Quido - the robot that won the Robotour 2011 competition

David Herman
Faculty of Information Technology,
Brno University of Technology,
Bozetechova 2, 612 66,
Czech Republic
Email: iherman@fit.vutbr.cz

Tomas Ondracek
Faculty of Information Technology,
Brno University of Technology,
Bozetechova 2, 612 66,
Czech Republic
Email: tondracek@artin.cz

Filip Orsag
Faculty of Information Technology,
Brno University of Technology,
Bozetechova 2, 612 66,
Czech Republic
Email: orsag@fit.vutbr.cz

***Abstract*—This paper describes robot Quido, which won Robotour 2011 competition. Quido was developed under the project Roboauto as a model of autonomous vehicle for park-like environments. The navigation architecture of the robot relies predominately on state-of-the-art artificial intelligence, such as probabilistic robotics and machine reasoning. This paper presents major components of the navigation architecture, which is able to steer the electronically controlled ground vehicle to a given destination without human intervention, and provides a brief introduction of the competition itself and the Roboauto project.**

I. INTRODUCTION

The Robotour competition is an outdoor delivery challenge which was started in Stromovka park in Prague in 2006. The main goal of this competition is to motivate robotic teams to design robots capable of transporting a load autonomously to the destination in park-like environments using the park paths only. Every year, the competition undergoes several changes, which make it more difficult (obstacles, concurent start, unknown start positions etc.). The sixth year was very similar to the previous one, because the last version of rules had proven extremely demanding for most of the robotic teams; thus, no new significant innovations were included.

This paper describes robot Quido, which won Robotour 2011, and its navigation architecture. Quido was developed by a team of researchers from Roboauto project, Brno University of Technology, to promote the state-of-the-art in autonomous driving of car-like vehicles. The main contribution of this navigation architecture lies in the idea of putting together several relatively simple approaches to solving particual problems in autonomous navigation and increasing the robustness of the whole system by high-level reasoning. Success in this competition is one of the results of intensive two-year development effort of Roboauto team, the primary goal of which is the development of a fully autonomous passenger car for urban environment.

The remaining part of this paper is divided into two sections: first section describes the hardware platform and the utilized sensoric system. Second section is a brief introduction to the multilayer navigation architecture.

II. HARDWARE PLATFORM

Robot Quido is a nonholomic car-like mobile robot designed and manufactured by Roboauto team. Quido is based on a remade electric-powered monster truck chassis CEN Racing Matrix5 (750x330x450 mm) with Ackermann steering. The basic chassis was extended by construction frame built of aluminium profiles, which carries most of the sensory systems. The total weight of the car is about 35.4 kg without any load. Quido is propelled by one brushless motor Turnigy Areodrive C5065 rotating at up to 1620 rpm. The motor speed is controlled electronically by Turnigy Brushless ESC 60A in ”rock crawler” running mode. Two maxi hitec-servos HS 805 BB are used for steering control. All motors are powered by a rechargeable 2-cells LiPo battery with 4.9 Ah.

A serial optical encoder with 24 ticks per rotation is used for speed feedback and gauge travelled distance. The steering angle of rear axle is measured with 0.4 degree resolution by four hall sensors. Next, the robot is equipped with high-precision tri-axis inertial sensor ADIS16355 for continual localization. The head angle is obtained from compass CMPS 03. For global localization, the robot has one GPS receiver GlobalSat BR-355.

The robot perceives the surrounding environment using three laser scanners SICK LMS 100/111. The data from them are used in terrain classification process and in collision avoidance system. For the reverse movement, the robot is equipped with two ultrasonic sensors SRF 08. All sensors, as well as the rest of electronic devices, are powered by the rechargeable Thunder-sky LifePO4 12V20Ah battery. The main control unit consists of a personal computer composed of m-ITX motherboard Asus M4A88T-I Deluxe with six-core AMD processor Phenom II, 4 GB operating memory and 64 GB SSD disk, mounted in plastic frame. The plastic frame also includes a wifi-router for wireless communication with the robot and for the connection to devices with Ethernet interface (laser rangers etc.).

III. NAVIGATION ARCHITECTURE

The navigation concept is based on parallel concatenated processing; thus, the communication between modules in different layers is sorted and buffered (see Figure I). The

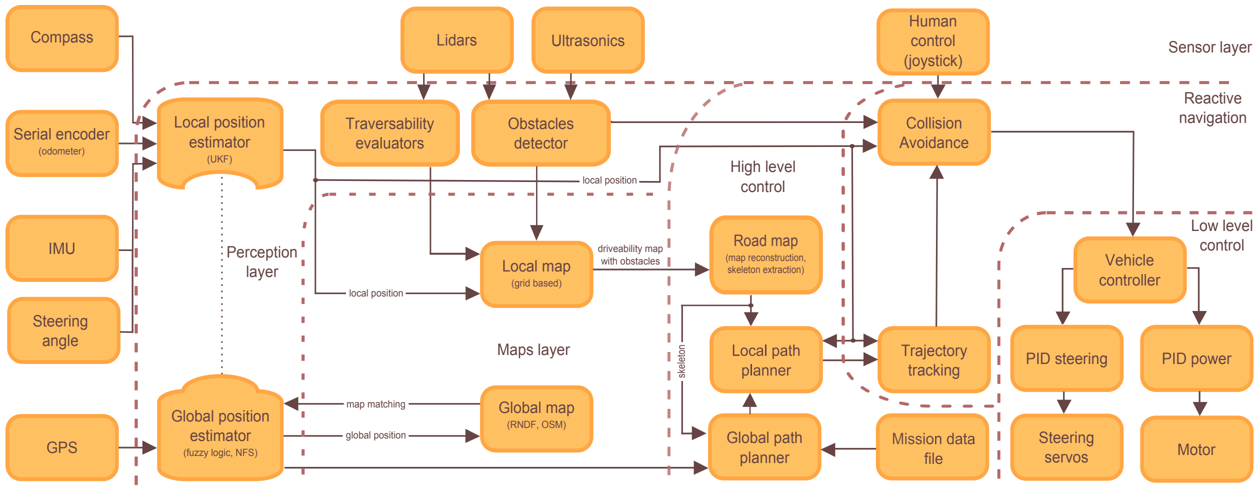

Fig. 1. Navigation architecture for robot Quido consists of twenty-five active modules

navigation system does not have any centralized arbiter. All modules are executed at their own space and can run on different computing platforms and communicate via TCP/IP protocol. There is no internal synchronization mechanism. Instead, all distributed data are globally time stamped. Besides TCP/IP, the inter process communication is based on shared memory and signals/slots mechanism.

The concept of navigation architecture consists of approximately twenty-five modules which run separately and concurrently in the six layers. The layers correspond to the following functions: sensor interface, perception, mapping, road estimation and path planning, reactive layer, and low level control.

- Sensor layer: every sensor has its own abstract class, which eliminates the interference of the rest of the system on the real sources (the data can come from a recording, a real sensor, TCP/IP, etc.); low level pre-processing of data is done here. Lidar data are received at 20 Hz from each sensor, the GPS position at 1 Hz, IMU measurement at 25 Hz, steering angle at 15 Hz, data from ultrasonic sensors at 5Hz.
- Perception layer: pre-process data are transformed to the internal data structures; the main modules here are for terrain classification and position estimation; the navigation architecture uses two positions for different level of navigation - continual and global. Continual position is used for map building and local navigation; global position reflects where the car is situated on the global map; the local position is not affected by the global position, which is very useful when the error characteristics of the sensors are diametrically different (GPS vs. IMU).
- Mapping layer: classified data are aggregated into a local 2D internal model (based on occupancy grid) according to the car position from the continual position estimator; global map is not being constructed during the run but is loaded at the start from the data file in Open Street Map format (OSM).
- Road estimation and path planning: this layer realizes high level of the reasoning; the road is estimated from the local map and is represented by a polygon; global path planner selects the local goal in the acquired polygon according to the main goals and the local planner plans the trajectory to them; the result of local planner, a sequence of maneuvers, is sent to trajectory tracking module.
- Reactive layer: consists of a collision avoidance system and path tracking; collision avoidance is a crucial component in mobile systems which are situated in dynamic environments; in our processing pipeline it represents the last active element which cannot be bridged and can affect the control of the car as a reaction to unpredictable external situation; path tracking is responsible for keeping the car on the planned path as closely as possible.
- Low level control: regulates the steering, acceleration and braking of the vehicle. Control loop feedback mechanism PID was used to achieve smooth motion on all surfaces.

IV. Conclusion

This paper provides a brief survey of the navigation architecture for the car-like mobile robot Quido that won Robotour 2011 competition. The proposed navigation mirrors two years of experience with autonomous driving in the park-like environments as well as with the competition itself. The main idea behind the presented navigation system is putting together relatively simple individual modules in such way which makes the whole system robust to unpredictable situations.

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