Engineering Notes

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Visually Coupled Systems as Simulation Devices

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Introduction

TECHNOLOGICAL development of visually coupled systems (VCS) began at AFAMRL in 1966 The major aim of this development has been to optimize the crew system interface by using natural human visual, perceptual, and psychomotor capabilities Visually coupled systems provide a way to improve weapon aiming accuracy and efficiency while enlarging the operational delivery envelope of the weapon system For example, VCS can provide larger delivery en velopes than head-up displays (HUD) used in current production aircraft Current HUD fields of view are typically no greater than 20 deg, whereas the slew angle limits of missile seekers range from 20 to 150 deg This results in a mismatch between weapon system capability and the crew member's ability to efficiently utilize it Although a wider HUD field-of view may improve this interface, it is impractical to match HUD designs to the total range of weapon capabilities Visually coupled systems can achieve a more effective crew system interface by using the natural ability of the crew to acquire visual information and provide an adaptive control of the weapon system which is not as limited as conventional cockpit displays

A visually coupled system may derive control information from the operator and direct the weapon system while simultaneously displaying weapon system information to the operator Control information is derived by a helmet mounted sight (HMS) and/or helmet mounted oculometer (HMO). Feedback information is provided by the helmet mounted display (HMD) It is the combination of these components that is termed a "visually coupled system"

Theory of Operation

The HMS senses helmet position and attitude with respect to some fixed reference Infrared, ultrasonic, electro-optical, mechanical, and electromagnetic sensing techniques have been developed and evaluated for this purpose These include sweeping infrared beam transmitters with infrared sensitive LED receivers, and electromagnetic transducers, one fixed in space and the other rigidly attached to the operator's helmet

The HMO combines a HMS and eye-position sensing techniques, allowing eye line of-sight to be summed with helmet position and attitude in order to compute gaze angle with respect to a fixed reference located in the crew station Eye position may also be sensed several ways Typical optical methods usually track reflections from the cornea or retina relative to the sclera and iris All of these techniques are somewhat nonlinear, causing some compromises between speed of detection of reflected light from the eye and line of sight accuracy While the HMS can be used alone, its com bination with the oculometer extends the utility and per formance of the visually coupled control in both airborne and ground based applications

The HMD receives data from the weapon system and presents it to the operator. The information can originate from flight control systems, missile seekers, or from synthesized sources (e g , computer image generation) Weapon system data or sensor imagery is transferred from electrical signals to images by miniature CRT's The CRT image is then magnified, collimated, and projected into the operator's eyes using optics and image combiners attached to the helmet

The applications for VCS can be numerous For example, in current air-to-air-ground and air to air missions involving two place tactical aircraft, the communication of visual line of sight information between aircrew members is difficult A VCS would allow one operator to establish a line of-sight angle with his HMS or HMO which would then be com municated to another operator via a HMD (since the second operator's head position is also known) Thus the gaze angle of one pilot can be quickly and accurately communicated to another In the same way, line of-sight information from aircraft subsystems can also be communicated (e g , line of sight to radar target, prestored navigation coordinates, etc) Some components of VCS are currently employed in several operational aircraft including the Army's attack helicopter and the Navy F4J's and F4N's

Generally, VCS offer several advantages over conventional control and display techniques These advantages are:

1) Better utilization of current and future weapon system capablities, such as wide field-of view missile seeker heads and off boresight launch envelopes

2) Rapid target acquisition, including replacement of radar system hand controllers and panel displays with head aimed sensor controls and displays (i e , sensor imagery projected on HMD; sensor aiming controlled by head/eye position).

3) Unconstrained or virtual crew stations, in which the cockpit displays, controls, and functions reside within the virtual space provided by the visually coupled system Cockpit layout is controlled through software and therefore is not constrained by physical space in the cockpit

Visually Coupled Airborne Systems Simulator

VCS technologies can be used to achieve the following: 1) provide low cost visual systems for simulators, 2) support research regarding critical issues of cockpit control and display design, and 3) help define the proper use of VCS components in the airborne environment The most effective method of simulating airborne VCS characteristics and scenarios is to incorporate VCS into the simulator itself The simulator is then capable of emulating a broad range of VCS applications and systems The Visually Coupled Airborne System Simulator (VCASS) was conceptualized and developed to explore these concepts In addition to the ability to perform advanced VCS research, the VCASS concept provides a low cost alternative to conventional simulator visual systems while extending the available performance of visual displays by increasing resolution, increasing total field of view, and increasing brightness

The key components of VCASS are the HMS and HMD The underlying concept of VCASS is to utilize the HMS to select information from a synthesized data based of visual

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*Project Engineer Visual Display Systems Branch Human Engineering Division scenery and utilize the HMD as a virtual display device to present a collimated image to the operator This allows a full sphere of visual information to be accessed in real time, including a simulated head-up display, out the window scenery, and even in-the cockpit displays The instantaneous view which the operator would have of the total field is based upon the field of view of VCASS HMD optics This window moves in a one-to-one correspondence with head position (as measured by the HMS) and thus, as the operator moves his head to look anywhere in the sphere, he is presented the proper visual scene which sould appear in that orientation The operator utilizes conventional control devices including stick, rudder, and throttle to simulate flight through a synthetic visual world Realistic vehicle dynamics are utilized to simulate the aircraft and weapon dynamics Information is taken from the HMS and combined with the flight trajectory in real time to obtain the instantaneous field-of view This imagery is transferred to the HMD for display to the operator Discussed below are features of some of the sub systems which contribute to the overall performance of the VCASS facility

The VCASS HMD relays the information generated on miniature CRT's to the observer. The HMD uses two collimated monoculars which, when viewed simultaneously, present a single wide field of view image An outline drawing of the VCASS HMD optics is shown in Fig 1 Each monocular consists of an 80 deg horizontal by 60-deg vertical field with less than 1% distortion across the entire field. The total field-of-view of the VCASS HMD can be changed by modifying the overlap between the monoculars, resulting in a total field of 100-140 deg with an overlap field of 20-40 deg The initial element in each optics path is a fiber optics faceplate on the miniature CRT, which is machined to match the characteristics of the optical path. Other specifications for the HMD include a weight of less than 60 oz, transmittance of less than 1%, a 35 5 mm eye relief, and an exit pupil of 15 mm The CRT's utilized in the VCASS HMD represent a major state-of the-art advance in miniature CRT design and development. The VCASS CRT's are approximately 1 in in diameter, 5 in in length, and 13 5 oz in weight Both the luminosity and ruggedness of these CRT's have been greatly increased while maintaining a high resolution To obtain these advances, a more rugged and efficient phosphor screen has been developed and used with an increased acceleration potential The resultant CRT, designated the 1M35, operates at 1300 ft Lamberts line brightness with a 16 μm spot size The P53 phosphor has a slightly yellow color (Kelly chart coor dinates $x=0.368$, $y=0.539$), a 300° C thermal quench temperature (making it resistant to electron beam burn), and a 10% decay time of 7 7 ms The yoke inductances have been reduced from previous miniature CRT designs by an order of magnitude to 12 18 μH.

The HMS system used in the VCASS is a six-degree-of freedom electromagnetic position sensing system The VCASS HMS utilizes a fixed radiator/movable sensor electromagnetic transducing system which sequentially ob tains sensor position and attitude with respect to the magnetic field sequentially through three orthogonal coils The coils are wound around a spherical ferrite and epoxy core encased in an epoxy cube. The field utilizes a carrier frequency of 10 6 kHZ. In addition to obtaining the position and attitude of the helmet in real-time, the VCASS HMS can perform real-time helmet data filtering and control cueing inside the cockpit

The HMS in VCASS supports two cockpit operation and measures two independent helmet positions simultaneously The system performs measurement of helmet attitude (pitch, roll, and yaw) and position (x, y, and z) with respect to an aircraft boresight, and outputs true data with a 14 bit resolution Accuracy of measurement exceeds 0 45 deg at 95% circular error (CE) over a 5 cubic ft motion volume in which the helmet can translate The angular measurement resolution over the same motion box is 0 025 deg The translational measurement accuracy is 0 35 in +2% of

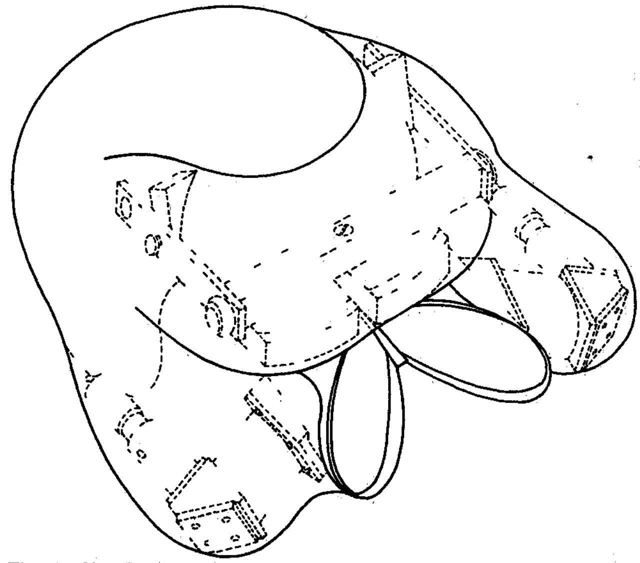

Fig. 1 The Visually Coupled Airborne Systems Simulator (VCASS) helmet mounted display

sensor displacement The basic computation cycle rate is approximately 90 Hz utilizing a converging algorithm

The combining of low distortion binocular optics, high-resolution CRT's, and dual graphics generators enables the VCASS system to display stereo information to the operator. This stereo or three dimensional perception is elicited by introducing retinal disparity within elements of the graphics displayed to both eyes The ability to present three-dimensional information in real time during an airborne mission permits exploration of the three dimensional display concepts for conveying information in depth during an airborne mission that is not possible with other simulator systems Research underway to quantify the nature of three-dimensional perception using binocular graphics is beginning to show that a stereographic display capability may significantly enhance the information transfer from computer-generated displays

Helmet-Mounted Oculometer Facility

AFAMRL has developed a second facility, termed the Helmet Mounted Oculometer Facility, which supports research in advanced eye control techniques and eye tracking hardware/software development The key component of this facility is a HMO which combines the functions of an eye position sensor and a magnetic HMS The eye line of sight and helmet position and attitude are summed and outputted to a general purpose processor which acts as the facility controller This controller drives several graphics monitors and cockpit controls based upon eye fixations, manual control inputs, and voice commands

Summary

During the last seventeen years AFAMRL has developed VCS components and integrated them into several applications, including airborne flight testing and ground based simulator research AFAMRL currently has two facilities supporting hardware development and research involving VCS Hardware currently being developed will result in a next-generation VCS based system with increased performance and a more efficient crew system interface Hardware under development at this time includes a subminiature CRT design which will yield a 10 mm diameter CRT to be incorporated into a lightweight, airborne qualified HMD, high speed and high accuracy HMS algorithms involving Kalman filter implementations, nonconventional graphics software to portray complex information rapidly and effectively to the operator, and advanced eye movement measurement concepts and algorithms