Chapter 1

Research Description

This chapter starts with a background on urban studies, specifically on the topic of accessibility for pedestrians. Then we discuss the current state of technology in relation to measuring and urban accessibility followed by our research objectives, scope and limitations, and the significance of our research.

1.1 Background of the Study

A city's urban design is responsible for shaping it's character through the arrangement of infrastructure, transportation systems, and public areas (*European Urban Knowledge Network*, 2012). Through urban design, a city becomes functional for its inhabitants through the network of streets, sidewalks, and roads that improve urban accessibility. However, majority of cities have been designed to favor vehicles rather than inhabitants. The amount of road construction and widening projects annually, which often leads to narrower sidewalks, is proof of this bias. These projects further incentive the use of vehicles as the primary mode of transportation within a city at the cost of the wellbeing of its inhabitants (Wen, Kenworthy, Guo, & Marinova, 2019). Because of this, traffic congestion has become one of the largest factors that affect a city's accessibility. The impact of traffic congestion on a city's accessibility has led urban designers to further look into urban accessibility.

Urban accessibility is the convenience that pathways provide to both able pedestrians and people with disabilities (PWDs) when traversing an urban physical setting (Shahraki, 2020). Among the goals of good urban accessibility is to design public spaces to be accessible, safe, and easy to use for PWDs. Streets that are designed for PWDs are streets that are accessible to all. Cities like Barcelona provide wheelchair friendly tourist spots, public spaces, public transportation, and overall flat street architecture. These features in a city help alleviate the accessibility issues that PWDs experience when they are moving around the city. Unfortunately, some cities around the world have not yet adapted their design to suit PWDs. This can be due to the lack of data that cities have when it comes to mapping out accessibility issues around the city. Barcelona's open data service has been the catalyst in driving the adaptation of the city to provide a comfortable and accessible experience for all types of individuals. The open data service provides different maps on urban qualities found in a city such as noise maps, air quality maps, and accessibility maps. Data on the accessibility of a city provides information on which parts of the city are inaccessible by analyzing the quality and availability of structures built to improve accessibility such as curb ramps, tactile pavement, or wide sidewalk widths. Accessibility data can be collected through different means such as manual inspection, annotation of accessible structures, and remote sensing.

Remote sensing is a type of geospatial technology that provides information about objects at the surface of the Earth based on their reflected or emitted radiation. This technology makes it possible to monitor the physical characteristics of an area without having to be physically present at the location (OmniSci, n.d.). Remote sensing can be used to provide an important and accurate source of spatial data to replace manual, slower, and more costly methods of data collection conducted by human interpreters on the ground. The information obtained from remote-sensing instruments comes in images that are still considered to be in a raw form of unstructured data. These images are interpreted by computers as rows and columns of pixel information, but applying artificial intelligence and machine learning models allow for further extraction that can transform the unstructured data to geospatial information products. Some applications of these include precision agriculture, change detection, target detection, and asset management (Esri, 2020).

The application of machine learning on remote sensing produces a workflow or an approach where in the model has the ability to learn without the help of human interpreters. Algorithms have been created to learn from either labeled or unlabeled datasets where the machine tries to make sense from extracting features and patterns on its own, and evaluating the accuracy of the training data. On the other hand, it is also possible for human-machine collaboration to be implemented in the workflow model compared to the algorithm working without the help of human interpreters. This hybrid, or human-guided, methodology allows for rich feedback from the human labelers to guide and fine-tune the model, correcting its predictions and labels to improve how the model responds to the data. This bidirectional feedback loop between the human interpreter and the algorithm works much more efficiently than traditional workflows (Robinson et al., 2020).

With remote sensing producing vast amounts of geographical data, it can be used widely in a whole range of urban planning processes. The accessibility and mobility of urban streets can be identified with the help of human labelers or even object detection algorithms. Related studies have used different workflow models to assess the accessibility of an area. Project Sidewalk, a web-based crowdsourcing tool for collecting sidewalk accessibility data, makes use of Amazon Mechanical Turks and online crowdworkers to remotely label pedestrian related accessibility problems (Saha et al., 2019). Their workflow followed a traditional approach of using human interpreters to manually put a label on sidewalk images that contain curb ramps, missing curb ramps, obstacles, and surface problems.

On the other hand, the possibility of assessing an area only through the use of algorithms have been conducted by Naik et al. (2016), which aimed to discover a relationship between the physical appearance of cities and the socioeconomic status and safety of its inhabitants by quantifying street view images through a computer vision algorithm. Their methodology included a dataset of images from Google Street View, and an algorithm that was trained to rank an area by giving it a score of 1 to 10 based on their perceived safety.

Lastly, research on hybrid methodology have also been conducted by Hara, Sun, Moore, Jacobs, and Froehlich (2014) on their web application called "Tohme", which is a custom-designed tool to remotely collect geo-located curb ramp information using a combination of crowdsourcing, computer vision, machine learning, and online map data. Tohme has a feature called "svVerify", which is a human-powered Google Street View Label Verification approach that relies on crowd workers to examine and verify the correctness of previously entered labels before they are fed into the pipeline. This approach of reliance in human verification helps the algorithm in reducing the percentage of its false negatives, yielding to results that are much more efficient.

Among the three types of remote sensing technology that were mentioned, namely traditional, artificial intelligence, and hybrid, we believe that the hybrid approach in remote sensing is the most optimal among the different approaches. This is because it provides a feedback loop between the person and the model that allows for continuous verification of data for re-training of the model. However, there are still challenges in existing hybrid approach tools used for evaluating sidewalk accessibility. "Tohme", for example, only detects the presence of curb ramps in sidewalks as its metric for accessibility. It focuses mostly on how friendly the streets are for wheelchair users and persons with disabilities. Based on our research, accessibility is more than just curb ramps as we also have to consider the uniqueness of sidewalk characteristics of different countries.

In this study, we will be addressing the research gaps in existing hybrid approach tools by considering more factors that affect sidewalk accessibility. Our metric will include the design of the sidewalk, the sidewalk's surface texture, the placement of the sidewalk, and obstructions blocking the sidewalk. In the Philippines, we also currently have a scarcity of convenient means to collect and access street data for urban planning use. Given this, we plan to improve the collection of sidewalk data in order to map accessibility problems in the Philippines.

1.2 Research Objectives

1.2.1 General Objective

The main objective of this research is to map and assess street-level accessibility of urban roads.

1.2.2 Specific Objectives

1. To identify sidewalks and their characteristics from street-level images
2. To develop a hybrid-assisted annotation tool for identifying objects situated on sidewalks from street-level images
3. To model the accessibility of sidewalks on urban roads

1.3 Scope and Limitations of the Research

Accessibility is the convenience (or lack thereof) which sidewalks provide to both common pedestrians and people with disabilities (PWD's). We define the accessibility model based on sidewalk characteristics that can be visually observed from a street-level image. Further research will be done into the field of urban planning and sidewalk design to identify common indicators of quality sidewalk accessibility issues, specifically issues common to the streets of the Philippines. For the purpose of our research, we will limit the definition of sidewalk accessibility issues to pedestrian problems that can be visually identified on Google Street View. Objects that contribute to sidewalk accessibility issues that can be visually identified on Google Street View will be labeled with a bounding box and its name.

In terms of geographic limitations, we will focus only on selected cities from Metro Manila given the time frame of our research. We will first prioritize certain areas in the cities of Manila, Makati, and Taguig. These cities were selected as they contain business districts, school campuses, and locations in which people usually walk, thus the importance of having a proper sidewalk structure and accessibility. Moreover, these cities also contain some locations with the most ideal sidewalk accessibility (see Figure 1.1), together with locations that have the worst sidewalk accessibility (see Figure 1.2). Our metric for evaluating sidewalk accessibility includes the design of the sidewalk, the sidewalk's surface texture, the placement of the sidewalk, and obstructions blocking the sidewalk. All of these four are further discussed in Chapter 3 of our document.

Figure 1.1: Google Street View image of a corner intersection at Bonifacio Global City, Taguig

Figure 1.2: Google Street View image of an area along Taft Avenue, Manila

In creating our accessibility model, we will be using off-the-shelf models for object detection and semantic segmentation. For object detection, we will use YOLOv5 to automatically annotate and label sidewalk accessibility issues. For semantic segmentation, OCR (ResNet-101) will be used to separate sidewalks from a Google Street View (GSV) image. In the context of this research, a sidewalk is defined as a paved path for pedestrians on the side of a road in an urban setting. With the sidewalk identified, the model would be able to limit its annotations to only objects that are seen in the sidewalk. The purpose of isolating the sidewalk from an image is to prevent our YOLOv5 from detecting instances of objects that are not on the sidewalk. To give context, parked vehicles on sidewalks such as cars, motorcycles, and pedicabs are deemed as objects that affect how easily accessible the sidewalk is to a pedestrian walking on the street. With this, we want to train our YOLOv5 model to detect these vehicles. However, we have to detect instances of these vehicles only when they are parked on the sidewalk and not when located on the road itself, thus the purpose of using a semantic segmentation model together with an object detection model.

Additionally, since we will limit our scope to selected cities from Metro Manila, there might be lesser instances that some objects will appear in our dataset which affects the number of samples needed to train for YOLOv5 to detect those objects. These might include construction materials, curb ramps, street vendor stands, and other objects that might have appeared more in our dataset had we included other cities of Metro Manila. But as mentioned previously, we need to limit our scope to specific areas given our time frame. With this, we plan to utilize our crowdsourcing tool to manually label those objects instead. On the other hand, objects in our dataset with enough samples from the COCO Dataset will be included in the automatic detection of our YOLOv5 model.

1.4 Significance of the Research

The outcomes to be presented by this research would hopefully pave the way for data collection in the field of urban planning. As a country with a densely populated capital, the Philippines must rely on quality urban planning to increase the quality of life of its inhabitants, and having access to sidewalk data with common accessibility issues is the best way for planners to identify mistakes from previous development projects. For this reason, one contribution we aim to make is to broaden any existing datasets of sidewalks which can be used for the interpretation of accessibility. In the specific field of sidewalk object detection, we aim to contribute by expanding the list of objects to be detected and assessed by YOLOv5. We plan to detect objects that may only appear specifically on the sidewalks of the Philippines, so that we may have a better way to evaluate the accessibility of our streets.

In the long run, the main benefactors of our research can be divided into pedestrians, future researchers, and city planning agencies. Opportunities for further research on the topic would have an easier time in sidewalk data collection because of the automated CV model. Not only will this model make it easier for current researchers on the topic, but the automated factor of it would entice more researchers to look into the field of sidewalk planning. One can also interpret the expanded dataset to determine security and other accessibility issues that exist within a local municipality. This research would benefit pedestrians and persons with disabilities who are the most affected groups of inaccessible sidewalks by encouraging policy-makers and development project leads to improve the quality of sidewalks throughout the country.