

Assignment

by Yan Zhang

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INTELLIGENT VEHICLE
PATH PLANNING AND
PATH FOLLOWING
RESEARCH



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Abstract

As an essential part of the intelligent transportation system, the intelligent vehicle can effectively alleviate traffic congestion, improve driving safety and avoid traffic accidents. It has a high research value and market application prospects. To this end, this research will take the intelligent vehicle as the research object, and research on its path planning and path following control technology.

The article contains five chapters. The first chapter is an introduction, which includes research purpose, research significance, research objectives and expected outcomes.

The second chapter introduces the background and the current development status of intelligent vehicles, and critically reviews the relevant research work in this field.

The third chapter introduces the various methods used in this topic, including research methods, development methods, data evaluation methods and risk analysis & limitations. The project will use positivist methods, deductive methods, literature review and iterative development models to research on this topic.

The fourth chapter introduces the hardware resources and software resources needed for this topic, and establishes a Gantt chart as a guide.

The last chapter is a summary and review of the full text

1. Introduction

This topic mainly studies the field of intelligent vehicles. In order to better complete the research, this paper lists the research purpose, research significance, research objectives and expected outcomes.

1.1. Research purpose

This topic aims to optimize the accuracy and reliability of local path planning algorithm and path following algorithm.

1.2. Research significance

This topic studies the path planning and path following control technology of intelligent vehicles, which has high research value and significance. From the perspective of contribution to human beings, the development of intelligent vehicles can effectively alleviate traffic congestion, improve driving safety and reduce traffic accidents. Secondly, no matter along the road of advanced assisted driving gradually to automated driving, or directly realize the technical route of intelligent driving, the research of this topic is an indispensable part of it. Finally, the research of this topic also conforms to the trend of industrial development.

From the perspective of intelligent vehicles, the intelligent vehicle needs to plan the driving path according to the information obtained by the environmental perception system, and then follow the path of the vehicle. Therefore, the controller with excellent design performance has become an indispensable key link in the development of intelligent vehicles.

1.3. Objectives

In order to complete the aim of the topic, the following objectives will need to be achieved:

- [1] Investigate and collect relevant information on path planning and path following of intelligent vehicles.
- [2] Analyze various methods of vehicle local path planning, compare different methods, and select the appropriate algorithm for local path planning.
- [3] Establish appropriate environmental models and vehicle dynamics models for path following.
- [4] Establish a vehicle dynamics model, design a suitable path following controller, and consider real-time and accuracy.
- [5] Evaluate the optimized algorithm, verify the feasibility in Matlab/Sumlink and simulate in the intelligent vehicle simulation software Carsim.
- [6] Compare the optimized algorithm with the original algorithm.

1.4. Expected outcomes

At the end of the research, it is expected to get the local path planning method of the intelligent vehicle that meets the requirements of real-time path planning, and complete the path following controller based on MPC theory, which is both real-time and accurate.

Finally, a detailed report will be written based on the analysis of the research process and conclusions of this topic, with a code attached.

2. Literature review

This chapter will cover the background research and some of the related work done in this area.

2.1. Background

With the continuous development of automotive intelligence and electrification, the intelligent vehicle has become a mainstream trend in the automotive industry. The intelligent vehicle can sense the road environment through the onboard sensing system, automatically recognize the road information without human intervention, and automatically plan the driving path to send people to the destination [1].

Google's intelligent technology has always been at the forefront of the world. At present, Google's intelligent vehicle 'Waymo' has a total road test mileage of 10 million miles [2]. At the end of 2018, Google announced the launch of its first commercial taxi service in Phoenix, Arizona, USA, making Google the first company to commercialize intelligent vehicles. It also signifies that Google's intelligent vehicles will enter a new phase. In 2015, Tesla officially launched the AutoPilot automatic assisted driving system, but this system was not achieved complete intelligent. At the beginning of 2019, Tesla CEO Elon Musk said that by the end of this year, Tesla will master the technology that can be driven on the road without any intervention [3].

Bosch plans to introduce a highway pilot system that will basically master driving skills and complete the required driving tasks on the highway in 2020, and then release an automatic pilot system that completely replaces the human driver in 2025 to achieve fully automatic driverless functions between the two locations. Volkswagen group has also carried out in-depth cooperation with Intel and Mobileye in the field of intelligent driving, and it is expected to release fully intelligent vehicle that can drive on the road in 2021. In addition, technology giants such as Apple and Uber have also entered the field of intelligent driving in recent years.

The British government has also been committed to the development of human-powered vehicles. The Department for Transport issued a statement saying [4], "It is expected to complete the commitment to have fully self-driving vehicles on British roads by 2021." It will also significantly promote the development of the UK intelligent vehicle market and is expected to reach 52 billion pounds by 2035.

2.2. Related work

In the critical technologies of intelligent vehicles, path planning and the path following control after the completion of planning have always been essential and challenging points in the field of intelligent driving.

E. W. DIJKSTRA came up with an algorithm [5]. First, save the distance from the starting point to all points to find the shortest one, then relax operation and find the shortest. The slack operation is to update the closest distance between the two points. This algorithm is ideal for solving static shortest path planning, but when the number of nodes n is large, the computational time complexity increases sharply. PETER E. HART [6] proposed the A* algorithm. Based on the Dijkstra algorithm, this algorithm adds heuristic function in the search process, avoids the expansion in all directions like the Dijkstra algorithm, and reduces the blindness of search and the number of nodes. However, the target motion path planned by this method is still not smooth enough, and when the number of grids is vast, it needs to spend a lot of computing time and resources.

Fast Search Random Tree is to randomly spread some points in the environment. These points can be connected by an algorithmic operation to form a path. Yu Tian [3] added directional parameters based on this algorithm, thus reducing the number of nodes and speeding up the calculation speed. Finally, the effectiveness of the method is verified by simulation experiments.

G. C. Marco Dorigo [7] founded that when foraging for food, ants will release and perceive a certain of pheromones used for information transmission between individual ants, and guide their next movement direction. Finally, the path formed by the concentration of pheromone in the ant colony is the optimal path. However, the path is carried out in the grid environment, and the search path is not smooth enough, and with the increase of the grid, its algorithm complexity and computing time increase. Zhongrui Yuan [8] improved the path selection strategy, pheromone allocation mechanism and heuristic function of ant colony algorithm, and proposed an improved ant colony algorithm. And the effectiveness of the method is verified by simulation experiments.

The artificial potential field includes the repulsive field and the gravitational field [9]. The target point exerts a gravitational pull on the object, directing it toward the target point. The obstacle exerts a repulsive force on an object to prevent it from colliding with it. The net force on the object at every point in its path is equal to the sum of all the repulsive and gravitational forces at that point. This method not only does not need to search the global path but also has the advantages of simple calculation, excellent real-time performance, smooth planning path and high repeatability, which can be well combined with the vehicle path following.

When the path planning is completed, the vehicle is required to perform path following quickly and accurately, which is another crucial technology in the intelligent vehicle. B. Soualmi et al. [10] used a fuzzy T-S control method to track the desired path by controlling steering wheel torque. In order to solve the nonlinear problem of

longitudinal velocity variation in transverse dynamics, a suitable T-S optimal controller is designed by using T-S and linear matrix inequality. Jongho Shin, Jinwook Huh and Yongwoon Park [11] proposed a gradual stable path following controller, which uses an error feedback system composed of a vector field and a robust integral-symbolic function. Finally, the collision test and autonomous navigation test verify the effectiveness of the algorithm.

Model predictive control (MPC) is also known as rolling time-domain optimal control. The controller considers the nonlinear dynamic model of the control system and predicts the output behavior of the system in the future period. By solving the optimal control problem with constraints, the following error in the future period is minimized. This method has strong robustness and can deal with constraints online and satisfy them dynamically.

Tamas' Keviczky et al. [12] proposed an intelligent vehicle steering method based on model predictive control (MPC). The controller can achieve strong wind resistance and meet its physical constraints to achieve follow-up to the path. Kong J and Pfeiffer M et al. [13] compared the errors of the kinematics and dynamics two degrees of freedom model in predicting the future state of vehicles based on the experimental data. The dynamic model uses linear tires to describe the interaction between tires and pavement, and MPC controller is designed based on the kinematics model. The simulation results verify the effectiveness of this control algorithm under windy roads and different speeds.

3. Methodology

This chapter will cover research methods and development methods for exploring and investigating research aim and objectives. The aim of this project is to optimize the accuracy and reliability of local path planning algorithm and path following algorithm.

3.1. Research methods

3.1.1 Philosophy

Positivism believed that all knowledge can only be derived from experience. The reliability of theory and hypothesis must be verified by experience. Phenomenology is opposed to positivism. It is a purely conscious view that differs from any subjective experience [14]. This topic will adopt the positivist philosophy method and draw conclusions through practical operation, simulation experiment, data collection and data analysis.

Inductive method refers to obtaining a more general rule in many cases. The deductive method is contrary to the inductive method, which is to deduce specific results from general principles [15]. This topic will adopt a deductive method to verify that the optimized path planning algorithm and path following algorithm are more accurate and reliable than before optimization.

3.1.2 Strategy

The type of research for this topic is exploratory research, not interpretive research and descriptive research. Because the purpose of this topic is to optimize the algorithm, it is necessary to explore how to optimize the algorithm.

The research strategy of this topic includes a literature review method and an experimental research method. The literature review method mainly understands the development status of path planning and path following technology through relevant literature, analyzes scientific and technical problems in this field, and comprehensively understands its development trend. The methods in the literature and the solutions to several typical problems can be summarized through the literature review. Then, analyze different algorithms and compare different combination algorithms. The experimental research method is mainly to carry out joint simulation experiments on Matlab/Sumlink and Carsim software, compare the effects before and after the algorithm optimization, and draw conclusions based on the experimental analysis results.

3.1.3 The study population and sample

The research object and sample of this topic are the path planning algorithm and path

following algorithm of intelligent vehicles. These algorithms are compared to select suitable algorithms for optimization.

3.1.4 Data collection methods

Data collection will use survey methods, interview methods, and literature review methods. The survey method is to join the relevant community website and collect the latest news about the path planning and path following algorithms on the website. The interview method is to obtain some suggestions by consulting related researchers in intelligent vehicles fields, such as the measurement factor of the intelligent vehicle path planning algorithm. The literature review is to collect and sort out some other optimization methods for path planning and path following algorithms by reading the literature. Finally, summarize the collected data and analyze various methods of vehicle path planning and path following. By simulating these algorithms to compare the effect of the different methods, and selecting the appropriate algorithm to optimize.

3.1.5 Reliability and validity

The reliability and validity of the data will influence the final results. The main factors affecting validity include history, testing, means, failure, causal relationship and so on. In general, the factors that affect data reliability include [16]:

- Interviewee and participant error
- Respondents and participants biased
- Observer error
- Observer bias

Therefore, we need to consider reliability and validity from the following perspectives.

Reliability:

- In other cases, will the measurement get the same result?
- Can other observers get similar observations?
- Is the process of drawing conclusions from the source material transparent?

Validity:

- Does the research result reflect the true face of things?

In order to ensure the reliability and validity of data, this topic will collect relevant information from the regular website and the included literature, and select researchers with years of experience in intelligent vehicle research as the interviewee.

3.2. Development methods

There are many mature development methods to choose from, such as waterfall development methods, spiral development methods, rapid application development methods and so on.

Waterfall model is common, but the process is usually fixed. The design of spiral model is flexible, but its software technology updates quickly. Iterative model development method can break tasks into small projects, reduce risk and make projects easier to succeed [17]. Therefore, the development method selected in this topic is the iterative model development method (as is shown in figure 1).

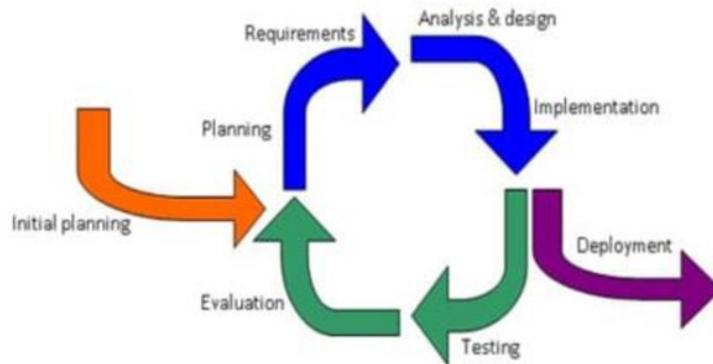


Figure 1 Iterative model development lifecycle

This topic will divide the task into several subtasks, and the techniques used for each subtask includes requirements analysis, design, implementation, testing, and evaluation. Therefore, this topic is very suitable for the iterative model development method.

3.3. Risks & Limitations

During the whole process of the topic, risks are inevitable, which are directly related to the topic and affect the progress of the topic. Some known risks and possible risks include:

- Not familiar with the software
- The results of the survey were not satisfactory
- Poor time management leads to topics not being completed on time
- Inappropriate objectives cause the topic to fail to meet requirements
- Some unavoidable factors, such as illness

In order to address these risks, project planning software such as a Gantt chart or PERT chart can be used to reduce the impact of time factors on topic progress. For example, by using the Gantt chart, the technical path and progress of the topic can be known. When collecting data, screen out useful information to avoid the interference of useless information on the investigation results. Besides, it is necessary to spend some time to learn and be familiar with relevant software.

In terms of topic limitations, some subtasks may not be completed on time due to lack of knowledge. The solution to solve this problem is to supplement relevant knowledge

through self-study and start from a simple task. Besides, make the next step based on the actual completion of the project to avoid inappropriate objectives.

The ethical or legal issue currently identified is the use of actual community sites to collect relevant information, so it is necessary to filter out information that violates ethical or legal when browsing the website.

3.4. Result Evaluation

In order to evaluate the experimental data, three parts will be evaluated. The first part is to evaluate the data of the path planning algorithm, including comparing the real-time and obstacle avoidance effects of the algorithm before and after optimization in the same environment to measure the path planning effect. The second part is to evaluate the data of the path following algorithm and compare the accuracy of the algorithm before and after the optimization in the planned path to measure the following effect. Finally, run both algorithms at the same time to measure whether the topic aim is met.

4. Design and implementation

This chapter will discuss the main design and implementation methods suggested for the purpose of this project.

4.1. Resources required

The hardware and software required to complete this project include:

- A PC or a laptop -- will be used for the entire project.
- Microsoft Topic, Microsoft Word, and Microsoft Excel -- for scheduling, recording, and analyzing data.
- Matlab/Sumlink software and Carsim software -- used to run code.
- Books in this area - will be borrowed from UWTSD libraries or purchased from Amazon.
- Related community sites - such as the intelligent vehicle forum and UrberPeople forum.

In addition to some necessary hardware and software resources, this topic also requires a programming language. Because this topic requires the use of Matlab/Sumlink software, so you must master the C language, which is the most basic and most important language. When using Sumlink, the module construction model will be used, so it is necessary to grasp the meaning and usage of the corresponding module. Carsim software is also graphically programmed and does not require an actual programming language, but must be proficient in the use of this software.

4.2. Gantt chart

In order to better complete this topic, the Gannt diagram is built as a guide for the topic (as is shown in figure 2).

Task Mode	Task Name	Duration	Start	Finish
★	Data collection and literature review	21 days	Sun 10/03/19	Fri 05/04/19
★	Learning software	17 days	Sat 06/04/19	Sun 28/04/19
★	Selection algorithm	13 days	Mon 29/04/19	Wed 15/05/19
★	Optimization algorithm	27 days	Thu 16/05/19	Fri 21/06/19
★	Test algorithm	7 days	Fri 21/06/19	Sun 30/06/19
★	Joint simulation experiment	11 days	Mon 01/07/19	Mon 15/07/19
★	Analysis of the final	12 days	Tue 16/07/19	Wed 31/07/19
★	Writing report	23 days	Thu 01/08/19	Sat 31/08/19

Figure 2 Project Gantt chart (1)

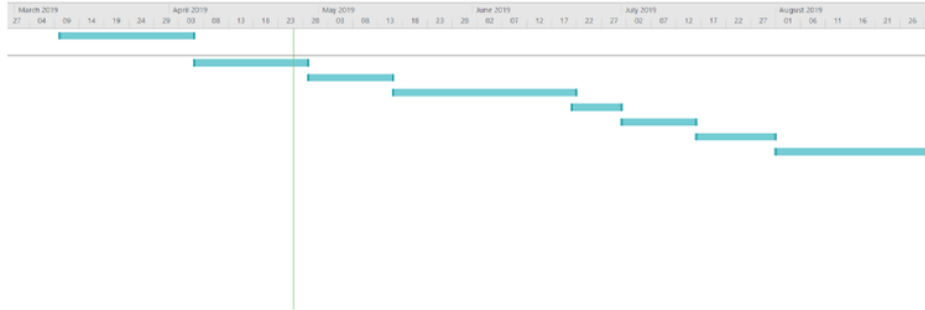


Figure 3 Project Gantt chart (2)

Data collection and literature review: This part is mainly for data collection of intelligent vehicle path planning and path following algorithm, and reading relevant literature to master the current mainstream algorithms.

Learning software: This part is mainly to learn Matlab/Sumlink and Carsim software. Matlab/Sumlink software is a popular software, which can be used for algorithm development, data analysis, data visualization and so on. The learning materials are plentiful and can be learned through video teaching or books. Carsim software is a powerful car simulation software, but because of the professionalism of this software, so the learning materials are not plentiful, and it will take more time to learn this software.

Selection algorithm: This part mainly uses different methods to simulate the path planning and path following algorithm, and compares the effects of different algorithms to select the appropriate algorithm.

Optimization algorithm: This part will optimize the algorithm chosen above, such as modifying related functions or parameters to improve its effect.

The test algorithm: This part mainly tests the effect of algorithm optimization. If it can improve the effect of the algorithm, it can be retained. Otherwise, it needs to continue to optimize.

Joint simulation experiment: After the path planning algorithm and the path following algorithm are optimized respectively, and the joint simulation experiment is carried out by combining Matlab/Sumlink and Carsim software to test the overall operation effect.

Analysis of the final: Compare the optimized operational data with the original operational data, then analyze it and draw conclusions.

Writing report: This part will summarize the topic start-up process, implementation process, and analysis process, and submit a research report in the form of a written report.

5. Conclusion

The subject research in this paper is mainly aimed at the path planning algorithm and path following algorithm of intelligent vehicles. Firstly, it shows that this research has a certain significance, and the research aim is to optimize the accuracy and relatability of local path planning algorithm and path following algorithm, and subdivide it into specific objectives and expected outcomes. Through surveys to understand the background and development status of intelligent vehicles, and then read the relevant literature to learn path planning algorithms and path following algorithms and related optimization methods.

In order to have further research on this topic, the research methods and development methods of the topic were selected. Finally, the hardware resources and software resources required for this topic are determined. The above work lays the foundation for the development of the topic, and then the next step can be carried out according to the arrangement of the Gannt chart.

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Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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GRADING FORM: NEW ASSESSMENT

YAN ZHANG**62****ENGAGEMENT WITH LITERATURE**

Description of how the work to be done by in the project relates to the work identified in the literature review; no Discussion of any ethical issues raised by the project Identifying what has already been done within the field

8**KNOWLEDGE AND UNDERSTANDING**

Introduction is very brief but the aim and objectives are clear. Conclusion is brief and can be expanded.

5**COGNITIVE, INTELLECTUAL SKILLS**

Clear statement of which development methods are to be used there is no dissection to why

10**PRACTICAL SKILLS**

Clear Research philosophy and approach Clear



Research strategy Clear Data collection methods for each objective. Reliability and validity Clear Gantt chart showing both timing and resource use; Completed ethics form; Limited and relevant appendices

31

TRANSFERABLE SKILLS



Well-presented proposal . referencing is consistence. descent word count

8