# DEALING WITH 3D POSITIONING HEAD ON

**JASON DEAN** ARGUES THAT CROWDSOURCING IS THE ONLY SENSIBLE WAY TO ADD VERTICAL POSITIONING TO INDOOR NAVIGATION APPS

Accurate floor level detection in smartphone apps is essential for truly context-aware localisation. In many ways it is the killer app. However, floor-level detection is also one of the most challenging goals in indoor positioning. The highest concentration of smartphone users reside in urban areas where multi-storey buildings are the norm, so accurate 3D detection is an ever-growing requirement.

At sensewhere, we all too familiar with the issues surrounding 3D positioning. In seeking to perfect a crowdsourced approach to indoor positioning, we are always aware of the 3D elephant in the room and dealing with it has occupied our R&D team for quite some time.

While we all see 2D positions every day – the X/Y on our mobile maps – we have no real reference point for the vertical axis in our everyday navigation applications. Wi-Fi fingerprinting can be deployed and may be effective in distinguishing floor levels with a relatively high degree of accuracy. But it requires extensive on-site manual surveying. Similarly, BLE hardware installations can provide some impressive results that can be tagged to specific floors, but who is going to build, install and maintain hardware infrastructure for every floor in every single building in Shanghai or Paris? These are not scalable solutions in anyone's book.

Here at sensewhere we realised early on that vertical mapping and automated detection were going to be the next big step-change in global location. In attempting to address the challenge, we early on concluded that to create a commercially viable level detection feature that would work in any building, anywhere, automatic crowdsourcing was the only viable option.

The data science and research teams here at sensewhere have spent more than two years working through the problems, and after much deliberation and experimentation we finally settled on an approach that we refer to as the 3D-Grid. The key principle behind the 3D-Grid is a location system that intelligently builds and learns to recognise different levels in a building, using existing signal sources, device sensor readings and machine-learning.

In building a workable solution, we came up against a lot of brick walls – in some cases quite literally. While studying device barometer data recorded simultaneously from multiple static devices at the same location, we found that pressure readings can differ by more than 1hPa and

substantially from sensor to sensor. We concluded that unfiltered barometric readings were not the answer in themselves, so we looked deeper into the raw data to seek a more intelligent approach.

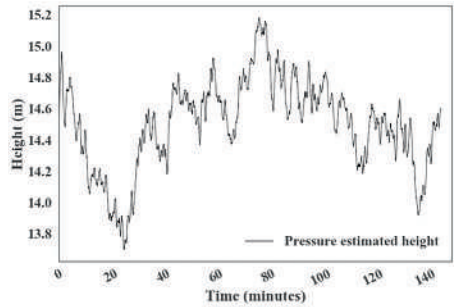
## How it works

The first building block is in detecting boundary events: knowing with a degree of certainty that a device has crossed the threshold of a building and in which direction. We worked on several techniques on both the client and server side to improve our understanding of the characteristics of boundary and threshold events.

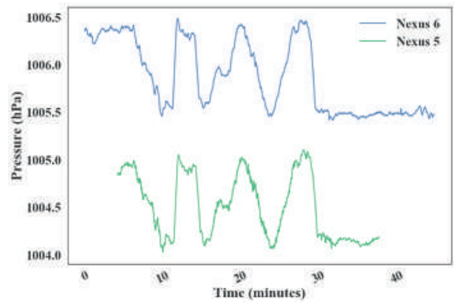
Once inside, the next step is to establish a 'ground zero' using the most recent GNSS data, as well as the likelihood that a device is at ground or street level when entering the building (which is not always the case) and the possibility that we have entered at sub-level or an upper floor via a raised access.

Once the ground level is established, the system will automatically combine multiple data inputs into dynamic profiles that will be continually updated by subsequent devices, but which will ultimately provide an anchor for the higher and lower levels.

The next challenge was detecting floor




Variations in estimated height recorded over 150 minutes from a static smartphone




Barometer readings from two different smartphones recorded simultaneously at the same location

changes. We take it for granted that there will be a lift, escalators, stairs or all three in a multi-floor building. However, learning to detect and predict the characteristics of each is a complex issue in its own right. Lifts do not stop at every floor, escalators can skip a mezzanine floor and connect ground to second floor – the permutations are daunting.

We studied each transitional type and with the aid of a temporal cache began to retrospectively build profiles at the start and end of each transition. The server system can adapt its understanding of each floor change and over a short period of time, starts to associate these points with unique levels.

By continually comparing crowdsourced data that is inbound to the server with the known references that make up an existing grid, we can adaptively detect with a very high level of accuracy which level of a building a device is located in regardless of atmospheric conditions or other input noise.

## The value of z

We see a lot of use-cases for the inclusion of an automatically detected Z axis in location. Consider an emergency call from a mobile device, where the caller is unable to provide a verbal location to the operator – how much more effective would the first responders be if they were able to request location and receive a position in all three axes? Not everyone lives on the ground floor of a building.

Proliferation of 3D contextual mapping may be thing of the future, but the technology is here and now.

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# MEETING THE SCALABILITY CHALLENGE

RADIO TRACKING TECHNOLOGY IS A GREAT ALTERNATIVE TO GNSS WHEN SATELLITES ARE UNAVAILABLE, SUCH AS WHEN INDOORS. BUT HOW DO YOU MAKE IT WORK WELL WHEN THERE ARE THOUSANDS OF OBJECTS TO TRACK? **THOMAS FÖRSTE** OFFERS A SOLUTION

Precise real-time tracking radio technology that works independently of satellite navigation is now being deployed across industries such as mining, manufacturing and healthcare to optimise management, increase productivity and drive compliance with safety regulations. Existing tracking technologies are highly accurate, but it has often been difficult to meet demands for scalability, such as when tracking thousands of objects in a defined area.

The most obvious way to track people, objects and vehicles is GNSS. However, this relies on navigation satellites being visible, which is hardly the case inside buildings,

tunnels or underground shafts. Furthermore, the accuracy of GNSS tracking is typically in the tens of metres, it has a relatively slow response time and is power-hungry, which can be a problem in battery-powered applications.

To address these issues, a neat alternative is provided by precise real-time tracking radio technologies. The basic principle is that an electronic RF transceiver measures the time that it takes a radio packet to travel a certain distance. Multiplying this time by the speed of light (the speed of radio signals) gives us the distance. For example, 1ns of travel time equates to 30cm.

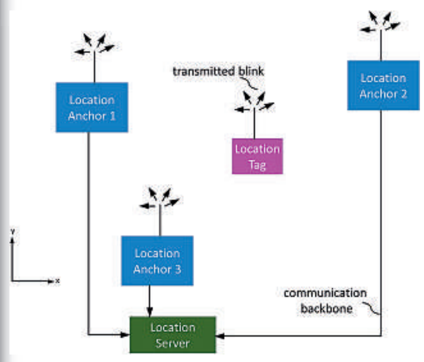
For battery-operated devices, integrated location controllers are required. They usually consist of a transceiver with a digital data interface housed on a single silicon chip. They are small, power-efficient and inexpensive.

An example is nanoLoc, the first location controller launched by nanotron Technologies in 2007. This chip uses chirp spread spectrum radio technology in the 2.4GHz ISM band. More than a million of these devices have been sold and they are still in production. A more recent development is Decawave's DW1000 Ultra Wideband (UWB) location controller, launched in 2012.

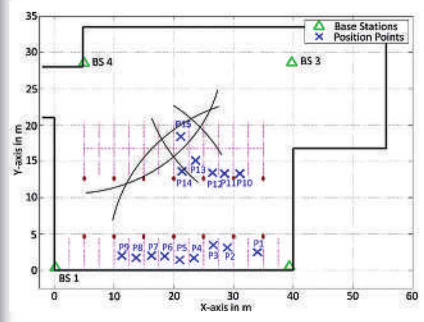
## Two approaches

The simplest way to calculate the position of a tagged object is to apply time of flight (TOS) methodology within a network of fixed reference points. These reference points, also called readers or anchors, and tags are all fitted with location controller chips.

TOF location methodology uses triangulation to calculate the distances between



TDOA methodology



TDOA trilateration

the tag and anchor reference points. In two-dimensional space this requires three distance values (see Figure 1). The nanoLOC chip requires approximately 2ms of airtime to measure each distance, meaning that calculating one position requires 6ms of airtime plus the processing overhead for each tagged object. Scalability rapidly becomes a serious issue as the cumulative time consumed by thousands of sequential calculations can quickly balloon out of control and overwhelm the tracking system, just when it is most needed.

An alternative solution is time difference of arrival (TDOA), which eliminates the scalability problem and enables the tracking system to seamlessly grow when more tags and anchors are added.

The principle of TDOA is shown in Figure 2. Location tags transmit broadcast messages (blinks), which are received by anchors in known locations. These anchors then generate time stamps for the blinks they receive, recording each one's time of arrival (TOA).

TOA stamps are then transmitted to a location server through a wired or wireless communication backbone. The server then uses these TOA stamps and the known positions of the location anchors to calculate the position of the tag.

The TDOA solution drastically reduces the required airtime. With the nanoLOC location controller, for example, this is only 0.5ms. The process easily accommodates multiple reference points (location anchors) for receiving packets, enabling more than three anchors to be used to substantially improve robustness.

Let's compare TOA with TDOA. With TDOA, the total airtime per position will be 0.5ms even when eight anchors are used, whereas with TOF 2ms would be required for each of the eight anchors, adding up to 16ms of airtime – 32 times that of TDOA. Hence, the more anchors and tags deployed in a system, the greater this difference becomes. That is scalability!

## Synchronisation issues

For TDOA to work, of course, the clocks of all the location anchors receiving a signal need to be perfectly synchronised. Earlier implementations used dedicated clock networks to synchronise all the location anchors in a system. However, this was expensive and complex to operate under real production conditions.

To overcome this problem, nanotron developed a patented virtual synchronisation method in which anchors and tags exchange timing information over the air. This eliminates the need for equipment-heavy clock synchronisation networks.

Synchronisation results are reported back to the server and used for calculating tag locations. TOA location blinks are processed using powerful location engine software and adjusted using the time information from the anchors. This means that a TDOA system continuously runs in the background from a single 'virtually synchronised' clock source.

Since it does not require any cell structure or hierarchy of network of readers, TDOA eliminates the need for expensive synchronisation mechanisms, is easy to deploy and scales smoothly.

In one real-world example, this technology has been used by nanotron and ATUT in a tracking system for the Park Thermic mine in Turkey. This system tracks 2,360 miners, as well as equipment and assets in real time, providing smooth 24/7 operation. It is highly scalable and covers tens of kilometres of mining tunnels and four excavation blocks.

"Automation and process optimisation, and the use of advanced tracking technologies has delivered substantial cost savings and improvements in efficiency. However, improved safety in intrinsically hazardous mining environments is a key benefit of TDOA; collision avoidance is but one example," said Michal Szebesta, project lead at the Park Thermic Coal Mine.

## Conclusion

Initially, users of satellite-independent tracking technology focused on location accuracy as the key performance metric. It turns out, however, that scalability and flexibility of the solution are equally important.

Any TOF approach quickly hits its limits of scale – the more devices that are added, the more airtime is 'consumed', which puts a natural brake on the system's continued expansion. On the other hand, TDOA scales well and uses a very light yet effective virtual synchronisation infrastructure.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