Surveillance Bots Research

1. A Smart Semi-Automated Multifarious Surveillance Bot for Outdoor Security Using Thermal Image Processing

Abstract - Unauthorized entry in restricted areas represents an obvious security issue. Therefore, strict monitoring is highly required in order to ensure security. This research presents a smart surveillance bot for highly restricted areas with (1) automatic surveillance of an area specified by the user and obstacle detection and avoidance using Ultrasonic Sensor (2) human detection using Infrared (IR) thermal camera and identification of friend or foe (IFF) using RFID tags (3) live video surveillance using camera and manual remote control mode. The bot has the ability to detect human presence in an area using thermal image processing. If the bot detects a human presence while operating in surveillance mode, it confirms whether the person is a friend or foe by reading RFID. If the bot identifies the person as foe, it automatically sends the user a notification of intrusion and turns on live video streaming. The user would be able to take total control of the bot remotely in order to verify and judge on the situation using live video streaming. It also exhibits warning message in its display and points a toy gun at the intruder. In real life cases, the toy gun can be replaced with actual ones. The user bears the authority to decide whether to shoot or not. Due to having tank rover chassis, the robot has the ability to maneuver in rough terrains which enhances its versatility and usability.

Functionalities -

- Automatic Surveillance and Object Detection (Automatically monitors restricted areas by dividing them into zones. The bot autonomously moves between these zones while avoiding obstacles)
- Human Detection (Detects human presence using thermal image processing, operational during both day and night)
- Human Identification (Distinguishes between "friend" and "foe" using RFID technology)
- Live Video Surveillance and Manual Control (Provides real-time video streaming and allows the user to take remote control of the bot)
- Rough Terrain Maneuverability (Enhances the bot's usability by enabling it to operate on uneven or challenging terrains)

How each is achieved -

1. **Automatic Surveillance and Object Detection -** Instead of using conventional infrared sensors, the bot makes use of a PixyCam, a camera with colour detecting capabilities, to

track predetermined routes for line following. Looks for obstructions in the way using ultrasonic sensors (HC-SR04). When the bot encounters an obstacle it halts and modifies its course. The user is notified to manually control the bot if it deviates from the assigned course, thus implementing a feedback mechanism.

2. **Human Detection -** For thermal Imaging, thermal pictures are captured using the Adafruit AMG8833 IR thermal camera. Image processing is done using pixel coding techniques to convert thermal pictures to greyscale. Uses background subtraction to separate extraneous background information from the foreground, or human presence. Makes use of high-boost filtering to improve human characteristics and eliminates noise for unambiguous identification. Entropy analysis and adaptive thresholding is done to identify human forms based on pixel intensity. This proves to be advantageous in low light and at night, when standard cameras might not be able to capture clear images.
3. **Human Identification -** RFID Reader (CF-MU801) identifies RFID tags within a 15-meter radius that are held by authorised persons. The bot looks for RFID tags after using thermal imaging to identify a human. It then recognises an RFID tag and marks the individual as a "friend." The bot flags the person as an intruder and sounds an alarm if no RFID tag is detected. Provides a live video streaming system for the user to evaluate the situation and a toy pistol pointed at intruders.
4. **Live Video Surveillance and Manual Control -** PixyCam may also be used to transmit live video. A local server network over Wi-Fi is established using the Blynk app for remote control. With a user ID and password, secure access is guaranteed. Allows the user to assume control of the bot during manual intervention or in difficult scenarios.
5. **Rough Terrain Maneuverability -** Uses a Rover Tank 5 chassis with high-torque motors for stability and navigation in rugged areas.

2. Effective Descriptors based Face Recognition Technique for Robotic Surveillance Systems

Abstract - The aim is to propose SPHORB Face Recognition technique for Robotic Surveillance systems. Surveillance bots with efficient face recognition system becomes even more powerful and adds to the applications of the bots. In this paper we compare the results of face recognition using SPHORB (a new fast and robust binary feature detector and descriptor for spherical panoramic image) [1] algorithm with ORB (Oriented Fast and Rotated Brief) [4] algorithm for classifying 2D and 3D images Database. In the first part 2D face images are randomly selected from LFW [32] with good sample of images across gender and ethnicity. The number of keypoints that were identified and number of matching keypoints between the 2D images using SPHORB and ORB were compared. From the results we determine that the SPHORB algorithm has identified more keypoints for the same 2D image than ORB, it has processed more images but ORB gives better accuracy than SPHORB for 2D images. In the next part we investigated the image matching between a front face 2D image with a 3D image. The front face image and 3D images are randomly selected from the ThatsMyFace.com [2] with good sample of images across genders, ethnicity and age. The front face image is compared with a randomly selected 3D image from the sample class set using SPHORB and ORB algorithms. The number of keypoints that were identified and number of matching keypoints between images using SPHORB and ORB were compared. From the results we determine that the SPHORB algorithm has identified more keypoints for the same image than ORB, it has processed more images and has accuracy comparable to the ORB algorithm.

Functionalities -

- Face Recognition (Recognizes and matches faces in real time, enabling the bot to identify individuals and control access)
- Handling 2D and 3D Facial Data (Matches 2D face images with their 3D counterparts for enhanced recognition accuracy)
- Algorithm Accuracy and Sensitivity (Ensures the surveillance bot can perform reliable face recognition even under challenging conditions)
- Image Keypoint Detection and Matching (Identifies unique points in images to ensure accurate recognition)

How each is achieved -

1. **Face Recognition -** The SPHORB (Spherical Orientated Fast and Rotated Brief) method, which is optimised for spherical panoramic pictures, is suggested in the study. This technique works well for real-time surveillance applications. As an alternative to 2D face recognition, ORB (Orientated FAST and Rotated BRIEF) is contrasted. For efficiency and accuracy, ORB uses rBRIEF descriptors in conjunction with FAST keypoint detection. A Brute Force Matcher with a distance threshold (such as 0.75), for example, is used to match. Images are

deemed to be valid matches if they have more than four matching keypoints. When it comes to 3D picture matching, SPHORB is especially resilient, managing issues like changing lighting, angles, and face expressions.

2. **Handling 2D and 3D Facial Data - U**tilizes the Labeled Faces in the Wild (LFW) database for 2D images and the ThatsMyFace database for 3D images. SPHORB was found to identify more keypoints than ORB when comparing 2D to 3D images, with 99.40% and 98.50% processing success rates for SPHORB in the respective datasets compared to ORB's 46.92% and 22.80%.
3. **Algorithm Accuracy and Sensitivity -** While SPHORB outperforms ORB in matching 3D images (87.58%), it performs worse on 2D datasets (53.85% vs. ORB's 72.22%). The robustness of SPHORB in identifying and matching keypoints is demonstrated by sensitivity and specificity measurements. Face alignment is one of the preprocessing processes in the process, which involves centring, rotating, and scaling faces to standard sizes prior to analysis.
4. **Image Keypoint Detection and Matching -** Spherical FAST (SFAST) is used by SPHORB for keypoint detection, which finds important points by taking into account the brightness of pixels and their neighbours. Spherical rBRIEF, a robust descriptor for geodesic grids, is used to build descriptors for these keypoints. Gaussian kernels are used to minimise noise and adaptive thresholding improves matching.

3. Autonomous Surveillance Robots : A Decision-Making Framework for Networked Multi Agent Systems

Functionalities -

- Real-Time Scene Analysis (Processes live video feeds to detect and interpret events such as intrusions or human activity)
- Event Driven Decision Making (Determines appropriate actions for robots in response to detected events)
- Autonomous Patrolling (Ensures coverage of all critical areas while balancing resource usage and task priority)
- Emergency Response (Detects emergencies like fires or unauthorized access and takes immediate action)

How each is achieved -

1. **Real-Time Scene Analysis -** Utilizes computer vision algorithms for tasks like human detection, activity recognition, and object tracking. Employs background subtraction and optical flow techniques to analyze motion and identify activities such as waving or trespassing. High-resolution cameras feed data to a centralized system, which processes images in real time.
2. **Event Driven Decision Making -** Uses Markov Decision Processes (MDPs) and Partially Observable MDPs (POMDPs) to make decisions under uncertainty. Robots prioritize tasks like patrolling, responding to trespassers, or assisting visitors based on urgency and available resources. Decisions are influenced by event type, location, and resource constraints, ensuring efficient allocation of robots.
3. **Autonomous Patrolling -** Robots are guided by topological maps, which divide the environment into discrete locations.Path-planning algorithms direct robots to visit areas systematically while responding to real-time events. Navigation relies on onboard sensors and ROS (Robot Operating System) tools for localization and obstacle avoidance.
4. **Emergency Response -** Robots use onboard sensors and cameras to verify alarms and assess the situation. Decision-making frameworks prioritize emergency tasks over routine patrolling. Robots can interact with the environment, such as issuing warnings to intruders or guiding people to safety.

4. Versatile Surveillance Bot: for Remote Monitoring in Hazardous Places

Abstract - Wireless sensor technology is the most important technology in the field of Electronics. This technology plays a supreme part in this surveillance act. In recent times, Surveillance plays a major role in privacy and security of each and every individual. A multi-purpose surveillance bot is proposed which can be used to live stream the video of an area under significance and it can be monitored by the user at the receiver end. The objective of this bot is to monitor the areas that are inaccessible by the human beings. Apart from the surveillance act, this bot is capable of detecting temperature and humidity of the atmosphere, the amount of toxic gases present in the environment, which allows to take necessary precautions before any disaster occurs. It is a highly effective and cost-efficient robot that reduces manpower in surveillance act, also it has the ability to avoid the obstacles which provides freedom to explore and rescue in all type of environment.

Functionalities -

- Real-Time Video Streaming (Provides live video feed for remote monitoring of hazardous environments)
- Obstacle Detection and Avoidance (Prevents collisions with obstacles during navigation)
- Environmental Hazard Detection (Monitors environmental conditions to detect hazards like toxic gases, high temperatures, or excessive humidity)
- Metal Detection (Identifies metallic objects in the bot's vicinity, useful in security and rescue missions)
- Long-Range Data Communication (Facilitates data transmission between the bot and the monitoring station)

How each is achieved -

1. **Real-Time Video Streaming -** The bot uses an IP camera (ESP32-CAM) for live streaming. The camera connects to a local Wi-Fi network and transmits video data to a PC at the monitoring station. The feed can be accessed via the camera's IP address and is crucial for visual inspection of inaccessible areas. This enhances situational awareness for users monitoring hazardous environments remotely.
2. **Obstacle Detection and Avoidance -** Utilizes an ultrasonic sensor mounted on a servo motor to detect obstacles. The sensor measures the distance to obstacles and triggers a buzzer if the distance is less than 30 cm. This information is processed by the microcontroller (Arduino Nano) to alter the bot's path dynamically, thus enabling autonomous navigation in cluttered environments, ensuring the bot's safety.
3. **Environmental Hazard Detection -** Gas Sensor (MQ-2) detects the presence of harmful gases like LPG, propane, hydrogen, and methane. Reacts to gas concentrations within the range of 400–850 ppm. Temperature and Humidity Sensor (DHT-11) measures atmospheric temperature and humidity. Outputs data in digital form for easy processing.

4. **Metal Detection -** Uses a metal detector module based on the Colpitts oscillator principle. The detector triggers an alert when metal is detected, aiding in applications like archaeological or security-related searches.
5. **Long-Range Data Communication -** Employs a LoRa (Long Range) communication module for wireless data transfer. LoRa enables secure and energy-efficient communication over long distances. The module supports multiple nodes for data collection, ensuring scalability in larger surveillance networks.

5. <u>Surveillance through Semi-Autonomous Bot</u>

Abstract - This paper consists of the design and implementation of the semi-autonomous surveillance bot. The idea presented in the paper is to monitor a surrounding or unknown area. This paper carries the different phases of realization such as the motion of the robot, obstacle avoidance, and video capturing and streaming. After the video has been captured the recorded clip is streamed to a remote server which assesses the surrounding. For the implementation of the idea, different tools were required for the execution of the precursor. For building the model, the hardware required was Raspberry Pi, infrared sensors, L293D motor driver. Raspberry Pi consisting of a Raspbian operating system running on python language for video capturing and obstacle sensing was used.

Functionalities -

- Real-Time Video Capture and Streaming (Captures and streams video of the bot's surroundings to a remote server for monitoring)
- Obstacle Detection (Identifies and avoids obstacles in the bot's path to ensure safe navigation)
- Semi-Autonomous Navigation (Combines user control and autonomous capabilities to navigate unknown environments)
- Environmental Inspection (Inspects inaccessible or hazardous areas such as tunnels, pipelines, or congested industrial sites)

How each is achieved -

1. **Real-Time Video Capture and Streaming -** A Pi camera is mounted on the bot to capture images and video. The captured video is streamed to a remote server using a Wi-Fi module and processed for real-time observation. Python scripts are used to control the camera and process the captured data.
2. **Obstacle Detection -** Infrared (IR) Sensors detect objects within a close range (1–20 cm) and send feedback to stop or redirect the bot. Ultrasonic Sensors measure the distance from obstacles (up to 100 cm) and control motor functions to avoid collisions. A motor driver (L293D) interfaces with the sensors and controls the movement of the wheels based on sensor inputs.
3. **Semi-Autonomous Navigation -** The bot is controlled through Wi-Fi using a Virtual Network Computing (VNC) viewer connected to the Raspberry Pi. When obstacles are detected, the sensors take over to pause or redirect the bot, combining manual and automated decision-making.
4. **Environmental Inspection -** The Pi camera records the surroundings and sends the footage to a remote location for analysis. Captured data can be stored for later use, allowing detailed analysis and documentation of the environment.

6. Overall

Paper/ Functionality	**Paper 1**	**Paper 2**	**Paper 3**	**Paper 4**	**Paper 5**
Object/Threat Detection and Avoidance	Colour Detection, Line following, Distance Measurement, Halts and Modifies course based on detection	-	Background subtraction, optical flow techniques to identify activities	Distance measurement (less than 30cm), modify path based on detection	Distance measurement for ranges of 1-20cm and up to 100cm
Long-Range Communication	-	-	-	Wireless data transfer over long range, multiple nodes for data collection for scalability	-
Real-Time Video Streaming	Live video transmitted over Wi-Fi, authorization done using Username Password	-	Computer Vision algorithms, background subtraction, optical flow techniques	Live video streaming over Wi-Fi to PC at monitoring station. Authorization done using IP address	Live video streamed to remote server through Wi-Fi
Metal Detection	-	-	-	Colpitts Oscillator Principle is used, alarm triggered upon detection	-
Environment Hazard Detection	-	-	-	Sensors used to detect gas and temperature	Sensors used to get data on surroundings
Face Recognition	-	SPHORB, ORB, SFAST	-	-	-
Human Detection/Identificati on	Image processing done using pixel coding techniques to convert thermal pictures to greyscale, background subtracti- on to separate extraen-	-	Computer Vision algorithms, background subtraction, optical flow techniques	-	-

	eous background information from foreground, high boost filtering to enhance human features and eliminate noise, entropy analysis and adaptive threshol- ding to identify human forms based on pixel intensity, RFID tags for security				
Event-Driven Decision Making	-	-	Markov Decision Process, Partially Observable MDP make decisions under uncertainty	-	-
Autonomous Patrolling	Colour detecting, line following	-	Path Planning Algorithms	-	-

7.