

Cultural Heritage Types:

Built environment, natural environment, artefacts

Categorization:

Tangible (movable, immovable, underwater) and intangible (oral tradition, performing arts, rituals..)

Heritage Cycle: → Understanding → Value → Caring → Enjoyment →

Acquisition e.g.:

DGPS (Differential Global Positioning System): Micro Topography

Long Range Laser Scanning

Close Range Laser Scanning

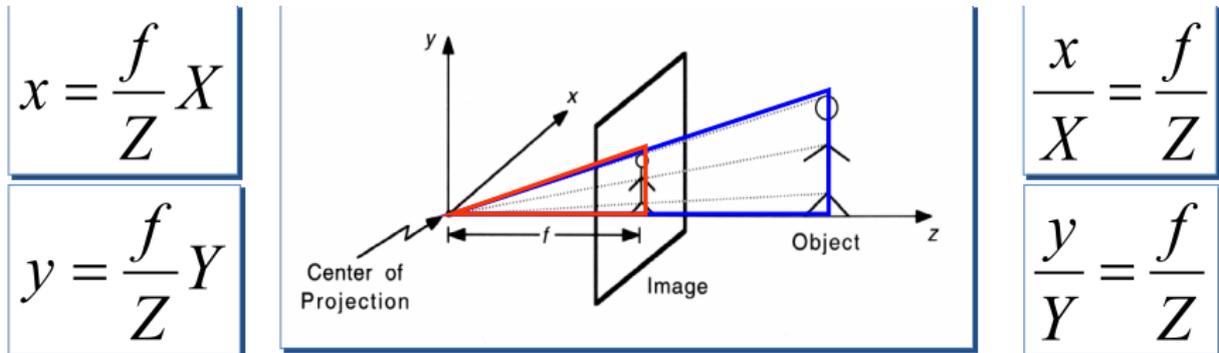
Photomodeling

After data has been collected through use of one of the methods above:

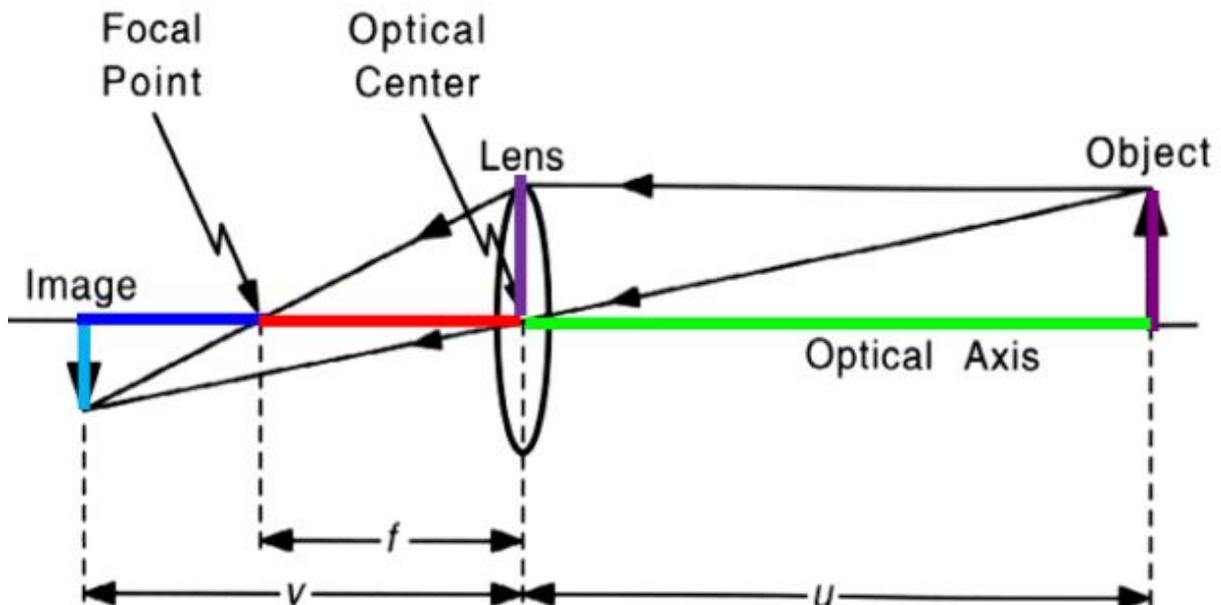
input of the data into 3-d and creating virtual space which represents the data in geo-spatial form → virtual heritage available in real time.

2. Image Acquisition

Perspective projection (non linear):



Thin lens law: $1/u + 1/v = 1/f$



Depth of field:

Bigger aperture → bigger blur circles

smaller aperture → sharper image

Bigger DoF → darker image

large aperture = small DoF

Radiometry

Radiance (amount of light that is reflected by a surface point)

Irradiance (amount of light that is projected from this point onto the image)

SHANNON THEOREM

Exact reconstruction of continuous-time baseband signal from its samples if signal is bandlimited and the sampling frequency is greater than twice the signal bandwidth

Lens distortions: Straight lines are curved because of shape of lenses

Infrared reflectography for studying underdrawings (some IR waves pass through upper surface while others are absorbed and reflected off underlying layers)

Bayer pattern: Green 50% because it lies in the middle of colour spectrum and eyes are more sensitive to green

UV Acquisition, X-Ray Fluorescence (underdrawings)

UV reflectography: similar to IR, very effective for analysis of papers and documents

UV fluorescence: examination of over-paintings, visualizes UV fluorescence radiation from painting panel (also visible for human eye)

Spectroscopy:

Study how species react to light, how much light an atom absorbs. Beam of radiation from source is passed through sample, radiation exiting sample is measured

Raman spectroscopy

Infrared spectroscopy

Laser speckle, electronic speckle pattern interferometry (ESPI): 2 interfering laser beams, provides info about defects and movement in an artwork

3. Multispectral Imaging

Human eye sensitive to radiation within 380 – 780 nm

Multispectral Images:

Visible → Grazing Light → UV Fluorescence → UV Reflected → IR False Colors → IR CCD → IR Reflectography → X-Ray Radiography

Multispectral: ca 10; hyperspectral: few hundreds

How to obtain: individual illumination, use of optical filters

Applications: Remote Sensing, Medical Imaging, Cultural Heritage

Example: LANDSAT, goal is global archive of satellite photos

MSI for CH:

Infrared reflectography, nondestructive testing method: visualizes IR radiation reflected from painting (not visible for human eye), paint layers become transparent with IR rays, visualization of underdrawings

UV Fluorescence: visualizes UV Fluorescence radiation from painting panel (also visible for human eye), examination of over paintings

UV Reflectography: visualizes UV radiation reflected from painting panel (not visible for human eye), highlight surface details

Image Registration Methodology:

1. Feature detection
2. Feature matching

3. Transform model estimation
4. Image resampling and transformation

LDA (discrimination between classes e.g. foreground and background)

PCA (reducing dimension e.g. from 3D to 2D)

4. 3D Acquisition Methods: Total Station

LED lights are the best, long lifetime, significant energy savings

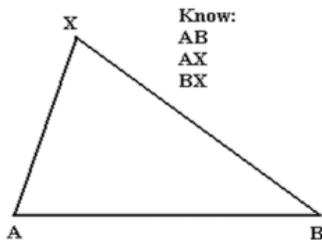
Purpose of field survey:

accurate location of points in the field so that their positions relative to each other can be plotted on a map

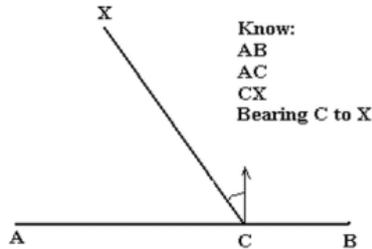
Plotting position is determined by:

1. Location by three measured sides (Triangulation):
Given three measured distances, AB (base line), AX and BX. Once location of X is fixed, additional triangles can be build
2. Location by offset: Given bearing and distance from known to unknown point
3. Location by intersection: Given two bearings from two known to an unknown point

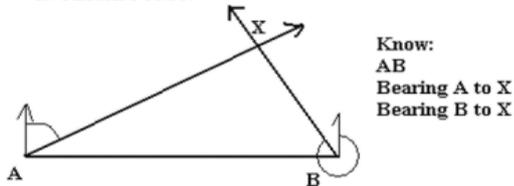
TRIANGULATION



OFF SET



INTERSECTION



Survey techniques to find correct planimetric positions of objects (horizontal distances between all objects on map are correct).

Abney level: small hand-held level to measure angles

Surveyor's Level/Transit: Telescope mounted on tripod, 3 crosshairs: central cross hair aligned to a level plane to calculate height, upper and lower cross hair to calculate distance

Total Station

Combination of Electronic Theodolite (angle measuring), Electronic Distance Meter and software data collector

It is an optical instrument used in Surveying and archaeology to take measurements of scenes

Measures: horizontal & vertical angles, slope, horizontal & vertical distances

Measurement recorded are x, y and z values:

x-value = easting

y-value = northing

z-value = elevation

Measuring angles: measure of difference between two directions

Vertical angle measured from zenith direction, horizontal angles measured from north direction (azimuth)

Requirement for vertical and horizontal angle measurement is that the total station is perfectly levelled.

Azimuth: based on location by offset, Total station calculates angle and distance from its location to an unknown point

Zenith: Total station calculates change in height using trigonometry

Errors: Collimation (cross hair not on the exact mechanical center), plate level (TS not properly leveled), miscentering (TS is not correctly plumbed over reference mark)

Measuring distance: EDM consists of emitter, prism reflector and receiver, emitter operated in Infrared range

Total stations can record survey data as a digital file which can be imported to PC programs like CAD or GIS

Recent developments: Complete Surveyor, built in GPS unit, data storage and processing, Bluetooth transfer...

5. 3D Acquisition Methods 2: GPS, 3D Scanner

GPS:

Orbiting navigational satellites, transmit position and time data

Handheld receivers calculate latitude, longitude, altitude, velocity

6 orbital planes ensure at least 4 or more satellites available

Control segments for calculations, signal from satellites to control segment and from satellites to user

How GPS works: we need to know where exactly the satellites are, their orbits are very predictable.

GPS receivers have an almanac programmed into them that tells them where each satellite is

Differential GPS can reduce errors, signal gets sent to user and correction signal gets sent from reference station to user, correction is calculated

ToF Scanner

Time of Flight, pulse light is emitted, time of the reflected pulse is recorded

Triangulation Scanner

6. 3D Acquisition Methods 3: Stereo, Photogrammetry & Remote Sensing

Stereo Analysis

2 views of an object enables 3d reconstruction by looking at geometric differences of the 2 2d projections

Disparity

Two stereo pictures and one object. If you put the both pictures on top of each other the object is on two different positions. Disparity is the offset of that difference in position

Stereo Analysis

$-Z = fB/(x_1 - x_2)$ with

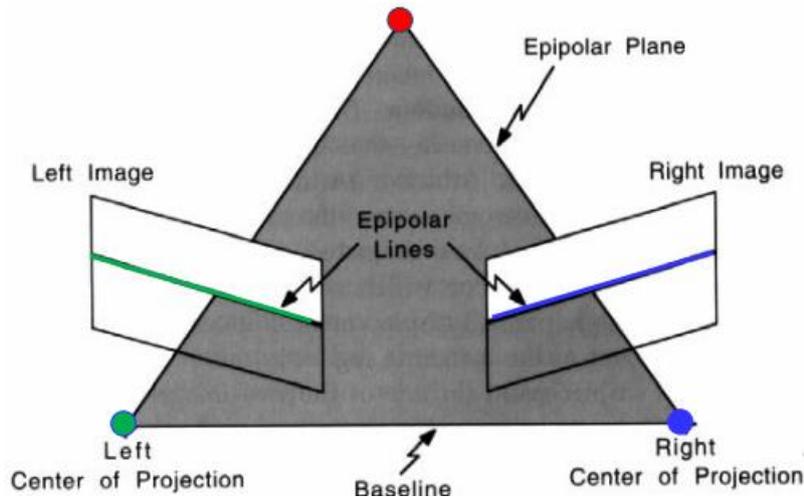
Z... distance to center of projection

f... focal length

B... Basis, distance between centers of projection

x... image coordinate

Epipolar geometry



Correspondence Analysis

Area based: compare intensity values, correspondence for each pixel due to similarity between intensity values

Feature based: compare features, correspondence for selected pixels due to selected characteristics of features (edge length, gradient...), more accurate

Hierarchical matching with L/R image pyramids and disparity pyramid

Shape from Video from sequences of images the 3D shape as well as motion and calibration of the camera are recovered, fully automated

Photogrammetry/Remote Sensing

Obtaining reliable measurements by means of images, turning images into 3D models

Input: Satellite images, airborne images, GPS data;

output: digital terrain/surface models, ortho-images, maps...

Photogrammetry: non-invasive, provides geometry & texture, efficiency increases with object size, images can be processed anytime, flexibility

(e.g.) plane/satellite flies over terrain and takes photos, needs at least 2 images, control points are given

Spatial resolution: pixel size of satellite images covering earth surface

Spectral resolution: numbers of spectral bands in which sensor can collect reflected radiance

Temporal resolution: specifies revisiting frequency of a satellite sensor for specific location

Different resolutions between those 3 are a limiting factor.

Technical constraint: either high spatial res with low spectral res or high spectral res with low spatial res

Trade off: take most important resolution for each application and accept other low resolutions OR no specific high resolution but therefore medium resolutions of all 3

Space-borne optical systems

Main components: platform + sensors + solar panel

Sensor can be

- CCD single sensor + mirror (whiskbroom scanning)
- CCD frame sensors
- CCD linear sensors (pushbroom scanning)

Whiskbroom

Scan in flight direction and scan lines, cell by cell, one pixel at a time, higher res than pushbroom

Pushbroom

scan in flight direction and scan small area by area, can gather more light than whiskbroom

Linear sensor

satellite takes image, orbits around and takes another image, across-track overlaps for stereo applications but difficulties due to time gap between orbits

3 linear sensor:

backward, nadir (straight down), forward sensors, along track, overlaps useful for stereo applications
Examples: Landsat, SPOT, Aster, Quickbird...

7. 3D Acquisition Methods 4: Stereo, Photogrammetry & Remote Sensing 2

Orientation= reconstruct rays from object point to image point.

Interior orientation: reconstruction of ray inside device +

Exterior orientation: reconstruction of image acquisition position and sensor attitude

Assumption: ray from object to satellite is straight, known is the orbital position of the satellite during image acquisition

Method: determinate 3D coordinates using "spatial forward intersection"

GCP measurements

ground control point. Known are point visible in images and either X/Y/Z coordinates. Consider well defined points like centers of circular objects or line intersections, well distributed over the image

Photogrammetry results: DSM or DTM extraction, orthophoto generation, monoplottting

- *Digital elevation model:* any kind of elevation model
- *Digital surface model:* surface with vegetation and man-made objects
- *Digital terrain models:* surface without vegetation and man-made objects

Reduction from DSM to DTM manual or semiautomatic, using different classification algorithms

Automatic DSM generation: capable of using cross correlation, regular object or image grid matching, only stereo matching

Orthophotos: Map = parallel projection, correct measurements of distances (horizontal) over whole map

Necessary data: Satellite image, orientation data for image, elevation model

Workflow: definition of orthoimage (X,Y-grid), for each orthoimage pixel: calculate z Value, calculate image coordinates

Error of orthophotos: objects not included in DEM, e.g. large building hides smaller building at certain image angle, take pictures of different angles and fill invisible parts

Monoplottting: measurement using only one image but DEM required and less accurate than stereo measurements

3D object extraction and modeling

Processing strategy:

Detection (find individual building) → reconstruction (generate 3D geometric description at a required resolution) → attribution (assign descriptive elements)

Photogrammetric measurement/modeling:

Manual: min. number of points to describe object, how to integrate additional info? How to deal with uneven point distribution?

Automated: image matching, laser scanning, very dense point cloud, mismatches...

CC-Modeler: Generic Texturing (automatic, texture library), Automatic Texturing (aerial imagery, realistic), Terrestrial Texturing (digital photographs, realistic, hi-res, manually)

Semi-automated approaches are a good concept for future

Example: drone + laser scanning

8. Archaeological Prospection

Definition: search for and recording of archeological residues

Goal: Inventory of archeological sites, features, find spots, etc. of a given region

Original focus: sites, Today: landscapes

Workflow:

Scale	Procedure
Region	Regional Survey <ul style="list-style-type: none">- Maps, archives, literature- Aerial/satellite images, Lidar
Subregion	Pedestrian Survey <ul style="list-style-type: none">- Collection of surface finds- Topographical survey
Site	Geophysical Prospection <ul style="list-style-type: none">- Magnetic/electrical measurements- Ground penetrating radar
Feature	Excavation

From Region to Site = archaeological prospection, bold: imaging techniques

Traditional Methods: historical maps, archives, literature

Pedestrian Survey: direct detection of surface features (earthworks, ruined walls, barrows) and indirect detection of subsurface features through traces brought to the surface (through ploughing, animal disturbance, building activity)

Methods using Imaging Techniques:

Sensors measuring physical variables of soil and vegetation, convert into digital image

Data interpretation based on expert knowledge, features may be recognized by shape, size, spatial order, clustering, topographical context

Aerial Techniques:

Photos used: Oblique images during special photo flights

Detection of residues:

directly (surface features e.g. ruined walls, barrows...) and

indirectly (buried features visible through crop/soil marks)

Alternative sources for airborne images:

vertical image series:

acquired for cartography or military purpose

advantages: coverage of large areas, time depth

disadvantages: military archives difficult to access

hyperspectral images:

advantage: detection of crop marks, thermal anomalies

disadvantage: low spatial resolution

Hi-res satellite imagery:

Much better than oblique aerial imagery

Template matching:

detection of circular graves with circular templates and algorithm

Airborne laser scanning/Lidar: active sensor, hi-res 3D geometric data, DSMs

Supervised Spectral Classification:

Training data known from tell sites used, supervised classification

Airborne laser scanning/Lidar:

Hi-res, active sensor, DSMs

Geophysical Techniques:

Looking into ground

Parameters: passive/active sensors, depth of penetration, source of energy, 2D info or 3D info

Applicability: small areas, open and accessible areas

Geomagnetic with tractor or handcart, Geoelectrics, GPR (Ground penetrating radar), seismics

Magnetiometry:

passive sensor measures local conditions of earth's magnetic field, distortions measured along surface (no depth info), can be disturbed by power lines, metals etc.

Geoelectrics:

Electrical resistivity/conductivity of the topsoil, requires minimum degree of humidity, mainly used in shallow contexts

GPR:

Active sensor measures reflected radar waves, walls/ditches, depth info through return time measurement, 3D info

Seismic refraction:

Seismic waves have differing velocities in different types of soil, waves are refracted when passing between different types of soil/rock

Sonar prospection:

surveys for maritime archaeology

Gravimetry:

Measures strength of gravitational field

Other methods: Geothermal (thermal energy generated/stored in earth), chemical soil analysis

9. 2D Applications

Archimedes Palimpsest

Creation: Book was taken apart, original text scraped off, sheets cut in half, rotated, new text, pages assembled, new book is bound

Imaging the text:

Multi-spectral imaging: most of text recovered, uses light of different wavelengths to distinguish between texts,

20-30% can't be read because the text is too faint or covered by mold, 4 pages contain paint forgeries (religious images which appeared to make underlying text forever illegible)

X-Ray Fluorescence Imaging makes text at forgeries almost completely readable again

Sinai Manuscripts:

Multispectral images from UV to near IR

Using feature matching and template matching

Image registration using an adapted SIFT approach:

no scale-space computation,

feature localization: Harris corner detector,

feature matching: nearest neighbor,

eliminating false correspondences: RANSAC,

affine transformation

Contrast enhancement: MSI data often highly correlated → dimension reduction to remove redundancy, enhance contrast, can be grouped in unsupervised and supervised methods.

Unsupervised: class labels not considered, just the data points

PCA: uncorrelated signals, finds orthogonal linear transformation

ICA: independent signals, basis is not orthogonal

Supervised: uses class information

LDA: useful for discrimination between classes, labeling of training data required, useful for deciding between classes

Labelling Method: Input image is image on which characters are most visible

Two stages:

Coarse enhancement: uses text lines

Fine enhancement: uses text lines and characters

LDA outperforms ICA/PCA

10. 3D Applications: Digital Michelangelo, Forum Urbis Romae

Digital Michelangelo:

Motivations: push 3D scanning technology, lasting archive

Marble not optically cooperative due to light entering object, false reflection

Range Processing Pipeline:

Steps:

1. Manual initial alignment
2. ICP (iterative closest point) to one existing scan
3. Automatic ICP of all overlapping pairs
4. Global relaxation to spread out error
5. Merging using volumetric method

Lessons learned: should have tracked gantry location, ICP unstable on smooth surfaces

Color Processing Pipeline:

Steps:

1. Compensate for ambient illumination
2. Discard shadowed or specular pixels
3. Map onto vertices – one color per vertex
4. Correct for irradiance, diffuse reflectance

Limitations: ignored interreflections, ignored subsurface scattering, treated diffuse as Lambertian, used aggregate surface normal

Scanning David – Problems:

1. View Planning: procedure: manually set scanning limits, run scanning scripts → need automatic view planning
2. Accurate Scanning in the Field: motions were sufficiently accurate and repeatable, remounting was not sufficiently repeatable, used ICP to circumvent poor repeatability
3. Insuring safety for the statues: avoiding collisions, surviving collisions
4. Handling Large Datasets

Forma Urbis Romae:

Back wall still exists but the map is destroyed