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SIMULATION SYSTEMS FOR UNMANNED AERIAL VEHICLES

In the presented article authors will discuss the most important types of solutions dedicated for simulation and training of unmanned aerial vehicles crews used on the civil and military market. The article will also discuss the directions of systems development and the emerging possibilities of modern simulation, Image Generation and visualization methods that can be successfully used in modern simulation systems dedicated to training crews, maintenance teams and commanders using Unmanned Aerial Vehicles. The techniques presented, such as augmented reality, extending into the civilian mixed reality market or the "classic" virtual reality due to its unique capabilities, can be used in many ways, which the author will try to bring in discuss it potential fields of use and profits from the use of individual methods.

KEYWORDS

simulation, training, augmented reality, virtual reality, military simulation,

INTRODUCTION

The rising availability and lowering costs of basic platform purchase allows civilian users to widely use of UAV platforms for variety of tasks from fully professional to amateur use, this translates into reducing the level of user awareness and skills in its basic use. Running initial training using flying platforms carries a number of threats for platform

user, bystanders, payload and platform. Amateur and professional users use UAV with specialized payload in dense populated areas, during mass events or in the close area to critical infrastructure.

In opinion of authors the key to popularizing safe use of UAV in civilian applications is popularization of training and simulation based on modern technologies that will increase training attractiveness and availability for every potential system user.
The number of small hobbyist drones registered in the United States is projected to grow from 1.1 million units in 2017 to 2.4 million in 2022, according to the Federal Aviation Administration (FAA). Commercial (small non-model drones) registrations totalled 110,604 in 2017 and are projected to grow to 451,800 in 2022. Except for the eight-month period from May 2017 to December 2017, the FAA required owners of hobbyist and commercial drones weighing more than 0.55 and less than 55 pounds to register them and mark them with a registration number, beginning December 2015. Larger drones—weighing over 55 pounds—must register with the FAA as traditional aircraft. [6]
In this paper authors will focus on the use of modern visualisation and simulation technologies in the training of operators of Unmanned aerial vehicle utilizing standard or classic human-machine interface of Unmanned Control Station (UCS).

1. CURRENT SITUATION DESCRIPTION IN SIMULATION AND TRAINING FOR UAV.

Training systems using simulation for unmanned vehicles have been successfully used since the beginning of their professional use for military and national security purposes. According to Unmanned System domain and main system purpose training systems focus on different set of skills and building trainee situation awareness methods, used training systems vary for platform and payload operators.
Depending on the domain, main system purpose, system configuration and it`s payload functionalities dedicated configuration of human-machine interface is used. In military application dedicated station with LCD screen, dedicated controls and radio module is the most efficient way of providing clear and uninterrupted connection to remotely controlled UAV. Civil market after short period of military application approach to system controls, have adopted everyday use communication platforms such as smartphone or tablet to allow operator to control platform flight and it`s payload use. The interface used for communication with system operator dictates visualisation and platform simulation method and limitation.
Low UAV running costs particularly smaller units decides that potential system operator avoids expensive simulation systems that often may be more expansive than UAV platform. Because simulation systems in principle are always result of compromise between simulation fidelity, system price and it`s availability dictated by required system basic training task, some of potential unmanned systems users decides to train on original UAV. However widespread cases of platform crashes because of incorrectly assessing distances by operator or inaccurate speed and manoeuvrability operations, show that training with dedicated interactive tools may have significant impact on civilian UAV platforms safe usage. Popularization of simulation games industry and open source projects providing training possibilities for UAV operators confirms that problem is current.
Currently, in the armed forces and intelligence agencies for the training of pilots of unmanned aircraft are used the training systems with a different configuration and a reality level. It is depending on training purpose, category, style of controlling and using of payload.

Fig. 1 UAV visualization - MetaVR

Depending on the above factors, the necessary level of reality mapping and completion of the training system are selected accordingly. Training goals that should be achieved during the use of the system have an impact on the use of the training system. In the case of pilot training, the level of pilotage autonomy of the aircraft is crucial. In the case of payload operator, the key is the purpose and required pilot-payload operator co-operation in the training cycle.

Fig. 2 Students from the Non-Commissioned Officer (NCO) Academy train in the Universal Mission Simulator (UMS). Photo: U.S. Army

Showed example on figure 2 of Universal Ground Control Station (UGCS) Embedded Trainer used by the U.S. Army for Shadow, Grey Eagle, Aerosonde and Hunter.
The simulation systems used to train teams using unmanned systems offer trainings designed for pilots, payload operators and mission officers. Thanks to such systems,

training can take place on many levels, not only training of piloting and piloting aircraft, but also payload operation, and mission management – this model of training is required for the preparation of teams using the system based on unmanned aircraft. The software includes also a number of classic features for this type of solutions such as:

- Simulation of an aerodynamic model of an aircraft with a differentiated from the training objective of the reality mapping quality,
- Possibility to use original Unmaned Control Station
- Simulation of sensors and a vision system,
- Interoperability using DIS or HLA protocols,
- Display using dedicated or COTS image generators.

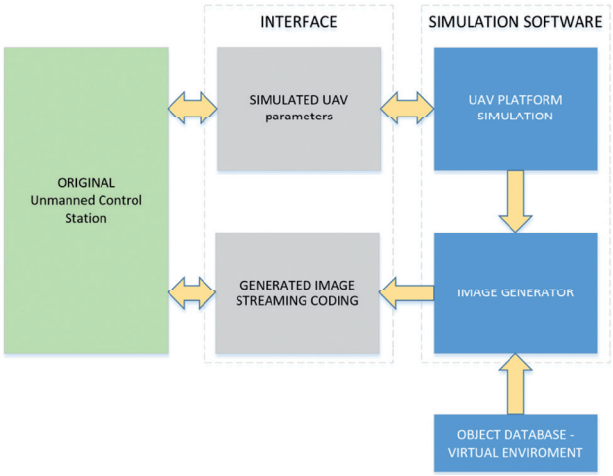

Fig. 3 Simplified UAV simulation system architecture.

The embedded solutions in the control station are also successfully used, it allows training of operators of such unmanned systems as Gray Eagle, Shadow or Hunter. These systems allow to work in cooperation with other units, such as JTAC. It is possible thanks to the use of the DIS protocol.

On the market there is also different software systems for simulation of Unmanned Aircraft.

In addition, the software enables the training of pilots and operators at home. The use of commercial simplified simulation systems significantly affects the safety of flights and reduces operator training costs, not only for the purchase of BSP, but also servicing of aircraft.

2. NEW SIMULATION SYSTEMS DEVELOPMENT DIRECTIONS - EMERGING TECHNOLOGIES AND ITS APPLICATIONS

The increasing access of commercial technologies (including gaming) to the market of professional simulation also affects the software and equipment used by the constructors and software developers of training and training systems for unmanned aerial vehicles.

Depending on the purpose and methods of controlling the unmanned vehicle in pilot training, you can successfully use a number of commercial technologies developed for the electronic entertainment market - the broadly defined computer games industry.

For UAV controlled with the use of a human-machine interface containing the image from one camera and used in the operator's visual line-of-sight, an excellent training solution will be the use of virtual goggles or augmented reality.
First integration of UAV control systems with payload and dedicated Virtual control software for Virtual Reality Headset with position tracking started in year 2014. Today you can buy UAV kits with controllers and HMD goggles that allow you to simultaneously control the platform and camera. It simplifies the use of BSP for professional purposes and significantly eases the implementation of simulation systems on the aforementioned platform The above-mentioned systems, due to their design and basic equipment, can easily be prepared to perform the function of a simulation system or they can successfully implement the concept of a built-in simulator and supplied as part of a basic package.

Fig. 4 The Parrot Bebop 2 FPV set.

Design and implementation of simulation and training system for UAV adopted to be used with VR headset for system control, is very similar to classic simulation concept. And this kind of simulation system won`t be concerned in this paper.

2.1 USING VIRTUAL REALITY TECHNOLOGY IN SIMULATION AND TRAINING

VR in the current and most popular form takes the form of a headset. It consists of a high resolution screen and two lenses in front of the user's eyes. This set is connected to a powerful PC workstation, which generates a virtual image and sends it to the VR headset. Thus, the user is obscured by the entire field of view, which ensures deeper immersion. However, when using VR, there are two factors that affect the comfort of use: resolution and delays.
Due to the fact that the image is viewed through the lens from a very short distance the projection resolution is a big problem. The best available sets may offer a resolution of about 2K. However, this is not a fully satisfying value because currently sets which are being developed, in the future will allow displaying the image even in 8K. Unfortunately, increasing the resolution also entails a significant increase in the requirements for the

rendering computer which sends the image to the headset. An important parameter of the display is also display rate. Modern VR kits have 90 Hz refreshment displays, but we can expect that this value will increase in the next years and with new generations of devices. This affects the flickering of the image, which in the long-term use is not comfortable.
It is also worth mentioning that the headsets are equipped with sensors that allow you to move the head movements to the virtual environment, enhancing the experience. However, it is estimated that delays affecting primarily computer performance should be no more than 20 ms. At higher values of 50 ms or more, the user will feel a lot of discomfort. An important feature is not only the low latency, but also accurate mapping of movements in the system. For this purpose, external positional trackers are used to provide the necessary data about the location of the system in 3D space.
The use of virtual reality system increases the risk of virtual reality sickness symptoms. Already in 1995, the symptoms of simulation disease were examined at the US Army research institute [1]. These were mainly: general discomfort, headache or abdominal pain, disorientation, and even nausea and vomitingAlso today, using the modern VR systems you can observe symptoms of this disease. Only 15 minutes of intensive training can cause these symptoms [2]. There is also evidence that resistance to disease is dependent on the user's gender [2, 3]. It turns out that, as in the case of motion sickness, here too the risk of symptoms among women is greater than among men.

2.2 UAV TRAINING SYSTEM CONCEPT BASED ON VR HEADSET

Part of the professional simulation and training industry for defence and national security purposes, different kind of system concepts ware presented but there is a lack of confirmed VR technology implementation for UAV training in the army. When UAV started to be used for team and section reconnaissance purposes, detection and strike against the enemy personnel with direct control take-over by personnel on site, new more immersive human-machine interface will be used taken from commercial market. [8].
Since 2017 starts to be more popular using of VR headset for UAV control and flight management operations. UAV operators, vendors and training centres start to use possibility of modern gaming technology for efficient and precise unmanned systems control for fast flying UAV.
Virtual Reality technology, which has been used for many years on the market of broadly defined electronic entertainment, is becoming more and more confident in the defense industry. A number of simulators or training and training systems use virtual reality systems such as Oculus Rift or HTC Vive.
The use of this type of interface will allow to successfully carry out UAV pilot training, which use only a take-off or a landing which takes place in any area, and a small mass of UAV increases its vulnerability to weather conditions. For the UAV operator in the training system is necessary to use the controller as similar as possible to that used in the original system.
With the use of VR goggles, the main obstacle in the implementation of the correct training will be: a virtual reality sickness and the visualization of the hands and specifically the fingers of the operator. There are more and more solutions available on the market that enable precise mapping of operator's hands to virtual reality.This type of training gloves or other systems enabling very precise mapping of the arm, forearm, wrist, metacarpal and finger movement are necessary to build a possible transparent and effective training system using virtual reality goggles.
The necessity to use the headset to visualization technology and the UAV operator's precise mapping system make that training systems extremely expensive in professional

use and unattractive, difficult to popularize in amateur use where the key element of popularizing this type of systems is the price of the training set.
Training with the use of VR can be successfully implemented in any open or close space or even at home. Full mapping of the UAV operator's movements will enable the instructor to effectively conduct training, both while exercising and by simultaneously entering the virtual environment in which the training takes place.
It will significantly reduce the costs of providing training through the possibility of its implementation at home or any lecture room without the need to ensure the continuous presence of the instructor in the same geolocation.
In summary, a VR-type training system can be successfully used to train operators or pilots where UAV observation is crucial when performing a task or during take-off/ landing. The VR system will have a high acquisition cost, low training costs and almost comparable training results.

2.3. USING AUGMENTED REALITY TECHNOLOGY IN SIMULATION AND TRAINING

AR technology will enable the training of operators and UAV pilots carrying out flights in the field and outside the field of view at low price. The use of original controllers in the real flight environment (outside) together with the visualization of the UAV flight realized with the use of the AR set provides training opportunities with correct consideration of all factors required for the proper training of low-flying vehicles operators.
The technological challenge in implementing this type of training for UAV operators for flights in sight will be the precise and stable positioning of generated images.
Augmented Reality is a kind of connection between a virtual environment and real image from cameras. AR systems can be divided into several groups due to a number of factors such as the type of visualization or the place of work of the system [4]. In simulators and software discussed earlier, two different methods of presenting augmented reality are used. The first of them, much more popular, assumes the use of a video signal to attach to it a layer of image generated in a virtual environment. The second one provides virtual images display in the natural environment. This solution requires the use of glasses with transparent screens (ensuring adequate transparency) and with a built-in sensor unit, usually a set of cameras.
The case of using AR technology to provide the operator with a series of data available directly from the video signal is a challenge in terms of the required computing power. The key applications presented earlier are the appropriate use of computer vision algorithms along with data from IMU sensors and GNSS systems. Data fusion from sensors together with additional algorithms for estimating measurements (e.g. Kalman filter) allows for stable results.
The data processing scheme is illustrated in the figure 2 below.

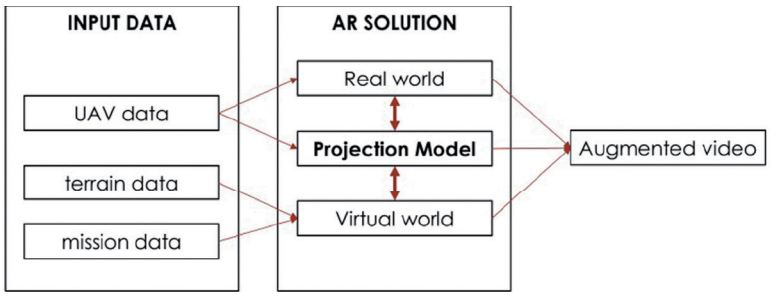

Fig. 5 The main modules of the AR tool [5].

The module responsible for the AR receives data from the UAV, also has input data of the terrain and mission under which the vehicle operates. Then all data is combined into one video stream. This requires a number of actions from scaling the coordinate systems to one format, by adjusting the path of the flight to all data, ending on camera calibration based on the camera intrinsic parameter matrix.
The use of head-mounted systems that allow the display of virtual objects in reality requires the use of many algorithms of computer vision and such issues as the extraction, pose estimation and other transformation. Often computational complexity means that in addition to software solutions, dedicated hardware solutions are required. An example may be Microsoft Hololens, which is a project under which the authoring chip for image processing was designed from scratch.
Thanks to the increasingly popular AR technology, new and more realistic ideas are created in providing trainings and trainings.
An interesting software is SmartCam3D from RapidImaging [9]. It allows a management of the mission in augmented reality mode. It overlaps the virtual layer on the actual camera image. This increases the operator's capabilities and provides valuable data about the space around and the state of the mission. It is possible to put a lot of relevant information, including tactical signs, road markings or street names. In addition, the image can be displayed in the Picture-In-Picture mode by extending the image from the camera with a virtual generated terrain topography (fig. 6).

Fig. 6 Picture-In-Picture mode in SmartCam3D from RapidImaging [9]

Another solution available using AR is the Edgybees software [10]. The presented materials show the use for rescue purposes, e.g. by fire brigades or other emergency services. Interesting is the use of software during floods. The aircraft operator or control station receives a camera image supplemented additionally with a layer with a virtual map of the area (fig. 7). What's more, such an image can be extended with any information, e.g. about the places where the SOS signal was sent (fig. 8). The combination of many additional data makes the operator have an easier task and can only to base on the received image.

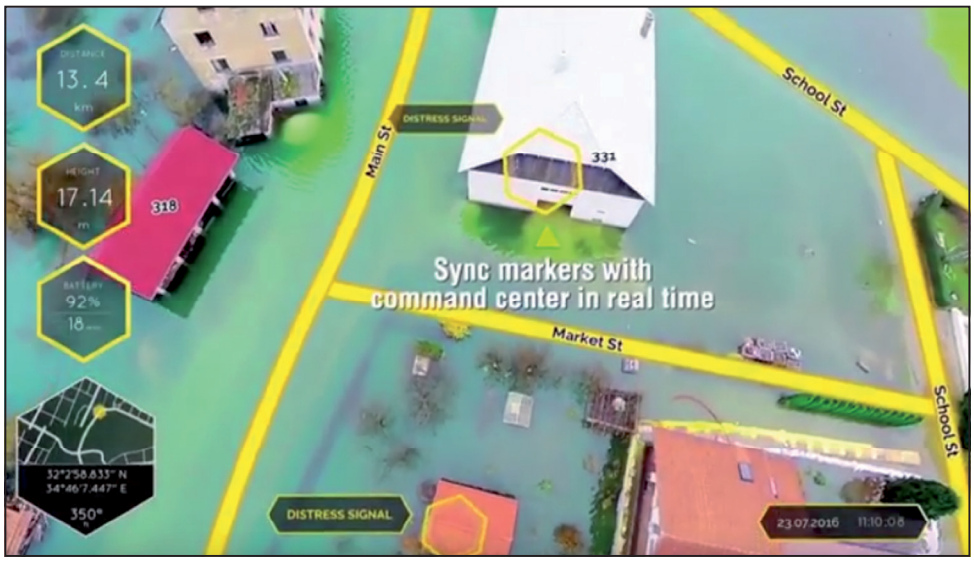

Fig. 7 Layer with a virtual map using AR in Edgybees software [10]

Fig. 8 Layer with a distress signals using AR in Edgybees software [10]

Epson and a producer of commercial drones DJI recently presented a simulator working with the AR technology [11]. This system using the technology created by Microsoft (holograms from Hololens) allows to display the virtual model in reality using specially designed glasses. The Epson glasses are now available for sale, while the software for controlling the virtual drone will be available later this year.

Fig. 9 A virtual drone in augmented reality by Epson and DJI [11]

Adequate and stable positioning of the visualization in the real world will be ctitical for the user's experience. This will allow for better immersion and visual effects.

3. OUR PROPOSAL TO USE AR IN TRAINING

After analyzing the available solutions on the market of augmented reality, we propose to use this technology during control or training and simulation of an unmanned aerial vehicle. It is a system that allows to protect the operator against dangerous situations while performing an UAV missions. That system could be used on the civil market for sport or recreational drones operators. It could also be used during Intelligence, Surveillance and Reconnaissance (ISR) military missions. The system approach requires that the operator will be early warning against hazards which should be expected. There are several factors that can affect aircraft safety:

- Operating range UAV
- Crossing Flight Information Region (FIR) boundaries and airspace classes
- Collision course with other aircraft
- Collision course with the environmental objects
- Weather conditions (e.g. wind)
- Maneuverability of UAV

Aircraft operator equipped with augmented reality glasses can receive a lot of additional information. When approaching the operating range of the vehicle, a safe area may be displayed, to which operator should be return or a path allowing to safety return to the take-off / landing area. In this case, the operating range can be understood as both coverage on the battery or fuel, as well as the communication range in which safe communication with the UAV is possible.

An important parameter from the operator's point of view is also to determine if the boundaries of the airspace have been exceeded. For flights in the vicinity of the restricted

areas or places, which has been authorized within the restricted area, there is the risk for security breaches. Such a situation may not only involve legal consequences, but also a considerable risk of causing a dangerous situation in air traffic. Thus, displaying additional information about approaching the restricted airspace is very important for safety.
Another important aspect from the point of view of security is also warning about the collision course with other aircraft or objects in the immediate surroundings. As mentioned earlier, a lot of aircraft accidents occurs with objects in the environment. This is due to the errors of the operator's perspective on the ground in relation to the aircraft operating at high altitude. The possibility of presenting warning signals for the operator in the form of graphics in augmented reality will allow to minimize the risk of making a mistake and, consequently, to improve the safety among operators of unmanned aircraft.

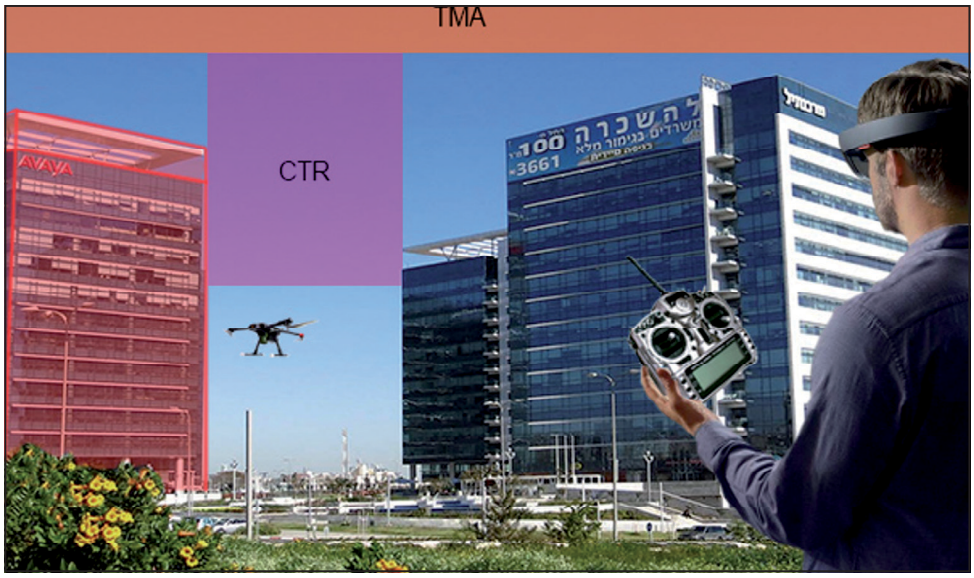

Fig. 10 Our proposal of AR in training.

Next type of warning that we propose to display in the operator's space are weather conditions. Due to the small weight of some vehicles, information about wind conditions is the most important. Providing information on areas where there are strong gusts of wind or changes in atmospheric fronts will allow to prepare for the weather situation in the area where the aircraft is heading.
For some types of the UAV, maneuverability limits the operator and determines his ability to change course. With AR technology, it would be possible to mark the predicted flight path based on the current parameters or if the route has been changed.
The factors mentioned above could be simulated during operators trainings or practices. This would allow, for example, to simulate the operation of UAV in limited airspace or with a small operating range. It would also be possible to simulate dangerous situations such as approaching other air traffic participants or fly too close to objects in space.

CONCLUSION

Countless cases of damage to infrastructure, other flying objects or controlled aircraft suggest the operation of an unmanned aircraft using a smartphone controller or a dedicated human-machine interface. This requires a set of skills enabling correct orientation in the surroundings, height control, the influence of atmospheric conditions (also those experienced by the operator on their own skin) or the status of an unmanned vehicle. Thanks to the use of AR technology it is possible to safely and cheaply train and execute flights for operators of unmanned aerial vehicles.

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