IRIS Team's Autonomous Car Development

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Abstract. IRIS ITS is a robotics team from Institut Teknologi Sepuluh Nopember. The team was founded in mid-2016 with the ambitious goal of competing in international robotics competitions with continuous research and technological developments. This paper presents the IRIS team brief overview of the hardware and software design of IRIS' Autonomous Car.

Keywords: Autonomous Car · IRIS · ITS

1 Introduction

The IRIS team competes in various robotics competitions, such as the annual KRSBI-B (a middle-size soccer robot competition organized by the Indonesian Ministry of Research Technology and Higher Education), where the IRIS team has consistently excelled since their first competition in 2017. IRIS Team achievements include 1st place in the KRSBI-B Regional II, 1st place in the KRSBI-B National competition, and Best Strategy in the KRSBI-B National competition. Internationally, the IRIS team has achieved significant recognition at events such as the RoboCup Asia-Pacific 2022, where IRIS earned 1st place in both the Open Challenge and Cooperation Challenge. The IRIS Team also secured 3rd place in the Middle-Size RoboCup League at RoboCup 2022 in Thailand, 5th place in the Technical Challenge at RoboCup 2024, and 6th place for the Scientific Challenge at RoboCup 2024, where the IRIS Team presented a paper highlighting their research advancements. As of 2017 to 2024, IRIS has done much research that improves the robots performance. There is some research that has been done by the IRIS team.

Autonomous cars, also known as self-driving vehicles, are designed to navigate and operate without direct human control by relying on advanced sensors, embedded systems, and decision-making algorithms. These vehicles use computer vision, sensor fusion, and control systems to perceive their environment, plan paths, and execute safe maneuvers in real-time. The development of autonomous cars presents a multidisciplinary challenge that integrates fields such as robotics, artificial intelligence, control theory, and mechanical engineering. In the context of this project, the IRIS team focuses on building a compact, vision-guided autonomous vehicle capable of navigating lanes and junctions in a simulated environment, aligning with the objectives of the FIRA Autonomous Car Challenge. Here is a picture of the IRIS autonomous car.

Fig. 1. IRIS' Robot

2 Hardware

2.1 Steering Wheel

In the vehicle's steering system, maintaining stability during turning maneuvers is a critical design In a vehicle's steering system, it is crucial to maintain stability during turning maneuvers. To achieve this, the Ackermann steering geometry is used. This principle ensures that all four wheels follow concentric circular paths that are appropriate for their positions while turning. This is especially important because the inner and outer front wheels trace arcs with different radii.

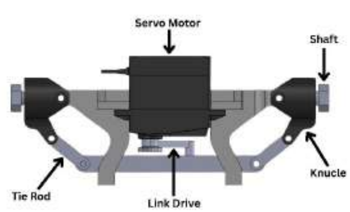

Fig. 2. Steering wheel

To maintain stability during turns, the Ackermann steering geometry is implemented. This principle is designed to ensure that all four wheels follow concentric circular paths appropriate to their respective positions during a turn. This is particularly important because the inner and outer front wheels trace arcs with different radii. The Ackermann geometry ensures that the inner front wheel has a larger steering angle than the outer front wheel, allowing all wheels to converge toward a common instantaneous center of rotation. This configuration minimizes tire slip and improves handling, especially during low-speed cornering. To actuate and control the steering angles accurately, a high-torque servo motor is employed as the primary actuator, enabling responsive and precise directional control in accordance with the Ackermann steering model.

2.2 Powering Transmission

The vehicle employs a rear-wheel drive (RWD) configuration, powered by a single DC motor. The selection of an RWD system is motivated by its ability to lower the center of gravity and enhance overall handling performance, particularly during dynamic maneuvers. This drivetrain layout contributes to better weight distribution and improved traction, especially under acceleration.

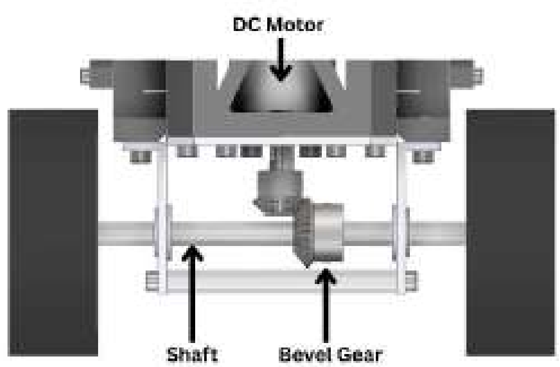

Fig. 3. Power Transmission

To effectively transfer power from the motor to the drive wheels, a bevel gear mechanism is utilized. The use of bevel gears is essential due to the difference in orientation between the motor shaft and the wheel axle. This gear arrangement enables efficient transmission of torque while accommodating angular misalignment between rotational axes, thereby ensuring smooth and reliable power delivery to the rear wheels.

The system employs a DC motor as the primary propulsion unit, which ensures efficient vehicle acceleration and stable motion control. To enable precise feedback and position monitoring, the motor is equipped with an integrated encoder. This configuration allows for accurate movement calibration and closed-loop control essential for reliable autonomous navigation.

In addition to the drive motor, the system utilizes a high-torque servo motor for steering actuation. This servo provides accurate and responsive directional control, offering accurate and responsive steering adjustments. This servo ensures dynamic maneuverability, essential for both autonomous navigation and remote-operated applications.

Both motors are driven by a custom-designed IR2184-based motor driver with high switching MOSFETs, ensuring efficient power delivery and PWM-based speed modulation. The control system integrates both drive and steering modules, enabling coordinated motion control for enhanced stability and precision in real-time operation. Both motors are driven by a custom-designed IR2184-based motor driver, ensuring efficient power delivery and PWM-based speed modulation. The control system integrates both drive and steering modules, enabling coordinated motion control for enhanced stability and precision in real-time operation.

2.3 Electronic system

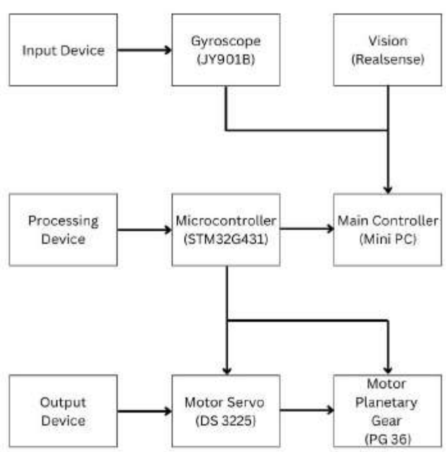

Fig. 4. IRIS' Robot

The electronic system is centered around the STM32G431K8T6 microcontroller, a 32-bit ARM Cortex-M4 MCU with integrated FPU and advanced timer peripherals, selected for its real-time performance, deterministic behavior, and suitability for embedded robotic applications. The microcontroller executes low-level tasks such as PWM-based motor control, real-time sensor interfacing, and feedback loop implementation with minimal latency. Power is supplied via a 24V Lithium-Ion (Li-Ion) battery, offering high current output to drive the electromechanical and computational subsystems. A step-down DC-DC converter regulates the voltage to 19V, providing stable input to the Mini PC, which handles high-level operations including image processing, perception, and motion planning.

The actuation layer includes DC and servo motors, interfaced through motor drivers and controlled using hardware PWM and encoder feedback for accurate position and velocity regulation. Orientation and motion data are using the JY901B IMU, which delivers multi-axis inertial readings via UART. These readings are essential for state estimation and maintaining stability during movement.

A depth-sensing camera provides three-dimensional environmental data, enabling object detection, road line tracking, and obstacle avoidance. This data is processed by the Mini PC and fused with IMU and odometry information to enhance navigation precision and autonomy.

The system architecture is modular, with reliable inter-device communication and synchronized data handling across all subsystems. It is designed with scalability, real-time constraints, and environmental adaptability in mind—ensuring robust performance during complex autonomous robotic tasks.

3 Software

3.1 Bird's Eye View

Fig. 5. Bird Eye View Camera

One of the problems of lane detection using camera-on-car perspective is the difficulty of processing the image will be harder hence makes it hard to do lane navigation using this perspective. We propose an idea where the image will be transformed into the Bird's Eye View perspective. We can formulate the relationship between the Camera-on-car view (x,y) with the bird's eye view projection (u, v) with these matrices:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} u \\ v \\ w \end{bmatrix} \quad \text{where } x = \frac{x'}{w'} \text{ and } y = \frac{y'}{w'}$$

3.2 Lane Detection

Once the system has got the bird's eye view of the image, it will continue to process the image to find the lane of the road. To find the lane we used canny edge detection and Hough Line Transform to find the lane of the road. Canny edge detection is indeed an edge detection algorithm developed by John F. Canny in 1986. It is widely used in image processing and computer vision applications to detect edges in digital images. The Canny edge detection algorithm involves several steps. Gaussian smoothing, Gradient calculation, non-maximum suppression, Double thresholding, and Edge tracking by hysteresis. The Canny edge detection algorithm is known for its ability to accurately detect edges while reducing noise and producing thin, continuous edges. It has been widely adopted in various applications such as image segmentation, object recognition, and feature extraction. The second part of the Lane Detection is the lines detection. For this we are using the Hough Line Transform. Hough line transform is a computer vision algorithm which proposes an efficient way for detecting lines in pictures [2]. It also can be used to detect other objects in an image as well.

3.3 Kinematic Control

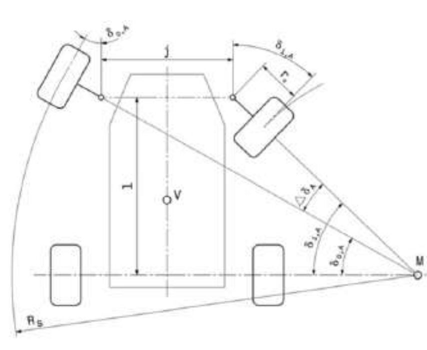

Fig. 6. Ackermann Kinematic

The kinematic control system governs how steering angles and wheel speeds are translated into physical motion based on the Ackermann steering model. This model is particularly suited for vehicles with four wheels, where the front wheels are responsible for steering and the rear wheels provide propulsion. The control algorithm calculates the appropriate steering angle required to follow a desired trajectory while minimizing slip and maintaining stability during turns.

$$\delta = \tan^{-1}\left(\frac{L \cdot \kappa}{1}\right) \tag{1}$$

$$\kappa = \frac{2 \cdot \sin(\theta)}{L} \tag{2}$$

$$x_{t+1} = x_t + v \cdot \cos(\theta) \cdot \Delta t \tag{3}$$

$$y_{t+1} = y_t + v \cdot \sin(\theta) \cdot \Delta t \tag{4}$$

$$\theta_{t+1} = \theta_t + \frac{v}{L} \cdot \tan(\delta) \cdot \Delta t \tag{5}$$

The system receives input from the vision module, such as the lane position and curvature, and converts it into real-time control signals. Using the vehicle's geometry—including the wheelbase and turning radius—the controller determines the correct angular displacement for the front wheels. This ensures that all wheels follow concentric circular paths, allowing smooth navigation around curves. Additionally, feedback from the encoder and IMU is used to validate the actual motion, enabling closed-loop correction for improved accuracy and responsiveness.

4 Conclusion

The autonomous vehicle system presented demonstrates an effective integration of mechanical design, embedded control, and computer vision to achieve reliable autonomous navigation. The implementation of Ackermann steering geometry, powered by a high-torque servo motor, provides precise directional control, while the rear-wheel drive configuration ensures efficient power transmission. The STM32 microcontroller facilitates real-time coordination of motion and sensor data processing. Visual perception is enabled through the integration of a depth camera and a JY901B gyroscope, allowing accurate lane and obstacle detection. The application of Bird's Eye View transformation, Canny edge detection, and Hough Line Transform enables robust lane detection under varying road conditions. Overall, the system reflects a compact and scalable platform suitable for further development in autonomous ground vehicle research and competition scenarios.

References

1. Lin-Bo Luo, In-Sung Koh, Kyeong-Yuk Min, Jun Wang, Jong-Wha Chong: Low-cost implementation of bird's-eye view system for camera-on-vehicle. 2010 Digest of Technical Papers International Conference on Consumer Electronics (ICCE). (2010).
2. Duda, R.O., Hart, P.E.: Use of the hough transformation to detect lines and curves in pictures. Communications of the ACM. 15, 11–15 (1972).
3. Ding, Y., Xu, Z., Zhang, Y. et al. Fast lane detection based on bird's eye view and improved random sample consensus algorithm. Multimed Tools Appl 76, 22979–22998 (2017).