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A NEW APPROACH TO A SMART HELICOPTER TERRAIN AWARENESS AND WARNING SYSTEM

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There are numerous accident reports giving examples of controlled flight into terrain (CFIT) and obstacle strike accidents of helicopters flying under visual flight rules (VFR). Some of these accidents are preceded by unintended flight into Instrumental Meteorological Conditions (IMC). Examples of challenging flight situations bearing an increased risk of CFIT are limited visibility, darkness, changing weather conditions in combination with complex obstacle environments at remote locations and demanding mission requirements.

Helicopter Terrain Awareness and Warning Systems (HTAWS) assist in preventing CFIT and obstacle strike accidents of helicopters forced to fly at low altitude because of their operational needs. Helicopter Emergency Medical Service (HEMS) flights are just the most prominent part of the flying scenarios for which this is true. Other examples from this non exhaustive list are SAR, border control, law enforcement and power line surveillance.

Current HTAWS systems rely on "customized" database information which has intrinsic limitations on accuracy in height and position, completeness and actuality. The typical absolute height accuracy of the ground surface of a database is approx. 60 ft.

Additionally, these databases are missing completeness of non-ground obstacles as they do not include for instance large trees, small power lines and aerial cableways. Nowadays databases typically include just a fraction of all man made obstacles. One new obstacle class the FAA was pointing out lately are so called MET towers (Meteorological towers), which are used to gather wind data necessary for site evaluation and development of wind energy projects. They can be erected very rapidly and are extremely hard to see. The most serious threat comes from almost invisible wires within the helicopter's flight path. However, database coverage of wires and cables is close to zero. These facts seem to be insufficient for low level helicopter operations and for take-off and landing.

Figure 1 - POWER LINE IN THE FLIGHT PATH OF THE HELICOPTER WHICH ARE ALMOST INVISIBLE

To achieve maximum safety for helicopter operations today's HTAWS consider very broad warning zones around obstacles like big broadcast towers to avoid collisions with all peripheral installations. This approach might deliver sufficient results for transit or transportation flights across country. However, for helicopter operations like HEMS it might be the objective of the mission to land exactly in those restricted areas and the pilot will not profit from the HTAWS system at all. The situation would be even worse because the pilot might be forced to fly or land in an area which is excluded from the HTAWS point of view. Also for operations in urban centers, for example landing in or in front of a stadium, this approach cannot work at all.

Another issue to be noted is the actuality of a database. New construction cranes, wind power plants or even large antenna masts literally seem to spring-up almost over night. Movable obstacles like truck cranes will certainly be missed in any kind of a database. Unfortunately the [DO309] only covers scenarios which can at least in parts be handled with a database used by standard HTAWS. An impressive example of the limits of a database HTAWS system is the NTSB accident report [DEN08FA122] of a Hughes 269 helicopter used for power line inspection. The accident took place at daylight with a visibility of 10 miles. The pilot did not notice a high voltage power line crossing the one they inspected and struck it.

The above mentioned limitations of current HTAWS weighted in the scales of absolute safety might be lethal. The pilot might rely on the HTAWS, it's database and hence the absence of obstacle which has nothing to do with the reality of his mission and might consequently lead to an increased threat for operations supported by HTAWS.

For a reliable CFIT and obstacle strike avoidance for helicopters it is essential to detect any obstacle at any location within the flight path of the helicopter. This can only be done by a highly reliable and accurate active sensor onboard. The new and smart approach as described In this paper constitutes a certified flight laser based obstacle warning sensor with a maximum range of at least 1200 m. The sensor is used for additional real time measurement and obstacle detection of the area in front of the helicopter. This eye-safe obstacle warning system has proven its capabilities even in the most adverse of VFR conditions with different customers world wide, e.g. German HEMS and Royal Thai Airforce. The resulting high precision 3D information, gathered by the sensor, is fused with the database to obtain a thorough basis for the TAWS algorithms in real time covering the complete range of ground and obstacle threats.

Usability of a smart HTAWS system requires an adequate and elaborate HMI interface. Coming from fixed wing aircraft world the [DO309] seemed to have a database map view in mind.

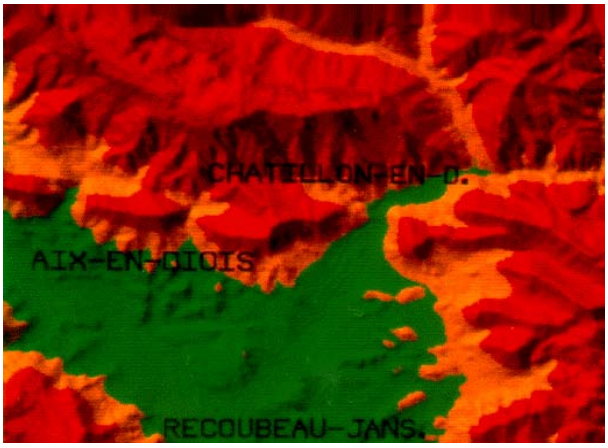

Figure 2 - DATABASE MAP VIEW WITH COLOR CODED ELEVATION LEVEL

Current HTAWS equipments are using this concept which is an appropriate choice for higher altitude cruise flights. For low-level flights in a complex obstacle environment this approach is insufficient. Simple call-out warnings combined with a color coded map view displaying potentially hazardous areas or obstacles only increase pilot's work load in situations where workload is already high. The pilot cannot clearly identify the real source and location of the threat. Only in rare cases the danger results from the obvious single pole on the top of the mountain. More imminent threats are given by everyday complex scenarios where power lines are intersecting each other at different heights above ground with additional threats given by large trees, poles or other structures in the vicinity. An examplary scenario may be the helicopter EMS approach to a remote landing spot or to an urban environment. In this case an insufficient HMI bears the danger to make the pilot believe he has noticed the most dangerous threat, e.g. a high voltage power line, while he is actually missing the real danger (e.g. a second smaller power line partly hooded by trees intersecting the other one perpendicular to the flight path).

Depending on altitude and flight profile the pilots should be supported by different and tailored display modes. While at higher altitudes a map view with a color coded threat display is an appropriate choice, a different concept is applied for low level flight operations. In those phases of flight when the pilot's workload is already very high and the situation regarding helicopter environment is changing rapidly an intuitive display with a pilots view perspective using an overlay of a camera or synthetic vision image with threat indications occupying a large field of view (FOV) is much more intuitive. Accordingly safety and mission success increases significantly by -at the same time- reduced pilot's workload.

A smart helicopter TAWS system – as described in this paper - requires a combined solution of database plus a real time laser based obstacle warning sensor system.

Another question which has to be asked is how to achieve a high level of acceptance. Because only if the added value of the system is obvious and the system is reliable and intuitive enough to reduce the workload the pilot will accept and use the system intrinsically.

Only a HTAWS system capable of issuing reliable warnings of every kind of obstacle in the flight path and any dangerous ground proximity combined with an intuitive HMI approach will ensure to achieve this target and reduce helicopter accidents such tragic helicopter CFIT or obstacle strike accidents in the future.

Augmented data base vs. database

The basis for the generation of smart HTAWS warnings is the fused information of a terrain database (TDB), an obstacle data base (ODB) and the data derived from a Ladar sensor. The TDB typically has a limited resolution only and needs to be augmented or refined in the regions closer to the helicopter by the Ladar data. In this case augmentation is not only given by adding elevations or mounds but rather by increasing effective resolution within the detection range of the Ladar sensor. This may for example be the case when flying along a ravine which seems to be outside the scope of current database only HTAWS systems because the database simply closes the gap of the ravine. Entering a ravine or a similar terrain feature may on the other hand be the operational task of HEMS operation. Nevertheless the database is an excellent augmentation for the sensor data under the most extreme IFR conditions where an optical sensor clearly has its limitations, e.g. when flying (intentionally or not) into a cloud. In these cases the database is an excellent fall back position for an efficient CFIT warning covering all the accident cases listed in the appendix of [DO309].

For obstacles the database is rather used for those outside of the detection range of the sensor. It gives an early prewarning for these obstacles included in the database. If the obstacle is coming closer to the helicopter it is detected by the Ladar and a matching has to take place to avoid doubling of warnings. The more accurate and more complete Ladar data of the obstacle replaces the obstacle data from the ODB. Obviously the Ladar data also includes those obstacles not contained in the ODB like smaller power lines or recently erected obstacles.

HMI Aspects

As stated above a smart helicopter TAWS requires a new approach for displaying the information to the pilot.

Derived from the above considerations there are several requirements which have to be fulfilled for using such a smart HTAWS in an extended flight envelope compared to the known HTAWS applications of today.

- The display for low level flight applications shall be pilot's view perspective instead of a map view as nowadays systems.
- Display of obstacles and ground coming from the database has to be clearly discriminated from obstacle warnings from the Ladar sensor.
- CFIT warning shall be different from obstacle strike warning.
- Obstacles need to be identified in the real world outside view. Therefore an obstacle warning shall be displayed as an overlay over a photorealistic view.
- Obstacle display shall use a color coding scheme derived from the requirements in [DO309].
- CFIT warning shall take into account the current flight path of the helicopter.

The proposed HMI is based on a camera image with superimposed symbology. For longer distances typically out of range of the sensor obstacles from an obstacle data base (ODB) are used and displayed as symbols in an overlay over the camera image. When these obstacles come into the detection range of the Ladar sensor the abstract obstacle symbology gets replaced by pixels of the actual 3D position of potentially high risk objects. The latter is already in operational use as an HMI for the obstacle warning system Hellas-W. Its capabilities and the minimization of pilots workload in critical situations has been operationally proven. Since the obstacle database is by definition incomplete also obstacles which are not included in the ODB are displayed in this so called high risk obstacle display mode. The following images give a short sketch of the idea. First an image with a purely ODB based obstacle symbol is seen, which gets replaced and augmented by the high risk pixel display as soon as the obstacles come into the detection range of the Ladar sensor.

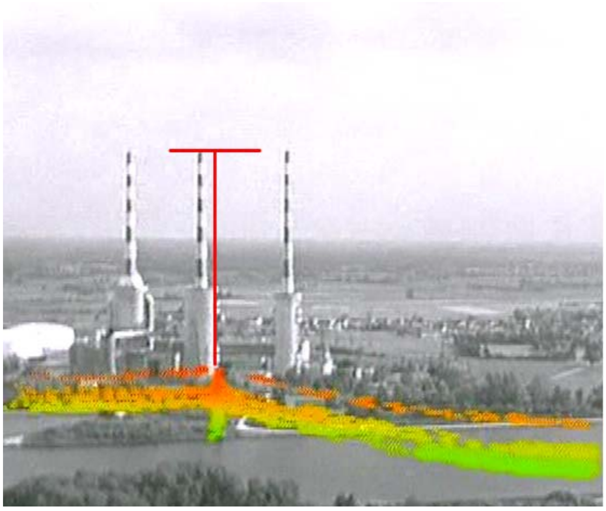

Figure 3 - APPROACH TO A POWER PLANT WITH DETECTED POWER LINE IN THE FOREGROUND AND SMOKE PIPES STILL OUT OF RANGE BUT IN THE ODB DISPLAYED AS A SINGLE OBSTACLE SYMBOL.

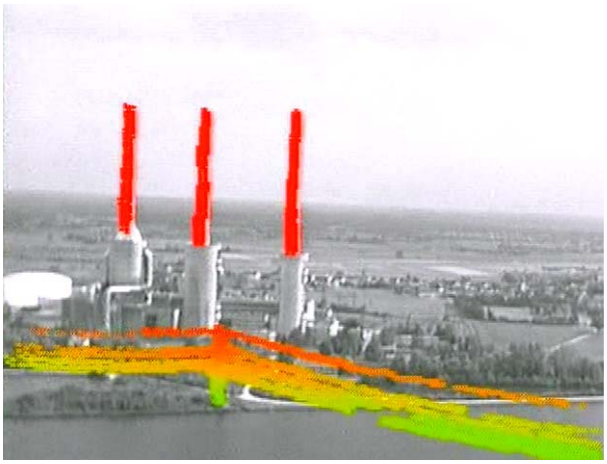

Figure 4 - CONTINUED APPROACH WITH THE SMOKE PIPES ALREADY WITHIN DETECTION RANGE AND DISPLAYED CONFORMAL TO THE CAMERA VIEW.

The classical CFIT warning is replaced by a CFIT warning taking into account the actual flight path of the helicopter including sink rate and turn rate. Therefore a warning is only issued if the helicopter really has a tendency to collide with the ground. On the other hand a warning also takes into account where the helicopter is going to be if it keeps up its current turning rate. This is to say that an obstacle straight ahead of a turning helicopter is much less dangerous than one right on his turning path. This concept is taken care of by calculating an evasion path for three sectors in front of the helicopter based on fused terrain database (TDB) and Ladar sensor data. Wherever Ladar data are available these will overwrite the TDB data to minimize false alarms due to absolute height errors of the TDB. The threat of a terrain is depicted in two forms: first a diamond is shown in each of the three sectors which displacement in the vertical direction gives a measure of threat potential. This sounds too complex for a pilot to correctly act upon but the simple pilots rule is to keep his flight vector above the diamond to avoid the terrain. This functionality can of course be augmented by the usage of a safety margin which can be adjusted for the relevant type of mission. A transfer flight can tolerate a higher safety margin than a control flight parallel to a power line. The following figures show snapshots of this CFIT warning function for an idle case where the safety margin (in this case 300 ft AGL) is not touched and a case where the mountain on the right hand side needs attention to avoid violating the predefined safety margin.

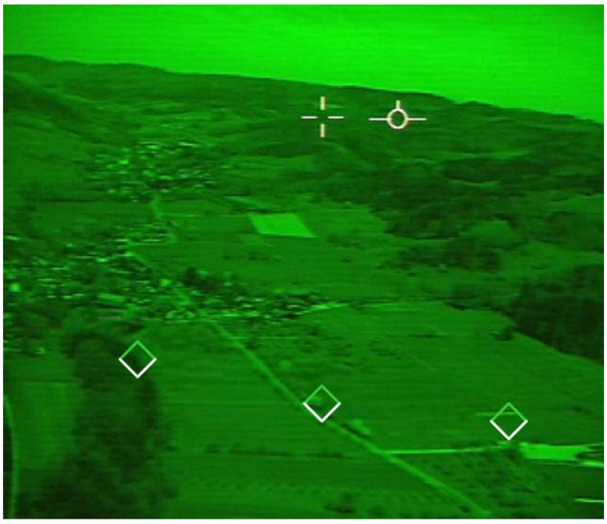

Figure 5 - CFIT WARNING WITH RISING DIAMONDS FOR A CASE SUFFICIENTLY ABOVE THE PREDEFINED SAFETY MARGIN OF 300 FT AGL.

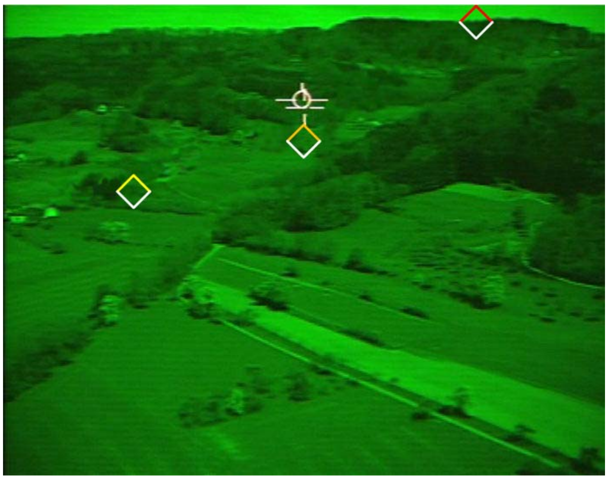

Figure 6 - CFIT WARNING WITH RISING DIAMONDS FOR A RISING TERRAIN WHERE THE HELICOPTER GETS CLOSE TO THE PREDEFINED SAFETY MARGIN OF 300 FT AGL STRAIGHT AHEAD AND CANNOT TURN RIGHT WITHOUT VIOLATING THE SAFETY MARGIN.

References:

[DO309] RTCA/DO-309 - MINIMUM OPERATIONAL PERFORMANCE STANDARDS (MOPS) FOR HELICOPTER TERRAIN AWARENESS AND WARNING SYSTEM (HTAWS) AIRBORNE EQUIPMENT, RTCA, Inc., March 13, 2008

[DEN08FA122] NATIONAL TRANSPORTATION SAFETY BOARD – FACTUAL REPORT AVIATION, NTSB ID: DEN08FA122