A calibration method for depth imaged volumes

Dayse Daltro, João Roberto Simões B. dos Santos, Neiva Zago, Jorge Campos PETROBRAS S/A, Brazil
Andres Estrada Schlumberger Information Solution, US

This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

Abstract

PETROBRAS has developed a new methodology for time to depth conversion using image rays (Filpo et al). It shows to be more adequate than vertical ray techniques when dealing with complex geological settings, including also well adjustment inside the process. Is proposed an additional accurate calibration to be applied after the image-ray time-to-depth conversion with the goal to honor the geological markers depths at the wells. This strategy was applied in an oil field which is located in ultra deep waters offshore Brazil. This oil field has an important turbidite reservoir structurally and stratigraphically complex. Because all the involved goals have very high associated costs it is critical to estimate the best possible depth at the top of the reservoir.

The results of this accurate calibration were considered very good where the geological markers were successfully tied to the seismic data.

Introduction

The image-ray time-to-depth conversion requires a proper macro-velocity model. In this work, the velocity model was built using an in house Petrobras technology. The results obtained by this procedure of time-depth conversion showed to be much better than those obtained from the traditional vertical ray conversion. This new method also allows the calibration of the result with depth information obtained from well data during its application. In spite of the good precision of this methodology, small differences on depth can occur when we compare the results with the true depths obtained by wells.

The challenge of this work was to create a methodology that makes an additional accurate calibration on depth resulting from the image-ray conversion, using interpreted geological markers. This methodology showed to be a fast process and easy to be applied when new data is acquired from wells.

The methodology applied for time-to-depth conversion

This methodology consists of considering different trajectories instead of vertical rays, like the normal rays and the image rays, which differ from that usually applied by the industry in which the depth imaging is obtained by making a direct change on vertical scale. The use of vertical rays considers the geological environment as a simple model of horizontal and plane layers. With this particular approximation, the image ray, the normal ray and the vertical ray are the same. So the use of the normal and image rays on time to depth conversion is more appropriate to simulate a real geological complexity with lateral and vertical variations of velocity.

The results of the applied methodology for time to depth conversion are showed in **figures 1 to 6**, where three seismic lines were selected along the 3D volume. **Figures 1** and **2** show the RMS velocity field before and after the calibration with depth information from well.

Figure 3 shows the interval velocity field in depth after calibration from well. **Figure 4** shows some of the results from time-depth conversion using the conventional vertical ray (above) compared to the Petrobras results (below). The Petrobras results showed a better image of faulting, as well as better resolution and positioning.

Finally, **figures 5 and 6** illustrate two depth-slice images obtained from the depth volume. **Figure 5** is a depth-slice obtained from time-depth conversion with conventional vertical ray, and **figure 6** is the resulting image from Petrobras methodology. **Figure 6** shows better resolution and position for the level of reservoir.

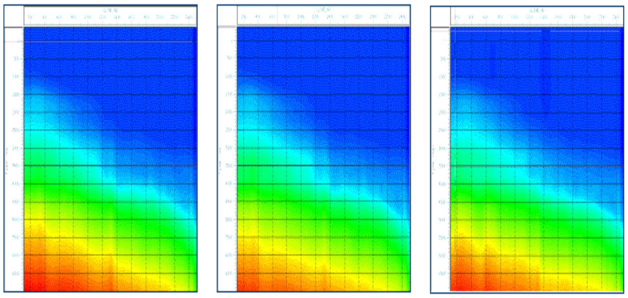

Figure1: RMS velocity before the calibration by well data.

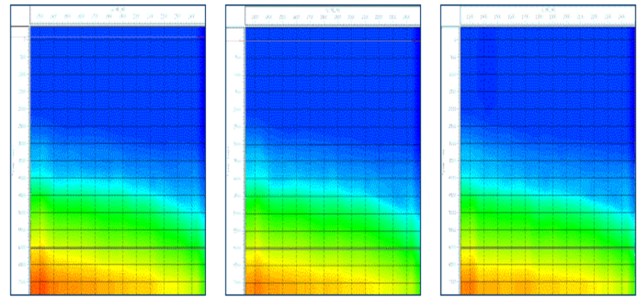

Figure 2: RMS velocity after calibration by well data.

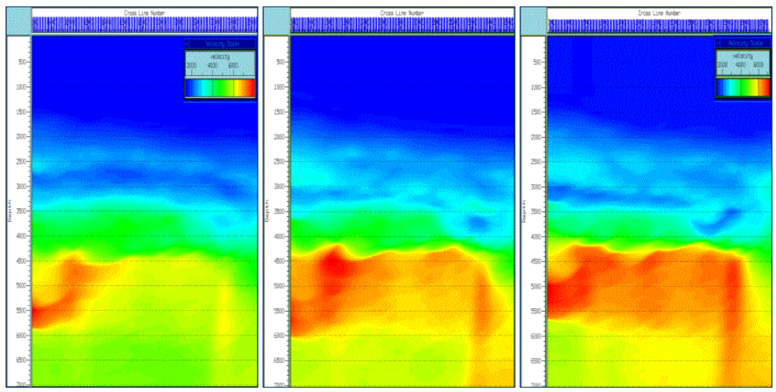

Figure 3: interval velocities in depth obtained from Petrobras technique also after calibration with depth information from well.

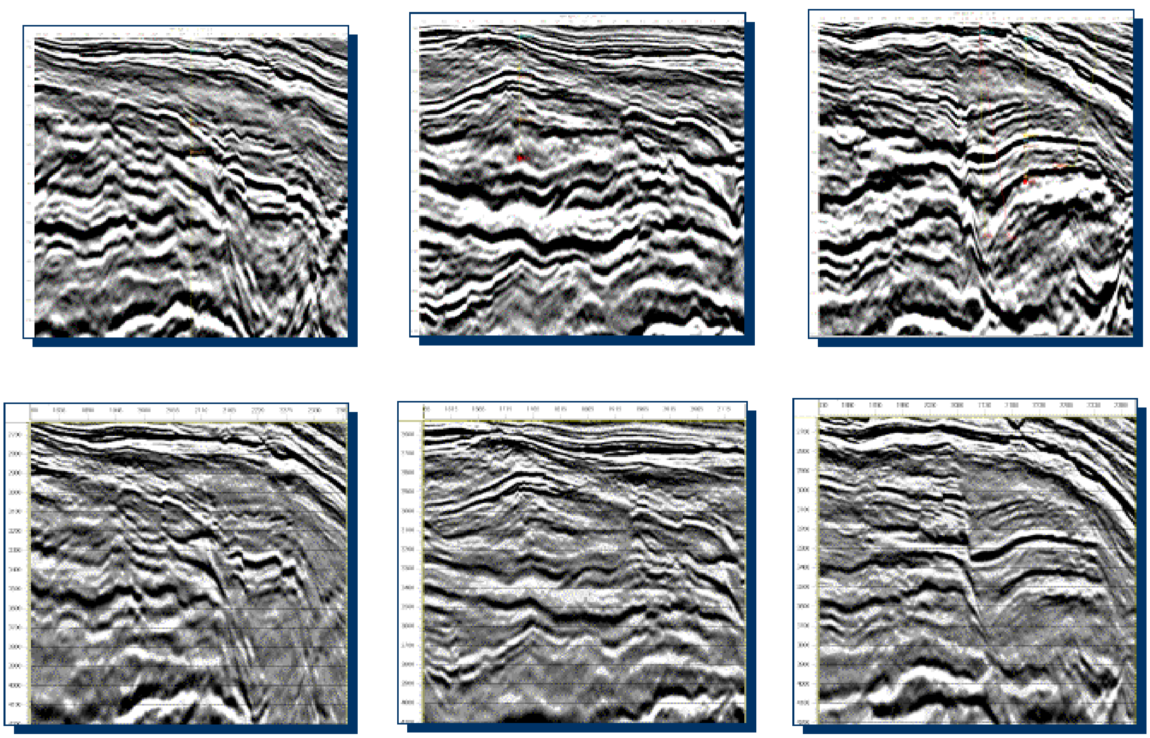

Figure 4: results from the time to depth conversion using the conventional vertical ray (**above**) compared with the Petrobras methodology (**below**). The results obtained using Petrobras methodology showed a better image of faulting, as much as the resolution as the positioning.

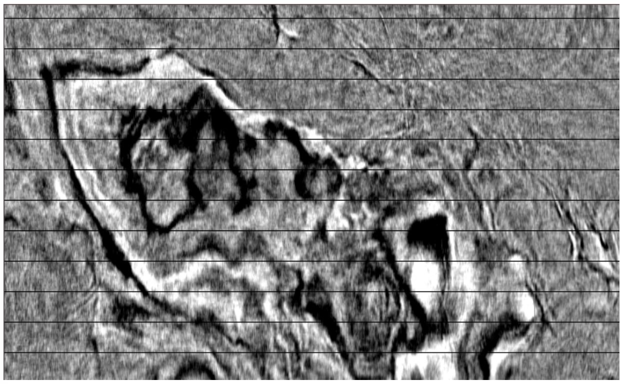

Figure 5: a depth-slice (3800m) obtained from time-depth conversion with conventional vertical ray.

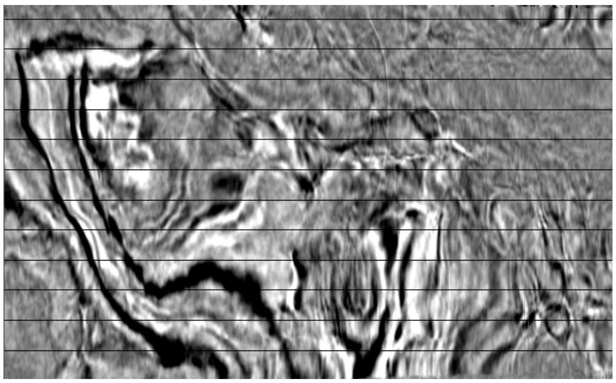

Figure 6: a depth-slice (3800m) obtained from time to depth conversion resulting from Petrobras methodology showing a better resolution and position at the level of the reservoir.

The additional accurate calibration method

The objective of this work was to create a methodology that could be efficient, fast, and easy to make an additional calibration of the seismic depth to a certain geological marker every time a new well is drilled in the field. This kind of calibration produces a more precise depth image of the reservoir, as new depth information is incorporated each time a new well is drilled.

Figure 7 illustrates the proposed workflow for this additional accurate calibration. Using the tool "Log Property Mapping TM (LPM)", it is possible to calculate the difference between the seismic horizons from the 3D depth volume resulting from the Petrobras methodology and the interpreted geological markers. With this procedure a calibrated depth horizon can be generated by a residual crossplot correction technique (**figure 8**).

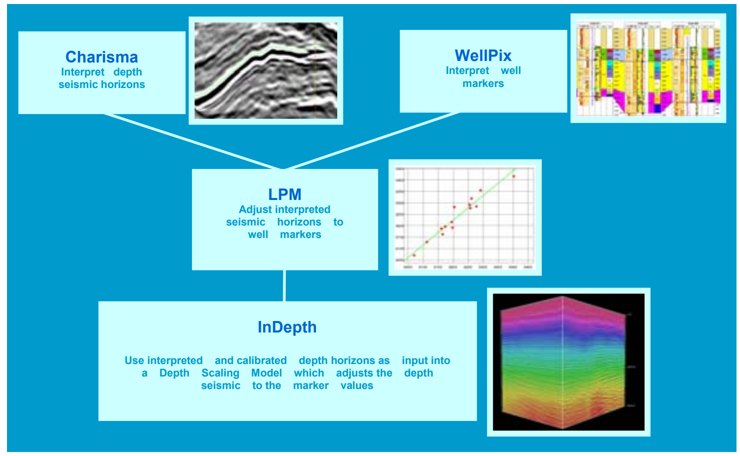

Figure 7: The additional fine calibration workflow.

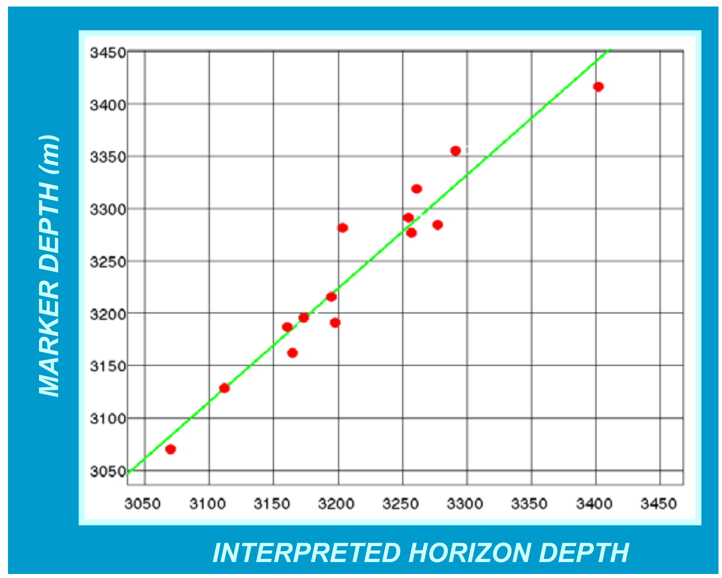

Figure 8: Geological marker depths versus seismic depth interpreted for the top of reservoir. The use of the LPM crossplot tool compares the difference between the markers depth and the seismic interpreted horizons. The Interpreted horizons are adjusted to the geological markers using the crosscorrelation as a residual correction technique.

Figure 9 shows the top of reservoir map with the adjusted values between the geological markers and the interpreted depth horizon, after LPM crosscorrelation (residual correction technique). The interpreted horizon and the calibrated depth horizons are then used as input to the program InDepth TM. With this program, a depth-scaling model is created and it is possible to calibrate the depth seismic in a way that it matches the geological markers (**figure 10**).

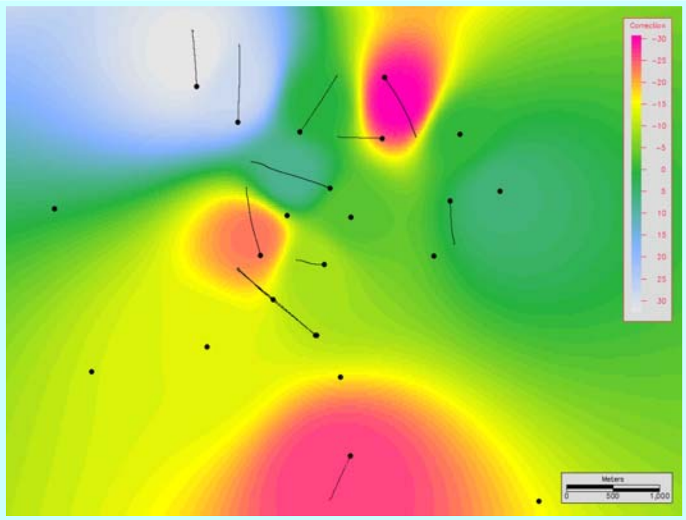

Figure 9: Map showing the adjustment values between the geological markers and the interpreted depth horizon after LPM crosscorrelation (residual correction technique). This correction was than applied to generate a calibrated depth horizon for the top of the reservoir.

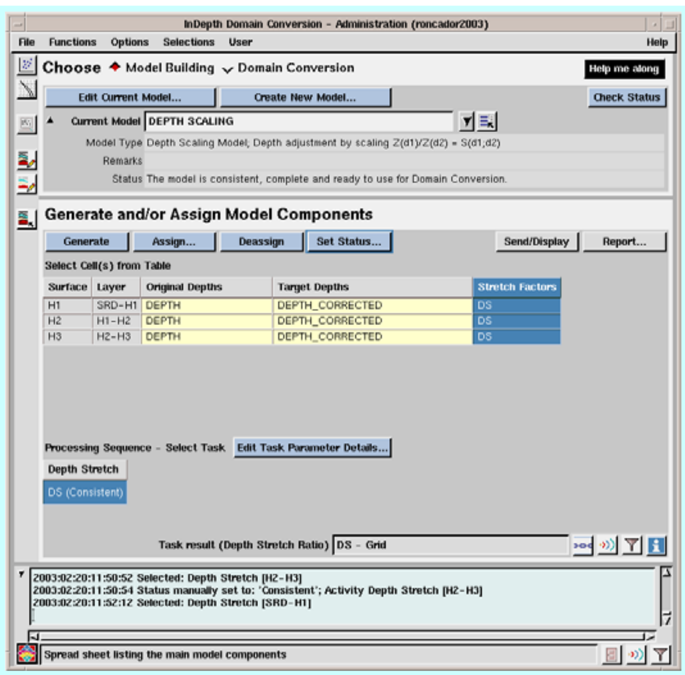

Figure 10: The program InDepth ™ where depth-scaling model produces an easy calibration of the depth seismic to the geological markers.
Original Depths - Select the interpreted depth horizons.
Target Depths - Select the calibrated depth horizons generated in LPM.

Results

Regarding the main discussion about the conversion methods, comparative results between the conventional time-depth conversion and the Petrobras methodology for time-to-depth conversion, both tied to well data are shown in the **figure 11**. Looking into the conventional vertical ray depth correction versus the Petrobras result, at a same well position, we can see that the geological markers were honored in the first case although this type of vertical conversion has created false structures. On the other hand the seismic image from the Petrobras methodology to depth conversion seemed to be very good but the geological markers were not tied to the seismic data successfully.

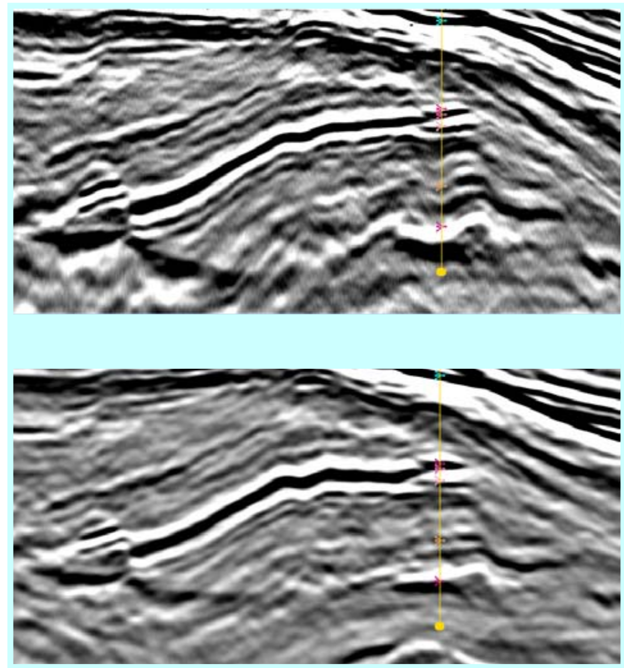

Figure 11: (above) – conventional vertical ray depth conversion with well adjustment produced by the program GeoQuest InDepth™. **(below) –** Image ray time-to-depth conversion with well adjustment (Petrobras Technology), where the geological markers were not tied to the seismic data.

After the image ray time-to-depth conversion was applied with well adjustment, the proposed workflow for this additional accurate calibration was implemented with success. **Figure 12** compares the result of this additional accurate calibration (depth scaling) versus the original result. On the first one (**above**), no changes in the seismic image were observed and the geological markers were very well tied. On the other hand, some slight differences occur between the geological markers and the corresponding seismic horizons in the original image ray time-to-depth conversion (**below**).

In **figure 13,** a quality control map for the top of the reservoir shows the interpreted depth horizon in red contours and the calibrated depth horizon in black contours. In this map the additional accurate adjustment was very small and it was done with success because no false structures were created in the process.

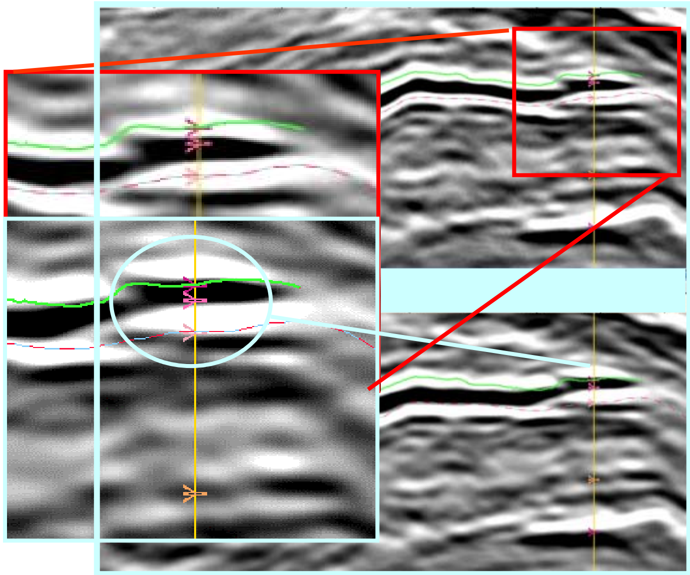

Figure 12: (**above**) – additional accurate calibration applied in the image-ray time-to-depth conversion with well adjustment. It was noticed that the geological markers were adjusted to corresponding seismic events. (**below**) – original image-ray time-to-depth conversion with well adjustment, where there still were slight differences between the markers and the corresponding seismic horizons. In this illustration the Interpretations correspond to the events in which the seismic data should be adjusted.

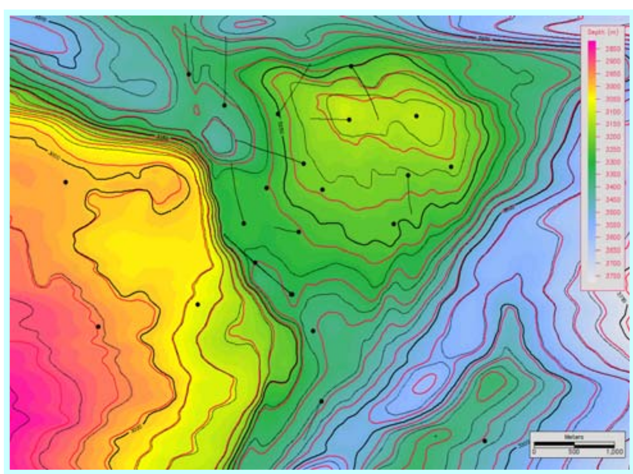

Figure 13: Original contour map versus corrected contour map for the top of the reservoir. The red contours are interpreted depth horizon and the black contours are calibrated depth horizon. Notice that the quality of the adjustment was very good because no false structures were created with the process.

To attest the benefits of this methodology, we analyzed a new deviated well recently drilled in the field. The difference between the predicted and the actual depth at the top of the reservoir was 3 meters only (**figure 14**). Previously, expected errors without the accurate calibration were around 15 meters.

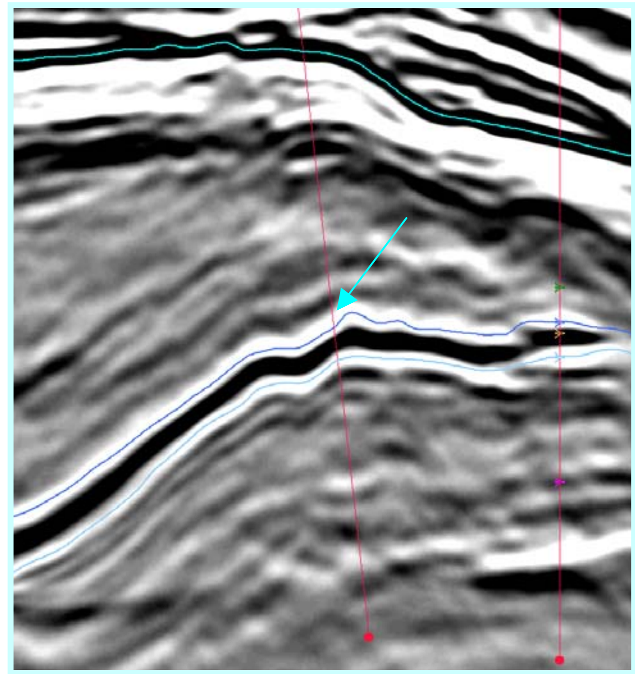

Figure 14: A new deviated well drilled in the field was signed with blue arrow. The error in the predicted depth was only three meters after the additional accurate calibration.

Conclusions

The presented workflow was implemented successfully. In less than one day, the 3D depth volume, which came from the image-ray time-to-depth conversion with well adjustment, was fitted to the geological markers. The good depth response at the top of the reservoir (about tree meters errors) confirmed the benefit of this accurate calibration methodology. Additionally new well depth information can be easily incorporated into the workflow to produce even more precise depths at the reservoir.

The additional accurate calibration proposed here could also be applied after a prestack depth migration data (PSDM), although to many geological situations the Petrobras methodology to time-depth conversion with well adjustment plus this additional accurate calibration can be a good alternative for the PSDM, which normally takes much more time to be processed.

Acknowledgments

We would like to thank PETROBRAS for permission to publish this work. Also thanks to Carlos Cunha and Eduardo Faria for paper revising.

References

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