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A State of Art on Pedestrian Simulation Model Based on Heuristic Search Algorithm

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ABSTRACT

A pedestrian algorithm has been used across many areas mostly in prediction such as software testing, artificial intelligence and autonomous vehicle predictions and is mostly used to consider the effect of on pedestrians' future motion behaviors. This paper present narrative reviews different heuristic search algorithms for pedestrian prediction in the domains mentioned above. Additionally, this paper explores Heuristic Search Algorithms used in Pedestrian Simulation Models, and how can Heuristic Search Algorithms be Feasible in Spatial Layout Design Elements for Pedestrian Flow. Basic guidelines of conducting narrative review were followed. Articles outside the scope of the paper were excluded. A total 17 peer-reviewed articles from google scholar and research gate databases were identified in the search. 4 articles were included in the final review as they met the inclusion and exclusion criteria. Finally, this paper not only presents a comprehensive overview of heuristic search algorithms in pedestrian simulation models but also underscores the critical role of predictive algorithms in shaping the future of pedestrian dynamics. By identifying research gaps and proposing directions for more effective definition of interacting agents in pedestrian algorithms, this study sets the stage for transformative advancements in heuristic-based pedestrian prediction and spatial design elements.

Keywords: *Pedestrian, Algorithms, Heuristic, Spatial, Layout, Simulation*

INTRODUCTION

The research areas on different domains of computer science such as artificial intelligence, machine learning, sensor cloud and wireless sensor network focus on adopting pedestrian algorithms (Ma, et. al., 2011). The algorithms have been used often with incorporation of heuristic search algorithms. The state of art research on pedestrian algorithm are more focused to handle problems like occlusion, handling challenging cluttered backgrounds (Guo, et. al., 2017). Classifier based pedestrian detection techniques use combination of various feature set and a classifier to search for the presence of pedestrian in images or videos in any of the application domains (Al-Shaery et al., 2022). Many pedestrian models have been proposed that used heuristic search algorithms that include only pedestrian-pedestrian interaction to address the defined challenges in computer science research domains (Maggiolino et al., 2023). Among the papers that include the pedestrian-vehicle interaction in the pedestrian's motion model, a great focus has been put on pedestrian road crossing behavior (Lima et. al., 2021).

Therefore, the focus of this paper is to examine pedestrian simulation model based on heuristic search algorithms. The specific objectives are to:

- Investigate the Heuristic Search Algorithms used in Pedestrian Simulation Models
- Explain the Path-finding Algorithms with localized rules for decisions to model pedestrian

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- Describe the Importance of microscopic pedestrian behavior models Development

HEURISTIC SEARCH ALGORITHMS USED IN PEDESTRIAN SIMULATION MODEL

This section present category of heuristic search algorithms used in simulation process of pedestrian models

Velocity Obstacle-based Model

The velocity obstacle-based model is an important technique used in pedestrian simulation models that helps predict pedestrian trajectories and avoid collisions. This is a type of Optimal Reciprocal Collision Avoidance (ORCA) model that incorporates a new concept called Pedestrian Velocity Obstacles (PedVO). PedVO is a model for pedestrian crowd simulation that is based on reasoning in velocity space, the model uses velocity obstacles to predict pedestrian trajectories and avoid collisions. The velocity-based model is developed based on the Collision Free Speed (CFS) model, which reflects the direction preferences of the individual moving process. The model can handle obstacles by computing the velocity field first neglecting the presence of the obstacles, then nullifying the velocity field in the obstacle region. The improved reciprocal velocity obstacles (RVO) model with path planning and emotion contagion is a recent development that uses the vertices of the obstacles to construct pedestrian path nodes for planning pedestrian evacuation paths (Kim et. al., 2015). The VO based model lack of realism makes it impossible for the model to simulate complex crowd dynamics realistically which potentially leads to inaccuracies in predicting pedestrian movements (Curtis, 2013). Another issue with the VO based model is when it is compared with data-driven techniques in pedestrian simulation it may not perform well potentially affecting its predictive accuracy and efficiency (Kouskoulis et al, 2018)

The figures below illustrate the velocity obstacle-based model

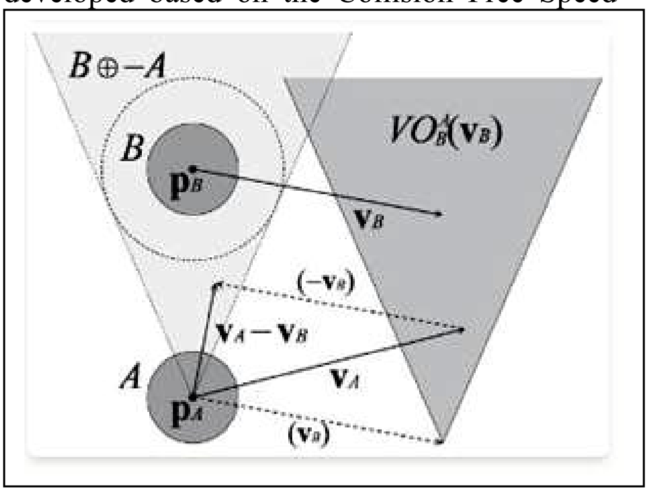

Figure 1: the velocity obstacle VO_B^A (v_B) of a disc-shaped obtsacle B to disc-shaped agent A (Van den berg et al 2008).

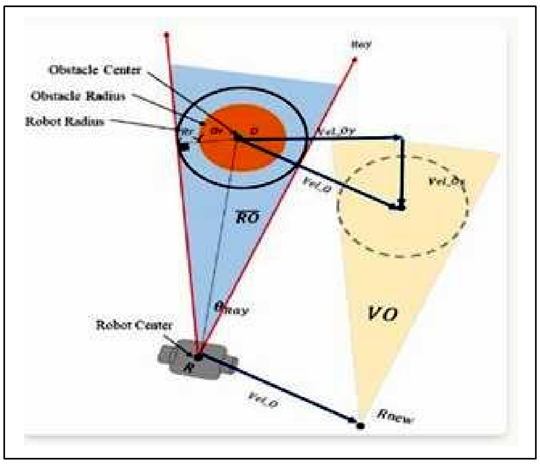

Figure 2: Velocity Obstacle Area (Chen et al 2022)

Grid potential field-based model

The grid potential field-based model is an important technique used in pedestrian simulation models that helps simulate pedestrian flow and navigation in complex environments. The model is based on the concept of potential fields, which are used to represent the attractiveness or repulsiveness of different areas in the environment. The model divides the environment into a grid of cells and assigns a potential value to each cell based on its distance from the destination and the presence of obstacles. Pedestrians then navigate through the environment by following the gradient of the potential field towards the destination. The model can handle complex environments with multiple obstacles and can be used to simulate pedestrian flow in different scenarios. The grid potential field-based model has been used in various applications, such as evacuation planning, crowd management, and urban design (Karmakharm, et. al., 2010).The challenges associated with the Grid potential based model in pedestrian simulation involves the inability to maintain stability in narrow passages or when facing discontinuity in the environment which potentially will result in erratic behaviour and collision (Koren and Borenstein, 1991). The overall structure of the GRID system is represented in the figure below.

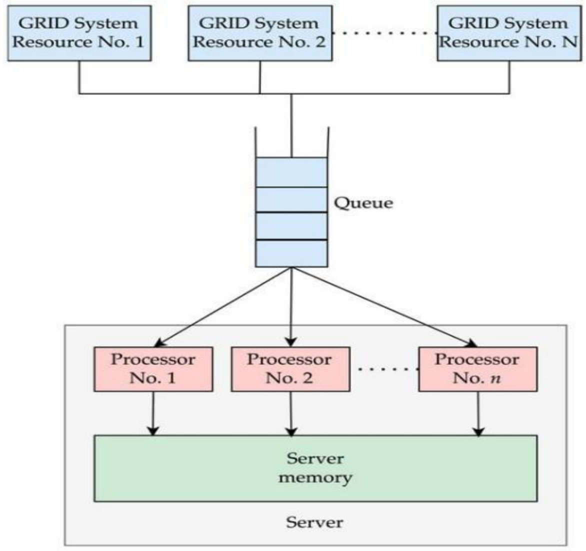

Figure 3: Generalized structure of the centralized GRID system (Tychenko et al 2023).

Improved heuristic-based model

The improved heuristic-based model is an important technique used in pedestrian simulation models that helps to improve the accuracy of pedestrian simulation by considering potential collisions and allowing pedestrians to adjust their desired speed based on the density of the crowd and the available space (Thelwall 2002). The improved heuristic-based model is a modification of the heuristic-based model that incorporates new features to improve the accuracy of pedestrian simulation. The improved heuristic-based model has been used to reproduce pedestrian dynamics on single-file staircases. The model has also been used in indoor pedestrian positioning, where it constructs membership functions to judge the pedestrian's motion based on the result of comprehensive evaluation. An improved Markov jump model based on the heuristic method has also been proposed to simulate the dynamic behavior of pedestrians. The author in (Thelwall, 2002), revealed that a document model alone is not sufficient to eliminate all anomalies in linking web behavior which itself is a limitation of the improved heuristic model's ability to manage all scenarios effectively.

Heuristic Search Algorithms in Feasible Spatial Layout Design Elements for Pedestrian Flow

Heuristic search algorithms can be used to find feasible spatial layout design elements for pedestrian flow by combining pedestrian simulation statistics with heuristic search techniques. This approach can help optimize pedestrian flow and improve the design of pedestrian spaces (Dora and Lakshmi 2022). Heuristic search algorithms can also be used to find feasible spatial layout design elements for pedestrian flow by combining pedestrian simulation statistics with heuristic search techniques Using cellular automata pedestrian flow statistics with heuristic search: This approach involves using cellular automata models to simulate pedestrian flow and generate statistics, which are then combined with heuristic search algorithms to automatically design spatial layouts that optimize pedestrian flow (Iia et. al., 2019).

Using four-way pedestrian flow statistics with heuristic search: This approach involves using four-way pedestrian flow statistics generated from feasible seating layout solutions with heuristic search techniques such as hill climbing and simulated annealing to find feasible spatial layout design elements.

Using an improved heuristic-based model: This approach involves using an improved heuristic-based model that allows pedestrians to adjust their desired speed based on the density of the crowd and the available space, and considers potential collisions during the moving process. This model can be used to reproduce pedestrian dynamics on single-file staircases and can be applied to find feasible spatial layout design elements for pedestrian flow.

Description of how Path-finding Algorithms with localized rules can be used for local movement decisions to pedestrian flow

Path-finding algorithms can be used in conjunction with localized rules for local movement decisions to model pedestrian flow by simulating pedestrian movement behavior, predicting pedestrian paths, and avoiding collisions (Grubb et. al., 2004). These techniques can help optimize pedestrian flow and improve the design of pedestrian spaces. Path-finding algorithms can be used in conjunction with localized rules for local movement decisions to model pedestrian flow in the following ways:

- Using grid potential field-based models: Grid potential field-based models divide the environment into a grid of cells and assign a potential value to each cell based on its distance from the destination and the presence of obstacles. Pedestrians then navigate through the environment by following the gradient of the potential field towards the destination.
- Using shortest path algorithms: Shortest path algorithms can be used to find the shortest available alternative paths on nondirectional graphs. A penalty-based strategy can be used to find the shortest available alternative paths on non-directional graphs.
- Using real-time pedestrian path prediction algorithms: Real-time pedestrian path prediction algorithms can be used to predict the path of pedestrians in cluttered environments. These algorithms use global and local movement patterns to predict pedestrian paths.
- Using algorithms to assign pedestrian groups dispersing at public gatherings: Algorithms can be used to assign pedestrian groups to unique selected paths. These

algorithms consider general networks where pedestrians can move in any direction.

- Using collision avoidance algorithms: Collision avoidance algorithms can be used to simulate pedestrian movement behavior and avoid collisions. These algorithms can be used in conjunction with path-finding algorithms to model pedestrian flow.

THE IMPORTANCE OF MICROSCOPIC PEDESTRIAN BEHAVIOR MODELS DEVELOPMENT

Developing microscopic pedestrian behavior models that consider various interactions on pedestrian dynamics at crosswalks is important for several reasons:

i. Accurate prediction of pedestrian behavior: Microscopic pedestrian behavior models can help to accurately predict pedestrian behavior at crosswalks. By considering various interactions among pedestrians and between pedestrians and vehicles, these models can provide a more detailed analysis of pedestrian behavior than macroscopic or mesoscopic models.

ii. Improved safety: Understanding pedestrian behavior at crosswalks can help to improve safety for both pedestrians and drivers. Microscopic pedestrian behavior models can be used to evaluate the service and safety level of pedestrian-related traffic, such as pedestrian movement in urban streets and crosswalks.

iii. Better design of pedestrian spaces: Microscopic pedestrian behavior models can be used to optimize the design of pedestrian spaces. By simulating pedestrian behavior, these models can help to identify potential problems and suggest design improvements that can improve pedestrian flow and safety.

iv. Understanding self-organization phenomena: Studying the self-organization phenomena of pedestrian crowds is an active subject in transportation science. Microscopic pedestrian behavior models can help to improve our understanding of these phenomena by providing a more detailed analysis of pedestrian behavior.

Model	Description	Advantages	Limitations
Velocity Obstacle based Model	Utilizes Pedestrian Velocity Obstacle (PedVO) to predict trajectories and avoid collisions	1. Predicts pedestrian trajectories effectively 2. Handles obstacles by computing velocity fields.	1. May lack realism when simulating complex crowd dynamics. 2. Performance compared to data driven techniques may vary.
Grid Potential fields-based model	Uses Potential fields to simulate pedestrian flow and navigation in complex environments	1. Systematic path planning 2. Guides Pedestrian effectively	Challenges in handling dynamic obstacles and real-time adjustments
Shortest path Algorithms	Finds shortest alternative paths on non directional graphs	Efficient in determining optimal routes for pedestrian	May not consider real-time factors and dynamic change in pedestrian behaviour
Collision avoidance	Essential for	1. Models	Requires continuous

Algorithms	simulating pedestrian movement behavior and avoiding collision	pedestrian flow effectively. 2. Enhances safety	update and adjustments to adapt to changing conditions
Microscopic Pedetrian Behavior model	Provides detail analysis of pedestrian behavior at crosswalks	1. Accurate prediction of pedestrian behavior. 2. Improved safety. 3. Better design pedestrian spaces.	Requires extensive data and computational resources for precise modelling

CONCLUSION

This paper summarized and highlights the potential applications of heuristic search algorithms in pedestrian simulation models. Heuristic search algorithms have a wide range of potential applications in pedestrian simulation models, from optimizing pedestrian flow and improving safety to advancing our understanding of pedestrian behavior. Cellular automata models and four-way pedestrian flow statistics can be combined with heuristic search techniques to find feasible spatial layout design elements. Grid potential field-based models can be used to simulate pedestrian flow and navigation in complex environments. Path-finding algorithms can be used in conjunction with localized rules for local movement decisions to model pedestrian flow. Microscopic pedestrian behavior models can help to accurately predict pedestrian behavior at crosswalks, improve safety, optimize the design of pedestrian spaces, and advance our understanding of pedestrian behavior

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