UDK 004.65

DIGITAL OBSOLESCENCE

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October 2011

Summary
Problems of digital obsolescence due to obsolescence of computers, software and data mediums are presented in this article. Librarians and archivists are mostly concerned because of the "digital dark age" phenomenon, and they are looking for more efficient solutions to preserve cultural and intellectual heritage in digital form in order to decrease expenses and prevent time wasting. Further in the article, disadvantages of some computer platforms and methods of temporary data revival are shown, but for now no efficient standardized and long-term strategy, which could be applied to all types of digital resources, has been established. Many examples of computer, format, program and medium obsolescence that are listed, should awake everyone's consciousness no matter what their professional occupation is, because contemporary business and social life can't be imagined without computer technology which makes communication easier and faster, but it can also disable and interrupt all connections with future generations.

Key words
digital obsolescence, Domesday project, emulators, format specifications, digital dark age, digital preservation, digital preservation strategies.

1. Introduction

Situation in which digital resource cannot be read anymore, either because physical medium that contains it is no longer in use, or hardware or software which executes it is not available, is known as the **digital obsolescence** phenomenon. Common text can be presented on a stone plate, on parchment or microfilm, and it will always be recognized as written text. However, as soon as the text is digital it presents only an electric impulses flow and those impulses are meaningful only when they are interpreted by software which created them or for which they were intended. Rapid evolution of technological innovations and spreading of various computer hardware, digital coding options, operational systems and general or specific software are followed by many serious problems which are questioning digital preservation.

Attention was brought to librarians and archivists in the 1990s. Experts in those branches discussed this topic a lot, but without any significant solution except for continuous and immediate transfer of data and information to latest media according to the current standards. Librarians were under pressure to use every innovation right after its invention in order to keep up. If the latest technology had failed, one of solutions out of the situation was to transfer all resources to newer digital media. Downside was money and time wasting, which are always deficient, which lead to resources being unavailable and libraries becoming museums of failed technology. (Crawford and Gorman 1995)

Digital media get worn out and damaged over time. These changes needn't be obvious as it is the case with photos or books, but they are present and almost everyone who owns a computer experienced that – hard disk crashing, compact disc scratching, bit rot on magnetic tapes, or just breaking down of data reader. Even if data remain intact and bites are still on media, it is necessary to keep up with information about which computer platform can read them and in which format they are. It makes the data retrieval process, with which librarians and archivists are faced with always growing data collections, even harder.

There is a known case of NASA (*National Aeronautics and Space Administration*) space recordings and pilotless spacecrafts Viking 1 and Viking 2 landing on Mars in 1976 saved on magnetic tapes. When the recordings were to be analyzed they turned out to be unreadable because they were in unknown format and their creators had meanwhile passed away or left NASA. The recordings were eventually extracted after months of resolving doubts through thorough research about how recording machines had functioned. (Blakeslee 1990)

2. BBC Domesday Project

One of the most famous examples of digital data loss due to digital obsolescence is the *BBC Domesday Project*, in which the entire British nation took part and whose research was compiled nine hundred years after the *Domesday Book* had been published. Original document known as the "*Doomsday Book*" presents census of eleventh century England started in 1086, ordered by King William the Conqueror. TV producer from BBC Peter Armstrong started an interesting adventure of reviving these traditional data collections with new additions, photos, precise locations, town descriptions and reports from people across the country about everyday topics in 1983. He gathered leading minds in technology and started one of the main interactive projects of the time.

This multimedia publication in which over million people took part was published in 1986. More than 2 GB of data were gathered, which was a stunning amount for that time and the most common way for transferring data among computers were 5.25" floppy discs. Considering their limited capacity of 1.2 MB, results of the project were finally put on adopted laser discs,

CD-ROM ancestors, in LV-ROM format (*Laser Vision Read-Only Memory*). Two discs, *Community Disc* and *National Disc* were in the size of a gramophone record (12") but they looked like compact discs we use today with 300 MB of storage space on each side of the disc. They were readable by a specially configured player Philips VP415 called the *Domesday Player*, on Acorn computer *BBC Master* increased by SCSI controller (*Small Computer System Interface*). User interface consisted of BBC Master Keyboard and trackerball by which the user could move cursor on a screen and choose action with a click. Software for the project was written in BCPL (*Basic Combined Programming Language*) which was not widely spread and can be considered a C language ancestor. (Darlington et al. 2003)

Several libraries bought the whole system package, but it was far from the original idea of wide distribution. Participants of the project were disappointed because their hard work wasn't easily available in public. As time went by this project became a basic example of digital obsolescence, because less and less machines had access to it. While information from the book are available nowadays, Domesday project discs with "more than 250.000 place names, 25.000 maps, 50.000 pictures, 3.000 data sets, 60 minutes of moving pictures" (McKie and Thorpe 2002) have become unreadable due to small ability of contemporary computers to read old formats and the ability to access laser discs is even smaller.

A group of researchers from Michigan and Leeds Universities formed the CAMiLEON consortium (*Creative Archiving at Michigan & Leeds: Emulating the Old on the New*) in 1999, in order to save data from Domesday discs. In 2003 CAMiLEON successfully improved the system. They enabled access to discs that were already in bad physical shape by original hardware emulator. During the process, CAMiLEON was researching and developing strategies to preserve digital material, so this project was an important testing ground for implementation of new strategies and development of the software emulating program. Another team which worked for The National Archives of Great Britain (The National Archives in Kew) traced the original 1" magnetic tape. It contained photos and maps of Great Britain with locations of all important data that were used for the discs. Photos and maps have been scanned and laser discs converted into new digital format which can be read on different machines. In July of 2004 data were published on the web but this version was removed from the web in 2008 when its author Adrian Pearce died.

BBC Learning team led by George Auckland published large amount of data from the Community Disc again in 2011 in format available on the web named ***Domesday Reloaded*** (http://www.bbc.co.uk/history/domesday). On this internet site, one can access photos and articles from the original project and see how life of British people has been changing in the last 25 years, while visitors can refresh information with their memories, photos and stories.

3. Types of obsolescence

Massive use of DVDs instead of video cassettes, or use of USB memory for data transfer instead of floppy disc, presents only few of many examples of **technical obsolescence** where new technology replaces the old one, becomes preferred and starts to be used more than the old one. Single products can be overtaken due to inability of technology to proceed with its production. It mostly happens when it is pushed from market either because its creator left business or it was bought by competitor which intentionally kills all his products.

Some products become **functionally obsolete** when they don't work anymore in the way they used to when they were created, either because of inevitable natural wear or because of some intervening act. Product can be intentionally designed

to use components that get worn out faster, which leads to planned obsolescence. Example for this type of obsolescence is producing some appliance designed to wear within five years from the shopping day, forcing customers to replace it with new after that amount of time.

Planned **systemic obsolescence** is intentional attempt to make product obsolete by changing its functional system in such a way that it makes its use harder. New software which is being introduced is often incompatible with older versions. Although, for example, older version of the word processing program is working well, it is mostly not able to read data saved in new version. Lack of compatibility is forcing users to buy new programs although the old programs are still working correctly. The other way to introduce systemic obsolescence is by eliminating maintenance services. If the product breaks down, user is forced to buy a new one. The only, but very important case where this example of systemic obsolescence can function is proprietary software which is licensed by exclusive copyrights, where the third party is not allowed to intervene on the product. Well known example of this is when Microsoft stops their customer support for older versions of Windows and older service packages on new versions, like disabling web browser Explorer 9 within operating system Windows XP.

Postponement obsolescence is a situation in which technological improvement of product is not introduced even if it is possible, when manufacturer is not able or doesn't want to sell some software service, but they enable users to install software on computer and use it for limited time. In the meantime, users can decide if they want to buy replacement, to upgrade it or to start using newer software. In some cases old technologies are used deliberately in order to avoid data intrusion, a strategy known as "security through obsolescence".

4. Emulation of obsolete computers

Computer hardware becomes obsolete when new generations of processors with increased capabilities replace the existing ones. Progress from large and expensive computers with calculating abilities to contemporary, powerful, cheap, fast and reliable computers in different sizes and features lasts less than an average human lifetime. The fact that computers which are available today will be outdated in five years is devastating. Some manufacturers stopped producing and their computers have automatically become obsolete, like TI-99, Commodore 64 and Amiga. On the other hand, new computer hardware opens doors to new and improved programs, thus directly influencing software and format obsolescence.

Thanks to the invention of hardware device i.e. software, the so called **emulator**, whose role is to imitate some other system that is not available, nowadays we can count on preservation of electronic data saved on media dependant on specific computer constructions, providing that special care is given to preserving media for storage for longer periods. Emulation is not focused on the digital object but on systematic surrounding in which the object is shown and from which it originates. (Van der Hoeven, et al. 2007) Through emulation, functions of a system are reproduced in such a way that they can be activated in some other totally different system which is going to act and look like the original system.

Imitation or "**emulation** is a special type of software application that creates a virtual object computer on a currently available host computer... Frequently, the object computer hardware is not available at the time the software engineers begin programming for it. Virtual hardware, or emulation, is commonly used to substitute for the unavailable object computer hardware to allow both engineering tasks to be developed simultaneously... Although emulation is most commonly used to emulate future hardware designs, it is also used – and arguably more easily – to

create virtual historic or obsolete computers." (Quick, Maxwell 2005) Their precious software is executed on modern computers thanks to emulators which can be found on websites like *http://www.amigaforever.com* and *http://www.c64.com.* "There is no comercial computer which hasn't been emulated in some way, from first personal computers like Commodore PET, or Apple II to contemporary Pentium PCs and Power Mac computers. Some of obvious reasons for emulator popularity are nostalgy, playing old games, need for software which doesn't exist on modern machines, and even education." (Ćalić 1998)

5. Storage media temporariness

Just as the advance of technology led to the computer hardware obsolescence phenomenon, a similar situation is present at data storage media which are leaving space for their faster, smaller, with larger capacity and easier to read heiresses. "Frequently the new hardware is not backward compatible with the older hardware's media for more than one generation." (Quick, Maxwell 2005) That is the case with device for the 3.5" floppy discs which haven't gone out of use completely, but this device is not being built in the new generation computers even though it used to be a part of standard equipment. Floppy disc used to be the main transferring medium between computers until the appearance of CDs and other advanced relatives, and today only its icon is in wide use as a metaphor for data storage on the interface of most types of software (e. g. option *Save* within Microsoft Office package).

It's a fact that bits on media get lost in time. One of the reasons for that outcome is physical features of materials the media are made from, which have variable characteristics that make them unstable. "Nature tries to equalize energy levels, and over time, it succeeds at erasing the data that is stored on most digital media. To store data for a long time, the media the data is stored on must be nearly entropically equalized to start with so that further deterioration will take centuries to happen." (Quick, Maxwell 2005) All magnetic mediums have high entropical energy, and only few optical media are close to be entropically equalized.

There are many commercial firms that offer media migration, format conversion and data recovery services and expenses vary depending on procedure difficulty. "Simple migration of standard format 5.25" disks can cost anywhere from $5-$50 per disk and up", data conversion increases the price of service while restoring data from damaged media costs even more. (Entlich 2004) "Even if data migration is flawless across intermediate media with repeated reading and writing using differing technologies, the time spent idle between migrations will take its toll on the stored data bits. Data migration success rates are never 100% and successive storage/migration cycles accumulate failures and expose the data to corruption and loss." (Quick, Maxwell 2005) Besides data preservation on media problems, there is a problem of reading media on which data are still present but are coded because decoding process is being deliberately hardened. Modern encryption is being more and more used in documents and media because publishers want to protect their copyrights by limiting usage of digital content and by method of DRM (*Digital Rights Management*).

Paul Conway pointed out that "as our capacity to record information has increased exponentially over time, the longevity of the media used to store the information has decreased equivalently." (Li, Banach 2011) Although all digital media are susceptible to the obsolescence phenomenon, the ones more equalized with standard and in wider use will obsolete slower. "When selecting a storage medium for digital materials, it's important to choose a type and brand that has a reputation for good quality. While all media will fail eventually, higher-quality media will last longer and ultimately help reduce the cost of

replacing media over time." (Bailey 2011) Also, making backup copies on different media will decrease possibility of valuable digital data loss. "To avoid storage hardware dependence, the storage media must not be tied to any one manufacturer and the retrieval device must be able to be crafted from simple parts. Future generations must be able to construct a device to read the media with minimal understanding of what is on the media and with simple, readily available parts." (Quick, Maxwell 2005)

6. Classification and cataloging data format

Although some format specifications are independent from specific software like coding ASCII and Unicode schemes, most of them are connected to related software groups. Software and format specifications on which it is based usually develop together and therefore are necessarily in tight connection. This is why discussions about format obsolescence must include software obsolescence issues. Usually efficient software is being upgraded. Although most applications can read files created by previous versions, or the one before, ability to read even older versions mainly doesn't exist. The latest versions of software most often can't read files which haven't migrated, while older versions of software often are not available or can't be run on current computer or under current version of operating system.

The most problematic formats are those formats whose specifications are **proprietary and closed** and which are being connected to efficient long lasting software. They have a tendency to grow fast and exist in many different versions for different platforms, and their compatibility with older versions is limited. Manufacturers follow commercial moment deliberately avoiding compatibility with older versions of their own software in order to force all users, including the ones who prefer older versions, to do upgrading. To make it work, attention of users is being held by attractive offers of additional functional applications, ensuring constant incomes. These formats are the most endangered ones because they face fast specification change on one side and depending on one product or company on the other.

Formats that are **proprietary and open** pose less risk of obsolescence because specifications are available in public allowing other companies to produce software which can read them. An example is a subset of proprietary format which was adopted as standard PDF/A, archive version of PDF owned by Adobe but is an open specification. PDF/A differs from PDF in that it requires XML format based metadata as well as removal of distracting elements which would complicate decoding and speed up obsolescence – like audio and video recording, JavaScript etc. This kind of specifications is still susceptible to market forces' caprices and can easily be abandoned for commercial reasons.

It can be said that specifications that are **non-proprietary and open** are the most secure for data storage. They are supported by international standards bodies whose representatives help equalizing needs of a variety of users who are not reflection of any single commercial interest in standard creating. Open formats are also called free file formats unless they are bound by copyrights, patents or other limitations, so everyone can use them for any purposes without charge. Compatibility with old versions is priority of these standards so there are no commercial pressures for rapid obsolescence.

Until today, thousands of formats and their versions have been created and only recently an effort has been made to catalogue and document them and understand their relations and variations. Without appropriate software file format documentation and specifications, attempt to interpret old file or even to determinate in which format it was written becomes scary. Digital protection department of the Great Britain Na-

tional Archive has developed an online information system about file formats and their following software products, PRONOM. Originally it was developed as support for access to electronic data records of the National Archive and for long termed preservation, and today it is available for every single person who needs information about software products, their support and technical requirements life cycle and about formats supported by some diferent software.

Many projects involved with preservation of cultural heritage are facing inevitable questions about digitalization – "how to digitalize, in which format, how detailed...?". NINCH (*The National Initiative for a Networked Cultural Heritage*), situated in Washington USA, lists the following formats as *de facto* standards which probably won't obsolete in close future: uncompressed TIFF and PDF for images, ASCII and RTF for text. (2002) Systems dependant on copyright types of software whose license conditions and software existence are not long-termed are not appropriate for archiving and for making digital collections of cultural heritage.

File formats in which data are saved should be used widely, compatible with previous versions with history of compatibility available, have reasonable upgrading cycles, solid support to metadata, built-in error checking, open, uncompressed or to use compression without loss, and finally work with wide specter of hardware and software configuration. (Bailey 2011)

7. Is it possible to escape from "digital dark age" and how?

While it is still possible to read our written heritage that is more than hundreds of years old on analog media, digital data that are only a few years old are in serious danger of being lost forever. An attempt to switch all digital media into analog form is almost mission impossible, even if the fact that it would take eternity is disregarded. Solid copies are more resistant to obsolescence, but they can't reflect the real nature of multimedial digital forms and by no means are they able to replace them. Suggestions to form digital museums in which old machines that can run original software and compatible obsolete formats would be kept also have no grounds. Maintenance expenses would be high, access to original digital documents would be possible in only few locations in the world and as already stated, computer hardware has limited lifetime. "The rate of digital obsolescence keeps accelerating, and the serious search for a long-term strategy for storage has yet to begin." (Brand 1990)

The main challenge digital generation is faced with is: "how can masses of machine-generated, machine-readable material be stored in a form that is safe, secure from degradation and – potentially most calamitous in the long term – accessible to subsequent generations?" (Huxley 2005) There have been many tactics for protection of digital data which can be successfully performed by persons and organizations on specific types of materials in specific surroundings. However, none of them is suitable for all types of data, neither efficient in all situations nor adequate for all institutions responsible for preserving cultural heritage. Variety of formats and specifications additionally make finding a unique solution harder. Appropriate strategy should be determined by the type of digital object which is to be preserved, by requests of users who want to access the object, and by politics of institutions that are responsible for preservation of digital sources.

Digital preservation is active managing of digital information through a wide specter of activities which will ensure their availability, increase their lifetime and protect them from being ruined, from physical damaging and obsolescence. This is a dynamic and continuous process during which methods and technical requirements change along with rapid technological changes and which is followed by constant investing of effort, time and money. Long-term

storage of information without error in proper formats and on long life media makes it possible to retrieve data in their original form, so a human can read and understand them but they can also be processed by a computer. "The "digital dark age", in other words, could yet become a digital golden age, with the total of human knowledge preserved for and accessible to everyone." (Colvile 2007)

7.1 Digital preservation strategies

1. **Bitstream copying** – strategy also known as *backing up data* is a process of making an identical copy of a digital object. Though a necessary component of all strategies for digital preservation, it is not a long lasting technique by itself because it deals only with data losses caused by hardware and media failure, whether it is normal malfunction and decay or system failure, malicious destruction or natural disaster. Bitstream copying is often combined with remote storage and saving copies on different locations in order to avoid the possibility that both the original and the copy are subjects of the same disaster.
2. **Refreshing** – this is a process of copying digital information from one long-term storage medium to another of the same type without any changes in bitstream (for example from older CD-RW to newer CD-RW). Modified refreshing is about copying data to another medium of similar type without changes in bit-pattern (from 100 MB Zip disk to 750 MB Zip disk). Durable media like Gold CDs can lessen the need for often refreshing and decrease losses due to medium weariness, but durable media don't have infinite influence on any potential loss source – they only give false sense of security.
3. **Technology preservation** – is based on preservation of technical surrounding in which a system is run, including operative systems, original application software, appliances and so on. Sometimes this option is called *computer museum.* It offers possibility to face medium obsolescence providing that medium is not broken so it can't be read anymore. This is not a strategy which can be run by a single institution because maintenance of obsolete technology requires significant investments in equipment and staff.
4. **Digital archeology** – includes methods and procedures of rescuing content from damaged media or from obsolete or damaged hardware and software environment. Digital archeology is explicit strategy for urgent recovery of bitstream from unreadable medium whether due to physical damage or hardware failure. Readable bitstreams can often be retrieved even from very damaged media (especially magnetic media), but if content is very old, there is a high possibility that retrieving may not be possible and that content will not be understandable.
5. **Analog backups** – involves conversion of digital objects into analog form according to archive standard and using durable analog media like microfilms for preservation in archive conditions. To this type of transfer most reliable are text and monochromatic photos because the loss of functionality of the original document is minimal. Considering high costs and limitations of creating analog backing up copies, this technique makes sense only for documents whose content deserves highest level of loss protection.
6. **Migration** – involves transferring data into new systematic environment, conversion from one format into another, from one operative system into another, from

one program language into another, from one computer technology generation into next generation, while old data remain unchanged. According to some, migration is used interchangeably with refreshing but it is a broader and richer concept than refreshing. Purpose of migration is to preserve integrity of digital objects so clients would be able to use them in the face of constantly changing technology. Some criticized this method claiming that it can offer neither integrity nor authenticity – there is always danger to lose during this process partial functionality which existed in old format, or that convertor itself won't be able to encode or transfer all features of original format (especially when it comes to data protected by copyright).

7. **Reliance on standards** – this method is based on adhering to stable, broad accepted and well-recognized open standards during creating and archiving digital sources. This kind of standards are not related to specific hardware or software platform and in that way they can delay inaccessibility of digital resources due to technological obsolescence. However, stable standards are not available for all types of formats.
8. **Normalization** – is a formalized implementation of reliance on standards. Within an archival repository all digital objects of specific type (e. g. color photos) are being converted into one chosen file format (e. g. TIFF) which will reflect compromise among many features like functionality, durability and preservability. By normalization of stored objects into set of chosen formats whenever it is possible, number of formats is controlled and complexity of file managing is decreased.
9. **Canonicalization** – technique designed to enable determination whether important document characteristics have remained unchanged through conversion from one format into another. It relies on creating representative type of digital object which conveys which are the key aspects of digital object. Once created, this form or pattern can be used to algorithmically test if converted file has lost any of its essence.
10. **Emulation** – combines software and hardware to reproduce running of another computer with all its main characteristics, allowing programs or media designed for certain environment to be executed in different, most often newer environments. Emulation requires creating of emulators, programs for transferring code and instructions from one computer environment so it can be properly executed in another. Well known use of emulators is at newer version of Apple Macintosh operating system, which enables use of programs based on previous series of processors no longer used on Apple computers. Most of emulators available today were written for computer games of obsolete hardware in order to run them on modern computers.
11. **Encapsulation** – technique of grouping digital objects and metadata to provide access to the object. Grouping process should decrease the possibility of losing any key component vital for decoding and presenting of the digital object. Appropriate types of metadata hermetically closed with the digital object include: reference (it provides one or more markers for unique identification of objects), representation of information (provides interpreting bits in appropriate way), provenance (description of object source), fixity (proof that object is intact), and context information (describes how object is related to other

information outside logical structures called "containers" or "shelves"). It is considered to be a key element of emulation.

8 Conclusion

It is very important to be aware of use and limits of different digital forms, which should meet not only temporary purposes but also to be functional and available in the future. Not many people think about the fact that almost all of our knowledge recorded in digital form cannot last even for our lifetimes. "To those who believe in the immortality of new media files, Rothenberg offers a suitably new-age adage: *Digital information lasts forever - or five years, whichever comes first*." (Huxley 2005)

Since microfilm proved to be one of the most durable media for data storage in analog form (it can remain intact more than five hundred years), some started thinking in that direction to store digital data on this medium. Company which deals with services in the area of information technologies, ACS (*Affiliated Computer Services*), applied a request in 2004 for patenting technology of archiving binary data, *Method and apparatus for preserving binary data*. (PatentGenius) In order to place binary data on microfilm, it is necessary to present them as images readable by machines. Creators of this invention suggested use of 2-D barcode symbols for encoding binary data, whose symbols join into images readable by microfilm writer device. Also, "any available microfilm scanner that can capture a clear image of the 2-D barcode symbol on the microfilm can return the image to a digital image in a computer." (Quick, Maxwell 2005) Correctly defined specification for encoding can be stored together with binary data in order to make easier later recovery of data even if techniques for coding become obsolete. (PatentGenius)

As far as it is known, this method for data storage hasn't still found its broad use but it certainly implies possibility to come up with some new techniques which will face key problems of digital preservation, no matter how unpopular they are at the moment.

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