Inclusivity and Diversity of Navigation Services

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Our car seats, watch straps, seatbelts, and our gym equipment are all adjustable because of the "jaggedness principle" which basically says nobody is average. If you gather many people or things and collect data about different aspects and features of them, you will find out none of the people or items you measured can match perfectly with "average". That is why we have watch adjustment holes and adjustable car seats. But if there is no average person to use the technology, then how can we design devices and technologies that can be used by everybody? What would happen if we designed navigation devices, pathfinding services, assistive technologies for an "average user" and expect everybody to use them? Would it be as dangerous as a car without an adjustable seatbelt or is it just a little different that can be ignorable by our forgiving end users? This editorial looks at the importance of human factor, inclusivity and diversity-by-design in navigation services.

On Average, There Is Zero Average Person!

In the 1950s, which was the glorious time to see new jet engines making aircrafts much faster, the US Air Force realised that their pilots seemed to experience some troubles with controlling their aircrafts. Of course, the pilots were the first to blame but very soon the US Air Force realised neither training nor higher level of experiences can stop non-combat accidents and crashes. They understood that it had been the cockpit that was the issue. The cockpits had been designed based on the size of an average pilot back in 1926, and apparently the US pilots had grown since then! The US Air Force decided to update their measurements and redesign the cockpits for a new "average pilot".
They invited 4,063 pilots and measured 10 physical dimensions that needed to be adjusted in the new design. They measured torso length, arm length, crotch height, etc. The data from all the pilots who had been measured, were averaged to define a new "average pilot" that was supposed to fit into the newly designed cockpit. Well, the underlying assumption for this new design was that the majority, or at least many of the pilots, were within the average range on the majority of dimensions. But none of the 4,063 pilots managed to fit within the average range of all ten dimensions! Only 14 among all 4,063 the pilots were within the average size for all three dimensions. And so to avoid designing a cockpit that is good for nobody, the Air Force response asked the engineers to design adjustable cockpits.
There are so many other examples that show the "jaggedness principle" stands. There is no "average" student, there is no "average" palm of hands, there is no average user. This makes one wonder that if there is no "average" user, how we can ensure our devices and services can be useful at all. And what are the implications of designing a technology, such as navigation devices and mobile apps, for an "average" user or a certain group of users while expecting everybody to use it?

Challenges of One-Size-Fit-For-All Navigation

A navigation service can have four main components: maps, path finding or routeing engine, positioning technology, and finally communicating the navigational instructions. Each of these components are designed and provided initially to a certain group of users. Each of these four components have some levels of adaptation and personalisation features to maximise the use, and to serve the majority of (the "average"?) users as best as possible. Let's go through each of them and see how inclusivity could have changed them and impacted the wider users:

- **Maps**

Studies show that people in wealthier countries, countries with longer coastal lines, and those with higher equality measures are generally better at reading maps (Coutrot et al. 2018). Even on an individual scale, one person at different ages can read maps better or worse. Our map-reading and navigation skills can be improved by exploring new environments and even education. So, it seems to be unlikely that one single map can serve all of us equally well.
Do our maps are produced for a certain group of users? Well, they used to be mostly two-dimensional, north up, and non-ego centric pieces of papers, produced by surveyors, pilots, and explorers. Perhaps that is why we have a very poor coverage of maps for indoor even for publicly open buildings such as shopping centres and airports. And are you so surprised if the outdoor maps do not have the features of interest of some minority users, such as the surface condition, which is crucial for bicycles and wheelchair users.
Even when we look at some mapping projects that are technically open to anyone to contribute and map and add any features or attributes of their interest, including the successful "crowdsourcing" projects such as OpenStreetMap (OSM), we see a significant level of bias both in terms of participants, and their data. Some studies have shown that due to lack of inclusivity in the mappers of a technically “crowd”-sourced platform, some of the features that are associated with feminised skills (e.g., ‘childcare’ or ‘hospice’) may not exist on maps while the sexual entertainment venues seem to have much more details and classifications (Gardner et al., 2020). A study has shown when women map, they are more likely than men to represent women’s specific needs and priorities. They also found that female mappers tend to add services often overlooked by men, such as hospitals, childcare services, toilets, domestic violence shelters and women’s health clinics.
Stereotypically men are thought to be better than women at reading maps. But could this be because maps and navigation apps have been designed and developed by men and so they considered men’s preferences better? There are some studies that show that women can find their destinations faster, with fewer mistakes (getting lost or turning onto a wrong road), while remembering a greater number of landmarks and with a much higher level of details than men in 3-dimensional environments. So yes, men may read maps better than women but only in the 2D world (Mohan et al, 2019).

- **Path finding**

We should acknowledge that most pathfinding and in general navigation services have been initially designed and developed for in-vehicle use. Non-drivers, including pedestrians and wheelchair users still use routing services designed for motor vehicles (as they are or with some minor changes), but this can cause problems. Unlike drivers, pedestrian or wheelchair users, are not limited to the road network and can move in any direction, go through buildings, or cross open areas such as parks and grasslands. This greater freedom of movement is not supported by most widely used pathfinding and routing algorithms (Basiri 2020)- which still calculate the path between an origin and destination using graph-based path finding algorithms. Pick two points within a park and see how Google Maps navigate you! It projects the origin and destination onto the existing network of paths, e.g. roads, and then navigates you through that. It completely ignores the fact that pedestrians can cross the grasslands and they are not limited to the network of roads.
For some certain user groups such as women and children the safest path is the best path. While almost none of widely used routing, services consider this need; the best is the shortest because we all are considered as cars! For some other users such as wheelchair users, the width of passage, surface condition, slope, and weather are very important features to optimise. These are not factored in the currently existing pathfinding algorithms simply because they are designed for cars which care more about fuel and traffic than surface condition.
Wheelchair users have more ‘freedom’ but a lower speed of movement than road traffic – akin to pedestrians in some ways. The ability to move across open spaces makes them less constrained than road traffic but more vulnerable than cars and pedestrians to environmental conditions. In addition, any changes in the pre-planned path can impose a significant amount

of energy and time to be spent. Ferrari et al (2014) showed that half of the trips in London become 50% longer for people with mobility impairments as they need to take longer trips or change the planned routes to avoid obstacles and inaccessible areas.

- **Positioning and tracking**

Humans, unlike aircrafts and ships, spend most of their time indoors and so may not have access to freely available Global Navigation Satellite Systems (GNSS) may not be a luxury that can have. Even when we are outside, we are more likely to be between buildings, e.g., urban canyons, where the GNSS satellites in view might be limited. Just recently we considered 3D mapping aided positioning despite having GNSS for several decades. This is partly because of the complexity of the issue, but also because urban navigation simply ignored it for some decades.

In addition, different users may prefer to have different levels of privacy, and reliability according to their context. Some studies discovered that location obfuscation (which is the degradation of locations in order to preserve users' privacy) could be a good solution, however different services and different locations (e.g., closer to their home or at work) require different levels of accuracy, reliability, continuity, and even associated cost. We need to study users privacy, battery and power, reliability, and cost-related concerns better.

- **Communicating Navigational Instruction**

The last component is about communication of navigational instructions. Our navigation apps can hugely improve through multi-modal communications, e.g., haptic, sounds, videos and images (of landmarks along the way). Some users may not feel safe or happy if they have to be attached to their phone to ensure they do not miss the next turning point. Some users may feel more confident that they haven't got lost when they see a building whose photo or video was provided as a part of their navigational instructions. Also, the sense of touch is one of the first senses we have and one of the last ones we lose, so vibration would be a good way for providing navigational instructions to those who can't hear or see as others.

As you see diversifying users and considering human factors and uniqueness of individuals can actually play an important role in usability of navigation services. Thankfully, this is now an important research in our area. Only in this issue of the journal of navigation Arslan et al. (2020) look at the usability of electronic chart display and information systems (ECDIS), which is one of the major components of ships' bridge navigation systems. They studied eye movement data, collected from experienced port pilots operating on three different models of ECDIS, and found a significant difference between the participant port pilots and expert users. Wang et al (2020) examined the effect of colour combinations on performance of visual search tasks and found that colour combination significantly affected response time of the participants while not having a significant effect on their performance. They recommended colour combinations with negative polarity (e.g., yellow on black and white on black) for presenting search interfaces. These findings are of importance in human–computer interface designs for information display under vibration conditions. Ghosh et al (2020) looked at student performance and assessment factors, and Iftikhar et al (2020) studied cultural elements in the design and visual preference of signage information. They explored the variance in design and visual preferences of wayfinding signage and its influencing elements and conducted a survey among participants from 170 university students and visitors. The results demonstrated that participants of Hong Kong preferred inline colours of signage, along with mono or less colour coding and detailed information. While the other group preferred attractive colours with multi-colour coding and less detailed wayfinding information with pictograms. Individual differences concerning age, literacy level and gender were also computed, however trivial differences have been recorded. This study suggests the need for detailed cross-cultural investigation concerning elements of signage design and visual preference to identify the drivers for culturally consistent university signage.

As we move towards more data-centric design of technologies, we should be even more careful about the representatives of under-represented groups of users, inclusivity and diversity at the heart of our data collection and engineering. This will allow future data-driven decisions technologies to consider, integrate, monitor, and customise according to the needs and demands of the end users, including the under-representative users. This will ultimately promote the equal opportunity and access to all the potential users. It is great to see that Royal Institute of Navigation's vision includes the two terms of inclusivity and diversity as the main way to live in a more navigable world.

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