RELEVANCE-AWARE INTUITION TECHNOLOGY TO MINIMIZE NON-PRODUCTIVE TIME AND LOSS OF REVENUE

Topic Areas:

Predictive maintenance of equipment, impact analysis of changes in subsurface environment, forewarning equipment degradation and non-productive downtime, context and relevance driven predictions.

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Prepared On: June 24, 2017

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SUMMARY

Owing to high operational cost and infeasibility of regular manual maintenance of the oil and gas facilities, the O&G industry is actively pursuing the idea of real-time remote monitoring and controlling of the facilities with a desire to reduce the operational downtime drastically. This project is in relation to generate forewarning of upcoming non productive time by applying the concept of *intuition* technology, an advanced form of predictive analytics.

Current trend in predictive maintenance is to apply sophisticated data science algorithms, however, this approach misses out on two critical challenges faced by the oil industry.

1) **Identification of "relevant" data:** Today enormous amount of data is stored across many business applications or operational applications. Identifying the "relevance" of information and connecting those pieces of data across applications before ingesting those into an analytics tool is not only time-consuming, expensive and painstaking but also in many cases, it is actually becoming almost impossible to achieve it for complex operations using standard data mapping approach. The need for a better tool is evident.

2) **Variety of data formats:** The intelligence that is relevant for predictions can come from any format of data. Some originate from equipment sensors that are stored in the Historian databases as time series, some are stored in applications' relational databases and some can come from comment-notes that the operators (human) take in natural languauge. This diversity renders large difficulty in near real time predictions for mitigating the failures or making appropriate decisions.

The novelty of our Relevance-Aware Intuition technology comes from the ability of identifying the relevance of data elements from vast pool of existing information and tagging them for ingesting into our cloud hosted Sixth Sense Suite and then processing structured, unstructured and semi-structured data in a connected way to generate automated, near real time forewarning against non-productive time. In a narrow sense, a scenario will be to genearate Lead-Time-To-Failure for an Electric Submersible Pump (ESP) or Gas Lift Compressors (GLC) in an oil rig operation.

Rig equipment failure can lead upto $15MM/day loss in revenue, therefore it is an important challenge the industry faces today. For the remainder of the whitepaper, we will consider rig equipment failure as the default use case though intuition technology can be applied to any use case; in fact, the application of Intuition Technology is not restricted to just upstream operation.

The belief behind our Intuition Technology is that monitoring the health state of a system alone, can not prevent it from failure; for that, the operational surroundings have to be modeled. An analogy can be with the human health. Unless a comprehensive model that includes the health monitoring and the surrounding germs monitoring is developed, sickness can not be avoided only by improving eating habits and exercise.

Therefore, our Intuition technology is designed to seamlessly ingest two kinds of data category, "core" and "ring". The Core data category includes all data that describe the health state of an object, say a rig machine; the ring data category includes all surrounding enviromental data that can potentially degrade the rig equipment health.

The technical value of our solution lies in three areas:

1. Identifying and tagging the relevant data needed for prediction from the vast pool of information existing in numerous applications or repositories in an oil compnay;
2. Adding external data to equipment degradation equation such as, the changing sub-surface temperature, tremor data which can be compounded with the Historian data, Well data, Laboratory Information data, Log data in a comprehensive way to generate forewarning against downtime.
3. Not all data are required to be ingested to begin forewarning. Data elements in each category can be added as and when available. This refines the quality of prediction.

TECHNICAL OVERVIEW

The discussion in this section is broken into several topics, e.g., industry challenges, solution architecture of Intuition Technology, understanding of data, our initial work and work ahead.

Challenges

Big-data analytics, cloud computing and Internet-of-Things (IoT), all are future defining technologies, however the approach marketed today for applying these technologies may need a complete shift if true industry problems are to be solved affordably and efficiently.

Most cloud platform players today are pushing their customers to move all their data into cloud with the promise of less in-house IT headache, better data security, unmatched computation power and a flexible service model where customers just can pay for their use. These are indeed great promises but moving all data from various data sources including IoT devices to cloud also means carrying a lot of "junk". Though this may mean good business for the cloud players, for clients such as oil companies, this not only means incurring much higher data transport cost but also means incurring higher computational costs on a perpetually recurring basis.

Too much data also means too much noise, which can easily make us clueless! Another drawback of too much data is loss of relevance or the meaning map of the data elements, esp., when the intelligence is segregated into multiple applications.

Oil industry typically uses many different software applications to carry out their business. The velocity of data accumulation can greatly vary between these applications.

Examples of some of the commonly used applications in the oil industry are given below:

1. Procount
2. Wonderware
3. Wellview
4. SAP Plant Maintenance
5. SCADA (Historian)
6. OFM
7. Spotfire and others.

Certainly, bringing quality data from all these sources together in a normalized way to ingest into a predictive analytics tool is a Herculean job. Most often it ends up consuming many months of hard, involved work, investing too much money in consultants and obtaining only fragmented results after all that. Marathon Oil demonstrated integration of key data platforms into one analytics tool, Tibco Spotfire for near-real-time, one-console view of current states of oil equipment (not prediction) which took 4 years of laborious effort. [1]

Therefore, a groundbreaking innovation is needed.

Architecture

We, in Senslytics turn our attention to learning from nature esp., in understanding how our human body esp., nervous system evolved with time to filter, ingest, and process information so smartly and on real time basis. Human body is like an extremely advanced IoT Analytics system. We are bombarded with exabytes of data every moment through our sensors e.g., eyes, ears, nose, tongue and skin however our body knows how to reject almost all that data and store only those information into our brain that are

relevant and important. The information and commands to respond to sensing, are carried out through the network of ubiquitous nerves, which is what the sensor network dreams to achieve one day to enable Internet-of-Things in a massive way. Our senses are trained with built in learning algorithm to filter noises at an incredible speed. This self-learning, real-time information filtration logic at every level of our body is the secret what makes this most complex big-data system extremely efficient and knowledge-gain driven.

Sixth Sense Suite Architecture is designed keeping human senses in perspective. Our relevance aware architecture filters unnecessary data and refines the dataset using relevance score at every step of processing. This is one of the underlying *key innovations* of our product.

Generating Lead-Time-To-Failure (LTTF) as opposed to age-old Mean-Time-To-Failure (MTTF) rooted in reliability engineering [2] is *another innovation* that is built into our product. Most data science techniques can only project probability of failure but cannot calculate the lead time beyond an estimation. Our method is novel in the approach that we calculate LTTF based on instantaneous equipment degradation rate determination and powerful trend analysis. A *third innovation* is the flexibility of our product to configure it for a given use case. There is a shopping cart concept being built which allows the product element to be connected in a logical way for solving the scenario. In a nutshell, there are three key innovations which lay the foundation of our Intuition Technology:

1. Relevance Generation
2. Ability to ingest structured, unstructured and semi-structured data to derive relevance driven LTTF forewarning
3. Shopping cart based product configuration catering to the need of specific use case scenario

Sixth Sense Suite is a cloud based Intuition platform that is by design scalable, modular, configurable, secured, big-data enabled, IEEE IoT standards compliant. It can send Lead-Time-To-Failure (LTTF) forewarning alerts to the mobile devices or to any dashboard or applications, as configured.

Sixth Sense Suite has three main Tiers e.g., Data Dendrons, Prognosis Platform and Wisdom Engine as shown on the high-level architecture diagram below.

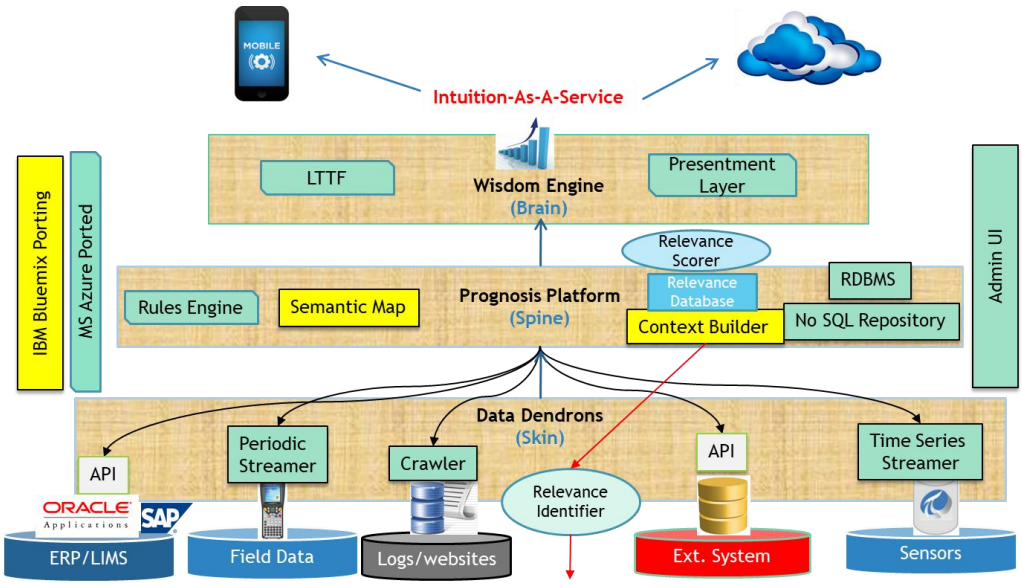

Figure 2: High Level Architecture for Sixth Sense Suite

- **Data Dendrons:** this tier has two main functions: one "relevance" generation in existing data pool and two, data ingestion into Sixth Sense Suite. Data Dendrons can be considered as the configurable connectors that can identify relevant data, then securely ingest and process them. The data can be structured, semi-structured or unstructured in nature. Data Dendrons support both pull and push mode of data transfer, where applicable. Dendrons consist of Streamers, Crawlers and APIs.

- **Prognosis Platform:** This tier consists of data repository and data filters. Prognosis platform can store relevant intelligence from vast amount of data and can support storage of structured (relational databases), unstructured (log, web, text) or semi-structured data (Historian).
- **Wisdom Engine:** This tier can predict context driven Lead-Time-To-Failure (LTTF) and present the prediction along with confidence limits and probability measure in a preferred presentment layer. The presentment layer could be mobile device, Senslytics cloud dashboard or any Analytics tool the oil company uses.

Core and Ring Data

Sixth Sense Suite divides all ingested data into two categories: Core and Ring Data. Core data category includes all data that describe the health state of an object, say a rig machine; the ring data category includes all surrounding enviromental data that can potentially degrade the rig equipment health.

Most rig equipment is constantly monitored for the automation purposes. Data such as, voltage, current, vibration, rpm etc. are collected from the equipment sensors and are stored in the SCADA applications (Historian database). Therefore, identifying and ingesting Core data into the Sixth Sense Suite is not difficult. Contrarily, Ring data is more complex. It requires the understanding of the causes of non-productive time in upstream operation which is explained in the next section.

Causes of Non-productive Time

Slugging, fines migration, liquid loading, corrosion, excessive loads, wax deposition, water coning, mechanical fatigue all can cause non-productive time in an operation [3], [4], [5]. To understand and monitor these reasons, we need to focus on the reservoir properties, fluid properties and fines properties. The changes of these properties not only can cause non-productive time but also can impact the rig equipment degradation towards failure. These properties are relevant to Ring Data. Table 1 gives a quick overview:

Reservoir Properties	Fluid Properties	Fines Properties
1. Formation Type 2. Initial Pressure and saturation of oil, water and gas 3. Porosity 4. Permeability	1. Phases (oil, gas and water) present 2. Compressibility 3. Viscosity 4. Density 5. Fluid Composition 6. Salinity of water	1. Specific Gravity 2. Average particle mass 3. Component analysis to determine erosive characteristics

Table 1: Factors determining Ring Data

Note: There are other factors that are not described by these properties, such as changes sub-surface environmental conditions e.g., changes in seismic activity that can greatly impact the operation. Tremor can cause the cement to crack leading to disastrous situations.

It is important to mention that based on the rig equipment category, different equipment can be affected differently by the changes in the properties mentioned on Table 1. Table 2 below attempts to map different datasets that should be monitored to order to forewarn performance degradation [6],[7],[8],[9],[10].

Causes	Meaning	Data	Data Source
Sucker Rod Pump			
Increasing mutual friction between rod and tubing	Free water production causes increase in the mutual friction between rod and tubing	1) Reservoir Properties 2) Fluid Properties 3) Production rate of Oil, Water and Gas 4) Dynamometer reading	1) Laboratory/Log data 2) Laboratory/ Log data 3) Flowmeter sensors/manual level measurment from the tanks 4) Dynamometer data
Gas Interference	A phenomenon that occurs when gas enters the subsurface sucker-rod pump. It does not cause premature equipment failure, but can indicate poor pump efficiency.	1) Reservoir Properties 2) Fluid Properties 3) Production rate of Oil, Water and Gas 4) Dynamometer reading 5) Setting depth 6) Compression ratio of pump 7) Pump Intake pressure	1) Laboratory/Log data 2) Laboratory/ Log data 3) Flowmeter sensors/manual level measurment from the tanks 4) Dynamometer data 5) Pump data sheets 6) Pump data sheets 7) Dyanometer data / fluid levels
Buckling	Rod buckling is the primary cause of tubing and rod wear failures. It is mainly caused by fluid pound and downward compressive forces.	1) Fluid Properties 2) Design specifications of the pump 3) Force to slide pluger in the barrel	1) Laboratory/Log data 2) Pump Manufacturer data 3) Dynamometer data 4) Dynamometer data
Sand Cutting	Sand particles will work their way between the barrel and the plunger, causing abrasion cuts commonly known as san cutting	1) Reservoir Properties 2) Fluid Properties 3) Production rate of Oil, Water and Gas 4) Bottom Hole Pressure 5) Fines size and concentration	1) Laboratory/Log data 2) Laboratory/Log data 3) Flowmeter sensors/manual level measurment from the tanks 4) Surface Pressure guage/chart recorder 5) Sensors on the pipeline and lab tests
Electrical Submersible Pump			
High Solid Content	ESPs can handle minimum amount of sand content caused by high production rates	1) Reservoir Properties 2) Fluid Properties 3) Production rate of Oil, Water and Gas	1) Laboratory/Log data 2) Laboratory/Log data 3) Flowmeter sensors/manual level measurment from the tanks
Progressive Cavity Pump			
Elastomer damage	Fatigue failures can be attributed to excessive cyclic deformation of the elastomer	1) Reservoir Properties 2) Fluid Properties 3) Production rate of Oil, Water and Gas 4) Oil and Gas Composition 5) Elastomer material used 6) Solid concentration	1) Laboratory/Log data 2) Laboratory/Log data 3) Flowmeter sensors/manual level measurment from the tanks 4) Lab Data/Log Data 5) Pump manufacturer data/report 6) Sensors on the pipeline
Gas Lift			
Paraffin problems	The cooling effect of gas expansion may aggravate the problem of lifting low gravity oil as it will compound the paraffin deposition problem.	1) Reservoir Properties 2) Fluid Properties 3) Production rate of Oil, Water and Gas 4) Gas used for injection and its properties and temperature 5) Depth of injection	1) Laboratory/Log data 2) Laboratory/Log data 3) Flowmeter sensors/manual level measurment from the tanks 4) Gas Lift design report 5) Gas lift design report
Gas compressor mechanical issues	An undesired effect, premature valve failure (broken valve plates, cracks of valve plates, wear on the plates, weak springs, seat worn) occurs in the process of	1) Injecetd Gas Properties and composition 2) Weather conditions - Temperature 3) Gas Compressor metal properties	1) Gas lift report 2) Weather data 3) Compressor manufacturer data

Table 2: Causes of failure for different rig equipment

Initial Work

Our cloud hosted Intuition platform - Sixth Sense Suite – is being developed for the past two years. The soution is based on several pending patents [11],[12],[13]. Currently, key innovative elements of the product are built and we are initiating the pilot testing phase. The beta version of the product is available now, further improvements and feature enhancements will be an ongoing process.

Our current capabilities include:

1. Identifying relevant datasets from applications using our proprietary Relevance Identification and Scoring mechanism. These can be any Operational or Business Applications, e.g., Well applications, SCADA systems, Laboratory Information Management System (LIMS), or ERP.
2. Ingesting identfied datasets into Sixth Sense Suite along with external data source e.g., Sub-surface environmental data, if available and relevant.
3. Ingesting natural language data source e.g., operator's log stored in any application or in PDF format in a repository in PDF.
4. Generating Lead Time To Failure (LTTF) for a rig machine that is associtated with the well data ingested, using our proprietary Wisdom Engine.

Once the main elements were developed, the relevance aware intuition technology was applied to predict an ESP failure use case. Quite a few historical failure datapoints (although some failure scenarios were simulated) were ingested into our platform in several occassions. Each failure scenario had the Core data and some Ring data elements. LTTF algorithm successfully calculated the lead time to failure in days and displayed on mobile device along with percentage probability of failure, confidence limit and likely reasons for failure. One particular test case description is given below.[1]

Core Data	**Data Nature**
Source: PI Historian	**Near Real Time**
Voltage	1 min
Current	1 min
Inlet Pressure	5 min
Outlet Pressure	30 sec
Vibration	1 min
RPM	10 min
Motor Temperature	1 min
Oil Reservoir Level	30 min
Key phasor Speed	60 min
Compressor Temperature	1 min
Ring Data	
Source: LIMS	XML Format. Periodic Tests for Water Content or Presence of Solids
Source: Operator's Log	
Notes from operator (In Spanish*)	Natural language data

Table 3: ESP Failure Scenario - Core and Ring Data

Historical Failure Data: In this round, there were 5 failure cases available from the operational historical data. 4 Failure data scenarios along with approximate timestamps and all leading cause data (some in time series) were ingested to learn the failure pre-cursor context. This knowledge was used to predict Lead-Time-To-Failure for the 5th failure.

[1] Exact reading, data, client or loction information can not be shared due to confidentiality agreement.

Three different failure causes were zeroed down for predictions.

1. Failure due to incorrect ESP operation. i.e. ESP running outside permissible min and max values
2. Motor Dead due to decrease of fluid and decrease of current and voltage and increase in Temp.
3. Deadhead due to presence of high volume of solid

Output: Lead-Time-To-Failure in days along with Probability and Confidence Limit and Time to Failure, which was sent to the mobile device.

Result: The prediction result was matched with the actual failure case (5th scenario) and LTTF showed excellent promise.

Table 4: Normal and troubled health status of equipment – displayed on mobile device

Work Ahead

We understand that our Intuition Technology has excellent promise however, as mentioned before different kinds of rig equipment perform differently under external conditions. We have not done a through work on ingesting and testing the impact of different variables on machine degradation and thus have not finetuned the predictions for different category of equipment.

Our next step is to ingest variety of data preferably all three kinds of data into Sixth Sense Suite (machine health data, subsurface environmental and crude oil properties data and operator's log) for the *same* well where the rig equipment is operational.

Our goal will be to watchdog the equipment and generate forewarning. Then repeat the same exercise a few more times. This can truly prove the potential of Intuition Technology in avoiding undersired events in rig operations.

Conclusion

If you are interested to carry out a pilot with Senslytics, please contact:

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