Autonomous Cars using Embedded Systems & Spherical Wheels

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Abstract— This paper presents the design and experimental implementation of a control system for the operation of automated vehicles using spherical tyres.

Key words: Autonomous Cars; Embedded Systems; Spherical Wheels

I. Introduction

Automation is the use of machines, control systems and information technologies to optimize productivity in the production of goods and delivery of services. The correct incentive for applying automation is to increase productivity, and/or quality beyond that possible with current human labor levels so as to realize economies of scale, and/or realize predictable quality levels. The incorrect application of automation, which occurs most often, is an effort to eliminate or replace human labor.When the term automation came into existence,the most technologies were electrical, mechanical, hydraulic and pneumatic.

Computing systems are everywhere. It's probably no surprise that millions of computing systems are built every year destined for desktop computers (Personal Computers, or PC's), workstations, mainframes and servers. What may be surprising is that billions of computing systems are built every year for a very different purpose: they are embedded within larger electronic devices, repeatedly carrying out a particular function, often going completely unrecognized by the device's user. Creating a precise definition of such embedded computing systems, or simply embedded systems, is not an easy task. We might try the following definition: An embedded system is nearly any computing system other than a desktop, laptop, or mainframe computer. That definition isn't perfect, but it may be as close as we'll get. We can better understand such systems by examining common examples and common characteristics. Such examination will reveal major challenges facing designers of such systems.

Doing away with the conventional wheel and axle setup, four spherical tyres, which can swivel their tread in 360 degrees to help the vehicle move in ways that today's cars never could. The wheels wouldn't be mechanically connected to the rest of the vehicle, but instead the body of the car would be suspended above its wheels by magnetic force. Sensors in the tyre could monitor road and weather conditions – and communicate this to other nearby vehicles – in addition to keeping an eye on the quality of the rubber tread. One of the most impressive features is the way these spherical tyres could help cars navigate in cramped spaces. Rather than being required to undergo a series of three-part-turns and back-and-forth shimmying to get into a tight parking space, spherical wheels that can move in any direction could let you just glide into any available spot without changing the orientation of the vehicle.

II. Proposed work

Our Concept revolves around the technologies which provide Omnidirectional, sphere-wheeled Autonomous Car using Embedded Systems with the help of computer vision, image processing and Artificial Intelligence.

III. Background work

Recent announcements that autonomous vehicles have safely driven hundreds of thousands of miles and major manufactures aspire to soon sell such vehicles, and optimistic predictions of their benefits, have raised hopes that this technology will soon be widely available and solve many transportation problems. However, there are good reasons to be cautious when predicting their future role.

There is considerable uncertainty concerning autonomous vehicle benefits, costs and travel impacts. Advocates claim that they will provide large benefits that offset costs, but they will require additional equipment, services and maintenance costs that will probably total hundreds or thousands of dollars per vehicle-year, and many of their benefits are unproven.

Current automated vehicles can only self-drive under limited conditions: significant technical and economic obstacles must be overcome before most households can rely on them for daily travel. Operating a vehicle on public roads is more complex than flying an airplane due to the frequency and proximity of interactions with often-unpredictable objects including other vehicles, pedestrians, animals, buildings, trash and potholes. If they follow previous vehicle technology deployment patterns, autonomous vehicles will initially be costly and imperfect.

During the 2020s and perhaps the 2030s, autonomous vehicles are likely to be expensive novelties with limited abilities, such as restrictions on the road conditions in which they may operate. It will probably be the 2040s or 2050s before middle-income families can afford to own self-driving vehicles that safely operate in all conditions, and longer before used autonomous vehicles become affordable to lower-income households. A significant portion of motorists may resist such vehicles, just as some motorists prefer manual transmissions, resulting in mixed traffic that creates new roadway management problems.

Vehicle innovations tend to be implemented more slowly than other technological changes due to their high costs, slow fleet turnover and strict safety requirements. Automobiles typically cost fifty times and last ten times as long as mobile phones and personal computers, so consumers seldom purchase new vehicles just to obtain a new technology. Autonomous vehicles will probably have relatively costly equipment and service standards, similar to airplanes, which may discourage some users. Large increases in new vehicle purchase and scrappage rates would be required for most vehicles to be autonomous before 2050.

Self-driving taxi costs are likely to range between carsharing ($0.60-1.00 per mile) and human driven taxis ($2.00-3.00 per mile), depending on factors such as their cleaning costs. This will make them a cost effective alternative to owning lower (5,000 annual miles) vehicles.

However, many motorists are likely to prefer owning personal vehicles for prestige and convenience sake. As a result, shared autonomous vehicles are likely to reduce vehicle ownership mostly in compact, multi-modal urban areas, and will have little effect in exurban and rural areas.

Advocates may exaggerate net benefits by ignoring new costs and risks, offsetting behavior (the tendency of road users to take additional risks when they feel safer), rebound effects (increased vehicle travel caused by faster travel or reduced operating costs, which may increase external costs), and harms to people who do not to use the technology, such as reduced public transit service. Benefits are sometimes double-counted, for example, by summing increased safety, traffic speeds and facility savings, although there are trade-offs between them.

Transportation professionals (planners, engineers and policy analysts) have important roles to play in autonomous vehicle development and deployment. We can help support their development and testing, and establish performance standards they must meet to legally operate on public roads. If such vehicles perform successfully and become common they may affect planning decisions such as the supply, design and operation of roadways, parking and public transit. To be prudent, such infrastructure changes should only occur after autonomous vehicle benefits, affordability and public acceptance are fully demonstrated. This may vary: autonomous vehicles may affect some roadways and communities more than others.

A critical question is whether autonomous vehicles increase or reduce total vehicle travel and associated external costs. It could go either way. By increasing travel convenience and comfort, and allowing vehicle travel by non-drivers, they could increase total vehicle mileage, but they may also facilitate car sharing, which allows households to reduce vehicle ownership and therefore total driving. This review suggests that they will probably increase total vehicle travel unless implemented with offsetting policies such as efficient road and parking pricing.

Another critical issue is the degree potential benefits can be achieved when only a portion of vehicle travel is autonomous. Some benefits, such as improved mobility for affluent non-drivers, may occur when autonomous vehicles are uncommon and costly, but many potential benefits require that most or all vehicles on a road operate autonomously. For example, it seems unlikely that traffic densities can significantly increase, traffic lanes be narrowed, parking supply be significantly reduced, or traffic signals be eliminated until most vehicle on affected roads self-drive.

A key public policy issue is the degree that this technology may harm people who do not use such vehicles, for example, if increased traffic volumes and speeds degrade walking and cycling conditions, conventional public transit service declines, or human-driven vehicles are restricted. Some strategies, such as platooning, may require special autonomous vehicle lanes to achieve benefits. These issues will probably generate considerable debate over their merit and fairness.

IV. Methodology

These multi-orientation tyres would provide superior manoeuvrability to today's mechanically aligned wheels, letting each tyre independently respond to potential hazards, such as ice on the road or sudden obstacles.

In theory, they could also provide a smoother ride, enabling the car to move sideways in instances like overtaking or lane changes, without requiring the nose of the vehicle to turn.

Sensors in the tyre could monitor road and weather conditions – and communicate this to other nearby vehicles – in addition to keeping an eye on the quality of the rubber tread.

One of the most impressive features is the way these spherical tyres could help cars navigate in cramped spaces. Rather than being required to undergo a series of three-part-turns and back-and-forth shimmying to get into a tight parking space, spherical wheels that can move in any direction could let you just glide into any available spot without changing the orientation of the vehicle.

Provided the car can actually fit in a free spot, you wouldn't have to worry about any other geometry – although that might not be a problem in the cities of tomorrow anyhow. That's all well and good, but how would it actually work? Tyres like this would use magnetic levitation to do their thing.

In other words, the wheels wouldn't be mechanically connected to the rest of the vehicle, but instead the body of the car would be suspended above its wheels by magnetic force.

It sounds pretty sci-fi, but the same principle applies in maglev trains and hoverboards, so it could be doable for cars in the future too. It's an awesome idea that could make sense someday.

Following are some algorithms used in analysis of the database:

A. Designing a Predictable Database:

Building a predictable database in a bottom-up fashion and in a principled manner, offers great insight into improving existing database products and can instigate a radical shift in the way that future databases are designed and implemented.

1) Cliff Guard:

A Principled Framework for Applying Robust Optimization Theory to Database Systems Cliff Guard is a practical framework that creates robust designs that are immune to parameter uncertainties as much as desired**.** Cliff Guard is the first attempt at applying robust optimization theory in Operations Research to building a practical framework for solving one of the most fundamental problems in databases, namely finding the best physical design.

2) Approximate Query Processing

Scanning 1TB of data may take minutes, even when the data is spread across hundreds of machines and read in parallel. BlinkDB is a massively parallel, sampling-based approximate query engine for running interactive queries on large volumes of data.

V. Objective of Work

A. Purpose

The spherical drive system idea is unlike any other vehicle that can be seen on the road today. Despite having seen spherically driven vehicles in futuristic movies such as IRobot, there has not been a huge push into the realm of the sphere. We believe that the versatility of the sphere drive can give us a whole new degree of freedom and safety that we have yet to discover. As a year long project class for San Jose State University, we will be applying all of the engineering theory/concepts to transform an ambitious and out of the box idea into a physical and marketable product. By the end of the school year, the final product will have all of the right hardware and software to enable it to self-balance and maneuver in any direction at slow speeds. Although balancing systems have been developed, adding another degree of freedom both increases complexity but also the possibility of instantaneous response.

B. Overview

1) Levels of Autonomous Vehicles

- Level 1 – Function-specific Automation: Automation of specific control functions, such as cruise control, lane guidance and automated parallel parking. Drivers are fully engaged and responsible for overall vehicle control (hands on the steering wheel and foot on the pedal at all times).
- Level 2 - Combined Function Automation: Automation of multiple and integrated control functions, such as adaptive cruise control with lane centering. Drivers are responsible for monitoring the roadway and are expected to be available for control at all times, but under certain conditions can disengaged from vehicle operation (hands off the steering wheel and foot off pedal simultaneously).
- Level 3 - Limited Self-Driving Automation: Drivers can cede all safety-critical functions under certain conditions and rely on the vehicle to monitor for changes in those conditions that will require transition back to driver control. Drivers are not expected to constantly monitor the roadway.
- Level 4 - Full Self-Driving Automation: Vehicles can perform all driving functions and monitor roadway conditions for an entire trip, and so may operate with occupants who cannot drive and without human occupants.

C. Components of the System/ Autonomous Vehicle Equipment and Service Requirements:

- Automatic transmissions.
- Diverse and redundant sensors (optical, infrared, radar, ultrasonic and laser) capable of operating in diverse conditions (rain, snow, unpaved roads, tunnels, etc.).
- Wireless networks. Short range systems for vehicle-to-vehicle communications, and long-range systems to access to maps, software upgrades, road condition reports, and emergency messages.
- Navigation, including GPS systems and special maps.
- Automated controls (steering, braking, signals, etc.)
- Servers, software and power supplies with high reliability standards.
- Additional testing, maintenance and repair costs for critical components such as sensors and controls.

D. Working Description

1) Theory:

The human approach in how the drive system will work is no different than how you would balance on a bicycle or on any unstable surface, by getting a inertial feedback for when you are about to fall over and correcting accordingly. From an engineering approach the problem is a standard controls problem which will replace the person with accelerometers/gyros and human correction with drive motors. The system which this project will be modeled after is called the inverted pendulum, which aim to keep an inherently unstable system from falling into it's stable state by having almost instantaneous response to outside disturbances. Ball Inverted Pendulum is an inspiration for us and shows some inner workings of possible solutions to our design problem.

2) Implementation:

The project can be broken down into several core components in which each member of the team will have a specific responsibility to ensure proper vehicle operations. The list of the components can be seen below:

a) Wheels:

The birth of this project came from the idea of having a vehicle that could travel in any direction, and with it necessity brought about the idea of reinventing the wheel, literally. The design of the vehicle does not use conventional wheels, and instead uses spheres. A spheres unique ability to both roll and spin at the same time will give the vehicle truly omni-directional maneuverability. The challenge we will face is that the drive system will be in contact at various points on the sphere, but the sphere itself can be under no constraints except for multiple contact points to keep it within the vehicle enclosure.

b) Drive System:

This system is unlike any other omni-directional vehicle in which the transmission to the wheels is done by having a fixed axle, the spherical nature of the wheel means that transmitting power for movement must be done purely with contact friction. There needs to be very minimal wearing effect on the friction drive wheels for non-parallel directions to create a reliable system. This method of driving the vehicle presents many challenges and potential for great innovation in creating a non-fixed axle transmission. In order to achieve the desired speeds and torque from the vehicle it is likely that either stepper motors or BLDC motors will be used for the drive.

c) Control System:

The system that will be used to control the vehicle is in no means a trivial task. The principle of operation of the control system is to take sensor readings from a gyro-accelerometer combo, and determine an appropriate response based on the input from the user as well as maintaining stability. The challenges posed by the control system, include an attempt to balance an inherently unstable system, interfacing with multiple drive motors, and combining potentially noisy sensor readings such as those from an accelerometer into something usable and reliable. The immediate scope of the control system will be to maintain balance and maneuverability at low speeds, with considerations taken for a modified high speed control.

d) Power Management:

The large amount of electronics onboard of the vehicle will mean that there will be a need to have a very intelligent and reliable way of sourcing the power as needed. The power management system, will need to store energy in a storage medium (likely to be LiPo Batteries), and be able to distribute the energy to the motors, controllers, and sensors. In addition to controlling the distribution of power, the system will also need to monitor itself for any potential faults, as well as ease of recharging from a high voltage source (such as 120V mains). The power management system is the heart of this project and will need to be built and sized for the rest of the systems on the vehicle.

e) Frame and Body design:

While the vehicle uses a very unique drive system, it is still in other aspects a motorbike. To provide unparalleled versatility for our application we will be designing an entirely new frame that will take into account room for the battery system, IMU's, Control Cards, and space to accommodate the motors we will be using to drive the vehicle. While conventional motorbikes use a single rear swing arm, this vehicle will make use of a front swing arm as well, posing an interesting challenge from a mechanical design perspective. The exterior body of the vehicle will be fabricated using fiberglass & carbon fiber to keep weight down while not compromising on strength and aesthetics.

VI. USE CASES AND INTERACTION DIAGRAMS

1) Rahil is an affluent man with degenerating vision. In 2016 his doctor convinced him to give up driving. He purchases an autonomous vehicle instead of shifting to walking, transit and taxis. Impacts: An autonomous vehicle allows Jake to continue using a car, which increases his independent mobility, total vehicle ownership and travel, residential parking demand, and external costs (congestion, roadway costs, parking subsidies, and pollution emissions), compared with what would otherwise occur.
2) Srushti lives and works in a suburb. She can bike to most destinations but occasionally needs a car. In a city she could rely on taxis and car sharing, but such services are slow and expensive in suburbs. However, when she started shopping for a car in 2016 a local company began offering fast and affordable automated taxi services.
   Impacts: Autonomous vehicles allow Srushti to rely on shared vehicles rather than purchase a car, which reduces her total vehicle travel, residential parking demand, and external costs.
3) Maxi and Vineet have two children. Maxi works at a downtown office. After their second child was born in 2014, they shopped for a larger home. With conventional cars they would only consider houses within a 30-minute drive of the city center, but relatively affordable new autonomous vehicles let them consider more distant homes, with commutes up to 60-minutes, during which Maxi could rest and work.
   Impacts: Affordable new autonomous vehicles allows Maxi and Vineet to choose an exurban home location, which increased their total vehicle, accident, parking and roadway costs, and the costs of providing public services such as utilities and emergency response.
4) Shaha is hard-working and responsible when sober, but a dangerous driver when drunk. By 2015 she had accumulated several impaired citations and caused a few accidents. With conventional cars Shaha would continue driving impaired until she lost her driver's' license or caused a severe crash, but affordable used self-driving vehicles allow lower-income motorists like Shaha to avoid such problems.
   Impacts: Affordable used autonomous vehicles allow Shaha to avoid impaired driving, accidents and revoked driving privileges, which reduces crash risks but increases his vehicle ownership and travel, and external costs compared with what would otherwise occur.

VII. RESULT

Limited automation (Steering, braking and lane guidance) is the current state of art developed and available on some new vehicles.

Level 2 – Limited automation (steering, braking and lane guidance)	Fully-autonomous vehicles available for sale.
Coordinated platooning	Autonomous vehicles become a major portion of total vehicle sales.
Level 3 – Restricted self-driving	Autonomous vehicles become a major portion of vehicle fleets.
Level 4 – Self-driving in all conditions	Autonomous vehicles become a major portion of vehicle travel.
Regulatory approval for automated driving on public roadways.	Market saturation.
Fully-autonomous vehicles available for sale.	Universal

VIII. OTHER APPLICATIONS

A. Likely Uses of Self-Driving Taxis

Suitable Uses
Trips currently made by taxi or carshare vehicles.
Utilitarian trips currently made by a private vehicle driven less than 6,000 annual miles.
Unsuited Uses
Motorists who take pride in vehicles or value extra comfort.
Motorists who drive more than 6,000 annual miles.
Motorists who require special accessories in their vehicles.
Motorists who normally carry tools or dirty loads in their vehicles (e.g., trades workers).
Passengers (particularly those with disabilities) who want assistance getting in and out of taxies, or with luggage.
Passengers who place high values on privacy.

IX. CONCLUSION

Autonomous vehicle implementation is just one of many trends likely to affect future transport demands and costs, and therefore planning decisions, and not necessarily the most important. This system uses spherical to minimize the effort taken during turns, helps during accidents and improves the regular autonomous vehicle.

X. Future Aspect and Scope

Future Aspects of autonomous vehicles are likely to impact transport planning as a whole.

1) Support large-scale autonomous vehicle testing. Evaluate their benefits and costs under actual operating conditions.
2) Study, and where appropriate support, autonomous implementations for specific applications such as taxi, car sharing and demand response services
3) If autonomous vehicles prove to be effective and common, consider dedicating some highway lanes to their use.
4) If autonomous vehicles prove overall beneficial and are majority of vehicles, it may be possible to change roadway design and management practices.
5) If autonomous vehicles prove to be very beneficial, it may be appropriate to restrict human driving.

Though the immediate scope of the project is to have a vehicle that can balance and maneuver at low speeds, the ultimate goal is to have a fully functional electric vehicle that will be able to have speed and range comparable to any other vehicle.

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