International Journal of Social Sciences Arts and Humanities Vol. 5 No. 1. 2017. Pp. 4-11

Full Length Research Paper

Applications of Unmanned Aerial Vehicle (UAV) Technology for Research and Education in UAE

Khaula Alkaabi* and Abdelgadir Abuelgasim
Department of Geography and Urban Planning, College of Humanities and Social Sciences, United Arab Emirates University, P.O. Box 15551, Al-Ain City, UAE.

Article history
Received: 01--09-2017
Revised: 07-09-2017
Accepted: 08-09-2017

Corresponding Author
Khaula Alkaabi
Department of Geography and Urban Planning, College of Humanities and Social Sciences, United Arab Emirates University, P.O. Box 15551, Al-Ain City, UAE.

Abstract
This paper presents usage of Unmanned Aerial Vehicle (UAV) as a valuable source for research and education purposes that could solve many aspects of inspection, surveillance, mapping, 3D modelling and various other data acquisition applications. An educational and technology transfer workshop was organized by Abu Dhabi Systems and Information Centre (ADSIC) and trained by ESRI to educate United Arab Emirates University geography students on using new software's and technology such as ArcGIS Pro, ArcGIS Online, ArcGIS Earth, tools such as Collector, Survey 123 and capturing drone imageries. The paper reports a typical photogrammetric workflow, 3D results like surface or terrain models, vector information, textured 3D models for United Arab Emirates University buildings. A unique understanding was developed within the participants for flight planning and its execution for generating 3D point cloud from drone imageries. Participants also learned about sharing the final products to other users and visualizing them using web and desktop client. The new technological innovation and advancements taught to the students is a part of larger project of 3D modelling for entire United Arab Emirates University campus. The knowledge innovation in education and new practical teaching pedagogy approach play a better role for United Arab Emirates University to contribute in a knowledge-based society and makes it one of the finest learning centres in Gulf region. The result and knowledge gathered through this particular training is useful for young students and future practitioners in need for successfully adapting UAV technology for their applications in various field of work. Particularly, the students learned highly needed values in a knowledge based-economy such team-work, collaboration, creativity and critical thinking.

Keywords: *Unmanned Aerial Vehicle (UAV), ArcGIS Pro, ArcGIS Online, ArcGIS Earth, United Arab Emirates University, Photogrammetric workflow, Point cloud, Research and Education, Knowledge Innovation, Collector, 3D Campus Model.*

Introduction

Many studies have shown the influence of innovative practical teaching approach in produce-learn-research network. Knowledge network among various entities affects both regional innovation ability and its competitiveness, so they have attracted much attention nowadays (Pond et. al., 2004). From the perspective of knowledge network, the factors that affect universityknowledge innovation ability are: inter-organizational network capitals, social capitals, the nature of knowledge flow, embeddability relations, inter-organizational learning (Huggins et. al., 2012). Academic capitalization is a driving force for science creation and presented by American entrepreneurial universities that transform original university-knowledge-innovation achievements (Chen, 2015).

Education and training practices in a knowledge based economy and particularly in the use of new technologies, departs from the traditional class room type. The model followed in such situations, as the workshops mentioned in this research, is problem based learning, through projects, and their execution. Class and field based project learning allows students a much deeper knowledge and expertise through tackling real-world situational problems and challenges (John Psarras, 2006). It was the preferred method of delivering knowledge for the mentioned project because it integrates actual knowledge, hands-on experience and developing expertise in the subject matter. Furthermore, such approach instil with the students in competencies needed for surviving in the modern era of knowledge based economies. Competencies such as team-work and collaboration are developed through the distribution of labour, creativity and critical thinking are developed through tackling real-world problems, and communication skills (Kozma, Robert B, 2005). Project management skills of organization, leadership and vision are instilled through the project - based learning model.

Unmanned aerial vehicles (UAV) demonstrates upcoming method for remote sensing data acquisition through aerial images. The technology is light-weight and cost-effective due to its miniaturization sensors for image capturing and reliability that can be used in every field of operations.At the Cornell University, the AR-Drone was used for experiments in UAV visual autonomous navigation in structure environments (Bills et. al., 2011). Moreover, machine learning approaches were applied to predict the position errors of the UAV following a desired flight path (Bills et. al., 2010). Other researches carried out around the world used drone as an experimental platform for human-machine interaction (Ng and Sharlin, 2011), autonomous surveillance tasks (Faigl et. al., 2010), and even as a sport assistance which aids the athletes by providing them external imagery of their actions (Higuchi et. al., 2011). The main differences between images captured from low level altitude UAV platform and higher altitudes data acquiring platforms has been investigated in previous studies such as comparative large rotational and angular variations between images, non-systematic flight lines, due to wind, visibility, terrain conditions, large perspective distortions due to relatively large height differences in a scene, small footprint of the images that needs more data capturing, unknown or inaccurate exterior orientation parameters, high variability in illumination and ground resolution (Haalaand Rothermel, 2012; Neitzeland Klonowski, 2011; Rieke-Zapp et. al., 2010). In a highly automated way it is possible, to estimate camera geometry and calculate a 3D model from a set of overlapping images, invariant to scale, orientation, distortion and illumination changes (Neitzel and Klonowski, 2011).

The newly introduced technique and methodology carried out in these earlier researches has opened new horizons for the future geography students to master the skills of Geospatial technology using an innovative tool-an Unmanned Aerial Vehicle. This helps the students to learn how to use critical thinking and practical application in making well-reasoned decisions and to solve research problems in 3D environment. It will extend their skills and enhance the competitiveness in job market. 3D modelling with drone is a time consuming and needs a lot of effort, due to several implementations, planning and 'low level' issues. Moreover, the drone control is not as easy as ground robots. The previous experience and research carried out in UAE is been shared in the next segment. The hardware and software for the training was provided by ESRI and Falcon Eye Drones to capture and process the aerial images for the United Arab Emirates University.The following section briefly summarizes the experiments carried out for 3D modelling of College of Humanities and Social Science building in United Arab Emirates University campus. The last section concludes the software training given by ESRI representatives in processing the images and creating a 3D model of the building using various new GIS software's.

Methodology

As both the projects offered education and research using Drone technology, it was communicated in the workshop that a new model is adopted by the company called BCN Drone Centre for imagery acquisition and analysis. The Mikrokopter Flight Planning Tool (MK FPT) was used minimizes the manual effort and increases the accuracy. The parameters were given by the expert team considering theweight, volume, speed and torque of the UAV; position, angular acceleration, orientation, shutter speed of the sensor and testing the manual control of the system, on ground receiver and emitter, frequency, channel number and functions of it. The pilot selected the Region of Interest on a map, final check of the camera resolution, flight altitude, speed, longitudinal and traversal coverage of each photo. The flight planning software uses these parameters and compute the full flight plan consisting of waypoints that are the location points where the UAV takes photographs along its flight path automatically. As told by the instructors, up to 100 waypoints can be entered with little manual efforts.

The orientation and Geo-referencing was carried out in Drone2map software of ESRI for bringing the acquired photograph stored in the waypoints and then can be processed after overlapping and removing unnecessary images. Furthermore, the Orthophoto and DEM was generated for GIS and Remote Sensing analysis and converting it in 3D mapping. The methodology flowchart (Figure 1) is represented in the diagram as below and the components are explained in the later part of the section:

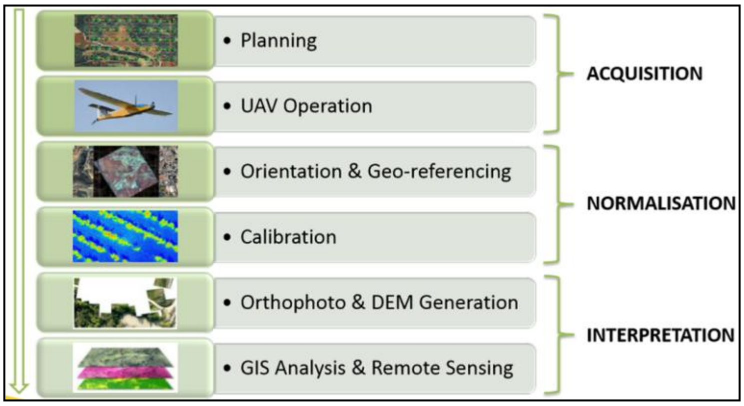

Fig 1: Flowchart adopted for 3D mapping using Drone Technology

The key features for these training courses organized both in ICBA and UAEU were to organize Hands-on practical workshops for mission planning and post-mission processing and also provide a project based learning approach to the students. They were introduced with many DIP software's (Bentley, Pix4D and AGISOFT) and Drones (fixed-wing and multirotor) for making a 3D model through UAV technology.

UAV project at International Center for Biosaline Agriculture (ICBA)

A workshop and course was offered on unmanned aerial vehicles for remote sensing and photogrammetry the first of its kind in the Gulf region organized bythe Arabian Gulf University and BCN Drone Centre at the ICBA headquarters in Dubai. The objective of the workshop was to guide the participants on integrating drones in a Geomatics projects by setting up a complete UAV mission pipeline, from UAV system selection to image post-processing techniques, taking into account the main characteristics of each mission type and objectives.The practical workshop organized in there consists of lectures, field demos, hands-on exercises to make participants aware of new technology of data acquisition and to involve in real UAV project of 3D modelling of ICBA. The duration of the training was from 20-29 March, 2017 held in Dubai, UAE, harnessing the full innovation potential of drone's integration into geomatics that starts inevitably with proper capacity building.

The training project for developing a 3D model of ICBA main building as a part of technical learning process started with all the government approvals of flying the drone. The ground control points placed on-sight to increase the precision marking and to be used in ortho-photo generation. The details of capturing the images through drone mapping and its methodology is highlighted in this study with the use of appropriate hardware equipments used and flight planning considered. This paper discusses training workshop that was organized in ICBA, particularly for the experts of Geomatics from various government and non-governmental entities, while the software training in processing the captured images for United Arab Emirates University isshown in other project detailed in the next sections.

UAV Selection

A variety of flying vehicles are available in the market as per the need and type of the project equipped with various cameras/sensors. Most common forms are small, electrically powered model planes with wingspan from 2-3 meters and even smaller ones called quadrocopters. The Unmanned Aerial Vehicles (UAV) have some distinct advantages in data gathering such as low purchase, maintenance and operational costs. The other advantages put together with the new innovative technology of using drones are its flexibility to operate in surveying assignments, easiness to steer with reliability and to keep it under control in harsher ambient environment such as strong winds through pilot and ground controls.

The quadrocopter used for the training purpose in ICBA (Figure 2) was of very high quality with frame made of lightweight material such as aluminium and carbon fibre carrying motors, battery, electronic parts and a high precision camera mounted on it. The technical aspect of the drone comprises of a Flight Control Unit (FCU)that is able to process and implement the input commands given by Ground Control Unit (GCU) for certain navigational tasks. The Inertial Measurement Unit (IMU) component designed for acceleration, actual alignment, and barometrical unit to be measured. The FCU controls the four brushless motor and triggers the rotational speed of the motors. It is also connected with the low cost-high precision differential GPS receiver to extend the navigational capabilities of the quadrocopter, e.g., functioning like position hold, coming home and flight according to pre-identified waypoints.

Fig 2: Fixed wing Drone Demonstration

Flight Path Planning and Data Acquisition

After finalising and testing the components of the selected UAV, the next stage of the training comes with planning the flight path and capturing the images. A flight planning tool is used to minimize the manual effort needed in flight planning processes such as overlapping of photo imageries to guarantee appropriate overlapping coverage. The pilot from the ground control unit then decides the region of interest on an interactive map, photo size and resolution, flight altitude above the ground, flight speed, and longitudinal and traverse coverage of each photo for maximum survey area coverage. The flight planning software uses these parameters to compute the full flight planning with waypoints generated where the quadrocopter takes photos automatically along the path generated (Figure 3). The operator than finally defines the start and end points of the flight path to be formulated.

The following flight process was also developed for capturing images of the main building of ICBA for generating its 3D model: (1) Checking the UAV hardware components including frame, motors, propellant, battery, sensors, signal availability; (2) Camera Calibration for high resolution image capturing; (3) Uploading the waypoints for the flight path; (4) turning on the quadrocopter and lifting it off the ground manually and then switching it to autonomous flight mode (Seibert and Teizer, 2014). The quadrocopter follows the pre-defined path and tasks autonomously afterwards and starts taking the pictures of the building at each waypoint storing it in .WPL file format. In case of unexpected event, a manual intervention is always possible but that did not happen in our case and the flight was smooth. After reaching the last waypoint and capturing the image, the UAV automatically switch to *"coming home"* mode and manually controlled by operator to land it (Figure 4 and Figure 5).

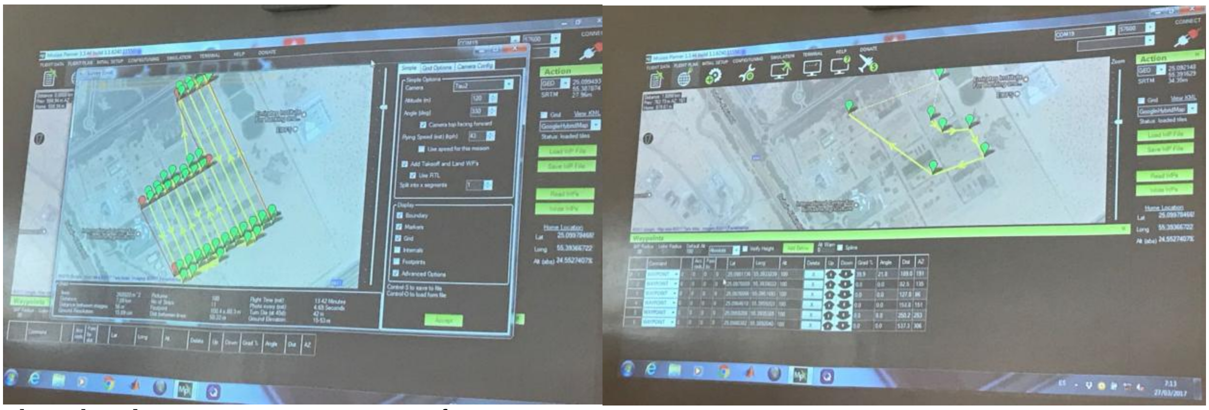

Fig 3: Flight Path and Waypoint Generation in Software

Fig 4: Camera calibration and feeding the parameters

Fig 5: Flight Preparation and Final Launch

D modelling of United Arab Emirates University Campus

The methodology adopted in the workshop organized by Abu Dhabi Systems Information Centre (ADSIC) for training and education purpose in capturing the high-resolution images of college of humanities and social science building in United Arab Emirates University campusthrough aerial platform was same as the UAV training given in ICBA. The only part extended for this workshop was the software training given by ESRI for new innovative data acquisition and processing tools developed by ESRI for 3D mapping and viewing purposes. The training was attended by students, researchers and faculty members to learn and share their views on 3D mapping technology. UAV based high resolution aerial images provide important basic data for all consequent geospatial analyses such as Mosaicing, Ortho-rectification, Digital Surface Model (DSM) generation, Point Cloud generation and many more. The training is given on the small sample from the whole project of 3D mapping of United Arab Emirates University, chosen due to the efforts of Department of Geography and Urban Planning in educating the students about the new innovative use of existing technology and provides them a hands-on experience on the new software's coming in the market for 3D mapping. The final 3D output was linked with the navigational application to be developed for the United Arab Emirates University in route identification and attribute generation within the campus.

Point Cloud generation and photogrammetric data processing
After capturing the images through a pre-defined flight path, a photogrammetric data processing is needed to generate a geo-referenced 3D point cloud from the overlapped surface image collection. Block bundle adjustment is computed for homologous areas, interior and exterior orientation. The Exchangeable Image Format (Exif) metadata from each digital image further provides approximate values for the focal length and image size.

Before importing the acquired images to the working software provided by ESRI, it needs to be processed. The method is simple yet important and follows three main parts: (1) align photo, (2) build geometry, and (3) build texture (if required). The ESRI software ArcGIS Pro provides several possibilities to adjust parameters, required for accuracy, structure of result and the processing time. The adjusted result could be seen as a digital surface model with matched texture, an orthophoto and a point cloud having all the images in it.

ESRI Drone 2Map Workshop
The hands-on workshop was organized for training and educating in producing 2D and 3D products from drone imageries captured. The participants get to know how to share products from ArcGIS online and visualize them using web and desktop clients. The final output was linked with attribute collecting tool for the building through Collector and Survey 123 applications. The importance of these whole packages is mentioned in the next sections of this paper.

Drone 2 Map for ArcGIS
In the past few years, drones are becoming widely accepted source of capturing high-resolution imagery of a small area. Drone images are generally tagged with geographic information and metadata that makes it ready to use in ArcGIS platform. Drone2Map for ArcGIS not only allows you to view raw drone images in map, but also to create 2D and 3D GIS products from the images.
The participants were trained on the software analysis part for processing the imageries, creating a 3D textured mesh and publishing the dataset to ArcGIS Online. The steps and procedures adopted for the exercise is as follows: (1) Viewing the images- Nadir and Oblique images were captured by the drone to create 2D orthoimages and 3D point cloud images which results in some navigable 3D scenes that could be shared. (2) Creating a new project- The processing of images is done by choosing from four project templates called Rapid, 2D mapping, 3D mapping and Inspection. The Rapid and 2D Mapping templates create orthomosaics and digital surface models (raster datasets that show the elevation of an area). The 3D Mapping template creates point clouds and textured meshes. The Inspection template orients the images in an inspection viewer, which allows you to cycle through and annotate overlapping images of the same area. A 3D mapping template was selected for this research for getting the maximum output. (3) Processing the imagery- The processing parameters is given using four types of options such as Initial Processing, Point Cloud and Mesh, Orthomosaic and DSM, and Resources. Initial Processing determines how Drone2Map analyzes each image to match them with the other images, while Resources specifies basic parameters about the project. The remaining processing options relate to the type of output data that you're creating. Since, we have created 3D template, point cloud and mesh is kept for processing.

The process is executed and took around 30 minutes to get completed due to the processing parameters and the number of participating images selected for a 3D mesh up. The 3D mesh contains an accurate representation of the building as shown in the original drone imagery. When zoomed in closer, the textures become more noticeable.
In the last exercises, the students were taught to publish their 3D mesh up output into ArcGIS online to be seen by the organizers of the workshop. The point cloud dataset and the OBJ file could also be opened in other ArcGIS applications and with these shareable results, the drone mission could be shown to interested parties.

Collector for ArcGIS
The use of collector is a part of a larger project for United Arab Emirates University to navigate each room and collect the details for them to map through inside of the several buildings in University campus. After importing the already existing floor plans in CAD design to GIS format, the students were taught to get a hands-on through downloading the mobile application in their smart-phones and collecting the details such as name, room number, type, location attributes created by the GIS analyst. The collector proved to be an important tool for collecting and updating the data captured to work. The maps connected to the application areused for ground verification of the data, making observations, and responding to the live queries. This improves the efficiency of the workforce and accuracy of the GIS.A sample is shown in Figure 6.

Survey 123 for ArcGIS
An additional feature from ESRI is also taught for the training workshop to capture the survey data planned in getting a sample of the various building heights, name, and locations of the fire hydrants. The predefined survey speeds up the collection process with predefined questions that provide logic and easy-to-fill answers, embedded audio, images and with multiple language entry option. The combine power of smart forms and geography data captured in survey 123 for ArcGIS is immediately available in the ArcGIS platform to optimize the field operations by the students, helping them to understand the data better and making the best decisions, communicating and sharing the field work (Figure 7).

Rooms First Floor

OBJECTID	Room Type	Room Number	Occupant Name
36	OFFICE	1009	Miss Badreyya Khanbooli
37	BREAKOUT/PRINTING/ARCHIVE	1033	<Null>
38	OFFICE	1061	Dr. Amna Al Ahbabi
39	MEETING ROOM	1024	
40	OFFICE	1005	Ms. Ulrike Wantig
41	OFFICE	1034	
42	OFFICE	1015	Dr. Ivan Jimenez
43	OFFICE	1036	Dr. Khaled Karim
44	OFFICE	1011	Dr. Martin J. Endley
45	OFFICE	1038	Dr. Daniele Mezzadri
46	OFFICE	1017	Dr. Hosni El Dali
47	OFFICE	1062	Dr. Phyllisa Deroze
48	CLASSROOM	1056	GIS Mster Students
49	OFFICE	1040	Dr. Alexandra Marquis
50	OFFICE	1013	Dr. Moza Al-Tenajiy
51	OFFICE	1022	Dr. Meera Al Kaabi
52	OFFICE	1032	<Null>
53	OFFICE	1042	Dr. Sami Boudelaa
54	CLASSROOM	1066	Mr. Ioannis Galanopoulos
55	OFFICE	1019	Dr. Zubaida Shebani
56	OFFICE	1031	Dr. Alexandra Marquis
57	OFFICE	1021	New Faculty
58	CLASSROOM	1067	Dr. Mohammed Al-Sadoun
59	<Null>	<Null>	<Null>
60	<Null>	<Null>	<Null>
61	STAFF ROOM	1025	<Null>
62	<Null>	<Null>	<Null>
63	<Null>	<Null>	<Null>
64	<Null>	<Null>	<Null>
65	OFFICE	1063	GIS Master Students
66	OFFICE	1043	<Null>
67	CLASSROOM	1068	Mr. Toomsa Alturnme
68	OFFICE	1044	Prof. Ali Shehadeh
69	OFFICE	1030	<Null>
70	OFFICE	1041	Dr. Rita Risser
71	<Null>	<Null>	<Null>
72	OFFICE	1064	
73	OFFICE	1069	Mr. Edward Chaffin
74	<Null>	<Null>	<Null>
75	OFFICE	1037	Dr. Philip Meadows
76	OFFICE	1047	Dr. Simon Langford
77	<Null>	<Null>	<Null>
78	OFFICE	1096	Ms. Noora Al Tenaiji

Fig 6: Data gathered using Collector tool for ArcGIS in United Arab Emirates University

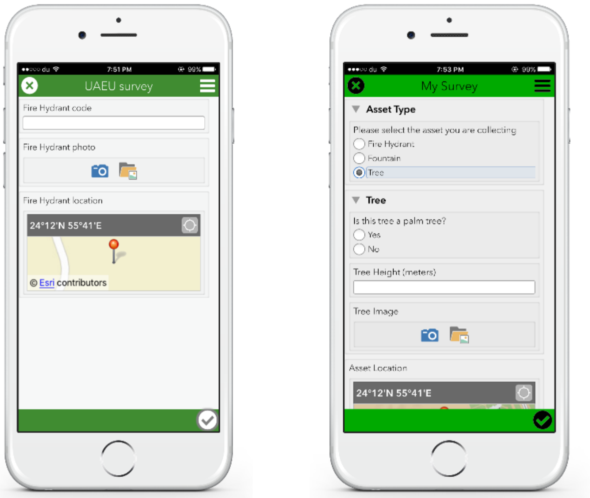

Fig 7: Mobile application to be filled with project attributes

Results and Discussions

The UAV took around 75 pictures through waypoints with an overlapping image rate of 60% longitudinal and 40 % Lateral. The computational processing time was approximately 30 minutes and the total time taken by the computer to generate final 3D output was around 2 hours depending on the performance of the machine.

The factors that were considered to impact the performance of UAVs were noticed during the experiment and errors were removed accordingly at every stage.

- Wind: Due to the unobstructed area, stronger thermal winds caused air turbulences for the UAV. Some blurred photos were manually removed.
- Safety and security: Since UAV equipment is a very costly and sophisticated equipment, special attention was given to the device while landing and taking-off.
- Time: Apart from automation and timely management of the project, it was a time-consuming task to take the pictures of the whole university noticing its enormous size and the evaluation of each photo to choose for ortho-generation was also not easy and requires expertise and time.
- Area of Coverage: The main advantage of an Orthophoto from the UAV is a geometrically corrected aerial photograph that is projected similarly to a topographical map. When viewed, an Orthophoto displays true ground position with a constant scale throughout the image. The area of coverage is more as the altitude of the drone increases but directly effects the picture quality that makes it difficult to do the photo adjustments in the final processing. This will also effect the scale of the image due to irregularities in mosaicking.

- Point Classification: The waypoints generated through the software gives a lot of points that are complex to study. It needs a rigorous task to eliminate the unwanted and useless pictures that cannot participate in ortho-generation.

The image block (Longitudinal and Lateral) allowed the generation of a very detailed and dense DSM. The generated DSM was finally used for the building footprint extraction, the cadastral updating of the area, or 3D building modelling (Figure 8).

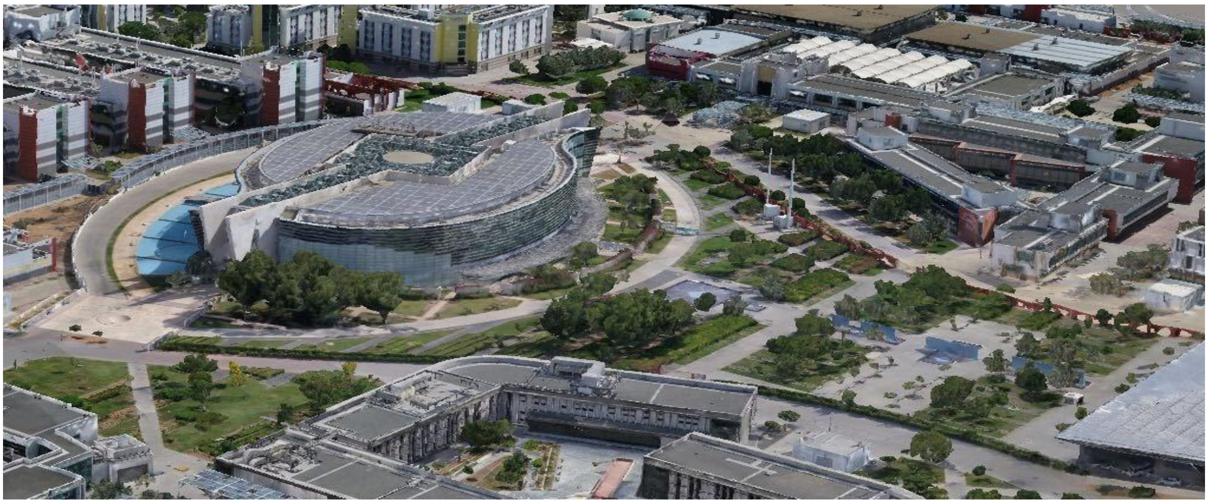

Fig 8: 3D output of United Arab Emirates University through Drone Technology

In knowledge-based economy learning through projects or learning by doing seems to be the most viable solution to achieve the maximum learning benefits. Learning and training in non-traditional non-formal settings as demonstrated by the examples discussed previously are becoming more common. The observable skills gained by the students through these examples constituted some of the key major skills needed in the economy of modern UAE. Particularly noticeable were:

- Improved team-work, distribution of work and collaboration
- Improved and direct and open communication by challenging ideas
- Open communication fosters trust, ethics and responsibility.
- Tackling real-world problems takes away students from the class room theoretical setting into world real situations they might encounter and help them develop their innovative skills for solving problems
- Students developed their abilities to work independently each on his tasks
- Learning project management skills and competencies

UAVs provided an excellent technological tool through which students were able to learn through project or learning by doing. They are becoming an increasingly useful tool within educational geography and geomatics departments to support learning by doing. Learning by doing through the use of UAVs will likely help the students into developing their own innovative ideas towards further applications and uses of UAVs, as well as perhaps ideas related to improved drone technology and hardware.

Conclusion

This paper presented an approach for understanding and evaluating the performance of an Unmanned Aerial Vehicle (UAV) and testing new software introduced by ESRI for 3D mapping in a test bed and field-realistic environments. The exercise performed explained the hardware components as well as novel flight planning tool that helps the pilot to launch the automated surveying tasks. The article presented an overview of existing UAV systems, problems, and applications with particular attention to the geomatics field through two case studies in UAE where the training and implementation occurred.

Unmanned Aerial Vehicles poses a great advantage of quickly delivering high temporal and spatial resolution information thus allowing a rapid response in critical situation by delivering high resolution 3d images. Indeed, they feature real-time capability for fast data acquisition, transmission, and, possibly, processing. UAVs can be used in high risk situations and inaccessible areas, although they still have some limitations in particular for the payload, insurance, and stability. In this study, we tried to highlight both the projects with the use of different type of UAV platforms either rotary wing that can even take-off and land vertically, while fixed wing UAV that can cover wider area in few minutes.

The methodology on how photo images are taken by the camera attached to the quadrocopter and processed to the final 3D output was explained. The images taken by the UAV was evaluated in a test bed environment and demonstrate the applicability of UAV in photogrammetric surveying for geography students. The two case studies were considered for evaluation focusing in particular on minimising the errors of a UAV based photogrammetric approach and educating the participating in surveying techniques. Parameters and processes are discussed to demonstrate the improvements taking place in data capturing and 3D creation through aerial images. However, some technical limitations are still there such as battery life limiting the flight duration, wind speeds and height. In this research, we found that drones are an excellent vehicle for student learning and research, through various case studies highlighted in the paper. The new trend of drone technology and its application attracts students who might not otherwise get involved in research activities also this new technology plays a significant role in motivating them for their technical projects. The training and hands-on experience provided in the workshop in both ICBA and UAE University delivers a scientific tool to the students for taking it as a career and guiding them for their course projects. Working seriously with 3D application provided by ESRI and other software companies requires substantial outlay but learning opportunities are much higher and have great value in job market.

References

Bills, C., Yosinski, J. (2010). MAV stabilization using machine learning and onboard sensors. Technical Report CS6780, Cornell University.

Bills, C., Chen, J., Saxena, A. (2011). Autonomous MAV flight in indoor environments using single image perspective cues. In: IEEE Int. Conf. on Robotics and Automation.

Chen Xialing. Study on the organization innovation path of Entrepreneurial University [M]. Beijing: Beijing Institute of Technology press.2015:157

Faigl, J., Krajník, T., Vonásek, V., Preucil, L. (2010). Surveillance planning with localization uncertainty for mobile robots. In: 3rd Israeli Conference on Robotics

Haala, N. and Rothermel, M. (2012). Dense multiple stereo matching of highly overlapping UAV imagery. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXIX, Part B1, pp. 387-392.

Higuchi, K., Shimada, T., Rekimoto, J. (2011). Flying sports assistant: external visual imagery representation for sports training. In: 2nd Augmented Human International Conference, pp. 7:1–7:4. ACM, New York

Huggins R, Johnston A, Thompson P. (2012). Network capital, social capital and knowledge flow: how the nature of inter-organizational networks impacts on innovation. Industry and Innovation. 19(3): 203-232.

John P. (2006). "Education and training in the knowledge‐ based economy", VINE, Vol. 36 Issue: 1, pp.85-96,https://doi.org/10.1108/03055720610667390

Kozma, R. B. (2005). National policies that connect ICT-based education reform to economic and social development. Human Technology: An interdisciplinary journal on humans in ICT environments.

Neitzel, F., Klonowski, J. (2011). Mobile 3d mapping with a low-cost UAV system. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVIII-1/C22 UAV-g 2011, Conference on Unmanned Aerial Vehicle in Geomatics, Zurich, Switzerland.

Ng, W.S., Sharlin, E. (2011). Collocated interaction with flying robots. Technical Report 2011-998-10, Dept. of Computer Science, University of Calgary, Canada.

Pond, R; van Oort, F; Frenken, K. (2004). The geographical and institutional proximity of research collaboration [A]; 7thWorld Congress of the Regional-Science-Association-International.

Rieke-Zapp, D.H., Bommer-Denss, B. And Ernst, D. (2010). Small format digital photogrammetry for applications in the earth sciences. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVIII, Part 5, Commission V Symposium, Newcastle upon Tyne, UK.

Siebert, S., &Teizer, J. (2014). Mobile 3D mapping for surveying earthwork projects using an Unmanned Aerial Vehicle (UAV) system. Automation in Construction, 41, 1-14.