BFMC 2025 : Status Report 3
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Overview of Project Status

January's integration test proved quite successful in terms of general operating principle. The vehicle was able to successfully manoeuvre around the track. However, the degree of precision to which the car was able to follow the reference path was very limited. Over the past month, the focus was on calibration and tuning on the software and embedded systems side : camera parameters and height, communication between microcontroller and microprocessor, PID parameters tuning, camera feed transmission revision.

Current Phase

The need for relocalization is crucial for our approach to the problem. Our vehicle estimates its initial position and then uses dead reckoning to advance until it identifies a known sign that it can use to update its position. This relocalization therefore needs to be as precise as possible, or else the dead reckoning portion of control will accumulate the error. To address this, extensive tuning of the optimal camera height, angle from horizontal were required. A new custom mount closer to the rear of the car as well as a calibration procedure were introduced.

Sharp jerks in the movement of the car came from sudden inputs to the speed and steering angles. To address this, a model based steering PID is being implemented on the microcontroller. This modification takes input steering angles from MPC, computes the expected yaw and uses a PID to match the real yaw and the expected yaw[1]. The MPC model was also tuned to give penalties to sharper turning and speed inputs. Overall, this has reduced the jerking motion of the car.

The smooth, reliable and instant feed of the camera is essential for our understanding of what is going on with the car through the dashboard. To this effect, the implementation of the launch of the camera was revised to launch all our scripts in a single node and the transfer of data modified to use UDP (user-defined protocol) instead of the standard TCP.

Task Status - Overview

The period of reporting for January went by faster than last status. With school picking up steam for some members, and internship work for others, less time was available than over the winter holidays. However, more integration tests were accomplished as the focus of the team is shifting with the qualifications coming up. A detailed status of the tasks can be found in the attached task tracker table export[2]. The main tasks will be briefly discussed in the following.

Power Distribution Board Replacement : This task was of high priority and is complete. The design was done completely by Xin Ya, with specifications and requirements defined in consultation with the rest of the team. The board has been ordered from the supplier. General and specific implementation is detailed in complementary documents[3].

[1] See *STM32_steering_control-combined_flow.pdf*
[2] See *task_tracker_export_status_3.pdf*
[3] See *PDB_requirements.pdf*

Model Based Steering : This task was of medium priority and is well advanced. The PID has been implemented and tuned. In unit tests, the response of the car[4] and the accuracy of following a planned trajectory was superior when using the model based steering approach. However, issues were encountered when this was employed in combination with the MPC controller. Further testing is required before it can be used in a real integration run.

Sign Based Relocalization : This task was of high priority and is close to completion. The height and angle of the camera needed to be modified for two reasons. The first was for the camera being up front gave us too narrow a field of view. The second was for the accurate estimation of the distance of the car from a given sign. After initial testing in the simulator, the optimal height was found. Design of the 3D printed mount was then done by Ferréol, with unit and general testing then being done by Simon and Malo. Accurate distance computation, a prerequisite for relocalization, is dependent on our camera angle which needs to be calibrated[5].

Blocking Points and Encountered Issues

MPC & PID : The steering PID gave promising results when tested out in unit tests with a slow rate of commands. However, when testing in combination with MPC's 10 Hz rate of sent commands, the response was very disappointing. Hypotheses as to the influence of the rate of commands and the callbacks within the RTOS have been formulated, and research into the root of the issue is under way. Another hypothesis has to do with the fact that both MPC and the PID are dependent on the feedback. These two systems may become unstable when used together.

Object Detection Improvements : Lighting greatly influences the accuracy of our object detection model. A lot of the images we collected from the competition last year in Romania are very bright because the tests were done on a summer day, which is different from the one we have in our lab. This means that our model which is trained on these bright images has trouble identifying the objects in our dimly lit lab. Another issue is the lack of data for some signs. In our dataset, we included many images that were taken by walking around our neighbourhood and taking pictures of the signs. However, in Québec, we don't have any roundabouts, and our highway exit and entry signs are different.

Next Steps

The following report will be the qualifications, therefore the objective is to prepare for these. The guiding principle for the next month will be : *What can our vehicle do, and how can we show it?* As such, it is anticipated that a lot of the work will be dedicated to preparation of the qualification run.

This does not mean that more technical and high level tasks will be put aside : far from it. These tasks will undergo a shift of focus from development to fine tuning. Rather than focusing on the ability to handle a variety of situations, we will be working on enhancing the reliability of the response to the situations that we are already able to handle. This means that few or no new modifications to the current state of the algorithm will be introduced.

In terms of concrete improvements, this past integration testing revealed the following deficiencies which will be the crux of the aforementioned fine tuning : errors in MPC computation stemming from combination of controller and camera node into one, instability upon integration of the PID with MPC, difficulties with object detection in low light conditions.

[4] See *PID_responses.pdf*
[5] See *camera_angle_calibration.pdf*