National Workshop for Research on Transportation Cyber-Physical Systems: Automotive, Aviation, and Rail

Position Paper: iSpace Model Reference CPS

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The NITRD Call for Position Papers has highlighted a vision of a Cyber-Physical Systems (CPS) for future transportation systems and has provided an excellent background information, opportunities, and challenges on this CPS vision. This position paper proposes and describes an iSpace (Intelligent Space) Model Reference Cyber-Physical Systems as a potential approach.

1. What are three fundamental limitations in the design and implementation of today's automotive, aerospace and rail CPS?

- Lack of a complete design methodology to capture distributed domain knowledge.
- Highly complex operating environments with large uncertainties.
- Extremely high performance demand due to safety and socioeconomic costs.

2. What are the three most important research challenges?

- Intelligently prioritize decision objectives under different operating conditions.
- Process massive data to extract features for proper decision making in real-time.
- Integrate real-time secure, reliable and fault tolerant network based C3: command, control, and communication for large-scale cyber-physical transportation systems.

3. What are promising directions?

- Model referenced automotive system tracking, analysis, detection, accident avoidance and guidance.
- Distributed real-time optimal and interconnected, autonomous "ad hoc" control.
- iSpace and mass sensor processing technologies.

4. What innovations and abstractions should be considered for future transportation CPS?

- Physical layer abstraction.
- Information layer abstraction.
- Seamless integration of these two layers as with cyberspace as a bridge.

5. What are possible milestones for the next 5, 10 and 20 years?

- **5 years out** – integration of driver-assist devices with resultant driver warnings. Voice recognition and execution of navigation demands with associated complete sub-maneuver management.
- **10 years out** - vehicle control override based on integrated monitoring / assessments / predictive path modeling. Interactive traffic management systems.
- **20 years out** – "Auto-pilot" mode for steady state driving conditions with low interruption conditions such as freeways.

iSpace (Intelligent Space) Model Reference technology integrates distributed sensors, distributed actuators, and distributed controller over secure and fault tolerant cyber spaces, to make intelligent real-time operating and planning decision for safe, reliable, efficient, and effective transportation systems. iSpace technologies collaborate/cooperate globally to solve local challenging problems that cannot be solved otherwise. The iSpace Model Reference CPS is based on:

- Distributed sensors/actuators, and distributed computational and artificial intelligence.
- Interconnected "ad hoc" model reference control.
- Advanced mechatronics and forward looking technology road map.
- Fault tolerant cyber space (e.g., smart communication routing/switching over different physical networks).
- Massive in-situ sensor measurements, communications, and data mining.
- Real-time parallel processing resource allocations.

In this CPS position paper, we propose to focus on automotive systems for analysis and testing. Extension of the proposed concepts/approaches can be readily extended to other transportation systems such as air and rail. A conceptual diagram of the iSpace Model Reference CPS is depicted in Figure 1. A major focus of the proposed CPS is in the use of massive real-time data to improve the driving safety of novice and impaired drivers who are over involved in crashes. Causes of these crashes include inattention, low alertness, aggressive/reckless driving, use of alcohol/drugs, and lack of experience. The highway system is complex and takes notable skill to negotiate safely on a continuous basis. This position paper describes an approach to monitor driver behavior and control vehicular dynamics for novice drivers as well as impaired, distracted and older drivers through the use of massive in-situ sensor measurements and communications ("ad-hoc control". The anticipated results will not only be improving roadway safety but also enhancing the efficiency in our transportation system, such as throughput, fuel efficiency, and long term planning.

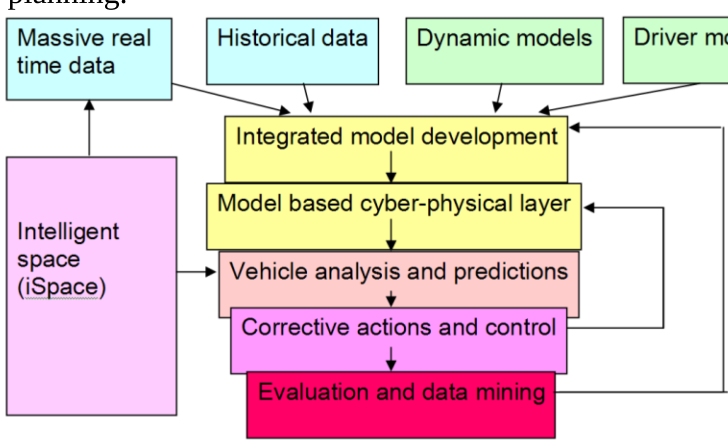

Figure 1: iSpace Model Reference CPS for Automotive Systems

The following tasks are suggested to develop the iSpace Model Reference CPS:

- Integrated modeling of driver, vehicle, and network dynamics
- Develop strategy to minimize congestion
- Develop supplementary driver aids/warning systems to avoid problems
- Investigate benefits of inter-vehicle data sharing (for potential problem predictions)
- Develop saleable technologies to reduce accidents & fatalities and to improve fuel / energy efficiency and emissions

- Verify safe and effective operation of systems over full operating envelope
- Real-time adaptive fault tolerant transportation
- In-situ data for real-time planning and operation in response to traffic conditions

Currently, the authors have two iSpace/vehicle systems related projects:

- "AIS Gene-library based real-time resource allocation on time-sensitive large-scale multi-rate systems," funded by National Science Foundation.
- "Massive Sensor Based Congestion Management System for Transportation System," funded by Department of Transportation.

These two research projects set the foundation for the proposed effort. The authors believe that investigating and developing an iSpace Model Reference CPS will usher in an amazing era of prosperity, innovation, and collaboration for transportation systems for the new millennium.

Biography

Timothy Chang is a Professor and Associate Chairman at the Department of Electrical & Computer Engineering, NJIT. Prior to joining NJIT in 1991, he was a Program Manager at Kearfott Guidance and Navigation Corp., NJ. His areas of interest include: ultra-high precision systems, genetic systems, robotics/motion control, traffic control systems, vehicle dynamics and control, decentralized control systems, and web-based experiments. Dr. Chang was a recipient of nine education awards and Thomas Edison Patent Award from the New Jersey Research Council in 2007. (973-596-3519, chang@njit.edu)

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