Phase Transition: Level 5 Autonomous Vehicles

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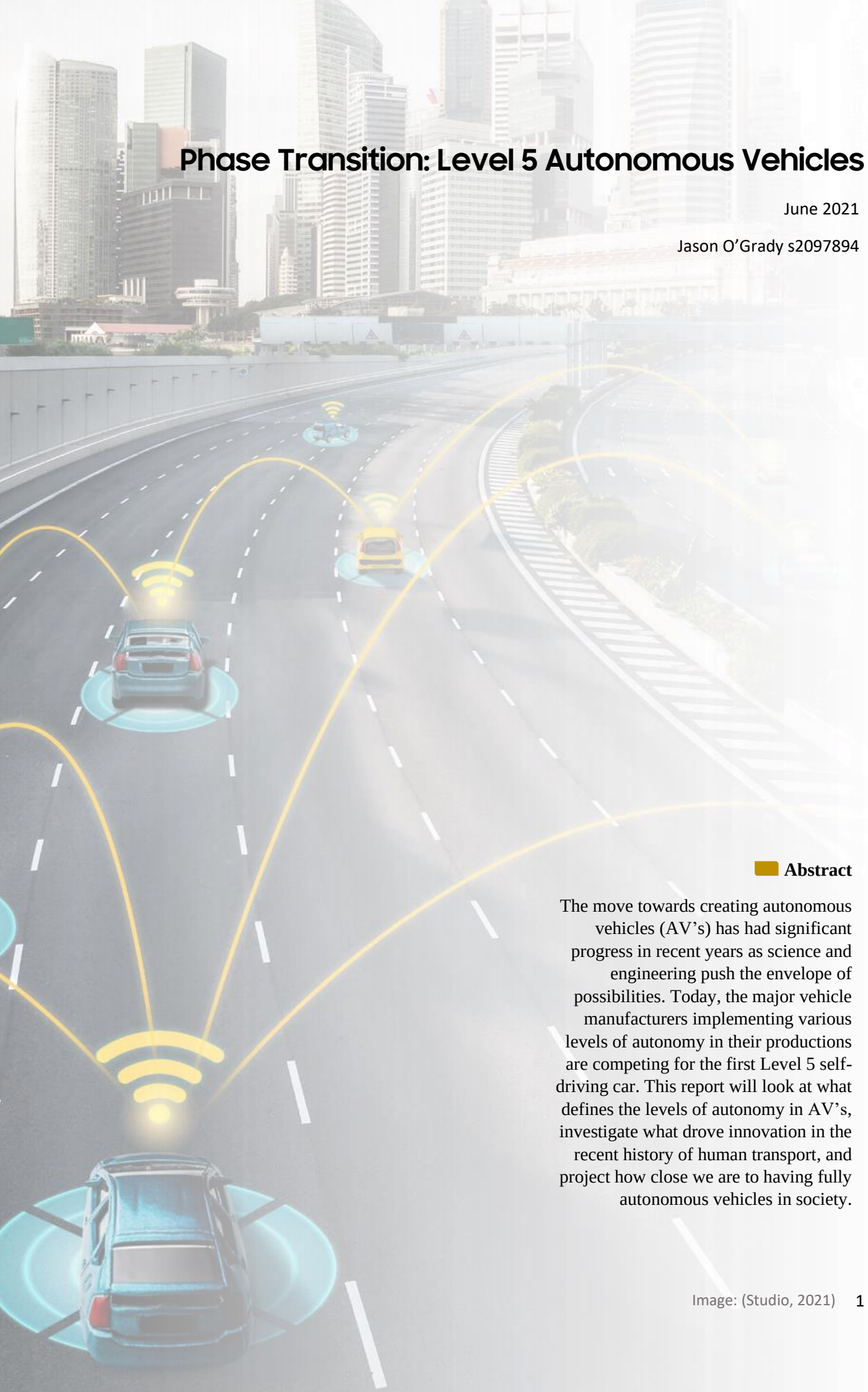

Abstract

The move towards creating autonomous vehicles (AV's) has had significant progress in recent years as science and engineering push the envelope of possibilities. Today, the major vehicle manufacturers implementing various levels of autonomy in their productions are competing for the first Level 5 self-driving car. This report will look at what defines the levels of autonomy in AV's, investigate what drove innovation in the recent history of human transport, and project how close we are to having fully autonomous vehicles in society.

Image: (Studio, 2021)

1. Introduction

The first Autonomous vehicle appeared as far back as 1925 when Francis P. Houdina used radio frequency technologies to steer an unmanned car (Fig 1) down the streets of Manhattan, capturing much public and media attention (Green, 1925). The rest of the 20th century continued to make progress in the area of AV's, but it wasn't until the US Defense Advanced Research Projects Agency (DARPA) started their Grand Challenge in 2004 that real technological progress was made, with the objective to create an AV that can safely navigate on its own through a 142 mile course in the Mojave Desert (DARPA, 2014). The technological advancements made during this time paved the way for the intelligent systems used within modern transport throughout the world today.

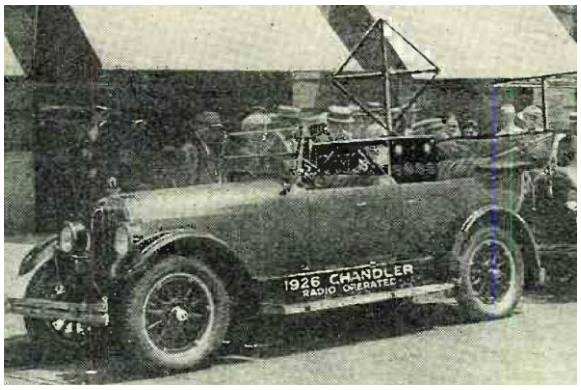

Figure 1: Houdina's American Wonder, 1925 (Green, 1925) Figure 2: Waymo's Jaguar I-PACE, 2020 (Waymo, 2020)

The technology today that drives a modern AV can differ greatly between manufacturers and models, therefore the Society of Automotive Engineers created a classification to define the 'levels of driving automation' that are determined by what features are engaged (International, 2019). The SAE International J3 016 can be classified as follows:

Level 0 Everything is done by the driver. No automation.

Level 1 Can sometimes assist with latitudinal and longitudinal tasks.

Level 2 Can sometimes assist with multidimensional tasks simultaneously.

Level 3 Can perform Object and Event Detection (OED). System will alert driver to take control.

Level 4 Can perform OED. System will respond to events but may require driver to take control.

Level 5 Fully autonomous, can drive everywhere and is able to navigate in all environmental conditions. No driver required, unlimited OED.

The basic autonomous functions of Adaptive Cruise Control or Lane Keeping Assistance fall into Level 1, and if both can work together at the same time to assist the driver, it achieves Level 2 automation. Level 3 is typically what people think of when hearing the term 'self-driving car' and this level begins to display much more intelligent capabilities. However, the only certified Level 3 car to date is Honda's Legend (Sugiura, 2021).

Tesla's Autopilot technology and Google's Waymo vehicles have been testing for Level 4 over recent years. This level alleviates the driver from piloting many tasks and can respond to emergency situations, which is a level of autonomy that often creates much discussion about driver responsibility. It appears that this level of autonomy is impeded by current driving laws in particular regions of the world (Schmidt, 2021).

Whilst over recent years many claims have been made towards releasing Level 5 autonomous cars, not a single manufacturer has released a working concept.

The capabilities of AV's are made possible using sophisticated engineering sensors that perceive environmental conditions with extreme precision. Vehicles are capable of perceiving information in light and sound spectrums far greater than the capabilities of humans, and can be increased further by sharing data with other AV's, allowing for a mechanical telepathy to unfold and emerge with grouped behaviors that lowers the risk of harm, lowers energy usage and enhances network flows (Meola, 2020). But the hardware is just the tip of the iceberg, what lies "under the hood" in the processing and response of this information, is what determines the autonomous capabilities.

1.2. Bleeding edge technologies

Planning how to respond to events is the key ingredient to success in the complex task of driving and many subcategories exist, all of which have important roles to play (C. Liu, 2017). Reactive Planning is a type of multi-level decision making that uses predefined rules to account for the state of the vehicle and any perceivable objects in its environment to immediately respond in a defined way. This can be helpful when encountering an unpredictable event, however since our roads are built to eliminate unpredictability, the main method used for piloting AVs is Predictive Planning.

Predictive Planning incorporates the use of Deep Learning and Neural Networks (Burke, 2019). This modelling technique is based on the same way our brains process data and learn. There is an overwhelming amount of detail within research in this area relating to the finer mathematical probabilistic systems used, but the point is they can be extremely effective at learning to respond safely to environmental blockades in order to reach their target.

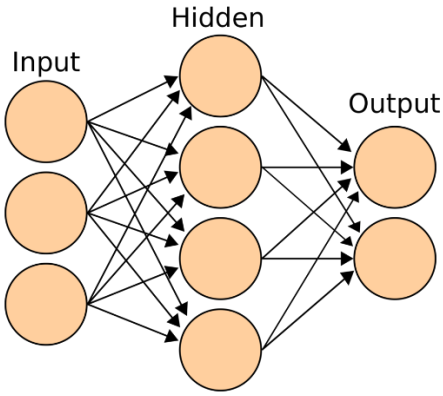

Figure 3: A Neural Network can be used in AV's, medical diagnosing, cryptocurrency and signal processing (Daityari, 2019)

2. Problems of the past

History shows that just over 100 years ago, we were facing very similar problems to what we are encountering today; The main method of transport - horses, had proven to be so successful for society that the unforeseen side effects had begun to emerge. Energy consumption, pollution, congestion, and safety were all areas that were responsible for much detriment in societal trade and transport, that the adoption of motor vehicles appears to have been motivated more by having to solve the problems faced at the time, and less about making technological advancements. (Morris, 2007). The costs involved for fueling horses, the waste that was created and the safety risks they carried only grew as population exploded during the early 20th century (Johnson, 2021). The transition to motor car saw transport related deaths drop 75% per capita from 1900 to 2007 and beginning in 1900 it only took 12 years for car sales in the US to rise from 4,192 to 356,000 vehicles sold per year.

Figure 4: Traffic in New York City circa 1935 (Katz, 2014) Figure 5: Traffic in Canada circa 2019 (Do, 2019)

The modern car was considered a positive environmental change. But over time as population has grown and more people have access to owning vehicles, the impacts of motor cars have accumulated to re-create the same problems of the past.

2.2. A hundred years later

In 2015, 193 countries of the UN General Assembly agreed to adopt the 2030 UNSDG's, a plan to create a sustainable future by focusing on key areas that require progressive change by the year 2030. "Affordable and Clean Energy", "Sustainable Cities and Communities" and "Ensuring the healthy lives and well-being for all" are key areas of focus with the UNSDG's, with directives to "halve the number of global deaths and injuries from road traffic accidents" (United Nations, 2015).

For the past 12 years, we have been tackling traffic congestion and greenhouse gas emissions on state and federal levels related to the automotive sector due to the massive increase in people on the roads (Edwards, 2008). Researchers have adopted to using heuristic optimization methods, metaheuristic algorithms and machine learning in both public and private transportation to solve the immense problems we are facing with traffic congestion (Sangmin Lee, 2020). Self-driving cars could help reduce these issues, so are we prepared legally and financially to implement them?

Rules surrounding the interaction between sapien and artificial intelligence have been openly discussed since the early 20th century, with Isaac Asimov being credited with creating the three rules of robotics, which have continued to be the cornerstone of human-machine interaction (Asimov, 1981). Today, the ethics around how an AV behaves is often open to public scrutiny, and whilst the headlines around AV's are mainly reporting failures, studies have shown many people are already accepting of autonomous technologies being on our roads. (Lynn M.Hulse, 2018). Automotive commentators have even outlined that if we already had fully autonomous vehicles in Australia, hospital admissions related to road trauma would free 40,000 hospitals beds per year (Butler, 2021).

Prices have seen a decline (Fig 6) with the cost of Tesla vehicles dropping, while equipment is being upgraded or revised (Guthrie, 2020). On top of that, software updates increase the cars efficiency over time and some models may be able to increase to a higher level of autonomy.

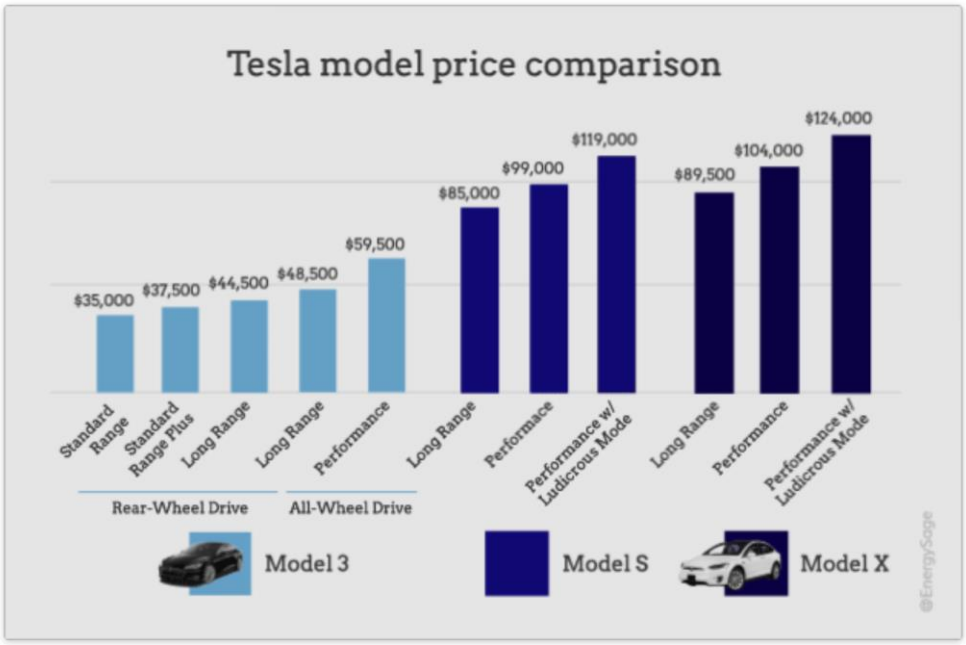

Figure 6: Current pricing for Tesla vehicles in Australia (Tesla.com, 2021)

Both manufacturers and government bodies are moving towards incentivizing drivers towards purchasing cars that encompass autonomous abilities. At the time of writing, Tesla promotes that drivers can save up to $2,648 in luxury car tax and also provide a number of more incentives on a state and federal level (Tesla.com, 2021) and overseas, car manufacturers are already discussing plans to offer autonomous abilities to be subscription based, where the level of autonomy can be suited towards budget and use case (Gauthier, 2021).

3. Think Different

Is it time to start thinking differently? The aim of the UN sustainable development goals is not just to solve the problem at hand, but to be thinking of the future we want for generations to come, so now is the time that we should be focused on creative and innovative thinking. George Hotz of Comma.ai has proposed he wants to be the one to solve autonomous driving by using an approach of installing modules into standard vehicles to give them intelligent capabilities (Investment, 2021). By taking this approach, the AV market could increase due to the low cost, which sits around USD$ 1,100 currently.

Scalability is something that should be in the forefront of problem-solving decisions made today, which means the area of congestion will likely require a complete paradigm shift in how we view traffic flows. Research from computer scientist Craig Reynolds during the 1980's around the area of flocking systems found in nature could prove to be quite helpful to us in this area (Reynolds, 1987). Reynolds was able to create algorithms that simulate natural schooling and flocking systems used by life forms on earth, from the micro level to the macroscale. Perhaps we should be utilizing our understanding of how natural systems are sustainable by using these algorithms to drive towards the lowest energy configuration.

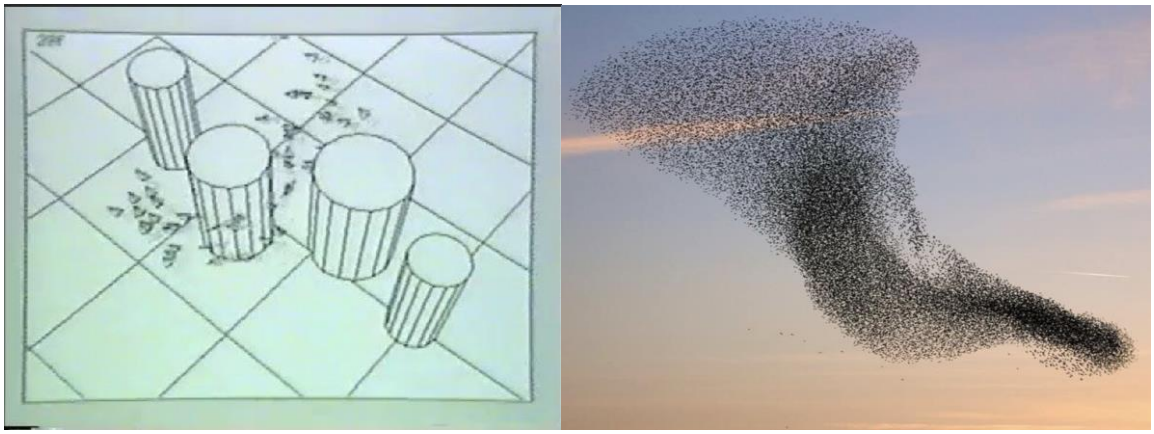

Figure 7: Craig Reynolds 'Boids' object detection simulation. Figure 8: Emergent flocking systems found in nature. (Oktober, 2016)

It is quite possible we are reaching a point where the car is no longer seen as a mechanical object, but something almost alive. Defined by its functional behavior rather than its material make up, we can begin to understand that training machine learning models is essentially the domestication of a mechanical beast.

4. Conclusion

It should be obvious that we can expect autonomous vehicles to take over by the end of 2030 and possibly quite sooner. The benefits gained from AV's will be pushed on every front to ensure we can continue to progress sustainably, therefore the way in which we use transport will see a drastic change. Vehicles will likely have dynamic levels of autonomy, where the cost is determined by the environmental context – driving alone in the snow at night will be much more expensive than driving with a micro fleet in a designed transportation environment. This new structure will define the future.

This is where level 5 autonomy will emerge. We will possibly never see a manufacturer release an actual vehicle that is able to perform level 5 on its own but instead only if it is connecting, communicating, and learning from other AV's. Our view may change to understand something of this magnitude requires a collective intelligence. Level 5 is currently being viewed as the ceiling of autonomous vehicle capability, but maybe we will soon discover it's actually the floor of another stage entirely.

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