Assured PNT Through Multiple Diverse Technologies

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

Introduction

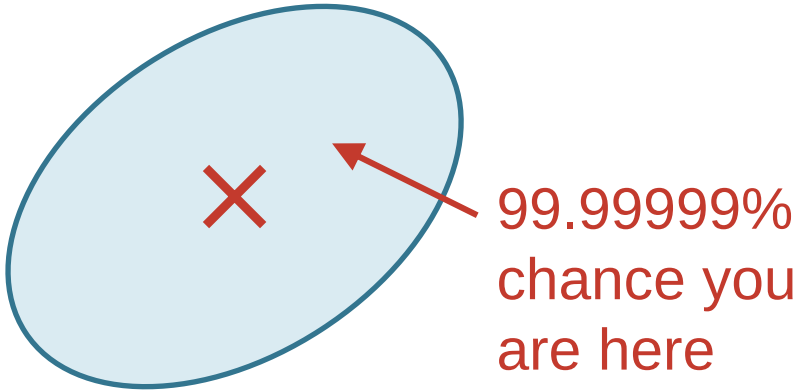
*"Panelists will have the opportunity to expound upon their vision of how **ubiquitous**, **high-integrity** **PNT** might be achieved"*

Ubiquitous means

- Works in different environments
- Works for different user behaviours
- You always have a PNT solution

High-integrity means

- You can always trust the PNT solution



CONFLICT

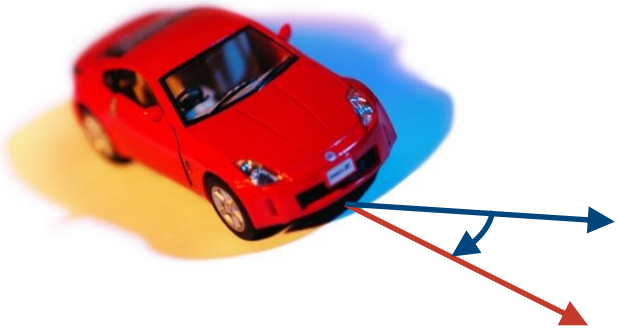
- No solution is better than an untrustworthy solution

No Positioning Technology is Reliable

GNSS and Other Radio Signals:

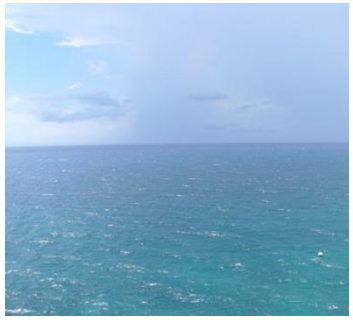
Jamming
Spoofing
Interference

Signals not always available



Dead Reckoning:

Errors grow with time



Visual Navigation:

Landmarks are not available everywhere

Things Break:

Reliability Means Multiple Techniques

Different navigation and positioning techniques must **fail under different conditions**

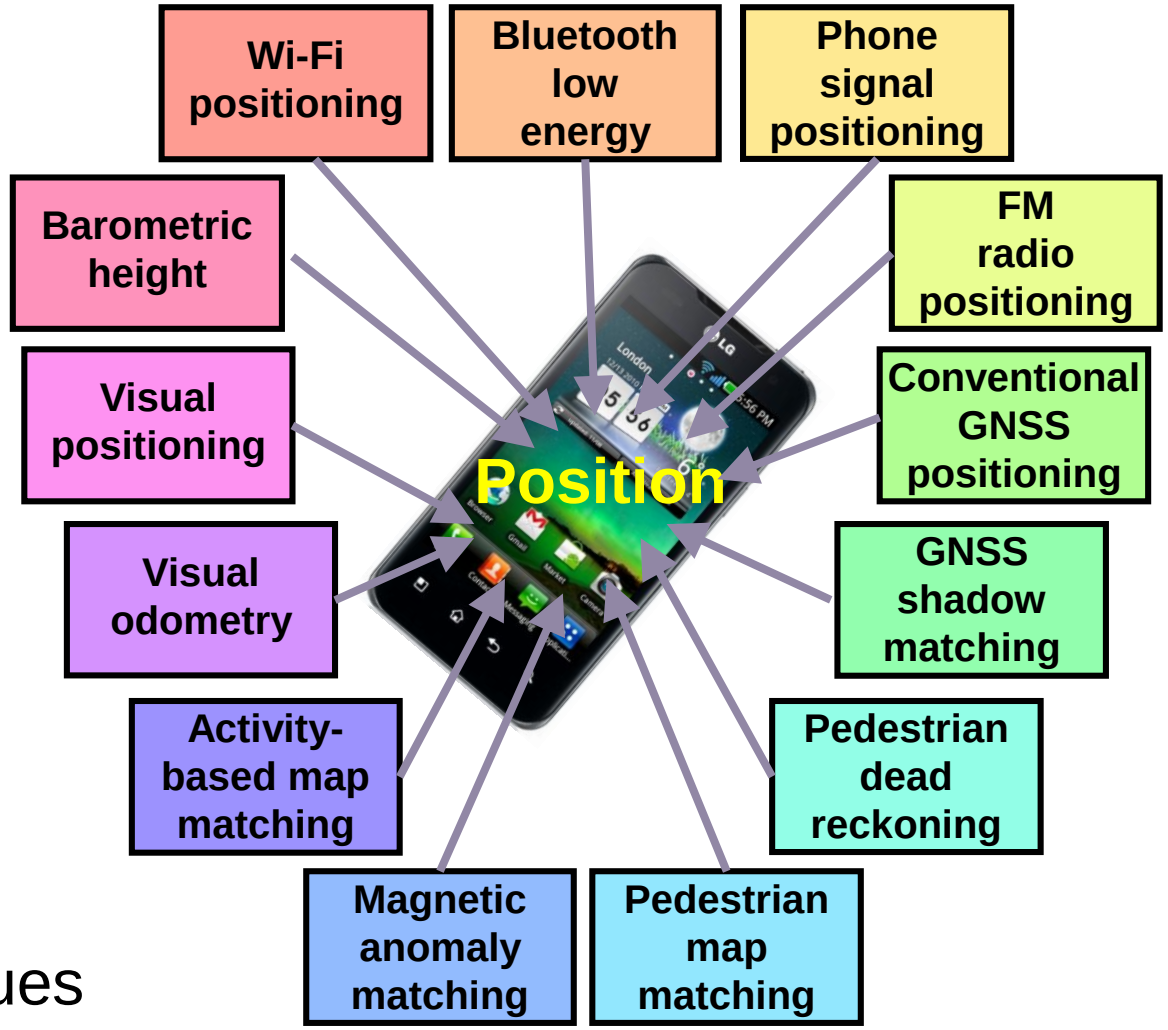
- Most **radio positioning** techniques perform poorly indoors
- **Wi-Fi** positioning works better indoors
- **Low-frequency** radio signals are difficult to jam or spoof
- **LF** signals also suffer from large propagation errors that must be calibrated
- Only **dead-reckoning** techniques provide continuous positioning
- **Dead-reckoning** position errors grow with time

What Do We Use When?

≥ 13 smartphone pedestrian positioning techniques

Other platforms use other techniques

Focus processing resources on the most viable techniques



What Do We Use When?

It depends on the **Context**

Environment

Open: Standard GNSS works well

Urban: Use 3D-mapping aided GNSS

Indoor: Wi-Fi generally best

Behaviour

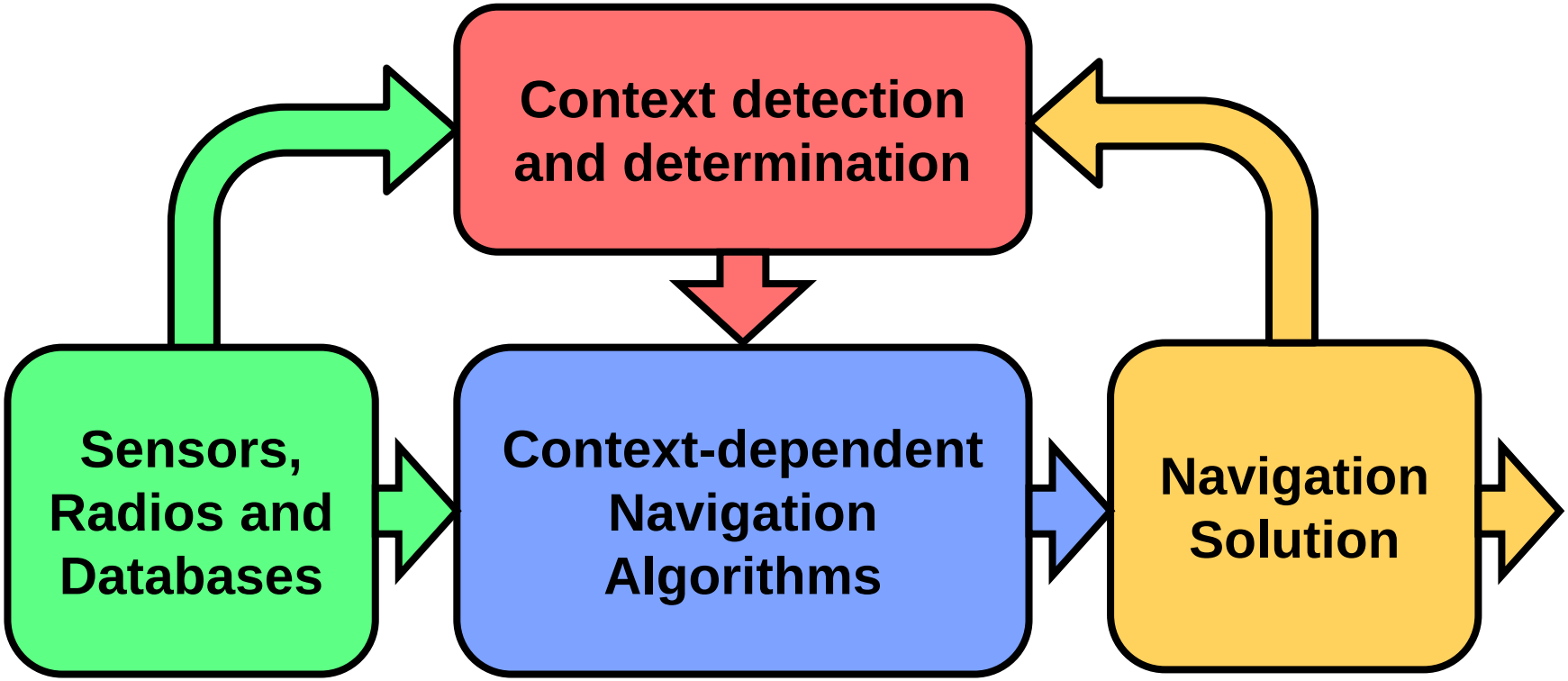
Pedestrians and Vehicles

- Different map matching
- Different motion constraints
- Step detection only works for pedestrians

Context-Adaptive Navigation

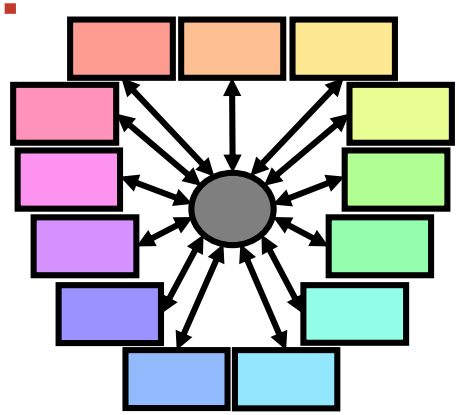
We detect the environmental and behavioural context.

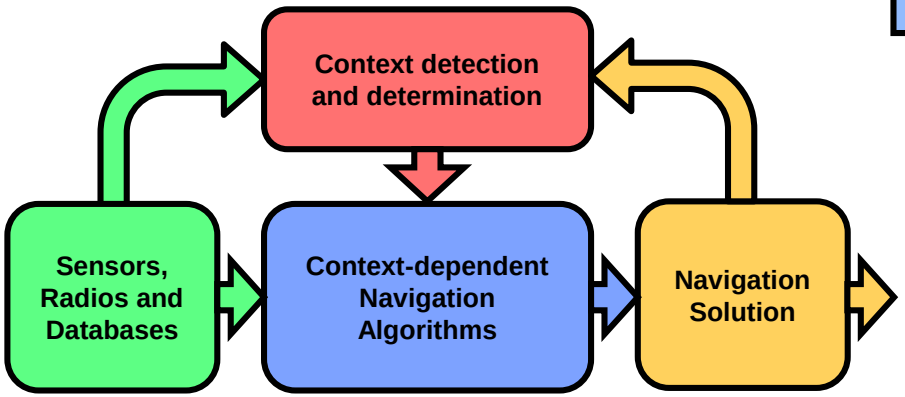
We select the appropriate navigation techniques



What Can We Trust?

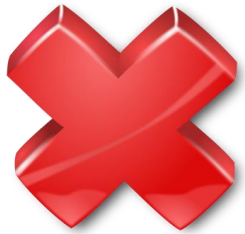
Multisensor Navigation can ensure that something will always work





Context-Adaptive Navigation ensures we select suitable techniques according to the environment and user behaviour

BUT how do we know whether our position solution is right?



We Need Solution Verification

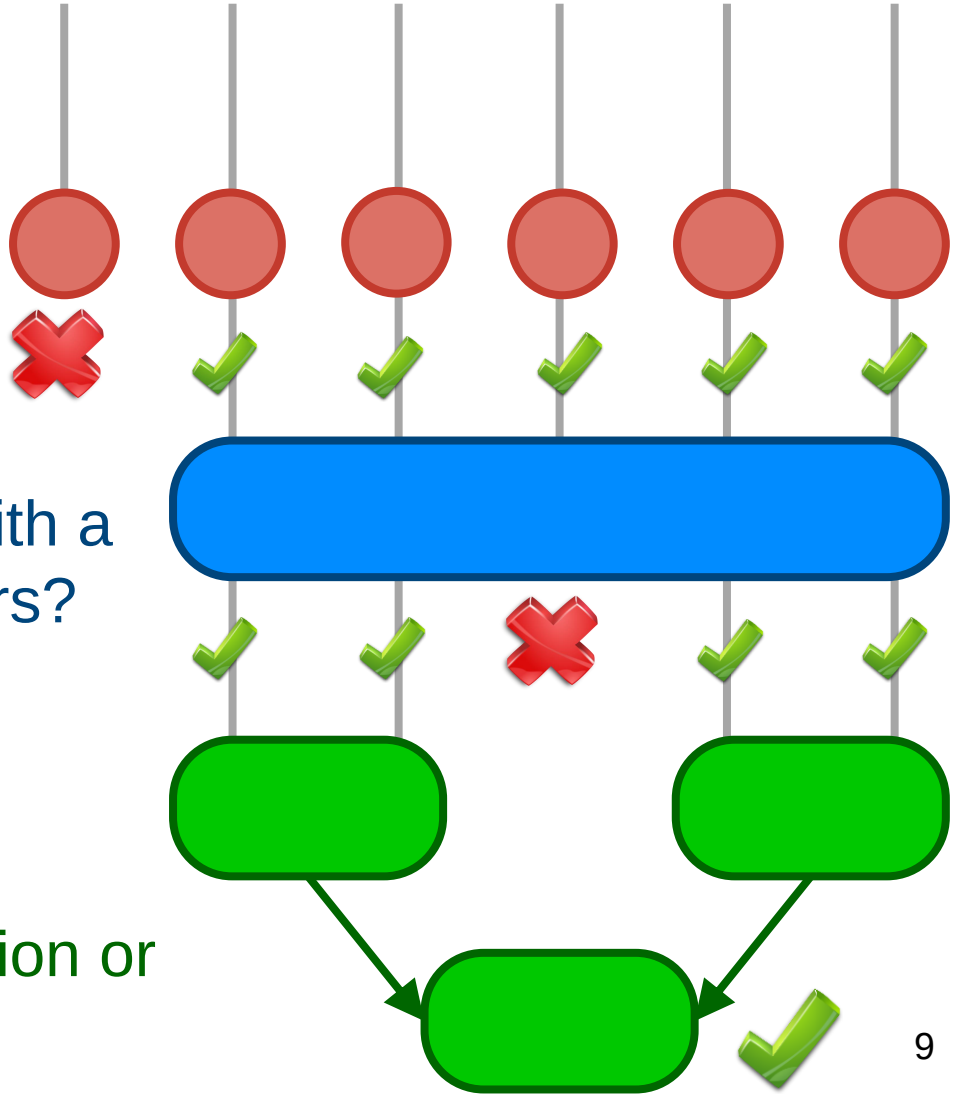
Measurements

Individual quality checks

Consistency checks – Does each measurement agree with a prediction made by the others?

Compute two independent solutions – Do they agree?

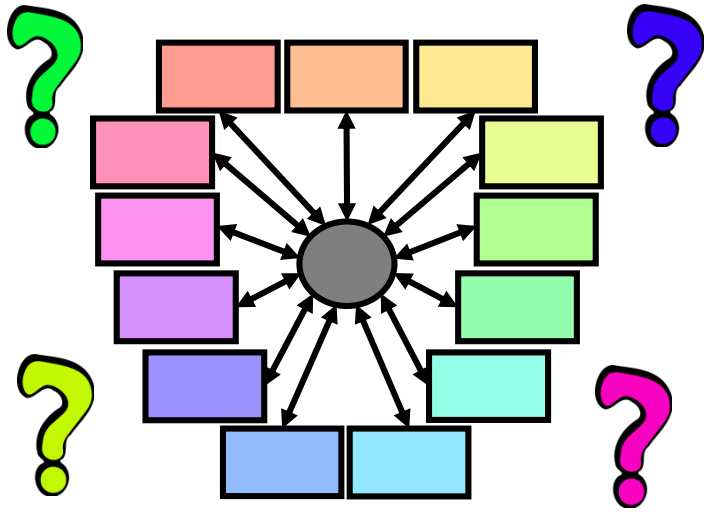
Can compare absolute position or change in position



The Complexity Challenge

To **combine** and **compare** different navigation technologies we need to **understand** them

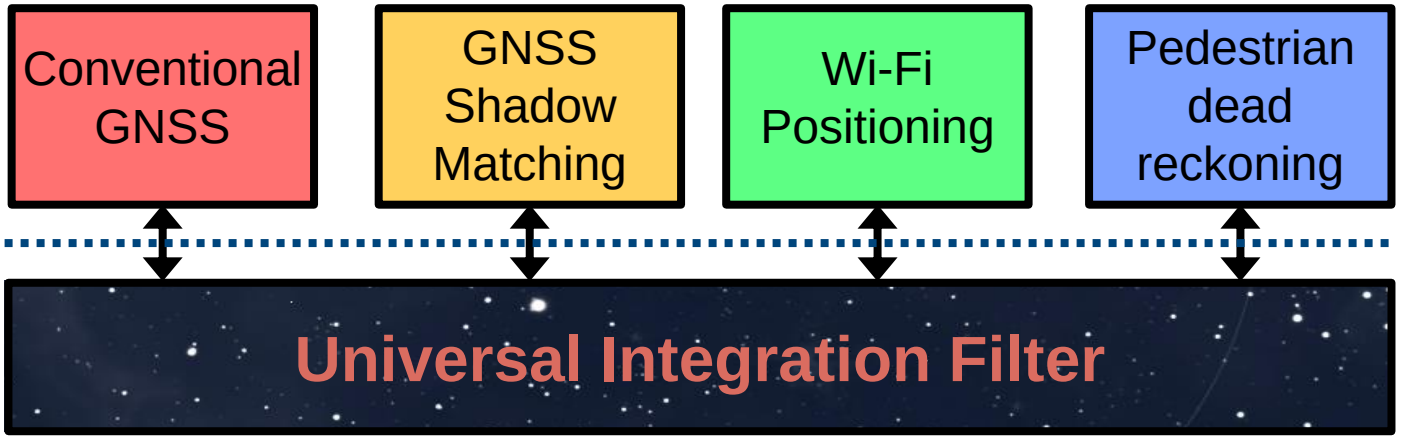
- Accuracy?
- Error characteristics?
- Correlation times?
- Failure modes?



How do we obtain **expertise** on **all** of the **different** subsystems?

- Difficult to find in one organization
- Essential information may be proprietary
- Full error characteristics may not be known

The Plug 'N' Play Solution



- Accepts several standard measurement types
- Configures automatically based on measurements received *with* sensor specifications

How do we trust the sensor specifications?

Certification Process? Expensive and time consuming

Learning Algorithms? Can we trust these?

Is a Standard Interface Realistic?

How do we persuade everyone to conform to it?

Businesses compete to sell products and services

- Is there a big enough **market** for ubiquitous positioning *and* high integrity?
- Is it **lucrative** enough for them to **share** information with **competitors**?

Governments promote technologies that:

- Potentially **create jobs**
- **Look good**, e.g. satellite systems and “quantum” technology

BUT Are they interested in more reliable PNT?

Conclusions

*"Panelists will have the opportunity to expound upon their vision of how **ubiquitous**, **high-integrity PNT** might be achieved"*

It is achievable **technically:**

1. Multiple PNT technologies with **different** failure modes
2. Context **adaptivity**
3. Multi-layered consistency-based **verification**
4. Plug 'n' Play integration with a **standard** interface

But, is it achievable **politically?**

Ubiquitous, high-integrity PNT needs **cooperation**