Unit-1

AI for Driverless Systems

Look : The MEMEX Reloaded, Inside a search Engine, Google and the Mind, Deeper and Darker. The Robotic Chauffeur: Getting to driverless, A cure for the deadliest disease, seven delaying Myths & The timeline.

AI plays crucial role in the development and operation of driverless systems, also known as autonomous vehicles.
These systems use a combination of h/w and s/w, including various AI techniques, to perceive the environment, make decisions, and control the vehicle.

Perception:

Sensor Fusion : Autonomous vehicles are equipped with various sensors such as cameras, LiDAR, radar, and ultrasonic sensors.
AI algms are used to integrate and process data from these sensors to create a comprehensive understanding of the vehicles surroundings.

Computer Vision: AI - based computer vision systems are employed to identify and interpret objects, pedestrians, road signs, lane markings, and other elements in the environment.

Decision Making:

ML: Decision-making algms use ML techniques

to analyze data, learn from past experiences.
RL, DL and other AI methods are applied to handle complex decision-making tasks.
Path Planning: AI algms are used to plan the optimal path for the vehicle by considering factors like traffic conditions, obstacles, and road-regulations.

Control Systems:
Vehicle Dynamics: AI-based control systems handle the vehicles dynamics, such as acceleration, braking, and steering to execute the planned path accurately and respond to dynamic changes in the environment.
ACC: Adaptive Cruise Control.
AI is utilized in ACC systems to maintain a safe following distance and adjust the vehicles speed based on traffic conditions.

Localization and Mapping:
SLAM - Simultaneous Localization and Mapping:
AI-driven SLAM algms enable the vehicle to accurately locate itself within its environment and build a map of the surroundings in real-time.

Communication and Connectivity:
V2X Communication:
AI facilitates communication b/w autonomous vehicles and infrastructure (V2I), other vehicles (V2V), and pedestrians (V2P).

Safety and Security:
Fault Detection and Diagnosis:
AI is employed to monitor the vehicles components and systems, detecting any faults or anomalies

and taking appropriate actions to ensure safety.

Cybersecurity: AI helps in developing robust cybersecurity measures to protect autonomous vehicles from potential cyber threats and attacks.

The field of AI for driverless systems is continually evolving, with ongoing research and development to improve the efficiency, safety, and reliability of autonomous vehicles.

Look :- The Memex Reloaded :-

way back in 1945 Vannevar Bush, then the director of the US officer of Scientific Research and Development (OSRD), suggested that scientific effort should be directed towards emulating and augmenting human memory.

MEMEX : a device which is a sort of mechanized private file and library ... in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility.

The MEMEX would be modelled on human memory, which operates by association.

Today you can Google persons you are about to meet and usually find half a dozen photos of them, in addition to much more, such as their Facebook page, publications (on speaking appearances, and snippets of their employment history.

Google handles over a 4 billion search queries a day. Everybody who has access to the internet uses search. From office workers to college students to the youngest of children.

What the Internet is Doing to Our Brains.

The MEMEX imagined by Vannevar Bush is now with us, in the form of web search.

Apart from being a tremendously useful tool, web search also appears to be important in a very fundamental sense.

Inside a Search Engine :-

Powering the innocent 'Google search box" lies a vast n/w of over a million servers.

Searching for data is probably the most fundamental exercise in computer science; the first data processing machines did exactly this i.e, store data that could be searched and retrieved in the future.

Google's million servers continuously crawl and index over 50 billion web pages, which is estimated size of the indexed WWW.

The English language itself contains just over a million words.

Additionally there are proper nouns, naming everything from people, both real or imaginary to places, companies, rivers, mountains, oceans, as well as every name ever given to a product or film or book.

Google has expanded to cover many languages, as well as index common phrases in addition to ~~an~~ individual words.

Computer science is all about coming up with faster procedures, or algorithms, such as the smarter and supposedly faster one just described.

The number of steps taken by naive algm is exactly proportional to the size of the i/p.

Further, while many web pages are static, many others change all the time. Additionally, new web pages are being created and crawled every second.

Google's major innovations, called "map-reduce", a new paradigm for using millions of computers together, in what is called "parallel computing".

Google's millions of servers certainly do a lot of number crunching.

Google's secret was "PageRank", a method of calculating the relative important of every web page on the internet, called its "page rank".

Google and the Mind:-

The page rank of each page is always accurate, which is the secret behind the quality of its search results.

There are 50 billions (or so indexed web pages, each possibly representing aspects of some human enterprise, person or event.

Google's Page Rank appears, magically, to be able to attach an importance to each page in a manner that we humans are able to relate to.

The fact is that people find what they want faster because whatever PageRank throws up first often turns out to be what they were looking for.

A rational model of human cognition seeks to understand some aspects of how we humans think by comparing it to a computational technique, such as "Page Rank".

Psychologists and cognitive scientists have used what is called a "semantic model" where pairs of words are associated with each other in some way, such as being synonyms of each other, (or) one a generalization of the other.

Page Rank is merely a computational technique for deciding the relative importance of a web page.

- Note that web pages link to other pages, while words in the semantic network link to other words; these two networks are completely unrelated to each other.

PageRank is so good that it is changing the way we navigate the web from surfing to searching, weakening the premise on which it itself is based.

The terms that are more often queried by users may also be indirectly affecting the importance of web pages.

The brain's look up mechanisms are certainly more complex than the fairly simple look up that a search engine uses.

The acts of remembering, knowing, and making connections are all intimately related

"Associative memories" are one class of computational models that attempt to mimic human memory's ability to dynamically form linkages based on similarities b/w experience.

The web-search model is rather poor at handling duplicates and especially near-duplicates.

A new way to find near-duplicates in large collections without examining all pairs was invented as recently as the mid 1990s. This technique called "Locality sensitive Hashing" (or LSH).

Deeper and Darker:-

The information 'available' on the web that is actually indexed by search engines such as Google is called the "surface web", and actually forms quite a small fraction of all the information on the web.

The "deep web" consist of data hidden behind web-based services, within sites that allow users to lookup travel prices, used cars, store locations, patents, recipe, and many more forms of information.

The volume of data within the deep web is in theory huge, exponentially large in computer science terms.

search engines, including Google, are trying to index and search at least some of the more useful parts of the deep web.

Googles approach has been to automatically try out many possible inputs and input combinations for a deep web page and figure out those that appear to give the most results. These results are stored internally by Google, and added to the Google index, thereby making them a part of the surface web.

Searching the deep web is one of the more active areas of current research and innovation in search technology.

All the worlds wealth resides in the computer systems of thousands of banks spread across hundreds of countries.

Every day billions of cell phones call each other, and records of "who called whom when" are kept, albeit temporarily, in the systems of tele-communication companies.

Every parking ticket, arrest, and arraignment is recorded in some computer in the other within most police or judical systems.

Each driving licence, passport, credit card, or identity card of any form is also stored in computers.

TIA – Total Information Awareness.

VOIP – Voice Over IP.

CDR – Call Data Record

Every time a mobile ~~tele~~-phone makes a call (or for that matter, a data connection, this fact is immediately registered in the mobile operator's information systems: a "call data record" or CDR, is created.

While each mobile phone is connected to the nearest cell phone tower of the chosen n/w operator, its radio signal is also continuously received at nearby towers, including those of other operators.

Seven delaying myths:

→ Autonomous driving technology will evolve out of today's driver-assist technology.

→ Technological progress is linear.

→ The public is resistant.

→ Driverless cars require extensive investment in infrastructure

→ Driverless cars represent an ethical dilemma.

→ Driverless cars need to have a nearly perfect driving record to be safe enough.
→ The adoption of driverless cars will be abrupt.

Anatomy of a Driverless cars: High definition digital maps, Digital Cameras, Light Detection and ranging (Lidar), Radio Detection and Ranging (Radar), Ultrasonic sensors (sonars), Global positiong system (GPS), the inner ear (IMU), Drive by wire.

Anatomy of a Driverless cars:-

Driverless cars "see" and "hear" by taking in real-time data that flows in from several different types of on-board sensors. Cars recognize their current location using a GPS device and a high-definition stored digital map.

High definition digital maps:

Humans learn their way around a new neighborhood by recognizing distinctive landmarks.
· Driverless cars find their way around with a GPS, with visual sensors and by following a high-definition (HD) digital map; a detailed and precise model of a regions most important surface features.

Driverless cars use ML s/w to deal with real-time traffic situations, and rich, detailed, and constantly updated HD digital maps to handle longer term navigation.

~~A digital car~~
A driverless car knows its ballpark location by looking up its GPS coordinates on a HD map.

An HD map depicts both big geographical features, such as mountains and lakes, and minor topographic details, such as the presence of trees and sidewalks.

An HD map for a driverless car focuses on the static surface details of a road or intersection for its lane markings, intersections, construction zones and road signs.

Traditional maps created for human eyes were 2-D pictorial depictions of a particular place where notable landmarks were indicated by static labels. HD map usually offers its user concealed powerful back-end. While an HD map usually offers its user a pictorial depiction of the region, behind the scenes, it's actually a database that contains millions of stored entries of topographical details, each other relevant details such as its geographical location, size and orientation.

The brain of the avg human houses a high-quality local map. Updating a HD digital map is a laborious process that involves exhaustively driving around with several cameras and lidar sensors.

Digital Cameras :-

Digital maps are stored, static data that help identify car's location. Digital cameras are the equivalent of human eyes, capturing the visual environment outside the car in a stream of real time data.

As digital camera technology continues to get faster and more precise, roboticists have eagerly harnessed these rapid advancements to improve the performance of mid-level control s/w.

The QuickTake, manufactured by Kodak, was famed for its portability and the fact that it could store 8 (640 x 480) color images at a time. Today an any consumer camera can take 30 high-resolution images a second.

A digital camera gathers light through a lens in the form of photons: Each photon carries a certain amount of energy.

Each photoreceptor absorbs its share of photons and translates the photons into electrons, which are stored as electric charges.

The brighter the stream of light, the higher the number of photons and the stronger the electrical charge.

The amount of light hitting the grid of photoreceptors is then transformed into a format a computer can understand: a collection of numbers on a grid that represent the location of each individual "picture element", or pixel.

JPEGs, GIFs are all other image files are just different ways of storing this array of light intensities.

Both in the silicon sensor and the retina visual data is broken up into several smaller units in order to be processed.

On the retina, millions of specialized biological photoreceptor cells called rods and cones absorb photons and convert the energy into neural signals that are sent to the brain to be processed into visual information.

In the human eye rods and cones are arranged in a random fashion, densely packed in the center

of the retina and less densely packed around the edges..
In a silicon sensor inside a digital camera, individual pixels are arranged in a rectangular pattern with regular spacing..
A one-mega pixel camera contains a silicon sensor that has an array of 1000 x 1000 individual photo receptors that correspond to a total of 1000000 pixels.
Some specialized digital cameras used for autonomous driving do more than just record pixel values.
Biological life forms have 2 or more eyes placed side by side, an adaptation that enables depth perception, in what biologists call stereo vision.
Digital cameras, do not have stereo vision, a limitation that has been one of the biggest problem in their appⁿ to autonomous driving.
Digital cameras capture information on the intensity of light into a grid of pixels, an elegant way to digitally capture a 3D world into a 2D format.
A potential solution is structured-light cameras that use a camera-projector combo that augments image data with depth information.
Digital cameras use image sensors (such as CMOS or CCD) to capture light and convert it into digital signals.
Resolution determines the clarity and detail of images captured by the camera.
Lenses and optical systems focus light on to the sensor, affecting image quality, depth of field, and field of view.

Cameras often include onboard processors to enhance images, reduce noise, and adjust color balance in real-time.

Light Detection and Ranging (LIDAR):-

Another primary image sensor is the lidar, an acronym of "light detection and ranging", also called laser radar.

A digital camera works by breaking down the 3D visual world into a 2D matrix of pixels.

A lidar device "spray paints" its surroundings with intense beams of pulsed light, measures how long it takes for each of those beams to bounce back, and then calculates a 3D digital model of its nearby physical environment.

Like digital cameras, lidar sensors have also followed the Moore's Law trajectory, morphing from gigantic.

Lidar sensors have been used for decades by surveyors to capture the topographic details of parcels of land.

The notion of mounting a device onto a moving vehicle to shoot laser beams into the environment is a more recent innovation.

Lidar sensors have been a crucial tool in driverless cars since the 3D-digital model they generate is highly detailed and contains accurate depth perception.

A laser beam is an ideal measurement tool. Unlike a candle, which radiates light in all directions, a laser beam shines in a SL for a great distance.

To create a full 3-D digital image of the surrounding environment, a lidar sensor spins its laser beams around and around at high speed.
A lidar sensor, like a digital camera, can vary in resolution. Multiple beams can work together continuously to scan and measure the surrounding environment in parallel.
In a driverless car, the data gathered by a lidar is fed to s/w that arranges the information in a digital model called a point cloud.
Lidar sensors do not capture colour information. In reality, the s/w that interpreted the point cloud adds the colour, artificially coding closer objects in blue tones and more distant objects in red ones.
Today's driverless cars use both digital cameras and lidar. Today, lidar sensors are expensive and slow compared to digital cameras.
As microprocessor speeds continue to improve the performance of both the digital camera and the s/w that processes the digital images.

RAdio Detection and Ranging (Radar):-

In addition to cameras and lidar, driverless cars use radar sensors, to "look" at the nearby environment.
If digital cameras capture a scene in a pixelated grid and lidar sensors are the equivalent of a can of digital spray paint, a radar sensor is similar to the surface of a pond.
Radar has its roots in military applications. During world war-II, radar towers were placed on beaches and fields to detect the approach of enemy aircraft, ships and incoming missiles.

Air traffic controllers used radar to track and confirm flight trajectories of commercial airliners.

In another demonstration of Moore's Law, radar sensors have become small and robust enough to be mounted on a moving car.

Radar sensors are used in modern human-driven cars in adaptive cruise control technology.

A built-in radar device senses the speed and location of cars in front of and behind a car, so the cruise control can adjust the brake and gas pedal accordingly.

A radar sensor detects the presence of physical objects in the nearby environment using EM wave echo.

A radar sensor consists of a transmitter, the unit that sends out the EM waves, and a receiver, the device that awaits their return.

Radar sensors are increasingly sensitive and intelligent.

To prevent the sensor from accidentally picking up the waves emitted by another nearby transmitter, the EM wave is sent out accompanied by a unique signature "chirp".

Some radar sensors can calculate which direction a reflecting object is moving by analyzing changes in the frequency of the reflecting wave.

Different radar sensors employ different As.

Short-range radar sensors that send microwaves into the distance can detect objects as small as cat or bycycle.

Electromagnetic waves reflect best off surfaces that have high electric conductivity.

A radar sensor can "look" only in a particular narrow direction, so most radar sensors are mounted in arrays that overlap slightly.
Electromagnetic waves travel easily through non-conductive and thin materials, EM waves prefer larger objects.
The biggest drawback of a radar sensor is its relatively low resolution.
Advantage of a radar sensor is that it can detect not just the position of an object, but also its speed, using the Doppler Effect, named after the 19th century Austrian physicist Christian Doppler.
Radar sensors use the Doppler effect to track the speed of moving objects. By recording the change in frequency b/w outgoing and incoming EM waves, a radar sensor can determine if the sensed object is approaching or moving away. The sensor can also calculate the objects speed.
On a driverless car, radar detectors complement the visual sensors in figuring out the surrounding environment.
RADAR is a remote sensing technology that uses radio waves to detect objects and measure their distance, speed and direction.

<u>Ultrasonic sensors (Sonars)</u> :-

If lidar and cameras are the equivalent of human eyes, sonar is like a human ear.
Sonar is the close-range cousin of radar.
Sonar uses sound waves instead of radar's EM waves.
The term sonar combines "sound navigation" and "radar".
A sonar sensor detects the position and speed of objects based on the time, frequency, and shape

of sound waves reflecting off their surfaces.
A sonar device is composed of two subunits:
→ an emitter
→ a receiving sensor.
The emitter generates sound waves that have a frequency above 20kHz, a sound beyond the range of human hearing.
The receiver listens for the echoes from the emitted sound waves and processing them.
Like radar sensors, they can see through fog and dust and they are not blinded by sun.
Sound waves travel much more slowly than EM waves, they can see much smaller objects at much higher resolution.
It contains electronic circuitry for signal processing and distance calculation. Some sensors also integrate 'T' compensation to maintain accuracy across different environmental conditions.

Applications:
→ Parking assistance systems in cars
→ object detection in robotics.
→ Liquid level measurement in tanks.
→ Proximity sensor in consumer electronics.

Global Positioning System (GPS):-
A GPS device supplies coordinates to pin down a car's exact location on its HD digital map.
GPS follows Moore's Law, has blossomed into a reliable, low-cost consumer appliance.
GPS devices are miracles of advanced engineering that listen to signals from satellites rotating in the heaven.

A GPS receiver in your car (or cell phone determines your latitude and longitude by listening to beeps that arrive from a family of satelites spinning high above the earth.

Each satelite follows an exactly prescribed orbit, all the while emitting a steady stream of electronic pulses precisely once a second.

24- satelites provide GPS signals, but the GPS receiver needs only 4 to calculate its own location on earth.

Each satelite emits its own unique signature beep, which enables the GPS receiver to attribute a particular beep to its satelite of origin.

As stream beeps ~~ste~~ in to the GPS receiver, the receiver listens carefully.

By calculating the time lapse b/w beeps a GPS receiver is able to calculate its own exact location using a mathematical process known as triangulation.

A total of 4 satelites are needed to pinpoint exactly where the receiver is; additional satelite signals refine the position even further.

In a normal driving environment, a typical GPS receiver is accurate to a distance of about 4 meters or roughly 13 feets.

Unfortunately, satelite signals can be blocked or delayed as a result of atmospheric turbulence, clouds, or rain, which can result in an inaccurate calculation.

IMU:

GPS failure can be catastrophic.

An Inertial Measurement Unit (IMU) is a multipurpose device that serves several functions.

An IMU contains acceleration and orientation sensors that keep track of the cars position.

A modern IMU is a complex bundle of devices including an odometer, accelerometer, gyroscope, and compass.

To keep track of a car's exact location b/w GPS readings and to compensate for GPS inaccuracies an IMU uses an ancient navigational technique known as dead reckoning.

On a driverless car, the IMU uses, when a car goes into a tunnel (or) travels through an urban canyon that blocks satellight signals.

The IMU uses its odometer to count the number of wheel revolutions from its last known location.

An IMU paired with a GPS and a compass is a powerful and foolproof combination.

The IMU needs 3 pieces of information to measure and track the car's physical orientation in space :

→ which direction its facing

→ at what angle its nose is titled up (or) down.

→ at what angle its titled to the side.

MEMS - Micro Electro Mechanical systems.

An IMU can't work without a GPS.

ECU - Engine Control Unit

TCU - Transmission Control Unit

USB - Universal Serial Bus

CAN - Controller Area Network

OBD - On-Board Diagnostics