

Feedback Control Models and Their Application in Pedestrian Navigation Systems

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Abstract—Feedback control theory has been widely used in many fields; this paper introduces this theory into a model for a pedestrian navigation system. Based on the model, several feedback channels are designed and analysed using control theory. The pedestrian is not only a data receiver but also a data collector. All collected information is stored in a temporal database and can be used for spatial-temporal analysis. At the same time, feedback control theory can integrate all modules of the system as whole, which can help to improve the overall effectiveness. Based on information fed back and feedback control theory, the pedestrian navigation system will help users to “see more, understand better, and decide more quickly.”

Keywords—Feedback control model, pedestrian navigation system, LBS (Location based services)

I. INTRODUCTION

With the advancement in communication, GPS and GIS technologies, vehicle navigation systems are now widely used. In recent years, pedestrian navigation systems have been increasingly an active research field. It is not always easy for pedestrians to find the right way to reach their destination in an unfamiliar environment. Pedestrian navigation systems can help them to find an optimal route. Navigation for pedestrians is different from that for vehicles. Different pedestrians may choose totally different routes. They can walk along a road, or across a square. They can also follow a twisting narrow pass, or even cross a muddy grass field. The pedestrian needs a highly efficient and individualized navigation service. Furthermore, the pedestrian may also want to know the current traffic situation before they decide which means of transportation to use.

There are many pedestrian navigation systems available, but most of their implementation focuses on how to accurately determine the user’s location or how to add more functional modules to the system. However, improving the overall effectiveness between several collaborating modules is still a problem that needs further study.

Some pedestrian navigation systems can collect and process information from different sources. This information can help users to choose a more suitable route. However, this data is usually considered transient and discarded after a short time. Archiving data for profiling user preferences or route information has not been used very much.

In this paper, we focus on the task of how to improve the efficiency of pedestrian navigation systems. In section 2, we briefly introduce related work in the field of pedestrian navigation and feedback control theory. In section 3, we describe why feedback control theory can be usefully applied in pedestrian navigation systems and how it may be modelled. The paper closes with some concluding remarks and suggestions of enhancements for a practical pedestrian navigation system.

II. RELATED WORK

A. Pedestrian Navigation Systems

Pedestrian navigation systems have been discussed for a long time. However, despite the fact that many navigation solutions include a pedestrian mode setting, none of these were worthy of that name [1]. Maybe this is an extreme verdict on the available applications for pedestrian navigation. However, it reflects that there still is a lot to do in this key area of location based services. Recent advances in mobile phones, positioning technologies, and wireless networking infrastructures are making it possible to implement and operate large-scale pedestrian navigation in the real

world and will result in them being more widely available in the future. Among them, NAVITIME is probably the most successful commercial navigation service for the public in Japan. Pedestrian navigation is one of its main services. It became available early this century and now has over one million users in Japan [2].

As a whole, pedestrian navigation is still on the edge of new positioning and communication technologies and several of its requirements have not been fully achieved. These include modelling the full complexity of walking routes, indoor navigation, personalized services suitable for various pedestrian behaviours and not implementing full 3D applications [3][4][5].

With the advent of more powerful hardware and software technologies in several key areas, including communication, computing, positioning and spatial representation, and more friendly and powerful pedestrian navigation services will become a reality.

B. Feedback Control Theory

Control theory is an interdisciplinary branch of engineering and mathematics, which deals with the behaviour of dynamical systems. The desired output of a system is called the reference. When one or more output variables of a system need to follow a certain reference over time, a controller manipulates the inputs to a system to obtain the desired effect on the output of the system [6] [7].

To avoid the problems of the open-loop controller, control theory introduces feedback. A closed-loop controller uses feedback to control states or outputs of a dynamical system. Its name comes from the information path in the system: process inputs (e.g. voltage applied to an electric motor) have an effect on the process outputs (e.g. velocity or torque of the motor), which is measured with sensors and processed by the controller;

the result (the control signal) is used as input to the process, closing the loop.

Feedback is a mechanism, process or signal that is looped back to control a system within itself. Such a loop is called a feedback loop. Intuitively many systems have an obvious input and output; feeding back part of the output so as to increase the input is positive feedback; feeding back part of the output in such a way as to partially oppose the input is negative feedback.

Negative feedback helps to maintain stability in a system in spite of external changes. Positive feedback amplifies possibilities of divergences (evolution, change of goals); it is the condition to change, evolution, growth; it gives the system the ability to access new points of equilibrium [8][9].

Feedback control theory is widely used in many fields, such as biology, climate science, economics, electronic engineering and mechanical engineering. But it is seldom used in navigation field, especially in pedestrian navigation system.

III. MODELING OF PEDESTRIAN NAVIGATION SYSTEM

The most important factor in a pedestrian navigation system is data. The system needs to get data from different sources and send processed data to users. Existing systems always take the pedestrian as an information receiver, which are typical open-loop systems. In this paper, the pedestrian is not only a data receiver, but also a data collector. The pedestrian can feed some information back to the system, which forms a closed-loop of information.

Fig. 1 is the feedback control model of pedestrian navigation system. As shown in the figure, there are three feedback channels in the system: user feedback, spatial-temporal analysis feedback and validity feedback. These three feedback channels all are negative feedback, which can help to maintain system stability.

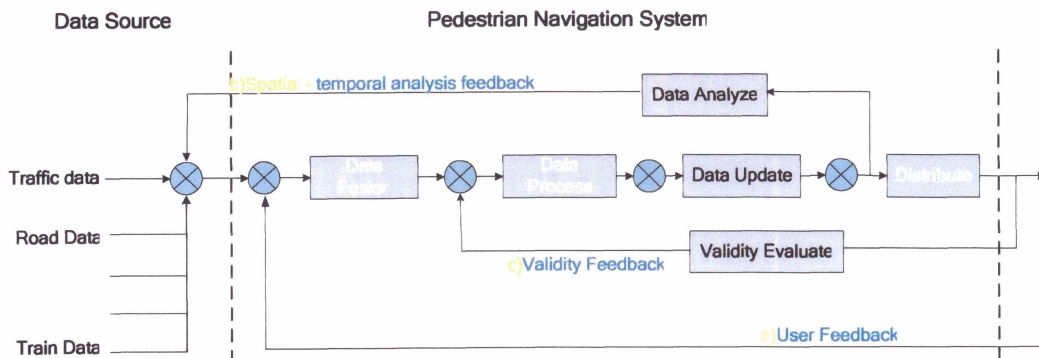


Fig. 1 Feedback control model

A. User Feedback

Because pedestrians are not limited in vehicle road network, they can walk across a square, or across a grass field. Therefore, compared with vehicle navigation systems, pedestrian navigation needs more information, including road network information, traffic information, POI (point of interest) information and some other information. One solution is to add more information source to pedestrian navigation system. In this system, the pedestrian is taken as an extra data source.

There are some data collecting interfaces in the system, so pedestrian can feedback data to the system in time. For example, if a pedestrian gets caught in a traffic jam, he can upload the congestion information to the pedestrian navigation system, which can help other people to avoid heavy traffic. For another example, if a pedestrian finds a new shop when he is walking along a street, he can send the name of the shop to the system. The exact location of the shop will be sent to the system at the same time. In this way, a pedestrian navigation system can get more general and timely information.

B. Spatial-temporal Analysis Feedback

Pedestrian navigation systems can get information from different data sources. Most systems use these data only once. In fact, we can find much useful information by analyzing historic data, which is another kind of feedback channel of the system.

A pedestrian navigation system needs to store several kinds of information. This information often evolves with time and location. So a temporal database will be constructed to store massive historic data. A temporal database supports the storage and retrieval of temporal data objects. Each entry in the database has one or more associated timestamps. All changes that occur are recorded and past states of the database may be retrieved. Two different timestamps may be used, the transaction time, corresponding to the moment when the information is introduced in the database, and the validity time, the time when that information is valid in the real world.

By analysing the spatial-temporal data stored in database, pedestrian navigation system can not only reconstruct the missing data, but also predict future data.

For example, real-time traffic information can help pedestrian to choose a suitable route. If the traffic information of some road segments is missing for some reason, we can reconstruct the missing data by analyzing historic temporal data. Results of spatial-temporal analysis can be feed back to the system as a kind of data source.

C. Validity Feedback

Different user may choose different routes. Some pedestrians want to choose a shortest route or a fastest path. While other pedestrians may want to choose an easy-walk route. The system will calculate a route according to the user's different requests.

But can the calculated results truly meet the needs of users? A sidewalk may be no longer a fastest path because of road-works. And a user may not think a path is easy to walk because of the mud after a rain storm. So it is very important to get the feedback from users about system validity.

In the process of navigation, the pedestrian can evaluate the precision of the data they receive and the validity of the calculated path. For example, each road segment will be assigned a number to represent the ease-of-travel over the road segment in advance. The smaller the number is, the easier the road segment is to walk. If a pedestrian thinks some road segment is not easy to walk, the system will increase the number after it gets the feedback from user. In this way, the system can obtain user's evaluation in time, which is also a kind of useful feedback to improve the data processing efficiency.

IV. CONCLUSION

This paper attempts to apply feedback control theory to pedestrian navigation. Three kinds of feedback channels are discussed. User feedback can be used to collect more information. Spatial-temporal analysis feedback can be used to reconstruct missing data and predict future data changes. And validity feedback is useful to improve system efficiency. Furthermore, these feedback channels connect different parts of the system into a unit. Based on these feedback channels, pedestrian navigation system will become more practical, more efficient and timely.

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