A Structure from Motion Approach for the Analysis of Adhesions in Rotating Vessels

3DV 2014, Int. Conf. on 3D Vision, The University of Tokyo, Japan, 8-11th December 2014
Patrick Waibel, Jörg Matthes, Lutz Gröll, Hubert B. Keller

PROBLEM
Adhesions inside rotating vessels such as rotary kilns can cause:
- Process downtime
- Repair costs
- Decreasing product quality

IDEA
Camera position shifted to rotational axis of vessel offers possibility to deduce on adhesion depth and height:
- Rotational center of adhesion’s circular motion in image sequence and depth of adhesion inside vessel are related
- Radius of adhesion’s circular motion and the height of the adhesion are connected

METHOD
Mathematical relationships between image data and 3D-real-world information
1. Rotational Center $\rightarrow$ Depth:
   $z = \frac{r}{2} \left( \frac{r - r_0}{r - r_a} \right) \left( \frac{r - r_a}{r_0} \right)$
   - $r$: vessel radius
   - $l$: vessel length
   - $z$: adhesion depth
   - $r_a$: radius of vessel back
   - $r_f$: radius of vessel front
   - $r_0$: radius at same depth without adhesion
   - $x_{c,a}$: image position of rot. center adhesion
   - $x_{c,b}$: image position of rot. center vessel back
   - $x_{c,f}$: image position of rot. center vessel front

2. Radius $\rightarrow$ Height:
   $h_a(x_{c,a}, r_a) = r \left( 1 - \frac{2r_a}{2r_a - \frac{r_a}{r_0} (r_f - r_a)} \right)$
   - $h_a$: adhesion height
   - $r_a$: radius of adhesion
   - $r_f$: radius of vessel front
   - $r_0$: radius at same depth without adhesion
   - $x_{c,a}$: image position of rot. center adhesion
   - $x_{c,b}$: image position of rot. center vessel back
   - $x_{c,f}$: image position of rot. center vessel front

IMPLEMENTATION
- Feature detection depending on specific task (e.g. SIFT, SURF)
- Feature descriptors
- Feature matching
- Adapted Kalman Filter for each feature point
- Minimizing least squares error to circle model for each track
- Application of SfM method for each track
- Adhesion data for each track

RESULTS AND CONCLUSION
Validation of proposed method based on image data of:
- Experimental setup
- Industrial cement rotary kiln

Comparison of image-based data and real data (H: height, D: depth; units: mm)

Future works comprise:
- Improvements in feature detection and tracking in industrial image data
- Usage of constrained ellipse fitting instead of free circle fitting

Exp. setup of a rotating vessel
Adhesion dummy w/ tracked positions
Image of cement rotary kiln with tracked adhesion

Exp. 1 | Exp. 2 | Exp. 3
---|---|---
Sample | Image-based | Real-valued
H | D | H | D | H | D
---|---|---|---|---|---
300 | 300 | 200 | 200 | 150 | 150
20% | 20% | 25% | 25% | 15% | 15%
Relative error | 2.3% | 3.0% | 2.9% | 3.6% | 3.7% | 1.1%