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# Design and Implementation of Geo-visualization of Human Mobility and Building Occupancy on Smart Campus

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**Abstract:**

University campus is a typical and special type of urban settings. Smart campus has been developing drastically based on the technologies and practices of smart cities (Verstaevel et al., 2017). Human movements on campus, which are combinations of regular and irregular itineraries, are mapped into digital trajectories with various positioning technologies. The human movement trajectories can further be used to optimize the design and management of smart campus. The estimated occupancy of buildings or facilities can show the hot spots and cold spots, which can help save energy and optimize space utilization. In this case, geo-visualization technique plays an important and unique role in revealing spatio-temporal patterns of human mobility and utilization of infrastructures (Oppermann and Munzner, 2020). In this work, we design and implement a procedure for generating and visualizing people's spatial trajectories and building occupancy based on anonymised network accessing log data generated by the Wi-Fi networks on campus.

To assist teachers' and students' work and study more efficiently, ubiquitous Wi-Fi networks are now common on university campuses. Wi-Fi network systems continuously record a large amount of accessing data, based on which users' location and moving trajectories can be extracted to a certain degree. Among the many means of trajectory data acquisition technologies, individual positions pinpointed by Wi-Fi networks and users' network access on campus can be acquired efficiently and effectively, which does not need any other instruments. When a user accesses the Wi-Fi network through access points (APs), the network management system normally records basic information, including time, media access control (MAC) address of the user's device, and the name of AP with which the user's device interacts. An AP qualitatively maintains its position by describing the corresponding location in its name, which realizes the attachment to the specific positions of spatial features such as rooms, facilities and corridors to pinpoint where the users are by using proximity measurement (Hightower and Borriello, 2001) and can locate the user to a specific room or facility. Therefore, 3D trajectories of human movement in a time period can be built from the network log data after data cleaning. The counts of online devices in different places can also indicate space occupancies.

To perform geo-visualization of 3D moving trajectory, 3D geospatial data of buildings, roads and other public facilities of the campus is reconstructed using civil engineering drawings and high-resolution remote sensing data. A topological 3D model of buildings, which consists of rooms, floors, corridors, and the information of APs is built. Movements of individuals from one place to another based on network access log data of APs are usually not continuous, and it is common to see outliers when the user is in places with weak Wi-Fi signals or even no Wi-Fi connections. A pre-processing procedure is implemented to connect related positions of an individual's show-ups into a consecutive time series.

Based on 3D trajectories, geo-visualization of individuals' and crowds' movements can provide an interface to explore spatio-temporal patterns of population on campus. Students and faculty members are two typical groups of individuals on campus. They can be grouped into subgroups based on levels and departments. Even finer criteria can be defined based on their behavior on campus. Therefore, interactive geo-visualization at different time scales, such as morning/afternoon/evening sessions, food time, and days of week, is designed and implemented to detect and reveal sub-groups of human crowds. This can also facilitate and validate the results of spatio-temporal clustering algorithms.

To ensure sufficient and economical public services, university management always monitors occupation of campus spaces, including classrooms, canteens, halls, stadiums, students' accommodations, etc. Based on the spatio-temporal clustering of human movements, animated geo-visualization of 3D trajectories in campus spaces at various scales is provided to help managers identify hot/cold spots and conduct corresponding actions.

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Personal privacy protection is an important issue that all kinds of projects with individual trajectory analysis should be cautiously considered. In this work, users' MAC addresses are anonymised by using the MD5 encryption algorithm, which removes the direct connection between the trajectories and users' devices. Furthermore, our database and geo-visualization system are encrypted. Only authorized personnel can access the system through private networks, and data usage is strictly scrutinized.

The Wi-Fi network system provides a way to capture data of moving trajectories and population counting. A geo-visualization platform for studying human mobility and space utilization in smart campus scenarios is designed, and typical functions are implemented. On this platform, users can visually explore human moving trajectories, identify groups of people according to various time and space conditions, and evaluate occupation of infrastructures on campus to support the construction of smart campus.

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