Colour-based Print Inspection on round-shaped Objects

Farbbasierte Druckbildinspektion an Rundkörpern

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Content

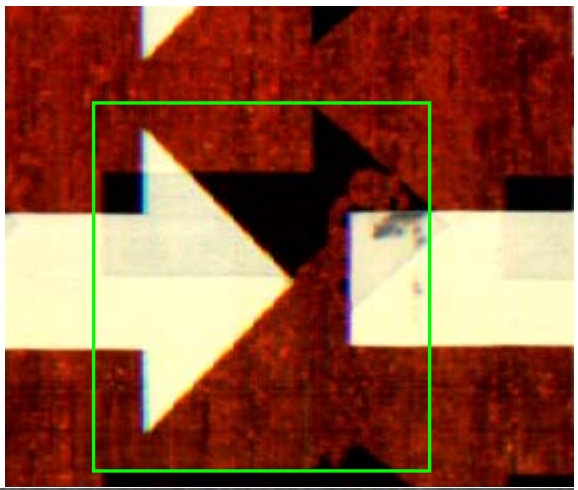
100% inspection of colour prints on bottles and tubes of different sizes
Defects must not be >= 0.3 x 0.3 mm

Detect and differentiate misprints and material defects:

- Defects of surface (bumps, scratches, inclusions)
- Colour dashes, gradients, offsets, smear
- Strong and pale prints

Detect and differentiate colour defects

- Missing colours
- Colour variations
- Colour smear

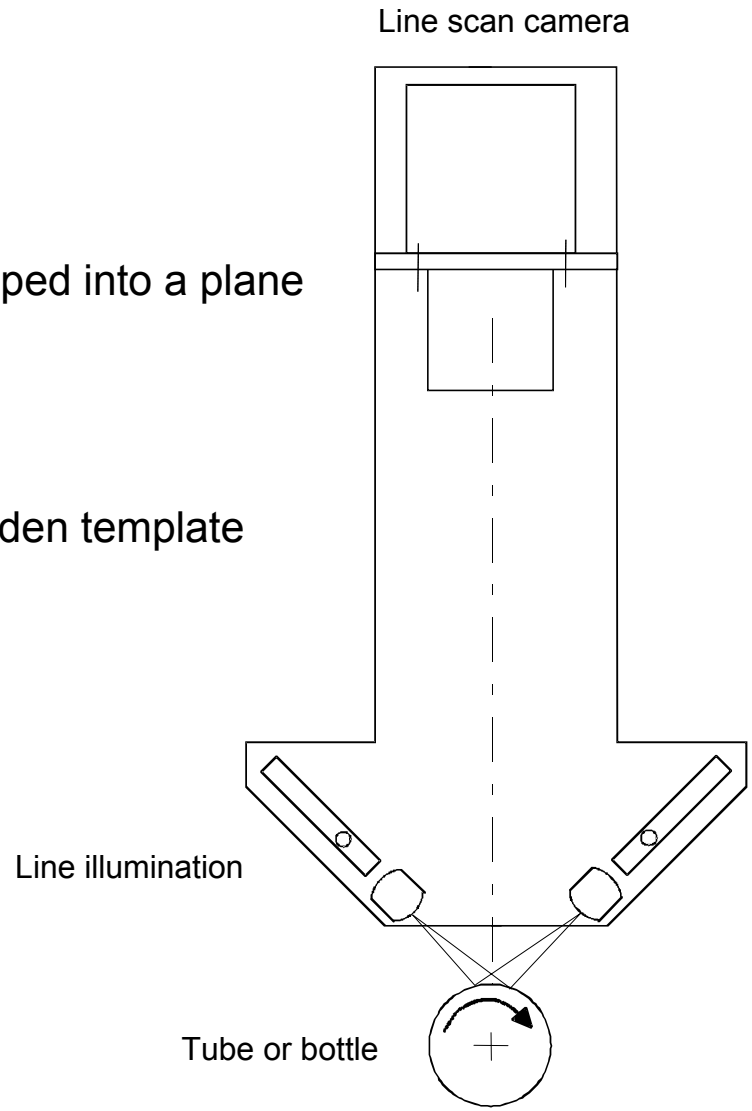


2. Solution

- Tubes / bottles rotate beneath a line scan camera
- The curved, imprinted surface is unwrapped and mapped into a plane

→ Task is reduced to a 2D-inspection problem

- Recorded images are registered and combined to golden template
- Template is used for pixel by pixel comparison



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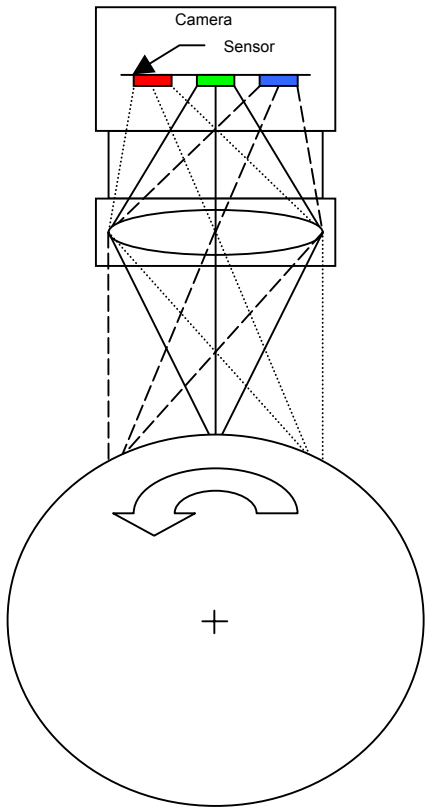
3.2 Tri-linear sensor

Taking images from curved surfaces with tri-linear line scan cameras leads to several problems.

Greater sensor distances need broader, homogeneous illuminated areas on objects surface.

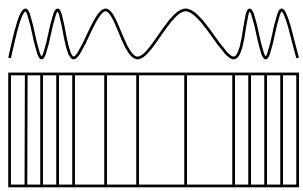
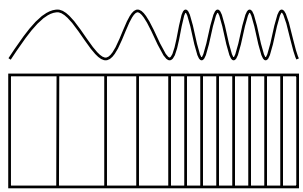
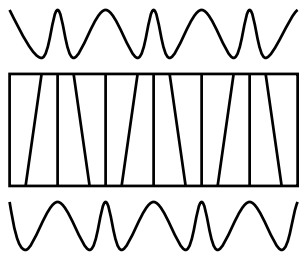
- → Different angles of reflection for every sensor
- → Fluctuations in brightness and colour
- → Color fringing at edges

We need to exactly calibrate drive, rotary encoder, exposure time and line delay.



3.1 Distortion

Taking images from rotating objects can lead to distortion.

Cause	Consequence	Example
Drive based oscillations	Compression and dilation in direction of recording	
Objects slip when accelerated	Dilation in direction of recording	
Objects are not centered around drive axis	Trapeziod compression and dilation at image margins	

4.1 Situation

Recorded images must be registered for golden template generation and inspection tasks

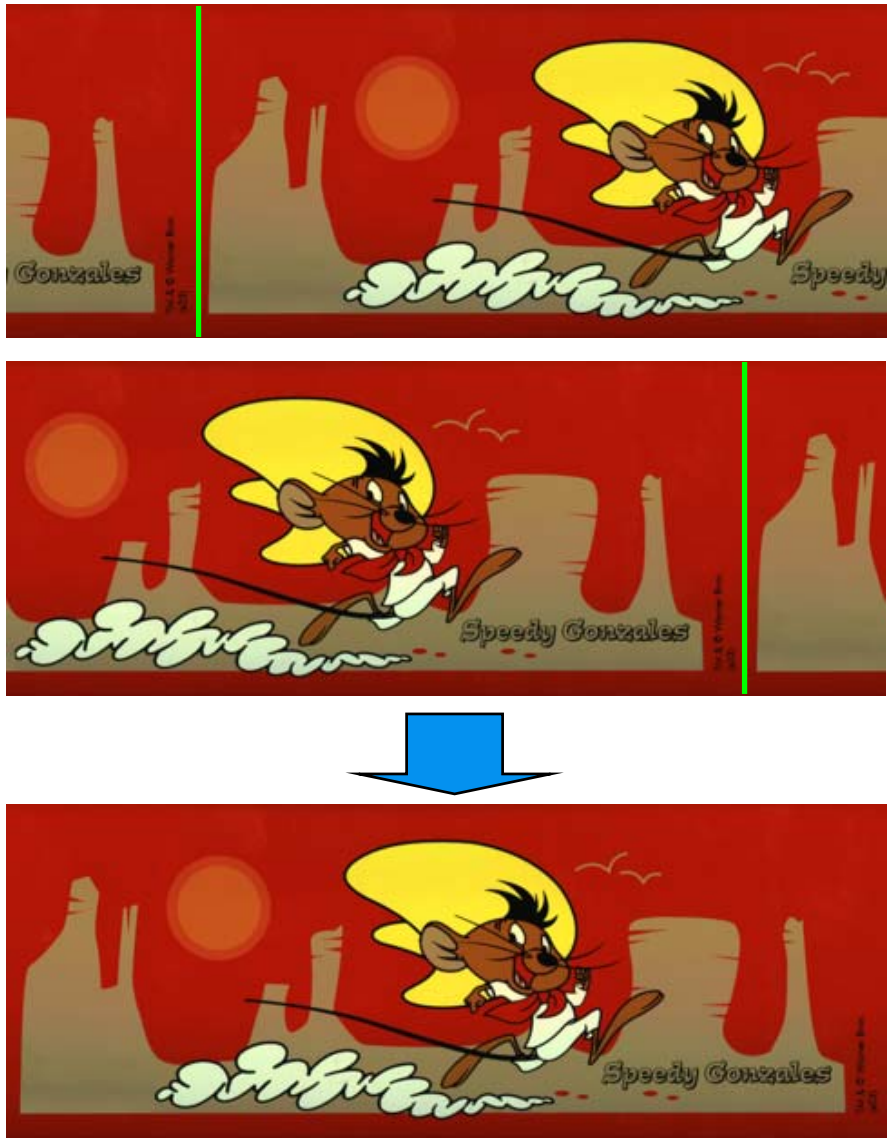
→ Finding a single starting point to align images

Problems:

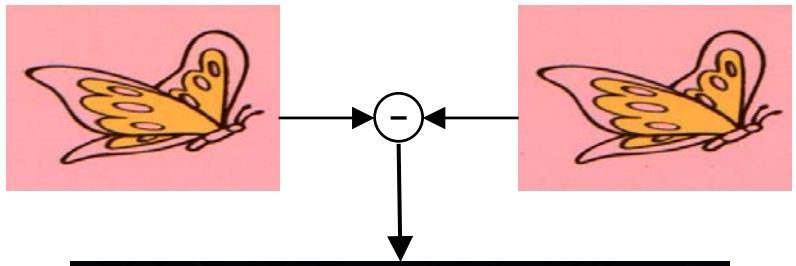
- Complete wrap-around imprints on bottles
- Pattern repeats
- Image doesn‘t contain complete unwinding
- Local distortions

Offset can‘t be clearly determined.

→ Registration process must be **distortion-tolerant**



4.2 Requirements



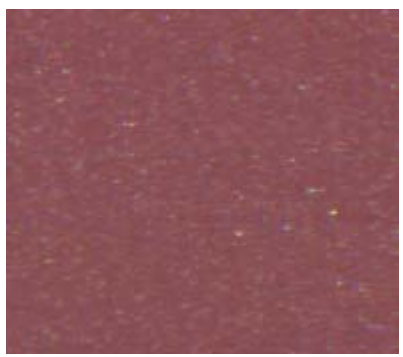
Offset correction requirements:

- Tolerant to distortions
- Tolerant to misprints and defects
- Insensitive to strong noise (undercoat, bottle material)
- Fast (Image sizes > 7000x4096)

distortion

Different methods were tested:

1. Conventional correlation methods
   - to slow
   - intolerant to noise and print defects
2. Correlation of image profiles
3. Point-pattern-matching (register extracted features)



noise

4.3 Profile correlation

- Calculating the energy of columns using different energy functions
- Correlate resulting profiles

Advantages:

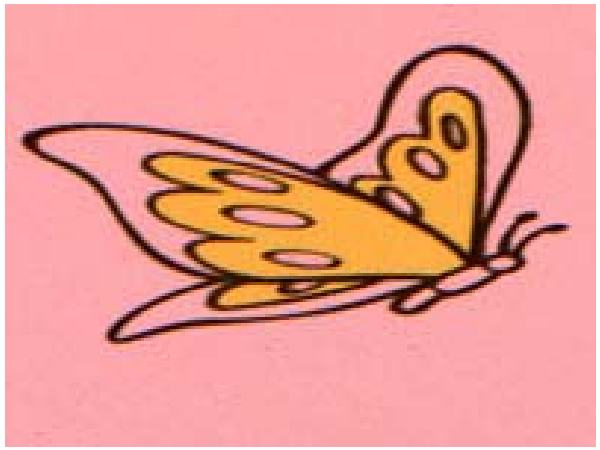
- Very fast
- Easy to implement

Disadvantages:

- Intolerant to distortions
- energy functions must be adapted to image content

- Min-max value
- Mean value
- Gradient in y-direction
- Median

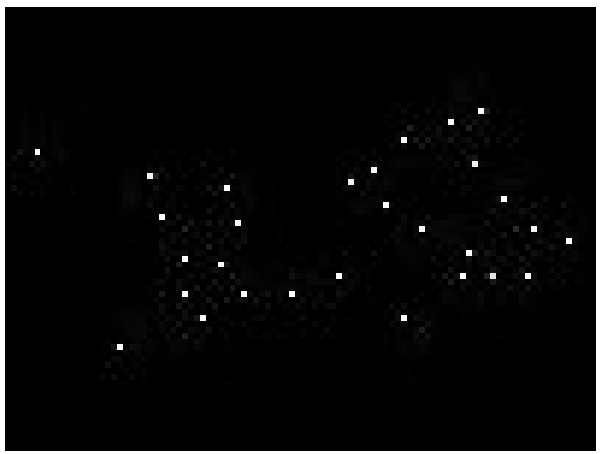
4.4 Point Pattern matching PPM



- Extraction of features (points) using Förstner algorithm
- Matching two partly equal sets of points

Advantages:

- Very fast
- Tolerant to distortions



Disadvantages:

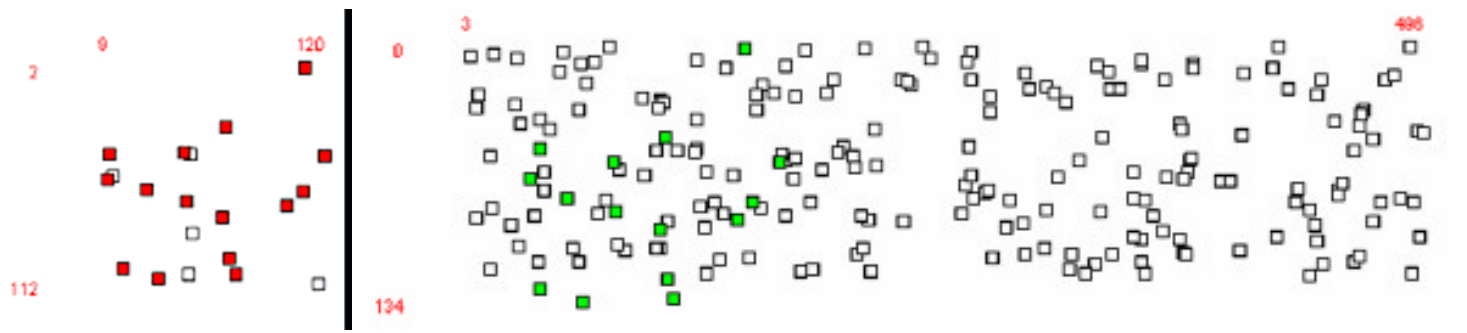
- Difficult parameter setup
- May find wrong solutions
- Sensitive to noise

4.5 PPM Search Strategie

- We used the „comparing neighbours“ strategy by Wamelen
- Other useful strategies are discussed by Cox and Jager

Optimising the search

- Use of kD-Trees for faster finding the nearest neighbours
- Setting up tolerance limits for transformations (dX, dY)
- Use of other point characteristics (like intensity or gradients) for calculating point distances



4.6 Combining single solutions

→ Combining advantages
→ Speed up slow algorithms

- Approximate offset with profile correlation
- Setting up limits for point-pattern-matching
- Using standard correlation in limited search regions for refined offset calculation

Because of local, nonlinear distortions maximum accuracy is around 4 pixel

→ Inspection algorithms must handle distortions of 5 pixels

5.1 Distortion tolerance

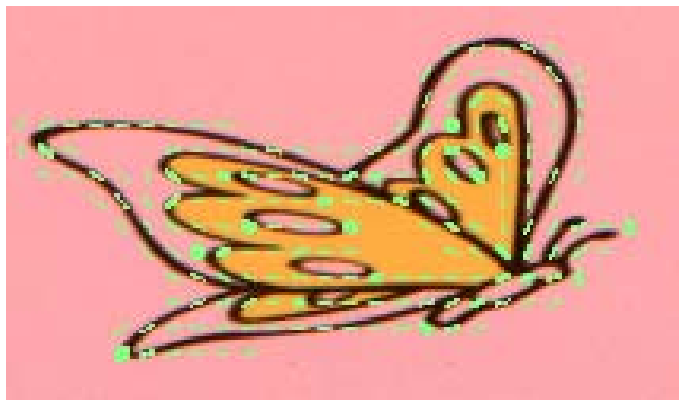
Setting up displacement limits for different image areas

Print defects could be falsely identified as local distortions.

This problem especially occurs on edges or lines.

Our approach:

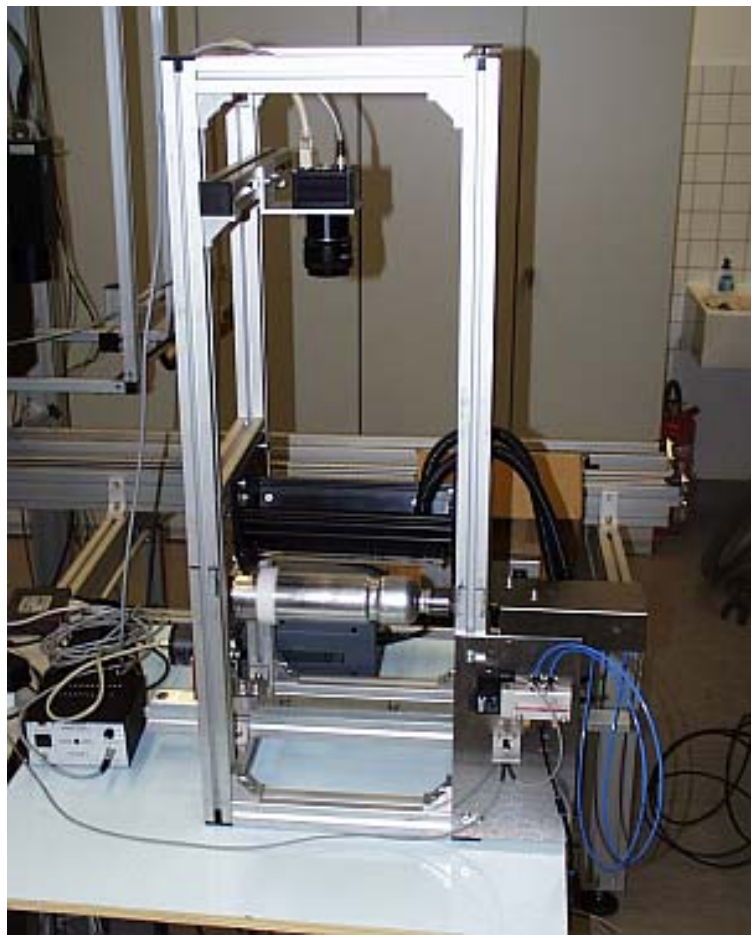
- Calculating the structure tensor matrix for single areas
- Determining eigenvalues and eigenvectors of the matrix
- Generating an elliptic bitmask from gradient angle and gradient energy
- Translation of an area to a given position - only possible if a suited bitmask is available



Hardware

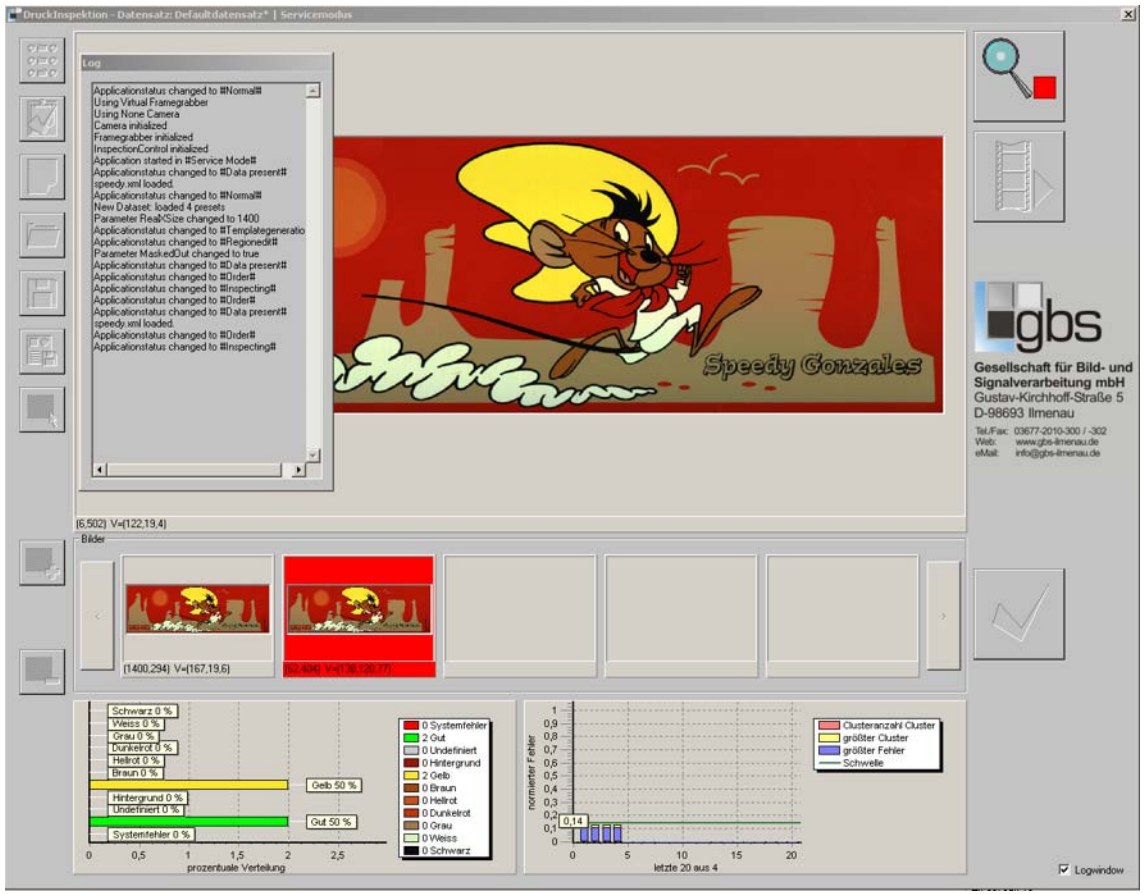
On the basis of our tests following hardware components were used:

- HQI cold-light fiber optic lighting system
- Dalsa Piranha Color PC-30-04K60 linescan camera
- Direct drive without belt
- Incremental encoder
- Height-adjustable construction,
  adaptable to various bottle sizes



Inspection software

- Modular system architecture
- Easily adapt to other problems
- Simple, intuitive user interface
- Job statistics



8. Summary

Our developed inspection system is capable to deal with

- Different kinds and sizes of bottles and tubes
- High resolution images
- Non-linear local distortions caused by image acquisition

Our developed inspection system is able to

- Detect wide range of defects
- Classify colour defects

Future work

- Colour-calibration by use of multi-channel sensors

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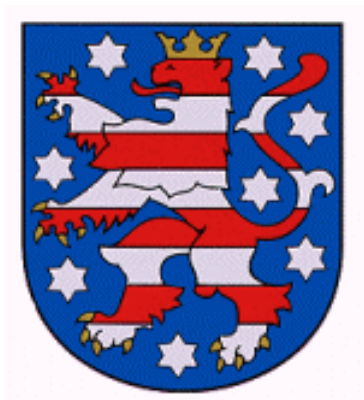

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Thank you for your attention