AUTONOMOUS VEHICLE

WHITE PAPER

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ABSTRACT

The progression in automobile sales is directly proportional to economic growth of the country. The automobile industry is always about innovation and economic growth. On top of automobile industry undergoing several technological revolutions, the road accidents are still concerning factor. Unless controlled, the road accidents are predicted to become fifth leading cause of death. The existing safety features Anti-Braking System, Air bags are not sufficient when compared to death numbers (at the order of millions every year) that are projected towards road accidents. From Advanced Driver Assistance System (ADAS), it is essential for the industry to swiftly move towards Autonomous cars. Equipping vehicles with this technology will reduce crashes, energy consumption and reduce the costs of congestion.

Building a driverless car with automated driving capabilities that exceeds human driving performance is not easy. Challenges involved are abundant and it includes car detection, lane keeping / overtaking, parking, obeying traffic rules, interpreting on road signs and following navigation system etc. Reducing these challenges involve multiple technologies almost like creating eyes, brain, hands, and legs of human being. The best part is coordinating all together. The proposal with 5 domain system masters all the above issues and challenges. 5 key systems comprises of Camera system, Laser system, Navigation system, DSP system and coordinating system. Each has its own functionality and responsibilities that resolves each and every problem with complete attention to details.

ABBREVIATIONS

Sl. No.	Acronyms	Full form
1.	ADAS	Advanced Driver Assistance System
2.	GPS	Global Positioning System
3.	AV	Autonomous Vehicle
4.	DSP	Digital Signal Processor
5.	LRF	Laser Range Finder
6.	ECU	Electronic Control Unit
7.	I/O	Input and Output
8.	ROI	Region of Interest

MARKET TRENDS AND CHALLENGES

Travelling by road is one of the deadliest forms of transportation with more than 1.2 million deaths by road crashes per year around the world. Almost all crashes (particularly fatal ones) are caused by human driver error. Driverless vehicles would effectively eliminate nearly all hazards associated. In addition to above problem, there are other problems such as traffic congestion, energy consumption, vehicle resource utilization, time consumption, and human stress in driving. The list extends itself to solution accommodating climatic changes. Considering all these factors, driverless vehicles are the single comprehensive solution.

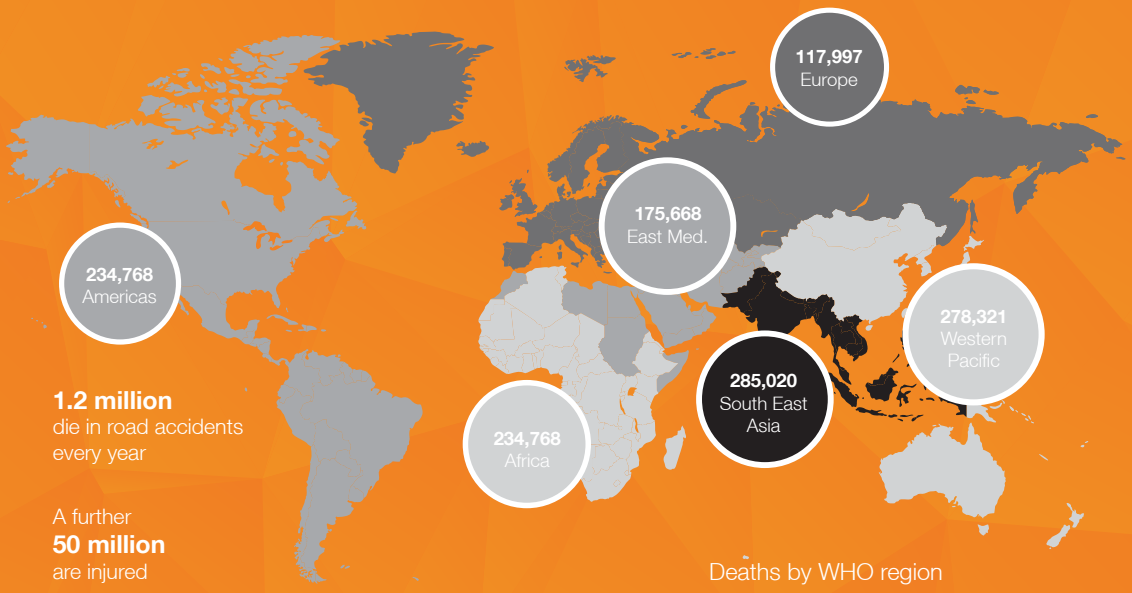

Figure 1: Road Traffic Accidents Statistics and Need for technology improvement

SOLUTION

The autonomous vehicles shall be capable of immediately ascertaining the prime purposes (as mentioned in below table) of the individual systems. Before getting to the solution, it is important to list down the functionality that are tangled in automation and they are, controlling steering, braking, speed, handling hills, parking, adhering to traffic rules, controlling Air conditioner, turn indicators, windows, lights, wiper, paying toll charges, infotainment system, handle on road scenarios like underway, potholes, speed bumps. In addition to above controls, it is important to provide safety if there are any crashes (from rear or sides) due to other vehicle errors or circumstance factors similar to reflex actions by human (e.g. Blocking when someone tries to hit). The solution consists of following 4 key systems,

Name of the system	Primary Purpose
Camera system	Object classification and assistance – Understanding the surroundings
Laser system	Obstacle detection and region of interest generator
Navigation system	Identifying and knowing / tracking destination – steering
DSP system	Acts as vision processor
Coordinating system	Central Processing Unit of the system – Decision making and Controls

Table 2: Purpose of systems in Autonomous Vehicle Solution

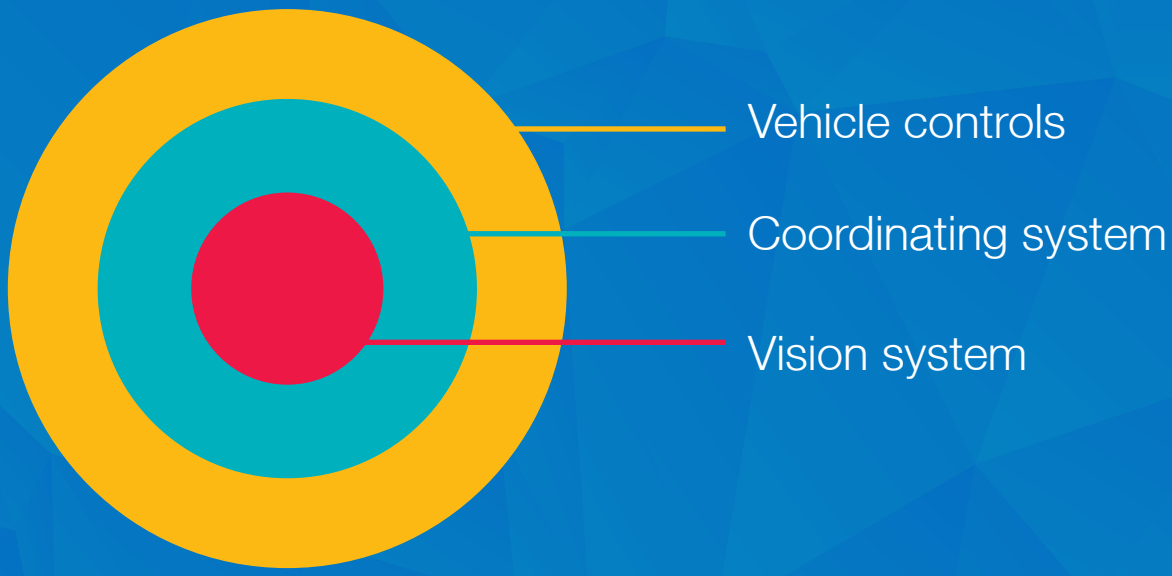

Figure 2: System design components

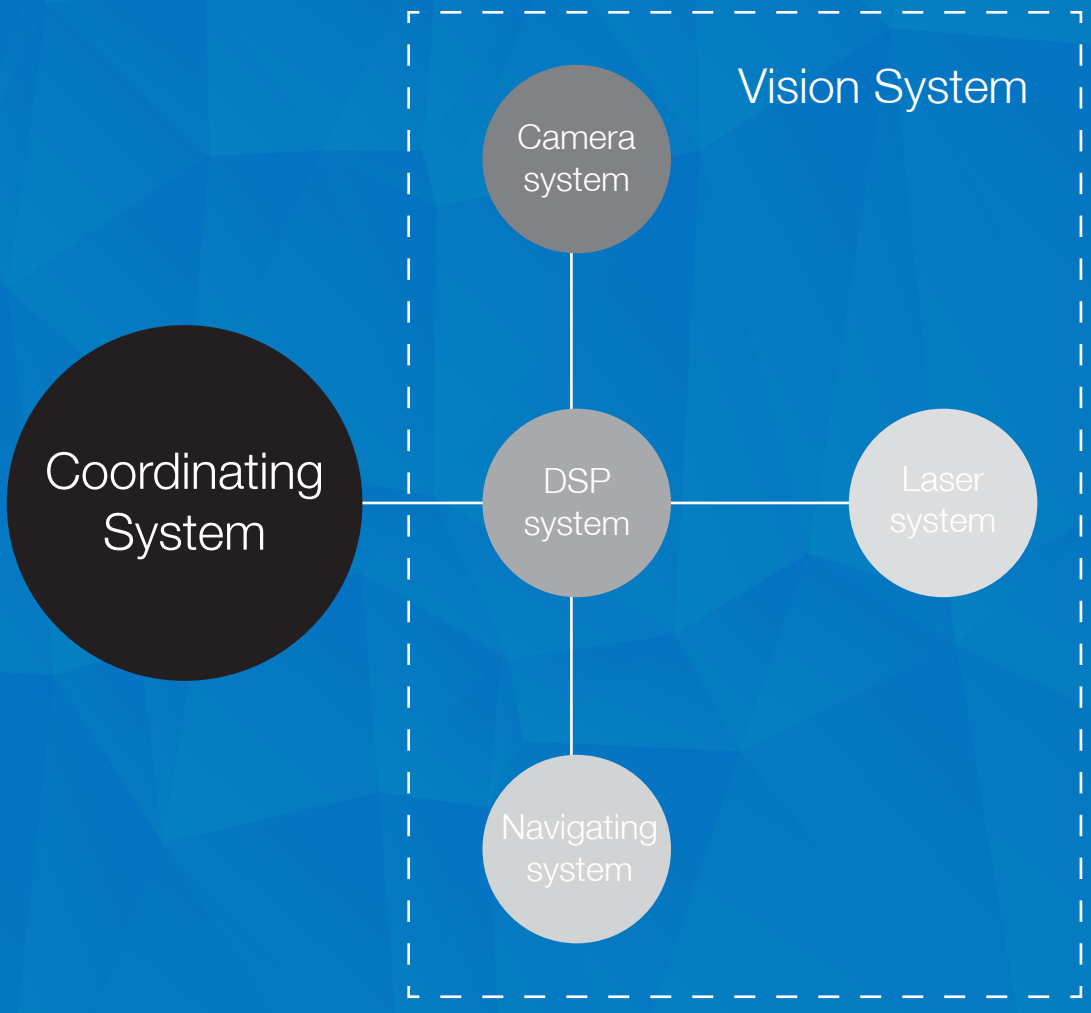

Figure 3: Representation proposed 5-system solution

Vehicle controls mentioned in figure 2 on left is, mechanism that runs the vehicle using human inputs currently (E.g. ECUs of steering, engine, electronic controls). The hardware requirements include, DSP, I/O connectivity, Interface to vehicle ECU, camera, display, LRF.

VISION SYSTEM

The figure 4 below consists of functionalities managed by Vision system (DSP, Navigation, Camera and LRF).

Figure 4: Functionalities of Autonomous Vehicle system

The vision system integrates the information from all LRF and camera. In turn utilizes the details and with the help of DSP provides decisive inputs to coordinating system. All the functionality depends on image processing right from object classification to wiper controls. Each module has its own design and deployment procedure.

The figure 5 represents the top level algorithm flow. The calibration is between the camera domain and LRF domain for its synchronization and mapping region of interest. The database consists of pre-trained on road objects. Traffic, terrain and map information are retrieved from navigation system and interrupts are received whenever voice command control is received or auto monitor and controller. This monitors in-car units such as, wiper, lamps, A/C, doors, windows, infotainment system.

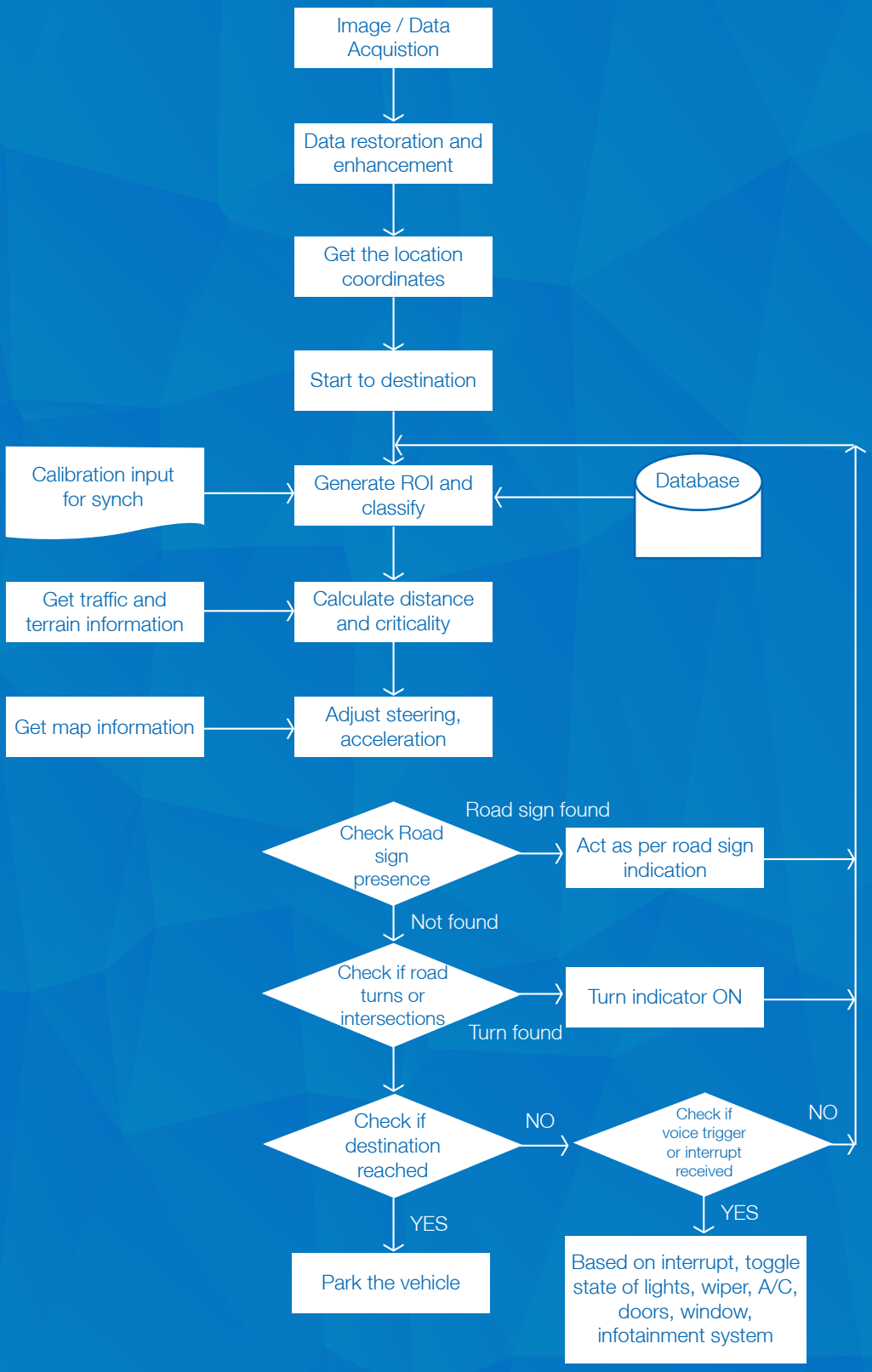

Figure 5: Algorithm flow of Autonomous Vehicle

CAMERA SYSTEM

Camera is together with laser, navigating system and DSP forms the vision system. There are 4 cameras that shall be installed in the unmanned vehicles, providing all side view. The 4 cameras placed around the driverless car sense the on-road information and sends to DSP system. The camera shall be capable of sensing the analog details and convert to digital form before sending. The camera system is the one that provides human understandable display. The camera shall be of HD quality and capable of providing maximum coverage and maximum details of the environment. The figure 6 below (on left) represents sample camera display.

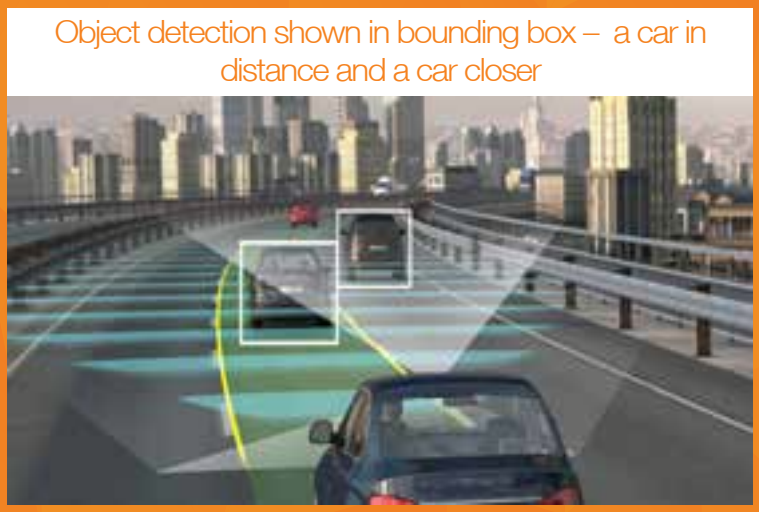

Figure 6: Camera system representation

Figure 7: LRF system representation

LASER SYSTEM

Laser (LRF) provides complete 360 degree view of obstacles around the vehicle. LRF shall be of 3 dimensional. There are difficulties towards identifying the obstacles from on road objects like median. This shall be handled in algorithm end to identify the differences. Laser calculates the data in polar coordinate system. Whereas the camera is of Cartesian coordinate system. It is necessary to synchronize laser data with camera data and hence both need to be calibrated for the purpose. Laser detects the obstacles and shall provide region of interest. DSP uses the region of interest over input from camera system. The figure 7 above (on right) represents laser sample output. Breaking point detection algorithm shall be used for identifying the obstacles around the vehicle.

NAVIGATING SYSTEM

This system shall provide the route information, traffic information, providing background information about the terrain e.g. bridge presence, underway, climate forecast information. Navigation system shall be capable of identifying current location of the vehicle and locate it on the map. It provides the inputs to the DSP system. Digital compass and antenna for communication shall be inbuilt to navigation system. Inter vehicle communication is also managed within this navigation system.

DSP SYSTEM

The solution needs all digital signal processing. The performance is real-time from DSP when it comes to image/digital data processing. Notice in below figure 8, the DSP@690MHz out beats the performance of CPUx4 1.2GHz. The DSP along with Camera, Laser and Navigation forms the Vision system. DSP also shall support interface to display.

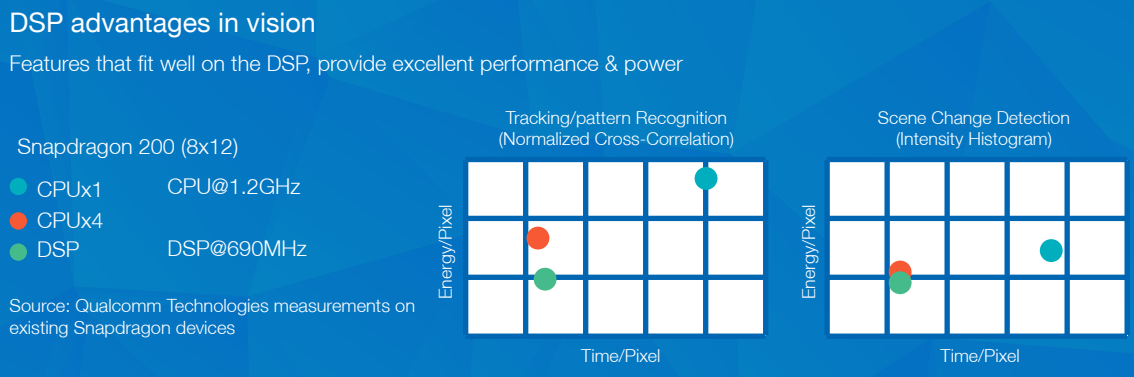

Figure 8: Need for DSP System

COORDINATING SYSTEM

This is the master system that makes timely decision and controls the vehicle all over the locomotion of the autonomous cars. This gets the inputs from DSP system (Vision system). The coordinating system interfaces with ECUs and controls the vehicle functions. The inputs what to act upon, when to act are from DSP system.

BEST PRACTICES

Common issues comprises of navigation issues like locomotion in desert being different from mountain, handling different types of obstacles, passing busy intersections, location where the road markings are not visible. The research is moving towards usage of multiple sensors (radar, laser, ultrasonic), whereas the proposal suggested in this paper relies on 3 major things, terrain or location knowledge of navigation system, LRF and camera system and its synchronization.

CONCLUSION

The statistics indicate that most of crashes are due to human error. Controlling this toll has become more than essential. The control is sustainable only with technology. Autonomous vehicle will greatly impact on day to day lives of human being. The technology will make driving safer, more convenient, less energy intensive and relatively cheaper. The autonomous vehicle in actuality has still further complications that need to be addressed. There are changes required from Government traffic policies, additional regulation to be added, communication between vehicles nearby would enable this technology to become reality faster. Once technology is served with necessary infrastructure and policy changes, it will serve the society. Science fiction future with AV is becoming close to reality.

Figure 9: Benefits of Autonomous Vehicle System

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