Opportunistic Positioning

Ramsey Faragher & Rob Harle

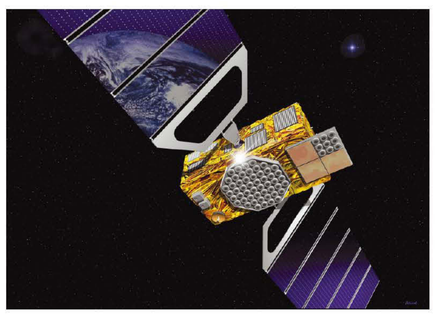
UNIVERSITY OF CAMBRIDGE
Computer Laboratory

Motivation

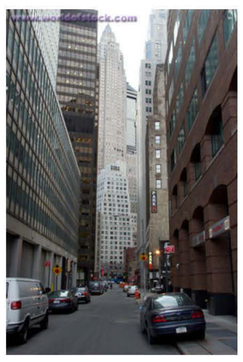
We rely heavily on Global Navigation Satellite Systems (GNSS) such as GPS for Aviation, Emergency Services, Defence, Academia, Mining, Agriculture, Telecommunications and even Banking. In 2011 it was noted that around €800 billion of the European economy is dependent on GNSS [1]. A study by the Royal Academy of Engineering in March 2011 entitled "Global Navigation Space Systems: reliance and vulnerabilities" provided an examination of society's strong dependence on GNSS and discussed twenty four failure modes of GNSS systems [2]. This research programme addresses the major concerns of this report by improving the reliability and availability of GNSS, without needing new infrastructure or devices.

1. What's wrong with GPS?

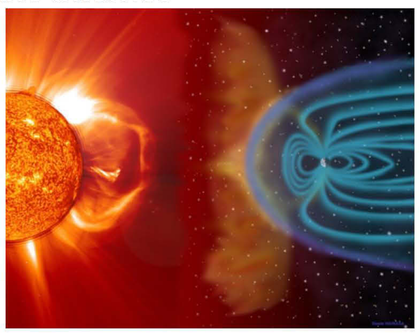
- 50 Watt transmissions from over 20,200 kilometres away
- Received signals are extremely weak (a *quadrillionth* of a Watt)
  - Affected by buildings, space weather, radio interference
  - GPS Jammers are cheaply available on the internet
- All GNSS suffer the same failure modes



Galileo GNSS satellite



Urban canyon



Coronal Mass Ejection

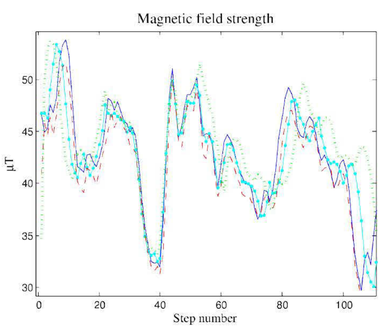
A £30 GPS Jammer

- GNSS need to be enhanced to protect our dependencies
  - Needs better availability, robustness, integrity
- The incorporation of opportunistic signal processing within a GNSS receiver can provide a robust tracking system capable of global operations without or without satellite signals, but requiring no extra infrastructure construction or maintenance costs.

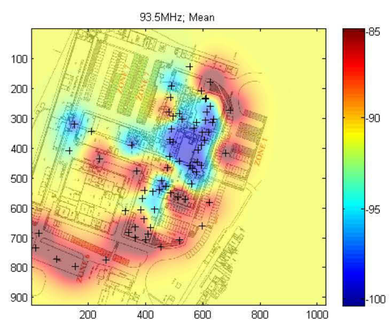
2. Opportunistic Sensing

- GNSS are so successful because of their global availability at low cost (to the end user)
- The most desirable enhancement will also be low cost, provide high availability and require no new infrastructure
- We are surrounded by *opportunistic* signals
  - Radio signals such as DAB, DVB, 2G, 3G, 4G, WiFi
  - Millions of times stronger on reception than GNSS signals
  - Deep penetration into buildings and other GNSS "blindspots".
  - Protection from jamming and space weather events
  - Also magnetic anomalies can provide stable position signatures

A track produced using GSM 2G cellular mobile phone signals



Excellent repeatability of magnetic signatures down a corridor on four separate days

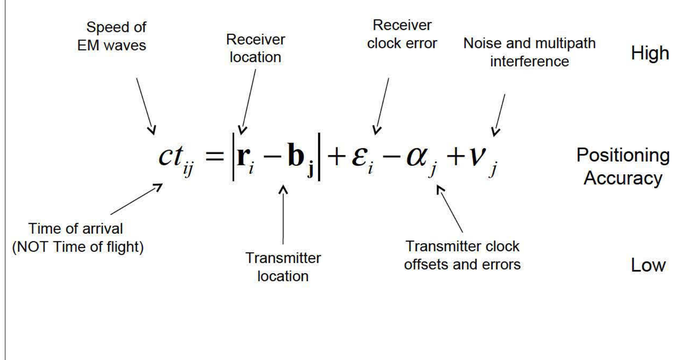


A VHF FM radio "heat map" showing the signal complexity indoors exploited by the indoor positioning system

- Previous opportunistic positioning systems have all depended on differential corrections from reference receivers or extensive prior knowledge (e.g. databases of transmitter locations).
- Here we exploit machine learning algorithms to permit stand-alone (non-differential) terrestrial positioning without any prior knowledge of the types or locations of the opportunistic signals.
- Outdoor positioning – timing and phase measurements
- Indoor positioning – signal strength and magnetic anomalies
- Simultaneous Localisation and Mapping and sensor fusion [3]

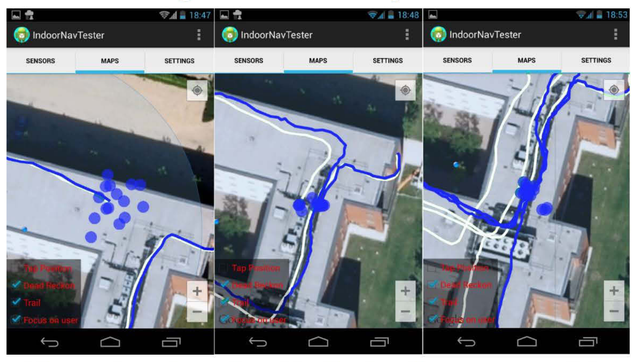
3. How does Opportunistic positioning work?

- Outdoors, opportunistic positioning can typically operate in a similar manner to GNSS given modern digital signals with certain properties.
- Opportunistic radio signals were not designed for this purpose and this must be considered to exploit these signals fully.
- Timing broadcast stability and transmitter locations are initially unknown.
- Machine learning algorithms called "Simultaneous Localisation and Mapping" (SLAM) were adapted to permit the use of unstable signals from initially-unknown locations.
- This new flexibility increases the robustness and availability of opportunistic radio positioning and has provided a big step forward in its practical deployment.

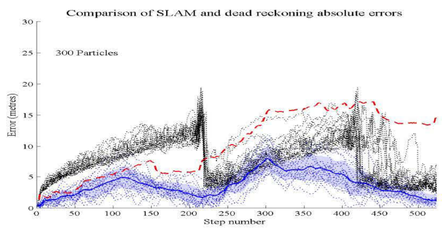


4. SLAM on a Smartphone

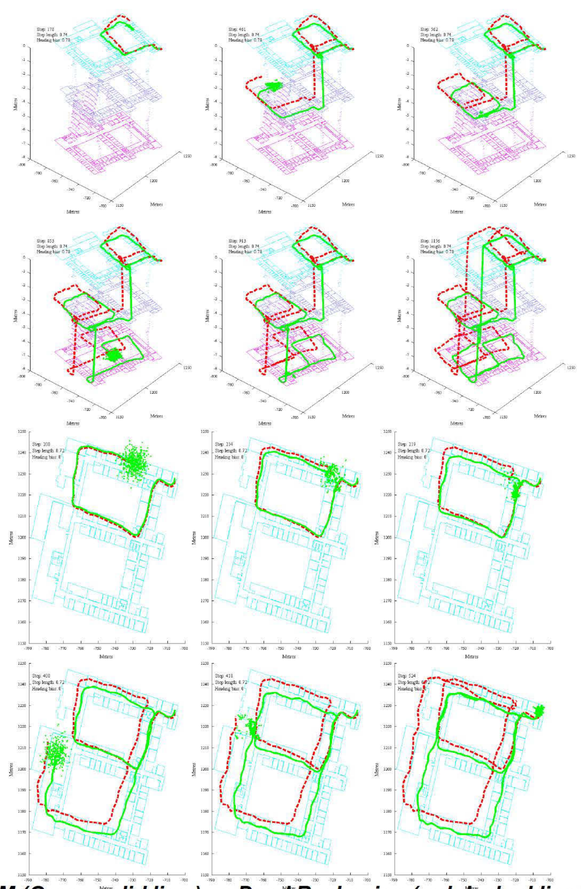
- We have developed an Android app that provides GPS-like positioning performance in any indoor environment.
- The system exploits magnetic anomalies, cellular signals, and WiFi
- The system needs no prior knowledge of the signals in the environment before use – it learns about the environment itself and gets better with use.
- At the core of the system is the smartphone's accelerometer, gyro, compass and barometer (providing 3D "dead reckoning" positioning).
  - These sensors provide the initial position estimates, which are improved over time as the system learns about the indoor signal and magnetic anomaly environment



The app in action – the white line is without opportunistic sensing and SLAM, the blue line is the full SLAM solution



SLAM constrains and correct the dead reckoning errors



SLAM (Green solid line) vs Dead Reckoning (red dashed line)

Contact: rmf25@cam.ac.uk

1."Report from the commission to the European Parliament and the Council, Mid-term review of the European satellite radio navigation programmes"
2."Global Navigation Space Systems: reliance and vulnerabilities." The Royal Academy of Engineering.London, UK
3.Faragher R. M. et. al. "Opportunistic Radio SLAM for Indoor Navigation using Smartphone Sensors" IEEE ION PLANS 2012 Conference paper

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