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The possibilities of using drones in the 3D object modelling field

Milan **Adamek** [1,a] *Vaclav* **Mach**, *Petr* **Neumann**

[1] Tomas Bata University in Zlín, Faculty of Applied Informatics, Nam. T. G. Masaryka 5555, 760 05 Zlín, Czech Republic

Abstract. This article is focused on the 3D Modelling of Objects from recordings taken by drones. The principles of multi-propeller devices and individual commercially-available parts for the construction of drones. A separate part is devoted to the Photogrammetry technique for the 3D modelling of objects from images taken by drones. It maps the currently available software for this method, and presents tools available online, as well as PC tools and mobile applications. The practical part describes the construction and assembly of one´s own multi-propeller machine and its subsequent use for collecting imagery material for the modelling of selected objects. The modelling process – with the support of selected software, is also described. The result is evaluated from the perspective of its possible use in Safety/Security Technologies.

1 Introduction

Nowadays, one can encounter 3D visualization in many disciplinary fields – like for instance, the Engineering, Construction, and Health fields. In most of these fields, models are primarily used for the purpose of obtaining additional information based on measurements. Models of larger objects - like the exteriors of buildings or whole areas served rather, as visual models, it requires a great deal of effort to the underpinning (documentary) materials in order to reconstruct them. Today, we already find them being used for the visualization of buildings or larger areas where they will not only act as a visual function; but it will also be possible to perform measurements and calculations on such models. These 3D visualizations can be used - for example, for modern GPS Maps, Mining, or the Reconstruction of Crime Scenes.

Currently, software solutions on the market have automated the 3D Modelling of Large Objects field that are based on a large quantity of input data. These software solutions are able to calculate spatial data from only input image material.

With the ever-faster development of unmanned aircraft and multi-propeller devices, it is more than reasonable to deploy drones to collect the data required for such processing. The use of drones has become effective - not only in terms of time but also in financial terms. Drones are able to deal with poorly-accessible spaces from within which input data is required. Thereby, it eliminates the danger for a person who would (otherwise) be forced to take risks in the course of acquiring the requisite pictorial material. Today's drone is able, with the right equipment, to acquire - apart from visual materials, flight route coordinates, temperature data, laser images and more, for example.

This article deals with the mapping of the possibilities of creating a custom-built drone capable of recording an image and assessing its suitability for use in the 3D visualization of an object, with the selected software. The practical part demonstrates the use of these assemblies on a selected object.

2 Drones

Unmanned Aerial Vehicles, (UAV from the English - or also as Drones) are unmanned devices which can be operated remotely by an operator, to fly independently with the aid of pre-programmed flight plans or with the assistance of more sophisticated Autonomous Systems. [1] Drones can include remote-controlled aircraft that use jet-propulsion drives, single-propeller devices, amphibious devices that combine flight as well as ground capabilities, or multi-propeller machines.

The principle of flight

The movement of flying machines in space is determined by a three-axis coordinate system.

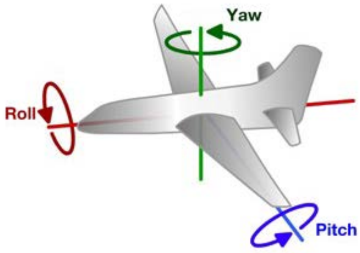

Fig. 1.3-axis Coordinate System Flying Machines Orientation [2]

In this system, we determine three fundamental movements for all (types of) machines. These are: Pitch, Yaw and Roll. By combining these movements, we are able to control a device/machine in space.

However, different types of devices use differing principles and techniques to achieve these three types of

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[a] Corresponding Author: adamek@fai.utb.cz

movements. To do so, aircraft simply use flaps on the main and rear directional wings.

The principle of multi-propeller devices

Multi-propeller devices, as can be inferred from their name - use more than two rotors located in certain positions for their controlled flight. The position of the rotors is determined by established standards for each type. Dependent upon the number of rotors, the following device-types exist:

- Tricopter - 3 rotors
- Quadcopter - 4 rotors
- Hexacopter - 6 rotors
- Octocopter - 8 rotors

In contrast to single-propeller devices, it is possible to consider the elimination of the setting of individual rotor blades with a complex mechanism in order to achieve a change in motion as being advantageous. For multi-copters, the principle of flight is resolved by controlling individual rotors independently - based on sensor values. Each rotor individually - with a fixed propeller on a shaft, is capable of changing the revolutions by adjusting the pitch. The individual setting of rotor values determines the direction and movement of the device in space is determined. Each rotor produces torque affecting the machine structure, which must be compensated for in order to stabilize the device in space. In contrast to single-propeller devices, compensation of this moment is resolved by the reversal of a multi-copter´s even/odd rotors.

For four-rotor (quadcopter) devices, this means that two rotors will rotate in a clockwise direction – CW; and two rotors (will rotate in a) counter-clockwise (so-called CCW direction). For six-rotor - Hexacopter devices - 3 rotors will rotate in a CW direction; and 3 rotors will rotate in a CCW direction.

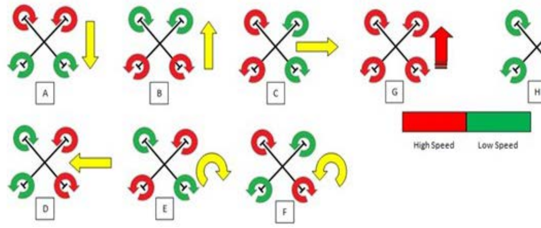

Fig. 2. Potential movements of multi-propeller devices aided by the regulation of their revolution speed. [3]

Drone control systems

MultiWii SE V2.0 Flight Controller Multiwii is the name of an Open Source project. It uses so-called:- “nunchuck” hard-ware - (a gyroscope and accelerometer); used in Nintendo Wii. These sensors were, at the time of the origin of the project very widespread; and thus, even code boards based on Multivii codes, expanded rapidly. By copying and upgrading the original open source code, many other projects and platforms were created, like - for instance:

- CC3D
- Naze32
- Flip32
- Crius

The afore-mentioned Multiwii SE V2.0, is a good example of boards that allows users to modify and expand it with GPS and Gimbal systems. The heart/core of the boards is the ATMega 328P microcontroller and is equipped with all necessary sensors able to provide for flight modes – like holding direction, position and height. The 6-axial values are assured by an IMU MPU6050 chip; containing a gyroscope and accelerometer. Furthermore, a 3-axial HMC5883L digital magnetometer and BMP085 pressure sensor are integrated on the board. The board is programmable through an FTDI interface.

Open Pilot CC3D revo 32bit F4 is another of the open source platforms that were based on the Multiwii platform – and, (ever) since 2010, it has specialised on Drones for Aerial Imagery and Video Capture. The selected board is a higher-end board. Its advantage is its fast 32-bit STM32F4 microcontroller. The board dispose of all of the necessary gyroscopic sensor, accelerometer, barometer, and magnetometer devices, as well as a pre-configured sensor port. This advanced unit provides users with many extensions for setting features like, for instance, USB connectivity for easy software editing and a 433 MHz OPLink Modem for the transmission of telemetric data to a ground control station.

NAZA M is one of the top control-drivers for multi-propeller devices. Although Naza is – unlike the above-mentioned control boards, a closed-end software solution over the above-mentioned board - it is known for its reliability. It's one of the control boards that dispose of a significant quantity of features and ease-of-setup. It is primarily characterised by its perfect flight stability – controlled by an advanced height-tracking algorithm; intelligent orientation control; failsafe mode; or “carefree flight”; where the device itself guards obstacles around itself. The built-in control GPS module provides accurate position and a “return-home” function in case of signal loss. The Naza control board is – thanks to its delicate characteristic of flight, the perfect solution for the need to capture aerial photos or videos because of its fine flight characteristics. It is one of the boards that support one of the highest-quality gimbal systems - DJI H3-3D from GoPro.

This advanced unit provides users with many feature extensions - like USB connectivity for easy software editing, and 433 MHz [4].

RC sets

One of the main components of a multi-rotor concept system, is its control. Under the term “RC set”, is the concept of a modelled radio-controlled radio - that includes a transmitter and a receiver devices. For older drone constructions made extensive use of frequencies ranging from 27 - 75 MHz.

This range of Radio Transmitters have a major disadvantage - in the form of interference. In the case of the simultaneous operation of multiple transmitters; there is a great likelihood that the same channels will be used - and may even lead to loss of control over the controlled device(s). The distribution of usable frequencies is governed by the given country's legislation.

Table. 1 Frequency bands using analogue modulation

Frequency band	Notes
27 MHZ	Amateur Radio Band - up to 11m
35 MHz	Frequency allowed in most European states. Use: to control RC aircraft. Channels are (set) at 10 kHz intervals.
40 MHz	Radio Band for Europe. Used for the control of RC ships and cars. Channels are (set) at 10 kHz intervals.
72 MHz	Radio Band for the USA. Used for controlling aircraft models. Channels are spaced 20 kHz apart
75 MHz	Radio Band for the USA. Used for the control of RC ships and cars. Channels (are) spaced 20 kHz apart.

Today's RC sets - in most cases, use the 2.4 GHz frequency to transmit. This Frequency Band is less prone to interference. The Frequency Range is to be found in the free band that also uses Wi-Fi wireless transmission - used for computer networks.

RC sets mainly differ in the number of potentially usable channels on their transmitters and receivers. The minimum number of channels for controlling a multi-rotor device is 4. (Along with) increasing requirements on the device - like autopilots … or tilt-able, multi-axis, camera mechanisms; (so does) the number of channels required increase. [5]

Furthermore, sets can differ (according to) available features like Programmability, and Integrated LCD Image Reception Display for image reception. The “irrescindability” of 2.4 GHz radio frequency transmission is ensured by DSSS - (Distributed Spread Spectrum) Modulation. The transmitter thereby uses a wide spectrum of frequencies for the given channel - among which it very rapidly switches in the course of sending data. Therefore, it is less likely that - if more than one transmitter of the same type will work in the vicinity; the same frequency will be disrupted.

A further enhancement, is the modulation of the FHSS (Frequency Hopping Spread Spectrum); mainly, this uses Futaba RC sets. This modulation not only switches when transmitting data, between the channel frequency range; but also among other channels. [6]

Image recording and transmission

When selecting a camera, several parameters must be defined to help determine the correct type for the drones. The encoding video standard is one of the parameters that we encounter when choosing a camera. However, it does not matter today which standard will be used because most devices support both standards. NTSC is predominantly used in North America, Japan and South Korea. PAL in most of Europe, Australia, Asia and most of Africa. Depending on usage, we will choose the resolution of the device. For panoramic aerial images, you will definitely need a camera with a higher resolution than a small drone set control using FPV. For 3D modelling of buildings it is advisable to use a camera with higher resolution. The sensor the camera uses is another parameter that needs to be taken into account when selecting the camera.

The 900 MHz, 1.2 and 1.3 GHz, 2.4 and 5.8 GHz frequencies are reserved for the picture transmission. Since 900 MHz is reserved for mobile operators in Europe and the 1.2 and 1.3 GHz bands are reserved for aeronautical and satellite radio navigation service, the frequency 2.4 and 5.8 GHz is most commonly used for image transmission. These frequencies have been the most used for image transmissions.

3 3D modelling of buildings

For the creation of spatial models, two main techniques are currently used in the commercial sphere on the basis of input data:

- 3D laser scanning,
- 3D Photo Scanning.

For 3D laser scanning, the main input is data from a laser scanning device that can contact the space coordinates of the object without contact. This device transmits a laser beam which is routed to the space by a rotating mirror and the distance based on the transmission and reception of the signal is calculated. Based on this data, the so-called "cloud of points" of the scanned space is created using the software.

Digital images are used as input data for 3D Photo Scanning. Compared with the previous technique, there are no coordinate positions of each model point. These are detected using the software algorithm that creates a spatial model from the image file. This technique falls within the field of photogrammetry.

Fig. 3. Sample scanning angles for object scanning [7]

In order to capture spatial realities in the construction, extractive industries, ecology, water management, architecture, or detailed modeling in architecture, robust software is needed with an algorithm capable of generating models with a high level of detail.

The current number of SWs on the market applicable to this issue, whether professional or amateur, is more than 40.

Table 2 Frequency bands using analogue modulation

Program	**Platform**	**Automatic modeling**	**Supported input data**
Propeller	web-based	Yes	Digital

			photos, Lidar, Ortho tiff
PhotoScan	Linux, MS Windows	Yes	Digital photos
3DF Zephyr	MS Windows	Yes	Digital photos,Video
Pix4Dmapper	MS Windows, web-based	Yes	Digital photos
ContextCapture	MS Windows	Yes	Digital photos,Video
Autodesc ReCap	MS Windows	Yes	Digital photos, Lidar

4 Modelling an object

To demonstrate modeling of objects using a specific dron assembly and evaluation of selected softwares, two distinct objects were selected. The first house was chosen as a family house, the second object was a monument high 13m. The limestone quarry was selected as the third object.

Image type:

- Vertical (or nadir) pictures - pictures taken with a camera pointing vertically to the ground. These images are used to capture large areas and then create orthophotomap and 3D surface models. Models made from vertical images only have a problem with the spatial display of more complex objects,
- oblique pictures - pictures taken at a certain angle of the camera that clings to the target object. These images are used to create detailed 3D models of spatial objects like buildings, masts, bridges, or tunnels

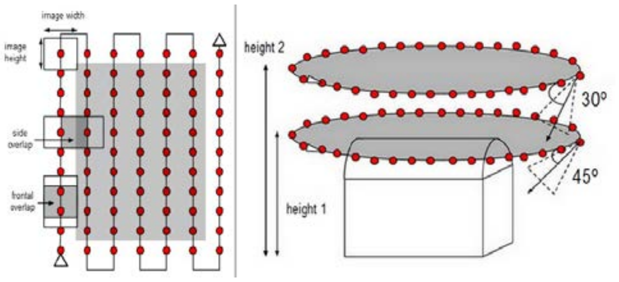

Fig. 4. Types of flight for taking pictures [8]

Image preparation

Most drones´ complex resolutions are based on an in-built solution to storing GPS values when capturing images - in EXIF data. This data from the log can be synchronised with individual images, based on time-data and to write each of them a so-called "geotag". The Complex Mission Planner program, in which flights were planned, is able to perform this synchronisation. After downloading the Flash Log Data of the given flight from drones and software images will detect time-deviations, in milliseconds, for each frame; and register the given GPS data. Images like this are ready for (further) processing in a 3D modelling program.

Processing images into 3D models

In the course of initial processing - the images are initialised in the project in the following steps:

- Initialisation of spatial images – and their implementation in the coordinate system
- The extraction of key images; (in the case of 14 Mpx quality of 100 images; which may correspond to 60,000 key-points per image)
- The use of key-points in the steps in individual image-frames are searched for; those that the program finds suitable - as well as unsuitable associations
- At this point, the software attempts to orient the images - based on matches and initial parameters of the camera - in relation to each other in spatial terms. Two frames are always compared against each other; based on triangulation
- The whole model is oriented in space on the basis of geotags - so as to avoid; for example, its´ overturning.

The total number of key points calculated from the data-set, was 3,173,437. An element of the course of the initial processing process, is also - the calculation of camera chip parameter deviations as the focal distance, from the initial values. Based on these deviations, it is recommended that one optimises camera parameters for initial processing; which are recalculated.

Table 3 Initial Processing Results

	Number of Key Points Per Image	**Identical Point Numbers on a Pair of Images**
Minimum Value:	24 817	1169
Maximum Value:	61 744	40 610
Average Value:	40 044	17 929

Fig. 5. Generated Cloud Points, before optimisation

The following step for completing the model, is to generate a Textured Network Model, on the basis of a "point cloud". This step can be performed concurrently in line with the "process cloud point calculation". Simplified, it has to do with the connection of points in a triangular network cloud; and the subsequent application of textures, (taken) from the images. The only parameter for texture creation, is its resolution.

Model optimisation

As with the initial image processing; so too does the subsequent formation of cloud points, result in the unwanted dissolution of the result; or the creation of artefacts in the cloud spatial points as a result of imperfections in the images.

Manual key points

In the case where a sufficient number of images exist in the project - in which places where an anomaly has been detected, and the images show that location from a sufficient number of angles; it is possible that Pix4D, with the aid of algorithms, to correct this inaccuracy by the addition of a manual key-point.

The resulting model

After applying the aforementioned process and then optimizing it to images taken by the dron's own assembly, the result is a high-quality, real-size spatial model with a real texture. The resulting model has an average sampling distance (GSD) of 0.98 cm per pixel.

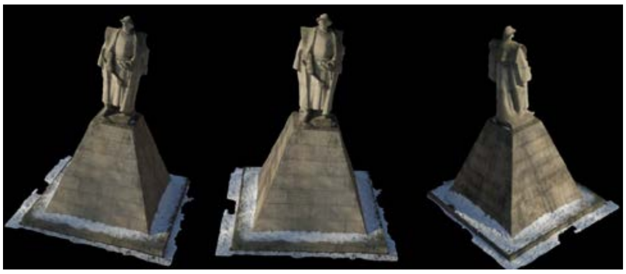

Fig. 6. The resulting model of the monument

5 Conclusion

The aim of the work was to map out the possibilities of modern modeling of space modeling using multi-spindle machines. At present, the method of automatic modeling of objects was possible using stationary devices. This technique should be tested using a custom dron assembly. The created model is able to perform the data collection in a fully autonomous way, the quality of the model being modeled on a realistic level. The presented method can find extensive use in security technologies, eg. in forensic sciences, at simulation floodplains, etc.

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References

1. Aerospace, Krossblade. History of Quadcopters and other Multirotors. Krossblade [online] [cit. 2016-03-12] In: http://www.krossblade.com/history-of-quadcopters-and-multirotors/ (2016).
2. TheBoredEngineers. The quadcopter : control the orientation. TheBoredEngineers. [online] [cit. 2017-05-10]. http://theboredengineers.com /2012/05/the-quadcopter-basics/ (2017)
3. Polytechnic, Ngee Ann. Basic Movement of a Quadcopter. Flight Theory – Multi-rotor. [online] [cit: 2016-02-15] https://sites.google.com/site/npaecopterguide/multirotor_getting_started/flight-theory-multi-rotor (2016).
4. Liang, Oscar. Types of Multicopter. OscarLiang. [online] [cit. 2016-03-10] http://blog.oscarliang.net/types-of-multicopter/ (2016).
5. Brown, Matt. Electronic Speed Controller Basics. Hooked on rc airplanes. [0nline] [cit. 2016-7-2017] http://www.hooked-on-rc-airplanes.com/Electronic-speed-controller.html (2017).
6. RCmodelReviews. 2.4GHz Radio Control Explained. RC model reviews. [online] [cit. 2016-03-15]. www.rcmodelreviews.com/spreadspectrum01.shtml (2016).
7. Correa, Zach. 123D Catch Tutorial. Sculpteo. [online] [cit. 2016-03-21] http://www.sculpteo.com/blog/2014/10/07/3d-print-autodesk-123d-catch/ (2014).
8. Pix4D. Products. Pix4D. [online] [cit. 2016-03-22] https://www.pix4d.com/# (2016).