Microscopic Pedestrian Flow Characteristics-A Development of an Image Processing Data Collection and Simulation Model(歩行者交通流の微視的特性-画像処理によるデータ収集とシミュレーションモデルの構築-)

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論 文 内 容 要 旨

Microscopic pedestrian studies consider detailed interaction of pedestrians to control their movement in pedestrian traffic flow. To provide better pedestrian facilities, the appropriate standard and control of the facilities need to be determined. To decide the appropriate standard and control of pedestrian facilities, pedestrian studies, which consist of pedestrian data collection and pedestrian analysis, need to be done. One of the objectives of the pedestrian studies is to evaluate the effects of a proposed policy on the pedestrian facilities before its implementation. The implementation of a policy without pedestrian studies might lead to a very costly trial and error due to the implementation cost (i.e. user cost, construction, marking etc.). On the other hand, using good analysis tools, the trial and error of policy could be done in the analysis level. Once the analysis could prove a good performance, the implementation of the policy is straightforward. The problem is how to evaluate the impact of the policy quantitatively toward the behavior of pedestrians before its implementation.

May (1990) suggested that traffic flow characteristics could be divided into two categories, microscopic level and macroscopic level. Microscopic level involves individual units with traffic characteristics such as individual speed and individual interaction. Most of the pedestrian studies that have been carried out are on a macroscopic level. Macroscopic pedestrian studies assumed that all pedestrian movements in pedestrian facilities are simply aggregated into flow, average speed and area module. The main concern of macroscopic pedestrian studies is space allocation for pedestrians in the pedestrian facilities. It does not consider the direct interaction between pedestrians and it is not well suited for prediction of pedestrian flow performance in pedestrian areas or buildings with some objects (kiosk, benches, seating, telephones, fountain, etc.). Microscopic pedestrian studies, on the other hand, treat every pedestrian as an individual and the behavior of pedestrian interaction is measured. However, the microscopic pedestrian study does not replace the macroscopic one, but considers a more detailed analysis for design and pedestrian interaction.

Compared to the macroscopic pedestrian studies, the microscopic pedestrian studies are still very much in its infancy. Despite the greater benefit of the microscopic pedestrian studies, the number of researches and papers on this subject has been remarkably few. Among those researches, some microscopic pedestrian analyses have been developed. The analytical model for microscopic pedestrian model has been developed by Henderson (1974) and Helbing (1992), but the numerical solution of the model is very difficult and simulation is more practical and favorable. Though microscopic pedestrian analysis exists through simulations, several problems have not been addressed by the previous researchers.

1. The microscopic pedestrian flow characteristics need to be understood. Most of previous microscopic pedestrian analyses were not concerned with the traffic characteristic or flow performances of pedestrians because the main concern were in the modeling of the simulation. Using the simulation model, what are the microscopic characteristics of pedestrian flow?
2. The tools to collect the microscopic data and to analyze microscopic pedestrian flow are still very much in its infancy. Microscopic pedestrian data collection has not been developed. Recently, several studies to perform pedestrian surveillance have been actively developed in the computer vision and image processing fields. Those studies, however, do not specify the purpose toward traffic engineering field, especially the microscopic level of pedestrian data. How to use the pedestrian traffic surveillance system to collect microscopic pedestrian data?
3. Once such microscopic pedestrian data is collected, another problem on how to measure the flow performance from the microscopic data collection arises. The results of microscopic data collection are the locations of each pedestrian at each time slice. How to reduce these huge data need to be reduced into information that can be readily understood and interpreted?

Thus, this study as reported in this dissertation is done to solve the aforementioned those problems.

The purpose of this study is to improve the quality of pedestrian movement behavior through microscopic pedestrian studies. The specific objectives in this study are:

1. To identify the existing stage of microscopic pedestrian studies;
2. To develop a data collection system for microscopic pedestrian studies;
3. To improve the existing microscopic simulation models;
4. To examine the microscopic pedestrian flow characteristics;
5. To discuss the application of the microscopic pedestrian simulation models.

This study is mainly concerned with the microscopic pedestrian traffic characteristics from both the simulation and the real world data. The systems that were developed in this study consider only pedestrians in two-dimensional areas. State of the Art of the pedestrian studies is written in Chapter 2. It considers the result of the previous studies about microscopic pedestrian studies, from data collection to analysis. Chapter 3 introduces the microscopic pedestrian data collection. A video processing system was developed to gather pedestrian database that called NTXY database. Chapter 4 describes the development of Microscopic Pedestrian Simulation Model. Chapter 5 combines the result of the data collection and the simulation model as Microscopic Pedestrian Characteristics. Before concluding chapter, the application of the analysis is demonstrated in another chapter.

The video processing method to gather pedestrian data that suggested in this research can be performed in four steps:

1. Conversion from Video to File
2. Collection of path coordinates (NTXY)
3. Trimming Data into Pedestrian Trap only
4. Conversion Image Coordinate to the Real World coordinates

This research have been developed image processing pedestrian data collection method that based on the automation development process, the collection of the path coordinate can be classified into three types:

1. Manual data collection
2. Semi Manual data collection
3. Automatic data collection.

Each pedestrian is followed from the time he/she enters the system until goes out of the system. The process is repeated until all pedestrian in the stack of image is tracked. The automation development of the data collection is presented. It was found that the microscopic speed resemble a normal distribution with a mean of 1.38 m/second and standard deviation of 0.37 m/second. The acceleration distribution also bear a resemblance to the normal distribution with an average of 0.68 m/ square second.

Pedestrian analysis is based on a Microscopic Pedestrian Simulation Model (MPSM), which is computer simulation model of pedestrian movement where every pedestrian in the model is treated as individual. The development of a new microscopic pedestrian simulation model (MPSM) that improves the existing MPSM is described.

Pedestrians in the microscopic simulation model are modeled as autonomous objects to be seen from above of the facilities. A pedestrian is modeled as a circle with a certain radius (uniform for all pedestrians). Each pedestrian own an initial location, an initial time, and an initial velocity and a predetermined target location (opposite to the initial location). These inputs can be determine by the user as a design experiment or specified randomly. A forward force drives pedestrian movements when there is no other pedestrian in the facility. The forward force makes the pedestrian path almost in a straight line. The facility (i.e. walkway) is modeled as two-dimensional space where the pedestrian is moving around. A part of pedestrian facility that the pedestrians can be seen are called pedestrian trap. Each pedestrian has origin and destination places. The pedestrian generators are locations at which the pedestrian are generated in some point of time. The location of the pedestrian generators is the location of the origin of the pedestrian. Pedestrian's destination is the attractor points where the pedestrian will disappear when reach this point.

When other pedestrians exist, the repulsive force, as the interaction with other pedestrians, is inputted to the autonomous system. The pedestrian is then optimizing the movement by taking the best path to go to the target location while avoiding other pedestrians. Two kinds of repulsive forces are working together with the forward force. One force is driving away the pedestrian actor while still quite far from other closest pedestrian, the other force strongly repulses against all other pedestrians in the surrounding. The first repulsive force is model the overtaking and meeting behavior of pedestrians. When two pedestrians meet each other, they usually move away from each other within certain distance that is quite far from each other. Although using the first repulsive force the pedestrian can move away from each other within certain distance, there is no guarantee that the pedestrians will not collide to each other when they are very close, especially when there are many pedestrians in the facility. Other repulsive force is needed to guarantee that no collision will actually happen between pedestrians. The second repulsive force is working to avoid the collision between pedestrians. To avoid the collision, it is assumed that each pedestrian has an influence radius that represents his or her security awareness.

Both Microscopic Video Data Collection and Microscopic Pedestrian Simulation Model generate database called αTXY database. Since the microscopic pedestrian characteristics can be derived from the αTXY database, it is useful to discuss about the nature of αTXY database first. The formulations of the flow performance or microscopic pedestrian characteristics are also discussed. Sensitivity of the simulation and relationship between the flow performances are described. Validation of the simulation using real world data is then explained through the comparison between average instantaneous speed distributions of the real world data with the result of the simulations.

The simulation model is then applied for some experiments on a hypothetical situation to gain more understanding of pedestrian behavior in one way and two way situations, to know the behavior of the system if the number of elderly pedestrian increases and to evaluate a policy of lane-like segregation toward pedestrian crossing and inspects the performance of the crossing. It was revealed that the microscopic pedestrian studies have been successfully applied to give more understanding to the behavior of microscopic pedestrians flow, predict the theoretical and practical situation and evaluate some design policies before its implementation.

論文審査の結果の要旨

交通分野において、歩行者交通流に関する研究は自動車交通流に関するものに比べ未発達といえる。自動車が限定された車線の中を走行するのに対して、歩行可能な場所を自在に移動する歩行者交通流においては、その観測やモデル化が著しく困難であることがその理由として挙げられる。一方、環境やエネルギー問題から、自転車や歩行者交通が「グリーン」な交通モードとしてもてはやされるようになってきているとともに、交通施設に対するバリアフリー化の要求も高まってきており、歩行者施設に関してより精緻な観測やモデルに基づく、より高度なデザインが求められるようになってきている。研究は、歩行者交通流に関して、解析のためのデータを収集する画像処理によるデータ収集システムを開発し、得られたデータの解析を通じて、微視的特性を考慮できる新たな歩行者交通流のシミュレーションモデルを提案したものであり、全7章からなる。

第1章は序論である。

第2章は従来研究のレビューである。過去の歩行者交通流に関する研究の多くが巨視的なものであったのに対して、歩行者施設の設計にあたっては微視的な解析が必要であることを指摘している。また、従来のデータ収集方法、および、これまでに提案された歩行者交通流シミュレーションモデルについてレビューを行っている。

第3章では、新たに開発したビデオを用いたデータ収集システムについて述べている。得られた画像から歩行者データを抽出するために必要なバックグラウンド画像の作成や、同一の歩行者として同定することにより歩行者の経路を得る方法などについて、新たなアルゴリズムを提案し、データ収集システムとして構築した。これは今後の歩行者交通流の解析に有用な手段を与えるものであり大きな成果といえる。

第4章では、微視的な歩行者交通流シミュレーションモデルの開発について述べている。開発したモデルは、従来から提案されている歩行者の速度および進行方向の変化をいくつかの「力」の作用として表現する手法をほぼ踏襲したものであるが、ここでは歩行者に作用する力として「目的地に向かわせる力」と、すれ違いなどの際に「互いに避け合う力」および、「衝突を回避する力」に集約したモデルを開発した。これは実用的なモデルとして高く評価される。

第5章では、観測およびシミュレーション結果に基づいて、歩行者交通流の微視的特性について論じている。両者を統一的に取り扱うための新たなデータ表現方法を提案し、歩行者交通の微視的特性を表現する各種の指標について論ずるとともに、シミュレーションモデルの各種のパラメータの決定を行っている。また、モデルに基づいて、歩行者交通流の自己組織化について論じている。自己組織化のモデルによる生成は全く新しい知見であり、大きな成果といえる。

第6章では、本研究で開発したシミュレーションモデルを高齢歩行者の影響や横断歩道における交通運用方法の評価に適用した結果について述べている。これまでの巨視的なモデルでは評価不能であった、微視的特性から見た遅れ時間や快適性の評価が可能となっており、これらは今後の歩行者施設の設計・運用に対して有用な知見を与えるものである。

第7章は結びであり、本研究を通じて得られた知見を結論として述べ、あわせて今後の研究課題に対する提言を行っている。

以上要するに本論文は歩行者交通流の解析に必要となるビデオを用いた簡易なデータ収集システムと微視的なシミュレーションモデルを構築することにより、歩行者交通流解析に有用な知見を与えたものであり、交通計画学および画像処理を含む情報科学の学際分野の発展に寄与するところが少なくない。

よって、本論文は博士（学術）の学位論文として合格と認める。