

▪ Supplementary File ▪

Future vehicles: interactive wheeled robots

Nan MA^{1,2}, Deyi LI^{3*}, Wen HE^{4*}, Yue DENG⁵, Jiahong LI^{1,2}, Yue GAO³, Hong BAO^{1,2}, Huan ZHANG^{1,6}, Xinkai XU^{1,6}, Yuansheng LIU^{1,2}, Zhixuan WU^{1,2} & Li CHEN^{1,2}

¹ Beijing Key Laboratory of Information Service Engineering, Beijing Union University, Beijing 100101, China;

² College of Robotics, Beijing Union University, Beijing 100101, China;

³ Tsinghua University, Beijing 100084, China;

⁴ Academy of Military Science, Beijing 100036, China;

⁵ Beihang University, Beijing 100191, China;

⁶ Beijing Union University, Beijing 100101, China

Appendix A Introduction

The Intelligent Interaction Team of Beijing Union University is guided by Academician Deyi Li, the Chinese Academy of Engineering and organized by Professor Nan Ma. The team is one of the few research teams in China which focus on interactive cognition, different from the traditional computational cognition way. Some authors of this paper come from the above-mentioned team, and others come from Tsinghua University, Beihang University, etc. who have long-term cooperation. They have been committed to the research and industrial implementation of intelligent interactive technology for self-driving vehicles.

Appendix B Catalog

This PDF file includes the deliverables of the Intelligent Interaction Team of Beijing Union University:

Figure. S1. The Intelligent Interaction Team of Beijing Union University developed the intelligent interactive central control system and applied it to BAIC's self-driving vehicles at 2018 Beijing International Automotive Exhibition.

Figure. S2. The Intelligent Interaction Team of Beijing Union University developed the RoboTaxi intelligent online vehicle reservation system and applied it to YUDAO self-driving vehicles in the 3th World Intelligent Congress and 2019 World Intelligent Connected Vehicles Conference.

Figure. S3. The Intelligent Interaction Team of Beijing Union University developed the voice interactive control system and applied it to the unmanned test of Zhengzhou-Kaifeng Avenue.

Figure. S4. The Intelligent Interaction Team of Beijing Union University developed the "Tianjin University version" driverless bus cloud intelligent interactive system and applied in the 4th World Intelligence Congress.

Figure. S5. The Intelligent Interaction Team of Beijing Union University has won the championship of the Virtual Scenario Match, World Intelligent Driving Challenge (WIDC) for three consecutive sessions in 2018-2020.

Appendix C Figure

The interaction between self-driving vehicles and multi-types people can be divided into inner-vehicle, outer-vehicle and remote cloud interactions from the perspective of physical space. The Intelligent Interaction Team of Beijing Union University has been practising self-driving vehicles since 2016. They developed the intelligence interactive central control system for self-driving vehicles, applied to the 2018 Beijing International Automotive Exhibition Shunyi Olympic Water Park, which achieves a good interaction between self-driving vehicles and humans. The system obtains cloud data through the Web interface, and graphically displays the running vehicles, driving status and real-time images of all vehicles through the display software, see Figure. S1, Annex 1.

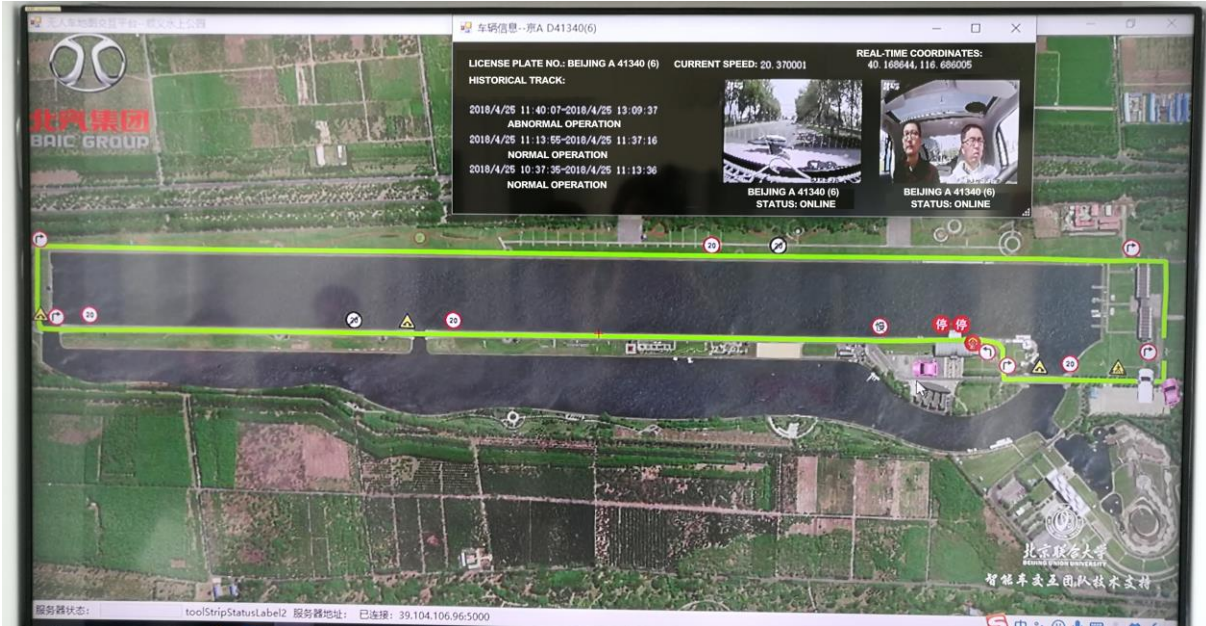


Fig. S1 The Intelligent Interaction Team of Beijing Union University developed the intelligent interactive central control system and applied it to BAIC's self-driving vehicles at 2018 Beijing International Automotive Exhibition.

The Intelligence Interaction Team developed the RoboTaxi online vehicle reservation system and applied it to the YUDAO self-driving vehicles. It was displayed in the 3th World Intelligent Congress and 2019 World Intelligent Connected Vehicles Conference. See Figure. S2, Annex 1. Passengers can carry on a test ride on a self-driving vehicle to achieve a friendly interaction between human and vehicles by the system.

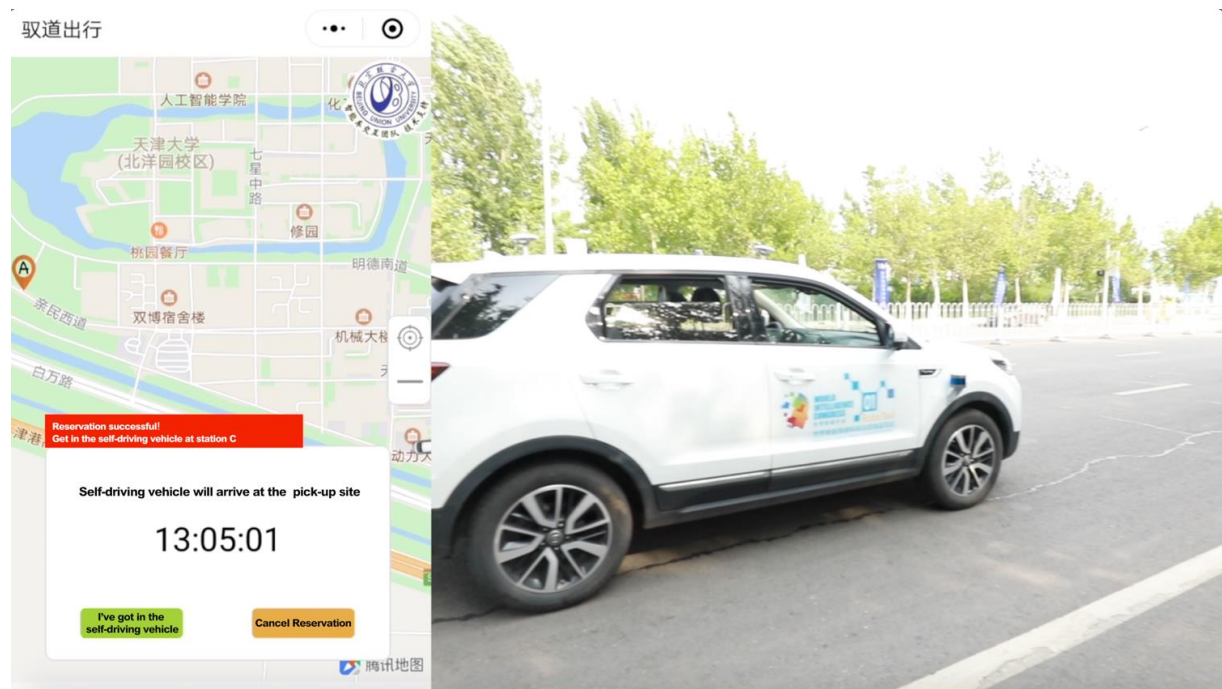


Figure. S2. The Intelligent Interaction Team of Beijing Union University developed the RoboTaxi intelligent online vehicle reservation system and applied it to YUDAO self-driving vehicles in the 3th World Intelligent Congress and 2019 World Intelligent Connected Vehicles Conference.

The Intelligence Interaction Team developed the intelligent voice interactive control system for self-driving vehicles and applied it to YUTONG self-driving bus, operated on the Zhengzhou-Kaifeng fully open intercity expressway, see Figure. S3, Annex 1. The system can broadcast the driving status of self-driving vehicles in real-time, and can control self-driving vehicles to start and decelerate by voice, stop at the station and other operations.



Figure. S3. The Intelligent Interaction Team of Beijing Union University developed the voice interactive control system and applied it to the unmanned test of Zhengzhou-Kaifeng Avenue.

It is worth mentioning that, the Intelligence Interaction Team of Beijing Union University cooperated with the Tianjin University Self-driving Vehicle Crossover Research Center, and develop the "Tianjin University Version" cloud intelligent interactive system for driverless commuter vehicles, see Figure. S4, Annex 1, which includes a map navigation, intelligent voice broadcast, interactive guidance, safety tips, route navigation, park introduction, virtual tour guide and other functions. It has been displayed in the 4th World Intelligence Congress and brought a good passenger interactive experience.



Figure. S4. The Intelligence Interaction Team of Beijing Union University developed the "Tianjin University version" driverless bus cloud intelligent interactive system and applied in the 4th World Intelligence Congress.

In order to improve the scientific research and technical ability of the Intelligence Interaction Team, we have participated in the Virtual Scenario Match of the World Intelligent Driving Challenge for three years, see Figure. S5, Annex 1.



Figure. S5. The Intelligence Interaction Team of Beijing Union University has won the championship of the Virtual Scenario Match, World Intelligent Driving Challenge (WIDC) for three consecutive sessions in 2018-2020.

In 2018, the team implemented unmanned intelligent simulation interactive system based on driverless virtual interactive simulation scenarios, which integrated environment perception and decision control, used vehicle identification technology, lane line and lidar obstacle detected techniques to achieve adaptive cruise control and lane keeping. Finally, the team emerged victorious from 91 teams and won the championship in the Virtual Scenario Match.

In 2019, the Intelligent Interactive Team designed the intelligent interactive simulation system based on the integration of GroundTruth vehicle information, obtained all information from GroundTruth through the Socket protocol, screened effective perception data and calculated the information required for decision-making based on the screened data, conducted the first-time planning through the interactive interface, and used the Frenet algorithm to complete tracking, following and overtaking, completed the decision control of the vehicle, and finally won the championship of the Virtual Scenario Match.

In 2020, the Intelligent Interaction Team designed the unmanned driving simulation interactive system to analyze the image, radar and other data provided by the simulation system and transmit it to the control decision module through the UDP protocol, to achieve the functions of highway following, overtaking and changing lanes, large curvature roads passing through large bends at high speed, and pedestrian avoidance on urban roads, and finally won the first prize of pedestrian collision competition and the second prize of highway competition.

In order to adequately carry out the interaction between humans and self-driving vehicles, the Intelligent Interaction Team carried out research on human action recognition based on vision. Taking the traffic police as an example, it developed the human action recognition system for self-driving vehicles, see Annex 1.

Annex 1: Supplementary Materials for Future vehicles: interactive wheeled robots