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An Expert Paper

Spatial Surveillance

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Scope

Spatial surveillance is concerned with monitoring the location of an object, animal or person. There are many reasons, many benign or positive and some not-so-benign, why we might want to do this. We might want to track a storm system and predict where warnings should be given; we might want to track a stolen vehicle with the intention of recovering it and apprehending the thief; we might want to provide up-to-date reports on traffic conditions on the road ahead; or we might want to observe how people navigate their way around a supermarket in order to understand their purchasing behaviour. Whatever the purpose of spatial surveillance, the key element is being able to measure location. This short discussion considers how we can measure location; how we can use this information to monitor people, animals or objects; and how we can use this information to monitor our environment.

Current Situation

Being able to establish one's location on the earth's surface has long been of interest to mankind. Our ancient ancestors erected monumental landmarks or learned to 'read' their environment or made sense of the night sky in order to fix a position on the earth's surface. Our more recent ancestors went to great lengths to fix position at sea (particularly latitude) for navigation and charting unknown territories. Today, the technologies available to determine location are rather more sophisticated but their development is so rapid that what we consider now to be cutting-edge technology may appear as crude as a sextant in a decade's time.

Current technologies to measure location generally fall into five main types: those based on trilateration; those based on sensors whose locations are known; those that record movement from a known starting position; those that infer location from visual imagery; and those where we geocode people's addresses as a means of capturing where they spend much of their time. We now consider each of these in turn.

Trilateration involves knowing distances from a person, object or animal to three objects in different known locations which can then be used to determine the location of the person, object or animal in question (strictly speaking, on a 3D surface such as the earth, distances to 4 objects are required to fix position). Many technologies can take advantage of trilateration; perhaps Global Navigation Satellite Systems (GNSS) are the most well-known. Until recently, there was only one reliable global satellite constellation, the US GPS, but others such as Russia's GLONASS system, the EU's Galileo system, and the Chinese COMPASS constellation, are being developed. The prospect of combining satellite data from different constellations will lead to greater coverage of signals as well as greater accuracy in determining

location. Currently location accuracy is around 5-10m for regular GPS but down to 2-5cm for RTK-GPS although accuracy depends on location, particularly how many satellites are in view of the receiver.

Satellites are not the only objects that can be used for trilateration and position determination. Mobile phone masts and bluetooth and Wi-Fi transmitters work in the same way and are increasingly being used to measure the location of objects and the people carrying them. Given there are over 47,000 mobile phone masts in the UK, this is an extensive network that could be used for positioning and efforts are being made in several countries to use mobile phone networks for real-time traffic monitoring. There are two ways to do this – one is to record the connections made to phone masts so that location is given to the nearest mast. Speed of movement can be inferred by the time it takes for a user's phone to lock onto to a neighbouring mast. An alternative is to try to use triangulation of signals from different masts to determine location continuously which would allow a more accurate measurement of movement and traffic speeds.

Registering on a sensor whose location is known identifies a location and, generally, time. There are many sensors that register location in this way and examples include CCTV cameras, of which the UK has over 5 million, and Radio-Frequency ID (RFID) tags which can be the size of a pin head and which are becoming so cheap as to be considered disposable. A limiting factor currently is the range of the sensors that pick up the RFID tag's signal but this range is subject to active research and is bound to increase substantially in the near future.

Movement and position can also be monitored by instruments such as inertial navigation units (INUs) and micro-electro-mechanical systems (MEMS) that measure distance and direction travelled from a known point. Such devices are useful whenever GNSS signals are not available for periods of time because they can maintain recording position until the signal is recovered.

A fourth way of measuring location is to calculate position from what you are seeing. If your camera (or phone) records an image and that image is recognised, then your location can be inferred from the position from which the photograph is taken. Prototypes of this form of positioning are beginning to appear and can be merged with various types of additional information provided to the user about the image being viewed. In this way, augmented reality will become commonplace simply by pointing a phone or camera at an object.

A fifth way of recording location is from addresses. An address gives a location where people are generally based during the night and at weekends and from which various activities are based. Addresses need to be geocoded by combining address-matching software with an address database. This works well in places with regular addresses but less well, as in parts of Ireland for example, where addresses are relatively poorly structured.

Anticipated Changes

Given the increasing range and availability of geotechnologies to record and monitor our location on the earth's surface, we are under increasing surveillance – a trend that is likely to continue until our presence can be monitored nearly continuously. We can already record our own location fairly accurately through increasingly cheap GPS chips being included in a variety of products. We can monitor the location of other people (currently with their permission) through various web-based services and increasingly this information will be available to our phones.

There will be more satellite constellations available in the near future and receivers will be able to utilise signals from different constellations (GPS, GLONASS and Galileo) to provide greater locational accuracy. RFID tags will become even cheaper and more ubiquitous. Many people will carry multiple items that are 'tagged'. More use will be made of image-based location determination. Phones and cameras will be able to provide localised information to their users. Sat-nav systems in cars will record much more than directions on a map – they will provide real-time traffic conditions, road conditions such as ice or high winds and dangerous bends. Pedestrian navigation systems and indoor navigation systems will be provided on phones. Cities may provide their own satellite equivalents such as pseudolites – towers broadcasting a signal over a limited geographical space to augment satellite coverage. Perhaps the huge investment in satellite systems will become less useful in densely populated spaces where other forms of location-determination are possible? A big challenge is to provide continuous monitoring indoors but that problem will be resolved – it is just not clear what technology will prevail to do this.

Impact of Changes

Monitoring the location of objects, animals and people is becoming easier and more prevalent. This is both good and bad. We can all immediately envisage an Orwellian future in which citizens are continuously monitored (even in the dark – a situation not contemplated by Orwell!) and some would argue we are well down that path already. But monitoring can be very beneficial – the ability to monitor the location of alzheimers' patients in a home or young children at school or at play would provide huge peace of mind and perhaps save lives. Knowing where our friends or where services are nearby could be extremely useful. Knowing where and when a storm system hits land could prevent a serious loss of life. Whatever one's view of the benefits of increased spatial surveillance, it seems inevitable, however, that we and our possessions will increasingly be monitored. The world will become one large sensor network. We will all be 'chipped' Our task is to ensure that the positive aspects of surveillance are maximised and the negative aspects minimised.

5 key points

1. The range of geotechnologies that can be used to monitor location is increasing rapidly and will continue to increase rapidly over the next 5-10 years. Combinations of technologies will increasingly be used to monitor location.

2. Access to locational technology will become cheaper and near-ubiquitous. Today's systems will seem very crude in 5-10 years.

3. Currently, most positioning technology is based on trilateration (to satellites or terrestrial masts) but image-based location determination will increase.

4. Mobile phones, sat-navs and other locationally aware devices (LADs) will provide an increasing array of location-based information. Augmented, locationally aware, information systems will become commonplace.

5. Our movements and those of others will be increasingly monitored. This will have both negative and positive influences on society.

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