Towards a Hybrid Indoor Positioning and Navigation System

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Abstract—**We propose a Hybrid Indoor Positioning and Navigation System (HIPNS), based on Li-Fi (Light-Fidelity) localization and optical camera positioning analyses deployed in an indoor environment. The localization approach is based on the fuse of two positioning strategies where the camera-based part is responsible for localizing individuals and recovering their trajectories in zones with low coverage of Li-Fi LEDs. A third-party element is planned to operate in the event of loss of contact. Step detection technique and heading estimation are used in a smartphone indoor localization application between two referenced points. The main contribution of this research work focuses on the integration of heterogeneous data, algorithms, and methods from different spheres of application.**

Keywords— Indoor navigation, Li-Fi-based localization, Scene analysis, Data integration.

I. Introduction

The Indoor Positioning Systems (IPS) has been developed using a wide variety of technologies and sensors, or even combining several of them in hybrid systems. The presented work is part of this approach as our indoor guidance system combines low-cost technologies that are simple to implement and operate: Li-Fi lamps and video cameras. Besides, we have chosen to process the positioning data from these sensors via a Web service platform, thus ensuring dynamic contact with the user and considering guidance constraints in real-time. Among all indoor positioning technologies, we will focus on those most often used with a mobile phone, namely Wi-Fi, low-energy Bluetooth (BLE), and inertial sensors. We also present solutions based on the use of light and computer vision.

After a reminder of the possible technologies and the existing hybrid systems, we then detail the architecture of our guidance system, the tests carried out, to finally conclude with the follow-up envisaged to our work.

II. A Hybrid System Model for IPS

The localization methods in an IPS are classified into two groups as noted in [1]: (1) based on distance estimation; and (2) mapping-based localization. In the first group, the distance estimation process employs techniques based on the signal strength and/or the elapsed time between two signals. In our work, we opt for the second group where the mapping-based localization works with pre-stored signals (tags) values in a database.

We apply the mapping localization approach in a Li-Fi based positioning system that uses a signal emitted from a LED (light source) to determine the position of the user's device (receiving device). The user's device, which is equipped with a receptacle (e.g., photodiode-dongle), receives the signal from the LED i.e., its identifier. So, we use the ID as a positioning tag associated with a LED lamp installed in a known location, both data stored in a database.

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We also use a vision-based positioning system to estimate the position and the orientation of a person indoor by identifying an image that is within a view. In [2] authors note that the commonly used methods for image-based indoor positioning are focused on calculating the Euclidean distance between the feature points of an image.

For smartphone-based indoor localization as a compliment, we opt for a Pedestrian Dead Reckoning (PDR) technique to give the position of a mobile user relative to a reference, as presented in [3]. We use the step detection technique (accelerometer) and heading estimation (gyroscope) to reassure the guided person between two identified positions in case of contact losses from other technics.

In this research and development project, we opt for a hybrid IPS system based on Li-Fi technology with path positioning from optical cameras placed in shadow zones to compensate for each other's shortcomings and take advantage of each other's strengths.

III. Implementation and Evaluation

In the proposed system model, the source of data dissemination is a Li-Fi lamp and a processed image from an OC, whereas the source data collection is a user device with a photoreceptor. The collected data are analyzed and processed, and the localization is performed via a Web service. When the user passes under a LED his smartphone can receive the tag associated with this LED lamp. Its path is followed by an optical camera to confirm the user's position. An alert message will be sent in case of remoteness from the prescribed path or in case of unexpected barriers. A reconfigured path will be then sent to the user.

A graph-path algorithm determines all intermediary points to be followed to guide the user to the destination. These intermediary points represent the graph-vertices where the Li-Fi lamps are positioned.

The data integration of the camera and the Li-Fi lamps is done through the Web service installed on a Node.js server running on a Raspberry pi 4. The reference points identified by the camera for the guided person are stored in the database. When the user passes through a Li-Fi point, the retrieved coordinates are compared with those transmitted by the camera. In case of differences, the coordinates confirmed by the position of the Li-Fi lamp are considered for the user's guidance.

IV. Conclusion

In this article, we present a hybrid IPS system based on the integration of data from heterogeneous sources: i.e. Li-Fi tags to determine the positioning of a user on a floorplan; trajectory tracking of the user by optical cameras; step counting by a smartphone application supposed to guide the user between two reference points and in case of loss of cameras tracking due to congestion, smoke or other disruptive events.

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