StairMap: Automated Accessibility Mapping via Delivery Workers' Body Camera Analysis

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1. Introduction

1.1. Background

Ensuring unrestricted mobility access for people with disabilities in modern urban environments remains a crucial social challenge. Particularly, architectural barriers such as stairs—from building entrances to interior commercial spaces like restaurants and cafes—pose significant obstacles for wheelchair users and elderly individuals. This issue has become increasingly pressing in South Korea, where the population of mobility-impaired individuals reached 15.51 million as of 2021. According to a recent survey [1] conducted by a South Korean non-profit startup whose mission is to provide accessibility information to people with mobility disabilities, accessibility (69%) is the primary concern for people with disabilities when choosing venues, with uncertainty about accessibility information (54%) being cited as their most significant challenge before visiting locations.

1.2. Problem Statement

Currently, mobility-impaired individuals primarily rely on blog reviews and street view data for accessibility information. However, these sources often contain outdated information and are limited to exterior building views and interior store images. Crucially, they fail to provide essential information about indoor pathways, such as the presence of stairs or obstacles between building entrances and store locations. While volunteer organizations attempt to address this gap by physically surveying and documenting these locations, the sheer scale of the task—with over 120,000 restaurants and cafes in Seoul alone [2] —makes manual data collection and regular updates impractical and unsustainable.

1.3. Proposed Solution

In addressing this challenge, we identified a unique opportunity leveraging existing infrastructure: approximately 80% of food service establishments utilize delivery services, [3] and many delivery workers use body cameras for personal safety during their deliveries. These body camera recordings contain valuable visual data of pathways from building entrances to store locations. We propose a computer vision system that automatically analyzes these video recordings to extract and update accessibility-related information, such as the presence and number of stairs and other mobility-relevant features. This approach is expected to present several advantages: (i) Automated data collection through existing delivery infrastructure. (ii) Frequent updates through continuous video feeds. (iii) Comprehensive coverage of indoor pathways typically invisible to traditional solution. (iv) Scalable solution for the vast number of commercial establishments.

In this paper, we present a computer vision system that automates the collection and maintenance of accessibility information by analyzing delivery workers' body camera footage. Our approach aims to improve how urban mobility information can be efficiently collected and maintained at scale.

2. Related Works

2.1. Line Extraction Methods

Traditional Approaches. Traditional computer vision methods for line extraction rely on edge detection algorithms such as Canny, Sobel, and line detection techniques like the Hough Transform [4–6]. These methods are used to extract stair features, which are then matched for detection. For instance, [7] identifies stair endpoints as three line segments converging at a point, while [8] considers parallel edges aligned from bottom to top, using an SVM for classification. [9] models stair structures as a periodic signal, with the distance between edges representing the period, and applies 2D FFT to isolate stair edges. Additionally, [10] utilizes a unique geometric feature of decreasing step height, and [11] leverages statistical properties of projection histograms for stair detection.

Machine Learning Approaches. Wang and Wang [12] proposed a 2D staircase detection algorithm using Real AdaBoost. They incorporated both traditional Haar-like features and PCA-based Haar-like features to train a cascaded classifier. This approach significantly improves early-stage false-positive rejection and is optimized for real-time processing, focusing on both detection accuracy and speed.

Deep Learning Approaches. Deep learning-based methods for stair detection are relatively limited. Typically, these methods employ object detection algorithms like YOLO [13] or RCNN [14] to extract regions of interest (ROIs) containing stairs, followed by traditional line extraction techniques [15, 16]. This two-stage process presents challenges for real-time performance. Some methods use deep learning classifiers to determine stair presence and classify direction (upstairs/downstairs) [17].

2.2. Plane Extraction Methods

Plane extraction methods primarily focus on extracting potential planes from input point clouds and filtering those corresponding to stair structures. Point cloud segmentation is commonly used for this purpose, with approaches often classifying planes based on their normal vectors to eliminate irrelevant ones [18, 19]. [20] introduces an algorithm for stair detection using a minimal 3D map representation and adjacency-based feature grouping to identify dominant stair structures. Supervoxel clustering is utilized in [21] for stair plane extraction, while [22] applies RANSAC to extract and model stair planes. Another approach [23] analyzes point clouds to detect consecutive rising planes as stair features.

3. Experiments

Under the Experiments section, we will conduct experiments using the following methods.

3.1. Computer Vision (CV) Methods

Our first set of experiments will involve traditional computer vision techniques, building on the methods discussed in previous works. We will apply edge detection algorithms such as Canny and Sobel, alongside the Hough Transform [4-6], to detect linear features that characterize staircases. The goal is to extract features like parallel lines and edges.

3.2. Pattern and Classifier-based Stair Detection (Machine Learning)

Another set of experiments will focus on a machine learning-based approach for staircase detection, combining visual pattern recognition and classification techniques. The foundation of this method will be based on Haar-like features and Real AdaBoost [24], as described in the study on 2D staircase detection [12].

3.3. Pre-trained Models and Deep Learning

In the third phase, we will leverage pre-trained models based on object detection architectures like YOLO [13] or RCNN [14] to identify regions of interest (ROIs) containing staircases. These models are trained on large, publicly available datasets and are capable of detecting stair features in real-time.

3.4. Dataset

We plan to use the StairNet dataset [25], which consists of approximately 510,000 images for staircase detection. This dataset is designed for robotic leg control and includes labeled data indicating whether a staircase is present, as well as how flat ground and staircases are combined in various configurations.

For the actual demo test, we will use continuous images extracted from videos that we capture ourselves.

3.5. Success Criteria for Stair Detection

The success of the stair detection system will be measured based on various conditions, as determined by the following criteria. (i) The main evaluation metric for the experiments will be the stair detection rate, assessing the system's ability to accurately identify staircases under various conditions (ii) Detection of the presence of stairs in the video (sequence of images) (iii) The number of correctly detected stairs compared to the actual number of stairs (iv) Detection of the height and length of the stairs

3.6. Anticipated Challenges

Due to the limitations of computer vision technology, various challenges are expected. (i) Low-light environments: Staircase detection may be unreliable in poorly lit areas, and traditional edge detection methods may not work effectively. (ii) Shaky footage: Movement-induced blur from body camera footage could reduce detection accuracy. (iii) AI upscaling for low-resolution images: Testing AI-based upscaling for poor-quality images could improve the accuracy of feature extraction by enhancing image resolution. (iv) Dynamic vs. Static environments: It will be essential to compare the system's performance in dynamic (body camera) footage versus static images, as dynamic environments may introduce challenges such as motion blur or inconsistent lighting conditions.

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