Center of Automotive Research on Integrated Safety Systems and Measurement Area
Technische Hochschule Ingolstadt

CARISSMA
Automotive Safety Research

# BAYLAT Scholarship Experience Report

Research Topic: Behaviour study of literacy conventional path planners application to a self-driving car simulation in Robot Operating System framework

Author: Marcus Vinícius Leal de Carvalho

27-05-2020
Ingolstadt

# Contents

# 1. Introduction

In this paper I will briefly describe the my professional and social experiences I had during my stay in Germany as master student researcher. At first I would like to express my immense gratitude to the Bavarian University Center of America Latina (BAYLAT) and Techische Hochschule Ingolstadt,the foment agency and the university respectively which supported the reinforcement of my master thesis content during the winter semester 2019/2020 with such unique opportunity, as well as provided me the condition to learn valuable features of self-driving cars technology the best worldwide professionals, in special my supervisor and professor Werner Hüber.

## 1.1 International Partnership

The Post Graduation Program and Mechanical Sciences (POSECM) of Federal University from Santa Catarina (UFSC) in Brazil and the Technische Hochschule Ingolstadt (THI)in Germany, have established a partnership in double-degree programs in June/2016. The agreement was celebrated during the AWARE Workshop "Research and Education" and CARISSMA inauguration ceremony. In order to enrich the networking between Brazil-Germany universities, The Bavarian University Center for Latin America (BAYLAT) has been promoting and making viable the dream of numerous students and researchers from Latin America to develop their projects with the best professionals and laboratories of engineering of the world. As natural consequence, the output of these researches assist in the building of Bavaria as a center for technology and innovation. In this context I hope my research contributes, enabling more branches derive from it and further strengthen this partnership, so that future students can have the same incredible opportunity offered to me.

## 1.2 About the Author

I am an Industrial Mechanical Engineer, currently finishing my masters in Robotics field. I have applied for the BAYLAT scholarship to enrich my master project, which was originally use the Robot Operating System (ROS) to implement a simulation for docking an Autonomous Underwater Vehicle (AUV) to perform intervention-repair-maintenance (IRM) offshore tasks. However, during an international workshop in Joinville, Brazil, after the approach of THI staff, I could extrapolate the boundaries of my project scope: To perform a self-driving car simulation in ROS and compare specific features regarding trajectory execution of these distinct vehicles in their correspondent environments.

# 2. Experience Description

In this chapter I will describe the current progress of my research as well as other essential topics, such as depict the excelent structure offered to me to develop this research, social and personal experiences.

## 2.1 Technische Hochschule Ingolstadt

The Techische Hochschule Ingolstadt covers 60.000 $m^2$, offers 5 faculties and has very well equipped laboratories, with the ultimate technology equipment supplied by big multinational companies such as BOSCH, SIEMENS, BERTRANDT, FESTO, BMW, etc. Describe the amount and the quality of each department and professionals of THI would demand a whole thick book for that. So I am going to describe just 2 of these numerous structures THI covers: The library and The Center of Automotive Research on Integrated Safety Systems and Measurement Area (CARISSMA), the spots which I have mainly spent my time do develop this research.

### 2.1.1 Library

The University counts to an incredible library structure and amazing very efficient professionals, which are always ready to guide the students to reach their purposes. The library offers interesting services, such as electronic books, the free rent of tablets to study use, reservation of private rooms to developing a more focus research, automatic windows, which block the excess of sunlight through smart angles adjustment, and so on. Personally I found very interesting and technological, the automatic printers and interactive panels located in this spot, where the student can put credit, perform purchases, transferences and numerous operations which facilitate his/her life regarding the use of restaurant, the printer and so on. A special feature is the free access every night and every weekend that the student is allowed to have in this area. All these facilities provided by THI for the students make for the last an easier life and more productivity.

### 2.1.2 CARISSMA

The Center of Automotive Research on Integrated Safety Systems is a huge area designed as a new scientific control center for vehicle safety in Germany. The research building has more than 4,000 square meters of usable space, including an indoor test facility for crash tests and driving tests, a drop tower, a laboratory for Car2X communication, and a laboratory for research on safe devices Energy storage, a simulation laboratory and a HiL laboratory. In addition, CARISSMA has a free test area for vehicle tests as well as a driving simulator with a hexapod movement platform and a pedestrian protection laboratory for the development of new test and sensing methods. The aim of the facility is to contribute to increasing traffic safety from all over the world.I expect from my first research that in future be one of the seeds among numerous other researches developed in this research center. And that it can contribute with their research projects, such as "Vision Zero" - the long-term goal of zero traffic fatalities.

## 2.2 The Survey: Self-driving car simulations in Robot Operating System

The Robot Operating System (ROS) is a framework that has gained numerous supporters over the past few years by presenting a modular programming structure, so to speak. This operating system is made up of several packages that continuously interact with each other to perform the most diverse functions that you may wish to apply to a robot. Besides that, it compiles code in several programming languages such as Matlab, Java, Python, C++, among others and allows configuration and customization of several path planners, sensors [8, 1], image processing algorithms, data fusion, driver reading, etc. All this in an open-source way, which means that the user does not need to reinvent not only the wheel, but also the chassis, the rearview mirror, the engine and so on. In other words, it is possible to reuse codes and packagesks created by other ROS users available on the network (usually stored in Github) for the specific application through a "simple" adjustment. In the self-driving car simulation, numerous ROS nodes (sub-components of ROS packages) are required to make the self-driving magic. Precisely because this type of simulation involves many different parameters, the research in ROS was to understand the interaction between these nodes and packages to generate a self-driven car simulation. This way the mapping, auto-location and trajectory planning packages were used from already conventional algorithms in the literature. Being them respectively, Gmapping, AMCL and TEB. Due to the short time of the research, the vehicle model was also not generated via 0 code, but the PRIUS vehicle model was used, since it was already practically functional to load in the simulation. The sensors used to read the data were also prioritized those that were already embedded in the PRIUS code. After combining these packages in the appropriate order, it was necessary to translate the output information from the trajectory planner algorithm (TEB, Eband, dwa or RRT) to the vehicle actuators. This is because the planners implemented in the ROS, among the majority, are planned for the use of industrial robots (linear speed: x,y and angular speed in Z). Thus it was necessary to convert this type of message format to the Ackermann type, suitable for car control. Several iterations were still necessary during the adjustment of the steering controllers of the car, as well as the parameters that compose the path planners. Finally, after many iterations, the goal was finally reached, an evasive maneuver deviating from an object with good safety margin using for the identification of the obstacle, sensors conventionally used in autonomous vehicles for accurate depth detection, the laser scan.

# 3. Social & Cultural Life

In this chapter I will describe important marks during the winter semester.

## 3.1 Trip To Berlin

To know the history through books is really exciting and interesting, however having the opportunity to relive these events is fantastic. I was one of the lucky students who were contemplated in the draw for this trip. The trip was amazing, and despite the intense cold and limited time, we could visit numerous museums in Berlin and relive great part of Germany History. Among the places visited, the Reichstag Palace, Brandenburg Gate, Bunker, East Side Gallery, Berlin Wall Memorial, Victory Column and several others are worth mentioning. I think this is a mandatory point, which every exchange student should visit when is in Germany. This and other trips were essential to make new friends of other countries and in this way interact with other cultures.

## 3.2 Audi Industry Visit

Ingolstadt is the home of one of the most huge and technological industries I have seen in my life: Audi. After my suggestion the Buddies group staff have decided to arrange a visit to Audi Industry. We have spent a whole morning visiting almost all the production areas from Audi and learning with the adorable woman guide, the production phases of their cars. It is impressive the amount of cars they produce just in a day (80.000 if I am not wrong) and the amount of robots employed in production. It is so fast and so technological that if someone had told me I was in 2050 in the future I would agree! After this, I have visited the Audi museum, which is another incredible place for car lovers to go! A mix of history with technology that makes the ticket worth every penny!

## 3.3 Personal Experience

I consider myself a lucky guy. Because as if all these experiences cited above (research and extra-class) weren't enough, I still had the grace of being welcomed by a family of a Brazilian married to a German. And through this contact They took to more incredible places, such as the Munich watch, parks, etc. And the best: I have driven their Audi A4 in the incredible A9 "Autobahn". One amazing experience which needs to be highlighted is the practical class professor Hüber provided for the students of the Advanced Driving Assistance Systems class (ADAS) and his lab collaborators: A tour in Audi Sport area. In this amazing Audi private area, we could drive the most technological cars, such as Tesla, Jaguar, Audi models, and also understand the technology applied into those vehicles. I am really grateful to this professor, which is my advisor in Germany. He is incredible as a professional and as a person, that were always available to help and give his best to THI. I also had incredible meetings with my Buddy Family, an special organization done by the THI german students, and we had very cool happy-hours tasting the german delicious beer!

# 4. Research Results

Extensive simulations with different standard motion planners were implemented in ROS framework. Each one of these path plannings presented pros and cons regarding some aspects, such as trajectory smoothness, reaction time to collision, safe distance, trajectory time execution, computational cost, numerous of feasible paths generated and so on. Some partial results were already taken. However ROS framework is still an state-of-art software under development, and in this way it does not present ready-to-use metrics to measure these parameters accurately. Therefore the partial results were assessed through a visual examination of the simulations. As the project become more complex then expected, these comparison metrics [6, 3, 7, 2] will require more time to be developed by this researcher in order to finish the path planners [9, 10] evaluation in a more accurately way.The partial results of the simulation are depicted in the images below:

## 4.1 TEB Local Planner

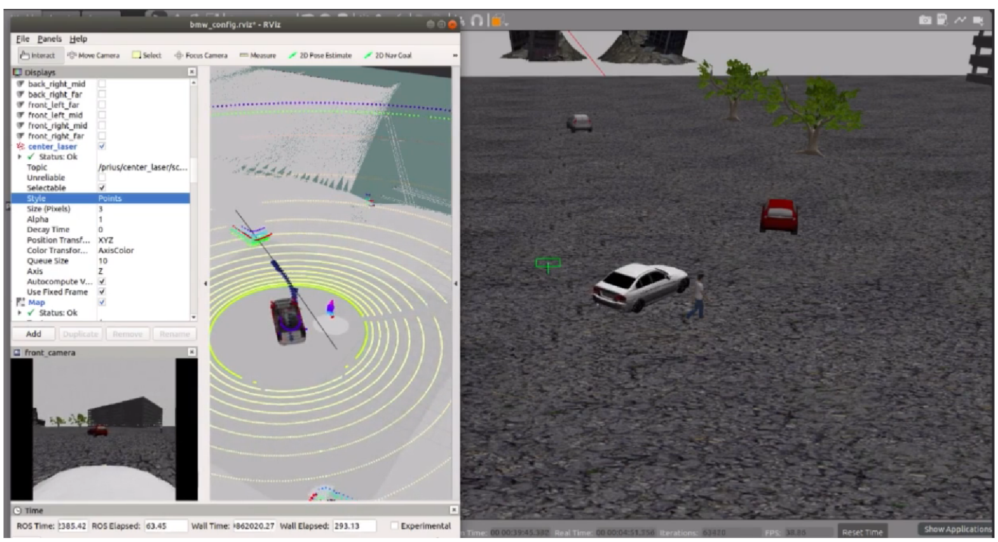

Figure 4.1: Time Elastic Band motion planner. Source: Own Authorship

### 4.1.1 Trajectory execution evaluation

The goal set to this simulation was behind the red car, as the path planner indicates below. The car took achieved the goal developing a constant velocity. Repeating the process 10 times to similar spots of this environment, it achieved the goal 10 times with success, however it collided 3 times with the boundary of the obstacles.

## 4.2 DWA Local Planner

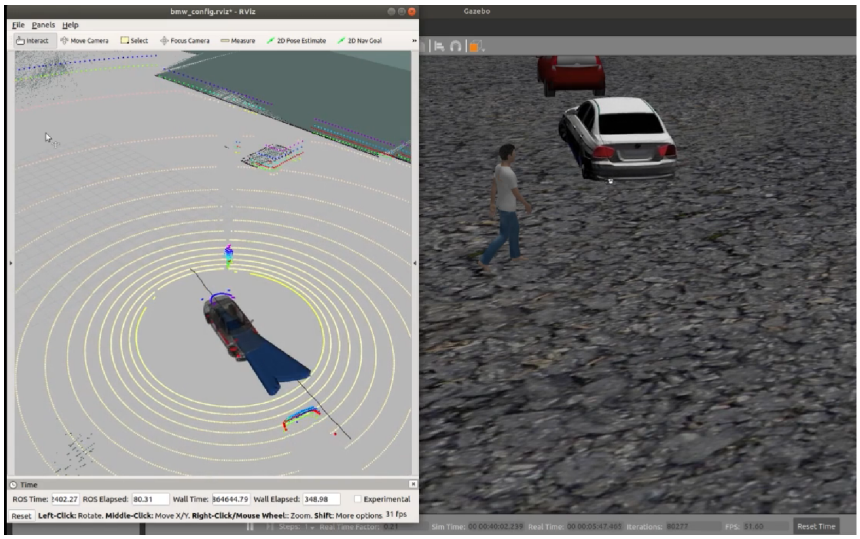


Figure 4.2: Dynamic Window motion planner. Source: Own Authorship

### 4.2.1 Trajectory execution evaluation

The dwa local planner demonstrated a conservative behavior, which means that it does not calculate as viable path the ones which require high wheel-steering angles. It does not generate multiples feasible trajectories and presents issues when a new goal spot is set to it, getting stuck if a new evasive maneuver[5] be required in short time after the realized first one. However it performs the trajectory in a reduced time comparing with the TEB local planner [4], once it simultaneously calculate just one conservative path while moving.

## 4.3 Eband Local Planner

### 4.3.1 Trajectory execution evaluation

The Eband local planner has a bigger delay in generating the trajectories, compared to the previous motion planners used. It works well to deviate from lateral obstacles, maintaining a regular the distance from them. However when it approximates an obstacle located in front of it, it stops and remains much time to recalculate a new path, and in the most times of the tests, it fails in redo the path and generate a feasible recover strategy to keep the car following the global path.

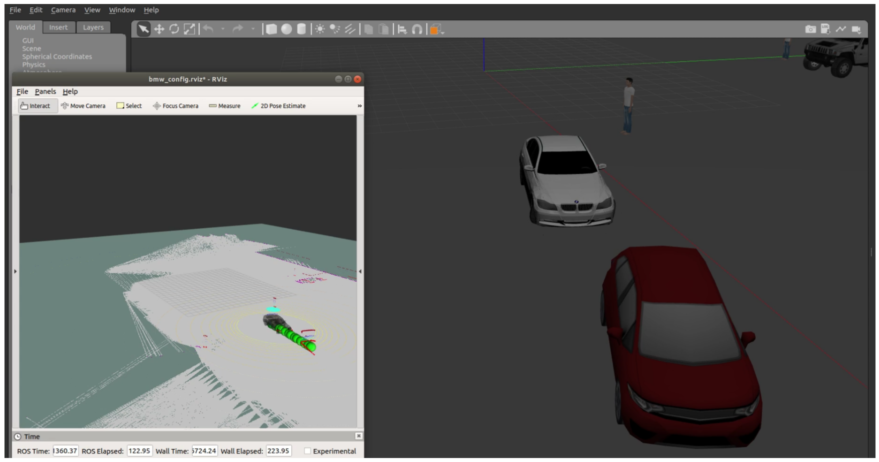

Figure 4.3: Elastic Band motion planner. Source: Own Authorship

## 4.4 RRT Exploration

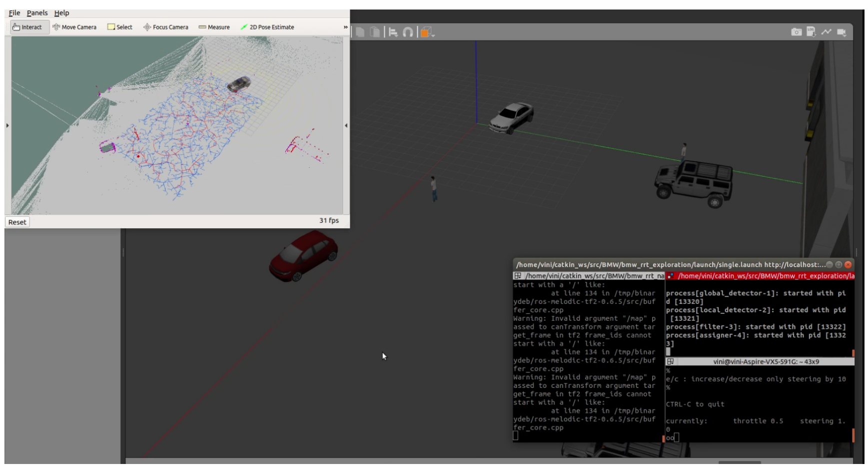

Figure 4.4: Rapidly-exploring Random Tree space explorer. Source: Own Authorship

### 4.4.1 Space exploration evaluation

The RRT [11] is being currently applied to go through the previous motion planners. It has an unique feature, which allows explore an area that was not mapped and generate feasible paths into this area, and addressing the one with best cost function to be followed by the car (drawn in red). The code to convert this exploration tree into an operational motion planner to be used by the self-driving car is currently under development

# 5. Concluding Remarks on the Stay in Germany

To conclude this report, I would like to say that I am more than satisfied with my stay in Germany, both in research aspects as personal experience. I would like to give a special thanks to BAYLAT,specially to Mr. Jonas Loeffles which always attended me in a very courteous and efficient manner, to my advisor, the professor Werner Hüber and the CARISSMA supervisor Mr. Florian Denke which guided me during an essential phase of this journey. Thanks to all these staff and personal effort I am very happy to spend more one semester in Germany to attend to an internship in AUDI, in an Advance Driving Assistance System (ADAS) area and simultaneously keep my study THI and improving my research and simulation in CARISSMA.

# Bibliography


[1] Irfan Baftiu, Arbnor Pajaziti, and Ka C Cheok. Multi-mode surround view for adas vehicles. In *2016 IEEE International Symposium on Robotics and Intelligent Sensors (IRIS)*, pages 190–193. IEEE, 2016.

[2] Alessandro Calo, Paolo Arcaini, Shaukat Ali, Florian Hauer, and I Fuyuki. Generating avoidable collision scenarios for testing autonomous driving systems. In *IEEE Intl. Conf. on SW Testing, Verification and Validation*, 2020.

[3] Benjamin Cohen, Ioan A Şucan, and Sachin Chitta. A generic infrastructure for benchmarking motion planners. In *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 589–595. IEEE, 2012.

[4] Jordi Ferrer Sánchez. Implementation and comparison in local planners for ackermann vehicles. 2018.

[5] Fernando Garcia, Pietro Cerri, Alberto Broggi, Arturo de la Escalera, and José María Armingol. Data fusion for overtaking vehicle detection based on radar and optical flow. In *2012 IEEE Intelligent Vehicles Symposium*, pages 494–499. IEEE, 2012.

[6] Christos Katrakazas, Mohammed Quddus, Wen-Hua Chen, and Lipika Deka. Real-time motion planning methods for autonomous on-road driving: State-of-the-art and future research directions. *Transportation Research Part C: Emerging Technologies*, 60:416–442, 2015.

[7] Harmish Khambhaita and Rachid Alami. Assessing the social criteria for human-robot collaborative navigation: A comparison of human-aware navigation planners. In *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, pages 1140–1145. IEEE, 2017.

[8] Ryosuke Okuda, Yuki Kajiwara, and Kazuaki Terashima. A survey of technical trend of adas and autonomous driving. In *Technical Papers of 2014 International Symposium on VLSI Design, Automation and Test*, pages 1–4. IEEE, 2014.

[9] Brian Paden, Michal Čáp, Sze Zheng Yong, Dmitry Yershov, and Emilio Frazzoli. A survey of motion planning and control techniques for self-driving urban vehicles. *IEEE Transactions on intelligent vehicles*, 1(1):33–55, 2016.

[10] Ioan A Sucan, Mark Moll, and Lydia E Kavraki. The open motion planning library. *IEEE Robotics & Automation Magazine*, 19(4):72–82, 2012.

[11] Hassan Umari and Shayok Mukhopadhyay. Autonomous robotic exploration based on multiple rapidly-exploring randomized trees. In *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 1396–1402. IEEE, 2017.