# Orosz Ground Robotics Experiment (OGRE)

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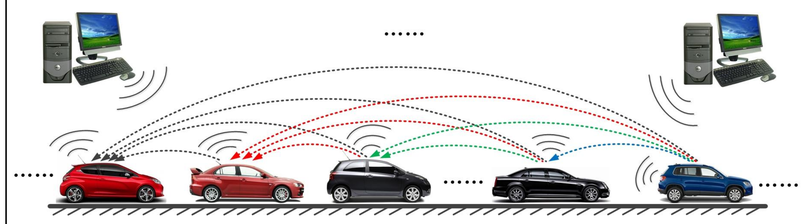
## Connected Vehicle Design

Vehicles on the road are becoming smarter day by day due to their enhanced capabilities in sensing, communication, computation, and actuation. Potentially, this can **increase safety, reduce congestion, and improve fuel economy**. However, scientists and engineers are still exploring the **large scale behavior** of the arising **cyber-physical system,** which demands **system-level modeling and analysis**. This also requires an experimental setup that allows one to reveal practical constraints and study the feasibility of integrating smart vehicles into the flow of conventional vehicles. Our goal in this project is to develop a **scaled experimental test bed comprising of connected ground robots**.

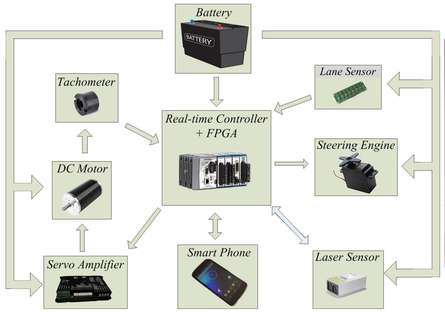


- Design **connected vehicle systems** based on **ad-hoc, broadcast-and-catch** communication
- Establish **vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I)** networks
- Study effects of **limited bandwidth and time delays** in sensing and communication
- Study the **collective motion of vehicles** for single lane and multi-lane configurations
- Emulate gasoline, hybrid and electric **powertrains using DC motors**

## Experimental Set-up

- Rescale the **longitudinal dynamics** of real automobiles
- Simplify the **vehicle model and steering design** while maintaining the essential dynamics
- Develop a low cost yet **efficient sensing system** to gather and integrate environmental information, e.g. laser range sensors, lane following sensors, and communication devices
- Develop a system for **robot-to-robot and robot-to-infrastructure communication**

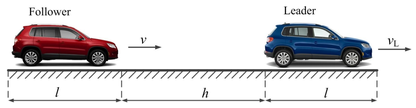
**Block Diagram of a Robot**




**Robot Prototype**

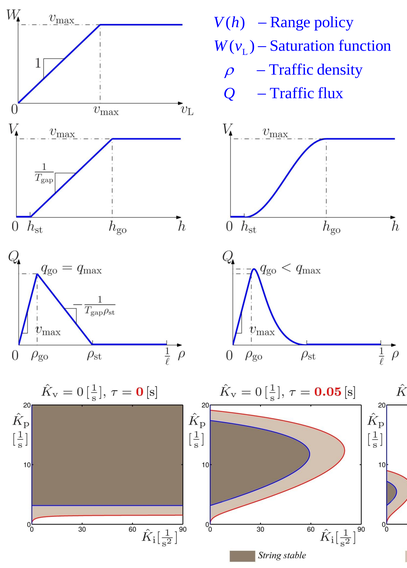
## Adaptive Cruise Control

- Design **adaptive cruise control (ACC)** based on the information of the leading vehicle that can operate in the entire velocity **to maximize traffic throughput**
- Explore different control scenarios to **ensure plant stability and string stability**
- Analyze effects of **time delays** arising due to sampling




Controller: $T_{en} = K_p\dot{z} + K_I z + K_V\left(W(v_L) - v\right)$

$\dot{z} = V(h) - v$



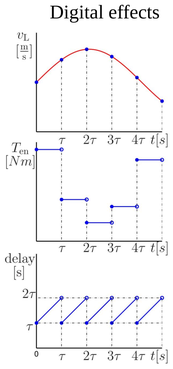

$V(h)$ – Range policy

$W(v_L)$ – Saturation function

$\rho$ – Traffic density

$Q$ – Traffic flux

Digital effects







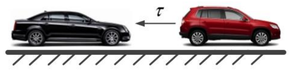
## Potential Impacts on Safety, Congestion & Fuel Economy

This research will **revolutionize ground transportation** and fundamentally change the way we drive our vehicles **with minimal infrastructure investment**. The system can be deployed starting today, locally and gradually, and it does not require major involvement of government or a paradigm shift by auto-makers. This will allow for a **safe, fast, and fuel-efficient** drive for both smart and conventional vehicles.

## Connected Cruise Control

- Design **connected cruise control (CCC)** based on the information obtained from other vehicles **to maximize traffic throughput**
- Explore different control scenarios to **ensure plant stability and string stability**
- Analyze effects of stochastic **communication delays**

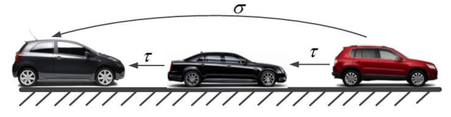

Decomposition

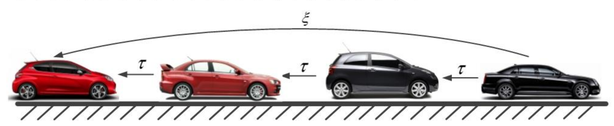



Controller: $T_{en,i} = \sum_{k=1}^{m}\gamma_{i,k}K_{p,k}\dot{z}_k + \sum_{k=1}^{m}\gamma_{i,k}K_{I,k}z_k$

$+\sum_{k=1}^{m}\gamma_{i,k}K_{V,k}\left[W\left(v_{i-k}(t-\tau_{i,j-k})\right) - v_i(t-\tau_{i,j-k})\right]$

$\dot{z}_k = V\left(\frac{1}{k}\sum_{j=i-k+1}^{i}h_j(t-\tau_{i,j-k})\right) - v_i(t-\tau_{i,j-k})$




## Research Plan

Design and manufacture a robotic vehicle fully equipped with sensors and actuators

Validate and implement engine, brake, steering control, and communication schemes

Connect vehicles via wireless network to enable communication

Refine the design and build more vehicles (up to 30 vehicles)

Conduct experiments and enhance system performance to make it usable for real vehicles

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