UNIVERSITÉ CÔTE D'AZUR

Advancement report of TER

Federated Learning for Autonomous Cars

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Contents

1 Advancement: Introduction

In this document we will explain, for each chapter, the content that we plan to write for the final report.
Here is the plan that we have to follow :

- Introduction / Identification of the project (title, students (with background), supervisor, type of project, date, etc.)
- Presentation of the subject (problem, context, users, scope).
- State of the art (Positioning of the solution in relation to the existing, Retained implementation, explanation of the software architecture and the core of federated learning)
- Realised work (Our thought process, implementation, deployment and metrics/results)
- Project management (Work organization, communication)
- Conclusions (Results obtained and perspective on the work)
- List of bibliographic references.
- Annexes

2 Planned chapters and advancement

Below, are all the sections that we plan to write in the final report. Some sections have full text that could be similar to the end results, others have bullet points.

2.1 Introduction

2.1.1 Presentation of the group

The introduction is composed of title, students (with background), supervisor, type of project, date, etc..

This project is supervised by :

- Diane LINGRAND
- Frederic PRECIOSO

Our project group is composed of four members :

- Hadrien BONATO-PAPE (SI5-WIA)
- Hossein FIROOZ (M2-EIT Digital)
- Vincent LAUBRY (M2-IoTCPS)
- Erdal TOPRAK (M2-SD).

Despite our differences in our specialities we all have some background in machine learning.

Hadrien studied at the Faculty of Sciences of Toulon in Electronics and Computer Science during two years. And since 3 years he study computer science at Polytech Nice Sophia, specialized in Web and IA. He have mainly worked for the French Army and for Cap Gemini, and "fostr", his own company.

Vincent studied at the Faculty of Sciences of Valrose. His first two years of study were in mathematics and computer science, his third in computer science only, his fourth in a Master's degree in computer science and finally, his fifth year currently at Polytech in IoT-CPS.

Erdal studied at the Faculty of Sciences of Valrose. His first two years of study were in mathematics and computer science, his third in computer science and his fourth and fifth in a Master's degree in computer science specialized in data science.

2.1.2 Presentation of the subject

Our subject, named "Deep Learning for Autonomous Cars / Federated learning, inter-object communication", is one of the two sub-projects for autonomous cars.
The first sub-project has for objective to make multiple computer vision models coexist together in the most efficient way.
Our sub-project has for objective to implement federated learning, a distributed way of doing machine learning, to compute constrained edge devices.

The project is placed in the context of technologies used by contemporary autonomous vehicles. By their nature, these vehicles have a limited computing capacity, and choices must be made in order to optimize the in order to optimize the use of Machine Learning models. This is part of a realistic approach: where the computational performance of on-board systems evolves rapidly, these performances quickly reach limits, because of energy consumption or cooling constraints for cooling for example.
The goal of our project is to decentralize this machine learning in order to reduce the weight of the embedded systems in autonomous vehicles. Moreover, it allows a certain "communication" between vehicles, which allows them to collaborate in the management of events that occur to them.

2.2 State of the art

2.2.1 Software Architecture

This section has not been finalized, here are the bullets points we want to write about:

- Explaining the basic architecture of an ML model
- Explaining the basic architecture of a federated ML approach
- Explaining some of the basic tools, computer languages behind the project

2.2.2 Federated learning

Federated learning (also known as collaborative learning) is a machine learning technique that trains an algorithm across multiple decentralized edge devices or servers holding local data samples, without exchanging them. This approach stands in contrast to traditional centralized machine learning techniques where all the local datasets are uploaded to one server, as well as to more classical decentralized approaches which often assume that local data samples are identically distributed.

Federated learning enables multiple actors to build a common, robust machine learning model without sharing data, thus allowing to address critical issues such as data privacy, data security, data access rights and access to heterogeneous data. Its applications are spread over a number of industries including defense, telecommunications, IoT and pharmaceutics.

2.2.3 Retained implementation

This section has not been finalized, here are the bullets points we want to write about:

- Explaining the variety of solutions for this problem
- Explaining why we retained X solution
- Explaining the pros and cons of the retained solution

2.3 Realised work

2.3.1 Understanding the algorithms

This section has not been fully finalized, here are the bullets points of what we did:

- Exploring the different federated learning algorithms
- Exploring the fed. avg. algorithm of flower

Here are the bullet points of what we need to do:

- Explaining, in a simple way, the concept behind the algorithm
- Explaining the pros and cons of our retained solution (and it's underlying algorithm)

2.3.2 Implementing a local proof of concept

This section has not been fully finalized, here are the bullets points of what we did:

- Implementing a POC of federated learning with flower
- Implementing a POC of federated learning with tensorflow (and the MNIST dataset)

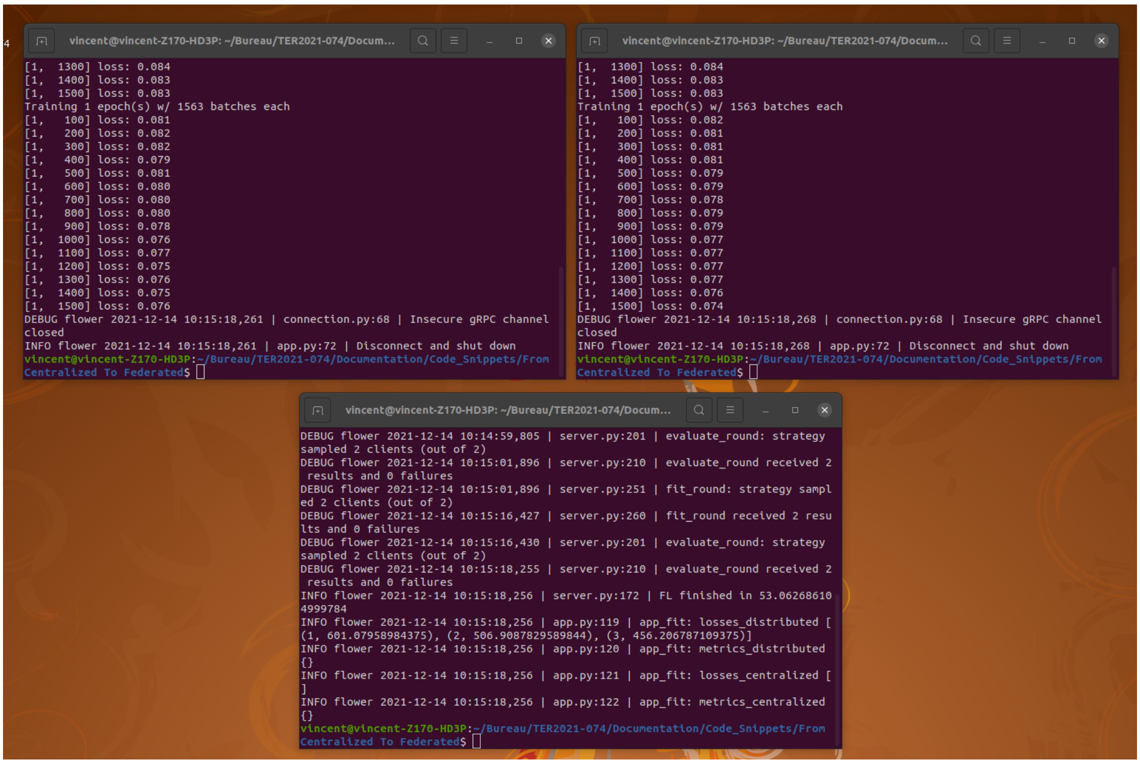

Figure 1: A first implementation of Federating Training with Flower Framework

2.3.3 Deploying our solution

This section has not been finalized, here are the bullet points of what we need to do:

- Test our local proof of concept on the track with the RC cars
- Observe, improve and modify if needed

2.3.4 Test, metrics and results

This section has not been finalized, here are the bullet points of what we need to do:

- Implement a working solution of the RC cars first
- Gather metrics, implement/deploy tests and write down the results

2.4 Project management

This section has not been finalized, here are the bullet points of what we need to do:

- Continue writing issues and documentation on our github
- Once the project is deployed we need to step back and analyze our final organization and how we could improve it later on

2.5 Conclusion and perspectives

2.6 Bibliography

2.7 Annexes

3 Advancement: Conclusion

So far, in mid December, we have advanced in a number of ways. We have been able to understand our subject, identify existing solutions and deploy a local proof of concept. We are now focused on deploying and testing our main use case which is lane detection and accuracy of our federated learning over time.

4 Advancement: Bibliography

[1] Federated learning page from *Wikipedia*. https://en.wikipedia.org/wiki/Federated_learning

[2] Federated learning documentation page from *TensorFlow*. https://www.tensorflow.org/federated/federated_learning

[3] Federated learning example for image classification from *TensorFlow*. https://www.tensorflow.org/federated/tutorials/federated_learning_for_image_classification

[4] Li, T., Hu, S., Beirami, A., and Smith, V. (2020). *Federated multi-task learning for competing constraints.* arXiv preprint arXiv:2012.04221. https://research.fb.com/wp-content/uploads/2021/05/Federated-Multi-Task-Learning-for-Competing-Constraints.pdf

[5] Smith, V., Chiang, C. K., Sanjabi, M., and Talwalkar, A. (2017, December). *Federated multi-task learning.* In Proceedings of the 31st International Conference on Neural Information Processing Systems (pp. 4427-4437). http://papers.neurips.cc/paper/7029-federated-multi-task-learning.pdf

[6] Zhu, H., Zhang, H. and Jin, Y. *From federated learning to federated neural architecture search: a survey.* Complex Intell. Syst. 7, 639–657 (2021). https://doi.org/10.1007/s40747-020-00247-z https://link.springer.com/content/pdf/10.1007/s40747-020-00247-z.pdf

[7] Tengchan Zeng, Student Member, IEEE, Omid Semiari, Member, IEEE, Mingzhe Chen, Member, IEEE, Walid Saad, Fellow, IEEE, and Mehdi Bennis, Fellow, IEEE *Federated Learning on the Road: Autonomous Controller Design for Connected and Autonomous Vehicles* arXiv:2102.03401v1 [eess.SY] 5 Feb 2021. https://arxiv.org/pdf/2102.03401.pdf

[8] Anh Nguyen, Tuong Do, Minh Tran, Binh X. Nguyen, Chien Duong, Tu Phan, Erman Tjiputra, Quang D. Tran *Deep Federated Learning for Autonomous Driving* arXiv:2110.05754v1 [cs.LG] 12 Oct 2021. https://arxiv.org/pdf/2110.05754.pdf

[9] Krunal Kshirsagar : Research Engineer And Writer @OpenMined *MAKING AUTONOMOUS VEHICLES ROBUST WITH ACTIVE LEARNING, FEDERATED LEARNING AND V2X COMMUNICATION.* Article posted on September 3rd, 2021. https://blog.openmined.org/making-autonomous-vehicles-robust-active-learning-federated-learning-v2x/

[10] Virginia Smith, Chao-Kai Chiang, Maziar Sanjabi, Ameet Talwalkar *Federated Multi-Task Learning.* 31st Conference on Neural Information Processing Systems (NIPS 2017), Long Beach, CA, USA. https://proceedings.neurips.cc/paper/2017/file/6211080fa89981f66b1a0c9d55c61d0f-Paper.pdf

[11] Xinchi Qiu, Titouan Parcollet, Javier Fernandez-Marques, Pedro, P. B. Gusmao, Daniel J. Beutel, Taner Topal, Akhil Mathur, Nicholas D. Lane *A First Look into the Carbon Footprint of Federated Learning.* https://arxiv.org/abs/2102.07627v3

[12] Gábor Szegedi, Péter Kiss, and Tomáš Horváth *Evolutionary federated learning on EEG-data.* http://ceur-ws.org/Vol-2473/paper14.pdf

[13] Lynda Ferraguig, Yasmine Djebrouni, Sara Bouchenak, Vania Marangozova *Survey of Bias Mitigation in Federated Learning*. Conférence francophone d'informatique en Parallélisme, Architecture et Système, Jul 2021, Lyon (virtuel), France. hal-03343288 https://hal.archives-ouvertes.fr/hal-03343288

[14] Shadi A. Noghabi, Landon Cox, Sharad Agarwal, Ganesh Ananthanarayanan *The Emerging Landscape of Edge-Computing*. GetMobile: Mobile Computing and Communications Volume 23 Issue 4 December 2019 pp 11–20. https://doi.org/10.1145/3400713.3400717 - https://dl.acm.org/doi/10.1145/3400713.3400717 - https://www.microsoft.com/en-us/research/uploads/prod/2020/02/GetMobile__Edge_BW.pdf - https://www.researchgate.net/publication/345139045_The_Emerging_Landscape_of_Edge_Computing