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The structure of anticipatory mechanisms in autonomous vehicles

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1. INTRODUCTION

Autonomous vehicles (AVs) rely on probabilistic neural networks (NNs) [1], which present known safety challenges [2]–[5]: edge cases always remain regardless of testing.

ISO 26262 [6], ISO/IEC TR 5469 [7], SADRA [8], and SOTIF [9] address failures, AI risks, system architecture, and hardware degradation respectively. A further gap remains: even with no failure and a competent designer, an inappropriate ethical intent can itself lead to danger. This paper addresses that gap through the concept of anticipation.

2. MICROETHICS AND ANTICIPATION

Ethical frameworks for AVs range from abstract principles to operational rules. ISO 39003 [10] derives driving rules from a five-layer hierarchy. Driving Rule DR2, for instance, requires a vehicle to avoid causing other road users to brake or manoeuvre unnecessarily—a rule whose application is non-trivial given road uncertainty.

We employ microethics [11]: ethics operating within specific concrete interactions. At an intersection where a pedestrian is obscured, three stances exist: (1) behave as if no pedestrian is present; (2) assume one is present; (3) do not turn. Option (3) best satisfies DR2—a policy adopted by some US carriers [12].

3. ANTICIPATORY MECHANISM

In the Prediction and Decision layer, a Behavior Prediction (BP) module estimates agent movements probabilistically. Its $O(N^2)$ complexity [13] constrains the effective range to roughly 30–50 m in dense scenarios [14]. A Behavior Arbitration module selects the final trajectory, prioritising safety, legal compliance, efficiency, and comfort.

We propose an Anticipatory Mechanism (AM) alongside BP (Fig. 1). AM tracks agents independently, reducing complexity to $O(N)$ and covering a wider area. Its goal is early detection of potentially dangerous configurations so that the vehicle can act preventively—by reducing speed or rerouting—before a collision becomes unavoidable. AM is analogous to the FSM checker pattern (C) in SADRA but provides heuristic, rule-based anticipation rather than deterministic enforcement.

4. DISCUSSION

In October 2023, a US Robotaxi (SAE Level 4) dragged a pedestrian thrown into its lane by a prior collision [15]. A jaywalking pedestrian and a nearby vehicle were both visible beforehand. Had an AM been active, the vehicle could have anticipated the hazard and acted preventively—without requiring agent–agent modelling, as $O(N)$ permits.

AM offers two further advantages: its rule-based logic is fully explicit and auditable, and by steering the vehicle away from dangerous configurations it enables certain edge-case scenarios to be excluded from testing, reducing the burden. Future work will formalise AM rules and integrate them with existing safety processes.

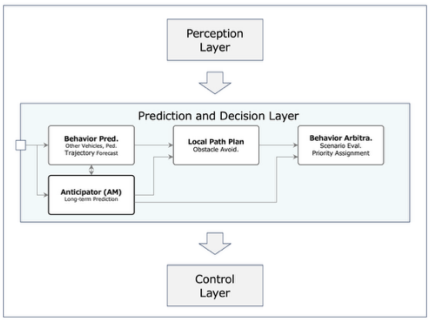

Fig. 1 Prediction and Decision Layer with Anticipator

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