Navigation through Fog Using Aircraft Cockpit Display

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Abstract -- **Navigation, particularly in aviation, has been affected since its beginning with the dangers of poor visibility conditions. Attempting to land an aircraft in fog is more difficult even with radar/ADS-B tracking. Due to the difficulty of backscattered radiation from landing light illumination similar to that experienced when using high beam headlights while driving in fog, the visible and near-infrared spectral regions have been ignored. This paper illustrates the development of a novel vision system for landing an aircraft in fog.**

Keywords: Navigation, Fog, Visibility, Backscatter, Image Enhancement

I. INTRODUCTION

NAVIGATION, especially in aviation, has been affected since its beginning with the dangers of poor visibility conditions. Our ground vehicles have problems in moving at night or in low visibility even with night vision augmentation because of the lack of contrast and depth perception. So, just think about trying to land an aircraft in fog is even more difficult. We know that aircraft outfitted with an Instrumentation Landing System (ILS) can land safely on runway in fog. Landing at an airport with an ILS is not considered safe because there is no means to sense small-scale obstacles that do not show up on radar but could cause a landing crash. We know that visible and near-infrared spectral regions have been avoided so far due to the problem with backscattered radiation from landing light illumination, similar to that experienced in turning on high beam headlights when driving.

Generally, this has been observed that when a ground vehicle tries to illuminate the terrain or road in front of the vehicle with headlights, the backscatter of the headlight radiation is so intense that there is not enough scene contrast left to differentiate the terrain ahead at night. During the day there is so much ambient radiation from the sun scattering into the fog that the reflections from the terrain ahead cannot be decided. What is required is a method to enlighten the terrain with radiation that can be used to receive what the terrain ahead looks like through the fog.

For landing an aircraft, the use of radar does not give adequate spatial resolution because of the very long wavelengths even though it does penetrate fogs well. Employment of the thermal infrared is not a practical alternative because although there would be adequate spatial resolution, the radiation does not penetrate the liquid water contained in fogs or on sensor optics. As the wavelength of the radiation gets shorter, there is extra scattering. Hence, the long wavelength visible to near infrared may be among the better spectral regions to utilize for the illuminating source.

In general aviation, the major accident category is sustained Flight into Instrument Meteorological Conditions, in which a non-instrument rated pilot continues to fly into deteriorating weather and visibility, leading to a loss of the visual horizon and a potential collision into unexpected terrain or spatial disorientation and loss of control. Finally, the greatest factor affecting airport delays is restricted visibility that trims down runway capacity and increases distances required for air traffic separation when weather conditions go down below visual flight rule operations.

Synthetic vision and enhanced vision systems are visibility solution to this visibility problem that would allow all aircraft to be flown under the virtual correspondent of visual meteorological conditions or plain daylight operations.

II. ATMOSPHERIC TRANSMISSION MODEL - FOG

The spectral transmission of the atmosphere for varying ranges allows a simple qualitative comparison of the visibility in dissimilar atmospheric windows. Figure 1 presents the spectral transmission for CAT I fog in mid latitude summer and rural aerosols. In the visible spectral waveband (0.4 - 0.75 microns) the transmission is momentously lower than in both thermal IR windows (between 3-5 and 8-12 microns).

In such conditions, a thermal imaging camera will see noteworthy further than the naked eye in spite of whether it is using a longwave or midwave detector.

When we decrease the visibility to CAT II conditions with radiative fog in the model, then it forecasts that only the LWIR (8-12 microns) band is better to the visible band, and that a midwave infrared camera will not see much additional than the naked eye (Figure 2).

Finally, in Cat III conditions (Figure 3), with visibility less than 300 m, there are no substantial differences between how far you can see with a thermal imaging camera and how far you can see with the naked eye.

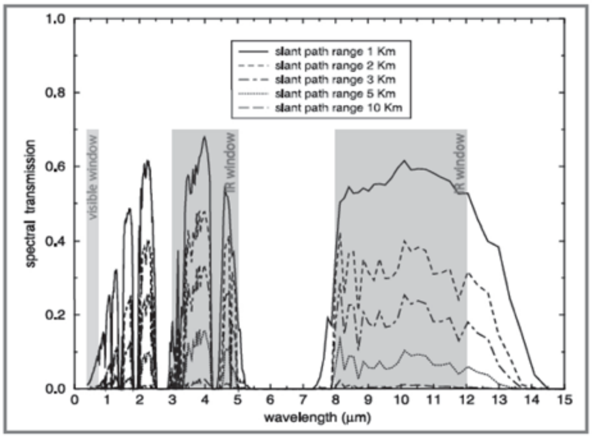

Figure 1. Spectral Transmission for CAT I Fog.

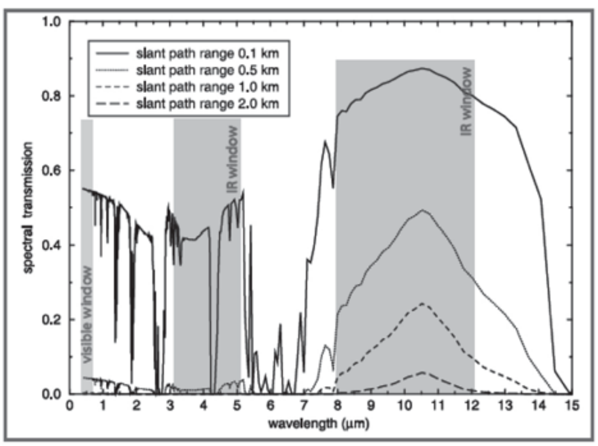

Figure 2. Spectral Transmission for CAT II Fog.

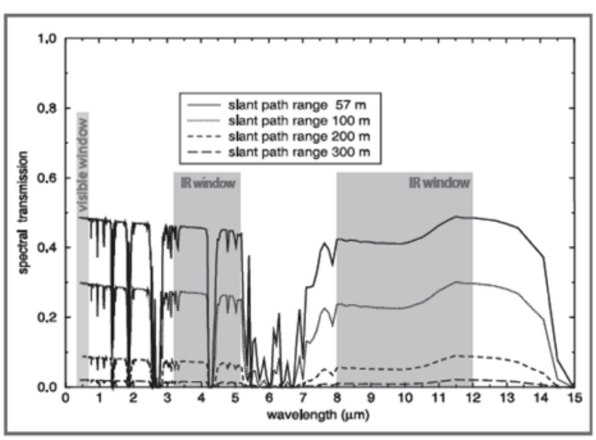

Figure 3. Spectral Transmission for CAT III Fog.

All detection ranges for IR are improved than the visual for Cat I type of fog. For Cat II type of fog, the result is four times superior with a thermal imaging camera equipped with a LWIR detector compared to visual.

In Cat IIIa and Cat IIIc types of fog, there is practically no difference between how far you can distinguish with a thermal imaging camera and with the naked eye since the atmosphere is the limiting factor. Radiation does not go through this dense type of fog in all (visible, MWIR and LWIR) spectral bands.

III. WEATHERING FOG AND DARKNESS

Followings are the systems which are used for the vision from the aircraft cockpit display.

A. Synthetic Vision

A synthetic vision system is an electronic means of displaying the relevant and significant features of the environment outside to the aircraft through a computer-generated image of the external scene topography using on-board databases (*e.g.*, terrain, obstacles, cultural features), exact positioning information, and flight display symbologies that may be collective with information resulting from a weather-penetrating sensor (*e.g.*, runway edge detection, object detection algorithms) or with real imagery from enhanced vision sensors.

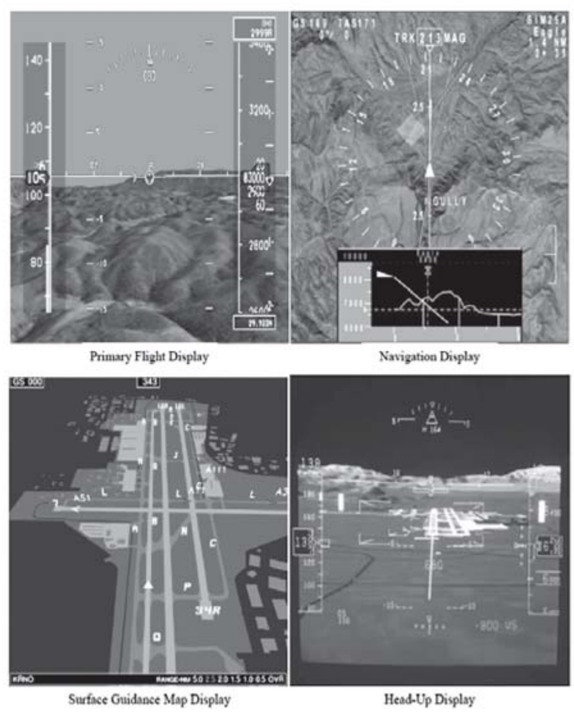

Figure 4. Examples of Synthetic Vision System Displays.

All aircraft categories can advantage from synthetic vision system applications, including general aviation aircraft, business jets, cargo and commercial airliners, military cargo and fighter jets, and rotorcraft. These systems may be shown on head-down, head-up, helmet-mounted, and navigation displays and be united with runway incursion prevention technology; database integrity monitoring equipment; enhanced vision sensors; taxi navigation and surface guidance maps; advanced communication, navigation, and surveillance technologies; and traffic and hazard display overlays. What characterizes the Synthetic Vision Systems technology is the spontaneous illustration of visual information and cues that the pilot or flight crews would normally have in day, visual meteorological conditions.

1) *Synthetic Vision System Elements:* Elements of synthetic vision system are Enhanced Intuitive View, Hazard Detection and Display, Integrity Monitoring and Alerting. Precision Navigation Guidance.

2) *Synthetic Vision System Components:* Synthetic vision system components are followings:

a) *Synthetic Vision Database/Sensors*

- On-board synthetic vision databases
- Weather Radar
- Radar altimeter
- Forward Looking Infrared (option)
- Millimeter Wave Radar (option)

b) *Synthetic Vision Displays:*

- Primary Flight Display, or imbedded display features
- Navigation Display, or display features/pages
- Interface with other cockpit displays, e.g., TAWS
- Head-Up or Helmet-Mounted Displays (option)

c) *Computers/Embedded Computational Functions:*

➢ mage Object Detection and Fusion

- Data confidence, detection threshold filtering, expected error Source data reasonability and integrity estimation
- Hazard detection
- Data fusion (correlated position of potential hazards)
- Image enhancement and fusion, where appropriate
- Integrity self monitoring and alerting

➢ System Integrity, Verification and Validation

- Database reliability, integrity, expected error
- Other source data reasonability and integrity estimation
- Generate appropriate system alert messages
- Integrity self monitoring and alerting

➢ Computations and Symbology Generation

- Cleared and actual path depiction
- Hazard element display integration and depiction
- Runway Incursion Prevention System
- Hold Short and Landing Technology
- Navigation and hazard situation awareness enhanced display elements
- Alert and warning generation and presentation
- Overall display symbol generation and/or integration
- Integrity self monitoring and alerting

d) *Equipment:*

- Dedicated synthetic vision system support equipment and crew interfaces
- Interface with other aircraft systems

e) *Associated Aircraft Systems:*

- Differential Global Positioning System
- Inertial Reference Unit/Attitude Heading Reference Set (IRU/AHRS)
- Air Data Computer (ADC)
- Radio
- RADAR
- Traffic Collision and Avoidance System (TCAS)
- Data Link aggregate (e.g., IFF Mode S, ADS-B)
- Terrain Awareness and Warning System (TAWS)
- Laser Altimeter (option)

B. Enhanced Vision System (EVS)

Enhanced Vision System (EVS) is the invention used to increase flight crew situational awareness by helping them see through fog, haze, precipitation and at night to improve overall safety and aircraft economic efficiency. This is skilled by using infrared EVS provides an image on the Head Up Display (HUD), a Head Down Display (HDD) or both to enable the pilot(s) to perceive the terrain/airport surroundings in low visibility situations. EVS appreciably improves situational alertness, not only during take-off, approach and landing, but also during ground maneuvering.

C. HUDs With Enhanced Vision

Enhanced vision systems (EVS) by means of infrared sensors to go through certain kinds of fog and low visibility conditions are the most recent improvement to head-up displays (HUDs). They are in rising demand in the regional airline and high-end business jet markets, as well as for air transports. But for corporate operators, many of whom fly into smaller airports with less sophisticated runway landing equipment, EVS provides both increased operability and added safety. When the pilots come in on an approach using ILS [instrument landing system] guidance, with EVS they pick up the lights faster. They can descend to lower minimums, but still must use the ILS guidance.

One might assume that with EVS's ability to look through fog or haze and detect runway lights sooner, ILS categories (Cat I, II and III) could become redundant. The enhanced vision system presents other payback, as well. The IR camera also is sensitive in the 3-to-5-micron range, which picks up not just lights, but the surrounding environment.

D. Millimeter Wave Radar

When fog becomes too thick for EVS to solve, millimeter wave imaging radar is being discovered by manufacturers seeking the Holy Grail of all-weather operations. Airlines are moving slower, more cautiously in obtaining EVS. One cause is that the new auto land systems in airliners united with HUD are allowing low-visibility landings with 700 feet runway visual range (RVR).

IV. CONCLUSION

Commercial aviation is among the secured modes of transportation. But, the requirement to fly in spite of the weather has led to an accident rate that is far from perfect. Aircraft accidents dish up as influential reminders of the risks involved and how much safer flying can and should be. Technology has advanced to allow for the appearance of novel vision systems that will deeply change how aircraft are worked in instrument conditions. By creating a virtual visual meteorological condition using novel vision system in cockpit display holds the guarantee to eradicate the precursor to many accidents and incidents (limited visibility) and substantially improve the safety and operational efficiency of aviation.

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