CT Wizard - Automatic determination of optimal CT measuring parameters for an unknown part

Christoph KUHN, Michael REITER, Stefan SCHRÖPFER, Stefan KASPERL, Daniel WEISS, Marco ERLER
How does the perfect coordinate measuring system look like?

“A box, just like a microwave oven, where I put my part in. Then I get a color-coded labelling green / red for good / bad.”

Quote from a Quality Manager at Volkswagen
Tasks

1. Complete 3D information about the part
   - X-ray Computed Tomography

2. Comparison with nominal data from CAD system
   - Color-coded result visualization

3. Automatic determination of optimal CT measuring parameters for an unknown part
   - CT Wizard
CT Wizard
Automatic determination of optimal measuring parameters for an unknown part

Goals:

Find optimal CT measuring parameters for an unknown part in a reasonable time < 5 Minutes.

No a priori information about the part is necessary, but can be used if available.

Parameters are determined directly at the CT system without extra software or hardware.

User can decide to work with the suggested parameters or not.
# System parameters and influencing variables

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- Parameters to be optimized
# CT Wizard

**Is – Is Not**

## What is optimized by the CT Wizard:

- Part positioning
- Position on the rotary table
- Magnification
- X-ray spectrum
- Voltage
- Filter
- X-ray spot size

## Which system effects are not considered:

- Noise in volume
- Total scanning time has to be defined by the user
- Volume evaluation settings
- CT Wizard optimizes quality of the reconstruction volume, the evaluation is not considered
Schematic process of parameter optimization

1. Automatic part positioning based on fast reconstruction of the convex hull of the part
2. X-ray spectrum optimization based on 3D image quality evaluation
3. X-ray current maximization based on tolerable unsharpness in 2d images
Concept for automatic positioning of the part

1. User interaction: New part in CT system
2. Calculation of convex hull
3. Calculation of optimal position on RT
4. User interaction: Guided repositioning of the part
5. Automatic setting of maximal magnification
Automatic Positioning

The part to be scanned …

... is placed in an X-ray translucent holder on top of the stage. The holder is attached magnetically and can be shifted along the stage by hand.
The part can be anywhere within the X-ray field of view.
A small number of views are acquired to obtain a 3D object approximation.
The object approximation is used to determine optimum part placement.
Automatic Positioning

According to instructions, the user shifts the part holder along the stage, all other movement is performed automatically to obtain maximum magnification.

Shift object by -26.1 mm on rotary table to improve magnification by 2.5x (visual pitch 291.7 vs. > 300.8 m/p)

26 mm
Concept for X-ray spectrum optimization

1. Fast measurement and reconstruction with different spectra
2. Calculation of quality measure for each measurement
3. Maximization of quality measure to determine the best image quality
Use low resolution reconstruction for spectrum analysis

- Analysis of histogram peaks of reconstructed volume

- Quality measure is
  \[ Q = \frac{\mu_2 - \mu_1}{\sqrt{\sigma_1 \cdot \sigma_2}} \]

- In addition to standard reconstruction, correction routines can be applied
Optimal X-ray spectrum

standard reconstruction

130 kV
130 kV, 1 mm Al
130 kV, 0.5 mm Cu
130 kV, 2 mm Cu
40 kV
60 kV
80 kV
100 kV
Optimal X-ray spectrum

Reconstruction with beam hardening correction

130 kV  130 kV, 1 mm Al  130 kV, 0.5 mm Cu  130 kV, 2 mm Cu
40 kV  60 kV  80 kV  100 kV
Optimal X-ray spectrum

Histograms are built for the original and for 3x3x3 median filtered volumes. Quality measure Q agrees well with subjective reconstruction quality.
X-ray current maximization

For the maximization of the X-ray current the following rule of thumb for the maximum spot size is used:

\[
\text{Spot size} = \frac{\text{Pixel size}}{\text{Magnification} - 1}
\]

For a given magnification and given X-ray spectrum it is then possible to calculate the maximum current depending on the specification of the X-ray tube.

![Diagram showing spot size and part for X-ray current maximization](image)
Summary

The CT Wizard is an assistance system which determines the optimal acquisition parameters including
- object orientation and position
- geometric magnification
- X-ray spectrum
- X-ray current

In contrast to simulation-based approaches the optimization is using several radiographic images of the real part. Previous knowledge about the specimen is not necessary but can be used. The time to determine the optimal CT measuring parameters is significantly shorter than the measurement time itself.
Acknowledgment

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References

- VDI/VDE 2630/Part 1.2 Computed tomography in dimensional measurement, Influencing variables on measurement results and recommendations for computed-tomography dimensional measurements