SC’21 Booth Talk Series

OpenMP® API and Autonomous Driving

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Programme

• Introduction
• Autoware platform
• Apollo AI platform
• Conclusion
• 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
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
• 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
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

Reference Line Generator

Lane 1
Reference Line Frenet Frame
- Optimizer
  - SL Projection
  - DP Path Decision
- Path Profile
- ST Projection
- DP Speed Decision
- QP Speed Planning

Lane 2
Reference Line Frenet Frame
- Optimizer
  - SL Projection
  - DP Path Decision
- Path Profile
- ST Projection
- DP Speed Decision
- QP Speed Planning

Reference Line Trajectory Decider

Feasible Car Trajectory
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