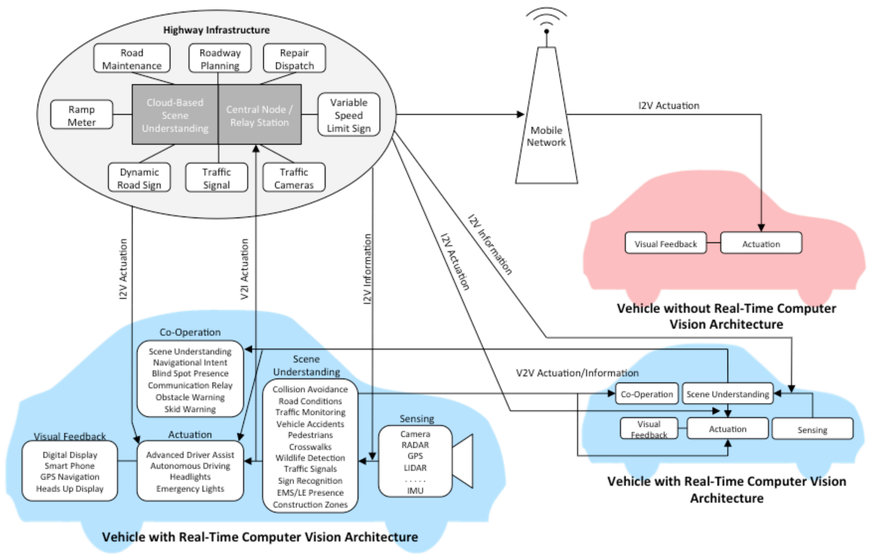
Synergy: Anytime Visual Scene Understanding for Heterogeneous and Distributed Cyber-Physical Systems

Overview

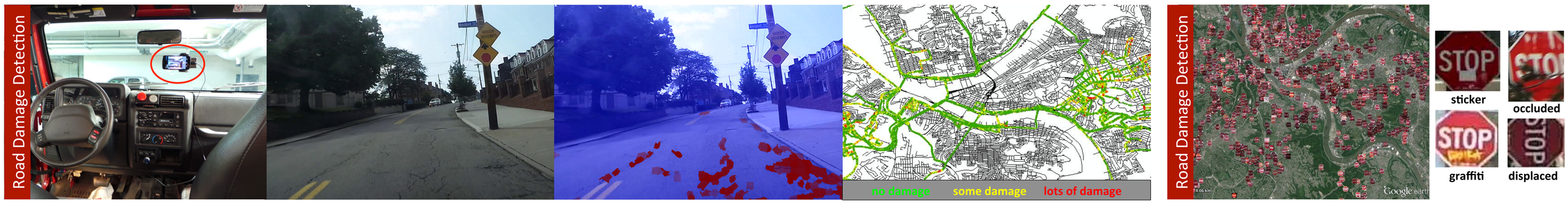
The theory and practice of cyber-physical systems has strongly impacted the development of autonomous driving, and has spurred ideas for future smart transportation and roadway infrastructure. This research trend is exciting but much remains to be done: (a) the best autonomous CPS platform today lags behind any responsible human driver; (b) V2V standards are emerging rapidly but most communication is limited to transfer of vehicle state such as position and speed; (c) smart roadway infrastructure development varies regionally and success is limited to semi-automatic traffic congestion re-routing (V2I).

In order to fully harness their potential, cyber-physical systems must be capable of exploiting one of the richest, and at the same time complex, cues that humans take completely for granted: seeing and understanding the visual world. If such a system existed, it would be possible to drive more intelligently and transfer information V2V and V2I about road and environment condition and events/anomalies to improve situational awareness. This proposal brings together experts from many disciplines – computer vision, sensing, embedded systems, machine learning, big data analytics, sensor networks – with strong experiences in transportation related projects, to make cyber-physical systems 'see' and 'understand' the visual world using cameras and 3D sensors.



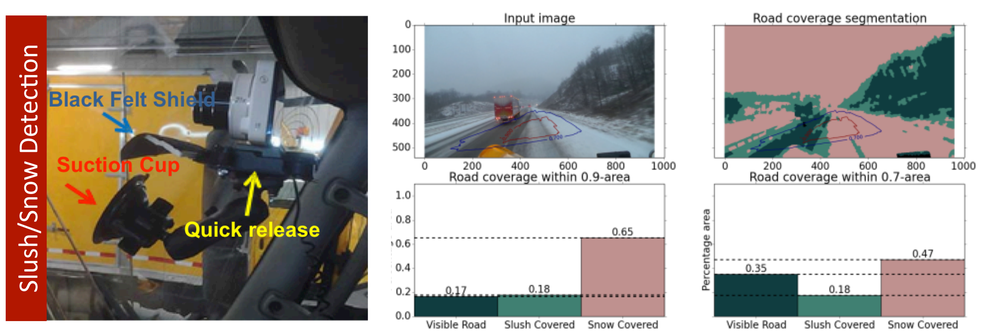
The proposed roadway CPS consists of heterogeneous sub-systems, namely, a vehicle CPS (shown in blue), vehicle-to-vehicle CPS, and a vehicle-to-infrastructure CPS. The sub-systems are capable of sharing rich scene information with each other to ultimately provide useful forms of actuation.

Infrastructure Inventory and Assessment



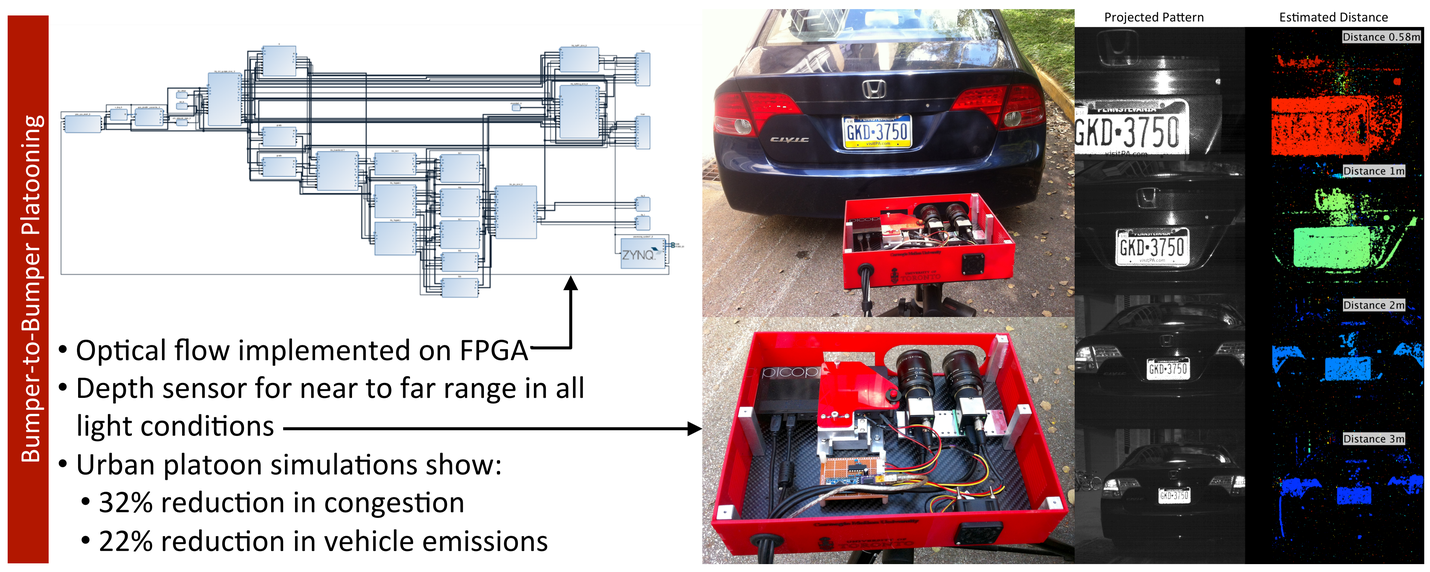
- Pilot projects in City of Pittsburgh, Marshall Township, and Cranberry Township
- Data collected: 2 years, 250 hours, 11,000 videos, 7 million images, 1,000 km unique roads

Road Condition Monitoring



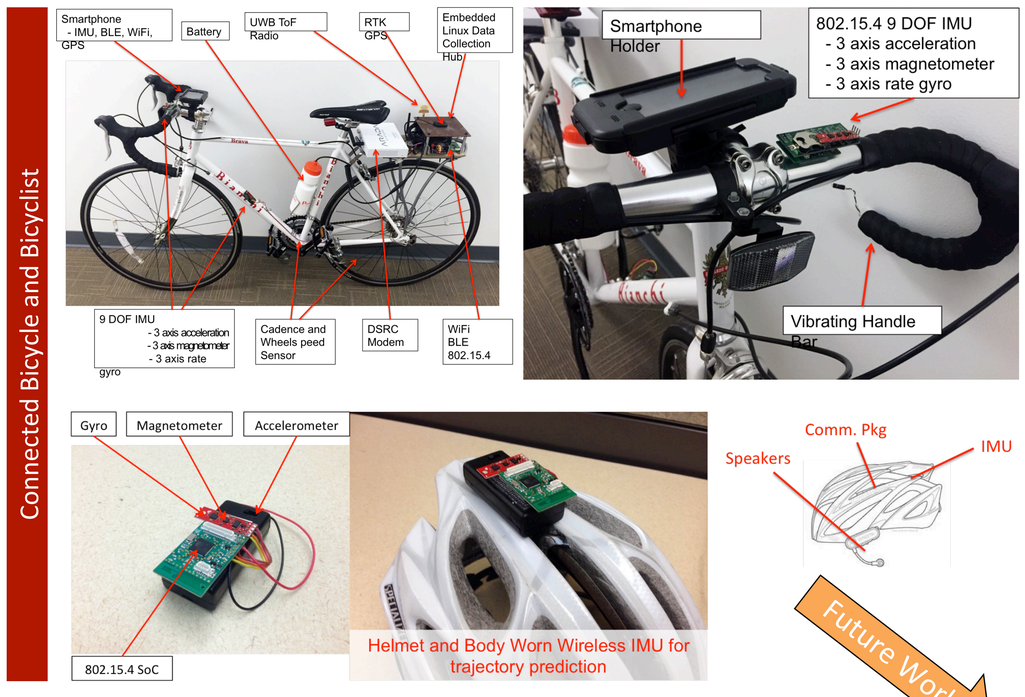
Deployed on public snow plows throughout Pittsburgh area

Vehicle Tracking

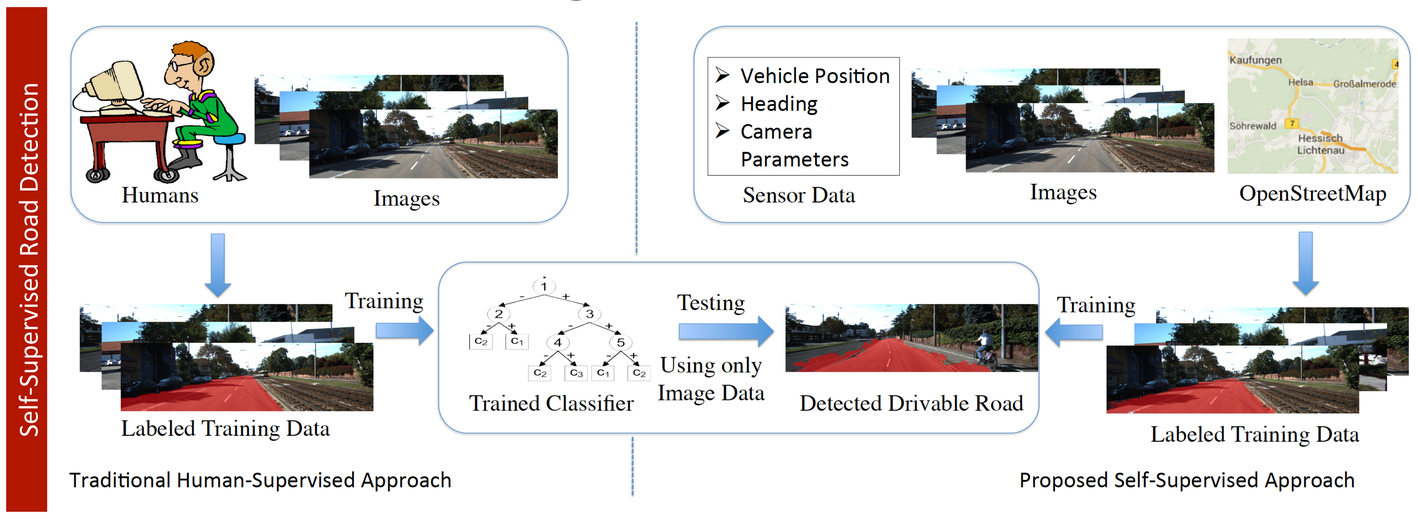


- Optical flow implemented on FPGA
- Depth sensor for near to far range in all light conditions
- Urban platoon simulations show:
  - 32% reduction in congestion
  - 22% reduction in vehicle emissions

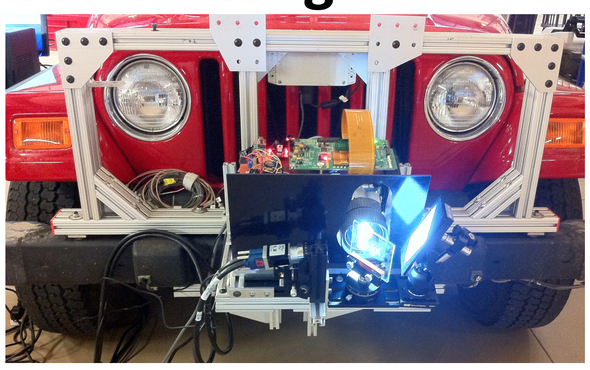
Safe Cyclist



Scene Understanding



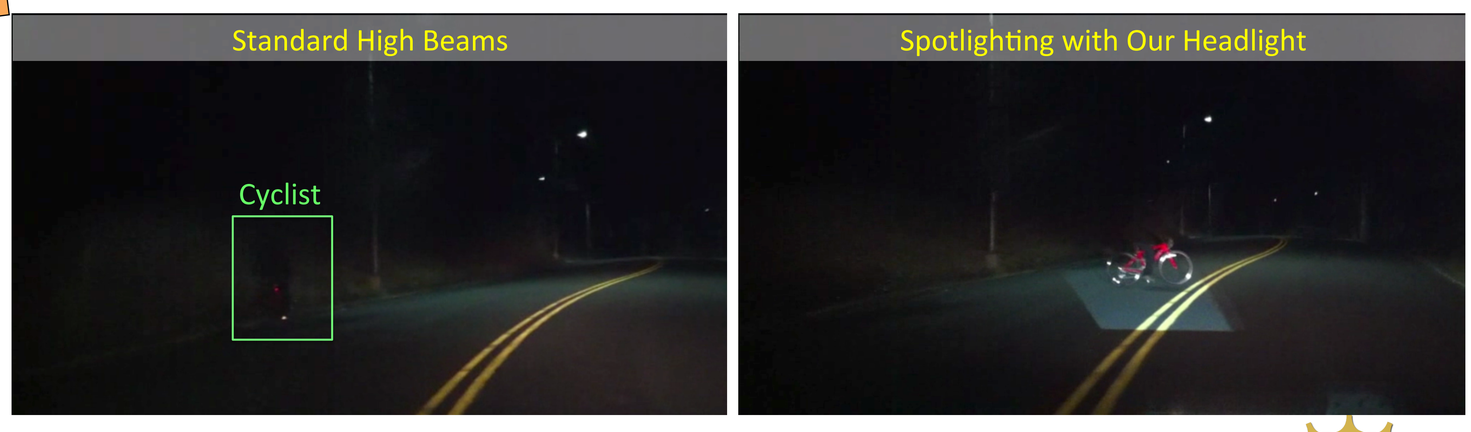
Smart Headlight



51,000 crashes with cyclists

69,000 crashes with pedestrians

25,600 crashes with animals



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