Development of an Indoor Drone Designed for the Needs of the Creative Industries

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***Abstract*—**With this contribution, we want to show how the AiRT system could change the future way of working of a part of the creative industry and what new economic opportunities could arise for them. Remotely Piloted Aircraft Systems (RPAS), also more commonly known as drones, are now essential tools used by many different companies for their creative outdoor work. However, using this very flexible applicable tool indoor is almost impossible, since safe navigation cannot be guaranteed by the operator due to the lack of a reliable and affordable indoor positioning system which ensures a stable flight, among other issues. Here we present our first results of a European project, which consists of developing an indoor drone for professional footage especially designed for the creative industries. One of the main achievements of this project is the successful implication of the end-users in the overall design process from the very beginning. To ensure safe flight in confined spaces, our drone incorporates a positioning system based on ultra-wide band technology, an RGB-D (depth) camera for 3D environment reconstruction and the possibility to fully pre-program automatic flights. Since we also want to offer this tool for inexperienced pilots, we have always focused on user-friendly handling of the whole system throughout the entire process.

Keywords—Virtual reality, 3D reconstruction, indoor positioning system, UWB, RPAS, aerial film, intelligent navigation, advanced safety measures, creative industries.

I. Introduction

NOWADAYS, aerial film or photography is an indispensable resource for the Creative Industries (CIs) since it expands their creative possibilities. The possibility of filming special shots from different angles and heights is a benefit for every photographer, if they can offer such a service in their portfolio. Camera men need to tilt or panning in movies when filming actors stepping out of a car or leaving a building. In the past, for shots like these, helicopters needed to be rented which resulted in high costs and only financially sound companies could afford them. Or, if the scene did not require high angle shots but just a shot from moderate heights, scaffolds, jibs or lifting platforms were usually hired or bought [1]. With the rise of the drone industry and the resulting drop of acquisition costs for those "flying robots", the CIs are employing more and more drones for aerial footage. This is quite easy to understand, since:

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- Costs are manageable
- Bulky infrastructure can be removed (scaffold, jibs, cable cam …)
- Drones are less invasive (they just fly out of the set and are removed)
- Drones lower the risks for the camera operator (no need to climb up a scaffold, lifting platform …)

However, professional drone use by CIs is limited to outdoor applications.

A. Barriers to Use Drones Indoors

Existing drones lack a precise, robust and affordable indoor positioning system (IPS), as well as advanced safety features. Everyone who has ever flown a drone understands why positioning systems are so important for drone flights. When filming outdoors, drones use a GPS, which not only helps the operator locate the drone and program flight paths, but also helps stabilize the drone and avoid drifting issues. This is an important factor for every camera man. So here is the problem: GPS localization does not work indoors. Firstly, the signal is too subdued, and secondly, even if it were not so, the GPS's precision is far too inaccurate with a meter range margin of error. Be that as it may, CIs would also like to use drones indoors, but there is not safe and affordable technology available for the CIs to do so. The only technology available to work in confined spaces is the following possibilities: The first, motion capture system, has a very reliable and precise (mm-range) IPS. However, this system is very expensive (>200,000 €) and it needs many auxiliary devices, which as a result makes setting up time consuming. The other, vision position system, is affordable; however, how it functions depends on its surroundings. For instance, on transparent or reflective surfaces the device might malfunction.

B. AiRT Project Goal

To overcome these issues, AiRT project [2] (Arts indoor RPAS Technology Transfer) will include a new IPS with cm range precision based on ultra-wide band (UWB) technology with an intelligent flight control system. Moreover, active and passive safety measures will be integrated, and professional camera control is included to ensure high quality filming. Given the target market, small CIs enterprises, special emphasis is also placed on simple handling and low acquisition costs. Offering such a tool for the CIs, especially SMEs, and other markets will allow companies to offer new services, which in turn will increase their chances to grow within the European and international market. In order to achieve this ambitious goal, the project was divided into seven specific objectives, as follows:

1. Analysis of CIs needs, ethical/security issues and risk analysis.
2. Adaptation of Pozyx's IPS for drones (see below).
3. Graphical user interface for drone indoor navigation.
4. Adaptation of drone according SO1 (CIs' needs)
5. Integration and validation of the different components.
6. Demonstration of the final product.
7. Elaboration of a proposal for a European legislation for indoor drone safety and security

II. Methodology

To achieve the main goal and the specific objectives, the design thinking method has been applied (Fig. 1). In the phase 1, observation, information was obtained through focus groups with users. This means that strategically chosen experts from 13 different CI sectors have been invited to guarantee that all their needs were detected. While forming those groups in the three participating countries (Belgium, Spain and UK), also special attention was paid that experienced drone pilots from the CI sectors participate. Within the AiRT consortium the CI sector is represented by the Creative agency *Clearhead Media* (UK) and by the *Universitat Politècnica de València* (UPV, Spain). For this reason, the choice of the participants for the focus groups and the evaluation of the results could be classified as successful. Like usual, information was codified and then, in the second phase (synthesis), analysed using qualitative analysis software. The elaboration of real use cases, comic strips describing the future use of the AiRT drone, helped to adapt the AiRT system as much as possible to the needed characteristics. In this phase, also important information to define better the customer segments and the value proposition was obtained. In phase 3, ideation, this information was used to debate about the different features to be added to the drone prototype, depending on the value for the customer, the cost for the partner who will manufacture it and the main technical difficulties to deal with. For this last design thinking phase, the Participatory Action Research (PAR), which is an approach that emphasizes participation and action of the invited CI experts, will be employed. As it can be seen in Fig. 1, this last phase is the testing phase of the final product, developed during AiRT project (of course future improvements/optimisations will be integrated). The testing phase will be carried out by the same participants from the focus groups, so they can judge whether AiRT meets their expectations and fulfils their detected needs.

Fig. 1 Detail of the Design Thinking methodology used in the AiRT project. Source: own elaboration adapted from [3]

III. Work Performed

The AIRT project's methodology is based on design thinking, where the participation of the CIs is present throughout the process [4].

In the first phase, concerning the identification of needs, three focus groups were held in Spain, the United Kingdom and Belgium. From these meetings, we were able to obtain information from thirteen 13 sectors of the CIs, where 40% of the participants were drone pilots. As a result, we obtained the needs analysis, the ethical issues and the risk analysis through the qualitative content analysis method and the social network analysis method [5]. The results have been incorporated in the base design of the drone, the development of the European Policy book [6] and the redefinition of the exploitation plan. On the other hand, in the second phase, from the synthesis of the information obtained in the focus groups and the specifications included in the grant agreement, we wrote a script and a breakdown of that script which were used to develop a storyboard representing the use of AIRT system in different creative settings, which allowed us to convey our main ideas more clearly.

In the third phase, by using the storyboard, we were able to extract the requirements to define the functionalities of the Airt system, which include the GCS (Ground control system) software, the intelligent flight control system and the final design of the drone.

Currently we are in the fourth phase. All of the components of the AIRT system are now ready and have been tested, with the system integration and technical validation in a relevant environment pending.

In the last phase, we will do a demonstration of the AIRT system with the collaboration of the CIs. Through the use of PAR [7], we will carry out the demonstration in real surroundings chosen by the users. Once the demonstration has finished and the results have been processed, the AIRT system will be presented in a workshop, not only to the CIs but also to other sectors of the industry, which will help the launch of the drone in the European Market.

IV. Progress Beyond the State of the Art

Four major innovations of the AiRT Project have to be highlighted:

A. Indoor RPAS

RPAS with innovative features are especially designed for the needs of CIs in indoor environment in filming and photography. It integrates an RPAS frame with passive safety measures and a fully automated flight control system with user-friendly features and functions such as return-to-home mode, proximity sensors, fail safe, encrypted communication. It also integrates other active safety features such as (1) a sophisticated IPS based on ultra-wideband (UWB) technology, with newly developed algorithms, which gives precision of few centimeters and it is cost effective. (2) An RGB-D camera on board which together with software advance algorithms allows 3D reconstruction of the space prior to the flights for filming. This allows to pre-program the flight paths and perform intelligent flights and moving of drone and allows also to repeat filming/photography sessions by using the same paths. The system will integrate a 4K camera with interchangeable lenses, able to turn in 360^0. The final system will be affordable for CI SMEs compared to other existing solutions and will also generate new creative possibilities for them. (3) A new flight mode system has been developed. In total 9 modes providing users with different degrees of freedom, from totally manual flight to totally autonomous flight, and a number of intermediate flight modes with configurable restrictions have been detected and will be integrated into the intelligent flight system (such as flight at a given altitude or keep a distance to the object in front). Thus, detection of a certain mode has a direct impact on the functionalities available for the operator and may completely limit its influence on the drone, e.g. in case of emergency (IPS datalink loss, radio contact loss, engine failures or low battery), or allow total control like in manual flight (proximity sensors off, no-flight zone deactivated, no flight plan used).

B. Indoor Positioning System (IPS)

The positioning system is based on wireless radio technology called UWB technology and is suitable for indoor environments. It is an improved hardware solution, adapted to RPAS, which consists of two types of modules (anchors, which are the fixed infrastructure of the system and tags, which are to be attached to the device to track) and achieves accuracy of a few centimeters in all axes. It provides accurate positioning and motion information and enables accurate navigation of robots or drones indoors, thanks to the improved update rate of up to 240 Hz and the 4-antenna approach with customized algorithms. It is also useful for other applications such as tracking of objects and persons. Moreover, an auto-calibration system is introduced. Pozyx implemented an algorithm which calculates the auto calibration error of the IPS and detects which anchor(s) are responsible for the encountered error. This helps the user to detect error sources and to rearrange the anchor setup and thus improve overall accuracy/precision.

C. 3D Mapping Software for Indoor Environments

The software allows 3D reconstruction of the indoor space (3D model). The 3D reconstruction is achieved in real-time from data that were collected from the RPAS prior to the filming process. It uses an onboard RGB-D camera and data from the IPS adapted to the RPAS based on UWB technology, which improves reconstruction precision. Additionally, the transmission and visualization of the image is in real time. Therefore, the user can move around the captured environment to study in detail the different areas of the scene while it is being scanned.

D. Multiplexers Designed for RPAS Indoor Adaptation

Due to the different requirements of the users, the RPAS must be able to fly in different modes, from a completely controlled one by a pilot (manual) to a fully automatic one. In all flight modes safety is top priority, therefore there must be total control while changing from one flight mode to another one. The responsibility for these changes relies on the multiplexers. In the current design, two multiplexers are integrated: one responsible for the flight control (selects which signal is sent to the Flight Control System (FCS)) and another one in charge of the recording control, acting on both the recording camera and the gimbal. The flight multiplexer selects which signal should be sent to the FCS, choosing between the commands of the manual control (RC command) and the automatic control via the OCS (On Board Control System). In addition, the flight control multiplexer monitors the changes from one mode to another, in order to switch to "emergency mode" if an error in the mentioned change is detected. The recording control multiplexer works in a similar way (depending on the flight mode), when recording must be performed. In this case, the recording control multiplexer allows to change safely between a camera operator and the camera control done by the OCS.

V. Potential Impacts

Apart from technological innovations, AiRT contributes to the economic growth of CIs and thus to European economic prosperity (1), and addresses socially relevant topics (2):

1) The drone market poses a real opportunity to foster job creation and a source for innovation and economic growth. Nevertheless, up to now, all this economic potential is only accessible for CIs when using RPAS outdoors, as the few existing indoor RPAS on the market do not fulfill their needs. Since our drone responds to these needs, it will open new perspectives and possibilities for indoor footage within the EU market for the CIs As a result, AiRT will contribute to creating employment in the CIs sector, especially for small companies and also to other sectors of the industry.
2) The AiRT system helps to suppress risky auxiliary means and thus improves the safety of the workers. Cameramen will not need auxiliary devices which present unnecessary risks to their safety or the safety of the workers on set.

VI. AiRT Project

To achieve the overall goal and those tasks, AiRT consortium is composed of ***Pozyx Labs*** (IPS experts), ***Clearhead Media*** (Creative agency), ***AeroTools-UAV*** (drone manufacturer) and the ***Polytechnic University of Valencia,*** UPV (ICT, CI and business model experts).

AiRT partners have been carefully selected with the main objective of a) being part of the CIs with a well-developed network of contacts within this community, b) having experience in aerial filming, c) being specialist in RPAS design, manufacture and elaboration of its operation systems, with d) large experience in marketing, e) providing precise and customizable indoor positioning solutions and f) having a wide expertise in 3D map modelling. All these qualities were decisive while forming AiRT consortium, in order to offer a novel indoor RPAS solution. Accordingly, AiRT consortium brings together a group of four partners from three European countries with a complementary and outstanding range of experiences, skills, competences and resources essential to achieve the innovation objectives as well as a successful and sustainable communication, dissemination and exploitation of the project results.

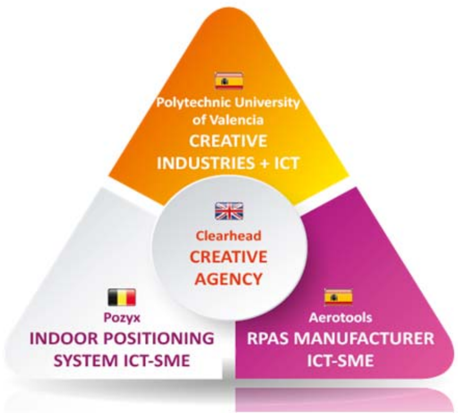

Fig. 2 Detail of the composition of the consortium in the AiRT project

Pozyx Labs from Belgium is a SME which provides indoor and outdoor hardware and software solutions for accurate localization. Their IPS is based on UWB technology, which provides cm-precise localisation, is very robust and can be included at reasonable costs. In AiRT project their main task is to adapt their system to the specific requirements for drone indoor flight.

From the perspective of specialists in creative activities and aerial filming, AiRT counts on Clearhead Media LTD (Clearhead). Clearhead used of drones as a professional filming tool for outdoor purposes already and are aware of the issues indoor, thus in confined spaces they could not employ drones up to now. Hence, Clearhead with its very well developed network within the CI community, helped to set up the focus groups in the three participating countries (Belgium, UK and Spain) with the goal to get as much information as possible from a primary source analysis. This task was supported by the UPV, counting within their infrastructure on both experts with large experience in drones (and its use) and specialists in setting up focus groups (see below UPV). Furthermore as target group and end-user, Clearhead are crucial to guarantee that the needs of the CIs are fulfilled.

AeroTools are specialized in developing drone systems according to different applications and purposes. Accompanying project research and the results of the focus groups, helped to build the basis to specify the prototype characteristics and finally build the firsts prototypes. In interiors, safety is even more important than outdoor, because intended obstacles must be taken into account (tables, chairs, lamps etc.). Therefore, they include advanced active and passive safety measures.

The project coordinator UPV is participating as an interdisciplinary team, the *Research Micro-cluster (MCI) Globalization, Tourism & Heritage*. They combine experts in CIs and count on a large experience in drone use on one hand, an on the other hand experts within different ICT sectors. Specialist experts in Computer Graphics, Augmented Reality and Advanced User Interfaces from the Computer Engineering Institute (ai2-UPV), with support from Pozyx elaborated a virtual environmental map (VEM). This helps to position to drone in a 3D indoor space and identify and avoid obstacles. Moreover, they design the Graphical User Interface (GUI) specification/requirements, with special focus on a user-friendly experience. The experts in CI (Faculty of Fine Arts) together with the Management (Faculty of Business Administration and Management) elaborated the AiRT design thinking method and took care that need analysis was correctly conducted and evaluated. This gave the basis for the a) need, ethical issues and risk analyses, b) the GUI interface and the development of advanced functionalities, c) the elaboration of a European policy book and d) the enrichment of the Exploitation plan. Moreover, the MCI supports the CIs to offer new business opportunities.

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