# Adaptive Mobile Indoor Route Guidance, The Next Big Step

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**Abstract.** Not all those who wander are lost… but when you are lost, there is a high chance that you are inside a building as we spend 90% of our time indoors. As opposed to outdoors, mobile indoor route guidance is not yet common practice, while the indoor environment can be far more complex than the outdoor one. As indoor navigation can be very challenging, we need supportive navigation systems that can ease the process. To this end, adaptive mobile indoor route guidance systems are being developed, which adapt the type of route instruction to the building configuration. This way, the right amount of information is provided at the right time and place. This work studies this type of smart route communication, and more specifically, its influence on the user. An online survey, a field experiment and a VR experiment were conducted to find out how building configuration can be quantified by the space syntax theory, which route instruction types should be used at which decision points and how this affects the performance, cognitive map, cognitive load and perception of the users. Prototypes were developed and eye tracking and position tracking were used to build the bridge between indoor route guidance technologies in smart buildings on the one hand, and the users of those smart buildings on the other hand. The results of this research can be translated into practical guidelines or implications for the design of adaptive mobile indoor route guidance systems, because this work has shown this is the way to go.

**Keywords.** Adaptive mobile route guidance, route instructions, space syntax, eye tracking

## 1. Introduction

Outdoors, we have a lot of options for navigation. We can use several apps on our smartphones, calculate the route for a vehicle or another transport

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mode, choose the time and date for which the route has to be calculated, avoid highways, estimate traffic and get notifications of speed controls. We can even change the voice in our app so that Batman can tell us we have reached our destination. Have we though? When we for example have arrived at the hospital entrance, have we really reached our destination? We still have to find the reception desk, we have to get to the waiting room and maybe grab a coffee on the way, but once we enter the building we're on our own. No apps that can say how long it will take, no funny voices to make us feel more comfortable.

In a world where many new construction projects have a digital twin, where not only people but also devices are connected through the internet of things, where sensors and cameras are generating big data and where everything has to be smart, indoor navigation is the next big step. However, this work does not focus on the technological implementation of indoor navigation. Instead, it focuses on the cognitive aspects of navigation in smart buildings, and more specifically on easing the decision making process during route guidance. As every decision point is different, the user's need for route information is also different at every point. Therefore, decision making can be eased by adapting the route instruction type to the needs of the users, and thus, to the decision point. Navigation systems that implement this idea provide the right amount of information at the right time and place. The usability of these systems is studied in the dissertation of De Cock (2021).

## 2. Three user studies

The first step in the design of an adaptive navigation system is to determine which route instruction types should be used on which decision points. In this research, this decision is based on the subjective preferences of the users, which was collected during an online survey. The case study building of this work is the iGent, the office lab of Ghent University, and for the online survey ten route videos were recorded in this smart building, and ten route instruction types were designed for these route videos (e.g., maps, symbols, photos, 3D-simulations). Participants had to indicate how complex they found a decision point and how they scored a route instruction type on every decision point of the recorded routes. The results indicated, first of all, which decision point categories were found to be most complex, and how this could be related to the building configuration, quantified by space syntax. Second of all, they indicated which route instruction type gained preference on which decision point category.

In a second step, the results of the online survey were used to develop a mobile indoor navigation prototype. The prototype was web-based, connected to the UWB sensors in iGent and automatically showed a new route instruction on the smartphone of the users. This route instruction could either be adapted to the decision point (i.e. symbols at starts and ends, 3D-simulations at complex turns and photos at all other points) or not adapted (i.e. photos on all points). The usability of the adaptive and non-adaptive system was tested with objective measures (e.g. eye tracking) in a field experiment where participants had to walk three routes with either one of the systems. The results of this field experiment showed that the usability of the adaptive system was higher, both in terms of cognitive load and performance.

In a third step, a virtual model of a building floor was designed and a virtual copy was made of the adaptive prototype from the field experiment. The same parameters as in the previous step were used to test the usability of the prototype, but this time the experiment was conducted in virtual reality. Because the virtual model was much bigger than the physical building, an analysis on the building configuration could be included. This way, the results of both the online survey and field experiment could be cross-validated in virtual reality. The lower cognitive load of the adaptive instructions that was found in the field experiment was confirmed in the virtual reality experiment.

## 3. Recommendations

First, we would like to address the implications of using turn-by-turn instructions. The comparison of turn-by-turn instructions with other ways of conveying route information is out of scope here, so it is impossible to give a full account of the usability of turn-by-turn instructions in general, based on the results of this work. However, we believe that certain results are caused by the general format of turn-by-turn route instructions, rather than the route instruction types specifically. This is the case for the general lower satisfaction of men in the online survey. This can for example imply that men are less likely to try a navigation aid when they know it uses turn-by-turn instructions, or that they will rather choose a navigation aid without turn-by-turn instructions. When they do decide to try it, it will not affect their orientation in a way that it becomes lesser than the orientation of women. This might be important to consider for example when the largest share of the target audience are men. A second difference between the prejudice of a system and actually using it, is the preference for a route instruction type. In the online survey, photo instructions were most liked by users, but when they had to use a navigation aid with photos in the field and VR experiment, this was no longer the case. As such, users might have a higher tendency to start using navigation aids when they know it uses photorealistic route instructions. In brief, the above mentioned results of the online survey might especially be of use to estimate the acceptability of a navigation aid before users can actually try it, as these results were not found in the other experiments. A result of the online survey that was repeated is the higher cognitive load on convex turns. This might be the result with the largest impact on the design of route guidance systems, as this goes straight against the navigation strategies without aid. This difference might be caused by the directed isovist during route guidance, and this seems to be confirmed both in the online survey and field experiment as only the local isovist measures correlate significantly. This means that designers of indoor navigation aids have to pay extra attention to the convex spaces as these are the hotspots of indoor turns. The convex space can be identified in a building by its local isovist characteristics, and more specifically by the compactness and occlusivity. Users will be in need of more support at these points, as they might be more confused and insecure by the rise in cognitive load. Luckily for future designers, we also found a way to reduce the cognitive load at these points: use 3D-simulations. The dwells will be smaller, which results in less screentime and more working memory devoted to the task. Moreover, it will not affect the user's walking speed, which is the case for photo instructions. At the same time, this might also be an advantage of the photo instructions. For example, when a building has very few or no convex turns, photo instructions might facilitate a faster walking speed, while this is not the case for 3D-simulations. Turns are not the only decision points where photo instructions induce a variable walking speed: at starting points, participants were clearly faster with the photo instructions, only this time compared to symbol instructions. At ending points, the role of photo instructions is again dubious, so the use of the route instruction type at end points will strongly depend on the layout of the building and the goal of the application: if there are a lot of possible end points at central places in a building, you have a chance of reducing cognitive load there with symbol instructions; if the main goal of the navigation aid is to get users as fast as possible to their destination, then this chance is also higher with symbol instructions. We could also make a case for the use of photo instructions at end points, as the first dwell was lower with this type, but the photo instruction does not provide extra help at the most complex points. All things considered, this nicely describes the role of photo instructions: overall this type has some advantages, but not on the most complex decision points. This also nicely affirms the preference ratings of the route instruction types. Regardless of the chosen route instruction type, the global building characteristics determine the cognitive load on ending points, which is in contrast to turns, where the local isovist characteristics are decisive. As such, designers should pay extra attention to the integration of end points in the building. This is also reflected in the orientation error that was most clearly influenced by the MVD. Furthermore, two final, general implications for the design of indoor navigation aids can be discussed. First, adding text to an instruction has been proven to have a high usability. On the one hand in the online survey, where users rated types with text consistently higher than the same type without text, and on the other hand in the VR experiment, as the timestamp analysis showed that users consistently read the text first. The final implication of adapting the route instruction type to the decision point for the design of indoor navigation aids speaks for itself: significantly less navigation errors will be made.

## References

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