FIG WORKING WEEK
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Micro UAV for Post Seismic Hazards Surveying in the Old City Center of L'Aquila

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Introduction

- After the devastating earthquake of April 2009, in the city of L'Aquila several institutions are now involved in recovery and reconstruction works on city monuments and public or private buildings
- Various surveys, structure controls and investigations allow to retrieve high precision and accurate data but…
- …there are difficulties in retrieving high resolution metric data regarding the areas that aren't easily reachable , like roofs and facades .

Targets

- The present work has two main targets:
  - Retrieving high resolution metric data in unreachable areas of the old city center of L'Aquila using a remote controlled Micro UAV
  - Elaborating the captured data to generate ortho images and to extract 3D models of the damaged buildings

Support the institutions for a better managment of recovery and reconstruction operations

Workflow

- What is a Micro UAV
- Why Using an UAV in an Old City Center Damaged by an Earthquake
- Case Study: The Proximity Aerial Photogrammetry on Piazza Palazzo
- Elaboration of the Captured Data
- Final Results

What is a UAV?

- The term **UAV** (**U**nmanned **A**erial **V**ehicle) indicates a class of aerial vehicles without the presence of a human pilot onboard, so remotely controlled
- There are many classes of UAVs, like planes, multirotors, helicopters…with different dimensions, characteristics and flight principles
- This work focuses the attention on multirotor classes and particularly on Micro Multirotor UAVs

Plane


Multirotor


Helicopter

The Micro Multirotors UAVs

- The flight principle is similar to the helicopters
- This type of UAV is commonly called “drone”, it has various
- numbers of motors and rotors, realizing different configurations called Quad, Hexa, Okto…
- Particularly, the term “Micro” encloses a subclass of UAVs with the following characteristics:
  - diameter of about 80 cm, operative range of 3-4 Km flight altitude between 0 – 250 m, payload of 1-2 Kg

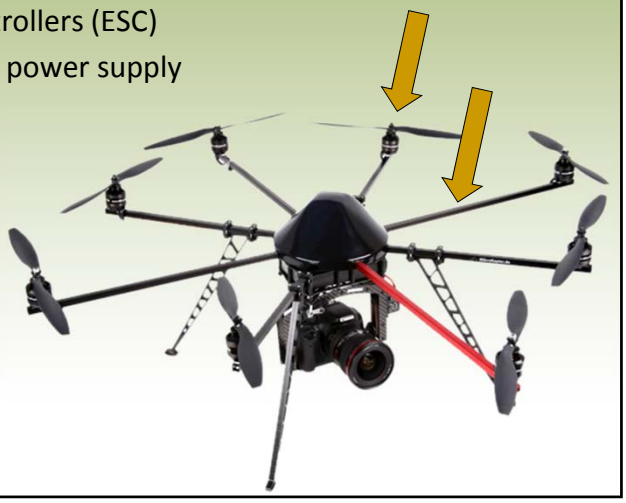

QUAD


HEXA


OKTO

The structure of a “drone” (1)

- Chassis (carbon fiber or aluminuim)
- Brushless motors
- Electronic Speed Controllers (ESC)
- LiPo Batteries used as power supply



The structure of a “drone” (2)

- Flight Control Board: it controls all the electronic parts and gives the drone the possibility to mantain a very stable flight attitude and to remain in hovering mode at a fixed altitude. A flight control board includes:
  - Inertial Measurement Unit (IMU) with 3 accelerometers, 3 gyro and a digital signal processor
  - Barometer (for altitude control)
  - 3-axis magnetometer
- GNSS receiver: it gives the drone the possibility to mantain a precise position during the flight and to follow fully automatically a pre determinated flight plan
- Sensor mount to transport several types of sensors (digital cameras, thermal infrared cameras…)

Flight modes

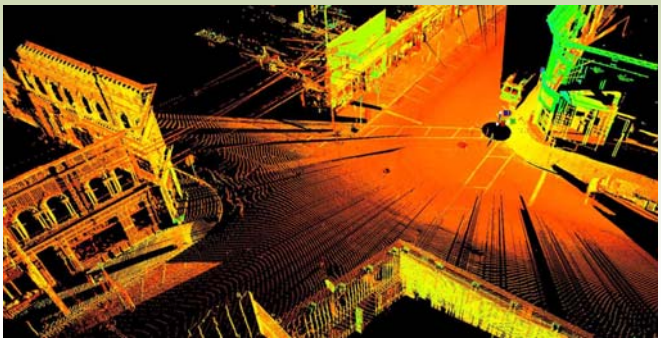
- There are two possible flight modes:
  - *Manual flight*: used to survey the buildings facades; this flight mode is remote controlled by an operator on the ground
  - *Fully automatic*: setting from a Ground Control Station (GCS) a pre determined number of waypoints that the drone can reach in a fully automatic way

Manual flight mode

Automatic waypoint flight mode

Why Use a UAV in the Old City Center of L'Aquila (1)

- Conventional surveying techniques using high precision total stations or laser scanners have many limits on investigating damaged roofs, facades of tall buildings and other inaccessible points.



Laser scanning

Why using an UAV in the old city center of L'Aquila (2)

- Standard aerial photogrammetry allows data retrieval on roofs but with low detail especially because planes cannot fly at altitudes lower than 300m.
- This technique is unaffordably expensive resulting in a low surveying repeatability

In case it is necessary for an even more accurate survey for example on the red highlighted area…
→

Why Using an UAV in the Old City Center of L'Aquila (3)

- Flying with a drone at 150 m altitude enables us to reach better details of a particular area of interest
- High repeatability of this survey with respect to the previous standard aerial photogrammetry

In case we need an even more accurate survey on a single roof of a building as in the highlighted yellow area

Why using an UAV in the Old City Center of L'Aquila (4)

- Flying with a drone at 60 m altitude enables us to capture high resolution images on a single building's roof; this allows discovering any damage caused by the earthquake

Advantages of Using an UAV (1)

- Possibility of capturing high resolution images with respect to the standard aerial photogrammetry or satellite images

Max detail reachable in a satellite image

Particular of the red highlighted area, captured by a drone at 60 m altitude

Advantages of Using an UAV (2)

- Safety: operating on damaged buildings, it's very important that there are no risks for the operators; the use of a remote controlled platform reduces the risks of endangering human lives to 0.
- Possible surveying on difficult or even non accessible areas in a very short time: considering a tall tower for example, with a conventional terrestrial photogrammetry it would be difficult to do a detailed survey due to a perspective effect that hides many important details
- Possibility to fly at low altitudes: from 0 to about 250 meters
- Low aeroacoustic impact, towards the damaged buildings, because of using small electric brushless motors
- High repeatability and efficiency

A Case Study: The Proximity Aerial Photogrammetry on Palazzo Square (1)

- Using the proximity (or low altitude) aerial photogrammetry the target is to represent tridimensionally the entire test area with high detail
- The survey was carried following the steps of the conventional aerial photogrammetry:
  - Creation of stereo pairs with at least a 60% overlapping
  - Materialization of the Ground Control Points (GCP) for a good geo-referencing.
  - Definition of the flight plan to determine the necessary altitude in order to cover the entire test area
  - Data elaboration with photogrammetric software

A Case Study: The Proximity Aerial Photogrammetry on Piazza Palazzo (2)

- The survey was carried out using a Mikrokopter multirotor UAV in Okto configuration, in order to guarantee more flight stability in wind conditions and to increase the payload to transport a digital reflex camera

Canon EOS 550D
Focal lenght: 18mm

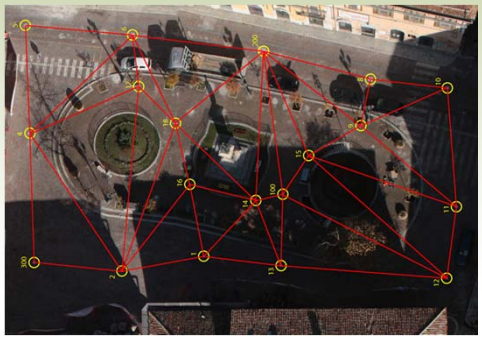
Surveying Phases

1. Ground Control Points (GCP) Materialization
2. Flight Planning
3. Flight Execution
4. Elaboration of the Captured Data
   - Camera calibration
   - DSM (Digital Surface Model) extraction
   - Ortho images generation
   - 3D models extraction

GCP Materialization (1)

- This step is important to georeference the photograms that are captured by the drone
  - GCP were determined by using GNSS techniques in Real Time Kinematic mode (RTK), generating a GCP network of 18 points

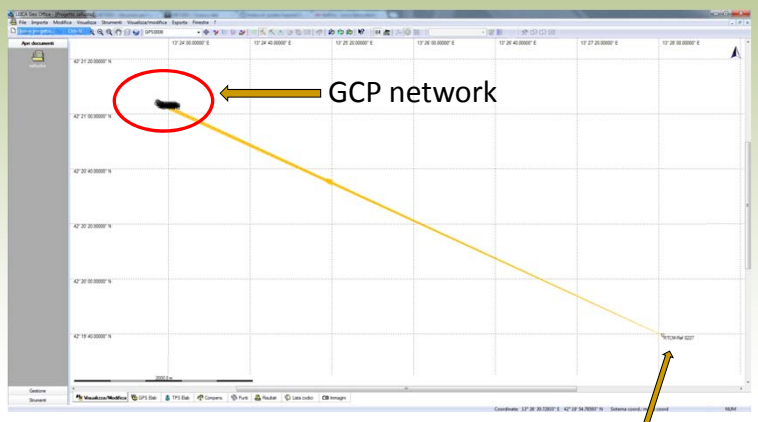
GCP materialization



GCP network

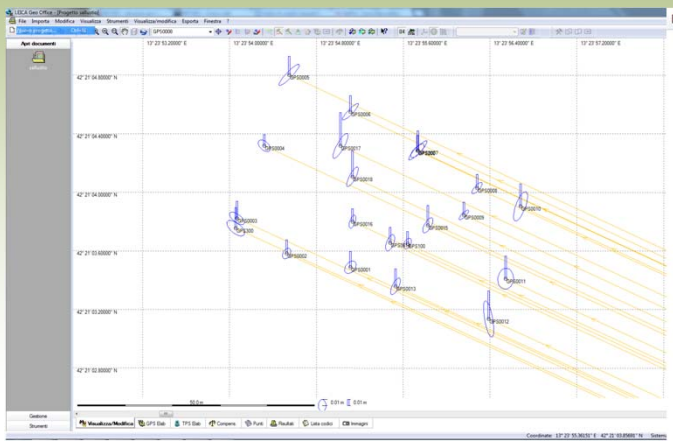
GCP Network (1)

- GCP Network with respect to the reference station



GCP Network (3)

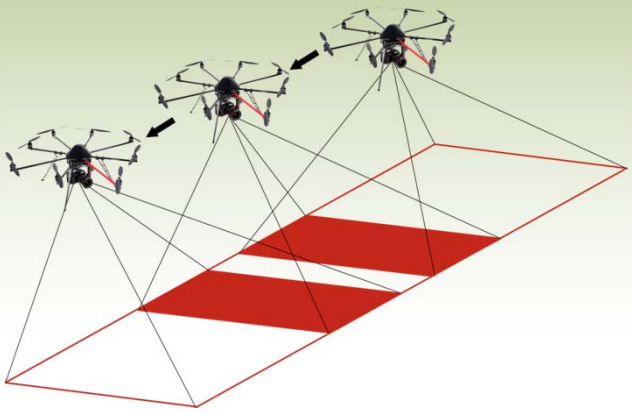
- Eclipse errors and root mean squares for each point



Dp. latit...	Dp. lon...	Dp. qu...
0.0101	0.0094	0.0254
0.0086	0.0069	0.0220
0.0101	0.0120	0.0272
0.0096	0.0098	0.0177
0.0171	0.0165	0.0300
0.0133	0.0129	0.0262
0.0154	0.0149	0.0310
0.0090	0.0083	0.0218
0.0078	0.0078	0.0204
0.0236	0.0112	0.0358
0.0169	0.0126	0.0364
0.0292	0.0082	0.0451
0.0137	0.0079	0.0282
0.0134	0.0071	0.0243
0.0121	0.0083	0.0318
0.0106	0.0056	0.0206
0.0203	0.0122	0.0531
0.0159	0.0094	0.0419
0.0086	0.0062	0.0192
0.0113	0.0110	0.0244
0.0125	0.0144	0.0336
0.0000	0.0000	0.0000

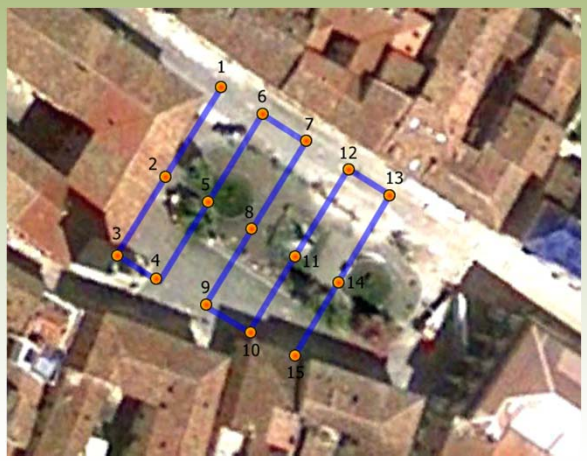
Flight Planning (1)

- In this phase the necessary flight altitude and the adequate number of waypoints were determined in order to guarantee the minimum 60% overlapping to create each stereo pair



Flight Planning (2)

An accurate flight plan was generated with a specific software, including 15 waypoints from which the drone captures the photograms at the altitude of 80m



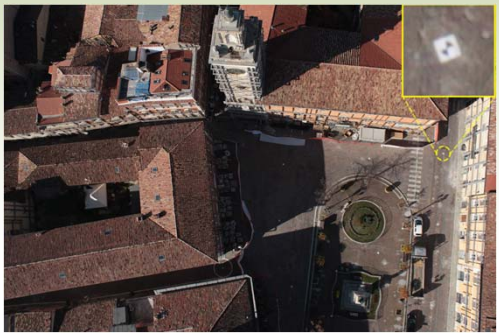
Survey Execution (1)

- Before flight on the test area some specific targets were positioned on the ground control points
- Each target has the dimension of about 30 x 30 cm, in order to be visible in the photograms in the data elaboration step

Survey Execution (2)

- The survey started in manual flight mode, taking the drone to the pre determined altitude of 80m
- Switching to the waypoint automatic flight mode, the drone followed the pre determined flight plan, automatically taking a photo on each of the 15 waypoints

Observing one of the photograms, the upper right highlighted area shows a zoom on a target that identifies perfectly the corresponding GCP

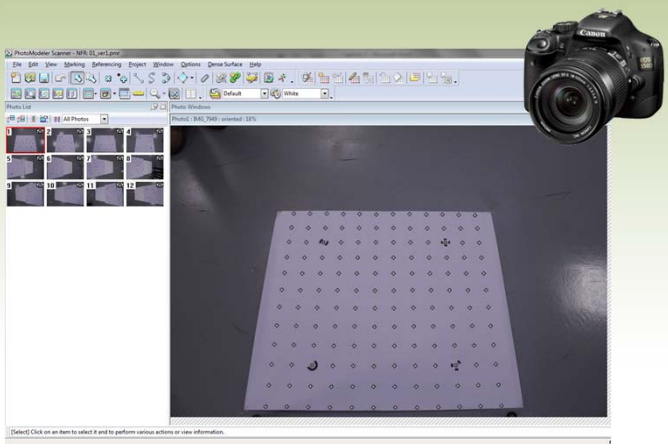


Survey Execution (3)

- After landing a raw mosaic of the 15 photograms a free image was made with composing software

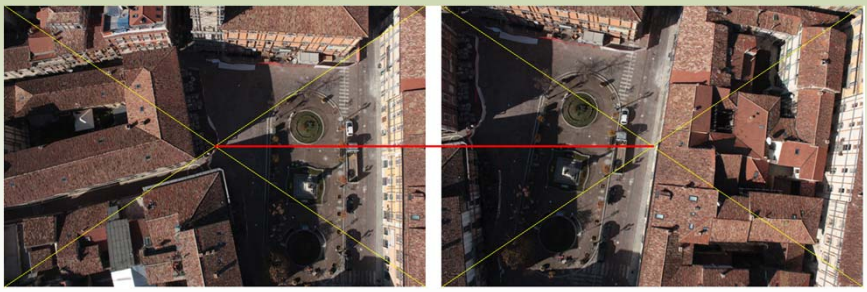
Camera calibration

- Having an amateur camera, the calibration parameters were automatically determined using a specific software



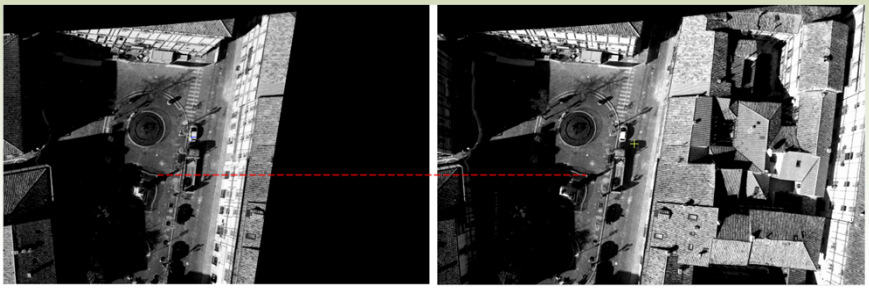
Extracting the DSM (Digital Surface Model) (1)

- First step to extract the DSM: choosing a stereo pair of photograms



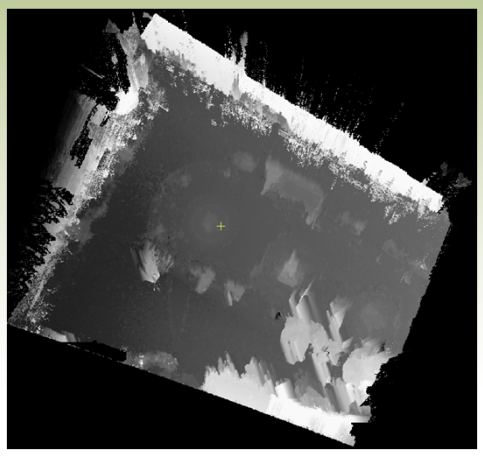
Extracting the DSM (Digital Surface Model) (2)

- Second step: generating epipolar images for a better tie point extraction



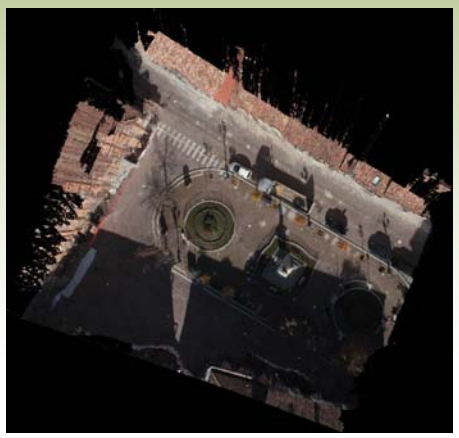
Extracting the DSM (Digital Surface Model) (3)

- Third and final step is the automatic DSM extraction



Generating High Resolution Ortophoto

- The obtained DSM model was used to generate a high resolution orthophoto



Extracting 3D Models of the Roofs

- Finally, also tridimensional models for roofs and particulars of the buildings

Conclusions

- Achievements:
  - High detail carthographic dataset
  - Ortho images
  - Three-Dimentional models of roofs
  - The data can be used for:
    - GIS and WebGIS applications
    - Both private and public entities

Thanks for your attention!