Solving the Urban Positioning Problem using 3D-Mapping-Aided GNSS

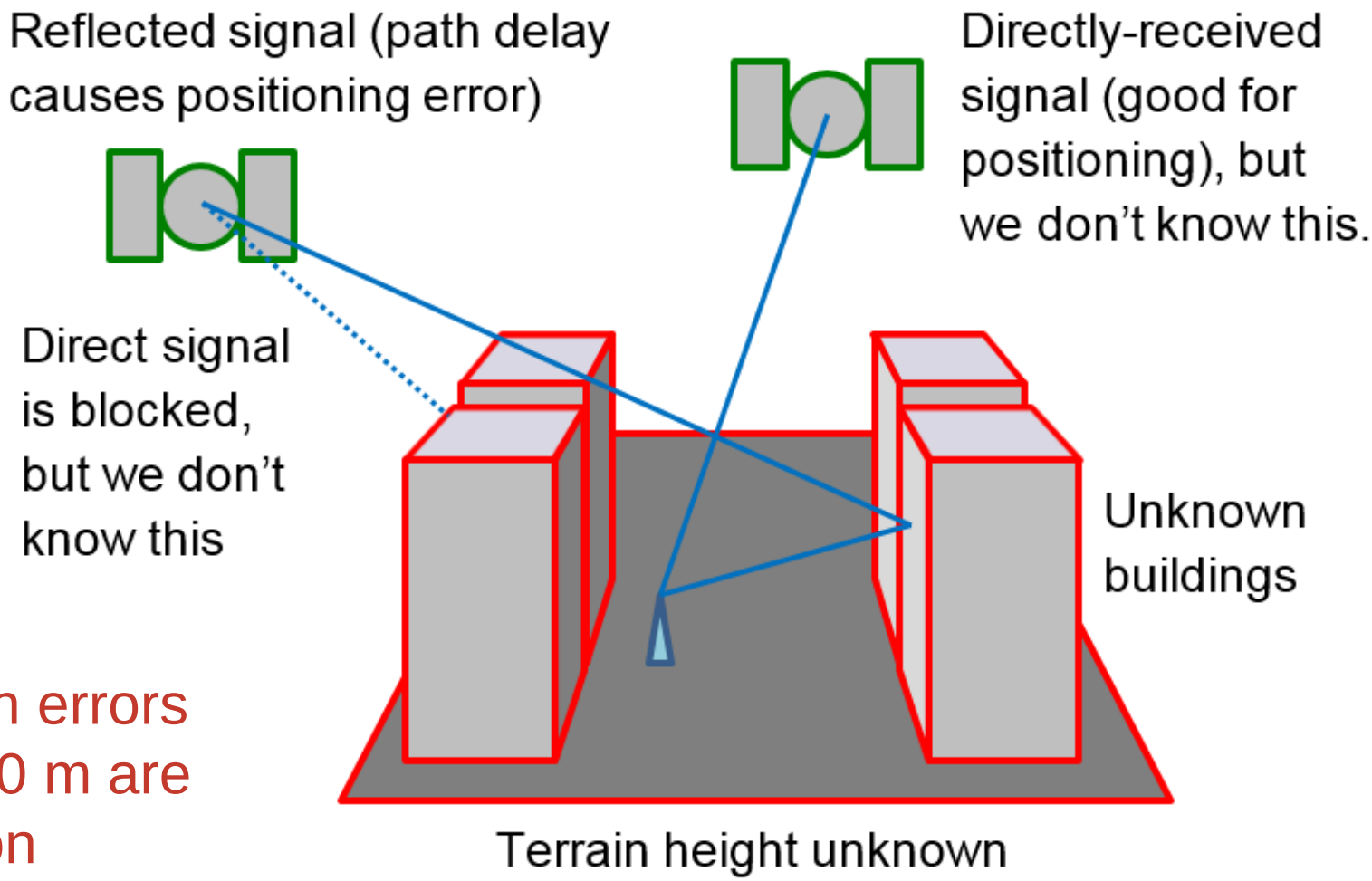
Dr Paul D Groves
Space Geodesy & Navigation Laboratory
University College London
(p.groves@ucl.ac.uk)

ION GNSS+ 2016
14 September 2016

UCL ENGINEERING
Change the world

EPSRC
Engineering and Physical Sciences Research Council

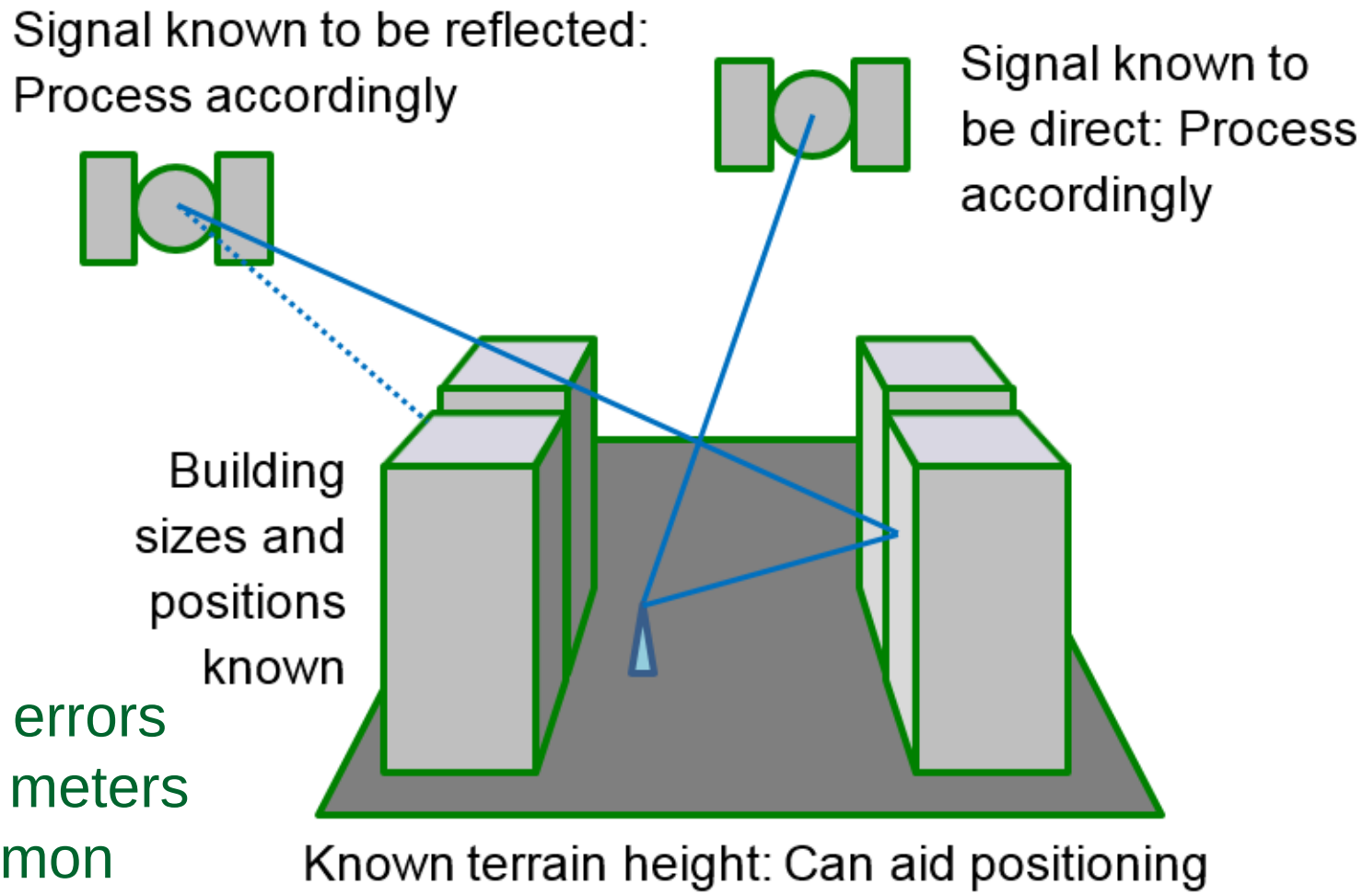
Urban GNSS: Without 3D Mapping



Position errors of 10-50 m are common

28 m RMS horizontal (2D) Single-epoch

Urban GNSS: With 3D Mapping



Position errors of a few meters are common

4 m RMS horizontal (2D) Single-epoch

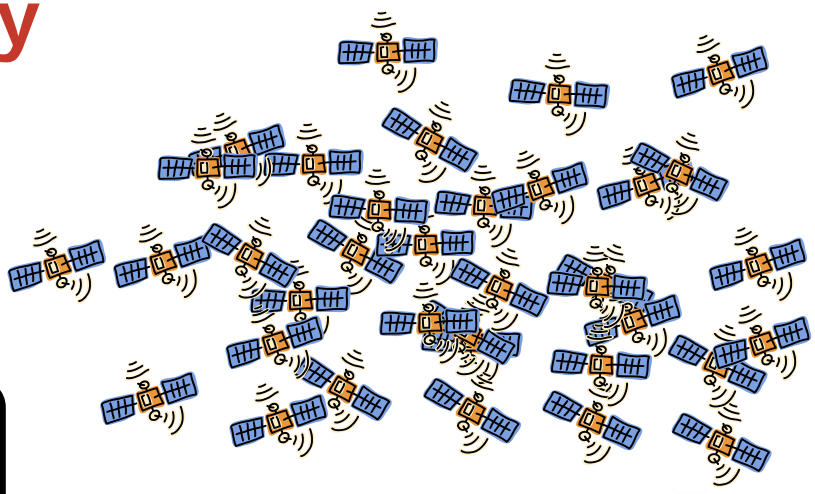
The Opportunity

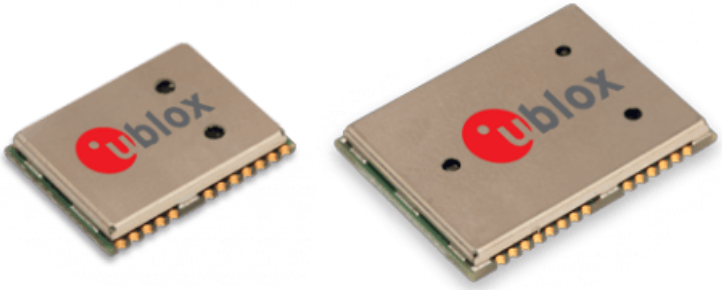
We Need

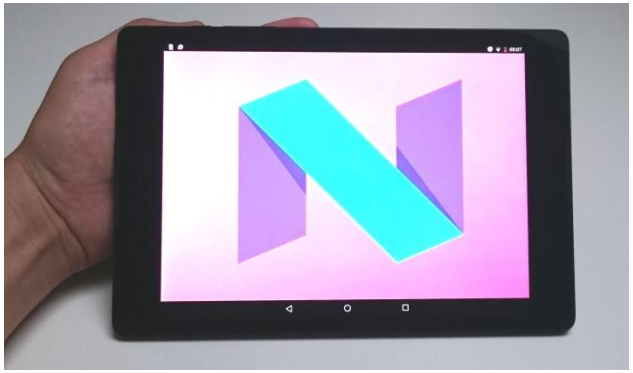
Measurements

3D Mapping

Algorithms



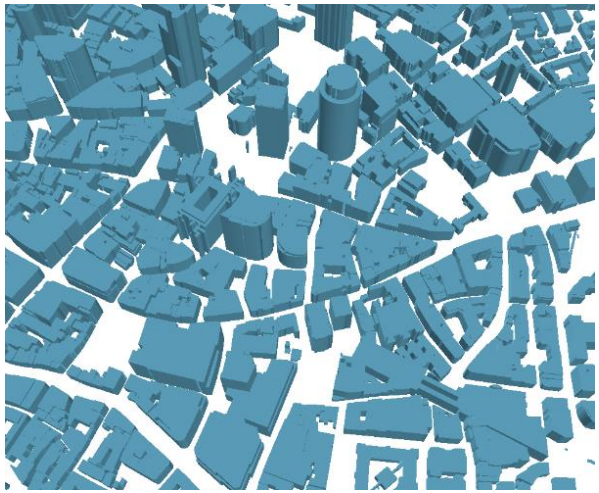




The Opportunity

We Need

- Measurements
- **3D Mapping**
- Algorithms

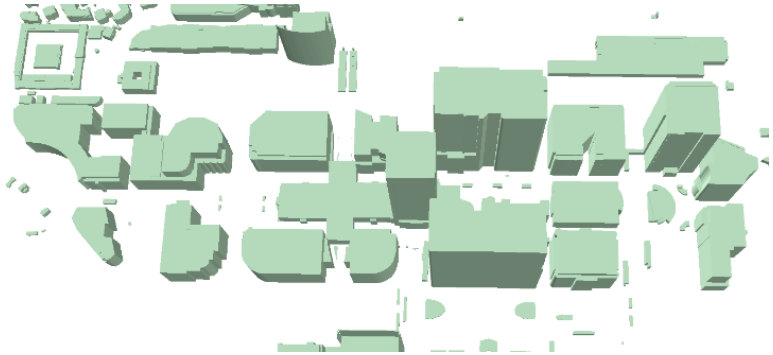


Data from Ordnance Survey Master Map

Simple ‘block’ maps are sufficient

Open Street Map

National Mapping Agencies

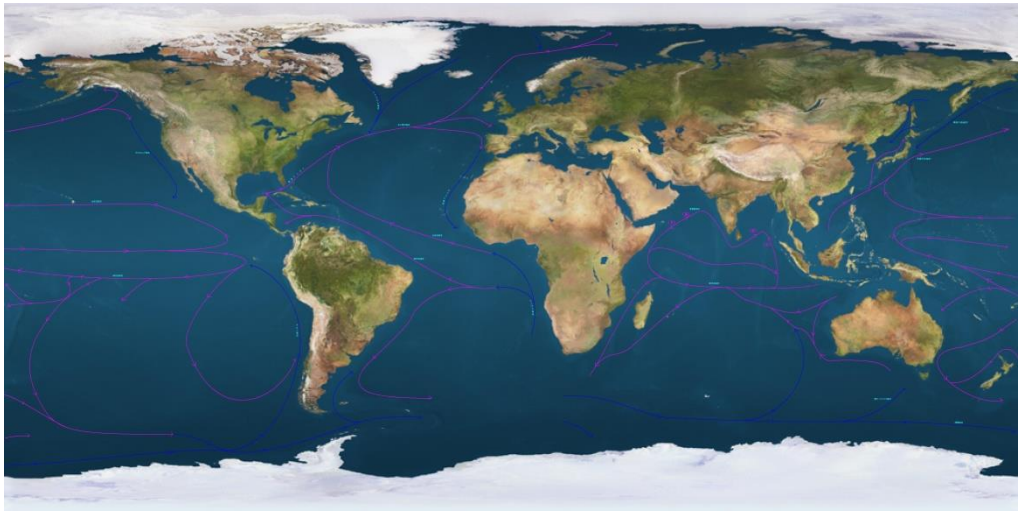


Data from Ordnance Survey Master Map

The Opportunity

We Need

- Measurements
- 3D Mapping
- **Algorithms**



Lots of research has been done since ~2010

~10 Research groups in Europe, Asia, North America & Middle East

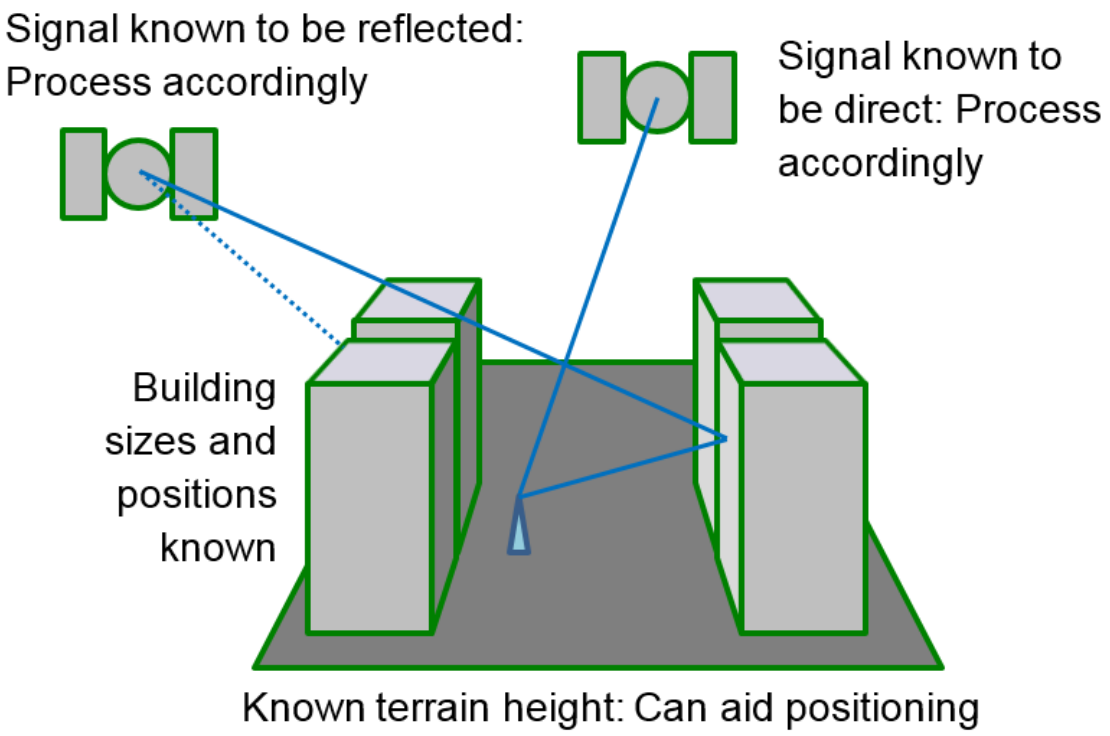
More than 50 papers published

3D Mapping Aids GNSS in 3 Ways

Height Aiding

Mapping-aided Ranging

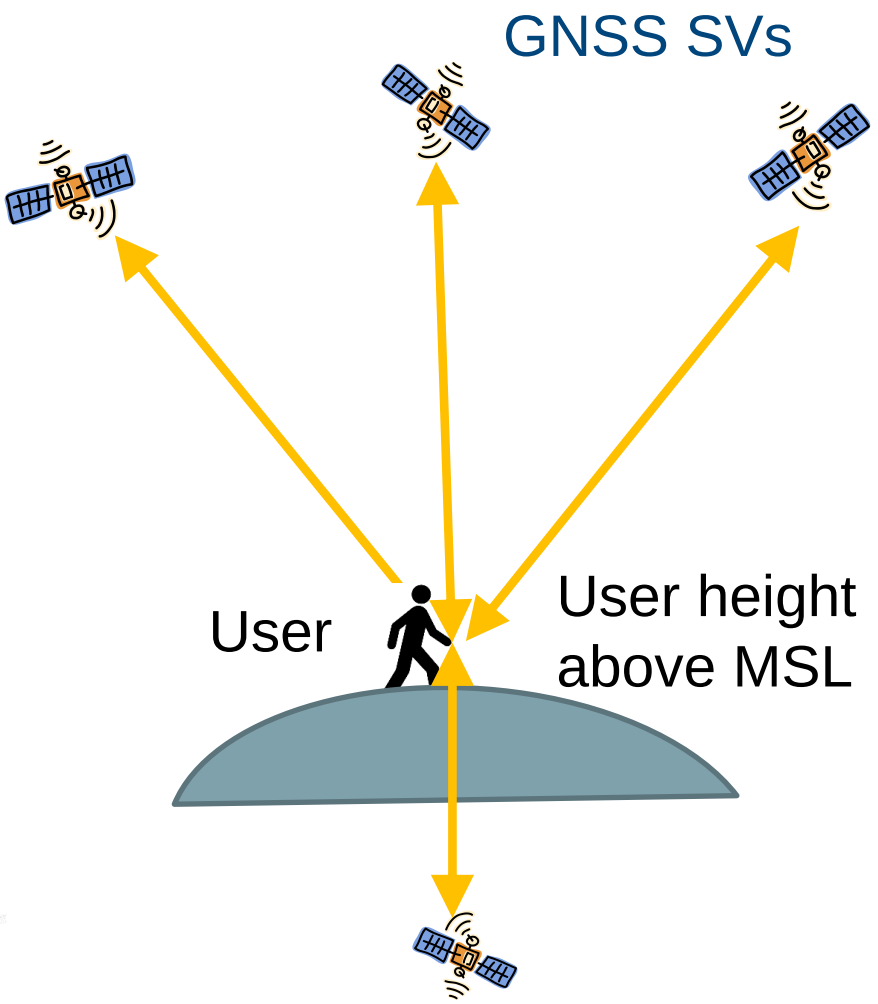
Shadow Matching



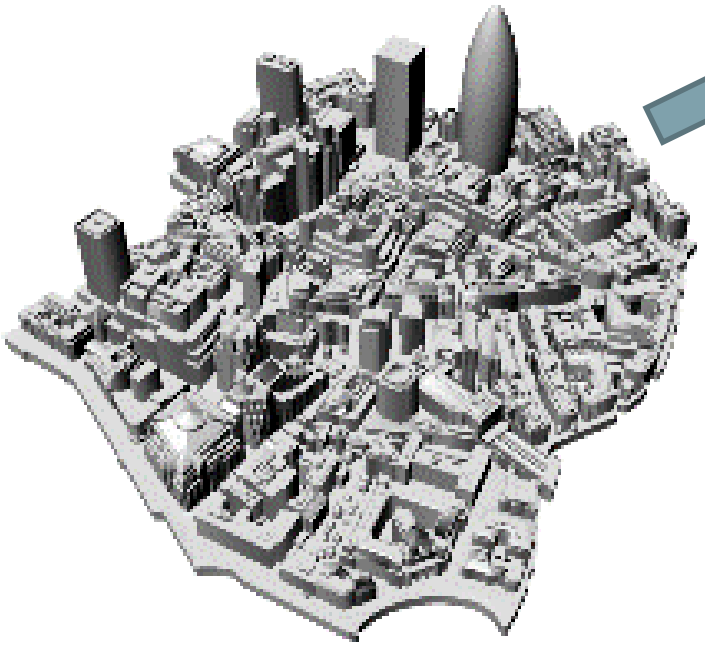
Terrain Height Aiding

In an open environment, this only improves vertical positioning

Where signal geometry is poor, horizontal positioning is nearly twice as accurate with height aiding



Non-line-of-sight (NLOS) Prediction

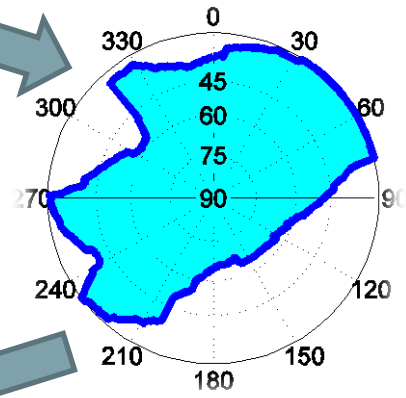


3D City Model

Ray tracing or Graphics processing

LOS/NLOS Predictions

GNSS Positioning algorithms

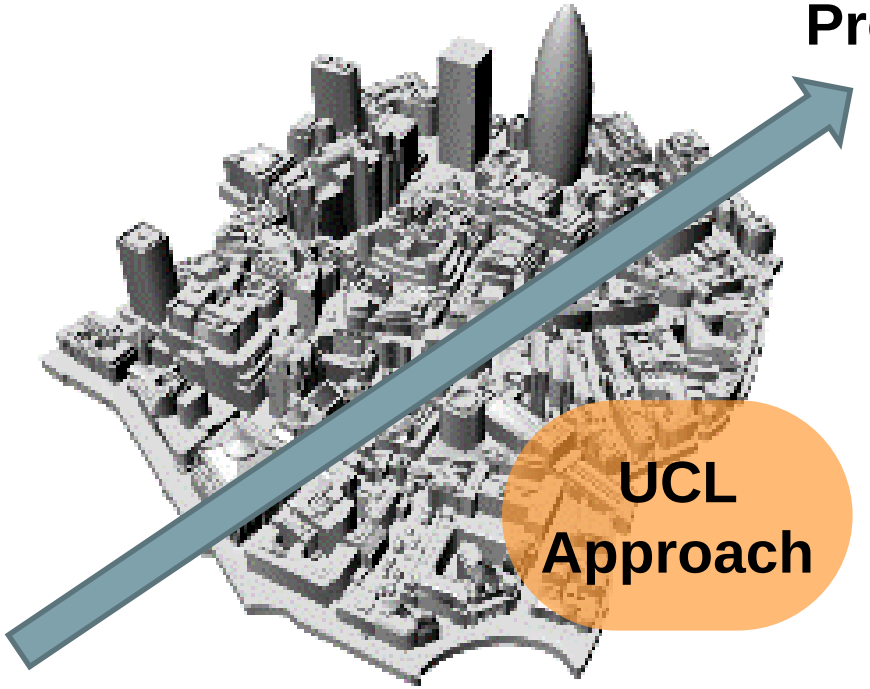


Building boundary file

3D-Mapping-Aided GNSS Ranging

NLOS Correction

NLOS Prediction



Single Candidate Position

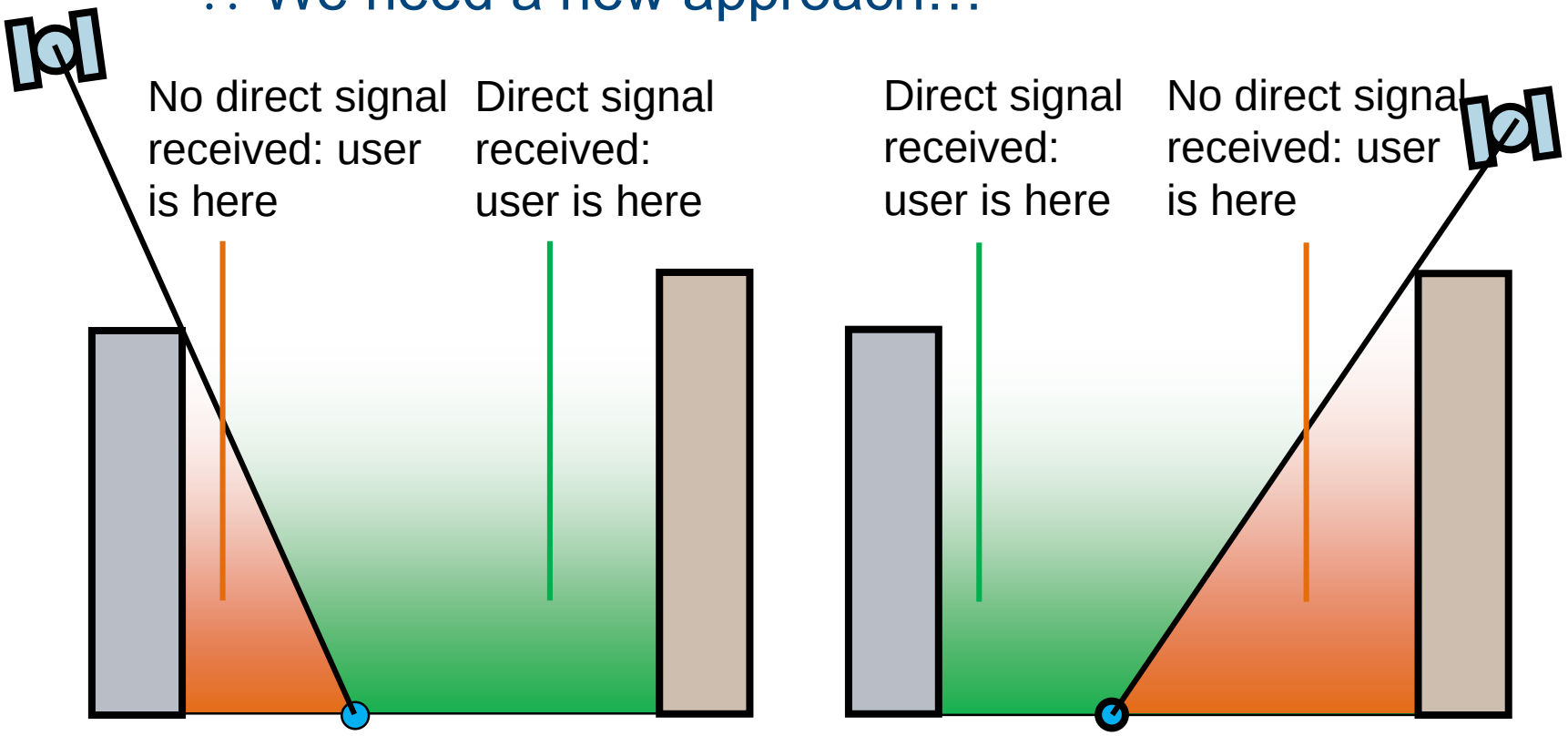
Multiple Candidate Positions

Other groups have implemented other approaches

Shadow Matching

Conventional across-street positioning is poor

∴ We need a new approach…



NLOS and untracked satellites contribute to positioning

Single Epoch versus Multiple Epochs

Single-epoch GNSS

Few alternatives to 3D mapping aiding

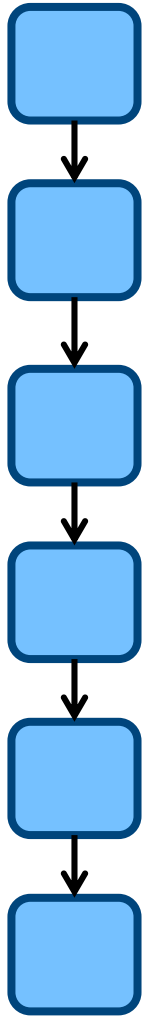
Multi-epoch GNSS

Many alternatives :

- Carrier smoothing
- Filtering (EKF)
- Integration with inertial and other DR sensors
- RTK carrier-phase positioning (potentially)
- Advanced signal processing techniques

But, these techniques need accurate **initialization**

3D-mapping-aided GNSS provides this in urban areas

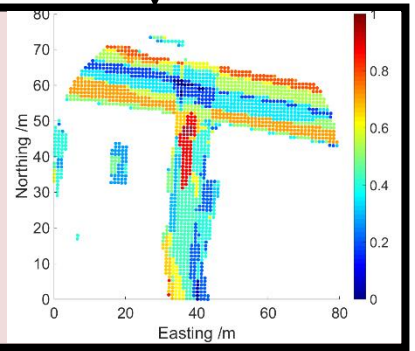


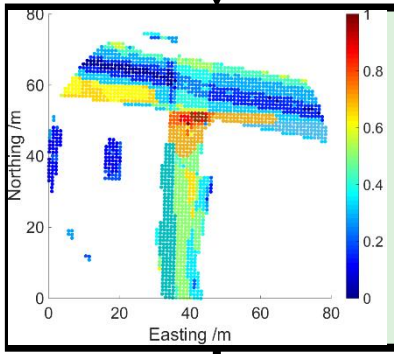
Intelligent Urban Positioning: Concept

Best performance is obtained by combining everything

Least-squares 3DMA Ranging

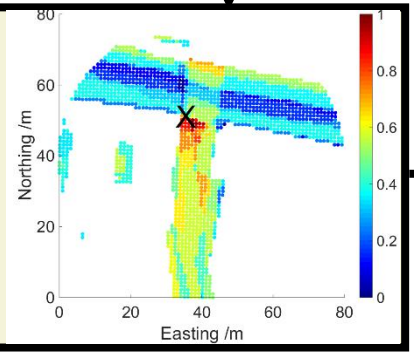
Shadow Matching
Uses SNR
Better across-street





Likelihood-based 3DMA Ranging
Uses pseudo-Ranges Better along-street

Hypothesis-Domain Integration



Position solution

All algorithms use terrain height aiding

Intelligent Urban Positioning: Results (1)

U-blox EVK M8T Single-epoch positioning

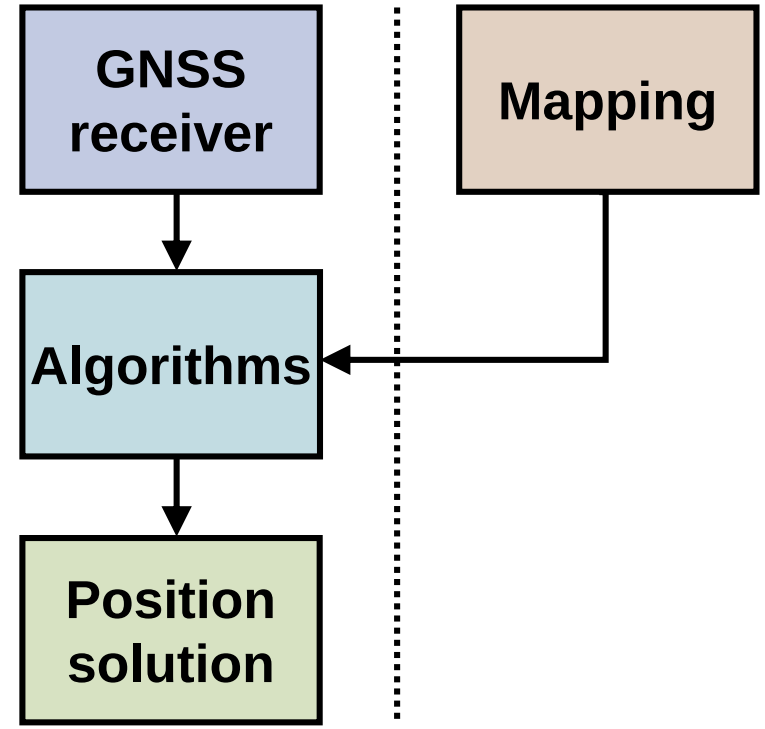
RMS Error	Conventional	IUP
Along-street	13.5 m	2.9 m
Across-Street	24.7 m	2.8 m
Horizontal	28.2 m	4.0 m

Intelligent Urban Positioning: Results (2)

Nexus 9 Tablet Single-epoch positioning

RMS Error	Conventional	IUP
Along-street	17.0 m	4.6 m
Across-Street	28.0 m	5.3 m
Horizontal	32.7 m	7.0 m

Practical Implementation: Receiver-Based



Suitable for navigation and continuous tracking applications

UCL algorithms take 233 ms per epoch on a laptop

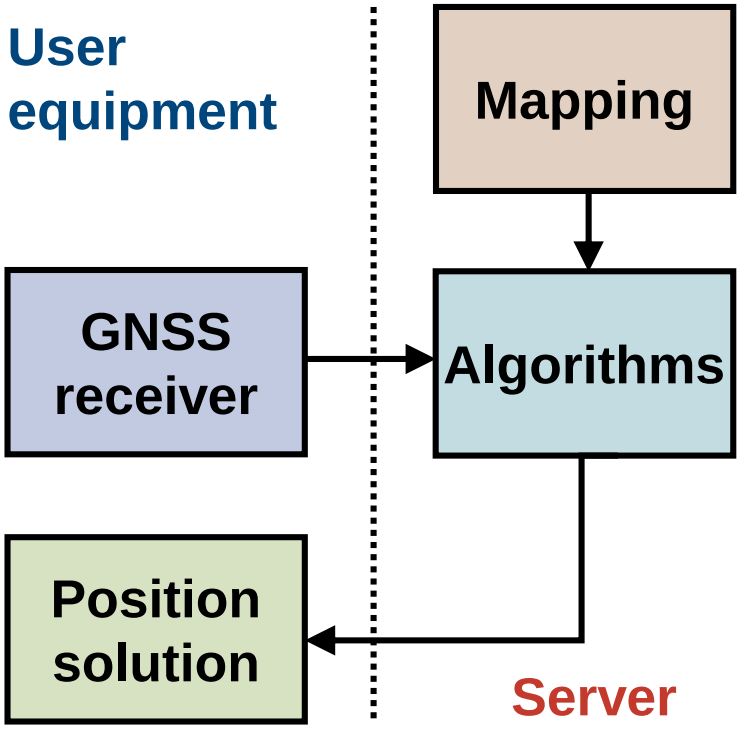
Real-time implementation on a mobile device at 1–2 Hz is feasible

Mapping can be streamed over a 3G or 4G link

Needs new GNSS receiver interface (Android Nougat)

Would benefit from multi-epoch algorithms (planned)

Practical Implementation: Server-Based



Suitable for:

- Location-based services (LBS) requiring a single fix
- Tracking applications with long update intervals

Can use existing AGNSS communications protocols, so should work with any mobile device

Suitable for current single-epoch Intelligent Urban Positioning algorithms

Summary

It's time for 3D-Mapping-Aided GNSS!

RMS Horizontal (2D) Position Error	Conventional	IUP
U-blox EVK 8MT Receiver	28.2 m	4.0 m
Nexus 9 Tablet (Nougat interface)	32.7 m	7.0 m

Further Information

- Inside GNSS September/October 2016 Dr Paul Groves (UCL)
- Session A5 Presentation 7 (Friday AM) Dr Mounir Adjrad (UCL)
- Session B6 Presentation 6 (Friday PM) Dr Taro Suzuki (Waseda Uni)

Thank You to Dr Mounir Adjrad of UCL