VIRTUAL AND REAL MAPS: ARE THEY INTERCHANGEABLE?

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1.0 Introduction

Historically, cartographers designed maps with an awareness of the mapping process and the final medium in which the map was offered. Knowledge of these conditions and past experience in their use allowed cartographers to maximize the benefits and avoid the consequences of the technology. Basic cartographic decisions on content and design were influenced by these characteristics where cartographers exploited the qualities of a particular output device such as the resolution of an offset printing press.

With technology advances, more and more maps are created and made available in digital form. Electronic files are created as cartographic products that replace maps traditionally made from processes such as film color separates. New delivery resources such as Internet-based mapping services for on-line viewing may never leave the virtual realm. Conversely, oftentimes users wanting a "hard copy" version transform these virtual maps into real maps.

Creation of electronic maps has altered the conventional approaches to map design and production. Traditionally, maps were designed and created with knowledge of the final output device and the media used for the cartographic product. Processes could exploit the strengths of the hard copy techniques and technology while diminishing or possibly circumventing their limitations. In the end, the traditional process of making "real" maps was controlled where the outcome was predictable.

It is the transformation of a virtual map to a real map that is the topic of this paper. Over time, software functions have improved in which advancements have altered conventional map production processes. The electronic file as a virtual map is transformed to a real map, which does not necessarily maintain the original design or properties as it was intended. One of the issues raised in this paper concerns the question of the interchangeability between real and virtual maps. Can a map that is represented in one of many ways in a digital environment be replicated to affect the same result as the original document or file?

2.0 Real and virtual maps

According to Moellering (1984),

> A real map is a cartographic product, which can be handled physically and usually carried around with relative ease. Such real maps can be used directly by a map-reader in a graphic two-dimensional form which directly shows the map image and from which spatial relationships are directly depicted. In addition, there is no differentiation as to whether that real map was produced by mechanical, electronic or manual means. With time, mechanical and manual methods have given way to producing maps within automated cartographic systems and geographic information systems.

Today, real maps are frequently derived from virtual maps.

Moellering goes on to define three types of virtual maps as indicated below:

Virtual Map (type 1). Has a directly viewable cartographic image but only a transient reality as has a CRT map image.

Virtual Map (type 2). Has a permanent tangible reality, but cannot be directly viewed as a cartographic image. These are all hard copy media, but in all cases these products must be further processed to be made viewable.

Virtual Map (type 3). Has neither of the characteristics of the earlier classes, but can be converted into a real map as readily as the other two classes of virtual maps. Computer based information in this form is usually very easily manipulated.

Moellering conveniently uses a table to show examples of real maps as well as the three different types of virtual maps. Each type is divided into a decision matrix that determines if it is directly viewable as a cartographic image and if it is of permanent tangible reality. A breakdown of cartographic sources, products and processes are allocated to one of the four matrices. This paper will focus primarily on virtual map types 1 and 3 (V_1 and V_3) and real maps (R). For V_1, the emphasis will be on maps viewed on the computer screen while for V_3, the emphasis will be on electronic cartographic products in digital memory and derivative spatial data resources as cartographic boundary files.

Figure A – Moellering (1984)

Directly viewable as a cartographic image

	Yes	No
Yes	*Real Map* Conventional Sheet Map Globe Orthophoto Map Machine Drawn Map Computer Output Microfilm Block Diagram Plastic Relief Model	*Virtual Map – Type 2* Traditional Field Data Gazetteer Anaglyph Film Animation Hologram (stored) Fournier Transform (stored) Laser Disk Data

No	*Virtual Map – Type 1*
	CRT Map Image
	  a) refresh
	  b) storage tube
	  c) plasma panel
	Cognitive Map
	(two-dimensional image)
		Virtual Map – Type 3
		Digital Memory (data)
		Magnetic Disk or Tape (data)
		Video Animation
		Digital Terrain Model
		Cognitive Map (relational
		geographic information)

(Row label at left: Permanent tangible reality)

2.1 Inconsistency in applying specified design characteristics in real and virtual maps.
In moving from one environment (V_3) to a different environment (R), the desirable goal is to maintain the design specifications so that all that is different is the form or media of the cartographic data. The goal is complicated by many factors, some of which are controllable and others are not. For example, resolution of the cartographic data is specified such that a level of quality is expected. In the transformation to a real map, the hard-copy output device such as a printer or plotter determines the resolution. Output media also impacts comparison between real and virtual maps. The stability of film allows high-resolution images while paper quality (granularity, composition, coatings) contributes to how well higher resolution images are deposited on the paper surface.

The computer screen controls the resolution for a viewable virtual map. Size of the viewing area is one of many device characteristics that create differences between real and virtual maps and functions such as panning and zooming in one form alleviate some of the differences (map extent) while in another context (scale change) these functions help to create further deviations.

The two images below are lines in which both have a line weight of 0.001 inch. The first line was output from an photographic image setter at a resolution of 2400 dots per inch. The second line was output from a typical GIS application that displays virtual maps at a screen resolution of 72 dots per inch. The second line was printed on a laser jet printer at "best" quality (600 dots per inch). Each example was forced to a line weight of 0.001 inch and both lines were created at the same scale. The difference in the visual dimension is very evident.

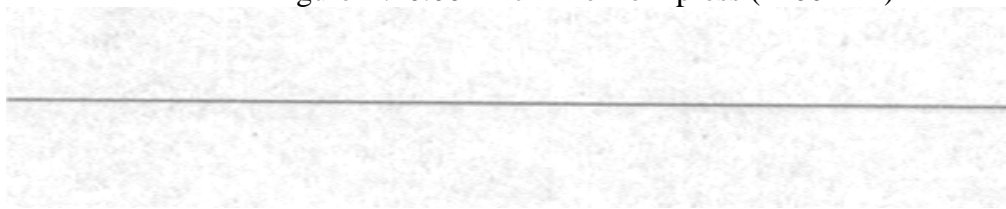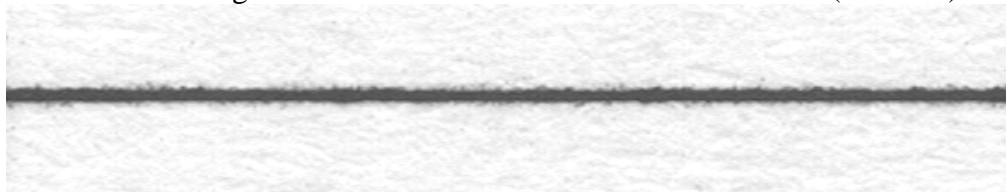Figure B. 0.001 inch line from press (2400 DPI)

Figure C. 0.001 inch line from Laser Jet Printer (600 DPI)

Beyond resolution, other factors influence the differences between a specified dimension in the virtual map and the resultant image of the real map. Figure A was produced on film while Figure B was produced on a laser jet printer using electrostatic technology on low-quality paper. The coarseness of the image is the result of the area electrically charged and matched with toner within the 600 dpi resolution. In inkjet technology, the coarseness would have been greater as the image is deposited by spraying the ink within a range determined by the resolution. In this latter point, the disparity between the source virtual map and the resultant real map is exacerbated by variable technology.

2.2 Virtual map to virtual map transformations
There are many variations to digital memory (data) as indicated in V_3. The V_3 to R has new complexities that require further discussion and possibly new definitions. In addition, derivative spatial data operations such as automated generalization from a source database to a derived database occur in a V_3 to V_3 transformation. The same is true for other spatial computations such as automated conflation. Generally, while dividing the examples into classes continues to hold true, increases in functionality, variability and flexibility warrant further investigation into classifying new forms and uses of cartography.

3.0 Use of color in map design
Color in map design is applied either as a symbolization technique or as a method for highlighting symbolized cartographic elements (points, lines, areas). In the former case, use

of color is equated with other techniques such as symbol form, dimension, and orientation. In the latter case, color aids in graphically emphasizing symbolized features.

General use multi-color real maps that are derived from virtual maps require the least common denominator in color design. This is a "safe" approach that is driven by a number of factors. The first is the uncontrolled map user environment. Virtual map producers rarely know the final output device and cannot restrict use of an electronic file for viewing and printing.

The degree of variability in color rendering is a characteristic of hardware and software packages. Selected color definitions in *Adobe Illustrator*, *Postscript*, and ESRI's *ArcInfo* produce different results. Computer monitors offer variable color palettes. The implementation of color use in hardware oftentimes is inconsistent across platforms.

The map specification may clearly state the conditions of color definition, however, the implementation in virtual and real maps results in unpredictable and inconsistent color use. The differentiation in color use minimally reduces the aesthetic quality of the map. In the worst case, the diversion of color from the original design changes the map message in the cartographic communication model.

Map interpretation by users is influenced by results from variable software interpreters, hardware translators, and technical specifications. For example, HPGL only recognizes the RGB color model while PS can handle many different models. Technology developments have expanded options for use of color while complicating the users interpretation. Map-readers with visual disabilities (color impaired and the color blind) have less control in interpretation. Designs that attempt to accommodate result in fewer color choices for consideration in the design phase.

4.0 Variations in printer technical specifications, language, and function
Producers of virtual maps are not aware of the users' specific predetermined approach to printing. This limitation is further aggravated by the technical uniqueness of the hardware solution (electrostatic versus ink-jet), the printer language (HPGL versus Postscript), and the hardware functions (variations in resolution – "draft", "normal", and "best"). The features and options available to the consumer in creating a real map complicate choices for maintaining the original intended design from the source virtual map.

Variations in printer and plotter hardware offer expanded functional capabilities, which give users additional capacity. Limitations in interoperability of printer hardware and software functions restrict standard interchange solutions. For example, there is no direct mapping of line weights between Hewlett Packard Graphics Language (HPGL) and Postscript (PS). HPGL has greater accuracy of the image. PS's resolution is 1/72in while HPGL's resolution is 1/1016in, therefore, HPGL can create finer line weights than PS.

Cartographers who design maps as electronic files that are transformed into real maps must take into account the limitations of the devices used to make the hard copy. A file designed to combine images into a composite graphic in one system (HPGL) will not have the same result in a system (PS) where the ordering of the image layers dictate that the last color processed is the only color displayed.

Image creation systems have their own advantages and disadvantages ultimately depending on the intended use of the map. Water-based inks typically associated with ink-jet printers produce different results from other image deposition approaches such as electrostatic and wax-based technologies. The creator of the virtual map may design the image with a preconceived visualization. Transformation of the file to a computer screen of lower resolution or to an image deposition technique different than the one intended likely will produce an undesirable outcome.

5.0 Fonts
5.1 Font metrics
Font handling in transformations from virtual map to real map is a challenging endeavor. Cartographers working with fonts are continually baffled by the unpredictability of their use within software and the frequent discouraging results in the final image, whether virtual or real.

The two images below (Figure C) were captured from the Census Bureau's $106^{th}/107^{th}$ Congressional District Atlas Project. The first image is a snapshot of a specific set of characters generated from ESRI's Maplex automated text placement software. The second image is a snapshot of the same set of characters, at the same scale, after the characters had been exported into an ESRI Arc/Info annotation layer. No user initiated post-processing or manipulation on the font metrics was performed regarding kerning or character spacing between the two images below. Note the character gap differences between the two images. This example shows how use of font is distorted in virtual maps using different software applications that in this case are provided by the same vendor.

Figure D

Maplex Font (Before Annotation Export)	Arc/Info Annotation (After Maplex Export)
BERMUDA 7 Chester	BERMUDA 7 Chester

5.2 Location of fonts and their effect on electronic maps
Fonts generally are handled in electronic maps in one of three ways. They are embedded, which means that the font is contained within the map file. Rather than embed a font, a call can be made within the map file that accesses a font that is resident on the output device (computer screen, printer, plotter). If the specified font is not resident, then the third option initiates in which a resident font on the device is invoked as a substitute font.

The two images below (Figure D) illustrate the difference between an embedded font in an Adobe portable document format (PDF) file and a downloaded font into a PDF file. It is preferable to know the final output before outputting a map to the PostScript format when dealing with fonts. If the final output is going to be the PDF format it is best to embed the font metric information into the PostScript file. This maintains a crisp appearance of the font in the PDF file and ensures that the text is 'searchable' with the search capability in Adobe Acrobat Reader®. If the final format of the map is PostScript, it is preferable to 'download' or stroke the font out to the PostScript file. This ensures a crisp appearance of the font in the PostScript file but no other applications recognize the characters as being part of a font beyond this point.

Figure E

PDF with Font Embeded	PDF with Font Downloaded
ABCDEFGHIJKLMNOPQRS abcdefghijklmnopqrstuvw	ABCDEFGHIJKLMNOPQRS abcdefghijklmnopqrstuvw
PostScript with Substituted Font	PostScript with Font Downloaded
ABCDEFGHIJKLMNOP abcdefghijklmnopqrstu	ABCDEFGHIJKLMNOPQ abcdefghijklmnopqrstu
Requested Font with PostScript Code (Font Name Referenced, Metrics written)	PostScript Code with Font Downloaded (Font translated and stroked out)
/AkzidenzGroteskBE-LightCn 71.99999 0 0 0 z save /krnary [27.09 27.09 27.09 28.62 24.06 22.62 28.62 28.62 12.06 24.06 25.56 22.62 36.12 28.62 28.62 27.09 28.62 27.09] def [1 0 0 1 71.97 143.97] e 19 (ABCDEFGHIJKLMNOPQRS) t T restore	F 253.29 76.59 m 253.29 82.23 l 256.32 82.23 l 256.32 76.59 l 253.29 76.59 l

5.3 Font origins

Prior to availability of commercial fonts, organizations that produced electronic maps either defaulted to the resident fonts on output devices or they created their own digital font sets. The latter basically are digital features (strings of coordinates) designed as text characters. One advantage is that the fonts are basic cartographic symbols in which outline fonts can be filled with patterns, screens, and colors along with different symbols that bound the character that, in effect, are symbolized areal features. The choices for design are limitless in that specific character designs can be created to meet organizational design requirements. One disadvantage is that, as features, the characters are not searchable as part of a font set unless they are converted to a font definition.

Commercial fonts have their own advantages and disadvantages as indicated in Figures E and F. One characteristic of a virtual map that commercial fonts support is the searchability of text (names and/or characters). From a map use perspective, this function is not possible on a real map. In terms of map design, a disadvantage of commercial fonts is their limitation on

design of characters. Currently, it is not possible to include a bounding symbol of a filled font that has a different description (symbol) from the "filled" design (Figure F).

Figure F
Commercial Fonts

Benefits	Drawbacks
May be embedded in the PDF format (Are 'searchable')	Cannot treat outline differently than fill (See Figure F)
Can be placed with automated text placement software	Often do not meet precise organization specifications

Figure G

Organization Specific Font – Different fill and outline	Commercial Font – Separate fill and outline not possible
CAMPO	CAMPO

Electronic map files in a virtual world are available in one or more file formats. As with any file, the description of how the file content is organized is a basic requirement. Each format has characteristics that differ from other formats, thereby offering advantages and disadvantages, depending on the format design. Additional differences include compatibility in applications/technologies, file size, rendering speed, and image quality. Four formats are briefly compared for their impact on both virtual and eventual real maps from the same electronic file. The formats include: PS; PDF; Graphics Interchange Format (GIF); and the Joint Photographic Experts Group (JPEG). (Environmental Systems Research Institute, Inc., 1998-1999)

Figure H

	Compatibility	File Size	Image Quality	Other
PS	Compatible with many graphics software packages. Not compatible for use over the Internet.	Very Large (~3 times as large as a PDF document)	Image quality is determined by an applications interpreter.	Different software applications can interpret the same PostScript file in different ways resulting in image quality, color, and even content differences.
PDF	Compatible with some graphics software packages. Compatible for use over the Internet only if the Adobe Acrobat Reader Plug-in is installed in the browser.	Not too large (~1/3 as large as a PS document)	Very Good. Resolution in excess of 2400DPI can be achieved.	Fonts may be embedded. Intended colors can be maintained in conversion to PDF format. The 'zoom' capability in the Adobe Acrobat Reader software allows users to zoom into an area of interest (intended resolution is maintained). If the fonts are embedded, a user can use the 'Find' capability to highlight a label of interest.

GIF	Compatible with most graphics software packages. Compatible for use over the Internet.	Very Small (good for quick transfers over the Internet)	Not great. Resolution directly corresponds to the amount of file compression which is specified by the user in the GIF creation process. Fonts are rastered and thus may not be embedded.	This format supports interlacing and transparency which is often very useful for images intended to be put on the Internet. This format is licensed and is not royalty free. Good for images with large areas of the same color. Limited to storing only 256 colors.
JPEG	Compatible with most graphics software packages. Compatible for use over the Internet.	Small (good for quick transfers over the Internet), slightly larger than GIF (~2%)	Not great. Fonts are rastered and thus may not be embedded.	Royalty free. Stores up to 16.7 million colors. Good for slight shifts in color shades. Good for photographs and aerial photography.

6.0 Conclusion

"Real" maps typically followed a single production process from early design compilation through product dissemination. "Virtual" maps, on the other hand, pose new challenges to cartographers.   In the virtual world of cartography, there are multiple mapping and dissemination environments available. As a result, cartographers can no longer choose a single path to serve their users, which creates new limitations. Choices that impact cartographic design and production include diverse examples such as color method selection, file format, output resolution, font characteristics, and most importantly, the unknown user environment. Compared to "real" maps, the native formats for each map in these two different cartographic realms generally are not interchangeable. Alterations to each approach allow some level of interchangeability at a cost to each. What remains, and what is lost as a result of a change to improve compatibility between real and virtual maps, are of interest to cartographers. The causes and effects are numerous and more often than not are the result of evolving technology. While technology offers more flexibility and faster performance, which are viewed as improvements, these same functions sometimes reduce cartographic consistency and quality. Evaluating the differences and identifying technical issues are the first steps in addressing interchangeability. Cartographers at the U.S. Census Bureau currently offer multiple versions of a single product to meet user demands where in the past; one version was the standard. This approach forced the recognition of the limitations of interchangeability between real and virtual maps, made more complicated with the growing expectations of maps and mapping on the Internet.   Advances and alternatives are explored as part of an on-going cartographic production line environment.

Bibliography

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