

Techniques for Update in Raster and Vector Cartography

This paper deals with techniques and issues concerning update of raster, vector, and hybrid digital mapping data. Examples are taken from live systems in place at the UK Hydrographic Office and other Laser-Scan customer sites, and concentrate on the synergy produced by blending vector and imagery techniques for edit and update.

Introduction

Cartographic production organisations worldwide are under pressure with increasing expectations from their consumers. Demands are being made about volume (more maps), quality (better maps), currency (up-to-date maps), accuracy (precise maps), cost (cheaper maps), variety (different maps) etc. Most organisations have turned to computer assistance to try and satisfy these conflicting requirements.

In the 1970s and 80s, digital cartography was limited by the storage and power of the computers available. It was used successfully for simple vector mapping at large scales (such as the Ordnance Survey Land-Line series at 1:1250 and 1:2500, referred to in section 2.4 below). It was also used as a graphic tool to produce some components of small scales mapping, while other components were produced conventionally. An example of this technique is the British Admiralty (BA) chart series produced by the UK Hydrographic Office (UKHO), referred to in section 2.2 below, where use of digital methods evolved from just contours and soundings to the bulk of the chart features over a period of 15 years.

In the 1990s, the relentless progress of hardware advances produced new generations of workstations and servers. These are capable at last of holding and manipulating the complete content of complex maps, charts, and atlas pages, not only in vector form, but alternatively as high resolution raster images. Now software products are available which take advantage of these new capabilities.

The use of raster provides quicker and cheaper methods of storing reproduction masters for printing. Investment in capture of vector data, although costly, allows flexibility to generate new and more attractive products from a master vector database of 'real world' objects. The advent of 'de facto' graphics standards, such as the PostScript page description language [2], and the TIFF (Tag Image File Format) raster format [3] allows such digital masters to be converted to hardcopy using a variety of plotting devices.

However, maps, charts and atlas pages are not static documents. The task of updating them to reflect changes in topography (eroding coastlines), demography (bigger towns), politics (new countries), infrastructure (new roads), etc is never ending. Until recently, available software and hardware was not up to the task of economically maintaining the full range of the separations needed for map and chart printing. This has now changed, and this paper summarises the available update techniques, covering raster, vector, and hybrid data.

Update of Vector Data

Introduction to Vector Data Handling

When cartography moved from the pen and drawing board into the computer age, the general shift was to handling maps and charts in vector form, as areas, lines, and points. Software for digitising, display and editing of such data is available in many guises, with different degrees of cartographic strengths:

- At one end of the spectrum are graphic-oriented tools such as Aldus Freehand on Apple Macintosh systems or Adobe Illustrator on Windows PCs. These provide great flexibility and immediate ease of use, but have limitations for production work in cartography because they have no knowledge of geography, of map projections, of standard representation schemes, or of databases.
- Next are tools such as AutoCAD, FastCAD, or Intergraph Microstation, which were created for handling engineering drawings, but have been extended to handle geographic and cartographic

data. They tend to lack certain facilities needed for geographic work, and confuse the cartographic user by providing an interface with many CAD facilities which are irrelevant to map and chart production. Some CAD products are unable to handle the data volumes involved in small scales mapping - the outline of Norway complete with its fjords, or that of the Pacific Ocean complete with its islands are way beyond what most CAD systems expect of a polygon feature.

- Next are the GIS tools, with particular strengths in analysis, such as ARC/INFO, MAPINFO, GENASYS, etc. These are designed for handling geographic data, but tend to be aimed at thematic data rather than topographic, and for research and investigation rather than production.
- Finally come the tools explicitly written for cartographic production, such as Laser-Scan's Automated Map Production System (LAMPS) suite [1]. These include data structures and operations that cover the range of map and chart production tasks. This extends from digitising and editing to give a real-world topographic database, through processing to cartographic representation and hardcopy or digital output. The rest of this paper uses these Laser-Scan cartographic tools as examples to illustrate techniques.

Edit using Screen and Digitising Table

The traditional method for capture and edit of vector data is to use a digitising table in conjunction with a workstation screen. As an example of this technique, the LITES2 program which is a major component of the LAMPS suite is a powerful environment for display and update of vector and raster data. At the UKHO, as at many similar sites, it has been used for much of the initial data capture from compiled sources and for subsequent update. This has involved using a chart compilation or other update document on a digitising table to give precise positioning information.

At the UKHO, other input techniques are used to maximise throughput, including use of input from voice recognition systems during digitising so that operators can enter attribute information (such as sounding depths) without having to switch from digitising table to keyboard and back.

The Feature Representation Table (FRT) mechanisms of LAMPS allow an agency to set up a cartographic representation scheme, and be sure that full WYSIWYG is enforced from capture through screen editing and check plotting to final hardcopy output. At the UKHO, this involves the full scope of their chart specifications, which have to conform to International Hydrographic Organisation (IHO) rules, and include very complex patterned linestyles and symbology.

Edit using Scanned Raster Backdrop

As workstations have become more powerful, there has been a shift away from handling sources as paper and film, towards handling them as raster scanned images. UKHO now use this technique for much of their vector capture and update, as operators prefer the 'heads up' method of digitising on screen from a raster backdrop, to the 'heads down' use of a digitising table. Channelling interaction via the screen and mouse allows use of tailored menus and icons to accelerate common operations. Other input techniques such as voice recognition can still be used.

Tools are available to rectify the raster-scanned backdrop to fit the chart projection. However, to minimise processing effort and because modern scanners are relatively free of distortion, the vector foreground data can be warped in real time as it is drawn, to fit the raster, based on four control points.

Certain parts of the data which lend themselves to automated procedures (such as bathymetric contours) are captured using the Laser-Scan VTRAK line follower [4]. This applies the philosophy of letting the computer do the drudgery (following along lines), while calling on the operator to make decisions about interpretation, such as at line junctions. For regular data such as contours, height attributes can be added automatically as capture progresses.

Edit using Remote Sensed Imagery Backdrop

An extension to the use of raster scanned maps as a backdrop is to use remote sensed imagery, such as a satellite image, or a scanned aerial photograph. Another large Laser-Scan customer site is the Ordnance Survey (OSGB) which is the national mapping agency of Britain. OSGB have used LAMPS for over ten years to capture their basic scales mapping (the Land-Line series [8]) for the whole country at scales of 1:1250 and 1:2500. This has involved the capture of some 225,000 map sheets.

The task that is ahead of them is to keep this enormous database up to date in a timely and economic manner. One of the main methods chosen for this task is to display the existing vector data superimposed on a backdrop of scanned aerial photography. Recent enhancements have provided on-the-fly warping of the raster to fit the vector, using a local transformation, after pointing at corresponding points in the two datasets.

This allows the operator to be working in the true and square space of the vector data, but to see the aerial photograph as a rectified backdrop. The full repertoire of commands is then available to allow efficient edit and update of existing detail, and capture of new detail. This process is sometimes referred to as 'monoplotting'. See figure 1 for a typical screen view.

The speed of modern workstations mean that the computation involved in warping of a screen full of raster in real-time is no longer a seriously limiting factor. However, it still takes time and care to set up registration control points accurately, and the distortions involved in aerial photography are not always systematic. So the tendency is to apply a relatively simple transformation (eg rotation and scaling) given by two or three points near to the localised area being updated. When the update in this area is complete, then a new setup is done around the next area to be updated. If suitable control is in short supply, then more points can be given over a wider area, and a least squares fit will minimise errors.

Certainly human judgement seems to be needed when identifying suitable control points, particularly when updating smaller scale mapping. This is because cartographic generalisation has been carried out previously on the vector data, and there is not necessarily a clear one-to-one correspondence between cartographic objects and real world objects. For smaller scales (1:50K and above), satellite imagery (eg SPOT) is an acceptable source.

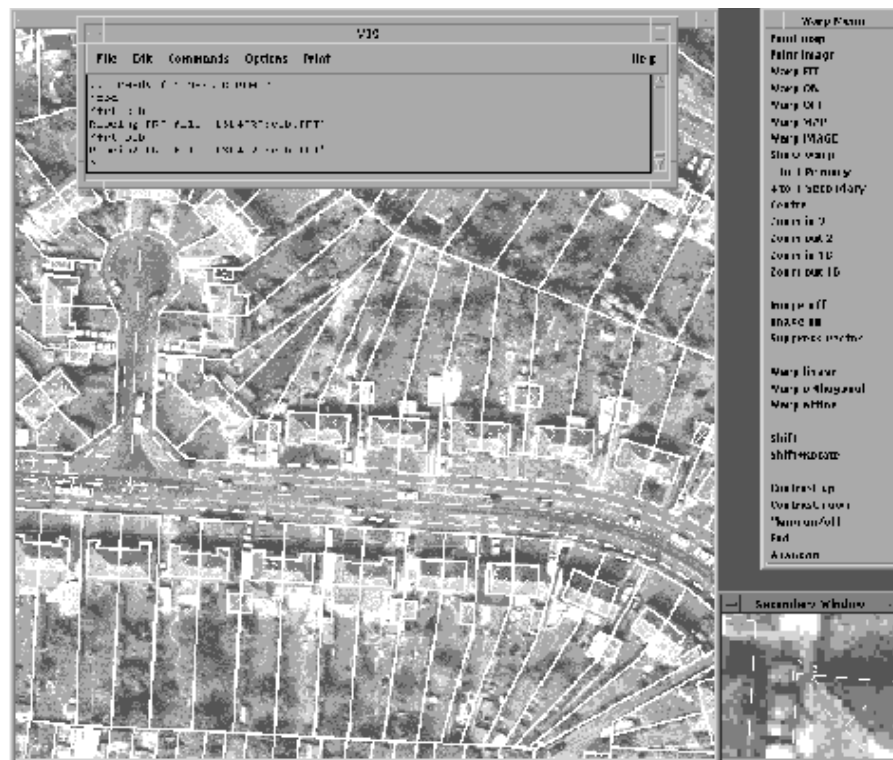


Figure 1: Monoplotting sample

Edit using Stereoplotter Superimposition

Another method used for update at the Ordnance Survey is photogrammetry, using LITES2 in combination with a Leica DSR15 or SD2000 [10] stereoplotter. In this configuration, the existing vector data to be updated is drawn in three dimensions into the image superimposition system of the stereoplotter.

This allows the operator to remain at the binocular eyepiece and to see in three dimensions the background aerial view with the existing vector data overlaid, together with the cursor and refresh highlighting for editing. The operator can then capture X,Y,Z coordinates for new or replacement features, but also has full editing capabilities available. A pop-up menu is also provided in the field of view, so that common edits can be done without needing to refocus the eyes.

Update of Raster Data

Introduction to Raster Data Handling

The term 'Raster Data' when applied to mapping covers a variety of data types, including:

- Monochrome scanned images of multiple printing separates at reproduction resolution, typically A0 size at 1000 to 2000 DPI.
- Colour coded scanned images of printed maps and charts, typically 8-bits per pixel at between 100 and 500 DPI.
- Greyscale scanned images of aerial photography, typically 8-bits per pixel at 2000 DPI.
- True colour (24-bit RGB) scanned images of photography or mapping, typically small format at 200 to 600 DPI
- Multi-band, remote sensed satellite images, often 7 bands of 10 bits per pixel.
- Digital Terrain Models - regular grid samples of ground height, often as 16-bit integers or 32-bit floating point values.

All these data types are handled by LAMPS, but we will concentrate for the next sections on update of cartographic images, particularly in the form of binary separates.

At UKHO there is now a flowline (Project Abraham) which covers update of the printing bases for the 3,500 BA charts. Unlike many maps which are out of date when they are bought, nautical charts used for navigation have to be updated for Notices to Mariners (NMs), which are issued weekly. This applies to the printed paper copies awaiting sale, but numbers of these are kept low, and frequent small print runs are made. It is important to update the film masters of the printing bases for NMs, and this used to be done using manual techniques, requiring substantial effort and risking deterioration of the masters.

In project Abraham, the monochrome film separations are raster scanned at high resolution (1016 DPI) into the tiled LSR (Laser-Scan Raster) format. These are registered and rectified to chart mm space. The resultant digital images can be stored indefinitely without degradation, and can be updated using raster or hybrid techniques, described below. See figure 2 for an example separation.

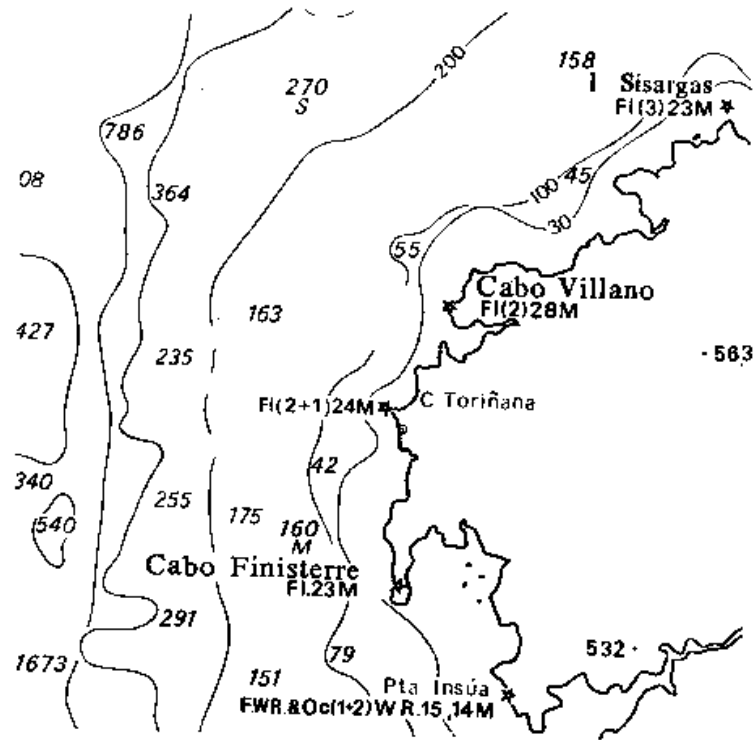


Figure 2: BA chart black separation

Raster Processing

Many raster handling systems available previously, have been designed for small (A4) size images, for screen or laser printer resolutions (100 to 400 DPI), for monochrome only, or for limited numbers of pixels (eg 6000 x 6000 for a satellite image). These have proved unable to handle the data volumes and complexities of large format reproduction resolution images, often over ten separations, bigger than A0, at more than 1000 DPI.

To cope with these, different technologies are required. These are typified by the LSR raster format and the associated LSRPROCESS utility of LAMPS. The LSR format is a geographic raster storage medium, optimised for real-time direct access and modification. The data is tiled into patches (usually 128 pixels square). There is an index to the tiles, and a header for metadata (such as ground registration). A variety of compression methods are available for compressing the pixel data within the tiles, and techniques are used to minimise data stored (such as not storing all-white tiles).

LSRPROCESS is a general purpose raster processing utility. It allows the user to specify one or more input datasets, and to specify required characteristics for an output dataset. It will then generate an appropriate output dataset, applying resampling, rectifying, clipping, filtering, recoding, as needed.

For example, within the UKHO flowline, it is used for the initial rectification of the scanned images, for colour classification, for filtering to remove isolated 'speckles' caused by dust etc, for clipping to the sheet boundary, for merging separates to give a colour coded image, etc.

Raster Paintbox

One of the most obvious techniques for update of raster data is the paintbrush. It is flexible, in that almost any required result can be achieved, but requires great skill and patience to do anything complex.

Using LITES2, the UKHO can display multiple raster images, optionally overlaid by vector data, and can edit any overlay. The raster edit facilities include a versatile paintbrush capability. This includes a choice of round or rectangular 'brushes' and of ink colour. It can be used for erasing unwanted detail, for 'touching up' poor linework, or for inserting small amounts of freehand line or area work.

Raster Objects

Although the paintbrush technique can be used to make changes 'longhand', there are 'shorthand' techniques for erasing, copying and moving involving raster objects. For example, LITES2 includes the ability to 'find' a raster object, that is a set of adjacent pixels of the same foreground colour. The operator puts the cursor over part of the required area, and gives the appropriate command (for example by button press or icon click). The extent of pixels of that colour is determined, and the boundary highlighted as a 'region' object. A variety of operations are then available on the object, including delete (fill with background colour), flood (fill with foreground colour), move, and copy. An 'Undo' operation is supplied in case of mistakes!

UKHO use these facilities in particular to erase or move chart detail to make room for new or amended detail during update for NMs.

Burn-in of Vector Representation

Although it is possible to create new linework, areas and symbology in the raster data using the paintbrush and copy object capabilities, this is slow, tedious and error-prone. UKHO instead prefer to use their extensive repertoire of vector representation and symbology, which ensures a perfect match with existing detail. They can display a vector overlay over the raster data, and summon up appropriate new symbols or linestyles from their Feature Representation Table (FRT).

The new detail is digitised into the correct position (possibly involving use of a digitising table, a separate scanned image backdrop, or keyboard entry of lat/long positions). It can then be moved, rotated, scaled, etc. as needed. The graphic appearance of the new vector data can use the full scope of the multi-part prioritised representation abilities of LAMPS, allowing complex symbolic linestyles (eg for fishing limits), roads with casings and patterned infill, hatched and symbol filled areas, etc.

Text features can be created, which use the Display PostScript capabilities of the workstation to give scalable, rotatable names in standard fonts (eg Univers, Times, etc). The 'de facto' standard Adobe type 1 fonts are used, giving access to thousands of commercial font designs.

When the appearance is correct, then LITES2's ability to 'burn in' overlaid vector representation into the raster is used to update the master raster image. Because this technique uses the X-windows library to do the vector to raster conversion, it is reliable, efficient and 100% WYSIWYG is assured. Once it has been burnt in, the vector data is no longer needed. However, it may be worth keeping it so as to build up a vector equivalent over a period of time.

Hybrid Raster and Vector

Why Mix Raster and Vector?

In an ideal world, the master versions of all discrete digital cartographic product data would be held in vector form. We exclude from this sweeping statement continuous tone images such as remote sensed backdrops, and terrain models such as height tints or hill shading. However, as many organisations have found out the hard way, capturing existing mapping into usable vector form is still a slow and expensive process.

The rise in capacity of computer systems over recent years has opened up the alternative of transferring quickly to digital methods by raster scanning the existing printing separates, and then using hybrid raster/vector techniques during a changeover period. During this period, raster masters are replaced by vector masters in a sequence determined by costs and business priorities. For example it may be economic to complete capture of the transportation overlay quickly, either because there is a market for selling the road network as a digital product to allow route-planning, or because it is subject to more frequent update than other overlays. The conflicts and opportunities raised by the shift from map maker to the extra role of data provider are described by Woodsford [5].

How to Mix Raster and Vector?

Previous sections have discussed techniques for updating vector data, sometimes using raster as a source material, and also updating raster data, sometimes using vector as a source. Clearly these techniques can be applied to particular separations (printing bases), according to whether their master copies are held in raster or in vector form. For example at an interim stage, the transportation, political boundary, and hypsography separations might be held in vector form, but drainage, vegetation, and place name texts might still be in raster form.

Mixing need not be just at a per overlay level. The update techniques discussed above involved raster paintbrush to erase followed by digitising of vector replacements, followed by burn-in of the vector into the raster. If the vector data is not discarded, then it would be possible to build up a vector equivalent to much of the raster over time. When this vector equivalent reaches a certain stage of completeness, or when triggered by business factors, then the vector capture of the remains of the overlay can be completed and the original raster overlay discarded.

Products from Raster and Vector Data

Conventional Products from Vector

At UKHO, as at many LSL sites, the updated vector data is output using LAMPS hardcopy representation capabilities into the requisite plotter language (PostScript, HPGL2, etc.). The hardcopy facilities use identical representation mechanisms as for screen display, giving total WYSIWYG for linestyles, symbology, and area patterns. The resultant plot data is then plotted on one of several high-precision photoplotters, giving a reproduction-quality image on stable base film which then enters the printing process along with the other base separations.

It is worth noting that there has been a shift of emphasis concerning WYSIWYG. Originally, the 'master' medium was the printed map, and the requirement was to duplicate that on the workstation screen. This was primarily so that update could be done without creating conflicts which were only detected when hardcopy plots were made. Now with the rise of GIS and the need for digital data to feed GIS systems, WYSIWYG is increasingly concerned with ensuring that hardcopy can duplicate the contents of the screen, which may be the result of a complex GIS query involving overlay of several datasets. This is in many cases, much harder, as screens are in many ways more capable than plotters.

Most workstations nowadays use an 8-bit graphics controller with associated video memory (1280 x 1024) and RGB colour lookup table, driving a monitor at 100 DPI with RGB phosphors. This gives a light-additive colour model, where each pixel can be set to a given intensity of RGB, giving 16 million possible colours for each pixel (only 256 of which can be on the screen at one time). It also allows the 8-bit graphics memory to be allocated as eg two overlays each four bits deep, by means of which a variety of translucency effects can be achieved when displaying vector foreground over raster backdrop.

This contrasts with a modern colour raster check plotter, which uses CMYK inks put down as four passes over the paper. For each primary colour, a given pixel receives or does not receive a spot of ink. This gives effectively 8 colours per pixel (adding black to anything gives black), but at a resolution of between 400 and 1000 DPI. This higher resolution allows use of 'dither patterns' to emulate intermediate colours, at the expense of resolution. Also, because there is no 'video memory' covering the whole plot, translucent overlay effects are generally not available, and the PostScript imaging model of 'last colour wins' is applied.

Conventional Products from Raster

Producing printed maps or charts from high-resolution images of the printing separates requires that they be plotted accurately and speedily. Once again, digital cartography stretches the capabilities of the previous generation of plotting hardware and software, which is not yet used to the combination of large format with high resolution involved. Laser-Scan's and UKHO's first trials at using PostScript to output

such raster data produced plot files which although legal PostScript managed to crash the RIP (Raster Image Processor) on almost every plotter manufacturer we tried!

The preferred method for plotting of pure raster data is to use a pure raster format, rather than a versatile page description language like PostScript. At UKHO, the resultant updated raster image from the Abraham flowline is then exported from LSR to TIFF for transfer to a high-precision raster photoplotter (an Emma Systems 250). This produces a reproduction-quality image on stable base film which then enters the printing process along with the other base separations.

Conventional Products from Hybrid

The above techniques for producing conventional products from vector and from raster data can be combined into hybrid flowlines. At UKHO, certain separations are available in vector form, and there will be a steady shift to increasing use of vector. However even in a flowline which is predominantly vector, there may be a need for some separations produced from raster data.

An example is taken from another Laser-Scan customer, the map and atlas producer Philip's. For their European atlas, they have a hill-shading overlay to highlight the terrain. For current areas, this has been raster scanned from the existing hand-shaded traces. For new areas, it is being computed using LAMPS software, from a terrain model produced from vector contours, spot heights and drainage lines. In either case, this separation is plotted from raster masters, but is then combined with other separations plotted from vector data (eg roads, drainage), to give the final map.

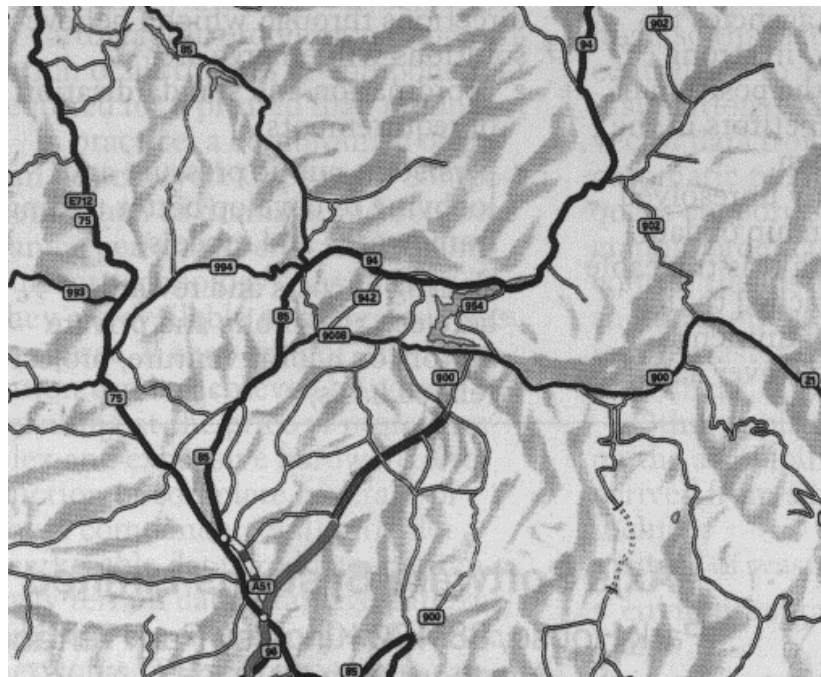


Figure 3: Hybrid Raster Vector Atlas Page

Digital Products from Vector

Among the strengths of vector data are its versatility and ability to be an active rather than passive medium. LAMPS includes export converters to a wide variety of formats (NTF, ARC/INFO, DXF, SIF, CEDD, MGD, etc.).

When vector geometry is combined with descriptive attributes and topological structures, it can be much more than just a graphic picture. The UKHO has a prototype flowline for generation of Electronic Navigation Chart (ECDIS) data in the S57/DX90 standard format mandated by the IHO. This flowline uses LAMPS and UKHO software in conjunction with a relational database of attributes, for capture and update of S57 data and subsequent export to DX90.

It will take some time before a reasonable amount of S57 data has been captured, and shipboard systems have been developed to use it. Then, the shipboard system will use the ECDIS data not just for display, but also to give warnings to the captain of impending problems ahead, such as shoals and wrecks.

Digital Products from Raster

There is an increasing requirement for mapping and charting agencies to supply their products in digital form. Supply of vector digital products has to wait while the slow process of digitising is complete. However, raster products can fill the gap and produce useful tools at low cost. One of the first UK organisations to produce a digital raster product, was the UK Military Survey, with their LAMPS-based ASRP flowline [9].

The Admiralty Raster Chart Service (ARCS) [6] is a new UKHO product which takes the source materials used to prepare conventional paper charts, and instead produces a digital raster product in the HCRF [7] format for use in shipboard electronic chart systems. See figure 4 for an example.



Figure 4: Example ARCS chart

The flowline for producing ARCS data takes as a starting point the up to date high resolution raster images of the printing separations being produced and maintained by project Abraham. The binary separates (usually six), are combined to give a single colour-coded image, applying user-supplied rules. These rules involve the printing colour of the separate, its screening percentage (if any), and whether it is opaque or translucent. The resultant image is then subsampled to a much lower resolution appropriate for display on a computer screen (127 DPI), using special algorithms to avoid loss of important detail.

The chart image is exported to the HCRF format on CD-ROM media as a set of tiles with a tile index. The image is accompanied by comprehensive header metadata, such as polynomial coefficients to relate raster pixels to ground positions in Lat/Long.

One of the strengths of the ARCS product is its incremental update capability. In this, an update CD-ROM is sent out weekly, containing just the modified tiles for a series of charts. Hence, using the original CD-ROM plus the latest update, the shipboard mariner has a perfect display of up-to-date navigational information.

Conclusions

- A range of capabilities is available for update of digital cartographic data, regardless of whether it is held in raster or vector form. Modern digital cartographic tools such as the Laser-Scan LAMPS suite provides all that is needed for a modern digital flowline.
- The choice of raster or vector is now not necessarily an overall decision, as hybrid techniques have been proven for update and for mixing raster and vector overlays to give cartographic products.

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[P.G. Hardy, Laser-Scan Ltd, Science Park, Milton Rd, CAMBRIDGE, CB4 4FY, UK and P. Wright, UK Hydrographic Office, Taunton, Somerset, TA1 2DN, UK]

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