Game Theory For Self-Driving Cars

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Abstract

Pedestrian behaviour understanding is of utmost importance for autonomous vehicles (AVs). Pedestrian behaviour is complex and harder to model and predict than other road users such as drivers and cyclists. In this paper, we present an overview of our ongoing work on modelling AV-human interactions using game theory for autonomous vehicles control.

Game Theory Model

A game theoretic model [13] is proposed and used for negotiations between an autonomous vehicle and a pedestrian at an un-signalized intersection, as shown in the scenarios in Fig. 1.

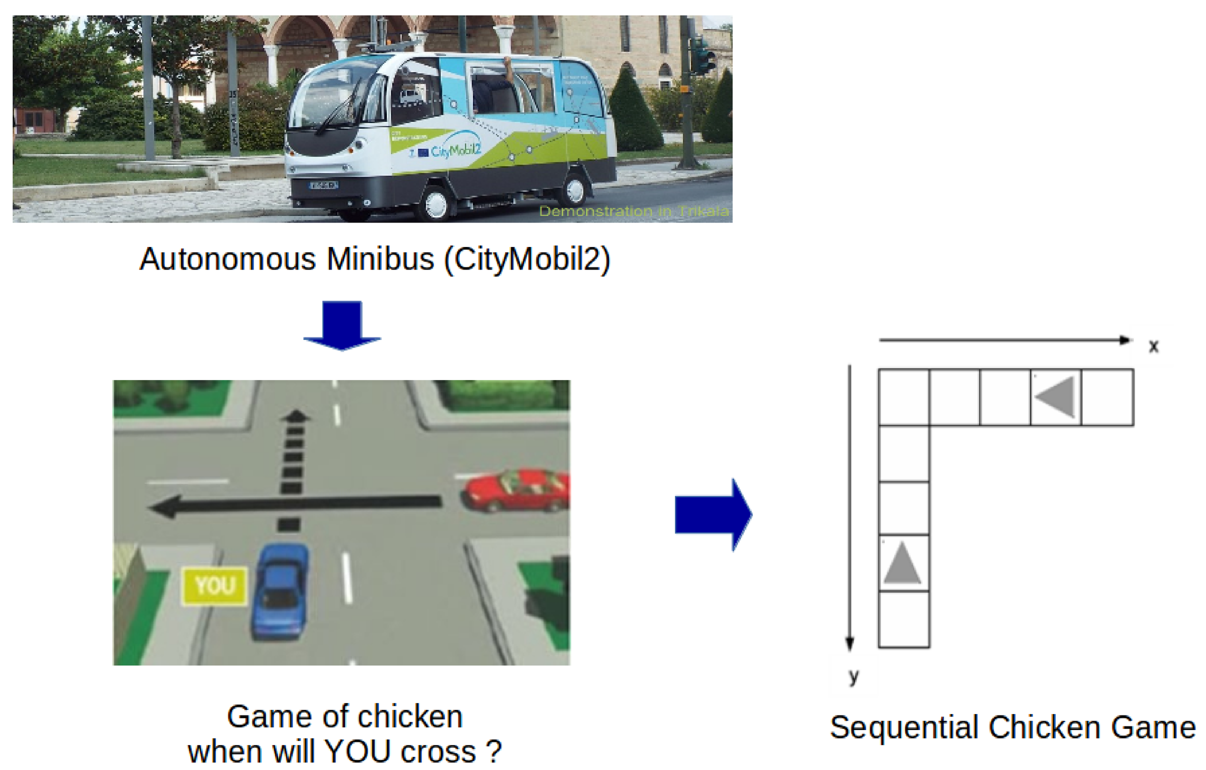

Figure 1: Game of Chicken: two agents try to cross over an intersection as quickly as possible while avoiding a collision. The first agent to pass wins the game (reward), the second looses (small penalty) and they are both bigger losers if there is a collision (large penalty).

Introduction

Autonomous Vehicles (AVs) also called "self-driving cars" are appearing on the roads, but their future interaction with other road users raise some concerns. AVs currently lack of the ability of human drivers to predict the behaviour of other road users and then interact with them. This inability of current AVs to accurately predict pedestrian crossing intent is their "big problem" [2].

Empirical Experiments

These studies provided an empirical understanding of the human factors required by future autonomous vehicles.

- **BOARD GAMES [11]:** Participants played the game of chicken as a board game. There were two types of games, *natural* versus *chocolate*.
- **PHYSICAL GAMES [5]:** A novel method based on tracking real humans in a semi-structured environment with participants playing the game of chicken physically (cf. Fig. 2).

Results: Gaussian Process (GP) regression analysis (cf. Fig. 3) showed participants' preference for saving time rather than avoiding collisions.

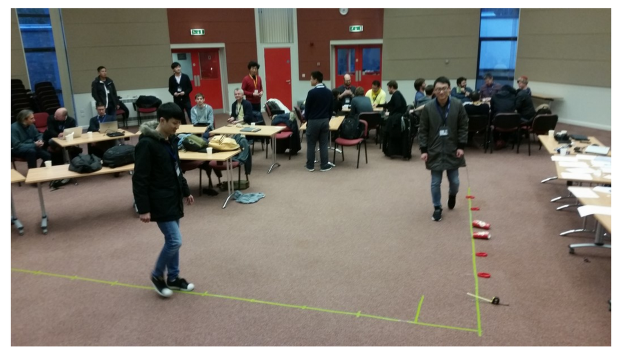

Figure 2: Experiment

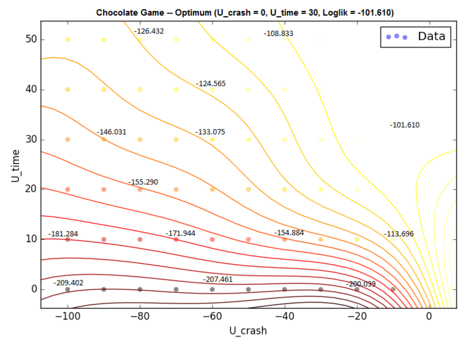

Figure 3: GP

Virtual Reality Experiments

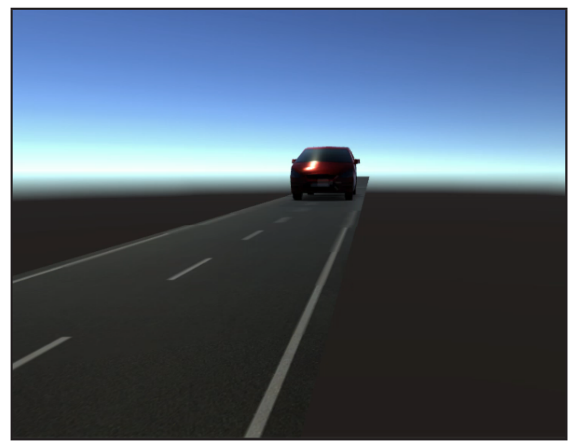

Figure 4: Virtual AV

Figure 5: Participant

We used VR to develop three simple experiments about pedestrian-AV interaction at non signalized crossings. **Goals**: understand pedestrian crossing behaviour in more realistic conditions than in our previous artificial laboratory experiments and also improve the game theoretic behaviour model of a virtual autonomous vehicle.

- **Objective in Experiment 1 [6]**:
  - 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. 4 and 5).

  Results: participants had a more cautious crossing behaviour than in the empirical experiments.

- **Objectives in experiments 2 and 3 [7]**:
  - Learn participants' behaviour preferences
  - Discover participants' preferred AV parameters (space and time)
  - Examine changes in pedestrian crossing behaviour within different environments and with different car models (cf. Figs. 6 and 7).

  Results: pedestrians prefer an AV that makes its decisions quickly and no behaviour change was observed with different car models and environments.

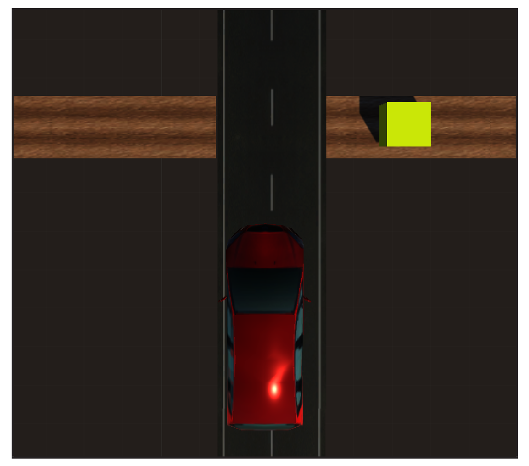

Figure 6: Scene Exp. 2

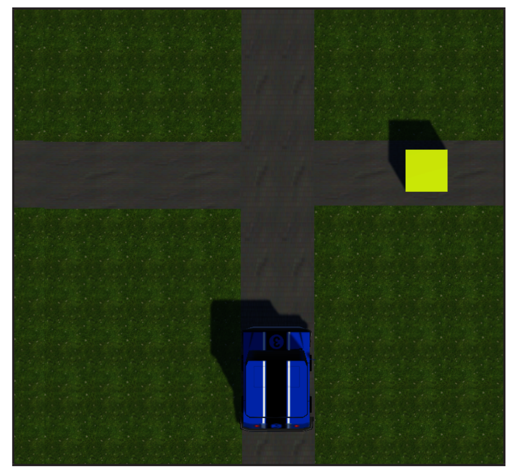

Figure 7: Scene Exp. 3

Sequence Analysis of Interactions

- **Sequence Patterns Recognition [9]**
  - A large scale data from real-world human-vehicle road crossings
  - Pedestrian-vehicle interactions decomposed into sequences of independent discrete events
  - Analysis of common patterns of behaviour using logistic regression, decision tree etc.
- **Filtration Analysis [8]**
  - Analysis of the temporal orderings (filtration) in which features (e.g signals from the pedestrian) can be revealed to an autonomous vehicle during interactions
  - How optimal stopping controllers may use such data to enable AVs to decide when to act.

Pedestrian Intention Estimation

To optimally interact with pedestrians, autonomous vehicles must be able to predict their crossing intent, thus we proposed a method to estimate pedestrian crossing intention.

- **A Heuristic Model [10]**, inspired by the Sequential Chicken model and based on tracking data.
- **Result**: the method is very efficient in estimating crossing intent for most of the interactions.
- **Drawback**: this heuristic model would fail in more complex and critical interaction scenarios.

Conclusion

This is a work in progress on self-driving car technology. We present game theory as a tool to model future human interactions with autonomous vehicles. Semi-structured empirical and VR experiments with human participants and interaction sequence analysis provide a better understanding of human behaviour. Future work will look into developing the game theory model on a real self-driving car and to test its validity by performing some experiments with human participants.

References

More details about the studies and the complete references are given in the conference paper n° 21:

[1] Fanta Camara and Charles W. Fox. Game theory for self-driving cars. In *UK-RAS Conference*, 2020.

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