OpenMP®

SC'21 Booth Talk Series

OpenMP® API and Autonomous Driving

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Programme

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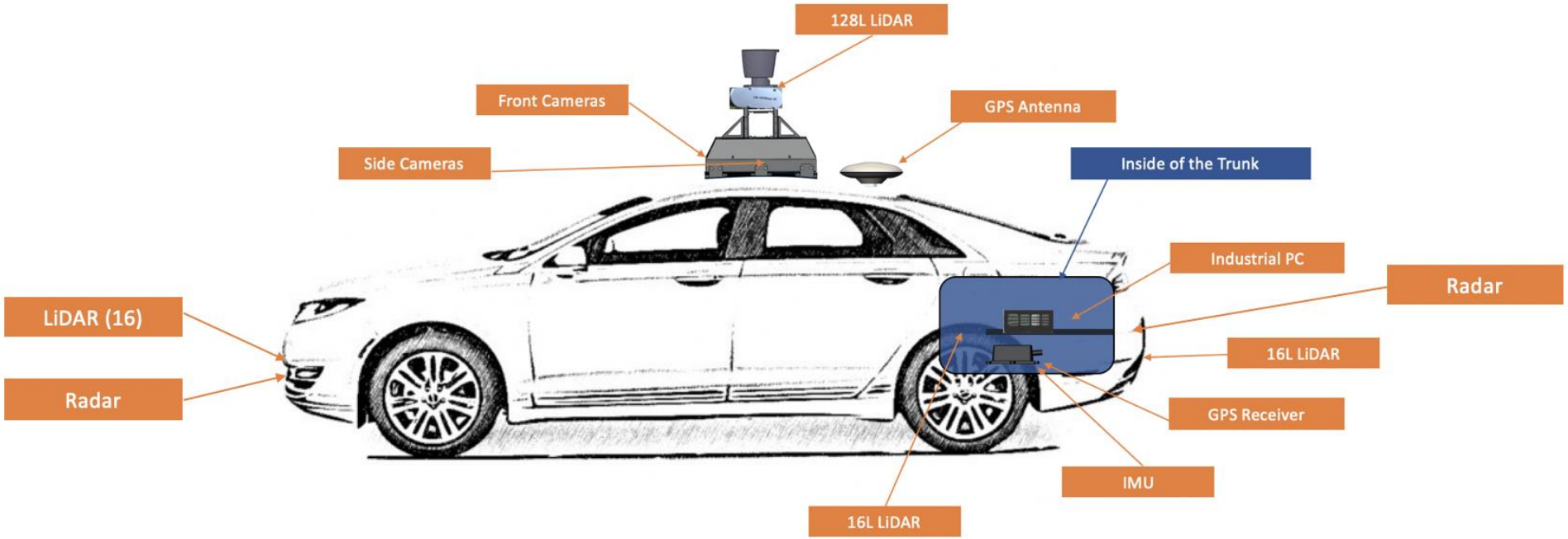
Introduction



Introduction

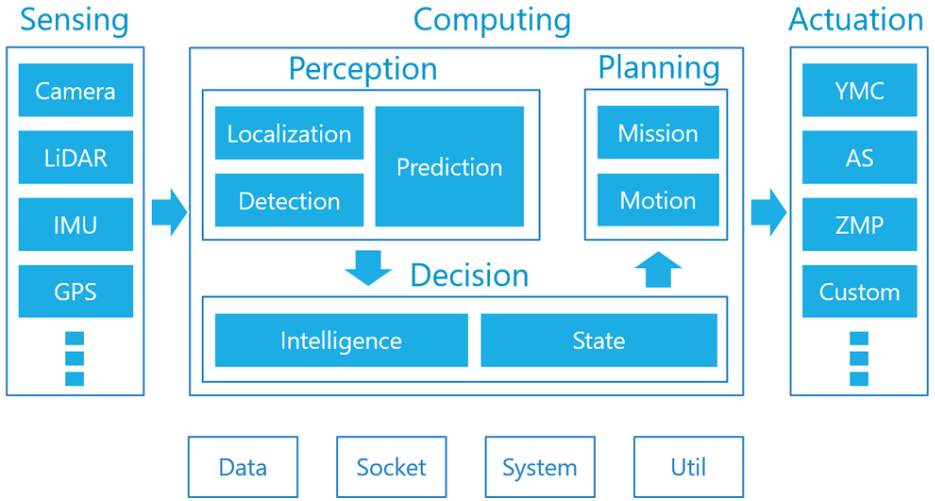
- Execution time of autonomous driving system is essential for safety
- Human driver reacts within 300 msec
- Autonomous system should react within 100 msec
- This booth talk discusses how OpenMP is used to speed up autonomous driving software running on embedded systems
- This work is the subject of a blog on the OpenMP website *www.openmp.org/blog*

Autoware platform

- Autonomous driving open source platform
- Founded in 2015 by Shinpei Kato of Nagoya University
- Sixty members
- Used in thirty vehicle models
- Qualified to pilot driverless vehicles on public roads in Japan
- Used in fifteen autonomous driving projects around the world

Autoware platform

- **Sensing** from multiple sensors
- **Computing** to plan the driving. This has as steps:
  - **Perception** of localization of vehicle and of its surroundings
  - **Decision** of next moment action
  - **Planning** of route, velocity, etc
- **Actuation** of output of computing for specific vehicle

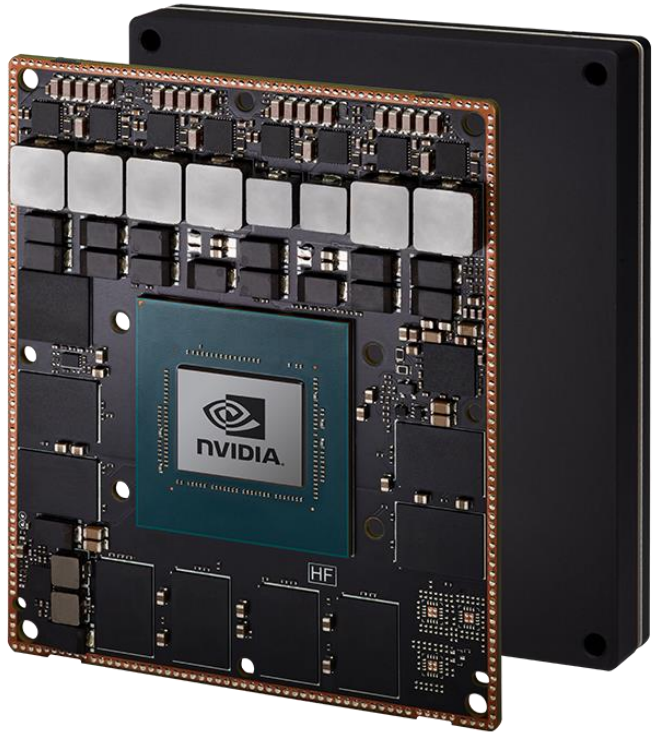


Autoware platform

- The OpenMP API has been used to parallelize
  - `euclidean-clustering` module used in the Detection phase
  - `points2image` module used in the visualization of the maps
- The following OpenMP language features were used:
  - `omp target teams distribute`
  - Allocation of memory that can be accessed by both host CPU & the GPU
- This work was performed by Lukas Sommer of TU Darmstadt

Autoware platform

- Target platform is
  NVIDIA Jetson AGX Xavier
- Embedded system with
  - 8 - core ARM CPU
  - 512 - core NVIDIA Volta GPU



Autoware platform

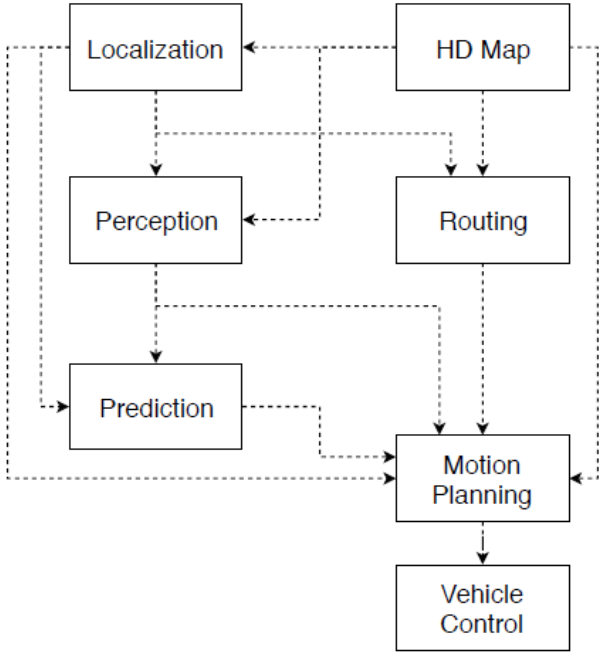
- Performance results:
  - Speed of `euclidean-clustering` module increased by factor of 3.25
  - Speed of `points2image` module increased by factor of 2.5

Apollo AI platform

- Founded in 2017 by Baidu
- Platform is used in Apollo vehicles:
  - Minibuses
  - Valet parking vehicles
  - Driverless taxis on one of the sites of the 2022 Winter Olympics
- Plans for 1000 fully autonomous vehicles in collaboration with BAIC
- First batch of T4 road test licences in China in 2019

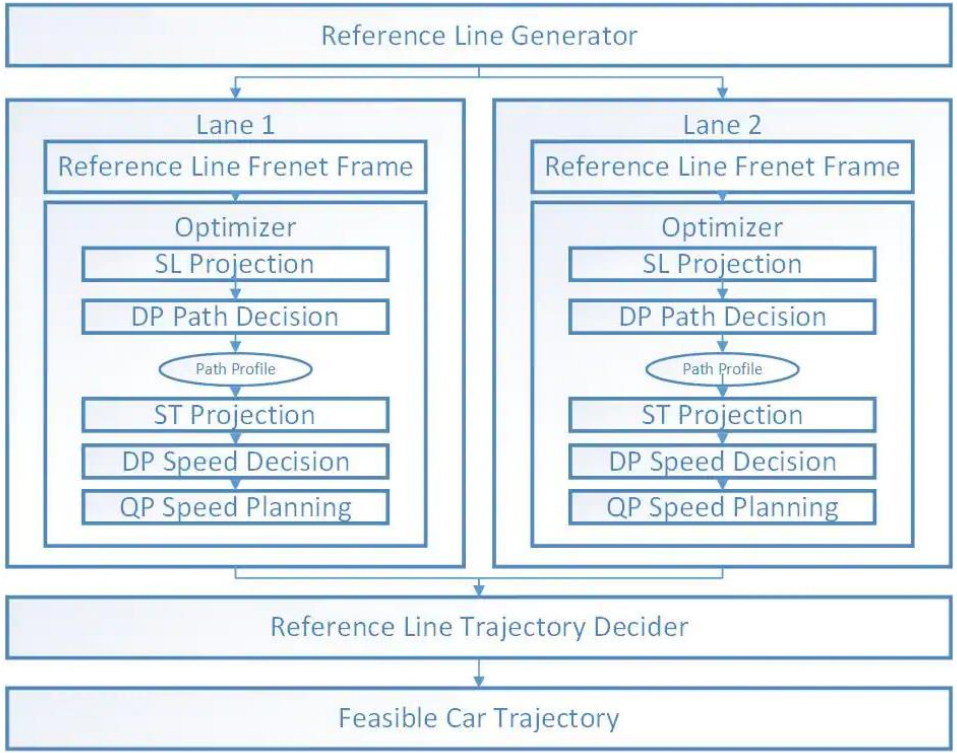
Apollo AI platform

Software overview



- This study focused on the optimization of the motion planning module
- Work performed by Hung-Ju Tsai, Yuan Chen and Yang Wang of Intel

Apollo AI - Overview of motion planner



Apollo AI - Target Platform

- Intel Atom CPU
  - C3995 CPU @ 2.1 GHz
  - X86_64 architecture
  - 16 cores
  - 16 GB memory

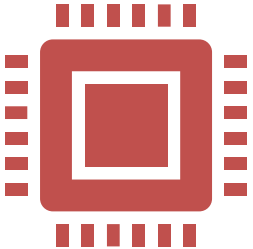
Apollo AI - OpenMP parallelization

- Loop candidates for parallelization were identified by analyzing
  - CPU time
  - Loop trip count
  - Loop dependence
- OpenMP multithreading was applied to selected loops
- The performance was improved by factor of 1.4 if 8 threads were used
- No gain was obtained with more than 8 threads

Conclusion

Autonomous driving

OpenMP has been used to optimize autonomous driving software



Embedded systems

OpenMP has been used to optimize software on embedded systems in cars

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link.openmp.org/sc21 Videos and PDFs of OpenMP SC'21 presentations