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Literature Survey on Autonomous Rover

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Abstract

In the present era of automation, the Autonomous Rovers have emerged as the prime technology for implementing security and surveillance system which handle human lives. Its potential of being navigated in the environment with no physical devices and human intervention has made it more eminent and efficacious. With the progressive technology, the provision of autonomous vehicles has enhanced their skill to assist and perform in exploration and rescue missions, etc. The survey determines the interpretation of various sensors, actuators and their assimilation for navigation and estimation of the autonomous rover.

Keywords — *Autonomous, Skid steering, Sensors, Lidar and Radio telemetry*

INTRODUCTION

Autonomous rover is a system that operates in an unpredicted and partially unknown environment. Self-operated vehicles have been grown drastically in various applications in recent times. The smart vehicles that are capable of functioning without human intervention are known as Autonomous Rovers. These automated vehicles are designed or developed for various indoor and outdoor application fields. Autonomous mobility for vehicles in an unstructured environment over long distances is still a daunting challenge in security and surveillance. There are many approaches to developing path planning and obstacle avoidance for rover movement.

The various parameters are observed by the sensors mounted on the vehicle and the necessary actions are implemented by the controller. The whole system function is generated with the coordination between the hardware and software arrangement. The approach of configuring the system formation with sensors and other components provides momentous interaction with in the rover. With the ability of the rover, it is categorised as:

1. Automatic: vehicle will be capable of operating itself in the instructed path and also deviates manual with operator control instructions
2. Automated: vehicle is limited with an ability to function in the instructed path using automatic functionality system.
3. Autonomous: self-governed vehicle that can be travelled without an operator with-in the specified path and guides the vehicle unassisted to navigate around fixed and mobile obstructions [1]

The paper deals with the various autonomy levels of the unmanned system with the different sections and design approaches.

DESIGN APPROACH OF AUTONOMOUS ROVER

In the design approach of the autonomous rover, the foremost task is design or development of the Vehicle body, then the selection of the hardware components, that fulfils the requirements of the vehicle in terms of sensing and movement in the environment.

Figure 1 describes the block diagram of the autonomous rover; the division of hardware and software section is shown.

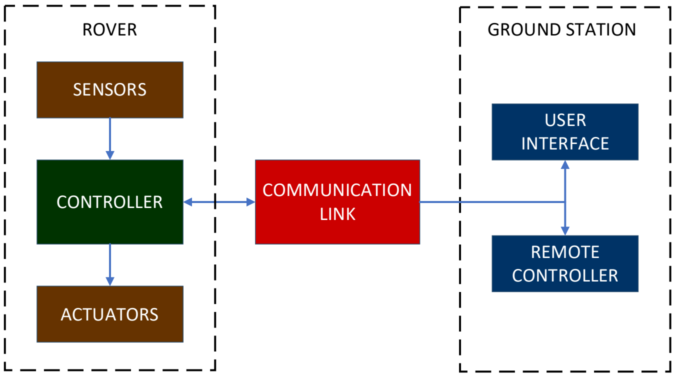

Figure 1 General functioning block diagram of the autonomous rover

A. Locomotion

The locomotion system is the most important feature in the mobility of the autonomous rover, here various factors that should be considered are **manoeuvrability, mechanical complexity, control complexity and power.** The hardware function mainly depends on the design of the vehicle body and its mechanism. For designing the vehicle effectively, the various approaches and methods are tabulated in table I, they are compared based on various criteria as manoeuvrability: mobility of vehicle, mechanical complexity: in designing, control complexity: in controlling the vehicle power: in terms of the vehicle movement with respect to the different steering modes of explicit, Ackerman, Skid and Axle articulated [2]

Table I COMPARISON OF DIFFERENT STEERING SYSTEMS

Type	**Explicit**	**Skid**	**Coordinated Ackerman**	**Axle Articulated**
Manoeuvrability	High/ Medium	High	Medium	Medium
Mechanical Complexity	Medium	Low	Medium/ High	Low
Control Complexity	Low	Low	Medium/ Low	Medium/ High
Power	Medium	High	Medium/ Low	Low

Figure 2 represents the compassion of different steering mechanism. The skid steering type mechanism is considered as the efficient mechanical function for vehicle movement [3]. The noteworthy difference between the explicit and skid steering is the carry of torque, in case of skid steering the motion is derived by applying different velocities to independent wheels, which limits rotation with in one axis. The concentrated drive can pass the torque instantaneously to each wheel. The major issue in the skid steering is the consumption of power, as all the driving wheels are coupled with separate motors independently so, the relevant power loss with dynamic friction is increased.

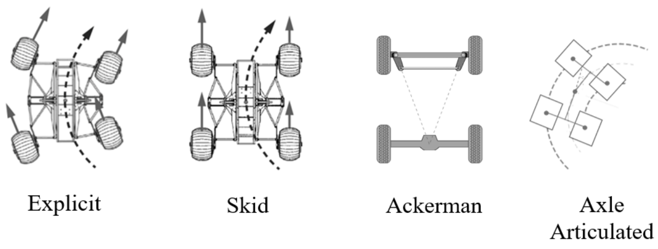

Figure 2 Different steering mechanism

B. Strategy

The plan of action in rover is achieved by the various methods of implementation like Image processing, GPS navigation, Simultaneous Localization and Mapping (SLAM) [4]-[7]. Each of these strategies are utilized according to the application required. In case of the outdoor rover the image processing may not be applicable for large area surveillance i.e., it is difficult procedure for rover movement and path planning. So, we use the GPS navigation for the vehicle movement. In case of indoor applications, the image processing can be used where the total room will be simulated in terms of map and movement is generated accordingly with the help of Robot Operating System (ROS). In Autonomous Rover we use the GPS navigation for path planning so that the vehicle moves in coordination with the GPS coordinates provided.

The navigation Strategy is majorly categorized into two ways as local and global navigation, they are categorized based on the distance and scale of the environment. For local navigation, grip of map is used to determine the navigation of the rover and for global navigation the coordinates connected with satellites are referred as position.

C. Sensors

The sensing function refers to the ability of the system to provide the position and reliable information regarding the vehicle surrounding. For coordinates, direction, orientation and speed we use global positioning system (GPS), magnetic compass, gyroscope and accelerometer are used respectively.

From table II required parameters and their corresponding sensors are tabulated. The exact location of the vehicle is crucial in autonomous rover. So, the GPS is used to locate the vehicle. The direction and orientation are calibrated using the magnetic compass and gyroscope.

TABLE II SENSOR'S REQUIREMENT

Sensor	**Parameter**
Accelerometer	Speed
Gyroscope	Orientation
Compass	Direction
GPS	Coordinates
Ultrasonic/ Range finder/ LiDAR	Distance measurement

D. Obstacle avoidance sensor

The significant feature that an autonomous rover should posses is sensing objects around itself from its environment. The distance measurement sensors are used for obstacle identification and avoidance, by getting the distance between the obstacle and the vehicle, avoidance can be obtained. There are numerous sensors in identifying the distance and they are tabulated in the table III [8]-[11]

TABLE III OBSTACLE AVOIDANCE SENSORS COMPARISON

Specifications	**Range finder**	**Ultra-Sonic Sensor**	**Lidar**
Range(m)	0.01-0.10	0.02-4.00	0.30-12

Minimum Field of View (deg)	25	15	2
Beam Pattern	Narrow (line)	Conical	Conical
Technology	VCSEL	Ultrasonic	LED

The efficient Lidar technology is used in detecting objects, with greater operating range of 0.3-12 meters and acceptable angle of 2.3 degrees. The working is shown in figure 3

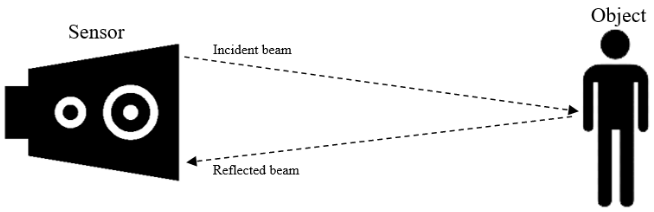

Figure 3 Working of Lidar

E. Communication link

With respect to figure 1 the link between the Rover and the ground station is achieved through the communication link. Communication is the essential part in remote operated vehicles and in time of manual operation, the human intervention is necessary during its operation. In the view of the application the range of the communication module is selected. Various communication modules are tabulated in the table IV [12]-[16]

TABLE IV COMPARISON OF THE COMMUNICATION MODULES

Specifications	Bluetooth	Wi-Fi	Radio
Range(m)	50	400	2500
Frequency	2.4Ghz	80Mhz	433Mhz
Module	HC-05	ESP8266	3DR

From table IV analysis the radio connection called as telemetry is used for communication between rover and the ground station. All the values from the sensor are seen in the ground station through these communication link, the parameters like acceleration, orientation, direction and position can be viewed in the user interface in ground station. The sonar contacts i.e., Lidar readings are also shown.

F. Controllers

The robustness of autonomous vehicle wholly depends on the controller. With the wide specifications of the controllers, diminishing the error and managing the vehicle in the correct position sets the vehicle self-reliant and adaptive. In this autonomous rover the sensors are crucial. In comparison of the table V, for each and every controller the corresponding sensors and their interfaces are tabulated, with the external mount sensors there might be slight lag or error present

TABLE V COMPARISON OF CONTROLLERS

Platform	**Processors**	**Sensor (On Board)**	**Interfaces**	**Software**	**Operating system**
Arduino Microcontroller	ATmega 328P Micro controller	Nil	Multiple low- and high-level sensors	Arduino IDE	Arduino CLI
Raspberry-pi	ARM1176JZF-S Processor	Nil	I2C, SPI, VNC	Linux, Raspberry pi OS	Raspbian
NI MyRIO	ARM Cortex A9	3 axis accelerometers	USB, 2 x16 Digital I/O port lines	LabView	Windows
Pixhawk	ARM Cortex M4	Gyroscope, accelerometer, Barometer, Magnetometer	PWM, PPM, ADC inputs, UART, CAN, SPI, I2C	Ardupilot, QGround station	Nuttx ROS
Nvidia Jetson nano	ARM® Cortex®-A57 MP Core processor	Nil	1x USB 2.0 Micro-B, 4x USB 3.0	JetPack SDK, DeepStream SDK	Linux

Likewise, in case of the on-board mounted sensors functions perfectly minimize the error. From the comparison table there are no on-board sensors mounted on the raspberry-pi, Arduino or any micro controller. In choosing these controllers for the autonomous rover creates a hardware complexity in integrating them all together. In another perspective all sensors are not compatible with all controllers, the transmission properties also matter. So here pixhawk autopilot controller works perfectly for our required specification. [17] – [20]

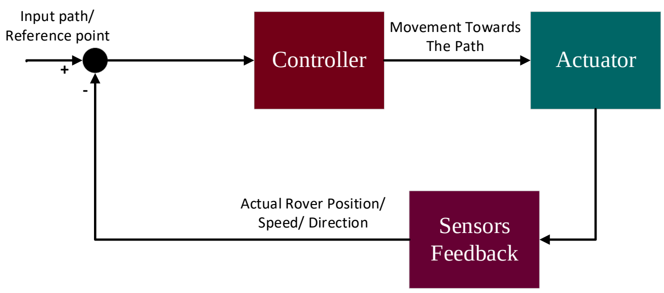

Figure 4 Block Diagram of Controller Working

Figure 4 represents the general functioning block diagram of a controller, with considered the reference point and matching it with the sensor's feedback keeps the rover more stable and accurate. From, table 2 all the sensors are required in positioning the rover accurately.

There are inertial based sensors mounted on the controller called as IMU (Inertial Measurement Unit). It is a combination of accelerometers, gyroscopes and magnetometers. These sensors are being mounted on the controllers where the system depends on them to serve applications. Calibrating these sensors based on the controller performance enhances the working of the autonomous rover. This sensor system is largely deployed in robotic and mobile navigation systems. Pixhawk is one of its kind for having IMU unit mounted.

SUMMARY OF VARIOUS APPROACHES

From specifying the block diagram of autonomous rover, the method of the locomotive system compared in table 1 draws the skid steering mechanism in bringing the more efficient power to the rover. The GPS navigation strategy considered for the outdoor movement of the rover on assimilation with the object detection parameter which strengthens the autonomous capability to the rover. From table 4, the stable communication setup with the radio frequency techniques enhances the long-range ability to the system with minimization of error and lag to the error in communication link. Table VI represents the overall comparison of various controllers integrated with different sensors. Skid Steering mechanism is efficient for the rover with the GPS navigation strategy, the movement of the rover will be in the specified path. The Lidar technology is more functional for the object detection with the transmission of light rays. All the sensors included in the controller i.e., IMU unit enhances the autonomous capabilities of the rover and establishment of the radio telemetry communication with long range provides the position and status of the rover.

CONCLUSION

The new technologies have enhanced and facilitate the way of life of human beings in which their exposure and environmental dangers and hazard have been cut down to the minimum. In this paper, we have been able to present a background and analyse the challenges of an autonomous rover. The objective of the autonomous operation in various location where human intervention is not feasible in all the situation, in that criteria self-diagnosis of faults and fault tolerance are the characteristics that an autonomous rover must possess. Utilizing a single sensor to detect the pose of an object may not be reliable and accurate thus, the use of multi-sensor is supported for effective performance. Finally, the paper emphasized some of the research areas that can be inspected for better work.

TABLE VI COMPARISON OF VARIOUS APPROACHES

S. N	Reference paper	Steering	Strategy	Sensors	Communication link	Controller	Software
1	J. Suthakorn, et al. [3]	Skid	Map generating and path planning	Compass, Acceleromete	camLAN	ARM 7	Windows form
2	Arif Ainur Rafiq, et al. [4]	Rocker Bogie	Image processing	Camera	Wireless Joystick PS2	NI MyRIO/ Arduino mega	IMAQ Vision/
3	M.Haritha, et al. [5]	Ackerman	GPS Navigation	GPS module, Ultra-sonic	Nil	Arduino mega 2560	Arduino IDE
4	Riccardo Giubilato, et al. [6]	Skid	Simultaneous localization and	Lidar	On board Communication	Nvidia Jetson TX2	JetPack SDK
5	İlker Ünal, et al. [7]	Ackerman	GPS Navigation	GPS module Ultrasonic	Microsoft SQL Server	Computer	Microsoft Visual
6	R.Vairavan, et al. [8]	Ackerma	Obstacle avoidance	Ultrasonic	Nil	Arduino uno	Arduino IDE
7	Sandeep Polina, et al. [9]	Ackerma	Line Following	IR	Nil	Arduino uno	Arduino IDE
8	Carlos Fernandez, et al. [12]	Ackerman	GPS Navigation	GPS module, Lidar	Mobile Telecommunication	Computer	Nil
9	Mohammed Z, et al. [13]	Skid	GPS Navigation	GPS module	Xbee	Arduino mega	Arduino IDE
10	Shridhar J A, et al. [14]	Nil	Machine Learning	Ultra-sonic, IR	RF Trans receiver	Arduino UNO	Arduino IDE
11	Yasir A, et al. [15]	Skid	Object detection	Camera,	Wi-Fi	Raspberry pi	Raspbian
12	Md. Razaul Haque Usmani, et al. [16]	Skid	Machine Learning	Camera	Wi-Fi	Raspberry pi, Arduino uno	Raspbian
13	Prof. Z.V. Thorat, et al. [17]	Ackerma	Machine Learning	Camera,	Wi-Fi	Raspberry pi	Raspbian
14	Raj Shirolkar, et al. [18]	Nil	Edge detection	Camera	Wi-Fi	Raspberry pi	Raspbian
15	N.Suganthi, et al. [19]	Nil	GPS Navigation	GPS module, Ultra-sonic	Wi-Fi	Raspberry pi, Arduino UNO	Raspbian, Arduino IDE

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