Enabling Pedestrian-related Traffic Studies through a Realistic Pedestrian Simulation Module in LocalSim

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Abstract: Pedestrian safety and behavior are integral components of comprehensive traffic studies. This necessitates advanced tools to better understand their role in the intricate web of local road traffic. This paper establishes a system architecture for a pedestrian module into LocalSim, a local traffic simulator, integrating it with the simulator's existing behavioral features for Filipino drivers. Through this approach, our project aspires to create a dynamic and realistic platform for simulating authentic local road traffic scenarios that include the pedestrians in the picture. A demonstration of the module using a four-leg intersection traffic shows how allelomimesis or mimicry of pedestrian movement results in herding. Pedestrian metrics such as travel times and waiting times at a crosswalk increase with increasing arrival rate of pedestrians in the system. With these metrics, the platform will serve as a crucial testing ground for evaluating the efficacy of various traffic policies and interventions, with a particular focus on enhancing the safety and mobility of pedestrians while ensuring the smooth flow of traffic for all road users.

Keywords: Pedestrians, Microscopic Traffic Simulation, Performance Metrics

1. INTRODUCTION

Traffic studies have long been a critical field of research, essential for ensuring the safe and efficient movement of people and goods within urban environments. They are pivotal for urban planning and management, addressing the multifaceted challenges of congestion, safety, and environmental impact. While much attention has historically been focused on vehicular traffic, pedestrians represent a crucial and often vulnerable component of the urban transportation landscape. In the Philippines, walking is still considered as an indispensable part of travelling [1], as significant number of Filipinos walk as part of their first and last mile journeys. Understanding how pedestrians navigate the complex environment of roadways, sidewalks, and intersections is essential for devising effective traffic policies and infrastructure improvements [2].

Meanwhile, simulation tools have become indispensable in traffic research, enabling researchers to experiment with various scenarios without real-world consequences. Recently, a Filipino traffic simulator, LocalSim, was developed, through government funding, to enable local traffic simulation especially with behavioral characteristics of Filipino drivers [3]. However, the simulator currently lacks the ability to simulate pedestrian mobility within the simulated traffic environment, hindering our ability to comprehensively study the dynamics of local road traffic.

To bridge this gap, this project focuses on the redesign of the existing pedestrian module in LocalSim. Although there have been pedestrian modeling softwares that are commercially available such as Vissim and Viswalk, aside from them being costly, often their focus is on environments such as human walkways where pedestrians are at the foreground, as opposed to being part of road systems [4]. We seek to include features that allow realistic pedestrian scenarios. The goal is to create a unified platform that not only simulates the movements of local drivers but also incorporates the intricate decisions and actions of pedestrians. This integration paves the way for the emulation of authentic local road traffic scenarios. Researchers can explore a wide range of situations to gain a deeper understanding of pedestrian mobility patterns and their impact on traffic flow. This platform serves as a powerful tool for evaluating the effectiveness of traffic policies and interventions, ultimately aiming to enhance road safety, mobility, and efficiency for all stakeholders.

2. LOCALSIM

LocalSim is a traffic simulation software that was developed to simulate the traffic environment in a Philippine setting, aimed to support the traffic management of local government units (LGUs). Currently, it can simulate accurate, realistic Filipino traffic situations, but it is largely focused on vehicular motion. It has a pedestrian module that is based on the standard Social Force Model [5], in which the motion of pedestrians is attributed to internal motivations of the individuals to perform certain actions. Pedestrians spawn and de-spawn at opposite sides of a crosswalk with pedestrian stoplights (Figure 1). Pedestrians cross at green light without conflict with vehicles, i.e., no tendencies of vehicles crashing into pedestrians. However, the crosswalks are lane-segregated to avoid pedestrian-pedestrian conflict so crossing pedestrians do not meet each other.

3. REDESIGN OF THE PEDESTRIAN MODULE

An ideal pedestrian simulation system would consist of (i) sidewalks, which are paved paths where pedestrians can walk through at the side of roads, (ii) crosswalks, which are marked parts of the roads where pedestrians have the right of way to cross with stoplights to regulate these pedestrian crossings (iii) spawning points where pedestrian could come from, and (iv) destination points where pedestrians are headed towards. The Social Force Model effectively encapsulates realistic pedestrian movement; apart from internal motivations (internal forces), influence of infrastructures and other pedestrians are modelled as external forces. However, the model parameters become high-dimensional and are difficult to fine-tune with real world observations. We propose a hybrid pedestrian model that uses the tendency of some pedestrians to copy other pedestrians, a phenomenon known as allelomimesis [6], which has been shown to be a generic mechanism that leads to clustering, herding and pattern formation [7].

3.1 Sidewalks and Crosswalks

Sidewalks are paved paths where pedestrians walk at the side of vehicular roads. They are mostly where spawning points are located such as unloading points for public utility vehicles. Sidewalks along with crosswalks Implementing this in LocalSim, the sidewalks were essentially extensions of already existing pedestrian links. However, conflict management was removed from these links to allow more pedestrian - pedestrian interactions.

On the other hand, crosswalks are marked parts of vehicular roads where pedestrians can cross. Crosswalks can either be signalized or unsignalized. In the case of signalized crosswalks, pedestrian stoplights and vehicular stoplights should be synchronized to allow pedestrians to cross at green light (red light for vehicles). The current pedestrian module of LocalSim was modified, removing lane-segregation at crosswalks, again, to allow more pedestrian - pedestrian interactions.

3.2 Spawning and Destination Points, Arrival Process and Routing

Spawning points act as entry points of pedestrians where they appear in the simulation. These objects represent real-life structures (e.g. buildings or malls) and passenger deloading points of public utility vehicles. Destination points, on the other hand, are the locations where the pedestrians are headed to such as entrance to buildings, malls or subways. They function as exit-points for pedestrians to de-spawn from the simulation. Spawning and destination points are usually found on the edges of sidewalks although they can also be found anywhere in the middle such as in the case of subway entrances and exits or footbridge stairs (Figure 2). Technically, a spawning point may also be a destination point as in the case of loading and unloading points of public utility vehicles. However, for clarity, this case is implemented as two points placed alongside each other.

Spawning and destination points are implemented in LocalSim by identifying their locations along the sidewalks. Pedestrians arrive at spawning points according to a Poisson process with average arrival rate, λ pedestrians per time interval**.** This can be set via a graphical user interface (GUI). By default, pedestrians will have a destination and a route at spawn point. The route is determined by Breadth First Search algorithm that outputs the shortest path from spawn point to destination point, including the edges of crosswalks if the pedestrian must cross towards their destination. Pedestrians that are within some tolerance to their destination points are de-spawned from the simulation.

3.3 Pedestrian Model

LocalSim implements the Social Force Model with a driving force towards the destination point, repulsive forces from nearby pedestrians, infrastructures such as stoplights, and the edges of the sidewalk they are on. Driving force is computed using the inverse of the pedestrian's relaxation time multiplied to its desired speed. A pedestrian's relaxation time is the factor that takes into account how much time it takes in order to completely reach the desired velocity of that pedestrian. The values of these parameters are arbitrary and can be set via a GUI. The deceleration of the pedestrians accounts how much they should slow down approaching an infrastructure or other pedestrians given a required space. These forces comprise the standard Social Force Model that are added together in order to get the resultant force at each time step to determine the next position and velocity of a pedestrian.

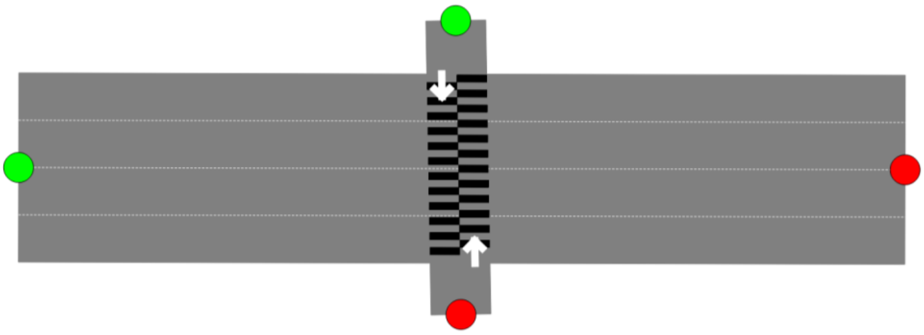

Figure 1. Current status of the LocalSim's pedestrian module. Pedestrians spawn and despawn at the opposite sides of the road and cross at green lights without conflict.

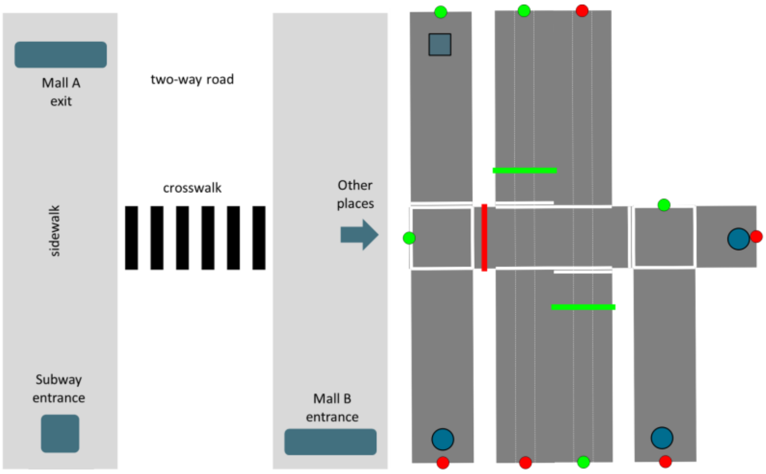

Figure 2. Abstraction of sidewalks, crosswalk, spawning and destination points (left) and its implementation in LocalSim (right). Spawning points are marked as blue squares while destination points are marked as blue circles.

However, group cohesion has not been implemented in the current version of LocalSim. As mentioned earlier, makes the model parameters high-dimensional and difficult to fine tune with actual observations. Moreover, the pedestrian model assumes that pedestrians know their precise destination at spawn point. This may not be the case for some pedestrians. Thence, we propose that pedestrian may be allelomimetic with probability ρ. If allelomimettic, the pedestrian first looks if there are any pedestrians to copy within their field of vision. If there are none, the pedestrian walks slowly as if to mimic those who are uncertain of where to go. Otherwise, the pedestrian follows another pedestrian by copying the direction of their movement, factoring in the speed as to not overtake them. In case the pedestrian actually wrongly followed another pedestrian, i.e. de-spawned, they revert back to having slow speed and look for a new pedestrian to follow. See Figure 3 for a schematic diagram. Note that when a pedestrian is allelomimetic, it may follow other allelomimetic pedestrians who may unknowingly follow another allelomimetic pedestrian.

3.4 Pedestrian Metrics

In an effort to make LocalSim a more useful tool for future traffic engineers and LGUs to design pedestrian - forward cities, we implemented some pedestrian metrics that may aid in policy formation and design of pedestrian – related traffic infrastructures.

- **Pedestrian occupancy level or density** is the number of pedestrians per square meter at any given time. This metric measures the average number of pedestrians across sidewalks per time step throughout the simulation divided by the total area of the sidewalks.
- **Pedestrian travel time** measures the average time that the pedestrians take in order to reach their destination points from their respective spawning points.
- **Pedestrian waiting time at a stoplight** measures the average amount of time the pedestrians must wait at a given red time cycle in a signalized crosswalk.
- **Pedestrian accumulation rate** measures the average number of pedestrians waiting at a given red time cycle.
- **Pedestrian crossing time** measures how long the pedestrians take to cross a given pedestrian link at green time.

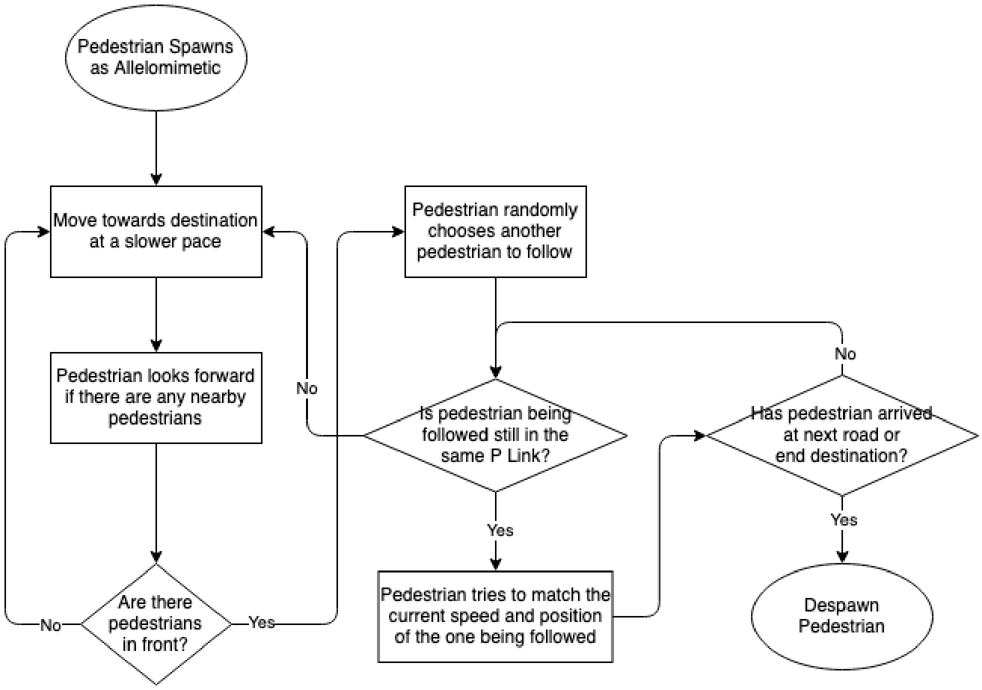

Figure 3. Schematic diagram for allelomimetic pedestrians.

3.5 Pedestrian Simulation in LocalSim

The following is a sequence of tasks needed to perform pedestrian simulation in LocalSim:

1. Create a vehicular traffic environment.
2. Create pedestrian walkways (sidewalks and crosswalks).
3. Locate spawning and despawning points along sidewalks.
4. Input pedestrian parameters for each spawning point: average arrival rate, allelomimetic tendency.
5. Identify pedestrian metrics to be recorded.
6. Input simulation time.
7. Run simulation.

4. RESULTS AND DISCUSSION

To demonstrate the capability of the redesigned pedestrian module of LocalSim, we simulated signalized pedestrian crossings through a signalized four-legged two-way intersection. Figure 4 shows sidewalks at the lateral sides of the four legs of the intersections. Two spawning and three destination points were located at the edges of these sidewalks. Pedestrian stoplights at the edges of pedestrian crosswalks are synchronized with the signalization of the vehicular traffic. At spawn point, pedestrians, shown as small green circles, were assigned random destination points. We can observe that pedestrians head towards their respective destination, crossing the appropriate crosswalk at green light. Allelomimetic pedestrians are shown as small purple circles linked to the pedestrians they respectively follow. We can also observe line formation as allelomimetic pedestrians follow other allelomimetic pedestrians. This indeed demonstrates the ability of allelomimesis as a mechanism to form herds and other patterns as observed in actual scenarios [8-10].

We can observe in the simulation snapshot in Figure 3 how pedestrians accumulate at red light at the edge of a crosswalk and study their average traverse time at green light. This is expected to vary as the average arrival rate of pedestrians at spawning points are varied. To demonstrate this, we simulated three different scenarios: **N**o **C**ongestion (300 pedestrians per hour), **M**oderate **C**ongestion (600 pedestrians per hour), and **H**eavy **C**ongestion (1200 pedestrians per hour) at each spawning point. The population of allelomimetic pedestrians is set at 20%. Fifteen 30-minute simulations were run for each scenario and the averages of the pedestrian metrics were computed.

Reasonable values of pedestrian metrics were found from the simulation as shown in Table 1. The average occupancy levels were 27.657 (2.270) for NC, 73.887 (4.102) for MC, and 197.829 (54.858) for HC cases (figures inside parentheses correspond to the standard deviations from the 15 runs). These values are approximately linear. On the other hand, the average travel time hints nonlinear congestion effects with the following values: 44.584 (0.776) for NC, 49.603 (1.420) for MC, and 65.008 (2.719) for HC.

Table 1. Pedestrian metrics in the simulated four-leg intersection traffic.

Pedestrian Metric	**No Congestion**	**Moderate Congestion**	**Heavy Congestion**
Average Occupancy level	27.657 (2.270)	73.887 (4.102)	197.829 (54.858)
Average Travel Time	44.584 (0.776)	49.603 (1.420)	65.008 (2.719)

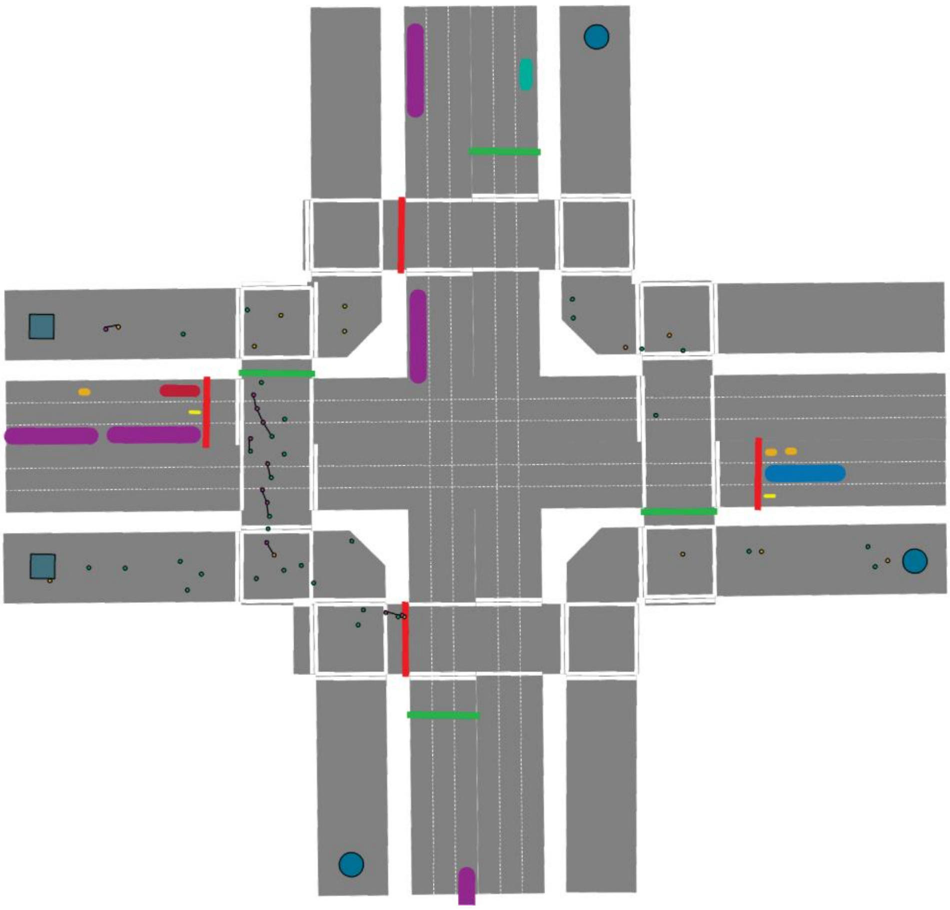

Figure 4. A simulation snapshot of pedestrian mobility in a signalized four-legged two-way intersection using the redesigned pedestrian module in LocalSim.

In situations where there is medium to no congestion, the average wait time of pedestrians before the green light turns on is less than the pedestrian red time of 62 s. This implies that pedestrians wait less than one vehicular stoplight cycle to cross the road. In contrast, wait times during heavy congestion reach more than 62 seconds, which implies that some pedestrians do not get to cross during the pedestrian green time, forcing them to wait for another stoplight cycle to get across. Shown in Figure 5 are the average pedestrian accumulation and their average wait time at the crosswalks. We observed that at PLink 2 (refer to Figure 5), there was an average accumulation of two to four pedestrians each time step in all scenarios, while 11 pedestrians at PLink 4 in the HC scenario. This explains the higher variation in pedestrian traverse times through PLink 4 versus Plink2 across the three scenarios.

The above demonstration is only illustrative of what the redesigned pedestrian module of LocalSim can achieve. Using the computed metrics for a particular traffic system simulated, policies can be made, for example, as to whether all four pedestrian crossings are necessary or not, or how to regulate pedestrian occupancy by identifying optimal locations of spawning and/or destination points such as loading and unloading points of public utility vehicles. This will have implications for the cost of infrastructures needed to be placed for pedestrian and other road stakeholders in the system.

Figure 5. A demonstration of studying pedestrian mobility in a four-legged two-way intersection showing average accumulation of pedestrians at red light and their average traverse time at green light.

5. CONCLUSION

In summary, this paper highlights a redesigned pedestrian simulation module in the LocalSim software that has inherent features of Filipino traffic scenarios. Walkways (sidewalks and crosswalks) are introduced with which pedestrians may now be spawned at identified locations and de-spawned when they get to their respective destinations anywhere within these walkways. The main feature introduced in this project is allelomimesis, which is the tendency of pedestrians to copy the behavior of other pedestrians, that effectively simulates cluster and pattern formations observed in real scenarios. Group motion can also be simulated using allelomimesis in lieu of cohesive forces to be implemented with the Social Force Model. The module also includes calculation of pedestrian metrics such as pedestrian density, travel times, accumulation and wait times at red light, and traverse times at green light. The pedestrian stoplights are also synchronized with vehicular traffic lights in a signalized intersection.

This endeavor aims to generate a wealth of invaluable data, shedding light on pedestrian behavior, congestion patterns, and potential safety risks in local traffic networks. With this knowledge, policymakers and traffic management authorities can develop evidence-based strategies and interventions that could prioritize pedestrian well-being and the interests of all traffic stakeholders. Ultimately, our project seeks to bridge the gap between research and actionable policies, contributing to safer and more inclusive local road environments for everyone.

6. RECOMMENDATIONS

At the moment, the current module is not yet capable of simulating unsignalized crosswalks. This will highly involve pedestrian-vehicle interaction. Another feature that will be implemented next in the module is the risk-taking behavior of pedestrians in the model. Pedestrians with high risk-taking behaviors may cross the road even when the pedestrian stoplight is at red (illegal crossing), or through a part of a road that is not intended for pedestrian crossing (jaywalking). Finally, other features such as obstacles and creative spaces would allow us to observe more complex pedestrian mobility patterns. These features will be beneficial for a comprehensive study of pedestrian safety and regulation [11].

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