Opportunistic Positioning

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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

   [Image of GPS satellite and 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 with 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

   [Image of magnetic field and signal strength]

   - 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.

   [Image of SLAM algorithm]

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, gyroscope, 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

   [Image of smartphone app and SLAM algorithm]

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1. "Report from the commission to the European Parliament and the Council, Mid-term review of the European satellite radio navigation programme”