Modeling Intent Communication Pathways for Human-Autonomous System Collaboration

Introduction to Research

The spotlight on safety of commercial autonomy grows ever brighter with reports such as the 272 failures of Google's self-driving car in 2015. Recent research has yielded a key issue with the safety of commercial autonomy is the lack of understanding of intent between stakeholders.

In response the purpose of this NSF EAGER grant is to explore the intent relationships between stakeholders in autonomous systems (Figure 1), first within an autonomous car paradigm and then within an industrial robotics paradigm.

The goal of this exploration is to produce and validate a set of methods that allow for the effective communication of intent between humans and autonomous systems.

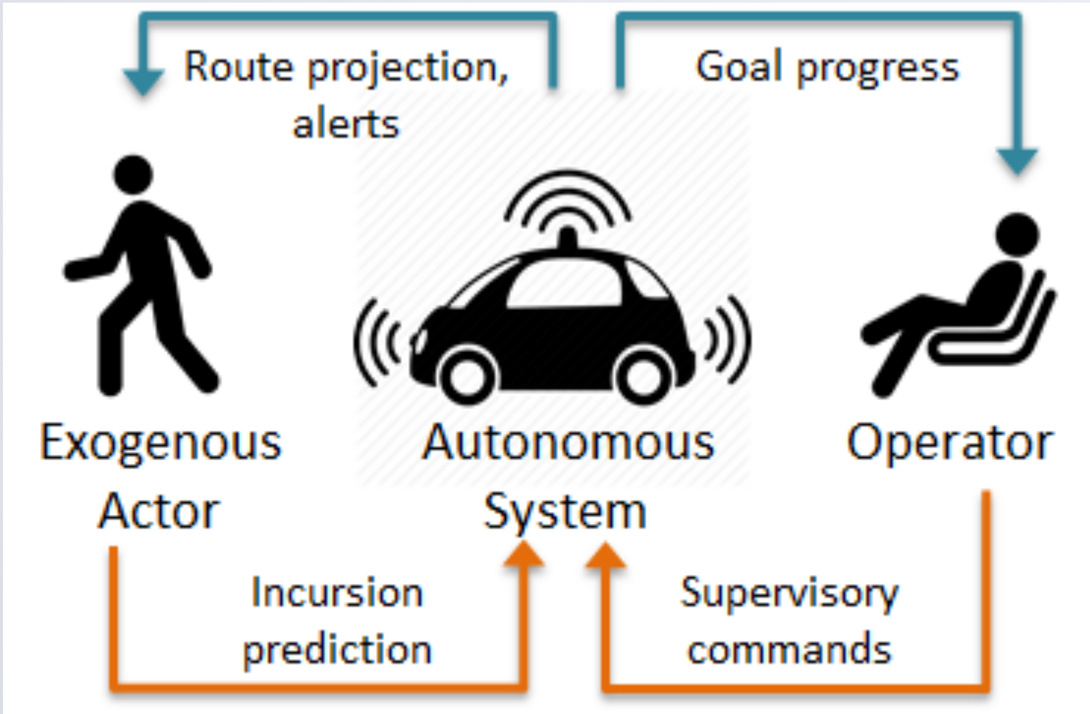


Figure 1: Diagram of Reciprocal Intent

Current Progress

Our current research focus is investigating communication of intent between autonomous cars and pedestrians. So far we have completed:

1. A comprehensive review of models of pedestrian crossing behaviors
2. A preliminary model of pedestrian decision making when crossing a street
3. A set of display prototypes to communicate vehicle intent to pedestrians
4. A design for an experiment to investigate the efficacy of the proposed displays

Review of Pedestrian Modeling

In our review of previous models of pedestrian behavior, two key relevant categories emerged:

Macroscopic
These models focus on modeling the flow of crowds/groups of pedestrians in terms of their motion and interactions. Macroscopic models are useful for predicting aggregate pedestrian behavior but lack the resolution to directly understand the intent of a specific pedestrian.

Microscopic
These models focus on modeling actions related to an individual pedestrian. Microscopic models provide descriptions of specific pedestrian behaviors but do not cover a variety of conditions.

Modeling Pedestrian Decision Making

In order to investigate methods for communicating vehicle intent to pedestrians, we developed a decision influence model of the variables that affect a pedestrian's decision of whether or not to cross a street (Figure 2).

The resulting influence model identifies three key categories of variables that influence the pedestrians' decisions:

1. Vehicle Attributes – Influencing variables that can be attributed to an approaching vehicle, such as speed
2. Individual Attributes – Variables associated with the pedestrian making the decision, such as age and destination
3. Environment Attributes – Variables associated with the environment and location, such as weather and traffic

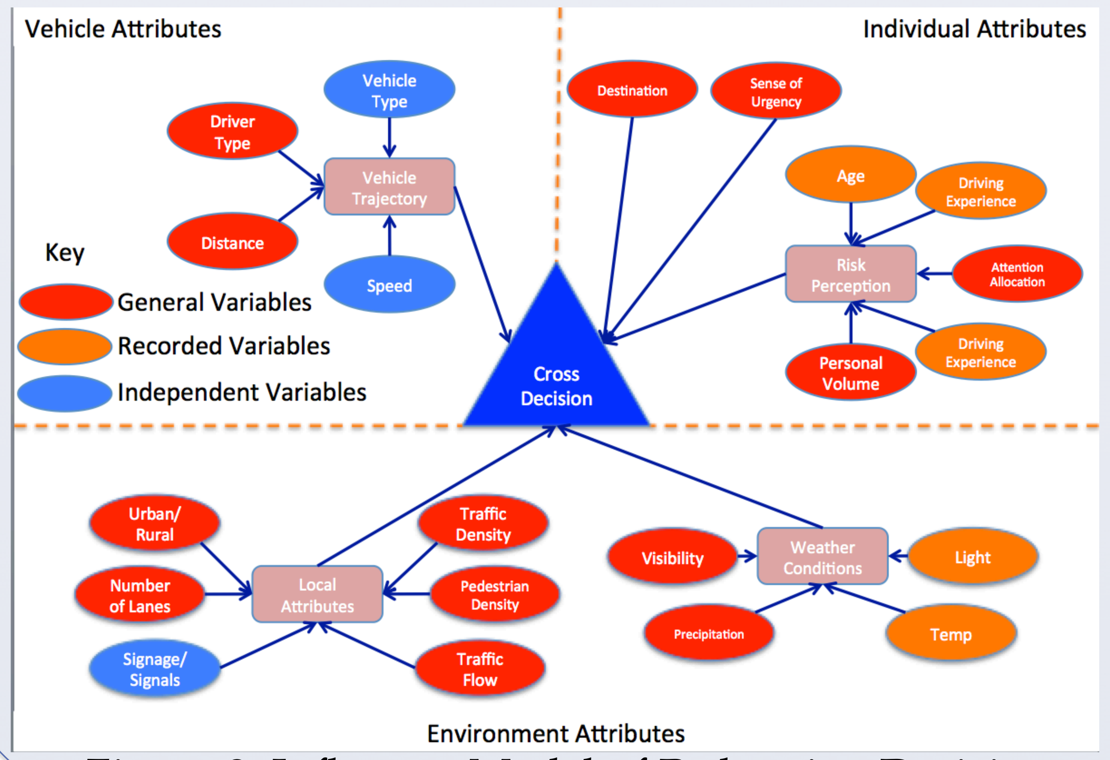
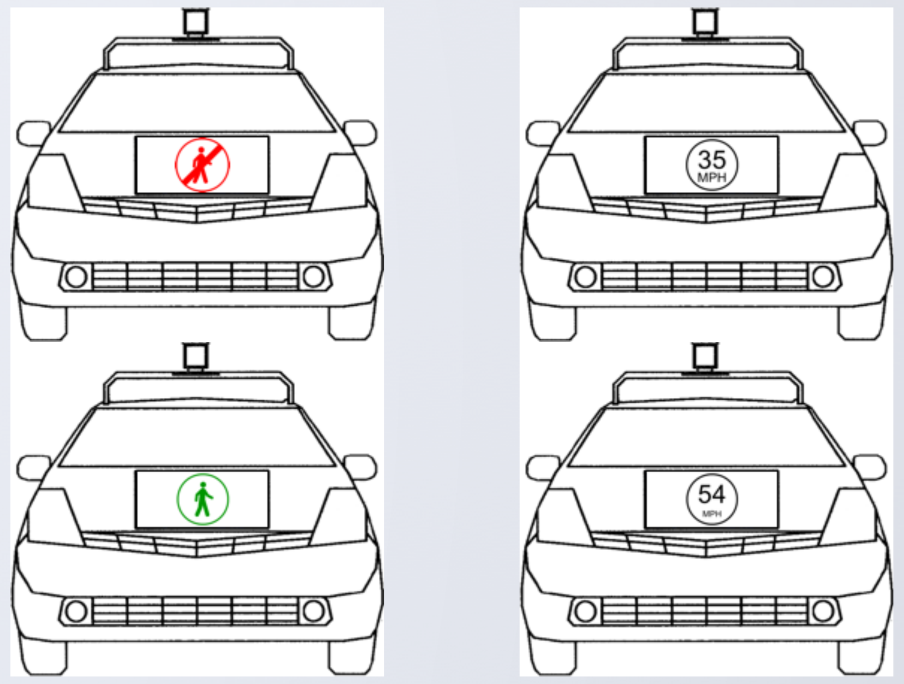


Figure 2: Influence Model of Pedestrian Decision

Communicating Vehicle Intent to Pedestrians

Methods for communicating intent to stakeholders should incorporate fundamental human factors principles. Previous concepts, such as one included in a recent Google patent, propose text displays to communicate vehicle intent when approaching pedestrians. These concepts fail to consider information processing limitations of these messages.

Using our influence model of pedestrian decision making as a foundation, we have developed two interfaces to communicate vehicle intent to pedestrians through a display mounted on the front of a vehicle. The first interface (Figure 3A) provides *advice* to pedestrians when is safe to cross in front of the vehicle; the second interface provides *information* by presenting the vehicle's speed to support more informed decision making.



A B
Figure 3: Vehicle Intent Interface Designs

Investigating the Effectiveness of Vehicle Intent Displays

We are currently running a study to evaluate the effectiveness the prototype vehicle intent designs. In this study, a vehicle will use the proposed vehicle intent displays to broadcast information to pedestrians about when to cross a street. We will record how those notifications affect pedestrian decisions to cross compared to a control condition with no display. During experiment trials, a vehicle (Figure 4) will travel at one of two predefined speeds along a road with two fixed crossing locations on opposite sides of the street (P1, P2; Figure 5). The goal of each trial will be for the subjects to observe the approaching vehicle and indicate (1) when it is safe to cross and (2) when it is no longer safe to cross as the vehicle passes. The results of the experiment will be used to help develop a model of reciprocal intent. This model will then provide insights in to how to design interfaces that effectively communicate vehicle intent.

Figure 4: Experiment Vehicle

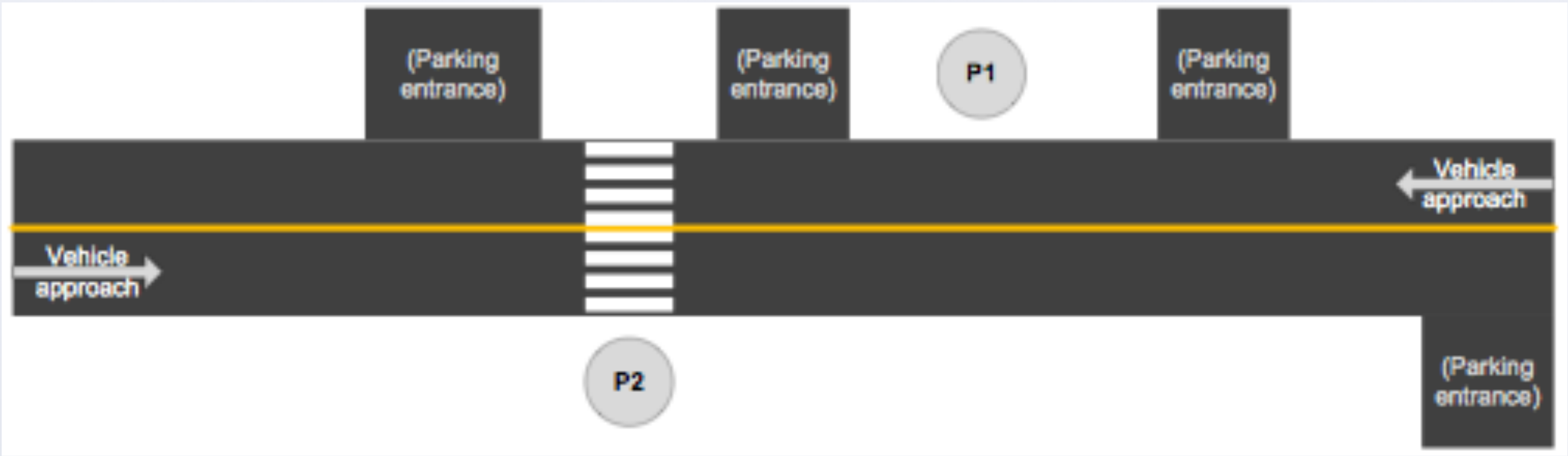


Figure 5: Experiment Environment

Pedestrian Decision Making

Summary:
In order to increase safety in commercial autonomous systems, we are examining how to communicate intent among stakeholders in and around autonomous systems. In order to do this we are developing a model of reciprocal intent driven by empirical data examining different methods for communicating intent between stakeholders.

Future Work:
Once the reciprocal intent model has been developed and validated, we will look at extending the model to an industrial robotics domain to determine how the model generalizes to other domains.