

Response to reviewer comments

We are sincerely grateful to the editor and reviewers for their valuable time spent on reviewing our manuscript. The comments are very helpful and valuable, and we have addressed the issues raised by the reviewers in the revised manuscript. Please find our point-by-point response (in blue font) to the comments (in black font) raised by the editor and reviewers.

COMMENTS TO THE AUTHOR(S)

What I meant with discussing different types of lidar it was not about the platform (satellite, airplane, etc.) on which they are launched, but if they are elastic, raman, incoherent, continuous wave, etc. Please either state which type of lidar this study is focused on (I imagine is elastic), or provide a short review of the types of lidar existent and which ones are used for aerosol detection.

Response: Thank you for your valuable and professional feedback.

The LiDAR we use is a Mie-scattering LiDAR. Since Mie-scattering is a type of elastic scattering, Mie-scattering LiDAR is also known as elastic-scattering LiDAR. The existing LiDAR include Mie-scattering LiDAR, polarization LiDAR, Raman LiDAR differential absorption LiDAR (DIAL), high spectral resolution LiDAR (HSRL), Rayleigh-scattering LiDAR resonance fluorescence LiDAR, and Doppler LiDAR. The lidars used for aerosol detection include Mie-scattering LiDAR, polarization LiDAR, Raman LiDAR, and differential absorption LiDAR (DIAL).

Are there any previous experiments in the state of the art of aerosol detection using intelligent driving technology?

Response: Thank you for your valuable and professional feedback.

Based on the literature and materials we have retrieved so far, most detection studies use unmanned aerial vehicles as the platform, and no experimental on the integration of intelligent driving technology with aerosol LiDAR has been found. Unmanned Aerial Vehicles, when used as a platform, primarily focus on surveying and mapping. We have also conducted some manned mobile observation experiments. Additionally, our team has also conducted some experiments related to autonomous driving path planning and obstacle avoidance.

Please can you increase the resolution of Fig. 1? Some of the text is hard to read.

Response: Thank you for your valuable and professional feedback.

Okay, we have improved the image resolution.

Lines 96-104: Please provide references for the hardware parts used. Indicate the product name IPC6000, and configuration M219F-2C-4G-64G-WIFI. Are they Trade Marked? I find of high importance the millimeter-wave radar, which I imagine is used for collision avoidance.

Response: Thank you for your valuable and professional feedback.

The computing platform we used is shown in the figure below: its name is Autonomous Driving Computing Platform, model is PFAutoECU-APF8000R, and it is produced by Chengdu Panfeng Technology Co., Ltd.



Since the lidar is not commercial, more details are required. If existent, please provide a reference showing its functioning performance. Otherwise, a section presenting the custom lidar structure, specifications, performance, manufacturing, etc. is required.

Response: Thank you for your valuable and professional feedback.

The focus of this paper lies not in the hardware manufacturing of LiDAR, but in the innovation of detection methods. For those interested in LiDAR hardware, this article can be referred to, as it contains detailed information on LiDAR parameters.

Kuang, Z.; Liu, D.; Wu, D.; Wang, Z.; Li, C.; Deng, Q. Parameter Optimization and Development of Mini Infrared Lidar for Atmospheric Three-Dimensional Detection. *Sensors*, **23** (2), 892. <https://doi.org/10.3390/s23020892>, 2023.

I feel that a wider explanation of collision avoidance is required. Are the objects detected by the millimeter-wave radar and then computed as a cloud of dots for collision avoidance? If true, how are 3-d clouds of dots converted into 2-d coordinates by the control system? Which are the limits of collision avoidance, e.g., which is the minimum size it can avoid?

Response: Thank you for your valuable and professional feedback.

We have updated the autonomous vehicle system, and the detection of the environment around the autonomous vehicle mainly relies on the on-board lidar and binocular cameras.

The on-board lidar used is the RoboSense 16-channel LiDAR (model: RS-LiDAR-16). The RS-LiDAR-16 adopts a hybrid solid-state LiDAR design, integrating a 16-channel laser module. It features a detection range of over 150 meters, a measurement accuracy of within 2 centimeters, a point cloud output rate of up to 320,000 points per second, a horizontal field of view of 360°, and a vertical field of view of 30°.

Its main functions are as follows: 1、3D Modeling and Environmental Perception: The multi-channel LiDAR can scan and generate a 3D model of the environment around the vehicle. By using relevant algorithms to compare environmental changes between the previous frame and the next frame, it can easily detect surrounding vehicles and pedestrians. 2、SLAM Positioning Enhancement: Simultaneous Localization and Mapping (SLAM) is another key feature of the LiDAR. By comparing the real-time global map with the features in the high-precision map, it can improve the vehicle's positioning accuracy and enable autonomous navigation.

The binocular cameras used are the Changjiang-5 Binocular Cameras produced by Beijing Zhongke Huiyan Technology Co., Ltd. These cameras are active safety driving assistance sensors designed for commercial vehicles; they can construct a real-time 3D spatial scene ahead of the vehicle's driving path, and the system can detect pedestrians, vehicles, and lane markings ahead in real time. Its main role in autonomous driving is as follows: Binocular vision ranging, similar to how humans observe objects with both eyes,

mainly uses the parallax between different cameras at the same moment to measure the depth of the target. Binocular vision relies on two images captured simultaneously by different cameras; by calculating the parallax of an object between these two images, the depth information in the images can be obtained.

Which are the limitations of this method? Which difficulties can it encounter in real-world operation?

Response: Thank you for your valuable and professional feedback.

We have updated the autonomous vehicle system, and the detection of the environment around the autonomous vehicle mainly relies on the on-board lidar and binocular cameras.

I apologize for the inconvenience caused to you.

Lines 110-111: Please explain more in detail the physical principles of Mie scattering. Please explain to the reader why Mie scattering is able to provide better information of optical properties of aerosols than Rayleigh scattering for instance.

Response: Thank you for your valuable and professional feedback.

We have made revisions in the manuscript. “In reality, a Mie-scattering LiDAR receives the sum of Mie-scattering signals from aerosol particles and Rayleigh-scattering signals from air molecules. However, within the boundary layer, Mie-scattering is dominant, and Rayleigh-scattering can be neglected.” (refer to lines 110-113 in the revised manuscript)

Remove “*” or change it into “•” in all the equations of the manuscript. Moreover, add spaces between “or” in Eq. (6) and (7) for instance.

Response: Thank you for your valuable and professional feedback.

We have made revisions in the manuscript.

Lines 176-180: Please provide a reference for the Bolza problem. For unexpert readers on control theory, this may seem disconnected with the rest of the text. A short explanation of the Bolza problem for optimal control would be beneficial.

Response: Thank you for your valuable and professional feedback.

The optimal control problem generally involves the dynamic differential equation of the controlled system, path constraints, boundary constraints, and performance index functions. The optimal control parameters are obtained by solving the performance index functions when the controlled system meets the constraints and reaches the minimum value.

The essence of vehicle movement belongs to the problem of solving dynamic systems. Describing the dynamic characteristics of vehicles and constructing dynamic system equations, along with constraint conditions and objective functions, constitutes the optimal control problem. The vehicle trajectory can be obtained by solving the optimal control problem.

The Bolza problem, initially formulated by Bolza (2000), was one of the main problems in the classical calculus of variations on the conditions for an extremum point (maxima/minima) subject to certain constraints(Wang et al., 2021). This problem has a special feature of the mixed nature of the functional represented as the sum of an integral functional and a function on the boundary. It not only emphasizes the system state at the terminal moment, but also stresses the requirements for the control system process. The Bolza problem for nonlinear optimal control can be described as:

$$\min \psi = \phi(\xi(t_0), t_0, \xi(t_f), t_f) + \int_{t_0}^{t_f} g(\xi(t), \mu(t), t) dt$$

We have also supplemented this content in the manuscript. (refer to lines 179-183 in the revised manuscript)

Fig. 5: Please provide a label for the color bar. If possible, increase the resolution of the figure.

Response: Thank you for your valuable and professional feedback.

We have made revisions in the manuscript.

Lines 260-262: Please provide quantitative values that support the affirmation of a pollution process. Does MERRA-2 data correlate with the aerosol concentration in the station?

Response: Thank you for your valuable and professional feedback.

Through our literature search, we found that there is no information specifying the pollution thresholds for MERRA-2 data. However, under normal circumstances, an AOD value of less than 0.1 indicates very good air quality and an extremely clean atmosphere. When the AOD value ranges between 0.3 and 0.7, it indicates that the aerosol concentration is at a moderate level. This is relatively common in urban areas and may be accompanied by a certain degree of pollution. If the AOD value is greater than 1.0, it is generally considered

a high aerosol concentration, and is often associated with pollution events, sandstorms, or similar conditions. The following references include studies that use MERRA-2 data. If you are interested, you may refer to the articles below.

Sun, E., Che, H., Xu, X., Wang, Z., Lu, C., Gui, K., ... & Shi, G. (2019). Variation in MERRA-2 aerosol optical depth over the Yangtze River Delta from 1980 to 2016. *Theoretical and Applied Climatology*, 136(1), 363-375.

Lines 70-71: Please remove “, which”.

Response: Thank you for your valuable and professional feedback.

We have made revisions in the manuscript.