Fei-Yue Wang, Editor

Drive Like a Machine: A Green Reflection of Red Flag Acts for Intelligent Vehicles

EDITOR'S NOTE

Please send your submissions for the "History and Perspectives" column to Fei-Yue Wang at feiyue@ieee.org.

In this column, we take a new look at the United Kingdom's historic Red Flag Acts for early automobiles more than 150 years ago and argue that we should design our future intelligent vehicles to drive like a machine instead of a human to achieve our goal of smart mobility and sustainability for future smart cities.

At the Transportation 5.0 Workshop of IEEE ITSC 2023 [1], the authors of this column met in Bilbao, Spain. Ding Wang is a young researcher at Yilun's Urban Computing Lab at the Shanghai AI Laboratory. Yilun Lin was a Ph.D. graduate and research associate of Fei-Yue Wang at the Chinese Academy of Sciences many years ago. Ding recalled Fei-Yue's talk at the 12th Multi-Country Urban Traffic Research Symposium organized by Beijing Jiaotong (which means "Transportation" in Chinese) University in 2011 when she was a freshman college student there, which stated that future autonomous driving would be possible

only after human-driven vehicles were no longer allowed. This reminded Fei-Yue of his first presentation at her university in 1999, as mentioned in the inaugural article of this column [2] on CASTLab; his keynote address at the IEEE Intelligent Vehicles Symposium 2017 in Los Angeles [3]; and his recent editorial for *IEEE Transactions on Intelligent Vehicles* titled "Drive Like a Machine" [4].

So, an interesting discussion on "drive like a human or a machine" started among us at Bilbao's conference center and continued at nearby coffee shops, bars, and restaurants during IEEE ITSC 2023. Fei-Yue's opinion (as illustrated in "Drive Like a Machine or Human?") was debated and analyzed, and the final result is this column you are reading now. We hope you are interested in this issue and will share your own ideas with us in this column.

Drive Like a Machine or Human

For more than two decades, dedicated scientists and researchers have been working hard to make autonomous vehicles (AVs) drive like humans. Given that humans were once the exclusive operators and creators of AVs, it's natural to deduce that if AVs could mimic human performance, their safety and efficiency would be assured [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15].

Yet, bearing in mind that humans have never surpassed a speed of 44.722 km/h, even on an open running track, it feels somewhat unrealistic to anticipate that mimicking human behaviors and reactions could lead us to design the most skilled drivers. Humans have become adept drivers not through a natural predisposition but through learning and adapting to ever-changing driving environments. This learning process has led us to develop systems and protocols that facilitate our driving, much like how we once designed saddles and carriages to aid horses in transportation.

Many researchers have observed and cataloged the unique characteristics that make humans relatively proficient drivers, using these data to program intelligent vehicles [16], [17]. However, as we reflect on our driving abilities, it's crucial to acknowledge our limitations. Humans often struggle with maintaining focus and accuracy during repetitive tasks, like driving, prone as we are to fatigue, distraction, and impatience. These factors often compromise the safety and efficiency of our driving.

Machines, on the other hand, excel where we falter. Given a broader field of view, quicker reactions, and more precise control, these intelligent vehicles can offer tireless vigilance and

consistent accuracy unparalleled by humans. Such a comparison raises a question: Should we impose human driving regulations on AVs, or should we permit them to exploit their inherent machine capabilities for driving, as they are designed to do?

This shift in thinking stems from the vision we uphold—that future transportation should be smart, smooth, and safe. Thus, akin to our transition from horse-drawn carriages to automobiles, it could be the right moment to replace human-like driving with a more advanced alternative. To actualize this vision, it is crucial to revolutionize the systems initially conceived for human operation to suit the specific dynamics of vehicles driven by machines.

Red Flag Acts and the Horse Manure Crisis

Such transitions will not be easy. Looking back at history, transitions in transportation have always been accompanied by skepticism and regulatory challenges, as seen in the late 19th century when automobiles first rolled onto the scene.

Despite the shock that cars brought—a carriage without a horse—people in the United Kingdom, and indeed wherever automobiles were introduced, initially viewed these machines with skepticism and concern. The public was accustomed to the slow and steady pace of horse-drawn carriages, and the idea of machines speeding along the roads was unsettling. The government, sensing these worries, decided to step in with a set of rules to keep things under control. These rules were known as the *Red Flag Acts* or the *Locomotive Acts* of the 1860s [18].

Red Flag Acts put a leash on early automobiles. In the 1865 act, cars were required to travel at a snail-paced 2 mi/h in bustling cities and, thankfully, a tad faster at 4 mi/h in the open countryside. But that wasn't all! To ensure that these automobiles didn't surprise or harm anyone, a person had to walk ahead, waving a red flag or lantern, heralding its approach (Figure 1).

At first, people nodded in agreement with these rules. Safety first, after all! But as the days rolled into months and months into years, a

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DRIVE LIKE A MACHINE OR HUMAN?

An excerpt from "Drive Like a Machine" by Fei-Yue Wang [4] follows:

Yes, it had always been my dream of designing intelligent vehicles that would drive autonomously like a human, until the turn of the 21st century. After two decades of research and development in autonomous driving, I started to doubt my initial objective, and by the middle of 2000s, I have convinced myself that we should and must design intelligent vehicles that would drive like a machine, instead of a human.

I understand that this is an anti-mainstream thinking, and the reason for my changed heart is not the lack of confidence in the intelligent vehicle technology, but the acceptance of the fact that our human driving behaviors are incapable of collaborating with intelligent vehicles for a safe and sustainable mobility which is required and compatible with our future lifestyle in smart societies.

To put it simply, the safety and sustainability demand and requirement of future mobility are beyond the capacity of our human psychology and physiology, just like that of modern mobility are beyond the capacity of horses' behaviors. We had already removed horses from our roads and highways in order to maintain a safe and effective modern lifestyle, we must remove human drivers from our future roads and highways, if we still use those labels, in order to maintain a safe and sustainable lifestyle in a smart society, be both effective and efficient, and do the right things in the right way. Therefore, intelligent vehicles should drive like a machine, and make human riders, not human drivers, safe and comfortable.

Remember the "Red Flag Acts" or the Locomotive Acts of Parliament in the United Kingdom during the beginning of automobile industry in the latter part of the 19th century? For example, the 1865 act required all road locomotives, including automobiles, to move no faster than 2 mph (3.2 km/h) on the urban roads or 4 mph (6.4 km/h) on the country roads, and in addition, a person wavering a red flag to warn pedestrian. As a matter of fact, a horse-drawn carriage travels at an average speed of 2–4 mph, so Red Flag Acts had actually mandated that an automobile drives like a horse draws a wagon, quite similar to our demand today that a smart computer drives an intelligent vehicle like a human-driven car moves. Sound ridiculous?

The reason is simple: automobiles driving like horses is not efficient, automobiles driving at their designated speed along with horses is not safe, since horses would be scared by the speed of automobiles and their coexistence is beyond horses' biological capacity.

Nowadays you can't see any horse and horse-drawn carriage on the roads except standing or loaded on livestock trucks. Before, horses and horse-drawn carriages were common household assets, and now only the superrich could afford them.

In the future, I believe you would be less likely to see human-driven vehicles on roads except parking on automated or autonomous trucks. Today, cars are average household assets, and only the superrich could afford them in the future.

The reason is very simple too: intelligent vehicles driving like human-driven cars is not efficient, intelligent vehicles driving at their designated speed along with humans is not safe, since human drivers would be scared by the speed of intelligent vehicles and their coexistence is beyond human drivers' biological capacity.

This also reminds me of The Great Horse Manure Crisis of 1894. Georg Hegel famously claimed, "The only thing that we learn from history is that we learn nothing from history." If you have time, please go back and review this interesting story, and learning some lesson from this crisis.

I must tell this: many research problems for intelligent vehicles we are concerning and consuming our times and energies are actually "Horse Manure Problems" for our future smart cars in our smart societies.

FIG 1 The Red Flag/Locomotive Act 1865 sign. This sign shows the past, when the cars had to crawl along the roads, with a person walking ahead waving a red flag as a warning to everyone around. It's a symbol of a time when the new and exciting technology of automobiles stepped into our world cautiously and slowly. (Source: Taken from [18].)

FIG 2 The historical image captures the essence of the Great Horse Manure Crisis of 1894 in London. In the article by John Elfreth Watkins, "What May Happen in the Next Hundred Years," he made remarkable predictions about the future of transportation, foreseeing a significant shift from traditional horse-drawn vehicles to automobiles. (Source: Taken from [19].)

murmur of discontent began to ripple through the land; cars were gradually being seen as opportunities and symbols of progress instead of threats. Not only the innovators constructing these vehicles but also the general public began to question the status quo.
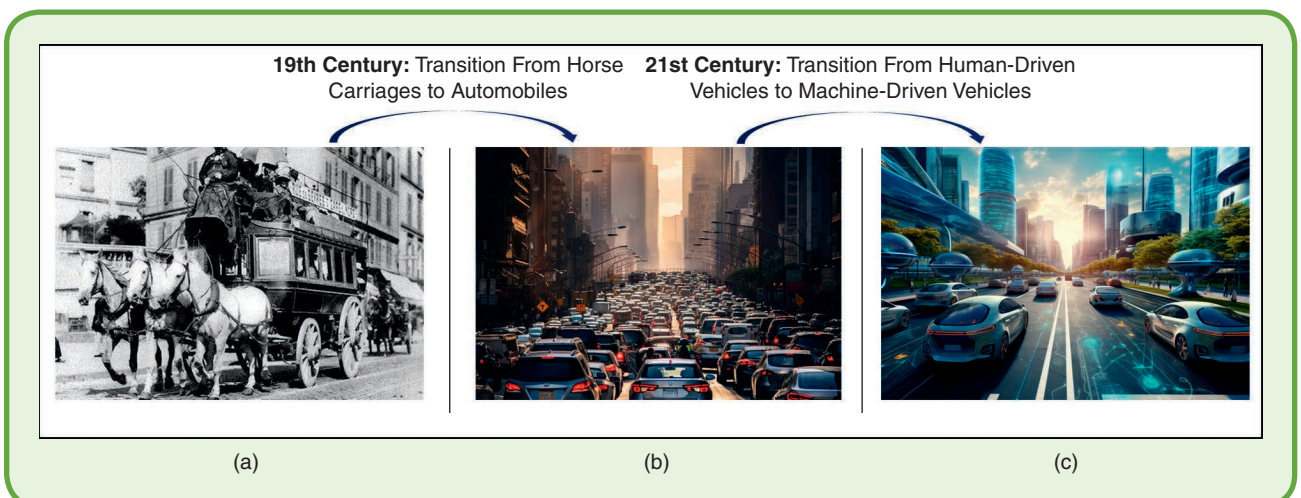
"Why should these fantastic machines be held back?" they wondered aloud. The murmurs grew louder, turning into calls for change. People began to discuss, debate, and deliberate on whether to tweak the Red Flag Acts or to throw them out the window altogether.

And so, the wheels of change began to turn, slowly but surely. The Red Flag Acts, with their red flags and lanterns, became milestones along the journey of history, reflecting the safety concerns of the time. Meanwhile, crises like the daunting "Great Horse Manure Crisis" [19] marked major bends in the road from another perspective (Figure 2). Such historical events served as nudges, or even strong pushes, shifting gears from horse-drawn carriages to automobiles.

Today, history seems to be rhyming as we find ourselves at the edge of another monumental shift, envisioning a future where automated vehicles might become the norm, and human-driven ones might become a relic of the past. Reflecting on these historical events provides invaluable lessons and insights for our present transition.

FIG 3 The evolution from (a) horse carriages (horse-drawn era) to (b) automobiles (human-driven era) to (c) intelligent vehicles (machine-driven era).

Smart Societies of Intelligent Vehicles

Just like when cars first appeared on streets that were once full of horses and carriages, we're stepping into a new world of travel with these smart self-driving vehicles thanks to the boom of artificial intelligence (AI) [20], [21], [22]. Envisioning the not so distant future, intelligent vehicles will be everywhere, and human-driven cars might become a rare sight, like treasures from the past. These intelligent vehicles will navigate with remarkable speed and accuracy that might be surprising for us humans, and trying to drive alongside them might feel a bit like racing with a superhero—thrilling but tricky!

Imposing restrictions on machine-driven vehicles to operate like human-driven vehicles or adhere to rules designed for human-driven systems is much like the Red Flag Acts that imposed restrictions on automobiles in history. It's neither practical nor safe to expect intelligent vehicles to act like human drivers, just like it was unrealistic to expect cars to act like horses in the 19th century.

Therefore, it is vital to shift our focus away from a world designed for human drivers and get ready for a future where machines take the wheel in this transition era (Figure 3). Instead of designing systems where humans drive for humans, it would be more important to create environments optimized for the machines driving for humans.

We, along with many researchers in the field, believe that machine-driven transportation can significantly enhance human safety and travel efficiency, in addition to providing easier access for those who can't drive. Moreover, the most significant advantage might be the potential time savings from widespread autonomous driving. This could free individuals to invest more time and energy into creative pursuits and enjoyable activities.

To this end, let machines drive for humans instead of like humans! Let's learn from the lessons and experiences of history and get ready to embrace the arrival of the machine-driven era in our smart cities!

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