Final Degree Project, Master and Doctoral Studies at the CAOS research group in the Barcelona Supercomputing Center

- Getting a Master/ Ph.D. degree is fundamental to your career if you want to reach key technical positions in IT companies (Microsoft, Intel, NVIDIA, ...). Besides, making a Ph.D./Master is an experience that will stay with you for the rest of your life.
- The Computer Architecture / Operating System research group (www.bsc.es/caos) at the Barcelona Supercomputing Center seeks for excellent Master and Ph.D. students to carry out research in the topic of accelerators (GPUs) and multicore architectures for automotive, avionics, rail, and space domains. The positions cover from dealing with real computing boards that can be used in future cars/planes/satellites to making cutting-edge proposals on hardware/software design to optimize embedded-system computing. Just in the automotive domain, current trends towards autonomous driving and electric vehicles do not only make this a very fertile area of research but also an area in which qualified professionals are highly demanded all over the world.
- The CAOS group has a prominent publication record in peer-reviewed top-tier conference and journals. The member of the CAOS group has coordinated European Projects and projects with the European Space Agency in the area of embedded real-time systems. Francisco J. Cazorla, the coordinator of the CAOS group, has also been awarded an ERC grant (https://erc.europa.eu/about-erc/mission), one of the most prestigious grants for a European researcher.
- The CAOS group offers candidates the opportunity to carry out doctoral studies in cutting-edge research topics.
- After their graduation, CAOS group PhD students have started their professional career in international companies including: Telefonica I+D (Spain), International Computer Science Institute (ICSI – affiliated with UC Berkeley), Barcelona Supercomputing Center (Spain), Cobham Gaisler (Sweden), IBM (USA), Arm (UK), Shenzhen Institute of Advanced Technology (China), Intel (Spain), Intel (Germany), Semidynamics (Spain).
- Below you can find examples of Final Degree Projects (Treballs de Fi de Grau/Trabajos Final de Grado) we are advising (will co-advise). This will give you an idea of the type of topics we cover.
- Do not hesitate in contacting me for any other questions such as: What Degree do I need to enroll Master/Doctoral studies? What qualifications do I need? How long does a Ph.D. take?

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Performance Analysis of GPUs and CPUs for Artificial-Intelligence Based Autonomous Systems

Scope

Autonomous driving (AD) cars are forcing automotive industry to adopt ***massively-parallel processors***, delivering much higher computing performance, in order to timely execute complex decision-making AI software. This has resulted in heterogeneous MPSoC (multi processor system on chip) hardware being considered in latest chip designs for the automotive domain (e.g. NVIDIA Orin). This trend is expected to continue as automotive on-board software (e.g. ***Advanced Driver Assistance Systems and AD***) already comprises more than 100 million lines of code, with performance demands achieving unprecedented levels.

Modeling the ***timing behavior*** of highly-critical automotive applications, comprising ***millions of lines of code***, and quantifying how performance changes for different types of applications on top of high-performance hardware is a hard endeavor. This is, however, an inescapable concern since autonomous cars are meant to provably to react within a stipulated time frame to ensure ***safe and timely operation***.

Project Description

As part of this project,

(i) the candidate will work with applications relevant for autonomous driving (AD), which will be run in automotive hardware platforms or simulators thereof to collect performance and hardware monitor measurements.

(ii) the candidate will analyze the behavior of the execution time of those applications with already available tools for statistical analysis correlating execution time with monitors' behavior, and quantifying performance variability and sensitivity to platform characteristics and configuration.

The result of the project will be submitted for publication to an international journal or conference.

Keywords *Automotive, Autonomous Driving, Performance and statistical analysis, Performance models*

CAOS group and BSC

BSC-CNS (Barcelona Supercomputing Center) is the National Supercomputing Facility in Spain and manages MareNostrum, one of the most powerful supercomputers in Europe. The mission of BSC-CNS is to investigate, develop and manage information technology in order to facilitate scientific progress.

The Computer Architecture - Operating System interface (CAOS) group has a long track record of in leading projects with industry (e.g. Intel, DENSO, Thales, Rockwell Collins, and the European Space Agency) and EU projects on embedded systems.

Project reference. FDW-CAOS-AutomotivePerfStatistics

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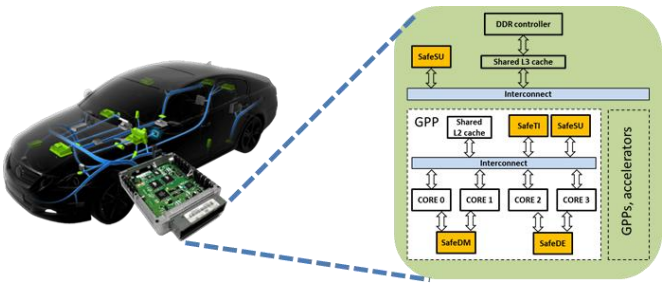
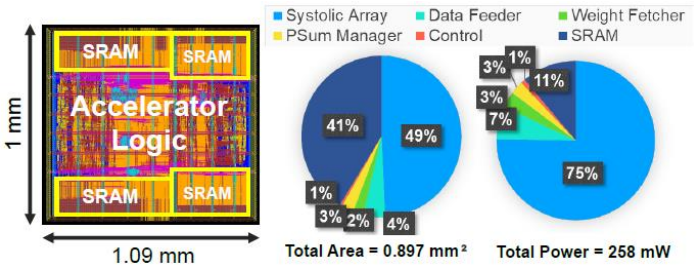
Automotive and Space Open Source Processor and Accelerator Designs

Scope

Oppositely to x86 and ARM Instruction Set Architectures (ISAs), **RISC-V emerges as an open source alternative** attracting high attention from industry worldwide, but particularly European safety-relevant industry (**automotive, space, avionics, robotics**, etc.). **RISC-V is becoming the new standard for hardware** design as **Linux became for operating systems** in the past.



While some open source RISC-V processors are already available, they **lack some hardware components** (e.g., accelerators, monitoring units, etc.) so that they can be adopted by relevant industries (automotive, space, etc.).



Extending those RISC-V processors with support for observability, controllability and AI acceleration is instrumental to get those processors adopted in safety-critical domains so that they can be guaranteed to **deliver the performance needed reliably**, and be tested easily against their corresponding safety requirements.

Project Description

As part of this project,

(i) the candidate will work with processor designs (Verilog, System Verilog, VHDL) for the automotive, space and avionics domains, using appropriate simulators and FPGAs. Those processors already include part of the hardware support needed to be adopted in safety-critical domains.

(ii) the candidate will evaluate those processors using industrially-relevant applications and benchmarks, and will enhance specific hardware components to increase performance (AI accelerators), test the processor (traffic injectors), and analyze its behavior (performance monitoring units).

The result of the project will be submitted for publication to an international journal or conference.

Keywords *Processor design, accelerator, AI, automotive, space, safety, performance*

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The Computer Architecture - Operating System interface (CAOS) group has a long track record of collaborations with key hardware design industries in projects (e.g., Intel, IBM, Frontgrade Gaisler, Infineon, Arm, etc.), and has already developed a number of open source RISC-V hardware components (https://bsccaos.github.io/).

Project reference. FDW-CAOS-HardwareDesignRISCV

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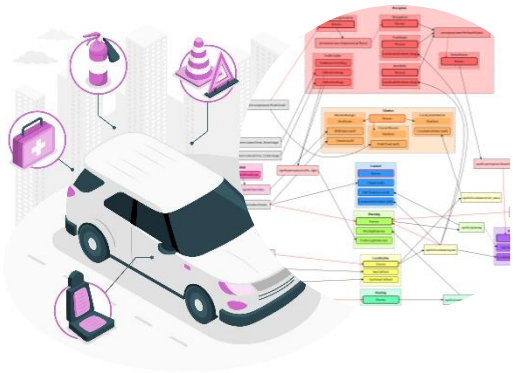
Optimized Middleware Solutions for Artificial-Intelligence Based Autonomous Driving Systems

Scope

Artificial Intelligence solutions have been increasingly deployed in the Automotive market to provide ***Advanced Driver Assistance Systems (ADAS)*** *solutions or even enable* ***Autonomous Driving (AD)*** *operation:* ***Pedestrian detection****, unintentional* ***lane crossing monitoring****, and* ***Tesla AutoPilot*** *are just few examples of this trend. As part of these AI-based functionalities, a huge amount of data from sensors like cameras and LiDARs is timely processed through a sequence of components (Perception, Routing, Planning, etc.) before triggering an action (e.g., speed reduction, breaking, or simple signaling). The complex interaction between modules is mastered with* ***specialized middleware*** *(e.g., ROS2, CyberRT, or Autoware) running on top of the automotive operating system.*



Assessing ***functional correctness*** *and* ***timely behavior*** *of such functionalities requires a deep understanding of how their execution is regulated by the (combination of) the* ***middleware and operating system scheduler****. Such knowledge is difficult to extract from the architectural description; nonetheless it is necessary to* ***optimize*** *the middleware configuration and* ***guarantee the correct execution*** *of the AI-based functions.*

Project Description

As part of this project,

(i) the candidate will work with reference autonomous-driving middleware solutions (e.g., ROS2, CyberRT, or Autoware) as well as relevant applications for autonomous-driving functions (e.g. image recognition) to be deployed and executed on top of a representative automotive hardware setup or simulators.

(ii) the candidate will study the interaction between the middleware and operating system layer in determining the system schedule and identify proper metrics and methods for devising optimal middleware configurations.

The result of the project will be submitted for publication to an international journal or conference.

Keywords *Automotive, Autonomous Driving, Automotive middleware, Schedule*

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The Computer Architecture - Operating System interface (CAOS) group has a long track record of in leading projects with industry (e.g Intel, DENSO, Thales, Rockwell Collins, and the European Space Agency) and EU projects on embedded systems.

Project reference. FDW-CAOS-AutomotiveMiddleWare