

Project Title: Game theory in Traffic Simulation

CHALLENGES

The project

Around the world, road crashes kill 1.3 million people per year and injure up to 50 million more. Autonomous vehicles (AVs) offer a potential safety solution to this issue if they can learn to effectively identify and avoid situations leading to crashes with other vehicles and road users. However, humans' responses to the introduction of AVs is uncertain. Humans may learn to behave differently around autonomous vehicles than manually operated cars if they believe that autonomous vehicles pose a different (perhaps lower) level of threat. This could lead to

		B. Car	
		Go	Stay
A. Bicycle	Go	0, 2	3, 1
	Stay	1, 3	0, 0

		B. Autonomous Car	
		Go	Stay
A. Bicycle	Go	3, 0	3, 1
	Stay	0, 3	0, 0

new crash scenarios and risks not previously present or imagined, particularly during a period of transition between manually operated and autonomous vehicles. A simple example comes from game theory. The following 'normal game' describes the pay-offs for a cyclist and a driver in a present-day scenario vs that of a cyclist and an autonomous vehicle that is programmed to drive conservatively. In the left-hand scenario, the Nash equilibrium exists in the lower left quadrant where the cyclist is incentivised to 'stay' in order to not be hit by the driver, and the driver is incentivised to 'go'. In the Autonomous car scenario (right hand side), however, the cyclist may not feel threatened by the prospect of being struck by an AV, knowing that it will always attempt to avoid a collision. In this scenario, the cyclist may therefore adopt a dominant strategy of 'go'. Repeated across a system, this could produce gridlock among 'safety conscious' AVs and increased collision risk among cyclists who then mistakenly behave similarly around manually operated cars.

Fig 3. A simple 'normal game' demonstrating the potential effect of changed pay-offs associated with human vs bicycle / AV vs bicycle interactions.

Solution details and the approach to the problems identified

A great deal has been made in the media of the increasingly hostile relationship developing both in Australia, and globally, between the cycling and driving community. However, solutions have tended to be primarily technical or engineering in nature; driven from the perspective that all vehicles in the road hierarchy (incorporating drivers and cyclists) are 'playing the same game' and that adequate solutions will be reached if each party simply obeys the 'rules'.

From a game-theoretical perspective, this assumes that each person and/or vehicle operator (person or machine) experiences identical motivations and pay-offs for speed, collisions, and on-road road rule observation. We propose that this starting point is inaccurate and cannot be ignored in the case of autonomous vehicle introduction. Instead, psychological barriers, financial liabilities, legal obligations, values, fears, and mental hierarchies that each classification of road user brings to their interactions at junctions determine the rules by which they interact. In the case of AV introduction, these factors and decision-weights are far from settled. Ultimately, they must be programmed in to the machine, itself. They may also need to be standardised.

Standardisation may be important because misjudgement, collisions and ‘clashes’ occur in games where players are operating under different assumptions regarding the rules of interaction, and perceived pay-offs or consequences of behaviour. The introduction of autonomous vehicles has potential to compound this problem given that humans will be required to negotiate interactions at intersections with machines that may be programmed to act inconsistently, or which they have potentially less regard for as legitimate road users, or which they will not have ‘eye-contact’ with in a manner analogous to that used by human drivers in uncertain traffic scenarios. This may be particularly problematic in a transition period where human drivers and AVs are operating within the same transport system at various ratios that also vary over time and location.

Using combined techniques of agent-based modelling, genetic algorithms and game-theory, this project will investigate and model interactions between individual synthetic drivers, cyclists, pedestrians, and autonomous vehicles at a variety of ‘typical’ intersections identified across Australia under a wide range of traffic volume scenarios. It will create a dynamic test-bed within which manufacturers can trial assumptions underlying the rules of interaction their vehicles operate under, and the likely adaptation and responses of humans to such regimes over time. The use of agent-based modelling will enable a flexible, large-scale bottom-up computational approach. The use of game-theoretical principles will enable dynamic pay-off and incentive structures to be attached to individual agents attempting to maximise their utility within the system. The use of genetic algorithms will enable the efficient exploration of the potential solution space related to optimisation of the safety and efficiency of AV interaction ‘rules’ and the overall transport system.

This project will develop a set of rules and guidelines for enhanced communication, understanding, and safety between vulnerable road users and autonomous vehicles at critical safety junctions. It will provide a fundamental basis upon which to understand the dynamic rules by which humans and autonomous vehicles may be expected to interact, and how this should be incorporated within AV software.

How does the solution sit within the current market offerings and how it is innovative?

Cities within advanced economies appear to be treading 2 paths. One focused on AV introduction, and the other increasingly recognising the economic and health benefits associated with urban design that encourages more cycling and walking. However, in cities where poor separation exists between motorised vehicles and vulnerable road users, injury rates per km travelled can remain high. It is therefore difficult for cities to at once encourage increased rates of cycling or walking without experiencing concomitant (though not proportional) increases in cycling crashes. While separated cycling infrastructure is one answer to this problem, the deployment of Autonomous vehicles (AVs) has also been promoted as an alternative solution if AVs can learn to accurately identify other vehicles and vulnerable road users, and either evade or avoid situations leading to crashes. Of course, while the ideal of flawlessly performing AVs exists, the technology required to ensure AVs can operate safely in the extreme variety of unpredictable situations vehicles face, to learn from these, and to then to make appropriately ‘moral’ decisions in the case of inevitable collisions, is far from ready.

However, this is not simply a case of recognition and avoidance of static human bodies. Humans are highly proficient at learning and adapting quickly to new environments, resulting in novel patterns of interaction. Regardless of whether AVs can learn to operate flawlessly in a transport system or not, this means that humans will display new behaviours in response to AVs' presence, especially when there is incentive for them to do so (e.g., through reducing travel time) and few moral barriers to delaying machines rather than fellow humans. Such adaptation is likely to create novel crash situations and risks that are not typically in-scope of discussion when considering the safety benefits of AVs, which tend more to focus the role of vehicle operators (e.g., drivers taking back control after a period of automation, etc.) or one-way recognition and avoidance actions. As proposed in this project, dynamic modelling perspectives that include surrounding humans' (e.g., cyclists and pedestrians) potential responses to AVs behaviour need to be included in discourse and modelling of human / AV interaction.

This project is therefore innovative because it takes a socio-technical approach that puts 'humans in the feedback loop'; a theme of increasing importance in AV and technological policy modelling efforts.

Once deployed, AVs will be held to a higher safety standard by government and community than human drivers. Community expectations hold that AVs will and should be safer in all circumstances. In this context, the financial, reputational, and legal consequences for AV manufacturers' vehicles contributing to crashes will be augmented in comparison to responsibility currently given to 'fallible' human drivers. This project takes a technological problem and places it within the context of human, community, political and social norms.