Automotive Usability: Human Computer Interaction in the Vehicle

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Abstract—Computer has become the most significant helper and tool around the world. It is used in all kinds of electronic devices and improves their usability much. Automobile is a great example in this topic to show how computer changes the way people interact with an item. During the past decades, more and more mechanical devices in automobile are replaced by electrical substitutions and the interface is evolved towards better user friendly experience. Among these changes, some make the automobile itself easier to acquaint and operate, like auto-transmission and power window/seat; some make driving safer for drivers and passengers, which we could see from safe belt alert light and parking sensors; and some make the experience on the road a funnier and comfortable thing rather than operating a frosty machine, like audio system, cruise control and navigation device. In all, intelligent interfaces accompanied intelligent automobile is the great trend in the near future, and which would bring human experience on the way to a brand new standard.

Keywords—automobile; usability; automation; safety; entertainment; networking

I. INTRODUCTION

Automobile has become a complex interactive system. Mechanical devices are transformed to the digital realm. It is common that drivers operate a vehicle and, at the same time, interact with a variety of devices and applications. Looking up an address in the map and taking a phone call are such examples that help the driver in driving but also increase the risk on the road. The need to have a car with decent and safer usability from driver drives the researchers and auto companies discover the possibilities of driving with a friendlier and more powerful human computer interaction interface in the car. As a result, various inventions on usability have been made and they together make the interaction with automobile an easy and safe thing.

The design of usability in automotive domain generally focuses on multiple goals including safety, comfort, enhancement, networking, etc. Actually in some cases the convenience is the same meaning with safety, i.e. the easier the driver finishes one task when driving, the safer he would be. Generally manufacturers improve the feeling of convenience by adding automatic features to devices in the car, a proper example here is power window which greatly reduce the complexity of controlling window in driving. For the need of entertainment, manufacturers usually upgrade the interaction with audio system – more functional buttons, and better effect – since people need to take an eye on the traffic but their ears are available.

Beyond the basic enhancements in HCI in automobile, recent years manufacturers are trying to integrate some more amazing features into the car by providing a powerful microcomputer and a central console with touch screen named vehicle telematics. These novel features include navigation system, auto drive and remote control etc.

Imagine this scenario: you start a new day with a cup of coffee in the car, watching the morning news from holographic projection that projected on the windshield. Following the presetting route, the car drives you to office after sending your children to school. You have a quick review on the whole day agenda while the car looks for a best place to park. After the car is parked, you leave it without locking with a key – the car will unlock itself when sensing your biometric identification around. Some parts of this fantastic scenario have been realization by the cutting edge technologies in automotive usability aspect.
In the following sectors we present how the usability of automobile is achieved in the aspects of safety, comfort, enhancement and networking by HCI technologies of each. Sector 2 describes the common interaction interfaces that ensure safety of drivers. Sector 3 talks about how components in automobile bring users a comfort experience. Sector 4 discusses the current enhancement that being installed in automobile to make driving an easier activity. Sector 5 talks about how people enjoy the connection with Internet and benefit emergency help via Internet when they are in vehicles. Sector 6 is the conclusion.

II. SAFETY

A. Introduction

Automobile safety is the study and practice of design, construction, equipment and regulation to minimize the occurrence and consequences of automobile accidents. Road traffic safety more broadly includes roadway design. One of the first formal academic studies into improving vehicle safety was by Cornell Aeronautical Labs of Buffalo, New York. The main conclusion of their extensive report is the crucial importance of seat belts and padded dashboards. However, the primary vector of traffic-related deaths and injuries is the disproportionate mass and velocity of an automobile compared to that of the predominant victim, the pedestrian. In the United States a pedestrian is injured by an automobile every 8 minutes, and are 1.5 times more likely than a vehicle's occupants to be killed in an automobile crash per outing.

Improvements in roadway and automobile designs have steadily reduced injury and death rates in all first world countries. Nevertheless, auto collisions are the leading cause of injury-related deaths, an estimated total of 1.2 million in 2004, or 25% of the total from all causes. Of those killed by autos, nearly two-thirds are pedestrians. Risk compensation theory has been used in arguments against safety devices, regulations and modifications of vehicles despite the efficacy of saving lives.

B. Two Systems

Technology is increasingly being seen to have a critical role to play in alleviating the negative aspects of road transport, such as congestion, pollution and road traffic accidents (Bishop, 2005). Many technological initiatives are considered under the umbrella term, Intelligent Transport Systems (ITS), where “ITS provides the intelligent link between travelers, vehicles, and infrastructure” (www.itsa.org, September, 2006). In this respect, in-vehicle computing systems are an important facet of ITS. Specifically, there are two core types of computing and communications systems which are either being implemented or developed for use in vehicles:

Information-based systems: which provide information relevant to components of the driving environment, the vehicle or the driver. Examples of systems include navigation (facilitating route planning and following), travel and traffic information (traffic conditions, car parking availability, etc.), vision enhancement (providing an enhanced view of the road ahead, when driving at night, in fog or in heavy rain), driver alertness monitoring (informing the incapacitated driver if they are unfit to drive) and collision warnings (presenting warnings/advice regarding hazards). Typically all lamps in panel should be classified into this kind of system. These lamps can warn you whether your car is in a good condition, is there something wrong with your engine. Also, when you leave your car with door opened, you will be warned by hearing continues sound. Information-based systems can improve safety for you and your car.

Control-based systems: which affect the routine, operational elements of the driving task. Examples of systems include adaptive cruise control (where the car is kept at a set time gap from a lead vehicle), speed limiting (the car speed cannot exceed the current limit), lane keeping (the driver’s vehicle is kept within a given lane), self parking (vehicle automatically steers in low speed operation to position itself within a selected parking space) and collision avoidance (the vehicle automatically responds to an emergency situation). Clearly, such systems fundamentally change the nature of what we consider to be ‘driving’. [1]

C. Safety Equipments

These two systems are major implications for safety. Then we will introduce specific facilities of automobile to keep safety.

1) Driver assistance

A subset of crash avoidance is driver assistance systems, which help the driver to detect obstacles and to control the vehicle. Driver assistance systems include: [2]
• Automatic Braking systems to prevent or reduce the severity of collision.
• Infrared night vision systems to increase seeing distance beyond headlamp range
• Adaptive headlamps control the direction and range of the headlight beams to light the driver's way through curves and maximize seeing distance without glaring other drivers
• Reverse backup sensors, which alert drivers to difficult-to-see objects in their path when reversing
• Backup camera
• Adaptive cruise control which maintains a safe distance from the vehicle in front
• Lane departure warning systems to alert the driver of an unintended departure from the intended lane of travel
• Tire pressure monitoring systems or Deflation Detection Systems
• Traction control systems which restore traction if driven wheels begin to spin
• Electronic Stability Control, which intervenes to avert an impending loss of control
• Anti-lock braking systems
• Electronic brakeforce distribution systems
• Emergency brake assist systems
• Cornering Brake Control systems
• Precrash system
• Automated parking system [3]

2) Crashworthiness
Crashworthy systems and devices prevent or reduce the severity of injuries when a crash is imminent or actually happening. It includes:

Seatbelts limit the forward motion of an occupant, stretch to absorb energy, to lengthen the time of the occupant's deceleration in a crash, reducing the loading on the occupants body. They prevent occupants being ejected from the vehicle and ensure that they are in the correct position for the operation of the airbags.

Airbags inflate to cushion the impact of a vehicle occupant with various parts of the vehicle's interior. The most important being the prevention of direct impact of the driver's head with the steering wheel and door pillar.

Laminated windshields remain in one piece when impacted, preventing penetration of unbelted occupants' heads and maintaining a minimal but adequate transparency for control of the car immediately following a collision. It is also a bonded structural part of the safety cell. Tempered glass side and rear windows break into granules with minimally sharp edges, rather than splintering into jagged fragments as ordinary glass does.

Crumple zones absorb and dissipate the force of a collision, displacing and diverting it away from the passenger compartment and reducing the deceleration impact force on the vehicle occupants. Vehicles will include a front, rear and maybe side crumple zones (like Volvo SIPS) too.

Safety Cell - the passenger compartment is reinforced with high strength materials, at places subject high loads in a crash, in order to maintain a survival space for the vehicle occupants.[4]

Side impact protection beams, also called anti-intrusion bars.

Collapsible universally jointed steering columns, along with steering wheel airbag. The steering system is mounted behind the front axle - behind and protected by, the front crumple zone. This reduces the risk and severity of driver impact or even impalement on the column in a frontal crash.

Pedestrian protection systems.

Padding of the instrument panel and other interior parts, on the vehicle in areas likely to be struck by the occupants during a crash, and the careful placement of mounting brackets away from those areas.

Cargo barriers are sometimes fitted to provide a physical barrier between passenger and cargo compartments in vehicles such as SUVs, station wagons and vans. These help prevent injuries caused by occupants being struck by unsecured cargo. They can also help prevent collapse of the roof in the event of a vehicle rollover. [5]

However, can we say that with all these safe systems, we can assure safety on the road and never got car accident? The answer is no.

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All of our proud, graphically oriented screen devices, especially those with touch-sensitive screens and a paucity of physical controls, may be delightful to use while in a comfortable environment, but they become safety hazards when also attempting to drive a car. If the eyes of the driver are off road for two seconds, studies show a dramatic rise in accident rate. Can you try programming a street address into a navigation system in less than two seconds? Impossible, you need more time. Moreover, because the driver is attention switching, not only must the eyes shift from road to device, and back again, but all the context must be restored: memory structures, intentions, planned activities. Task switching lengthens the time to do each task considerably, thereby magnifying the danger.

The way to alleviate dangerous while you are driving is using acoustic warning system instead of visual warning system. New car should have sound to report current speed coordinates with speed panel. Thus when driver drives on a speed limit road, driver only need focus on front views and see if other cars runs in left or right lane, acoustic warning system will report whether the car is surpassing speed limit. [6]

III. COMFORT

A. Original Entertainment Equipments

More and more people not only care about the driving experience of a car, but also care about the comfort of a car, this is the reason why more and more advertisement focusing on interior trim. With CD/FM becomes the common equipment in a car, more and more people treat car as a “small home”, not only a driving tool.

Of course if you want to pay more money, you can have more entertainment equipment in your car. In-Car Entertainment is a collection of hardware devices installed into automobiles, or other forms of transportation, to provide audio and/or audio/visual entertainment, as well as automotive navigation systems (SatNav). This includes playing media such as CDs, DVDs, Free view/TV, USB and/or other optional surround sound, or DSP systems. Also increasingly common in ICE installs are the incorporation of video game consoles into the vehicle.

In-Car Entertainment systems have been featured TV shows such as MTV's Pimp My Ride. In Car Entertainment has been become more widely available due to reduced costs of devices such as LCD screen/monitors, and the reducing cost to the consumer of the converging media playable technologies. Single hardware units are capable of playing CD, MP3, WMA, DVD.

B. New Facilities

As the time change, In-Car Entertainment systems also involved new features, such as AUX, heat seat and Internet. When you get tired of listening FM music and tired of changing CD one by one. You can just link iPod or MP3 into your car by AUX. Then you can listen all music in that iPod or MP3. For heat seat, imagine this, in a cold winter, you got up really early and you saw snow covered everything near you. Is there something better than seating into a warm seat while driving to company? Internet is an increasingly popular option in cars. According to a study by market researcher Invensity that by the year 2013 every new car built in Europe will be equipped with Internet connection. [7]

Comfort of car may make us love to drive, however, it also bring negative effect to our safety while driving. It is important to note that there is actually a third category of in-car computing system, include those systems which do not provide any functionality to support the driving task. These systems are an important consideration though, as they can negatively influence safety, particularly through the potential for distraction (Young, Regan and Hammer, 2003). Such systems may aim to enhance work oriented productivity whilst driving (e.g. mobile phones, email/internet access) or be primarily conceived for entertainment/comfort purposes (e.g. music/DVD players, games).

IV. ENHANCEMENT

Modern world has completely changed our lives by providing us with new technology and advancements. Automobiles possesses an important place in everybody life. Even though there are lots of types of cars that serve different purposes of various customer groups, the very basic functionality of automobiles is always driving. As automobile industry is such a large and profitable industry, manufacturers make every effort to research and apply new technologies to enhance people's driving experience. Automatic transmission has made driving an easy task to almost every person. Other techniques like cruise control and auto-piloting aims at continuing save people further from
driving control. Indeed, an age of driverless car is approaching to totally free users from driving.

A. Automatic transmission

Automatic transmission is one type of motor vehicle transmission that can automatically change gear ratios as the vehicle moves, freeing drivers from having to shift gears manually.

Besides automatics, there are also other types of automated transmissions such as a continuously variable transmission and semi-automatic transmissions, which free the driver from having to shift gears manually, by using the transmission's computer to change gear, if for example the driver were redlining the engine. Despite superficial similarity to other transmissions, automatic transmissions differ significantly in internal operation and driver's feel from semi-automatics and continuously variable transmissions. [8]

A conventional, 5-speed manual transmission is often the standard equipment in a base-model car. Manual transmissions generally offer better fuel economy than automatic or continuously variable transmissions. However the disparity has been somewhat offset with the introduction of locking torque converters on automatic transmissions. For most people, there is a slight learning curve with a manual transmission, which is likely to be intimidating and unappealing for an experienced driver. And because manual transmission require the operation of an extra pedal, and keeping the car in the correct gear at all times, they require a bit more concentration, especially in heavy traffic situations. The automatic transmissions, on the other hand, simply require the driver to speed up or slow down as needed, with the car doing the work of choosing the correct gear. [9]

B. Automotive Navigation System

An automotive navigation system is a satellite navigation system designed for use in automobiles. Many modern vehicles are equipped with in-vehicle navigation systems that utilize global positioning systems (GPS), digital maps, and automatic route calculation. An navigation system typically uses a GPS navigation device to acquire position data to locate the user on a road in the unit's map database. Using the road database, the unit can give directions to other locations along roads also in its database. Just entering a destination will typically generate an accurate route that is displayed to the driver. Although the activity of entering a destination is not easy, especially while driving, voice activated systems are bringing to the market to solve this problem. These systems can greatly improve the driving experience by helping drivers navigate in unfamiliar setting and reduce the mental load of remembering where to go.

Navigation systems rely on good human-computer interaction. A quality design here helps drivers find their location and directions easily. As the driver approaches a change in direction, the application warns him in advance of an upcoming change. These systems typically include calculations and displays of time and range to destination. It would be easy to ignore safety issues by pointing out the troubles with driving and looking at a paper map.

The introduction of information systems into vehicles is a growing trend that can provide drivers with useful tools for navigation, communication, and exploration. However, in-vehicle information system (IVIS) cannot be allowed to distract users from the demanding task of driving. Among these IVIS, car navigation systems have been among the most widely adopted technologies. The decision to open up the map is the driver's own. However, car navigation system manufacturers have a responsibility to society to produce safe systems in addition to possible liability caused by their systems facilitating accidents. There are lot of research focusing on exploring the safest ways to present navigational vehicles.[10]

C. Cruise control

Cruise control, sometimes known as speed control or auto cruise, is a system that automatically controls the speed of a motor vehicle. The system takes over the throttle of the car to maintain a steady speed as set by the driver.

Modern cruise control was invented in 1945 by the inventor and mechanical engineer Ralph Teetor. His idea was born out of the frustration of riding in a car driven by his lawyer, who kept speeding up and slowing down as he talked. Daniel Aaron Wisher invented Automotive Electronic Cruise Control is 1968. His invention was the first electronic gadgetry to play a role in controlling a car and ushered in the computer-controlled era in the automobile industry. Two decades lapsed before an integrated circuit for his design was developed and as a result, cruise control was eventually adopted by automobile manufacturers as standard equipment.[11]
Cruise control is really useful for long drives, in which it helps reduce driver fatigue, improve comfort by allowing positioning changes more safely, across highways and sparsely populated roads. This also results in better fuel efficiency. Besides, a driver who tends to unconsciously increase speed over the course of a highway journey may avoid a speeding ticket by using cruise control.

The advantage of electronic speed control over its mechanical predecessor, which was featured on luxury models but never gained wide acceptance, was that it could be easily integrated with electronic accident avoidance and engine management systems.

Some modern vehicles have adaptive cruise control systems, which is a general term meaning improved cruise control. These improvements can be automatic braking, which allows the vehicle to keep pace with the car it is following, or dynamic set-speed controls which uses the GPS position of speed limit signs to dynamically control speed.

D. Autopilot

When it comes to driving, human beings have an appalling safety record. With motor-vehicle accidents claiming more than a million lives worldwide annually, car companies are pushing the development of technology that increasingly borrows control from erratic human beings allowing the car to drive itself.

An autopilot is a mechanical, electronically, or hydraulic system used to guide a vehicle without assistance from a human being. An autopilot usually refers specifically to aircraft, self-steering gear for boats, or auto-guidance of space craft and missiles. But because of its technical constraints and great expenses, autopilot has been evolved to common motor vehicles until the recent years. However, low-level autonomous safety features have been around in various forms for decades.

Antilock brake systems, which automatically sense when a wheel is skidding and reduce brake pressure, were introduced back in 1971. In 1997, General Motors introduced an Electronic Stability Control system that can sense the difference between the direction a car is going and the angle of the steering wheel, and then pump the brakes to keep the car on course. These safety features are so commonplace today that federal legislation requires they be installed on all new cars, along with airbags and seatbelts.[12]

And the next generation of autonomy is already here. The 2010 Ford Flex boasts Active Park Assist — just target a spot and the car uses ultrasonic range finders to park itself. The 2010 Toyota Prius has a Lane Keep Assist system that uses a camera to detect lane markers and automatically steers the car toward the center of the lane. And the Honda Accord comes standard with Adaptive Cruise Control, which uses a radar pulse to scan ahead for other vehicles and then increases or decreases speed to maintain a safe following distance. The current set of semi-autonomous safety features can quickly combine into something more. For example, a car could use Lane Keep Assist and Adaptive Cruise Control together to drive itself under highway conditions, sticking to one lane and not hitting the car in front. The next step is to expand these capabilities. Adaptive Cruise Control currently works only over 25 mph, but the next version (called Full Speed Range ACC) lowers that number to zero so that cars can begin to handle traffic jams in the city.

E. Driverless car

Fully autonomous vehicles, also known as robotic cars, or driverless cars, already exist in prototype, and are expected to be commercially available around 2020. According to urban designer and futurist Michael E. Arth, driverless electric vehicles—in conjunction with the increased use of virtual reality for work, travel, and pleasure—could reduce the world's 800 million vehicles to a fraction of that number within a few decades. This would be possible if almost all private cars requiring drivers, which are not in use and parked 90% of the time, would be traded for public self-driving taxis that would be in near constant use. This would also allow for getting the appropriate vehicle for the particular need—a bus could come for a group of people, a limousine could come for a special night out, and a Segway could come for a short trip down the street for one person. Children could be chauffeured in supervised safety, DUIs would no longer exist, and 41,000 lives could be saved each year in the US alone.[13]
Before the computer technology evolved to be good enough, manufacturers brought the usability of automobile to customers with a focus mostly on driving itself. The traditional solution were consist of a bunch of on-board embedded electronics systems that performing various operational functions focusing on different purposes, such as seat heating for comfort, cruise control for enhancement, parking sensor for safety, etc. While these helpers are already utilized in most of today’s modern vehicle, new need on networking is raising recent years due to the development of Internet digit devices such as tablet and smart phone. Seeing this potential usability area, manufacturers begin to research and install more and more in-vehicle embedded system that focus on providing better functionalities, robust operation and higher degree of convenience to the in-vehicle users in the networking level. Within this trend, advance of wireless communication and information technology in the digital era has promoted new killer applications to the in-vehicle drivers and occupants. Among these advanced killer applications, services provided in the area of the telematics and information/entertainment have attracted most attention in the automotive industry.

F. Telematics Service

Telematics were considered as the system that provides location-based services for mobile vehicles over wireless communication networks. Typical example of automotive telematics services includes emergency call system, which instantly connects vehicle users to a service center for emergency assistance or roadside services while automatically reporting the vehicle’s position. Normally the emergency call system requires a wireless transceiver for voice and data communication and an on-board GPS receiver for positioning. Telematics system was considered as the core technology in an Intelligent Transportation System (ITS) and applications of telematics services to ITS have been proposed and developed in some countries. An integrated positioning system were developed to realize an efficient and cost-effective GPS based electronic road pricing system by He, Law, and Ling [14]. In, the importance of “situational awareness” in conveying the state of the automobile to other parties across a communication link was addressed and a novel interactivity environment for integrated intelligent transportation and telematics systems was proposed.

G. Information/Entertainment Services

As more and more people are traveling with Internet-enabled information appliances (IA) such as laptops, tablets, smart phones, digital cameras, MP3 players, etc., there is a desire to connect to the Internet permanently from anywhere, at any time, without any disruption of service, particularly for those people who spend a significant amount of time in mass transportation systems in weekdays or in their own vehicle during weekend [15]. In order to access the Internet, an in-vehicle local area network or personal area network environment must be established, and the in-vehicle embedded system shall become the mobile gateway for these Internet-enabled IA. Ernst, Uehara, and Mitsuya [15], detailed the networking requirements for connecting vehicles to the Internet by displacing an entire IPv6 network and network mobility support in the InternetCAR project. The software and hardware requirements in designing human-computer interface for an in-vehicle information system were proposed such that the safety of the in-vehicle drivers is discussed. A distributed service-based architecture [16] were proposed to provide fault tolerant application services to remote in-vehicle computers and mobile devices, such as Wifi-enabled tablet and smart phone. It seems that research trend has shifted to providing an infotainment server system for the in-vehicle users such that the network-enabled IA can access the information from the in-vehicle network and also obtain the entertainment services from the entertainment server.

H. Products in practice

A well-known example of telematics system is GM’s OnStar service which provides multiple emergency services. Typically the OnStar in installed in the bottom of rearview mirror. The OnStar service relies on CDMA mobile phone voice and data communications well as location information using GPS technology. Drivers and passengers can use its audio interface to contact OnStar representatives for emergency services, vehicle diagnostics and directions. The OnStar service allows users to contact OnStar call centers during an emergency. In the event of a collision, detected by airbag deployment or other sensors, Advanced Automatic Collision Notification features can automatically send information about the vehicle's condition and GPS location to OnStar call centers. This Advanced Automatic Collision Notification service is designed to assist emergency response efforts[17]. All OnStar equipped vehicles have Stolen
Vehicle Tracking, which can provide the police with the vehicle's exact location, speed and direction of movement.

VI. CONCLUSION

Massive new technologies are rapidly entering the automobile to improve automobile usability and user's in-car experience. New forms of automation interact with the driver, some don't even bother to interact but simply take over, to enhance driving experience. There is also an ever-increasing number of third-party add-ons, such as music players, video game players, cell phones, hand-held navigation systems, and computers to improve driving safety and conformability. User's interactions with their automobiles are not only limited within their own cars. Networking devices are connecting the in-car information systems with outside networks and other vehicles to provide communication services. With all the possible technologies brought with the application of in-car computer and information systems, there are no limitations on the improvement of automotive usability. And modern automobile is becoming an intelligent system that brings users unimaginably comprehensive and autonomous interaction experiences with their beloved cars.

REFERENCE

[8] Automatic transmission,