Observing the causality of network state variables on autonomous system decision making

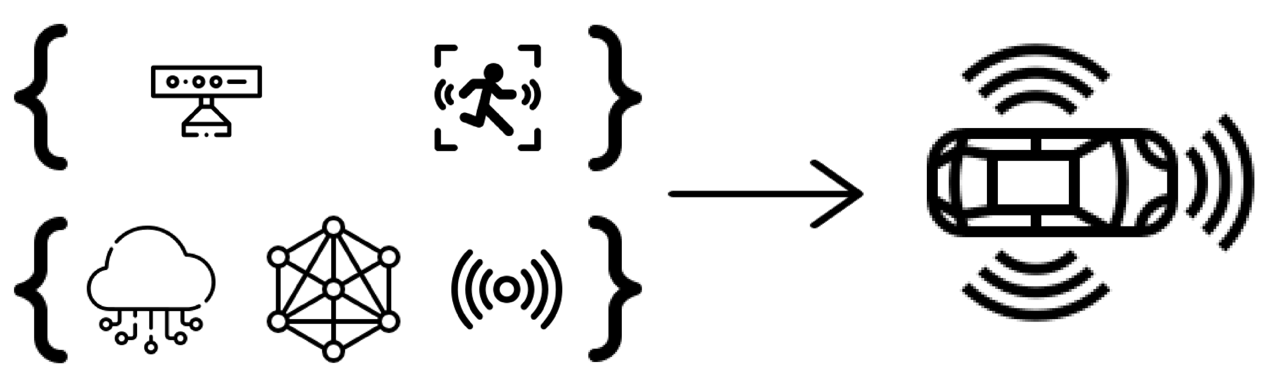
Lancaster University

Authors: Xavier Hickman, Dr. Daniel Prince

Brief introduction

Autonomous systems, much like the human brain require multiple sets of data, often quantifying different phenomenon in order to converge at the 'optimal decision'.

A common example of this concept is a fleet of self driving cars using both sensory data and communication data in order to make informed decisions. The sensory data is measured by devices such as inertial measurement units, global positioning systems and gyroscopes. The communication data could be any data transmitted or received via a network. In the case of decision making it is likely to be messages received from other nearby nodes containing data on their current physical state and intentions.

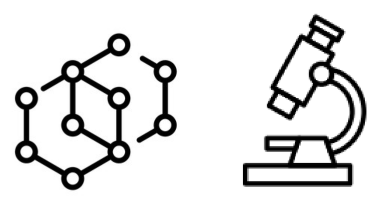


Overview and Hypothesis

We are using the H-D (Hypothetico-deductive) model to examine the relationship between network state variables and autonomous system decision making. Our independent variables are bandwidth, throughput, latency, packet loss and uptime/availability. Our dependant variables are the number of incorrect or erroneous decisions which in this case is classified in two ways. Class 0: a node enters the boundary of another node in the same time step (boundary incursion), class 1: the coordinates or 2 nodes match in the same time step (collision).

Examples of potential applications of the research outcomes are self driving vehicles and autonomous drones/UAVs.

Hypothesis: *Manipulating one or a combination of the following variables; (1) bandwidth, (2) throughput, (3) latency, (4) packet loss (5) uptime/availability will have a measurable affect on the probability that an autonomous system makes an erroneous decision.*



Research Goals

1. Empirically prove a causal relationship between network state and decision making through experimentation.
2. Generalise findings to real world autonomous transit applications.
3. Formulate a set of scientifically rigorous methods to remedy the observed phenomenon.

Methodology (Experiment Phase 1)

Basis:

- Model a set of autonomous nodes as a distributed system of independent machines.
- Configure an ad-hoc overlay network for which the nodes will use to communicate with one another in a peer-to-peer fashion.
- Provide an application context for the distributed system of autonomous nodes i.e. self driving vehicles/UAVs by equipping nodes with an applicable communication standard such as IEEE 1609 V2X.
- Each node will recurrently perform this task c times in a d dimensional space with . Let $c \in \mathbb{Z}^+$, $0 < d \leq 3$:
  1. Each node will take and random start and end point, generate a route vector with a specified degree of noise or entropy. i.e. the higher the noise/entropy the less direct the route vector is.
  2. The nodes will follow their route vector in discrete time steps, with each node broadcasting a set of variables describing its state according to an accepted standard.
  3. Upon receiving a message, a node will update its view of the shared space using the transmitted data.
  4. The node will then make decisions based on both the data received from other nodes (communication data) and their direction and position (sensory data).

Method: Experiment structure, design and statistical analysis

Independent variables:

- Link bandwidth
- Link throughput
- Link latency
- Link packet loss rate
- Link uptime

Dependant variables:

- Number of collisions
- Number of boundary incursions

Control variables (per simulation):

- Number of nodes
- Route vector entropy
- Size of space
- Number of walks/routes

Baseline data (per simulation):

- Simulation with no link shaping

Simulation structure, n = number of nodes:

- S1. $n = 10$
- S2. $n = 25$
- S3. $n = 50$
- S4. $n = 100$

Statistical analysis:
Rigorous statistical analysis will be conducted on the recorded data, the metrics of interest are the following:

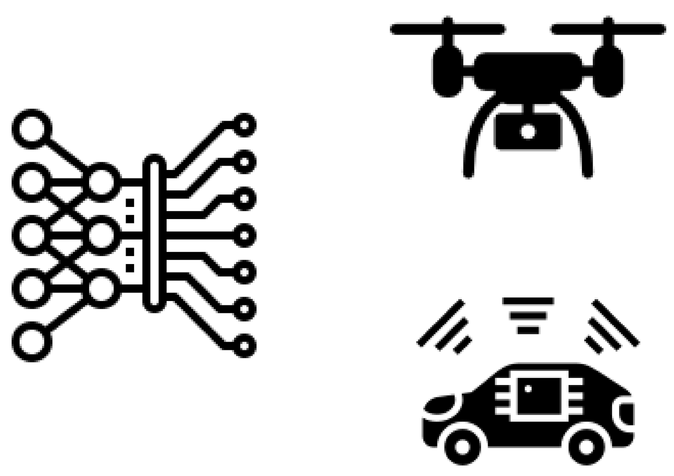
- Change in mean from baseline to experiment.
- Change in standard deviation from baseline to experiment.
- Regression analysis to determine how the manipulation of a given independent variable is affecting a dependant variable.
- Hypothesis testing.

Future research

This phase of the experiment, while potentially yielding interesting findings will only provide a basis for a more complex simulation making use of extensive use of data fusion and more specifically an intention prediction model.

The key point here is the fusion of communication data and complex sensory data is an essential step in autonomous decision making, especially in application contexts such as self driving cars and drones/UAVs.

The future of this research will be looking at specific properties of intention prediction models and the logic they use e.g. Bayesian, DST to build a deeper understanding of how network state variables can influence autonomous decision making.



This work is supported by the Engineering and Physical Sciences Research Council [grant number: EP/V026763/1]