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

- **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

- **ZBS / TUI 1994:**
  - combination of color image processing and 2D – measurement for quality assurance
  - 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.**
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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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**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

- **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

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

- **ZBS / MAZeT:**
  - color sensor calibration

- **ZBS / La Roche:**
  - color measurement on medical test strips
State of the art and challenges in image processing and image analysis

**ZBS 2002:**
- 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

- 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 nanospositioning- 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

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
  - 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: five 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 and lateral) for growing measurement areas, e.g., 500 mm wafers
  - very high data throughput, 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

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
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 / ENVI-LAND)
  - 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, . . .)
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)

- 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)