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Developing a conceptual design framework for multi-format map publishing

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Introduction

Map design for print does not necessarily translate to the screen. Today, screens vary from the large computer monitor and wide screen television, to the hand held smart phone. The utility of maps hasn't changed, merely the method of delivery..

Good cartographic design is critical to the exchange of information between the cartographer and the map user. Traditionally cartographers have designed maps for particular uses and users, such as topographic maps for bushwalking, road atlases for car touring, or student atlases for children, to name a few. Each user has their own particular requirements and the particular cartographic design takes these into account, such as larger text and vibrant basic colours for student atlases; or clean white backgrounds and clear class distinctions between roads for a road atlas—all decisions taken by a cartographer (or cartographers) when designing a specific map for a specific user.

As we enter the digital age however, designing maps for web sites or mobile devices has presented the cartographer with interesting challenges. How best to convey user specific information on a screen that comes in various sizes and resolutions, in conditions that the cartographer cannot predict (indoor, at a desk, in a shopping mall, or outdoor, in the sun or rain, or in-car)? The transition from purely printed map products to purely digital is moving apace now, with publishers struggling to keep up with the pace of change. Large cartographic libraries of work need to be moved across to the digital platform without sacrificing the design integrity of the initial map design. This is not simply a matter of converting the digital file to a raster format, rather careful consideration needs to be taken into account of modifying each design feature of the map, such as font sizes, colours, line weights, symbols sizes, to work on the device they are intended to be displayed upon.

This research will propose a design framework whereby cartographers can modify each component of their print map designs to successfully'work' on the digital device they intend to display it upon, whilst still retaining the integrity of the design—a 'design once, publish many' model. The research has reviewed existing research done by experts in their field and applied it to a 'conceptual' framework. Whilst we have created a framework that does 'work', it is conceptual in the fact that this framework needs to be built into an existing software application, or created as a web page where design parameters can be input and applicable outputs are presented to the user to apply to their cartographic design. To date, the framework has been created in the a spreadsheet application to display its functionality. An example output using this design framework is also provided as a proof of concept.

Mapping: print, web and mobile

For the purpose of this paper, multi-format map publishing is defined as taking GIS data comprising of multiple themes and producing maps for print, web and mobile media from this data. The data may be stored in a form of database, where geographic features are represented as point, line and polygon objects and are stored with a spatial component. Typically spatial databases are a method of storing data and allowing complex querying to be done to that data, however more recently this spatial data is being used as the foundation for map production.

For the cartographer, designing for one media is a skill developed over time. Understanding the media involves understanding the choice of colours, selection of fonts, styling of lines and design of symbols. For instance print mapping takes map artwork and separates this artwork into four colours, cyan, magenta, yellow and black (CMYK), and recombines these colours on a printing press to recreate the map artwork. Map features, such as lines, points, areas and text are made up of these four basic colours.

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Selecting colours for print requires understanding of the process colour system, what percentages of cyan, magenta, yellow and black make a particular colour.

Web mapping involves creating digital versions of a map or maps that can be static or dynamic and be displayed on a monitor. Monitor colours are represented by coloured pixels created using combinations of wavelengths of red, green and blue (RGB) light. The RGB display of colours involves 256 wavelengths or red, green and blue, or 256 x 256 x 256 = over 16.7 million colours available on screen. A vast palette for use on a map, however not all RGB colours are the same as CMYK. Converting a design between the two colour spaces does not necessarily give exactly the same result.

Mobile mapping displays raster or vector maps on hand-held devices, such as smart phones, tablet devices and e-readers. Since this technology is in its infancy the most popular mapping application has been Google Maps, which has been available for the major mobile operating system platforms—Apple's iOS and Google's own *Android*. Google Maps uses a Tile Map Service (TMS) to serve to the user small raster tiles of a map area at various scales. The TMS allows the user to zoom in to see more detail and pan around a geographic area. For the purposes of this research a TMS is assumed for use on mobile devices. The main difference between a web map and a mobile map, for the purpose of our definition, is the screen size that the map is delivered on and the resolution of the screens.

There has been a great deal of research into cartographic design over the last 70 years or so, with researchers such as Robinson,(1952), Petchenik, (1976), Keates, (1993), Bertin, (1983), MacEachren, (1995) and many others contributing significantly to our understanding of cartographic communication and map design for print. This foundation work has covered areas such as correct fonts styles to use, font sizes, symbol sizes, legibility, proportional symbols, correct line weights and styles, visual variables and many other nuances of cartographic design. This foundation work in cartographic cognition has spilt over to studies in designing maps for children, atlas publishing, symbol design, colour, and map projections to name a few examples. This print map research has stood the test of time and is a staple of cartographic training that all new cartographers accept as a point of truth in map making. This paper doesn't question these long-held beliefs and accepts them as truisms for the profession, however, later research has shown that they do need to be modified when designing maps for screen display.

In 2008 Jenny, et al, compiled a set of guidelines for designing maps for the internet. At the time, maps on the internet were becoming mainstream. GoogleMaps had brought web mapping front and centre into the consciousness of the general public and visualising location, finding and calculating routes and always having a map at your fingertips was now a reality. Jenny et al's guidelines took into account the existing technology of the time— "...limited screen resolution and anti-aliasing, minimum dimensions and distances for map features, the generalisation of information density and geometry, screen typography, colour rendition…". In four short years since we have seen the introduction of smart phones (2008) and tablet devices (2010), each with their own unique issues and design constraints.

This individual research gave us some guidelines about what minimum standards apply to design elements for particular media technology, albeit technology that is now aging As Meng (2003) stated, "The development of cartographic theories and methods lags far behind the technical evolutions." The proposed multi-format publishing model requires a set of design guidelines that can be applied across a range of outputs (media). Whilst design elements and technologies will vary, the design framework should be flexible enough to create minimum design specifications for multiple outputs, saving time and money in the process—a 'design once, publish many' model.

Towards a design framework

Publishers may often take the quickest and cheapest option when going down the multi-published route. The cheapest workflow often involves creating artwork for print products (Figure 1), either a map or book of maps, converting this artwork for use on a website, often Flash-based, and re-purposing the Flash-based map artwork for use on tablet devices (Figure 2). Whilst there are cost benefits to this approach, the resulting variety of file formats and poor reproduction quality reflect back to a compromised production approach, or, at the very least, one that was hastily adapted to meet emerging technological or consumer demands.

The optimum approach is to carefully assess the final delivery methods required, what technology is best able to deliver a high quality result, create a design specification that will create a product that looks good in print, on the web and on mobile devices, regardless of software platform, hardware used and delivery technology utilised. Whilst map designs will be universally different depending on the cartographer, being able to port a design to a digital platform with confidence is critical in the design process. The framework proposed in this paper endeavours to take the guesswork out of what may or may not 'work' on screen displays based on existing research done on legibility, as well as present the relationship of map and data extents required for multiple production platforms.

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Figure 1: Jacaranda Atlas 7th edition, print atlas example. (Ramsdale, J. et al., 2010)

Figure 2: myWorldAtlas 1st edition, iPad example. (myWorldAtlas 1st ed., 2012)

Before print map production begins the cartographer will ask questions such as:

- what will the geographical extents of the map be?
- what physical size will the finished map be? and
- what is the most suitable map projection and scale?

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In the multi-format publishing environment, the answer to these questions will often be different for each media. A print map will be limited by the sheet or page size, which is often dictated by the press size used by the printer. A web and mobile map, on the other hand, are limited by the screen display and resolution of the device being viewed upon, however the geographic extents can potentially be global. Scale is fixed for a print map, whereas web and mobile can have multiple scales, if the user has the ability to zoom the map. Map projection in a TMS is defined in the Web Mercator projection, something not often used in print products. The Web Mercator projection contains high levels of distortion towards the poles, making digital map extents physically larger than a similar scaled print map using a more appropriate projection.

In multi-format publishing the variables of scale(s), projection, extent and screen resolution, need to be defined early in the design phase to better quantify project parameters. As will be seen later, these values can also help in the production process.

Design considerations for print maps

For maps to be printed they need to be produced in the CMYK colour space. Each colour on the map is specified as a percentage of Cyan, Magenta, Yellow and black (K stands for Knockout). In instances of black type placed over colour this needs to be further specified as an overprint, and consideration needs to be made for colour trapping. All necessary components of preparing artwork for printing on a multi-colour printing press.

Minimum line weights on a paper map have traditionally been around 0.1 mm or 0.25 pt. In part this is due to what the eye can perceive, but also due to the photomechanical method of plate making and the tolerances it can work within, and the tolerances of printing presses in registering such fine lines when they are made up of percentages of cyan, magenta, yellow or black.

There are no hard and fast rules when it comes to symbol size on print maps, and they will vary depending upon the type of symbol being displayed and its use on the map. Due to the high resolution of the finished artwork—around 300 dots per inch (dpi) for modern printing presses—symbol shapes can be distinguished down to small sizes. For example a circle can be distinguished from a square when it is displayed at a size of 0.8 mm, (Jenny, et al 2008).

Fonts come in all shapes and sizes, however when used on a map there are certain cartographic conventions that hold true based on the research of Robinson (1952) and others that sans serif fonts are easier to read on maps. Font sizes and styles may vary, however the minimum legible point size on a print map is around 5 to 6 pt, depending on the font used (font heights vary from font to font).

These minimum standards in print provide a baseline from which the cartographer knows the print map design can be reproduced successfully and be legible to the user. These minimum standards create the platform for the conceptual design framework to build upon.

Design considerations for web maps

Preparing a map for screen display on the other hand has a different set of requirements. The colours displayed on screen will be in the RGB colour space (sometimes expressed in HEX [hexadecimal] notation). The amount of different colours available in the CMYK colour model is less than the RGB colour model, which limits the choice of colours available when looking at a multi-published design. Whilst there is no way to precisely convert a CMYK colour to an RGB colour, colour tools from graphics software applications give a good approximation of what the user will see both on screen and in print. It is notable that some colours that are viewable in one system cannot be replicated in another and older monitor models cannot display the full spectrum of 16 million + colours that are available on present-day (24 bit) monitors

Screen sizes and resolutions vary in computer monitors. Jenny, et al's 2008 research highlighted the variations in an attempt to determine minimum specifications for design web maps. Results of the monitor research are shown in the Table 1.

Table 1: Size and resolution of commonly used liquid crystal displays (LCD) (Jenny, et al 2008)

Display Size	Number of pixels	Visible area	Pixel size	Resolution dpi
17''	1280 x 1024	338 x 270 mm	0.264 mm	96
19''	1280 x 1024	376 x 301 mm	0.294 mm	86
20''	1400 x 1050	408 x 306 mm	0.292 mm	87
20''	1600 x 1200	408 x 306 mm	0.255 mm	100

Symbols for web and mobile maps will be represented by pixels, so issues regarding pixelation and anti-aliasing may occur around the edges of the symbol, which will affect small features. Shapes of symbols need to be quite different from one another to be instantly distinguishable, yet simple enough to be understood at various sizes. Symbol designs have to be familiar and meaningful and used in a relevant context, and should be designed at the size that they are being used, (Hofmann 2011).

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Brown et al. (2001) suggested a series of conventions to be followed when labelling features on maps for the web, such as keeping minimum point sizes to 10 point for legibility, increasing inter-letter spacing, using simple sans-serif fonts, avoiding italic text where possible, especially on non-horizontal text, adding a thin white line (halo) around text to increase legibility and keeping label density to a minimum to improve readability. Jenny et al. (2008) also concluded that sans serif fonts were optimal for screen reading, with the use of sans serif fonts only to be used for larger screen type, and specifically using sans serif fonts designed for screen display.

The work presented here by Jenny and Brown et al. provides a basis for calculating minimum standards acceptable for screen display of map elements. The scale factors calculated form the 'design operators' used in the conceptual design framework.

Design considerations for mobile maps

Mobile devices use the similar screen technology as computers—but with smaller screens. Colours appear in the RGB colour space, therefore the colour constraints mentioned in the previous section are still relevant to designing in the mobile space. All major models of tablet devices have 24 bit displays.

Screen sizes and resolutions vary from computer monitors to mobile devices (smart phones and tablets). The latest Apple iPad and iPhone have screen resolutions of 264 ppi (pixels per inch). To update Jenny, et al's 2008 research Table 2 shows the latest screen resolutions of the two market-leading tablet devices.

Table 2: Size and resolution of the market-leading tablet devices (Apple, 2011; Samsung 2012)

Model	Display size	Number of pixels	Visible area	Pixel size	Resolution ppi
Samsung Galaxy 2 10.1	10.1"	1280 x 800	218 x 136 mm	0.17 mm	149
Samsung Galaxy Tab	7"	1024 x 600	154 x 90 mm	0.15 mm	169
iPad and iPad 2	9.7"	1024 x 768	197 x 148 mm	0.192 mm	132
new iPad	9.7"	2048 x 1536	197 x 148 mm	0.096 mm	264

As can be seen from Tables 1 and 2, in the space of four years display technology has become vastly improved with the introduction of more pixels. Images are sharper and the visible appearance of pixels on screen has become diminished.

Jenny, et al (2008) estimated that computer monitors were viewed from a distance of around 60 cm which assumed a minimum viewing line width of 0.17 mm. Paper maps, on the other hand, had a viewing distance of 30 cm, which had a minimum viewing line width of 0.09 mm, hence a long held belief that the minimum line width for paper maps should be 0.1 mm.

Due to their hand-held nature, mobile devices (tablets and smart phones) would have a different viewing distance to computer monitors. Whilst this viewing distance will vary from person to person, the resolution of devices affect the quality of the line widths displayed. Using Jenny's calculations, we can see (Table 2) that the new iPad almost exactly replicates the ideal minimum line width to be displayed on paper-based maps. The earlier iPad models and the Samsung Galaxy tablets have the same screen resolutions as a computer monitor, but when viewed at a distance of 30 cm the lines become pixelated and not rendered crisply.

In the area of multimedia cartography, scale is one level of abstraction that affects the user's understanding of the map displayed, (Cartwright and Peterson, 2006). When working with a static map, scale has a purpose. The representative fraction is generally rounded to the nearest thousand, ten thousand, or million to allow for easy distance calculation and measurement. In multimedia cartography the need to measure and calculate has in most instances been removed, as the application can do this for the user. In a TMS, scales are based around the standard 256 x 256 tile size and Web Mercator projection and as such displaying static scale bars becomes less necessary. As screen resolution changes, so too does the physical size of the TMS tile. For example, a 256 x 256 pixel tile on a device with 132 ppi resolution the tile will be 1.93 x 1.93 inches or 49.02 x 49.02 mm. On a device with 264 ppi resolution the tile will be 0.96 x 0.96 inches or 24.63 x 24.63 mm in size—half the size and one quarter of the area as that displayed on the standard screen. Screen resolution impacts considerably on the way tiles are displayed, compressing the tile size and the content on the tile changing the scale of the map displayed.

A conceptual design framework

When considering a design framework for multi format publishing we are trying to draw together the minimum standards of the various media formats to deliver an outcome that allows us to develop one master design that we are confident will work across the various media—a 'design once, publish many' model.

At the beginning of a mapping project the design may be unknown or not specific, as design is a fluid concept that evolves through an iterative process, refining design components to achieve an overall product that communicates clearly and concisely.

The conceptual design framework proposed here takes the final print map design and modifies this by a series of 'design operators'. These 'design operators' are applied to the various design elements—colours, lines, symbols—and converting the print design to one that will work on the web. By incorporating the screen resolution of the mobile device the map will be displayed

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upon, units will be calculated to modify the design elements for display on the required device. By using this design framework a map design will be modified for display on multiple media. The user of the map products should have the same design experience across all media the map is delivered on.

During the initial design phase care should be taken to include colours that display well across the various media, symbols are designed so that present well and are easily distinguishable and understood, and choice of fonts include styles that are legible and easily read across all media. If these basics are adhered to, the resulting design for the various media will appear cohesive and seamless.

GIS software and illustration software allow the cartographer to create templates or libraries of styles to record individual design elements. Perhaps the closest to this is the eXtensible Markup Language (XML), which comes in various flavours depending upon its use, such as Geographic Markup Language (GML), used in the spatial industry.

A derivation of XML is XSL (eXtensible Stylesheet Language) (Berglund, 2006), that, through written expressions, allows us to specify design components to be used in web design mainly, though it can be used in any software application that can read xml. The XSL language has been around since 1999, though there are very few examples of this being used widely. XSL appears to have been overtaken by CSS (Cascading Style Sheets) (Celik, 2008) as the language of choice for web designers, as this is not as complex and is more intuitive for non-coders. CSS has now been introduced to cartography through the software application *TileMill* (2012), which uses a derivation of CSS known as *Carto*, that enables styles to be created as code for map objects, and rendering these in a TMS.

Significant work has been done by Roth, et. al (2011) in the development of a design schema, named ScaleMaster, to assist cartographers when creating seamless multi-scale maps. In the words of Roth, ScaleMaster is "a conceptual schematic for organizing, maintaining, and sharing the scale-dependent design specifications of a multi-scale mapping project." Defined in a series of spreadsheet tables, ScaleMaster uses unique codes to describe actions done to data, such as turning data layers on or off, filtering data, reducing line weights or font sizes, and many others. In this way clear rules are established and map designs can be replicated on other projects across a series. Figure 3 displays the unique codes and the actions they describe to be done to data.

Figure 3: An example of Scale Master's design schema. (Brewer and Hatchett, 2010)

ScaleMaster for Proposed Design for Multiscale Topographic Mapping from USGS National Map Data, Cynthia Brewer and Chelsea Hanchett, Penn State Geography, July 2010

Data Themes	Operation Order for Content, Generalization, and Style Changes Through Scale				
Hydrography	1	2	3	4	5
Hydro areas	**La**, reduce label font size; **GC**, High Res. hydro replaced by 50K LoD	**C-**, filter small waterbodies; La, reduce label font size	**C-**, filter small waterbodies; **La**, reduce label font size	**C-**, filter small waterbodies; **La**, reduce label font size	
Hydro lines	**La**, reduce label font size; **GC**, High Res. hydro replaced by 50K LoD	**C-**, eliminate diffs	**C-**, filter small waterbodies; **La**, reduce label font size; **Se**, lighten line color; **Sa**, reduce line weight	**C-**, filter small waterbodies; **La**, reduce label font size; **Se**, lighten line color; **Sa**, reduce line weight	**C-**, filter small and medium flowlines and centerlines; **La**, reduce label size; **Se**, lighten line color; **Sa**, reduce line weight
Physical	1	2	3	4	5
Hillshade	**Go**, smooth DEM at r=15				
Contour	**Go**, smooth DEM at r=15	**Go**, smooth DEM at r=30	**Go**, for mountainous environments, smooth DEM at r=50		
Summit	**Lp**, change label position to centered on point; **Se**, remove point	**C-**, remove layer			
Wooded	**C-**, remove layer				
Transportation	1	2	3	4	5
Freeway/Highway/Ramp	**C-**, eliminate Ramps	**Se**, reduce line weight	**La**, reduce shield size		
Collector/Local/Service/4WD	**C-**, eliminate Service and 4WD	**C-**, eliminate Local; **Sa**, reduce line weight	**C-**, remove layer		

ScaleMaster differs from this proposed conceptual design framework in that our framework considers minimum standards required for all media and provides conversion factors necessary to achieve optimal results. Our framework could be used in conjunction with Scale Master to work across multiple media, whilst ScaleMaster deal with design in a TMS.

In the ideal map design world, a stylesheet or template with design elements should be able to produced for use in multiple software packages used in creating maps for print, web and mobile. A product or schema such as this doesn't exist, however with a it is envisaged that having a design template that could be used across multiple packages and includes a series of 'design operators' to translate styles dependent upon the delivery method of the design, would be the ideal tool for the cartographer and publisher.

How will the conceptual framework operate?

In a 'design once, publish many' world we want the design from one media source to be reflected across other media, to

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provide a consistent user experience for the user. To achieve this, design elements need to be broken down into their individual components and turned into data. Individual design elements such as colour, line weight, area patterns and font size are all elements that can have a value that can be stored, retrieved and manipulated.

The conceptual design framework allows the user to input known parameters for the print map and readily calculate the necessary parameters for web and mobile maps. As an example, standard line weights in millimetres can be input, and the most suitable line weight size in pixels can be calculated based on the screen resolution of the monitor the map will be displayed on. This is a simple mathematical equation based on a number of known values: the monitor resolution (in pixels per inch); and the line weight (in millimetres), with the equation looking like this:

$$X = Y \times 72/Z$$

where X = *line weight in pixels; Y =line weight in points; and Z = monitor resolution in ppi*

This overarching design framework we are calling a ‘design operator’ that can translate known design elements from a print map to optimal values for screen display. The user has control over the screen parameters by adjusting the monitor resolution, which in turn adjusts individual design elements as described above.

Conceptually, a design framework for multi-format publishing would consist of the following elements: a spatial database; a comprehensive set of design assets (consider this a design template or stylesheet); an application to create the map or maps with; and a ‘design operator’ that translates the design to various media formats (Figure 4).

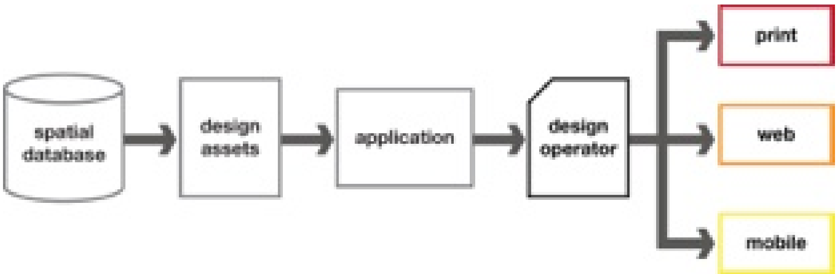

Figure 4: Conceptual design framework which includes a ‘design operator’ to translate designs to various media formats.

To date, the ‘design operators’ have been developed in a spreadsheet format, incorporating the mathematical equations required for converting design elements and testing to ensure that each design element translates correctly. The spreadsheet template also contains map parameters that cannot be readily translated at this stage without the appropriate software, such as print map projection and sizes translated to TMS Web Mercator projection. It is envisaged that if this design framework was adopted, these parameters would be calculated through appropriate GIS or web mapping software.

What is the structure of the framework?

Figure 5 is a view of the spreadsheet application containing the design elements (indicated in bold) and the resulting values (indicated in red) of the ‘design operators’. The design framework template contains the basic information required when planning to create a multi-published map. In detail they are the following:

- Map size of the print map
- Projection of the print map
- Scale of the print map

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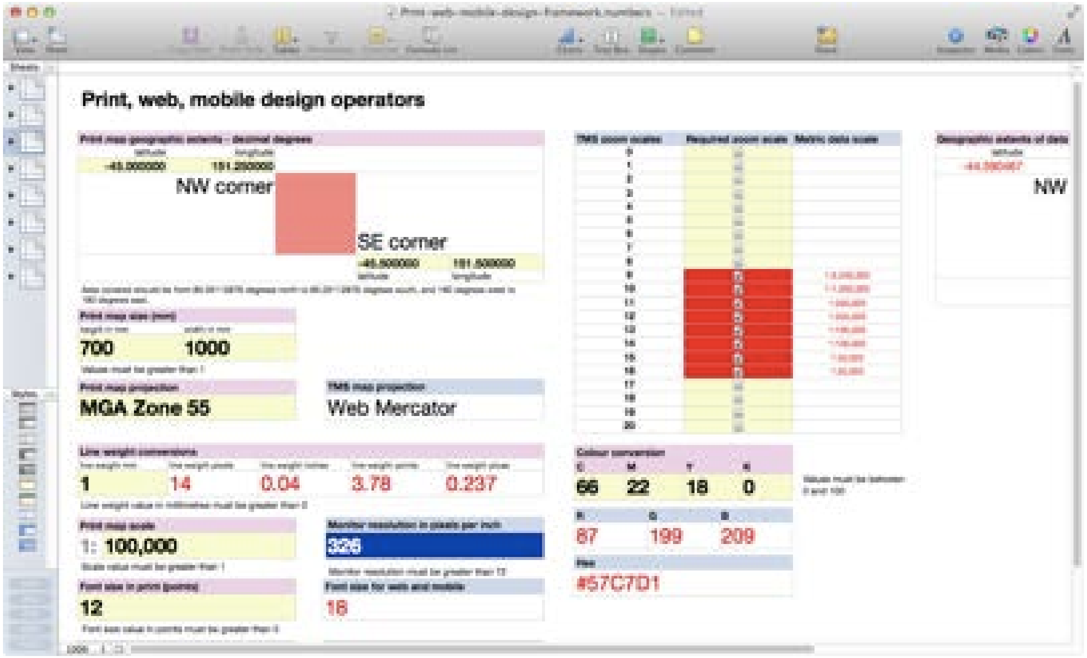
Figure 5: Conceptual design framework containing 'design elements' which are modified by 'design operators', giving resulting values to assist in creating designs for a multi-published map. The conceptual design framework has been created in spreadsheet applications for both Mac and Windows.



These parameters are not affected by 'operators' as such, but are included for reference and planning, however it is envisaged that if this conceptual framework was adopted more broadly and automated within a GIS application, factors such as change in projection from print to TMS could be calculated and extents for the new Web Mercator projection could be created.

When determining a colour palette for print, web and mobile maps the design framework allows the user to input the print CMYK values and automatically calculate the RGB and Hex values suitable for use on web and mobile map design. The RGB and Hex values have been calculated by a complex workflow of translations done in the spreadsheet.

The formula for the translations was sourced from open-source information found on easyrgb.com (2012). Conversion formulae from RGB to HEX values were derived from Cardillo (1996).

Determining the screen resolution of web and mobile devices provides a 'design operator' to select appropriate line weights and symbol sizes. This 'design operator' is essential to ensure line weights are correctly calculated when designing for the various screen resolutions available in modern computers and mobile devices. As stated earlier, resolution will affect the size of tiles displayed using a TMS, which in turn affects the line weights displayed on screen.

Line weights are variously calculated by simple unit conversions from millimetres to inches, picas and points—all units used in the printing industry. Pixel widths have been calculated by multiplying the inches value by the monitor resolution, as monitor resolutions are determined in pixels per inch. A rounding has been applied to the resulting pixel line weight to ensure that an integer is created, as pixels can only ever be a whole value.

When reading type on screen, the minimum point size of a font is important. This may be larger than the point size used for display on a printed map, which typically has a minimum of 5 or 6 points, for screen it should be 10 point, (Brown, et al. 2001). (Note: 1 point = 1/72 inch.) Jenny et al. (2008) suggested that type should be set at a 12 point minimum for screen display, but suggested that sans serif fonts could be displayed as small as 10 point. For the purposes of this design framework we have approximated 10 point as a minimum. To allow for this, the 'design operator' multiplies print font sizes by 1.75, making 6 point text 10.5 points in size, 12 point text would become 21 point, and so on. These larger font sizes are to be used as a guide, as cartographers will want to create their own font hierarchies, however, as Brown suggests, it is recommended to not use font sizes less than 10 point for type on screen.

The last major feature of the conceptual 'design framework' is a utility to determine what scale datasets to use for which TMS zoom level This is useful for using datasets that come from one data provider, such as Geoscience Australia, that provides various scale topographic datasets which have been generalised for the particular display scale. The design framework also uses this zoom level information, in conjunction with the print map geographic extents, to determine the maximum geographic extent for the uppermost zoom level. This is important for clipping data to the optimal geographic extent when preparing maps for the TMS, as geographic extents of the print map may fall at a point within a tile's extents rather than neatly finish at the edge of a tile, (Figure 6).

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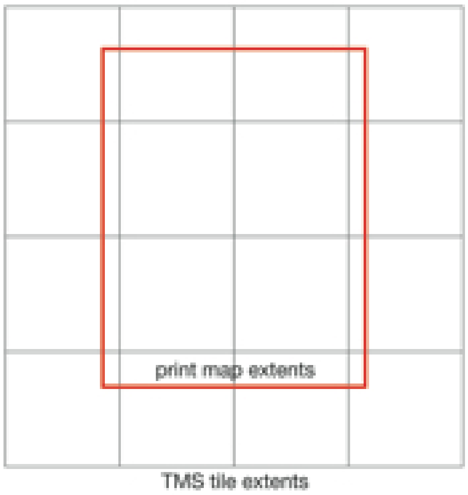
Figure 6: Difference between print map geographic extents and TMS tile geographic extents.

To calculate geographic extents for the maximum zoom level tiles the uppermost zoom level number have been selected from

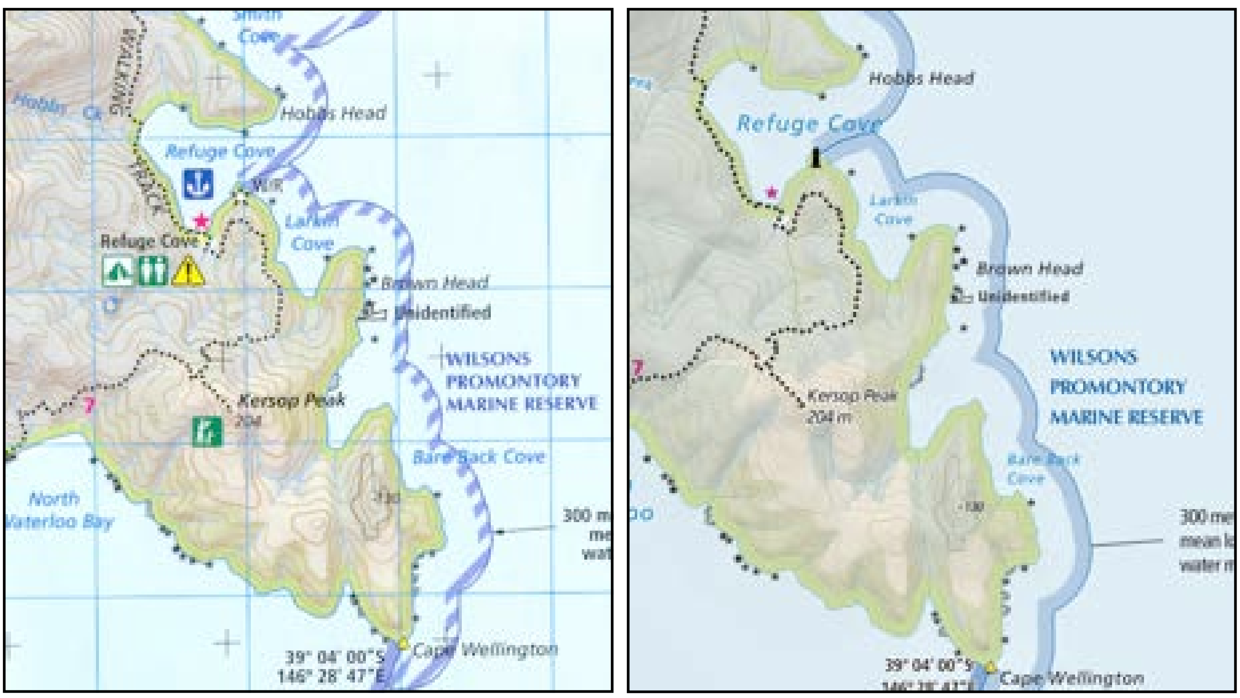


the TMS Zoom Scales table (Figure 4), that is the lowest selected number whose value = TRUE, as zoom level selection is controlled by a Boolean operator. Calculations for converting latitude and longitude extents to tiles and converting tiles to latitude and longitude were sourced from OpenStreetMap wiki (2012).

Testing of concept

To verify that the conceptual design framework and the ‘design operators’ created do work, a map was produced by the authors of Wilsons Promontory National Park. The print map design was created with the final map produced in Adobe Illustrator, using the MAPublisher plug-in to import and export data. Data was styled using existing design specifications which were stored in a graphic style library within Adobe Illustrator. These design styles were created with a print map specifically in mind. Character styles were created exclusively for a print map. Figure 7 shows or portion of the map design for print. Of note are the font sizes and used on the print map, ranging from 6 to 7 point in the sample shown, whilst the web map font sizes range from 10.5 to 14 for the web map. As much as possible colours and styles have been retained.

Figure 7: Left, portion of Wilsons Promontory print map (Spatial Vision, 2012). Right, portion of web map (Spatial Vision, 2012) using ‘design operators’ to calculate line weights, font sizes, symbols and colours. (Note that the print map is at 1:50,000 scale, whilst the web map is displayed at zoom level 14, approximately 1:36,000)



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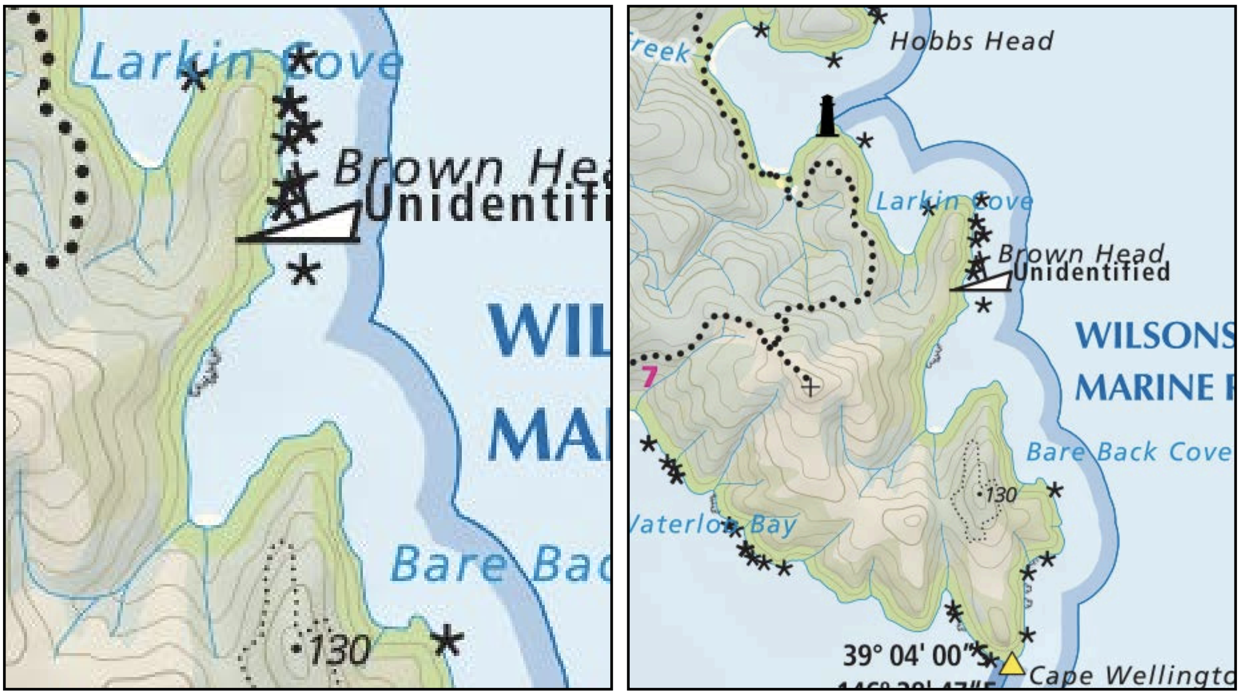
A tile set was also created for a mobile device, in particular an Apple iPhone with a retina display with a screen resolution of 264 ppi. As the pixel resolution is double that of the standard screen display, tiles from the TMS get reduced 50%. A scaling factor of 2 was applied to all design elements, line weights, fonts and symbols, to allow for the halving in size of the tiles (Figure 8).

The 'design operators' created for the design framework on visual inspection appear to retain the look and feel of the print map's design. The scaling factors for line weights give the user of all maps the impression that they are looking at a consistent design across different media. The fonts and symbol 'design operators' bring a consistency to web maps, however when scaled for high resolution displays a straight 200% enlargement appears visually too much and will need to be tested further achieve a more harmonious and consistent result.

Figure 8: Left, portion of Wilsons Promontory map for retina display (Spatial Vision, 2012), with features scaled 200%. Right, portion of map shown at display size. (Note images shown at at zoom level 14, approximately 1:36,000)



Future development

Naturally there is more to map design than colours, fonts, symbols and lines. More research is required in the area of pattern representation in web maps, such as how certain patterns display when rendered in pixels. Understanding what conversion factors are required to scale these patterns needs to be tested further. Likewise, the use of textures, as an alternative to patterns, is an area with little research. How this could be measured empirically and be controlled by 'design operators' would require further testing. Calculating the correct scale factor for fonts and symbols for high resolution displays will further improve the quality of output for mobile devices.

The concept of 'design operators' in a multi-publishing environment has been tested here in a simplified manner, using a spreadsheet application to apply mathematical 'operators' to design elements. In the perfect world we would like to see these 'operators' applied to stylesheets or style libraries from one media to create new stylesheets or style libraries for another media. To illustrate this concept further, a map style library from Esri's *ArcGIS* could have 'design operators' applied to it for creation of a CSS version for use in *TileMill*—not only would colours, line weights, fonts and symbols be exported correctly, but a readability factor would be built in to enhance the design for screen display.

Conclusion

Multi-publishing is an evolving area, not just in spatial science but the publishing industry in general. In cartography it draws on many areas of existing research for print and web map design. Research has been done in areas of generalisation and schema development, but less so in areas of design.

Designing for multiple media is different for designing for a single media. Consideration needs to be given to colours that can be displayed in different colour spaces, fonts need to be legible on print and screen, at various resolutions, symbol sizes and designs need to easily understood at small and large sizes, and line weights and styles will be variable across the media. It is essential to determine the geographic extents of the map(s) early in the design process to ensure a smooth workflow and save time

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and money in the production process. The framework presented here attempts to put some certainty into designs when moving across media platforms.

The conceptual design framework presented here is very much in its infancy and is a stepping stone to further research in this area, working towards a multi-publishing workflow for student atlases. The simple spreadsheet application should be further enhanced to be presented as a web page or built in to an existing mapping application.

The use of a 'design operator' will enable the cartographer to convert the design elements of a print map to design elements suitable for display on screens of varying resolutions, such as those found in the multitude of mobile tablet devices in use today.

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