From Nautical Chart to Digital Marine Mapping

Digital marine mapping became possible with the arrival of the electronic chart. The authors, who pioneered the re-engineering of this data for use in GIS, question whether the requirement has been fully met or whether fundamental issues still exist.

It has been over ten years since UK marine environmental and engineering consultancy, Metoc, started to re-engineer UK Hydrographic Office data to make it suitable for use in GIS. Mike Osborne and John Pepper, who pioneered this work and are now directors of marine data management and GIS specialist, OceanWise, consider how the requirement for digital marine mapping has changed over this time, whether this requirement is now fully satisfied, or whether fundamental issues still exist, despite the presence of more open data and the INSPIRE Directive.

The Nautical or Navigational Chart

There is no equivalent to Ordnance Survey for UK seas. Similar to most countries, the primary remit of the UK’s Hydrographic Office (HO) is to ensure the safety of life, property and the environment through the creation and maintenance of navigational products and services. For over 200 years, this has meant the compilation and publication of navigational charts, notably the ubiquitous Admiralty Chart. Used by over 60% of the World’s shipping, the Admiralty Chart is designed and created purely with the mariner in mind and rightly so, as it is trusted and relied upon by many people globally.

This situation means that geographic feature types depicted on navigational charts match those required for safe navigation. Individual features are included, omitted and sometimes modified to ensure charts provide the minimum amount of information required for safe navigation. They need to be clear to read and understand in often difficult circumstances, so unnecessary ‘clutter’ is avoided. For safety, depths are minimum depths and may depict the seabed as being shallower than the mean depth by several metres; known as ‘shoal-bias’. The chart is not therefore in the land mapping sense a map of the sea, i.e. a consistent, comprehensive, accurate, authoritative depiction of the real world designed and maintained for a multitude of different purposes.

Furthermore, navigational charts are compiled on an individual basis and, unlike land-based map sheets, overlap at the edges. The chart scale is determined to match the area of interest to the mariner, e.g. the Approaches to Portsmouth, and hence there are many more scale levels for charting than for land mapping. There is no consistent projection per country or zone; each chart often has its own projection. The same features may be present on one chart and missing from an adjacent chart. Features crossing chart boundaries, e.g. depth contours very often do not match, especially when comparing charts that border neighbouring countries.

Electronic or Digital Charts

The International Hydrographic Organisation (HO) introduced the Electronic Navigational Chart (ENC) in the 1990s, with the aim of creating a world-wide ENC database (WEND) and providing the standards and other instruments to support it. Since that time HOs worldwide have been digitising paper charts to create ENCs. It should be noted that in parallel, a number of private companies began digitizing charts and creating unofficial electronic copies that were sold to the mariner under licence, and the UKHO launched the Admiralty Raster Chart Service (ARCS) containing scanned and geocoded copies of paper charts. However, in all cases the issues of content inherent in the paper originals were and are still present in these digital equivalents.

The reason for this is that the source of information for HOs from which to create ENCs was (and still is) the original paper chart. This is because HO’s generally manage the majority of their data at a product level, i.e. the data only exists within the product; in this case the paper chart. It also had to be done relatively quickly, so even if there was a desire to change this to a more data-centric approach, the time involved would have been prohibitive. The downside is that this arguably short-sighted approach has led to a patchwork of ENCs being created (the ENC ‘scheme’) and all of the problems with content and discontinuous boundaries being transmitted from paper charts to ENCs. Further, certain decisions about how some features should be captured have led to some anomalous results. However, at least now all of the data captured is in the same coordinate reference system, i.e. WGS84, as mandated by the ENC specification – or a local coordinate reference system that could be used as a compliant surrogate, e.g. ETRS89.

Whilst this paper chart approach to ENC production created effective ‘charts on screens’, it did very little to address the need for seamless layers of data required for more advanced navigational type applications, such as command and control and more recently electronic or e-navigation. It also did little to address the need for wider uses of HO data in response to extending the change in the IHO’s constitution from purely being to protect life at sea to include economic growth and protecting the environment. This wider remit is being addressed through the IHO’s Marine Spatial Data Infrastructure (MSDI) Working Group, which the authors helped establish and are now technical advisors. It is also being addressed through the marine data management courses that OceanWise has been running internationally since 2011 with the support of individual HOs, Regional Hydrographic Commissions and the IHO.

The Move to GIS

Metoc began re-purposing data derived from navigational charts by converting data captured by ‘private producers’, as they are called by HOEs, into proprietary GIS formats (e.g. CM93 to Esri shapefile). After some convincing, and drafting, Metoc was granted a licence to allow this re-use, which is distinct from a navigational licence and attracts up to ten times the royalties. Although ‘Charted Vector’, as the data product was called, could be read directly into GIS, each chart was provided as an individual dataset and none of the content issues described above were addressed. Moreover, use of the data relied a lot on how the data was portrayed, not only on content, thus emphasising the point that a successful mapping project requires input of the system developer, data provider and the end user. At least users now had the ability to load nautical charts into GIS, with an appropriate legitimate licence in place, rather than self-digitizing, which was commonplace but expensive in time, inaccurate and often illegal.

The next step was to create a continuous layer of data from the chart derived content. It also meant adding source data where it existed to provide much more complete and comprehensive datasets that did not just rely on charting. An example is wrecks and obstructions, which UKHO did manage at source, albeit in an unfriendly text format. This continuity was achieved by ‘cookie cutting’ smaller scale data and inlaying larger scale data. This meant that the best available geometry for any given area was made available but it also meant that some features that were depicted on smaller scale charts, but were missing from larger scale charts (and yes there are some), were removed from the dataset altogether. Although the launch of ‘HydroSpatial’ in 2005 marked a major step forward, the dataset and its derivatives, which is still being used in a few places, still suffer from all of the discontinuities in geometry of the paper chart and containing multiple superfluous features as a result.

At the same time as UKHO data was being repurposed by licensees, many organisations also responsible for marine datasets started to make their data available in GIS-compatible formats. This included British Geological Survey, with DigSBS250 and DigRock250 and JNCC with marine protected areas. Some of these datasets initially suffered from the same issues as charting but the original paper sheet boundaries were soon dissolved and new seamless datasets published. Many but not all of these datasets were made publicly available at no cost to the end user (there is no such thing as free data, only who pays for it). With the advent of INSPIRE, open data and open standards (e.g. Open Geospatial Consortium standards) more and more data is being made available in ways that make it usable in desktop GIS and web GIS, and looking to the future in enterprise, national and regional SDIs. However, while a lot has been expended on Technical Standards and Information and Communication Technology (ICT) not so much effort has been put into the other two ‘cornerstones’ of SDI, namely Policy and Governance (People) and Geographic Content (Data – and Metadata).

The Marine Science Strategy and MEDIN

The Marine Environmental and Information Network (MEDIN) has been encouraging organisations responsible for marine datasets to make them available publicly in ways they can be easily downloaded and consumed in accordance with INSPIRE Guidelines, and ideally under an Open Government Licence. The datasets are being collated on the MEDIN website under ‘Reference Layers’. However, numerous problems still exist. In the absence of a clear strategy and funding model to ‘strengthen’ existing data and to create new data products and services, which according to the agencies responsible for Marine Spatial Planning are sorely needed, many organisations, including the UKHO, do not have the remit from Government nor the resources to move in this direction. This situation is frustrating, inefficient and ineffective but shows little sign of being resolved, even though the need for improved data management is identified in the Marine Science Strategy, for example.

Marine Themes

Marine Themes was developed by OceanWise as a third generation digital marine map in 2011 and includes several key improvements over its predecessors, Charted Vector and HydroSpatial:

- Carefully selecting appropriate features and geometry from different scale or use bands of ENCs, thus including the features missing from HydroSpatial
- Addressing and, where appropriate, combining the fragmented geometry inherent in paper charts across ENC boundaries, and addressing discrepancies in attributes wherever possible
- Incorporating source data from UKHO and other agencies and more carefully merging this data with the chart derived data to create a much more comprehensive and reliable dataset
- Providing persistence links to source data, which includes concatenating source identifiers where multiple geometries have been combined, thus presenting total provenance to the user and laying the foundations required for change only updates

In addition, a seabed Digital Elevation Model (Marine Themes DEM) was created that uses original hydrographic survey data rather than chart derived data as its input wherever possible. The result is a much higher resolution and accurate surface model
of the seabed suitable for multiple applications, including as input to habitat modelling. Other advantages include a rule-based
de-confliction method that ensures that overlapping surveys are selected on merit rather than being averaged, which can be
misleading, and the inclusion of a height attributed coastline, meaning that the creation of an integrated land-sea surface model
becomes much easier; an important consideration in response to recent storm events and adverse weather patterns.

The Future

There are many benefits to HOs moving from a product-centric approach to a data-centric one, something that OceanWise and
the IHO MSDI Working Group is promoting as readily as possible. Managing themed layers of data in this way and using it in
multiple products and services, rather than updating ENCs individually, means that HOs are able to support numerous other
applications, including e-navigation, realise additional value from their data holdings and deliver significant operational
efficiencies. HOs rely on a lot of third-party data, for example, aids to navigation from ports and national lighthouse authorities,
sensitive sea areas from environmental agencies and coastlines and onshore features from land mapping agencies. The data-
centric approach means that HO data not only contributes properly to an SDI but that HOs benefit from more efficient and
accurate data exchange mechanisms to obtain this data from suppliers.

By managing data as seamless themed layers, the discontinuities inherent in paper charts – and by association in ENCs – will
be addressed at source. The next step is then to consider the provenance and hence efficacy of this data. Many features only
exist historically on a paper chart and they are drawn there to be illustrative only to the mariner. Consequently, they are not – and
were never meant to be – a definitive reference. To be so requires the HO, the organisation responsible for each feature type, if
it can be identified, or a third party to undertake data ‘strengthening’ work by modifying that feature to ensure that its geometry is
correct, e.g. it relates to a statutory or other instrument that initiated it, and to incorporate attributes required for multiple users.
Examples in the UK include harbour areas and anchorage areas but there are many more. All are required to be as authoritative
as possible for marine spatial planning, for example, otherwise their very existence will be open to legal challenge.

Finally, HOs must address the issue of licensing and that navigational products are being used, and potentially abused, for
purposes for which they were never intended. It is possible to access navigational products directly in GIS, contrary to their
intended use or permitted licence. The reasons for this include users not being able to access more appropriate data due to
licensing restrictions and availability, and price; navigational products are cheaper to licence. This practice must stop, as it is
misleading, potentially dangerous and detracting from many of the real issues described above. Only when HOs actively support
the wider uses of their data, and realise the benefits as a result (many of which are internal benefits), and put in place a licensing
system that supports all of these uses favourably, will the real issues have been addressed.

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