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Autonomous Scaled Race-Car Platform for Safe Aggressive Vehicle Maneuvers (RU-Racer)

Alborz Jelvani, Dimitri Duma, Aliasghar Arab, Kuo Chen, Jiaxing Yu, Jingang Yi (Faculty Advisor)
Department of Mechanical and Aerospace Engineering, Rutgers University, Piscataway, NJ 08854, USA

❑ Motivation

Enable safety maneuvers for autonomous vehicles in the consistently increasing self-driving vehicles market and improving vehicle safety.

❑ Objective

Develop a capable autonomous scaled race-car platform for performing aggressive maneuvers in an indoor controlled environment (RU-Racer).

❑ Research Aims

- A scaled racecar platform capable of performing real-vehicle aggressive maneuverers.
- A distributed computing approach for providing efficient control and integration with multiple machines.
- An experimental testbed that will integrate control of RU-racer on a road-like surface for aggressive maneuvers.

❑ Approach

- Develop a motion tracking system to provide real-time information to RU-Racer.
- Integrate multiple sensors into the RU-racer platform and embed the system with the Jetson TX2 and ROS.
- Integrate sparse-RRT* algorithm for generating minimum-time feasible trajectory with nonlinear model predictive control (NMPC) to maintain safety region.
- Extend the embedded system design to an autonomous scaled truck platform for outdoor applications (RU-Rover).

❑ Up-to-Date Research Results

- Developed the RU-Racer platform and conducted closed-environment experiments.

❑ Ongoing Work

- Integrate infrared markers into motion tracking system.
- Development of the RU-Rover platform for outdoor applications.

❑ Acknowledgments

- Custom Jetson TX2 carrier board was developed by Prof. Yan Wan's team at the University of Texas at Arlington.

• Overview Design of the RU-Racer

— A circular racetrack with an overlooking stationary camera.
— RU-Racer is localized through 3 LED markers.
— Data is transmitted over the network and processed in ROS.
— Commands are sent back to RU-Racer for control.

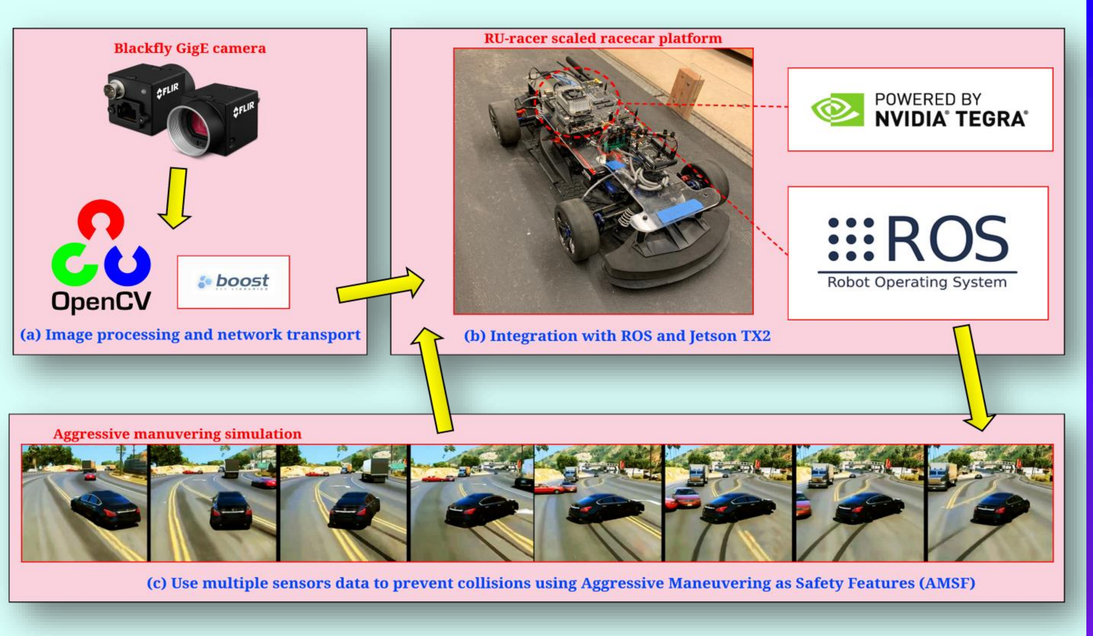
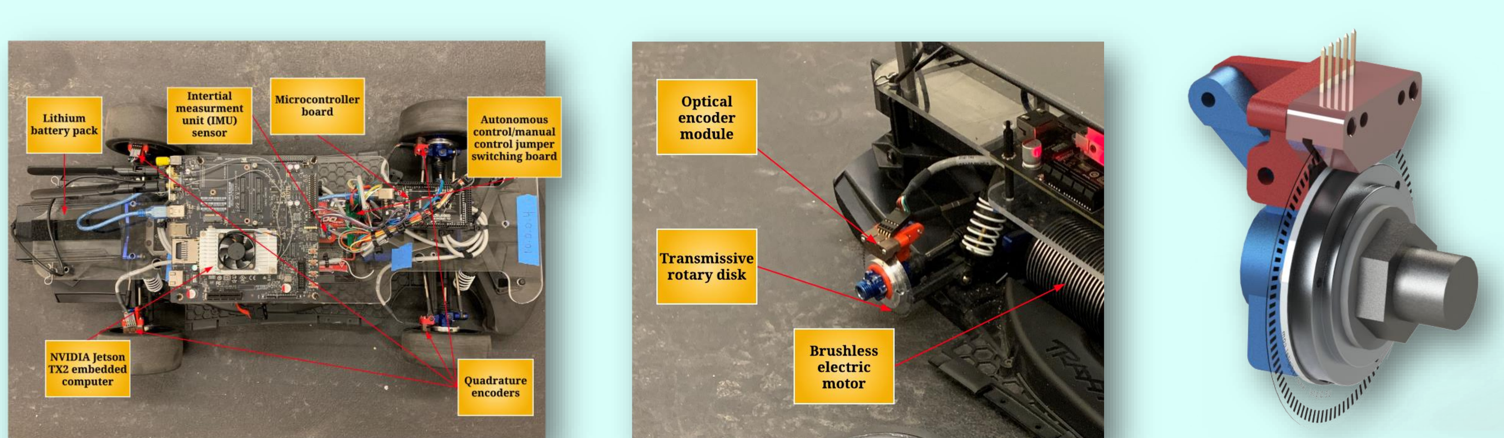


Figure 1: Diagram of RU-Racer system usage layout.

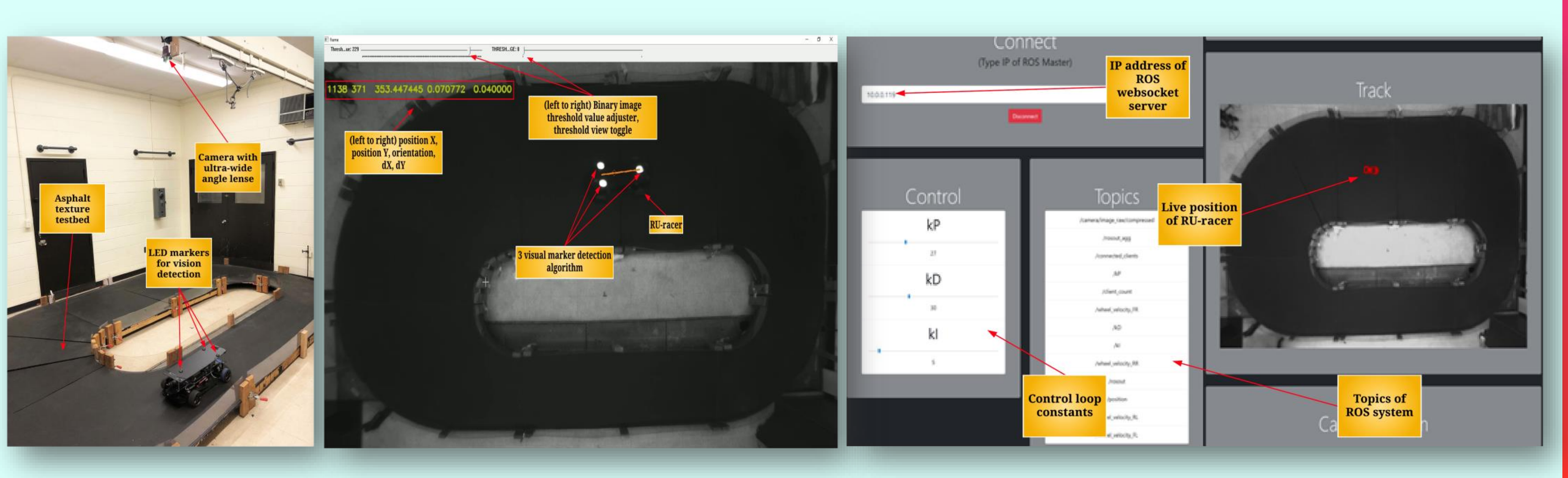
• Hardware and Software Architecture Design

— With custom designed optical encoder assemblies, RU-Racer provides angular velocities for individual wheels.
— An onboard microcontroller can perform closed-loop control of vehicle velocity, steering, and monitoring of wheel speeds.
— Custom web interface allows the monitoring of RU-Racer in real time or for data playback after running experiments.
— OpenCV application tracks RU-Racers' motion and orientation data.



(a) (b) (c)

Figure 2: The RU-Racer's sensors and electronics. (a) Top of view overview of hardware electronics without cover. (b) Close-up view of wheel encoder integration. (c) A 3-D model of the encoder mount design.



(a) (b) (c)

Figure 3: (a) The experimental testbed setup. (b) Screenshot of OpenCV application developed to track the RU-Racer and provide motion data to ROS. (c) Web interface developed to monitor RU-Racer.

• Distributed Computing Layout

— Process intensive tasks are computed on stationary systems and relayed to RU-racer's embedded system over the network.
— This design is modular and additional nodes can be added at the desire of application requirements.

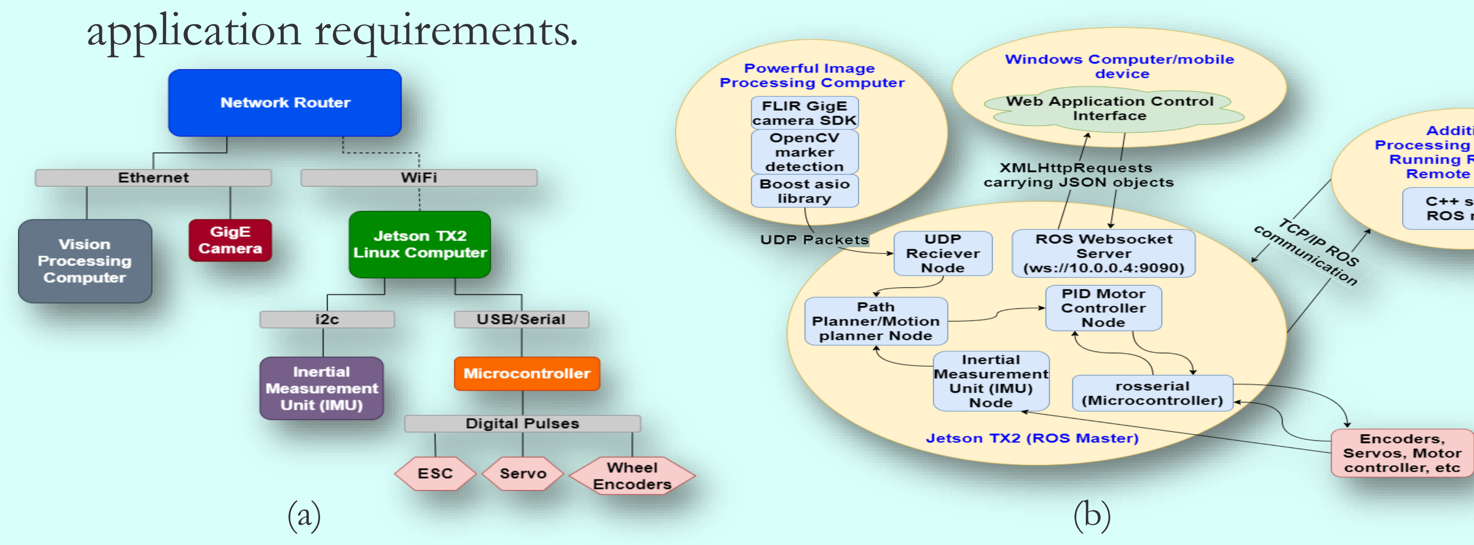


Figure 4: (a) A schematic of the physical network layout of the testbed. (b) A schematic of a possible network communication layout utilizing ROS and distributed computing.

Offloading Computationally-intensive Tasks

- In order to implement AMSF into RU-racer, spars RRT* and sum-of-squares (SOS) optimization are offloaded to a remote computer and processed much faster than the embedded system on RU-racer.

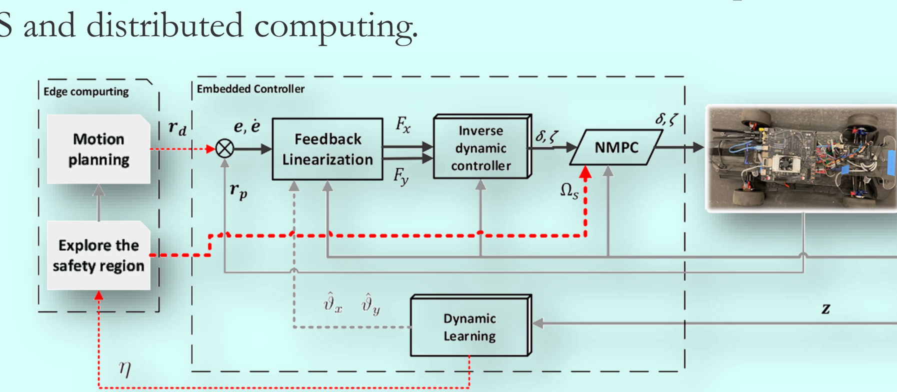


Figure 5: A schematic of the control systems design for implementing AMSF, note the edge computing block.

• Experimental Performance Evaluation

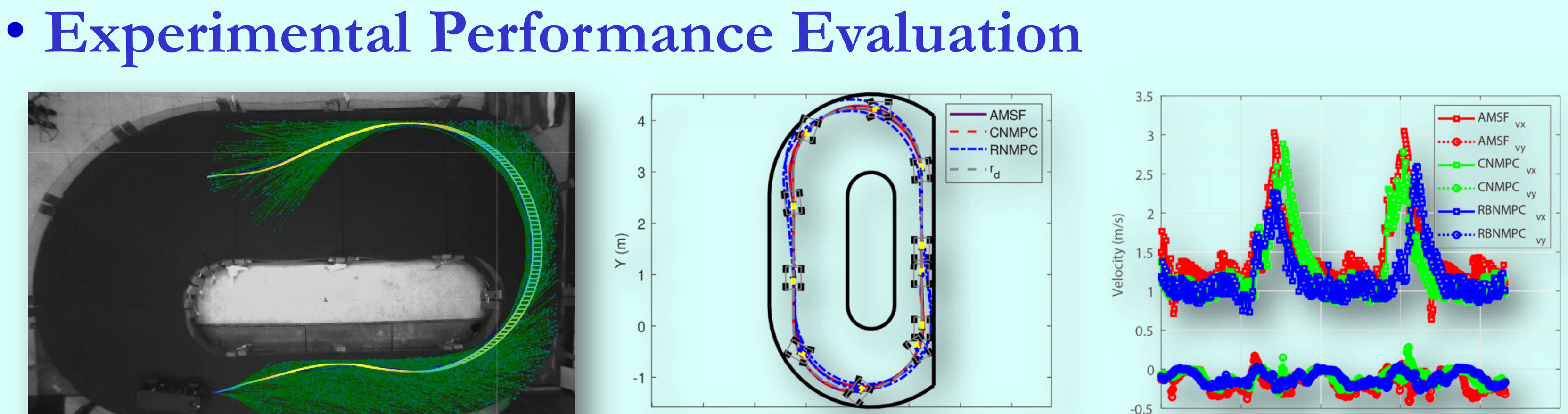


Figure 6: (a) The trajectory generated by sparse-RRT*. (b) Vehicle tracking performance of multiple autonomous controllers. (c) The vehicle velocity profiles from multiple autonomous controllers.

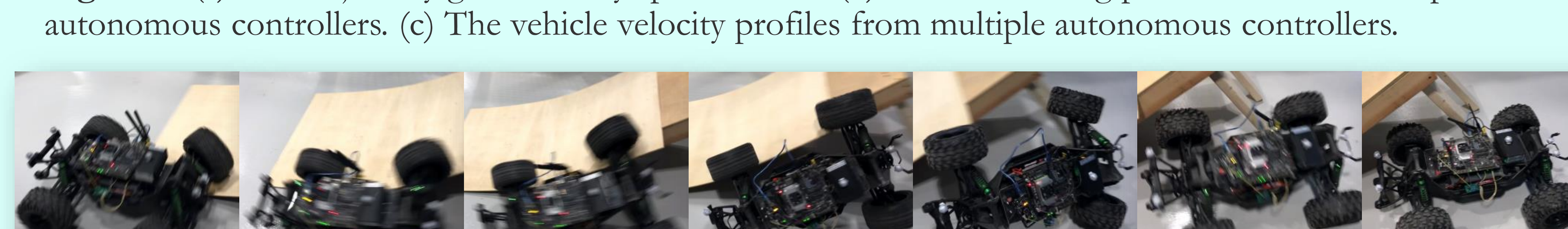


Figure 7: (Left to right) The RU-Rover performing a manual controlled stunt maneuver. This platform is in development and will be used for applications such as stunt maneuvers and item delivery.

• References

— A. Arab, K. Yu, J. Yi, and D. Song, "Motion planning for aggressive autonomous vehicle maneuvers," in *Proc. IEEE Conf. Automat. Sci.Eng.*, Dallas, TX, 2016, pp. 221–226.
— A. Arab, K. Yu, J. Yi, and Y. Liu, "Motion control of autonomous aggressive vehicle maneuvers," in *Proc. IEEE/ASME Int. Conf. Adv.Intelli. Mechatronics*, 2016, pp. 1663–1668.