Review article

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Autonomous Trucks

Abstract

A short review of the formation of the **International Neural Networks Society (INNS)** is followed by a research review of how **Autonomous Trucks (AT)** uses computational intelligence. Using the power of pairs of biological sensor structures -- "agree, signals; disagree, noise" for all weather conditions, and the modern lithium batteries, electrically driven trucks can ship goods non-stop by replacing batteries from depot to depot by former truck divers serving as depot managers. Together these can solve modern supply-chain challenges and promote the 4th economic boom.

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Introduction

Autonomous Trucks (AT)

The AT is an interesting application of Artificial Intelligence (AI). Our nation is developing vehicles at various automation levels, but the beginning level in mind is an autonomous vehicle that still has a human driver in the loop, doing office work in the car. That kind of *semi-automated level* is likely to take too many years to achieve – possibly by 2038. That is really a shame because this kind of semi-autonomous vehicle is needed to drive America beyond a supply-chain-challenged economic boom.

Historically, Harold Szu helped the International Neural Network Society (INNS) incorporate during SPIE[1] Workshop in Leesburg Xerox International Education Center Virginia, involving 17 colleagues in an international interdisciplinary team, including a colleague from the Rockefeller University. He organized the Workshop and became the secretary and treasurer to incorporate the INNS, while a Naval Research Lab intern Mr. Joe Landa and colleague Franck Pochinghorn helped log in several hundred members. INNS was a precursor to the development of artificial neural network applications that are a foundation for autonomous vehicles.

Autonomous trucks and economic generations

The realm of Autonomous Trucks (AT)[2] represents a compelling application area where human involvement persists, albeit initially as a supervisory capacity. Positioned in the metaphorical shotgun seat, we envision a scenario an operator can seamlessly delegate vehicular responsibilities to a vehicle, thereby affording the luxury of engaging in office tasks within the confines of an automobile. Our nation is currently engaged in multifaceted developments in vehicular autonomy, but the current conceptualization centers on an automated vehicle paradigm that retains a human driver in the decision-making loop, enabling one to conduct professional duties from the comfort of a car. The realization of this semi-automated level need not be a protracted endeavor, and its timely achievement is imperative, as we firmly believe that such semi-autonomous vehicles possess the potential to propel the Walmat, Amazon, Cosco, etc chain stores to American economy into unprecedented growth.

Reflecting on historical precedents, the expedited deployment of this semi-autonomous technology parallels transformative moments in American history. Analogous to President Eisenhower's visionary construction of the interstate highway system, which catalyzed economic prosperity in its first generation, the advent of semi-autonomous vehicles stands poised to emulate this economic impact. The second generation witnessed President John F. Kennedy's audacious commitment to space exploration, underscoring the transformative power of setting ambitious national goals. The ensuing technological pursuit of "ultimate control of precision electronics" has since shaped industries, steering the trajectory of precision computing from its nascent stages to the contemporary landscape.

In the third generation of transformative developments, the internet emerges as the driving force, fueled by initiatives such as the ARPA programs that sought direct scientist-to-scientist and scientist-to-program manager communication. This era, characterized by "high-risk, high payoff" efforts, not only facilitated global research collaboration but also became instrumental in enhancing economic circulation.

As we contemplate the fourth generation of transformative advancements, we posit that Autonomous Vehicles will play a pivotal role in shaping the trajectory of societal computation. Advocating for a strategic societal shift towards this autonomous direction, we foresee significant revenue generation and widespread societal benefits emanating from the integration of autonomous vehicle technologies. In this evolving landscape, the fusion of human supervision and machine autonomy stands as a testament to the ongoing narrative of technological progression and its profound implications for society at large.

The fourth economic boom is poised to originate from AVs that steer computation in our society toward not only generating revenue for the collective benefit but also revolutionize the transportation sector, particularly in the movement of goods between depots. The crux of this vision lies in eliminating the most expensive element: the truck driver. The prospect of a trucking system "without the truck driver" is not a distant reality, but could be accomplished within a six-year timeframe, representing an expedited and strategic starting point for our future trajectory. This proposed level may currently seem to require a dozen years for realization. But the implementation of autonomous vehicles has the potential to instigate a profound economic upswing in America. This technology, functioning as a catalytic force, holds the key to transforming our economic landscape.

Importance of a focus on ATs

The focus extends beyond mere consideration of the vehicle. Particularly intriguing is the transformative potential inherent in autonomous trucks, especially in the context of point-to-point transportation between depots. The pivotal factor here lies in the removal of the truck driver, the most costly component in this logistical chain. A paradigm shift to a trucking system devoid of human drivers is not an aspirational concept reserved for a distant future—it is an achievable reality within a more compressed timeline of six years. As we gaze into the future of autonomous vehicles, the nexus of development converges upon the realm of trucks.

The intricacies of city driving pose unique challenges, where humans exhibit a distinct and sometimes unpredictable behavior in such environments. It is a well-known fact that within city limits, adherence to laws and regulations can be erratic, reflecting the inherent creativity of human decision-making. Thus, for autonomous vehicles navigating urban landscapes, the human touch remains indispensable. However, consider a scenario where the truck operates autonomously between fixed points, and the human role involves overseeing nuanced tasks such as cargo mixing. This synergy of autonomous technology and human supervision presents itself as the cornerstone of what could be the fourth economic boom in the United States.

The roles of fuzzy logic and human cognition

To realize this technological vision, it becomes imperative to extend our focus beyond computational intelligence -- a profound understanding of human behavior becomes equally vital. Recognizing the intricacies of human decision-making, encompassing both adherence to legal frameworks and occasional rule violations, forms the linchpin of this integrated approach to autonomous trucking technology.

In the realm of human cognition, our thought processes exhibit a remarkable degree of fuzziness, not in the sense of cognitive confusion but rather in the nuanced domain of emotional behavior. This observation naturally leads us to ponder the integration of fuzzy logic[3] and fuzzy membership functions into computational frameworks. Delving into the intricacies of this integration, it becomes evident that it is not a straightforward endeavor; otherwise, the substantial global investments in this area would have yielded more immediate results. The realm of fuzzy logic sheds light on AT complexities and potential avenues for resolution.

Understanding the intricacies of human thought processes becomes imperative, as it forms the bedrock for effective incorporation of fuzzy logic into computational models. While not advocating that computers have emotions akin to human sentiments, an understanding of human emotions is crucial. Consider the unpredictability of human emotions, especially in scenarios influenced by external factors like the consumption of alcohol. This unpredictability is a significant factor contributing to the conundrum of why computers, proficient in games like chess, struggle to navigate the complexities of driving a car.

Fuzzy logic and human behavior

The opportunity posed by fuzzy logic lies in its departure from the realm of **probability** to that of ***possibility***. Unlike probability, which operates within ***fixed sets***, fuzzy logic contends with the ***infinite set of possibilities*** that extend beyond conventional expectations. For instance, at a red light, and the possibility of individuals crossing the street is not confined to a predetermined probability; it exists as a broad spectrum of potential actions beyond conventional foresight.

The inherent difficulty in accommodating such vast possibilities within the finite constraints of a computer, a machine conceptualized by ***John von Neumann***, becomes apparent. Storing infinite sets of possible real integers, even limiting it to positive integers, exceeds the computational capacity of a finite state machine. This limitation prompts the question: How can we effectively encode human behavior, characterized by the infinite openness of fuzzy membership functions, into a finite computational framework?

The concept of fuzzy membership functions, by nature, represents an ***infinite open*** set. Yet, through the collective synergy of interconnected computers, there arises an intriguing dynamic—individual fuzziness converges into a more defined, albeit narrower, computational framework. The amalgamation of ***fuzzy sets***, such as "***young***" and "***beautiful***," exemplifies this process. While individual memberships remain inherently fuzzy, the logical triangulation employed by computers renders the collective set more distinct, crisp, and comprehensible. ***Young and beautiful***, once seemingly fuzzy attributes become more crisply defined through computational logic.

Essentially, the key lies in formulating precise computational representations for inherently fuzzy attributes, such as youth and beauty. Developing formulas that generate these attributes is a formidable task. However, once achieved, these formulas empower fast computers to compute and, through logical triangulation, yield results that align with current contextual needs. This intricate interplay of computational logic and fuzzy membership functions is at the forefront of addressing the challenges posed by fuzzy thinking within the realm of artificial intelligence and computational systems.

Fuzzy logic and automated truck technologies

When delving into the logic governing AVs, the challenges are distinct from the nuanced attributes of "young" and "beautiful" in human behavior. In the realm of AVs, the intricacies lie in understanding the dynamic variables affecting vehicle movement, such as road friction and weather conditions. Unlike human attributes, these factors are dynamic and demand real-time computation. This dynamic aspect can be likened to the term "Einstein Brownian motion," where Newton's equations intertwine with tire friction, constituting essential variables.

In this intricate dance of variables, the age of the tire, road conditions (wet or dry), and other factors are dynamic components that must be considered in a dynamic equation. The computational challenge lies in the need to compute infinite possibilities in real-time. For instance, tire friction varies with the road condition, and the car must adapt its movement accordingly. Additionally, external factors play a pivotal role, necessitating the car's awareness of its surroundings.

Typically, lidar, or laser radar, is employed for environmental awareness. While a single laser radar suffices for many applications, the question arises: Why not use two? Drawing inspiration from biological principles, such as having two eyes for depth perception, employing two laser radars introduces redundancy and reliability. Evolutionary lessons from biology highlight the effectiveness of redundancy, where agreement between two signals signifies a reliable output, while disagreement implies noise or potential error.

This principle of redundancy extends to computational thinking. Even with laser radar, the concept of a "pair of sensors" becomes essential. Beyond environmental awareness, the precise location of the vehicle is paramount. The current GPS, offering position accuracy to one meter, needs refinement to a one-foot level. Precision matters significantly in computational thinking, where miscalculations could have severe consequences, particularly in ensuring the safety of pedestrians and other vehicles.

The GPS uses multiple satellites for triangulation, a process that involves intricate radian computations involving 66 satellites. This sophisticated network ensures precision down to the one-foot level, empowering the autonomous vehicle with the capability to make informed decisions, such as when to stop. By drawing from both biological insights and advanced computational techniques, the logic governing unmanned autonomous vehicles integrates redundancy, precision, and real-time computation to navigate the complexities of the dynamic environment and make judicious decisions.

The recent incidents involving fatal accidents with AVs serves as a poignant illustration of the challenges inherent in the coexistence of autonomous machines and humans. In one case, a car went through a red light, and the autonomous vehicle failed to stop in time, resulting in a tragic collision.[4] Notably, the insurance company covered the financial aspects for the affected individual, emphasizing the immediate cessation of operation upon human impact, a crucial safety protocol. However, the aftermath of this incident saw the insurance company filing a lawsuit against the autonomous vehicle's operator, Uber. The underlying issue points to the fundamental challenge of designing machines that seamlessly coexist with humans. While machines exhibit exceptional autonomy within controlled environments like factories, the transition to sharing spaces with humans demands a nuanced understanding of human behavior. The lack of such understanding can lead to decisions that might be deemed "fuzzy" in the absence of comprehensive knowledge about human actions. This knowledge gap contributes to the prolonged timeline for achieving widespread autonomy in vehicles— a significant factor in the envisioned 12-year timeline.

Addressing these challenges requires a dynamic approach, particularly in formulating and implementing 14 dynamic equations that encompass various driving-related factors. By leveraging this dynamic approach, the focus can shift towards achieving a more expedited six-year timeline for the development of autonomous driving technology. Such a shift holds the promise not only of reducing casualties during human driving but also of creating a harmonious synergy between human and machine capabilities.

ATs and human nature

The potential for human multitasking during autonomous vehicle operation becomes a crucial consideration in this context. Humans can engage in conversations and perform other tasks while driving, which represents a level of cognitive flexibility that machines currently lack. By harnessing the strengths of both humans and machines, a synergistic relationship can be forged, resulting in benefits that extend beyond safety to include enhanced efficiency and earlier societal advantages.

In essence, the pursuit of a dynamic and comprehensive understanding of human behavior, coupled with the strategic implementation of advanced computational models, holds the key to expediting the integration of autonomous vehicles into our society. This transformative approach not only addresses safety concerns but also positions itself as a catalyst for the anticipated fourth economic boom, underscoring the profound impact that autonomous technology could have on societal well-being and progress.

Research needs for autonomous vehicles (AVs)

Engaging in research within the realm of AVs and fuzzy logic demands a multifaceted approach that encompasses both theoretical understanding and practical experimentation. Here are some recommendations for conducting research in this dynamic field:

1. **Incorporate fuzzy logic into educational curricula:** Emphasize the teaching of fuzzy logic and fuzzy membership set logic at educational institutions. Move beyond traditional Boolean logic and delve into the nuances of fuzzy logic, focusing on open sets and dynamic equations. Introduce students to the Walter Freeman dynamical equation approach, enabling them to comprehend the infinite possibilities inherent in fuzzy decision-making.
2. **Focus on fuzzy membership functions:** Prioritize the understanding of fuzzy membership functions, emphasizing that they are not merely logical constructs but dynamic entities. Foster a comprehension of these functions through dynamical equations, emphasizing computation over storing results. This approach facilitates a more adaptive and real-time response to dynamic environmental conditions.
3. **Hybrid approach for testing and experimentation:** Implement a hybrid approach for experimentation. Develop and test model cars in controlled environments, employing fuzzy logic and membership functions. Create scenarios where model cars can cross paths, evaluating the efficacy of the new approach in minimizing collision risks. This practical testing can provide valuable insights into the real-world applicability of fuzzy logic in autonomous vehicle scenarios.
4. **Explore dynamical equations in motion:** Encourage research that explores dynamical equations in motion, considering factors such as road friction, weather conditions, and tire dynamics. Utilize Lyapunov control theory in conjunction with dynamic equations to model and simulate higher speed and more complex travel scenarios. This approach allows for a deeper understanding of the intricate balance between various elements influencing vehicle dynamics.
5. **Consider human driving dynamics:** Acknowledge the peculiarities of human driving dynamics and incorporate this understanding into the research framework. Experiment with scenarios that mimic human driving behaviors, such as the use of centrifugal force in turns. Investigate whether autonomous vehicles can learn and replicate these subtle human-driving nuances.
6. **Collaborate across disciplines:** Promote interdisciplinary collaboration between computer science, engineering, and behavioral sciences. Recognize the importance of not only advancing computational models but also gaining insights into human behavior. Collaboration can enrich research outcomes and contribute to a holistic understanding of the challenges posed by autonomous vehicles in human-centric environments.

Summary

By combining theoretical foundations with practical experimentation, researchers can contribute to the advancement of autonomous vehicle technologies, paving the way for safer, more efficient, and socially integrated transportation systems. The intricacies of driving, a truly peculiar and culturally nuanced endeavor, underscore the importance of a comprehensive approach to autonomous vehicle research. Reflecting on experience when learning high-speed driving one is reminded of the subtleties involved—such as sensing centrifugal force in turns. Autonomous vehicles have yet to acquire this intuitive understanding.

To bridge this gap, a dynamic understanding of car motion, coupled with control theory, becomes paramount. Modeling and simulating higher-speed scenarios, intricate road dynamics, and traffic light interactions in a controlled laboratory environment are essential steps toward achieving a more sophisticated level of autonomy. The real-world situational awareness required for driving—reading traffic patterns and responding to diverse scenarios—poses a challenge that demands comprehensive interdisciplinary research.

Looking ahead, it becomes evident that the synthesis of theoretical advancements, practical experimentation, and insights from disciplines ranging from computer science to behavioral studies is crucial. Schools play a pivotal role in this journey, with a need for dedicated laboratories that foster hands-on exploration. Moreover, interdisciplinary collaboration is essential for studying the intricacies of the human brain and behavior, providing a holistic understanding that can inform the development of autonomous systems capable of navigating the complexities of real-world driving scenarios.

By embracing these principles, researchers can accelerate progress, laying the foundation for a future where autonomous vehicles not only navigate traffic but also embody the subtleties and adaptability inherent in human driving. This journey, while challenging, holds the promise of earlier accomplishments and sets the stage for a transformative era in transportation—one where technology and human understanding converge for safer, more efficient, and seamlessly integrated driving experiences.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

References

1. *SPIE is the international society for optics and photonics*. 2023.
2. Finn A, Scheding S. Vol. 3: *Developments and challenges for autonomous unmanned vehicles*. 2010.
3. Zadeh LA, Aliev RA. *Fuzzy logic theory and applications* (edition unavailable). World Scientific Publishing Company. 2018.
4. *Self-driving Uber kills Arizona woman in first fatal crash involving pedestrian*. 2018.