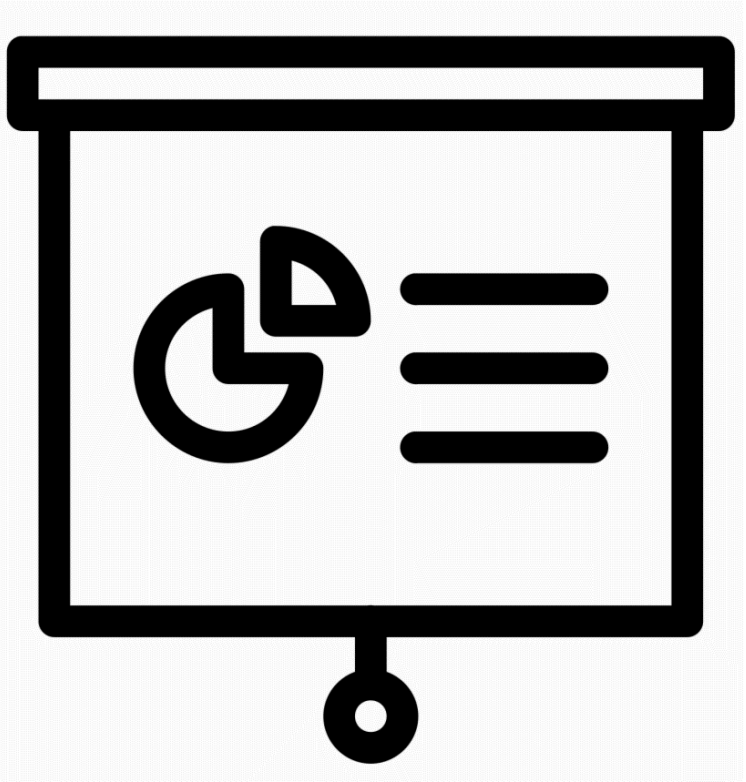
Automated Well Log Pattern Alignment and History-Matching Techniques: An Empirical Review and Recommendations

DEVEX 2022

ANSA

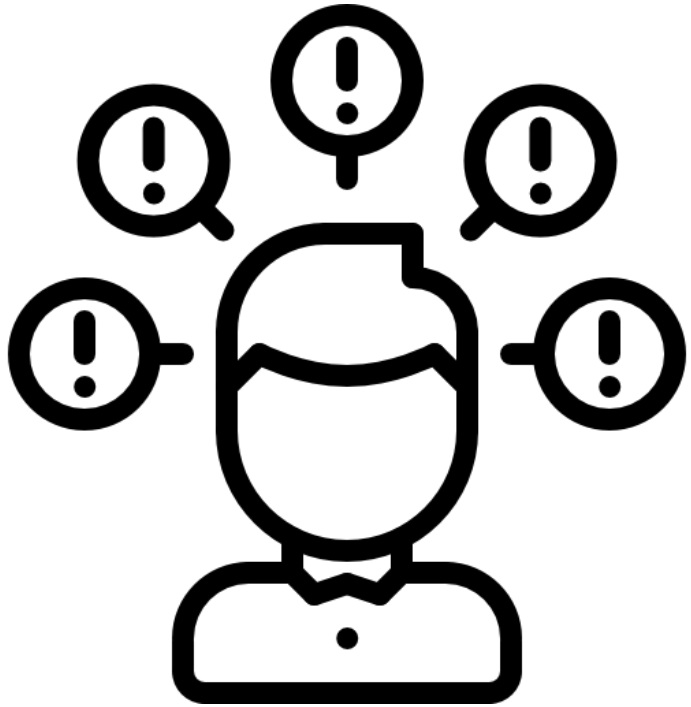
Outline

- The depth matching problem
- Approaches to depth-alignment
- Dynamic Time Warping (DTW)
- Constrained DTW
- Correlation Optimised Warping (COW)
- COW: Key challenges and the way forward
- Conclusions



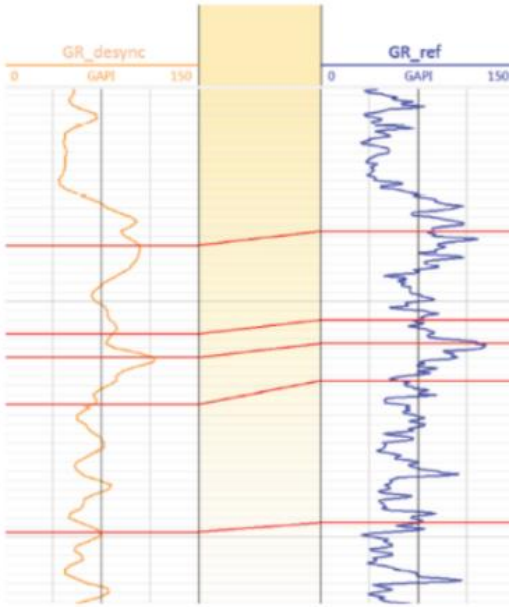
The depth matching problem

- The fullest picture is usually formed by the combination of multiple Logs, acquired by different companies, using different conveyance methods at different times
- These multiple Logs are never perfectly “on depth” from the get go
- Before Logs are depth-matched and can all be cross-referenced, it is often impossible to further process and analyse the data



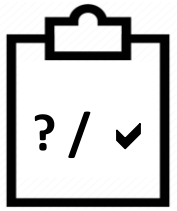
Approaches to depth-alignment: concerns

Manual Approaches



Subjective: different people will generate different results

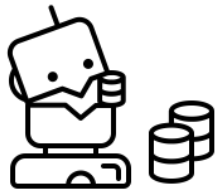
Time-consuming: how long will it take to match 1 million feet worth of data



Lack of consistency: no consistent metric for QC

Approaches to depth-alignment: concerns

Automated Approaches



Machine learning methods are very **data hungry** and often require re-training to achieve the best possible performance for each type of data

Methods can be extremely **computationally heavy** requiring cloud computing access

“Black-box” solutions are often met with **scepticism** by customers

Approaches to depth-alignment: desired outcome

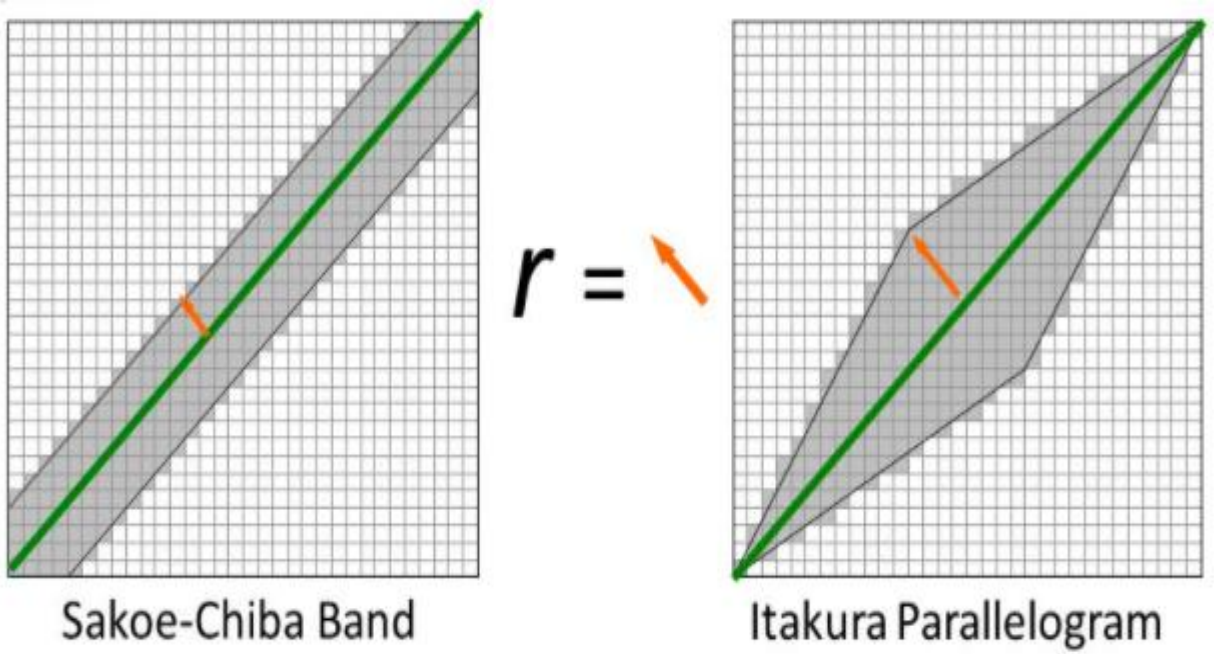
Automated Approaches

- A performing, shape-preserving, light-weight, easy to implement and deploy, automated depth-alignment technique
- Data type agnostic
- Easy to scrutinise and understand

We therefore revisited, reviewed, and sought to improve the known warping techniques – DTW, constrained DTW, and COW.

Dynamic Time Warping (DTW)

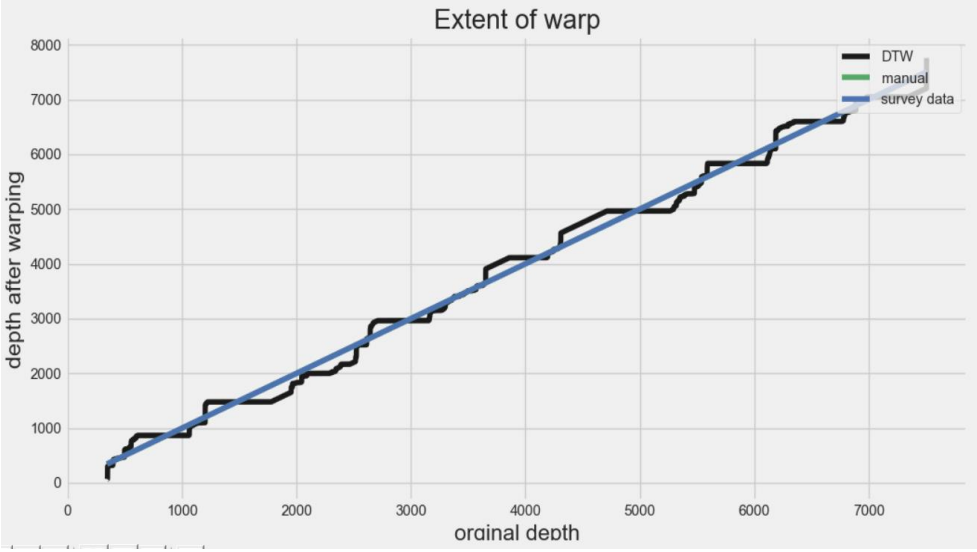
Two popular global Constrained DTW



r : window size or max-slope

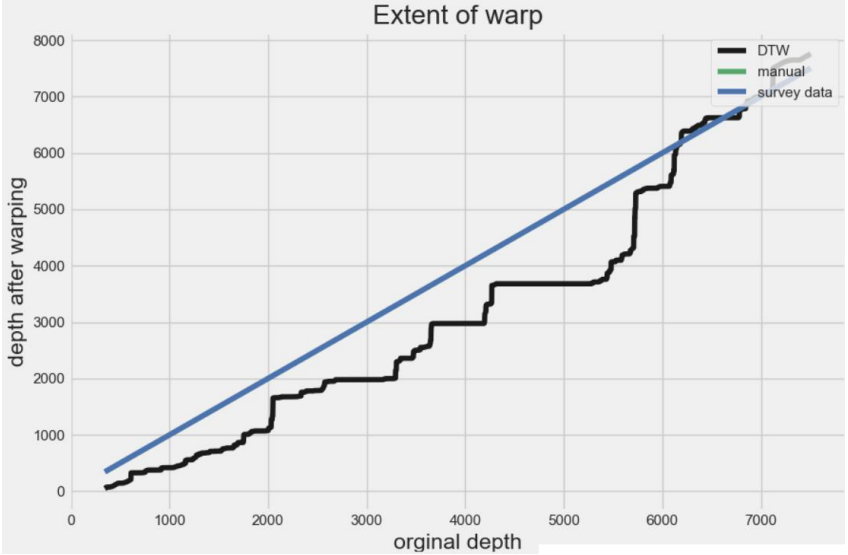
Constrained DTW

Sakoe-Chiba band on a Z-score normalised median filtered signal (r = 2)



Correlation with reference : 0.7187
Correlation with manual: 0.8133

Itakura parallelogram on a MinMax normalised SG filtered signal (r= 2)



Correlation with reference : 0.9099
Correlation with manual: 0.6225

DTW and Constrained DTW: Summary

- Filtering and normalisation have improved the results of dynamic time warping.
- Constrained DTW improved the warping quality.
- DTW and constrained DTW cost-function is sub-optimal.
- They are not shape-preserving.

Not quite there…

Correlation Optimised Warping (COW)

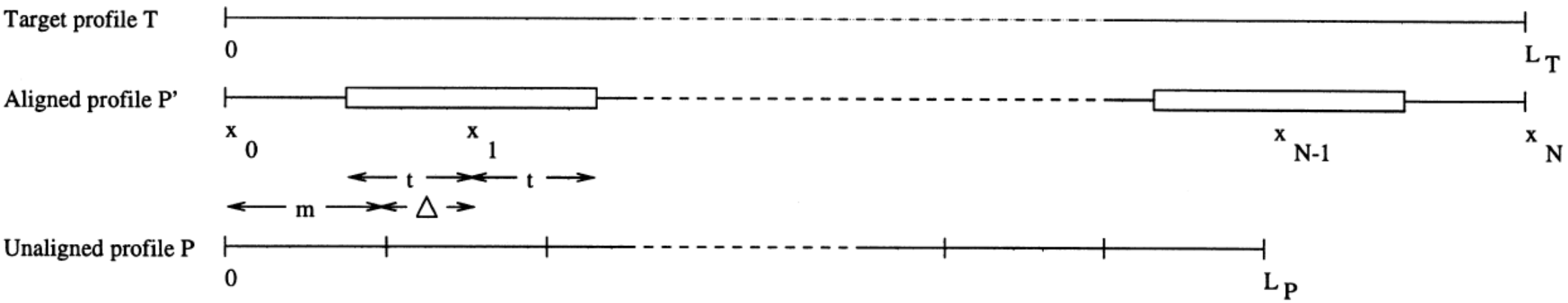
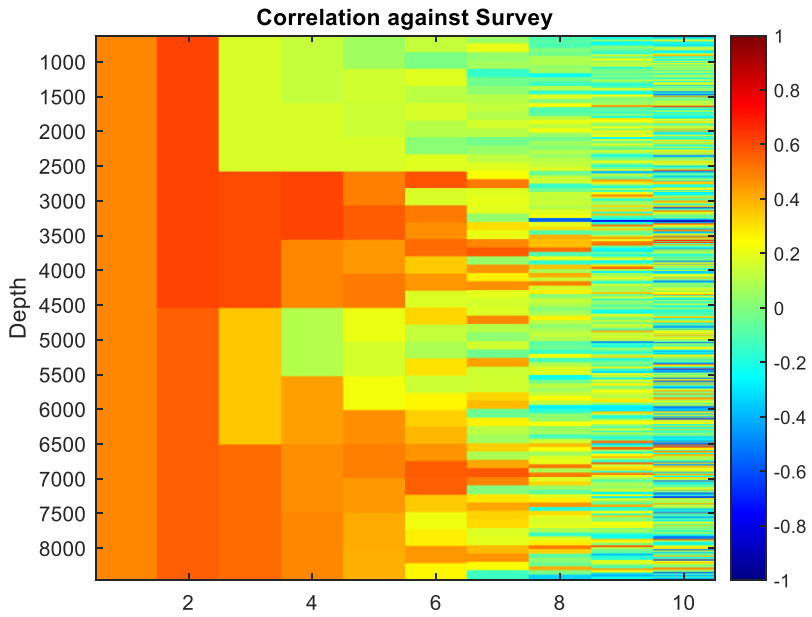


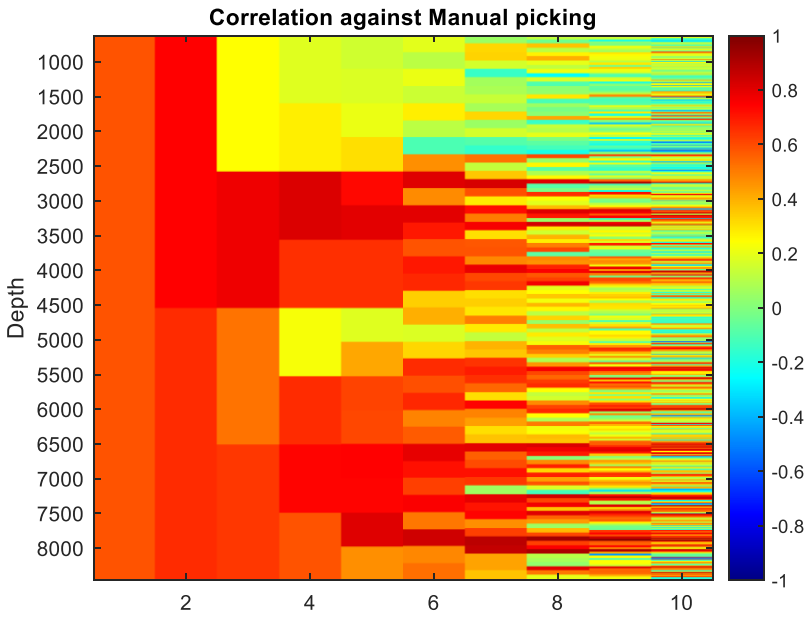
Fig. 1. Schematic presentation of the structure of the optimal warping problem.

Correlation Optimised Warping (COW)

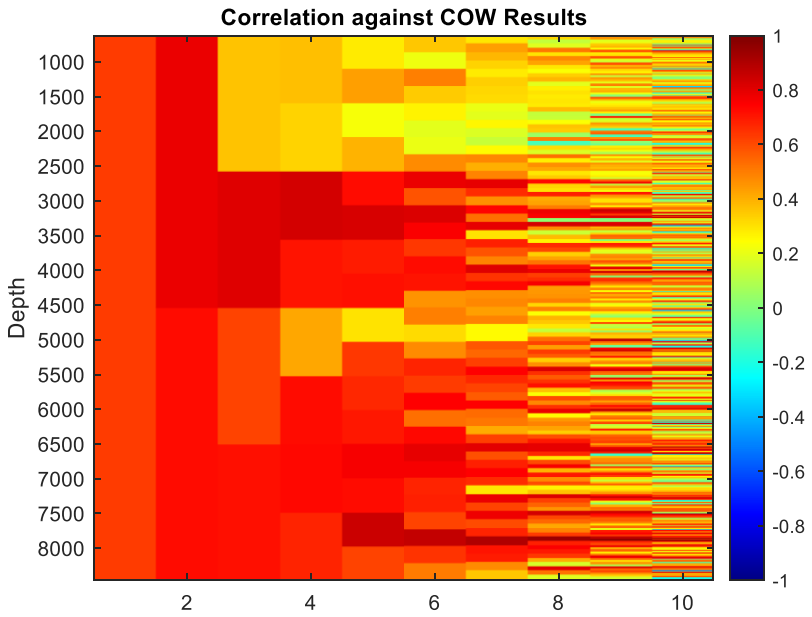
Correlations of the reference log with other logs



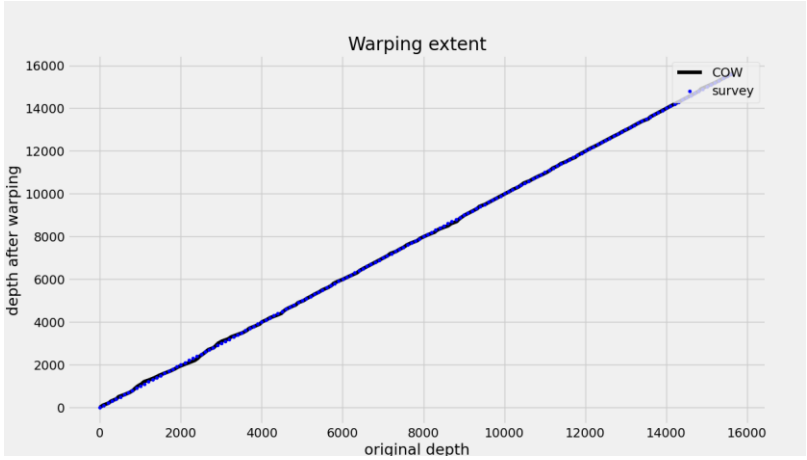
Global Correlation = 0.4826

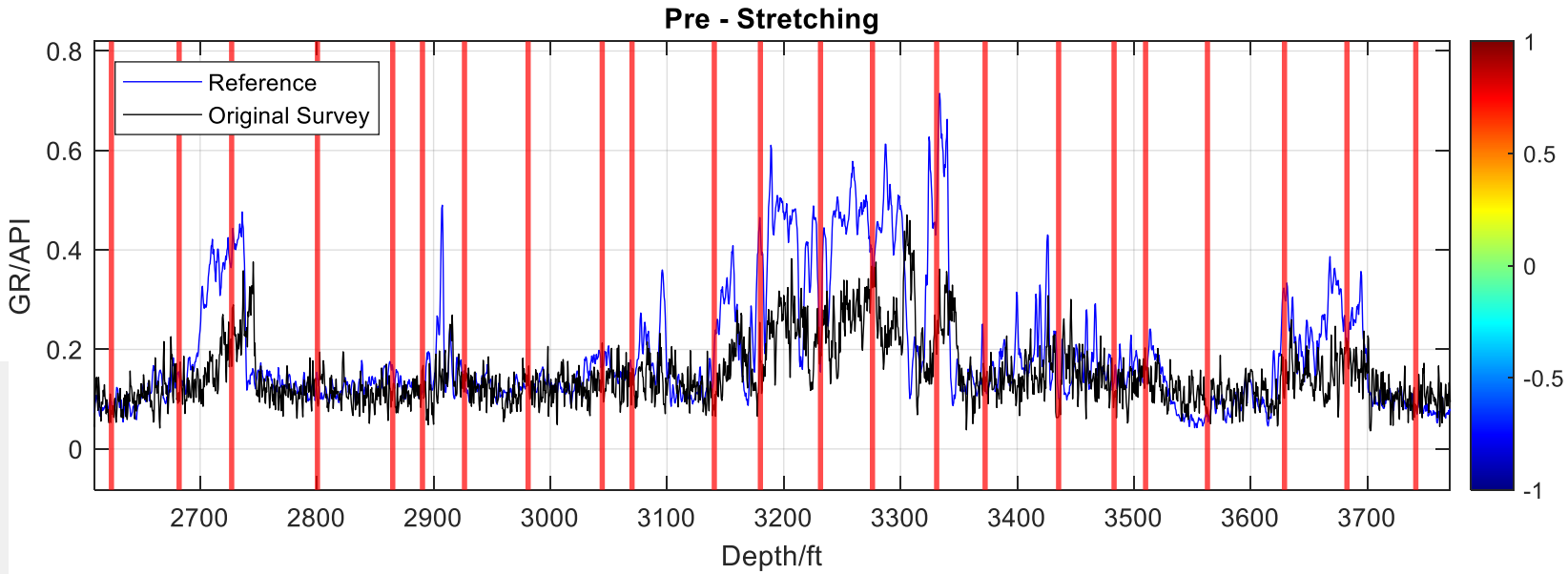


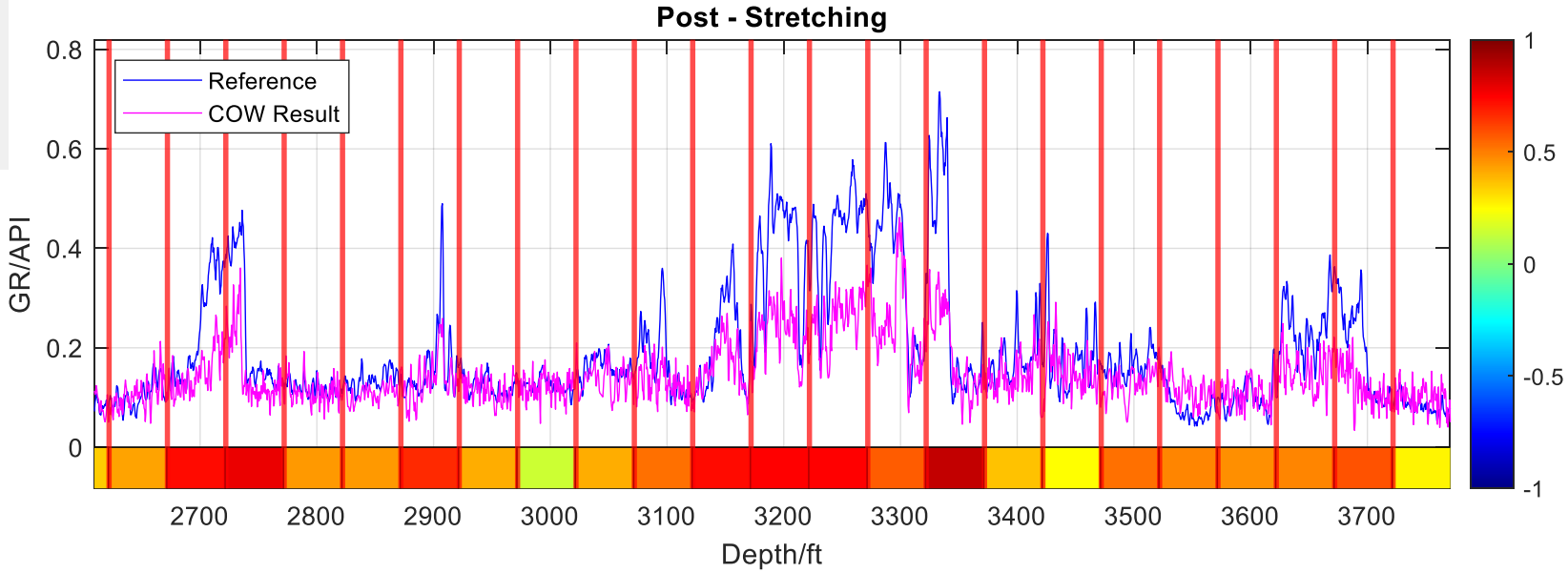
Global Correlation = 0.5828



Global Correlation = 0.6307


Warping extent
COW
survey
depth after warping
original depth
0
2000
4000
6000
8000
10000
12000
14000
16000


Pre - Stretching
Reference
Original Survey
GR/API
Depth/ft
0
0.2
0.4
0.6
0.8
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
1
0.5
0
-0.5
-1


Post - Stretching
Reference
COW Result
GR/API
Depth/ft
0
0.2
0.4
0.6
0.8
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
1
0.5
0
-0.5
-1

COW: Key challenges & advancements

- The original implementation requires manual selection of parameters, different segment lengths and slacks
- Bad parameter selection can generate very poor matches

What is needed?

- Novel pre and post processing techniques are required
- Automatically determination of best parameters and sensitivity analysis necessary to prevent over reliance on parameter selection
- Performance / Optimisation issues need addressing

Conclusions

- Existing automated log-alignment methods have been reviewed
- COW has shown a **better performance** than DTW and its variants
- COW has **optimisation issues** which can and have been addressed by our research
- New method delivers **superior accuracy** and **speed** with less reliance on manual parameter selection
- Production use of our code has allowed ANSA's analysts to **save hundreds of hours** of manual processing

Thank You

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