The application of Digital Infrared Sheet of Light Beacons (DISLiB) developed for the localization of autonomous mobile robot vehicles can be extended to other diverse fields. The suitability of DISLiB system to applications where the localization and guidance are of great importance, like intelligent control of the public transportation system as well as guidance of differently-able personnel are envisaged. An adaptive traffic control system should ensure safe and smooth traffic flow and inform the drivers about the traffic status. Guidance and obstacle avoidance systems for visually impaired personnel should provide less body gear and adequate information about the environment.
6A Traffic and Transport Control

This section describes the design, characterization and implementation details of a encoded digital infrared sheet of light based beacon system for intelligent control of the public transportation system. The system consists of an encoded infrared sheet of light beacon, which can convey the current location and traffic information to the vehicles. The system is capable of receiving traffic status input through a GSM (Global System Mobile) modem. The vehicles have an infrared receiver and a processor capable of decoding the information, and generating the audio and video messages to the driver.

6A.1 Introduction

Congestion and delay on roadways continue to increase everywhere. As congestion increases, heavier traffic loads are placed on streets. New construction to satisfy this ever-growing demand is not only costly but also raises environmental, social, and political issues. “Building our way out of congestion” is no longer a feasible approach. As a result, a great deal of emphasis is being placed upon programs to manage traffic and efficient use of available roadway capacity. This has led to the development of various types of intelligent traffic management systems.

The modernization of public transportation system is of great importance, to increase the performance, which may result in fuel saving, reduction of time loss in traffic congestion and even to overcome the constraints on building new roads and transit systems. The increasing motorization demands better operation and control of road traffic. Increased traffic congestions faced by the drivers day-by-day, lead to reduced safety, increased energy consumption, environmental pollution and even missed traffic signs or important information.
The application of advanced technologies in electronics and communications to transportation systems results in the design of intelligent and friendly traffic management and control systems [127, 128, 129]. The various systems used in some developed countries include traffic flow maps, frequently updated websites, changeable message signs, advisory radio, electronic traveller information displays, etc. The use of an intelligent system for solving the traffic and transport problems improves the utilization of existing infrastructure, reduces demand for new roads, makes traffic better, saves cost significantly, increases safety, improves mobility and livability for the region.

People use traveller information to assess traffic congestion in their route, judge the effects of incidents on their trip, decide among alternate routes and estimate their trip time to reach the destination [135]. For providing this information the traffic management centers/systems collect and coordinate traffic flow data using various sensors and technologies. Real-time data coordination allows traffic flows to be adjusted in response to changing conditions. This results in safer and more efficient traffic flow. Information regarding the conditions of the road gives carriers the best routing options, which may reduce delay, making them reach destinations early. The use of electronic clearance systems at the inspection points of the border crossing reduces delays and truck stops.

The purpose of a traffic control system is to ensure safe and smooth traffic flow, and it has functions for controlling traffic signals by traffic data acquired by various sensors and informing the drivers about the traffic status [130]. Today, each and every country requires an upgradation of their traffic control system in order to solve traffic problems such as increased traffic accidents, aggravated traffic congestions etc. It involves heavy detectorization of the streets and highways.
where traffic data can be transmitted to the traffic control center [131, 132], and appropriate traffic management can be implemented.

The concept calls for monitoring traffic flow conditions on all roadways by the help of various detectors like camera and providing that information in a variety of ways to vehicles travelling within the city or streets. The motorists can then make timely decisions about the route he has to take, and a more balanced use of road facilities will result. A high degree of coordination is jurisdictional entities in the operation of traffic management and control system for roadways [133, 134].

This work proposes a simple, efficient and economic system to control the road traffic. The system consists of an encoded infrared sheet of light beacon, which can convey the current location and traffic information to the vehicles. The system is capable of receiving traffic status input through a GSM (Global System Mobile) modem from the traffic management center and traffic personnel, which eliminates the need for a dedicated channel and the associated instruments. The vehicles have an infrared receiver and a processor unit capable of decoding the information, and generating the audio and video messages to the driver. The receiver in the vehicle can refer to an inbuilt database and get the above information with negligible computational overhead. The vehicle unit can be manufactured based on the sophistication demanded by the user. The immediate alterations or changes required in traffic, perhaps due to an emergency or a VIP being on the road can be communicated instantly to the driver. Even activating speed limit to conventional vehicles and restricting to sidetracks can help the easy passage of ambulance and VIP vehicles.

6A.2 Outline of Traffic Control System

Beacon based traffic and transport control as well as driver safety support systems are used in some developed countries to improve their transportation
systems [136, 137]. Most of them use infrared, ultrasonic or radio frequency beacons for implementing the same. These have inherent emission characteristics that may affect the performance of the system. Most of the existing traffic control systems are complex, expensive and error prone. Hence it is essential to consider a robust, cost effective and easy to implement system for the assistance of the driver and improved quality of the existing traffic.

![Image of traffic signaling installation](image)

*Figure 6.1 A traffic signaling installation using an encoded infrared sheet of light beacon.*

This work describes a beacon assembly utilizing infrared LED source that confines the distribution of the light intensity to a sheet of light. A microcontroller derives the appropriate digitally encoded information and the infrared beacon transmits the same. The system is also capable of exchanging information through a GSM modem to the central or distributed traffic control stations. The traffic control center has a computer with GSM communication facility and is capable of receiving current traffic status through various means. The receiver at the vehicle
capable of decoding the signals displays the various traffic status and signs with audio indication.

The functional diagram of the system is shown in figure 6.1. An infrared light sheet assembly consisting of three infrared LEDs is mounted on an arm attached to the top of a mast as shown. The beacon controller is fixed to the bottom portion of the mast for convenient access. The power supply requirements can be met with the help of a solar panel or conventional electric supply. For tackling an emergency situation, portable units with the beacon assembly mounted on a stand in a side looking way can be used if needed.

6A.3 Infrared Sheet of Light Beacon

The DISLiB scheme similar to the one described in chapter 4 is considered here. A beacon transmitter assembly of different dimensions as shown in figure 6.2 has been developed. The infrared beam is guided through the space between two identical sand blasted parallel metal plates of dimensions 0.15m x 0.15m, kept 15 mm apart. These metal plates are acting as Lambertian scattering surfaces (diffuse reflectors) and their dimensions have effects on the sheet thickness as well as infrared light intensity. Three infrared LEDs are mounted on the housing, 0.05m apart as shown in figure 6.2. The variation of effective infrared light sheet thickness (ELST) against the mounting height of this assembly has been studied and the results are shown in figure 6.3. Above a height of three metres the light sheet thickness is seen to be around one metre and the beacon receiver can read the encoded data within this distance with vanishingly small errors.
The infrared LEDs of the beacon transmitter mounted on a structural assembly made up of sand blasted metal plates, which act as Lambertian scattering surfaces providing a sheet of light.

![Image](image_url)

**Figure 6.2** The infrared LEDs of the beacon transmitter mounted on a structural assembly made up of sand blasted metal plates, which act as Lambertian scattering surfaces providing a sheet of light.

The Digital Infrared Sheet of Light Beacons (DISLiB) constructed using the above assembly are location as well as traffic data encoded and are designed around a 18F452 PIC microcontroller. The functional block diagram is shown in figure 6.4. The same carrier frequency of 40kHz with the Sony Infrared Remote Control (SIRC) protocol is used to transmit the position and traffic information. Besides continuously transmitting the encoded position and traffic information, the microcontroller in the beacon transmitter drives the three infrared LEDs by switching a transistor in series with a current limiting resistor.
Figure 6.3 Variation of effective light sheet thickness against the mounting height of the beacon (h).

Figure 6.4 Functional block diagram of the beacon transmitter consisting of a microcontroller, which generates the encoded signal for driving the Infrared LEDs mounted inside the special assembly and a GSM Modem for establishing the communication with a traffic management center.

A beacon Identification Number (BIN) and the mobile number of the GSM service provider are assigned to every beacon transmitter for identifying the
location of installation and the establishing communication. The required traffic signaling information like speed limits, sharp turnings, warnings, etc. can be encoded and transmitted through the beacon. A traffic management center or a mobile traffic control unit can communicate through the GSM link incorporated in the system, so that the traffic signaling commands can be modified online, thereby updating the encoded information in the beacon. Even from the mobile phone of the traffic control personnel the beacons can be programmed for managing the traffic.

6A.4 The Beacon Receiver and Vehicle Unit

The functional block diagram of a beacon receiver used in vehicles is shown in figure 6.5. While crossing the sheet of light, the information gathered from the beacon by the infrared receiver module is processed by the microcontroller system on the vehicle that manages the traffic signal and guidance. With an effective light sheet thickness of around 1m (figure 6.3), there is no limit on the maximum speed of the vehicle because even at a speed of 200km/hr the receiver can take multiple readings.

![Block diagram of the vehicle unit consisting of the infrared receiver module, a microcontroller and its associated components.](image-url)
The graphics LCD panel interfaced to the microcontroller is capable of visualizing the traffic signs and location information and the audio system provides appropriate sound to attract the driver. An SD card interfaced [149] to the system stores the database for traffic signals and location. This SD card can be easily updated by means of a website or fuel filling stations or other public places where this can be made available to the users. Territory/state wise detailed database can be created and easily updated. During long journey the vehicles may pass through various territories, but replacing the appropriate SD card can solve the information update process. The on-chip SPI interface in the microcontroller is utilized for interconnecting the SD card module.

The traffic authorities can classify the vehicles under different categories and assign different privilege levels for smooth movement of ambulances and official vehicles. The system generates the traffic sign and warnings by considering its category as well as the privilege level assigned to the vehicles.

6A.5 Installation and Working

Most of the intelligent traffic and transport control systems require the installation of multiple beacons at known locations. By properly installing the Digital Infrared Sheet of Light Beacons (DISLIB) at known locations vertically above the road as shown in figure 6.1, the vehicle unit can receive the beacon while passing through the encoded infrared light sheet and identify the beacon (location) and receive the encoded traffic status and sign information. In a typical structure (figure 6.1), the beacons should be mounted at a height of about three metres for the ELST to cover the entire width of the road without any disturbance to the traffic flow. For greater road widths either more infrared LEDs or increased mounting heights within the reading threshold of the beacon is preferred. Even
multiple infrared assemblies with the same controller unit are recommended for wide highways.

The vehicle unit firmware and database play a very important role in guiding and supporting the driver by displaying the optimized and time dependant traffic signs and warnings. The database stores all the traffic sign, symbol data and location information corresponding to the beacons. The vehicle unit receives the encoded information for the traffic signs and locations, which may vary from time to time for smooth traffic flow. The system decodes the same and displays the graphical sign with audio message to support the driver. The various time dependant traffic signs are speed limit, one ways during peak time, no left/right turns, no entry for certain category of vehicles etc.

![IR Receiver Module](image)

Figure 6.6 Photograph of the prototype of the Vehicle Unit

The vehicle unit can display the location name and distances from various reference points (main cities/streets). The unit can even calibrate the odometer by passing through a number of beacons. A route map can be built for frequently used
destinations to assist the driver. The parking places and parking restrictions can also be communicated to vehicles a few metres ahead of those locations/area. The driver must feed direction information (bit) to the system for identifying up and down journeys for interpreting certain functions. A pre recorded voice chip can be activated upon receiving the beacon and appropriate voice messages can be played back in driver’s own language. The driver can enable or disable these features as required. The photograph of the prototype of the Vehicle Unit is shown in figure 6.6.

6B Differently-able Assistance

A guidance system for assisting the visually impaired in structured indoor and partially outdoor environments is described in this section. The system consists of a number of encoded infrared sheet of light beacons installed at appropriate locations and a small receiver module attached to the shoulder of the visually impaired person. The system is intended for use in indoor environments, such as home, office buildings, supermarkets and airports. The Digital Infrared Sheet of Light Beacons (DISLiB) transmit the encoded location information and an infrared receiver module decodes this data and the message is retrieved from the corresponding location in a voice recorder/playback chip. The orientation of the person can also be informed through the natural language.

6B.1 Introduction

Considerable effort has been made over the past few decades for developing navigation and guidance devices for the visually impaired. Electronic Cane using optical triangulation technique with laser diodes and Photo-detectors have been developed since 1973[138]. Thereafter various ultrasonic systems [139,140] have been reported for obstacle avoidance and navigation in different forms. Radio Frequency Identification (RFID) based canes and robot guides have been
developed for assisting the visually impaired in a structured environment [6, 141, 142]. The motorized wheelchair [150] equipped with modern sensors like vision system, sonars, differential GPS etc. [143] are very helpful in assisting the differently-able persons but the need for a powerful computational unit and reduced portability affects the use of these systems.

Accurate sensing of the position and attitude of visually impaired personnel is of great importance in designing navigation and guidance system for them. Most of the localization techniques used in mobile robots can be easily adopted for the use of visually impaired personnel, if the physical size and shape of the system is wearable. In order to navigate and guide to their destinations, the personnel must have some means of estimating his position and direction. A variety of technologies [144, 145, 146] have been developed and used successfully to provide position and attitude information. However, many of these existing systems have inherent limitations in practical environment such as large computational overhead and body gear, poor performance and reliability.

For the successful navigation and guidance of visually impaired persons, a well-defined and structured environment is required [147]. This can provide position and attitude information for reliable estimation of the position and navigational path [151]. For outdoor applications Differential Global Positioning System (DGPS) based localization techniques provide adequate resolution, whereas for indoor use, this resolution is insufficient and moreover the satellite signals may be obstructed, which further aggravate the situation. These localization systems, which utilize triangulation or trilateration techniques [28], have high uncertainty in position estimations and incur extra computational overheads as well as results in increased body gear.
The above examples brief the diverse ways of position estimation and support systems for differently-able people that are already in use. Their limitations open the scope for further research opportunities for improvement and innovations. The technique presented in this section is based on encoded infrared sheet of light beacons and receiver, which require only low power miniaturized hardware that reduces the body gear carried by the user. Therefore, the navigation and guidance of a visually impaired can be achieved with a reduced physical load, which verbally guides the personnel. The user can use this system in conjunction with the conventional navigation aids or a guide dog too.

6B.2 Localization of the Visually Impaired

DISLiB transmitter and its assembly developed for guiding the visually impaired personnel has the same characteristics, dimensions, encoding scheme and features has that of the one developed for localization of the mobile robot vehicle. Each beacon transmitter transmits the assigned BIN and the coded navigation information regarding the environment. So beacon to beacon there may be a change in the transmitting information. This change in information normally needs a change in the firmware of the beacon transmitter. A generalized firmware can be configured by the microcontroller by reading the changes in the status of the micro-switch inputs interconnected to it. By establishing an RS 485 network among the beacons and a host computer, the position information as well as other navigational commands can be modified online. The system can be made user friendly by incorporating an RS485 network with the host computer.

By properly installing the Digital Infrared Sheet of Light Beacons (DISLiB) at known locations vertically above the passage, an accurate and robust representation of the environment can be achieved for better assistance. The beacon distributions can be identified based on the structure of the environment.
6B.3 The Beacon Receiver

The functional block diagram of a typical beacon receiver (shoulder unit) is shown in figure 6.7. Two infrared receiver modules are employed in this design for estimating the position and orientation of the visually impaired personnel. A user interface for the control and configuration is inbuilt with the system. A ChipCorder (voice record and playback integrated circuit from Windbond Electronics Corporation, USA) [148] has been used to store the natural language commands and description of the environment. With the help of the microcontroller the appropriate voice message can be retrieved from the ChipCorder and the message is made available to the visually impaired personnel through an earphone. For the prototype design, ISD4004-08MP ChipCorder has been used. This ChipCorder provides high quality, fully integrated, single-chip Record/Playback solutions for eight minutes messaging applications that are ideal for use in navigation systems and other portable products. Various commands for address and control are accomplished through a Serial Peripheral Interface (SPI) port of the microcontroller. The chip is integrated with sampling clock, anti-aliasing and smoothing filters along with the nonvolatile multi-level voice storage array, providing zero-power message storage. The message and guidance information are stored directly into solid-state memory in their natural, uncompressed form, providing superior quality voice reproduction. The standby current for the device is less than 1μA, which is ideal for battery operation.
Figure 6.7 Block diagram of the beacon receiver consisting of PIC18F2550 microcontroller, which manages the audio record playback ChipCorder

During path execution, the position information gathered by the infrared receiver modules from the beacon is processed by the microcontroller system attached to the shoulder of the visually impaired personnel that supports the navigation and guidance. As the person crosses the infrared light sheet of thickness \( \text{ELST} (d) \), the microcontroller based support system directly captures the location encoded information (BIN) and updates the corresponding absolute position from the database. By specifying certain scaling factors and the encoded value, it is possible to reduce the memory requirements of the system. The receiver takes 6ms for position decoding and hence at least 12 ms is required for a guaranteed position update while crossing a DISLiB.

**6B.4 Position and Heading**

Two infrared sensor modules arranged inline are utilized to receive the beacon and these information playbacks the position and heading of the visually impaired personnel who is wearing the module on his shoulder. The sensor can read the beacon data, which corresponds to a particular position as well as other signalling information regarding the environment for the visually impaired personnel. The visually impaired personnel wear the shoulder unit in which two
identical sensors $S_1$ and $S_2$ are mounted at a distance of $2a$. If the axis of symmetry is normal to the sheet of light both the sensors receive the signal simultaneously and the personnel is assumed to be moving normal to the sheet of light. If the person crosses the beacon with a heading angle “$\alpha$” (not equal to zero) there will be a lag or lead between the received signals, which is a measure of the heading angle of the personnel. The signal waveforms derived from the start pulse is shown in Figure 6.8 (inside the circle), in which the time duration $t_b$ is the time required to cross the beacon and the lag or lead time $t_d$ is the time required to cover the distance “$c$” by the person. The lead or lag time $t_d$ is a measure of the orientation of the person wearing the shoulder unit.

For a person crossing the light sheet with a velocity $P_v$, the heading angle can be estimated as follows.

$$
\alpha = \tan^{-1} \left( \frac{c}{2a} \right) = \tan^{-1} \left( \frac{t_d P_v}{2a} \right) = \tan^{-1} \left( \frac{t_d d}{t_b 2a} \right)
$$

(6.1)

Figure 6.8 A typical posture of the shoulder unit and the footprint of the effective light sheet thickness (ELST) $d$. The heading angle $\alpha$ is the angle between the ELST and the axis joining the beacon sensors $S_1$ and $S_2$. The time delay $t_d$ between the encoded signals reaching the sensors is also shown.
A typical posture of the shoulder unit under the beacon transmitter is shown in figure 6.9. The velocity of the moving personnel $P_v$ has been estimated by the system in auto mode by measuring the beacon crossing time $t_b$ or the ELST value $d$ can be directly fed during initial configuration of the system. Microcontroller will compute the time $t_d$ from the sensor readings. In a practical environment the sensor readings may be affected with the posture errors as well as the angle of incidence of the beacon. The resolution of the system is adequate in guiding visually impaired personnel. The photograph of a typical shoulder unit shown in figure 6.10 includes an LCD for easy debugging at the development stage, which can be detached later.
6C. Summary

A techniques for reducing the traffic congestions and location identification are introduced in this chapter. The need for an intelligent traffic control for the modern public transportation system has been well illustrated. The realization details of a traffic and transport control system using the existing GSM network are discussed. A flexible and friendly vehicle unit design has also been proposed.

The DISLiB based visually impaired personnel support system described in this chapter is simple, cost effective and provides less body gear without much computational burden or significant processing. The diverse ways of position estimation and support systems for differently-able people that are already in use have also been briefed. The natural language assisting capability of the system by incorporating a ChipCorder has also been addressed.