Learning Pedestrian Behaviour for Autonomous Vehicle Interactions

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Abstract

To navigate in human social spaces, self-driving cars and other robots must show social intelligence. This involves predicting and planning around pedestrians, understanding their personal space, and establishing trust with them. This poster gives an overview of our ongoing work on modelling and controlling human–self-driving car interactions using game theory, proxemics and trust, and unifying these fields via quantitative models and robot controllers.

Game Theory Model

A game theory model is used for negotiations between an AV and a pedestrian at an un-signalized intersection, as shown in the scenarios below.

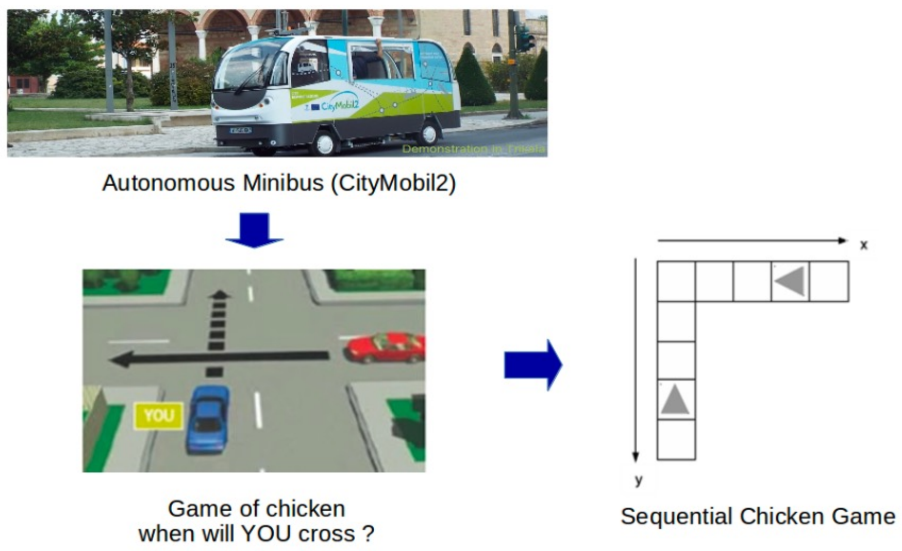


Figure 1: Game of Chicken: two agents try to cross over an intersection as quickly as possible while avoiding a collision. The first agent to pass wins the game, the second looses and they are both bigger losers if there is a collision.

Human & VR Experiments

Figure 2: Virtual AV

Figure 3: Participant

We developed several studies to learn pedestrian behavioural parameters from real-world empirical and VR experiments. **Goals**: understand pedestrian crossing behaviour and also improve the game theoretic behaviour model of a virtual autonomous vehicle.

- learn participants' behaviour preferences, i.e. time delay vs collision avoidance, with a virtual AV making its decisions based on the Sequential Chicken model (cf. Fig. 2 and 3).
- Discover participants' preferred AV parameters (space and time)
- Examine changes in pedestrian crossing behaviour within different environments and with different car models (cf. Figs. 4 and 5).

Results:

- participants had a more cautious crossing behaviour in VR than in the empirical experiments.
- pedestrians prefer an AV that makes its decisions quickly and no behaviour change was observed with different car models and environments.

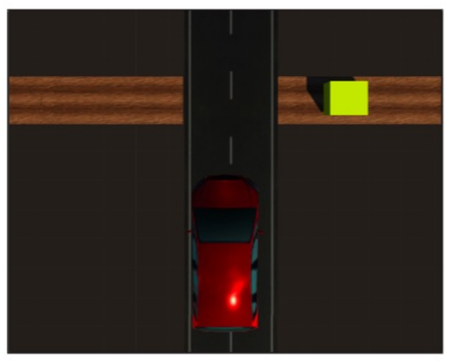


Figure 4: Scene Exp. 2

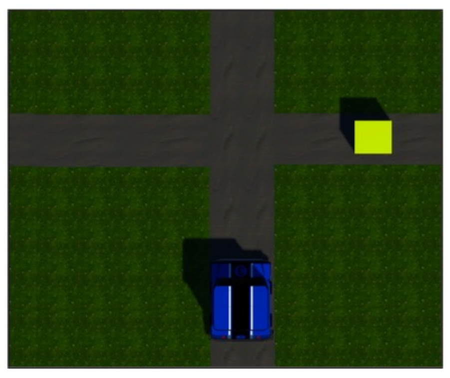
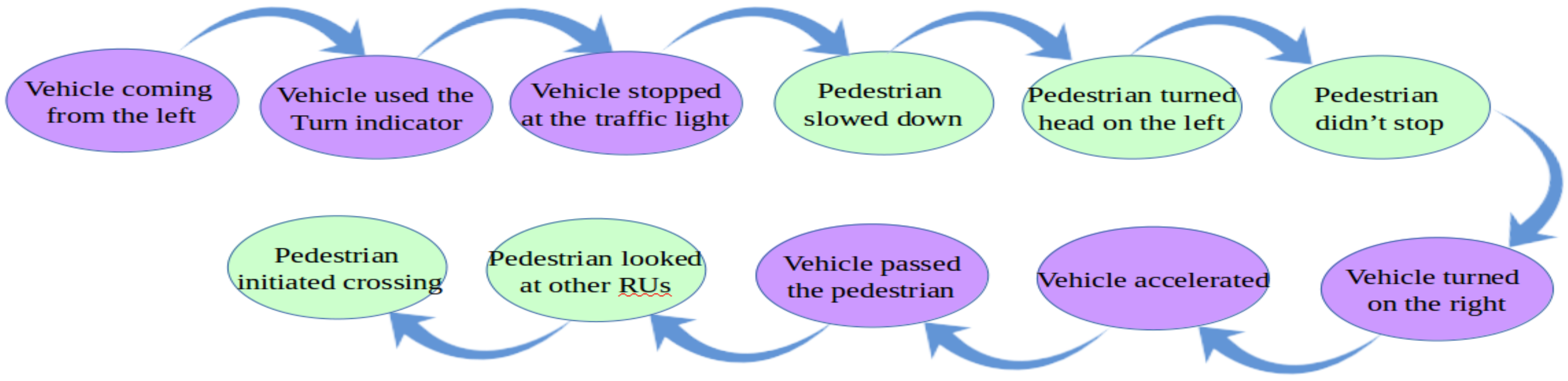
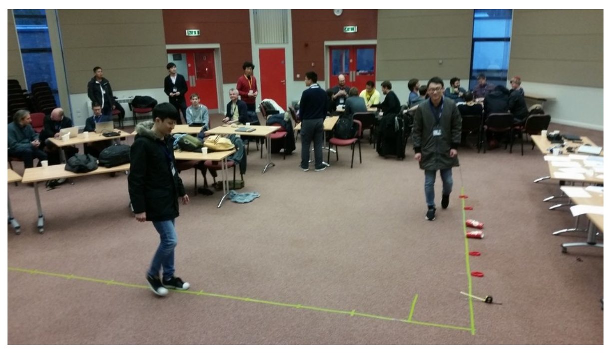


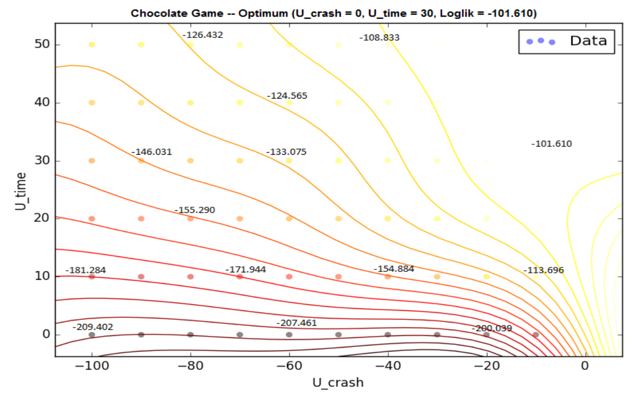
Figure 5: Scene Exp. 3



Pedestrian-Vehicle Interaction Sequence Pattern Analysis

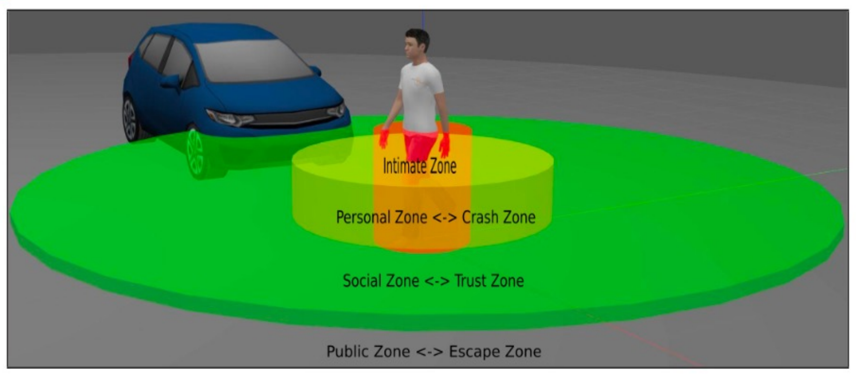


Pedestrian-Pedestrian Interaction



Gaussian Process Regression

Unifying Proxemics & Trust



We developed the first unified quantitative model of proxemics and trust for AVs and pedestrians interactions. This can be used to replace the credible threat of actual collision with the lesser but more frequent threat of invasion of personal space. We define the trust zone as the area of the proxemics zones where trust is required i.e., one agent called *Agent1* is in a position of vulnerability and has to rely on the actions of a second agent called *Agent2* during the interaction. We define *physical trust requirement* (PTR) as a Boolean property of the physical state of the world (not of the psychology of the agents) with respect to Agent1 during an interaction, true if and only if Agent1's future utility is affected by an immediate decision made by Agent2. This model assumes that the two agents are approaching each other at a right angle as shown in the figure above. It then defines the following zones:

Crash zone is the region close to Agent1, $\{d : 0 < d < d_{crash}\}$,

$$d_{crash} = v_2 t_2 + \frac{v_2^2}{2\mu_2 g}, \quad (1)$$

Escape zone is the set $\{d : d_{escape} < d\}$ with

$$d_{escape} = v_2 t_1 + w_2 \frac{v_2}{v_1}. \quad (2)$$

Trust zone is the region $\{d : d_{crash} < d < d_{escape}\}$ where the PTR is true. Agent2 can here *choose* to slow down to prevent collision, but Agent1 is incapable of making any action to affect this outcome themselves.

Results: The PTR model generates Hall's empirical zone sizes to 1% accuracy.

OpenPodcar

OpenPodcar is a new low-cost, open source autonomous vehicle research platform, based on an off-the-shelf, hard-canopy, mobility scooter donor vehicle, together with a full automation open source software (OSS) stack. System build cost from new components is around 7,000USD in total in 2022. This will enable other groups to replicate our complete system and experiments, and to use their own research to extend and contribute to a single shared system, which can evolve over time towards real-world use.

Figure 7: OpenPodcar: open source hardware AV.

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