**Intuitive Interfaces to Support Smooth Control Authority Exchanges between Driver and Automation**

Quad Members: Brent Gillespie (PI), Akshay Bhardwaj (UM), Paramsothy Jayakumar (U.S. Army GVSC), John Walsh (Ford)

**Motivation**
Smooth transitions of control authority between a driver and automation system are critical to safe driving. Haptic Shared Control (HSC) offers a means to combine driver and automation control, with the promise of improved control transitions.

An automation system that also supports two-way communication in the grip axis might further enhance team performance.

**Fundamental Research Question**
Can two-way haptic communication in the grip axis be used for communicating takeover requests, acknowledgements, and negotiations without interfering with steering?

**Objective**
Develop a steering wheel with embedded force sensing and shape changing mechanisms in the axis of grip to support timely and transparent negotiation of control authority between driver and automation. Since the grip axis is orthogonal to the steering axis, it is a natural candidate for communicating takeover requests, acknowledgements, and negotiations without interfering with steering.

**Approach**
1. An applied grip force reduces the distance between spring-loaded plates.
2. Hall effect sensors detect displacement and transmit to control sharing algorithm.

**Pressure-based Grip Force Sensing and Shape Changing Wheel**

- Inflatable tubes mounted on steering wheel
- Driver grips harder
- Automation forces fluid into tube
- Pressure increases
- Tube expands

**Modeling**

- Fluid port
  - Fluid mass \( m \)
  - Pressure \( p \)
- Mechanical port
  - \( R_1, R_2 \) shape
  - Grip force \( F \)

**Continuing Work**
- We have developed a prototype multi-axis handwheel that can be incorporated into a driving simulator.
- Using a driving simulator study, we will assess the safety, effectiveness and intuitiveness of this approach.
- We will quantify the contribution of haptic and multimodal communication to the development of mutual trust and successful human-machine teaming.