Solving the Interferometric Processing Bottleneck

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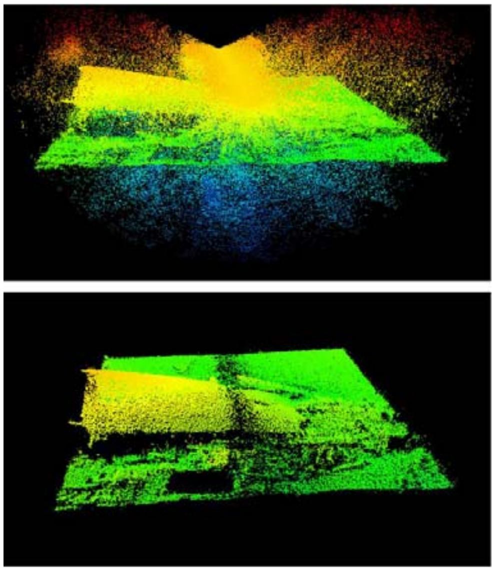
The two main swath mapping sonars in use today are interferometric and beamforming multibeams. Increasing numbers of interferometers are being seen in survey operations worldwide, but in places there is a perception that the data produced can be difficult to handle. Some surveyors report that advantages in the field are offset by processing issues, especially when using post-processing tools designed for beamforming systems. This article looks at the origin of these perceptions, and discusses recent advances in processing systems that can cope with interferometric data.

In the last decade interferometric technology has made significant advances, and the newest generation of systems compete with beamformers in depth accuracy and feature detection, particularly in shallow waters. The interferometer has become a very useful tool for small-boat and AUV surveys, having advantages in cost, transducer size, field of view and simultaneous true digital side scan. Gridded bathymetry shows typical depth accuracy of 3cm-5cm, and interferometric surveys are now used for high precision work such as dredging, river flood modelling, and measuring the thickness of the Arctic ice sheet.

Many shallow survey projects are ideal for interferometry. There are huge efficiency gains in large area surveys in water depths less than 15m. Shallow coastal areas, estuarine systems, and many offshore windfarms fit this description. High resolution surveys in deeper waters are also a good fit: where the sonar must be near the bottom for feature resolution, but a wide survey corridor is needed. To match these requirements an ROV or AUV-mounted interferometer is often the best choice. Many C3D interferometers (Teledyne-Benthos) have been supplied in a towed configuration, and there are several Gavia AUVs (Teledyne-Gavia) running commercial surveys fitted with the GeoSwath (Kongsberg-GeoAcoustics) or SWATHPlus (SEA) interferometric sonars. More recently work has commenced on programs with the new EdgeTech 4600 interferometer (Edgetech-ORE) on ROVs and ROTVs in the Oil & Gas markets.



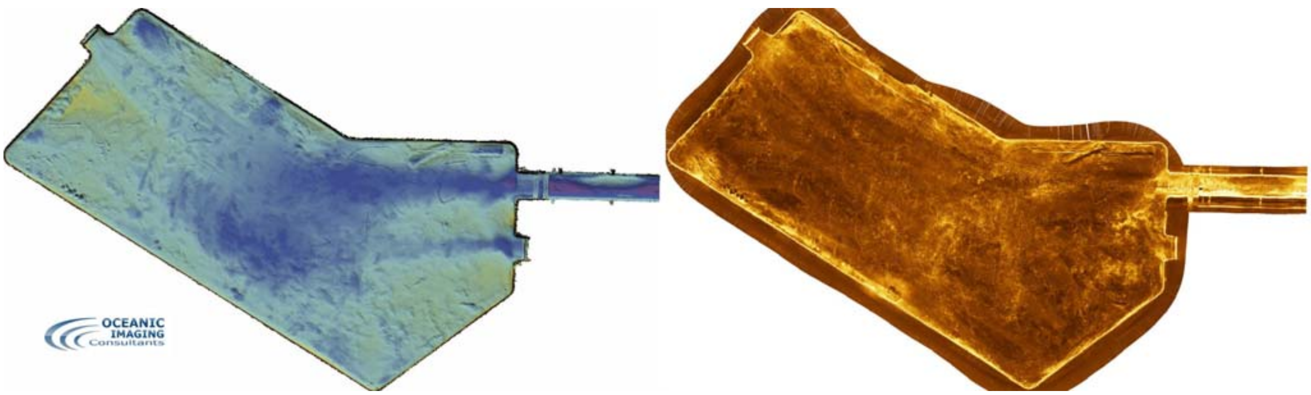
A typical Interferometric data cloud from a few seconds of survey, before (top) and after (bottom) processing. Data from an AUV survey over a wreck and debris field, 80m swath width. Processed using filters designed for interferometric data in CleanSweep3. Data: Teledyne-Gavia, image: OIC Inc.

Interferometers and beamformers are used to produce superficially similar results (a depth map), but interferometric technology takes a fundamentally different approach to depth determination, so the uncertainties associated with the data are very different to beamformer data. This leads to many of the problems seen today in the post-processing of interferometric data. Understanding these problems requires a basic knowledge of how the interferometric systems work, and the type of raw data that can be expected.

The Interferometer as Side-Scan

An interferometer is just a multi-stave side scan. It sends out a side scan ping and detects the returned sound on several side scan receiver staves. The data sampling is a time series of amplitudes, like a side scan, but the interferometer also measures the phase of the returning sound. Comparing the phases from the multiple receive staves gives the angle of arrival of the sonar signal, so the basic interferometric data series is a time series of angles to the seabed. This conceptual image can be used to help plan an interferometric survey: whenever the side scan image looks confused, that is when the interferometer bathymetry data will be less than ideal: for example you should survey a pipe trench from a line offset to one side, not from directly above (with the caveat that algorithms designed for multiple simultaneous angles of arrival can help).

At first glance the interferometer accuracy should depend on the smallest change in range to the seabed that can be measured, and the smallest change in angle of arrival that can be distinguished. Detecting a change in range depends mainly on the sample rate (note this 'depth resolution' is NOT the same as the ability to resolve two objects at different ranges, which depends on the sonar bandwidth). Detecting a change in angle depends on the resolution of the phase measurements. Since both the range and phase measurement are from timing they can be measured with great precision. By this reckoning a typical interferometer should be able to find golf balls at 100m. But this doesn't happen with real sonars, and the reasons for this are key to understanding why interferometric data processing is so different from beamformer processing.



Interferometric bathymetry (0.5m grid) and sidescan (0.2m mosaic) of Chatham Docks, London, UK, from a 500kHz GeoSwath plus survey processed using CleanSweep3 software. Note the returns from under the docked vessels (the hull outlines on the north quay are visible in the sidescan image). Data: Peel Ports Medway, Images: OIC inc.

Real Seabeds and Real Data

The phase of a return from the seabed is a very noisy thing to measure, for two reasons: first, the seabed scatters sound from all the different grains and rocks in the sonar footprint, so any two receive staves will be measuring the returns from slightly different patches of seafloor at any instant. Second, the ambient thermal sea noise will affect the phase measurements and this noise is uncorrelated between staves. These two noise sources result in a random, rapidly varying noise contribution to the comparative phase measurements, so that the resulting calculated angles will be noisy. This gives a distribution of seabed data which is spread around the true angle: the 'cloud' of data seen in interferometer raw datasets. On the other hand the sample density from an interferometer (the number of data points per meter of seabed) is usually very high, as the phases can be measured very rapidly.

This means that the data properties from an interferometer are very different to those from a beamformer. Angle uncertainty is large, range uncertainty is small, and data density is high. This difference means that processing tools designed for beamformer systems are not appropriate when handling interferometer data. Handling the sonar's output in a way that makes the most of the data is key to good survey results with interferometric systems.

Replay Processing

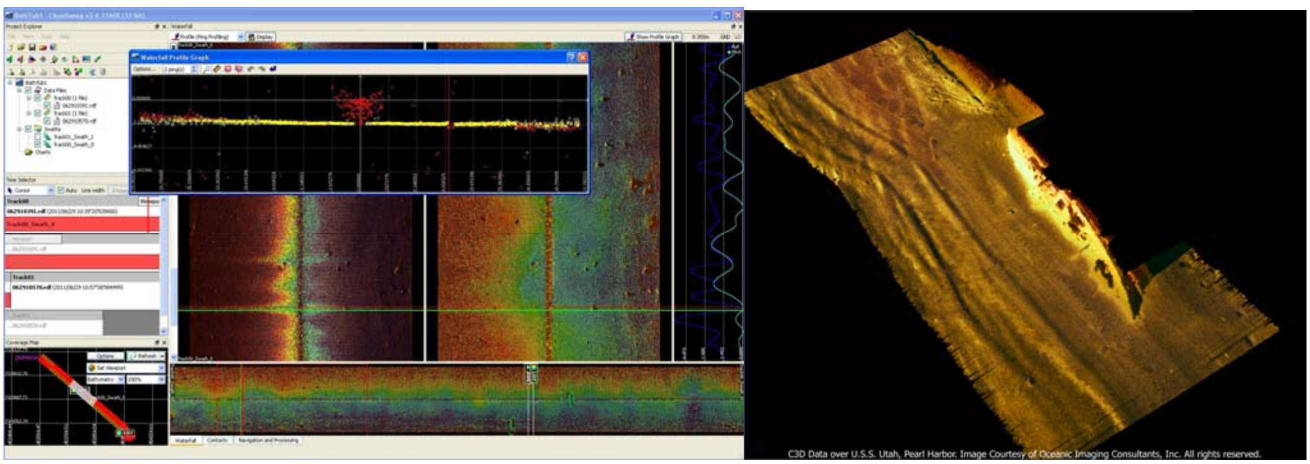
Two early commercial interferometers were developed in the UK in the late 1990's; the Submetrix ISIS 100 (later developed into the SEA SWATHPlus) and the GeoAcoustics GeoSwath Plus. These can both trace their history back to Drs. Cloet, Edwards and Denbigh at Bath University (UK) in the 1970s and

'80s. By the early 2000's it became apparent that beamformer processing tools were not appropriate for datasets from these systems, so the manufacturers put some effort into developing better processing tools. These coped well with the interferometric data characteristics, but were essentially developments of the acquisition systems. This meant they were based around a 'replay' approach to processing.

'Replay' processing relies on the sonar data, ancillary data streams, and survey metadata being re-played through the processing software, which then produces the georeferenced bathymetry and side scan. This replay approach requires a run through the entire survey, line-by-line. Any changes to the metadata or filters requires replaying the data again, possibly several times. For a small demonstration dataset this is an acceptable approach, but experience has shown that for larger multi-day or multi-week surveys it can mean days and weeks of re-processing for even minor changes.

Batch-Interactive Processing

Another approach to processing interferometric data was being taken in the USA. This can be traced back to the SEAMARC sonar program at the University of Hawaii. In the 1990s further developments by Ocean Imaging Consultants Inc (OIC) of Honolulu, Hawaii, led to commercial interferometric processing software. This was first used for processing cable-route survey data in the 1990s, and was also deployed by the US Navy Oceanographic Office (NAVOCEANO), for the Navy interferometers. Since 1996 this software has been a key part of NAVOCEANO's hydrographic survey fleet data post-processing capabilities. The latest commercial release is 'CleanSweep3'.



Left *- Batch-interactive data processing screen in CleanSweep3, showing some of the the simultaneous interactive displays and the global cursor. Data: Teledyne-Gavia, Image: Thurne Hydrographic Ltd.* ***Right*** *- USS Utah, Pearl Harbor. Bathymetry and co-registered side scan data from a Teledyne-Benthos C3D survey, data processed in CleanSweep3. Image: OIC inc.*

The OIC approach uses a 'batch-interactive' processing model, rather than replay. Time is considered as just another data index, allowing rapid movement around the data and rapid prototyping and application of different processing filters in difficult areas. This can speed up data throughput enormously and handle very large data sets. It also allows detailed data inspection and rapid monitoring of the effects of post processing, giving better confidence in the final results.

The CleanSweep3 batch-interactive approach, combined with its suite of appropriate interferometer post-processing tools, makes a commercial survey more practical, both in terms of quality of deliverables and time spent in processing. The improved workflow using this approach is likely to help drive an increased uptake of the new generation of interferometric systems in all areas of shallow water surveying.

Dr. Tom Hiller *has been involved in the development and application of interferometric sonar technology since the mid 1990's. He founded* ***Thurne Hydrographic Limited*** *of Norwich, UK, (www.thurnehydro.com) to provide engineering consultancy, marketing representation, survey support, and data processing services to the worldwide hydrographic industry. ThurneHydro represents OIC inc. in the EU, selling and supporting the GeoDAS and CleanSweep ranges of sonar acquisition and processing software.*