The Revolution of Close-range Photogrammetry: Drawing Maps Directly on Images of Regular Cameras

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AGC NYS Construction Industry Conference

December 2014

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Geomatics Expert Systems

About Datumate

- Leading vendor of 'Field-to-Plan' software products
- Few hundred customers: mostly land surveying firms

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Founder & CTO

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Co-Founder & CEO

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Outline of this seminar

- What are the drivers of the close-range photogrammetry revolution?
- Understanding the theory: how does close-range photogrammetry works?
- Learning the practice: choosing your tools and tips for field work
- Making it all work: real-life case studies of land surveying projects

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Agenda

Why close-range photogrammetry?

Key principles: how does it work?

Choosing your tools

Best practices in the field

Real-life surveying case studies

Summary

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What is photogrammetry?

Obtaining reliable information about physical objects and the environment from photographic images

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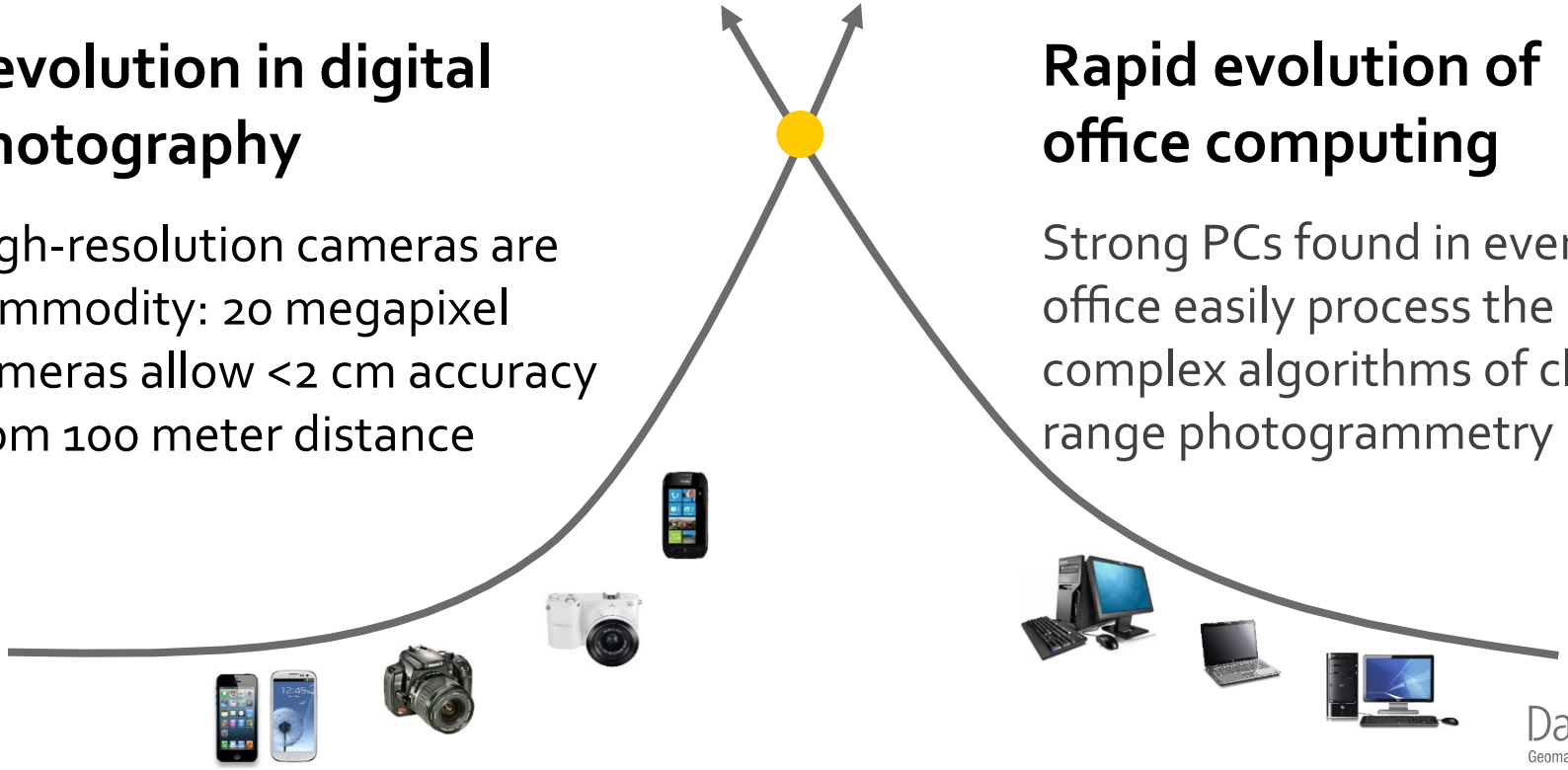
Why now?

The key drivers of close-range photogrammetry

Revolution in digital photography

High-resolution cameras are commodity: 20 megapixel cameras allow <2 cm accuracy from 100 meter distance



Rapid evolution of office computing

Strong PCs found in every office easily process the complex algorithms of close-range photogrammetry

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Field-to-plan today…

Expensive, laborious, complex and error-prone

Making field measurements

Sketching in field by hand

Drawing of maps and plans

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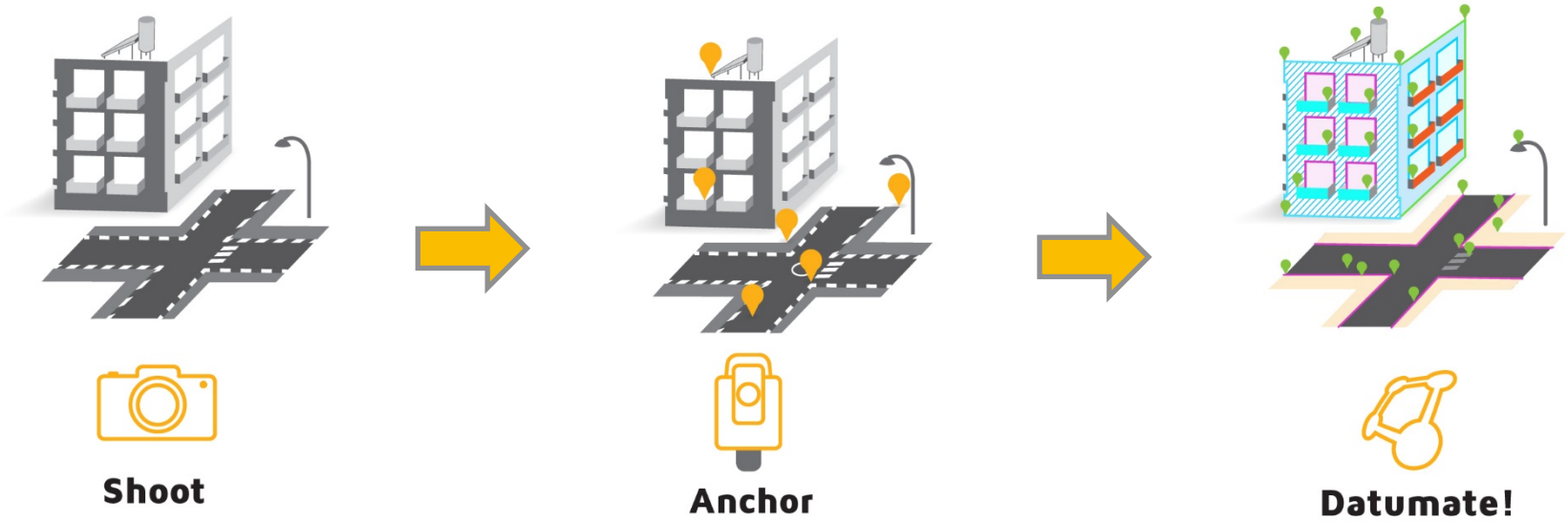
Close-range photogrammetry: Field-to-plan with regular cameras

Cost-effective, simple and accurate



Photograph the surveyed area/object

Geo-reference the images

Measure & draw directly on images

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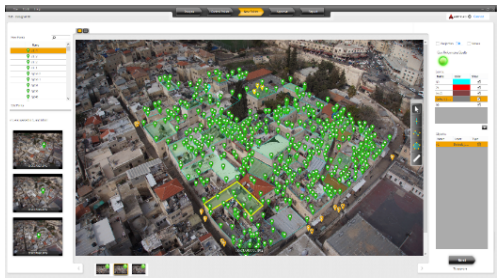
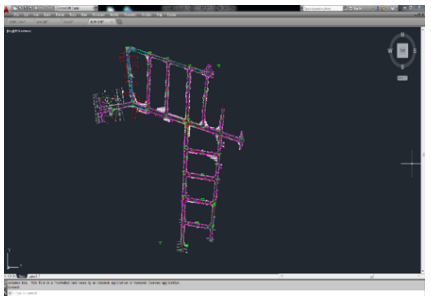
Drawing directly on images

No need for digitization in stereoscopic views: the user can **draw objects directly on the images** with full 3D results, since positions of new points marked on the images are automatically found in real-time





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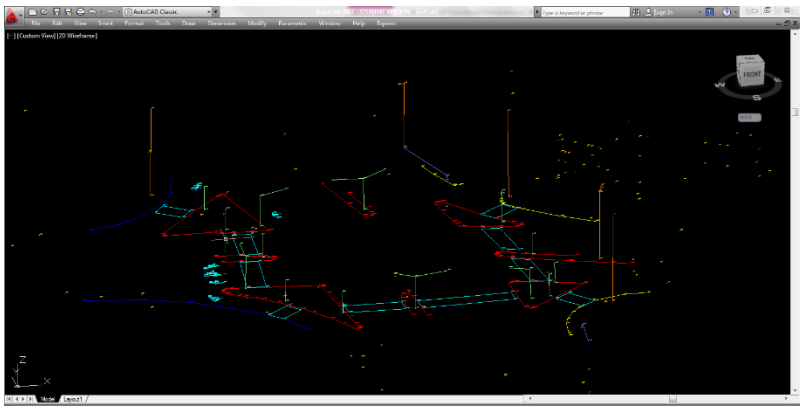
Case study #1: intersection

The task: survey the intersection

Key challenges: traffic-intensive road, occupational safety.

Planned effort with conventional methods: 3 days (2 days in the field, 1 days in the office).

Actual effort with close-range photogrammetry: 1 day (½ day in the field, ½ day in the office).



Camera: Sony Alpha NEX-7 24MP, 16mm fixed lens, mounted on a 20' telescopic pole, Wi-Fi controlled

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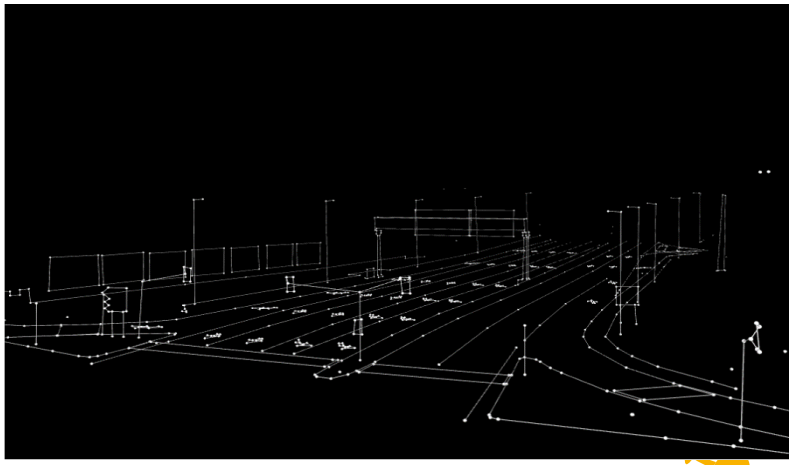
Case study #2: roadway mapping

The task: survey the road, traffic markings, overhead signs and street lighting structures.

Key challenges: traffic-intensive road, occupational safety.

Planned effort with conventional methods: 5 days (3 days in the field, 2 days in the office).

Actual effort with close-range photogrammetry: 1 day (½ day in the field, ½ day in the office).



Camera: Sony Alpha NEX-7 24MP, 16mm fixed lens, mounted on a quadcopter at 50', Wi-Fi controlled

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Case study #3: stockpile

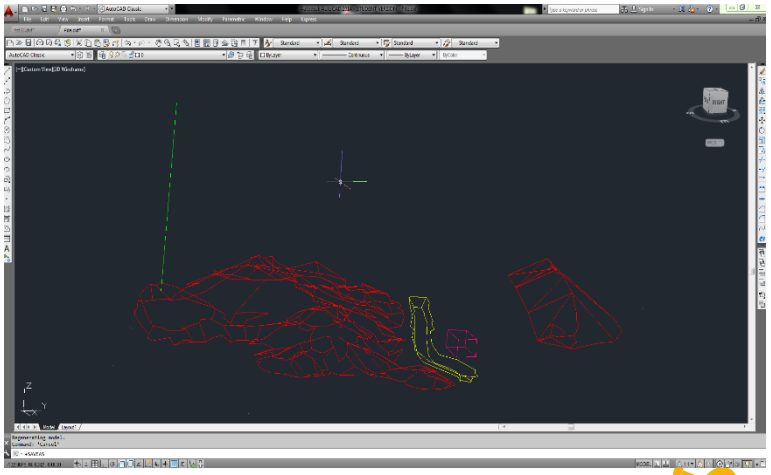
The task: survey stockpile to calculate volume.

Key challenges: climbing the stockpile, traffic of dump trucks and bulldozers

Planned effort with conventional methods: 2 days (1 day in the field, 1 day in the office)

Actual effort with close-range photogrammetry: 5 hours (1 hour in the field, 4 hours in the office)

Camera: Nikon S-6500 16MP, 24mm fixed lens



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Case study #4: pedestrian bridge

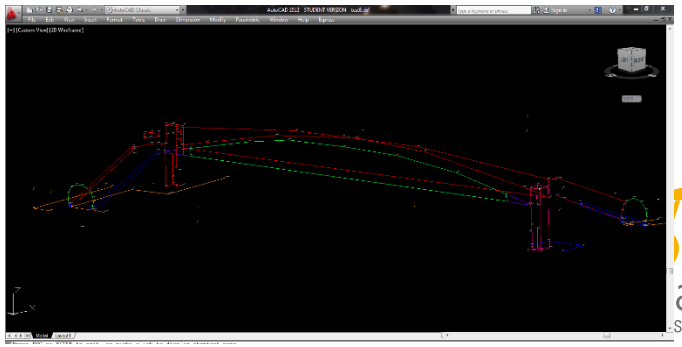
The task: survey a bridge across a highway.

Key challenges: traffic-intensive road, occupational safety, reflective surfaces

Planned effort with conventional methods: 3.5 days (2 days in the field, 1.5 days in the office)

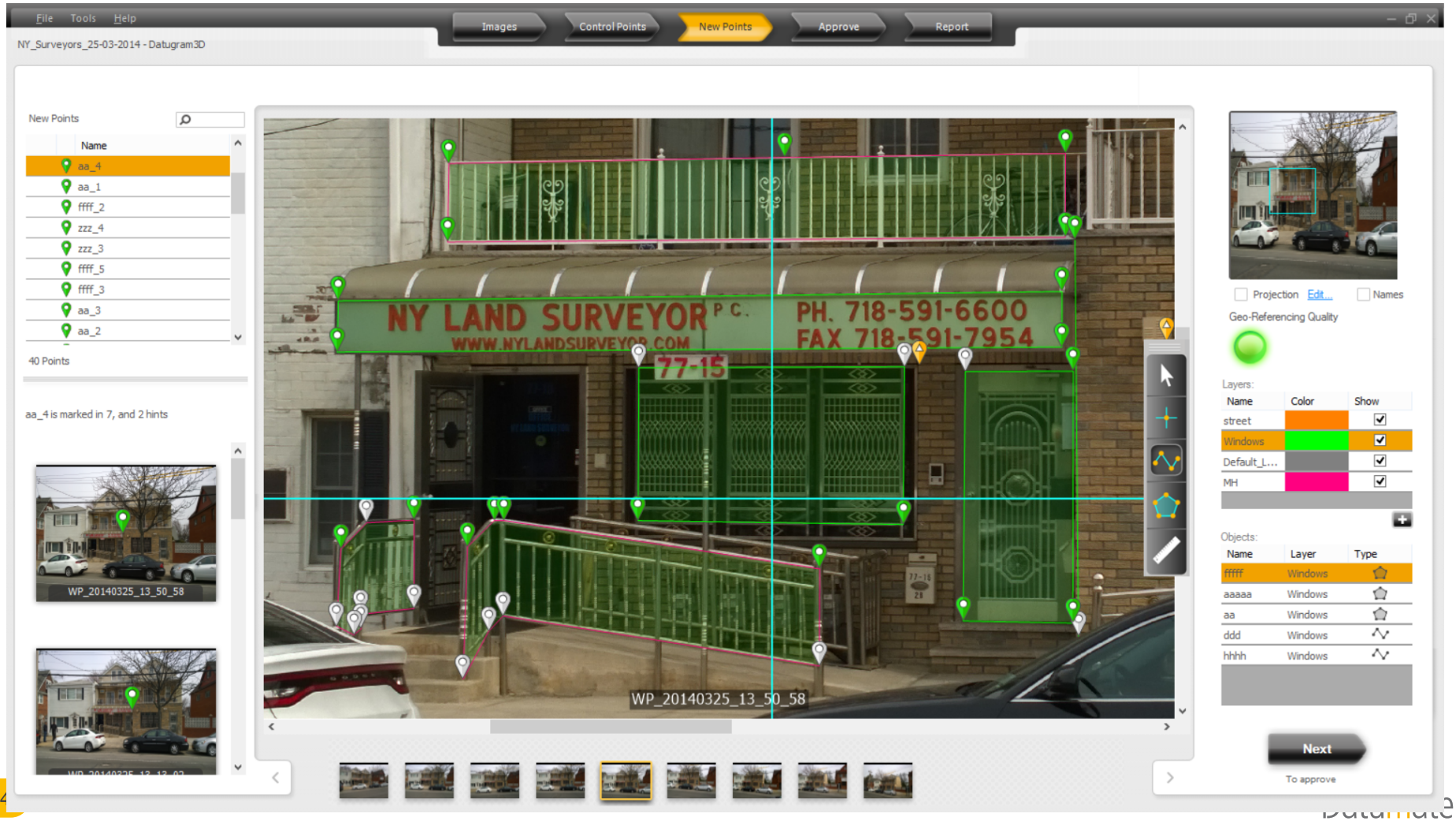
Actual effort with close-range photogrammetry: 5 hours (1 hour in the field, 4 hours in the office)

Camera: Cannon Rebel 650D, 24mm fixed lens



DatuGram™ 3D demo

GeoForm+ Most Innovative Product AWARD WINNER 2013



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The value of close-range photogrammetry to surveyors

Step function in productivity save field and office time

First time right no need for follow-up works

Faster turnaround times offer next day delivery

Exceptional quality control see what was measured

Enhanced occupational safety OSHA regulations

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Agenda

Why close-range photogrammetry?

Key principles: how does it work?

Choosing your tools

Best practices in the field

Real-life surveying case studies

Summary

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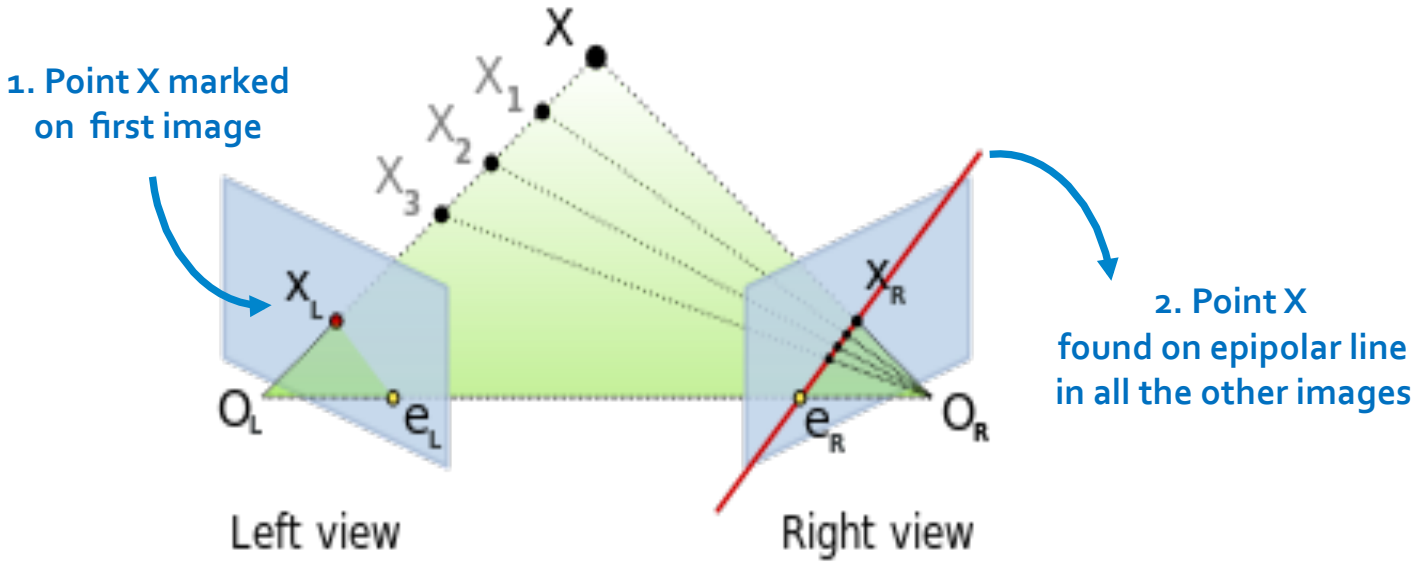
The key principle

The 3-D coordinates of any point may be calculated, when:

1. The point is located in more than two images;
2. In each image, camera position and orientation is known; and
3. The focal length and radial distortion of the camera are known



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Types of photogrammetry: Aerial photogrammetry

Photographs made by airborne platforms

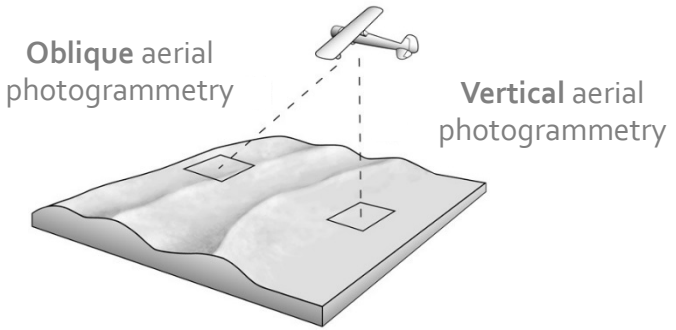
Photographs are oblique or vertical

Dedicated metric camera systems

Complex and expensive to operate

Rely on known position and orientation of images

Provides medium accuracy > 10-15 cm



Good only for 1:500 large-scale mapping

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Types of photogrammetry: Close-range photogrammetry

Photographs made by surveying crews

Photographs made from the ground-level

Using regular digital cameras

No need for position and orientation of images

Simple and cheap to use

Provides high accuracy < 1-2cm

Good for daily 1:250 scale surveying work

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Measurement accuracy

Position accuracy in close-range photogrammetry depends on:

- Camera resolution in mega-pixels
- Distance from camera of measured object
- Accuracy of geo-referencing the control points
- Minimum angle between images

18+ mega-pixel camera allows 1-2 centimeter accuracy from a distance of ~100 meters

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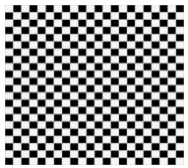
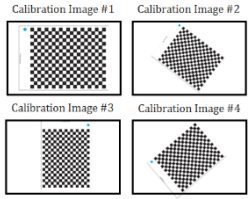
Under the hood of close-range photogrammetry software suites

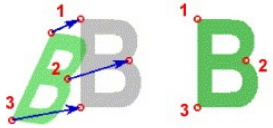
1 Automatic camera calibration



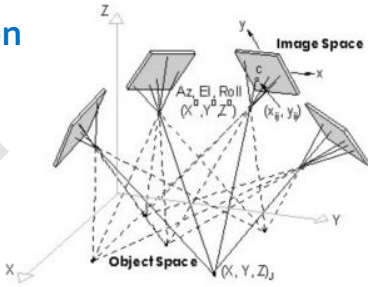


Use any regular camera

2 Automatic image association



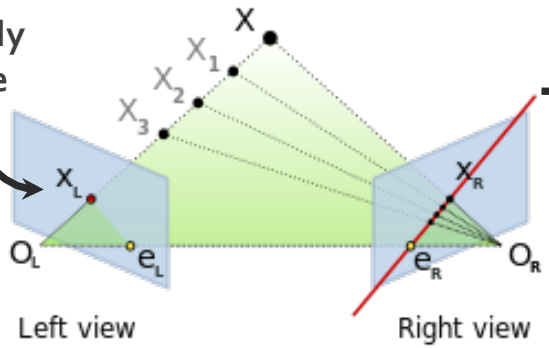
No need to know camera position and orientation



3 Automatic image orientation

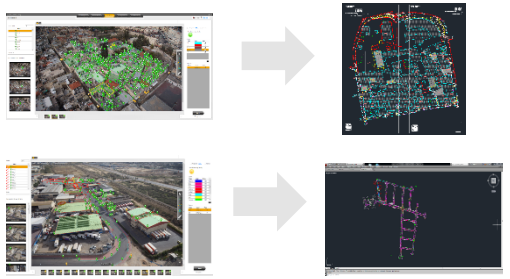
4 Automatically finding new points in images

Point X manually marked on one image...



...automatically found in all other images

Draft 3D plans directly on 2D images



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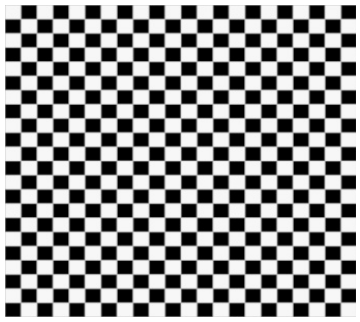
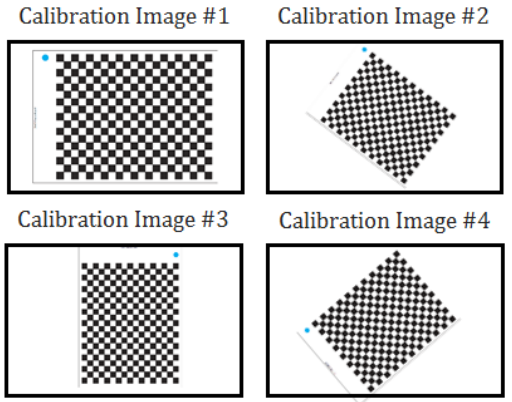
Automatic camera calibration

- Finding the **focal length** and **radial distortions** of the camera
- One-time procedure: print, measure, shoot, and load images
- Initial camera parameters automatically found and stored
- Parameters automatically continuously refined
- As a result, the user may use any camera for photography

Print and shoot calibration target



Load images to the software



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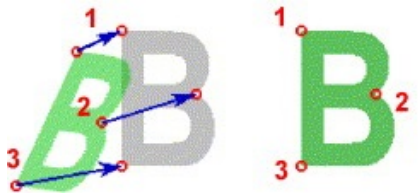
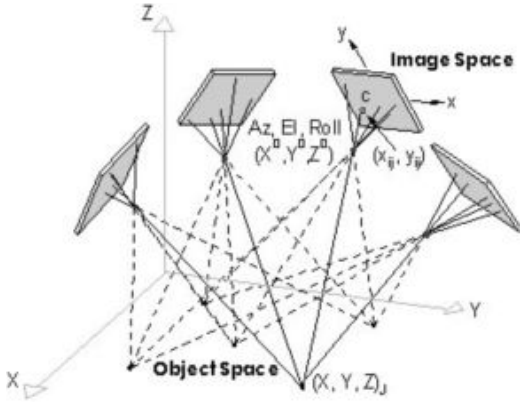
Automatic image association and orientation

- Images are automatically associated and oriented using **homological tie-point** and **bundle adjustment** algorithms
- Images are **geo-referenced** by anchoring to few control points measured in the field



Automatic image association with homological tie-points



Calculating image orientation with bundle adjustment

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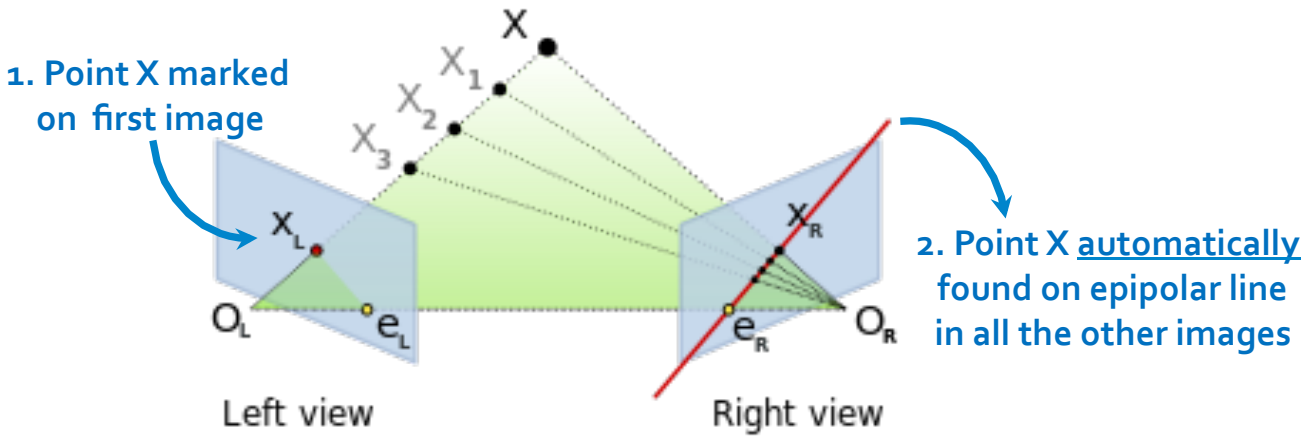
Automatically finding new points

- Measuring a point's 3-D coordinates requires identifying it in at least two images, preferably more.
- Any new point marked in one image is **automatically found** in all other images using **image processing algorithms.**



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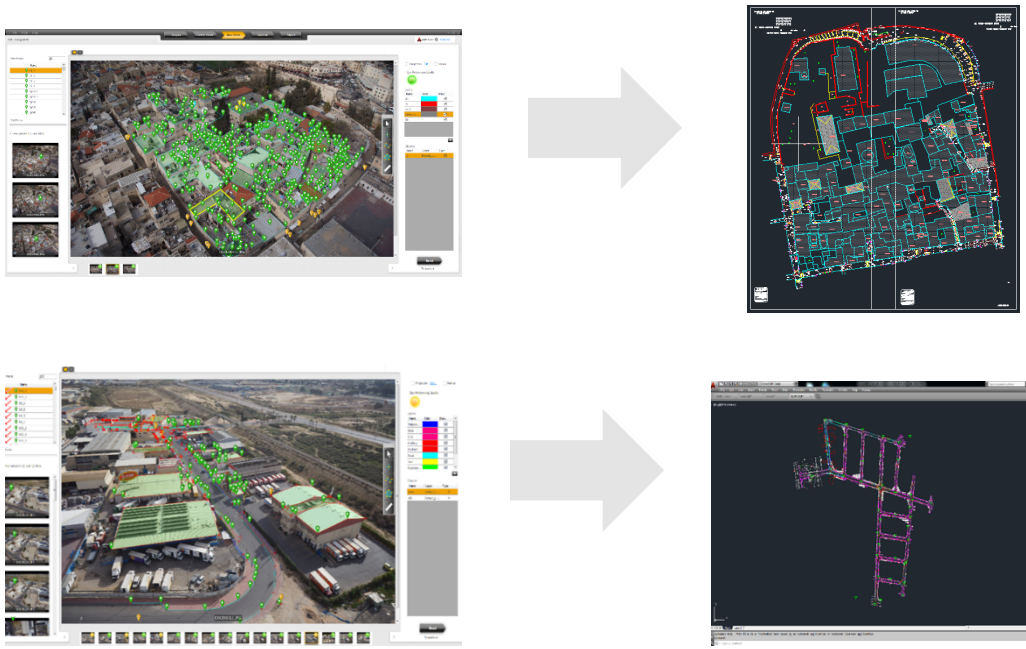
Drawing directly on images

- The user can **draw objects directly on the oblique images**, since positions of new points marked on the images are automatically found in real-time
- **No need to digitize stereo pairs or orthophotos**



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Why close-range photogrammetry?

Key principles: how does it work?

Choosing your tools

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Choosing the tools

- Camera and lens
- Tools to elevate the camera
- Close-range photogrammetry software

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Choosing a camera and lens

Use a high-resolution camera

- Better resolution allows higher accuracy
- Recommended: **18 megapixel and better**

Use a wide-angle lens

- Larger field-of-view; crisper images; less weight
- Recommended: **16 mm focal length or smaller**

Use fixed focal length lens

- Zoom changes the calibration parameters
- Recommended: **lens without zoom**

More expensive is not necessarily better!

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Examples

- Compact camera
- > 20 megapixel resolution
- Interchangeable lens
- < 16mm fixed focal length

Samsung NX2000
20 megapixel

Sony NEX-7
24 megapixel

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Elevating the camera above ground level

- It is recommended to elevate the camera above ground level to minimize foreground obstructions hiding features surveyed
  - Such as fences, vegetation, cars, etc.
- Take photographs from an elevated vantage point:
  - From the rear of a truck
  - From a building overlooking the survey area
  - Using a telescopic pole
  - Using a mini quadcopter

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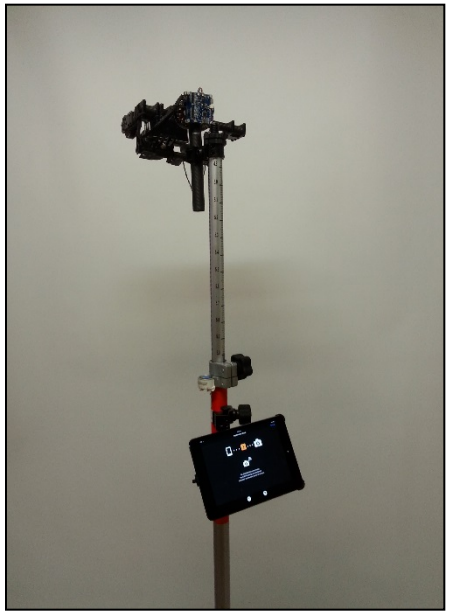
Using telescopic poles





- Portable poles and car-mounted masts
- Camera may be Wi-Fi controlled by smartphone/tablet
- Dedicated poles for photography: lightweight, compact

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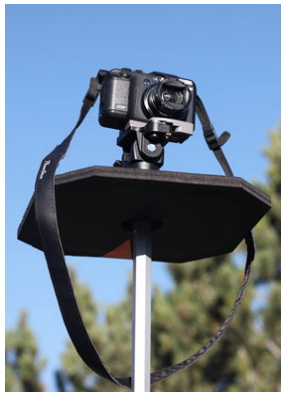
Example

- Pole Pixie telescopic pole kit: 18 ‘ lightweight hex aluminum telescopic pole; camera adapter and tilt mount; resting plate



www.polepixie.com

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Deploying mini quadcopters

- Highly effective for surveying
- Small, lightweight, simple to operate
- Camera Wi-Fi controlled by smartphone
- *In legal limbo in the US, but coming soon…*

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Using UAVs: a legal limbo?

- Two recent court cases involving the FAA and users of UAVs
  - Rafael Pirker v. FAA
  - Texas EquuSearch v. FAA
- In both cases, the FAA's 2007 policy memorandum on UAVs declaring that model aircraft may not be operated "by persons or companies for business purposes" were found by the court to be not legally binding.

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Evaluating close-range photogrammetry software packages

- Measurement accuracy
- Automatic camera calibration
- Automatic image association and orientation
- Automatically finding new points in images
- Allows drawing directly on images
- Integration with CAD software packages

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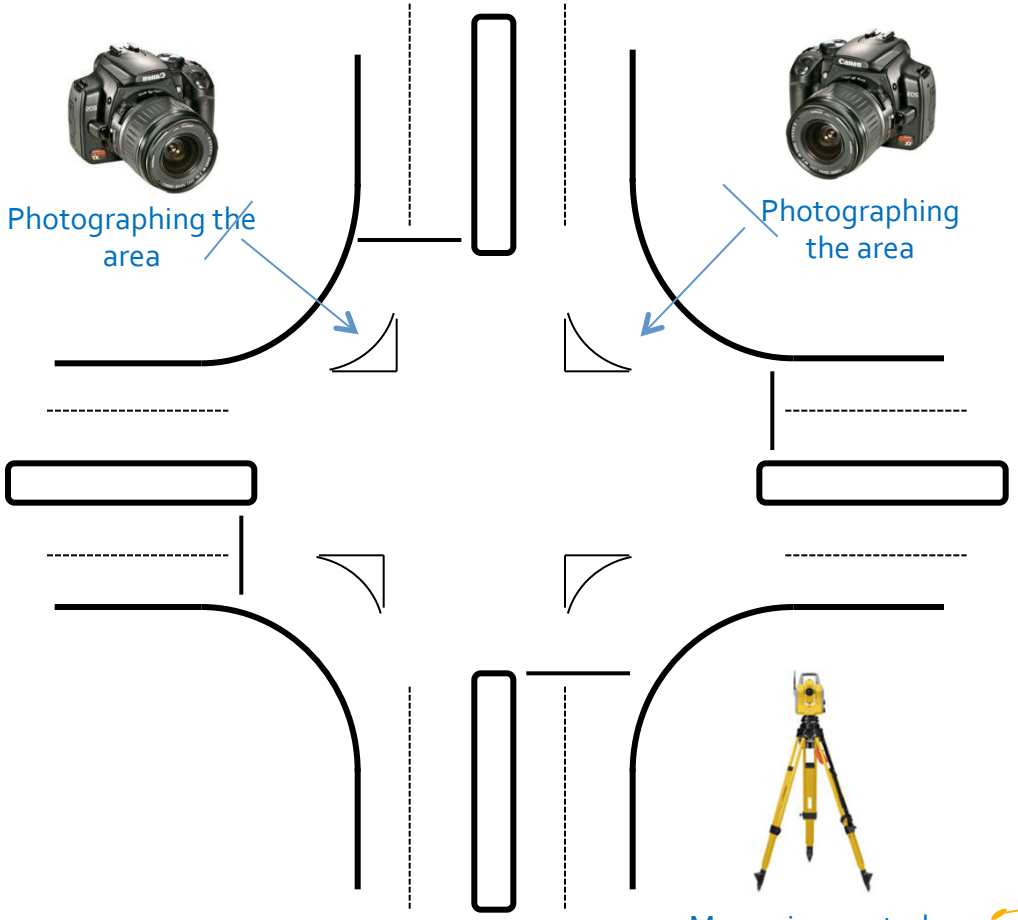
Close-range photogrammetry in the field

1. Photographing the survey area from several angles
2. Measuring few control points to geo-reference the images



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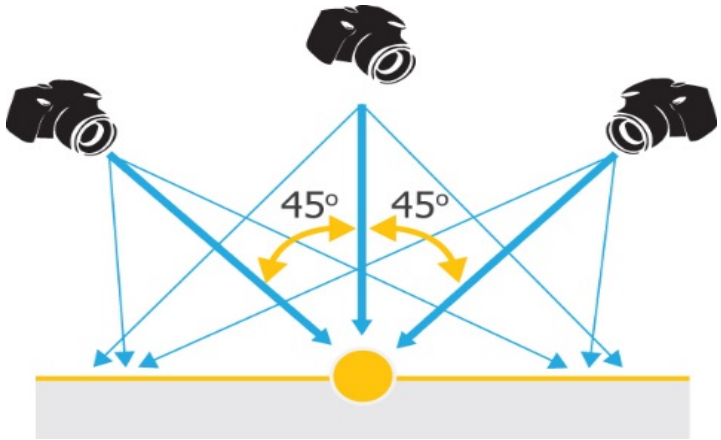
Photographing the survey area (1)

Every point you measure must appear in at least two images taken at different angles.

To achieve optimal measurement accuracy, the angle between the orientations of images should be close to 90°.



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Photographing the survey area (2)

If you use a zoom lens, do not change its settings while taking images.

- Modifying the zoom setting changes a camera's calibration parameters. Thus, use a lens with fixed focal length rather than a lens with zoom capabilities.

- However, if you do use a zoom lens, set it to the widest field-of-view and do not change this setting when photographing

Zoom lens | 30mm fixed lens | 16mm fixed lens

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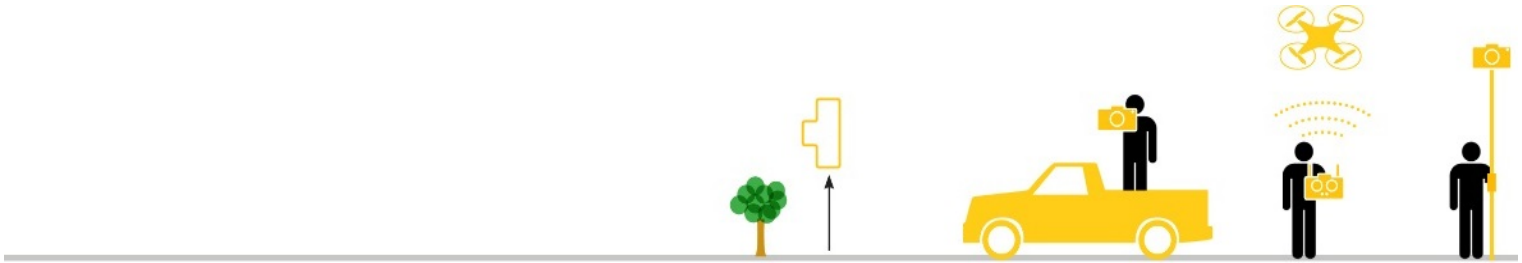
Photographing the survey area (3)

Elevate the camera above ground level to minimize foreground obstructions hiding features surveyed

- Take photographs from an elevated vantage point:
  - From the rear of a truck
  - From a building overlooking the survey area
  - Using a telescopic pole
  - Using a mini quadcopter



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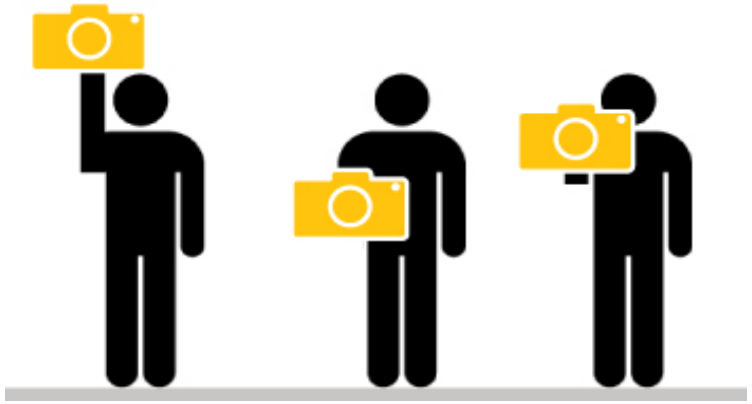
Photographing the survey area (4)

- **Slightly vary the camera's elevation for each image.**
- This will ensure optimal measurement accuracy



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Photographing the survey area (5)

Take your images in consistent lighting conditions

Take all images in similar lighting conditions, preferably at the same time of the day.

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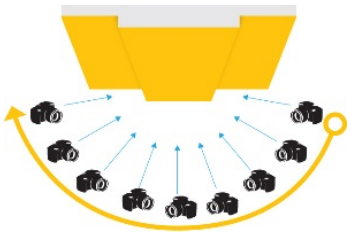
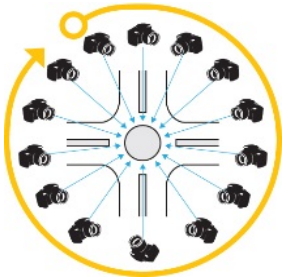
Photographing the survey area (6)

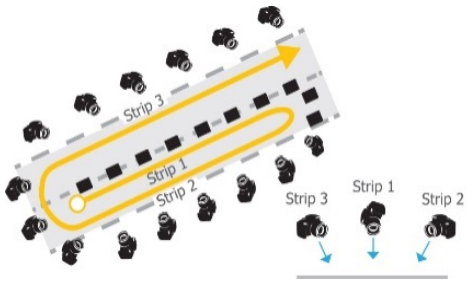
Take as many overlapping images as possible

- The more images you take of the survey area, the better the automatic algorithms will perform to associate images and detect new points.

- To achieve optimal results, **take at least 20 to 30 consecutive images** of your survey area with good overlapping between the images.







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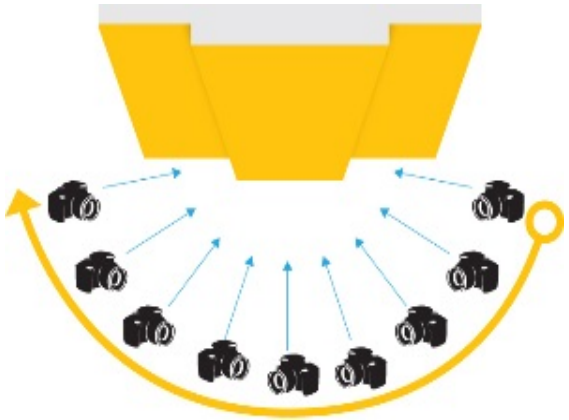
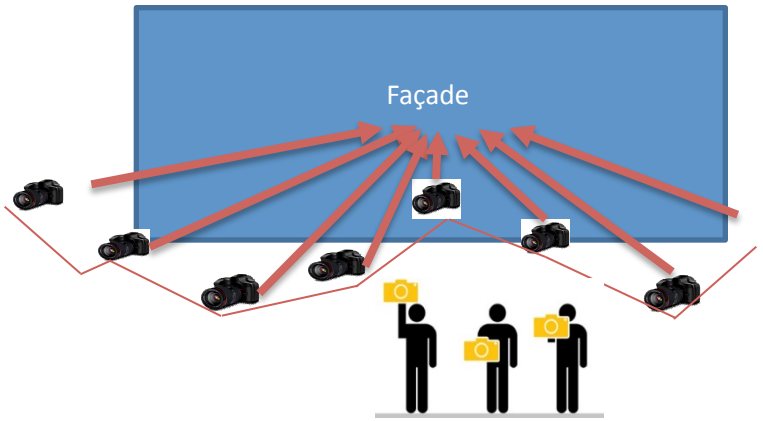
Surveying a façade

- Take 20 to 30 consecutive images as you walk along the façade.
- Take a new image every few meters.
- Keep your camera centered on the center of the façade.
- Elevate the camera above ground level to minimize obstructions.
- Modify the elevation of your camera between images.





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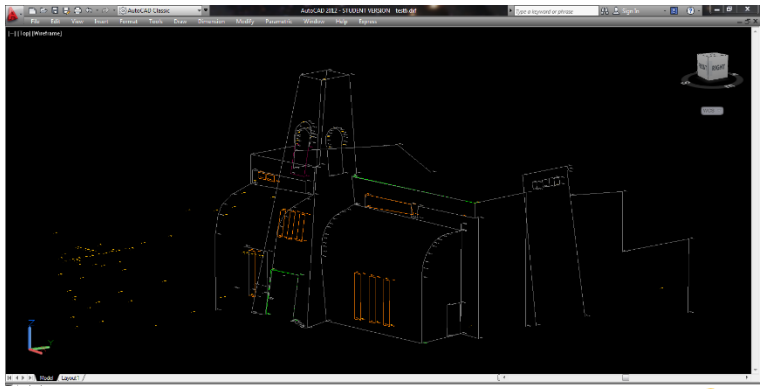
Case study #5: church façade

The task: mapping of the facade

Key challenges: a very hot and humid day…

Planned effort with conventional methods: 2 days (1 day in the field, 1 day in the office)

Actual effort with close-range photogrammetry: 4 hours (1 hour in the field, 3 hours in the office)



Camera: Canon EOS T3i 18MP, 18mm lens

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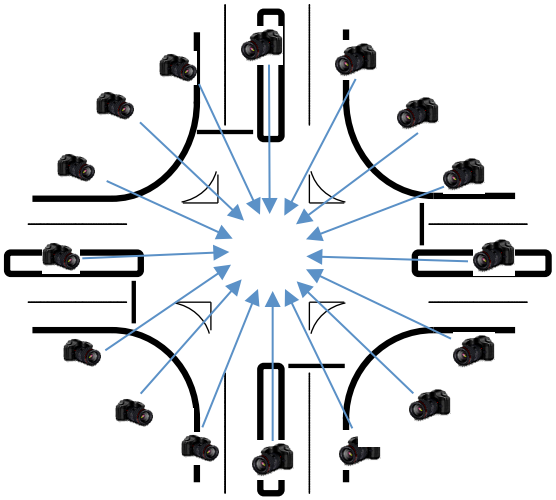
Surveying a junction

- Take 20 to 30 consecutive images from the junction's perimeter.
- Take a new image every few meters.
- Keep your camera centered on the center of the junction.
- Elevate the camera above ground level to minimize obstructions.
- Modify the elevation of your camera between images.



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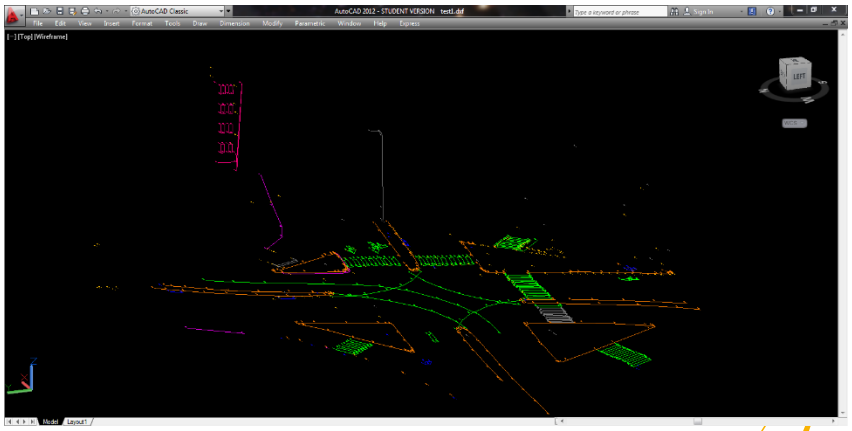
Case study #6: street intersection

The task: survey and map road intersection using a regular camera.

Key challenges: heavy traffic

Planned effort with conventional methods: 3 days (2 days in the field, 1 day in the office)

Actual effort with close-range photogrammetry: 5 hours (1 hour in the field, 4 hours in the office)



Camera: Samsung NX2000 20MP, 16 mm lens

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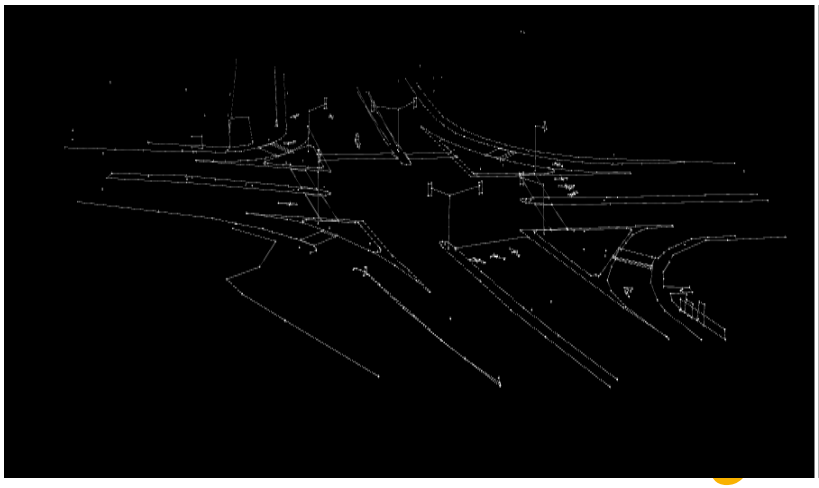
Case study #7: street intersection

The task: survey and map road intersection using a regular camera.

Key challenges: heavy traffic

Planned effort with conventional methods: 3 days (2 days in the field, 1 day in the office)

Actual effort with close-range photogrammetry: 5 hours (1 hour in the field, 4 hours in the office)



Camera: Samsung NX2000 20MP, 16 mm lens

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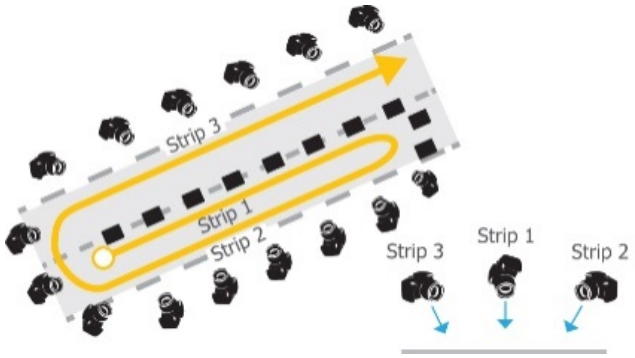
Surveying a road

- Divide long roads to sections, each about 750-meters in length.
- Take 20 to 30 consecutive images from both sides of the road.
- Keep the camera centered on the middle of the road. Maintain an overlap of at least 60% between consecutive images.
- Elevate the camera above ground level to minimize obstructions. When using a quad-copter, take the images in three strips: two strips of oblique images from the sides of the road & a strip of vertical images from above.
- Modify the elevation of your camera between images.



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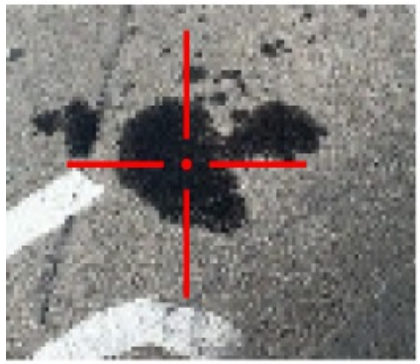
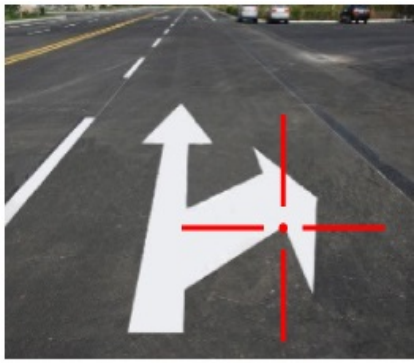
Geo-referencing the images: measuring control points (1)

Choose clearly defined control points: unambiguously and easily identifiable in the images

- Use prominent objects in the landscape, or deploy your own markers in the area if no appropriate features are available.
- Good choices are pointed objects such as corners of a building or tips of objects. Avoid using extended objects.





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Geo-referencing the images: measuring control points (2)

Take care to measure the position and elevation of control points with an accuracy of better than 2 cm

- Remember, the accuracy of measuring the position and elevation of control points sets the accuracy baseline for all the measurements and drawings related to the images.

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Geo-referencing the images: measuring control points (3)

Scatter the control points in the survey area

- To attain maximum accuracy, scatter your control points across the survey area relative to breath, depth, and height.

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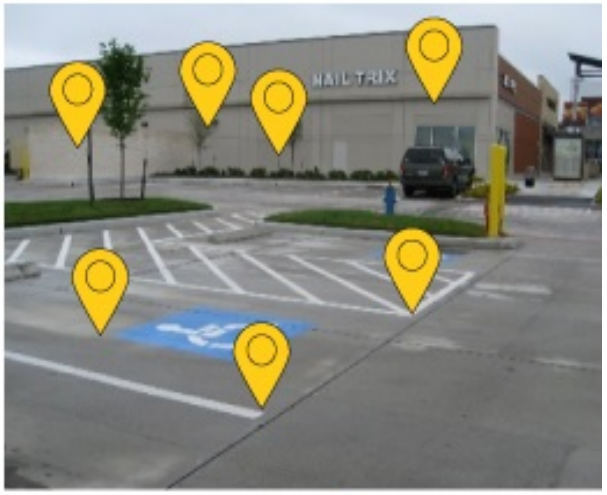
Geo-referencing the images: measuring control points (4)

Choose control points on more than one plane

- To attain maximum accuracy, select points at both ground level and elevated positions.



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Limits of using close-range photogrammetry

- You have to be able to see in the images what you want to measure
  - Challenges: vegetation, traffic, fences, etc.
- You have to see the object in at least two images
  - Challenges: tunnels, trenches, etc.
- There must be some features on the measured objects
  - Challenges: featureless piles industrial-grade material

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Why close-range photogrammetry?

Key principles: how does it work?

Choosing your tools

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Case study #8: 6.5 km road in an industrial area

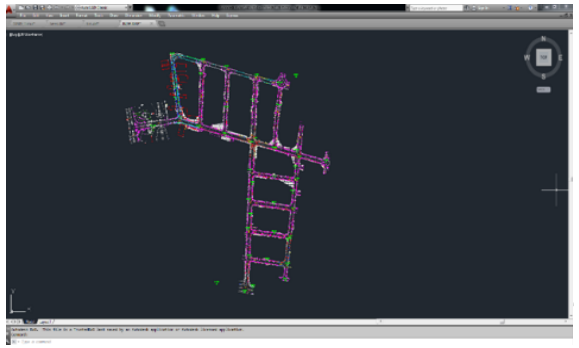
The task: as-built update survey of a road in an industrial area

Key challenges: traffic-intensive area, right of passage

Planned effort with conventional methods: 25 days (15 days in the field, 10 days in the office)

Actual effort with close-range photogrammetry: 6 days (1 day in the field, 5 days in the office)

Four-fold increase in productivity

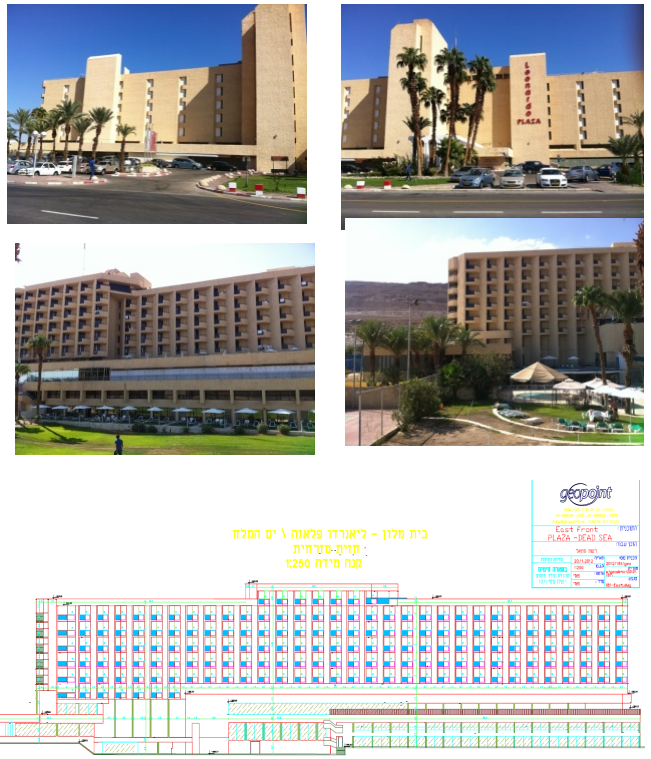


Case study #9: large hotel

The task: prepare a detailed plan of the hotel and its surroundings

Planned effort with conventional methods: 10 days (5 days in the field, 5 days in the office)

Actual effort with close-range photogrammetry: 3 days (1 day in the field, 2 days in the office)



Three-fold increase in productivity

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Case study #10: urban façades

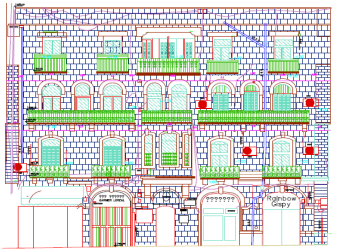
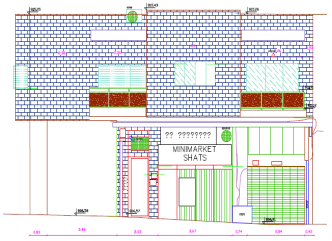
The task: prepare a detailed plan of 7 façades for reconstruction

Planned effort with conventional methods: 12 days (6 days in the field, 6 days in the office)

Actual effort with close-range photogrammetry: 4 days (1 day in the field, 3 days in the office)





Three-fold increase in productivity

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Summary

The revolution in digital photography

is changing the way land surveyors work:

measuring and drawings directly on images!

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World's leading Field-to-Plan software suite

making land surveying works easier, faster, safer

and with superior accuracy

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Thank you!

Haim Zelikovsky

CEO, Datumate

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