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Autonomous Car With Swarm Intelligence

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***Abstract*—Transportation made much improvement in the human race, and it is inseparable from life. The researches based on making cars more faster and safer is on the rise still the accidents involving cars are increasing every day. Reduce the rate of accidents can be controlled by the semi-autonomous system, a machine assist that help the human drivers avoid the possible accidents taking control of the car in crucial situations. Based on this the researches based on the fully autonomous cars (AV) also began. Autonomous cars which can drive around like humans or better than humans, being the most researched area in recent years many building techniques and algorithms discussed. Swarm intelligence a natural phenomenon which helps the birds and flies to fly in optimum speed without colliding with each other. Incorporating this intelligence into autonomous cars helps in avoiding collision with neighbours and also enables cooperative driving between autonomous cars. This paper discusses a building technique of AV with swarm intelligence capabilities.**

***Index Terms*—swarm intelligence, autonomous cars, genetic algorithms, collision avoidance**

I. Introduction

Collective of autonomous cars are like a swarm of AV's like a group of termites and animals, despite their size and the ability of the individuals they able to complete the most complex formations and achieve the most significant results. Swarms solve the complicated problems by getting some independence and intelligence with each unit. With suitable numbers, each member perceives the environment with different mechanics and communication with the other members which makes the whole swarm more intelligent. Trying to replicate this idea in AV's every car given some intelligence and some intelligence, a technical report by Queen's University Canada, explains the concept of how the swarm intelligence is working in the natural organism []. We can convert this phenomenon into mathematical functions. Hardware needed for implementing the AV's also discussed in this paper.

II. System Architecture

The hardware requirements for building an AV explained at Jakub and Zdenek's work [2]. RC Car model with 1:8 ratio model, only chassis and motors have to be taken, forward and reverse movements controlled with BLDC motor with hall sensors. This car has Ackerman steering geometry and a four-wheel drive. The basic block diagram of the autonomous car given in fig 1.

Fig. 1. basic block diagram of the autonomous car

A. Design Basics

Perception is like the vision of the organisms; the ability of the birds can fly longer distances without colliding with each other; vision is considered to be the most critical sense in the birds. They can see through over longer distances, according to Jakub and wenhao zong [2] [3]. A good build camera can serve the purpose of the vision, and using edge detection algorithms like cannyman algorithm can be used to detect the obstacles in the road. The car can classify each of the objects based on their color structure, Using the image classification technique. Addition to this different kind of sensors also included in the system, to decide whether the object is moving or not. Part of the vision system as the cameras may fail in the tricky situation like fog and smoke in the air. To aid the vision of the car in these situations system different kinds of sensors are used, but sensors are costly. The balance between the cost and effectiveness of the equipment used are evaluated; the ultrasonic sensor helps in identifying whether it is a moving or stable obstacle, a speed of the obstacle also can be detected. LiDAR is a light sensing and ranging technique which helps in identifying the world in a 3D plotting,in fig 2. Perceiving more from the environment Global Positioning System (GPS) also installed it returns the current position of the vehicle in the Global Map. Combining all the units in the simultaneous localization and mapping (SLAM) helps in tracking the current position in the global/local Map. Number of Plans adopted for the number and positioning of the sensors and cameras most cheapest way explained in the wenhao zong et al work [3]two regular cameras, 3 millimeter wave radar one surrounding camera and one twelve unit ultrasonic sensors but this set mostly dependent on the computer vision load on the computational side is very high. Design phase, control phase, and action modules described in the following sections, Perception achieved by getting the individual information from the sensors which comprised into a single frame through the data fusion module. This data uploaded to the local map/

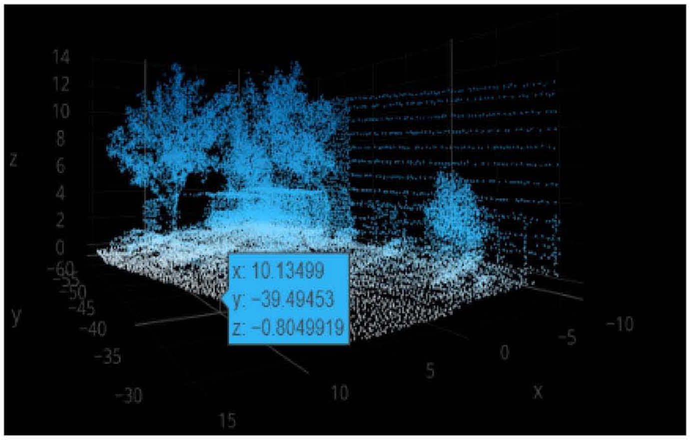

Fig. 2. 3D –Real-Time-LiDAR image

global map.[4]fig3.which will helps in making the swarm intelligent.

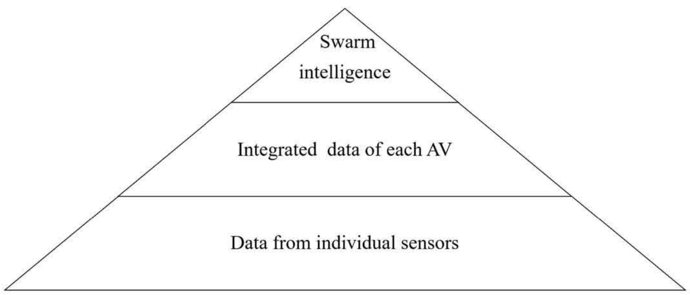

Fig. 3. Layers of Perception

III. ALGORITHMS

A. fuzzy logic in steering control

fuzzy logic in obstacle avoidance Steering control for the vehicle done with the fuzzy logic controller[2], The sensors provide the distance from the obstacle and the details of each obstacle. With the data's from ultrasonic sensors, the position and speed of the objects can be Determined. Design of the AV is done with 2 steering controller as one controls the vehicle to the target and another steer away from the obstacle. When the distance between the vehicle and the obstacle is equal or lesser than the 20 meters, avoidance controller takes control for steering away from an obstacle. Then the steering control is given back to the controller for leading to target. Chen et al. [5] proposed a better fuzzy logic system for human-like driving, the data from the sensors are fuzzified and majorly Mamdani model is used .human reaction to the situations are captured using stimulator and experienced drivers response is collected with the help of the computer system explained in yutao et al work[6].

B. Genetic algorithm for path planning

an autonomous vehicular path has to be computed so that the optimum results achieved; a multi-objective optimization is used to achieve the multiple objectives in the path planning, the different objectives in the path planning are minimum path length, minimum path vulnerability, and path smoothness [5]

- minimum path length
  Every path planning module should give output as the shortest path to the destination, the map data either local or global taken into consideration in the 2-D space the 16*16 or 32*32 grid is plotted the distance from one grid to another is the same for all the cells, so the minimum number of grids has to be taken to reach the destination.
- minimum path vulnerability
  Each cell holds a different level of vulnerability based on the obstacle present in it so when a path took a sum of all the cells values is the total vulnerability related to that path, path with the minimum value should have taken into considerations.
- path smoothness The smoothness of a path evaluated with the sum of all the angles in the selected path; the smoothness is a desired attribute when calculating the path, The overall power consumption and overall travel time reduced. Selecting the smoothest paths given in many of the problems but, it is an essential factor that affects performance, efficiency and user experience.

All the above-said objectives are important the perfectly balanced between these objectives are essential, the optimized results obtained with the elitist multi-objective algorithm (NSGA – II) which is a non-dominated sorting genetic algorithm (NSGA – II) in Deb et al.[8].a modified version of this algorithm is explained in faez et al. [7], the third objective the path smoothness is used as the decision maker.

IV. TRAJECTORY CALCULATION

Once the optimized path is found perfect trajectory need to be decided for that Andreas et al. work [9] numerical algorithm for the trajectory planning, with the vehicle metrics, temporal, spatial specifications, and energy-related requirements, as a simultaneous arrival problem where all the vehicles in the road reach the same target.

Mathew et al. [9] work proposed the idea of giving two envelopes for the steering of the vehicle they are stable handle envelope Which consist of maximum value that is the stable state beyond this the vehicle should not steer, that destabilizes the car. Another envelope is environmental envelope deals ensures not to collide with any other obstacle or vehicle.

A. Control Section

Centralized architecture that has been used for years to control the autonomous vehicle, where All the sensors and actuators connected to the bus called controller area network (CAN). The actuators also connected to that CAN. Algorithms used in AV's with computational intelligence algorithms and have a large amount of load to the processing system. Hence the single system may not able to cover the whole computational loads. Handling huge computational load could be a significant concern while building a new autonomous car jo et al.[10] proposed a distributed system for autonomous vehicular

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controlling[11]. By decentralizing the computational load into the sub computing modules also jo et al. work proves that the decentralized system improves the overall system's stability and efficiency because it can accomplish the task parallel rather than loading onto the single system. Also it much safer to use the decentralized system rather than depending on the single system, the risk involved with the failure of the decentralized system is very high, where the decentralized system can continuously check the health status of the other modules in the system. This paper also gives the details of software architecture for the building an autonomous car.

B. Action module

Action module consists of different actuators like an accelerator pedal, braking pedal, and steering controller. For converting a standard vehicle to the AV, some motors installed for steering the vehicle, controlling accelerator pedal and braking pedal. Nowadays cars like waymo come with completely wired configuration; virtually we can't see any of the controllers, internally they are connected to the controllers only few control buttons like start ride, emergency control seen in the car.

V. Swarm intelligence in Autonomous Cars

A technique inspired from nature which enables the organisms like birds and flies to flock as a group without colliding with each other, according to the technical report from the Queen's University, Canada [1] flocking behaviour of the birds, where they follow certain rules to flock together. Applying these techniques to autonomous cars not only makes them safer also cooperative with all other autonomous cars on the road.

A. Nearest neighbour principle

This technique explains that no matter how many AV's present in the road the car will only communicate are look after the neighbour, in a single lane traffic a single car continuously monitors the nearby vehicle front, back, right, left (using the word the "rear" will confused in terminology) four objects namely NF, NB, NR, NL denotes neighbours in front, back right, left respectively, according the movements of the neighbour each car can cooperative with each other, with the help of the shared map technology. Each AV will update its position and velocity in the shared map, each vehicle will change its position and speed constantly. based on the nearest neighbour. Other techniques which are adopted from the flocking of birds concept is,

- flock centring
  Flock members try to close with the other members of the swarm cars needs to stick to each other with minimum boundary distance. So that keeping the safest distance from its neighbours.
- Collision avoidance
  Avoids the collision with the neighbours by their relative position.
- velocity matching matches with the neighbours velocity.

each of the unit will have the its own speed and velocity it is consciously monitored by nearby neighbours, and neighbour will constantly update it speed, this will ensure that the whole swarm travels with the optimum speed according to the swarm optimisation algorithm reported in Queens university Canada [1] report. Introducing the maximum velocity of the swarm not greater than the slowest top speed of the vehicle in swarm, represented as v_{max}, v_{id} is the velocity of i^{th} particle in d^{th}dimension.

$$v_{\max} < v_{\text{id}} \tag{1}$$

- positon of the particle (here AV) is represented with x_{id} positon of i^{th} particle in d^{th}th dimension as far as the dimension is concern AV deals in 2-D map, it moves along the 2-D map.
- p_{id} represents the historically best position of i^{th} particle in d^{th} dimension.
- p_{gd} represents the swarms best particle x_g in the d^{th} dimension or it is the global best fitness value attained by any particle.

the value of the velocity and position of the particle can be updated to the new position then velocity updating equations are

$$x_{\text{id}} << p_{\text{id}} \;\; and \;\; x_{\text{id}} << p_{\text{gd}} \tag{2}$$

algorithm will enforce the particle (AV) to attain the current best position of the i_{gd} particle which is identified as the global best position the velocity of each particle also updated to global velocity.System architecture with swarm intelligence given in the fig 4 we can see that the centralized architecture that deals contains the WI-Fi module for communication with nearby vehicles and get constant updates on its position in the global map, also swarms intelligence module is incorporated in the design and planning module to update velocity and position of the vehicle the system offers the optimum speed and performance achieved within the swarm. Also, the proposed architecture is very reliable against present architecture, which has no communication with other vehicles other than sensing their speed and relative position. However, swarm intelligence makes the AV's more cooperative between each other, when there are n numbers of an autonomous vehicle similar to the independent birds in the air they have to be cooperative with each other.

VI. Challenges with building autonomous cars

On building the autonomous cars, man challenges regarding the usage of perceptive devices as the cost of them can be more and may not be affordable in commercial use so perfect balance between the cost and effectiveness have to be considered. Failure conditions of the sensors and cameras have to considered in fog or smog conditions cameras may fail to capture the continuous images, and sensors also fail at hard temperatures so depending on a single device will not help, the proper usage of the combination of devices have to use, security of the vehicles should also ensure when connected with nearby vehicles. The connection should be very secure so that the uploaded data should not be misused in any other way,

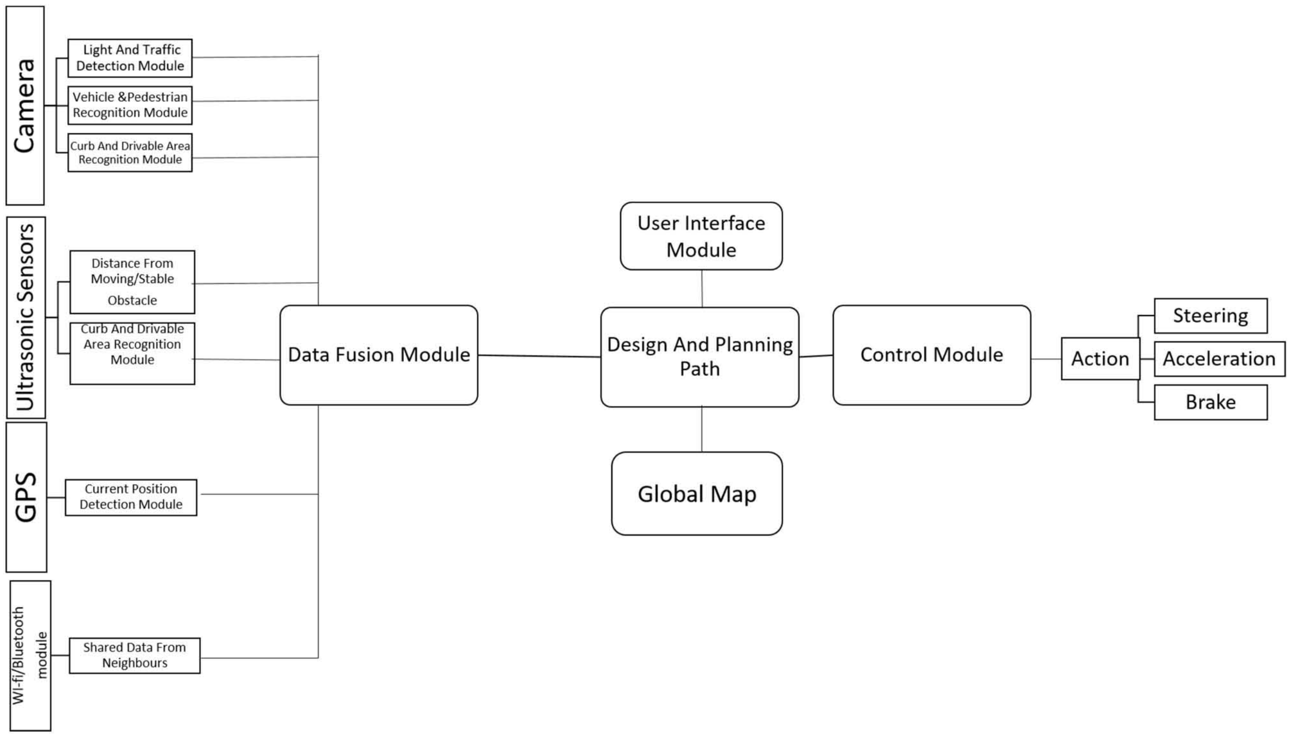

Fig. 4. architecture of a autonomous car

remote controlling of the car avoided in all the time, as it may lead to severe issues in traffic congestion, also hypothetical challenges also have to observed where can either save a passenger in the or pedestrian on the road. These challenges are still observed in building an AV.

VII. Conclusion

The AV is the car which can drive around without a driver on the wheels, a piece of computational intelligence algorithms that can drive like humans or drive better than humans. This paper proposed the natural phenomena Swarm intelligence, that can improve the AV's driving skills as it mimics the real organisms character. Cooperative nature of the swarm of autonomous vehicle can be improved.

VIII. Future scope and open research area

The number of AV's are increasing on the roads are increasing every day, in the near future many AV's can see the behaviour of these cars has to be controlled or decided without harming the whole swarm behaviour, the research area extended to Unmanned Aerial vehicles (UAV), Unmanned underwater vehicle(UUV), how they behave in the respective swarm. In 3-D space the challenges will be more significant. Supervised learning and unsupervised learning of driving of vehicle in this area of AV is also significant.

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