Autonomous Drones and Crawlers Combined with State-of-the-Art Sensors Set to Take Over the O&G Monitoring Space: Learn How

June 20, 2017

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Poll Question

What is your job title?

Poll Question

Who is your employer?

Poll Question

How many years of experience do you have?

Poll Question

What geographic region are you from?

Poll Question

Are your responsibilities principally onshore or offshore?

The SPE Research & Development Technical Section (RDTS) presents:

Autonomous Drones and Crawlers Combined with State-of-the-Art Sensors Set to Take Over the O&G Monitoring Space: Learn How

John Barratt
Founder/CEO, Oil & Gas Innovation Center

Brad Tomer
Chief Engineer, GE Oil and Gas/Chief Operating Officer, Avitas Systems

A systems approach to robotics, sensors, and data analytics to automate dull, dirty, and dangerous oil and gas asset inspections

Brad Tomer
COO, Avitas Systems, A GE Venture

Agenda

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- Review current inspection methods
- Introduce systems approach to inspection automation
- Illustrate robotic platforms and uses
- Discuss analytics and deep learning

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O&G Manual Inspections

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DATA GATHERING

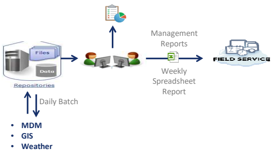
Expensive / Labor intensive:
- Multi-billion yearly cost to industry
- Time-based inspections

Dual, dangerous and dirty:
- Multiple confined space deaths each year
- Data is inconsistent across inspectors
  - Weather dependent

VALUE EXTRACTION

Inconsistent:
- Much left to interpretation
- Different business unit siloes

Expensive:
- Data ingestion is manual/ad hoc
- Field crews have limited access



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Automated Inspection System

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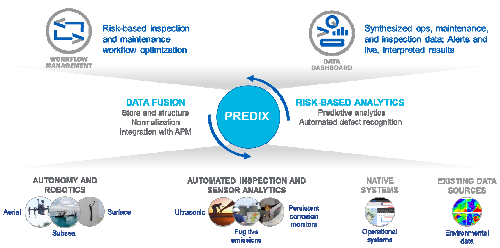

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Significantly reduced costs, better safety, improved quality & repeatability and more efficient operations

Unmanned Aircraft Systems

Current inspection approach
- Camera/video mounted on helicopter
- Rope access
- Scaffold
- Crane and man baskets

sUAS Technology Today
- Manually controlled flights/photogrammetry and LiDAR to build 3D model of asset
- Mission planning with repeatable autonomous inspection
- Better visibility, more thorough asset inspection with precise targeting and ability to fly close to structure
- Higher quality data with the ability to mount RGB and IR cameras
- Faster, more reliable process
- Particularly effective for vertical assets and well pads/platforms

sUAS Moving Forward
- Improved autonomy
  - GPS denied environments
  - Sense and avoid
- Beyond Visual Line of Sight
  - Requires FAA approval
  - Sense and avoid
- Greater use of fixed wing aircraft
  - Effective linear asset inspection
  - Longer duration flights

FAA Authority over sUAS

- **Section 333 of the FAA Modernization & Reform Act of 2012 (PL 112-95)** - FAA authority to determine if airworthiness certificate is required for a UAS to operate in national airspace system (NAS)
  - ***Today:*** used to authorize UAS over 55 lbs and off-shore ops
- **Title 14 CFR Part 107, Operation and Certification of Small UAS**, became primary authorization for commercial operation of UAS under 55 lbs within visual line-of-sight
- **Section 2210 FAA Extension, Safety, and Security Act of 2016** directs the FAA to grant case-by-case authorization under Section 333 for activities beyond visual line of sight, during daylight and/or night time, for operations associated with critical infrastructure

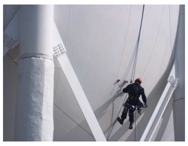
Considerations for BVLOS

- Command & Control
  - LTE, Radio, Satellite
- Communication: let others know your presence
- Detect and avoid
- Navigation performance
- Reliability/redundancy
  - Mitigations
- Concept and area of operations
- Pilot qualifications
- Airspace integration and traffic avoidance
- Positive identification so authorities know permitted to fly over infrastructure
- Features to minimize risk to people and property on ground

Robotic Crawlers

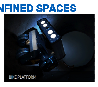
Current inspection approach
- Rope access
- Scaffold
- Crane and man baskets

Crawler Technology Today
- Eliminates scaffolding & rope access
  - Safer
  - 7-10 days time savings per tank
- Controlled, precise, repeatable inspection plan
- Better visibility, more consistent and thorough asset inspection
- Higher quality data with the ability to mount RGB and IR cameras, stereo, structured light, PEC and UT
- Faster, more reliable process




Tethered Crawler Examples

INSPECTION IN CONFINED SPACES

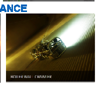



- No human entry
- Automation / Autonomy
- On- / Off-shore

AUTONOMOUS NDT


- UT / EC Inspection
- Autonomous weld inspection
- Corrosion mapping
- On- / Off-shore

ROBOTIC MAINTENANCE

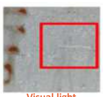



- Cleaning
- Inspection
- Paint removal
- Painting
- On- / Off-shore

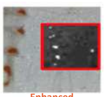
Untethered Crawler Example

HIGH RESOLUTION VIDEO


Sub 0.5 mm resolution



Visual light



Enhanced

SWAPPABLE SENSOR ARRAY
- 4K Video, 20Mp still, IR tested
- Developing PEC & UT
- Developing Multispectral module

GROUND AND TANK CAPABLE
- Crawl to tank
- Autonomous external inspection of tank farm
- Multi-kilometer range

CLIMBS STEEL SURFACES
- Front, rear and side cameras
- Stereo front vision
- Live streaming video for steering, live inspection camera and IR feeds

PURPOSE BUILT MULTISPECTRAL CAMERA ENHANCED DEFECT RECOGNITION
- Detection of corrosion not visible to inspector
- Automatic quantification of area

Crawler Technology Moving Forward

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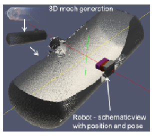

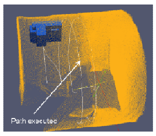

LASER BASED SLAM *(3D Point Cloud)*

- **IMU Data** (inertia measurement unit)
- **Odometry Data** (wheel rotations)
- **Data fusion** (SLAM + IMU + Odometry)
- **Autonomous Operation**
  - Robot creates the 3D model on the fly
  - Predefined plan executed
  - Link position / inspection data

TANK WALL

- Following pre programmed paths
- Automatic compensation of drift & slippage
- Image referencing
- Detection of obstacles and warning / system stop

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Case Study – Propane Tank

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TANK DIMENSIONS		
Tank diameter		44.4 m
Circumference		139.5 m
Shell plate size		2 m x 4 m (welded horizontally)
Weld inspection	(10% of bottom five courses)	13.9 m x 5 = 65 m
	(10% of vertical welds)	0.2 m x 60 = 12 m

SCANNING TECHNIQUE	MUT	AUT
	Straight beam for lamination two different angles from each side	One or two TOFD set-up Phased Array for inner- and outer surface
Number of scans	Six per weld →	One per weld
Time spent (horizontal welds)*	420 minutes →	52 minutes
Time spent (vertical welds)*	80 minutes →	10 minutes

*Does not include set up time, which is slightly longer for AUT technique

Benefits

- Reduced costs/meter weld inspected
- Eliminate use of scaffolding; ~7 - 10 days cost savings
- Increased quality of inspection and Probability of Detection (POD)
- Results less dependent on subjective operator error / analysis
- Remarkable reduced inspection time
- Improved documentation of inspection
- Improved flaw localization and sizing
- Reduced number of "false calls" benefits the final product and economy
- ISO 9712 or EN 473 level 1 personnel can be used for set-up and data acquisition

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Advanced Data Processing

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STREAMLINING DATA INGESTION

> Asset Mapping
> Containerization of data/sensor streams
> Normalization, geo tagging, correlation, and collation for advanced analytics

DEEP LEARNING

> Image analytics for automated and assisted detection and classification
> AI patterns analysis and workbench for rapid customization

RISK MODELS

> Asset risk models and customer extensible risk calculus
> Basis for optimization and simulation for decision support systems

DASHBOARDS & REPORTING

> Configurable dashboarding and self service capabilities
> Automated reporting and "smart" archiving

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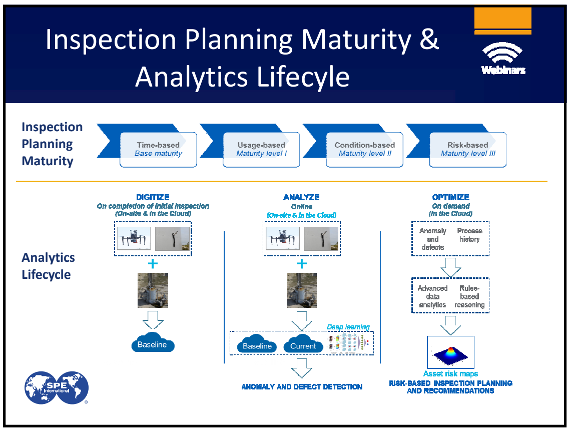
Inspection Planning Maturity &
Analytics Lifecyle
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Inspection Planning Maturity
Time-based
Base maturity
Usage-based
Maturity level I
Condition-based
Maturity level II
Risk-based
Maturity level III
Analytics Lifecycle
DIGITIZE
On completion of initial inspection
(On-site & in the Cloud)
Baseline
ANALYZE
Online
(On-site & in the Cloud)
Deep learning
Baseline
Current
ANOMALY AND DEFECT DETECTION
OPTIMIZE
On demand
(in the Cloud)
Anomaly and defects
Process history
Advanced data analytics
Rules-based reasoning
Asset risk maps
RISK-BASED INSPECTION PLANNING AND RECOMMENDATIONS
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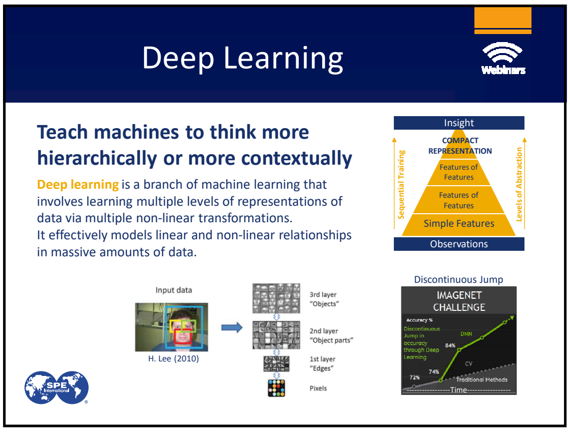
Deep Learning
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Teach machines to think more hierarchically or more contextually
Deep learning is a branch of machine learning that involves learning multiple levels of representations of data via multiple non-linear transformations.
It effectively models linear and non-linear relationships in massive amounts of data.
Insight
COMPACT REPRESENTATION
Features of Features
Features of Features
Simple Features
Observations
Sequential Training
Levels of Abstraction
Input data
H. Lee (2010)
3rd layer "Objects"
2nd layer "Object parts"
1st layer "Edges"
Pixels
Discontinuous Jump
IMAGENET CHALLENGE
Accuracy %
Discontinuous Jump in accuracy through Deep Learning
DNN
84%
CV
74%
72%
Traditional Methods
Time
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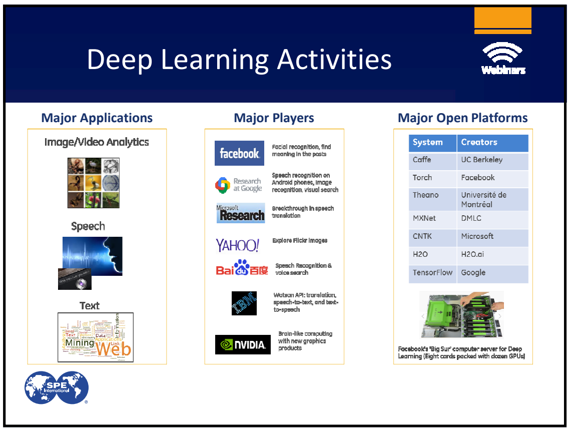
Deep Learning Activities
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Major Applications
Image/Video Analytics
Speech
Text
Major Players
facebook
Facial recognition, find meaning in the posts
Research at Google
Speech recognition on Android phones, image recognition, visual search
Microsoft Research
Breakthrough in speech translation
YAHOO!
Explore Flickr images
Baidu 百度
Speech Recognition & voice search
IBM
Watson API: translation, speech-to-text, and text-to-speech
NVIDIA
Brain-like computing with new graphics products
Major Open Platforms
System | Creators
Caffe | UC Berkeley
Torch | Facebook
Theano | Université de Montréal
MXNet | DMLC
CNTK | Microsoft
H2O | H2O.ai
TensorFlow | Google
Facebook's 'Big Sur' computer server for Deep Learning (Eight cards packed with dozen GPUs)
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Deep Learning Applied to O&G

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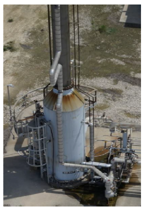
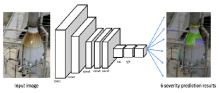


DEEP LEARNING NETWORK



Families of deep learning algorithms, such as fully convolutional networks

- **Training phase:** Image with ground truth used to set the right weights (W) by a process called back-propagation that used the difference between the result and ground truth to change the W
- **Run time**: trained network now is able to ingest an image and return the desired result

DEEP-LEARNED DEFECTS

- Paint breakdown
- Insulation breakdown
- Loose, cracked, broken, or missing bolts
- Cracking
- Corrosion
- Concrete spalling
- Heat distortion
- Numerous other that are asset and part specific (blocked drain, blocked nozzle, kinking, loose ignitor tubing, damaged support/guides, water logging)

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Future Inspection Capabilities

Built upon exponential technology areas

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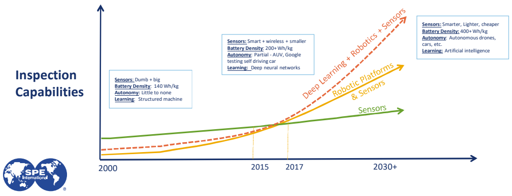
Convergence of key exponential technology areas

Smaller/improved sensors Deep Learning/Analytics Improved robotic platforms



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Summary

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- Full benefits of robotics, sensors and analytics requires integrated systems approach
- When combined these technologies have the potential to provide exponential benefits
- Deep learning is accelerating the use and impact of these technologies

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Small Unmanned Aerial Vehicles (SUAV)
"It's all about the sensors"

Oil & Gas Innovation Center, Inc.
John Barratt, President
June 2017

SUAV – Drone Types

What is a Small Unmanned Aerial Vehicle (SUAV)?

U.S. Federal Aviation Administration (FAA) classification

- SUAV weighs 55 lbs or less
- Hobbyist rules
- Commercial user rules

FAA Rules for Hobbyists

- Stay 5 miles away from airports
- Fly no more than 400 feet above ground
- Operate within visual line of sight

FAA Rules for Commercial Users

- SUAV must be operated no more than 400 feet above ground level or above a structure
- Maximum flight speed of 100 mph
- Daytime operation
- Visual line of sight operation
- No operation above people not involved in the SUAV operations
- Waivers to these rules are possible

FAA Rules – Why Care?

- Govern the way SUAVs can be used commercially in the U.S. oil & gas industry
- Define near term use cases such as monitoring offshore platforms, flare stacks, other critical infrastructure
- Delineates the sensor types needed to expand SUAV operations – beyond line of sight

SUAV (Drone) Marketplace

- Hundreds of U.S. based producers
- Fixed wing, quadcopters
- Hand and catapult launched
- Battery and gasoline powered
- Drones are increasingly commodity products
- Drone sensors are the key!

Drone Sensors

- Compact radar to overcome line of sight operation
- Lightweight, air cooled infrared imaging system
- Coin sized sensor for GPS and inertial navigation
- Miniaturized atomic magnetometer

Drone Compatible Radar

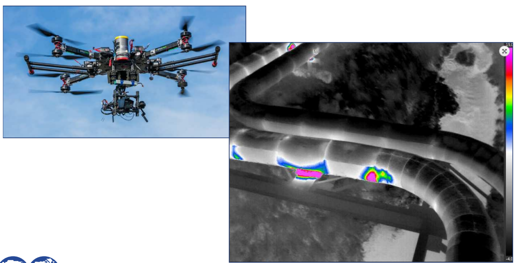
- Electronically scanning radar
- No moving parts
- Low cost, size, weight and power requirement
- Works in rain, fog, snow, dust, darkness
- Detect a human at 500 meters+
- Detect a small plane at 3 km
- Designed for use on SUAVs

Drone Compatible Radar

Compact Thermal Sensor for Drones

- Drone compatible thermal imaging system
- Delineate temperatures up to 1500° C
- Accurate within 2° C
- Resolution 640 X 512 pixels
- Real-time imagery to a ground controller
- Weighs 400 grams (<1 lb)

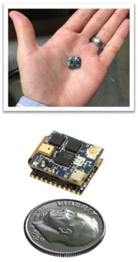
Compact Thermal Sensor for Drones



Coin Sized GPS/INS

- Tiny, precision calibrated, low cost, GPS Inertial Navigation Systems (GPS/INS)
- Smallest commercially available GPS/INS
- Angular rate, linear acceleration, magnetic field, barometric altitude, GPS geo-position
- Drone orientation (roll, pitch and heading), velocity and position

Coin Sized GPS/INS



Miniature Magnetometer

- Latest advances in electronics miniaturization
- Sensor head (19 mm x 19 mm x 47 mm, weighs 18 g)
- Electronic control module (35 mm x 19 mm x 95 mm, weighs 62 g)
- Sensitivity beats most commercially available non-miniature magnetometers

Miniature Magnetometer

- Small size
- Low power
- Low cost
- Long term stability

Drone Sensors – The Future

- Continuous sensor improvement
- Miniaturization = more sensors per drone
- Sensors to avoid obstacles = beyond line of site operation and swarming
- Swarming = one individual operating multiple drones

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