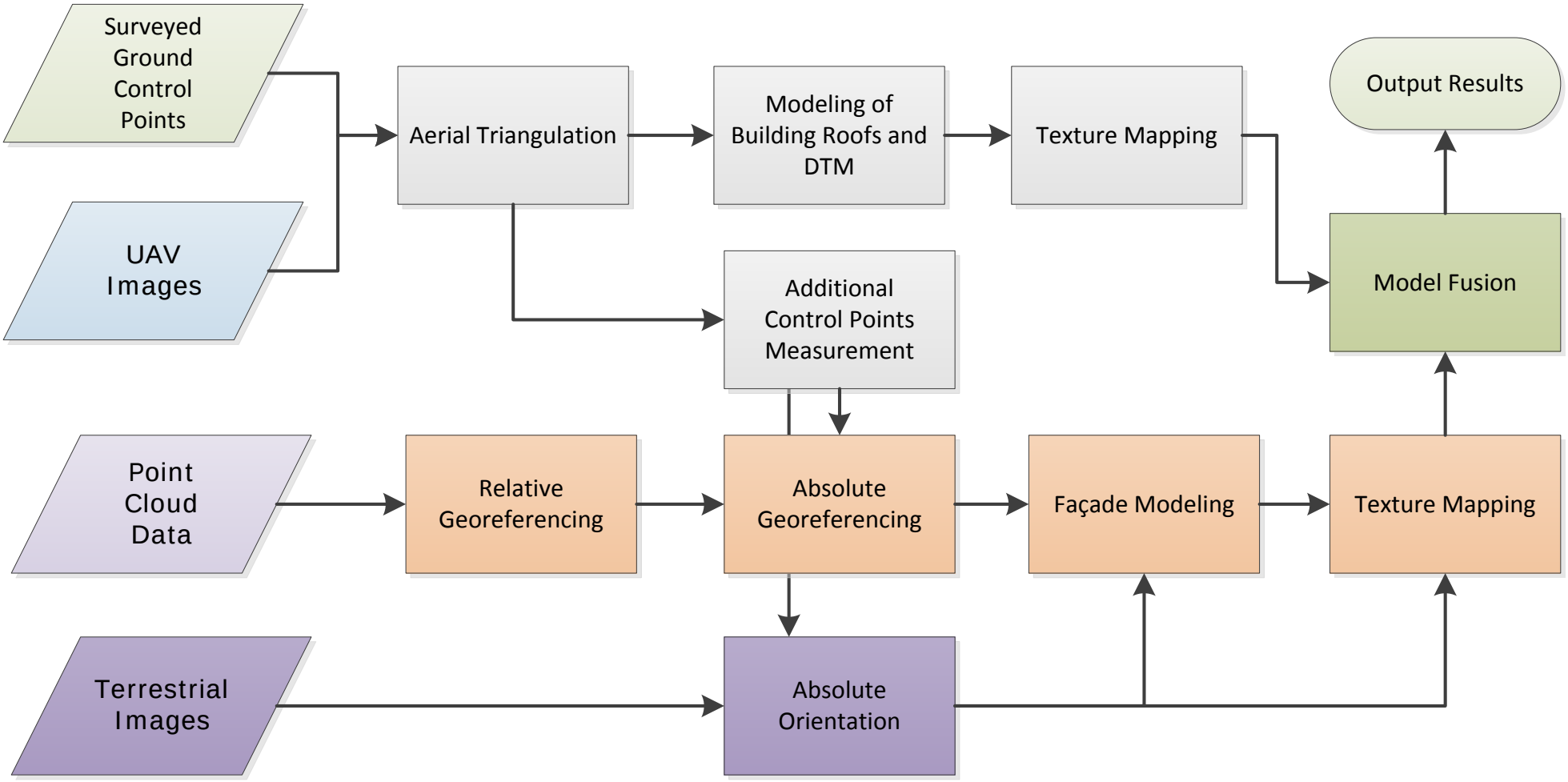
Output

3D hybrid site model, achieved by integration of these input data

Main steps of our work

(a) UAV images aerial triangulation/geo-referencing
(b) Integration of UAV-derived GCPs to geo-reference and adjust the MMS point cloud data
(c) Modeling of the roof landscape from UAV images
(d) Modeling of trees from UAV images and MMS data
(e) Merging of DTM data from UAV images, MMS point clouds, total station measurements and from existing maps
(f) 3D modeling of façades from MMS data
(g) 3D modeling of façades and other object parts from oblique UAV images and terrestrial photogrammetric digital images
(h) Fusing façade and roof models to generate a complete model
(i) Texture mapping

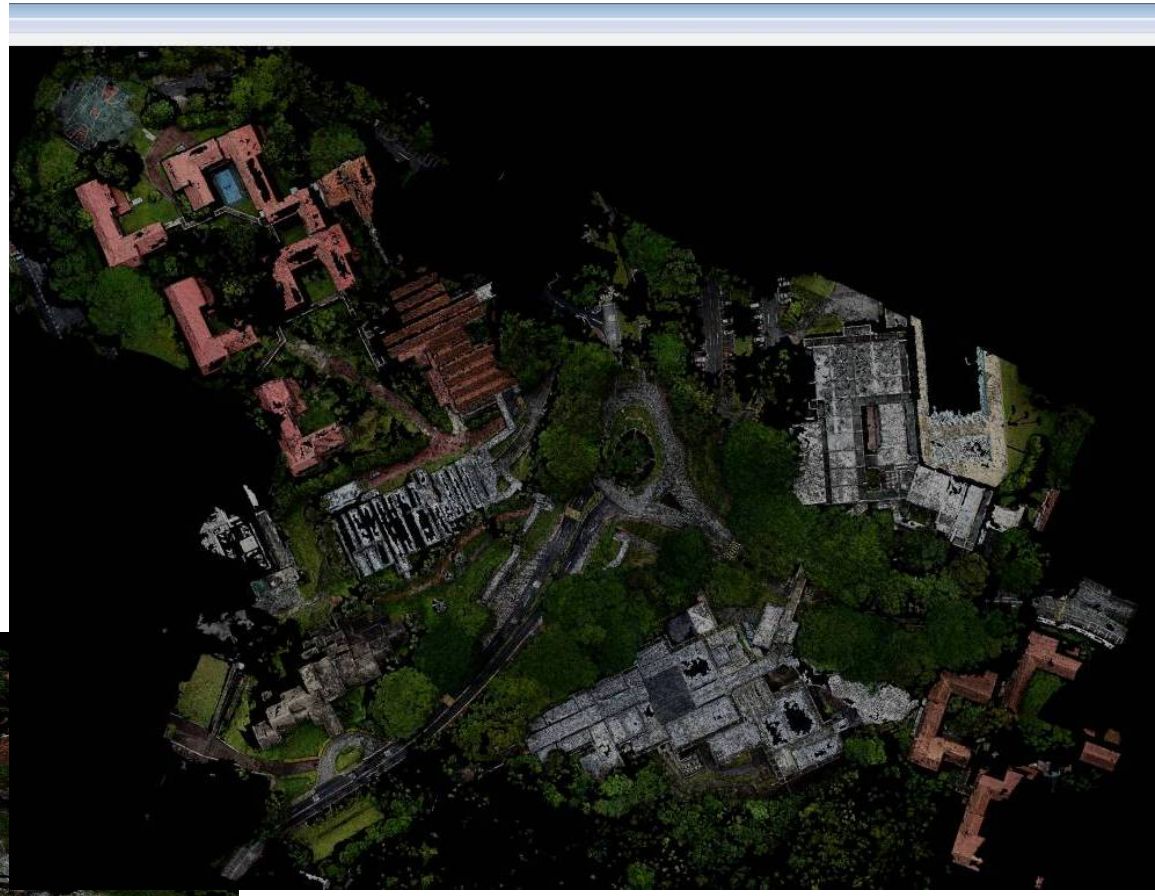
Data processing steps

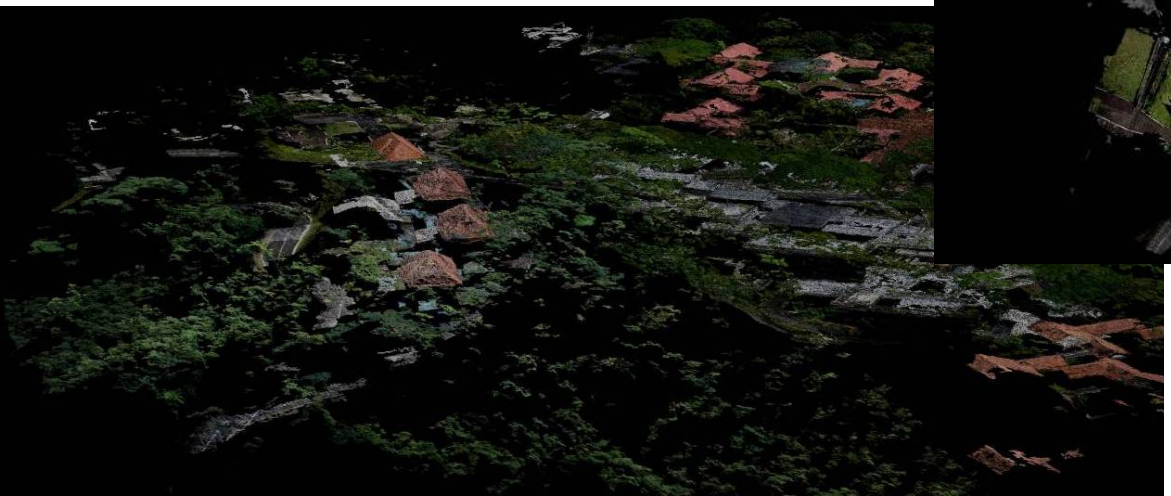


Object measurement strategy

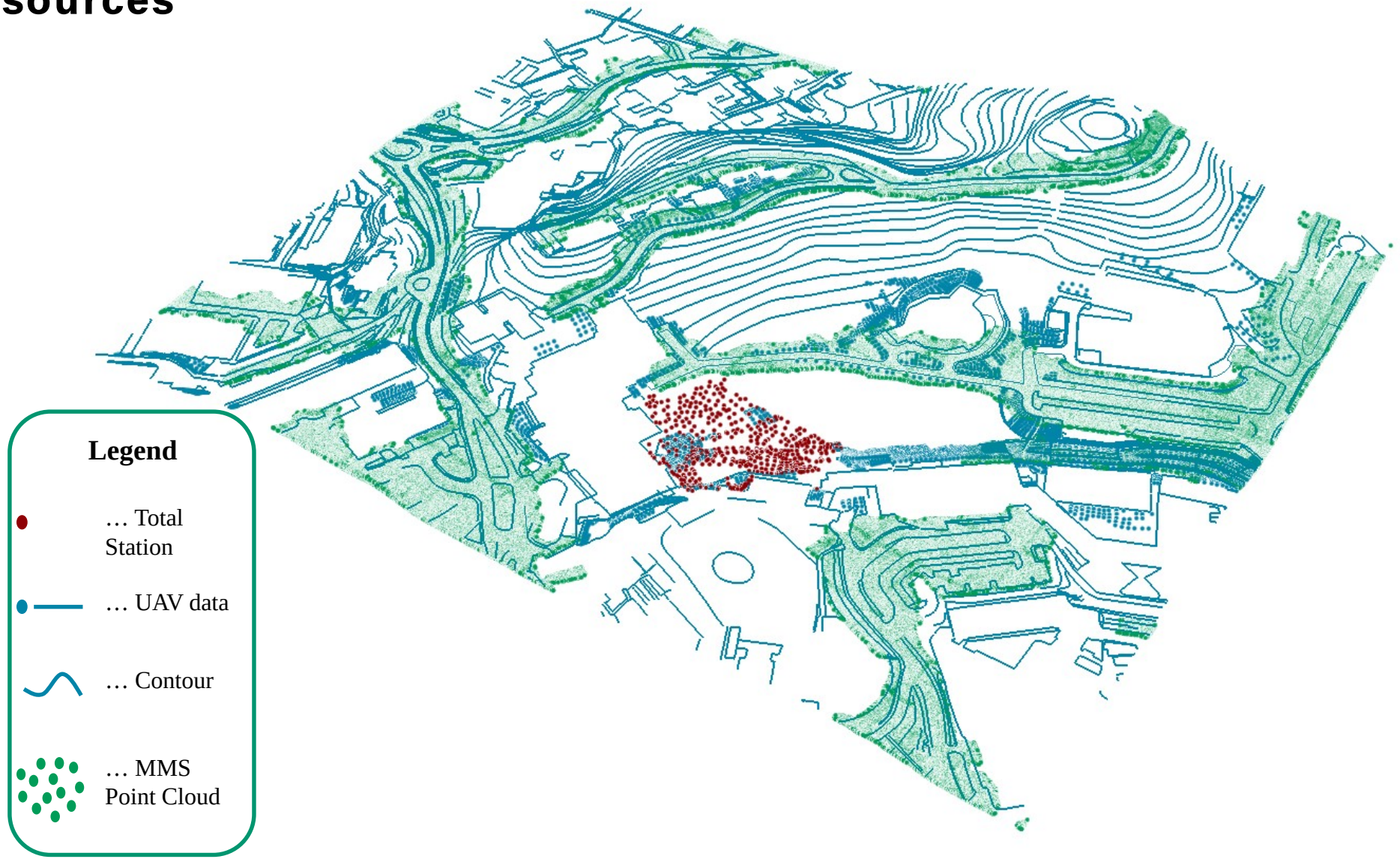
- **Buildings/roof-landscape** : Cyber City Modeler: semi-automatic procedure
- **Facades**: 3ds Max, manual modeling from point cloud
- **DTM-** manual measurement: Profiles + break-lines, combining with mobile LiDAR data for area under plant canopy and contours from older maps
- **Vegetation**: Parametric measurements: one point on tree top, tree diameter. Use of plant pre-defined model (2000 trees).
- **Light poles** (>900): Similar approach
- **Texture:** Self-developed software for roof texturing.

NUS Campus, point cloud from image matcher





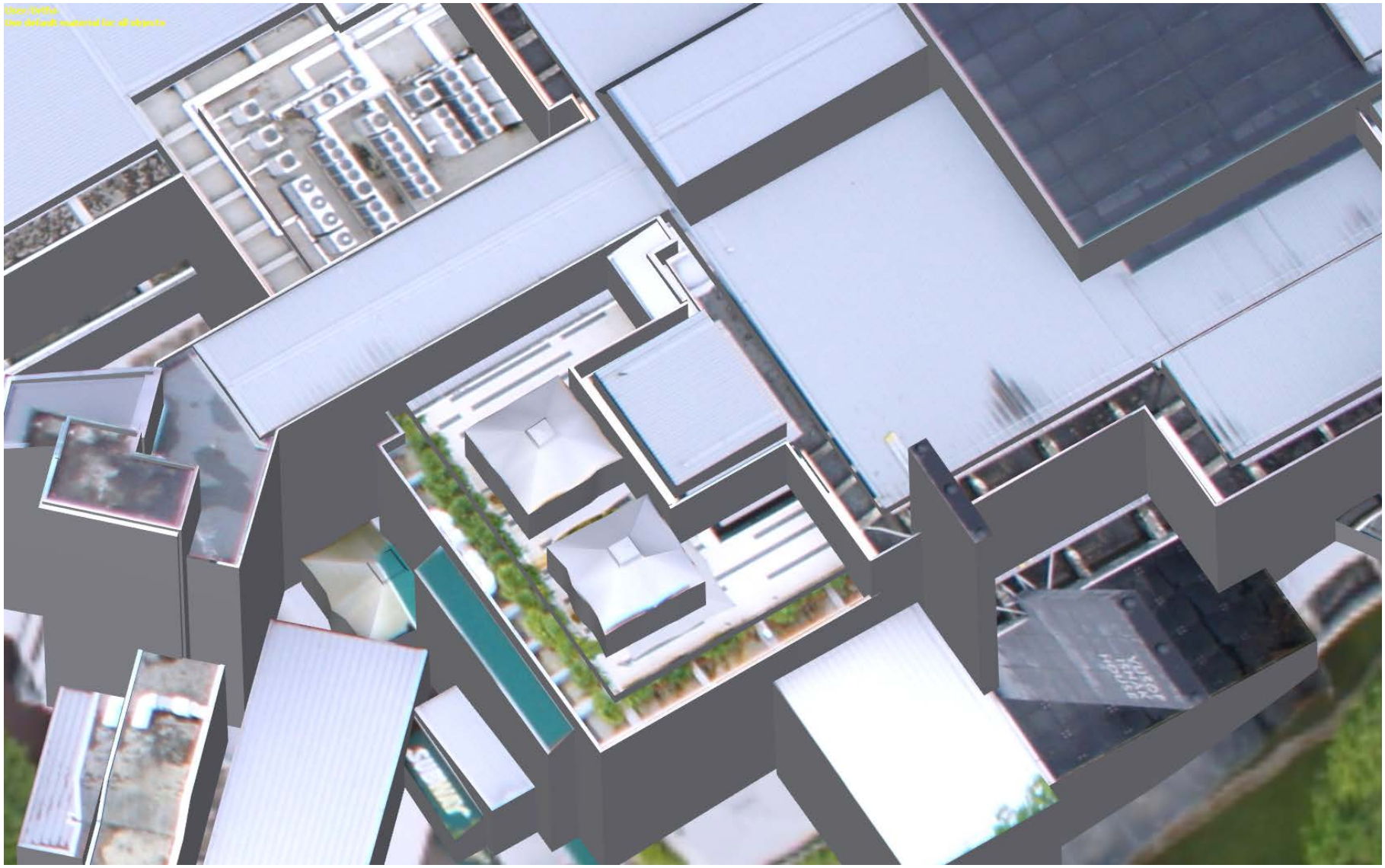
DTM from multiple sources



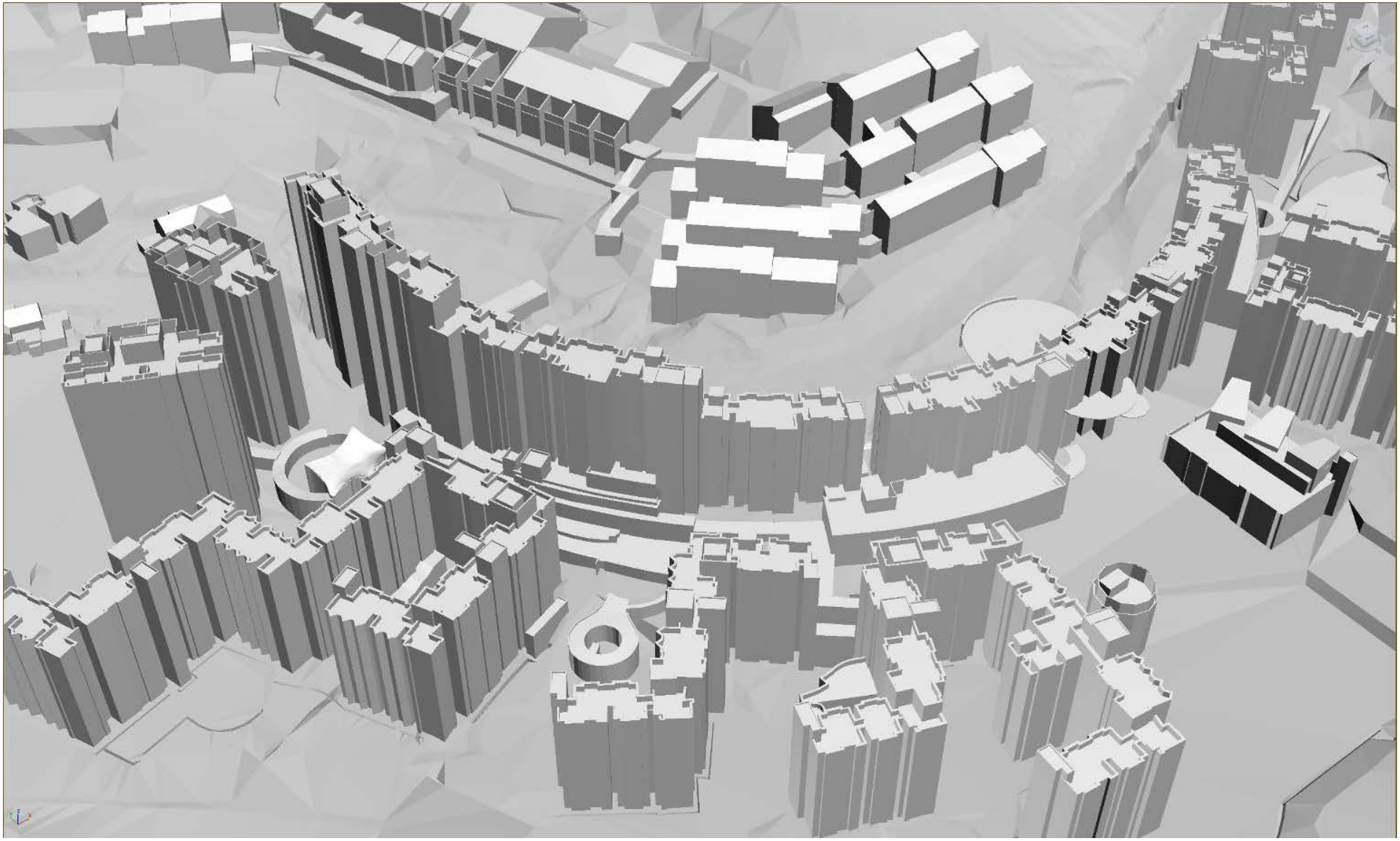
Problem: Model content definition

NUS Campus

NUS Campus

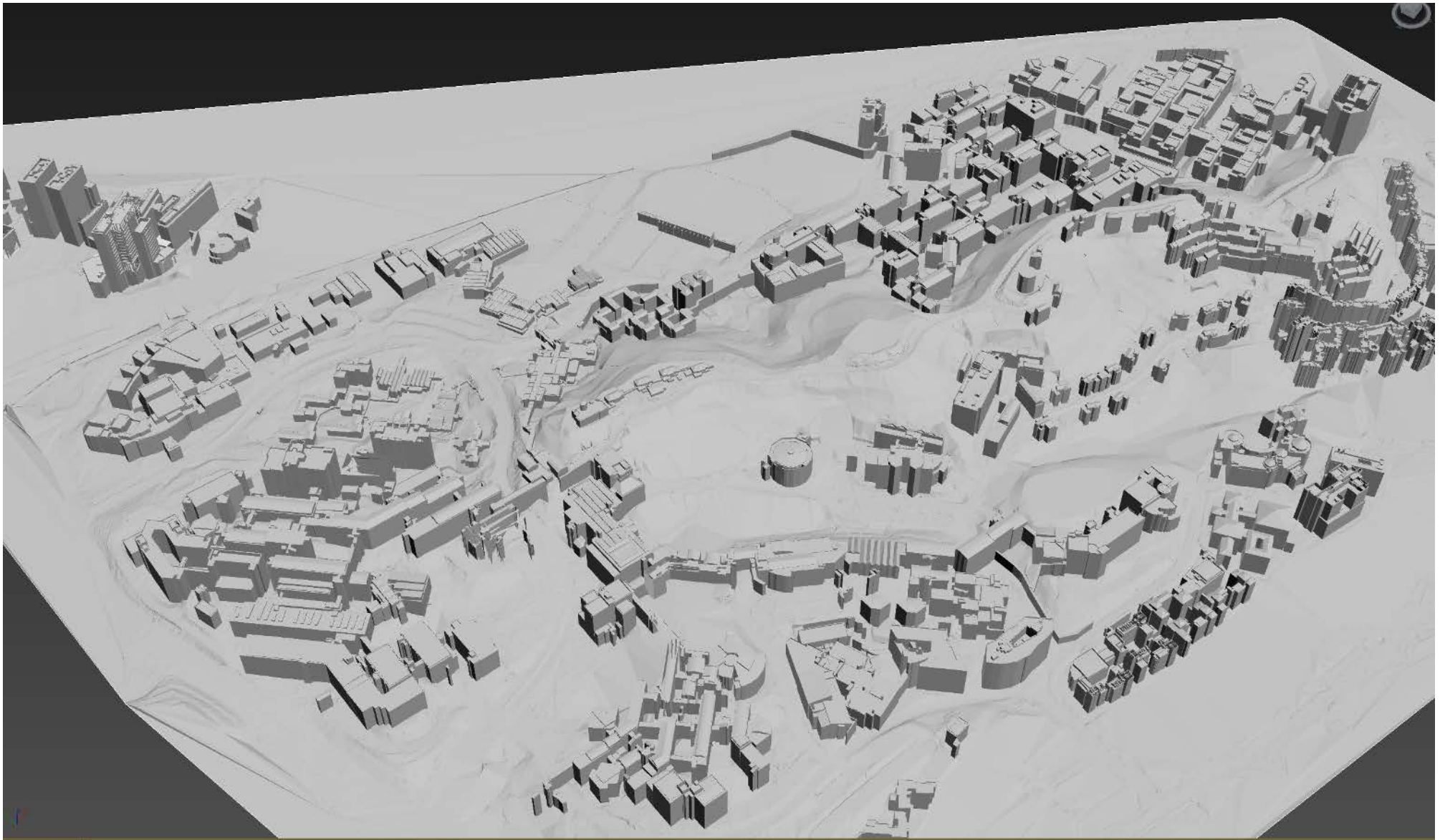


NUS Campus: Model resolution



NUS Campus: Overview

Flyover geometry



University Town

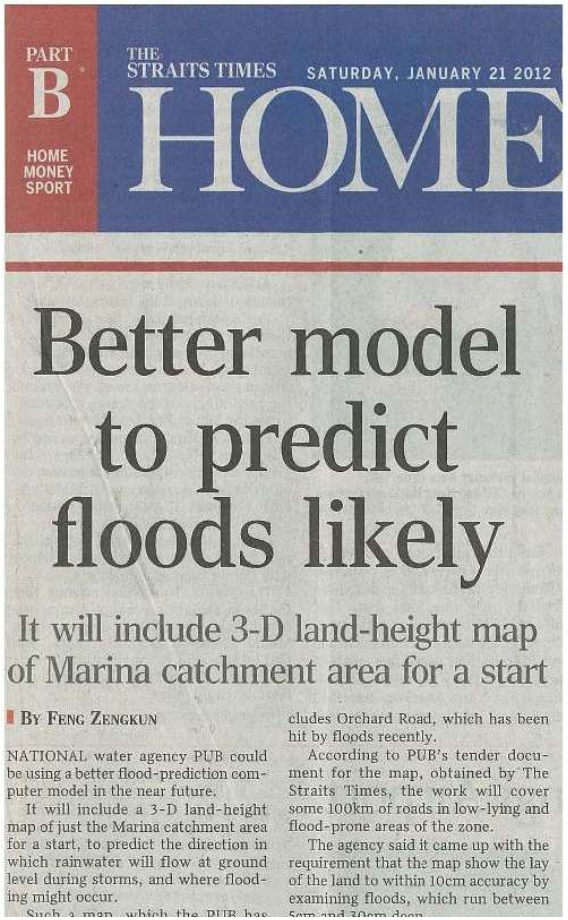
NUS University Town – Sports Center

Flood modeling for Singapore

The Straits Times Published on Jan 14, 2012

Elevation map that can help fight flooding may cost up to $125m
Data from such mapping can be used in a computer model to predict floods, experts say
By Feng Zengkun

The Straits Times. 21 Jan 2012.



PART B

THE STRAITS TIMES SATURDAY, JANUARY 21 2012

HOME

HOME MONEY SPORT

Better model to predict floods likely

It will include 3-D land-height map of Marina catchment area for a start

BY FENG ZENGKUN

NATIONAL water agency PUB could be using a better flood-prediction computer model in the near future.

It will include a 3-D land-height map of just the Marina catchment area for a start, to predict the direction in which rainwater will flow at ground level during storms, and where flooding might occur.

Such a map, which the PUB has

cludes Orchard Road, which has been hit by floods recently.

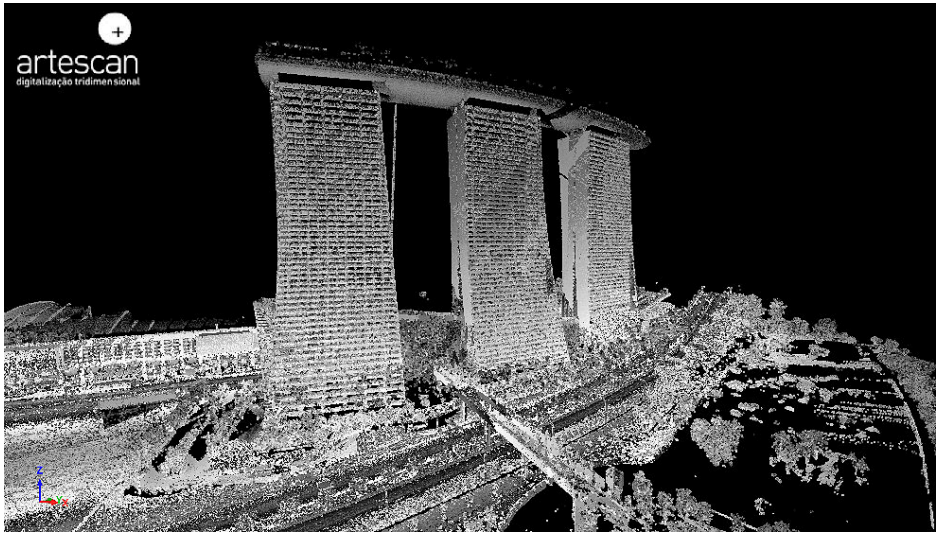
According to PUB's tender document for the map, obtained by The Straits Times, the work will cover some 100km of roads in low-lying and flood-prone areas of the zone.

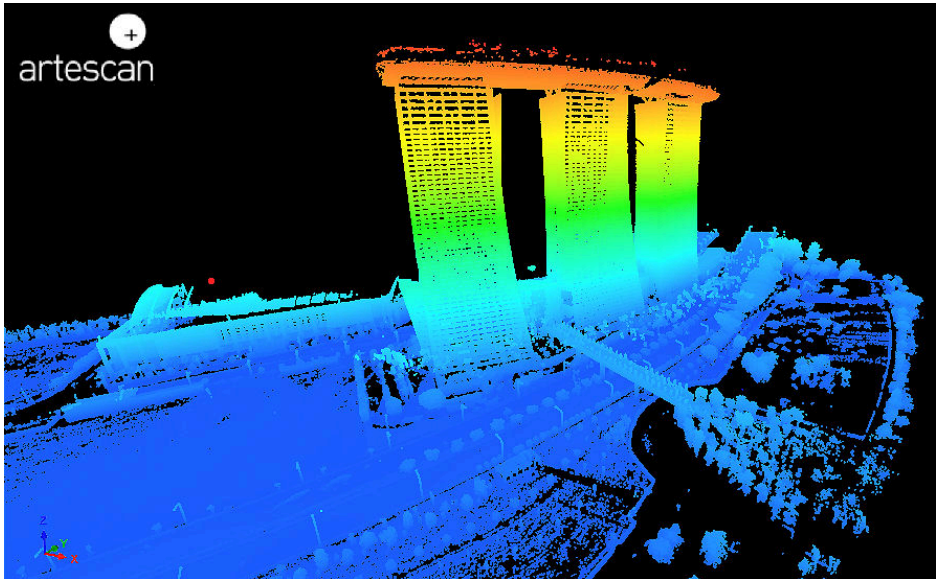
The agency said it came up with the requirement that the map show the lay of the land to within 10cm accuracy by examining floods, which run between

JakartaGlobe
Your City. Your World.

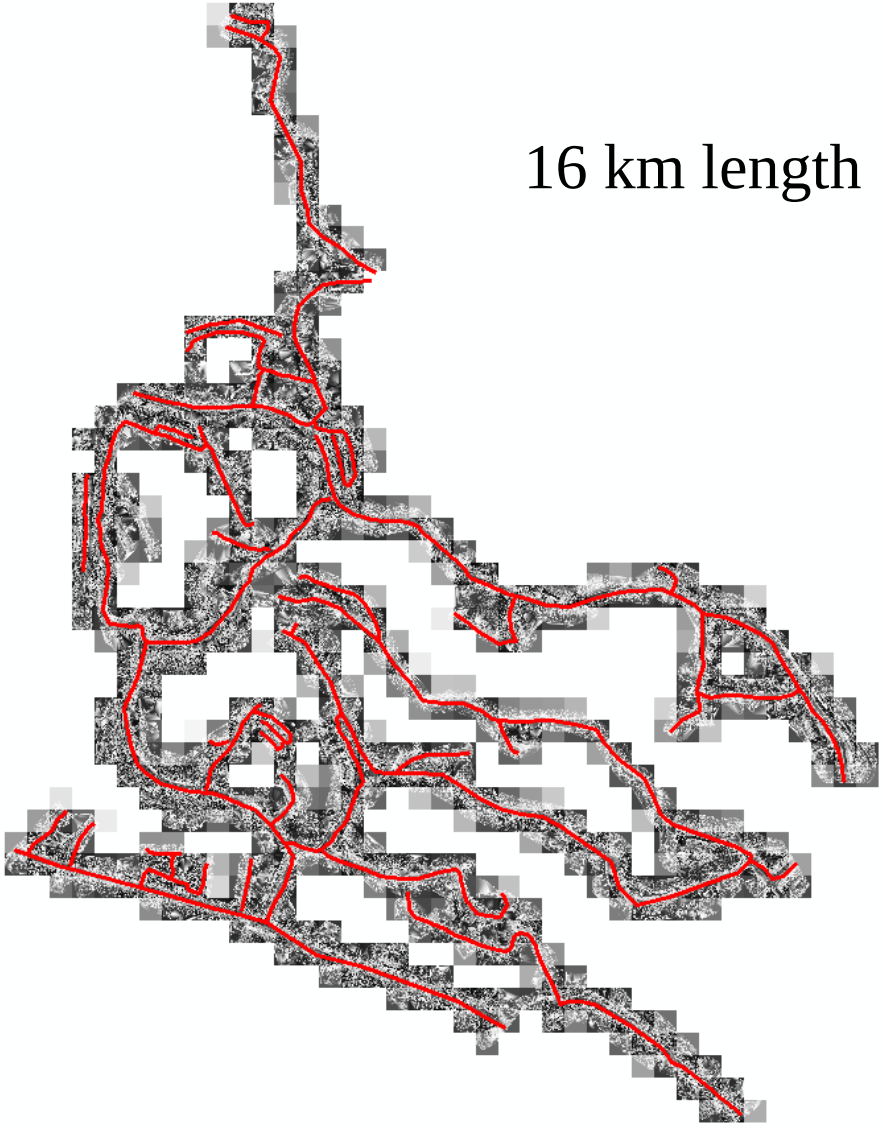
Better Model to Predict Floods Likely in Singapore
Feng Zengkun - Straits Times Indonesia | January 21, 2012**Singapore.**
National water agency PUB could be using a better flood-prediction computer model in the near future.
It will include a 3-D land-height map of just the Marina catchment area for a start, to predict the direction in which rainwater will flow at ground level during storms, and where flooding might occur.
Such a map, which the PUB has commissioned, will depict land height in that area to within 10cm accuracy.

Singapore Mobile Mapping (flood simulation)



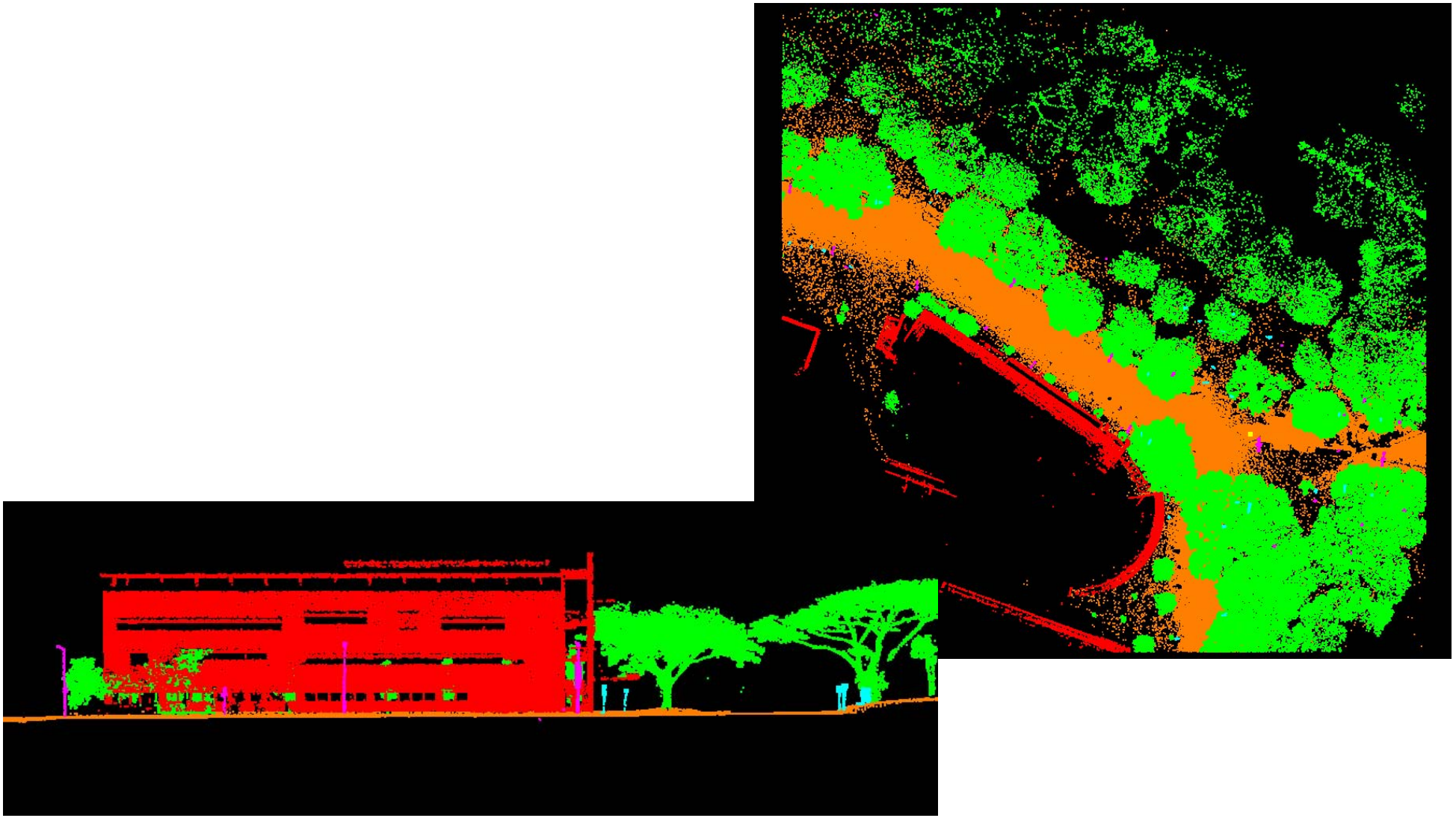


Mobile Mapping: NUS campus (trajectory)



16 km length

NUS pointcloud classification

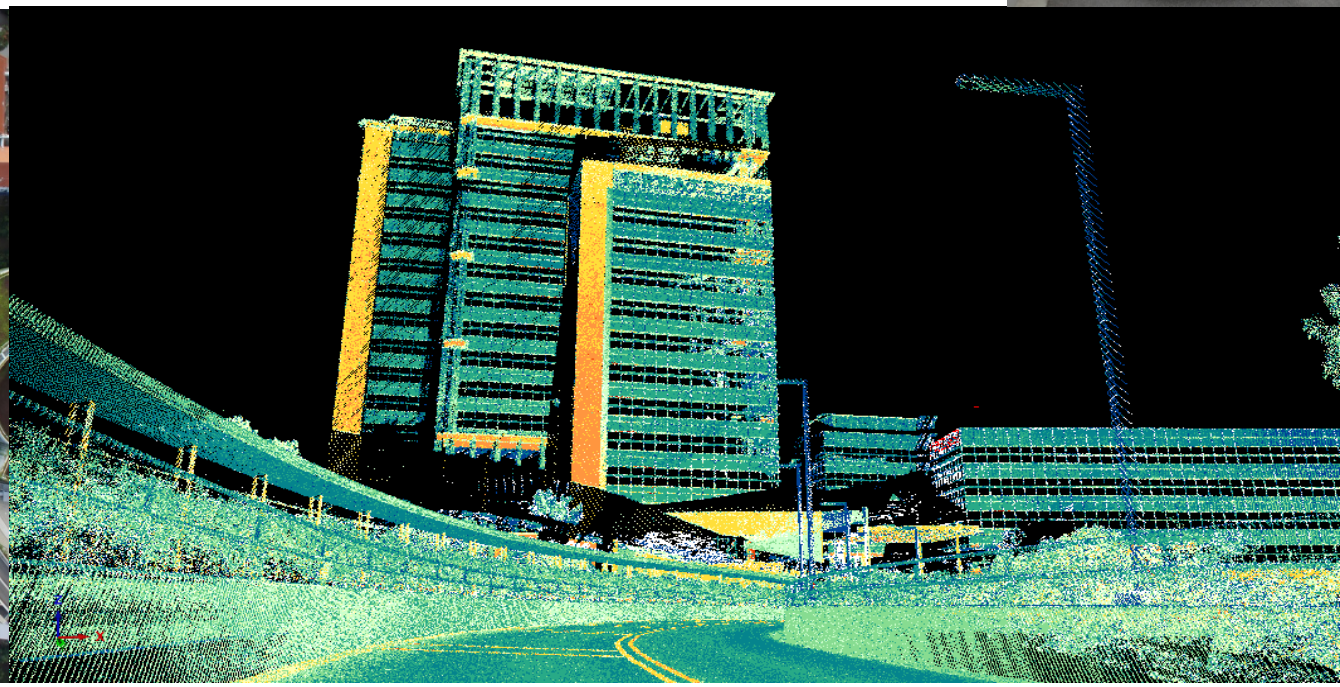


NUS (CREATE) building reconstruction

raw data

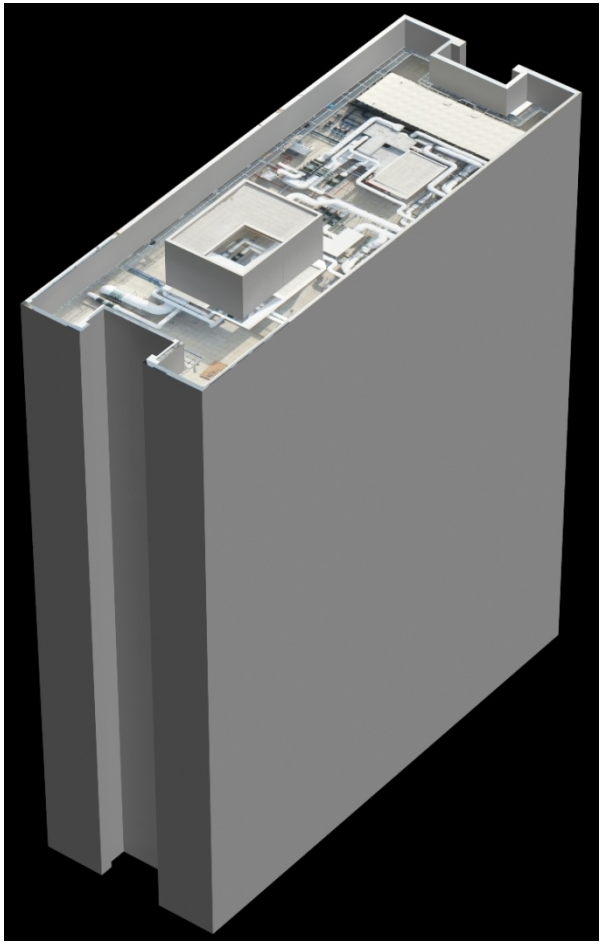
UAV images

MMS laserscans

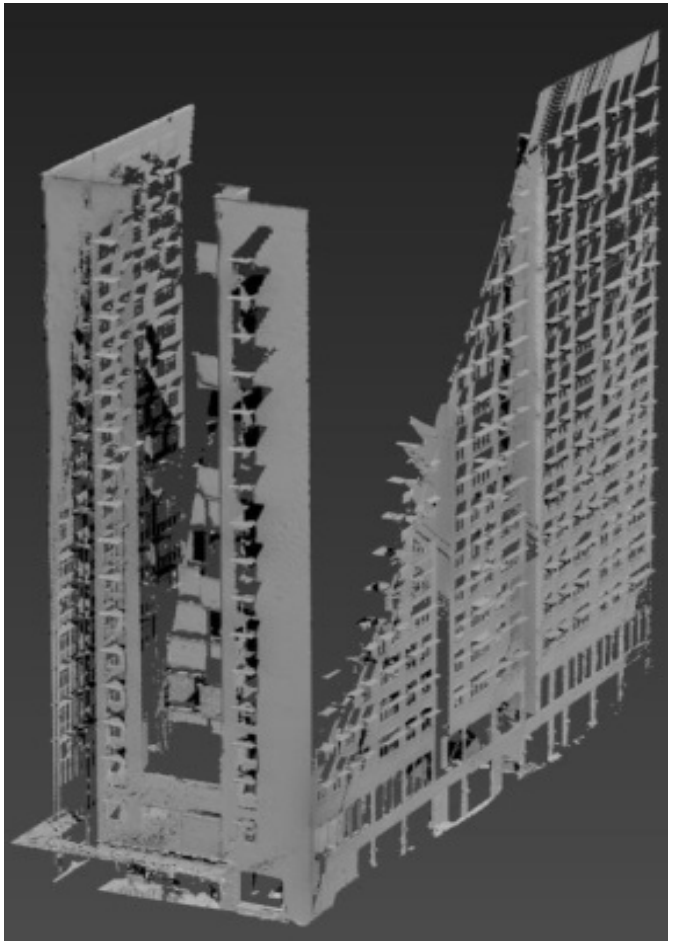


NUS building reconstruction

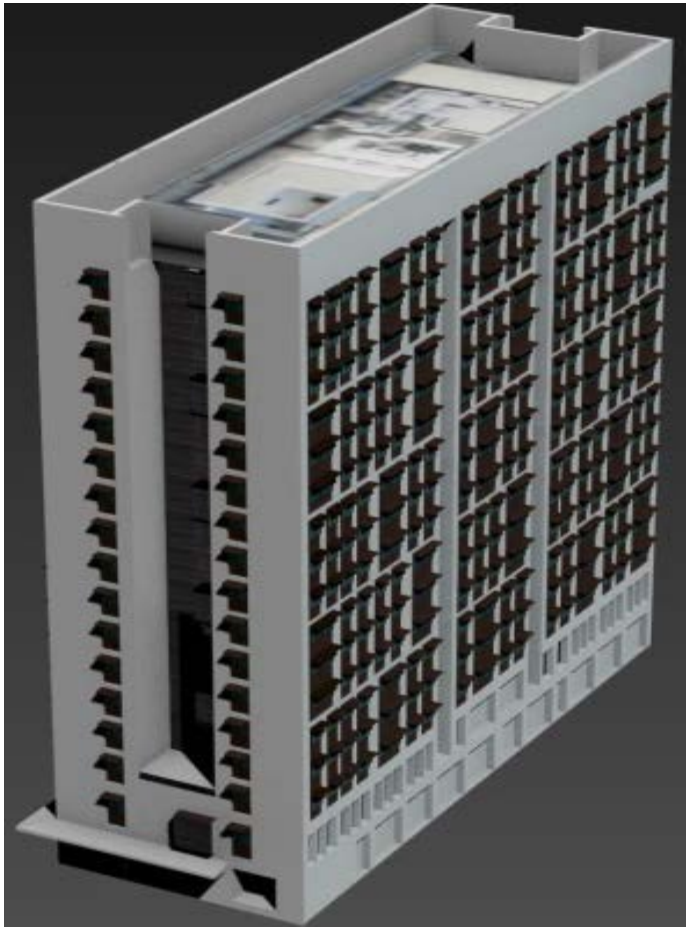
UAV images and MMS laserscans



Roof from UAV images



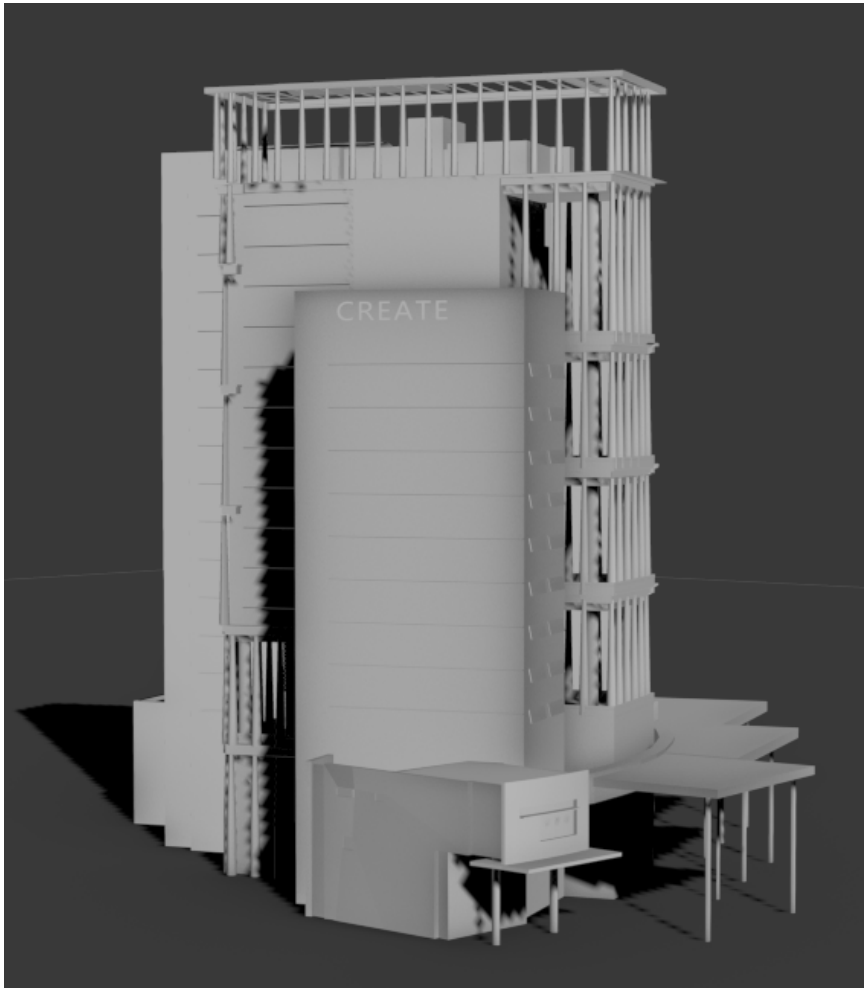
Wrapped point cloud

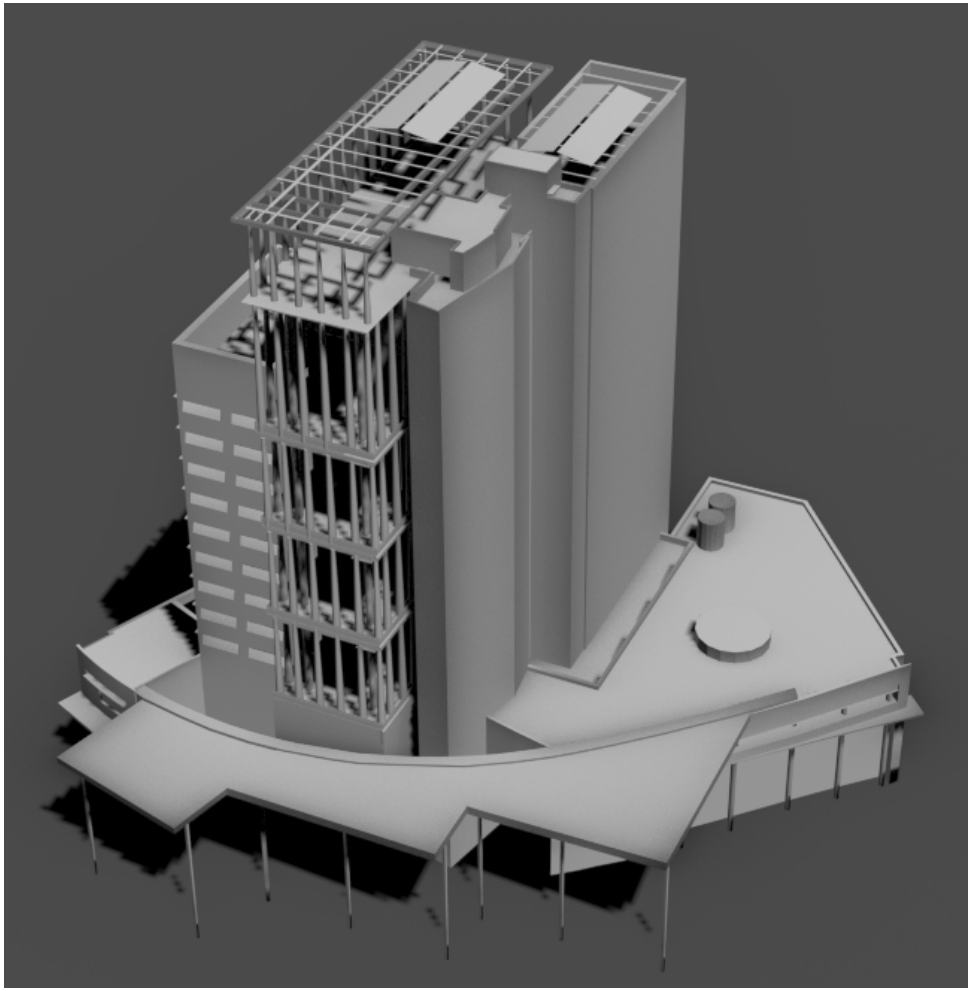


Complete Model

NUS CREATE building reconstruction

From UAV and terr. images and MMS laserscans



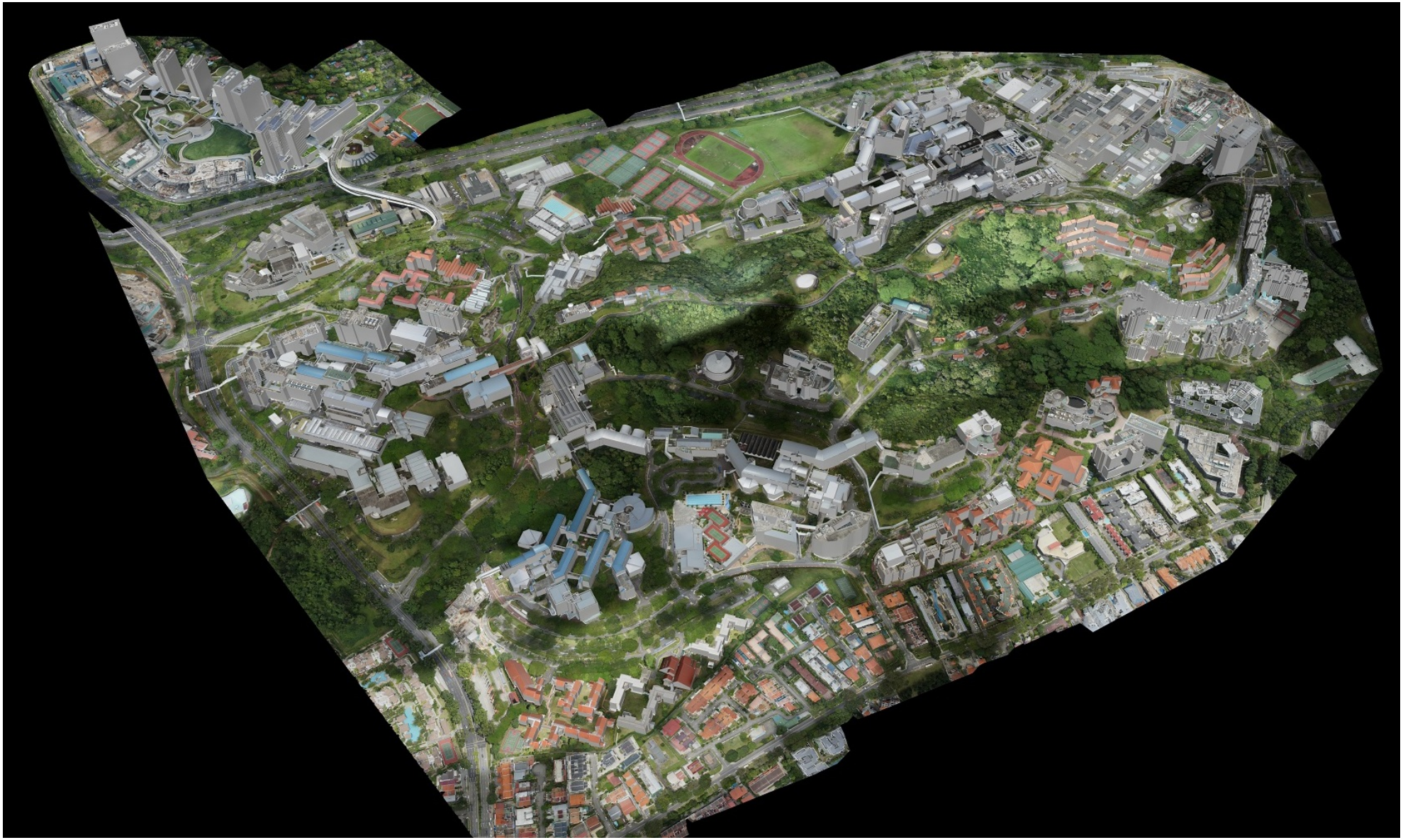


CREATE building

NUS T-Lab building reconstruction

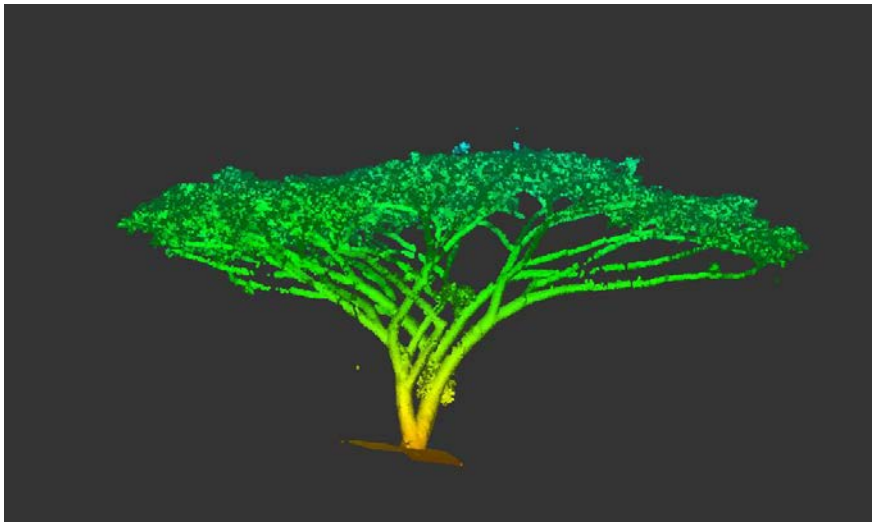
From UAV and terr. images and MMS laserscans

NUS model - overview



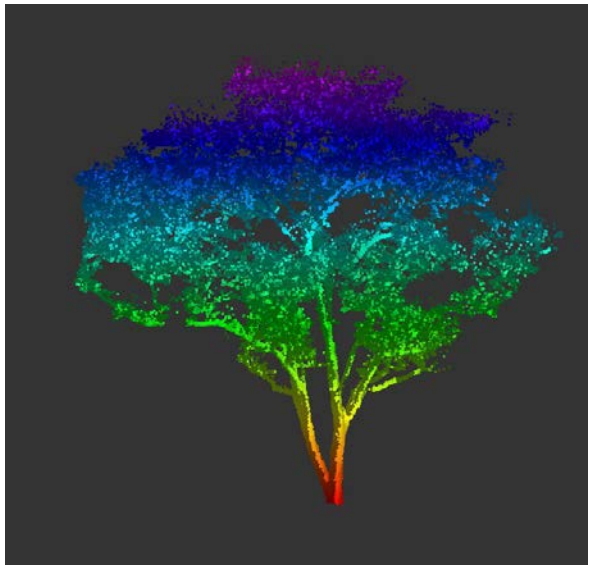
Tree modeling from terrestrial laser-scans

Rain Tree



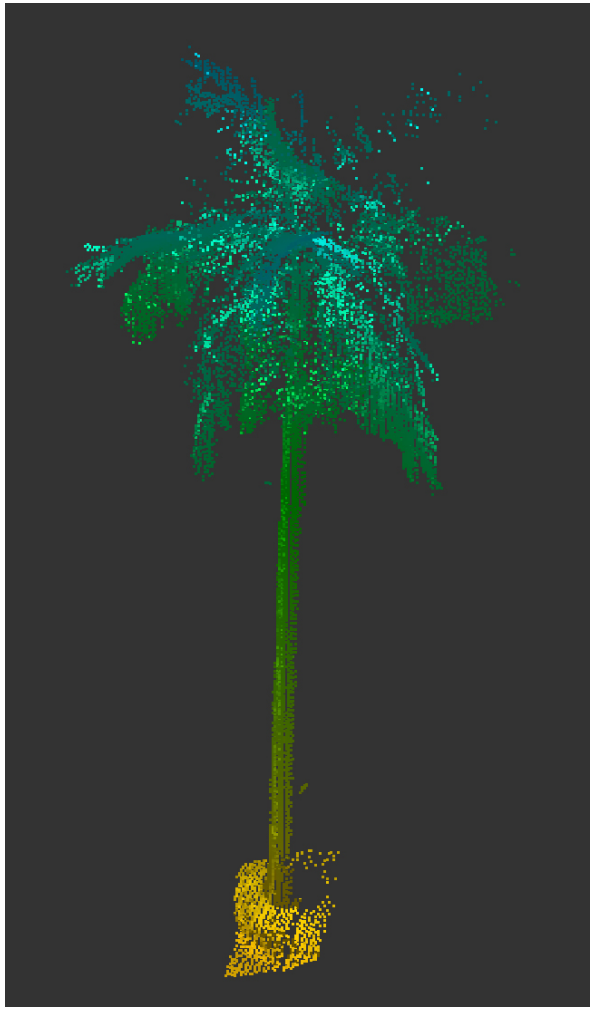
1. ***Pointools Edit.*** Separate point cloud of a tree from the whole scene
2. ***Geomagic Studio.*** Wrap the tree points into triangular mesh
3. ***3ds Max***. Draw spline lines manually along the stems: skeleton of the tree
4. ***3ds Max***. Generate columns along the spline lines using the tool “loft”
5. ***3ds Max***. Texture the loft as stems and the left triangles as canopy, using images captured in the field.

Tree modeling from terrestrial laser-scans

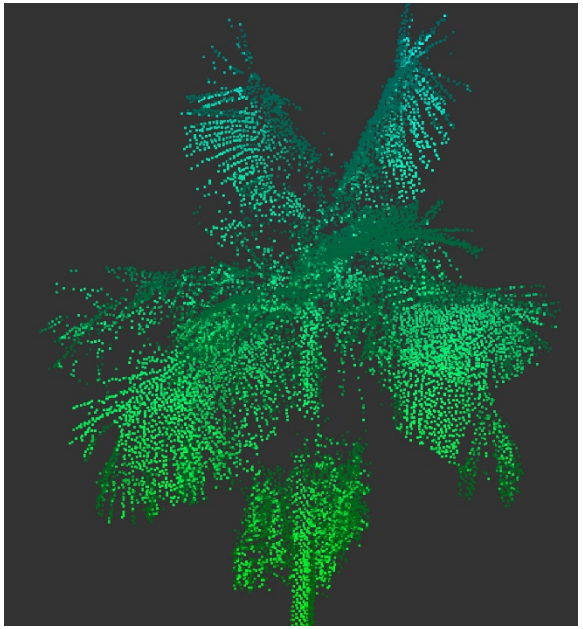


Tree A

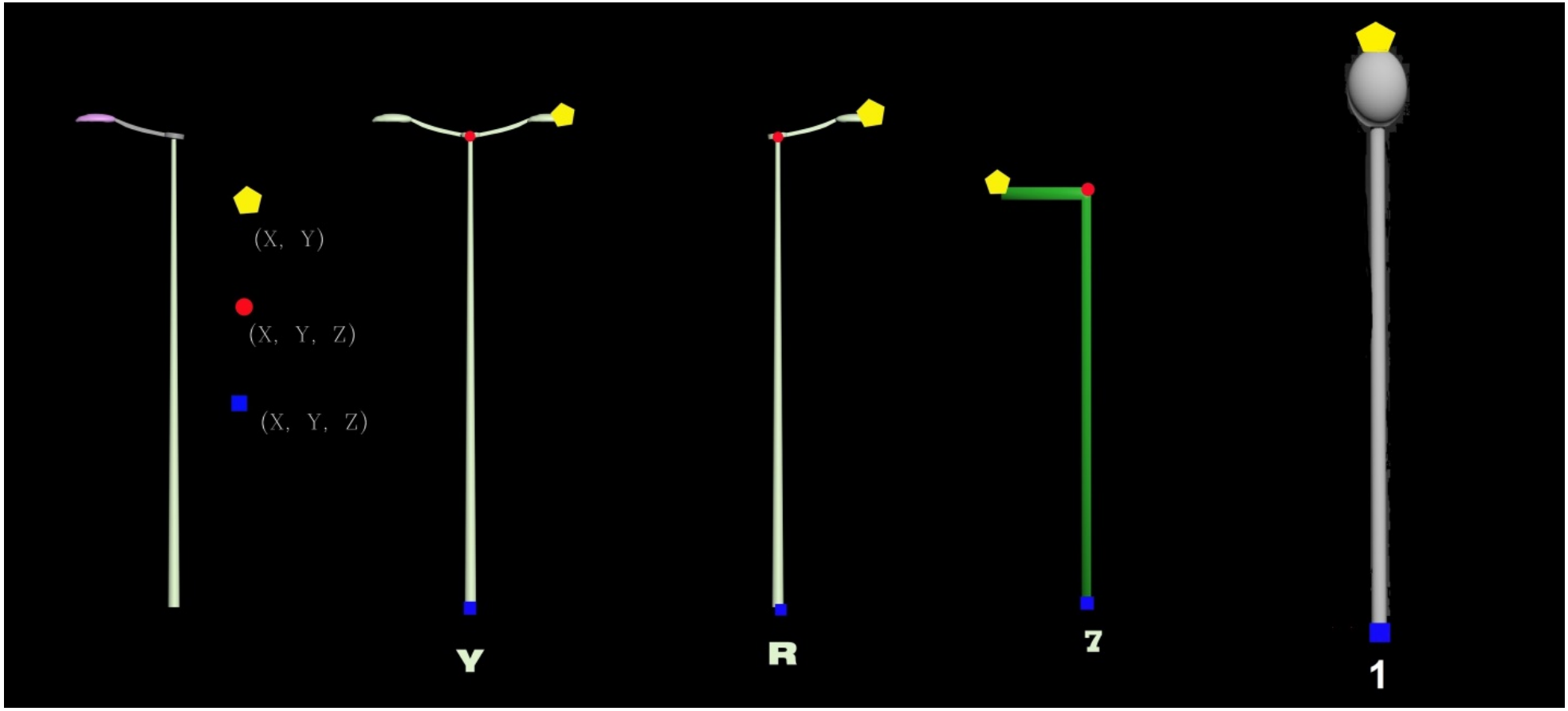
Tree modeling from terrestrial laser-scans



Palm tree

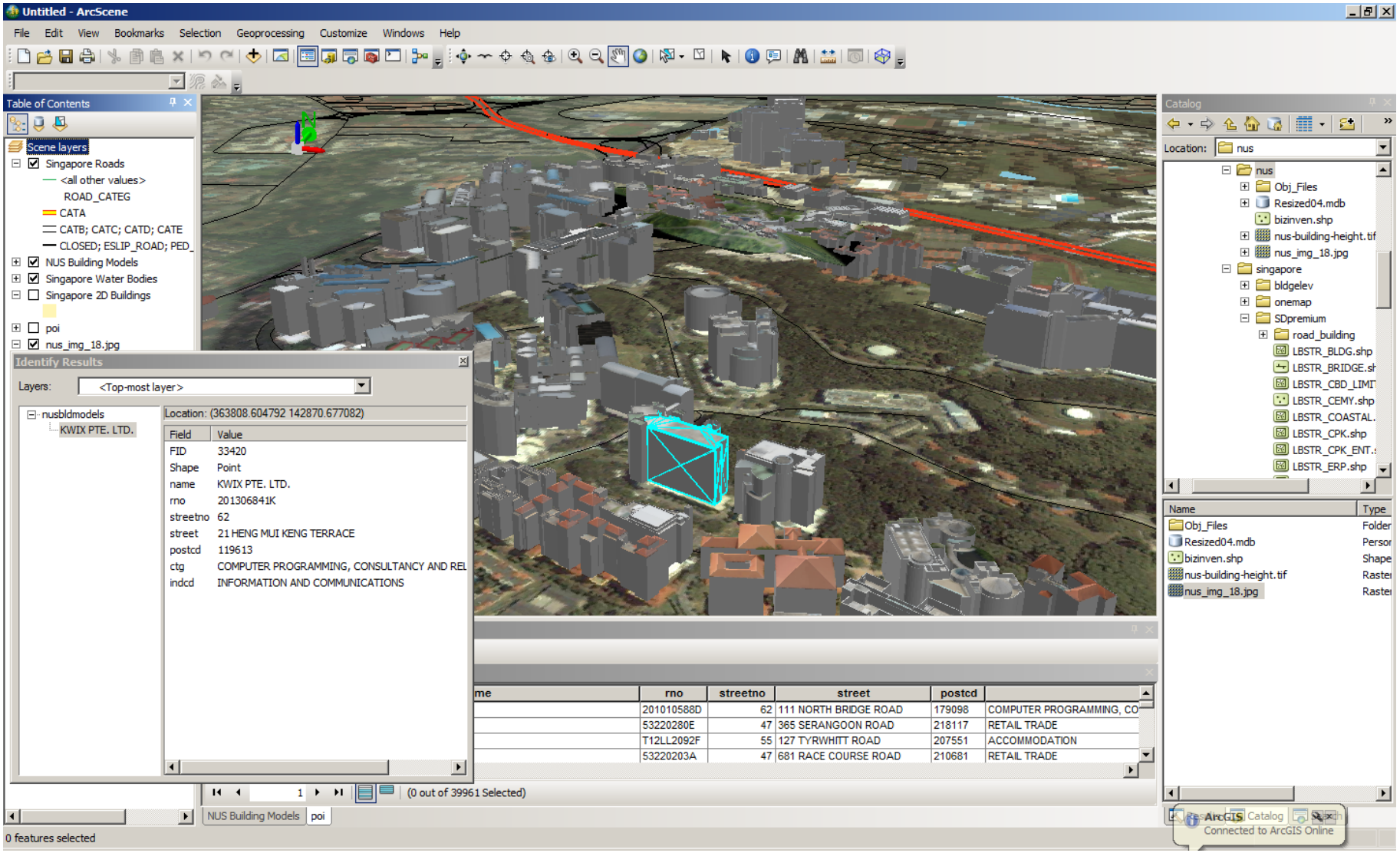


Light pole models (900)



GIS integration

Model geometry 576 MB obj/745 MB 3Dmax
Model texture 4.15 GB bmp/tiff



Unfortunate events

Unfortunate events

A28 | ASIA
SATURDAY, MARCH

Toy copter kills toddler in freak accident

SEREMBAN (Malaysia) – A radio-controlled miniature helicopter crashed into a crowd and killed an 18-month-old baby girl in a freak accident that marred the official opening here of the country's first synthetic football pitch.

Nurdamia Hisnina was in her father's arms when the helicopter, which was being flown as a gimmick at the event on Wednesday, flew through the crowd at the Paroi Sports Complex and slashed her head with its blades.

Her father, Mr Banee Yamin Idris, 35, who works in the Attorney-Gener-

In a freak accident at the Paroi Sports Complex in Seremban on Wednesday, this radio-controlled miniature helicopter (above left) crashed into the crowd there and killed 18-month-old Nurdamia Hisnina (above right). PHOTOS: CHINA PRESS

Potential UAV projects in Singapore (Gov. Agencies)

National Environment Agency (NEA):

- Real-time detection and tracking of oil spills
- Detection and 3D measurement of water pools where Dengue fever mosquitos reside
- Micro-climate modeling, city hot spots

Urban Redevelopment Authority (URA):

- Building and tree (vegetation) models for smart city management

Public Utilities Board (PUB):

- DSM generation for flood modeling. Generation of 3D façade models for water entrance analysis

Singapore Land Authority (SLA):

- Base map data in 3D and change detection from street level data

Detecting breeding grounds of Dengue mosquitos

THE STRAITS TIMES HOME | B25

Virtual 3-D project 'can help fight dengue, floods'

Researcher sees potential after creating model of NUS campus

By LEE JIAN XUAN

Swiss researcher Armin Gruen with the virtual 3-D campus model of NUS, an unmanned aerial vehicle and a pair of 3-D glasses (on the table). The model was generated using images taken by unmanned aerial vehicles and data from ground-based laser scans. ST PHOTO: NG SOR LUAN

AFTER completing a highly detailed 3-D virtual model of the National University of Singapore (NUS), a Swiss researcher is hoping to take his project forward and use it to combat pressing problems in Singapore like dengue and flooding.

Professor Armin Gruen, who piloted the high-resolution model of the campus, is

ested areas soon, The Straits Times understands.

Earlier last year, he had also told The Straits Times that the model could prove useful in flood prediction here.

PUB had announced plans last year to create a 3-D land-height map of the Marina catchment area to improve flood prediction. Prof Gruen said he would be keen to work with PUB if the opportunity arises.

As for the newly completed 3-D model of the NUS campus, data retrieved from it will come in handy for students and staff alike.

NUS civil engineering associate professor Vladan Babovic said the higher resolution offered by the model would help predict floods in the campus vicinity more accurately.

"With this, we can better pinpoint where flooding will happen, and how deep it will be."

First-year undergraduate Ronel Tan, 22, also finds it useful: "It can get hard to navigate (the campus) because the maps at bus stops are a bit old, so this will help."

But Prof Gruen also acknowledged that some issues still need to be addressed.

Man-made changes to the landscape, such as new buildings, mean the model must be constantly updated, while the use of UAVs in densely populated areas requires security clearance, he said.

But he also claimed that the model is superior to popular location-based app Google Maps.

"The data offered here is much more detailed and precise... It is for professional use," he said.

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UAV specific problems

+ Cheap sensors – low data quality (GPS/IMU)
  Navigation/positioning often not accurate enough
+ Interference with external microwave sources: Mobile antennas – electronic compass; control signal disturbance
+ Cameras (off-the shelf), 24Mpi, temperature instability, but main problem: Lens (colour refraction/colour seams, unsharpness in corners)
+ Errors in system software (spurious images, images and GPS/IUM not synchronized)
+ Overlap often irregular
+ Sometimes oblique images, complex networks
+ Much room for improvement of data processing methods

Conclusions

+ UAVs are very flexible devices for recording (cameras, orientation, navigation, real-time capabilities)
+ Cost-efficient
+ Many diverse applications, if area is not too large
+ Niche function. No replacement of large format sensors

But:

- Technology (system hard- and software) not mature

- Much room for improvement of data processing methods

- Flight permissions, safety concerns