Development of an Indoor Positioning and Navigation System using Wi-Fi network and BLE beacons for the Smart Campus: A case study

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1. Introduction

Over 30 000 students attend Wrocław University of Science and Technology (WUST). Multiple scientific meetings and conferences are held there on a regular basis. For numerous visitors and first year students navigating in such a place can be hard and troublesome. Nowadays, thanks to the universal access to mobile devices in everyday life, growing demand for Smart City solutions and the progress of GIS, this type of inconvenience could become non-existent in the near future if the indoor positioning and navigation systems (IPNSs) gain popularity. Potential implementation sites range from shopping malls, through various public buildings, to underground mines. At the WUST, we are currently developing a IPNS of the main building of the Faculty of Geoengineering, Mining and Geology. The aim of this research is to briefly describe the procedure of creating IPNS and highlight the difficulties one could face during the development of such a system..

2. Data model of a building

The first step in the process of creating an indoor positioning and navigation system is to create a structured, topological model of a building. It can be done with various types of typical spatial data, like shapefiles of floor plans, CAD or BIM models, though some specific additional information is needed. Building numerical model must have an integrated topological network for routing and navigation purposes: each part of a model (often called a *cell*), representing e. g. a room, a staircase or a corridor, should include an information about connections to other elements, which in reality consist of doors, stairs or elevators. Moreover, system users need a way to quickly identify and find certain features in a building. A clear and consistent labeling scheme is required in order to implement an effective and user-friendly search tool in the application. Further enrichments of a system can be based around improving those connections through inclusion of data about paths non-traversable for some users (restricted areas, handicapped-unfriendly routes) or adding multimodal network connections (e. g. to local public transport network). Those additions would allow for a better user experience for human-targeted application, but for an IPNS designed for robotic applications, they would be a vital part of a properly functioning, robust system.

Currently, there are few solutions which cater for IPNS building model creation. Open Geospatial Consortium (OGC) promotes their standard based on Geographical Markup Language (GML), IndoorGML. It was thoroughly described by Li *et al.* (2019). Notable open-source software has been developed by STEM lab of Pusan National University: JINeditor, which provides simple vectorization tools for creation of IndoorGML model. For our case study, the ArcGIS Indoors software was used for gradual development of a L-1 WUST 3D building model (Lewandowska, 2019), as it provides special toolboxes, allowing semi-automatic feature creation from floor plan data. Fig. 1 shows the stages of model evolution.

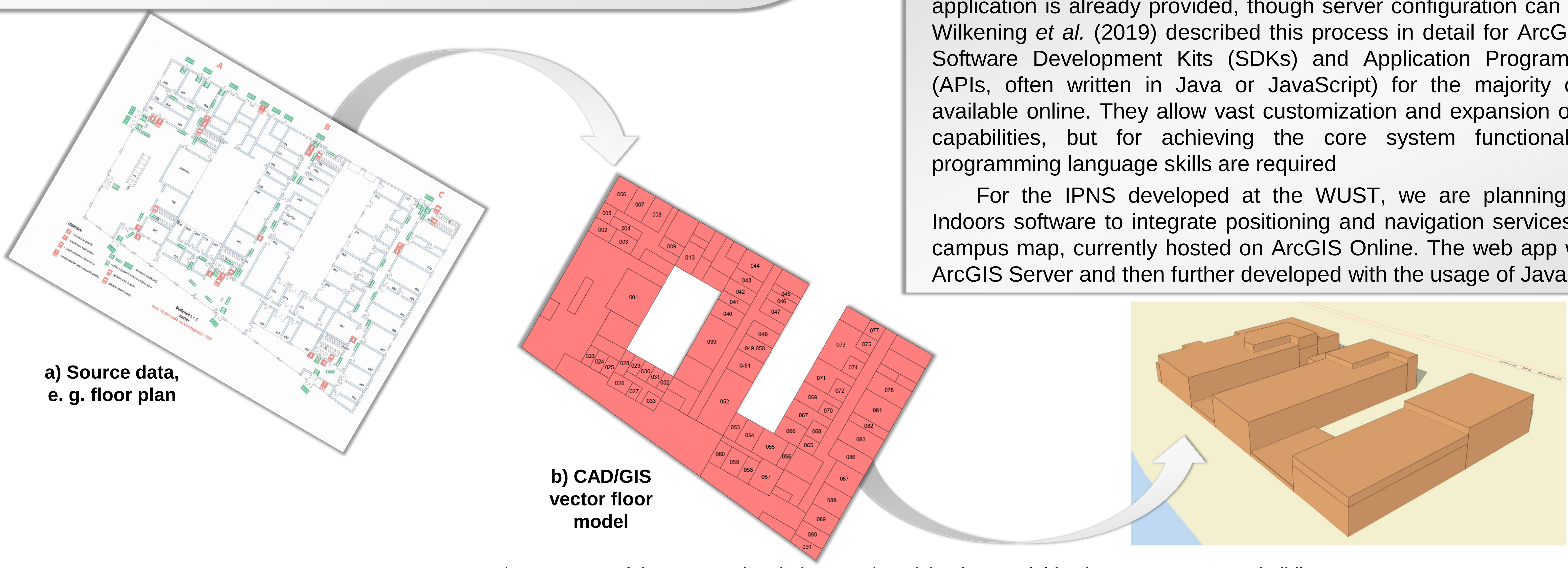

Fig. 1. Stages of data processing during creation of the data model for the IPNS: L-1 WUST building

3. System infrastructure

IPNS also needs a proper positioning infrastructure: a network of radio devices. Wi-Fi Access Points (APs) are often chosen, as they are usually already present in the building to provide Internet access, and their signal can cover relatively broad area, although the positioning accuracy of such a system is rather low. BLE beacons are noticeably less expensive, but their signal is weaker than Wi-Fi. Ultra wideband (UWB) beacons provide the best accuracy and a good range. However, solutions based on UWB cannot directly use mobile device sensors: the user must carry a localization tag, which makes this technology less convenient for human-oriented applications.

At the WUST, we are trying to build a hybrid system through extension of our Wi-Fi network with additional BLE beacons. Currently, there is no such out-of-the-box solution available on the market. Research has been carried out to determine optimal locations for installing the BLE beacons. With the help of WUST IT Department, Wi-Fi APs in the L-1 WUST building were mapped and Received Signal Strength Indication (RSSI) was measured using Acrylic Wi-Fi software and a laptop. The data was then transferred to GIS. Signal strength raster was interpolated with Inverse Distant Weights (IDW) and the raster of APs count in satisfactory range (estimated roughly at about 20 m) were created. Southern and northern corners of the building were chosen as priority sites of BLE beacons installation due to low Wi-Fi network coverage in these areas.

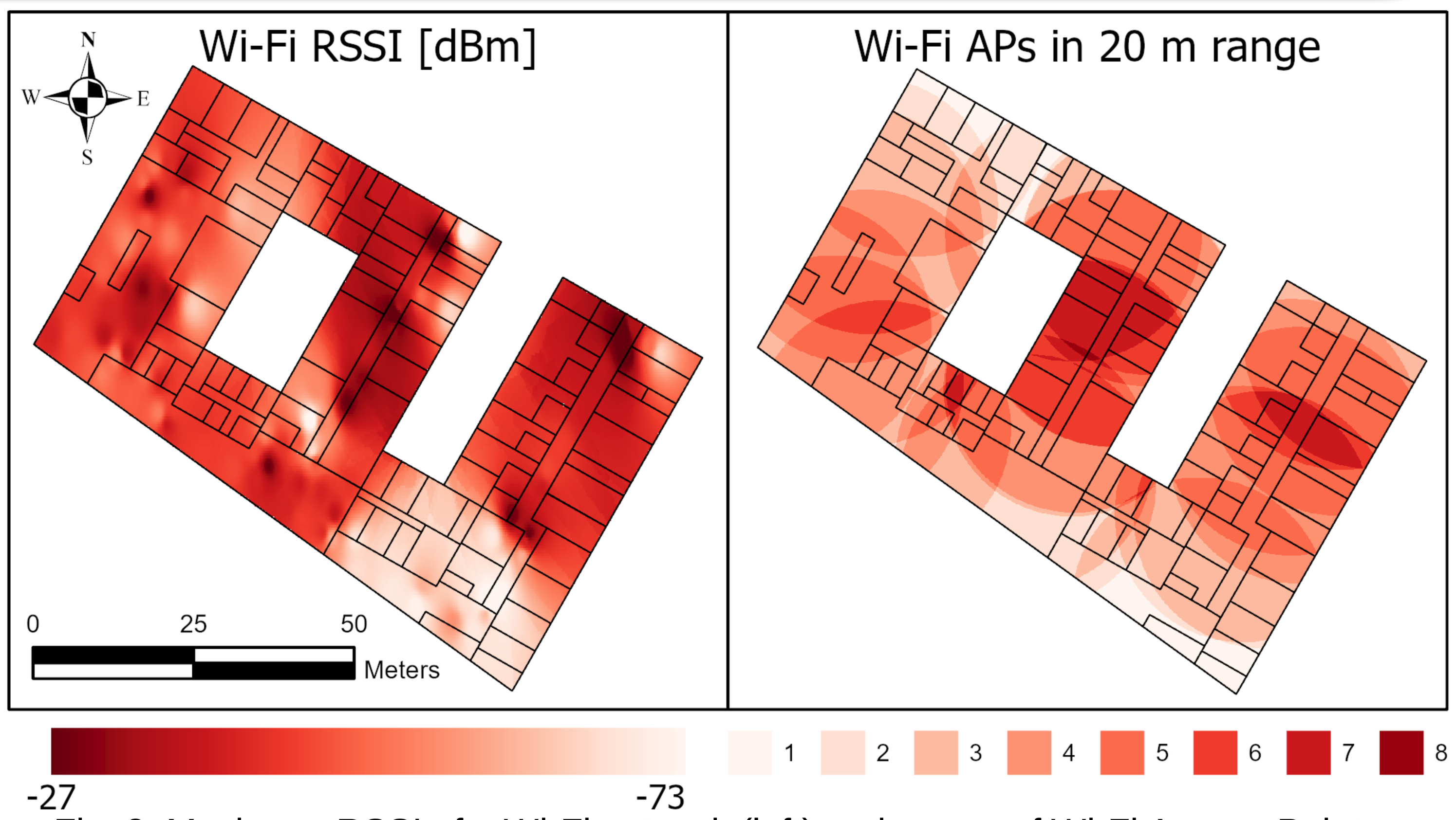

Fig. 2. Maximum RSSI of a Wi-Fi network (left) and numer of Wi-Fi Access Points in 20 m range (right) on the 1st floor of the L-1 WUST building

4. Future works: web application

IPNS is usually based on the server-side calculation service, but for simpler systems calculations can be entirely done in a mobile application or a web app. For most solutions in the market, like ArcGIS Indoors or Indoora, the mobile application is already provided, though server configuration can be troublesome. Wilkening *et al.* (2019) described this process in detail for ArcGIS Indoors. Rich Software Development Kits (SDKs) and Application Programming Interfaces (APIs, often written in Java or JavaScript) for the majority of solutions are available online. They allow vast customization and expansion of the application capabilities, but for achieving the core system functionality, no explicit programming language skills are required

For the IPNS developed at the WUST, we are planning to use ArcGIS Indoors software to integrate positioning and navigation services with our online campus map, currently hosted on ArcGIS Online. The web app will be moved to ArcGIS Server and then further developed with the usage of JavaScript API.

5. References

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