Multi-source Information Fusion Augmented Reality Benefited Decision-making for Unmanned Aerial Vehicles

A effective way for accurate operation

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Abstract: **Augmented reality UAV multi-source information is obtained by overlaying a variety of other sensors and the database data in the airborne video of CCD sensor. More substantial and credible information display can then be obtained. Our research includes the establishment of binocular stereo camera, improved feature matching algorithm with high matching speed and robustness, pose measurement methods making control operators observation immersion better. The method used for manipulation of augmented reality provides enhanced decision support information to improve the personnel control decision's speed and accuracy.**

Key words: data fusion, augmented reality, decision-making, unmanned aerial vehicles

I. INTRODUCTION (HEADING 1)

Augmented Reality is committed to combine computer-generated information with real-world scenes together. It can provide accurate and efficient secondary interface to operators, and also construct engaging interactive training environment. Trainers can wear the head tracking device camera to capture the surrounding environment. They will capture the information transfer to the computer for processing, and processing the scene after the formation of the analog output to the training of military personnel wearing the head display unit available to realistic battlefield scenarios. Augmented reality can be seen as between completely real and completely virtual environment as shown in Figure 1[1].

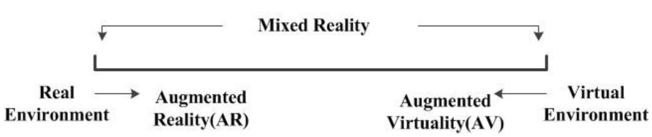

Figure 1 relation graph of the real and virtual reality

The goal of augmented reality is to add information and meaning to a real object or place. Unlike virtual reality, augmented reality does not create a simulation of reality [2]. Instead, it takes a real object or space as the foundation and incorporates technologies that add contextual data to deepen a person's understanding of the subject.

UAVs' Operator can improve their capability of obtain information in training and actual combat by augmented reality which can send aerial reconnaissance of UAV in real time to three-dimensional video display. They can get key regional features superimposed tips, target guidelines. In other cases, augmented reality might add audio commentary, location data, historical context, or other source of sensors that can make a UAV Operator's experience of a thing or a place more meaningful [3].

The field of military technology has paid considerable interest in augmented reality: head of the pilot equipment display and Helmet observations have had a history of equipment used for the navigation map superimposed on the pilot perspective on the real scene. In addition to providing basic navigation and flight information, these graphics have been even locating the target in the environment above target for weapons. With AR technology research, the future of augmented reality system can be used indoors or outdoors in any environment without being confined cockpit and other small spaces. Outdoor augmented reality system supporting information available to the soldier to play a lot of navigation, location, target search, and so a very crucial role. It can be used in wartime or peacetime military training.

A plan funded by Minnesota Department of Defense was to develop battlefield soldiers' primordial vision enhancement system. By using the system, a digitized battlefield was created, which could play an important role in battlefield in support of the soldiers, ambulance and so on. U.S. Navy Research Institute of the battlefield augmented reality system (Battlefield Augmented Reality System, BARS), with the perspective of the system type HMD[4], soldiers can not only see the actual picture of the battlefield, but also watch the enhanced infrared or night vision image displayed And command the means of communication with the remote came in a variety of reconnaissance information, command and orders to achieve the command center and all the fighting between the strategic and tactical unit of information transmission, on this basis can be developed enhanced multi-user cooperative Reality system. NASA Ames Research Center, augmented reality-based air traffic control tower was studied for the control of members of the engineering prototype of augmented reality glasses, to display the augmented reality environment, airport, and air traffic state.

Optical Engineering, Beijing Institute of Technology has successfully developed a large field of color display helmets, ultrasonic positioning tracking devices, optical image processing using data gloves and other VR peripherals hardware prototype. A series of studies, such as three-dimensional image processing, augmented reality environment in respect of the registration of color marks point, no signs point and illumination model augmented reality system were also carried out. Zhejiang University has had some useful exploration in augmented reality-based surgical navigation technology [5, 6].

II. MULTI-SOURCE INFORMATION FUSION

A range of technologies can be used for augmented reality. Many augmented reality projects use headgear or a similar device that projects data into the user's field of vision, corresponding with a real object or space the user is observing.

A well-built augmented reality system should have three features: real and virtual, real-time interaction and three dimensions. Augmented Reality through the stereo matching method, UAV operator can see the real environment around and enhanced computer-generated information at the same time, including three-dimensional model of the object, non-geometric information, etc. Multi-source information fusion augmented reality applications include:

A. Auxiliary Navigation

Existing inertia, GPS, astronomy, navigation methods have their own characteristics and lacks, while stereo vision based augmented reality navigation UAV control personnel can become an alternative way of supporting navigation. Real-time, high-precision augmented reality information can greatly improve the UAV control personnel on-site flu and awareness.

B. Non-contact measurement

The reconstruction of three-dimensional model and the real scene only have difference in a global scale factor. So if the scene is given a reference to any size, it can be re-modeled, if specify a reference coordinate. What's more, any point's absolute position can be obtained. As a result, non-contact method, for some large, shape difficult to measure or to facilitate accessed objects can do fast, accurate measurements. Through augmented reality display, UAV operator can directly access the relevant characteristics of the environment information.

C. Realistic control

For many years, military aircraft and helicopters have used Head-Up Displays (HUDs) and Helmet-Mounted Sights (HMS) to superimpose vector graphics upon the pilot's view of the real world. Besides providing basic navigation and flight information, these graphics are sometimes registered with targets in the environment. They can provide a way to aim the aircraft's weapons. For example, the chin turret in a helicopter gunship can be slaved to the pilot's HMS, so the pilot can aim the chin turret simply by looking at the target. Future generations of combat aircraft will be developed with an HMD built into the pilot's helmet.

Immersive realism manipulation is all UAV operators' hope to achieve the ideal state. At the same time, real-time three-dimensional information obtained can also be used to achieve the effect of augmented reality. The purpose of the so-called augmented reality virtual is put objects (graphics, data) into real scenes, real-time images (video). The actual situation in order to achieve the purpose of seamless integration is the core problem of embedded virtual objects to solve real scene images (video) in the geometric consistency.

D. Fusion of sensors measurements

The vision system measures the image positions of targets known in world coordinates. Assume the camera observes a static scene. Suppose n features are detected and tracked in the scene. $p_k = (p_x^k, p_y^k, p_z^k)$ is the k^{th} feature point in the world coordinate frame. Then, under perspective projection, at time t_i, its projection $P_{k,i} = (P_{x,i}^k, P_{y,i}^k)$ on the image plane is

$$\begin{bmatrix} P_{x,i}^k \\ P_{y,i}^k \end{bmatrix} = \begin{bmatrix} f \dfrac{R_1(\psi_i)\cdot[P_k - r_i]}{R_3(\psi_i)\cdot[P_k - r_i]} + n_x \\ f \dfrac{R_2(\psi_i)\cdot[P_k - r_i]}{R_3(\psi_i)\cdot[P_k - r_i]} + n_y \end{bmatrix} \quad (1)$$

where f is the focal length of the camera, and R_i is the i^{th} row vector of rotation matrix $R(\psi)$. n_x and n_y model the measurement noise of feature detection.

Usually inertial sensor consists of three orthogonal rate gyroscopes to sense angular rates of rotation along three perpendicular axes. The gyroscopes are analog devices, so a 16-bit A/D card is used for sampling and digital conversion. Since rate gyroscopes only measure the angular rate of rotation, we implement a low-level A/D driver library with time-integration and calibration algorithms to achieve a 1 KHz-sampling rate.

Let $\omega_i = (\omega_{x,i}, \omega_{y,i}, \omega_{z,i})$ represent the angular rates measured from the gyros with random-distribution noise n_{ω_i}

$$\omega_i = \overline{\omega_i} + n_{\omega_i} \quad (2)$$

where $\overline{\omega_i}$ is the true noiseless angular rate. In the integration update interval ΔT, the related rotation angle $\psi_i = (\psi_{x,i}, \psi_{y,i}, \psi_{z,i})$ in the inertial body coordinates can be calculated as

$$\psi_i = \sum_{k=0}^{\Delta T-1} \omega_{i,k} = \sum_{k=0}^{\Delta T-1} \overline{\omega_{i,k}} + n_{\psi_i} \qquad (3)$$

where n_{ψ_i} is random-distribution integration noise. For the absolute rotation angle (Euler angle) $\theta_i = (\theta_{x,i}, \theta_{y,i}, \theta_{z,i})$ in the world coordinate, the relationship to the angular rate is

$$\omega_i = W^{-1}(\theta_i)\dot{\theta}_i$$

Where $W(\theta_i)$ is the Jacobian matrix that relates the absolute rotation angle to the angular rate, defined by

$$W(\theta_i) = \begin{pmatrix} 1 & \sin\theta_{z,i} \tan_{y,i} & \cos\theta_{z,i} \tan_{y,i} \\ 0 & \cos\theta_{z,i} & -\sin\theta_{z,i} \\ 0 & \sin\theta_{z,i} / \cos\theta_{y,i} & \cos\theta_{z,i} / \cos\theta_{y,i} \end{pmatrix} \qquad (4)$$

The goal of the fusion filtering is to estimate the camera pose parameters of (1) from the measurements of the vision and inertial gyro sensors. Since the vision and gyro sensors have different sample rates, a complementary motion estimate filter is implemented as shown in Figure2.

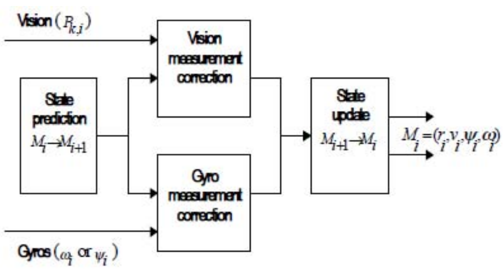

Figure 2: Fusion filter framework

Currently, an EKF is used for the filter implementation. The complementary filtering structure is a variation of two parallel EKF banks sharing one common state prediction module, i.e.

State prediction (common):

$$\begin{aligned} M_{i+1}^- &= A_i M_i \\ P_{i+1}^- &= A_i P_i A_i^T + Q_i \end{aligned} \qquad (5)$$

Measurement correction (vision or gyro):

$$\begin{aligned} K_i &= P_i^- H_i^T (H_i P_i^- H_i^T + R_i) \\ P_{i+1} &= (I - K_i H_i) P_i^- \\ M_{i+1} &= M_{i+1}^- + K_i (m_i - \hat{m}_i) \end{aligned} \qquad (6)$$

where

A_i : the state transition matrix

P_i : the state covariance matrix

Q_i : the process noise covariance matrix

R_i : the measurement covariance matrix

H_i : the Jacobian matrix of measurement

K_i : the Kalman gain

m_i : observed measurement from vision or gyro tracking

$\hat{m}_i$: predicted measurement given current state estimate

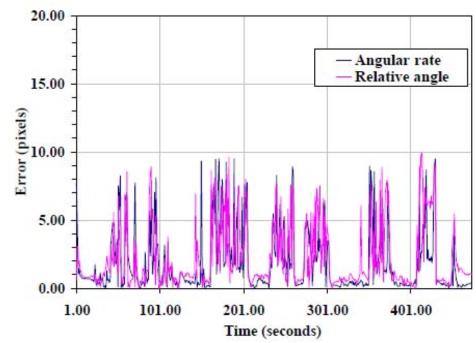

Figure 3: Tracking errors

As figure 3 shows in the image plane: blue line denotes the tracking errors when directly using Gyro angular rate. The resulting max tracking error: 9.5 pixels; average error: 1.84 pixels; and error covariance: 5.32 pixels. The red line denotes the errors when using the integrated relative angle. In this case, the max tracking error: 9.93 pixels; average error: 2,18 pixels; and error covariance: 5.62 pixels.

III. AUGMENTED REALITY SUPPORTED DECISION

Since presently, intelligent control and UAV platforms are difficult to achieve fully autonomous flight control, the operator of the UAV task execution results still have a great impact, especially when the UAV in an unknown surroundings or performing tasks in harsh environments. It is particularly important to provide the operators a realistic flight interface even with augmented reality, as shown in Figure 4. That will greatly improve the efficiency of UAV control. Most augmented reality system is only suitable for indoor environments, has developed a successful environment for augmented reality systems are used in controlled environments. The future of augmented reality system should have a good environmental adaptability, either outdoors or indoors. It should have high registration accuracy and the use of freedom, which will play a greater role in the wild, remote operation.

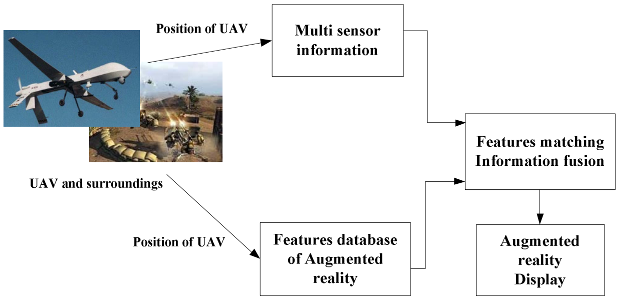

Figure 4 augmented reality Supported UAV Decision system

Augmented reality involves multiple difficult, crossing factors as in realization applications, including signal processing, computer graphics and image processing, human-machine interface and psychology, mobile computing, computer networks, distributed computing, information retrieval and information visualization, and new displays and sensors design. Augmented reality system will not require displaying the full scene, but due to requirements of analyze large amounts of location data and scene information. It is needed for computer-generated virtual objects can be precisely positioned in the real scene. Therefore, augmented reality systems generally include the following four basic steps:

(1) Getting the real scene information;

(2)Analyzing the real scene and camera position information;

(3) Generating a virtual scene;

(4)Merging the video or directly displaying the graphics system. The first location information can be calculated based on the camera and anchor in the real scene. The virtual objects to the camera as the plane affine transformation, transformation matrix can then be followed obtained for the UAV as drawn in virtual objects. Finally the real scene and fusion information will be directly displayed through the optical display helmet or video display.

In augmented reality systems, display technology, location and registration technology, interactive technology and locating the actual situation of the scene are key technologies to achieve fusion scene for UAV operators' decision. Therefore, the studies of matching method for virtual information and real video information overlay, achieving two-way real-time image acquisition, transmission and display, and finding relevant features accurately are important. UAV operator can be provided more extensive control and timely decision-making information to improve the control of personnel decisions' speed and accuracy.

A. Three-dimensional track and registration method

UAV control augmented reality system's effect depends critically on the performance of three-dimensional technology whether it can track up anywhere in any environment that meets the requirements of the background, and also can meet the requirements of real-time tracking accuracy. Augmented reality in the three-dimensional registration technique consists of the following two parts:

(1) Registration the head of user that the sight's location and orientation;

(2) Registration of virtual objects. That is virtual objects' position in real space.

Registration based on computer vision technology research is currently in a dominant position, but this method cannot determine the position in the complex environment and difficult to achieve good results. Current international trial of outdoor augmented reality tracking system sensor technology include: global positioning system, but its application is controlled by the United States military. And in the room, canyons, or other complex terrain under the normal reception of GPS signals are often invalid.

Inertial navigation system's main problem is the angle drifting of the object being tracked and the location of the tracking error increases over time. Electromagnetic, optical or ultrasonic means to track commonly used in certain situations of a fixed range of augmented reality systems. Digital compass' main problem is the magnetic field distortion, noise and the sensor output is delayed. Tracking methods mentioned above have their limitations, so good solution is to use hybrid tracking technology. Using the different tracking methods, it can learn from each other, that is, the output through the integration of multiple sensors to get accurate tracking results.

B. AR ToolKit-based three-dimensional registration

AR Toolkit is a C language based on augmented reality system with secondary development package. It takes advantage of the identity of the external box with a black point of view to calculate relative to the observer position and orientation of a known identity. It also supports the enhancement based on visual or video Reality applications. In fact, the exact three-dimensional registration function allows engineers very conveniently, quick developing augmented reality applications. Figure 5 shows the runway and cockpit using augmented reality display. The environment at night or fog, you can clearly see the runway or direction to determine the surrounding environment. It can be realized under the harsh environment safe takeoff and landing UAV operations.

Figure 5 the shows based on Augmented Reality

C. The attitude measurement in augmented reality

Operator and target tracking in three-dimensional space normally are expressed by the six degrees of freedom respectively. Along the spatial X, Y, Z translational axis and around the X, Y, Z axis rotation, the coordinates are called position and angle coordinates. UAV control augmented reality system operators 'attitude tracking gaze direction information need to be accurately obtained in time. Information measured by real-time feedback is used to enhance the software generated data's accuracy. Then the information can be superimposed to the real video to achieve synchronization of visual information display.

In the augmented reality system, movements can be measured using six degrees of freedom tracker information, or three degrees of freedom for pose tracker and operator. Tracker performance is usually divided into the following aspects: accuracy and resolution, response time, interference and gregarious [5].

From a point of view of structure, tracking systems can be divided into active and passive ones. Active tracking system fixes both the transmitter and receiver in one of the objects to be tracked (such as head, hands, etc.), and the other fixed in a relatively static object as a benchmark. Tracking system calculates the transmitter unit and receiver relationship to determine the location of target tracking and other information. Relative to the active tracking system, the passive tracking system uses only a receiver to achieve the position and attitude tracking. According to the different realization, it can be divided into electromagnetic, acoustic style, inertial, optical and so on.

Gyro inertial tracker measures the moving objects three-axis angular rate through an integral goal of attitude. Three-axis acceleration sensor measuring acceleration vector, can obtain movements by double integration of the three directions. The main problem of inertial tracker is the measurement error increases with time. Attitude measurement based on the earth's gravity field and magnetic field can obtain result with tilt sensor which has three degrees of freedom pose parameters the inertial parameters. It can make the system with tracking a wide range of small size, low power and so on series of advantages, especially for the UAV augmented reality systems. Augmented Reality-based UAV control shown in Figure 6 has three-dimensional glasses and touch screen display enables easy configuration under the conditions of single soldier [6]. Its structure is also illustrated in Figure 6.

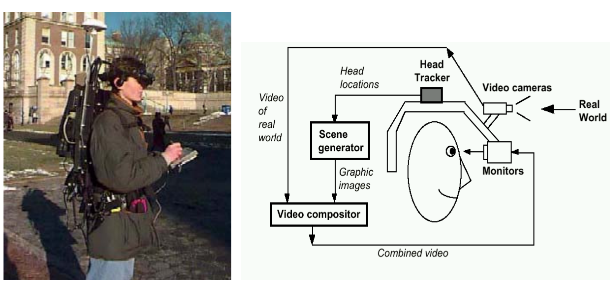

Figure 6 the UAV operator with augmented reality equipment and it's structure

IV. Conclusion

Multi-source sensor fusion method of augmented reality does favor for observation and control of UAV operators. It can improve their ability to access information, provide basis for decision making. Meanwhile, the UAV operator wearing a three-dimensional helmet can get more stable, immersive and accurate control decision results.

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