STREET SMART:
CITY MODELING AND OTHER NEW GEOSPATIAL TECHNIQUES IN URBAN MAPPING AND NAVIGATION
BEFORE WE BEGIN

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Creating 3D City Models

- Describing 3D Cities
- Creating 3D City Models
- Other Sources of 3D Data
- Open Research Challenges
Describing 3D - Levels of Detail (LoD)

- These LoDs were originally proposed as part of the specification of CityGML, which is an Open Geospatial Consortium standard for modelling and exchange of 3D city models.
- In practice, many datasets are mixed LoD.

Source: http://filipbiljecki.com/research/phd.html
Starting from 2D - Photogrammetry

- Specialist cameras on board a plane take 60% overlapping images
- Overlap allows creation of ‘3D’ stereo orthophotos
- These photos allow semi-automatic topographic feature extraction (2D map creation)

Source: Dietmar Backes/Dr Jan Boehm, UCL
LoD 1 – Extrusion – Fixed Height

• ‘Grow’ the 2D buildings to a given 3D height
• Rapidly create a city-wide 3D model
• Requires 2D vector topographic mapping data

Source: Ordnance Survey (Crown Copyright)
LoD 1 – Extrusion – Variable Height

- Requires the use of an additional data source for height information
- Light Detection and Ranging (LiDaR) is very useful
- Better height values from dense point clouds

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LoD 2 - Adding Roof Detail

- Detail extracted from LiDaR, photogrammetry or both
- Basic roof structures can be derived almost automatically
- Less standard buildings require manual intervention
LoD 3 - Adding Doors, Windows and Texture

- Photogrammetry and Laser Scanning (LiDaR) at ground level
- Oblique images are also useful
- Images are easy to produce (e.g. Google Street View)
- Extracting intelligence – i.e. identifying the doors and windows as individual objects – is less easy

Source: https://www.ucl.ac.uk/3dim/bim/green_bim
Other Sources – Building Information Models

- Very detailed 3D models created by architects and engineers
- Include indoor and outdoor information, as well as construction material
- Only available for individual buildings or large infrastructure projects

Source: UCL Chadwick BIM, with thanks to Charles Thomson
Other Sources - ESRI City Engine

- Uses procedural modelling to rapidly create a 3D city model
- Model can be based on 2D topographic data, with rules for different roof types and building heights
- Result is realistic, not real
Other Sources - Sketch-Up and Google Earth

- Allows non-experts to create 3D models of buildings
- Can then import these into Google Earth, and add images
- Opens up 3D to non-experts, but issues with quality and coverage

Source: “3D Martin” downloaded from Google Earth, February 2010
Other Sources – Open Street Map

- Crowd Sourced Map of the World
- Free to use
- Buildings recently included, so coverage and quality can vary

Source: http://wiki.openstreetmap.org/w/images/thumb/2/28/Heidelberg_II.jpg/800px-Heidelberg_II.jpg
In Summary …

- Creating high quality, high detail, 3D datasets for an entire city at low cost is not a solved problem.
- Research is ongoing to identify:
  - Who will use 3D data and for what purpose.
  - What to map (roof detail, doors, windows, bricks?).
  - What scale(s) to map at.
  - How to extract features from point clouds (LiDaR and Laser Scanning).
  - The importance of ‘real’ versus ‘realistic’.
- However: Lots of 3D city model data is now available free – e.g. Berlin, Rotterdam, Toronto.
RAHUL GUPTA
Spirent Communications

GREGORY MOURA
OKTAL Synthetic Environment
GPS World Webinar
July, 16th 2015
Gregory Moura
Rahul Gupta
GNSS reception in urban environment

GNSS Propagation in urban environment is disrupted by the buildings surrounding the receiver:
- The masks created by the buildings prevent the signal from reaching the receiver

Availibility → problem

- The signal interacts with the local environment. Multipaths are received

→ Performance problem (errors, fading effect...)

Spirent Communications

PROPRIETARY AND CONFIDENTIAL
How Simulation Can Help…

- OKTAL Synthetic Environment has developed the software SE-NAV to assess the propagation and reception of GNSS signals in 3D Synthetic Environment.

- SE-NAV computes the interactions between the signal and the environment (building, cars, antenna’s carrier) by taking into account:
  - Shadowing effects (availability of the system)
  - Multipaths (performance)

- SE-NAV uses the deterministic method of Ray Tracing combined with Geometrical Optics and Uniform Theory of Diffraction to compute multi-paths (Reflections on surfaces, Transmissions through walls and Diffractions on the edges).

- SE-NAV embedded a proprietary GPU Raytracing kernel to render in record time the propagation in realistic conditions.
A Synthetic Environment is a virtual representation of a real environment. It mimics the geometries (terrains, buildings, vehicles etc…) as well as the Physics (material, atmosphere…).

Synthetic Environments can be sorted out in two types:

- “Geo-typical” Environment: These mock-ups model a realistic environment, i.e. an environment that does not exist but that looks like familiar (e.g. an European dense cities, mountainous areas etc…)

- “Geo-specific” Environment: These mock-ups model a real environment, i.e. an accurate description of a real scene in term of geometry and physics.
**Multipath**

### Geometrical Optics

- **Reflected rays**
- **Transmitted rays**
- **Diffracted rays**

**UTD**

Deterministic software = multipaths can be displayed and their attributes (power, delay, phase etc…) are known
Interface with Spirent’s SimGen

- SE-NAV is fully compliant with SimGen’s interface.
- SE-NAV returns, in real time (through TCP/UDP protocols), the propagation information (power, delay, doppler…) in order to compute the impact of the local environment on the performance of a real receiver.
- SE-NAV can also provide deterministic 3D mask in LMM File Format.
Video – Examples of simulations
Results

Table 5: Re De Remusat simulated vs live captured data

Remusat Live Error

Remusat Simulated

Remusat Simulated vs Live

- Remusat Live
- Remusat simulated
- Rue de Remusat Reference
Thank you!

- Grégory MOURA, Product Manager, OKTAL-SE
  - Email: gregory.moura@oktal-se.fr

- Rahul Gupta, Business line manager, Spirent
  - Email: rahul.gupta@spirent.com

- More videos on YouTube: [http://www.youtube.com/user/SENAVSimulator?feature=watch](http://www.youtube.com/user/SENAVSimulator?feature=watch)
Better GNSS Positioning in Cities using Enhanced 3D Mapping

Paul D Groves
Space Geodesy & Navigation Laboratory
University College London, UK

GPS World Webinar
16 July 2015
Poor GNSS geometry in urban canyons

- Signals available along the street
- Signals blocked across the street

Good accuracy along the street

Poor accuracy across the street
Without 3D Mapping

Position errors of 10-50 m are common

Reflected signal (path delay causes positioning error)

Directly-received signal (good for positioning), but we don’t know this.

Direct signal is blocked, but we don’t know this.

Unknown buildings

Terrain height unknown
With 3D Mapping

Position errors of 2-5 m are common.
3D Mapping Aids GNSS in 3 Ways

- **Height Aiding**: Signal known to be reflected: Process accordingly.
- **Model-aided Ranging**: Signal known to be direct: Process accordingly.
- **Shadow Matching**: Building sizes and positions known. Known terrain height: Can aid positioning.
Height Aiding (1)

In an open environment, this only improves vertical positioning.

Where signal geometry is poor, height aiding also improves horizontal positioning.
### Height Aiding (2)

<table>
<thead>
<tr>
<th>Terrain Aiding</th>
<th>RMS Positioning Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal</td>
</tr>
<tr>
<td>No</td>
<td>46.1 m</td>
</tr>
<tr>
<td>Yes</td>
<td>26.1 m</td>
</tr>
<tr>
<td>Improvement</td>
<td>43%</td>
</tr>
</tbody>
</table>
Non-line-of-sight (NLOS) Prediction (1)

3D City Model

Ray tracing or Graphics processing

LOS/NLOS Predictions

GNSS Positioning algorithms
Non-line-of-sight (NLOS) Prediction (2)

3D City Model

Ray tracing or Graphics processing

LOS/NLOS Predictions

GNSS Positioning algorithms

Building boundary file
3D-Model-Aided GNSS Ranging (1)

- Single Candidate Position
- Multiple Candidate Positions
- NLOS Prediction
- NLOS Correction
- UCL Approach

Processing Load

Other groups have implemented other approaches
### 3D-Model-Aided GNSS Ranging (2)

<table>
<thead>
<tr>
<th>With Terrain aiding</th>
<th>RMS Positioning Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D-Model- Aiding</td>
<td>Horizontal</td>
</tr>
<tr>
<td>No</td>
<td>26.1 m</td>
</tr>
<tr>
<td>Yes</td>
<td>20.7 m</td>
</tr>
<tr>
<td>Improvement</td>
<td>21%</td>
</tr>
</tbody>
</table>

(BACKGROUND IMAGE © 2013 BLUESKY © GOOGLE).
Shadow Matching (1)

Conventional across-street positioning is poor.
∴ We need a new approach...

NLOS and untracked satellites contribute to positioning.
Shadow Matching (2)

1. Determine search area
2. Predict satellite visibility
3. Observe satellite visibility
4. Score position hypotheses
5. Determine position

3D mapping or building boundaries

GNSS receiver

3. Observe satellite visibility
Shadow Matching (3)

Cross-street positioning error (m)

- Conventional GNSS: 11.25 m
- Single epoch shadow matching: 6.54 m
- Particle filter shadow matching: 2.41 m

Routes: A, B, C, D, E, F, G, H

Image © 2014 BlueSky
Next Steps

Integrate everything together in one system

Improve the reliability
More information
http://www.ucl.ac.uk/geomatics/research/themes/rpnr
ION GNSS+ 2015 papers can be requested by email

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