Pipeline Landmark Detection for Autonomous Robot Navigation using Time-of-Flight Imagery


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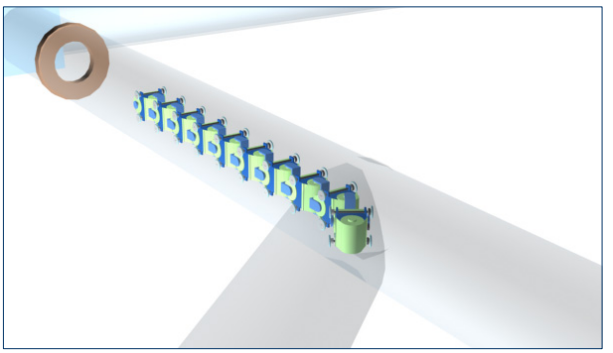
Pipeline robot navigation

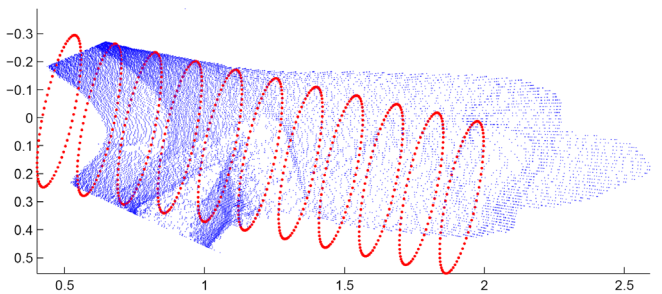
Task:
Autonomous robot navigation in pipelines
based on detection and tracking of junctions and bends
using a time-of-flight (TOF) camera.



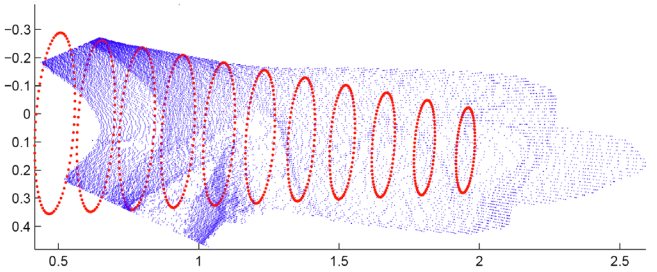
Robot approaching junction in pipeline.

Algorithm:
1. Fit a cylinder to TOF range image of pipeline
2. Group pixels deviating from estimated cylinder into blobs
3. Classify blobs as features based on shape and compactness
4. Track features over time using feature position history

Cylinder versus cone fitting

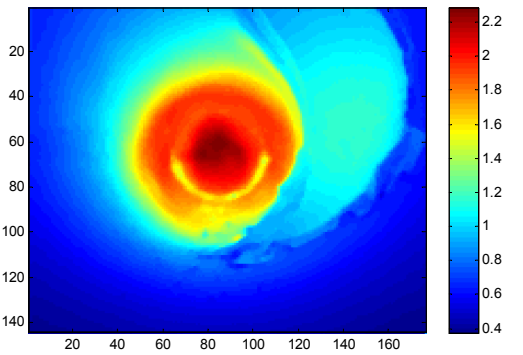


The best fitting cylinder points slightly off-axis due to
- poor camera calibration
- secondary reflections
- lens scattering
- unevenly distributed data poins

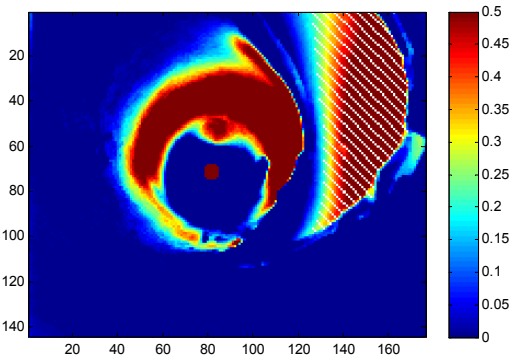


The cone model estimates the pipeline axis more accurately by implicitly correcting for these effects.

Deviation from fitted cone

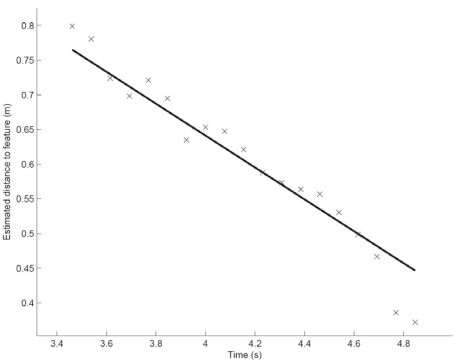


TOF range image of pipeline with junction.



Deviation from cone. Pipewall deviation equals zero.
The junction, marked by the shaded area, deviates clearly.

Feature tracking over time



Crosses indicate tracked distance to junction in each frame.
Solid line shows calculated distance using path traversal timing.

Conclusion and outlook

The TOF camera has been shown to be a promising sensor for pipeline robot navigation, using basic landmark detection.

Future work:
- Improvement of geometric primitive deviation analysis
- Fusion of secondary sensor data for model verification
- Development of landmark classification algorithms