Kickoff meeting - CAAP award

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COLORADO SCHOOL OF MINES
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A Fast and Accurate Algorithm for Automatically Matching Anomalies Across Consecutive Pipeline Inspections

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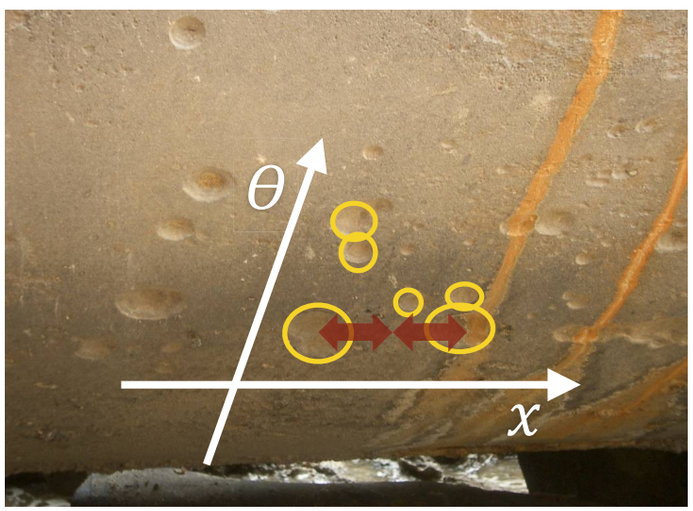
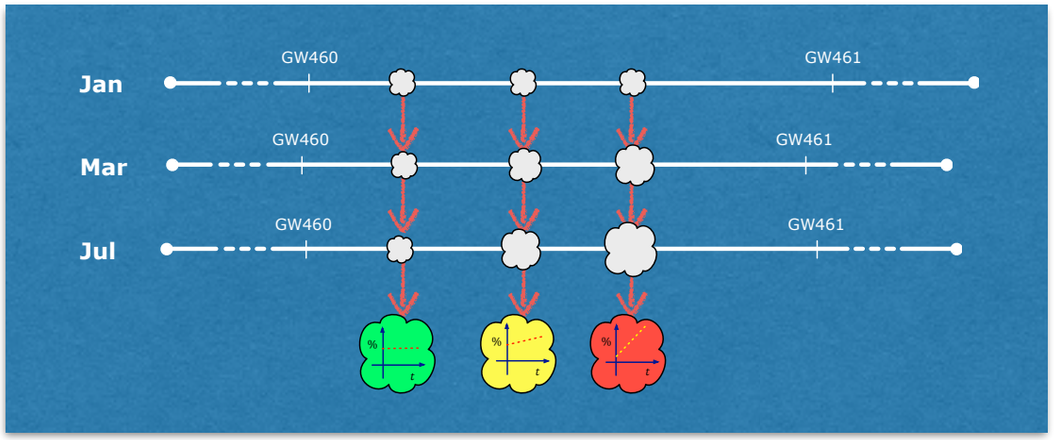
Domain - Corrosion Rates

- 4-D (time) profiles of *individual* corrosion anomalies
- Supporting Integrated Cleaning and Inspection Pigs (ICIP)



Palmer-Jones, Roland, Phil Hopkins, and D. Eyre. "Understanding the results of an intelligent pig inspection." Penspen Integrity 8 (2006): 1-16.

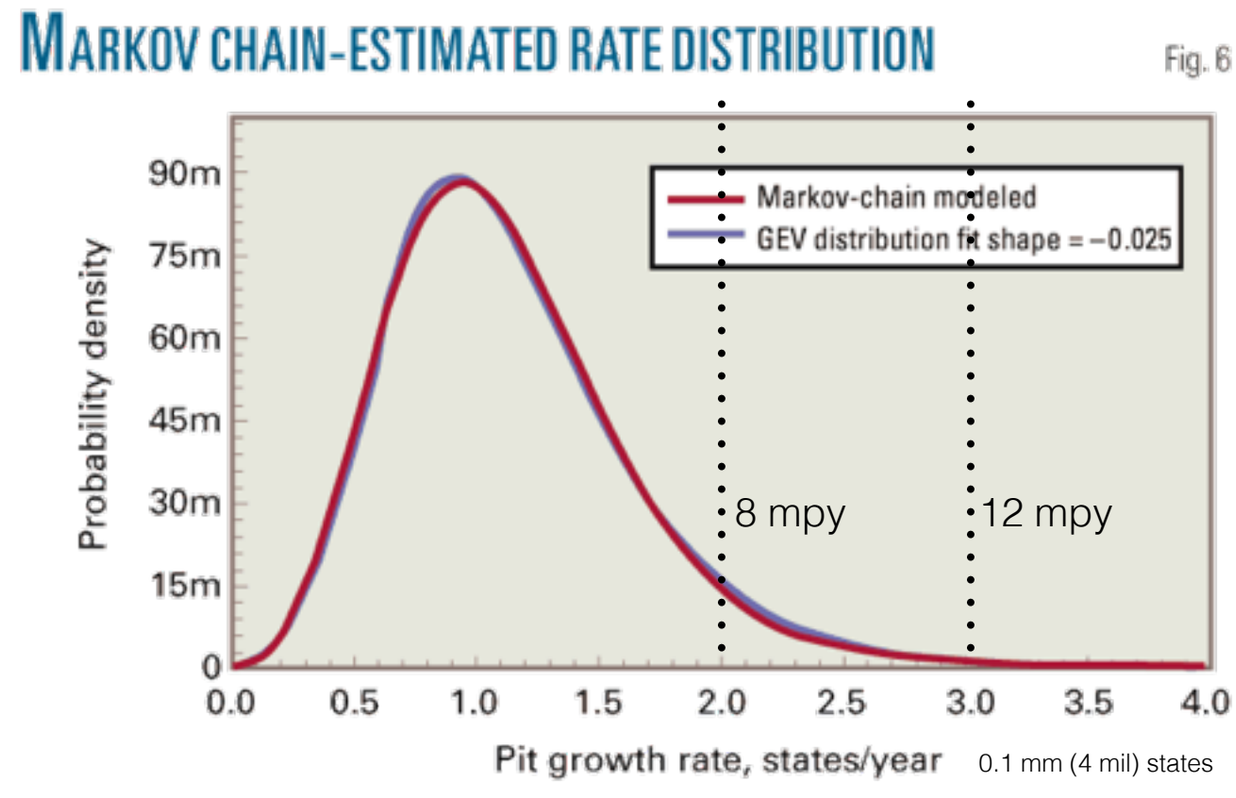


Goal: *Algorithm* to quickly and correctly match anomalies across consecutive inline inspections (ILI's)

Background

- Global rates compromise between average and extreme

- Measured rates benefit the average AND catch the extreme



J.C. Velazquez, A. Valor, F. Caleyo, V. Venegas, J.H. Espina; "Corrosion - Conclusion: Pitting corrosion models improve integrity management, reliability; Oil and Gas Journal; July 27, 2009; (online) http://www.ogj.com/articles/print/volume-107/issue-28/Transportation/corrosion-conclusion-pitting-corrosion-models-improve-integrity-management-reliability.html

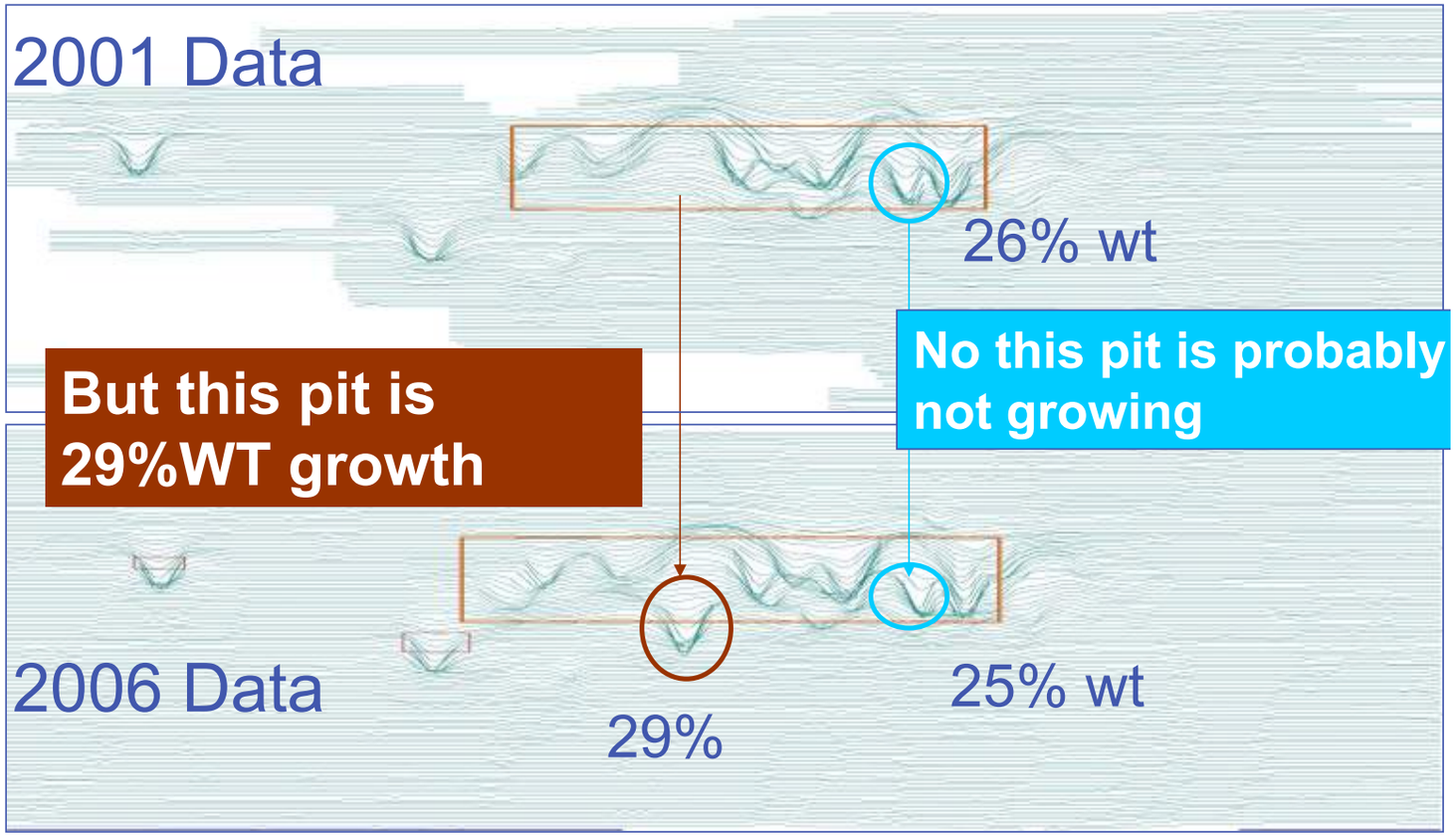
McNealy 2012
- 48" Gas Transmission
- ILI 2007 and 2009

Re-inspection
- 12 mpy - 4.5 yr
- **measured** - 2.0 - 2.5 yr

Richard McNealy, Steven Osgood, Lucinda Smart; "Effect of Corrosion Growth Rate Estimated from Consecutive Assessments on Response to In-Line Inspection Anomaly Predictions" NACE Corrosion 2012 Conference and Expo; C2012-0001560; 2012.

Measuring CGR with ILI

- Match anomalies
- Compare depths



Kevin Spencer, GE; "PHMSA Pipeline Safety: Workshop on Anomaly Assessment and Repair"; October 22, 2008; Gaylord National Resort and Convention Center, 201 Waterfront Street, National Harbor, MD; Last checked May 6, 2014; (Available) http://www.ingaa.org/file.aspx?id=7759

Challenges

- Matching is slow and error prone
- Signal matching only works on same tool
- Infrequent (expensive) data collection

Anomaly Matching

1. Correct tool position
2. Match known features
3. Pattern match anomalies
4. Verify and correct

Yeagley 2014
- 90% automatic matching (box)
- 10% missed

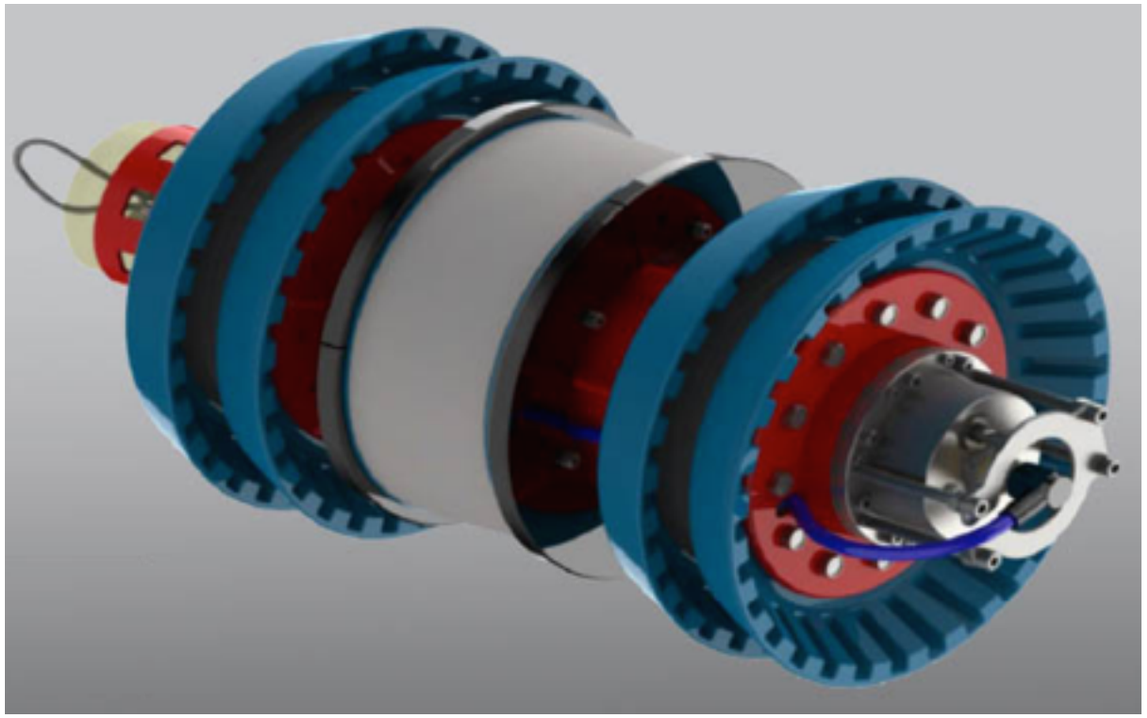
Implications
- Humans must verify
- 10 Km for every 100 Km
- Takes months

Brian Yeagley and Mark Madden; "Leveraging Previous Inline Inspection Assessment Results" in Pipeline & Gas Journal, Volume 241, Number 3, March 2014.

Current practices vis a vis ICIP :
- Too slow
- Too labor intensive
- Tool/ calibration/ sensor sensitive

Integrated Cleaning and Inspection Pigs (ICIP)

- 1.5D Disk Cleaning Pig
- Hardened, low cost sensors (MFL, EMAT, EMIT)
- Requires minimal training
- Part of routine maintenance (weekly, monthly)



"SIG | ICIP : Integrated Cleaning and Inspection Pigs (ICIP)"; Subsea Integrity Group R&D Showcase; Last checked May 8, 2014; (Available) http://subsea-integrity.com/icip.asp

Better granularity shows CGR variability

- Product composition
- Inhibitor Effectiveness
- Missed anomalies

Research Goals

Better anomaly matching algorithm

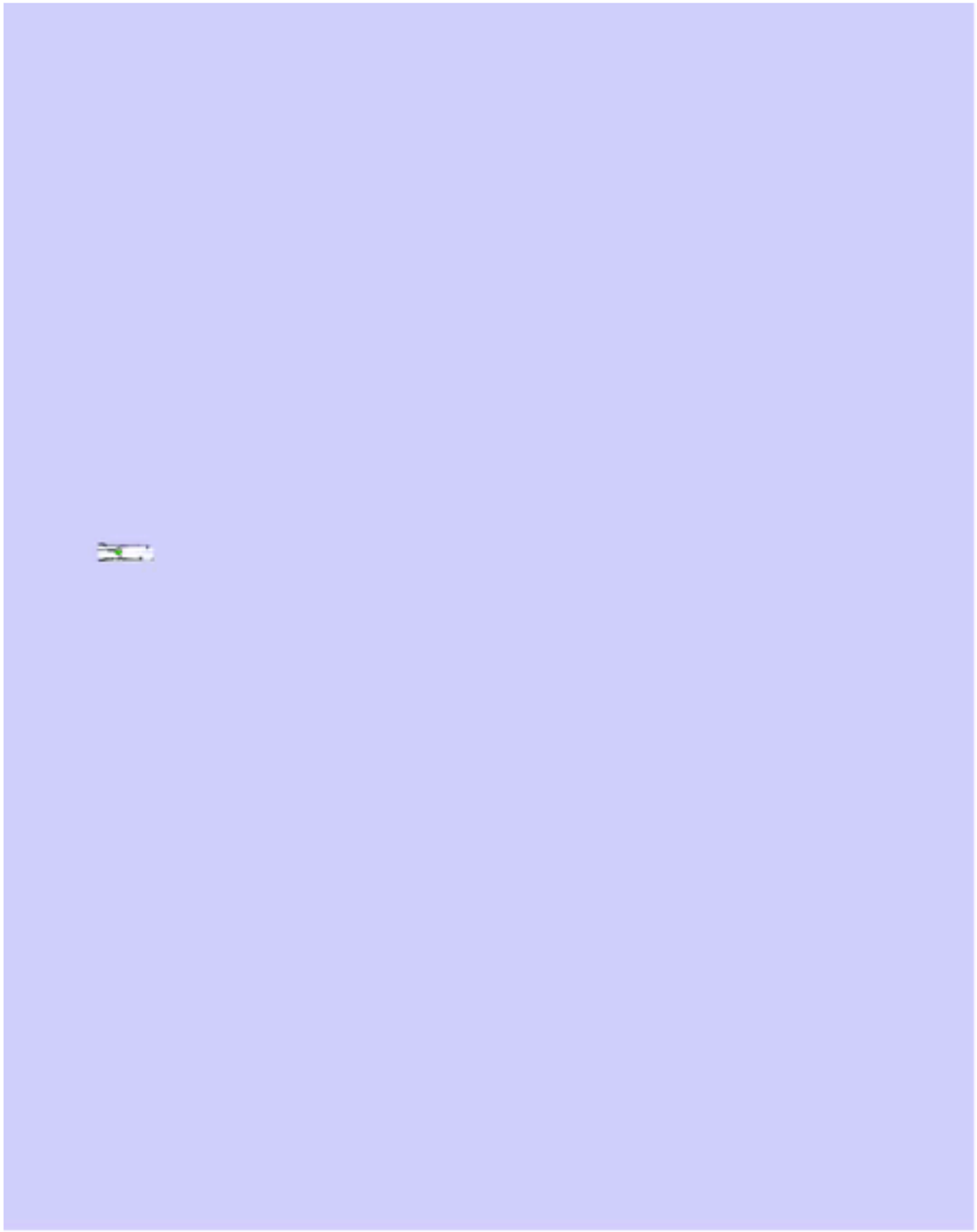
- Fast
- Accurate
- Position neutral
- Tool neutral
- Sensor neutral
- User friendly

Simultaneous Localization and Mapping

- Map and locate self
- Stored uncertainty
- Loop closure

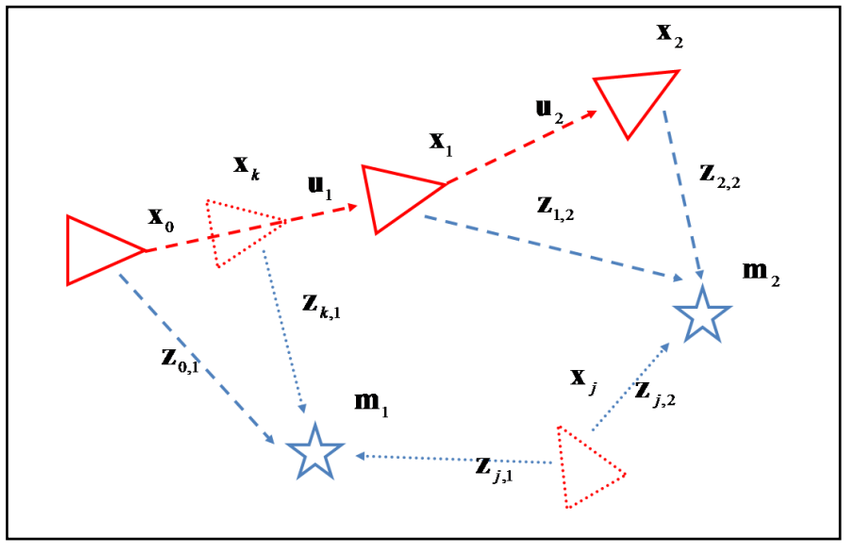
Robotic Navigation - SLAM

- Bayesian (single pass)
- estimate position based on landmarks
- map landmarks relative to current position
- store then resolve uncertainty

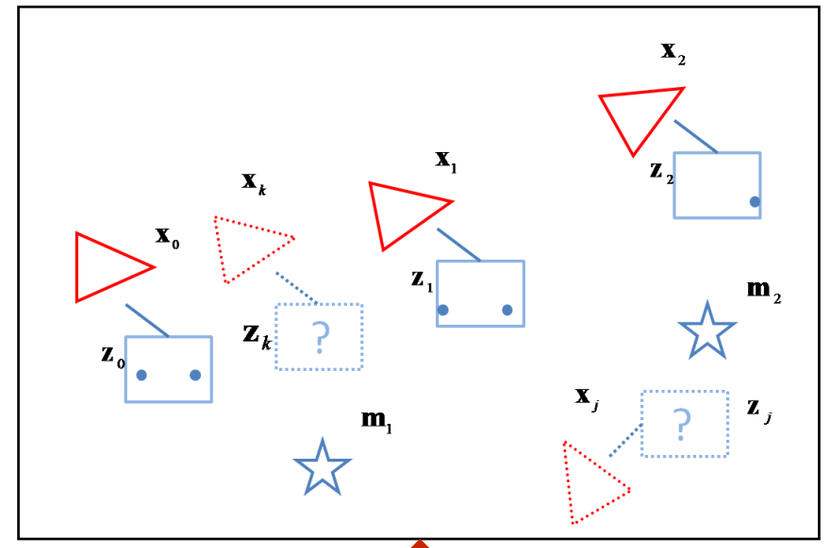


SLAM Family

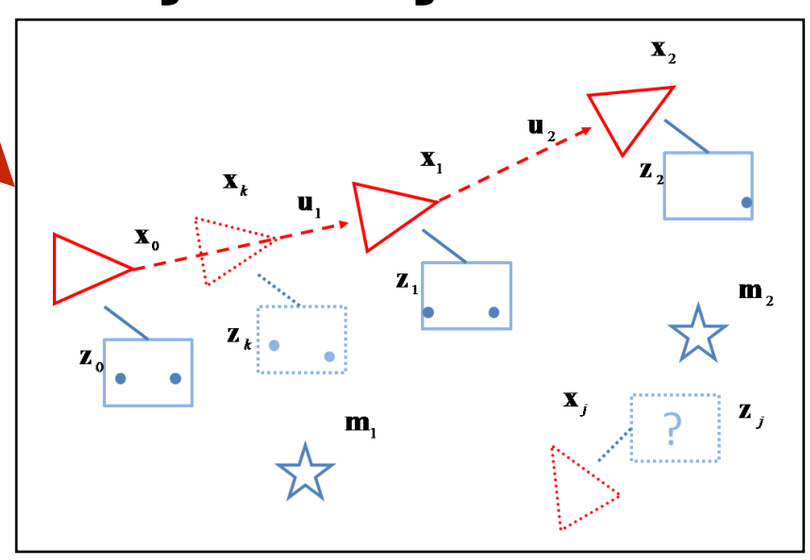
Geometric



Appearance



Trajectory



- Interpolation
- Metrics

- Recognition
- Neutrality

Approach - SLAM

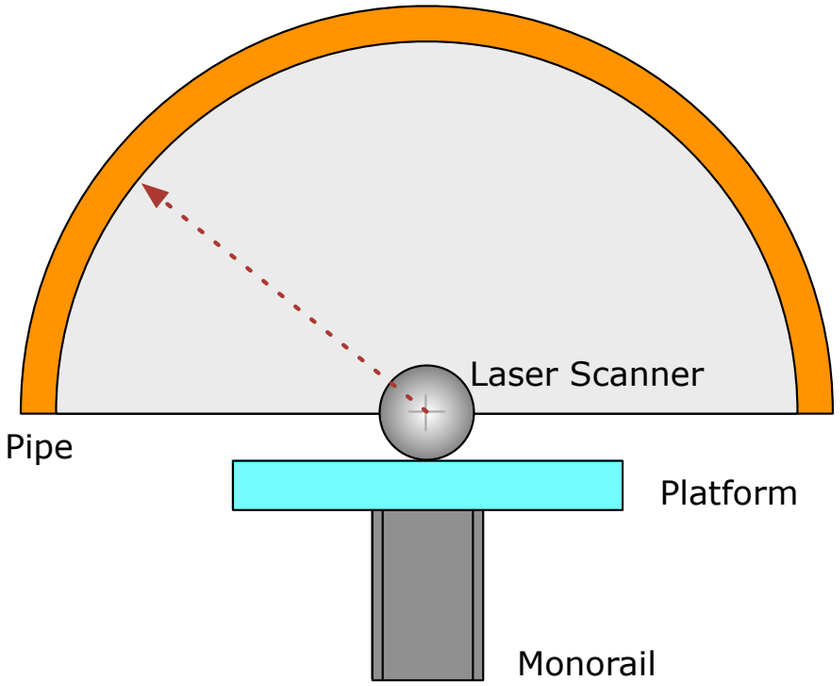
- single pass through data (fast)
- stored uncertainty (accurate)
- match relative position (position neutral)
- match shapes (sensor/tool neutral)

Scope of Work

- Synthetic Data
  - Prototype on Montrac monorail conveying system
  - Laser scanner mounted perpendicularly
  - Half-pipe above track centered on laser

http://www.montratec.com/index.php?nav=19,320

- Compare SLAMS
  - CAT-SLAM
  - FAB-MAP, et al
  - CAM



- Real Data
  - Characterize
  - SAM vs
  - CAM

Timeline

		2014	2015				2016		
TASK	MILESTONE	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Experimental Setup	Build test rig	x							
	Collect synthetic data	x	x						
	Collect data from pipe sample				x	x			
Baseline SAM	Adapt CAT-SLAM as a SAM algorithm	x	x						
	Test on synthetic data	x	x						
	Test on real data					x			
Real Data	Collect and clean data				x				
	Characterize data					x			
Compare SAM and CAM	Identify additional SAM candidate algorithms		x						
	Implement >2 additional SAM approaches		x	x		x			
	Compare SAM algorithms - synthetic data			x		x	x		
	Compare SAM algorithms - real data						x	x	
	Final Report						x	x	
Intern	Chevron Energy Technology Company				x				x

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