XPOSURE – MORE THAN JUST THE FASTEST LINE-SCAN CAMERA

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MOTIVATION

• We believe: Today, inline inspection systems have to do far more than just 2D surface scanning - we have to scan a bundle of physical surface properties to get the required inspection quality

• We observe: CMOS-technology-based image sensors and cameras have made a tremendous technological progress as for speed, data throughput and image quality, but line-scanning imagers for inline scanning lag far behind

• We propose: fast and flexible multi-line-scan camera technology with low NRE for easy adaption to specific inline inspection application

• You get: several application examples of a fast and flexible multi-line-scan technology
NEED FOR INLINE ACQUISITION OF VARIOUS PHYSICAL SURFACE PROPERTIES

- 2D color (36 km/h and 0.05 mm)
  High-resolution color

- Inline 3D-stereo (130 km/h and 0.06 mm)
  Depth map

- 2.5D Photometric stereo (200 km/h and 0.2 mm)
  Surface curvature

- Line field OCT (2 MHz A-scan rate)
  Layer structure of tissue

- Hyperspectral Imaging (60 channels: 10 kHz)
  Material properties

- Inline Light-field (12 views: 50 kHz)
  Denser sampling BRDF
FAST AND FLEXIBLE MULTI-LINE-SCAN TECHNOLOGY
AND ITS VALUE FOR VARIOUS APPLICATIONS

• 2D high-speed line-scan -> high-resolution color images
• Inline 3D inspection -> high-resolution depth map
• 2.5D Photometric stereo -> detailed surface curvature
• Line field OCT ( > 2 MHz A-scan rate) -> Volume scan of tissue
• Multi-spectral imaging with far more than 3 spectral bands
  -> robust material classification
• Multi-line-scan light-field imaging for versatile inline inspection tasks
  -> more stable acquisition of surfaces with “difficult” reflection
  properties by exploiting the 4D nature of the light field
2D COLOR PRINT INSPECTION @ 10 M/S – 
BOOST RESOLUTION

state of the art
0,20 mm

goal
0,05 mm
2.5D RAIL INSPECTION WITH PHOTOMETRIC STEREO

- Resolution 0.2 mm – 2 color channels
- scanning speed: 200 km/h
- → 300 kHz line rate (RB)
3D ROAD SURFACE INSPECTION

- 2 xposure cameras 3D stereo
- 60 µm resolution
- 130 km/h for highways
METAL SURFACE INSPECTION – FINDING A NEEDLE IN A HAY STACK

• Defects in micrometer range
• Hundreds of square meters
3D VOLUME SCAN WITH OPTICAL COHERENCE TOMOGRAPHY

- Swept-source line-field OCT
- Biomedical (eye, skin)
- > 2 MHz A-scan rate
WHITE LIGHT INTERFEROMETRY

Intensity @ Detector
$I_D$ acquired during depth scan of reference arm

$I_D = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos(2\pi \tau v)$

$I = z/c$
WIDE-BAND LIGHT SOURCE

Poly-chromatic source

$u(t)$

$z_1, z_2$

Detector

$I_D(h)$

Spektrum of wavelengths

30-200nm

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STATE OF THE ART LIGHT FIELD TECHNOLOGY IS NOT INLINE COMPATIBLE

<table>
<thead>
<tr>
<th>Light field</th>
<th>Photometric stereo</th>
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</thead>
<tbody>
<tr>
<td>Absolute depth (+)</td>
<td>Relative depth (-)</td>
</tr>
<tr>
<td>Low depth detail (-)</td>
<td>High depth detail (+)</td>
</tr>
</tbody>
</table>

Bulky, expensive, slow, error-prone, etc.
AIT INLINE COMPUTATIONAL IMAGING (1/2)

Constant illumination

Multi-line scan camera

Inspected object

Transport stage

Standard non-telecentric optics

[Štolc S. et al., JEI 2014]
Opportunities

• Single multi-line scan camera / constant illumination
  (low system complexity)

• Joint multiplexing of viewpoint and light direction
  (i.e. light field & photometric stereo; neither strobing nor multiple exposures are required)

• Allows for computational imaging
  (depth reconstruction, refocusing, increased SNR, extended DoF, super-resolution, etc.)

• Suitable for high-speed inline applications

Limitations

• Small stereo baseline ⇒ limited depth resolution
  (can be increased using photometric stereo)

• Requires precise transport control
  (can be compensated computationally)
VIEWPOINT AND LIGHT DIRECTION MULTIPLEXING WITH AIT INLINE COMPUTATIONAL IMAGING (ICI)
INLINE PHOTOMETRIC STEREO

- AIT's xposure camera with up to 600 kHz line-rate
- 4strobed LED lines illuminating for different directions
- -> inline photometric stereo with 150 kHz line-rate
AIT XPOSURE CAMERA - A PROTOTYPE OF A FAST AND FLEXIBLE MULTI-LINE-SCAN CAMERA

New type of scanning device

- fast
- sensitive/low noise (short exposure time)
- flexible

Flexible switching between readout modes, e.g.

- 600.000 fps single line
- 300.000 fps RB color
- 200.000 fps RGB color
- 100.000 fps 6 color channels
- 10.000 fps 60 color channels
CONCLUSION

• Today scanning of different physical surface properties is necessary
• Technological progress of line-scanning devices lags far behind area scanning devices
• Gap is closed by a fast and flexible multi-line-scan technology …
• … that can easily adapt to a variety of inline inspection situations
• There are several applications benefiting from a fast and flexible multi-line-scan technology
REFERENCES


REFERENCES (CONT‘D)


THANK YOU!

www.ait.ac.at/hpv