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REVIEW PAPER

Sensors in Unmanned Robotic Vehicle

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ABSTRACT

Unmanned tracked vehicles are developed for deployment in dangerous zones that are not safe for human existence. These vehicles are to be fitted with various sensors for safe manoeuvre. Wide range of sensors for vehicle control, vision, and navigation are employed. The main purpose of the sensors is to infer the intended parameter precisely for further utilisation. Software is inseparable part of the sensors and plays major role in scaling, noise reduction, and fusion. Sensor fusion is normally adapted to enhance the decision-making. Vehicle location and orientation can be sensed through global positioning system, accelerometer, gyroscope, and compass. The unmanned vehicle can be navigated with the help of CCD camera, radar, lidar, ultrasonic sensor, piezoelectric sensor, microphone, etc. Proximity sensors like capacitive and RF proximity detectors can detect obstacles in close vicinity. This paper presents an overview of sensors normally deployed in unmanned tracked vehicles.

Keywords: Sensors, unmanned robotic vehicles, robots, actuating mechanisms, unmanned tracked vehicles

1. INTRODUCTION

Reconnaissance, mine clearance, nuclear fuel handling, insurgency operations often cause human casualty often. To minimise human casualty, programmed machines or robots replacing human operators are a good option when threat perception is known in advance.

A robot can be programmed to carry out certain predefined jobs in an orderly way repeatedly without fatigue. It cannot adapt to a new situation as a human operator who handles new situations with ease by applying rudimentary judgment. In warfront and insurgency, the ground veracity is very difficult to predict in advance. Therefore, a completely programmed machine/robot for such circumstances is difficult to realise. Deployment of robots in danger zones and human operators in safe zones is a good combination for keeping the casualty to the minimum.

Robots of such applications need to be transported to the scene of action and deployed for end objective only. Unmanned ground vehicles would be the best choice for deployment in a hazardous environment. Such robotic vehicles are constructed and integrated with sensors, actuating mechanisms, computers, and software. Sensors are the devices that allow gathering of information about certain physical parameters. These devices can be grouped into various categories in tune with the application and the purpose. Vehicle sensors, vision sensors, obstacle detectors, orientation sensors, and communication sensors are a few that are vital in unmanned ground vehicles. A brief description of the sensors and their roles in an unmanned ground vehicle are discussed.

To set motion of the vehicle without a driver, a number of sensors are to be strapped onboard.

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Each sensor would be intended exclusively for the discernment of various kind of senses namely vision, hearing, smell, contact and other relates senses useful for driving. Sensed signals work on structured algorithms on the computer, set the motion of the vehicle in accordance with the ground situation. Vehicle motion can be automated through electronic circuit along with appropriate sensors and control elements. Drive-by-wire technology is matured and achieves complete motion control through operations of switches and other accessories provided on the dashboard of the vehicle. Remote driving is realisable through onboard drive by wire and RF technology.

Navigation of the vehicle can be achieved through specific sensors namely GPS or DGPS that mark the geographical location. Digital cameras can be employed to have the vision information. Laser detection and ranging (Ladar) or light detection and ranging (Lidar) give the obstacle assessment (Fig. 1). Fusions of data obtained from various sensors culminate in safe passage of the vehicle on the ground.

2. SENSORS IN UNMANNED GROUND VEHICLES

2.1 Proprioceptive Sensors and Extroecptive Sensors

Unmanned ground vehicle sensors can be classified as proprioceptive and extroecptive. Proprioceptive sensors are the ones that measure the internal values such as the speed, heading, and battery voltage. Exeroceptive sensors gather information from the environment. Some example of these sensors are : obstacle sensors, geographical position, light intensity monitors, etc.

2.1.1 Proprioceptive Sensors

2.1.1.1 Heading Sensors

Heading sensors measure the data regarding directional information of the unmanned ground vehicle. They can be configured to give three-axes orientation as pitch, yaw, and roll.

Heading sensors, in their simplest configuration, are constructed with a gyroscope and an inclinometer. These are used for determining the orientation on ground planes.

These can also be constructed using magnetometer, inclinometer, and integral vibrating gyrosensor. The sensor detects terrestrial magnetism and produces compass data. Magnetic variation correction can be automatically made to get accurate heading data.

2.1.1.2 Compass

Compass is an important strapped-on sensor in unmanned ground vehicle for quantifying the current

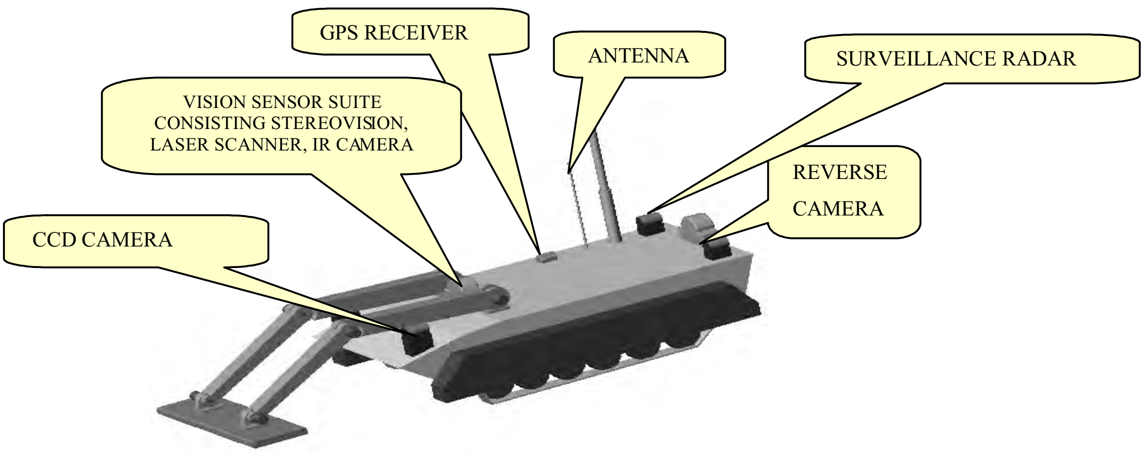

Figure 1. Vehicle with various sensors and other equipments.

directional information. Electromagnetic compass, Hall effect sensor, and flux gate compass are the commonly used compass in robotic applications.

Electromagnetic compass provides a highly accurate and stable readout of the heading with reference to the true north.

Hall effect is a measure of voltage drop across a semiconductor material when constant current is passed through the perpendicular sides. The voltage drop varies across the semiconductor as a consequence of rotation in magnetic field while the current is kept constant. Compass is constructed on the Hall effect principle and variable quantity voltage is calibrated to the orientation with respect to magnetic north.

Flux gate compass uses two coils wound on ferrite core and mounted in perpendicular axis. When both the coils are supplied with alternating current, magnetic field imposes phase shift in them differently due to the orthogonal orientation. Measurement of phase shift in the coils gives the measure of orientation.

2.1.1.3 Gyroscope

Gyroscope is a sensor to measure the rotational change of orientation about axis of the unmanned ground vehicle. The rate of change of angular position is detected and the data is applied for the vehicle control.

2.1.1.4 Accelerometer

Linear acceleration of unmanned ground vehicle in the forward direction is measured with the accelerometer. This measurement enables better motion control of the vehicle. Accelerometer works on the principles of the displacement of a known mass when subjected to acceleration against known stiffness of a spring. The displacement of the spring is the measure of the acceleration in that particular axis.

2.1.1.5 Speed Sensors

Speed sensors measure the relative motion between the unmanned ground vehicle and the environment. In mobile robots, Doppler-based motion detectors are generally used. Doppler sensors emit electromagnetic or sound waves with a predetermined frequency. The reflected wave frequency is a function of speed.

2.1.1.6 Brake Sensors

Hydraulic braking systems are normally used in vehicles. Sensing the oil pressure in the hydraulic circuit is the objective of brake sensor. A brake sensor prevents wheel lock-up during emergency stop. Also, it enables steering control and works to stop in the shortest possible distance under most conditions. The sensor monitors the hydraulic pressure in the brake drum. Associated electronic circuit makes it possible to have smooth braking during vehicle motion.

2.1.2 Extroecptive Sensors

2.1.2.1 Navigation Sensors-GPS/INS

Global positioning system (GPS) is a navigation sensor that provides range and range-rate measurements.The primary role of GPS is to provide highly accurate position and velocity worldwide, based on range and range-rate measurements. The acceleration vector is then determined from positions at different time epoch, by differentiation of these positions wrt time. Integration with one or more external systems capable of sensing forces, with an INS, enhances reliability in navigation, as the GPS signals may not be available at all times. In that sense, the basic idea behind the integration of GPS and INS is to estimate the inertial sensor errors online using GPS.

2.2 Passive and Active Sensors

Passive and active sensors are another classification made with reference to the sensing mechanism. Passive sensors measure a parameter through the energy absorbed by the sensor. For example, temperature probe, microphones, and CCD camera are passive sensors. Active sensors initiate the measurement by emitting energy into the environment and measuring the reaction to the emitted energy. Some of the active sensors are the ladar, ultrasonic sensors, MMW radar, etc.

2.2.1 Vision Sensors (Optical-Passive)

2.2.1.1 CCD Camera

A CCD camera transforms light (wavelength 400 nm to 1000 nm) into a charge, which during readout is transformed into voltage.The CCD cameras create high-quality, low-noise images and thus are the sensors in the high-end digital cameras. These cameras process an image in two stages–as image acquisition and video generation. The acquisition unit is based on a CCD chip, which consists of a 2-D matrix of light-sensitive elements, which change the incoming photons to electrons and thus accumulate charge. The exposure time is electronically controlled because it is critical parameter for image acquisition. After acquisition, the pixel charge is transferred to video generation with any one of the standards CCIR (Consultative Committee for International Radio) or EIA (Electronics Industries Alliance).

The CCD uses control circuits that consume lot of power, as much as 100 times more power than an equivalent CMOS sensor.

2.2.1.2 CMOS Sensors

The CMOS sensors are based on photosensitive diodes which are connected to resistors in series. As a result, the photo current is continuously converted in to an output voltage. Thus, no integration takes place and it works on simpler circuit. The relation between the output voltage and the light intensity is nonlinear.The CMOS sensors are more susceptible to noise. Low-end cameras use CMOS technology as these consume little power. The CMOS chips can be fabricated on just any standard silicon production line, so these tend to be extremely inexpensive compared to the CCD sensors.

2.2.1.3 IR Camera

Thermal energy is transmitted in the infrared wavelength (1 μ to 100 μ). Thermal energy applied to capture image in this wavelength is closely related to visible light. Thermal infrared imagers translate the energy transmitted in the infrared wavelength into data that can be processed into a visible light spectrum video display. Thermal infrared imaging can be performed in a wider range of environment including night vision.

2.2.1.4 RF Sensors

- *MMW Radar*

Millimeter wave (MMW) radar satisfies requirements of outdoor autonomous vehicle navigation. The short wavelength, compared to microwave units provides a high-resolution measurement and the radar gives improved performance in inclement weather compared to optical sensors such as lasers.

The MMW radars provide direct range and may also provide a Doppler velocity measurement, and are most likely be a standard sensor for automated vehicles.

2.2.2 Vision Sensors (Active Sensors)

2.2.2.1 LADAR (Laser Detection and Ranging)

The LADAR works on the same principles of radar, except the energy source, which is a laser, and there is a difference in the optical part of the electromagnetic spectrum. The sensor is employed to detect the distance of an object. The measurement starts on transmitting a laser beam towards an object and recording the time taken for detecting the return beam. The object distance is correlated to the time of travel and can give very precise data.

2.2.2.2 LIDAR (Light Detection and Ranging)

The LIDAR instrument transmits light, a narrow pulse or a beam of light, to a target. It can send up to 50,000 pulses per second. Some of this light on interaction with target gets changed. Some of the light is reflected/scattered back to the instrument where it is analysed. Receiver of the LIDAR measures time and shape of the returning light. The change in the properties of the reflected light can be correlated to some property of the target. The time for the light to travel out to the target and back to the LIDAR is used to determine the range to the target.

Using the speed of light, one can calculate how far a returning light photon has traveled to and from an object. It can be expressed as

$$\text{Distance} = \frac{\left(\text{Speed of light x Time of flight}\right)}{2}$$

There are three basic generic types of LIDARS namely laser range finder, differential absorption lidar (DIAL), and Doppler lidar.

- *Laser Range Finder*

Laser range finder (LRF) works on the principles of reflection of light from an obstruction and the time delay involved in it. A pulse is transmitted towards the hard object from the LRF. Reflected pulse takes time proportionate to the distance of travel. The time and distance can be calibrated and the calibration can be applied subsequently for measurement.

- *Ultrasonic Sensor*

SONAR works on transmitting a pulse of sound outside a range of human hearing. This pulse travels at a speed of sound in a cone shape. SONAR waits for the reflected sound signal in the form of echo. If echo is received, the distance of the object is computed based on the elapsed time.

3. CONCLUSIONS

Several sensors are used for teleoperated and autonomous ground vehicles. Integration of a number of sensors makes a synergistic intelligent system that works efficiently in various kinds of environment. Sensor fusion is the result of integration of data from different sensors for decision-making. It also enables interpretation and control of the vehicle in any dynamic situation. Proper selection of sensors for any application is very important and the paper gave an overview of sensors used in unmanned ground vehicles.

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