Center for Embedded Systems (CES)

A CISE-funded Center

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Design Tool for Mobile Low-power Processors

Embedded smart devices such as cellular phones and tablets have emerged as the new technology drivers for the semiconductor industry. Mobile low-processor chips have evolved from single core processors into multi-core architectures that integrate 10-20 processor cores, 40-60 customized hardware units or accelerators and many memory blocks. In other words, the state-of-the-art mobile processors integrate upwards of hundred fairly complex intellectual property (IP) blocks into a single chip. A constant need is higher performance, stringent low power requirements, and short time to market. The on-chip interconnection architectures that connect these IP blocks together in cohesive systems have emerged as a key determinant of mobile processor performance and power consumption. These interconnected architectures are implemented as a Network-on-Chip (NoC); that consists of interconnected routers and IP blocks.

CES researchers have developed a computer-aided design (CAD) tool chain for developing the NoC architecture for future Qualcomm mobile processor chips. The NoC tool chain automatically generates high performance, low power on-chip interconnection architectures that are able to successfully address multiple traffic classes, multiple use-cases, deadlock avoidance, multiple clock islands and bit-width optimization. In minutes, the tool chain is automates and performs design task that can take several weeks of manual effort. Consequently, the synthesized interconnection architecture and the overall mobile processor depict better performance, lower power consumption, and less time to design. The next generation smart phone products will have much higher performance requirements with the same or incrementally longer battery lifetimes. Consequently, future generations of mobile processor chips will integrate ever-increasing numbers of IP blocks on the same chip. The NoC design tool developed by the CES team is a key technology that will enable Qualcomm to maintain its dominant position in the mobile low power processor market.

> **Economic Impact:** A center sponsor, Qualcomm Inc is the market leader in mobile low-power processors aimed at smart phones and tablets. There are an estimated 5.2 billion cellular phone subscribers worldwide. It is expected that the number of low power mobile processors that are utilized by such devices will hit the 500 million mark by 2015. The increases in efficiency and development savings can be expected to have substantial economic impacts on the electronics industry and on the nation's competitive position.

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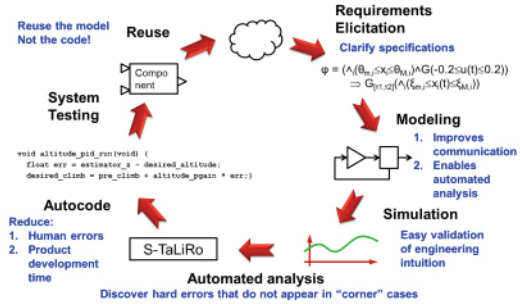
Safer Automotive and Aerospace In-Vehicle Control Systems

Current system design practices do not guarantee correct system functionality under the prevailing short development cycles. Since automotive and aerospace systems are safety-critical, design methodologies that can improve confidence in the overall system design are sought after by industry.



Model Based Development (MBD) cycle using S-TALIRO.

One such design methodology is the Model Based Development (MBD) framework where the design of the system starts with a model of the system. Such models are usually developed in a modeling environment that supports a block diagram Graphical User Interface (GUI). GUIs enable modeling of both the physical components of a control system (modeling of the automobile engine), as well as the cyber components (modeling of software that controls engine performance).

CES Researchers developed S-TALIRO, a software tool that systematically checks a given system's model by searching for an input that demonstrates that a functional requirement is not satisfied. Such a functional requirement could be that the engine never stalls while the vehicle is cruising. The process of discovering systems' operating conditions that produce the desired system's behaviors that violate functional requirements is referred to as falsification. Even if a falsifying behavior cannot be found, the system behaviors that came the "closest" to violating the desired property are returned to the user.

The advantage of this technology is that most formal verification methods seek a mathematical proof that a property is satisfied. Unfortunately, these mathematical methods do not scale to the complexity of a typical industrial control application, nor do they mathematically "understand" the model's semantics due to proprietary modeling formats. Because S-TALIRO is a simulation-based approach it is immune to these difficulties and, thus, is a more robust 'model-based verification' that for the first time is being made available to industry. The primary applications of this advance are in automotive and aerospace in-vehicle control systems such as powertrain control and avionics.

> **Economic Impact:** The complexity of modern automotive and aerospace systems is enormous. Sponsors consider this a breakthrough even though results are still at the research stage and have not yet been applied on actual development projects. Currently, both the automotive and the aerospace industries are moving into MBD practices. There is a clear need for tools that verify the correctness of a system with respect to functional requirements. It is often said that verification represents 50% of the development cost of in-vehicle control systems. It is within the realm of possibility that S-TALIRO could reduce development costs factor by 5 to 10%.

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