Autonomy on the Water

The Challenge of Speed and Safety

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Autonomy Through the Years

Some of the first human travel without the use of animals occurred using boats. Dating back to as early as 4000 B.C., boats have helped people navigate waterways and fish for food (Vance et al., 2023). From the dawn of boats, a rudder has been used to steer (Boating New Zealand, 2021). However, as years have passed, the methods by which the rudder is adjusted have developed. Initially, the rudder was simply a stick moved by a person standing at the rear of the hull. As ships advanced, it became impractical for someone to constantly hold the rudder to steer. Thus, a wheel with a series of shafts and gears was invented so the boat's helmsman could simply turn the wheel to adjust the angle of the rudder and change the trajectory of the vessel. Eventually, electronics to control both the speed and direction of the boat, along with autopilot systems for navigation and joysticks for finer movement controls, allowed for the captain of the ship to be even less involved in the mechanics of steering.

Recently, there has been an uptick in companies attempting to introduce autonomy into their fleet of boats. On top of simply steering the vessel, autonomous systems can provide a variety of upgrades to the speed, safety, and efficiency of boats (Sinay Maritime Data Solution, 2023). Autonomous technologies include robotics technology, big data, Internet of Things (IoT), monitoring systems, and artificial intelligence (AI). Robotics technology allows humans to avoid monotonous and hazardous work on boats, and it is also aiming to address current labor shortages in the industry. Big data, coupled with cloud systems, is being utilized by autonomous systems to analyze trends and create patterns to allow for data-driven insights of a variety of tasks onboard. IoT sensors are being placed on navigation systems and other components on vessels, where they transmit data and develop relationships between historical and current data which can be used to spot problems in real-time. Autonomous monitoring systems are always observing the environment around them, measuring air and water quality, traffic, weather patterns, and much more. AI works to connect each of the aforementioned technologies. Building a network of data from a variety of systems, decisions can be made in real-time to adjust numerous components to accomplish the current task in the most efficient way possible. Currently, companies like Rolls-Royce are attempting to introduce systems like this into their fleet of boats, by first creating an unmanned coastal vessel, then progressing to an autonomous unmanned ocean-going vessel by 2035 (Rolls-Royce, 2016).

Autonomy and AI provide great benefits if done properly, yet there are many ethical concerns still with introducing AI into systems that humans currently control. It is still early in the development of artificial intelligence systems, but it is difficult to fully understand if the systems contain an implicit bias in their decisions (UNESCO, 2023). The implementation of AI was supposed to make tasks simpler and less prone to errors involving bias, but many people do not trust AI to be able to successfully accomplish both goals. It will be interesting to watch the development of AI and how it continues to affect maritime autonomy and other workplace tasks in future years.

Autonomous technologies are working to increase effectiveness in their algorithms to complete a variety of tasks on boats and other maritime vessels. In the technical project, my group is developing an autonomous boat that can complete a five-mile course safely in the quickest time possible. Just as we will implement speed and safety for the capstone project, speed and safety are also paramount features of auto racing. Drivers push their cars to the limits but rely on the car to protect them in the event of an accident. This begs the question: how have the deaths of drivers led to increased safety in Formula 1 (F1)?

Designing an Autonomous Boat

The American Society of Naval Engineers (ASNE) is the leading professional engineering society for engineers and scientists alike who work with naval ships and their associated systems and subsystems (ASNE, 2023). Beginning in 2018, ASNE hosts a boat-racing competition for college students called Promoting Electric Propulsion (PEP). The world is increasing its emphasis on renewable energy sources due to the rising air pollution. One of the ways to slow contamination of the air is to use renewable energy for fuel instead of gasoline, which emits carbon dioxide, a main contributor to global warming (U.S. EIA, 2022). Therefore, as the competition name suggests, all boats must contain electric propulsion.

The competition rules can be divided into two main categories. The first is the rules which govern the safety of the participants and spectators. These rules include that the vessel must appear seaworthy, be one piece, secure the battery within the hull, and have mechanisms that provide easy removal of the boat out of the water at the end of the competition (American Society of Naval Engineers, 2023). The other rules relate towards the overall goals of the competition and the methods which the boat must follow to complete the competition. These rules include having electric propulsion, being unmanned, and being able to complete the five-mile course with remote operation. Although the competition rules constrain the design of the boat, the purpose of them is clear. With any autonomous system, the main goal when the technology is in development is to keep all involved parties safe. While competition performance is incredibly important, safety remains the top priority of the technical project.

As this is the University of Virginia’s first year competing in PEP, the design of the technical project will focus less on the design of the hull itself and more on the reliability of the cooling, turning, and controlling systems on the vessel. As seen in Figure 1, students created an aquaculture farming boat in 2022 which has several useful mechanisms that will help guide the design for this year (VICTOR Lab, 2023). The previous design does not have a rudder in the back of the boat and rotates using multiple propellers in the rear of the boat. Operating the propellers at different speeds allows one side of the boat to move faster than the other, thus turning the ship. The operation of the ship is administered by a combination of a Raspberry Pi module and a computer. Using a Remote-Control receiver, signals from a controller are received and used to navigate the vessel. Coolant is transported around the electronics to allow for safe operating temperatures within the vessel. A combination of these mechanisms will allow the boat for this year's PEP competition to complete the five-mile course successfully and safely.

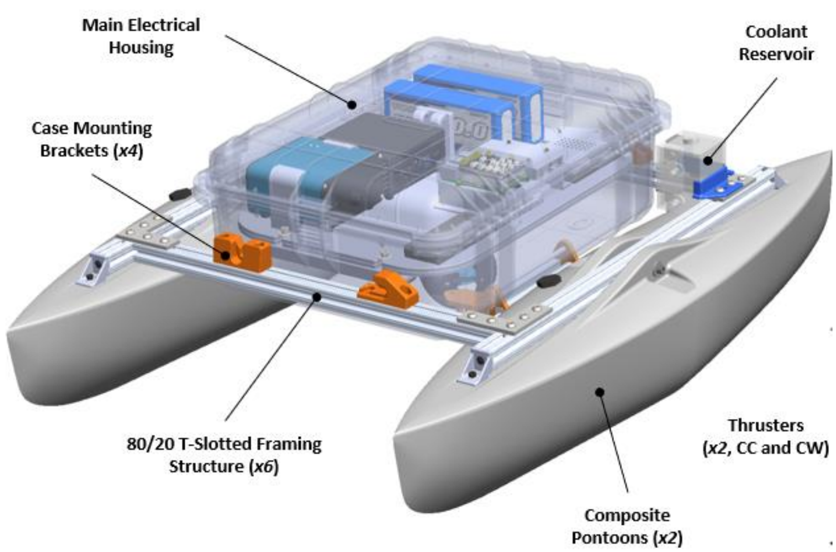

Figure 1. Diagram of the 2022-23 Aquaculture Vessel (Image source: VICTOR Lab, 2023)

Safe Development

Ayrton Senna, a three-time world champion in F1, entered the 1994 season driving for Williams. The car was incredibly fast, as he scored pole position in each of the first three races of the year (Thompson, n.d.). However, the car was also incredibly dangerous to drive, lacking the active suspension and traction control that the previous season's car possessed (Wikipedia, 2023). As seen in the results, Senna spun off the course in the first race and was out of the second race via crash. The car had incredible speed, but its drivability left any driver worried about the outcome of every corner. When qualifying for the San Marino Grand Prix, Roland Ratzenberger, an Austrian rookie, crashed around the Villeneuve curve, impacting the wall head on and passing away in the incident (Sports History Weekly, 2022). Senna confessed to his girlfriend that he did not want to race the following day but did after being convinced by his team. Senna was leading on the sixth lap, and Michael Schumacher, who was closely following him, noticed sparks coming out the back of the Williams after bottoming out around a corner (Williams, 2010). On the following lap, at the same corner that Ratzenberger had died 24 hours earlier, Senna's car entered at 192 mph. In a horrific series of events, Senna's car did not turn, resulting in him impacting the wall at 131 mph. The impact was not enough to kill him, but there were three separate injuries, each of which could have caused death (Palmer, 2021). The first was the wheel rebounding from his car and hitting his helmet, the second was a piece of suspension penetrating his helmet, and the third was an upright assembly that pierced his visor.

Those events and how Formula 1 responded to make the sport safer can be analyzed using Latour's actor network theory. In his work, Latour explains the dynamic between the human and nonhuman actors in a situation. In F1, the safety of the drivers is paramount. The Fédération Internationale de l'Automobile (FIA) is the governing body for world motor sport and strives to ensure safe, sustainable, affordable, and accessible mobility for all global road users (FIA, 2015). One of the points Latour makes is that human actors have as much of an influence over nonhuman actors as nonhuman actors have over humans (Latour, 1992). Nigel Mansell, a competitor of Ayrton Senna, stated that while he is sad to see that some tracks have become too safe, he is amazed that drivers can walk away unscathed from huge accidents (Wilde, 2022). Mansell's point shows that the nonhuman tracks have a large impression on both how the drivers race, but also how drivers and fans perceive the racing to be. Latour also mentions how the nonhuman artifacts do not play a passive role in the development of technologies, but an active one. As track layouts, or even the weather at the circuit, change, drivers make different decisions about how they race around certain corners. The connections between the drivers and their own decision-making, as well as other drivers, teams, and fans are shaped by a variety of nonhuman artifacts at the track.

However, the statements from drivers and fans can cause adjustments in track layouts and how drivers push their cars around different corners. At the 2021 British Grand Prix, Max Verstappen crashed with Lewis Hamilton, causing the Dutchman to go spinning into the barriers in a crash that was an estimated 51 g (McMahon, 2023). He returned to race just two weeks later. Simply comparing the brutality of Verstappen's crash with Senna's speaks to the vast improvements in safety within Formula 1 since 1994. The back-and-forth nature of driver statements and changes in nonhuman artifacts show how the network of connections actively plays a role in the development of technology. Through findings from various sources, such as interviews with drivers or surveys of fans, the different perspectives of how Formula 1 has changed since 1994 will be brought to light.

Analyzing Increases in Safety

The prior section suggests that safety within F1 has developed since the death of Ayrton Senna in 1994. Although it is difficult to say if Senna's crash still would have been deadly in 2023, there are ways to find strong evidence that current drivers have survived crashes of equal or worse magnitude than that of Senna at the San Marino Grand Prix. Bibliometrics and surveys are two research methods that will be used.

Data analytics will be combined with bibliometrics to get the full picture of crashes in F1. Finding data on the magnitude of the crash, then pairing the data with driver and fan statements, will provide numerical evidence of the increased safety. References to crashes in different years can show trends in the statistics of impact force, damage sustained, and injuries over time. Similar bibliometrics can be used for the various racecar requirements from the FIA. Updated regulations can follow successful testing of safer equipment, and track layout changes can show how the FIA prioritizes the safety of its fans and drivers. Using data alongside bibliometrics is an easy way to find trends in safety throughout the years in F1.

Surveying fans will allow for the collection of public opinions about F1. A possible series of questions to be posed is the following: How do you feel about the evolution of Formula 1 with the various regulation and safety changes over the years? Do you think these changes have enhanced or diminished the quality of racing and your enjoyment of watching F1 races? By using Reddit, these questions will be delivered to a wide audience of people, all of whom care about F1.

With the methods described above, it should be able to be seen how safety within Formula 1 has been improved since 1994, as well as what fans think of the changes made.

Conclusion

Autonomous systems are developing around the world at an increasing rate. One of the industries most involved in this development is the boating industry. The development of autonomous boats will allow for improvement of a variety of processes, like military tactics or deep-sea exploration. Even though the advances in autonomy provide substantial possibilities, safety must remain the top priority. The same principle applies in Formula 1. While drivers want to win at all costs, the upmost importance is their safety. Over the past 30 years, F1 has improved the protection of drivers while remaining one of the top sports around the globe, showing that safety does not have to be sacrificed for innovations to be made. Keeping this in mind while developing autonomous systems, specifically autonomous boats, will allow for proper growth of an industry that can provide countless benefits going forward.

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