Robustness Analysis of Imaging System for Inspection of Laser Beam Melting Systems

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What is Laser Beam Melting (LBM)?

“3D printing” with metal powder

• Layer-based, iterative
• Laser melts metal powder according to layer geometry
Motivation of this Work

Provide Quality Control and Process Documentation for LBM Systems

- Acquire layer images of powder layer and melt result
- Enable image analysis with high precision (measurements, surface analysis)

Laser line width: 90 µm
1 Pixel: 20…30 µm
Our Imaging System

Custom camera mount with geared head (3 axes)

29 Megapixel camera (monochrome)
The Problem

Powder Deposition Mechanism of LBM System

Recoater Blade
Part Layer
Powder Container

Vibrations
Objective of this Work

Enable precise layer image analysis

Vibrations may move camera: misalignment of layer images

- **optimum**: perfect alignment
- **worst**: large deviations

- Analyse robustness of imaging setup against vibrations and shocks
Method

Build calibration markers in multiple layers and compare positions

1. Define templates and search regions in reference layer image
2. Find markers in other layers using template matching [1]
3. Compute distance $d$ to reference position

Results

<table>
<thead>
<tr>
<th>Process</th>
<th># layers</th>
<th>Distance [pixels]</th>
<th>Median</th>
<th>75%-Quantile</th>
<th>Max.</th>
<th>Laser scan width: 90 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>250</td>
<td></td>
<td>1.12</td>
<td>1.46</td>
<td>3.16</td>
<td>Max. distance: 156 µm on part</td>
</tr>
<tr>
<td>B</td>
<td>249</td>
<td></td>
<td>3.48</td>
<td>3.88</td>
<td>4.91</td>
<td>Most deviations &lt; 46 µm on part</td>
</tr>
<tr>
<td>C</td>
<td>601</td>
<td></td>
<td>1.00</td>
<td>1.46</td>
<td>3.82</td>
<td></td>
</tr>
</tbody>
</table>

Example: Analysis Plots (Process B)

Distances

- median 25%...75% - 99% quantile
Conclusions

Objective: Analyse robustness of imaging setup against vibrations/shocks

- Deviations are significant for measurement task (compared to laser width)
  - impact on image analysis
- A single calibration of perspective correction is not sufficient (drift)

Build markers every N layers and repeat calibration
- detect markers using presented template matching method
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