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The HIT Cube; Matching Monte Carlo Simulated Pseudo-Wells to Seismic Data for Predictions with Uncertainties

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SUMMARY

Pseudo wells are realizations of newly drilled wells within a study area and have found widespread use in reservoir characterization. The Hit Cube assigns spatial positions to stochastically generated pseudo wells with the aim reservoir properties throughout a seismic cube.
In this method two groups of pseudo wells (namely Hit-targets and False-Hits) are generated through Monte Carlo simulation. Synthetic traces from these pseudo wells are then matched with real traces at every sample position throughout the seismic volume. A 'Hit' exists when the similarity between traces exceeds a defined threshold and the rock properties defined by both considered the same. Output cubes from the algorithm show the Hit patterns, model rankings and scores for all pseudo wells at each sample position. Probability cubes are obtained as a ration of the Hit and Score cubes of the targets to those of the False-Hits.
Reservoir presence and distribution within a 3D migrated seismic dataset from a deltaic setting was investigated using the procedure and algorithm. The predicted distribution of gas-filled units defines distributary channel systems known to be present in the area while water saturation logs in the three real wells confirmed accurate prediction of hydrocarbon presence.

Summary

Current applications of stochastically generated pseudo wells are limited because they do not have geographical locations. A workflow and algorithm (hereinafter called The Hit Cube) have been developed to assign spatial positions to stochastic generated pseudo wells within a 3D seismic volume. Results from an application of the workflow and algorithm to the characterization of a gas field in a deltaic environment show the reliability of the technique.

Introduction

Pseudo wells (1D stratigraphic columns with attached well logs) are realizations of newly drilled wells within a study area and have found widespread use in reservoir characterization (e.g. de Groot et al., 1996; Oldenziel et al., 2002; Spikes and Dvokin, 2004). The Hit Cube assigns spatial positions to stochastically generated pseudo wells with the aim to predict reservoir properties with relative uncertainties throughout a seismic cube.

In this method two groups of pseudo-wells (the Hit-targets and the False-Hits) are generated through Monte Carlo simulation (see Mardia et al., 1979; Deutsch and Journel, 1992; de Groot, 1995). Synthetic traces from these pseudo wells are matched with real traces at every sample position throughout the seismic volume. A 'Hit' exists when the similarity between the model and real seismic traces exceeds a defined threshold- the rock properties defined by both are considered the same. Outputs from the algorithm include cubes of Hits (time thickness of the targets), Scores (cumulative similarity) and Winner wells (model with highest similarity) at each sample position. Probability cubes are obtained by dividing the Hit and Score Cubes of the Hit-targets by those of the False-Hits.

Reservoir presence and distribution within a 3D migrated seismic dataset from a deltaic setting was investigated using the procedure and algorithm. The predicted distribution of gas-filled units defines distributary channel-systems known to be present in the area while water saturation logs in the three real wells confirmed accurate prediction of hydrocarbon presence.

The Workflow

Pseudo wells are generated using real well data, geological knowledge and Monte Carlo statistics according to a stratigraphic integration framework (see de Groot, 1995).

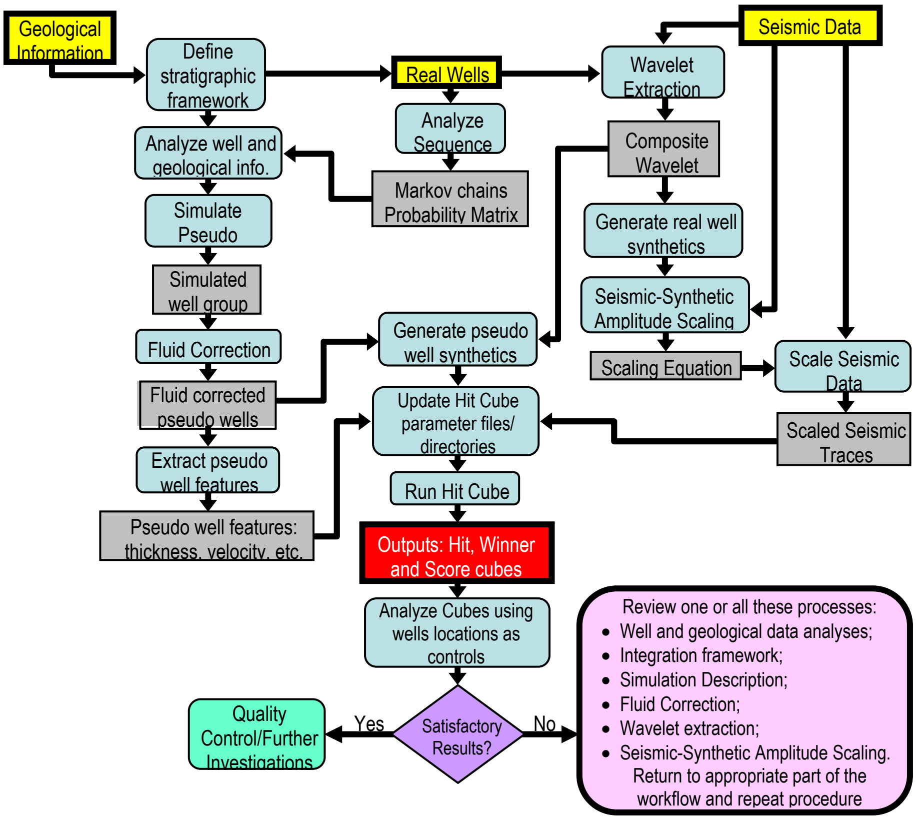

FIG. 1: Hit Cube workflow showing the available data (yellow rectangles), processes (rounded ovals), generated data (grey rectangles), and final outputs (red rectangles).

Two well groups are generated:

- Hit-targets: pseudo wells with desirable properties (e.g. thick gas-filled reservoirs)
- False-Hits: pseudo wells with undesirable properties (e.g. brine-filled reservoirs)

After accounting for fluid effects, synthetic seismic traces are generated for all pseudo wells using a composite wavelet extracted from the seismic data. The real and synthetic seismic traces are then scaled to similar amplitude ranges. The workflow is summarised in Figure 1.

The Algorithm

The Hit Cube algorithm matches the synthetic (model) traces with real traces at every sample point (on a trace-by-trace, sample-by-sample basis) throughout a seismic cube. If the match (similarity) between the two traces is above a specified threshold, rock properties defined by both are considered the same and a 'Hit' exists. The algorithm structure is shown in Figure 2. The degree of separability of the pseudo well models (and hence the minimum useable similarity threshold) is determined by either cross-matching the Hit targets and False Hits or by using a composite similarity plots (for a wide range of possible rock property changes).

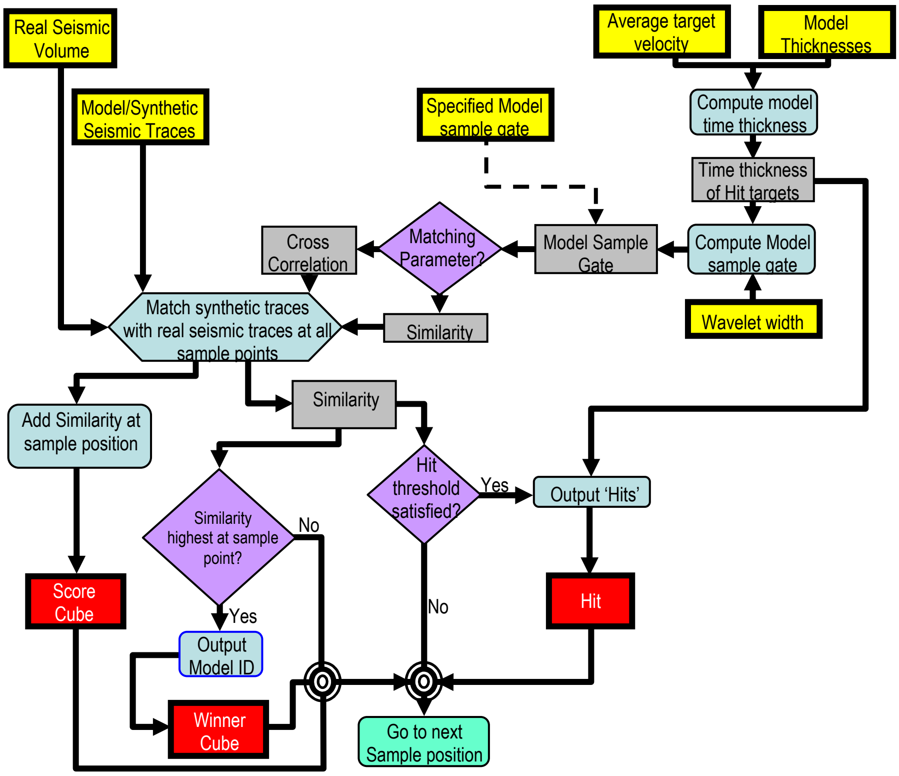

FIG. 2: Hit Cube algorithm showing the input parameters (yellow rectangles), processes (rounded rectangles), generated data (grey rectangles), and final outputs (red boxes).

Outputs

Primary outputs (see Figure 3) at each sample position include:

- Hit Cube: integer sums of Hits equivalent to the time-thickness of the Hit targets;
- Score Cube: sum of similarities/correlation-coefficients; and
- Winner Cube: model ID's of pseudo wells with highest similarity.

Secondary outputs include:

- Probability of Presence : Ratio of Hits Cube from the Targets to that of the False Hits
- Probability Score: Ratio of the Score Cube of the Targets to that of the False Hits

Case Study

Using the proposed workflow and algorithm, reservoir presence and distribution within a 3D migrated seismic dataset [Area: 20x14.4Km^2; TWT: 1400-2800ms] from an offshore deltaic setting was investigated using three wells (A1 to A3) as controls. The area is dominated by fine-grained clastic Pliocene sediments. Sand-rich channel systems form the major hydrocarbon exploration targets. dGB's GDI package was used for the analyses and integration of well and geological information (into a stratigraphic framework) and for pseudo well simulation. Hampson-Russel's STRATA™ and dGB's OpendTect were used for wavelet estimation and visualization respectively.

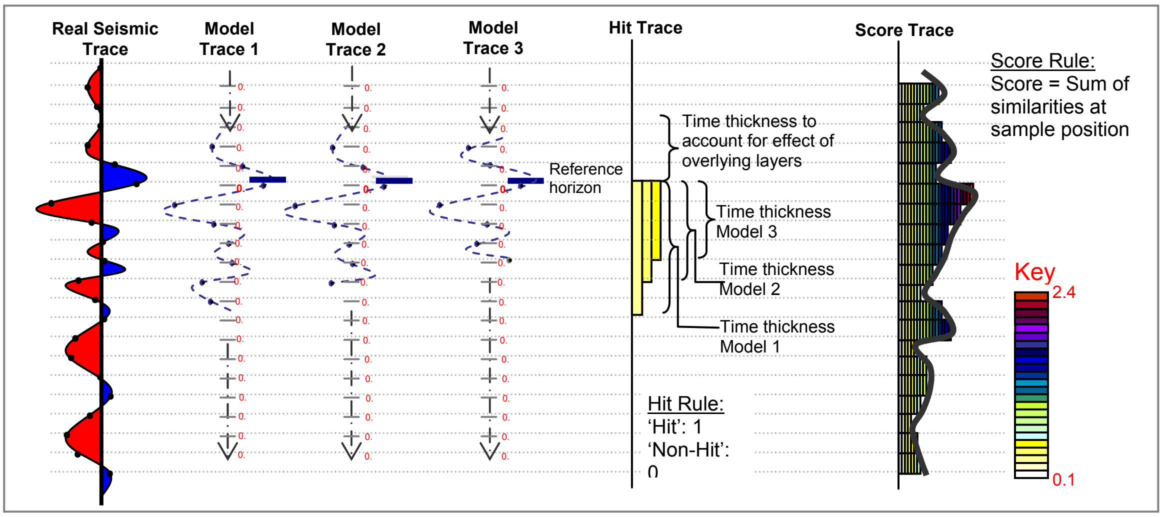

FIG. 3: Schematic illustration showing the generation of a Hit and a Score trace.

100 stochastic models each were generated for the Hit targets (gas-filled reservoir) and False Hits (brine-filled reservoir). The cross-matching results (not shown) suggest a minimum useable similarity threshold of 0.55. Selected Hit, Score and probability results (at 0.65 similarity threshold) in parts of the seismic volume are presented in Figures 4 (Green colour indicates highs while yellow indicates lows). The ovals indicate known locations of hydrocarbon presence in test well A2. In Figure 5, the green parts have high probabilities, while the yellow parts have the least probabilities of containing hydrocarbons. The potential gas-filled units define channel features known to be present in the study area (however not all the features have high probabilities). There is a good match between the probability results and water saturation log from well A2 (see Figure 5) as well as segments of wells A1 and A3 (not shown).

Conclusions

A workflow and algorithm which allocates spatial locations to pseudo wells within a seismic volume has been developed and tested. Prediction of reservoir presence and hydrocarbon distribution using the workflow and algorithm has also been demonstrated. In the case study, predicted reservoir distribution defines distributary channel systems known to be present in the study area. Water saturation logs in the three real wells confirmed accurate prediction of hydrocarbon presence. Further tests and development of the concept and algorithm (e.g. to include AVO effects) are on-going.

Key References

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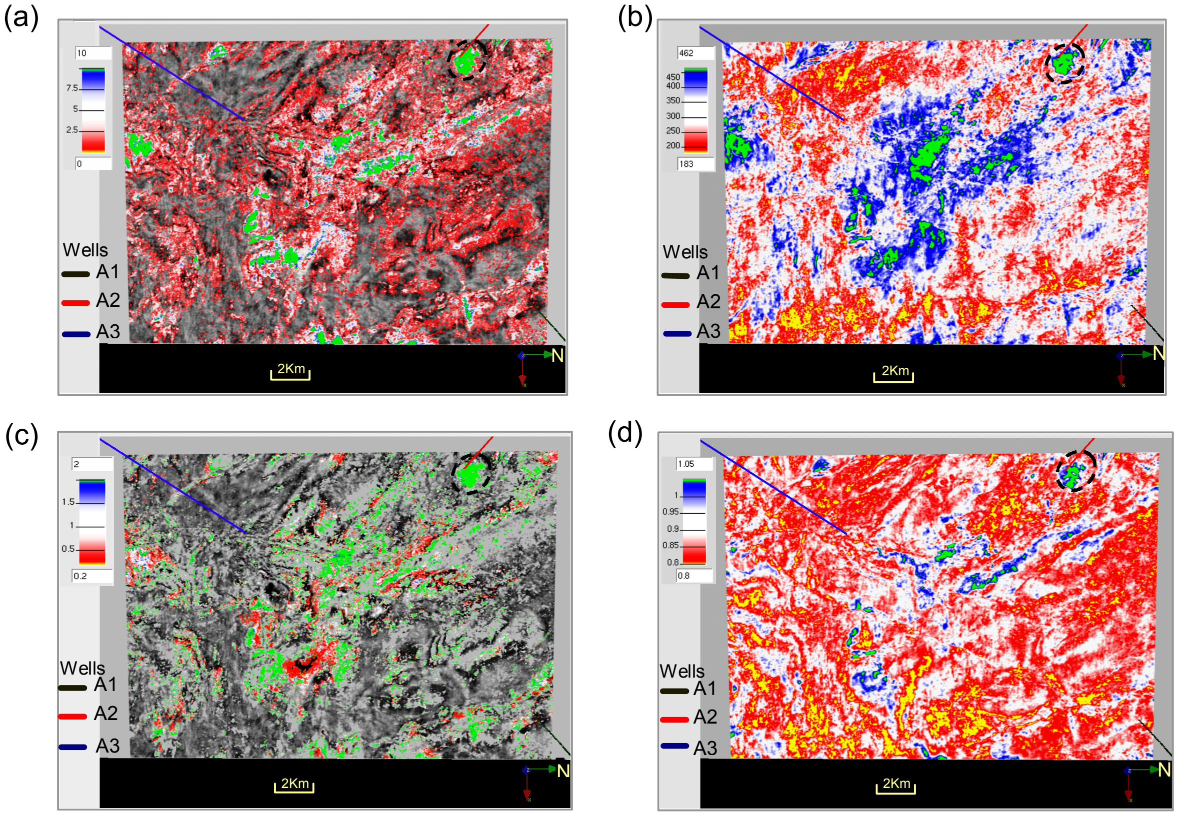

FIG. 4: (a) Hits (b) Scores for the targets. (c) Probability of presence (d) Probability score.

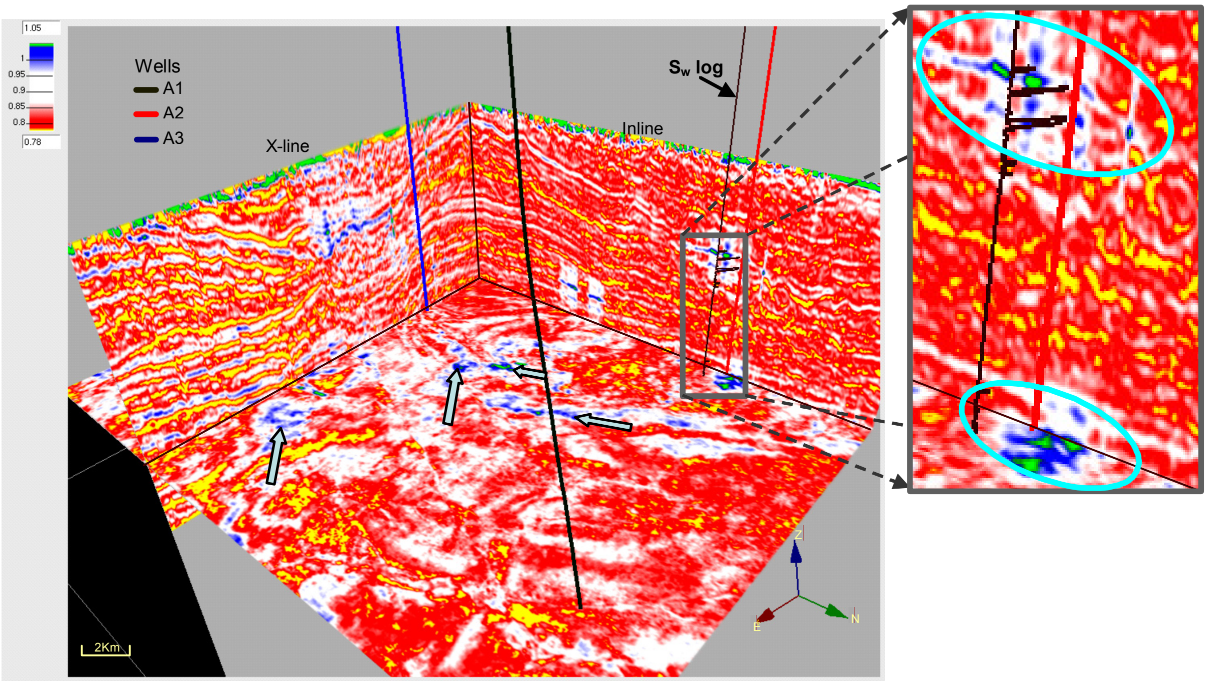

FIG. 5: 3D view of the probability score [Crossline 1212, Inline 1722, Time Slice 2308ms].