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CAP metrics as an aid to image file format selection

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CAP METRICS AS AN AID TO IMAGE FILE FORMAT SELECTION

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Those needing to make a comparative evaluation of image file formats face a daunting task.The main difficulties arise from the large diversity and quantity of image file formats in use. This, coupled with lack of any standard way of describing formats, leaves the unfortunate enquirer with an unenviable job. This article introduces some new format metrics and uses these to show that trends are developing and that the market has already established some clear favourites.

The principal objective of a good image file format is to provide a structure which maximizes the utility of image data across a set of applications. Given the diverse nature of applications (e.g. astronomy, military/government, medicine, biology, and publishing) it is hardly surprising that there is such a profusion and variety of image formats in the world. A recent survey found almost 100 different formats in use (Call93). Given that a digital image is essentially just a two dimensional array, such an abundance of file types indicates there are many differing needs or opinions as to the best way of structuring image data. Thus, the selection of an appropriate image file format can be a most difficult task.

Which Image Format ?

So, the question arises, how does one select a format for a particular application? In some cases, the format choice is dictated by the use of a third party imaging package (e.g. Khoros users will adopt VIFF). However, those writing their own imaging software will have a less constrained choice. For such developers, if portability is a prime issue then a major factor might be the relative popularity of formats. For others, reducing programming effort or increasing software performance might outweigh portability considerations. Popularity is sometimes obtained by making the format general purpose which can in turn make it more complex, thereby increasing programming overheads or reducing performance. In these circumstances, a developer might prefer to use his own internal format, sometimes referred to as a "homebrew" format, which is well tailored to the application. The high position of homebrew formats in the popularity rating (see following table) is clear evidence of this. It is apparent that in making the decision on which format to adopt, information on the popularity, complexity and functionality of formats would be useful. Whilst, in theory, this information could be extracted from file format specifications, in practice the diverse origin of these formats means that they are frequently difficult to understand and make any comparative analysis a tedious affair.

Metrics to the Rescue

In everyday life, high level specifications are often found to be helpful when narrowing down choices prior to more detailed technical investigations (e.g. when buying a car or stereo). Such high-level specifications can equally be used as an aid to image file format selection. Recently,

a set of high level specifications referred to as ***CAP metrics*** has been proposed which address the problem of comparing the virtues of image file formats. CAP metrics describe such characteristics as the popularity of a format, its relative complexity and potential flexibility. For example, the following table lists the most popular formats (***popularity rating***), together with two other CAP metrics, complexity ratings (referred to more formally as a ***transformation index***) and ***HI-FI taxonomies***.

FORMAT	Popularity	Complexity	Taxonomy
GIF	1	3	FI
TIFF	2	5	HE
PBM	3	2	FI
Homebrew	4	-	-
SunRaster	5	3	FI
Targa	6	4	HI

This popularity ranking was obtained by averaging the results of two informal USENET polls, the first conducted in 1991, the second earlier this year. The complexity rating is a measure loosely related to the number of transformations a software reading routine might have to perform on a given format before it can be displayed (e.g. decompression). The taxonomy is based on the premise that internal field hierarchy and labelling have a fundamental effect on the overall logical structure of a format. This taxonomy categorizes image file format structures as being one of four main types: **HE** (Hierarchical Structures with Explicit Labels), **HI** (Hierarchical Structures with Implicit Labels), **FE** (Flat Structures with Explicit Labels) and **FI** (Flat Structures with Implicit Labels). The use of field hierarchy and labels increases the flexibility of a format but places an overhead on a format reader which must be able to deal with these structures. Thus, as table 1 also illustrates, such structures increase the complexity rating. More information on CAP metrics and details of the informal polls can be found in the paper by the author, listed at the end of this article (Call93).

Popularity gives evidence of the potential user base, whilst the taxonomy might be used to assess the flexibility of the format. Complexity provides an indication of the relative programming difficulty. Such information can be difficult to distill from the varied and frequently complex format specifications. Another factor to consider is how well the features a format offers are matched to your application. A useful graphical representation known as a ***functionality profile*** is also included in CAP metrics and gives a simple pictorial impression of the quantity and distribution of features within a format. In essence, a functionality profile is a histogram describing the distribution of features within a format.

As with most decisions, the choice of format will usually be a compromise between conflicting ideals. Thus, when choosing an image format, one has to balance such aspects as programming complexity, flexibility and popularity. The CAP metrics represent a convenient mechanism of summarizing some of the main factors involved and should serve as a good starting point for those searching for a suitable application format before they expend too much time wading through rather lengthy and complex descriptions of the standards themselves.

Current Market Leaders

Clearly, the popularity ratings given above show the general purpose market place has established GIF and TIFF as image file format leaders. These standards have commercial

rather than governmental roots. GIF (Graphics Interchange Format) was developed by Compuserve, an on-line information service, to give its users a hardware independent way of exchanging colour image files. The latest version of GIF (89a) was introduced in July 1989. TIFF (Tagged Image File Format) was developed in 1985 to service the needs of scanning and desk-top publishing companies. Its aim was to help prevent the introduction of competing proprietary standards which, it was felt, would be counter-productive to market interests. In order to eliminate the need for multiple standards, TIFF was designed with powerful functionality which makes it relatively complex to program. As was stated earlier, there are many other file formats, some offering significant advantages within a particular domain. Whilst TIFF and GIF are platform independent, those interested in commercial products should also consider standards such as the Sun Corporation's SunRaster and ZSoft Corporation's PCX (PC graphiX) and the variant PCC (PC Clip art). These are well established in the Sun and IBM PC community, commanding number seven and ten slots in the popularity polls despite being platform dependent.

Future Developments

For some time, there have been calls for an international standard to be developed in the hope that it would stem the profusion of formats and bring some officially sanctioned order to this turbulent application area. Fortunately, such an international standard is currently being developed under the auspices of the ISO and is known as the IPI (Image Processing and Interchange) standard. It started life in 1990, after an ISO letter ballot, and is slightly unusual in that it addresses both image transfer and processing. The standard is organized into three parts: generic architecture, programmers' imaging kernel system (PIKS) and the image interchange format (IIF). If the number of competing image file formats is to be reduced, IPI will need to be capable of widespread application whilst keeping its level of complexity low enough to ensure easy usability. Only time will tell how successful the proposed ISO standard will be at unifying the image format field. On completion, which is probably two years or more away, the standard will be assigned the number ISO-12087.

Although not shown in the above table, most new formats such as PhotoCD, HDF and IPI can be shown to belong to the HE taxonomy group with CAP complexities (transformation index) of 4 or above. Hence, it is apparent that there is a clear trend in new formats to sacrifice complexity for increased flexibility. In many respects, this is inevitable as, if a file format is to assume the mantle of a real standard, it needs to be able to adapt to the unavoidable technological advances that will occur over its lifetime. Thus, some would argue there is dilemma that only the market can solve; programmers want simplicity but successful standardization demands flexibility and thus increased complexity. Which view will predominate? The answer is in your hands!

Further Reading:

Callaghan V, et-al, "Structures & Metrics for Image Storage & Interchange", published by the SPIE in the Journal of Electronic Imaging, Vol.2 No.2, April 1993, ISSN 1017-9909, pp126-137.

This paper provides an introduction to the principles of formats, a description of common formats, including: PBM, SunRaster, GIF, PCX, PCC, FITS, TIFF, EPS plus some of the newer formats such as IPI (the new international standard), HDF & DSF. It also includes popularity

rankings showing format usage derived from two recent surveys and offers some methods of assessing format complexity (& the difficulty of writing software to support them). In addition it includes a listing of sources of image format information (e.g. other publications, addresses where format specifications can be obtained, ftp sites etc.).

Carpenter L A, Mumford A M, "*File Formats for Computer Graphics - Unravelling the Confusion*", Technical Report No.10, published by UK Advisory Group on Computer Graphics, Loughborough University, February 1992.

This is a most comprehensive report on computer graphic format issues. It was presented as a "state of the art" review on the subject at the Eurographics '92 conference held in Cambridge (UK) during September 7th to the 11th 1992. It includes a discussion of common data structures and compression techniques such as: vectors, RLE, Quadtrees, Huffman, LZW, Fax, JPEG and MPEG. A variety of bitmap, vector and object formats are described including TIFF, GIF, EA IFF 85, X, SunRaster, PICT, PCX, Targa, OFF, PS, HPGL, NTF, PHIGS, CGM, FITS & DXF. This report includes an informative discussion on international standards and a most useful reference list. The report is available from the Computing Services at Loughborough University, UK (contact: Mrs. Bradwell).

Carlson W E, "*A Survey of Computer Graphics Image Encoding and Storage Formats*", Computer Graphics (ACM), 25(2), 67-75, (1991).

This paper makes good use of diagrams to illustrate the principles of common data compression algorithms and file structures. Compression algorithms described are: LZW, RLE, differencing, Hierarchical (e.g. quadtrees). File formats described are: TIFF, PICT, TIFF, GIF, Targa, SunRaster, GKS and fax. The paper also includes a useful reference list.

Clark A, "*An Introduction to the Image Processing and Interchange Standard*", in Eurographics (Tutorial programme T7), Cambridge England, 7-11th September 1992.

This paper makes an excellent job of giving a most comprehensible description of what is a relatively complex standard. For those seeking an introduction to this new standard, without the inevitable overheads of synthesizing key facts from an official draft, this paper from a member of the committee responsible for drafting the standard is the answer.

Kay D C, Levine J R., "Graphics *File Formats*", Windcrest/ McGraw Hill, 1992, ISBN 0-8306-3059-7, U.S. $24.95.

This book covers PCX, MacPaint, TIFF, GIF, GEM, IFF, Targa, BMP, PBM, XBM, XWD, JPEG, FITS, DXF, HP-GL, PIC, PCL, PostScript, WMF, PICT, CGM, and other file formats. It has a nice style and each format is described in sufficient detail to allow a programmer to encode and decode the files.

Internet Archives: For those in the academic and research community with access to internet, a useful source of information are the following anonymous ftp archives: zamenhof.cs.rice.edu (in directory pub/graphics.formats), ftp.ncsa.uiuc.edu (in directory /misc/file.formats/ graphics), titan.cs.rice.edu (in directory public/graphics.formats)and peipa.essex.ac.uk (in directory ipa/file-formats)