THEM Geophysics Inc. DSP Technology

For a more accurate and precise processing

THEM Geophysics Inc. (http://www.themgeo.ca/)

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Introduction

THEM Geophysics Inc. has been dedicated right from the start to cover new ground as far as Digital Signal Processing (DSP) is concerned. Far from being conservative, THEM Geophysics Inc. is constantly looking at new way to process and understand the data. THEM engineering team aims at delivering concrete solutions for its clients that go beyond the typical results available today.

Currently, two key elements make THEM DSP software unique : Wavelet processing and Lagrangian optimization. Wavelet processing is used both to remove spherics (spikes) from atmospheric discharges and generic de−noising at the channel level. Lagrangian optimization is used to compensate for the motion of the system within magnetic fields.

Wavelet DSP

Older processing software in this context rely on Fourier Transform and lowpass/highpass filters. While these approaches are workable, they are certainly not optimal and are flawed in many respect. We are concerned by two type of noise : high frequency noise (close to our acquisition frequency) from atmospheric discharges and somewhat lower frequency noise of a more generic kind (wind, vibrations, etc.) which have frequencies of the order of a thousand to tens of thousand times our acquisition frequency.

Atmospheric discharges must be identified and eliminated at the beginning of the processing. Using traditional methods we could not completely remove these components and these components only and one reason for this is the fact that our signal does have high frequency components which are not atmospheric discharges related. We have designed the processing so that only the very small time interval where the discharge happened will be de−noised. This is made possible thanks to the localization both in time and frequency of wavelets and also by the perfect reconstruction theorem. Therefore, if an atmospheric discharge happens at time x and last y second (y is typically of the order of 1/1000 of a second) then the signal will only be modified from x to $x + y$ (allowing for a very small margin before x and after $x + y$).

As for generic de−noising, we use Wavelet Shrinkage which is a type of non−parametric de−noising designed by David Donoho (Stanford University) and al. The goal is to use neither a lowpass nor a highpass but rather a *multiscale filter*. All relevant frequency information is kept. Since we cannot characterize the noise, we need to use such non−parametric de−noising or else otherwise we will tend to introduce systematic losses in the information content (aliasing, lowpass filtering, Gibbs effect, etc.). We designed a customized Wavelet Shrinkage and improvements over previous de−noising approaches with a sophisticated lowpass filter are sometimes stunning (see Fig. 1). We do think that preserving most of the features in the channel is important even though we might only be interested in the most visible anomalies. Details within these anomalies can be valuable and the current widespread approach in the industry which amounts to very agressive lowpass filtering, looses these important features and might not be a very scientific approach. There is not reason to believe that anomalies should be smooth and that high frequency components are noise. Quite the contrary, if we want to target as precisely as possible the anomalies, we need all the information we can get and smoothed out curve will waste available information about the exact location of the anomaly.

Baseline Correction

Achieving a good baseline correction is a key point for this DSP software because an airborne system is constantly in (random) motion. A bad baseline means that the information content is destroyed completely or partially. Anomalies can be missed and never been seen if the baseline correction is deficient.

The task is not easy because all sort of noises can be present, from 60 Hz noise to wind motion. To achieve optimal robustness and precision, an algorithm based on Lagrangian optimization, splines and average interpolation was designed (called SIMn). It was thoroughly tested and is known to be safe. Even in the worse conditions, it was found to be robust.

Software implementation

The latest implementation is entirely object−oriented (C++) and attempts to satisfy the usual industrial C++ specifications including ANSI C++. There is also an almost complete Java implementation for optimal portability (Linux, BeOS, Unix) using Java Swing and running under HotSpot (Java High Performance Engine).

The object−oriented design is based on plugable objects and on an encapsulation of the signal and channels. Therefore we can easily and quickly modify, specialize or improve the processing without constant debugging and reengineering.

Conclusion

Our team is constantly working on improving both the software and the quality of the processing. In particular, we have worked on a totally new way of looking at the collected data thanks to 3D numerical modeling (see Fig. 2). Other R&D projects are underway.

As for the current DSP software, while others smooth out anomalies to get pleasing curves, our processing attempts to stay true to the information content and provide the client with as much valuable information as possible (and we are possibly much more precise than our competitors in some cases). As we have shown above, every step is taken to get the best possible results from a scientific approach rather than a trial−and−error approach.

Overall, we can safely say that THEM is on the leading edge of signal processing technology.

Daniel Lemire, Ph.D.

Daniel Lemire is an independant R&D consultant and an entrepreneur. He also offers seminar and training in technology. He is a minority shareholder in THEM Geophysics Inc.

Appendix I. Figures

Figure 1. Improvements achieved with wavelets in processing channels

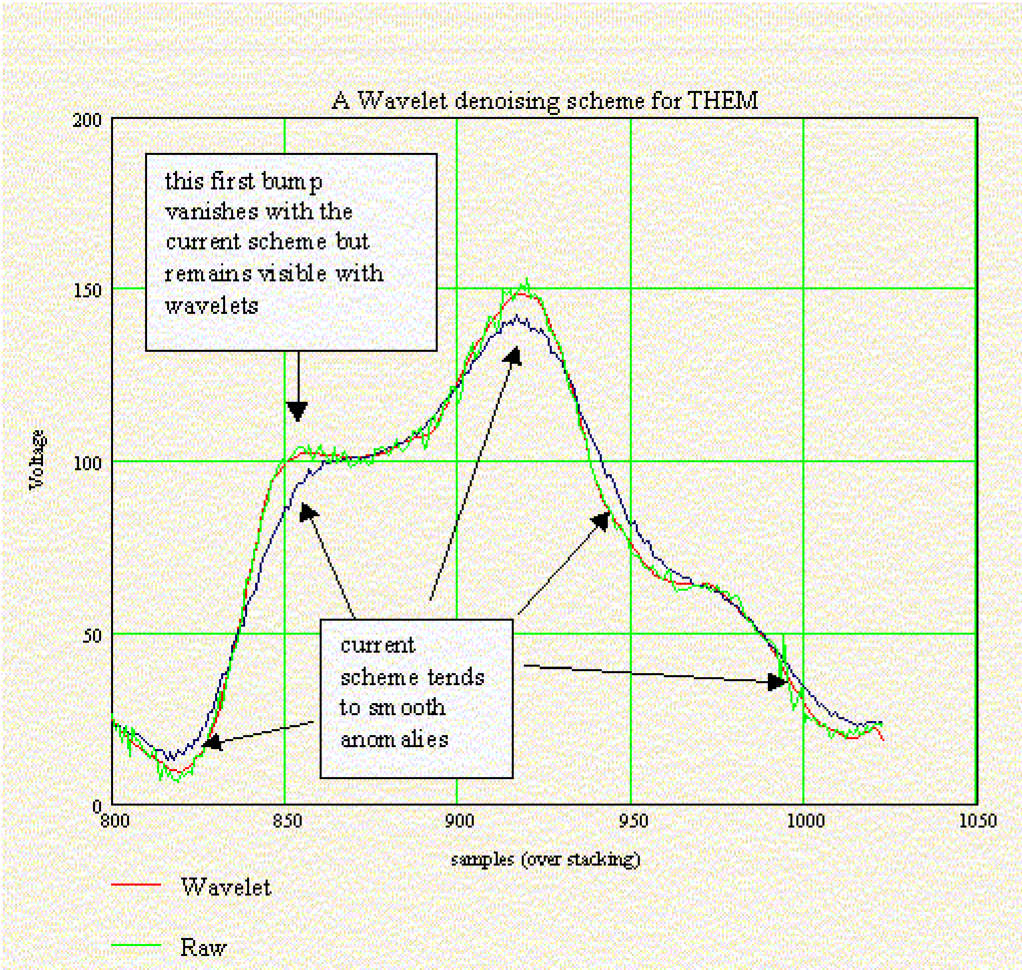

Figure 2. A sample of our numerical analysis work (F.E.M based)

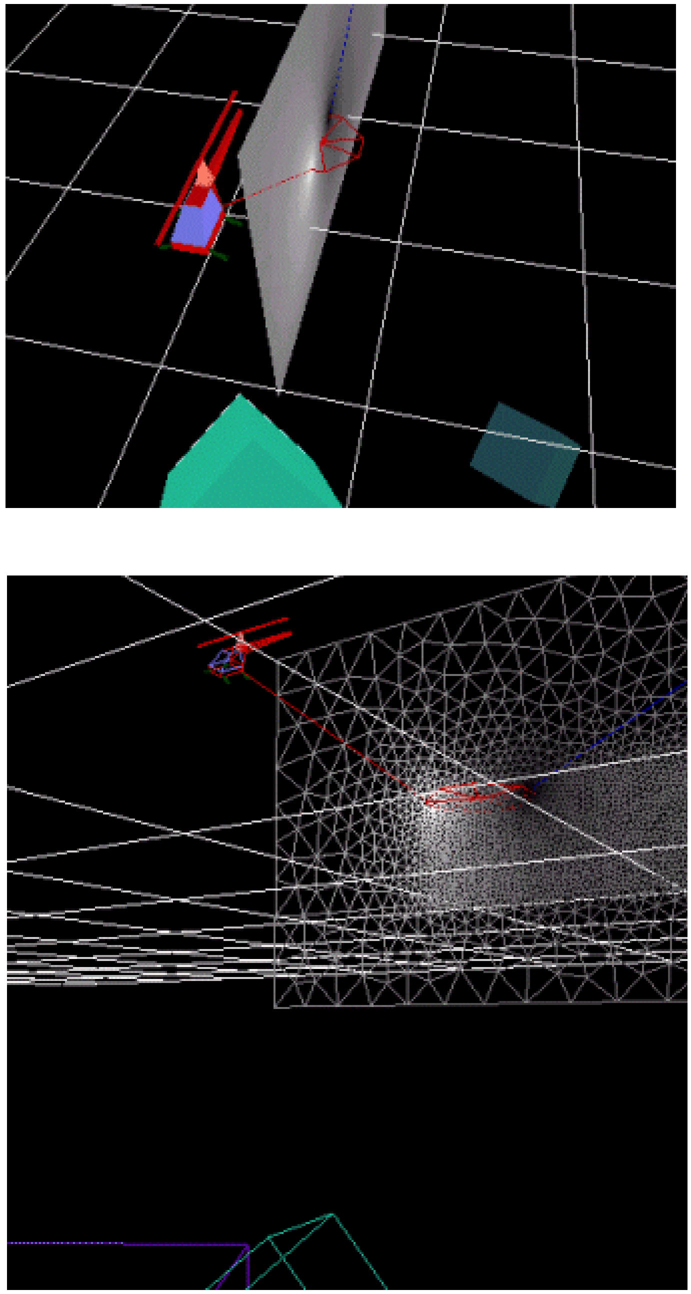

Figure 3a. THEM's system in the air

Figure 3b. THEM's system in the air

Figure 4. Some components

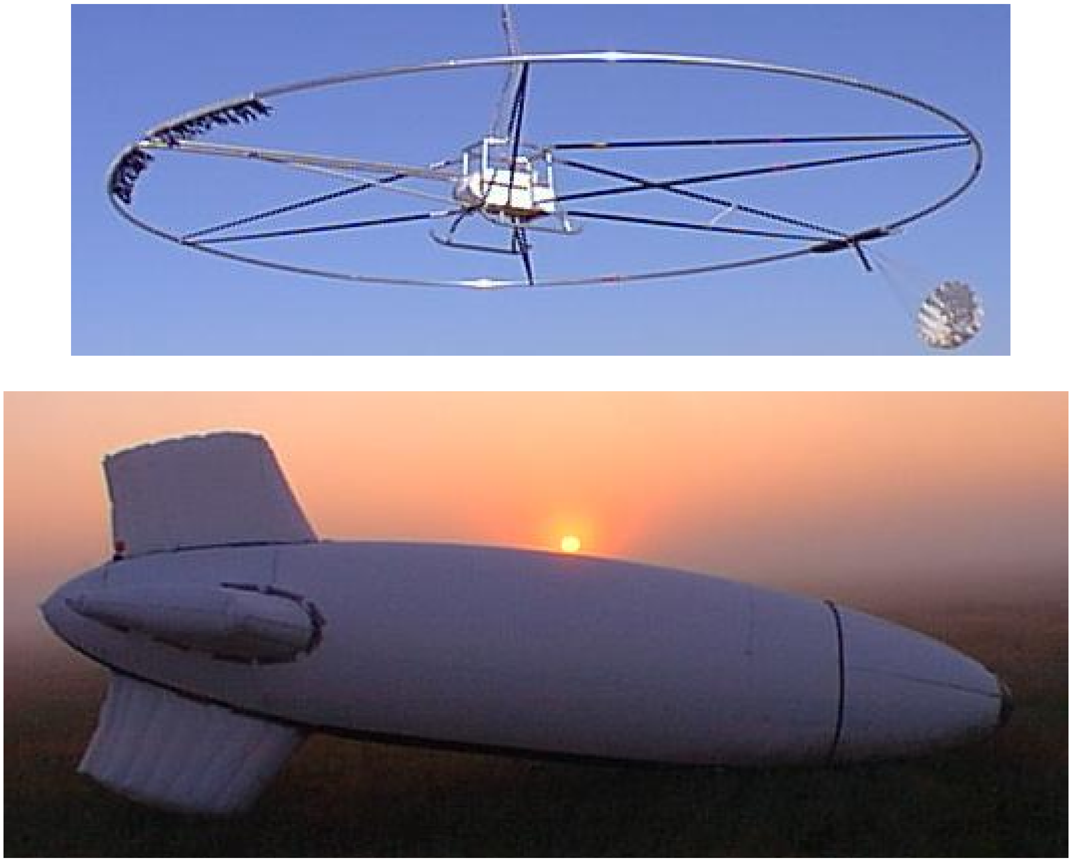

Figure 5. An anomaly detected by our system