# *Jaguar:* Indoor Navigation System for Organizations

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## ABSTRACT

Global Positioning System (GPS) technology is widely used for outdoor navigation, but it is still challenging to apply this technology to a mid-scale or indoor environment. Using GPS in this way raises issues, such as reliability, deployment cost, and maintenance. Recently, companies like Google have begun to provide accurate indoor mapping. However, current implementations rely on both Wi-Fi and cellular technologies which have a hard time identifying the user's exact location in an indoor environment. There are two research questions in this paper: (1) How do we design a flexible and cost efficient indoor navigation system for organizations? (2) How to find an optimized path in a mid-scale/local environment. Here we propose *Jaguar*, which is a novel navigation system that utilizes a customized KML map with NFC technologies to address above questions. Our system includes an Android mobile application, a web-based map authoring tool and an implementation of a Cartesian plane based path finding algorithm. The initial testing of the system shows successful adaptation for a school campus environment.

## Author Keywords

Mid-scale Navigation; Near-field Communication (NFC)

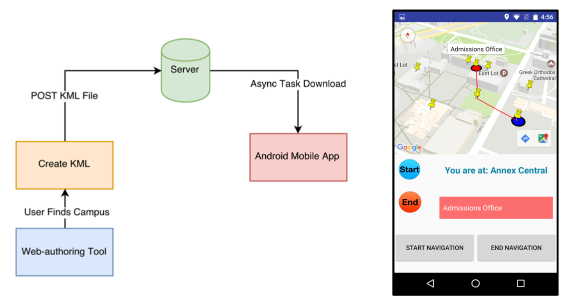
## ACM Classification Keywords

H5.2 Information interfaces and presentation: User Interfaces - Graphical user interfaces (GUI)

## INTRODUCTION

Indoor navigation systems are needed in many situations. However, using GPS in a mid-scale or indoor setting raises issues, such as reliability, deployment cost, ease of use, and maintenance. Although Google proposed and implemented an indoor navigation system, organizations first need to sign up and send in their floor plans for the service [1]. This multi-stepped process can cause the organizations to overlook the usefulness of indoor mapping. On average, people spend 90% of their time indoors [2] which makes the navigation of indoor spaces extremely important.

In this paper, we propose a new system, *Jaguar*, to address the issue of indoor and mid-scale navigation. *Jaguar* consists of two subsystems: An Android mobile application and a web-based map authoring tool. The Android application helps the user navigate environments which were set up by administrators. Although the design was centered around the need for fast and accurate indoor navigation, the system can be used in mid-scale environment without additional hassle (Figure 1).




Figures 1: (left) System architecture, (right) Android app.

## RELATED WORK

Much research has been done in the past dealing with making indoor navigation easier and more reliable. Particularly, research done in [3, 4, 5] has led to some interesting developments and results with the use of Near-field communication (NFC) in indoor navigation. NFC is a new short-range wireless connectivity standard that uses magnetic field induction to communicate between electronic devices in a close proximity [6]. For path finding, there are many methods proposed in the past [7, 8, 9, 10]. However, in *Jaguar,* we decided to develop a novel algorithm to compute the path that users should take when navigating through the environment set up by the administrator.

## METHODS

*Jaguar* started from a low-fidelity paper prototype, and underwent prototype testing, design and implementation, as well as usability tests. To support our touch-and-go design, we adopt NFC tags, which we can program and deploy to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indicate location information. NFC tags have four types and each type has a different memory size to store data, i.e. type 1 (96 Bytes), type 2 (48 Bytes, can extend to 2 KB), type 3 (2 KB) and type 4 (up to 23 KB).

Custom map creation utilizes KML (key-hole markup language) which is an XML notation to express geographic annotation and visualization within maps [11, 12]. Our Android mobile application uses the KML file to recreate the map on the user's phone and generate directions between starting and ending locations. Our initial testing included deploying NFC tags across the WIT campus, generating a custom map of the campus using the map authoring tool, and finally using the *Jaguar* mobile application to navigate successfully.

## ALGORITHM

One research question for this project is:

*How would we define an optimized path between two locations (vertices) on any given map? The map may be either within a building or across buildings.*

### *Pre-KML creation phase:*

- Create $n$ nodes by clicking on any given map
- Define $(x, y)$ coordinate of each vertex (this is done automatically by Google Maps)
- Determine the weight of each edge (calculated automatically at runtime)

Note that the node defined here will be the location of an NFC tag, which will be programmed to encode its location information.

### *Path finding phase:*

The main idea of the algorithm is to divide the whole space of $\mathbb{R}^2$ into smaller subspaces until the ending node is reached. After each iteration, a new source node is utilized.

Given a subspace $A$ in $\mathbb{R}^2$ containing $N = \{v_1, \dots, v_n\}$, where $n$ is the number of nodes on the graph. The optimized path is considered as $\{\delta \rightarrow \beta \mid \delta, \beta \in N\}$, where $\delta$ is the start node and $\beta$ is the destination node. Each node is defined as a Cartesian point containing $x$ and $y$ components. The pseudo code to find an optimized path is as the following:

1. Initialize $P = \{\}$, $\delta = (\delta_x, \delta_y)$, $\beta = (\beta_x, \beta_y)$.
2. Create a new subspace $A'$, which is a rectangle. Its width is defined as $|\delta_x - \beta_x| + c$ and the height is defined as $|\delta_y - \beta_y| + c$.
   a. $\{A' \subseteq A \mid \forall v_i \in N, i = 1 \dots n\}$ The nodes contained within $A'$ are in between the $x$ and $y$ components of the two nodes $\delta$ and $\beta$.
   b. $c$ is a constant which can be used to increase / decrease the size of the subspace as needed.
3. Pick a node $\delta' \in A'$ which is chosen to be the node with the closest euclidian distance to $\delta$.
   a. Add $\delta'$ to the set $P$
   b. Repeat the steps 2 to 3 until $\delta' = \beta$.
4. The path constructed in the set P from $\delta$ to $\beta$ is the enumeration of $P$.

## DESIGN AND IMPLEMENTATION

*Jaguar* consists of two subsystems: a web-based map authoring tool used to create a navigable map and a Android mobile application to provide GPS-like navigation.

### *Web-based Authoring Tool*

The Web-based authoring tool was designed to provide an interface for the organizations to create a customized map, in the KML format. This KML file will be downloaded to the user's phone for pathfinding, via the algorithm mentioned in the previous section.


Figure 2: A Web-based authoring tool for the organizations.

### *Android Mobile App*

When opening the Android application, the user can click the NFC Navigation button, the system then prompts the user to tap an NFC tag. When this is done, the appropriate map is downloaded from the server and the user will be given an option to select the destination and start route guidance. The map(s) created by the authoring tool were implemented using the Google Maps API with KML overlays. The KML overlays contain NFC tag locations. These locations are represented as push pins on the map. The system uses Android's TTS (Text-to Speech) functionality to provide spoken directions to the user. This design provides a UX similar to a traditional GPS system (i.e. the directions are spoken out individually).

## CONCLUSION

There are two research questions in this paper: (1) How would we design a flexible and cost efficient navigation system? (2) How to define an optimized path in a mid-scale/indoor environment? In this paper, we proposed a new system, *Jaguar*, to address above questions. There are three main contributions in this paper. First, we developed a web-based map authoring tool to allow the organizations to create a customized KML map for navigation purpose. Second, we designed and implemented a new Android mobile application to use the customized KML map and NFC tags to provide GPS-like navigation support. Third, we proposed a new algorithm to find an optimized path in a mid-scale environment. The initial test of the system shows that it can be used to create a customized map and provide GPS-like navigation for a campus environment. We plan to conduct a user study to get more feedback from the users.

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