BINGO

Bundle Adjustment and camera calibration, latest developments and special applications

Mélykuti Balázs, Erwin Kruck

2015 Fény-Tér-Kép, Gyöngyös

Geoinformatics & Photogrammetric Engineering, Dr. Kruck & Co. GbR

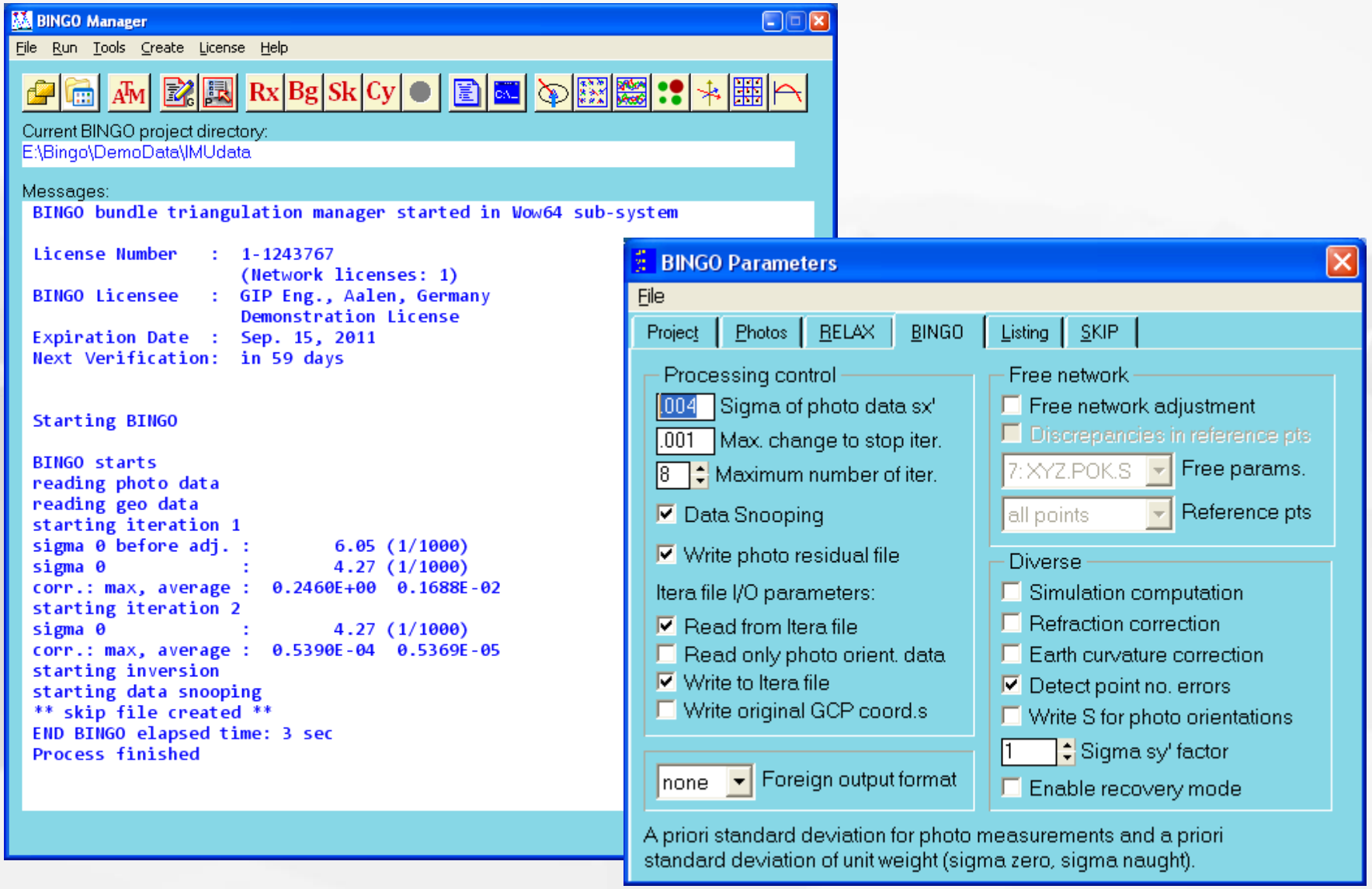
Platanenweg 24, D-73430 Aalen, Germany, www.bingo-atm.de

bingo
GIP. DR. KRUCK & CO. GBR

BINGO Development

- 1981 First BINGO version for terrestrial photogrammetry
- 1982 Expansion for large blocks and camera calibration including additional parameters.
- 1983 Expansion for aerial triangulation, introduction of Baarda's Data-Snooping, integration of survey measurements.
- 2002 New calibration possibilities for digital cameras including calibration of PPS.
- 2006 Support for multi-headed cameras like. New GUI for data file handling (control points etc.)
- 2009 New visualisation of image measurements and their residuals, Automatic tie-point measurement.
- 2010 BINGO 6.0 with GPS-viewer, BINGO export function, enhancements of graphics modules, BINGO 64-bit

BINGO 6.x Manager



BINGO
Outstanding Mathematical Features

- Balanced L2-Norm adjustment for error elimination.
- RANSAC (Random Sample Consensus) algorithm for error elimination. This algorithm provides correct results as long as the number of good points is higher (e.g. 51%) than the number of bad points.
- Automatic / attended error elimination using Baarda's Data-snooping. The software to eliminate faulty data from the photo coordinate file.
- Free network adjustment, the bundle triangulation can at first run without ground controls to clean-up the photo data.
- Variance component estimation to get correct weighting for all groups of observations, to separate between weighting and measurement errors.
- Precision and reliability for all unknowns and all observations.

BINGO
More Outstanding Features

- Combined adjustment: aerial, oblique, terrestrial photos, GPS and INS data Survey measurements, lake levelling ….
- Full camera calibration with additional parameters Special tools for digital aerial survey cameras with stitched sensors.
- Simultaneous IMU system calibration without ground control points
- Graphical presentation on all graphical devices with confidence ellipses, residuals, block layout ...
- Automatic removal of rank defects (e.g. in case of parallel photo rays)
- Closely integrated in photogrammetric systems (direct or with interface)
- Stereo-metric camera conditions
- Solution for stiched or oblique camera conditions

Interactive 3dViewer

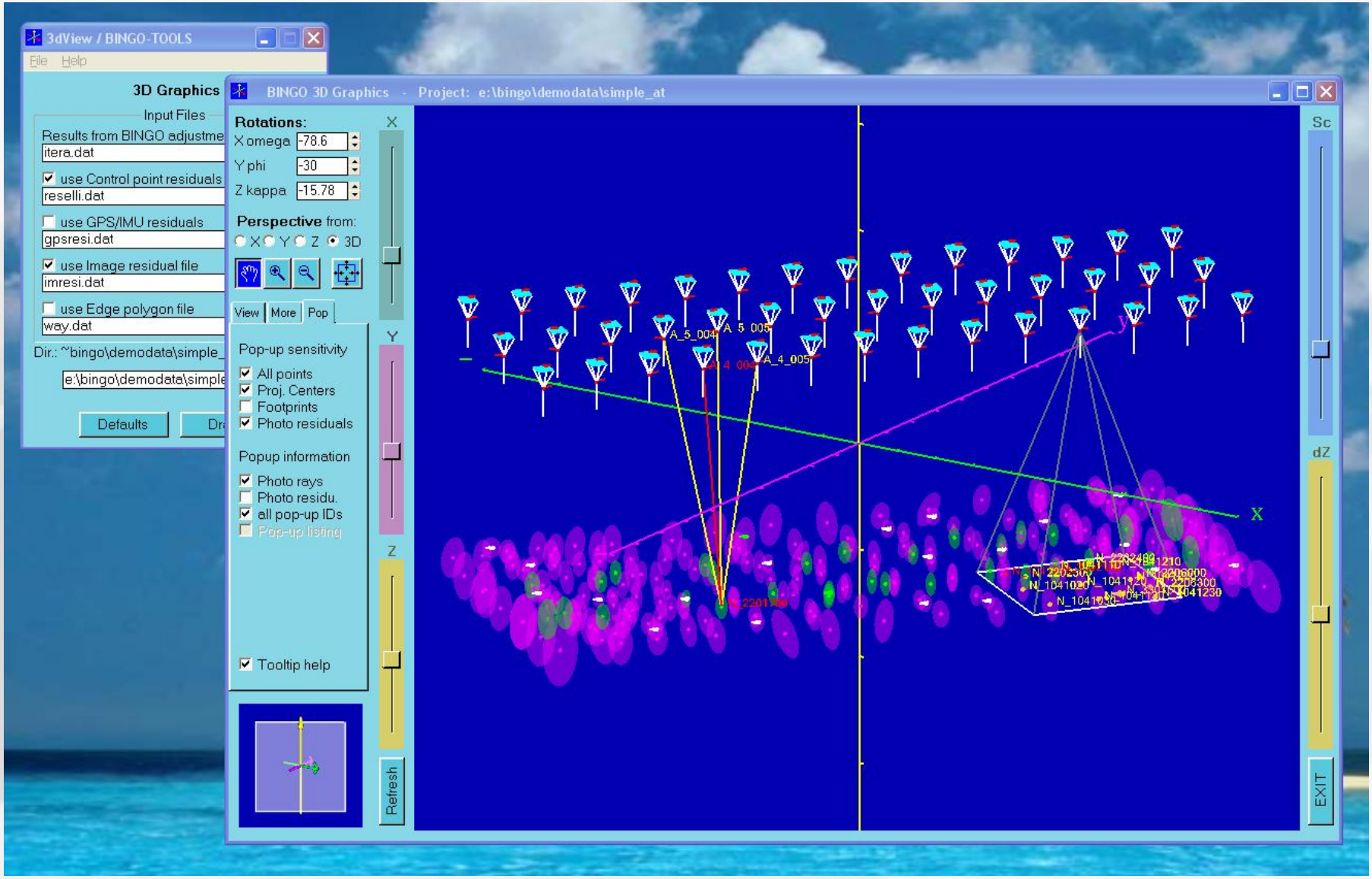
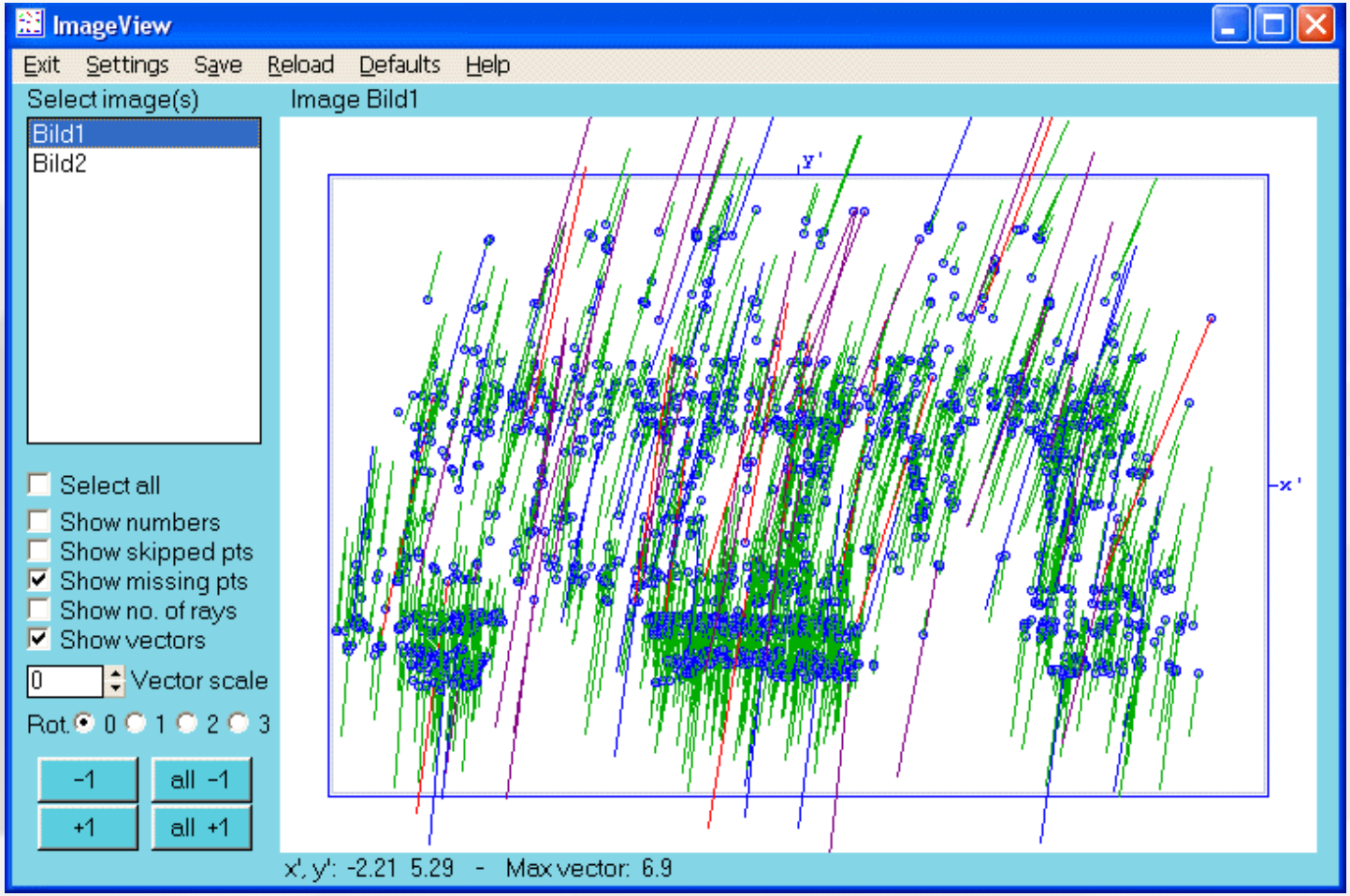


Image measurements and image residuals

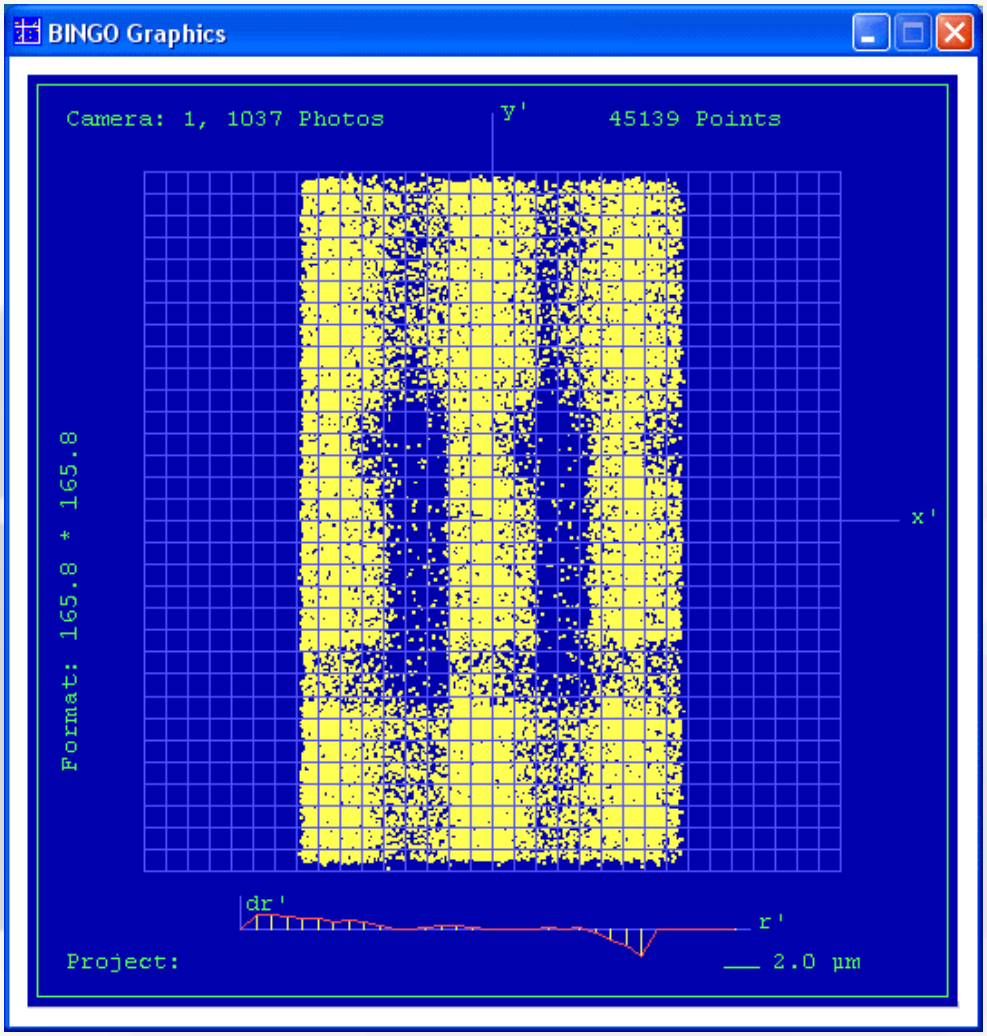
- Image residuals are expected normal distributed.
- If they show systematic effects, adjustments results might not fit to reality.
- The reason for the problems has to be searched and eliminated.

Graphical presentation of adjustment results



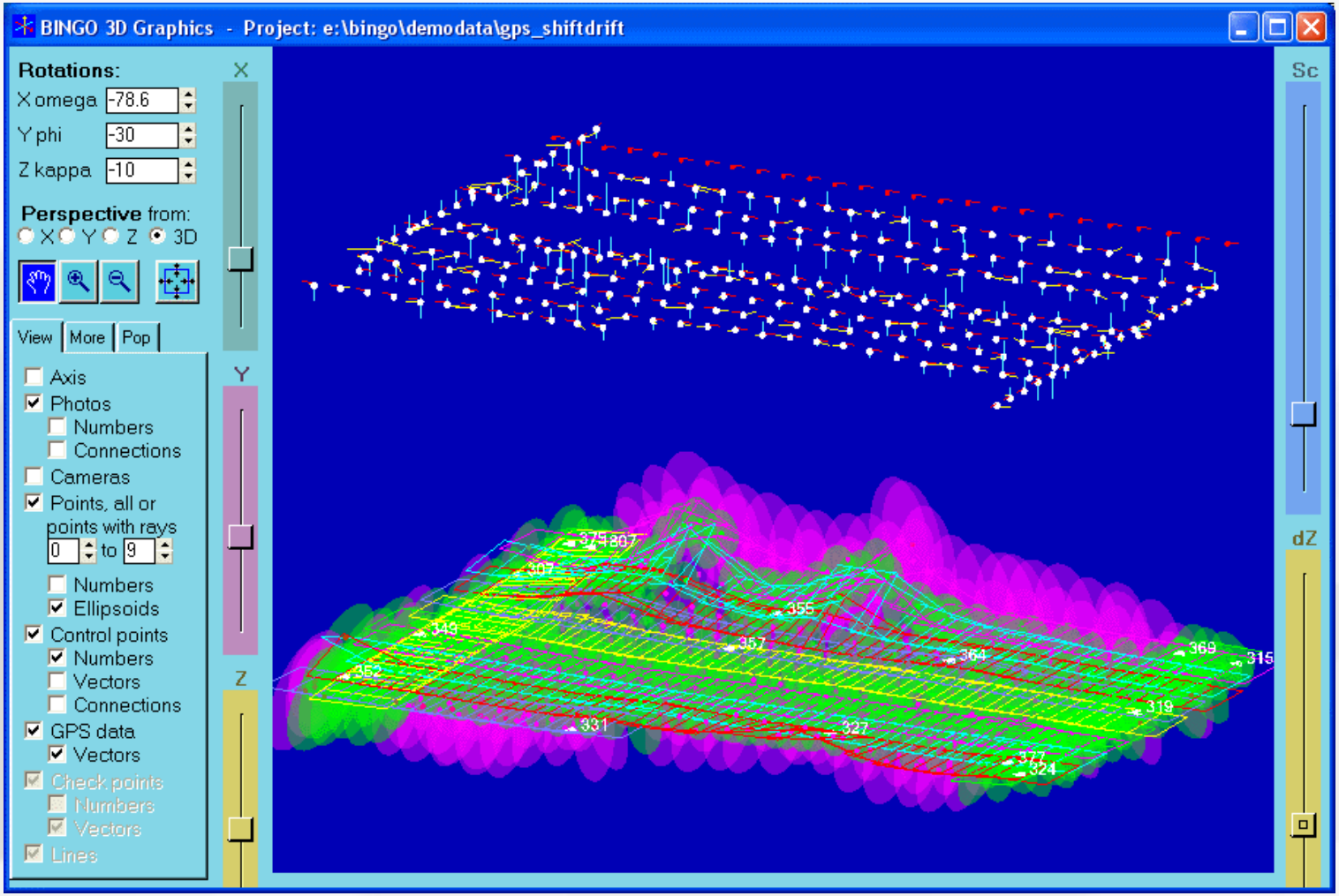
Surprising systematic image residuals with moving object points
It is nearly impossible to find without graphical analysis

Graphical presentation of adjustment results



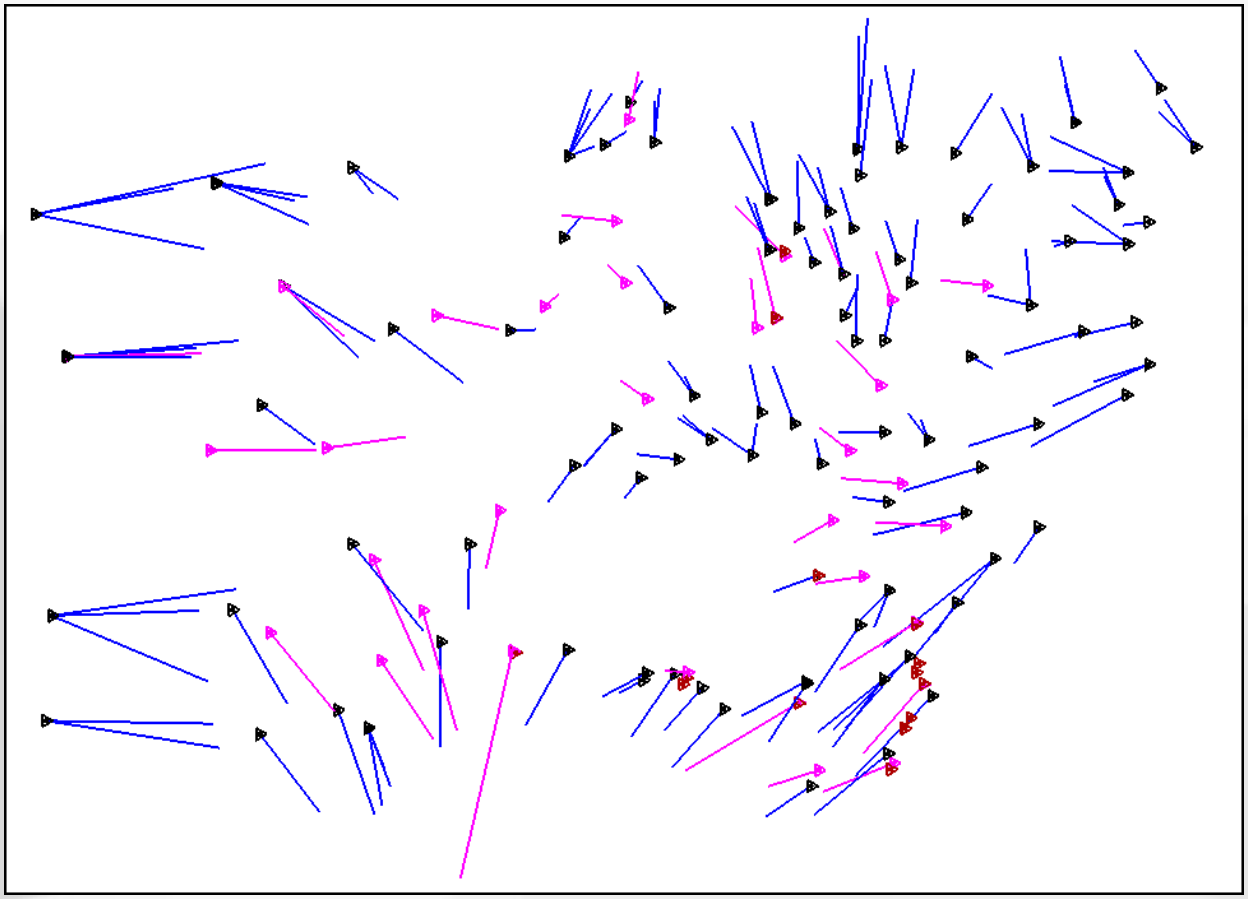
Summarized point distribution from 1037 photos with 45139 photo measurements

Graphical presentation of adjustment results



GPS data are missing for the first flight line.
As result we have larger confidence ellipsoids in that region.

Graphical presentation of adjustment results



Ground control point residuals showing systematic effects. Additional parameters for different scales in x′ and y′ remove this problem completely

Graphical presentation of adjustment results

GPS/IMU residuals of different projects.
Systematic effects and relations between GPS and IMU data can be easily identified.

Variance component estimation

For correct weighting and to separation between weighting and measurement errors

Condition: $\frac{s_{0_G\ aposterion}}{s_{0_G\ apriori}} \Rightarrow 1.0$

Group	Test Value	No.of Obs.	Redundancy
Image coordinates :	1.25	5906	2760.93
Camera data incl. vector e' :	0.47	5	3.00
Coordinates of control points :	1.31	45	20.14
Control points only in X :	0.94	15	7.96
Control points only in Y :	1.70	15	7.77
Control points only in Z :	1.09	15	4.40
Exterior orientations incl. GPS:	0.98	669	106.91
Sum of all observations :	1.24		

Program Capacity

Max no. of points	no limit
Max no. of photos	no limit
Max no. of different cameras	100
Max no. of photo measurements	no limit
Max no. of ground control points	no limit
Max no. of survey measurements	no limit
Max no. of GPS/IMU data files	no limit
Max no. of points per photo	no limit
Max no. of photos per point	no limit

High Speed Processing

Block	Photos	Points	Unknowns	Time [min:sec]	Comments
Earthwatch	1.118	73.567	227.409	2:07	GPS, AAT
Montgomery	2.728	8.144	40.800	0:51	Standard aerial
KLM2000 SA	2.033	8.267	37.154	1:15	GPS, IMU, cross runs
SKW	940	1.506	10.164	0:05	Close range

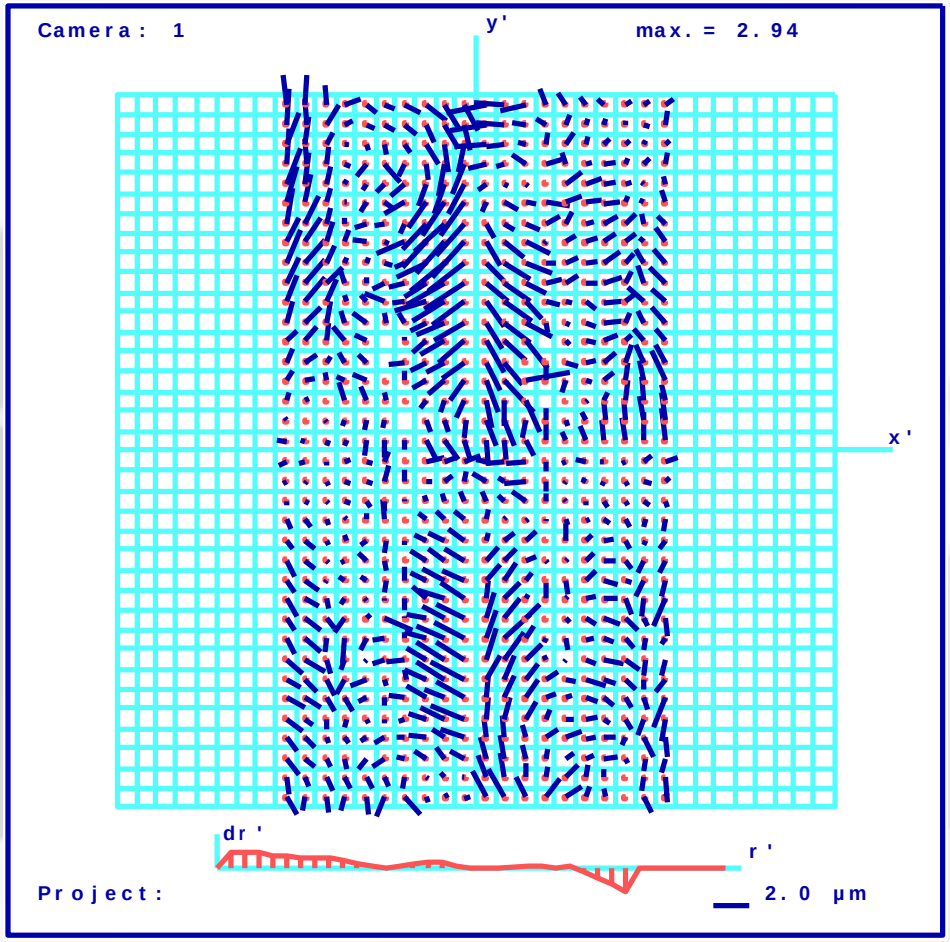
Each block with 3 iterations, inversion, data snooping, variance component estimation

Computer: X9650 Workstation, 3 GHz, Raid disk system, 4GB RAM, WinXP-32

New digital cameras

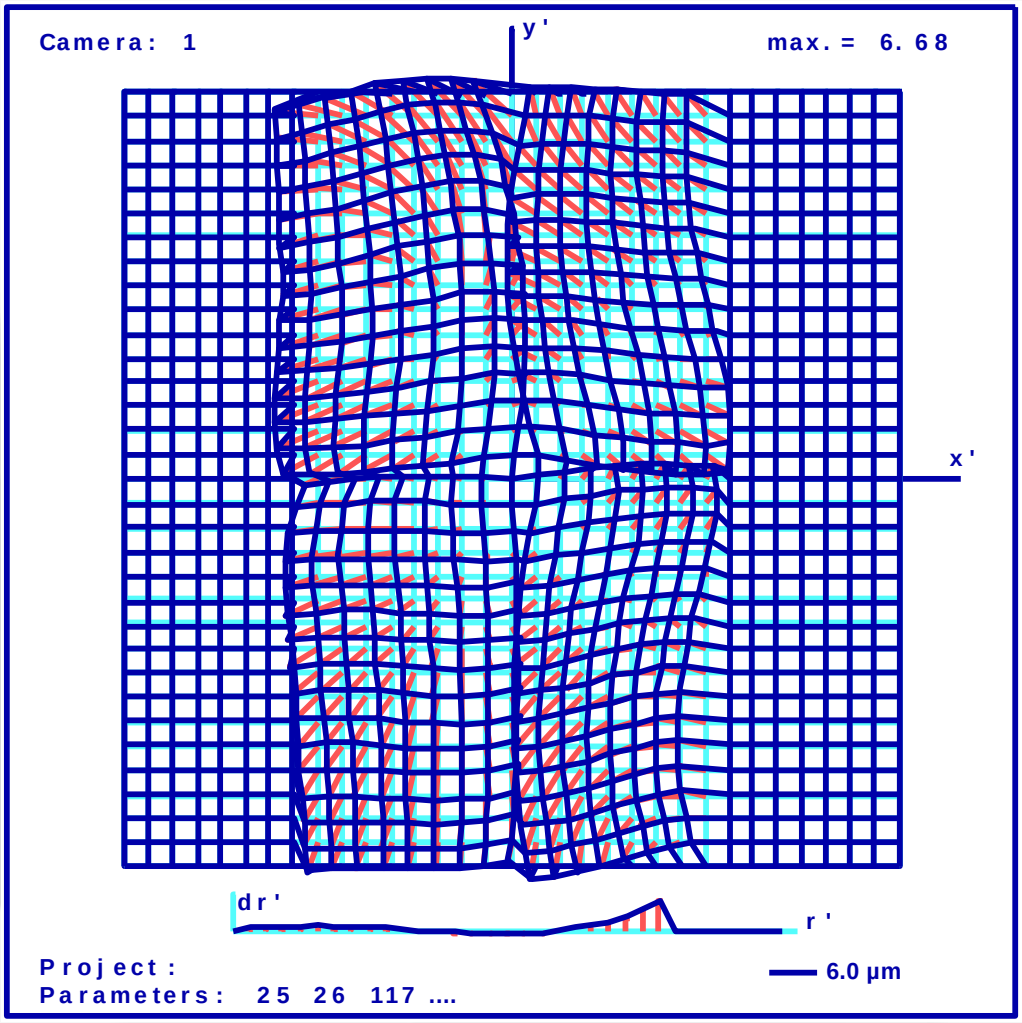
- Many more images – data increased once more again
- Stiched images
- Simultaneous camera calibration is required for best precision
- Specially for semi-metric cameras

Graphical presentation of adjustment results



Systematic image residuals in stitched images combined from 1037 photos

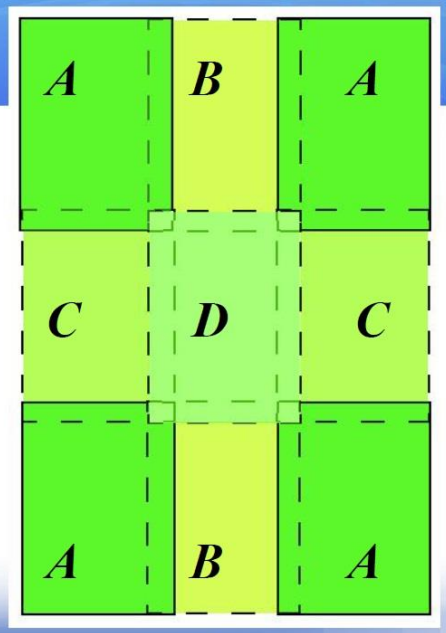
Graphical presentation of adjustment results



Effects of special self-calibration parameters on the image geometry

UltraCam camera calibration

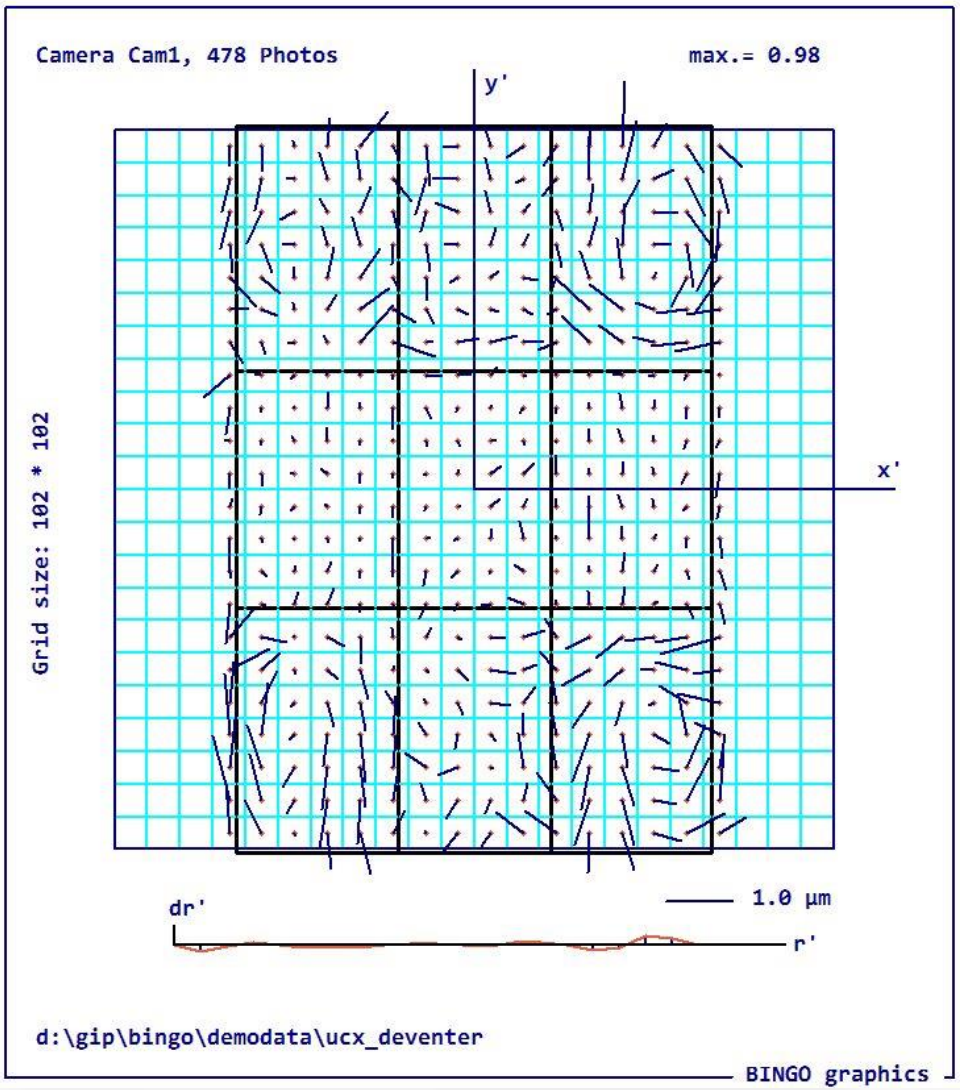
Microsoft



- 4 Cones
- 4 Lenses
- 4 Focal Planes
- 9 CCD SensorArrays
- 12 Overlap Areas

VEXCEL IMAGING
a Microsoft company

UltraCam camera calibration



UAV calibration
with special parameters

eXom
senseFly

eXom
The intelligent mapping & inspection drone

Meet eXom, the sensor-rich drone for professionals, offering TripleView imaging and advanced situational awareness.

eBee
senseFly

eBee Ag
The precision agriculture drone

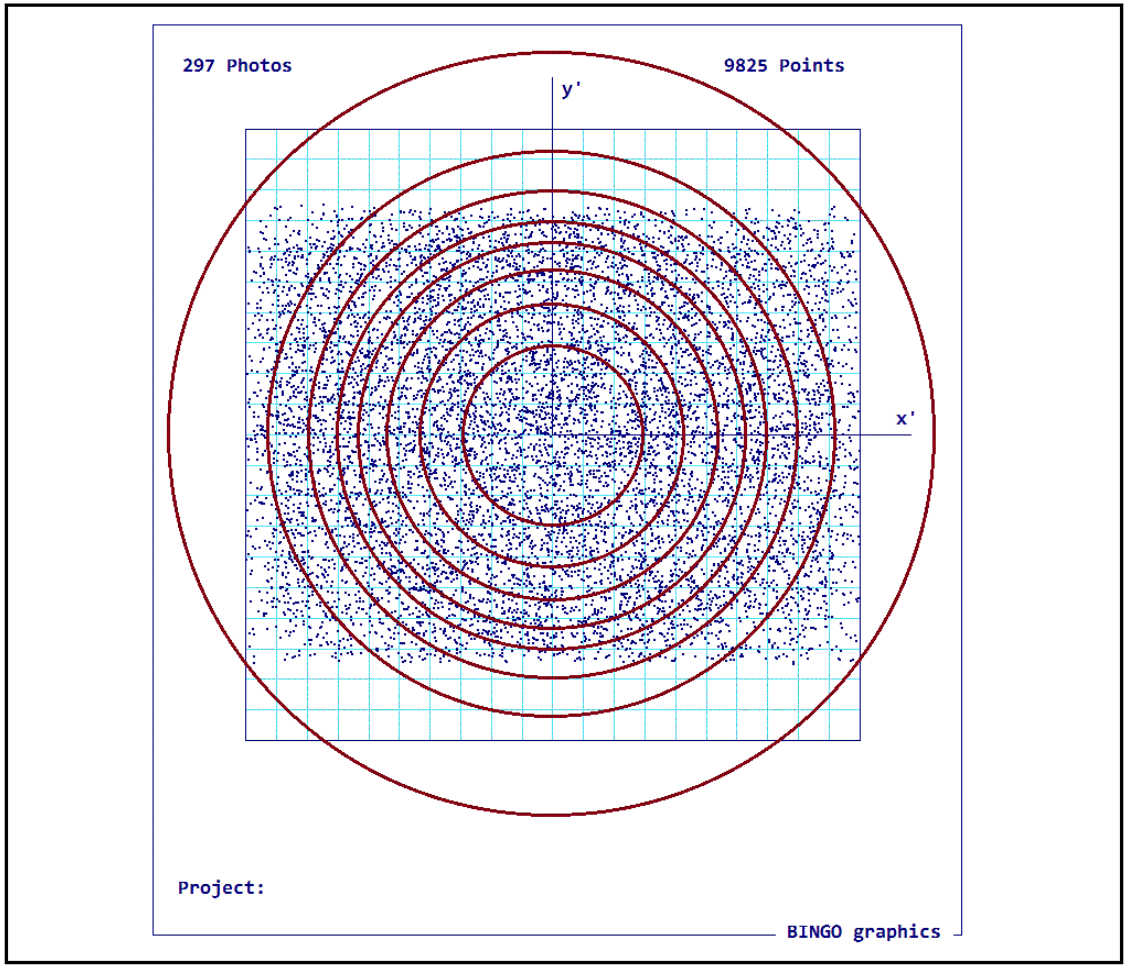
The eBee Ag is the only precision farming UAV you need. With its full drone-to-tractor workflow you can scout your crops, assess plant health, create prescriptions and begin treatment all on the same day.

Camera Calibration with Radial Variance Component Estimation

Expectation

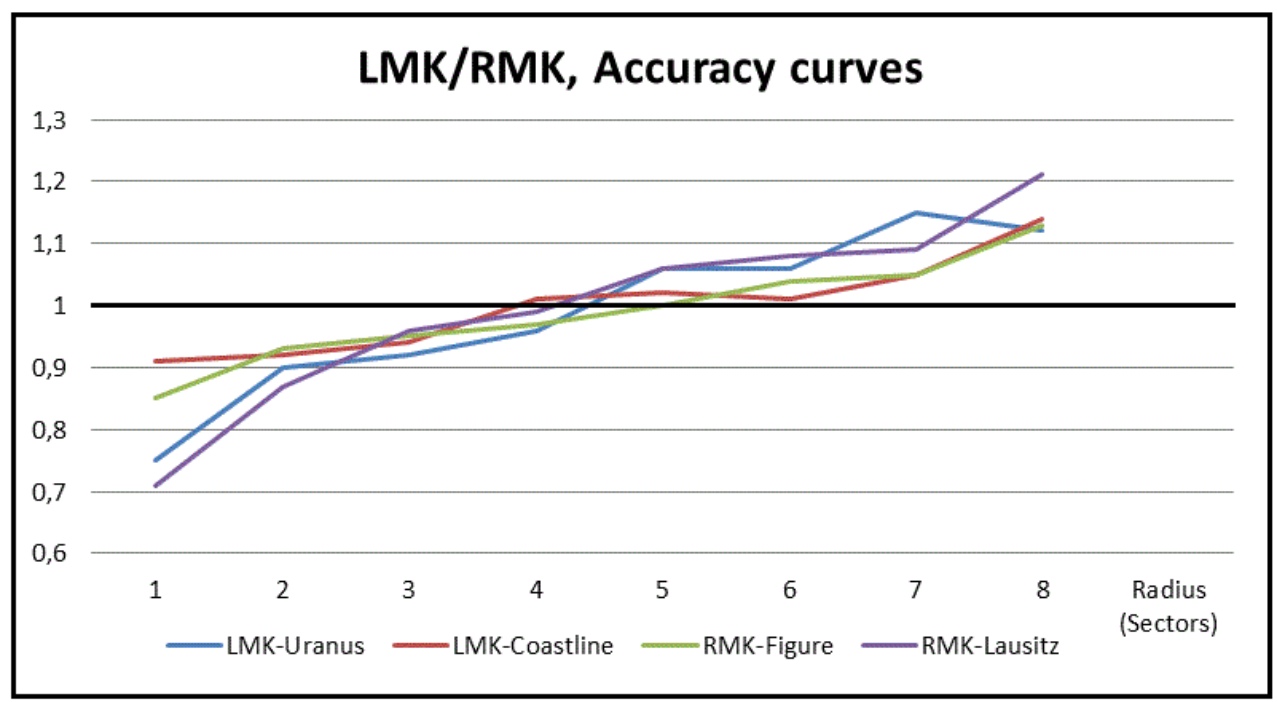
- It is prospected to have a better precision of photo measurements in the center of images then along the edges or in the corners
- With statistical methods the accuracy of photo measurements in dependency of the distance of points from image center has been analyzed
- A high number of camera types have been tested with well penetrated point measurements in image space

Photo Measurement Distribution



bingo
GIP. DR. KRUCK & CO. GBR

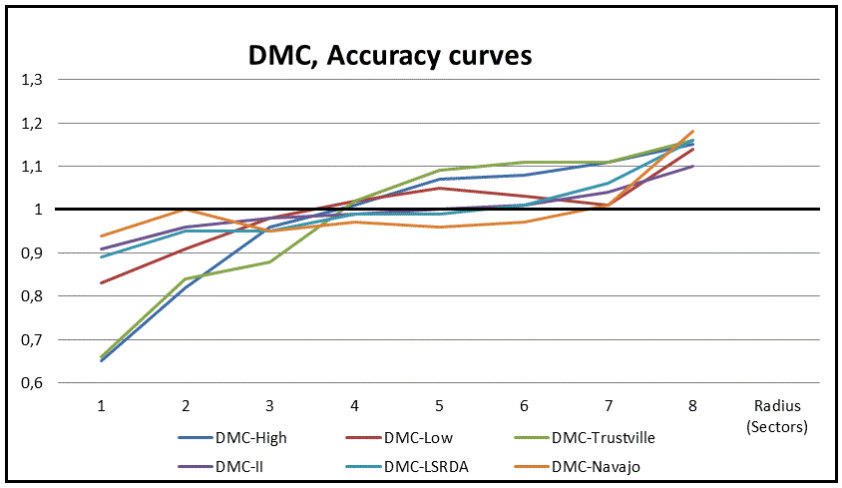
Aerial Film Cameras

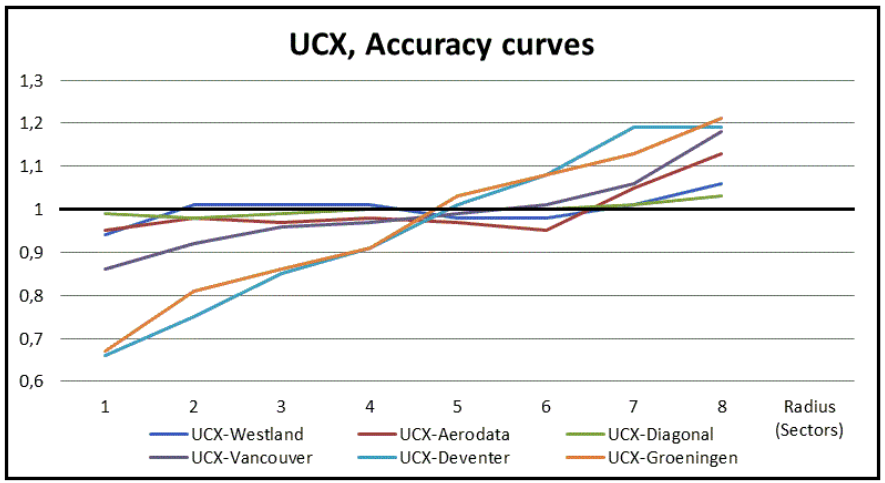


- Close to linear curve
- Slight deviation between the cameras
- The difference in the accuracy is app. 70%

bingo
GIP. DR. KRUCK & CO. GBR

Digital Aerial Photogrammetric Cameras

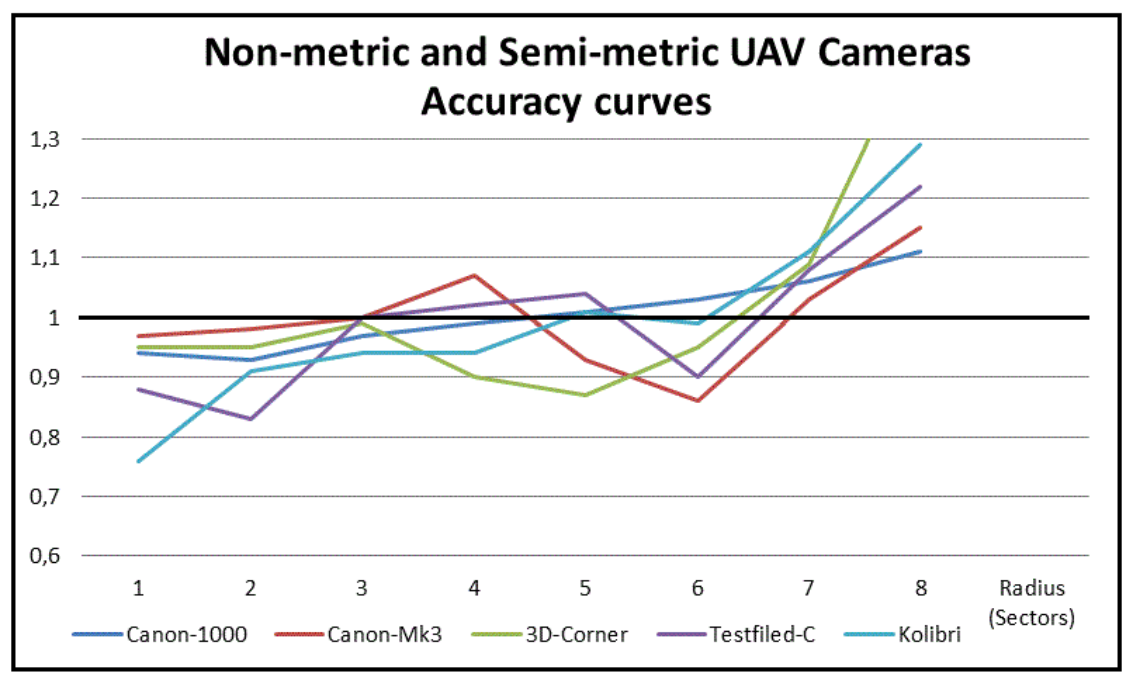




- Close to linear curve
- Higher deviation between the cameras
- The difference in the accuracy is between 20%-70%

bingo
GIP. DR. KRUCK & CO. GBR

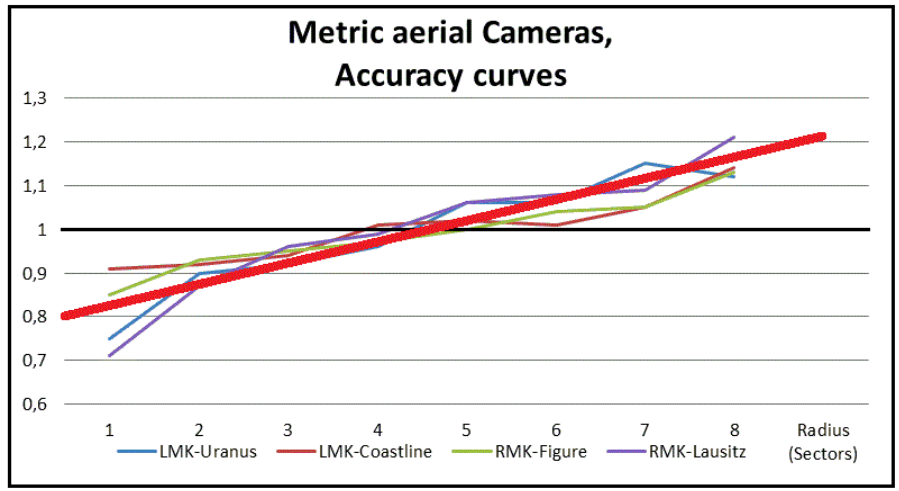
Non-Metric and Semi-Metric Cameras

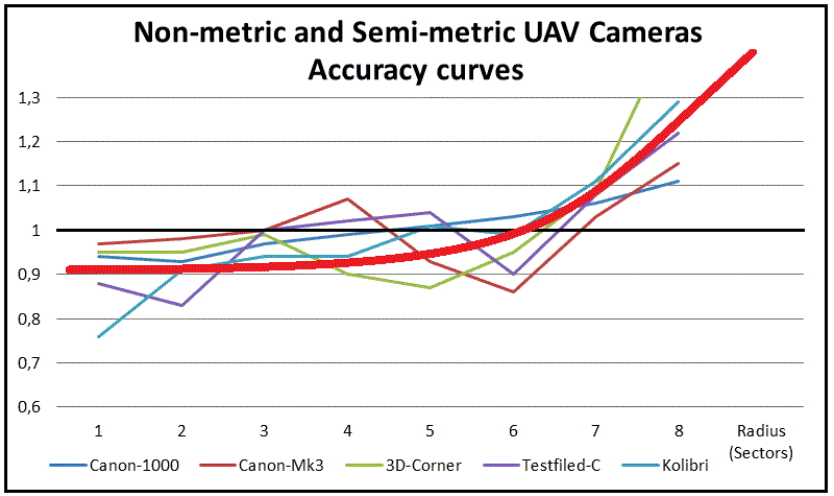


- The curve is not linear, steep ascending curve
- Low deviation between the cameras
- The difference in the accuracy is between 20%-80%

bingo
GIP. DR. KRUCK & CO. GBR

Modelling the Radial Accuracy





Goal was to design general curves which should described the accuracy changes of the camera type:

- For the photogrammetric cameras ascending straight line
- UAV camera types can be described by a curve

bingo
GIP. DR. KRUCK & CO. GBR

Conclusions

- The functional connection between accuracy and radial distance exists
- Accuracy is always higher at the center and less accurate in the direction to the borders
- Our tests prove that there is a curve for the measurement precision as function of the photo radius
- Varies depending on the camera types and camera groups used

bingo
GIP. DR. KRUCK & CO. GBR

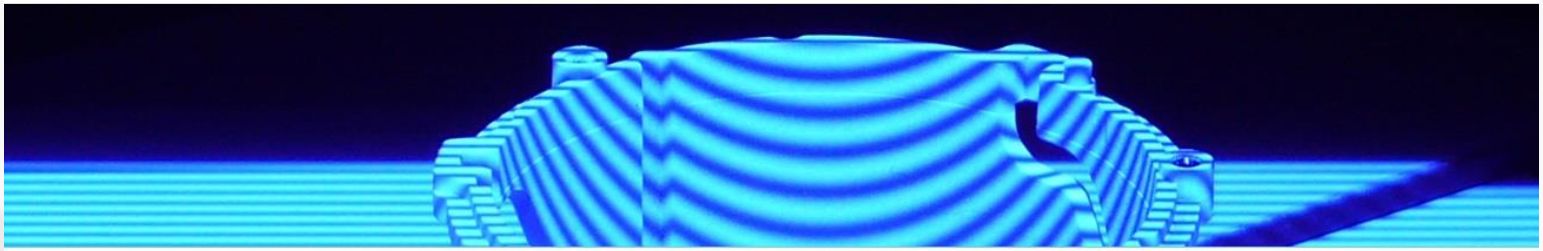
Special Applications

- Industry

  Production, Quality Assurance
- Textile Industry
- Medicine

...

OTTO
VISION TECHNOLOGY



Test stations for punched stripes

Optical 3D measurement technology

FLEX-3A

Add-ons

Software

Customer-specific test stations

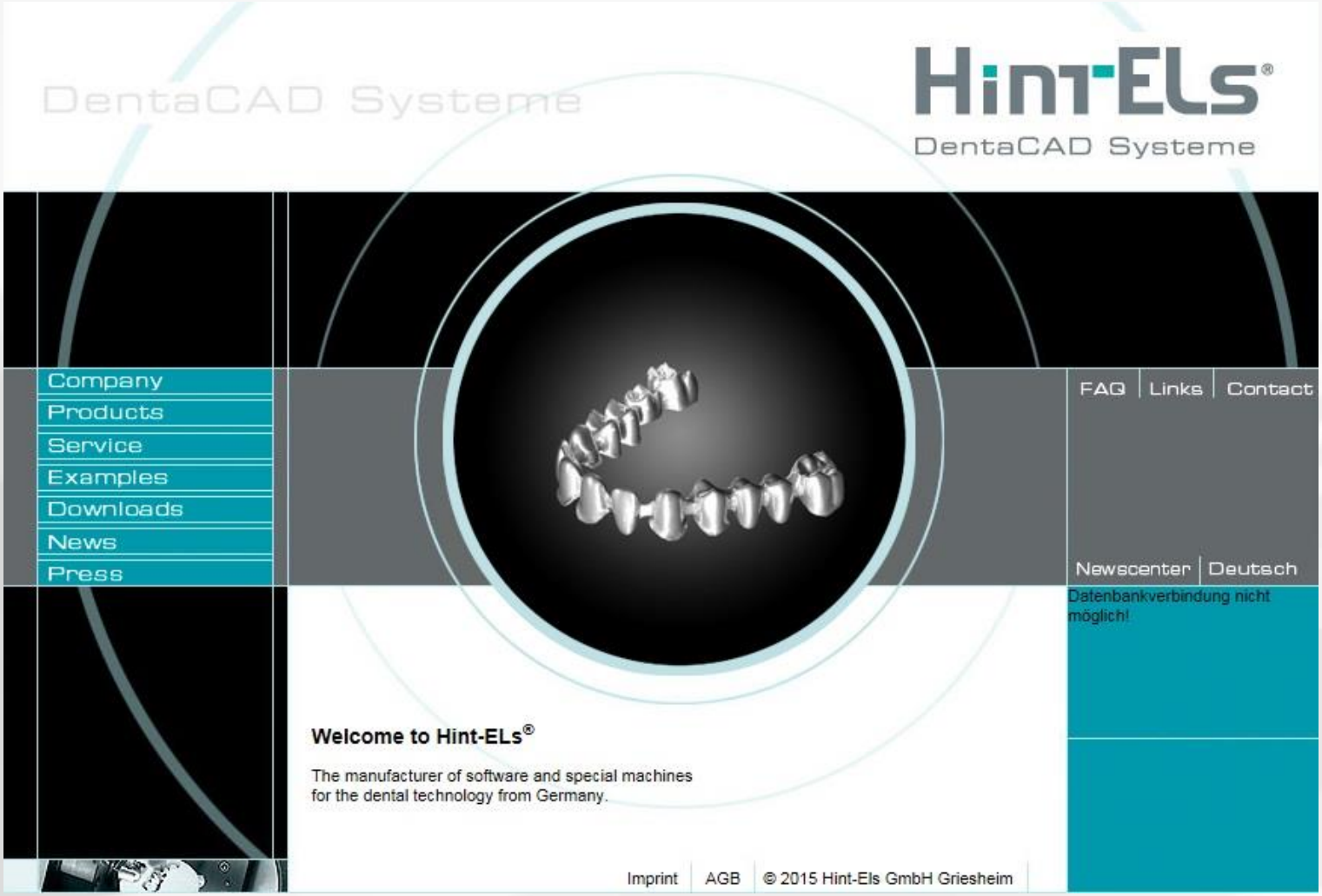
Vision systems and software

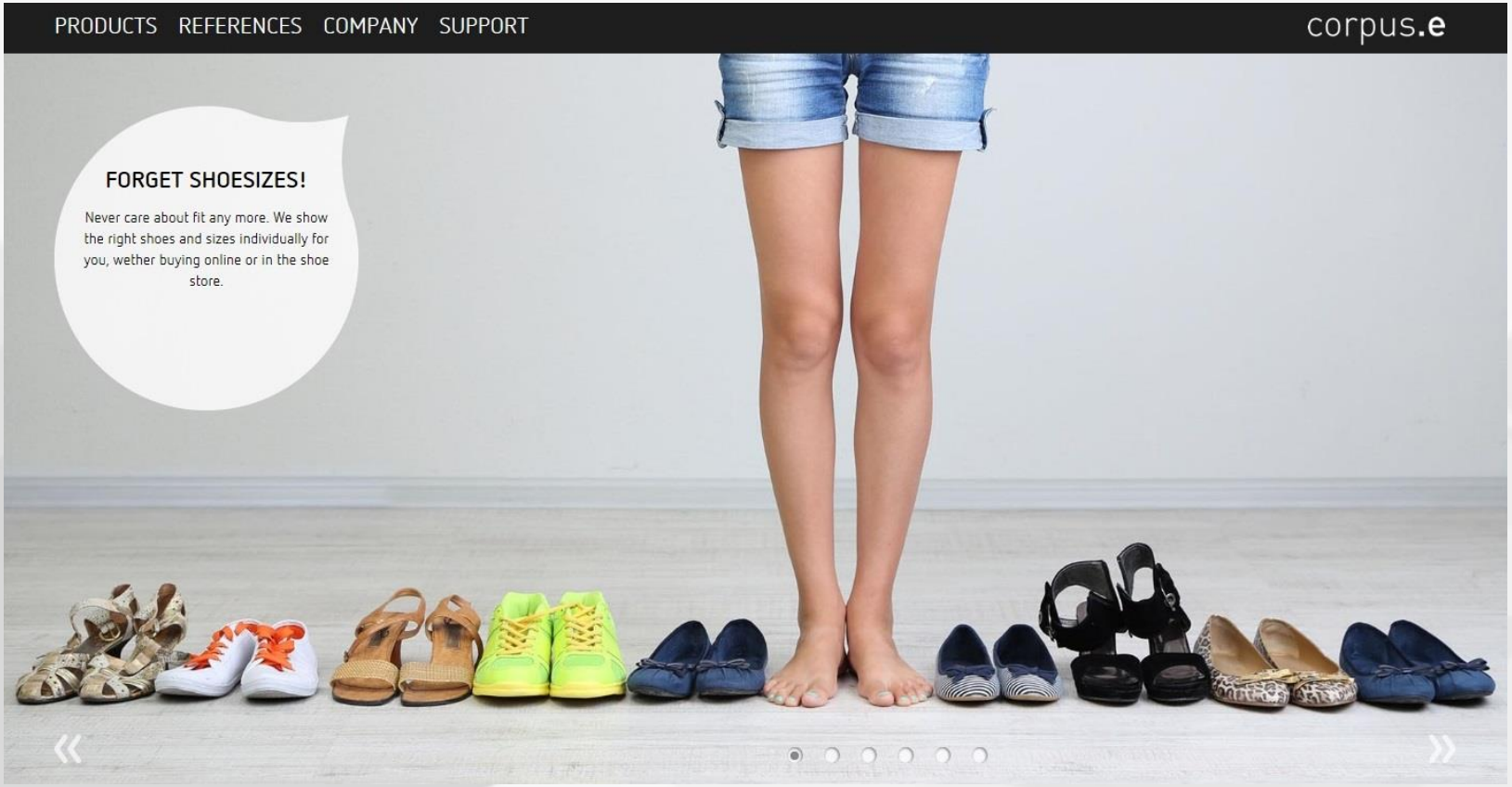
OPTICAL 3D MEASUREMENT TECHNOLOGY

Our non-contact 3D measuring systems based on white light scanning deliver **complete surface data in short time, high point density and accuracy.** Therefore optical 3D measuring systems are more and more applied in quality inspection in all stages of production beginning with initial operation, optimization and first articles up to serial inspection.

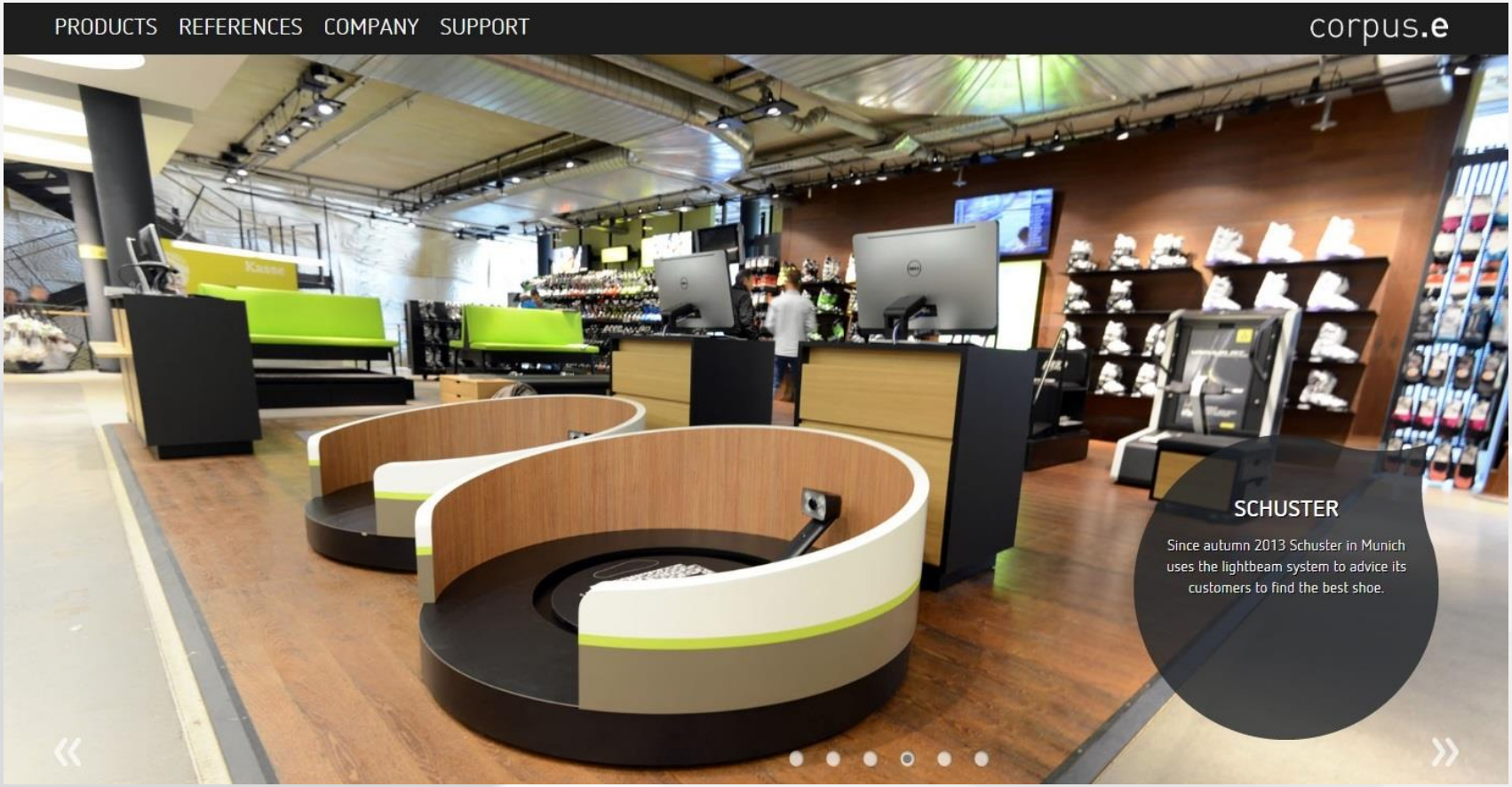
Broad opportunities like the **fast deviation analysis to CAD model**, dimensioning and tolerancing up to the creation of of digital models within a reverse engineering support the user by the realization of a zero-defect strategy.

bingo
GIP. DR. KRUCK & CO. GBR



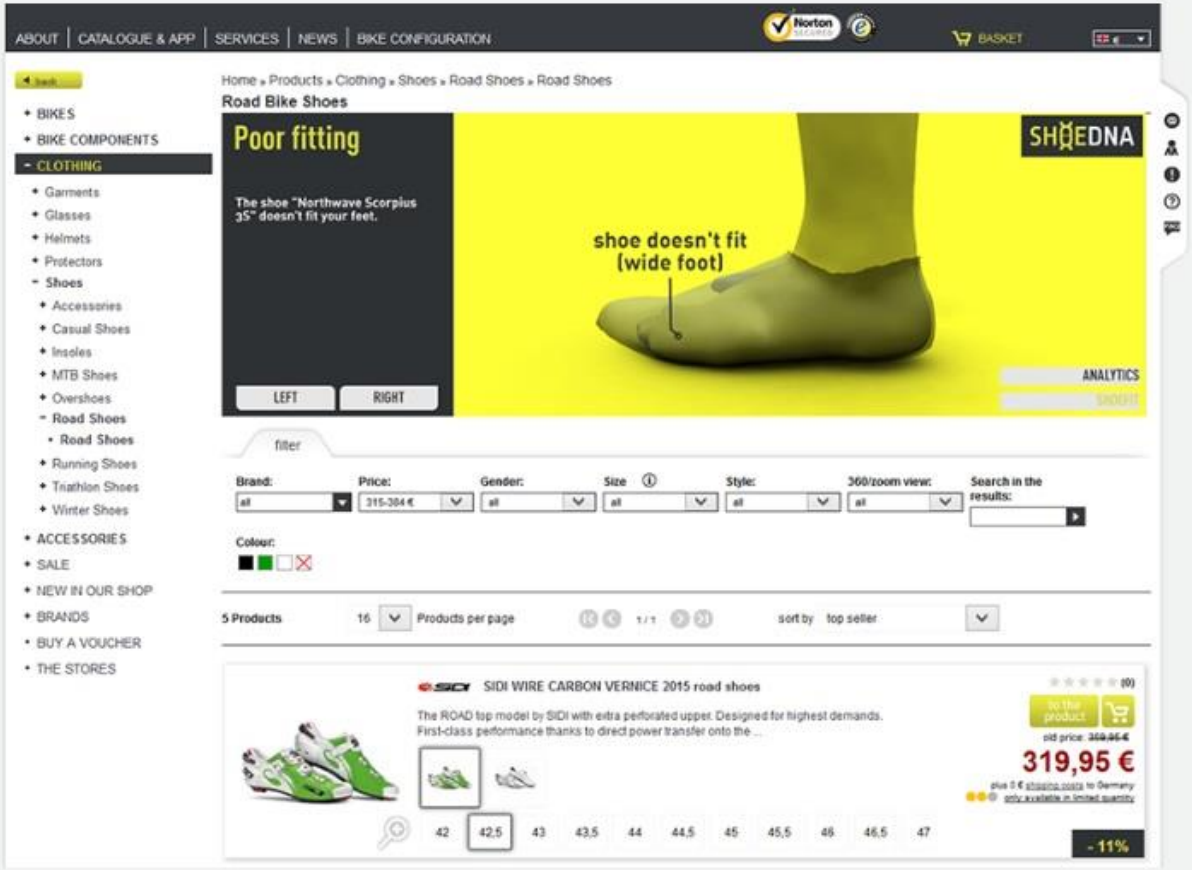


bingo
GIP. DR. KRUCK & CO. GBR



bingo
GIP. DR. KRUCK & CO. GBR

Web & Mobile Integrate Customers and their Fit into your Online Shop



bingo
GIP. DR. KRUCK & CO. GBR

Geoinformatics & Photogrammetric Engineering, Dr. Kruck & Co. GbR

Platanenweg 24, D-73430 Aalen, Germany

www.bingo-atm.de