

Research on Cockpit Sensors for Pilot Behavior Recognition

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Abstract: Pilot behavior plays a critical role in ensuring flight safety. To provide a solid theoretical basis and technical support for improving flight safety, this paper focuses on the research of cockpit sensor technology for pilot behavior recognition and deeply analyzes various sensor technologies and their specific applications in pilot behavior monitoring. This paper compares in detail the principles, characteristics, advantages and limitations of various sensors, and analyzes their importance in enhancing flight safety through specific case studies. This paper aims to systematically collect, recognize and analyze pilot behavior through the study of cockpit sensors and data processing technology. The impact of sensors on pilot behavior is deeply explored, and the behavior characteristics of pilots and their collection standards are studied in detail. This paper also combs through the key steps of data collection, processing and analysis of sensors in the process of behavior recognition, and further studies the specific impact of sensors on pilot operations in combination with the two research dimensions mentioned above, in order to provide theoretical basis and practical guidance for further improving flight safety and operational efficiency. Findings suggest that multi-sensor data fusion technology can effectively improve the accuracy and reliability of pilot behavior recognition, and points the direction for the design and optimization of future cockpit sensor systems.

Keywords: Pilot behavior recognition, Cockpit sensors, Impact of sensors on pilots, Sensor wearing methods.

1. Introduction

Pilot behavior is crucial to flight safety. Pilots are directly responsible for flight safety. Fatigued driving is one of the main causes of flight accidents. According to ICAO data, nearly 20% of flight accidents are related to pilot fatigue, and human factors, such as judgment errors or improper operations, can also pose a threat to flight safety [1]. This paper investigates cockpit sensor technologies with a focus on pilot behavior recognition, and the research is structured around several key areas: First, a systematic study is conducted on the classification, layout, and data processing of sensors in the cockpit. Second, research is carried out on data collection, analysis, and processing of sensors in pilot behavior recognition. Third, the impact of sensors on pilot operations is explored, and the key behaviors of pilots and their collection standards are introduced in detail. In addition, the data collection and processing process of sensors in behavior recognition is sorted out. Finally, the impact of sensors on pilot behavior recognition is summarized. The main research method of this paper is through literature analysis and comparative analysis, taking specific experimental cases in the literature as objects for citation as data references, proposing personal research ideas, comparing with

the methods in the references, and proposing improvements and optimizations. Conducting research on cockpit sensors for pilot behavior recognition can achieve real-time and accurate monitoring and analysis of various pilot behaviors during the flight process. This not only helps to detect potential safety hazards in time and provide strong support for flight safety but also provides a scientific basis for pilot training and assessment, optimizes training programs, improves pilots' professional quality and emergency handling ability, and thus comprehensively improves the safety and reliability of aviation operations.

2. Research and development status of sensors

In the 1960s, research on pilot behavior began to develop, mainly focusing on the detection of abnormal behavior of pilots in the cockpit and its triggering mechanism. In the field of abnormal behavior recognition and detection, a method using depth maps to recognize the limb movements and behavior states of pilots in the cockpit was developed to detect pilot behavior. An intelligent visual Internet of Things detection system architecture was established, which can meet the requirements of signal data collection, transmission, processing, and feedback. A video semantic analysis model was proposed to conduct a collaborative analysis of human behavior recognition and facial recognition, achieving the monitoring and analysis of personnel behavior. For the recognition and detection of abnormal human behavior in videos, a summary of methods for extracting behavior features was provided, along with common abnormal behavior detection datasets and related algorithm performance. A system was developed to automatically detect abnormal limb behavior and states in operational tasks through surveillance videos. A twin network model capable of simultaneously capturing appearance and motion information was designed, which can make better use of appearance and motion information in video abnormal behavior detection. A flight simulation experiment under wind shear conditions was established, creating a dynamic flight simulation model affected by turbulence. For microburst wind shear, the flight operations for longitudinal and lateral recovery were analyzed. Using a deep convolutional network, abnormal behavior was detected and analyzed in standard RGB images during the flight process. Some pilot behaviors during the flight process, such as smoking and using mobile phones, were classified as abnormal behaviors. In the literature by Chen Nongtian et al., an improved YOLOv3 (You Only Look Once) algorithm for pilot driving abnormal behavior monitoring and recognition was proposed. This algorithm uses a deep learning-based abnormal behavior target detection algorithm, with an improved Intersection Over Union (IOU) for localization, and finally, features are extracted using a convolutional neural network for pilot abnormal behavior monitoring and recognition [2].

3. Pilot behavior recognition by sensors

3.1. Classification and definition of pilot behavior

Pilot risk behavior mainly refers to improper behavior caused by individual factors of pilots during the flight process.

Individual factors of pilots include psychological, physiological, technical, and management aspects. Specifically:

- a) Psychological factors: The psychological quality, emotional stability, and stress coping ability of pilots.
- b) Physiological factors: The physiological state, fatigue level, and health level of pilots.
- c) Technical factors: The flight skills, knowledge level, and operational proficiency of pilots.
- d) Management factors: The management mechanism, training system, and reward and punishment system of the airline.

Depending on the context and cause of the risk occurrence, it can be classified into psychological risk, physiological risk, emotional risk, and operational risk categories. During the execution of flight tasks, pilot behavior risks can lead to flight accidents, errors, or violations, which may have a serious impact on aviation safety, and even cause casualties and property losses.[3]

3.2. Pilot behavior collection

According to Figure 1, it mainly consists of four modules: abnormal behavior recognition, abnormal behavior detection, abnormal behavior warning, and abnormal behavior storage. The abnormal behavior recognition mainly involves recognizing, capturing, and collecting all behaviors of pilots in the cockpit during the flight process. After collecting all the behaviors of the pilots, they are uploaded to the abnormal behavior detection module, and the images of the behaviors exhibited by the pilots are stored in the database. These images are then compared with the images of abnormal behaviors in the database. If the matching degree of the collected behavior with the abnormal behavior image in the database reaches more than 85%, the abnormal behavior warning module will be triggered. The warning is issued through audible buzzers and visual light signals. The abnormal behavior storage module will store the warning information in the local memory card and upload the relevant data to the cloud, enabling real-time transmission of abnormal behavior data and traceability [2].

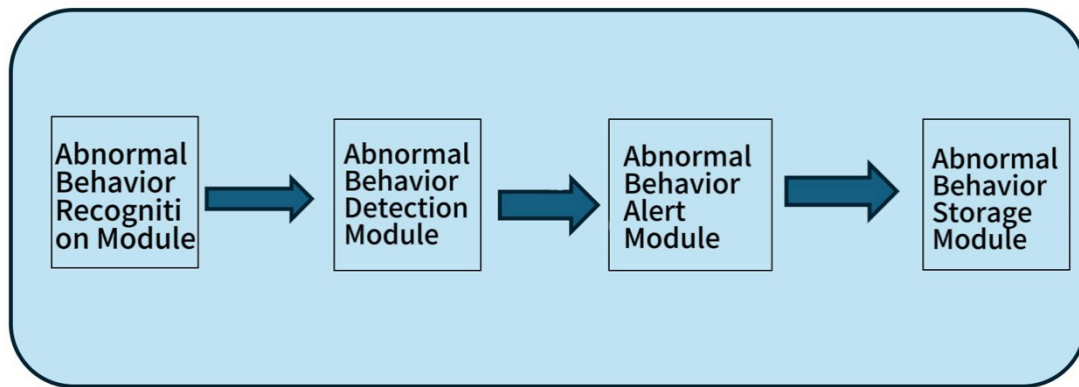


Figure 1: Composition of abnormal behavior collection module

3.3. Pilot behavior data processing

As mentioned in 3.2, the detection of pilot behavior consists of four different modules. In the abnormal behavior recognition module, cameras capture all the actions and behaviors of pilots in the cockpit during the flight. The collected data samples are then processed using an improved YOLOv3 algorithm based on skeleton recognition to determine the actions and postures of pilots in the cockpit. The captured abnormal behaviors are uploaded to the abnormal behavior detection module. In the abnormal behavior detection module, the suspected abnormal behavior images that have been preliminarily screened and uploaded from the abnormal behavior recognition are compared with the abnormal behavior images in the database using the YOLOv3 deep learning detection algorithm. If the similarity reaches 85% or more, it is determined to be an abnormal behavior. At the same time, the detection information is uploaded to the abnormal behavior warning module, which then issues a warning command. When the abnormal behavior warning module receives the information from the abnormal behavior detection module, it automatically turns on the buzzer and emits a preset warning sound, while the multi-color LED light begins to flash. Two types of alarms are triggered simultaneously to prompt the pilot in the cockpit to correct their behavior in a timely manner. During the pilot's correction process, the abnormal behavior recognition and detection modules perform recognition and detection again. If the result is normal, the abnormal behavior detection module sends

a termination command to the abnormal behavior warning module. When the warning, buzzer, and LED light are turned on or off, the warning module uploads the warning information and abnormal behavior images to the cloud and labels the time. Finally, the abnormal behavior storage module saves the video material recorded by the camera to the local storage for 24 hours. The next 24-hour video information will automatically overwrite it, while all recorded content is uploaded to the cloud for storage. Ground supervision staff can log in to the cloud to observe and analyze the abnormal behavior of pilots in the cockpit during the flight.

The YOLOv3 detection model mainly uses the Darknet-53 backbone network for feature extraction, which consists of one DBL module and five residual bodies. Darknet-53 has 53 convolutional layers, with the first 52 layers being the core network. Using this network model in YOLOv3, an increase in the number of convolutional layers in the neural network may induce "degradation" [2].

4. Impact of sensors on pilot operations

4.1. Comfort assessment of pilots

As a complex human-machine environment system, the cockpit is the area where pilots perform operations and control. Pilots will control the aircraft by using throttle levers, control levers, pedals, etc. Therefore, operational comfort is very important for pilots. It is also an important link in the efficiency of human-machine work and affects pilots. Workload, health, fatigue and safe flight are important factors. Comfort includes the subjective evaluation generated by the combination of psychological and physiological, but subjective psychological feelings can also be evaluated through physiological objective measurement results. Currently, cockpit comfort is evaluated using both subjective and objective methods. Among them, the subjective evaluation operation procedure is simple and the experimental cost is low, but the evaluation results completely depend on the subjective judgment of the operator, and the individual differences and randomness are large. In contrast, objective evaluations—such as those utilizing three-dimensional motion capture systems or physiological indicators—can be conducted under simulated conditions or using prototypes, offering more consistent and quantifiable results. These objective approaches require fewer participants, involve shorter testing durations, and can be integrated early into the cockpit design process to improve ergonomics and human-machine interaction [4].

4.2. Sensor wearing method

The main purpose of wearing the sensor is to detect whether the pilot's behavior and state during the flight meet the standards, so as to prevent dangerous situations and ensure the safety and stability of the flight. The goal of the sensor identification problem is to judge an ongoing action or activity based on sensor data (online or offline) [5]. With the development of wearable sensors, there are different kinds of sensors that can accurately collect human behavior data. Sensors are widely used in wearable devices such as bracelets, watches and mobile phones [6]. However, for pilots, the comfort and stability of the sensor are more important.

·The common ways to wear sensors are as follows:

a) Wrist wear

i . Smart watch/band type: integrate the sensor into a smart watch or bracelet and wear it on the wrist. For example, the PPG sensor estimates the heart rate by emitting light to the skin of the wrist and measuring the amount of light reflected or emitted by blood flow. This way of wearing is convenient for daily activities and suitable for long-term wear.

ii. Piezoelectric sensor type: For example, the flexible PZT piezoelectric sensor developed by Nagoya University in Japan is used to measure the pulse waveform of the radial artery. The wearing method is to place the sensor on the cushion and then fix it in the natural position of the wrist with the wristband.

b) Wearing on the chest

i. Chest strap type: such as Polar Pro sensor, fixed on the chest through the chest strap. When using, you need to wet the chest belt electrode area first, then insert the sensor into the chest belt and adjust it to a comfortable position.

ii. Clothes embedded: Embed the sensor into special clothing, such as the Polar Team Pro shirt, and insert the sensor into the pocket on the back of the shirt.

c) Body table attachment

i. Disposable patch type: For example, the sensor of Abbott's auxiliary instant sense® glucose monitoring system needs to be applied to the back of the upper arm to avoid scars, moles and other areas, and choose a place with flat skin and a certain distance from the insulin injection site.

ii. Flexible patch type: Some new flexible stretchable sensors, such as sensors based on stretchable organic electrochemical transistors (ISOECT), can be made in the form of patches and attached to the skin surface for monitoring biological signals such as myoelectricity.

d) Finger wear

i. Ring type: Integrate the sensor into the ring. For example, some new flexible PPG sensors can be integrated into the ring for the measurement of physiological parameters such as heart rate and blood oxygen.

e) Ear wear

i. Headphone type: Integrate sensors into headphones, such as PPG sensors can be used to monitor physiological parameters such as heart rate.

f) Other ways to wear

i. Insole type: The sensor is embedded in the insole to monitor gait, pressure distribution, etc.

ii. Clothing type: integrate sensors into ordinary clothes, such as shirts, trousers, etc., and monitor physiological signals through fabric electrodes and other means [5-7].

5. Conclusion

This article mainly discusses the research and analysis of aircraft cockpit sensors and the development status of sensors, and further studies and analyzes the behavior recognition of pilots by sensors. It is mainly divided into three parts to discuss. First, the pilot's behavior is classified and defined, which can better Provide accurate and effective data when identifying pilot behavior. Secondly, the collection of pilot behavior by sensors and the algorithms applied are studied, and then the processing of these collected data. The third section explores the impact of sensors on pilots, mainly in terms of comfort and the subjective and objective evaluation of comfort. Finally, the wearing style of sensors is analyzed, and the performance characteristics of different sensors are analyzed. These technologies have shown great potential in practical applications, but they also face some challenges. For example, the complex cockpit environment may increase the noise of sensor data, affecting the recognition accuracy. In addition, the sample data of abnormal behavior is limited, and it is difficult to meet the training needs of deep learning models. Future research needs to further optimize the sensor layout, improve the efficiency and quality of data collection, and explore more efficient data fusion and analysis methods.

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