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Multidisciplinary 4D visualization: Perspective from a software vendor

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SUMMARY

Introduction

The complexity and sophistication of modern hydrocarbon production systems have yielded an enormous increase in the volume and complexity of relevant data. Moreover, significant competing demands on the multi-disciplinary asset team mean that data must be synthesized, and the resultant decision making processed, at increasingly rapid rates. Such integration across geoscience and engineering disciplines is essential for maximizing recovery from today's complex reservoirs. A relatively recently emerging example of this trend is the need to incorporate time-lapse seismic data into the full-field model of reservoir development and depletion. The digital nature of the current workplace makes it natural that teams and enterprises will turn to computer software to help address some of these demands.

As a software vendor we are privileged with a unique perspective taken from across multiple global enterprises. Noteworthy, perhaps, is a consistency and similarity in the demands that operating companies make of software providers. This paper summarizes some of our findings and offers potential solutions for geoscience and engineering integration challenges.

Method

In this section we detail some of the requests often made by the multidisciplinary asset teams regarding integration software from vendors. We discuss the challenges faces, and some possible solutions.

Data Access

Almost certainly the biggest issue in achieving cross-disciplinary integration is data access. Typically an enterprise will have access to dozens of software products specific to subsurface data analysis, with perhaps even more vendor-specific data formats and protocols. Moreover, these data may be in different coordinate systems, with varying projections, ellipsoids, datum, and units. Furthermore these data can be constantly changing and updated: for example top picks in a well are liable for reinterpretation, reservoir simulation runs are constantly being refined, and production data can be assumed to be in a constant state of collection.

Two requests are most often heard from a team facing with this influx of data: access to *all* the data should be as rapid, seamless and transparent as possible (ideally with no overhead whatsoever); and there must be easy ways of finding and using the *correct* data, be that the most recent interpretation, the "best" history match, or the latest seismic processing.

In context however, asset teams are in a constant state of activity and have little or no tolerance for downtime. Hence software integration solutions that involve large-scale (hence disruptive) reformatting and migration of data are usually not ideal. Solutions have we have seen operate effectively include live links to the target data, without the need for data reformatting, and yet staying updated given changes in the source data. Data can also be flagged and tracked to capture the last and "best" approved version. Visual access works best as a technique to pick the necessary data from within a larger potential pool.

Dynamic / Temporal Data

Time-lapse or 4D seismic are only one of a multitude of dynamic (time-variant) data that are typical of a modern hydrocarbon exploitation system. Additional dynamic data include reservoir simulation runs, well / completion status, repeated well log data, PLTs, production data, pressure / temperature logs, tiltmeter / surface expression recording, and microseismic data, in addition to static reservoir property / structural models. A well-articulated need within many multidisciplinary teams is the need to better integrate time varying data with other diverse data streams to better understand reservoir

conditions and make optimal reservoir management decisions. Moreover, temporal diversity and wide-ranging granularity of such data is the norm: anywhere from microseconds in a passive seismic experiments to decades for a flow simulation run. In our experience, to fully understand and integrate chronological aspects of the field development, the rapid and easy access of the diverse temporal data should be as easy as access to the equally diverse, yet more familiar, spatial data (Figure 1).

Figure 1 Temporal data integration. Left panel shows a reservoir simulation grid at a specific time-point displayed with ternary colours: red, blue and green representing gas, water, and oil respectively. The production fluids from the well highlighted in blue are shown in the time-series plot at the upper right (oil, water gas, along with flow hours). Lower right is a temporal plot for the simulation grids highlighted in white in the 3D view. Note the strong correlation between the predicted simulation fluids and the measured production. Only by having easy access to all the available 4D data can correlations like this be made on-the-fly for real time decision making.

Qualitative Analysis

Once data entry challenges are overcome, the primary responsibility of the team is the integration of these data to achieve better decision making, for example planning new infill drilling locations, depletion strategies, monitoring water floods, and general reservoir surveillance.

Figure 2 An example of a visualization environment using multiple views allowing simultaneous manipulation and comparison of a range of different properties or time steps from a single simulation

run. Likewise, geologic uncertainty, such as fault transmissibility, could be rapidly reviewed across multiple realizations with consequent changes in reservoir initial conditions fed back to the simulator.

Given the high density of coincident spatiotemporal data, tools and techniques for visualizing and analyzing overlapping datasets are key (Figure 2). Solutions can include multiple model windows, animations, data grouping, and visibility cycling. Moreover, decision making sessions often include experts from a variety of disciplines, management, and external stakeholders. In these situations clarity and ease of access to visual presentations significantly reduces overhead and leads to better-informed decision making.

Quantitative Analysis

Regardless of power and scope of available qualitative integration techniques, much data analysis, and hence interpretation, depends on flexibility quantitative analysis techniques. Usually requests of this nature are for the collocated statistical comparison of spatially overlapping, yet dissimilar datasets. Typical examples are the need for quantitative comparison of well logs with seismic volumes or reservoir simulation grids. In this specific case an essentially 2D data set (the well log) is being compared to a space-filling 3D data volume.

The notion of quantitative comparison also extends into the temporal domain. The time domain of simulation grids may be compared to the time-domain of time-lapse seismic data, for example, requiring a 4D back-interpolation across diverse geometrical and temporal geometries (Figure 3).

Figure 3 *Quantitative comparison of co-located, yet dissimilar, datasets can take many forms. One of the more complicated is a full 4D to 4D back interpolation where the dynamic time-lapse seismic amplitude volume (left) is sampled into the reservoir simulation cellular grid geometry (centre). Once this back-interpolation is performed results can be analysed in a cross-plot or other statistical tools.*

Well Planning

One of the primary outputs of the subsurface data integration effort are locations for in-fill drilling and the sighting of injector / disposal wells, sidetracks etc. It makes sense, therefore to have a well planning capability directly incorporated into the teams primary co-visualization environment.

Example

In this example integration software shows data from a turbidite channel reservoir from offshore northwest Europe. The measured 4D seismic response was qualitatively compared to the predicted reservoir simulation flow. It was observed that between the 2002 and 2004 seismic monitor surveys, the pressure was not maintained in the lower producing reservoir, an observation not consistent with the prediction from the reservoir simulation (Figure 4).

Furthermore, analysis of an upper sand revealed much higher than expected pressures in that interval. It was concluded that the perforations into the lower sand were blocked, leading to a lack of water injection into that interval, and much higher than expected water volumes into the upper sand. Remedial action was taken. Not until all the relevant data -- reservoir simulation, time-lapse seismic

data, well and completion locations, and production data -- were analysed visually and in an integrated fashion was this important insight made by the asset team.

March 1998

November 2002

September 2004

January 2005

Figure 4 Data from an offshore reservoir is shown at four time-points: March 1998 time point shows extracted amplitude data from top reservoir in the base (1993 base survey), red anomaly indicates a gas cap above an oil leg that is already being produced. November 2002 time point shows an amplitude difference map between the 1993 base and 2002 monitor surveys; green colours indicate maintenance of pressure conditions in the reservoir. By September 2004 a new monitor survey illustrates significant pressure drop in the reservoir, and a lack of injected water support, production data are also shown. This observation was not consistent with the reservoir simulation (January 2005 time point). See text for more details.

Conclusions

The challenges facing modern hydrocarbon development groups in complex, usually offshore, areas can be notably consistent across the industry. From our perspective as a software vendor key issues are data access, chronological appreciation, and rapid (near instantaneous, interactive) quantitative analysis features, yet with ease-of-use and ease-of-implementation of the available integration solutions. Moreover the communication power of the resulting visual solution is critical, as these data are often used in team and partner meeting decision making situations wherein not every participant can be assumed to be an expert in the particular information under discussion.

Solutions to these various problems can be provided by a proactive and engaged software development industry. In our experience such solutions are best developed as projects in close collaboration with the end-users, with proficient communication channels for the rapid prototyping of ideas and the iteration of possible solutions.