3D MAPPING:

TUMULTUOUS CHANGES

INSPIRATIONS FROM THE INTERNET

PARADIGM SHIFT FROM FULLY DIGITAL IMAGE ANALYSIS WORKFLOWS

SENSOR EVOLUTION

TECHNOLOGY EVOLUTION

COMPUTING EVOLUTION

PHOTOGRAMMETRY EVOLUTION

JACIE 2010

SENSORS & PROCESSES FOR 3D MAPPING AND A LOCATION-AWARE INTERNET

Franz Leberl
Graz University of Technology
Institute of Computer Graphics and Vision
Austria

THE FIRST DIGITAL DECADE [1)]
1998-2008

[1)] Bill Gates, Jan 2008

1
THE INTERNET
→ LOCATION AWARE

Since 2005

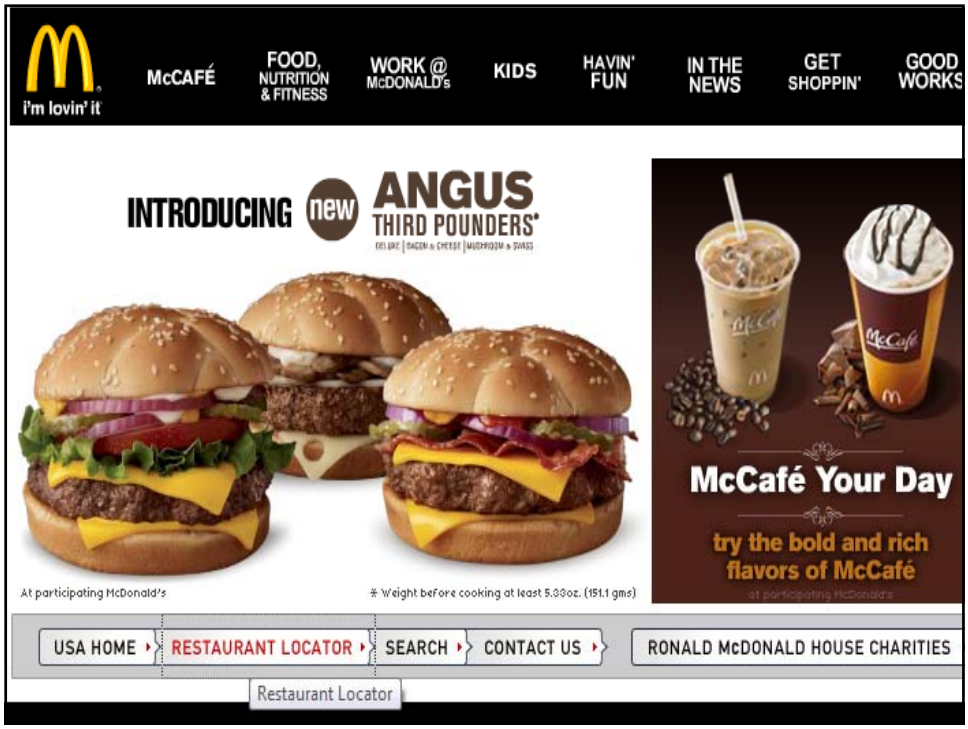
www.bing.com/maps

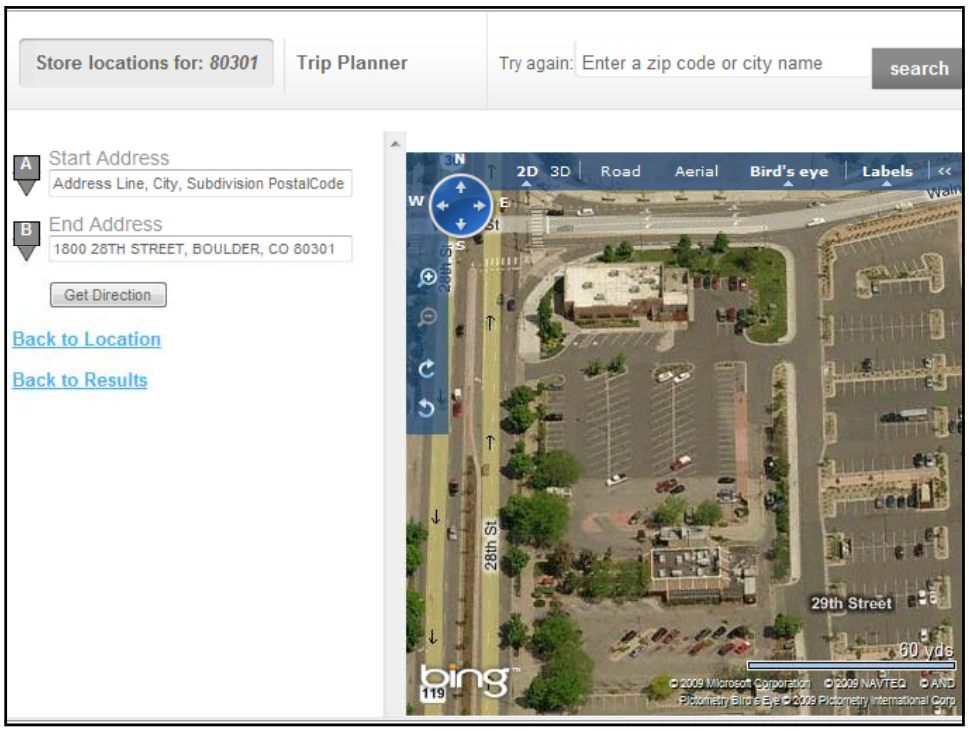
maps.google.com

BUSINESS MODEL?

Yellow Pages &
Local Advertisement
US$ 60 Billion/Year

Empowering Customer Websites with Location Awareness

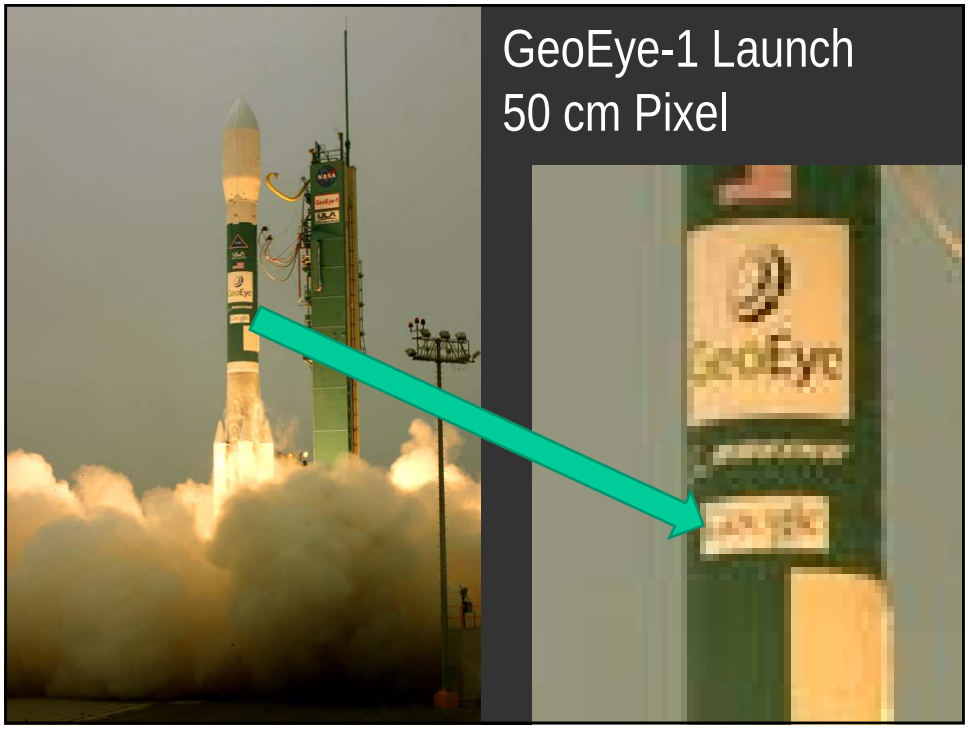



Store locations for: 80301
Trip Planner
Try again: Enter a zip code or city name
search
Start Address
Address Line, City, Subdivision PostalCode
End Address
1800 28TH STREET, BOULDER, CO 80301
Get Direction
Back to Location
Back to Results
2D 3D Road Aerial Bird's eye Labels
28th St
29th Street
60 yds
bing

Validation by Enterprise Customers
Extensive Corporate Customer Base
UNITED STATES POSTAL SERVICE
BRITISH AIRWAYS
ECHELON
VOLVO
Georgia-Pacific
Bank of America
FedEx Kinko's
EarthLink
BLACK & DECKER
citi
GEICO
WELLS FARGO
Lifeboats
ALLIED WASTE
bp
Best Western
verizon
THE HOME DEPOT
experiencewa.com
goconcierge.net
NORTHSTAR TRAVEL MEDIA
BED BATH & BEYOND
CVS pharmacy
BEST BUY
SAFEWAY
ConocoPhillips
EXPLORE THE WORLD OF MGM MIRAGE
GAP
McDonald's
ups
SIEMENS
CHOICE HOTELS INTERNATIONAL
Hallmark
SAIC From Science to Solutions
7 ELEVEN
Expedia.com
LOWE'S
BARNES & NOBLE BOOKSELLERS

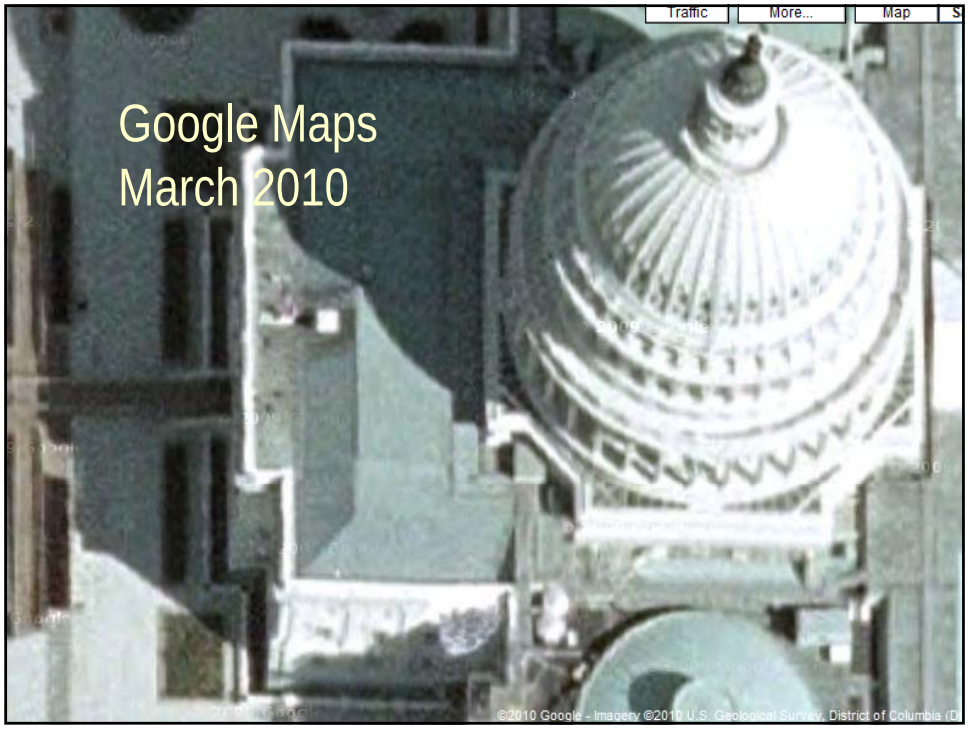
SHOP PRESENTATION

GEODATA SOURCES

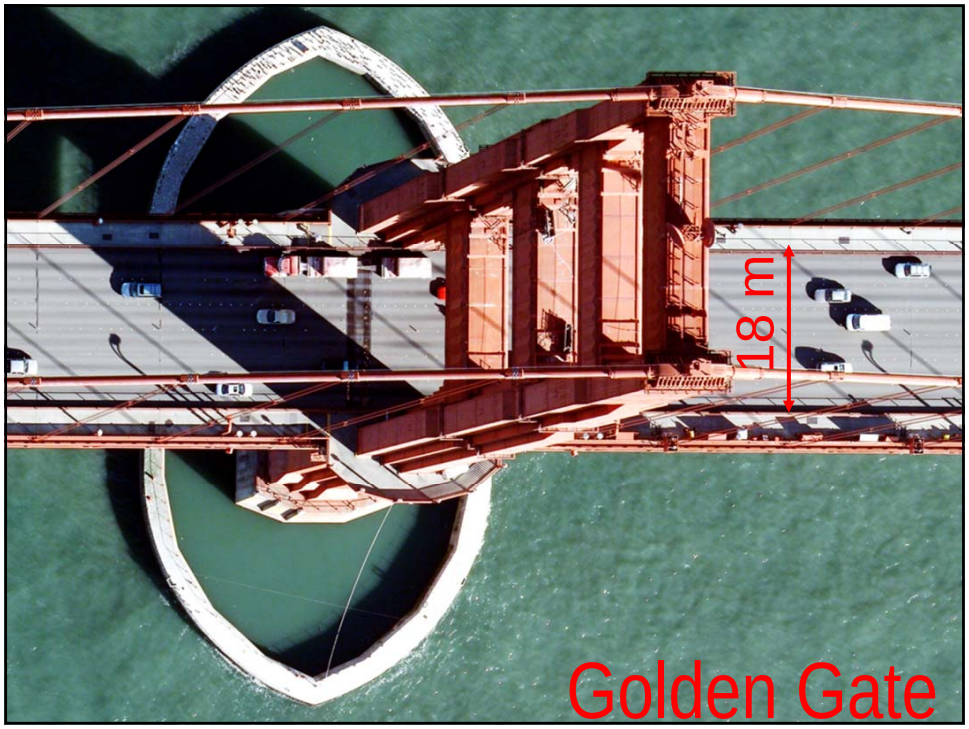

GeoEye-1 Launch
50 cm Pixel

Kiev
Bing Maps
100 m

Google Maps
March 2010


Traffic
More...
Map
Google Maps
March 2010
©2010 Google - Imagery ©2010 U.S. Geological Survey, District of Columbia (D

New Zealand Aerial Mapping
Rockwell 690 Turbo Commander
ZK-PVB


18 m
Golden Gate

SA
S
?

New Zealand Aerial Mapping
Rockwell 690 Turbo Commander
ZK-PVB
YES

BYTES?

THE EARTH'S LAND MASS

THE EARTH'S LAND MASS

The World in 15 cm per Pixel

~ 20 Peta Bytes, 2-D

Kilo
Mega
Giga
Tera
Peta
Exa
Zetta
Yotta

THE EARTH'S LAND MASS

The World in 15 cm per Pixel

~ 200 Peta Bytes, 2-D

At 10x Redundancy

Kilo
Mega
Giga
Tera
Peta
Exa
Zetta
Yotta

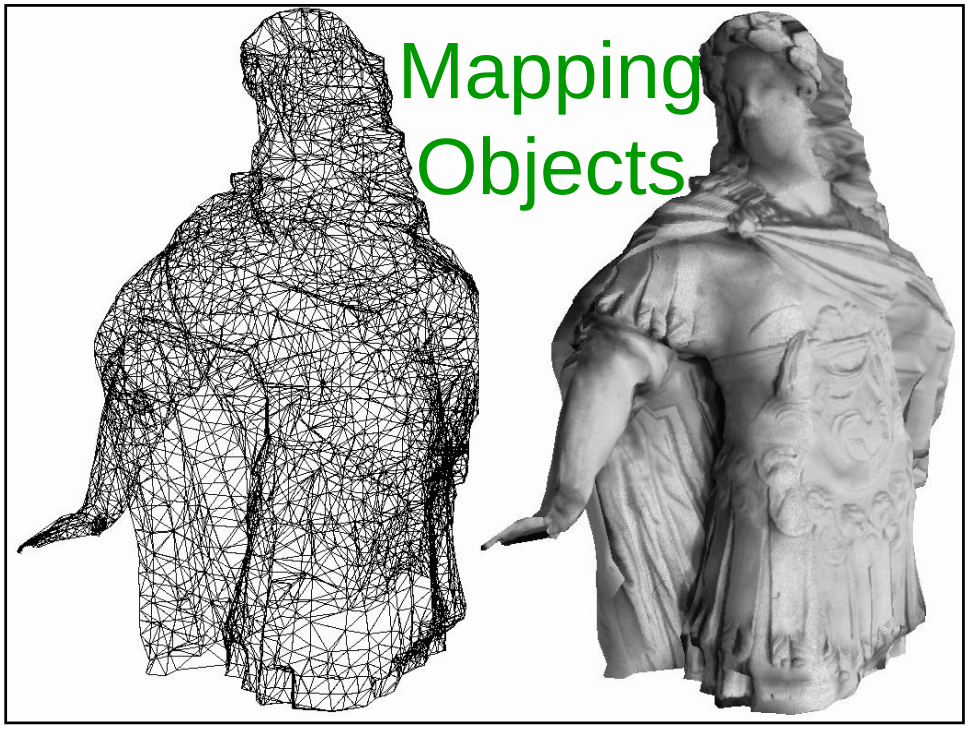
HUMAN SCALE

↓

STREET SIDE

Bank Austria

indoors
0.5 Centimeters



BYTES, REVISITED

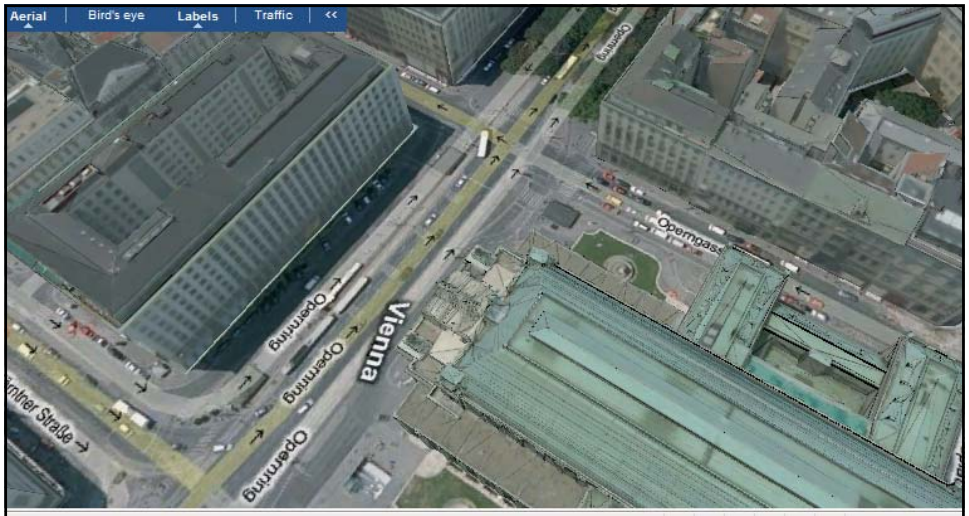
THE EARTH'S HUMAN HABITAT

The World in 15 cm per Pixel

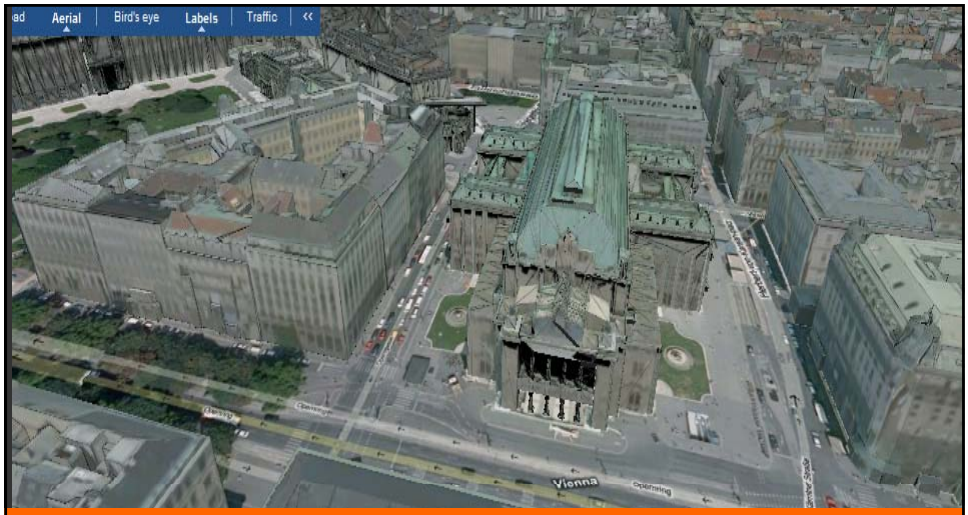
Street Side in 2 cm
Interior in 0.5 cm

…and with 10 x redundancy

Towards 1 Exabyte



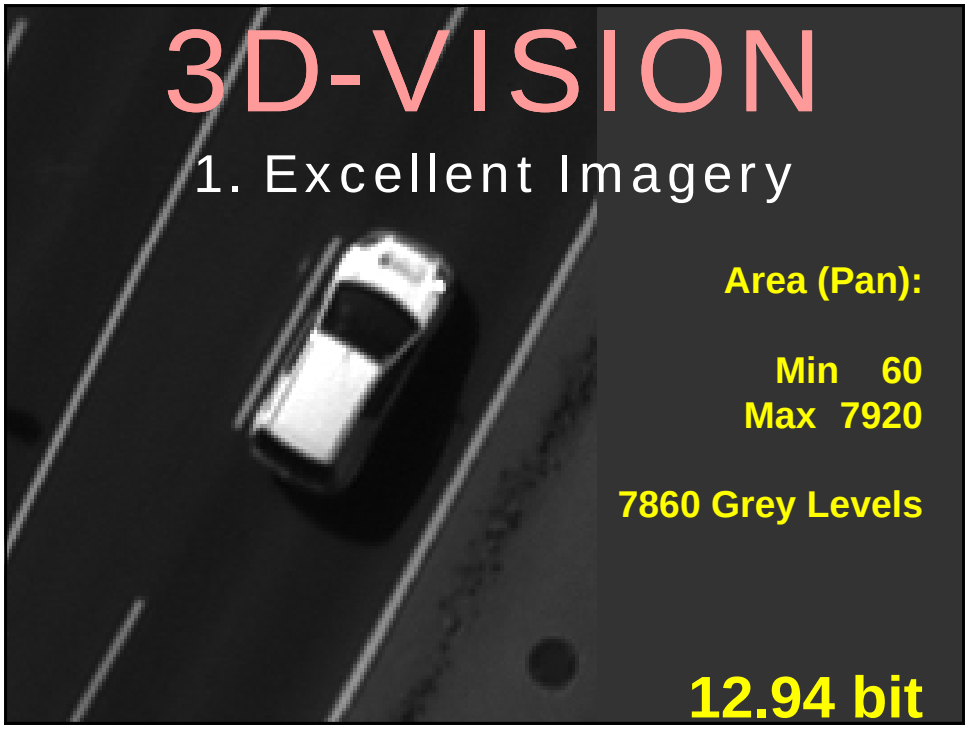
WE WANT 3D

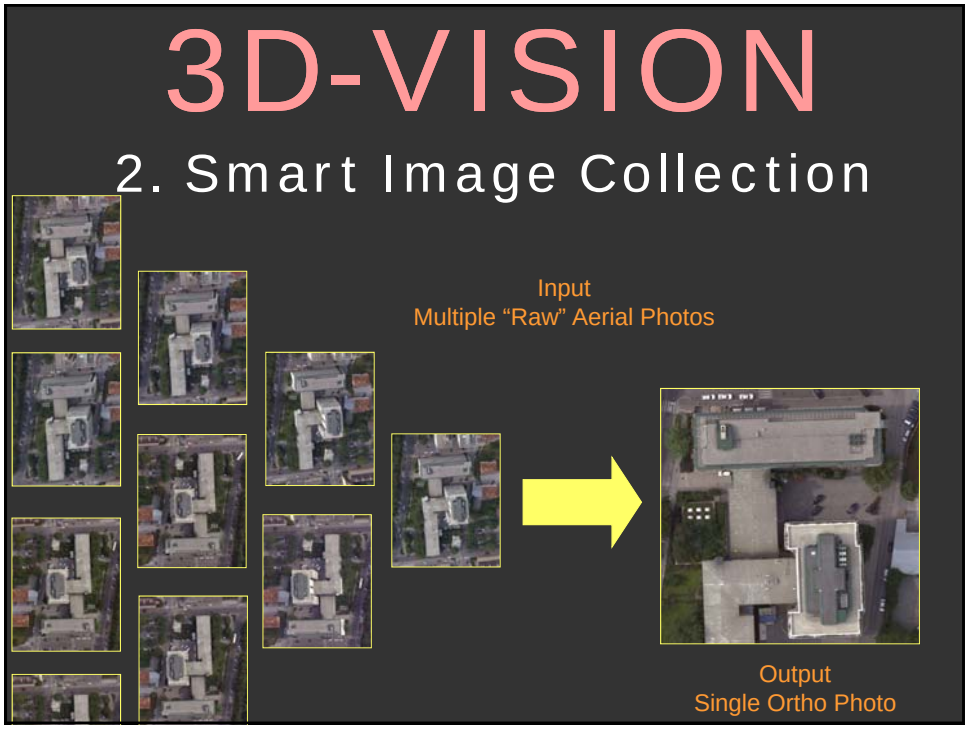


WE WANT 3D

2
FULLY DIGITAL WORKFLOW

3D-VISION
1. Excellent Imagery


3D-VISION
1. Excellent Imagery
Area (Pan):
Min 60
Max 7920
7860 Grey Levels
12.94 bit

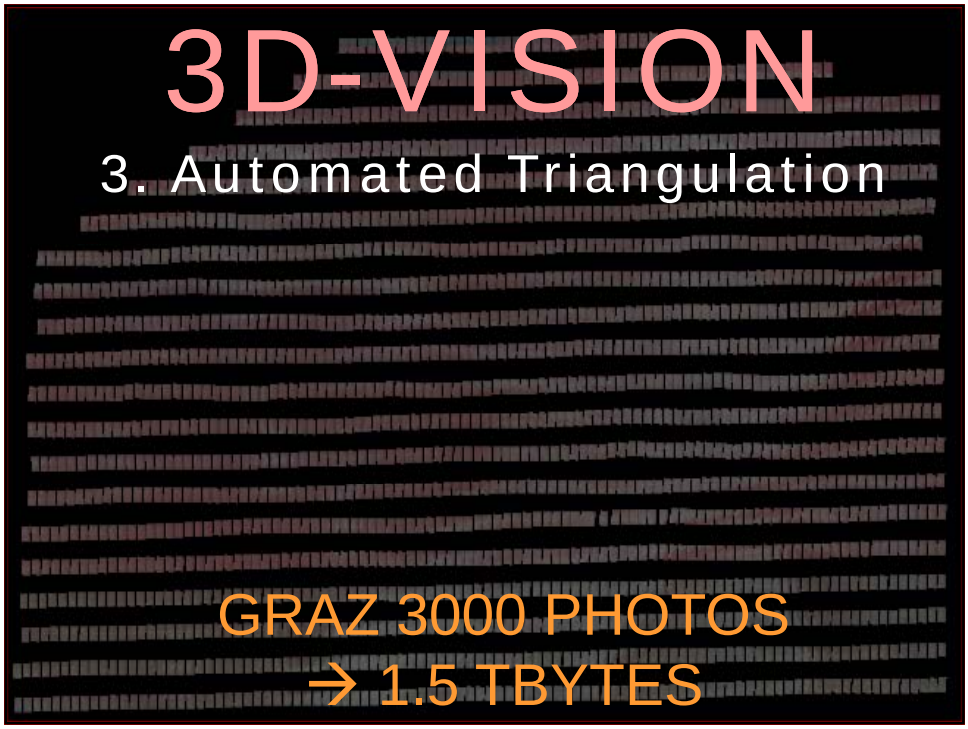

3D-VISION
2. Smart Image Collection
Input
Multiple "Raw" Aerial Photos
Output
Single Ortho Photo

3D-VISION
2. Smart Image Collection
Redundancy → accuracy

3D-VISION
2. Smart Image Collection
Redundancy → automation

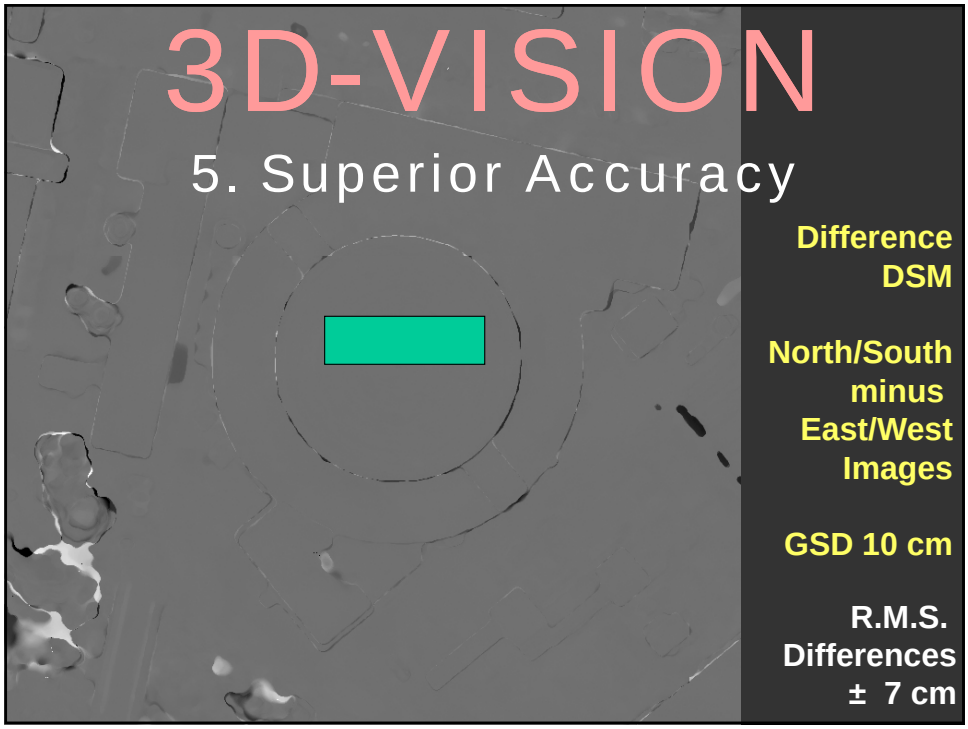
3D-VISION
2. Smart Image Collection
Redundancy → occlusion avoidance

3D-VISION
2. Smart Image Collection
Redundancy → outlier detection


3D-VISION
3. Automated Triangulation
GRAZ 3000 PHOTOS
→ 1.5 TBYTES

3D-VISION
4. Dense Matching
Winston-Salem DSM to DEM

3D-VISION
5. Superior Acc y
Two Flights
North/South
East/West
Dense
Surface
Model
@ 10 cm Pixel


3D-VISION
5. Superior Accuracy
Difference DSM
North/South minus East/West Images
GSD 10 cm
R.M.S. Differences ± 7 cm

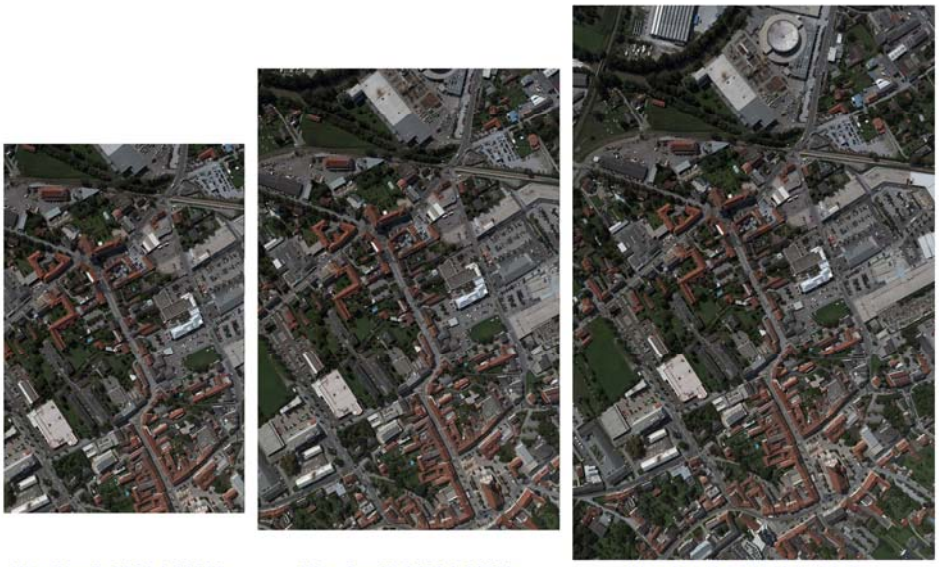
3D-VISION
6. Limitless Detail

3
CAMERA EVOLUTION

→ DIVERSITY

Microsoft/Vexcel Aerial Frame Camera Evolution

UltraCamD-03 UltraCamX-06 UltraCamXp-08



UltraCamD, 7500 * 11500 UltraCamX, 9420 * 14430 UltraCamXp, 11310 * 17310

Leica ADS-80

12000 Pixel Push Broom

Intergraph RMK-D&Dx

"Medium Format" Frame, 11K x 11K

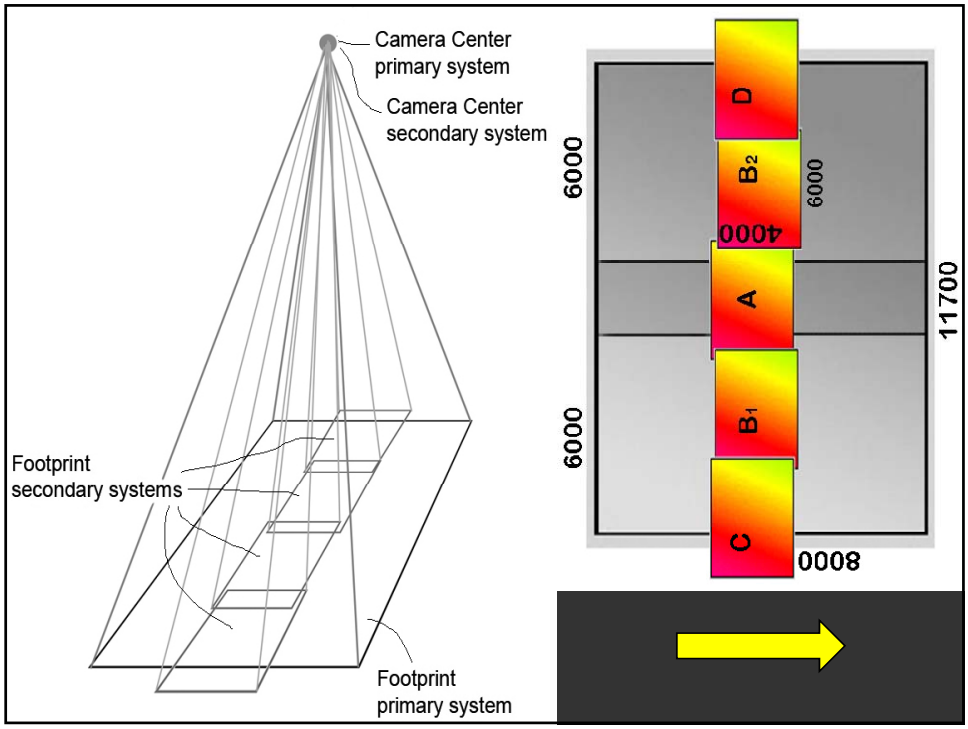
UltraCam XpWA

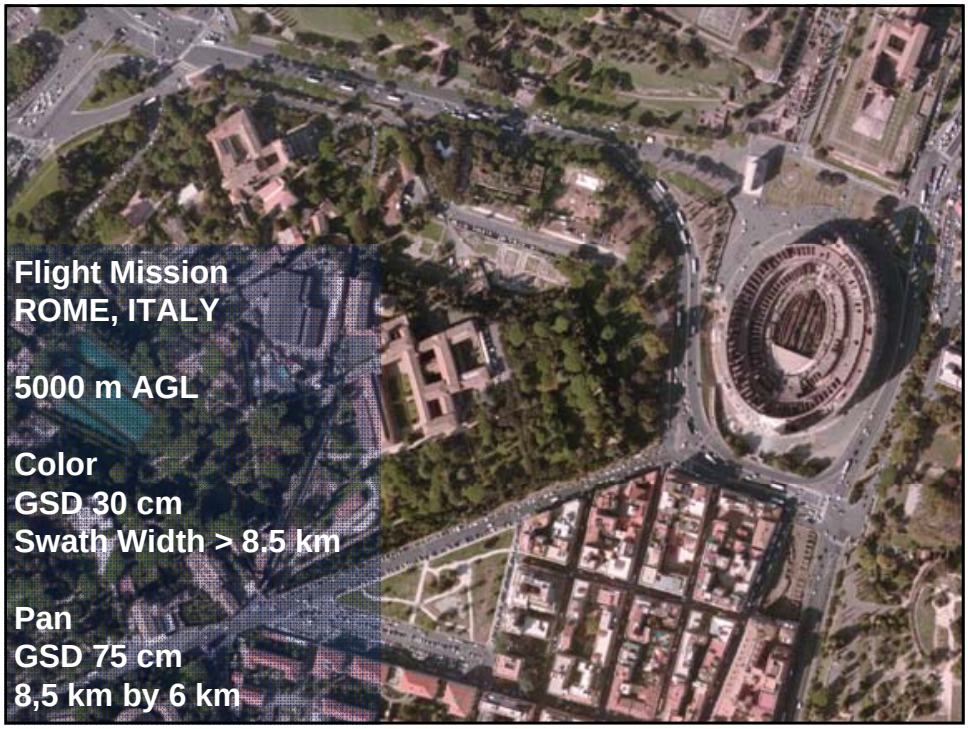
Pixels:
17.3K x 11.3K

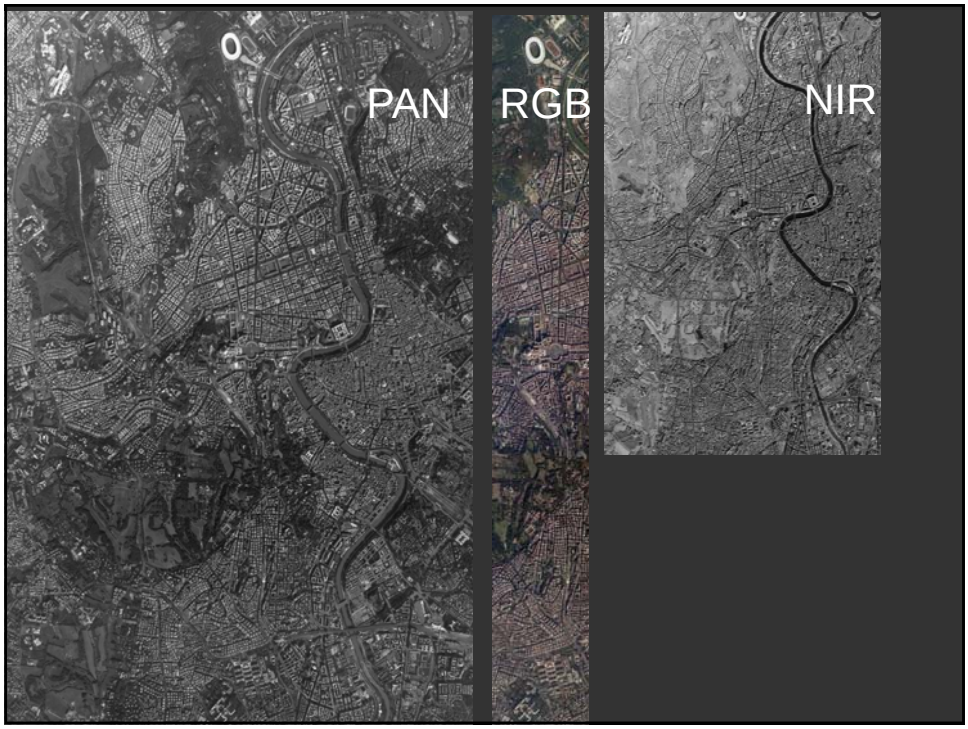
Angle of View:
70º

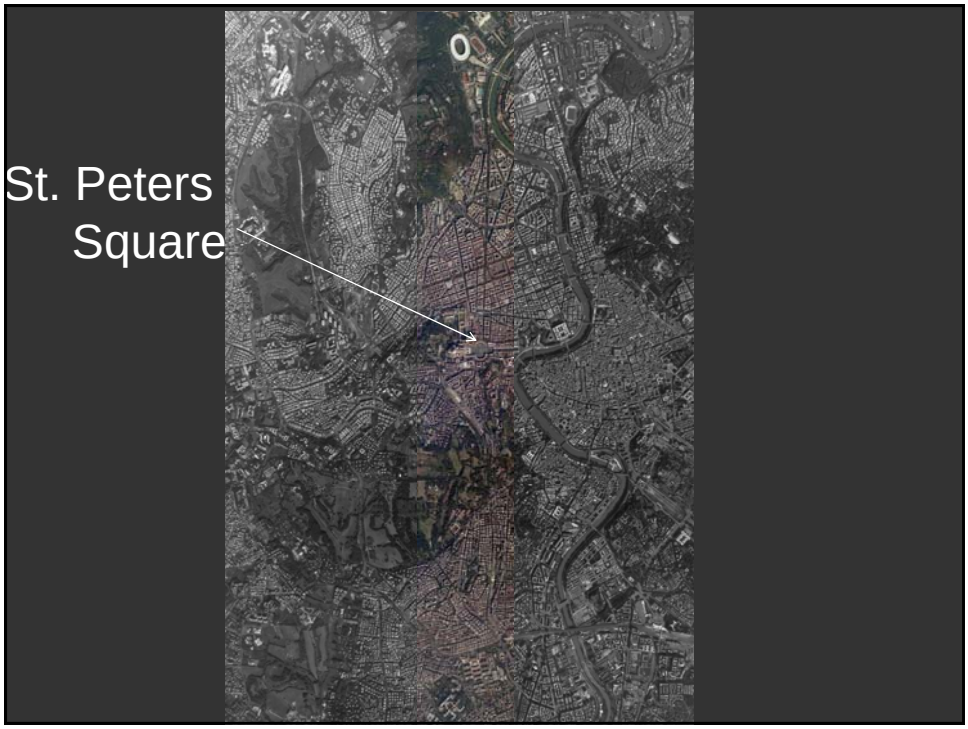
THE “CLEAR 30” PROJECT

WITH THE ULTRACAM G


Camera Center
primary system
Camera Center
secondary system
Footprint
secondary systems
Footprint
primary system
D
B2
A
B1
C
6000
6000
4000
6000
11700
8000

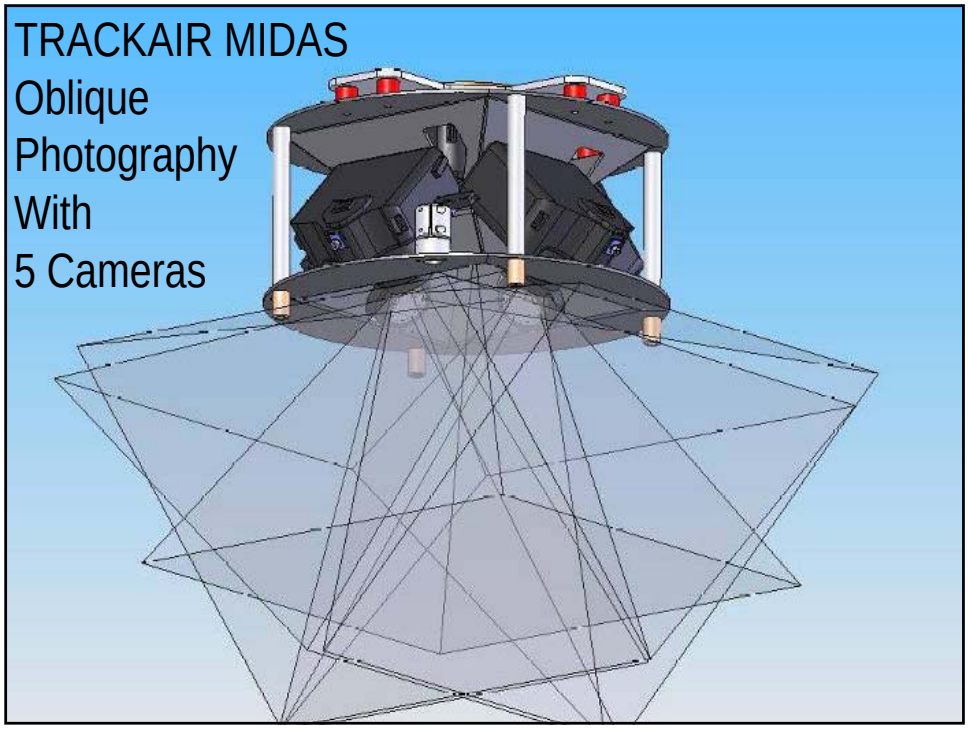

Flight Mission
ROME, ITALY
5000 m AGL
Color
GSD 30 cm
Swath Width > 8.5 km
Pan
GSD 75 cm
8,5 km by 6 km


PAN
RGB
NIR


St. Peters
Square

IGI Digicam
Applanix DSS
7.2K x 5.4K Pixels

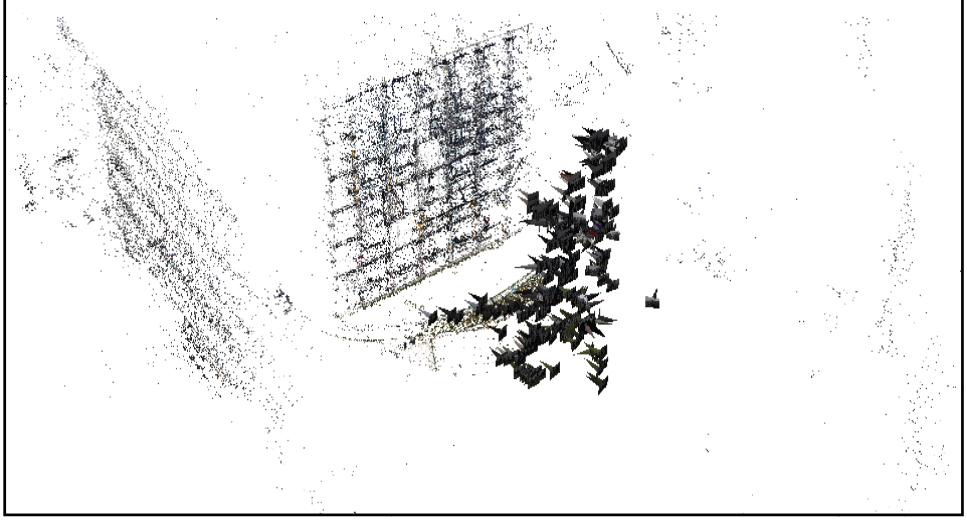
Pictometry
Oblique
Imagery



Vision Map A3:
Rotating Pair of Frame Cameras

239 Images
64K 3D-Points
756K Measurements
4K x 3K Pixels

Fully automated analysis
625 images
± 1 to 3 cm residuals



4
TECHNOLOGY EVOLUTION

→ DIVERSITY

LASER SCANNING

VS

PHOTOGRAMMETRY
(3D-VISION)

LASER SCANNING
500 Systems?

VS

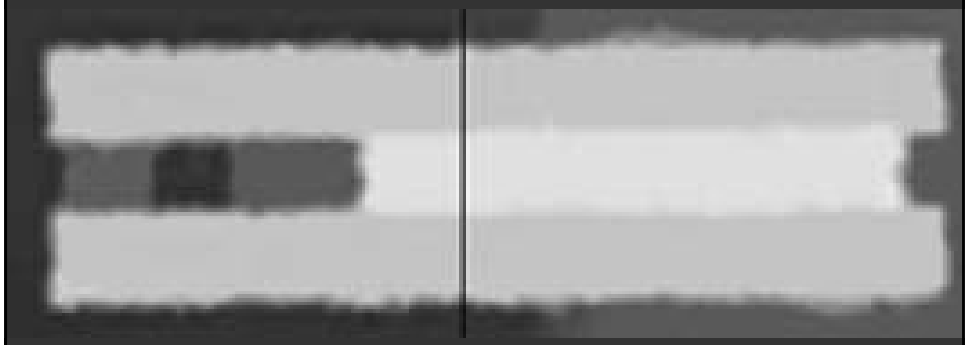
PHOTOGRAMMETRY
250 Systems?

3D-V
Surface Noise
~ ± 6.5 cm

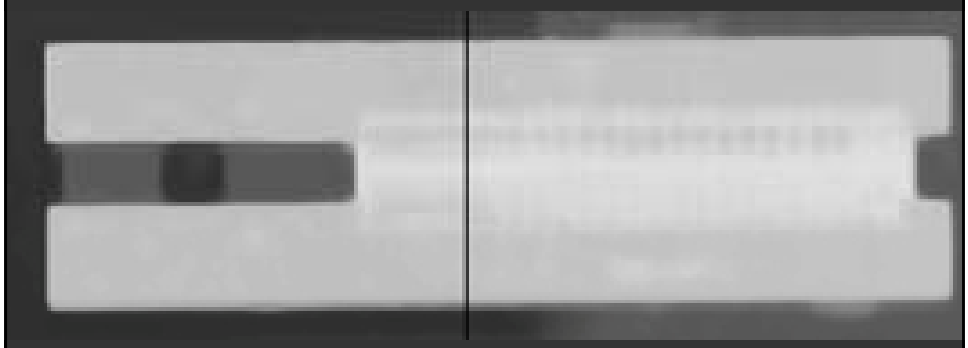
Recall:
GSD 8 cm
Triangulated
to within ±1 Pixel

ALS
Accuracy
from GPS/IMU
~ ± 20 cm

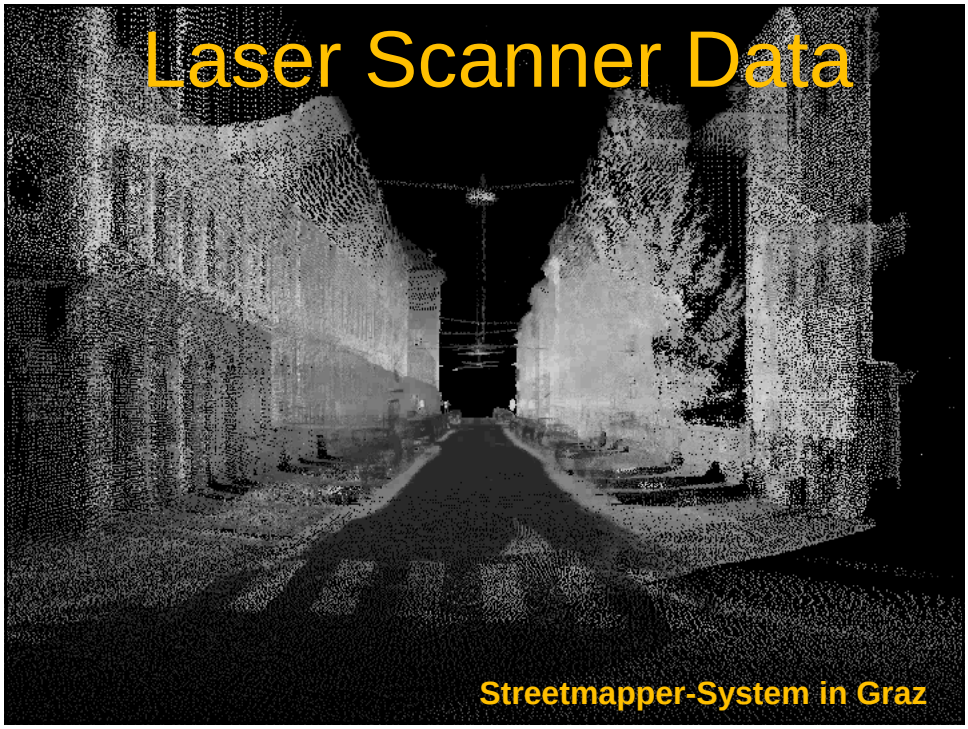
BUILDING SHAPE FROM ALS

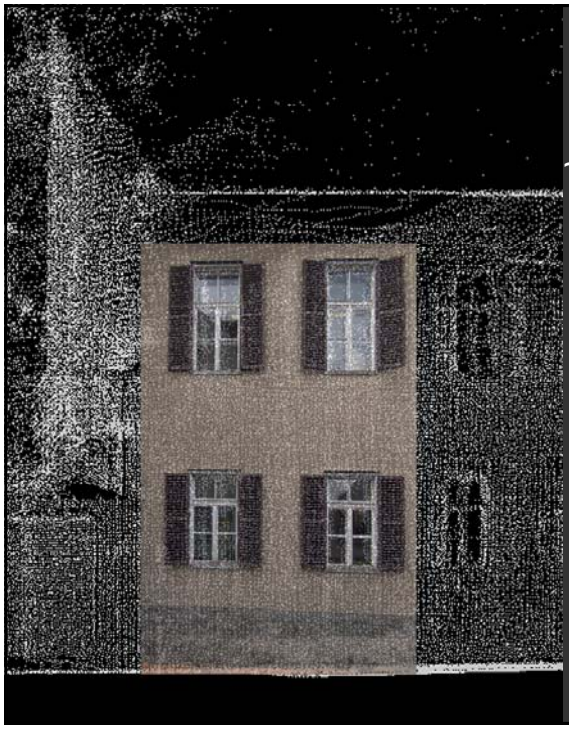


BUILDING SHAPE FROM 3D VISION



STREETSIDE
LASER SCANNING
VS
STREETSIDE
PHOTOGRAMMETRY
(3D-VISION)

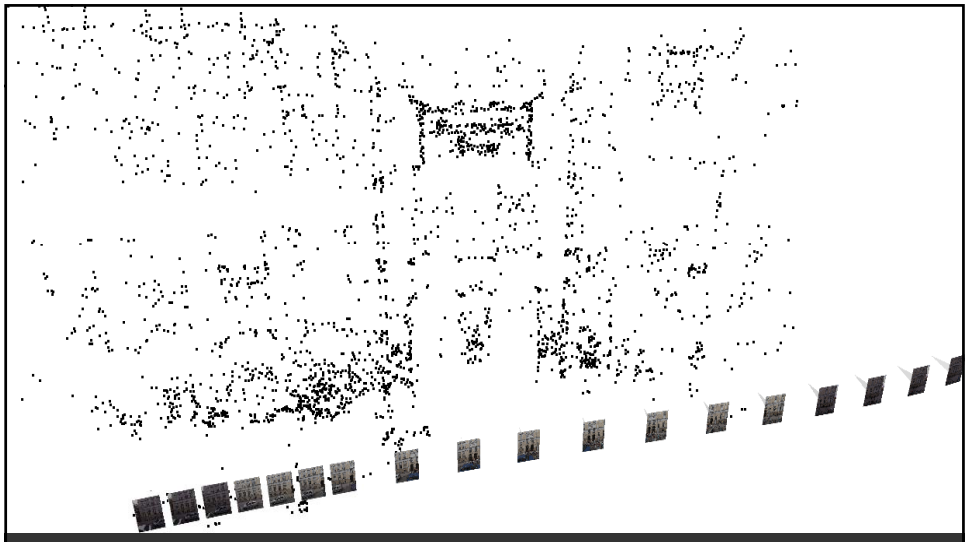




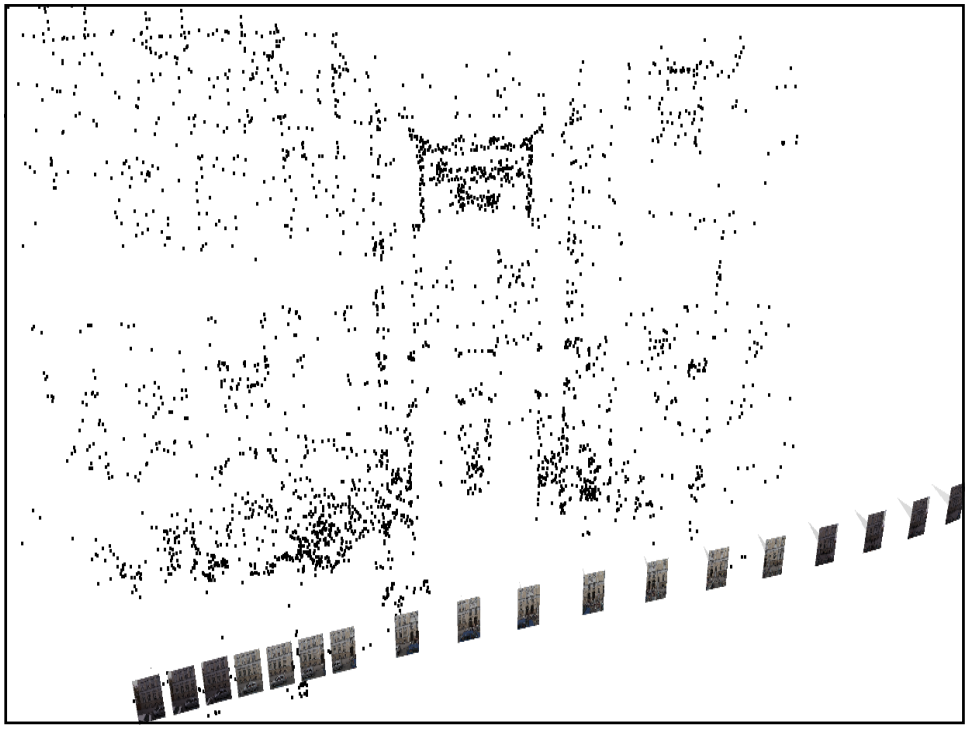
~ 60 Laser Points/m^2

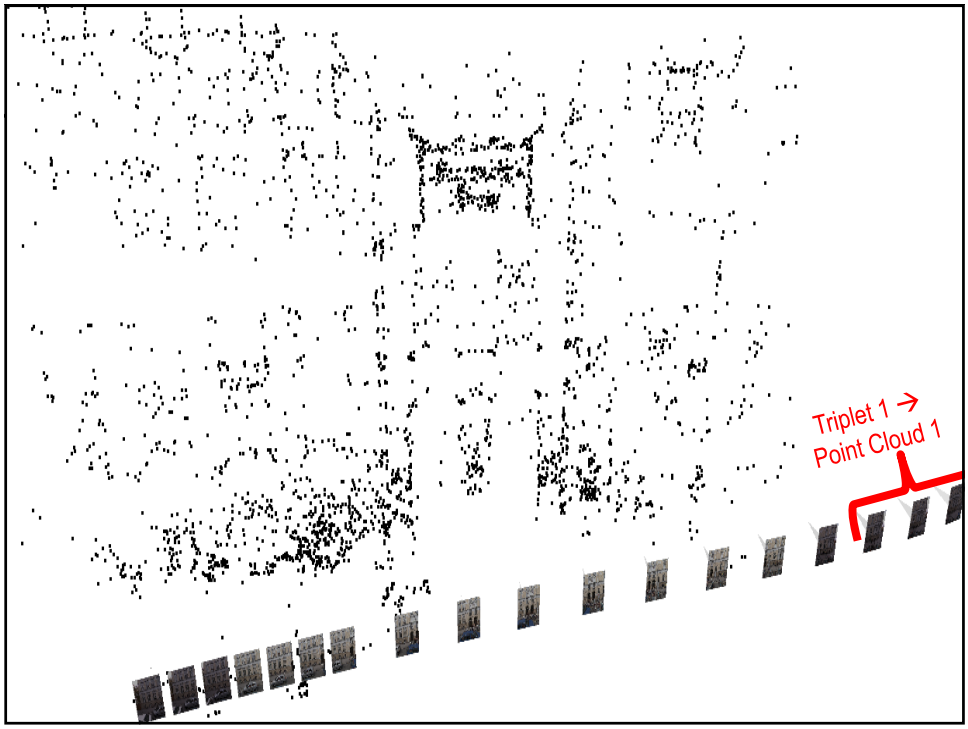
~ 7000 Pixel/m^2

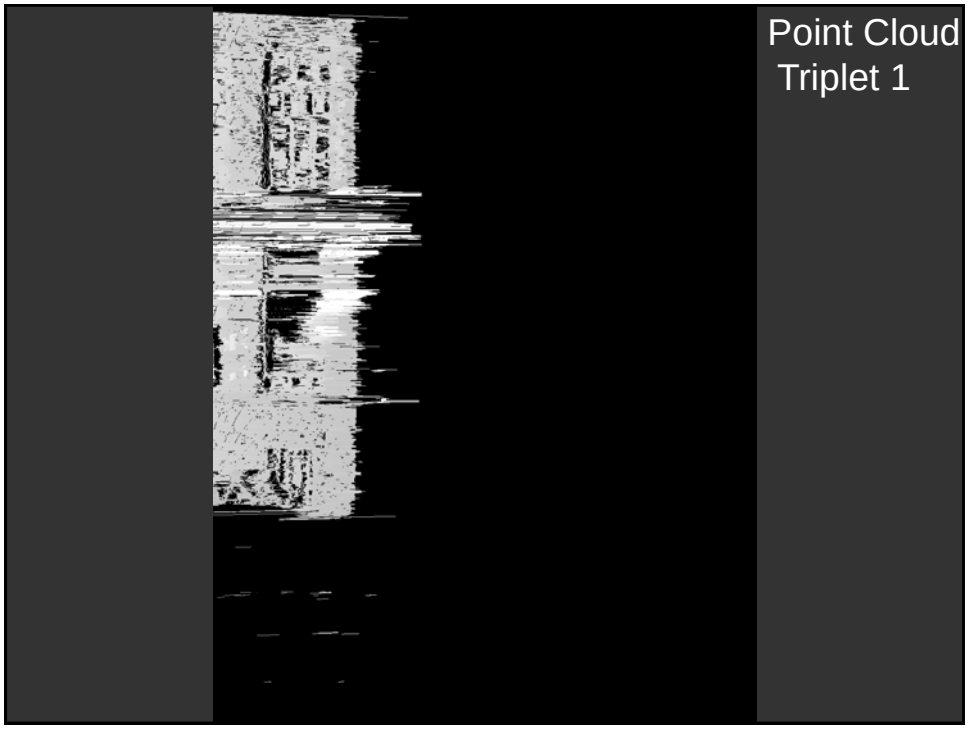
New Laser Scanning
500 pts per m^2

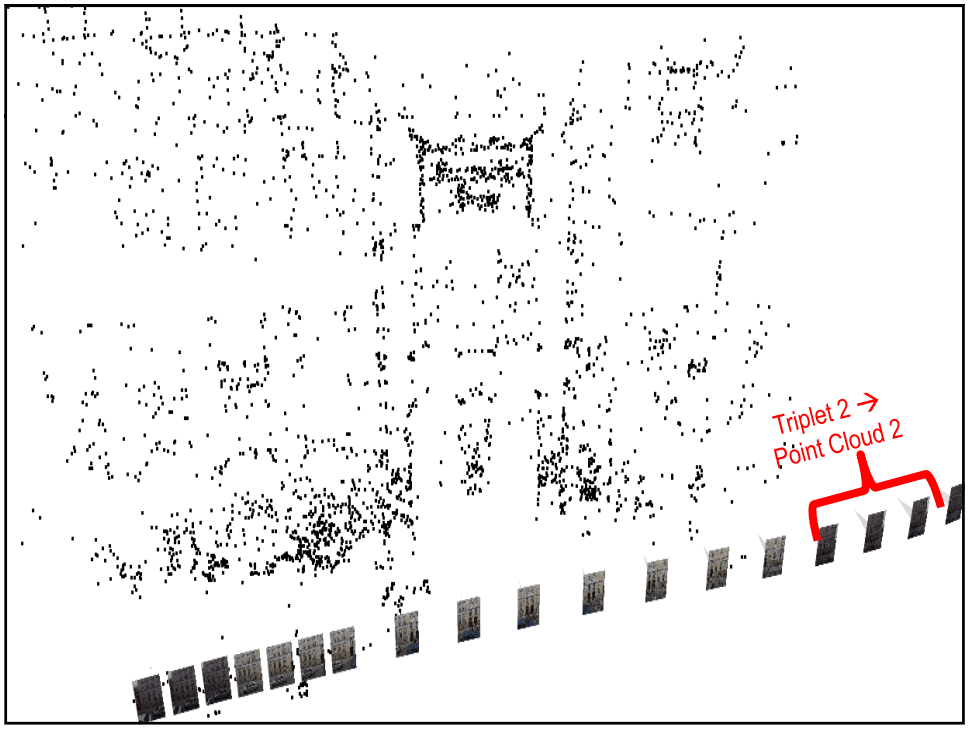


18 Images
Width x Height = 1024 x 1360 Pixel, f = 744 Pixel
2870 Triangulated Points (SIFT-Features)

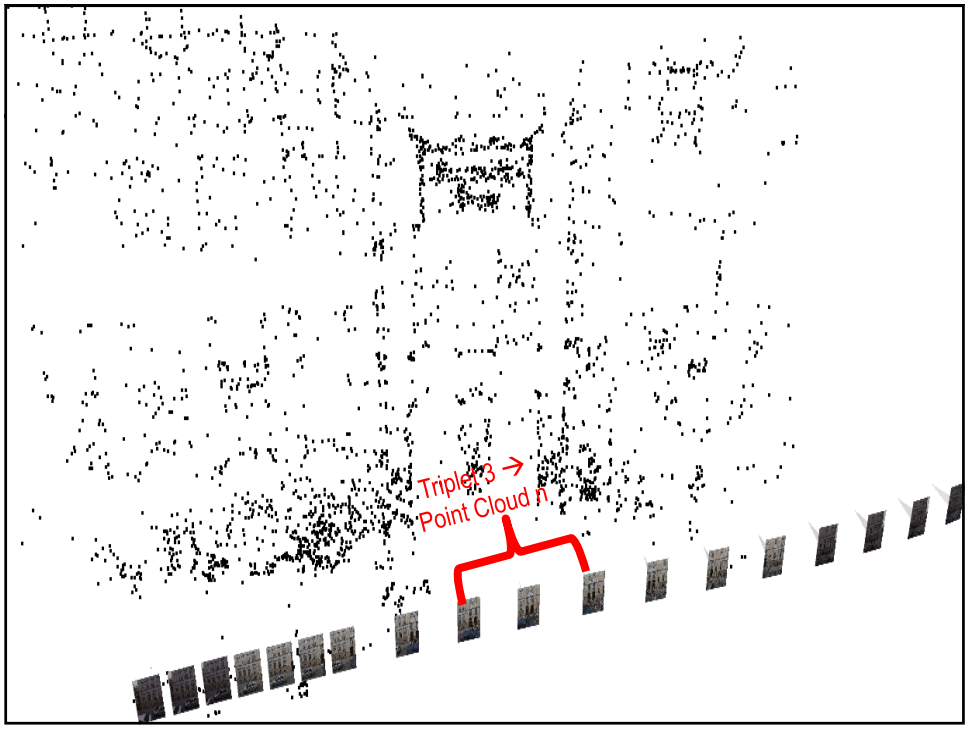


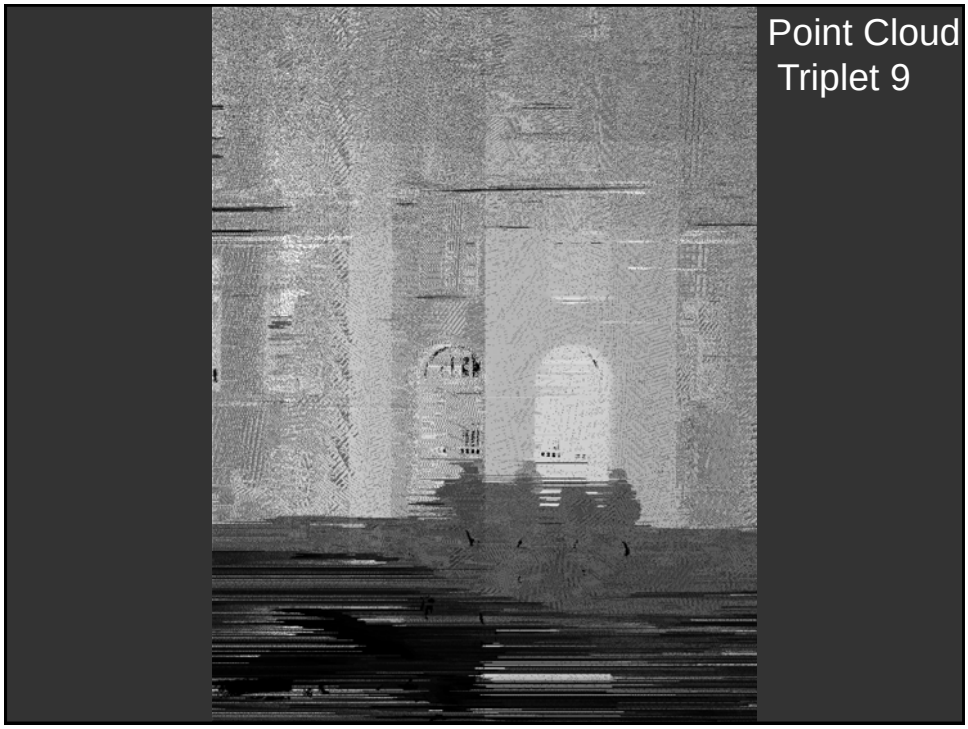

Triplet 1 →
Point Cloud 1


Point Cloud
Triplet 1


Triplet 2 →
Point Cloud 2

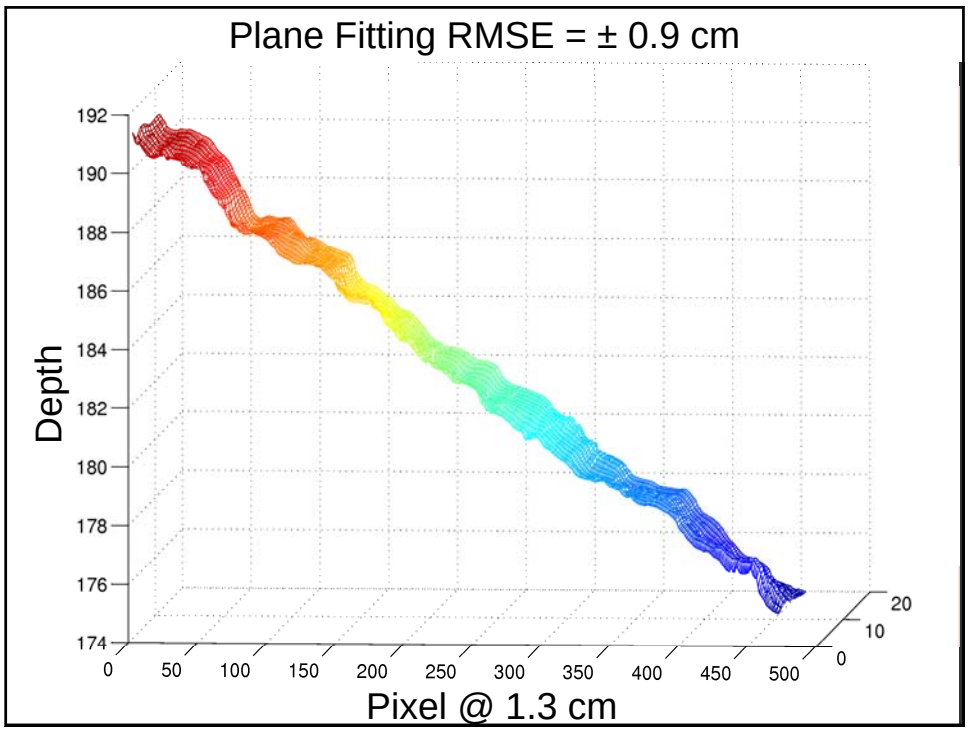
Point Cloud
Triplet 2

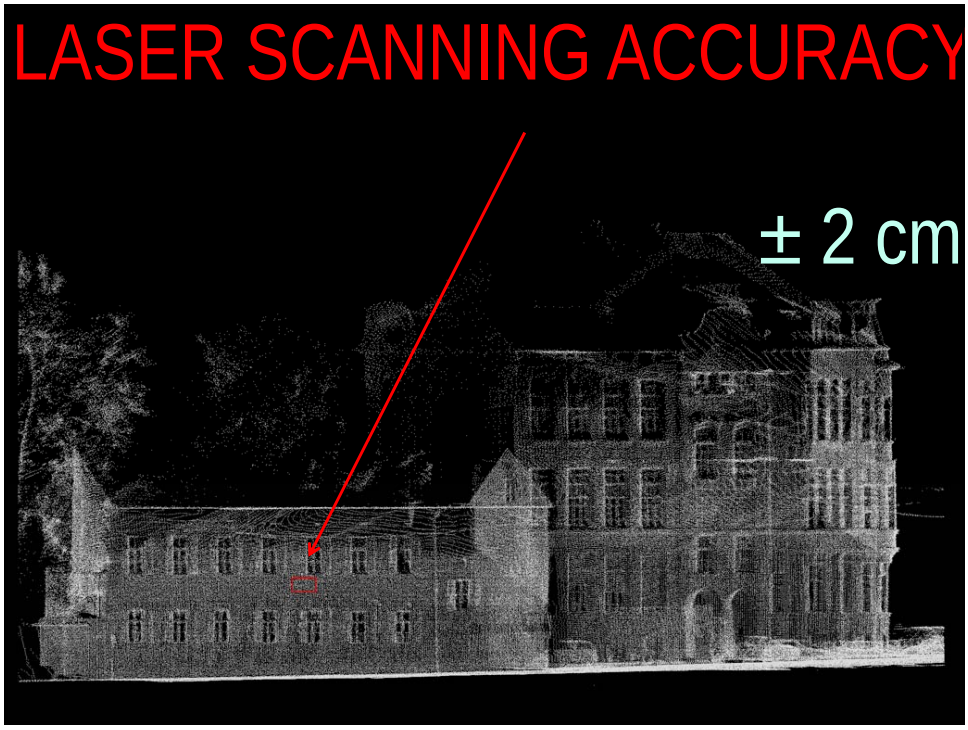

Triplet 3 →
Point Cloud n


Point Cloud
Triplet 9

Points : 1392640

Hauptschule
Krones


Plane Fitting RMSE = ± 0.9 cm
Depth
192
190
188
186
184
182
180
178
176
174
0
50
100
150
200
250
300
350
400
450
500
0
10
20
Pixel @ 1.3 cm


LASER SCANNING ACCURACY
± 2 cm

3 COMPLAINTS ABOUT 3D VISION

"Redundancy" → data overload

Costs of a Terabyte Disk

GPS/IMU insufficient for dense matching → Triangulation needed → Automated workflow non-existent

Multiple automated workflows in existence

Dense matching → CPU-consuming, slow. Perhaps 1 hour/ aerial photo?

GPU-Aided Computing

GRAPHICS PROCESSING UNIT GPU

Image Triplet Match ~ 1 to 3 Seconds

GPU-acceleration factor 30 to 100

4 GPU-PC → Acceleration by up to 400

GPU/CPU Speedup: between ~ 30x and ~ 100x

3 COMPLAINTS ABOUT 3D VISION

16 ADVANTAGES OF 3D-VISION VS LASER

"Redundancy" → data overload

Costs of a Terabyte Disk

GPS/IMU insufficient for dense matching → Triangulation needed → Automated workflow non-existent

Multiple automated workflows in existence

Dense matching → CPU-consuming, slow. Perhaps 1 hour/ aerial photo?

GPU-Aided Computing

5
COMPUTING EVOLUTION

→ Moore's Rule

1977

Karl-Franzens University Graz
1977 JOINT
AVAILABLE
DISK SPACE
Graz University of Technology
80 MEGABYTES
~ € 100,000

2007
BICYCLE
OUR (THEN) UNIVERSITY
VICE-PRESIDENT THEURL

2007
VICE-PRESIDENT THEURL
Retired with 4 GB of personal data

BUYS DISK SPACE
500 GIGABYTE
€ 100

1977-2007

Improvement 12,500,000

Exceeding Moore's Rule by 12.5

2010-2040

1 MILLION?

"HONEY,
PICK UP A 6-PACK OF
COMPUTERS ON THE
WAY HOME"

Mark Weiser, 1996
Xerox-PARC – "Ubiquitous Computing"

6

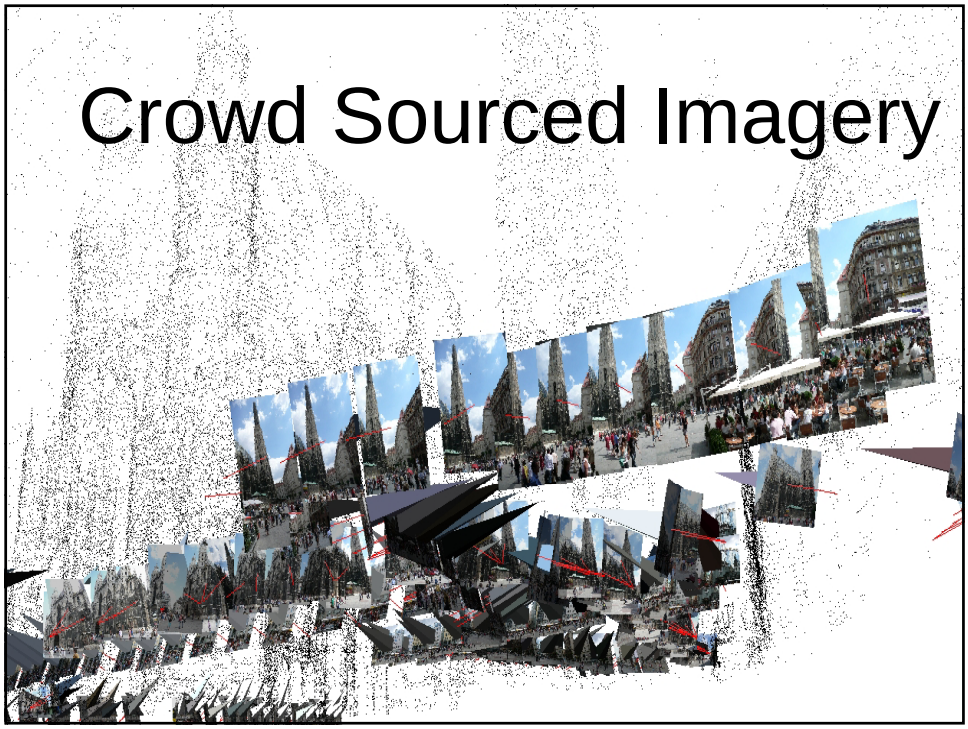
PHOTOGRAMMETRY EVOLUTION

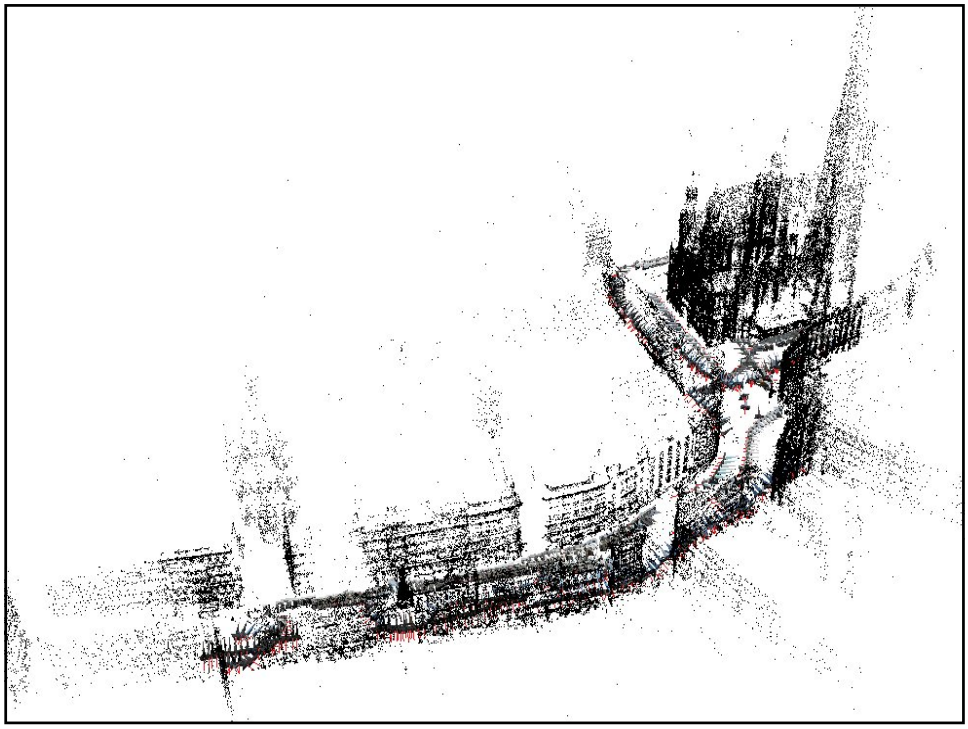
→ “NEO-PHOTOGRAMMETRY”

RECALL

THE 1 EXABYTE
3D WORLD MODEL

Microsoft Live Labs
Photosynth TECH PREVIEW
USER
INVOLVEMENT


Crowd Sourced Imagery



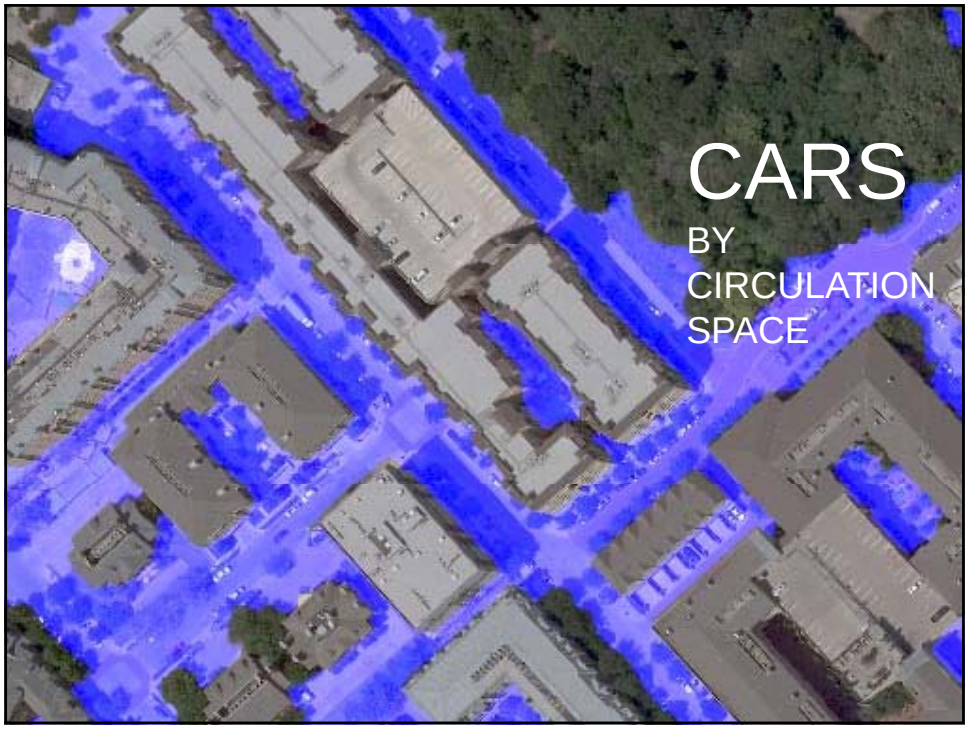
AUTOMATED
COMPUTER VISION

Sky
Façade
Circulation Space
Vegetation
Roof

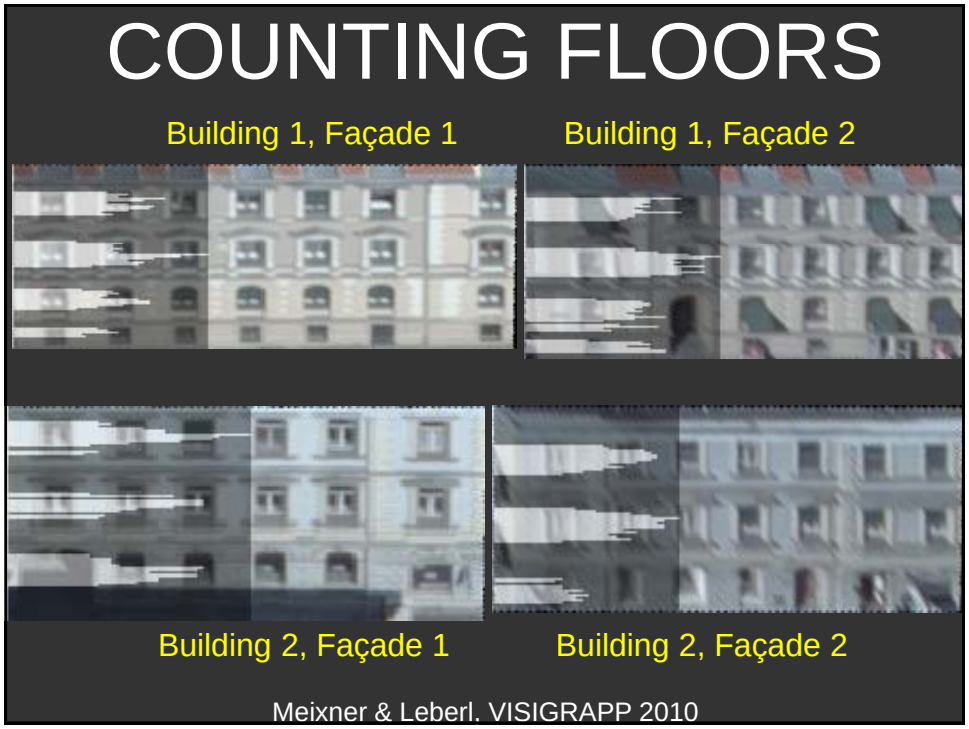
CARS

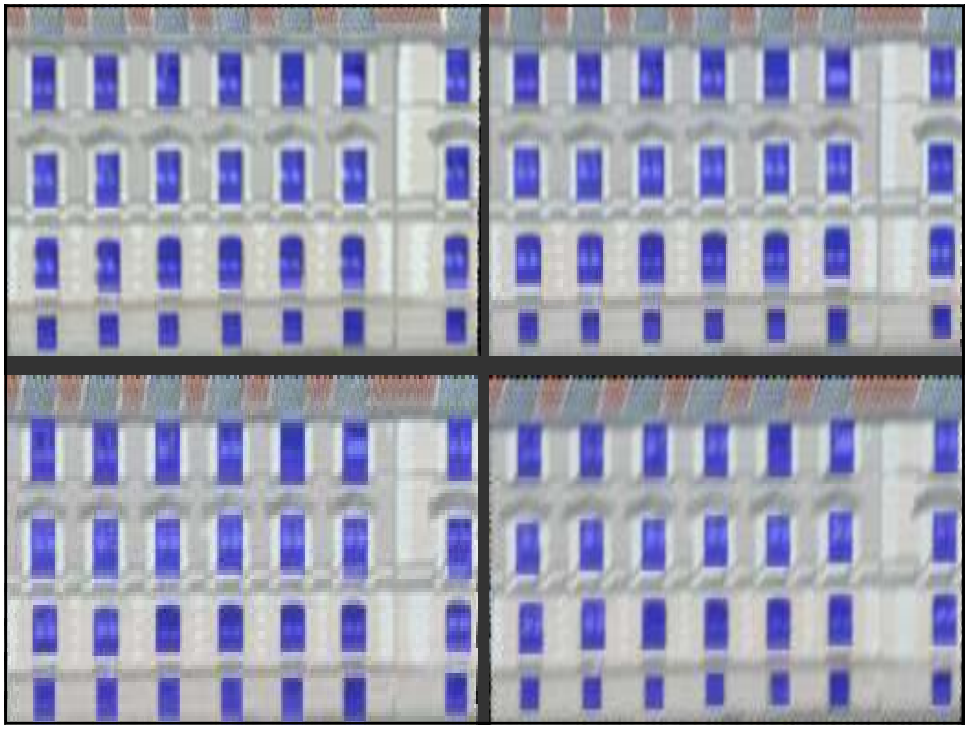
CARS

CARS
BY
BOOSTING


CARS
BY
CIRCULATION
SPACE

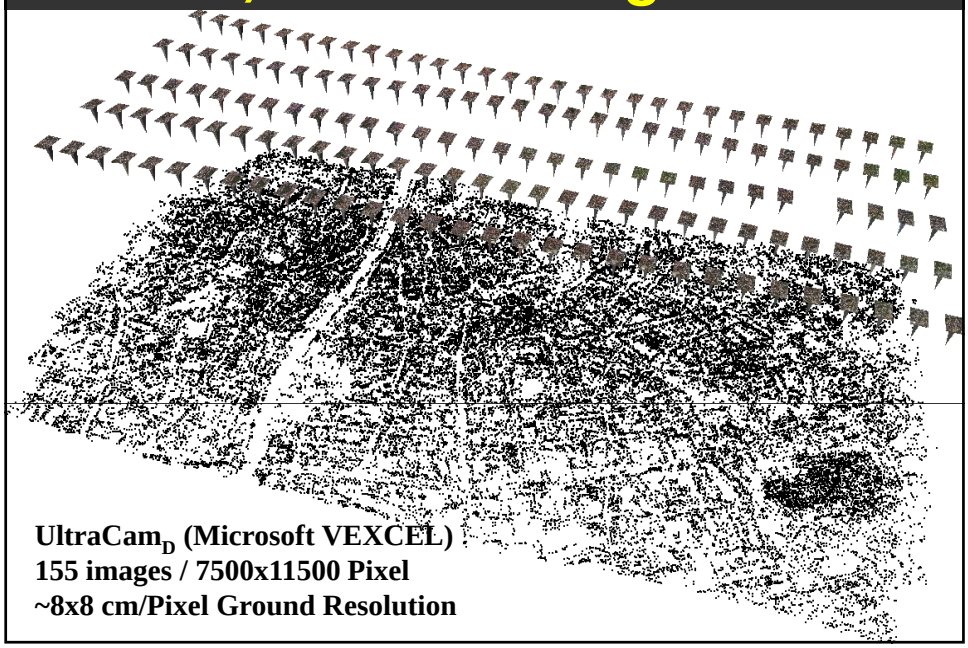
Windows
→ Floors


COUNTING FLOORS
Building 1, Façade 1
Building 1, Façade 2
Building 2, Façade 1
Building 2, Façade 2
Meixner & Leberl, VISIGRAPP 2010



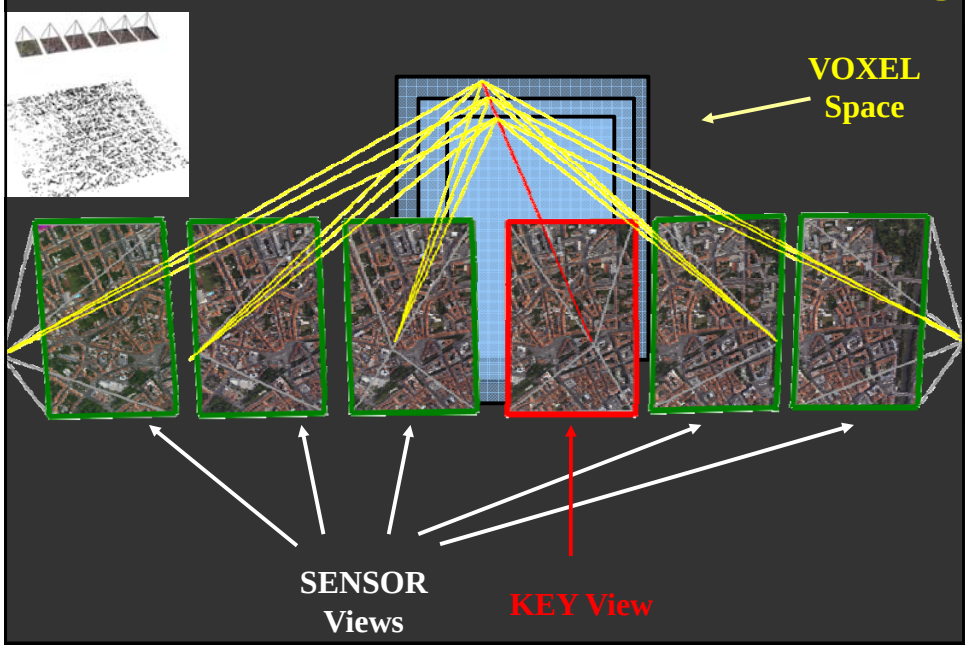
NOVEL
MULTI-RAY MATCHING & MULTI-RAY GEOMETRY

Graz, Aerial Triangulation

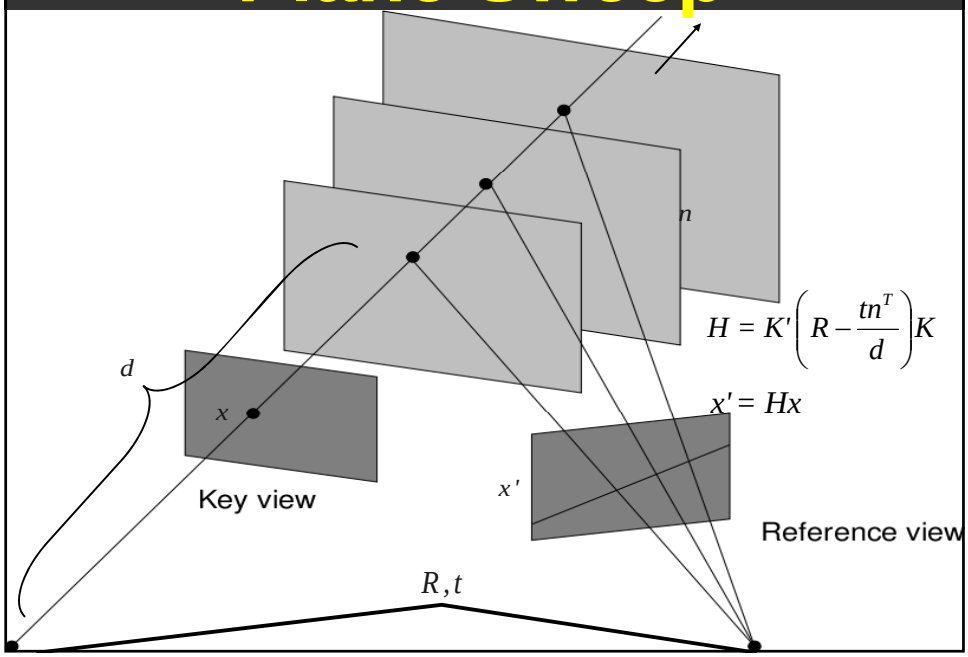


UltraCam$_D$ (Microsoft VEXCEL)
155 images / 7500x11500 Pixel
~8x8 cm/Pixel Ground Resolution

Multi-View Dense Matching



Plane Sweep



KEY view

SENSOR view 1

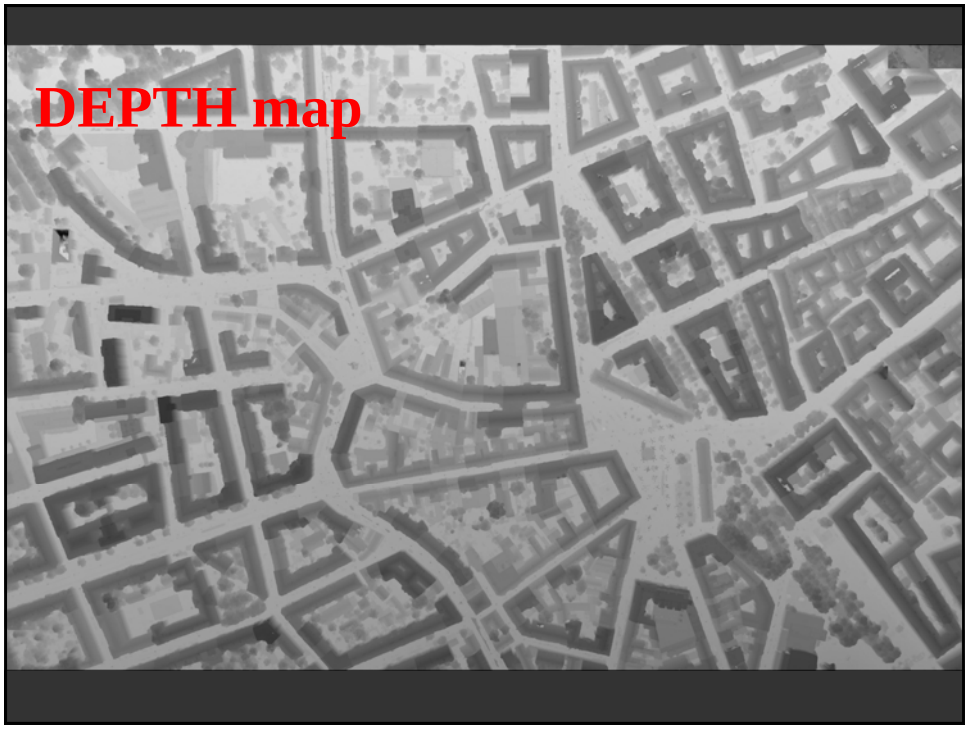
SENSOR view 2

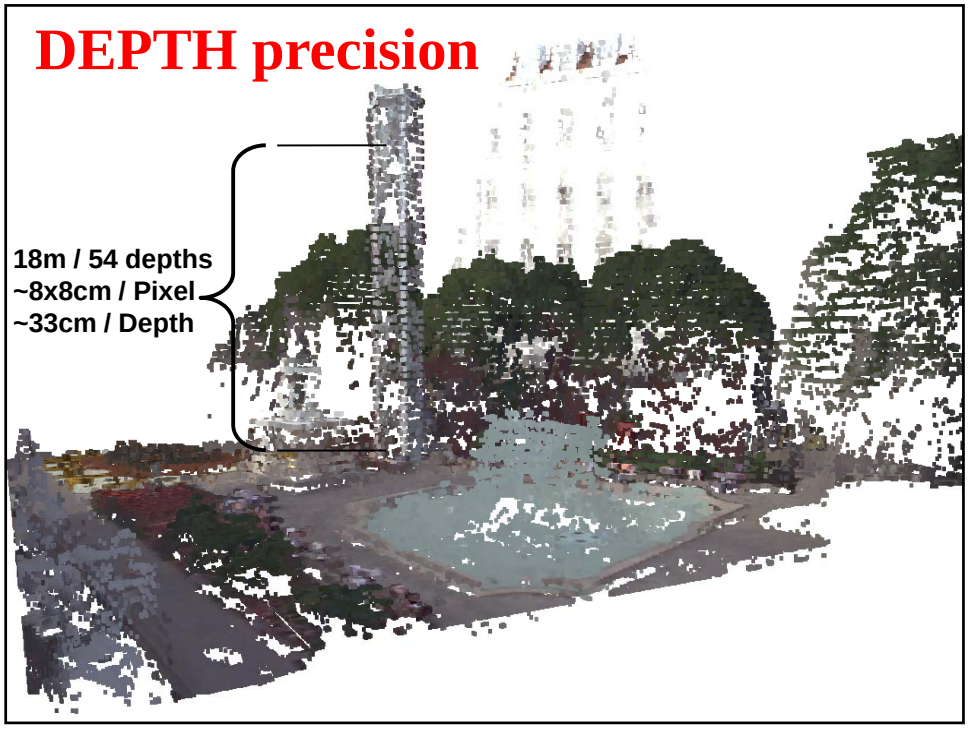
SENSOR view 3

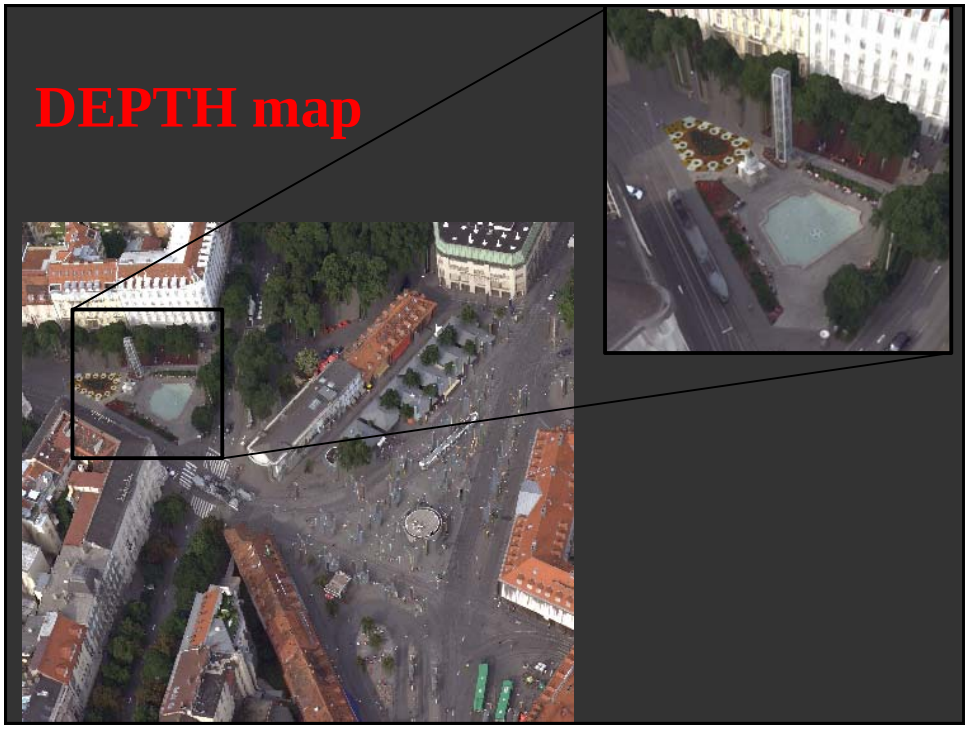
SENSOR view 4

SENSOR view 5

KEY view


DEPTH map


DEPTH precision
18m / 54 depths
~8x8cm / Pixel
~33cm / Depth


DEPTH map

LOCATION-AWARE INTERNET APPLICATIONS

Search/Advertisement

Navigation [Car, Walking]

Games

e-Commerce

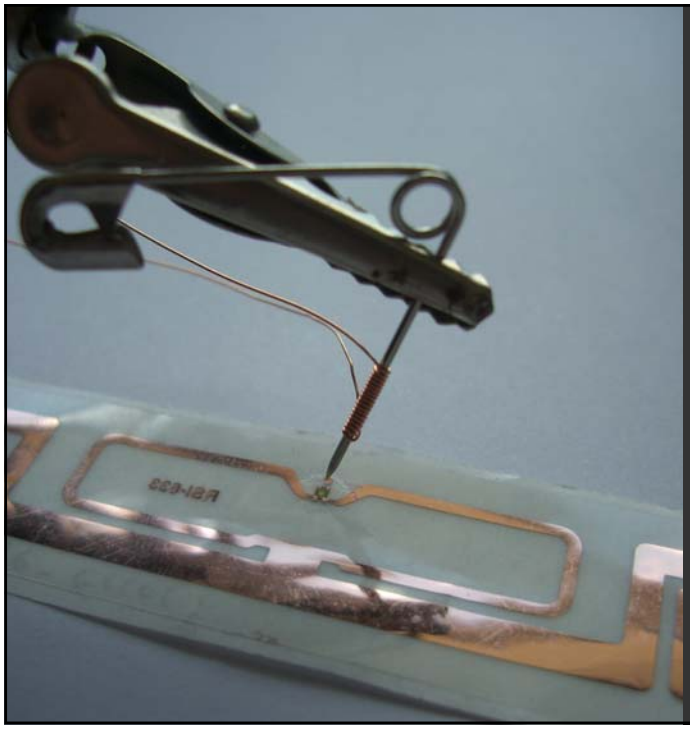
Smart Phones

Mixed Reality

Internet-of-Things

Chips on Body

……



RFID

0.5 * 0.5 mm^2

RFID

0.5 * 0.5 mm^2

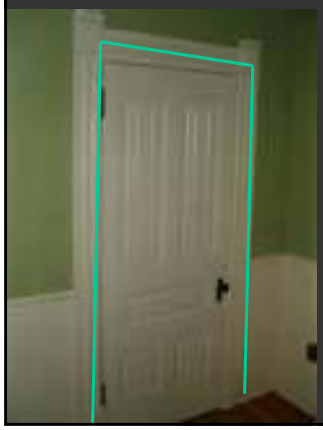
plus

Internet

RFID
0.5 * 0.5 mm^2

plus
Internet

plus
Smart
Phones



RFID
0.5 * 0.5 mm^2

plus
Internet

plus
Smart
Phones

plus
Sensors

UBIQUITOUS COMPUTING

↓

AMBIENT INTELLIGENCE

WEB 2.0

↓

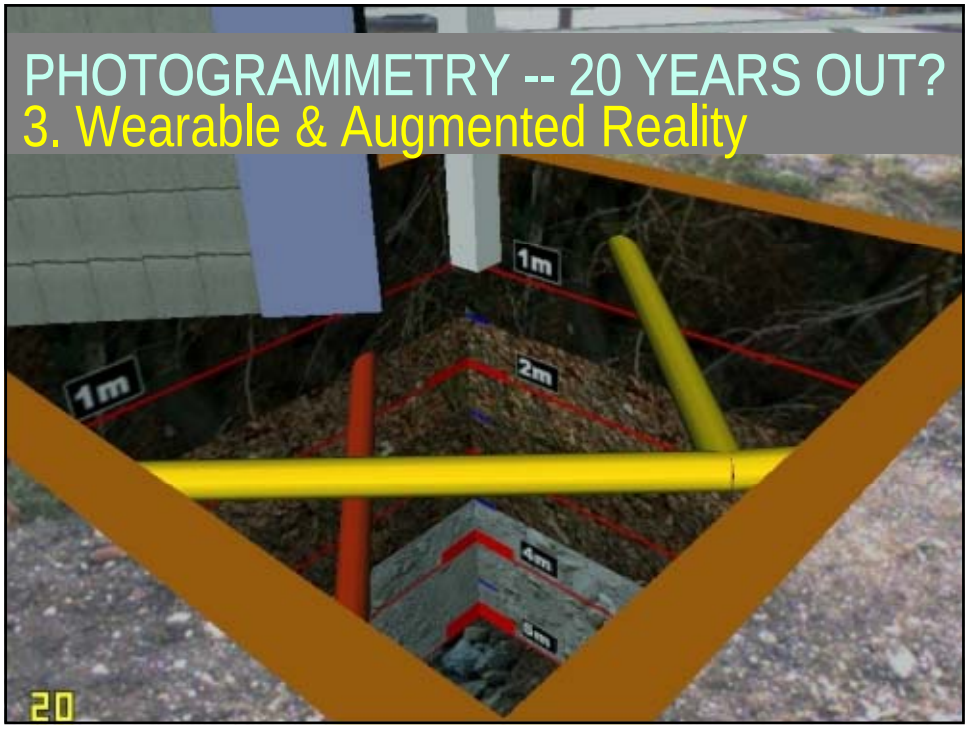
WEB-SQUARED?

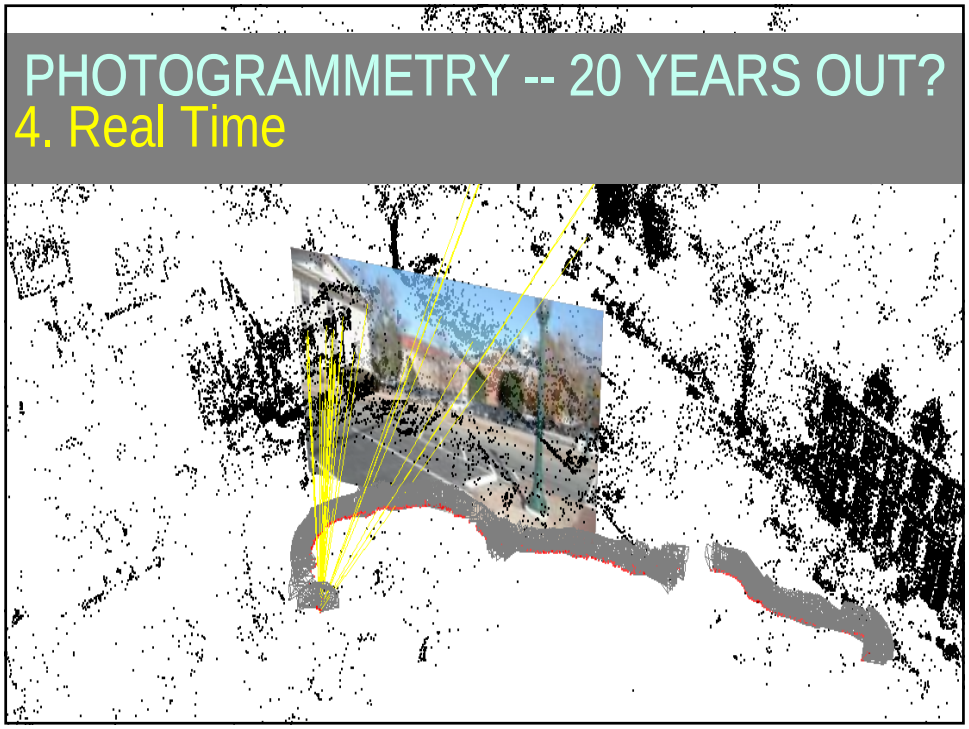
PHOTOGRAMMETRY -- 20 YEARS OUT?

1. Exabyte 3D World Model

PHOTOGRAMMETRY -- 20 YEARS OUT?
2. Commodity-Type Sensors & Platforms

PHOTOGRAMMETRY -- 20 YEARS OUT?
3. Wearable & Augmented Reality

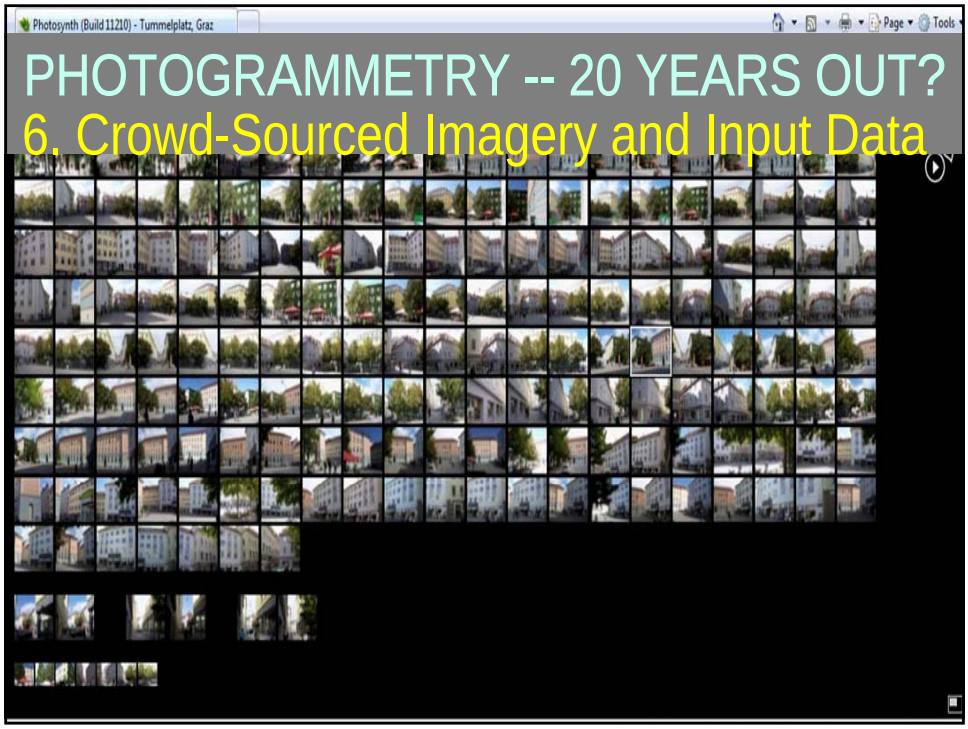

PHOTOGRAMMETRY -- 20 YEARS OUT?
3. Wearable & Augmented Reality
1m
1m
2m
4m
20

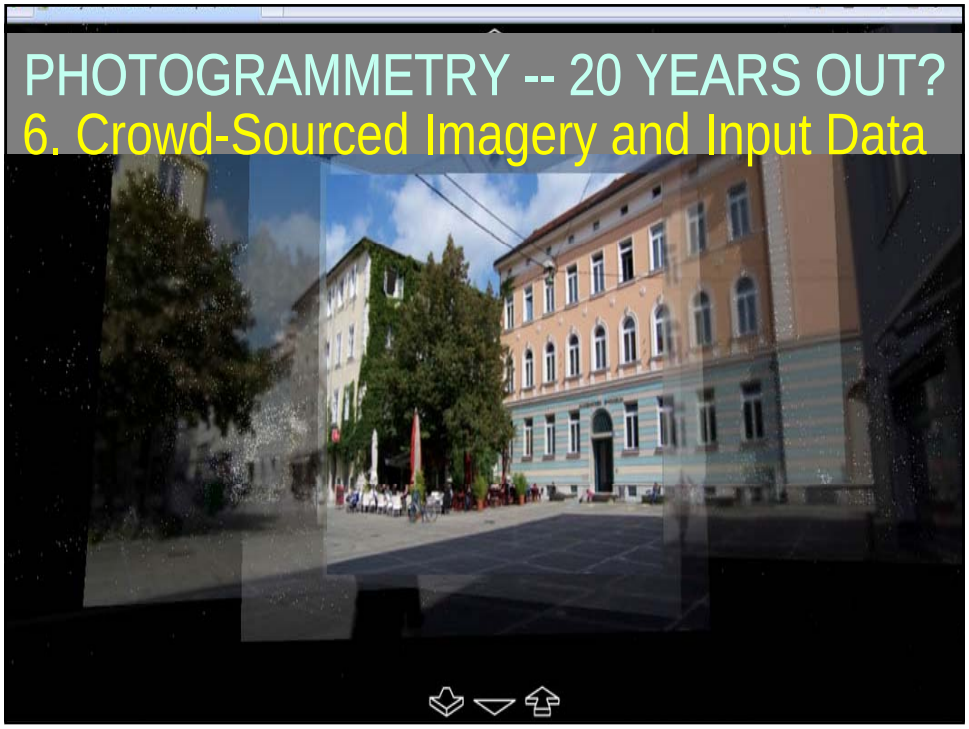

PHOTOGRAMMETRY -- 20 YEARS OUT?
4. Real Time

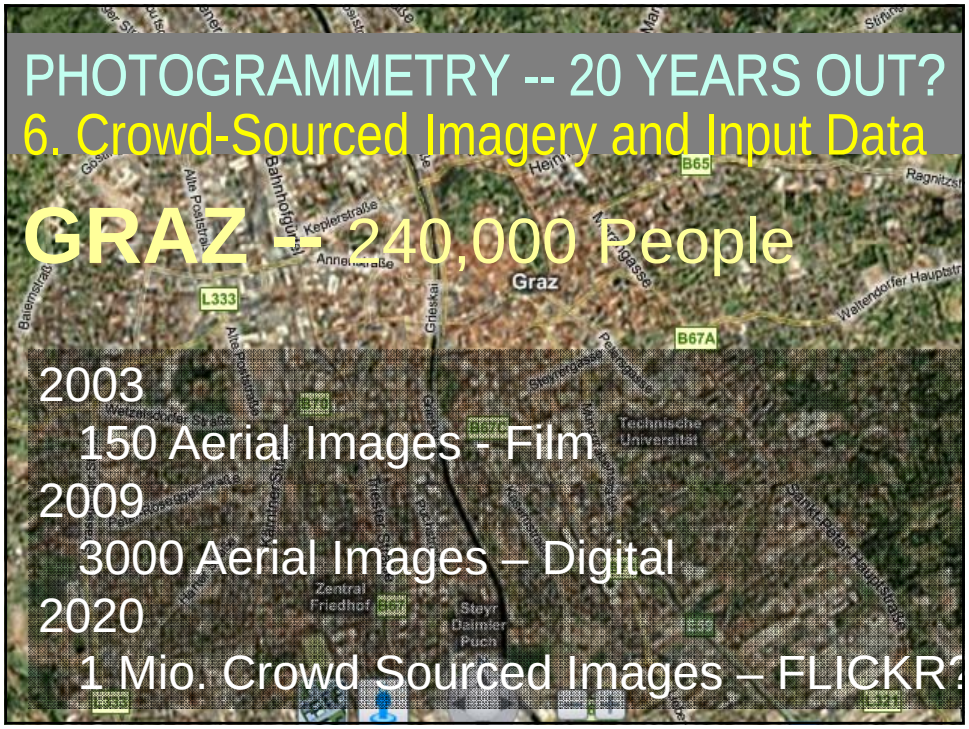
PHOTOGRAMMETRY -- 20 YEARS OUT?
5. Multi-Sensors

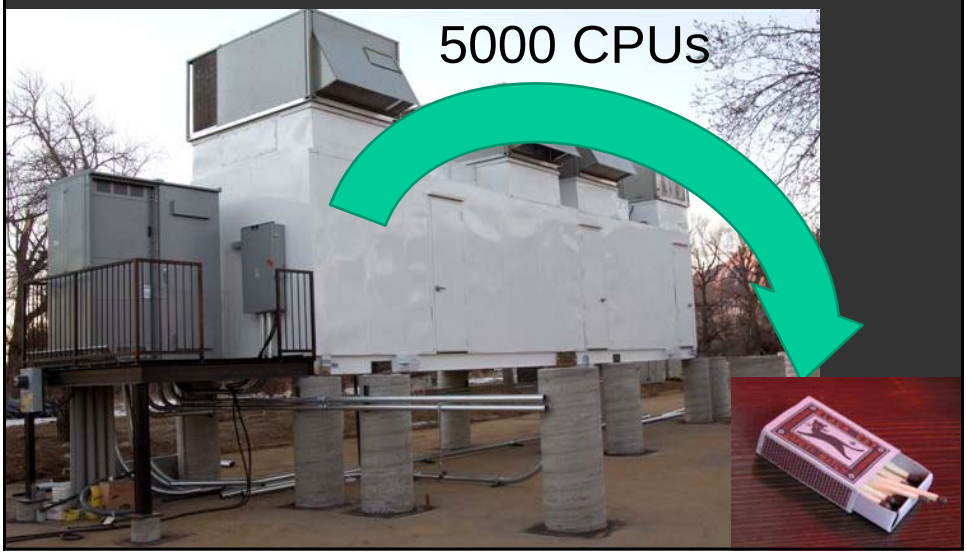
Cameras
Microphones
GPS
Compass
Accelerometer
RFID-Reader
Laser

PHOTOGRAMMETRY -- 20 YEARS OUT?
6. Crowd-Sourced Imagery and Input Data




PHOTOGRAMMETRY -- 20 YEARS OUT?
6. Crowd-Sourced Imagery and Input Data


PHOTOGRAMMETRY -- 20 YEARS OUT?
6. Crowd-Sourced Imagery and Input Data
GRAZ -- 240,000 People
2003
150 Aerial Images - Film
2009
3000 Aerial Images – Digital
2020
1 Mio. Crowd Sourced Images – FLICKR?

PHOTOGRAMMETRY -- 20 YEARS OUT?

7. Supercomputing → Wearable