Historical roots, state of the art and challenges in image processing and image analysis

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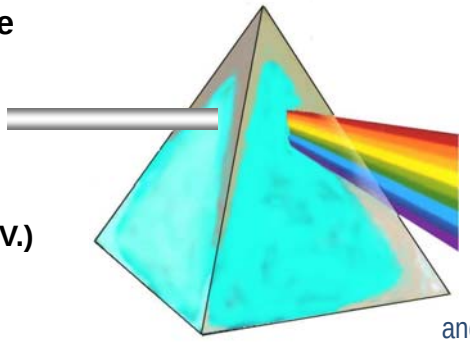
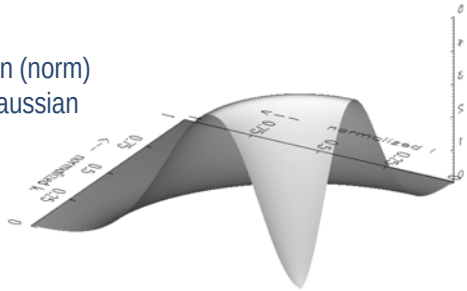


light
and color

transfer function (norm)
Laplacian of Gaussian



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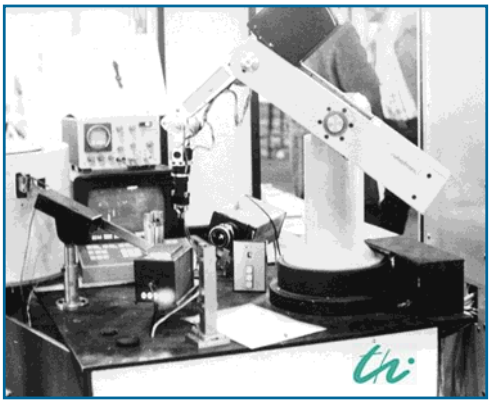
Transnational German – Eastern network for optical technologies and machine vision (GEN-OTMV)

Historical roots, state of the art and challenges in image processing and image analysis

At the beginning some historical minds

- *1960s and the early 1970s:*
  - simple image processing operations on images of airborne cameras, for medical application and in microscopy
  - in computer centers and laboratories
  - mostly simple image improvement, no analysis
- *middle of the 1970s:*
  - solid image sensors, micro computing and improved memory technology
  - image enhancement for simple image analysis
  - mostly simple image improvement, no analysis
- *TUI 1978 → start of my own investigations and R&D-efforts at Ilmenau Technical University (TUI) :*
  - simple 2D measurement and sorting tasks for industrial applications
  - simple image sensor application in robotics

"eye-hand-system":
camera controlled robot

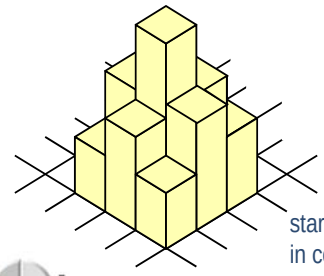


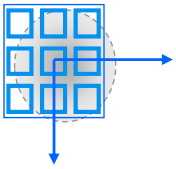
Historical roots, state of the art and challenges in image processing and image analysis

- *TUI 1984:*
  - simple image sensor control for sorting and assembling of work pieces
  - assurance of completeness of automatic mounted device

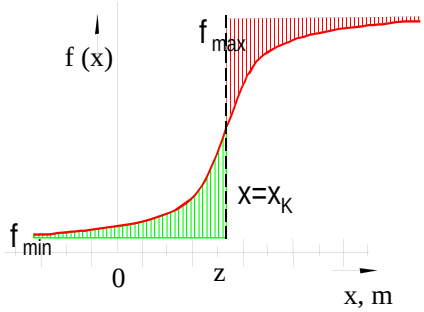
airbag part

- *TUI 1988:*
  - first steps in the field of color sensing and color image processing for quality assurance tasks
  - image based high precision 2D geometric measurement
  - subpixeling by different methods using different object models
  - star sensors for space ships





star sensor Astro 1M
in cooperation with
Jena-Optronik GmbH



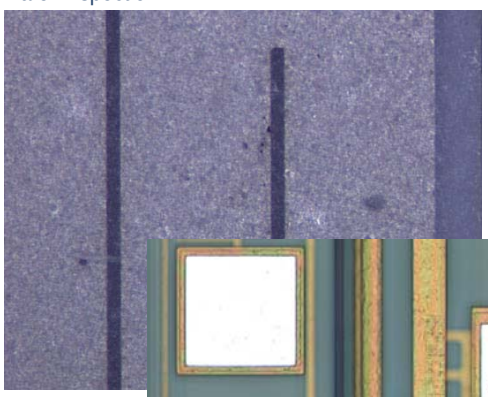
subpixeling

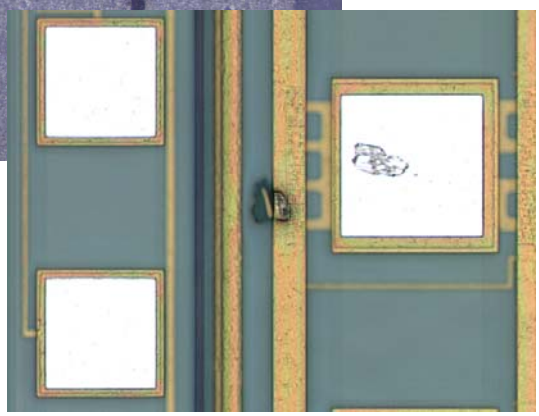
Historical roots, state of the art and challenges in image processing and image analysis

- *ZBS / TUI 1994:*
  - combination of color image processing and 2D – measurement for quality assurement
  - full video resolution (ca. 720 x 576 x 24 bit)
  - wafer inspection in video real time with special hardware processing units
  - 3D – data acquisition for industrial scenes and space applications
    (WAOSS in the project Mars 94/96)

please start Wafer_kurz.avi for further information

Wafer inspection





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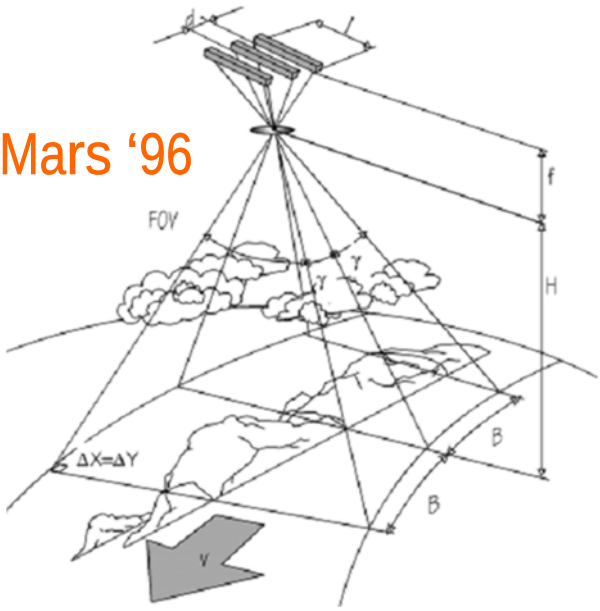
Mars '96



different measurement volumes:
- wide angle optical stereo scanner (WAOSS) for 3D measurement of MARS surface
- 3D industrial measurement technology (about 1m³)
- 3D electron microscopy

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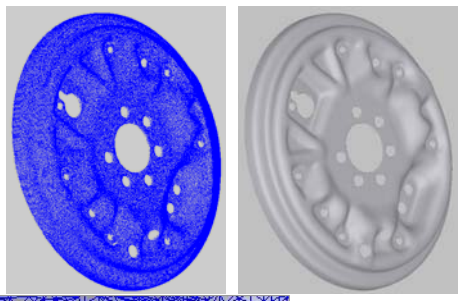
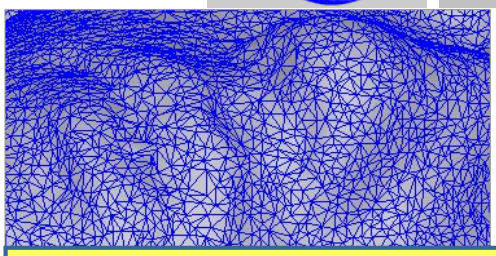
3D - measurement





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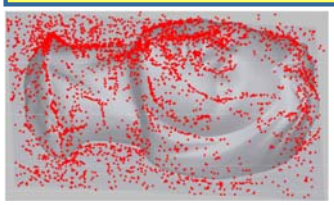

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- wide angle optical stereo scanner (WAOSS) for 3D measurement of MARS surface
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Historical roots, state of the art and challenges in image processing and image analysis

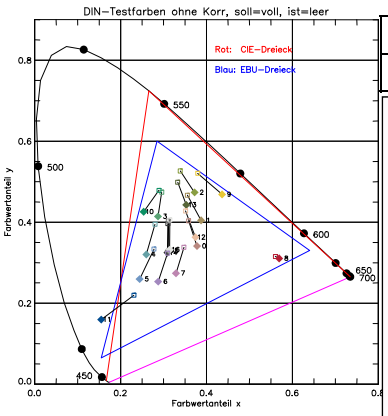
- *ZBS 1998:*
  - combination of 3D – measurement and color image processing in complex scenes

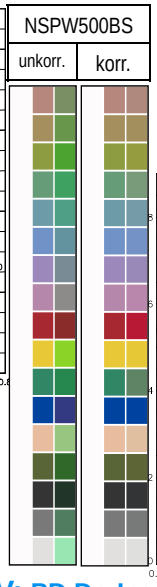
inspection of waste water channels

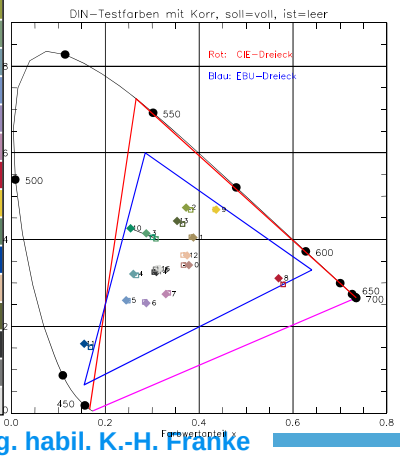
please start Kanal_sehr_kurz.avi for further information

State of the art and challenges in image processing and image analysis

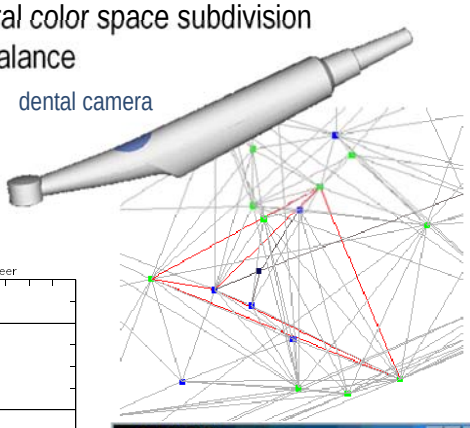
- *ZBS 2002:*
  - color sensor qualification, sophisticated analysis of color and multidimensional images
    - target related nonlinear color calibration, e,g. by tetrahedral *color* space subdivision
    - reference free color correction, color constancy & white balance

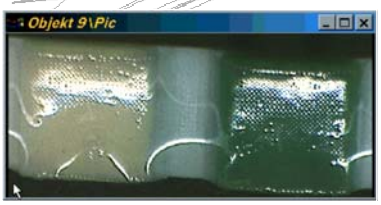






dental camera





ZBS / La Roche:
color measurement on medical test strips

color sensor calibration
ZBS / MAZeT:

State of the art and challenges in image processing and image analysis

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  - color sensor qualification, sophisticated analysis of color and multidimensional images
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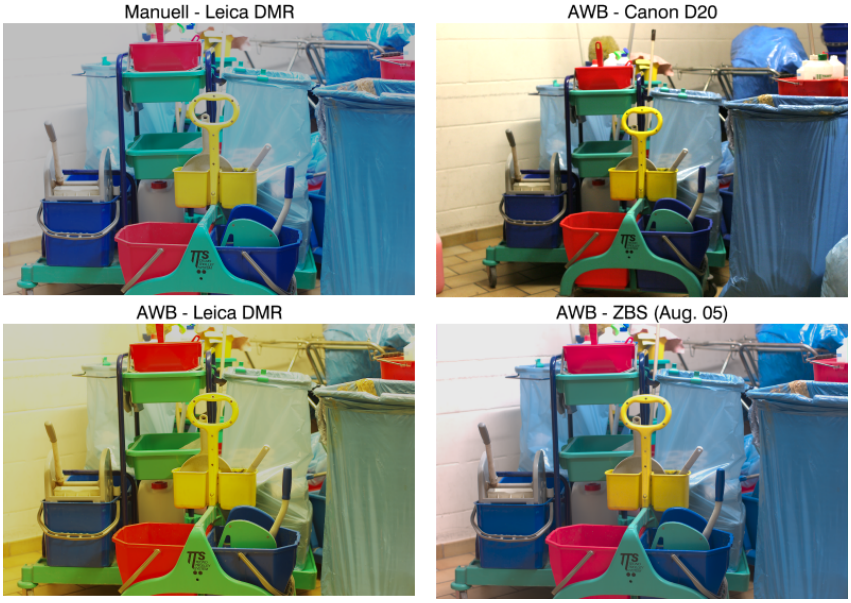
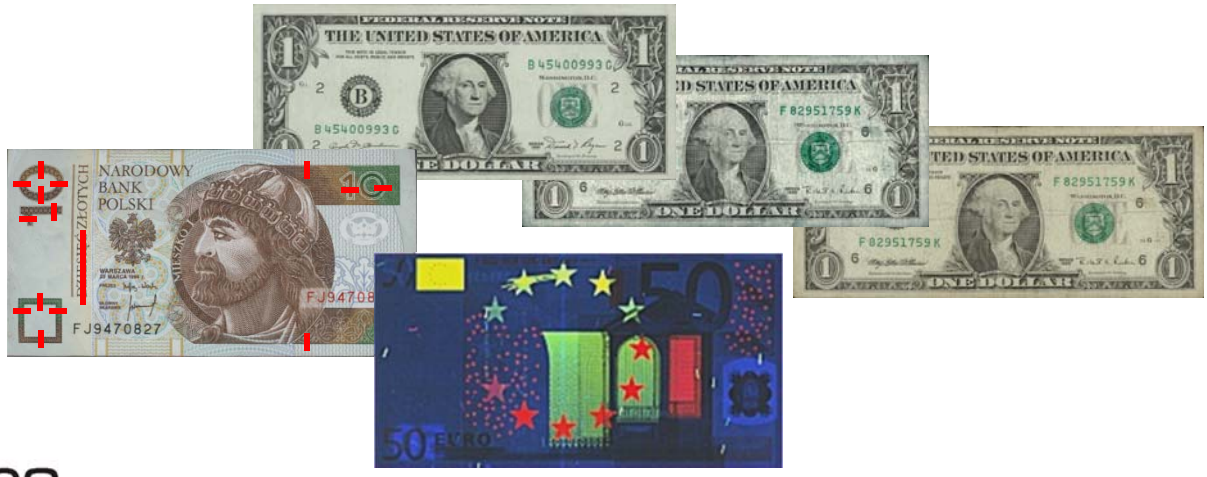
scene “cleaning things”:
automatic color correction →
ZBS compared with Canon and Leica

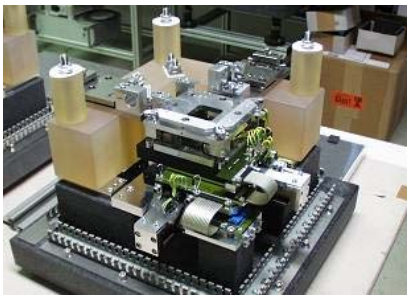


State of the art and challenges in image processing and image analysis

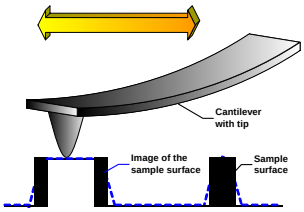
- *ZBS 2002:*
  - sophisticated analysis of color and multidimensional images
    - target related nonlinear color calibration, e,g. by tetrahedral color space subdivision
    - reference free color correction
    - distortion tolerant quality inspection at printed objects
    - analysis of additional spectral channels, for instance fingerprints on bank notes



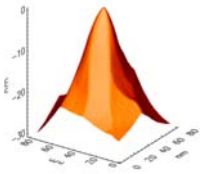
State of the art and challenges in image processing and image analysis



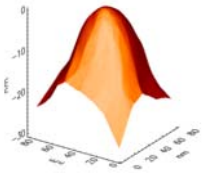
- *ZBS / TUI 2003:*
  - 3D data acquisition and processing of the resulting point clouds for nanopositioning- and nanomeasuring machines
    - measurement with the highest of movement precision and speed
    - volume of measurement: 25 x 25 x 5 mm³
    - precision: 0.1 nm, positioning tolerance: < 10 nm
    - important tasks for ZBS are the interaction between object and probe, tip estimation and 3D image data reconstruction as well as compression according to signal quality



tip related morphological effects

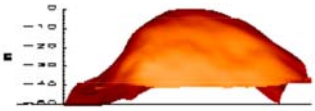


new tip

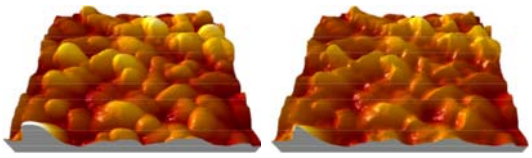


eroded tip

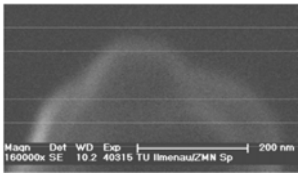
R_{3d}=83 nm



result of blind tip reconstruction



original data reconstructed data



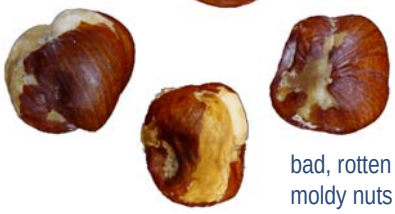
REM image of the tip

State of the art and challenges in image processing and image analysis

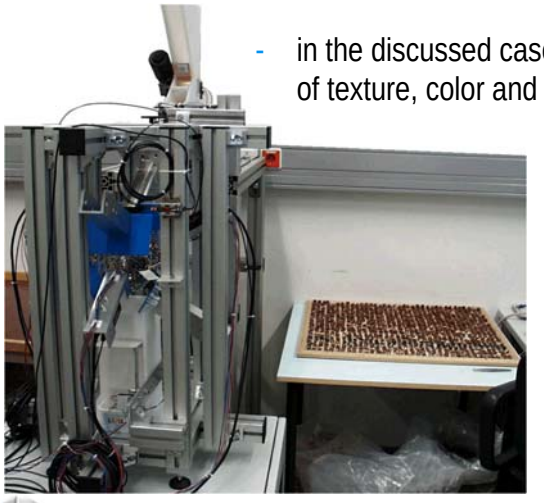
- *ZBS 2004:*
  - all around inspection of natural products and food (e.g. nuts)
    - extensive feature variety of both, normal surfaces and defects →
    - very powerful algorithms are needed for feature extraction, learning and classification
    - in the discussed case: combination of texture, color and shape

good nuts

nut with insect bite



bad, rotten and moldy nuts



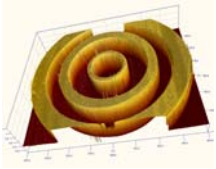
- high throughput (20 nuts per second / 1t per hour) →
- parallel processing with special units (signal processor / FPGA, . . .) is needed (in the discussed case of nut inspection: fife processing units per inspection channel)

please start Nüsse-mit-VS-kurz.avi for further information

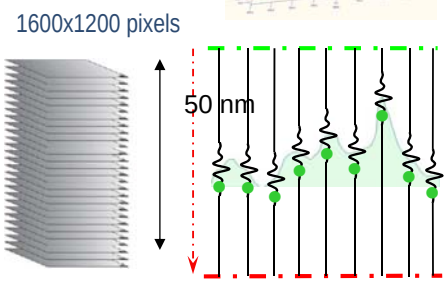
Challenges in image processing and image analysis

Branch of measurement

- *General demands:*
  - 3D – measurement at highest precision (lower nm range, down to subnanometers, e.g. 0,1 nm for measurement on 13 nm structures)
  - highest precision and nm-resolution (depth an lateral) for growing measurement areas, e.g. 500 mm wafers
  - very high data thoughput, huge images and enormous data amount



- *ZBS / TUI example:*
  - white light interferometry
  - computing of 2 Mio. interferograms needs very fast computer technology



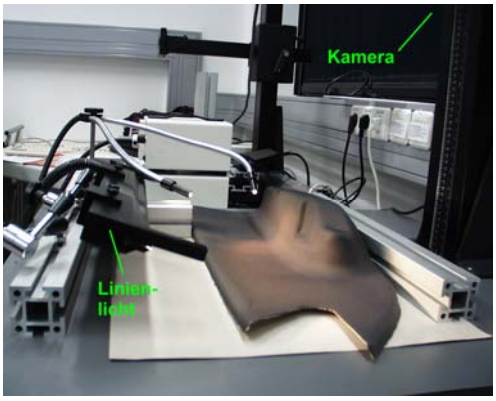
- *ZBS / TUI in the near future:*
  - higher speed by a special kind of subsampling
  - higher accuracy and lower noise by spectral light composition and geometrical beam formation
  - higher lateral resolution by micro scanning and deconvolution

20.0 µm / 0.05 µm * 2 Mio. Byte → 800 MByte at 8 bit / measured value

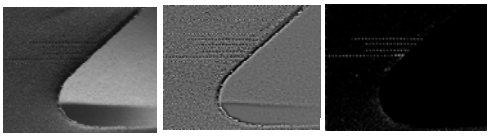
Challenges in image processing and image analysis

Branch of inspection and image interpretation, quality assurance

- *General demands:*
  - true color, highest precision of color measurement, using of perceptual equidistant color spaces
  - extraction of spectral signatures at high 2D resolutions, processing and analysis of such images
  - combination of color, spectral signature, texture and 3D-shape



- *ZBS / TUI example:*
  - measurement of 3D shape of car inserts
  - detection of small defects in texture and color under geometric caused distortions (3D) in signal and texture

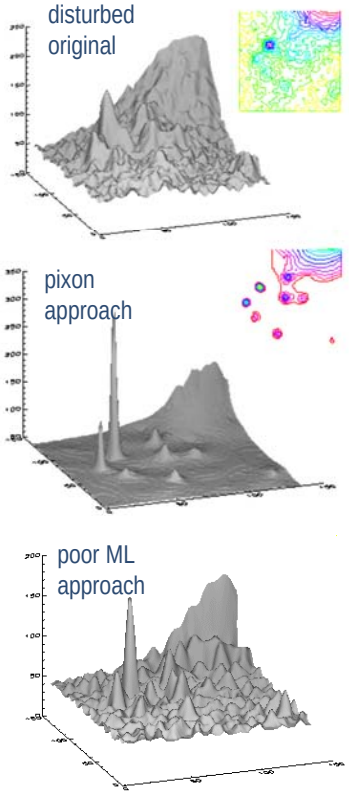


- *ZBS / TUI in the near future:*
  - model based illumination control and correction
  - modeling of texture distortion
  - distortion tolerant defect detection

Challenges in image processing and image analysis

Branch of image enhancement and image reconstruction

- *General demands:*
  - enhancement of heavy disturbed image data for image display and image analysis
  - elimination of negative influences of sensor device features
- *ZBS / TUI example:*
  - digitizing of analog photo plates with star images
  - elimination of distortions from astronomic instruments and disturbing effects from photographic film material (developing process, ageing etc.)
  - improvement of heavy disturbed images for medical applications
- *ZBS / TUI in the near future:*
  - regularized image reconstruction
  - using pixon image model for pixon regularized inverse filtering
  - adaptive filters, anisotrope inhomogeneous diffusion filters



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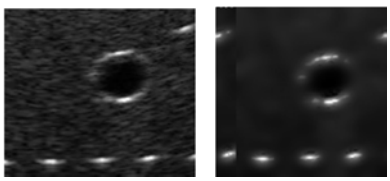
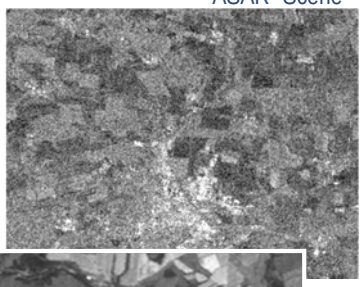


Challenges in image processing and image analysis

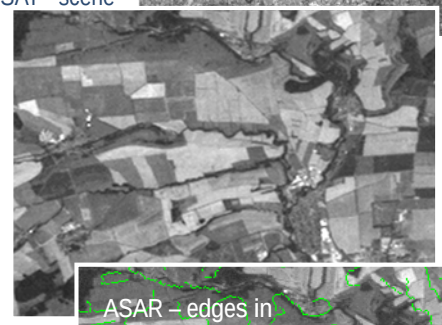
Branch of image segmentation, object classification

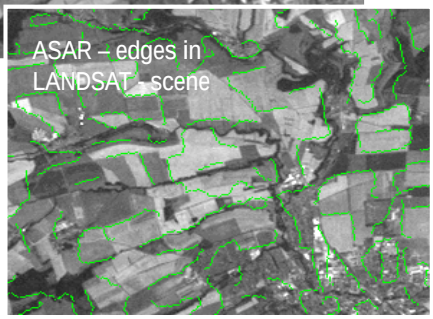
- *General demands:*
  - using of multi channel images and spectral signatures for pixel feature extraction and segmentation
  - fusion of images from very different image sources (different sensor principles,e.g. optical, SAR, . . .)
  - improved and sophisticated description of class distributions in feature spaces
  - modern and powerful concepts for classification and learning systems
- *ZBS / TUI example:*
  - Structure based registration / image fusion of satellite images (ENVISAT / ENVILAND)
  - Segmentation of traffic scenes (cross roads, traffic control)
- *ZBS / TUI in the near future:*
  - Registration and segmentation of satellite images at highest resolutions (Rapid eye (<50cm), TerraSar)
  - sophisticated classification concepts and learning methods (land cover, change detection, . . .)

ASAR -Scene



One channel of LANDSAT - scene





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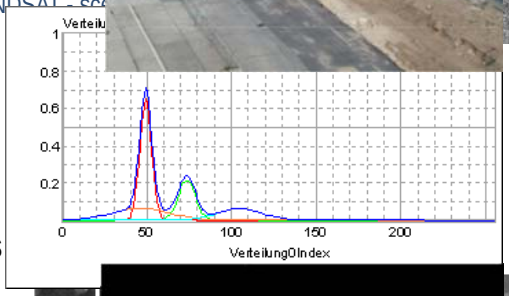
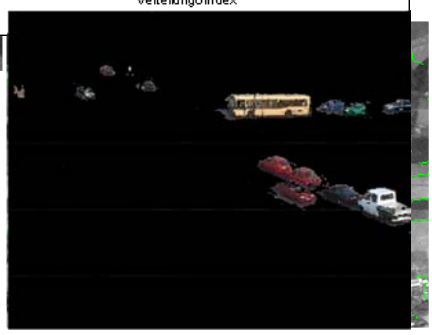
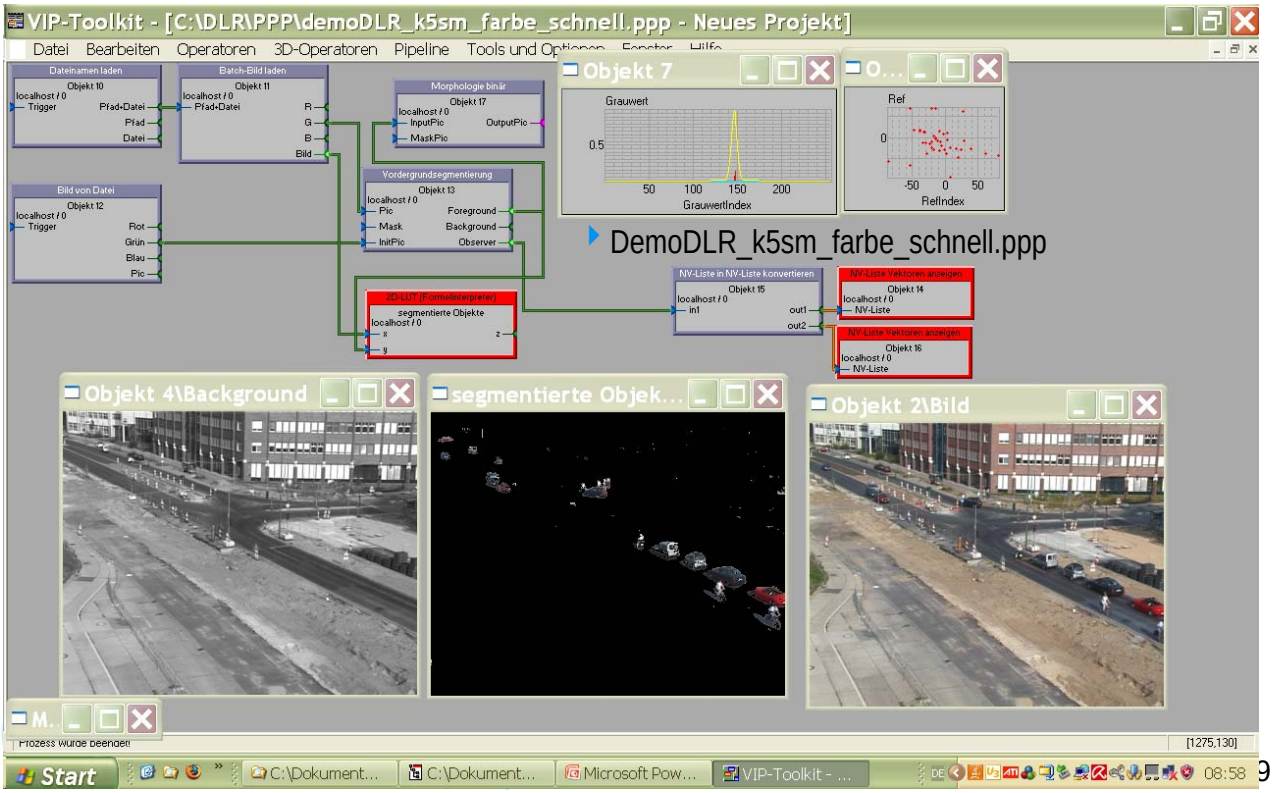




The ZBS modular program of post gradual education „Industrial image processing for automation and quality assurance“

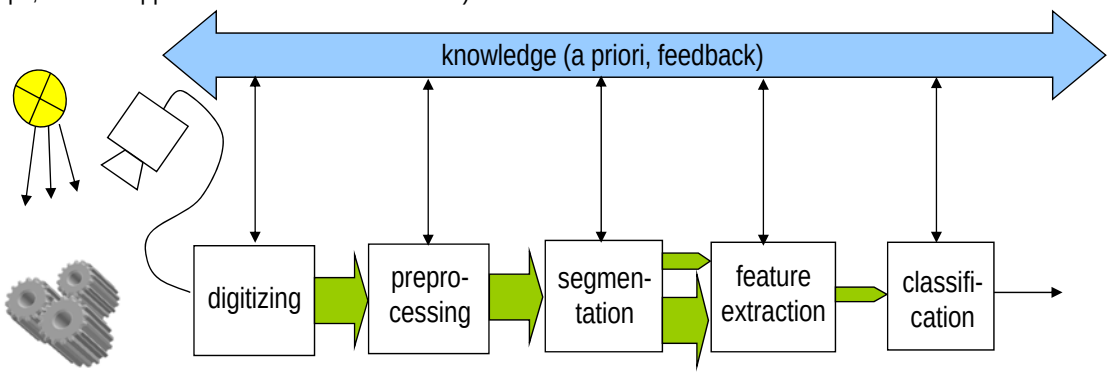
- Example to analysis of traffic scenes and traffic control (ZBS VIP-Toolkit):



- DemoDLR_k5sm_farbe_schnell.ppp

classical paradigm of image processing and analysis (overview)

- the classical paradigm (well structured framework, using knowledge based and neural approaches in different processing steps, modern approaches use feedback as well)



classical paradigm of image processing

- the knowledge based paradigm (center of gravity: knowledge representation, data mining, expert systems)
- the neural paradigm (center of gravity: bioinspired systems, selforganizing systems, neural networks, nonlinear collective processes)