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SPECIAL MOBILITY STRAND

Application of terrestrial laser scanning and UAV-based photogrammetry in the building facade inspection process

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24.03.2020.
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Causes of loss of performance of building structures

- *Physical*
- *Mechanical*
- *Temperature*
- *Chemical*
- *Electrical*
- *Biological*

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Causes of loss of performance of building structures

- *Aging*
- *Natural disasters (earthquakes, landslides and floods)*
- *Climate change*

(wind, temperature, groundwater levels, the influence of the sun)

- *Dynamic and static loads of the structure.*

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The consequences are different types of deformation

- *Tensile*
- *Compressive*
- *Shear*
- *Torsion*
- *Bending*
- *Distortion*

Building structure response

- *Cracks*
- *Tilt (Inclination)*
- *Relative bending*
- *Bending of construction*
- *Twisting*

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Assessment of condition of the building structures facades

- *Imperatives in job include quality, cost-effectiveness, efficiency, minimal time consumption and automatization.*

- *The traditional approach to this process entailed visual inspection, which is expensive, time consuming and leads to data redundancy.*

- *Modern terrestrial laser scanning (TLS) and Unmanned Aerial Vehicle (UAV) based photogrammetry technologies are faster, more reliable, objective, accurate and, accordingly, their use is fully justified.*

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Unmanned Aircraft Vehicle (UAV)

- *UAV, also known as drone, represents an unmanned aircraft vehicle controlled by a ground operator or computer located within the vehicle.*

- *UAV is a part of UAS (Unmanned Aerial System) that usually consists of an aircraft platform mounted with one or more sensors combined with a ground-based control station from where it is operated.*

Based on landing, they can be divided into:

- *Horizontal Takeoff and Landing (HTOL)*
- *Vertical Takeoff and Landing (VTOL)*

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Types of UAVs

Multi-copter

Fixed – wing

Motor parachute

Glider

Chopper

UAV mapping system

- *UAV body from ultra light materials*
- *Electro engine and servo motors*
- *Bateries*
- *Sensors:*
  - *Gyroscope, Barometer, Accelerometer, GPS, Magnetometer, Rangefinder, Inertial Measurement Unit (IMU), Obstacle avoidance,..)*
- *Cameras: RGB, Multispectral, NIR...*
- *Software for flight planning, mapping and landing*
- *Software for data processing*

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UAV photogrammetric workflow

- *Within data acquisition, the object must be captured from a minimum of two camera positions in order to obtain information about the three spatial coordinates.*
- *The created imagery represents a stereo pair that allows creation of object's 3D model that provides information about its real dimensions (shape, position, size)*
- *Based on the analysis and measurement of UAV-collected two-dimensional images, automated digital photogrammetric method Structure from Motion (SfM) is used for reconstruction of physical objects.*
- *Quality and usability of images acquired by UAV depends on the number of parameters that should be defined within the mission planning phase. These parameters should be defined in relation to the mission goal.*

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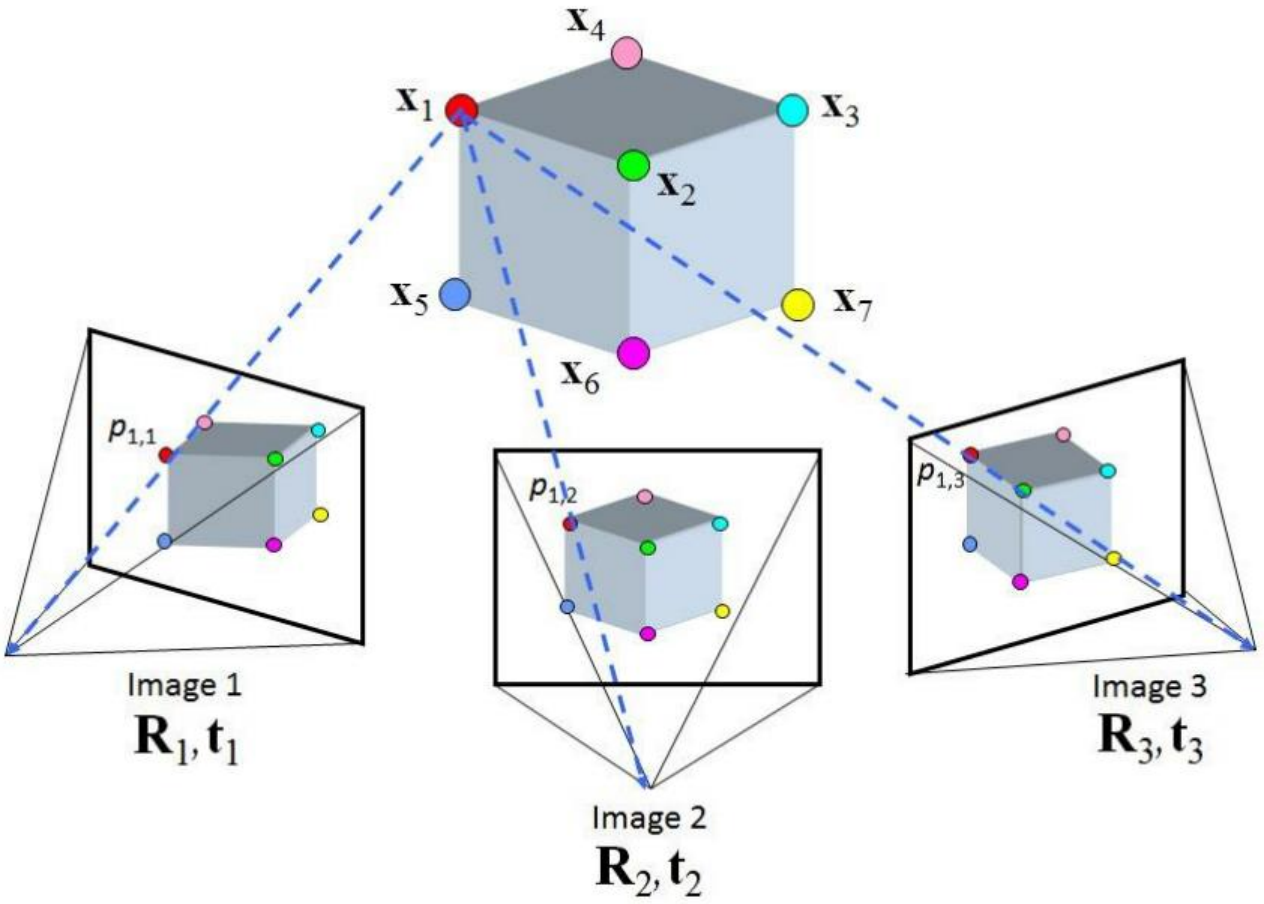
Structure from Motion method



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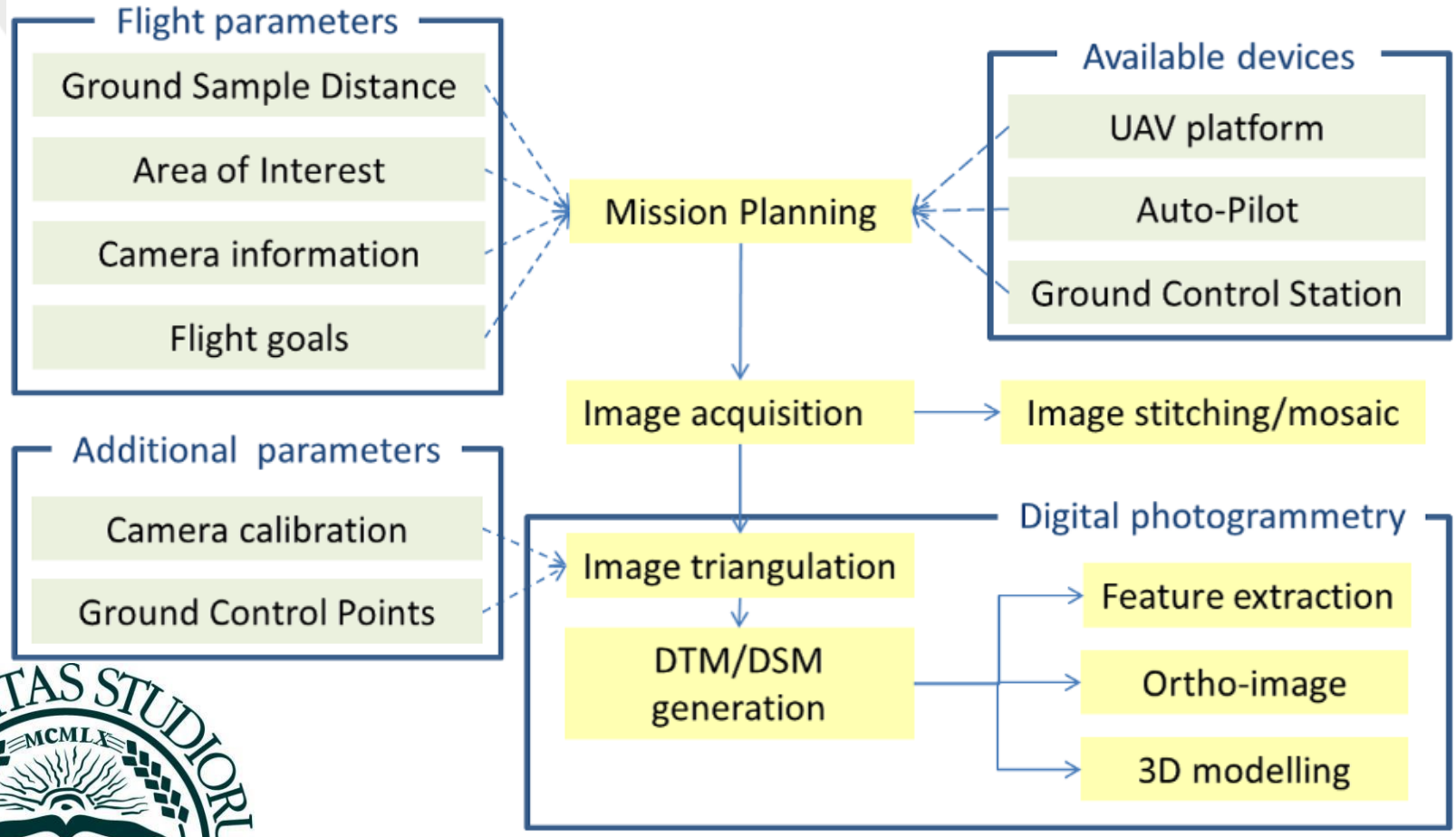
UAV photogrammetric workflow



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UAV photogrammetric workflow

Presented workflow is divided into three phases:

- *mission planning*
- *image acquisition and*
- *data processing.*

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Mission plan

Mission plan should be established based on the area of interest, the acquired GSD and camera specification.

Parameters that should be defined in this stage are:
flight mode, path, speed, image overlaps, camera angle, flight altitude and distance from the target surface.

The selection of optimal flight parameters depends on the mission goals, as well as on the available devices.

Factors that should also be considered in the process of flight planning are limitations related to UAV battery life, legal regulations and weather conditions.

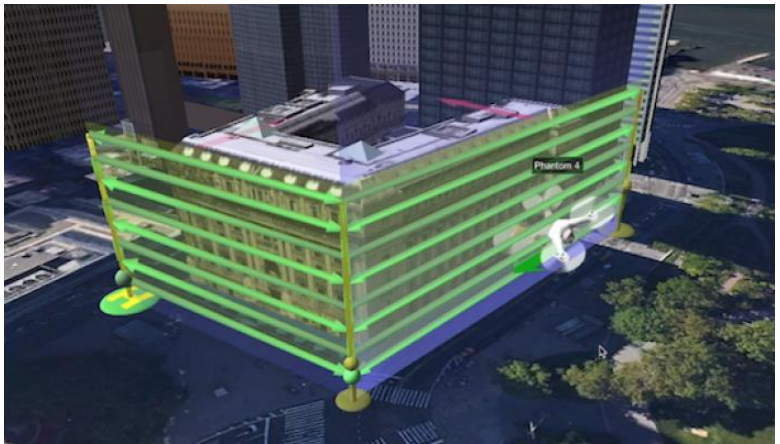

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Image acquisition

Within the image acquisition phase, flight is usually performed in manual or autonomous mode, based on the performances of available devices (platform, auto-pilot and Ground Control Station (GCS)) affecting the quality of the collected data.

In autonomous mode the flight path is set based on GNSS/INS (Inertial Navigation System) waypoints which UAV will follow using navigation system (auto-pilot).
In this case, GCS observes UAV platform providing insight into real-time flight data such as drone position, flight speed, attitude and distances, battery level, etc.

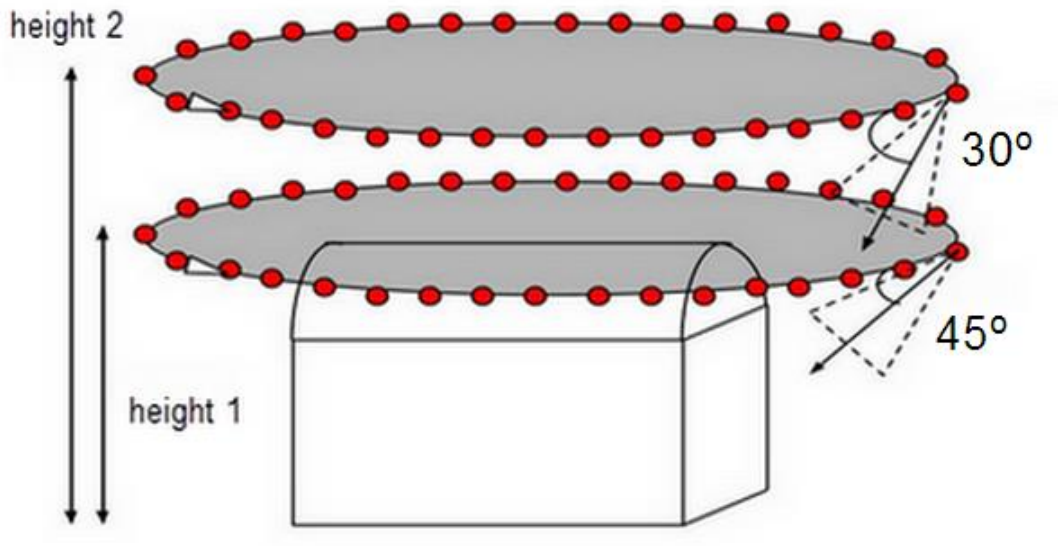

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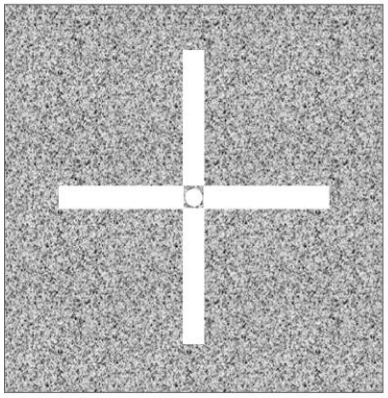
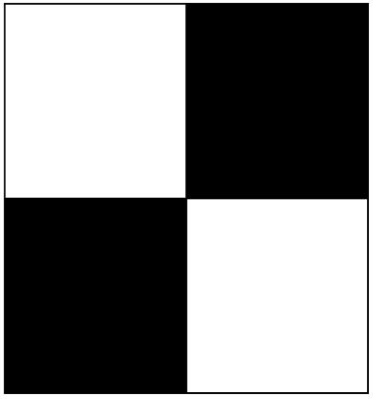
Image acquisition

In manual mode, platform is remotely controlled by operator from the ground station and image acquisition process usually results with irregular image overlap and acquisition geometry.

An additional step to the image acquisition process is placing and measuring of Ground Control Points (GCPs) on site for scaling and geo-referencing purposes. This is done though a traditional surveying method of using a total station or GNSS positioning method.



(a)



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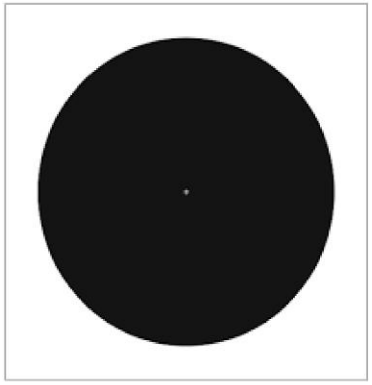

(c)

Data processing

The final phase represents processing of UAV acquired images.

In order to successively generate a Digital Surface Model (DSM) or Digital Terrain Model (DTM) camera calibration and image triangulation should be initially performed.

DSM and DTM can be finally used to produce 3D models, orthophoto maps or for the extraction of further metric information.

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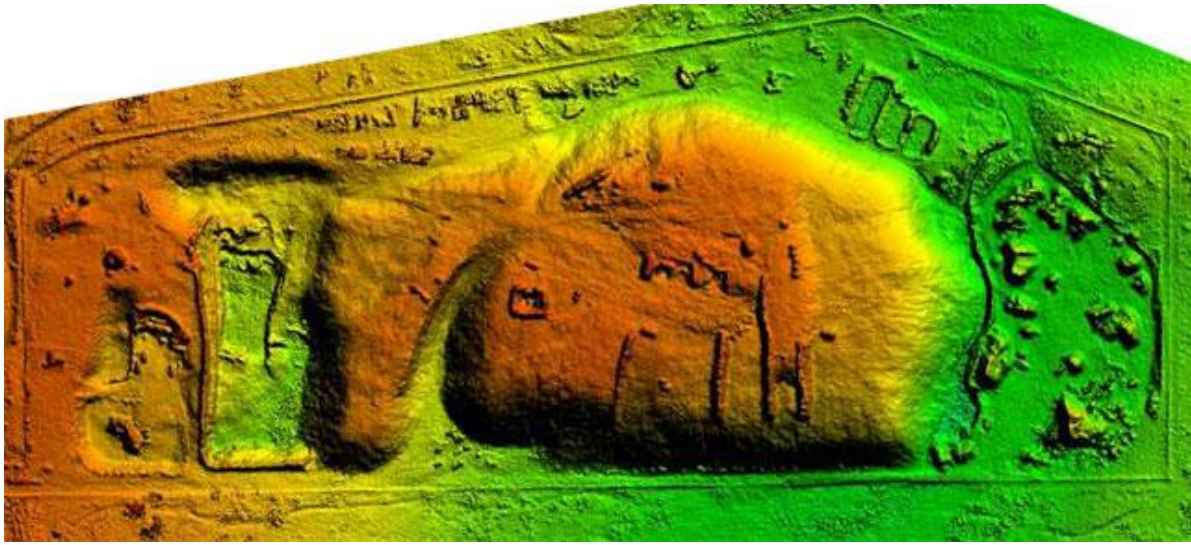
Results of mapping using a UAV

3D model

Digital elevation model



Point cloud

Orthophoto map/image

Case study – Residential building in Novi Sad, Serbia, Crack detection

UAV – Parrot Anafi	
Aircraft Specifications	
Take-off weight	320 g
Dimensions	175x239x63.5 mm
Max flight time	25 min (no wind)
Operating temperature range	0 – 40°C
Maximum work range	4 km
Satellite Positioning System	GPS/GLONASS

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Case study – Residential building in Novi Sad, Serbia, Crack detection

UAV – Parrot Anafi	
Camera Specifications	
Sensor format	6.194 x 4.646 mm
Sensor	1/2.4” CMOS
Lens	FOV 180°
ISO range	100-3200
Image resolution	4608 px X 3456 px
Pixel Size	1.12 µm
Focal length	4 mm
Diagonal crop factor	7.487

UAV – Parrot Anafi	
Flight Plan Parameters	
Flying distance from the façade	6 m
Pilot mode	Manual
Ground Sample Distance (GSD)	2.1 mm
Area covered by a single image	9 m x 7 m
Overlap	
End lap (along flight lines)	Side lap
89%	89%

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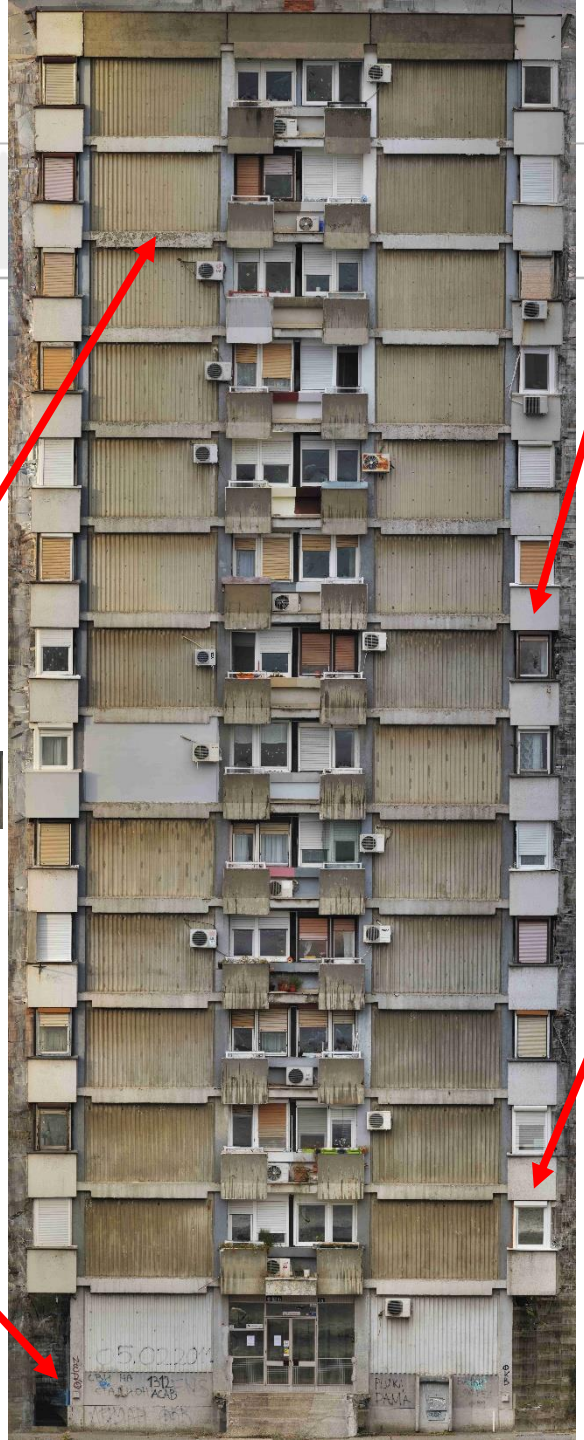
Case study – Residential building in Novi Sad, Serbia

Crack detection



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Terrestrial Laser Scanning (TLS)

- *Laser scanning is developing rapidly as a method of surveying.*
- *Areas of application: Civil engineering, Architecture and urban planning, Mining, Geology, Energetics, Industry, Forensics, 3D visualization, Cultural heritage, etc.*
- *The application of laser scanning is not only limited to the determination of the geometry of building structures but is also used to determine the geometrical changes of those structures.*

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Terrestrial Laser Scanning (TLS)

- *During deformation monitoring, geometry changes of structures of order of magnitude from parts of millimeters to several centimeters can be detected, so the analysis of data collected by laser scanning technology is performed at a level close to the scanner resolution.*

- *The TLS method enables the rapid, remote measurement of hundreds of millions of points without the need for point signaling, thus providing a large amount of spatial data in a short time period.*

- *The result of such a scan is a dense point cloud that allows accurate modeling of structures.*

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The classification of TLSs according to their distance measuring method

Measurement method	Range [m]	Accuracy [m]	Company
Flight time	<100	<10	Optech, Leica, Mensi, Callidus, Riegl
	<1000	<20	Optech, Riegl
Phase difference	<100	<10	IQSun, Leica, Visimage, Z+F
Optical triangulation	<5	<1	Mensi, Minolta

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TLS parameters

- *Beam Divergence*
- *Angular Step*
- *Range Distance*
- *Field of View*
- *Points Per Second*
- *Size and Weight*

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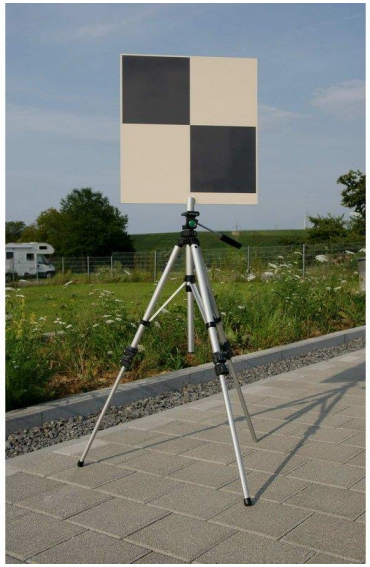
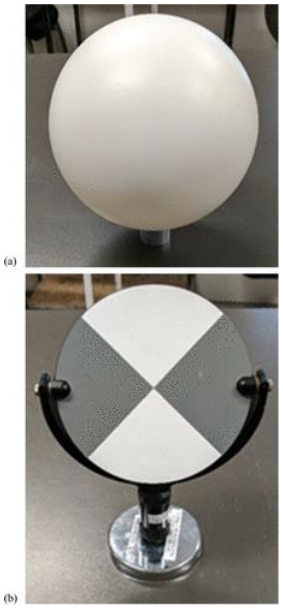
TLS system

Target poles



Tribrachs

Targets



TLS on tripod

Software for data processing

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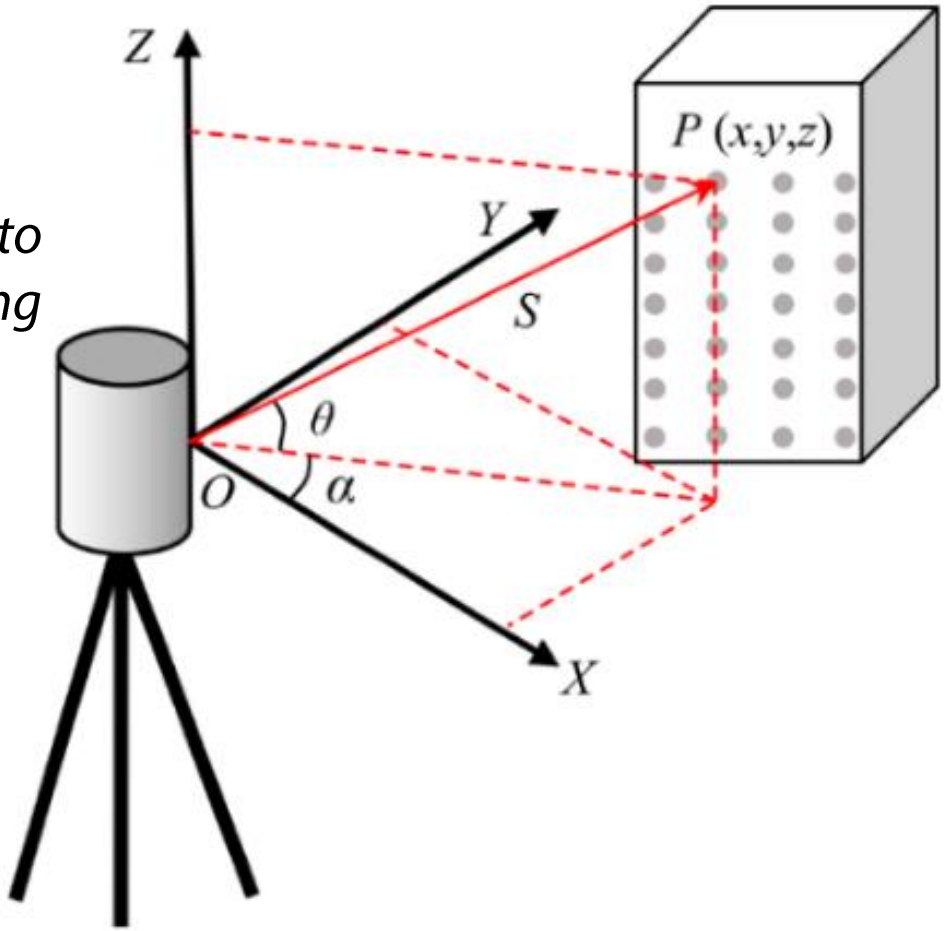
Measuring principle of the terrestrial laser scanning

- *The principle of 3D coordinate extraction using TLS is based on measuring the time it takes for the laser pulse to travel from its source to an object and return, and computing the distance based on the travel speed of the pulse.*



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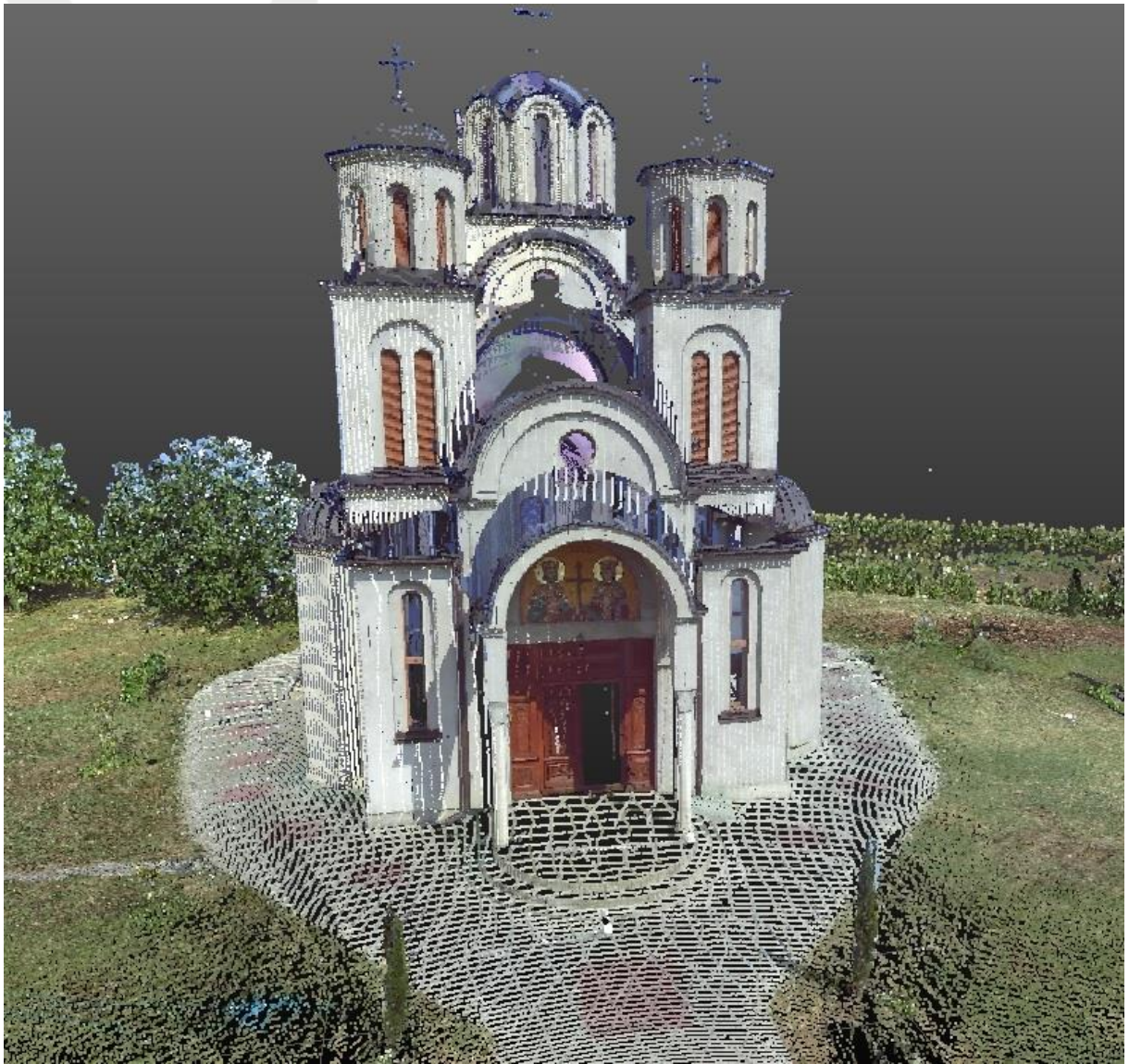
Point cloud generated using TLS technology



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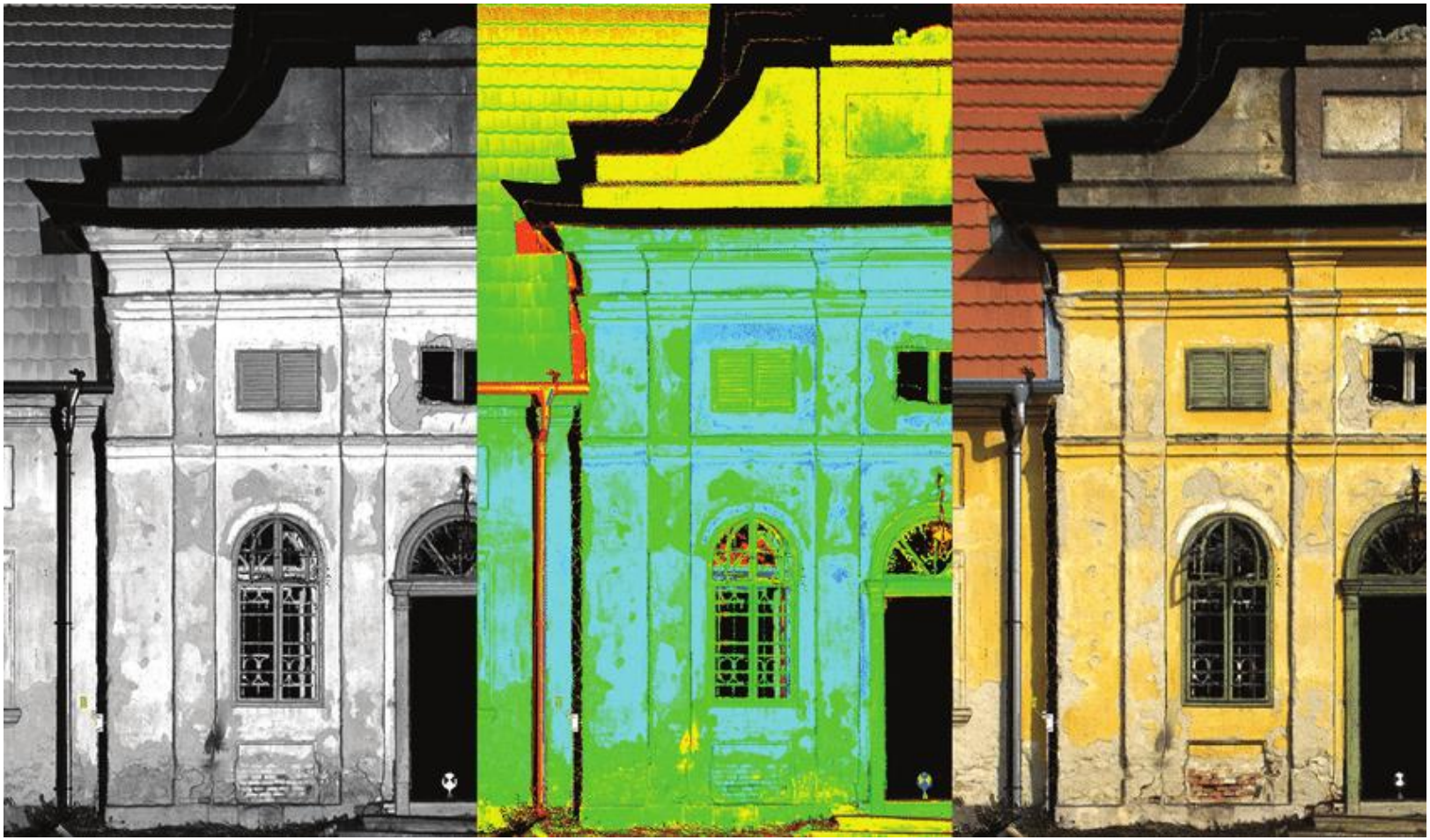
Different types of point cloud styles

Gray scale intensity | Intensity | RGB



Case study

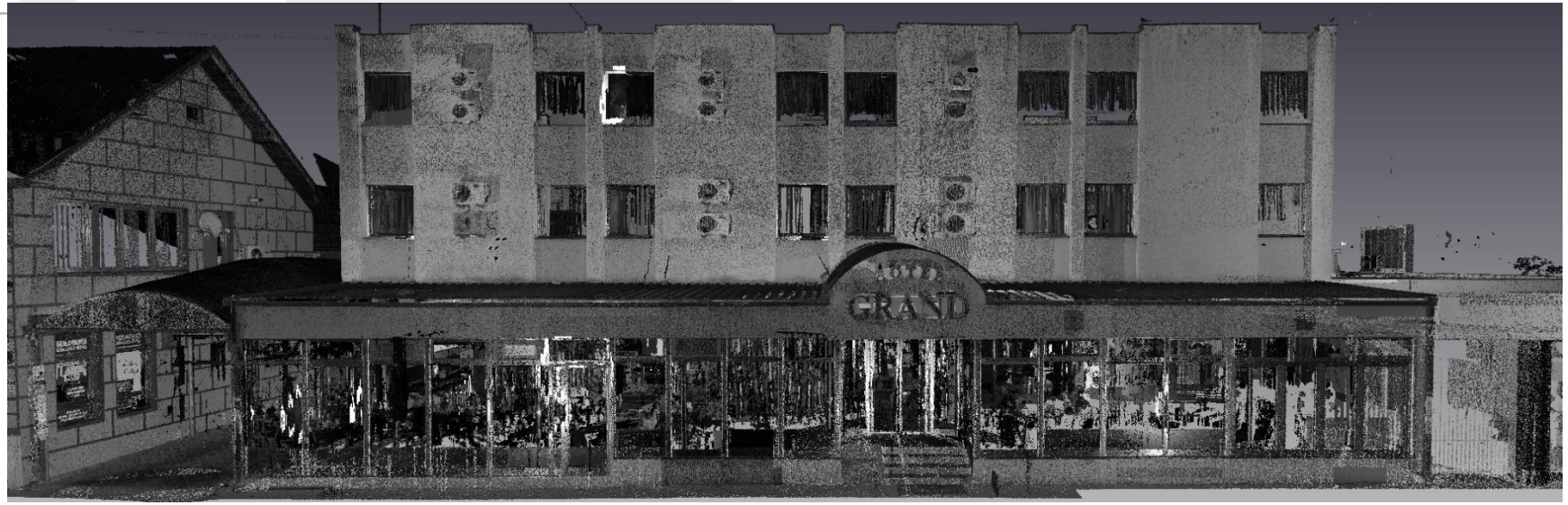
TLS – Trimble FX	
Scanner type	Phase difference
Dimensions	425 L x 164 W x 237 H mm
Weight	11 kg
FOV	360° x 270°
Operating temperature	5 °C to 45 °C
Power Supply	DC 19–24V, 3.5A; AC 110–220V
Ambiguity Range	1-pass: 70 m; 2-pass: 70/140 m
Data capture rate	216,000 points per second

Case study

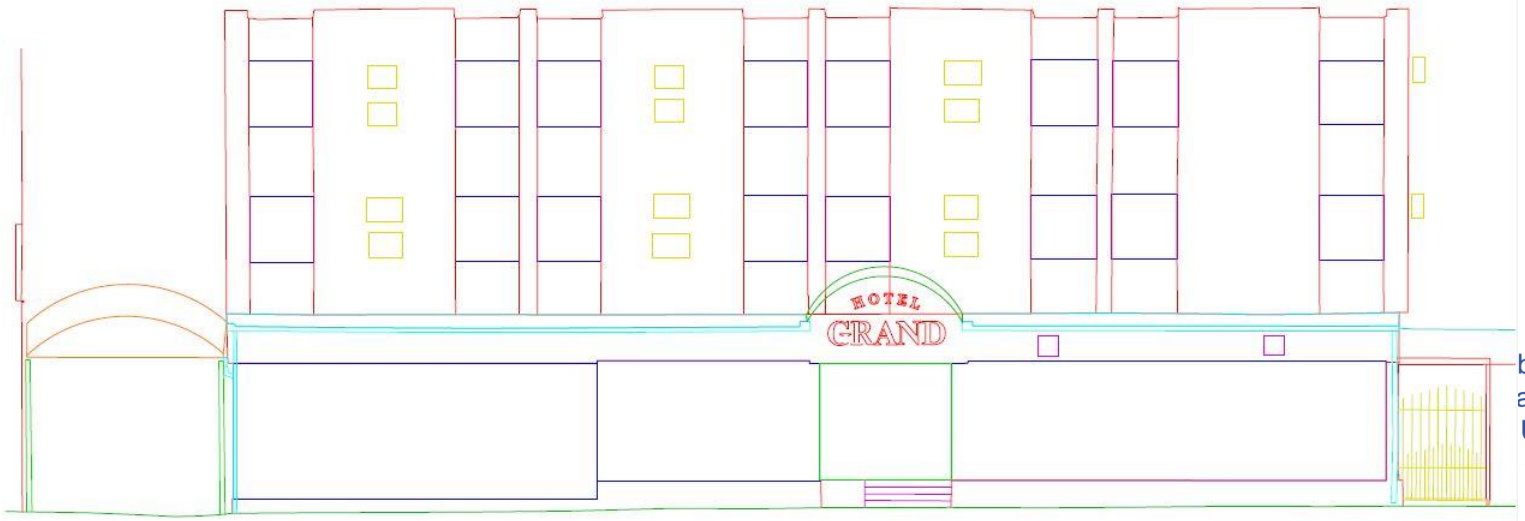
TLS – Trimble FX	
Typical scan time	5 minutes (single pass)
Position accuracy	0.4 mm @11m; 0.8 mm @21m; 2mm @50 m
Angle uncertainty	<30 arc second (1.6mm @11 m; 3mm @21 m; 8 mm @50 m)
Angular resolution	8 sec
Beam diameter	2.3 mm @ 5 m; 16 mm @ 46m
Range uncertainty	1 mm @ 15 m single pass (on 90% reflectivity)
Distance accuracy (std dev.)	0.6 mm @ 11 m; 0.8 mm @ 21 m; 2.4 mm @ 50 m; (on 90% reflect.)

Case study – Hotel in Indjija, Serbia, Reconstruction

Point cloud of the front facade of the Hotel



Detailed 2D .dwg drawing



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Pros and Cons TLS

- *Advantages of using TLS:*
  - *high density, high resolution, high accuracy, and low uncertainty*
  - *no in situ instrumentation of sensors,*
  - *no difficulties to reach structures or structural members,*
  - *more robust (i.e., lower likelihood of inadequate results)*
  - *independence of natural light sources*
  - *no wiring costs and,*
  - *typically quicker to post-process.*

- *Disadvantages of using TLS:*
  - *expensive,*
  - *accuracy of the measured point clouds degrades with distance,*
  - *surveying the exterior of tall objects is especially problematic because of the need for large distance from the object. In this case, it is even more of a problem if such a facility is in the narrow streets of urban areas*
  - *specular surfaces such as objects made of glass or mirror-like metal negatively affect reflection's diffusion when scanning with TLS.*

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Pros and Cons UAV

- *Advantages of using UAV :*
  - *cheaper technology,*
  - *typically lighter and more compact tecnology,*
  - *images contain all the information required for 3D reconstruction of the scene as well as the photo-realistic documentation*
  - *lower power requirements and,*
  - *more easily serviced or replaced.*

- *Disadvantages of using UAV:*
  - *requires more careful setup of control points and coordinate space to ensure sufficient network geometry and datum definition,*
  - *requires much closer proximity to the target area for precise observations,*
  - *negative impact of sunlight directed at the drone camera*
  - *longer data processing time and,*
  - *dependence on data from other sources (GNSS or total station provides scale, orientation, and location)*

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CONCLUSION

- *Both methods, TLS and UAV, have their advantages and disadvantages and one cannot generally tell which method is better and more applicable.*

- *It is always necessary to look at the requirements of the project:*
  - *what is the subject of the surveying,*
  - *what is the required accuracy,*
  - *what level of detail is required and,*
  - *at what time interval it is necessary to collect the data and deliver product.*

- *As a recommendation in documenting the condition of the facades, the integration of two modern methods - UAV and TLS can be adopted as the best solution*

- *To obtain complete data coverage, TLS technology must be used, while UAV can be used to capture facades that are not in the scanner's field of view due to various obstacles in order to obtain complete data coverage.*

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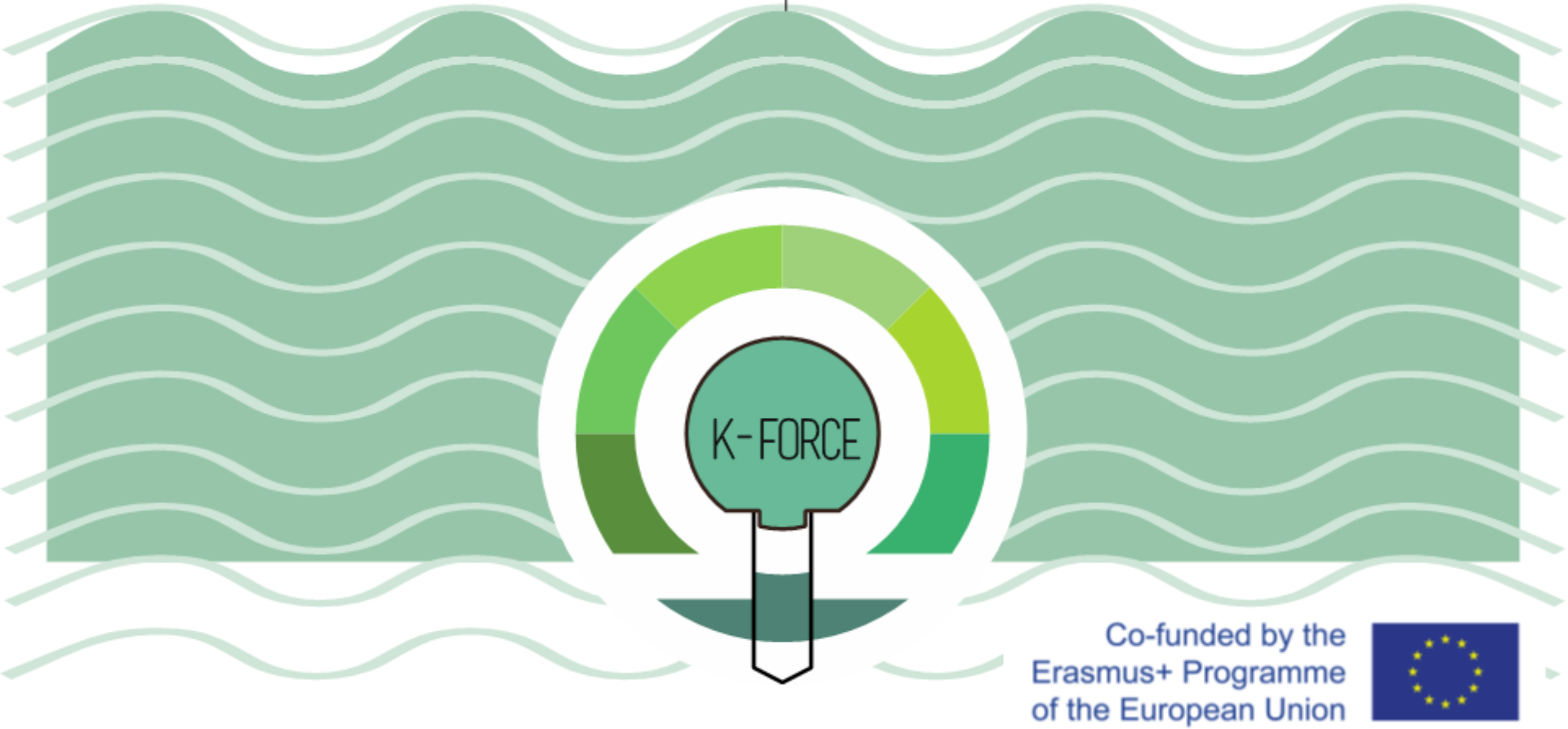

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Thank you
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