Featured Articles

Winning in Oil and Gas with Big Data Analytics

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OVERVIEW: Disruptive innovation in an unconventional oil and gas industry such as the shale industry offers a promise to change the world's economies. Advances in technologies such as horizontal directional drilling and hydraulic fracturing have fueled growth in the industry. However, oil and gas industry operators are facing tough business challenges. Shale sub-surface geology poses challenges in terms of proper characterization. Operators want to maximize production output from their acreage through assembly-scale operations. The orthodox approach of modeling the shale upstream operations have proven inadequate. Big data technologies can augment traditional methods in developing a deep understanding of the shale oil and gas operations to address the challenges faced by operators in a holistic way. Hitachi prioritizes the requirements by understanding such customer challenges through voice-of-customer surveys. Collaboratively creating solutions with customers, and collaboratively evolving the lifecycle of the solution with the customer as the focus has been championed by Hitachi's oil and gas analytics technology. Hitachi consolidates and builds analytics on data from multiple upstream processes which gives the customer multiple, rich contextual views.

INTRODUCTION

THE oil and gas industry can be broadly categorized into upstream, midstream and downstream processes organized along the direction of the stream. The upstream process comprises the following phases, in order: exploration, drilling, completions, and production. Advances in upstream shale oil and gas processes such as horizontal directional drilling coupled with completions through hydraulic fracturing technologies have increased the potential for recovering more resources. However, they have also added to the complexity of upstream processes. Shale sub-surface geology poses challenges in terms of appropriate characterization for the above processes. Operators want to maximize production output from their acreage through assembly-scale operations. Understanding the factors affecting the steep decline curve will help operators build the right strategies from these assets. Nonproductive time, especially in drilling adds to the total cost to the tune of approximately 30%. In sum, operators have to take difficult operational and top-side facilities planning decisions[1].

Understanding such customer challenges through voice-of-customer surveys, building a collaborative solution with the customer, and collaboratively evolving the lifecycle of the solution with the customer has been put into practice in developing Hitachi's oil and gas analytics solution. Hitachi's oil and gas analytics solution allows customers to ingest data from a variety of data sources collected through the lifecycle of the oil and gas assets, and discover deep insights from these cross-process dependent data sets. Hitachi's oil and gas analytics solution also allows the user to build custom hypotheses and evaluate them with a rich data set context.

In this article, the authors discuss at length the efforts involved in building the solution. Hitachi consolidates and builds analytics on data from multiple upstream processes which gives the customer multiple, rich contextual views. Hitachi is developing an agile platform that rapidly integrates data in varied formats from different sources, and enables analytical solutions to be built on top of it. The plan is to supply the solution to customers through multiple mechanisms, including software-as-a-service (SaaS). Finally, the analytics use cases are fine-tuned based on periodic feedback from customers.

DEVELOPMENT OF LANDSCAPE FOR DATA-DRIVEN SOLUTIONS IN OIL AND GAS INDUSTRY

As part of Hitachi's Global Center for Social Innovation – North America (CSI), Big Data Lab has pursued cutting-edge projects at the intersection of operation technology (OT) and information technology (IT) technologies. Hitachi's oil and gas analytics solution is the flagship project in the oil and gas industry that has followed the CSI philosophy of "collaborative innovation with customers," both in letter and spirit. As shown in Fig. 1, this entails the four-pronged step of engaging with the customer very early in the process to identify the problems; building, testing, and validating an initial solution prototype; scaling the solution to multiple customers; and finally rolling out a commercial solution. As the first step toward systematically understanding the requirements and challenges of our customers in the industry, Hitachi conducted a voice-of-customer exercise. This involved surveying 58 companies and interviewing a total of 22 people with operational decision making capabilities at large-cap, mid-cap, small-cap, and private companies as well as service providers about their current practices. The input from this broad spectrum of companies validated our notion about how traditionally oil and gas operators have looked at data across each individual process, and therefore, face challenges in terms of analyzing the data holistically to address cross-dependencies across processes. With the ability to handle multiple data from different contexts, rich domain centric attributes, superior analytical tools, and user-friendly visualization, Hitachi's oil and gas analytics solution is well-poised to address the challenges and provide value-added benefits as acknowledged by the customers.

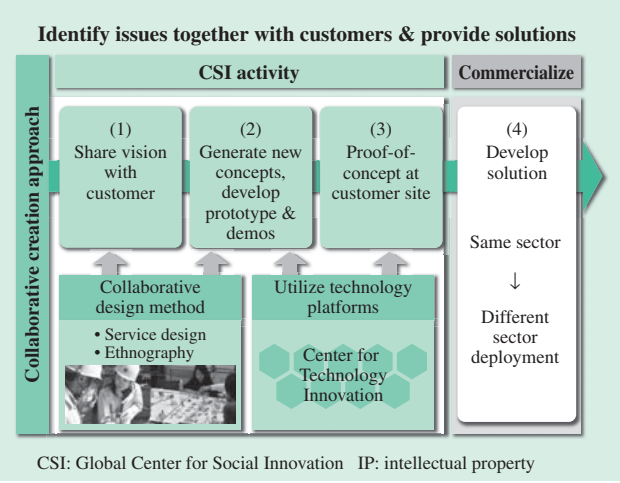

Fig. 1—CSI Methodology for Collaboratively Creating Innovative Solutions with Customers.
The methodology involves developing an industry landscape, developing competencies and core IP, validating the concepts through proof-of-concept projects at the customer's site, and commercialization of the technology (including addressing scale up and scale out requirements).

SOLUTION SCOPING AND DEVELOPMENT OF HITACHI'S OIL AND GAS ANALYTICS PLATFORM

Digital Oil Fields and Remote Operation Centers

With the advent of digital oil fields initiatives in the oil and gas industry, the expectation is that the digital oil field encompassing both instrumentation tools and the processes surrounding measurements, and data acquisition across the entire suite of upstream processes, will allow operators to capture more contextual data, with greater frequency, from all parts of the oil and gas value chain and analyze it in real or near-real time to discover cross dependencies in these data sets. Managers of the assets can hence better understand and address a wide range of topics including design decisions and improving process operational efficiencies, developing drilling strategies, optimizing reservoirs, well mechanics, and top-side facility planning and performance. The deployment scheme is shown in Fig. 2. Digital oil field initiatives combined with big data analytics can address the challenges while maximizing oil field recovery, significantly reduce non-productive time, and enable value chain integration through integrated operations and workflows. Digital oil field workflows combine business process operations and management with advanced information technology and engineering practices performed by cross-functional teams. Augmenting the digital oil field solutions with big data solutions will help realize the full potential of the digital oil field solutions. New-age big data analytics technologies promise to bridge the gap between domain experts, process managers, data scientists, and IT systems users.

Hitachi's Oil and Gas Analytics Solution Architecture

Hitachi's oil and gas analytics solution is unique and state-of-the-art in terms of its design and implementation. To address the challenges faced by

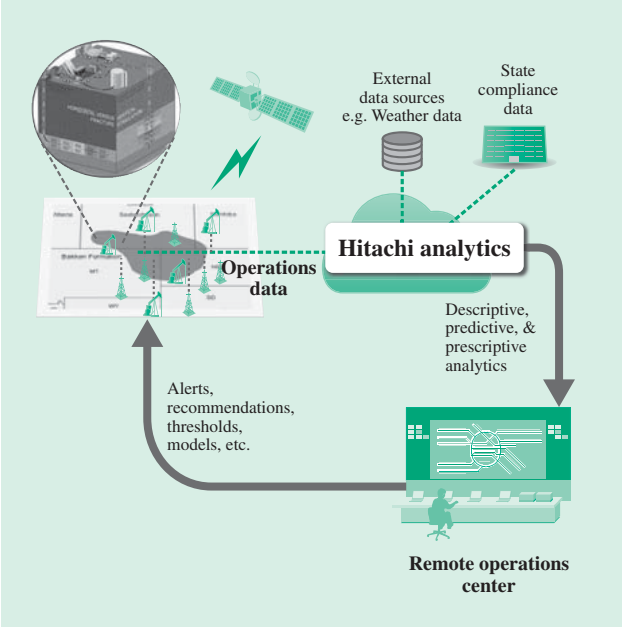

Fig. 2—Deployment Scheme for Hitachi's Oil and Gas Analytics Solution.
Digital oil field initiatives combined with big data analytics can address the challenges associated with maximizing oil field recovery and significantly reduce non-productive time.

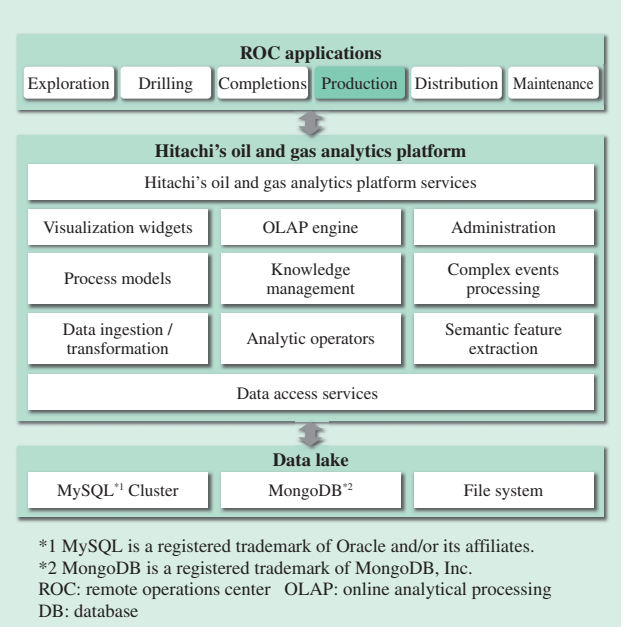

Fig. 3—Reference Architecture for Hitachi's Oil and Gas Analytics Solution.
Hitachi's oil and gas analytics solution framework is based on service-oriented architecture principles and enables rapid development of analytics-enabled oil and gas applications.

customers, Hitachi's oil and gas analytics solution framework allows for analytics-enabled applications. Hitachi's oil and gas analytics solution framework shown in Fig. 3 was developed based on service-oriented architecture principles comprising the following key services: a) data ingestion operators with the ability to ingest data in multiple formats (flat files, databases, streaming, and unstructured well logs), and persist the data in a data lake, b) data transformation operators that check for the consistency and integrity of the data and apply complex transformations to the data sets, c) a feature extractor to extract relevant *features* from the data, and d) analytics operators to develop custom hypotheses. The architecture boasts an integrated service-oriented interface to support both build-to-order and subscription-based business models.

The core Hitachi oil and gas analytics solution system integrates complex analytics and machine learning techniques seamlessly with the above-discussed key services. This capability provides the ability to ingest data from the entire oil and gas asset lifecycle offering a 360-degree view of the asset and its process models.

The system enables users to discover cross dependencies between data sets. The insights are designed to be learned both automatically by the system as well as allowing users to learn them through exploratory analysis. Example applications include learning the behavior of newer wells from older wells. Intent-based exploratory analysis in Hitachi's oil and gas analytics solution is provisioned by enabling management and execution of user-defined hypotheses, in which the user can visualize the results in line while constructing complex hypotheses. For this, Hitachi's oil and gas analytics solution provides a catalog of domain-level functionalities for the user to choose from. Each functionality is able to provide descriptive, predictive, and prescriptive views. Hitachi's oil and gas analytics solution also provides search capabilities over structured and unstructured data sets. The users can also define particular behaviors for the wells they are interested in and monitor this behavior across space and time. The system provides the capability to compare and contrast behavior of different wells by computing performance envelopes.

In a production environment, Hitachi's oil and gas analytics solution can be deployed using a core and edge model where the system-wide learning is done at the core and this learning is pushed to the edge to enable closer and faster monitoring of on-site wells. The system is offered in both stand-alone customized mode as well as in a secure SaaS mode.

Production Characterization Application for Digital Oil Fields Solution

To demonstrate the capability of the Hitachi's oil and gas analytics solution system, Hitachi developed a well production characterization application that analyzes data from over 30,000 wells in the state of North Dakota. Fig. 4 represents the digital wall depicting the dashboard developed for several application functionalities for a remote operations center. These include allowing oil and gas operators to monitor their assets through several key performance indicators (KPIs), including oil production, gas production, and gas flaring as well as water cut. These KPIs are calculated spatially as well as temporally via a decision cube. The future trends for such KPIs are built using statistical forecasting techniques. Further characterization of the production profile of wells is carried out using several features from different stages of the lifecycle of wells. These features include rock property description, perforation length, orientation of well trajectory, and density of well heads from drilling, and total water volume and chemical composition from completion. The features from underlying subsurface geology are extracted from unstructured handwritten files and correlated with production behavior using regression techniques(2). Total perforation length, and water volume used during completions have a statistically significant correlation based on Spearman's rank correlation procedure. Wells with similar behavior across all these features are identified using a composite similarity matrix.

Spatial characterization of wells is computed by clustering well heads using Gaussian mixture models to identify regions of high density. Neighborhood behavior is analyzed using the concept of "interference," where the distance between wells is computed not just between the well heads but also between the overall trajectory including the perforation stages. The impact of such distance on the initial production behavior of wells is analyzed.

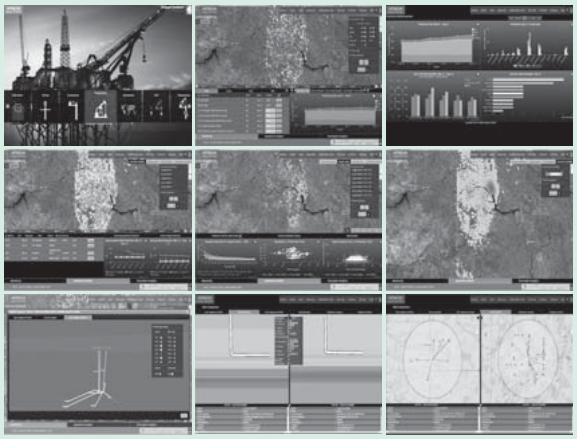

Fig. 4—Production Characterization Application for Hitachi's Oil and Gas Analytics Solution.
The dashboard illustrates several application functionalities integral to a remote operations center solution allowing operators to monitor and improve their asset operations through better knowledge and insights by applying big data analytics technologies.

CONCLUSIONS

Hitachi's oil and gas analytics solution is uniquely positioned to address customer challenges in terms of its ability to bring in data from multiple processes and provide a full suite of descriptive, predictive and prescriptive analytics to its customers. The robust architecture allows scalable solutions to be deployed securely. Working closely with Hitachi's partners and business units, Big Data Lab is rapidly furthering the development of Hitachi's oil and gas analytics solution as well as engaging multiple customers to enhance the solution.

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