Assured PNT Through Multiple Diverse Technologies

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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
• No solution is better than an untrustworthy solution

CONFLICT

99.999999% chance you are here
No Positioning Technology is Reliable

**GNSS and Other Radio Signals:**

- Jamming
- Spoofing
- Interference

[Images of a car and a tower with a thief.
Images of a tunnel and a signal.
Images of a car and a thief.
Images of a tunnel and a signal.
Images of a car and a thief.
Images of a tunnel and a signal.]

- Signals not always available

**Visual Navigation:**
Landmarks are not available everywhere

**Dead Reckoning:**
Errors grow with time

**Things Break:**

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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

- Conventional GNSS
- GNSS Shadow Matching
- Wi-Fi Positioning
- Pedestrian dead reckoning

Universal Integration Filter

- 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

“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