Transmission Line Unmanned Aerial Vehicle Obstacle Avoidance System Incorporating Multiple Sensing Technologies

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Abstract. UAVs have been used in a large number of applications in transmission line inspections and job monitoring. Infrared detection perception, ultrasonic radar, visual recognition and other perception technologies are integrated into the obstacle perception of UAVs, adding a variety of obstacle detection methods to the UAV, enabling inductive transmission line equipment without dead angles to be detected early. Line equipment and devices in front of man-machine, and can reasonably perform obstacle avoidance operations, effectively reduce the collision accident between UAVs and lines, and improve the safety and reliability of unmanned aerial vehicles on transmission line inspection work, and ensure transmission lines operational safety has a very important role.

1. Introduction
Currently UAVs have been in power the scene, line inspection, maintenance and other work applications, has played a significant role in greatly reducing the cost of transmission line inspection and shorten the inspection cycle. However, due to the complicated on-site environment of power, after the multi-rotor UAV takes off, obstacles can only be observed by the human eye, and the collision with towers and lines can easily occur due to poor prospects, causing transmission line accidents to occur. There are gaps in the application of multiple obstacle awareness technologies for UAVs in the power industry. Through the fusion of multiple obstacle perception detection technologies such as infrared detection, ultrasonic radar, and video image recognition, a UAV obstacle avoidance device and system with multiple obstacle perception methods are formed. The device is installed on a UAV, and the obstacles such as towers and cables are automatically detected in real-time during the take off inspection of the UAV. When a line obstacle is found, an obstacle alarm signal is sent to the UAV to make the UAV temporarily stop flying [1, 2]. The obstacle avoidance system sends the obstacle avoidance flight route and mode to the UAV. After the operator receives the information, it can control the operation. The UAV avoids obstacles and continues to fly or return to the air, avoiding collisions of UAVs and an unexpected accident caused by manual misoperation, and realizes the obstacle detection and obstacle avoidance in the course of inspections of transmission line UAVs [3].

2. UAVs Major Obstacle of Perception

2.1. Ultrasonic Perception
Most of the distance systems encountered in life are using ultrasonic technology. The directional ultrasonic transmitter and receiver are installed on the UAV, and then it is connected to the flight control system [4]. However, ultrasonic waves also have obvious interference problems in the application of obstacle avoidance systems for UAVs. Although the ultrasonic obstacle avoidance system will not be exposed to light, dust, and smoke, it will also be affected by sound waves in some
scenes. Second, if the ability of the surface to reflect ultrasonic waves is insufficient, the effective distance of the obstacle avoidance system will be reduced, and the safety risks will be significantly improved [5]. In general, the effective distance of an ultrasonic wave is 5 meters. The material of the corresponding reflective object is a concrete floor. If the material is not a flat, solid object, such as a carpet, the reflection and reception of ultrasonic waves will cause problems.

2.2. Tof Obstacle Avoidance System

TOF UAV obstacle avoidance system is using an optical phase detector. There are two types of detection methods: light time and light phase. But in general, the light is shot out, and then the reflected light is detected to determine whether there are obstacles around the UAV, distance geometry, and so on. As with ultrasound, light waves can also be disturbed. Light pollution between buildings in an urban environment currently poses a problem for the TOF obstacle avoidance system. The light emitted from the system must avoid the main energy band of sunlight to avoid sunlight. Direct, reflective, etc. interfere with the obstacle avoidance system. At present, the TOF can measure up to 10 meters in the room and 5 meters in the outdoor glare. In the hovering state, the TOF system keeps rotating fast and rotates 2-5 times per second. During the rotation process, the system can quickly scan the 360° range around the effective radius to find obstacles at a faster speed, and then issue an instruction to adjust the position of the flight control system so as to avoid causing any damage to the surrounding people or property. Injury; when in flight, the TOF system will stop spinning and only emit light in the forward direction. In the fixed direction, the effective distance in the outdoor can be increased to 8-10 meters. For a typical UAV the ideal flying distance is about 10 meters. After detecting the obstacle response time of 1 second, the UAV can use a large acceleration to stop the advance.

2.3. Binocular Vision System

The Realsense automatic obstacle avoidance module uses the "active stereo imaging principle", imitating the "parallax principle" of the human eye. By shooting a beam of infrared light, the left infrared sensor and the right infrared sensor track the position of this light, and then use the trigonometric positioning principle. Calculate "depth" information in 3D images. With a depth sensor and a full 1080p color lens, gestures, facial features, foreground, and background can be accurately recognized, allowing the device to understand human movements and emotions. Realsense's effective range of up to 10 meters, can identify the nearest 0.7 meters, up to 15 meters of obstacles; horizontal viewing angle of 60 degrees, vertical viewing angle of 30 degrees. The advantage of binocular vision is that, at long distances, binocular vision can guarantee three-dimensional accurate information. For example, two mountains in the distance can see one near one far. But the small goal in the distance is not possible.

3. UAV Obstacle Induction Analysis

3.1. Ultrasound

The basic principle is to measure the time of flight of an ultrasonic wave and measure the distance by the formula \( d = \frac{1}{2} vt \), where \( d \) is the speed and \( t \) is the flight time. Specifically, a wave packet consisting of ultrasonic pulses with a frequency of several tens of kHz is generated by a piezoelectric or electrostatic transducer. The system detects a reversed sound wave that is higher than a certain threshold, and uses the measured time of flight to calculate the distance after detection. Ultrasonic sensors generally have a short range of action. Common effective detection distances are within a few meters. If you use frontal vision to avoid obstacles, the UAV may not have enough time to brake, so it is generally used to sense the distance from the ground. The advantages are that the technology is mature, the cost is low, and the debugging is simple; the disadvantage is that it is vulnerable to other sound waves and the distance is short. The ultrasonic sensing system structure is shown in Figure 1.
3.2. **Infrared**
Infrared sensors have infrared emitters and CCD detectors. The general infrared sensing principle is based on triangulation. The infrared emitter emits an infrared beam at a certain angle. After encountering the object, the light will reflect back. After the CCD detects the reflected light, the distance of the object can be calculated through the geometric triangular relationship on the structure. Common infrared sensors measure distances that are relatively close, while long-distance measurements also have a minimum distance limit. In addition, the infrared sensor's requirement for obstacles is the exact opposite of ultrasonic. It requires a diffuse reflection surface. For transparent or near-black objects, the infrared sensor cannot detect the distance. The advantage is that the technology is mature and the cost is low; the disadvantage is that the ability to combat ambient light interference is poor, and diffuse reflection objects are required to detect it, and the distance is short.

3.3. **Laser**
The principle of common distance perception of laser sensors is based on the time of flight, that is, TOF obstacle avoidance. The laser sensor includes a transmitter and a receiver, the transmitter irradiates the obstacle with a laser, and the receiver receives a light wave that returns in reverse. There are two methods of laser ranging, one is the time difference of the detection light, and the other is the difference of the phase shift of the detection light. The detection time difference is similar to the aforementioned ultrasonic ranging formula. However, the phase shift of the detection light is relatively simple. The sensor emits a certain amount of modulated light at a known frequency and measures the phase shift between the transmitted and inverted signals. The wavelength of the modulated signal is $\lambda = \nu / f$, where $\nu$ the speed of light is, and $f$ is the modulation frequency. After measuring the difference in $\theta$ between the transmitted and reflected beams, the distance can be calculated from $\lambda \theta / 4\pi$. Due to the high cost of laser ranging, a low-cost triangulation scheme is commonly used for ranging, but the range is limited, typically within a few meters, and the accuracy is relatively low. The advantages are long distance and high precision; the disadvantages are high cost, need diffuse reflection objects to detect, and cannot be in the main energy band of sunlight.

3.4. **Binocular Vision**
Binocular vision ranging is essentially a triangulation method. Since the positions of the two cameras are different, like the two eyes of our person, the objects seen are different. The same point seen by the two cameras will have different pixel positions when imaging. At this time, the distance of this point can be measured by the triangulation.

The binocular stereo vision algorithm consists of a large number of algebraic equations. The amount of data processed is huge, and it requires a powerful processing capacity for collaborative calculation. Of course, due to camera principle problems, binocular vision has no way to sense the environment under low light conditions. The advantages are excellent distance, high precision, and low cost. The disadvantage is that the calculation is complex and requires a well-lit environment.
4. Power UAV Obstacle Establishment Methods

Through the common obstacle avoidance technology and environmental perception principle analysis of UAVs, it can be seen that infrared, laser, and vision sensors all adopt the triangulation method and the cost varies. Each manufacturer will choose different sensors according to its own product positioning. Deal with various practical scenarios. This shows that using a variety of sensor combinations for environmental awareness and obstacle avoidance is an effective method. Transmission site environment is relatively complex, in order to ensure the accurate perception of obstacles, a variety of perception methods complement each other, with remote sensing, high sensitivity characteristics, using a visual identification, ultrasound and infrared sensors combined UAV obstacle avoidance system. The combination of multiple sensors can create a more complete autonomous obstacle avoidance system, thus making it more intelligent and safe in autonomous flight, and at the same time reducing the threshold of UAV operation technology.

4.1. Features of UAV Avoidance Applications

4.1.1 Fusion application of multiple obstacle perception technologies. In the patrol inspection work of transmission line UAVs, it is possible to sense ahead of time the obstacles such as towers and cables in front of the flight lines, which is the key to the research of obstacle avoidance systems for UAVs. Because in order to ensure the perception accuracy of the obstacle avoidance system of UAV and avoid the occurrence of missed reports and false alarms, infrared sensing, ultrasonic radar and visual recognition are integrated into the obstacle avoidance system to form a suitable for the transmission line UAV obstacle avoidance technology. A variety of obstacle perception technologies, including infrared sensing, ultrasonic radar, and visual recognition, must have independent perception detection capabilities. Through their perceptions, the awareness early warning signals are converged into the obstacle avoidance system and complement each other and do not interfere with each other.

4.1.2 The avoidance system engaged with UAV system. The obstacle avoidance system needs to be seamlessly connected with the UAV system so that an obstacle warning signal can be sent to the UAV in real time so that the UAV can perform obstacle avoidance operations. The obstacle avoidance system has the functions of obstacle perception receiving and judging, and the obstacle avoidance system can calculate the accuracy of the obstacle sensing through the logic algorithm calculation based on the infrared sensing, ultrasonic radar, and the sensing signal sent by the visual recognition. After the obstacle avoidance system of the UAV determines that the obstacle in front is sensed, it transmits an early warning signal to the UAV system, and a UAV flight avoidance route and operation method.

4.2. Integration of a Variety of Perception UAV Obstacle Avoidance

Based on the operation and maintenance of transmission lines, based on the structure and system of multi-rotor UAVs, the UAV obstacle avoidance system is designed, combined with a combination of visual identification, ultrasonic, and infrared sensor sensors, all-round, multi-angle perception of obstacles, meet the transmission line in a variety of environments, weather, and light use requirements. The system is equipped with obstacle awareness and early warning functions. The system is connected to the UAV system. When the system senses an obstacle, it sends a warning signal to remind the UAV operator that there is an obstacle in front of the UAV. At the same time, the UAV suspends the flight. After the barrier system calculates the obstacle avoidance flight route and operation method, it sends it to the UAV system, and the operator controls the UAV to change the route to avoid the obstacle flight or return the original route.

An integrated device with a variety of obstacle perception functions, integrating infrared obstacle detection, ultrasonic radar, and various obstacle perception technologies for capturing and recognizing video images, integrates an infrared obstacle detection module, an ultrasonic radar module, an image acquisition module, and an electromagnetic field sensing module into one body Inside the device.
There are four antennas and cameras on the outside of the device. The divisions are in the upper, lower, left, and right areas of the device. The device includes: ARM processor, infrared detection module, ultrasonic transmitter, infrared signal cable, electromagnetic coil, signal output module, video cable, and power supply module. The integrated sensing device is mounted on an AUV, powered by an AUV, and connected to the AUV via a data cable. When the AUV is in flight, the integrated device automatically detects obstacles such as the front line towers and wires, and sends an obstacle perception signal.

UAV obstacle avoidance system for transmission lines adopts infrared laser technology, image recognition technology, ultrasonic radar technology, embedded technology, system operation obstacle sensing integrated device, and controls the emission of infrared laser and ultrasonic signals to automatically monitor the transmission distance when the transmission distance is less than the set safety distance; the obstacle avoidance system obtains the obstacle signal. The four cameras of the device cover the UAV's field of view 360 degrees, collect panoramic images in real time, automatically identify abnormal objects in the image, and get obstacle signals from the obstacle avoidance system. After the obstacle avoidance system obtains the obstacle signal, it uses a multi-sensor pre-judgment mechanism to feedback from infrared, ultrasonic, and visual recognition signals to determine whether it is a real obstacle. After determining the perceptual obstacle, it sends an obstacle warning signal to the AUV.

The application of the obstacle avoidance system in UAV operation is to connect the obstacle avoidance system of the transmission line UAV obstacles to the UAV system, and complete the obstacle warning information transmission and obstacle avoidance guidelines. The obstacle avoidance system automatically calculates the flight path and operation method for avoiding obstacles, and sends it to the UAV system to perform obstacle avoidance flight to complete the obstacle avoidance during transmission line inspection. Obstacle-sensing integrated device is installed on the AUV and applied on the site of the transmission line to test the sensing sensitivity of the line device and cable, adjust the sensing range of the system and device, and realize the advance of obstacles in the transmission line UAV flight. Perceive and promptly warn the UAV to stop the advance flight, and follow the obstacle avoidance route instructions to avoid obstacles and continue to fly.

5. Conclusion
Infrared detection, ultrasonic radar, and video image recognition multiple obstacle perception detection technologies are combined to form an unmanned aircraft obstacle sensing device and system, and the device is installed on a UAV. During the unmanned aerial vehicle take-off inspection process, infrared detection is performed. Ultrasonic radar, video image recognition, real-time automatic detection of obstacles around the transmission line, when the line obstacles found, the system sends an alarm signal to the UAV, the UAV stops the flight, or keep the stop state, while calculating the obstacle avoidance route and The method of operation sends an obstacle avoidance line to the UAV system. After the UAV receives the signal, the operator controls the UAV to avoid the flight or descends to complete the avoidance of obstacles during the inspection of the transmission line. Avoid accidents caused by manual operations, improve the driving safety of unmanned aerial vehicles on site, and avoid collision accidents. Improve the safety and reliability of the patrol work of the UAV transmission line and ensure the stability of the transmission line operation.

6. References
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