Video Analytics for Smarter, More Efficient Subsea Inspection

Hani Elshahawi, Ilkay Darilmaz, Georgios Papadopoulos Shell
Nader Salman, Schlumberger
Jack Vincent, OneSubsea
Definitions & Cautionary Note

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate legal entities. In this presentation “Shell”, “Shell group” and “Royal Dutch Shell” are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words “we”, “us” and “our” are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. “Subsidiaries”, “Shell subsidiaries” and “Shell companies” as used in this presentation refer to companies over which Royal Dutch Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to as “joint ventures” and “joint operations” respectively. Entities over which Shell has significant influence but neither control nor joint control are referred to as “associates”. The term “Shell interest” is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management’s current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management’s expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as “anticipate”, “believe”, “could”, “estimate”, “expect”, “goals”, “intend”, “may”, “objectives”, “outlook”, “plan”, “probably”, “project”, “risks”, “schedule”, “seek”, “should”, “target”, “will” and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell’s products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the implementation of projects and the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions.

No assurance is provided that future dividend payments will match or exceed previous dividend payments. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell’s Form 20-F for the year ended December 31, 2016 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward-looking statements contained in this presentation and should be considered by the reader. Each forward-looking statement speaks only as of the date of this presentation, May 3, 2017. Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation.

We may have used certain terms, such as resources, in this presentation that United States Securities and Exchange Commission (SEC) strictly prohibits us from including in our filings with the SEC. U.S. investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov. You can also obtain this form from the SEC by calling 1-800-SEC-0330.
Digital has disrupted several deeply rooted industries - Now Re-shaping the Energy System

Changing landscape

- Energy Transition & Mobility Shifts
- Digitalization & other
- Shifts in Demographics & Consumer behaviours

Technology: faster and cheaper over the past ten years

- COST OF SENSORS: $1.30 → .60
- COST OF BANDWIDTH: 40x → 20x
- COST OF PROCESSING POWER: 50x →
- COST PER MB OF CLOUD INFRASTRUCTURE:

Key trends potentially re-shape several industries
Shell Digital Strategy

A coherent approach across Shell to realize and accelerate value through digital
led by business – supported by Digital COE

FIVE DIGITAL DESIGN PRINCIPLES

CUSTOMER/USER IS CENTRAL
DATA IS AN ASSET
BUSINESSES OWN DIGITAL
BUILD IN-HOUSE CAPABILITY
ACT OUR WAY INTO THE FUTURE

UNDERPINNING CRITICAL SUCCESS FACTORS

CAPABILITIES
OPERATING MODEL AND WAYS OF WORKING
LEADERSHIP, MINDSET AND BEHAVIOUR
Asset Integrity Inspection Today

- Asset integrity inspection data is getting greater by the year
- Need cost-effective solutions that can enable to detect elements of interest within the data
- Need scalable and computationally efficient prediction models
Artificial Intelligence and Machine Learning

Artificial Intelligence
Early artificial intelligence stirs excitement.

Machine Learning
Machine learning begins to flourish.

Deep Learning
Deep learning breakthroughs drive AI boom.

Source NVIDIA
Application of Machine Learning to Subsea Integrity Monitoring

3.3 TB of Data
1300h+ of video
605 logs

x 75

Offline

Real-time

Auto Eventing Log

Mantis
Application of Machine Learning to Subsea Integrity Monitoring

Acquire data in real time → Annotate some data → Train an NN → Inference → Detected objects
Deep Supervised Learning - Challenges

Database: 25,000 images
Labeling rate: 80 images/hr

312 hrs/database

Manual box annotation:
- Needs expert annotator
- ~80 to 150 images/hr
Data Mining - Semantic Data Extraction

Unstructured

- Other
- Strake
- Fairing
- Anode
- Bull’s eye
- Orientation level
- Indicator
- Umbilical buoyancy
- Anode measurement
- Buried flowline
- Free span
- Flowline joint
- Marine debris
- Other

Quasi-structured

- Other

Semantic data extraction

Seed models

Label and retrain

Data Mining - Semantic Data Extraction

Quasi-structured

- Strake
- Fairing
- Anode
- Bull’s eye
- Orientation level
- Indicator
- Umbilical buoyancy
- Anode measurement
- Buried flowline
- Free span
- Flowline joint
- Marine debris
- Other

Other
Data Mining - Semantic Data Extraction

3.2 TB unstructured data (videos and images)

1,319 h of video

Locate videos + Cross correlation + Frame extraction + Classification

>1,700 h → 26 h
Data Labeling - Multiuser Labeling

- Frames
  - Web server
  - Schlumberger annotation tool
  - Label schema
  - Annotation cache

- Labels

10 users
3 locations
15 classes
70,000+ labeled images
110,000+ labels

Platform-agnostic user
Real-Time and Embedded Implementation at the Edge

Intel Movidius

Nvidia TX2

Nvidia Xavier

Frames per second (FPS)
Real-Time Anomaly Logging

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1015</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1016</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1019</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1020</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1022</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1023</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1024</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1025</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1026</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1027</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1037</td>
<td>Damaged strake</td>
</tr>
<tr>
<td>1041</td>
<td>Damaged strake</td>
</tr>
<tr>
<td>1042</td>
<td>Damaged strake</td>
</tr>
<tr>
<td>1043</td>
<td>Damaged strake</td>
</tr>
<tr>
<td>1072</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1074</td>
<td>Missing strake</td>
</tr>
<tr>
<td>1075</td>
<td>Missing strake</td>
</tr>
</tbody>
</table>

4-20 x Faster Acquisition
Conclusions

- Machine learning is a powerful tool for automating and digitizing subsea asset integrity video analytics.
- Automation of the machine learning workflow is crucial to efficient ingestion, processing, and actioning of the results.
- This type of workflow orchestration (DATA $\rightarrow$ INFORMATION $\rightarrow$ KNOWLEDGE $\rightarrow$ ACTION) is key to unlocking digital opportunities in asset integrity in subsea and across a wide variety of oil and gas use cases.