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RISK ANALYSIS FOR UAV SAFE OPERATIONS: A RATIONALIZATION FOR AN AGRICULTURAL ENVIRONMENT

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Abstract: The road to the automation of the agricultural processes passes through the safe operation of the autonomous vehicles. This requirement is a fact in ground mobile units, but it still has not well defined for the aerial robots (UAVs) mainly because the normative and legislation are quite diffuse or even inexistent. Therefore, to define a common and global policy is the challenge to tackle. This characterization has to be addressed from the field experience. Accordingly, this paper presents the work done in this direction, based on the analysis of the most common sources of hazards when using UAV's for agricultural tasks. The work, based on the ISO 31000 normative, has been carried out by applying a three-step structure that integrates the identification, assessment and reduction procedures. The present paper exposes how this method has been applied to analyze previous accidents and malfunctions during UAV operations in order to obtain real failure causes. It has allowed highlighting common risks and hazardous sources and proposing specific guards and safety measures for the agricultural context.

1. Introduction

The use of new technologies and techniques in the agricultural environment has arisen in the last decades. This remarkable increment, named Precision Agriculture (PA), has allowed reducing the use of pesticides, maximizing the irrigation efficiency or having an actual knowledge of the crop status. A significant part of these advances lies in the aerial imagery. This possibility is provided by several means, from satellites to airplanes, each one with its own advantages and disadvantages. Nevertheless, for some years ago, both the agricultural and robotics societies have assisted to the mini Unmanned Aerial Vehicles (mUAVs) development. Due to their large availability, reduced price and great flexibility, they are considered to be the best alternative for this kind of applications.

However, in spite of all their large set of advantages, they present also inconveniences. The main one is derived from the relative youth of these devices, which makes to have not a solid legal framework neither a great robustness. It inevitably implies risks during operation, with a great potential damage capacity due to their air-vehicle condition. In this work, these risks have been analyzed, presenting an overview of the main hazards for UAV operations in agricultural tasks.

2. Risk analysis

2.1 Legal framework

The applicant legislation is based on a generalist assessment of potential hazards, so –apart from being compulsory- supposes a first step in the risk analysis. Nevertheless, since the Unmanned Aircraft Vehicles are relatively new, this normative and legislation are still under current development (JAA/EUROCONTROL, 2004). Diverse organisms -both national and international; both official and non-official- are implied in this development. The US' FAA and the European EASA, together with EUROCAE, JARUS and some other organizations, reached a consensus in 2005 [6] to define formal policy for UAV certification and a clear regulation for the National Air Space (NAS) management. Nevertheless, this agreement only considers large and heavy drone, leaving the Light UAVs (UAVs under 150 Kg) regulation to the corresponding national Air Authorities.

Apparently, the most advanced frameworks for regulating the UAVs operation are present in UK, Australia, Austria and France (P. van Blyenburgh, 2008). Nevertheless, they have used different classifications for organizing the drone's regulation, making harder the standardization process. The common points in the on-going proposals have considered mUAV to those aerial vehicles lighter than 7/15Kg, 150m maximum height and flying under Visual Line of Sight (VLOS). On that basis, they have limited the maximum energy on impact, the maximum flight speed, distance to populated areas and altitude, as well as the airworthiness requirements.

2.2 UAV specific methodology

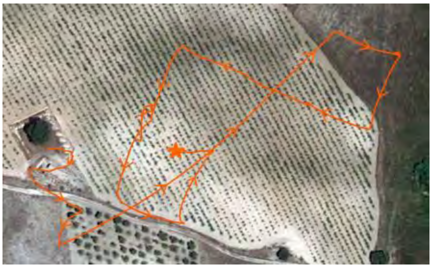
After a careful study of both the specific and general regulations, it has been considered that current normative is not clear enough (K. Hayhurst et al, 2006). In spite of many groups and organisms are working on it, a common regulation does not seem to be available in a short/medium period, even less if expecting concrete recommendation for agricultural environments (R. Clothier et al, 2007; P. Hokstad et al, 2006).

In this sense, in (Sanz et al., 2012) is described a three-step architecture specific for this kind of missions. It is based on ISO 31000 normative and aims to enhance the evaluation overcoming the context-limitations and deficiencies observed. The first step corresponds to the Risk Identification (RI), including not only the limitations imposed (physical, temporal, behavioral and environmental restrictions), but also the potential hazardous situations and breakdown sources. In this regard, both external and internal sources have been considered, distinguishing the hazards according to their nature.

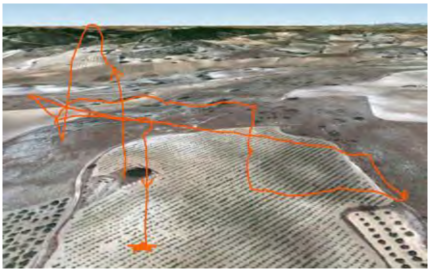
The following step is where all these identified risks are evaluated according to the application: Firstly, this risk assessment method enhances the factors considered in ISO 31000 (Seriousness of the damage and probability of occurrence). It is complemented by using parameters like the affiliation of the agents involved in the event, or by extending the severity-of-the-injures rate. Secondly, as far as this step allows weighting the importance of some parameters, it is possible to adjust the assessment for an agricultural environment. It allows the final step (Risk Reduction, RR) to decide where to intensify the effort: design process, prevention/protection methods or safety procedures.

3. Agricultural environment: a case of use

This architecture is not only valid for analysing the potential hazards, but also for evaluating an accident. Figure 1 presents the partial layout of an imagery mission that resulted in disaster, where it is possible to distinguish a sudden fall.



a) Top view of the path



b) Isometric view of the path

Fig. 1. Real mission layout

Following the three-step methodology for analysing the risk, the first step was to analyse identify the potential hazards. On the one hand, those ones derived from the system restrictions: In relation with the physical limits, it was checked that the payload (camera, 126gr) was balanced and that not overcome the maximum Take-Off Weight (MTOW, 550g of payload). It was also checked that the wind speed (11 Km/h) was suitable and the battery charge.

Regarding to the temporal limits, it was assumed the use of the battery (6h) and the motors (around 10h the older one). The mission’s duration (14min) was under the theoretical limit (20min) and the link quality was good. As well, in reference to the environmental limits, it was considered that the closer airport or military facility was dozens of kilometres away, and the nearest populated is at 2.5 Km far from the test area. Besides, the higher relative altitude of the mission was 55m, below the non-segregated air space level, and no body, apart from the pilots, was present in the test area. The GPS signal was excellent, as well as the climatological conditions.

Finally, in respect of the behavioural limits, the autonomous mode was set, supervised by an expert pilot.

On the other hand, also the hazards derived from breakouts were considered, focusing in the controllable stages (Preparation, start-up, maintenance and operation). Among them, Assemble, Adjustment, Interferences and Conservation processes where estimated as the most hazardous ones, so a special attention was paid on these processes. Nevertheless, as far as the accident happened, telemetry data have been used to focus on the analysis of possible breakdowns: Figure 2 presents the charts associated to the linear speed (V, green), the relative height (rH, red) and the acceleration (A, blue), all of them along the time and referred to the Z axis. It is possible to observe that during the mission, *V* and *A* are kept almost constant around 0, as could be expected since the *rH* is also stable. It could be also observed that from t=6'16'' to 6'19''there is a small descent, non-compensated by the quadrotor yet. This could be due to some changes in the orography, a maintained wind or a battery status warning. Nevertheless, the critical point is placed in t = 6'20', where the drone suddenly changes not only in terms of *V* and *A*, but also its attitude and angular rates.

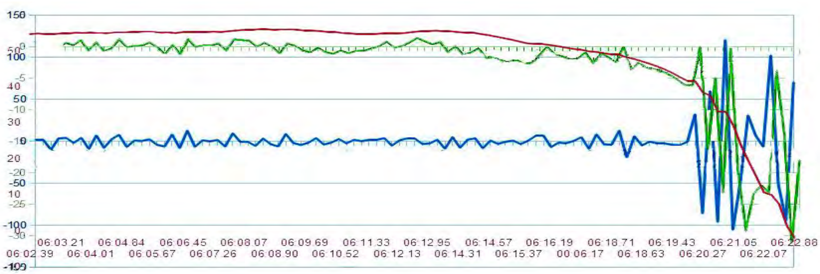


Fig. 2. Partial flight telemetry for breakdown analysis.

Since these changes do not compensate the drift, few problems could be considered: errors in the control/navigation system, failures in the link stream (both GPS and communications), mechanical breakdowns, battery dead or unmanageable weather conditions. The three last options are not probable, since the telemetry was received without problems, highlighting a good GPS signal; the battery warns when it is exhausted and enters in an emergency landing procedure; and the weather conditions where fine. Only control and mechanical troubles remain, and as far as their effects are quite similar – unbalance of the system's equilibrium- is really hard to distinguish between them. Even so, given that *V* and *A* seems to be saturated trying to counteract the fall vector -changing to the contrary when the drone turns- could be supposed that the error has a physical nature. The driver/shifter, the propeller or the rotor could be the responsible of the accident.

Further analysis showed that, although broken due to the impact, the propeller was steadily fixed (and it is not probable to be broken during the flight). As well, the later test showed that the rotor worked properly. This leads to set that the driver –burned- caught fire during the flight.

4. Conclusions

As could be expected, breakdowns and failures could be present despite of the precautions and methodologies applied. In this sense, only physical guards, such as a parachute or a safety ring, or redundancy systems (e.g. voltage regulators and limiters), could increase the safety figure, by warning in advance or by limiting the potential damage to be caused.

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