BROWNOUT / WHITEOUT SUPPORT SYSTEMS

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Abstract

In arid or snow covered regions starting and landing a helicopter may become a risky task because the outside view during these critical flight phases may become obscured by blowing dust or snow. These degraded vision effects are called brownout or whiteout, and may cause a complete loss of outside reference within a split second. Here an advisory system called DeViLa (degraded vision landing aid) is introduced that is designed to support the pilot even in these critical moments but thanks to the active obstacle warning capability also during flight. The modular design of the system is intended for an incremental development and implementation of this system. The first step aims at an immediate display of highly precise height above ground and drift velocity information.

The second step introduces a dust penetrating moving obstacle detection system, the so called electronic bumper. This electronic bumper warns of objects intruding the cleared landing space, such as cars, trucks, other aircrafts or even persons. The third step enhances the system by providing an obstacle warning function in flight with the motion animated display of a synthetic view of the landing area and the surroundings during landing. The data is based on up-to-date ladar data combined with data base information.

The sensors used for the phase 1 are a high precision Inertial Measurement Unit (IMU) especially adapted for precision drift measurement and one or multiple laser altimeters optimized for usage in dust or snow environment. The information is displayed to the pilots via a Multifunction Display (MFD) and via Helmet Mounted System / Display (HMS/D).

1. THE BROWNOUT AND WHITEOUT PHENOMENON

One of the most common operational tasks of helicopters is a transport mission to a destination and back. This applies to commercial missions as well as to non-commercial missions, like military or emergency response operations. In particular in the latter case it is crucial for a successful completion of the mission to be able to land and take off at the specified destination area. Unfortunately in most cases there will be no prepared helicopter landing pad available. Instead, the pilot will have to land in an unknown and hence unprepared area.

In out of area missions like in Afghanistan most of the envisaged destination areas will be covered with dust. While the helicopter is approaching, the dust is dispersed by the main rotor downwash which results in a restricted visibility of the outside world just in the most critical phase of the flight. Thus, the pilots loose the visual reference to the ground and objects in the close vicinity of the helicopter. These visual cues are necessary to control the helicopter near the ground. As a consequence, this brownout effect increases the risk and may result in spatial disorientation of the pilot and hence in an accident. In February 2008, the US Army stated, that 3 out of 4 helicopter accidents in desert conditions were directly attributable to the brownout phenomenon [2].

A similar situation arises if the surface is covered with snow. Although different physical conditions have to be treated, a snow cloud has the same impact to the pilot as a dust cloud. Recently, for instance, a helicopter of the German Air Force (Luftwaffe) sustained an accident during the take-off from a snow-covered surface in Norway. Due to spatial disorientation caused by snow swirl and the resulting visibility conditions the pilot was unable to control the helicopter and crashed [3]. Although in the following chapters only the terms 'brownout' and 'dust' are used they do also apply for whiteout and snow.

2. CURRENT COUNTERACTIONS

Current counteractions are spread over a wide variety of methods and can only be covered very briefly here. There are numerous attempts to suppress development of the brownout cloud by chemical or mechanical means (e.g. mats). Nevertheless these actions only proved successful for a short period of time and are limited to known and friendly landing zones.

Other potential counteractions cover enhancements to the aerodynamics of the helicopter downwash. Despite significant efforts in this field the only operational transport helicopter claiming a reduction or rather widening of the brownout doughnut is the EH101. All transport helicopters currently used operationally in Afghanistan or Iraq are facing the brownout problem.

There are several initiatives and research activities aiming at supporting the pilots during brownout landings by enhanced sensors and means of display.

2.1. Procedural Counteractions

All nations using military helicopters in regions where brownout or whiteout may occur have developed procedural counteractions. These counteractions, although being quite diverse are aiming first at staying in the brownout cloud for a time as little as possible. This results in specific landing procedures, usually with steep descents and rapid landings when enclosed in the brownout/whiteout cloud. Secondly there are some counteractions practiced which are aiming to keep ground reference for a prolonged time. This is e.g. done by dropping backpacks or other contrasting things over a landing zone when expecting whiteout. Some procedures are even using a human reference point standing in the landing zone. The method of the remote eyes, i.e. the man on the ramp used by German Army Aviation falls in the same category.

Generally procedures and training seem to reduce the risk of brownout/whiteout landings but they cannot cure the basic problem.

2.2. Current Support Systems

One of the best known research an technology initiatives trying to overcome brownout was the Sandblaster project. Within this project a 2D scanning mm-wave radar was developed and tested in flight. This sensor was combined with a flight control system and a synthetic vision system (see e.g. [1]). Although the flight tests were successful the project was aiming mainly for the next generation of fly-by-wire helicopters. The published data showed the possibilities but also the resolution limitations of a scanning radar. It was also stated that certification issues were out of the scope of this project.

Most nations on the other hand have a large fleet of older helicopters which are in operation e.g. in Afghanistan. These legacy aircrafts have a quite different complexity of existing sensors and available avionics equipment. Worth mentioning is the low visibility landing (LVL) project in the UK. This project aims at providing a so called conformal symbology, i.e. three dimensional symbols giving visual cues to support landing. These visual cues are displayed in a HUD system. The cues are placed around the landing zone, sitting on the ground surface extracted from a DTED database. Reliably and stably placing these cues also seems to be the major challenge in setting up an operative LVL system with conformal symbology.

In Germany the SELA project was aiming at developing sensors and a system to display a symbology to aim brownout landing. Within this project the predecessor of the DeViLA symbology was developed and tested in a simulator. Also a the prototype of a high resolution radar altimeter was developed and flight tested.

3. THREE PHASES APPROACH

The need for a system supporting helicopter pilots in active duty in arid areas is extremely urgent. Some technologies are ready to use, others are at the brink of successful flight testing while others are still in the research and development phase. This situation lead to a product development named DeViLA (Degraded Vision Landing Aid) by EADS Defence Electronics. This development is divided into different phases allowing for an early implementation of available technology with the possibility to sequentially upgrade the system when new technology becomes available.

The first phase consists of a symbology display with precision height and drift indication. The second phase enhances the symbology by the usage of a dust penetrating scanning mm-wave radar providing warnings of objects moving into the landing zone. The third phase further enhances situational awareness by providing an enhanced synthetic vision display based on actual ladar data collected just before entering the brownout situation.

4. PHASE 1 SYMBOLOGY SUPPORT

The most critical information for a pilot landing a helicopter under brownout or whiteout conditions are height above ground and drift speed. Both information can be provided to the pilots by available sensors or at least a combination of sensors available on the market.

For height above ground the DeViLA system uses two redundant height sensors (see architecture in figure 1). One is a COTS radar altimeter which is certified for flight guidance applications. This radar altimeter was selected in such a way that pilot experience reports showed no reported difficulties with this sensor when flying over changing surfaces which seems to be a typical problem with standard radar altimeters. The disadvantage of this sensor is that its precision is limited to ±2 ft during landing approach. A higher precision is desired though. This precision height information is provided by a laser altimeter designed by EADS IW. It gives height information with a precision of approx. 1 ft from 200 ft down to touch-down. This laser altimeter was modified in such a way that it works even in extremely dusty environment. Lab tests proved a full functionality down to visibilities of 9 m. In brownout situations the dust cloud forms in a doughnut shape. Therefore underneath the aircraft the visibility is fairly good. This is also proven by the current procedure of the German Army Aviation giving "remote eyes support" by a man on the ramp visually checking the area underneath the helicopter.

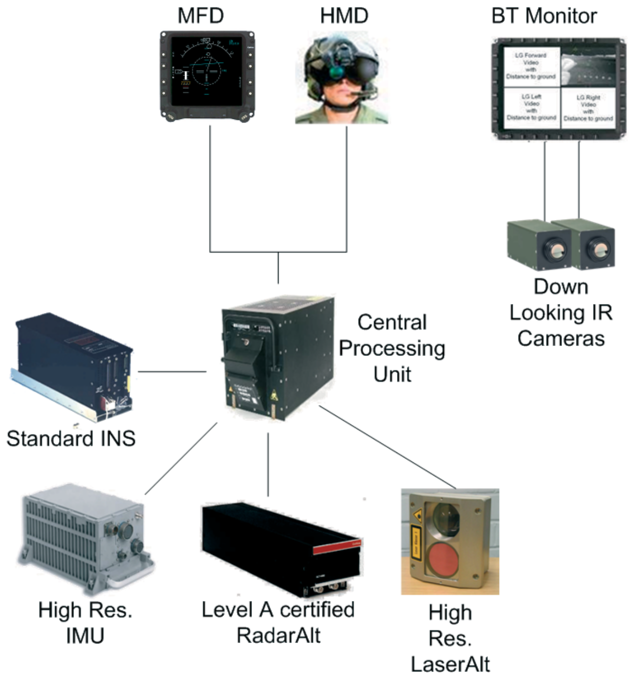

Figure 1: Architecture of the DeViLA concept in phase 1 with sensors for drift and height above ground detection.

The AGL information is presented to the pilots as a rising deck symbol together with a numeric AGL reading in feet.

Operational pilots request that drift speed shall be detected to the limits of current technology because the landing procedure of most helicopters asks for no cross drift at touch-down. This is to avoid damage or even tripping over of the helicopter. The resulting requirement is to detect helicopter drift, i.e. speed above ground with an accuracy of at least 5 cm/s. Unfortunately standard drift detection devices (e.g. Doppler velocimeters) are not capable of providing this accuracy. Nevertheless this precision can be achieved by high-end inertial reference units. This data is again monitored by a standard INS to achieve a sufficient level of redundancy and reliability. The drift speed is indicated as a vector plus a numeric reading of ground speed in knots.

Additional information displayed to the pilots are vertical speed and helicopter attitude as well as heading provided by the INS. An import help in using the drift velocity indication as an aid for flight control is the usage of a so called acceleration cue giving a prediction of magnitude and direction of the drift velocity after a predefined period of time. This information is based on the filtered acceleration measurements of the INS.

Also the distance to the predefined landing zone using a so called doghouse symbology is displayed to the pilots.

All symbology is displayed on a head up display (HUD) to allow the pilot flying for keeping a constant outside view. In addition the same information is displayed on a hover page of the multifunction display (MFD) (see fig. 2).

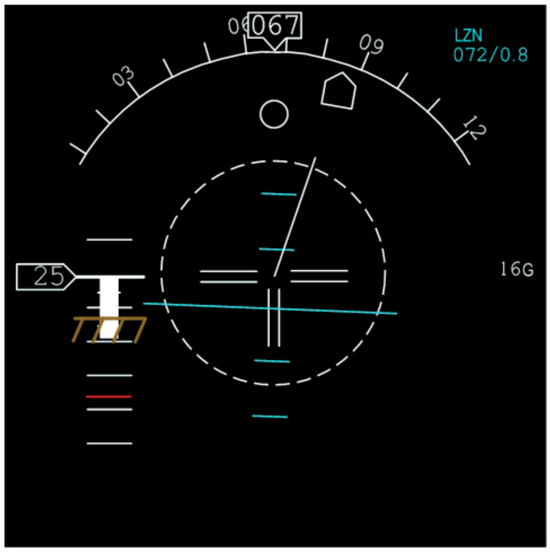

Figure 2: Symbology to be displayed on the MFD including rising deck, VSI, drift vector, acceleration cue and doghouse. The symbology is a further development of the symbology developed in the German SELA project.

As a replacement of the "remote eyes support" of the man on the ramp, the system also comprises two cameras monitoring the landing zone underneath the aircraft. These images are displayed on a separate monitor for the board technician. These camera images also serve as an independent backup and monitoring of the other systems components.

5. PHASE 2 MOVING OBSTACLE WARNING SYSTEM

Experience from operational pilots and incidence reports proved that another threat during brownout landing seems to be friendly or hostile vehicles approaching the helicopter which is still in the air covered by the dust cloud. To a limited extend the same is true for people running into the dust cloud towards the helicopter. During formation landings knowledge about position and movements of the other aircraft hidden by the dust cloud are crucial.

Such a warning for moving object within the designated landing zone (typically 80 m x 80 m wide) can only be provided by a dust penetrating sensor.

The DeViLA sensor uses a rotating mm-wave radar for this purpose (see architecture in figure 3). The radar provides a 2D map of radar echoes within the landing zone and outside at a scanning rate of 4 Hz. This 2D map is processed to subtract self movement of the helicopter and extract moving objects in the landing zone. This is necessary to significantly reduce so called false alarms that may be caused by ground surface echoes.

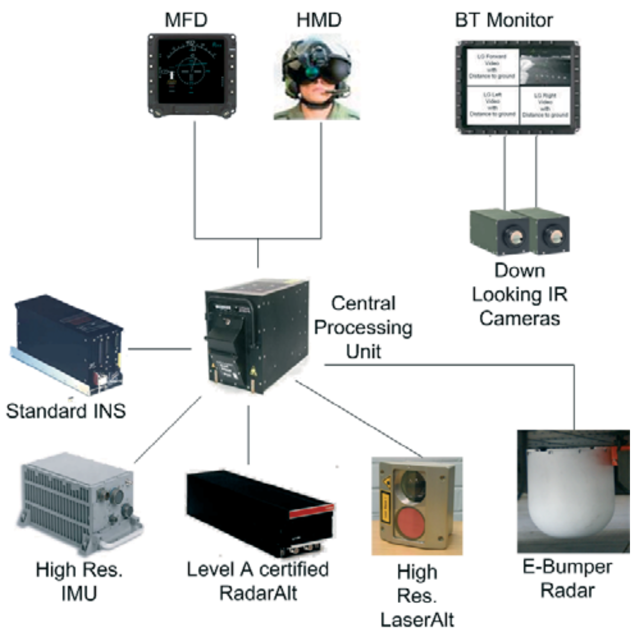

Figure 3: Architecture of the DeViLA concept in phase 2 with an additional E-bumper radar sensor.

Warnings to the pilots are again issued as a symbol displayed on the HUD and the MFD. Depending on the distance between the moving obstacle and the helicopter this warning symbol will displayed flashing at two different rates. Caused by the operational requirements a rather simple symbol (arc of circle) was chosen to avoid cluttering of the display.

6. FUTURE WORK (PHASE 3): ENHANCED SYNTHETIC VISION

For landings in unknown potentially hostile environments a high degree of situational awareness is required. In a brownout situation this can only be provided by a synthetic vision display showing an artificial but unobstructed view of the landing zone and the surrounding to the pilots. The sensor used as the basis for the synthetic vision is a ladar, i.e. a scanning laser distance sensor (see architecture in figure 4). Such a sensor, named Hellas-W, is already in operational use as an obstacle warning system with the German Federal Police. An obstacle warning system for military applications was developed for the NH90 and is currently finishing its final qualification. This sensor provides more than 50,000 single high resolution range measurements per second at ranges up to 1,200 m.

During final approach these 3D data points are collected and mapped to a geo-referenced frame of reference. To minimize pilots workload the 3D data cloud has to be processed before displaying it to the pilots.

A first step in data processing is the separation of ground surface and elevated objects (see figure 5 for illustration). The ground surface is reconstructed as a triangulated net or a high resolution rectangular net, which is compatible with the DTED standard. The achievable resolution goes down to DTED level 4, i.e. down to a grid size of 3 to 4 m. This ground surface can be displayed to the pilot with different means of shading appropriate for the required task.

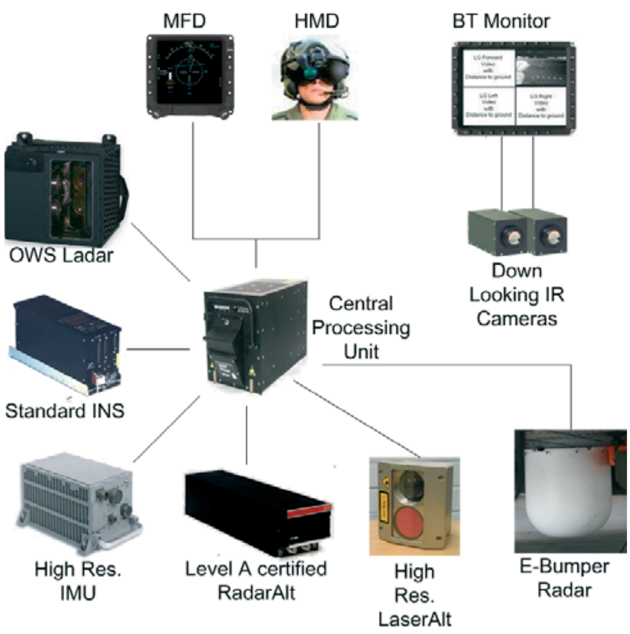

Figure 4: Architecture of the DeViLA concept in phase 3 with an additional OWS ladar sensor used as the basis for synthetic vision display.

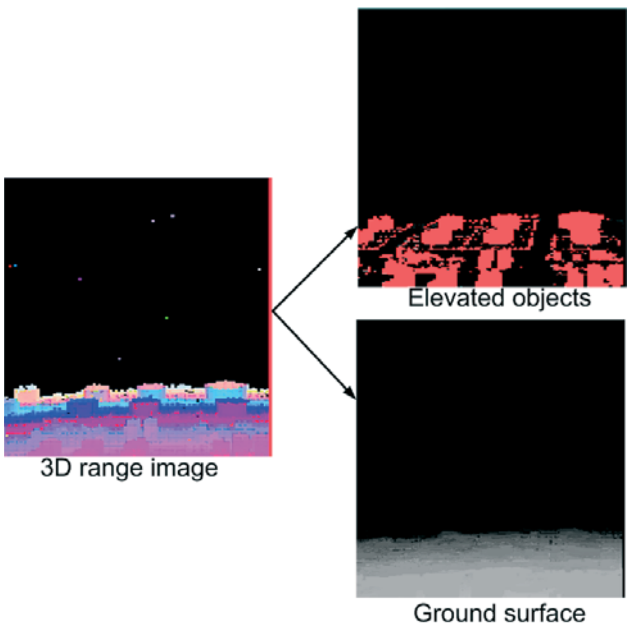

Figure 5: Separation of 3D data sets into ground surface and elevated objects. In the 3D range image distance is coded in pseudo-colors.

On this ground surface classified obstacles, like power lines and poles are displayed as obstacle symbols. Unclassified but elevated objects can be either displayed by a geometric primitive showing their envelope or as 3D voxel clouds.

When used together with a line of sight steerable HUD the 3D data easily allows for denoting an anticipated landing zone during approach. For doing this the pilot focuses the anticipated landing zone and sets a trigger. The system then calculates the intersection of the line of sight vector with the measured ground surface. During the remaining landing procedure the system then can guide the pilot to this designated landing spot.

A crucial point for usage of synthetic vision in a brownout situation is flight safety and following certification. Processing power of currently available graphics processors that may be used in an operational flying environment is several years behind the ones used in PCs. Therefore it is crucial to reduce the amount and the complexity of objects and surfaces which have to be displayed. Another consideration may be to display the synthetic view only to the pilot non-flying to survey the surrounding and preparing for a potential go around.

7. REFERENCES

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[3] Presse- und Informationsstab der Luftwaffe: Unfall eines Helikopters bei der Übung Cold Response, 09.03.22