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An Efficient Architectural Model for Building Cognitive Expert System Related to Traffic Management in Smart Cities

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Abstract: One of the major goals of developing countries is to build smart cities to avoid different kinds of congestions, accidents and many kinds of inordinate delays. The most important consideration is intelligent traffic management system. An intelligent traffic management system can be conceived through many of individual sub-systems which include Bio-sensing system, imaging system, messaging system, cognitive system and visualization system, remote sensing and communication system. Each of the sub-system while is expected to research independently it should also be in existence in unison along with other sub-systems. To implement automated traffic control system there is a need of cognitive subset which is the decisive-core of the integrated system. It essentially researches like a virtual human operator. An embedded remote-control takes in various traffic conditions such as undetected accidents, VIP movement and abnormal environmental conditions as inputs from the police force to the cognitive control system to control the traffic flows at signal post systems. Designing a cognitive subsystem with high precision, to take real-time decisions with varying multiple inputs is a complex task. It should take inputs from all the other subsystems and the man-operator, process the gathered data and then issue control signals accordingly. This study emphasises on the design and application of the cognitive expert system in a simple yet efficient manner to suite the smart city environment.

Key words: Smart city, intelligent systems, cognitive expert system, traffic management system, India

INTRODUCTION

Any gadget of present times is in a demand of being smarter which can think on its own and make decisions for us to make our lives more organized and a lot easier. This demand has already been met by cell-phones which transformed from merely being a bit more than walky-talky to a bit less than personal assistant. This “smart device” can be made intelligent by adding cognition into it.

A cognitive system can be understood as an intellectual system which can take decisions by processing and analysing the data. A cognitive system makes the total system smart and helps in taking human-like decisions. It is an essential of a socio technical system where human intelligence provides the basic functionality and technology researches in duality with it. By building a robust cognitive system which can plan, manage and take decisions helps in enhancing the human capability and effectiveness of the whole system.

Cognitive systems should not be mistaken for the ones which replaces and acts as a substitute for human thinking instead they are meant to collaborate with us and research along to extent our bounds of creativity and logic. Human involvement is required to provide necessary commands and functional inputs to the system which helps in making it more compatible and flexible to the changes which in turn improves its accuracy and dependability.

Such kind of cognitive system must be adaptive and applicable to real time systems like traffic management system, transport system, military command and other large-scale products. They have proved themselves to be the saviours of the whole system multiple times in various scenarios. Some of such examples are oncology which provides the doctors with the apt treatment procedure that can be implemented for a patient, it takes the patients symptoms and conditions as inputs and compares it with all the previous databases and makes the decision for the doctors making their research lot easier and accurate. Effective use of these cognitive systems is extensively found in cockpit control and air traffic management systems, military fleets and also in nuclear power plants it is already applied successfully to internet and many other tech gadgets used by public. In this study, a trial has been made to apply cognitive systems in traffic management in a smart city. Cognitive intelligent systems must be adaptive and intelligent and must dynamically evolve as r the changes taking place in its neighbourhood

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and also based on the inputs provided by the human beings from a remote location. Transportation is one of the basic needs in modern-day society which has transformed world to be a global village. Road transportation has a lion's share in this system with the increase of population, traffic density on roads has also risen tremendously leading to large scale use of automobiles causing pollution, congestion and more accident rates as a whole greatly impacting the social life of people both directly and indirectly. For regulating these automobiles, there are many traffic management systems across the world and for making-up an efficient system many constrains are to be taken into account like increasing mobility of vehicles as much as possible, minimizing the risks of collisions and traffic jams an alternate path for emergencies and VIP movements reducing the unnecessary delays in traffic, managing bad weather conditions, providing primary services in accidental cases, speed management, surveillance, tracking particular required vehicles for vigilance, environmental aspects like air and noise pollutions, etc.

This system in India is mostly done manually which requires a lot of man power and it does not provide accurate and reliable outputs always. Hence, there is a requirement for an effective updating of this system that makes it smarter and adaptable to the situation instead of just working based on a non-flexible set of rules and such a system can be called as an intelligent traffic management system.

An intelligent traffic management system can be conceived through many of individual sub-systems which include bio-sensing system, imaging system, messaging system, cognitive system and visualization, remote sensing and communication systems. Each of the sub-system while is expected to work independently, it should also be in existence in unison along with other sub-systems.

Cognitive systems when embedded into these traffic management systems makes it adaptable and dynamic enough to control and meet the demands of increasing traffic densities. This Intelligent Traffic Management System (ITS) has a huge amount of data to be processed and analysed. The data may come as input from different resources and hence must be processed differently. They must then be analysed to make appropriate decision and transform them into different outputs which are in turn given to a centralized server and also to multiple sub-systems which display and inform the public. To accomplish this important and basic task there is a need for a smart system which is cognitive expert system which is generally positioned as a signal post system. Here, the role of cognitive system is to receive the information collected by all sub-systems and process them. Transform all the processed data into appropriate output and send it to the respective sub-system. Various subsystems that interact with core signal post system are shown in Fig. 1. The communication between the sub-systems and the core cognitive signal post system is two ways and generally constructed through a star topology.

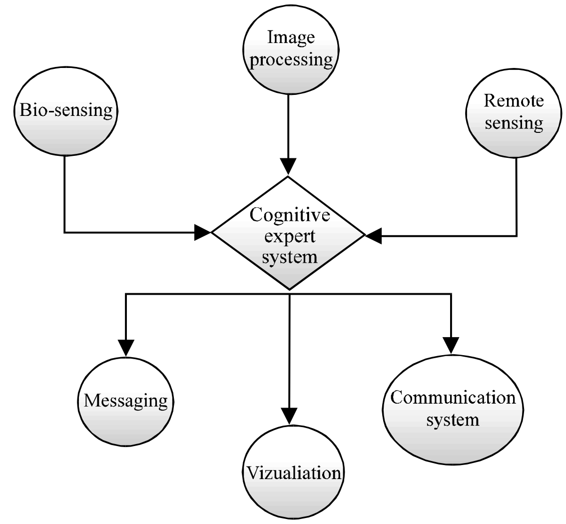

Fig. 1: Topology of a traffic management system

The cognitive system along with these sub-system inputs takes in other inputs those which are undetectable by the electronic machinery are given as manual input. This can be implemented by using an embedded remote control which interacts with the cognitive system. One of the requirements of the cognitive system is to collect information from police who include acute traffic, abnormal environmental conditions undetected accidents, malfunctioning of equipment, traffic culture, route changes, directional changes, emergency situations, VIP movement, etc.

A real time implementation of cognitive systems for traffic control at a single junction can be represented as shown in Fig. 2. Figure 2 depicts all the inputs and outputs involving cognitive system indicated by data-flow arrows marks.

There are some complexities that arise while implementing cognitive systems for traffic management which must be handled for successful implementation of traffic management system. Some of those complexities include the following.

Converting the inputs into a suitable format: The inputs that are provided to the cognitive systems are in different formats. For example, input from bio-sensing can be through an Ethernet in contrast emergency call from

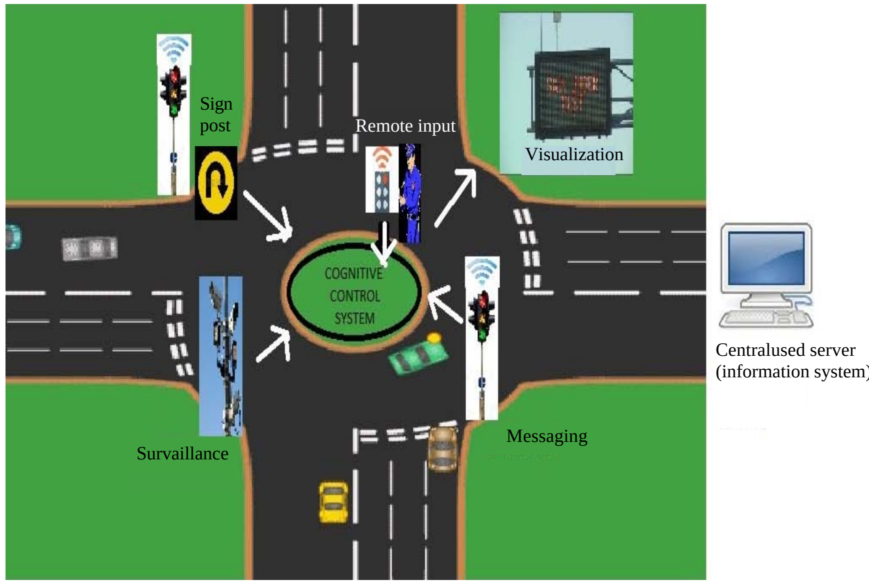

Fig. 2: Real-time representations of cognitive systems at signal post position

police, i.e., through the embedded remote can be through Bluetooth and data from remote-sensing is arrived through satellite, etc. All these modes of communication are transformed into appropriate format of data which is suitable for analysing and processing.

Data collection and storage: In real time, the number of vehicles to be managed are very huge and it is definitely not an easy task to gather information in relation to all the vehicles and as such it is a huge task to store the data within on-board memory dynamically through a process of overlaying or can be sent to a centralized server to keep a track of it.

Retrieving the collected data for processing: Getting the data from the centralized server for processing.

Setting the basic rules for traffic management: Deciding the limit and threshold values for certain parameters that are measured by other sub-systems. Giving the information about the things that are to be done when VIP movements and emergency services like ambulance are encountered. For example; setting a threshold for value of air-pollution levels to take appropriate measures.

Taking decisions based on the constraints: Deciding what must be done in a situation according to pre-set rules and current situations. Like releasing the traffic on one arm of a junction where there is greater traffic density or pollution as compared to other arms.

Interfacing with various subsystems: Ability to communicate with peripheral, local and remote management systems through adapting most suitable communication standard such as Wi-Fi, cellular, microwave and satellite and an inter-mix of them.

Outputting them in required format to other sub systems: All the decisions taken must be sent as outputs to various sub-systems which inform public by means of sign boards and traffic light control.

Ability to control heavy traffic: Heavy traffic jams are a major disadvantage for any traffic management system but as the root cause of this which is increase of vehicle density cannot be avoided it is a necessity that it must be controlled only by proper planning and correct regulation of traffic flow. This demand must be met by dynamic control of traffic lights, i.e., setting priority to the junction and the lane where the density is more. And, this decision of an optimal time of signal post's cycle time must be taken precisely.

Averting the redundant setback of vehicles: At certain junctions, sometimes even if there is no traffic, people have to wait. Because the traffic light remains red for the pre-set time period the road users should wait until the light turn to green. If they run the red light they have to pay fine. The solution of this problem is by developing a system which detects traffic flow on each road and set timings of signals accordingly. Moreover, synchronization of traffic signals in adjacent junctions is also necessary.

Controlling and monitoring emergency situations: Usually during traffic jam, the emergency vehicle such as ambulance, fire brigade and police will be stuck especially at the traffic light junction. This is because the road users waiting for the traffic light turn to green. This is very critical problem because it can cause the emergency case become complicated and involving life.

Ability to control traffic when multiple emergency vehicles are present at an intersection: There is no problem when there is one emergency vehicle at a junction but in times of multiple vehicles an optimal and im-partial decision has to be made.

Acquire the information from the corps: Various situations that can be only perceived by the human beings can be pre-coded and converted into rules the data of which has to be acquired through a properly developed user interface. More and more rules are to be added dynamically and the action to be taken on the satisfaction of the rules must also be coded. An expert engine is required that can interpretative the rules, execute the same and take appropriate action based on the satisfaction of the rules.

Traffic management system involves generally three levels of monitoring and control which include signal post level, base station level and monitoring and controlling from a remote location.

Out of all, the signal post level of monitoring and controlling is provided through a local host control. The local system is responsible for collecting numerous local devices which are heterogeneous in nature and uses varied protocols for communication. The local system must also provide cognitive based support through related communication interfaces. The local system must also be dynamic and self-adaptable as the changes to the system required have to be carried while the system is up and running. The system as such needs to be developed using in-built artificial intelligence and expert systems which are required for processing the data to be able to generate out for controlling and regulating the traffic moving in different system. One such controlling is related traffic lamp management.

Thus unified solution based on embedded technologies has to be built that provides interface with varying gadgets/sensors able to communicate using different communication protocols has built in cognitive model and generate the controlling outputs based on artificial intelligence and expert system based decision making model (Kurzweil, 1999).

Literature review: Wen and Yang (2006) presented automatic traffic light control expert system for solving the road congestion problem. They have proposed a framework for a dynamic and automatic traffic light control expert system combined with a simulation model which composed of six sub-models to help analyse the traffic problem. The model adopts inter-arrival time and inter-departure time to simulate the arrival and leaving number of cars on roads. In the experiment, each sub-model represents a road that has three intersections. This simulation results physically proved the efficiency of the traffic system in an urban area because the average waiting time of cars at every intersection is sharply dropped when the red light duration is 65 sec and the green light time duration is 125sec. Further analysis also shows if we keep the inter-arrival time of roads A-C and change that of roads D, E and F from 1.7-3.4 sec and the inter-departure times at the three intersections on roads A-C are equal to 0.6 sec, the total performance of the simulation model is the best. Finally, according to the data collected from RFID readers and the best, second and third best traffic light durations generated from the simulation model the automatic and dynamic traffic light control expert system can control how long traffic signals should be for traffic improvement.

From this research, we can implement the experimentation procedure to decide dynamically on the timings of the traffic lights, i.e., duration of red, green and yellow lights. This procedure has its scope defined only to recognise the correct timings but it is not designed to have control on the traffic lights adaptively.

Al-Alawi (2009) proposed the intelligent traffic management system consisting of a master unit and a number of slave nodes sparsely located at different geographical sites and interconnected together through the internet. A prototype of the proposed system has been built with two nodes. Each node controls and monitors an intersection of two roads called A and B. A circuit board with LED s arranged like traffic lights around the two road intersection plus two switches for sensing traffic flow in each direction is interfaced with each node controller. Each node is equipped with an embedded web server which is responsible for monitoring and controlling the traffic signals, traffic sensors.

They implemented software to simulate a junction which is far from other nodes. The proposed system highly graphical in nature used the Windows system and allowed simulation of different traffic conditions at the junction. The system made comparisons of fuzzy logic controller and a conventional fixed-time controller and the simulation results showed that the fuzzy logic controller had better performance and was more cost effective.

Osigwe stated a way of implementing ITS. Their methodology is a hybrid of two standard methodologies:

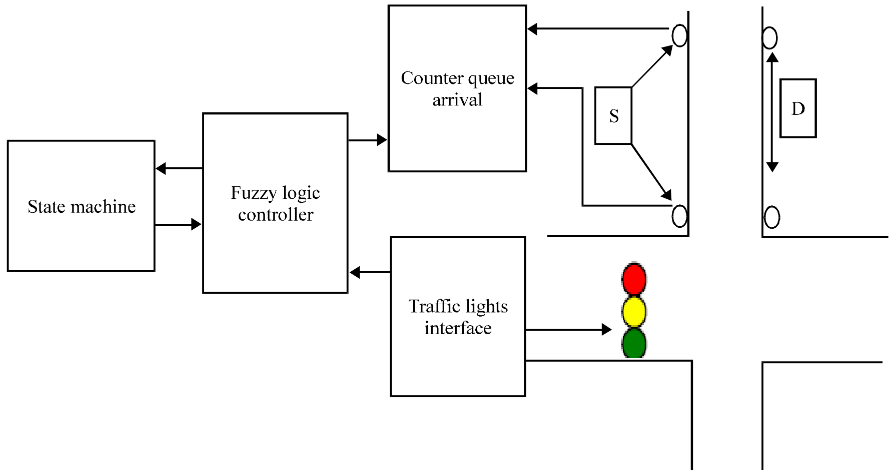

Fig. 3: Fuzzy based design architecture

the Structured System Analysis and Design Methodology (SSADM) and the fuzzy based design methodology. The architecture is shown in Fig. 3.

Based on the analysis of this traffic control system, the following assumptions became necessary in order to develop a feasible system. The system will only research for an isolated four way junction with traffic coming from the four cardinal directions.

Traffic only moves from the North to the South and vice versa at the same time and at this time, the traffic from the East and West is stopped. In this case, the controller considers the combination of all the waiting densities for the North and South as that of one side and those of the east and west combined as another side. Turns (right and left) are considered in the design. The traffic from the West lane always has the right of way and the west-east lane is considered as the main traffic.

Volodymyr Miz, Vladimir Hahanovin proposed a smart traffic light in terms of the Cognitive road Traffic Management System (CTMS) based on the Internet of Things. This study makes use of CTMS infrastructure. Global traffic management system such as CTMS requires environment which provide the Internet connectivity to all vehicles on the road. This can be achieved by synchronizing your mobile phone with the vehicle. Smart traffic lights system takes into account the workload of the road and switch traffic light signal depending on the number of vehicles. This will prevent needless delays at intersections in that case if one of the roads is less loaded than the other. It makes possible to calculate the total emissions of carbon dioxide which can be one of the switch parameters of the traffic light. But, this kind of an approach only helps pedestrians and cyclists on the roads but it cannot be implemented to automobiles.

Sumathy proposed solving the traffic congestion in urban places by implementing an automatic pre-emption traffic control system that ensures preferences given to all the emergency vehicles. The algorithm considers a number of factors such as traffic volume, waiting time, vehicle density, etc., after which green light sequence will be determined. Intelligent Transportation Systems (ITSs) are automatic road traffic management systems that manage road traffic with the intention of improving traffic safety and minimizing the energy consumption of vehicles running on the roads. An ITS consists of 4 subsystems, a surveillance system a communication system an energy efficiency system and a traffic light control: fixed time, actuated system. Some of the currently used traffic light pre-emption systems can be classified based on its operation into a optical system, sound based systems, radio controlled systems, GPS System and sensor based system.

Abdul Kareem and Jantan (Zhanbo *et al*., 2011) proposed an intelligent traffic light monitoring system using an adaptive associative memory. The research was motivated by the need to reduce the unnecessary long waiting times for vehicles at regular traffic lights in urban area with ‘fixed cycle’ protocol. To improve the traffic light configuration, the study proposed monitoring system which will be able to determine three street cases (empty street case, normal street case and crowded street case) by using small associative memory. The experiments presented promising results when the proposed approach was applied by using a program to monitor one intersection in Penang Island in Malaysia. The program could determine all street cases with different weather conditions depending on the stream of images which are extracted from the streets video cameras. The flow used to achieve traffic light pre-emption system is shown in Fig. 4.

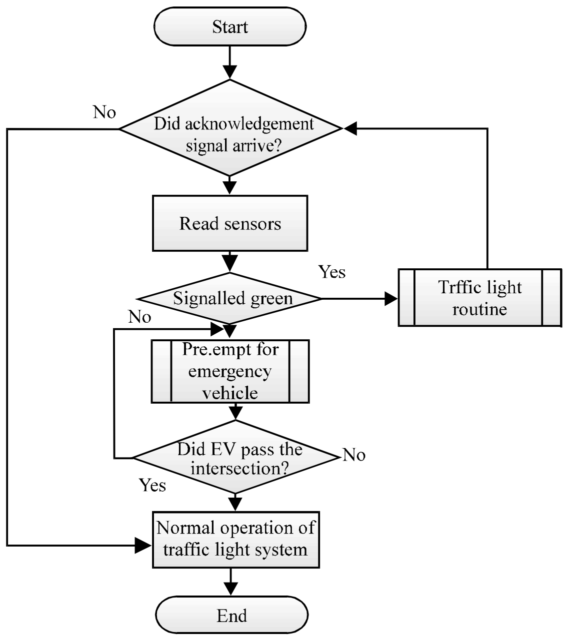

Fig. 4: Flow-chart for traffic light pre-emption system

John proposed an Advanced Traffic Management System using AI. The goal of Advanced Traffic Management System (ATMS) was to efficiently manage existing transportation resources in response to dynamic traffic conditions. Several inputs have been considered into the model which include traffic management decisions, model predictions, traffic congestion reports, police/public safety reports, event schedules, attendance and status, transit schedules and status, airport schedules and status, ship line schedules and status, commercial trucking, commercial traffic reports, weather reports, emergency calls, incident reports, traffic spotters, traffic sensors, video cameras, cellular phones, sites of interest, directory of accommodations and directory of services (Chinyere *et al*., 2011).

MATERIALS AND METHODS

Architectural modelling of signal-post systems: The architectural modelling of the signal post system is shown in Fig. 5 that shows various peripheral connections and kind of communications that takes place among the devices and various computing locations. The model also shows the extent to which redundancies are built to create a fail-safe operational system.

In the proposed architecture every one of the individual subsystems including imaging, remote sensing, visualisation, bio-sensing, messaging meant for monitoring and controlling one of the aspects of traffic management system through use of embedded technologies which are to be integrated using yet at another process controller which is also built using embedded technologies. Raspberry Pi board has been selected for providing the integration of sub-systems as it has most of the interfaces required for connecting the individual embedded systems. This board also contains several interfaces including Wi-Fi, Bluetooth, cellular, satellite and microwave for being able to communicate local devices, long distance base stations and also remote monitoring and controlling systems.

The signal post system also provides for the interface required to get cognitive inputs from the cop about the traffic conditions prevailing at a time. The signal post control system should have built-in expert system for making dynamic decisions which are related to traffic monitoring and controlling. The system must also provide varied communication protocols so as to communicate with all peripherals using Wi-Fi, wired, cellular, microwave and satellite based communication.

Every subsystem is connected to signal post system, built around Raspberry Pi board containing multiple interfaces. The communication protocols used by different subsystems vary. Integration is made feasible by the usage of an RC board which establishes the connectivity with all the subsystems. This board is capable of taking in varying bandwidth inputs and output them individually as requested.

RC board inputs are connected with every interfacing of each subsystem which is essentially the input for cognitive system. The output of the RC board is connected to the cognitive Raspberry Pi board. RC board outputs distinct signals received from different subsystems to the different interfacings of the cognitive system. Thus, the ability to take varying inputs is made feasible with an RC board.

Most part of the system is automated there is a need of manual inputs the knowledge, perception, thinking and experience which are to be fed into the system. The cognition is established into the system through a cognitive radio which will communicate through cellular network.

The output of the cognitive system reaches visualisation, messaging and other systems either directly through an RC board or via base station. Parallelism of base-stations is established to avoid the loss of data when either of the lines is dead. These base-stations output the received data to the other systems. The outputs of the cognitive can take an alternative path via the nearest signal post to maintain reliability which will again pass through a base-station. All of these base-stations are connected to a central monitoring system which will issue control signals to monitor all the stations. The Raspberry Pi board is the main processing unit that caters for acquiring inputs from cross section of sub-systems which are interfaced with it using one of

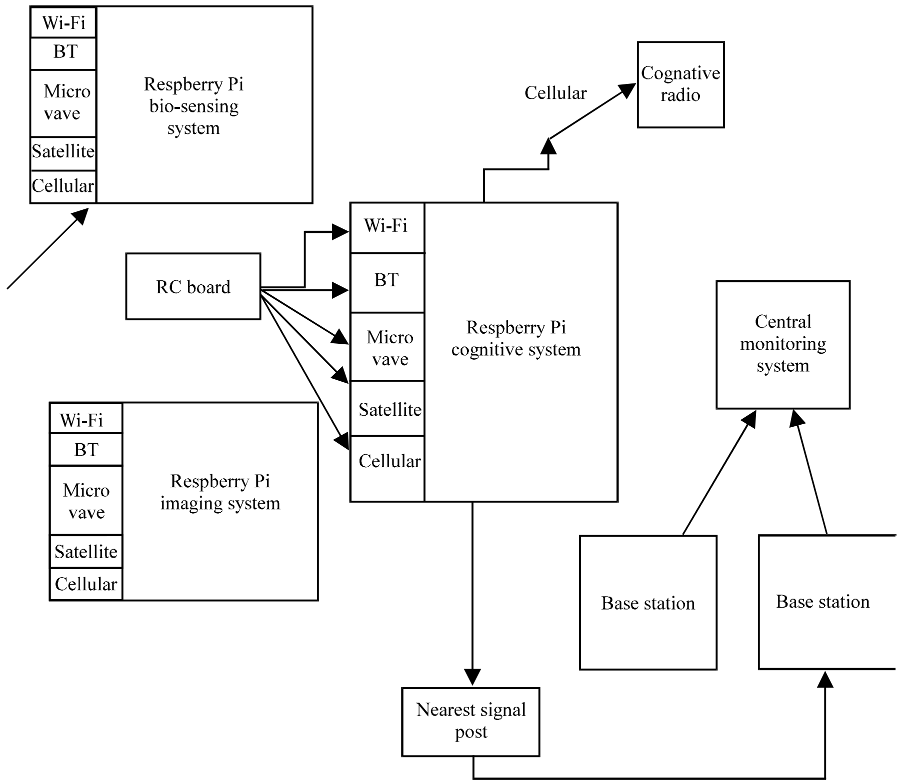

Fig. 5: Architectural modelling of signal-post systems

Fig. 6: Raspberry board typical architecture

the communication protocols. The board has the logic to monitor and control through external devices such as visualisation boards and variable signal signs. The schematic of raspberry board shown Fig. 6.

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do from browsing the internet and playing high-definition video to making spreadsheets, word-processing and playing games.

Table 1: Comparison of various technologies for automated control

Technology	AI for intelligent traffic management	CTMS based on IOT	Cognitive control based on fuzzy logic	Pre-emptive systems	Adaptive associative memory
Adaptability	Highly accurate	Highly adaptable	High	High	Low
Control on correct timings	Yes	Yes	Yes	Yes	Yes
Communication protocol for acquiring data	Radio signals	Ethernet	Electromagnetic is sensors which constitute Ad-hoc networks	Optical systems, GPS, Acoustic systems	Video cameras to extract images
Ability to control parameters based on climatic conditions	Yes	Yes	Yes	Poor	No
Control mechanism	Varying timing	Embedded into microcontroller flash ROM	SSADM (Structured Systems Analysis and Design Methodology)	Wireless communication to convey traffic situation	Three street cases using small associate memory

RESULTS AND DISCUSSION

Self-adaptability and configurability of cognitive systems through expert systems: The system is capable of adapting itself to varying inputs in real-time. The outputs generated by the system will suit to that point in time. The system has an ability to generate control outputs in real-time and also has in-built capability to modify the software while the system is up and running. In practical implementation, there is always a need to update the system based on varying parameters. In such times, the code can be dumped to the system from the station which gets automatically configurable. The adaptability makes the system highly reliable.

Cognition into the system is built by means of manual inputs fed to the automated system. Most of the system is automated; there is a need of manual inputs this knowledge, thinking, perception and experience of a human are to be fed into the system. The reason the cognitive systems can take real-time decisions after having processed multiple inputs is because of its intelligence, self-adaptable nature which makes it an expert system.

On finding a proper cognitive systems: Different types of cognitive systems projected in the literature have been surveyed and a comparison of the same has been done based on the technology used for finding the best one that can be used as a cognitive sub-system within the signal post system. The comparison is shown in Table 1.

Comparing various technologies for cognitive management of traffic no entity as such meets all the requirements. In such scenario, it is mandate to integrate two or three of the existing technologies in unison with the proposed system to implement an effective architecture for the automated traffic control. Here, we found that it is not optimal to use pre-emptive control for the emergency vehicle managements because of its high noise susceptibility and low-coverage range. Therefore, in times of this system failure we instead use an embedded remote control to take-in multiple inputs from a man-operator. These remote inputs are communicated to the central system using either the Wi-Fi or Bluetooth protocols through the raspberry board interface which will then process them. A typical interface diagram that interfaces a cop with signal post system is shown in Fig. 7.

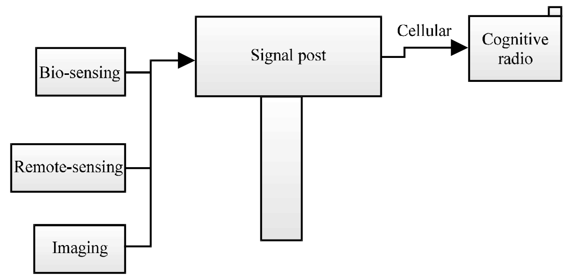

Fig. 7: Cognitive interface systems

CONCLUSION

Signal post system enables automation of the traffic light system. The system must receive inputs from various other subsystems like imaging, remote sensing, through various communication interfaces, protocols and methods. This study emphasised on all composite aspects of automated control the design and applicatio of the cognitive expert system in a simple yet efficient manner to suite the smart city environ.

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