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Digital Techniques for Cultural Heritage and Artifacts Recording.

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Abstract

This paper will examine the current techniques available for recording of heritage sites and archaeological artifacts, that is: cultural heritage. Techniques include: digital freehand sketching, digital measurement, photographic techniques for generation of panoramas, 3D models and interactive tours, generation of 2D and 3D models to create interactive virtual tours, VR techniques and other trends. The paper will review the available hardware and software, the different workflows, processes, software, types of tools available for those interested in recording digital heritage. Future and expected trends will also be discussed.

Keywords

Computers; Cultural Heritage; Digital Cultural Heritage; CAD; Photogrammetry; HBIM; BIM

1. Introduction

1.1. Definitions

Cultural heritage is all items of historical, cultural or anthropological value related to all human activity and expression that has been transmitted, acquired or inherited from past generations, whether material or intangible. This can include material heritage such as: **Architectural Heritage**, which is anything that has been used to create and enclose space (historical monuments, buildings, archaeological sites and digs, landscape, historic towns and villages, underwater archaeological sites…etc.), **Heritage Artifacts** (all artifacts, tools, equipment, jewelry, pottery, metalwork, utensils, carpets, textiles and all other material objects), all art forms and expression (painting, sculpture, performing arts, film, photography, music, songs), **Literary Heritage** and forms of expression and Heritage recording (literature, prose, poetry, grammar, logic, rhetoric, manuscripts, drama, speech, folklore, myths and legends, tales, oral traditions rituals, customs, ceremonies..etc.), **Scientific and Traditional Heritage** and Skills (pottery, textile and carpet weaving, embroidery, traditional crafts, traditional methods for manufacturing, chemistry, arithmetic, geometry, astronomy, surveying…etc.), even **Olfactory Heritage** (perfumes, incense, spices and other) and **Food Heritage** (food recipes and beverages).[(Archaeology, 2018); (What is Cultural Heritage?, 2018); (World Heritage Sites, 2018); (Food Heritage, 2018)]

Archaeology is the scientific study of the material remains of Cultural Heritage. (Archaeology, 2018) The field of Archaeology can be considered a wide field that encompasses other specialized fields like: History, History of Architecture, History of Art, Architectural Preservation and Conservation, Preservation and Conservation of

Organic and Non-Organic Artifacts.

Digital Archaeology, and **Digital Cultural Heritage** can thus be defined as the use of all forms of digital devices (mainly computers and subsidiary devices) in the field of Archaeology and cultural heritage.

Throughout this document, we will use the term Cultural Heritage to mean Digital Cultural Heritage and Digital Archeology.

1.2. Use of Computers in Cultural Heritage.

Computers have been used in Archaeology as early as 1958, (Cowgill, 1967). Needless to say, computer technology in both hardware and software has drastically changed since the late 1950's, with today's era definitely a "Digital Era". Computers and other computing devices (Smartphones included) have become an integral part of our lives and infiltrating all disciplines, becoming a standard and indispensable tool. With the current rate of development in computer technology, we can expect more adoption of digital technology in our lifestyles with smaller and more intelligent devices that are becoming an essential and indispensable part of our daily activities and professional careers.

Today, computers are used extensively in Archaeology for the Recording, Archiving, Analysis, Visualization, Presentation and Publication of Archaeological data. Simply put, and to use computer jargon, this is simply "Data Processing" of the available amount of knowledge we acquire for a certain topic, something which computers have been designed to do. The use of computers in all steps of the Archaeological processes, whether in digs or in later studies, analysis, reconstructions and in academia, has become the trend, greatly changing the manual workflow and creating a new methodology for all aspects of the practice and study of Archaeology. (Tsiafaki & Michailidou, 2015).

Other disciplines integrate their IT knowledge and experience into archaeology for digital cultural heritage. IT skills for archaeologist and all involved in cultural heritage are now mandatory. The integration of computer technology in Architecture is now mature, so we find that Architects have greatly contributed in the recording and visualization of cultural heritage for archaeology and art history ((Digital Karnak, 2016)), making the cross discipline integration and convergence of paramount importance. More and more architects are being involved in built cultural heritage restoration, rehabilitation and re-use. Likewise, Archaeological Restoration professionals are broadening their expertise borrowing from architects' practices and procedures and tools. Academic archaeology schools are slowly integrating IT technology their curriculum, some programs offering complete integration in the discipline, teaching their students the most needed skills. Stanford University offers several courses in digital archaeology as part of its undergraduate curriculum (Stanford, 2019). Post-graduate programs are offered by some universities, examples include the MSc. In Digital Heritage offered by the University of York in the UK (University of York, 2019), UCL in London offers an MSc. In Computational Archaeology (UCL, 2019), University of Leiden offers a degree in Digital Archaeology, with two computer laboratories (Leiden, 2019). Numerous Italian scholars and archaeologists have demonstrated their adoption of the technology in numerous projects (Ott & Pozzi, 2010), and some courses are offered in the universities of Pisa, Bologna (Summer School, 2019) to mention but a few. In Egypt, the Faculty of Archaeology in Cairo University offers a course on the use of computers in archaeology for both graduate and undergraduate programs and other course in the use of technology in the Restoration Department, University of Suhag offers a 5 day training course on the use of computers for archaeology (Suhag University, 2018). Interest in the use of computers in cultural heritage has also been shown in some research on the topic from Egypt (Farid & Abdelhamed, 2018).

Further convergence and cross discipline integration between many apparently unrelated and disparate disciplines with new opportunities are opening up for use in Digital Cultural Heritage. To mention but a few we see convergence and cross integration between computer and mobile phone technology and hardware, programming, photography and film, gaming, simulation, CAD (Computer Aided Design), CAM (Computer Aided Manufacturing), model making and rapid prototyping, remote sensing, Sonar, Radar, X-Ray, photogrammetry, GIS (Geographic

Information Systems), map making and many other disciplines. More options will open up and we need to keep an open mind and investigate the most useful techniques and processes that we can borrow, adapt and use for Digital Heritage from whatever discipline we can.

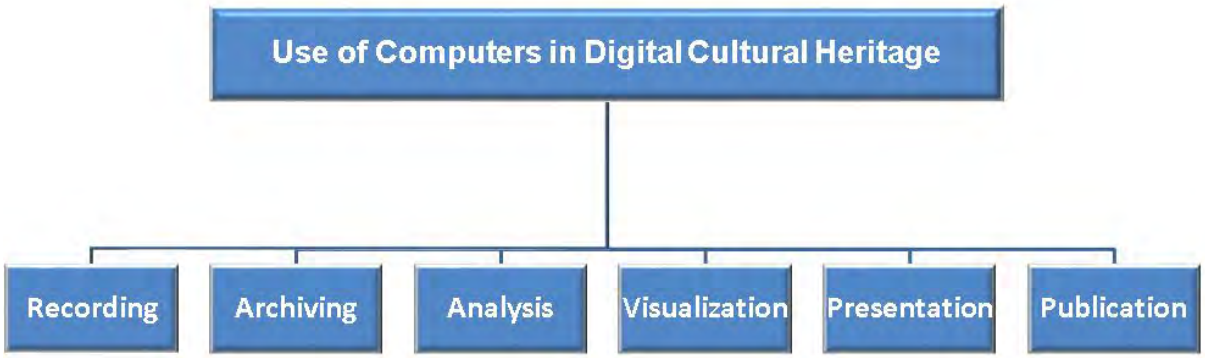

Figure 1. Computer Uses in Digital Heritage & Architecture (Author)

1.3. Recording of Cultural Heritage Data

In this paper we will limit our discussion to the use of computers in the Recording of Archaeological data, the initial and most important phase when considering any Cultural Heritage and study or application of Archaeology or any of its subsidiary careers. Needless to say, there is a direct relationship between the recording techniques used and the way that data will be used for the other phases (Analysis, Visualization, Presentation and Publication), thus we will be investigating numerous recording methods due to the variety of activities in the subsequent steps in the process, in an attempt to lay out the theoretical framework for the inclusion of all methods available to us in the workflow and use of computers in archaeology. The use of 3D digital technologies in archaeology has come to dominate the process, some considering it as the main issue behind the process, "3D recording, processing, visualization, representation and reconstruction of archaeological sites" (Tsiafaki & Michailidou, 2015). What we will discuss is not exhaustive of all recording methods available to the Archaeologist or Architectural Historian, but will be limited to the most common and standard methods that are readily available in the market and can be easily obtained and implemented. There are numerous other digital methods and technologies that are also available that we will not discuss, such as remote sensing, airborne LiDAR (Light Detection and Ranging) technology, SONAR, Magnoemtery, X-ray Fluorescence Spectroscopy (pXRF), Ground Penetrating Radar and other geophysical techniques plus other technologies. (Horton & Heyd, 2015) . The methodology for this study will be to lay out the theoretical framework under which we can categorize the different hardware, software, processes and methods that may be used for Recording of Digital Heritage information, so that we can easily add or categorize new methods, techniques and workflows. In the upcoming discussion, the assumption that the reader has basic knowledge and experience is made, meaning familiarity with basic desktop software (Office packages, email and internet browsing) and some exposure to other software and basic hardware (printers, plotters and scanners). The creation of databases and integration with GIS and images is also of paramount importance, one example of such a tool is ARCHES (ARCHES, 2019). There are many examples of custom cultural heritage solutions that have successfully utilized digital technology for cultural heritage, most notably what we can find on the web sites of the leading museums (Louvre, Hermitage, British Museum, Metropolitan and others), in addition to hundreds of examples of specific digital recording of cultural heritage sites and artefacts, like Digital Karnak and many others. In Egypt, we have relatively slow adoption, but perhaps one of the best and earliest examples of digital archaeological documentation is the Theban Mapping Project which clearly demonstrates the excellent use of maps, CAD and images in a cultural heritage project (Theban Mapping Project, 2019). CULTNAT (The Center for Documentation of Cultural and Natural Heritage) uses a complete array of IT applications for heritage recording (CULTNAT, 2019).

1.4. Analysis

For the Analysis of Archaeological data computers have proven to be an indispensable tool, whether with standard off the shelf programs like spreadsheets, to specialized software like statistical analysis software. Database programs that are used for compiling and displaying data in different ways are now becoming a useful tool for analysis. Other applications are also available. The merging with other fields is important and can create countless possibilities, one example would be the of Computer Simulation and re-enactment of seismic and natural aquatic movements (floods, storms, tsunami waves) on built heritage or sites.

1.5. Archiving

Recording and archiving data for retrieval is of paramount importance, and all archiving systems are computer driven. There are many solutions available for storage and retrieval of information, from simple storage on standard hard disks to sophisticated data centers with dedicated software and hardware for storage and retrieval. Web storage with databases of images and data is also another example. Digital Asset Management systems help users store, organize and retrieve all types of images and videos with sophisticated database queries for optimal retrieval. The use of such systems for cultural heritage has now become standard.

1.6. Visualization

Computer visualization of different cultural heritage items from whole buildings and towns to small artifacts has reached an unprecedented level of realism and sophistication with details and studies that were never available before. However, with the help of computers the visualization of cultural heritage is now easier than ever and opening up new avenues for analysis and study. Digital restoration of buildings and archaeological sites or archaeological artifacts is now possible without touching the precious original, opening up unprecedented avenues for study and analysis. We have several levels of visualization, from simple 2D sketches to photorealistic 3D immersive experiences of archaeological sites and augmented reality applications.

1.7. Presentation

Presentation of archaeological information ranges from printed text, simple slide presentations, digital publishing and informative web sites, multimedia presentations to interactive fully immersive experiences. The full array of options is driven by computers and their peripherals and displays, with unprecedented presentation experiences with the use of Virtual Reality (VR), Augmented Reality (AR), Holograms, 3D Printed artifacts, coupled with a large array of tools and interfaces and different user experiences that has redefined presentation and dissipation of archaeological data. This has also widened the target users and popularized cultural heritage to new types of users that are different from the traditional specialist archaeologists and art/architecture historians.

1.8. Publication

Today, publication of research and archaeological information has never been easier, especially with the internet and social media. Publication media whether printed text, online text and web sites, multi-media, video, film and other media, exhibitions, museums, conferences, seminars, lectures and presentations have all gone digital and are all done on computers and controlled by computers.

2. Computer Hardware for Cultural Heritage

For our discussion, we will divide Computer Systems into: Personal Computers (desktops, portables: notebooks/netbooks/ultrabooks, hybrid convertables (laptop/tablet), laptops with touch sensitive screens and stylus), Hand Held Systems (hand held computers, tablets, tablets with stylus, slates), High Performance Systems (workstations, servers, main-frame computers and super-computers) and we will also include Smart Phones (Android and IOS based) among the Computer Systems. Smart Phones have increased in hardware capabilities and have a large array of offered software, with built in cameras and connectivity flexibility making them an indispensable tool for the archaeologist, replacing at times their larger counterparts, especially in day to day communication and recording of information. All computers are in need of input and output devices to function efficiently.

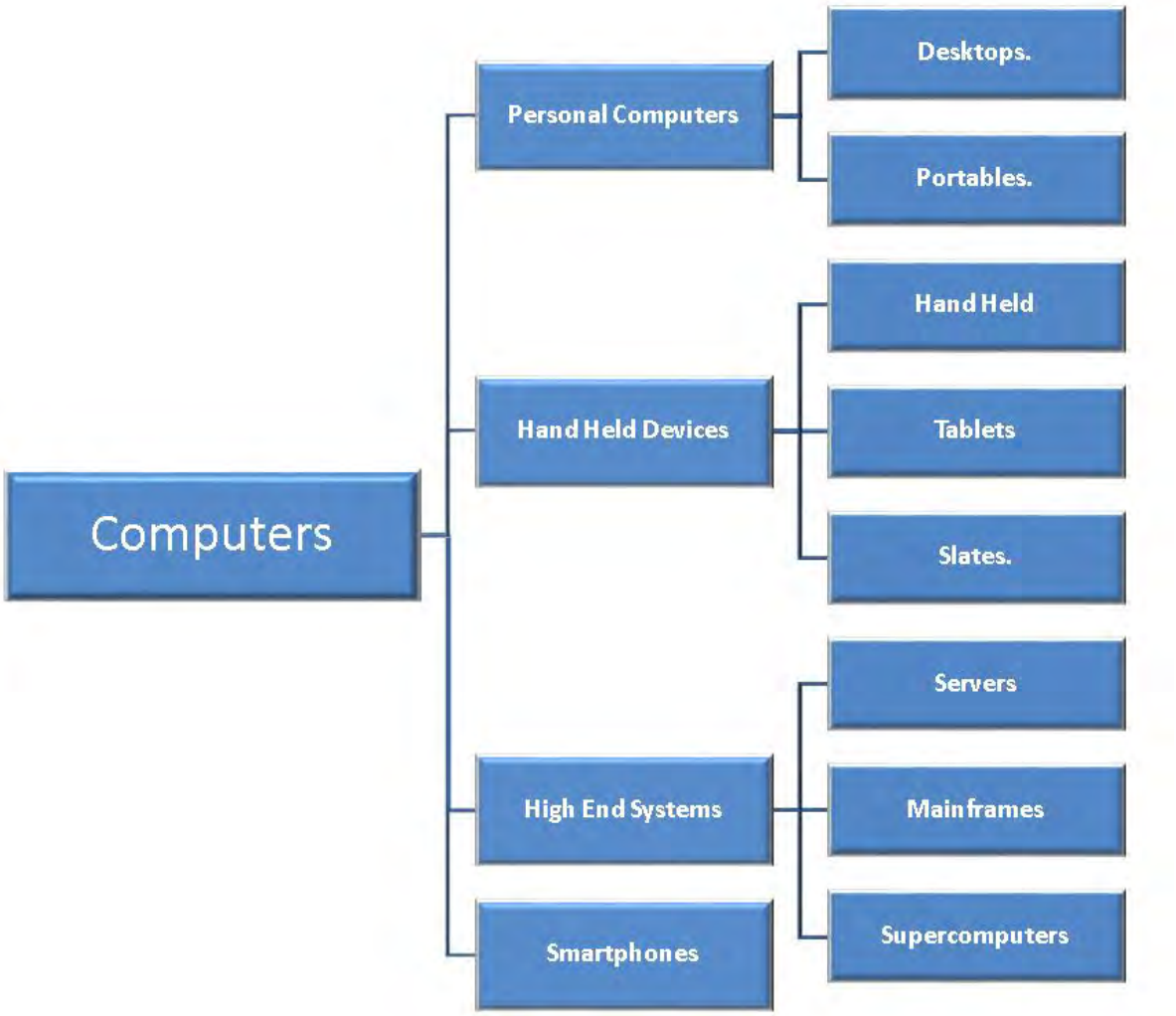

Figure 2. ComputerSystems for Digital Cultural Heritage (Author)

3. Software for Cultural Heritage

The following figure illustrates the type of software available on the market. For the purpose of this paper, we will limit our discussion for cultural heritage recording to the Desktop Applications and Graphics Software applications.

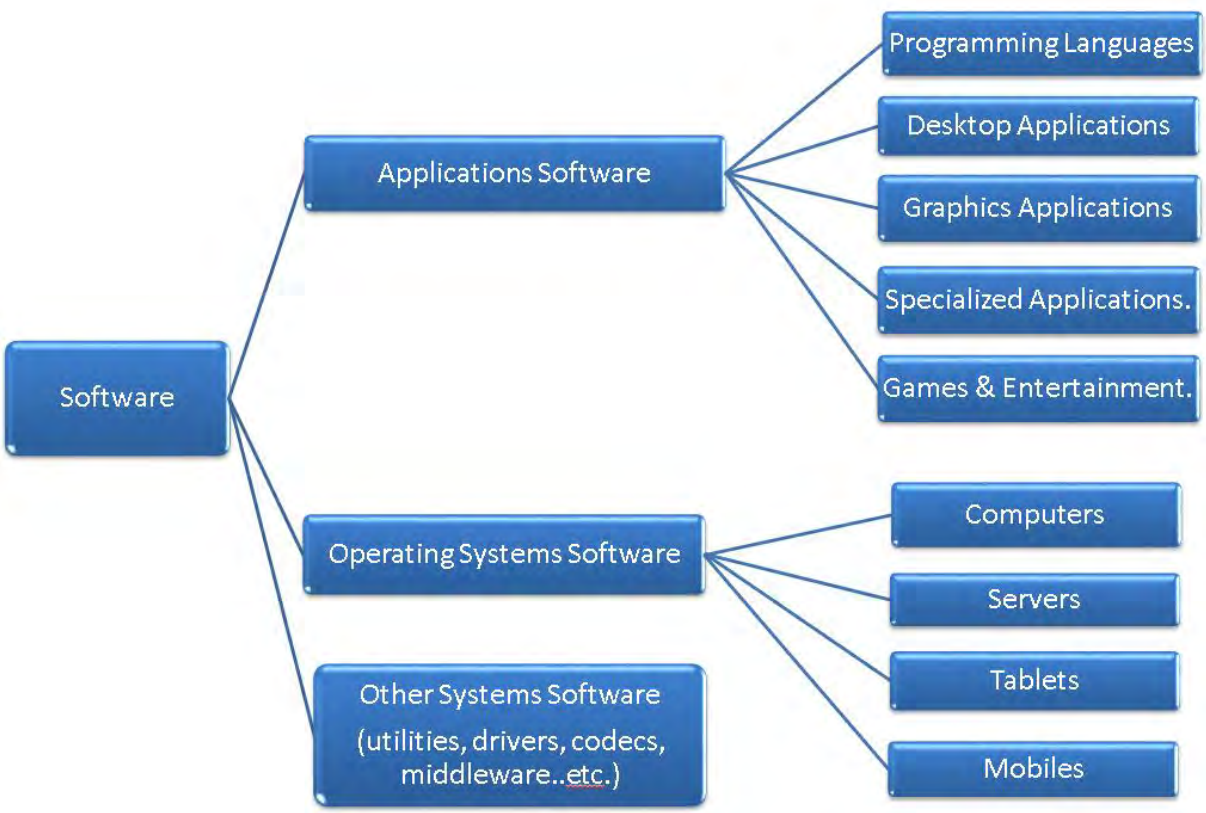

Figure 3. Types of Software (Author)

3.1. Application Software for Cultural Heritage.

There is no consensus on how to categorize Application Software, but generally speaking application software available may be divided into five types (see fig. 3 above) programming languages, desktop applications, graphics applications, specialized applications and games.

3.1.1. Programming Languages

This is the software that creates all the other software. Computer programming language compilers and tools can be considered as a separte software category. Specialized training and experience is required for the use of such software. Depending on the complexity of the project for cultural heritage, some types of this software may be required for use for cultural heritage.

3.1.2. *Desktop Applications*

Include most standard software that is in daily use to facilitate our daily tasks. Those applications are usually available commercially, either in shops or as downloads or through dealers, don't require specialists for installation or training and are quite common worldwide, and may be available in multiple languages. This software covers a great variety of function for recording, management, sharing, analyzing information and calculations. The common software packages that are the "Office Suite" of programs are among this category. Those packages include: word-processors, spreadsheets, desktop publishing, databases, presentation, communication, email, internet browsers, personal productivity, utilities, entertainment, time management, scheduling, project management, simple accounting programs and many others.

For cultural heritage, most of the desktop applications will come into use.

3.1.3. *Graphics Applications*

This will include all software that relies on or generates graphics as CAD (2D & 3D), drawing, sketching, drafting, modelling, animation, rendering, video editing, image editing and processing, GIS, paint programs, illustration programs, publishing programs, virtual reality, augmented reality, mixed reality, games, game engines... etc.

For cultural heritage, graphics applications are of paramount importance in all their categories.

3.1.4. Specialized Applications.

Those packages usually require a specialist for operation, support, maintenance and training. That software includes specialized software also known as vertical applications for industry specific sectors (education, defense, government, aviation, tourism, manufacturing... etc), enterprise resource planning systems (ERP), systems for specific trades or professions, accounting systems, personnel systems, customer relations management, resource management, ...etc.

There are very few systems created specifically for cultural heritage, one such example is ARCHES by the Getty Foundation (ARCHES, 2019). I hope the in the future more such systems will be seen. For specific cultural heritage projects, the work of specialized programmers is needed, tailoring a solution for the cultural heritage project. However, depending on the size of the entity involved in cultural heritage, some existing specialized applications mentioned above may be of use.

3.1.5. *Games & Enterainment Software*

Are a software category that is different from the above categories. It is available for all ages and all types of users and on all platforms. Although not initially created for cultural heritage, there are many games that have been created that entertain and also record or teach the users about cultural heritage.

3.2. Operating Systems for Cultural Heritage

Different operating systems are used on the different hardware platforms (fig. 4).

Worldwide statistics of currently available operating systems give us very interesting information regarding the trends one can find in the market for Personal Computers (desktop/notebooks) (Fig. 5) : Windows 70.46%, OS X (11.41), iOS (5.3%), Linux (1.57%), and others (Statcounter Globalstats, 2018) . For Tablets, Apple tablets dominate the market with iOS (72.41%) while Andorid tablets are 27.25%. For mobiles, Android devices dominate the market with 74.92% followed by Apple products with iOS at 22.2% (Statcounter Globalstats, 2018) . For high end systems (Servers, Main-Frames and Super Computers) (Fig. 6) Windows Server dominates the market at 71.9% followed by Linux, Unix and other systems (Statista, 2018).

Choosing the hardware platform directly affects the operating system used. It is a matter of personal choice which system to choose, but one should look at the capabilities to perform the task first, then at the operating system. However, it must be noted that the dominance of the Windows based hardware and software should be considered.

4. Digital Cultural Heritage Recording Techniques

For cultural heritage, we can suggest five basic methods for using digital recording of cultural heritage data:

- Text
- Camera Based Images
- Video/Film Based Recroding Methods.

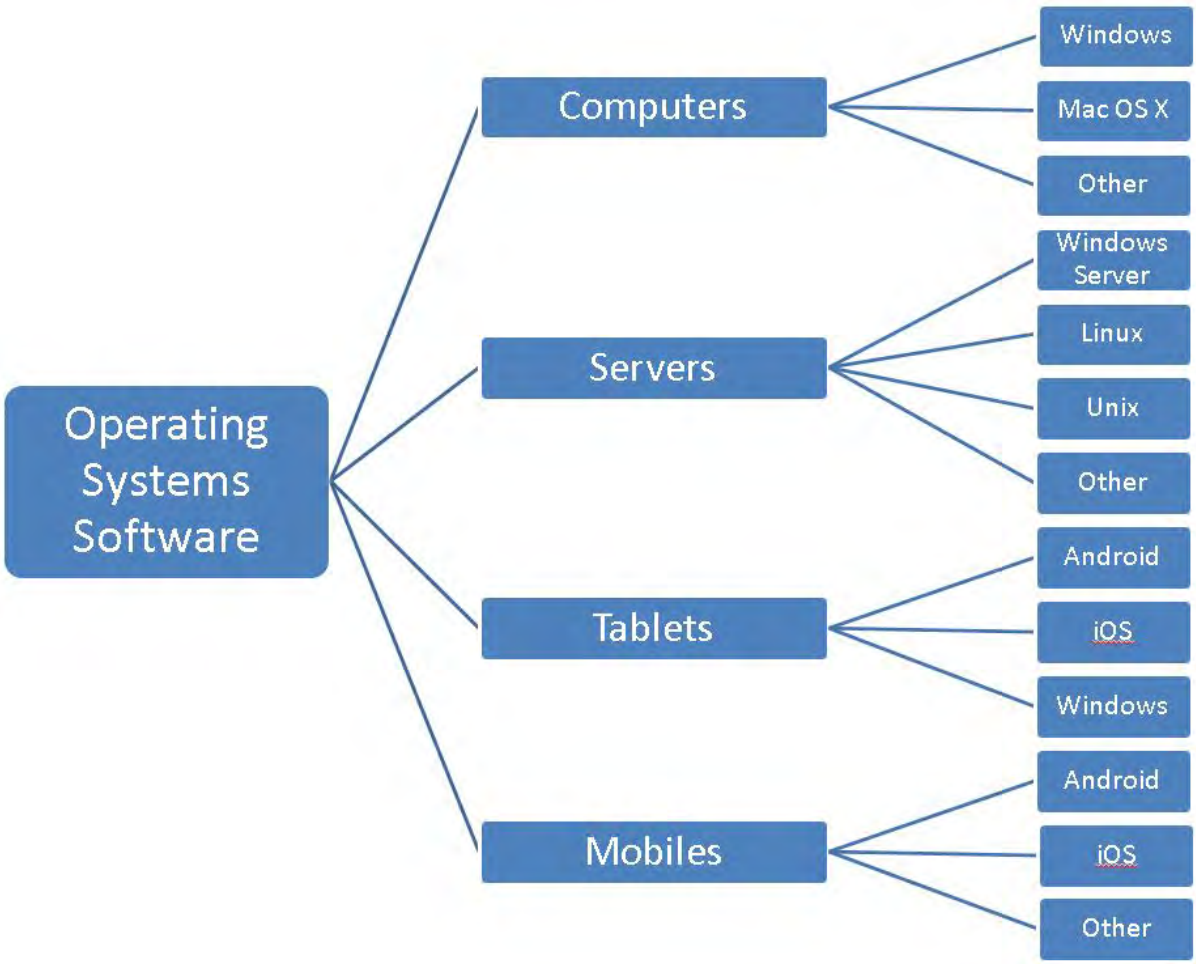

Figure 4. OperatingSystems Software Types (Author)

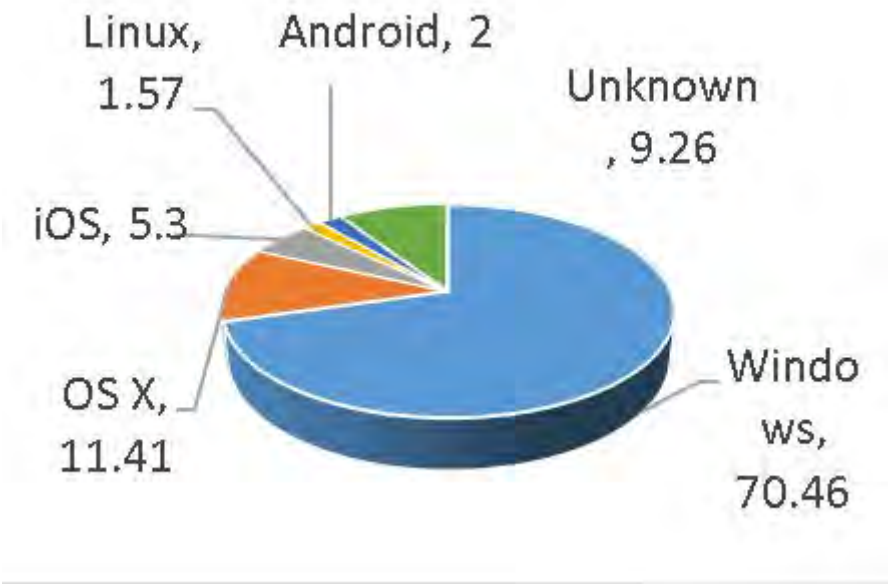

Figure 5. Desktop & Tablet OS, 2018 based on: (Statcounter, 2019)

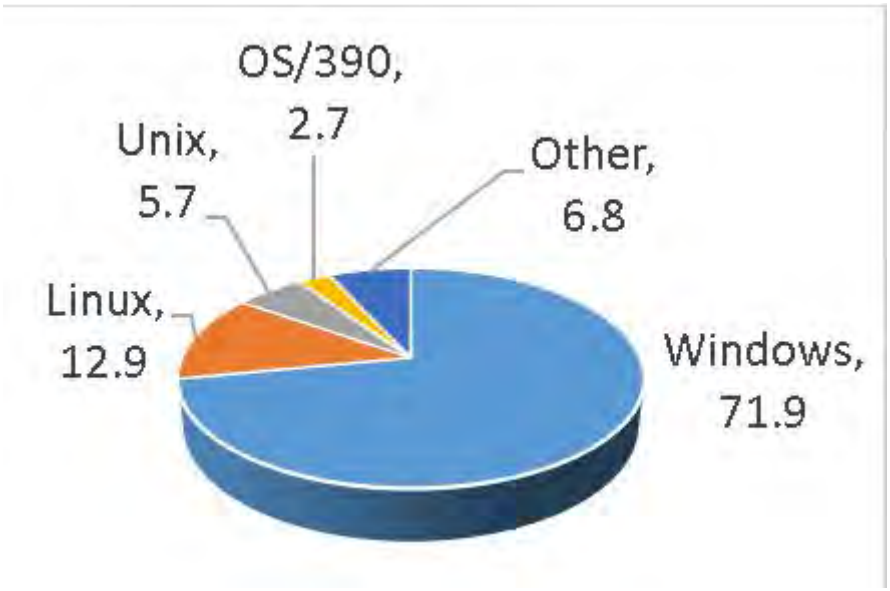

Figure 6. Server Operating Systems 2018, based on: (Statista, 2018)

– Graphic Recroding Methods

– Data Collection Devices & Sensors.

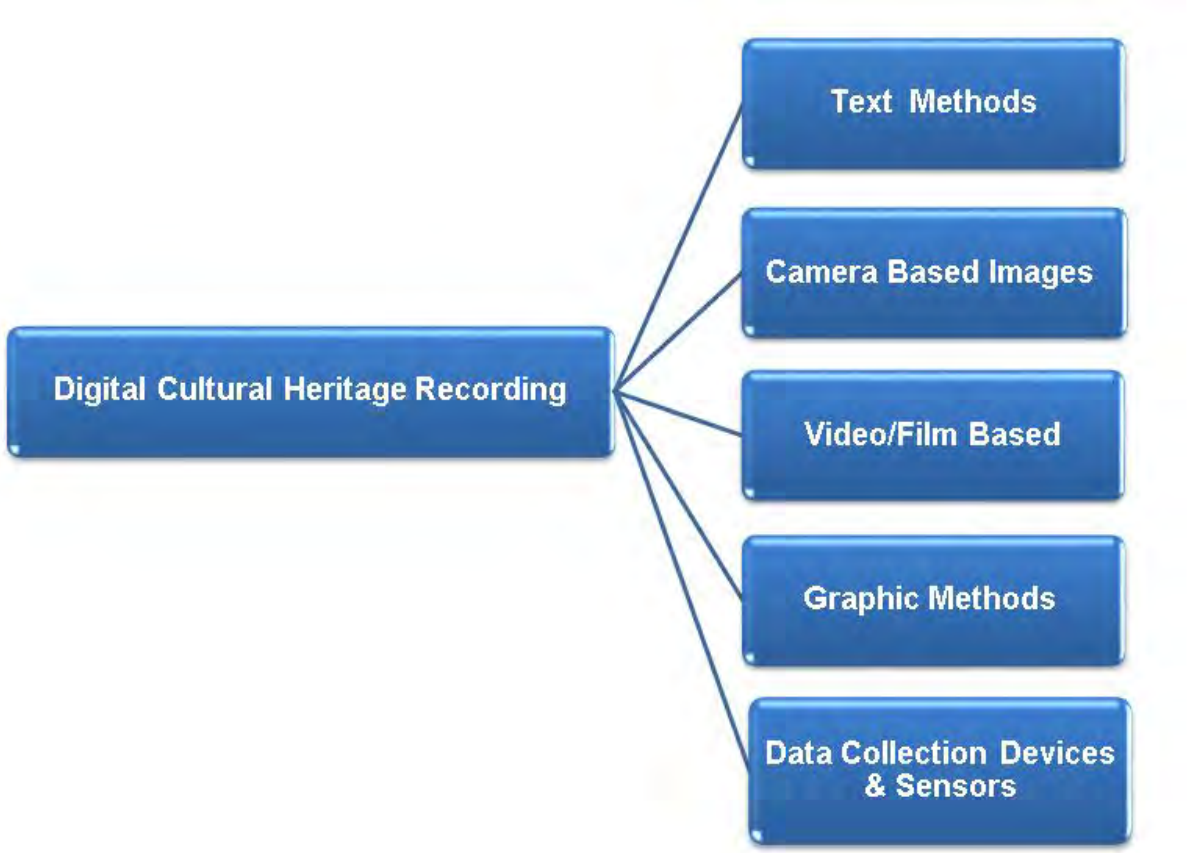

Figure 7. DigitalCulture Heritage Recording Techniques (Author)

4.1. Text Input Methods for Cultural Heritage

Text recording of cultural heritage information is one of the most basic and efficient methods. Usually, handwritten notes on paper that are taken during digs or research or lectures or site visits or museum visits or discussion are converted to digital format using word processors on computers. Depending on the type of data, other software may also be used for storage of information, like spreadsheets and databases. Recording with drawings and pictures will be discussed below.

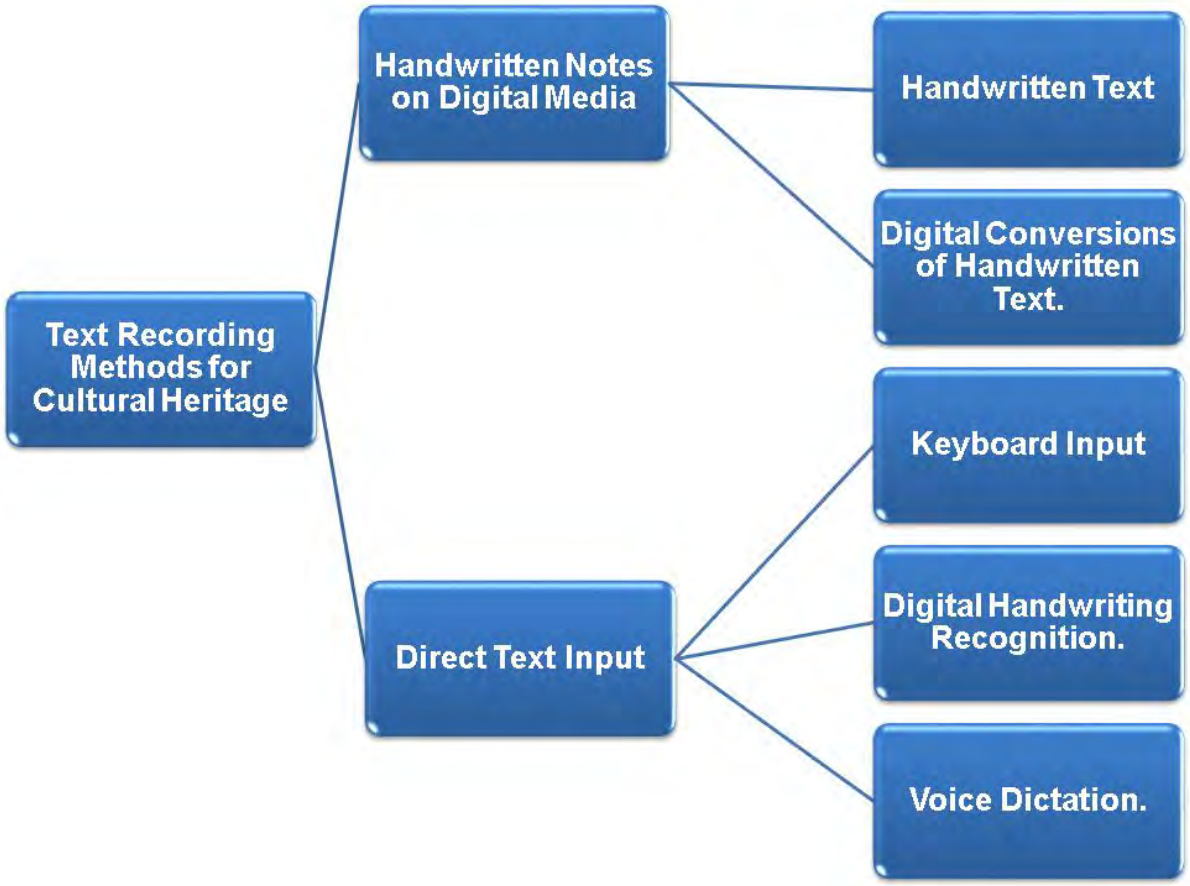

Figure 8. Text Recording Methods (Author)

4.1.1. The Software: Word-processors, Spreadsheets and Databases

Using a word-processor for documentation/reports/research/papers...etc. is a basic use and skill necessary for all archaeologists. There are two types of software available on the market, commercial (which includes shareware) and free software (total free software, public domain and freeware). Text data can also be input using other programs like spreadsheets and databases. The industry has come to bundle those three basic pieces of software in what is referred to as an Office Suite, which is an integrated set of software for different functions. The industry standard is Microsoft Office. In addition to a word processor software (Microsoft WORD), depending on the version, the office suite can include a spreadsheet (Microsoft Excel), a database (Microsoft Access), presentation software (Microsoft Powerpoint), and may include a desktop/web publishing software (Microsoft Publisher). Other software that is also packaged in the Microsoft Office is One Note (digital scrapbook), Outlook (email client).

4.1.1.1. Commercial OFFICE Suites:

The industry standard for commercial word processors is Microsoft Office. Other options are available like Corel Wordperfect, G Suite, Thinkfree Office and other packages.

4.1.1.2. Free Word Processors

The current Microsoft policy is that it offers its software for use on any platform for free as long as the screen being used is less than 10". Other than that you have to pay either a monthly or an annual fee for the use of its software. However, free alternatives are available. There are several packages from other parties that offer free office suites, either since their copyrights are in the public domain, that is, no royalty fees should be paid for their use, or simply free versions of the software with some capabilities removed, to get you to buy the full functioning version. The most well-known free Office compatible software packages are: Libreoffice, WPS Office, Free Office, Google Docs, and Star Office. All offer the same type of functionality and even offer more applications like drawing applications or mathematical formula creation or email clients. All those packages are compatible with Microsoft Office Suite files, can read and write Microsoft Office file formats, and work in a way that is quite similar to the Microsoft Office programs, offering the same integration. Microsoft once offered a trimmed down version of its Word and Excel programs in a suite called Office Starter Edition that used to be distributed for free with new PC's, however, it is not compatible with Windows 10. Although support for this package has been discontinued in 2014, but you can still download and use it on an older operating system. However, Microsoft Office still remains the industry standard and sets the bar which others try to attain or imitate capabilities and functionality.

4.1.2. Text Input Methods: Handwritten Notes on Digital Media

4.1.2.1. Handwritten Text

Traditionally, a paper and a pen are used for taking notes. Now, we can take notes and draw sketches using digital media: a touch sensitive screen or tablet. A stylus is necessary, although you can perform most operations using your finger, yet using a stylus gives a user experience that is quite close to using pen and paper but with substantially greater capabilities, never dreamt of before using traditional media and methods. What you use is a subjective experience and choice. Why would we want to do that? Using digital media and using the available digital tools opens up many options and gives the user numerous capabilities that are extremely difficult or perhaps impossible to achieve using traditional manual methods. With digital text one has full control over changing colors, fonts, linetypes, sizing, resizing, cut and paste, editing, moving, adding and integrating your notes with sketches, images, extracts from documents or from web sites, the internet, reports, other documents, taking camera pictures in real time and integrating it with the notes, making copies and sharing them via email or Whatsapp or other application... are just a few of the advantages of using digital handwritten text and sketching.

As for the hardware, best experience is with a Windows based tablet with stylus such as the Microsoft Slate or Surface Pro with Microsoft Pen (Walter, 2018), the Hp Elite X2, ASUS Transformer, Wacom Cintiq, Lenovo Yoga Book and many others. Android based tablets are also available from Samsung and Huawei. A laptop with touch screen and stylus can also be used, and depending on the digtizer/stylus, you may be able to use a standard notebook or desktop. For IOS, the IPAD Pro with Apple Pencil provides the best user experience.

Under Windows: Software needed is Windows 10 with Windows INK. Several other software options are available: Microsoft Office OneNote, MyScript Nebo, Sundaram Applied Technologies Inc. INDEX CARDS, and many others.

Under IOS and Android: many applications are available (Johnson, 2018) like: Apple Notes, Ginger Labs Notability, MyScript Nebo, Microsoft OneNote, TopHatch Inc. Concepts, WriteOn Notes Plus, Crayon Cardflow+, Inkspace, and others.

4.1.2.2. Text Input: Handwriting Conversion:

Software is available which can recognize hand written notes and convert them to typed text, like OneNote which has built in handwriting recognition features, so does Nebo and several other packages. This requires some practice, and I believe is more useful for taking notes and making sketches as drafts.

Figure 9. Handwritten text and sketching, using CONCEPT Software on an IPAD Pro with ApplePen (Author).

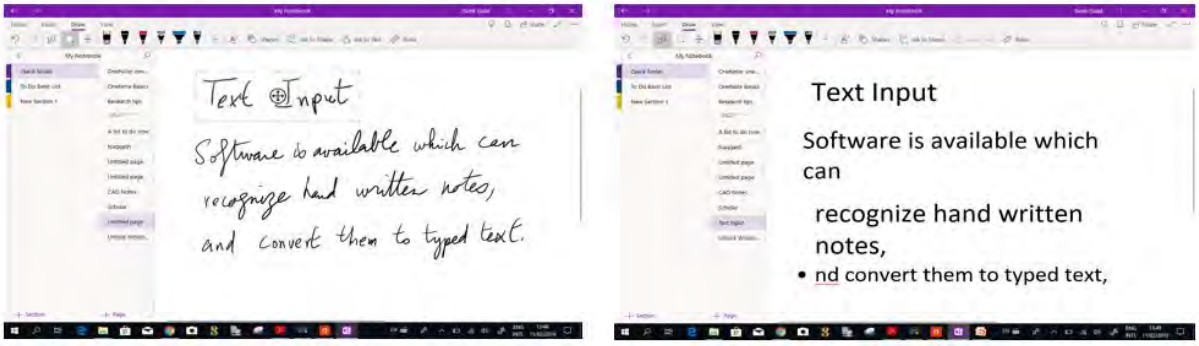

Figure 10. TextRecognition and Conversion in Microsoft One Note. (Author)

4.1.2.3. Direct Text Input

4.1.2.3.1. Keyboard & Mouse Input

There are many keyboard and mouse types available, and in addition to standard desktop keyboards there are wireless and Bluetooth keyboards, special ergonomic keyboards for ease of use, making the combination of using a keyboard and mouse for data input a basic facility for all users. Mouse types vary in shape, size, number of keys and technology, however, the most common is the wireless optical mouse with wheel track and two buttons for Windows, and the single button mouse with IOS. However, this is not the only interaction and input method with your computer. For our purposes we can consider two more methods: Handwriting Recognition and Voice Recognition.

4.1.2.3.2. Handwriting Recognition

Under Windows 10: Using the same equipment for freehand writing and sketching (a computer system with a touch sensitive screen, a stylus) and Windows INK software or add a Microsoft Stylus to a Microsoft Slate or a stylus to any touch sensitive ultrabook or notebook with touch screen) and you are also ready to use handwriting recognition. Data input using hand recognition is a practical tool that may be used by anyone for data input. This is quite a subjective experience and choice, and is also a matter of habit. Some may opt for the experience of being able to write directly on the computer screen and the system will automatically recognize and convert their hand input into typed text. Accuracy is quite high, and although the process takes some getting used to, but for anyone who is not very comfortable with a keyboard or is a two finger typist, it is a very viable and practical solution. It is

also very useful taking notes in meetings or on site or in lectures. If you are using Office OneNote, you can also covert your handwritten text into typed text by simply selecting it and choosing “ink to text”. In addition to INK, there are other available software options like: Google Handwriting Input and OneNote.

Under IOS and Android: Several packages are available for the Ipad Pro with Apple Pen and Android based tablets like those sold by Samsung and Huaewi. Software package examples include: Codetel NoteTaker, MetaMoji Note, Google Handwriting Input, Myscript Nebo and others (Dove, 2018).

4.1.2.3.3. Voice Dictation:

Speaking to your computer/smartphone has been around for a long time. With Windows, few considered using the feature since it had a high error rate and the machines were not fast enough. Foreign language dictation was also a problem. Under IOS, Iphone users are used to talking to SIRI, their personal assistant. Nowadays, smartphone voice translation apps have appeared, for both Android and IOS and are becoming quite popular, so I believe that voice dictation will also gain more popularity in desktop uses with the increase in processing power and software capabilities. Under both operating systems, voice dictation and voice recognition is currently a valid and practical input method for email, letters and many other uses, and most users should make use of the technology, which is getting better all the time.

Figure 11. Voice Dictation on iOS (Lifewire, 2019) Under Windows: Windows 10 has its own built in voice-recognition utility, which is still not very efficient. Using native Windows systems in voice dictation remains a challenge (Hachman, 2017), however, with the current faster systems, the correct software and hardware add-ons (dedicated microphone) you can use a Windows system quite efficiently for voice dictation. Better software alternatives are available from off the shelf software, the most widely acclaimed being Dragon Naturally Speaking (DNS). Other options include Google Docs Voice Typing and Diction.io. [(Wood, 2014); (Duffy, 2018)].

Under IOS: using the built in voice dictation feature on the IPAD Pro or the Iphone (preferable Iphone 6 or newer) (Lifewire, 2019) is very practical, to say the least [(Nations, 2018); (Use Dictation on your iPhone, iPad, or iPod touch, 2018)]. It can also recognize Arabic, and from personal experience, using voice dictation on an Ipad pro in Arabic for emails and letters works quite well. Other packages exist under IOS, like Gboard and Speech Recognizer. (Duffy, 2018).

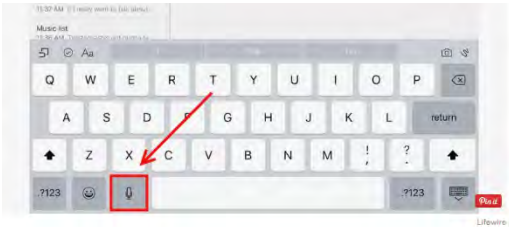

Figure 11. VoiceDictation on iOS (Lifewire, 2019)

4.2. Camera Based Methods for Recording

Camera based methods for heritage recording relies on the tool itself: the Digital Camera, and **the computer graphics software that will be used**

4.2.1. The Tool: Camera Types.

Other than the Smartphone cameras, there are four basic camera types: Digital Single Lens Reflex Camera (DSLR), simple point and shoot, bridge cameras, and bridge cameras with interchangeable lenses. Depending on your level of expertise, you should choose the appropriate camera, however, for professionals working in the cultural heritage field, eventually you will need a DSLR camera, whatever the specifications or brands. Nikon, Canon, Pentax, Fuji

and Sony are among the most popular. Most cameras can record video, which will be discussed below. First we will discuss with what we can do with still images on a computer.

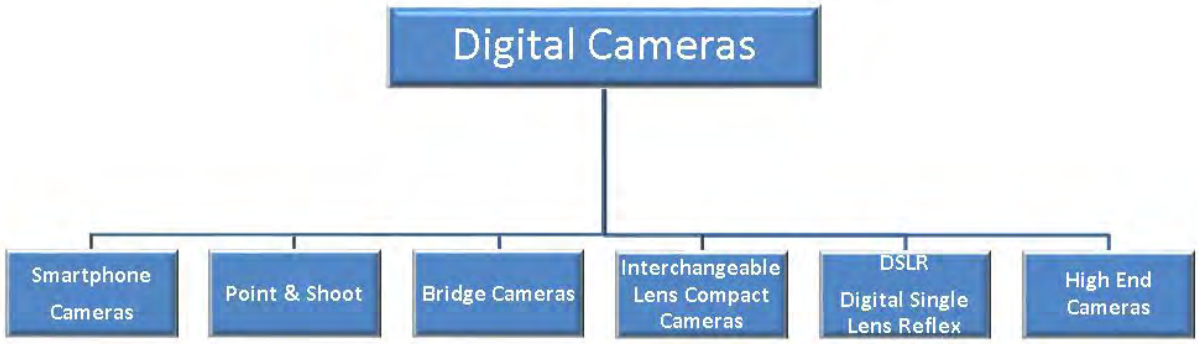

Figure 12. Digital Camera Types (Author).

4.2.2. Graphics Software

We can divide the graphics software available into two main categories, software for graphics Creation and processing, and graphics software for Post Processing, that is, after the images and graphics are created.

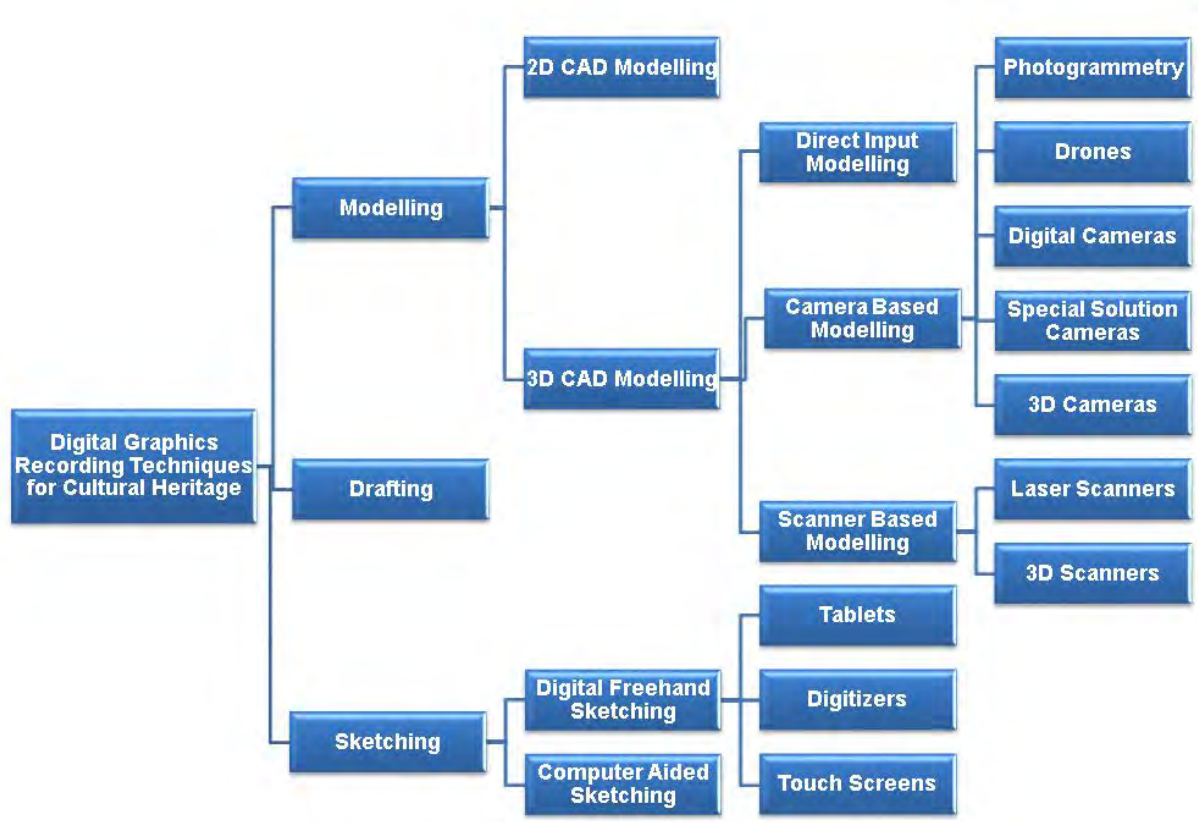

Figure 13. GraphicsSoftware Types (Author)

4.2.3. Graphics Creation, Manipulation and Processing Software

We can categorize three types of graphics manipulation software: Pixel based, Vector based and CAD (Computer Aided Design) software.

4.2.3.1. Pixel Based Software

Pixel Based Software work by direct manipulation of the pixels, so if you draw a line it will be created by a series of dots or pixels, giving the software complete control and flexibility in manipulation of the pixels on screen. We can categorized three types: Digital Darkroom software, Photo-Processing software and Digital Art and Painting software.

4.2.3.1.1. *Digital Darkroom Manipulation and Archiving Software*

It is essential to have some kind of archiving system for fast retrieval. A simple naming system for the subdirectories in which you store the images is a good starting point. You will also need a utility for organizing the pictures on the hard disk. Such software utilities also offer what is called Dark Room capabilities, which are minor retouching, changing illumination, shades, colors, cropping, renaming and organizing the images, and some limited digital photographic manipulation of the images. There are commercial programs like: Adobe Lightroom ACDSEE PRO Photo Manager, Apple Aperture, Picture Windows Pro and many others. There are free Digital Darkroom programs that work quite well like: PICASA (support discontinued in 2016 but still available), Google Photos, Windows Live Photo Gallery, LightZOne, Darktable and others. Those programs offer standard and simple image processing features, but don't have the full capabilities of dedicated Photo-Processing and paint software. Those packages include the processing features that are most used: resizing, cropping, color correction, addition of graphics and text, correction and removal of unwanted elements in photos, correction of mistakes, adjustment of proportions and perspective.

Digital Asset Management is a term that is used to describe the process of storage, organization and retrieval of images and other multimedia elements (video or sound).

4.2.3.1.2. *Photo-Processing Software:*

Programs for image processing are usually pixel based software packages that provide numerous image processing capabilities like: photomontage, photo-merging, special effects, paint capabilities with multiple brushes, and numerous other capabilities, giving full control to create, adjust, add to or manipulate any image or create new ones. The industry standard for pixel based Photo-Processing Software is Adobe Photoshop. Numerous other commercial packages exist like Affinity Photo, Corel Photopaint, Autodesk Sketchbook (free), Paint.net, Microsoft Paint 3D and many others, public domain packages like GIMP are also excellent contenders so are other free programs. The old Microsoft PAINT program that has been part of Windows since its early releases still exists and has its limited uses.

4.2.3.1.3. *Digital Art and Painting software*

These programs are actually pixel based Photo-Processing programs with high capabilities. These programs are used by artists for creation of digital art, painting, film and video games art, since the software simulates traditional real life painting techniques (water color, oils, gouache, pointillism...etc.) and styles. This makes its capabilities and learning curve a lot different from the more limited and standard uses and capabilities of other pixel based software. Software like Adobe Photoshop, Corel Painter, Procreate, Krita, Artweaver, ArtRage 5, Microsoft Fresh Paint, MyPaint, and others, give artists painting tools and brushes, capability to mix colors and created real life effects, canvas types and surfaces and many other options. To that group we can also add the specialized packages for comic book illustration artists like Astropad, ClipStudio, Twistedbrush and other packages, however, I don't believe that they would be of much use for cultural heritage unless being used for a very special project.

4.2.3.2. Vector Based Software

Vector based software creates drawing entities (lines, curves, and shapes) and handles them as such. This allows easy editing and control of those entities. Those types of programs are sometimes called layout and graphic design software packages. The industry standard for commercial vector graphics software is Adobe Illustrator, with Corel Draw a strong contender behind it. Both offer excellent vector drawing capabilities and cover whatever may be needed for sketching. CAD (Computer Aided Design) programs are actually vector based, however, due to their complexity and capabilities they are usually given a category of their own, which will be considered below when discussing graphics.

4.2.4. Using Still Images(Photographs) In Cultural Heritage

Photographs or Still images remain to be one of the most important tools for anyone recording/studying cultural heritage. They are the starting point for any research or documentation for any built heritage or artefact. Photographs taken by digital cameras while recording cultural heritage sites and artifacts will be eventually stored on a computer hard disk. In order for those images to be usable, they must first be stored properly in a manner which allows easy retrieval, which we can call archiving. Images are needed as a basic element in archaeology for the following uses:

- A Basic element in recording of buildings, artifacts and digs.
- For documentation and archiving of information and archaeological data and findings.
- Need for sketches and explanatory diagrams created on a PC.
- Reconstruction of buildings and artifacts for restoration.
- Inclusion in graphics and explanatory sketches.
- As parts of maps for recording of heritage sites.
- Parts of details and studies of buildings and artifacts.
- For Brochures

And numerous other uses. The photographs themselves can be adjusted or processed for many uses in cultural heritage. The computer provides excellent opportunities and capabilities for the modification, correction and use of still images. Such a process is called “image processing” or photo-processing. The following list for applications of image processing is not exhaustive:

- Adjustment and color correction, shade, shadows, lighting and tint.
- Adjustment of perspective.
- Adjustment of size or focus of images by cropping.
- Addition of text for explanatory images and diagrams.
- Reconstruction or restoration of artifacts or buildings.
- Reconstruction of past-states or historical reconstructions.
- Inclusion as part of an image database.
- Use in presentation, visualization and as part of renderings or reconstructions
- For repairing old photographs and maps.

And numerous other uses.

Figure 14. AdjustingPerspective (Author)

Figure 15. Reconstruction of Past States (Bab Zuwaila, Cairo) (Author)

4.2.5. Panoramas and Virtual Tours for Cultural Heritage

A panorama is a still image that is taken with a wide and extended field of view, usually beyond the "wide angle" of standard lenses and the human eye field of view. The field of view can extend from 160^0 to 180^0 to full 360^0 on the horizontal. Fully circular panoramas cover 360^0 on both the horizontal and vertical axis, providing a sphere of vision allowing the user to view all the surroundings from all angles. Viewing a panorama is also called a "Virtual Tour".

Interactive panoramas have the added ability of allowing the user to navigate to different embedded virtual tours. This type of interaction is created by embedding several panoramas in a main panorama, using points that are known as "hotspots" to hyperlink from one panorama to another. This allows the user to open a panorama, move around, zoom in or out, then when he clicks on the hotspot he will be directed to another panorama. This is called "virtual tour", simulating an actual tour of the built heritage site photographed. This requires the creation of 360^0 tours then linking them together using Virtual Tour software.

4.2.5.1. Panorama Creation Methods

4.2.5.1.1. Stitching

Stitching is merging several shots to create one large horizontal shot. Usually it would be impossible to create such a shot with any kind of lens due to the distortion or parallax problems that are created by wide-angle lenses, but you can generate a perfect perspective with no distortion of a very wide angle using multiple photographs and stitching. An example is given below. This allows the use of a standard lens camera, taking multiple shots from the same position, with an overlap between each subsequent shot. A 20% overlap is usually enough. The next step is using special software for processing the images to create the stitched picture. The end result is a shot with an aspect ratio of more than 1:2. Notice that there is no distortion at the sides and no curvature in the horizon line. Several Smartphones offer a Panorama mode, however, you must be careful of the curvature of the horizon line. Any image viewer can view this type of "stitched file. Stitching is included as a function in several photo-processing programs like Adobe Photoshop. There are also some dedicated packages for stitching like Arcsoft Panorama Maker, PTGUI, Clevr, Hugin, Autostitch, Panoweaver 10 and many others.

4.2.5.1.2. Panoramas and Virtual Tours with Digital Cameras

Horizontal Virtual Tours – 180^0-360^0: Taking a series of pictures then using a panorama stitching software can create a horizontal panorama, which is a picture with the viewer in the center, but using special viewers, you can move right or left to continue viewing the picture, panning around around up till 360^0. Special software can create this "horizontal" panorama. Most Smartphone cameras have this capabilitiy, but you will need a special viewer to see this panoramic shot (see below).

Creating 360^0 Spherical Panoramas (Virtual Tour): The 360^0 Spherical Panoramas will require the use of Fish Eye Lens and a tripod or monopod to create the pictures. Panorama software will do the stitching and creation of the 360^0 sphere, however, extra editing and stitching is required to remove the central tripod image (called the "nadir") from the final shot, creating in the end a seamless spherical tour. Special viewers are required to view such an image, and the user can rotate his line of sight 360^0, that is, in all directions. There are many excellent packages for virtual tool creation, like: Kuula, HoloBuilder, Cupix, Tourweaver 7, Arcsoft Panorama Maker, PTGUI, 3DVista Virtual Tour Suite, Tourwizard, Virtualtour Easy, Panotour, 3DVista Virtual Tour, and other packages (Capterra, 2018). Numerous web sites publish those panoramas, like: Google StreetView , 3dMekanlar, Kuula, Airpano and many others.

Viewing Virtual Tours: Virtual tours can be seen in any web browser provided it has a plug-in installed. 360^0 media players allow the viewing of both still and video virtual tours. There are also stand-alone viewers, like PtGUI Viewer, which allows you to view the panorama without publishing it to a web site. All virtual tour creation

Figure 16. StitchingPictures to create one large picture (Author)

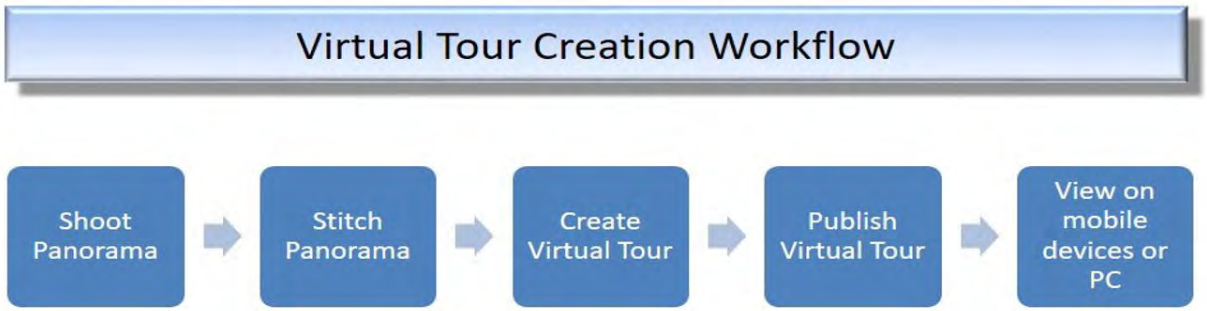

Figure 17. How to create a virtual tour, web published.(Author based on (Easypano, 2019))

software also allow viewing. Other software is also available like GoPro VR Player, Marzipano, Google VR Viewer for the web, FSP Viewer, LizardQ Viewer and many others.

Smartphone Based Panoramas.: Any standard Smartphone without a fish eye lens can be used to create a 360^0 panorama using certain "apps" or programs that are specifically made for Android and iOS systems. However, most of those panoramas can't be viewed except on the device, the web, or can be shared on social media. There are several programs like: JustPano, Fyuse, 360cam, Panorama 360 Camera, DMD Panorama, Camera 360, Phereo 3D Photo (Android), PopPic (iOS) and many others.

Google StreetView Panoramas: Google StreetView (GoogleStreetview, 2019) is linked to Google Maps for all seven continents, and on that map there are thousands of spherical panoramas taken in different locations, so you can explore those places, and after you install the software on your mobile you can also add your own spherical panorama using your smartphone camera. The process is easy and automatic, and with your smartphone mobile internet connection you upload the panorama. You can keep it private or share it publically. Quality is excellent and is definitely the fastest way to create a panorama. You can also use any 3D camera to capture the scene. Google uploads its own content, using different methods to mount its 3D camera system like Street View: Car,

Figure 18. Logos for Fuse, 360cam, Camera 360, DMDPanorama, PopPic.

Trekker (wearable backpack with camera system), Trolley, Snowmobile and Trike (tricycle based camera system). Google even has a "Street View Camera Loan" program, under this program they "may offer to lend you a Street View Trekker backpack or a Street View app-compatible 360 camera, depending on availability and what may best match your needs." (Street View Camera Loan, 2019).

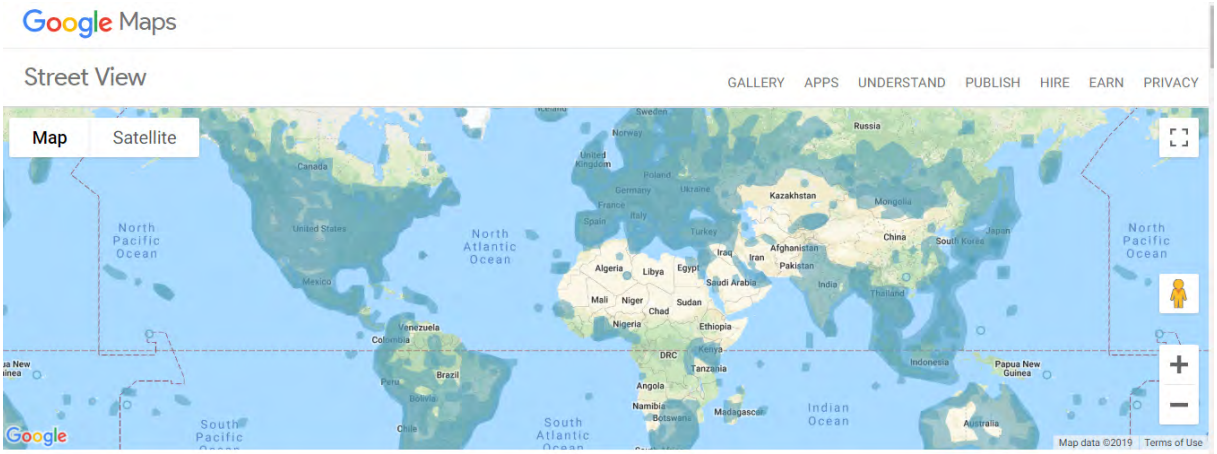

Figure 19. Google Street View Web Site (GoogleStreetview, 2019)

4.2.6. Video/Film Recording Methods.

4.2.6.1. Standard Video

Recording cultural heritage using video using professional digital movie cameras has increased in the past years with the increase of satellite channels that are interested in cultural heritage, like: National Geographic, Discovery Channel, History Channel, H2 and numerous other programs that document, record and comment on buildings and archaeological sites, with commentaries by historians and archaeologist. There are even programs that actually perform digs for archaeological sites like "Digging for Britain" on the BBC, "Time Team" and others, while in Egypt there is the excellent series with Dr. Hamza Al-Hadda, named . Needless to say, this has increased awareness of cultural heritage and its importance and brings archaeology to the common people. However, this always required specialized equipment (cameras, flood lights, sound equipment..etc.) to record such sites, which is expensive and not readily available for archaeologists as a tool for recording cultural heritage.

For archaeologists, recording built heritage and artefacts is now so much easier and accessible with Smartphones and most digital cameras which have video recording capabilities. Resolution used to be an issue, but the Full HD resolution of 1920x1080 at 30 fps is now becoming standard, and so is the full ultra-high resolution (UHD or Ultra HD) 4K resolution (3840x2160) which is available on many smartphones and on most DSLR's. This is one more method for recording cultural heritage, and provides excellent evidence of the nature and conditions of sites, digs, procedures, state of buildings, restoration processes for buildings and artefacts, experiments and numerous other uses. Its use as part of the education of archaeologists and for bringing cultural heritage awareness to the public is unsurmountable in its simplicity, impact and importance.

4.2.6.2. 3D Video

3D video is a new format which allows the recording of video which you can interact with and actually spin 360^0 while the actual video footage is running. This gives us unprecedented coverage of sites and actual recording of all that is transpiring while recording the video and not only in the direction to which the person recording is concentrating. This requires special cameras and post processing of the output, but is now commercially available and cost effective, with the Samsung Gear 360 (2017) costing as low as 80$. Other entry level 360^0 cameras at 4K resolution are available on the market, like the RICOH THETA V, Garmin Virb 360, Insta360 One X, Kodak PixPro Orbit 360, Nikon KeyMission 360 to mention but a few. Using those cameras, you can also generate 360^0 still images that can be used in 360/180 panoramas (Digital Camera, 2018). Professional 360^0 high end cameras boast 8K and even 11K resolution like the Insta 360 Titan. Other professional cameras include: the Pilot Era Professional 360 Camera, the Vuze+1s, Z CAM S1 Pro, Insta 360 Pro and many others (The 360 Guy, 2019).

Samsung Gear 360 (2017)	Ricoh Theta V	Garmin Virb 360	Insta360 One X	Kodak PixPro Orbit 360	Nikon KeyMission 360

Figure 20. Examples of Entry Level 360^0 Cameras

4.3. Digital Graphics Recording Methods for Cultural Heritage and Architecture

Digital Graphics Recording Techniques for Cultural Heritage

1. Sketching.
   (a) Digital Freehand Sketching
   (b) Computer Aided Sketching
2. 2D CAD Modelling.
3. 3D CAD Modelling.
   (a) Direct Input Modelling.
   (b) Camera Based Modelling.
      i. Digital Cameras
      ii. 3D Cameras..
      iii. Special Solution Cameras.
      iv. Drones.
   (c) Scanner Based Modelling.
      i. Laser Scanners.
      ii. 3D Scanners.

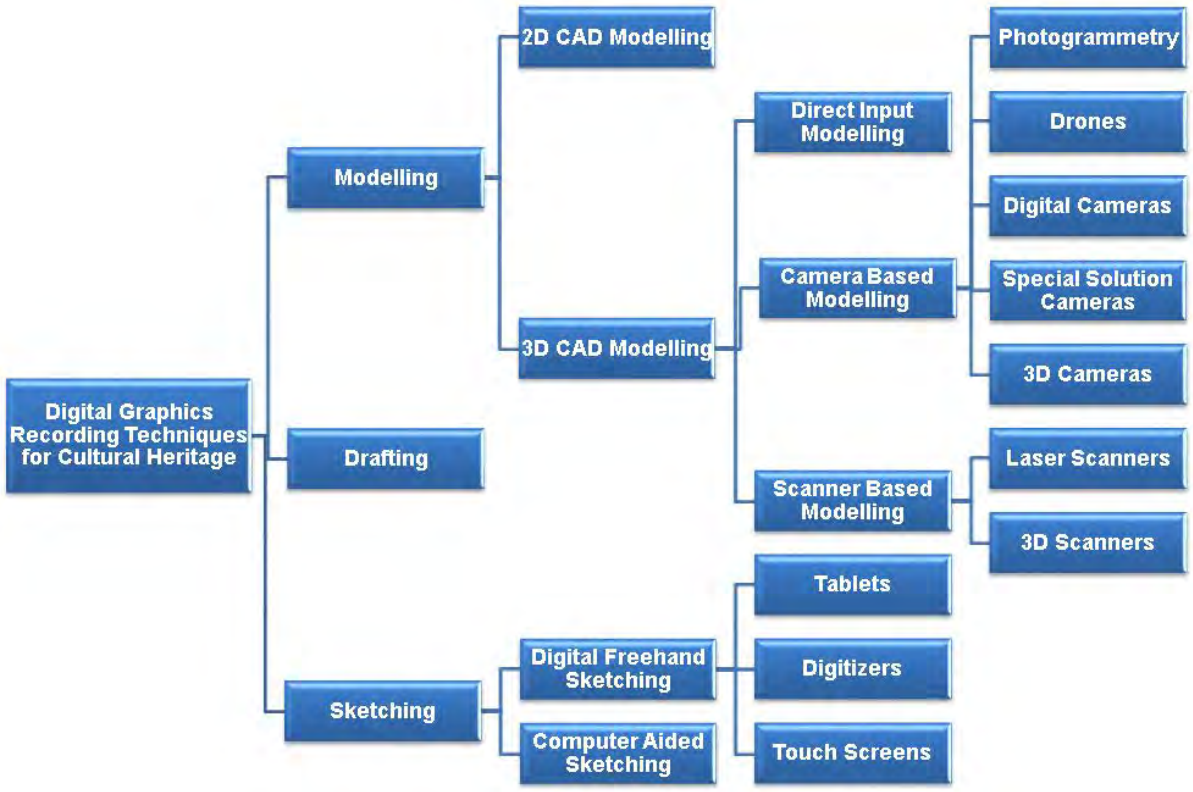

Figure 21. Graphics Recording Techniques (Author)

4.3.1. Sketching

We can consider two types of sketching, Digital Freehand Sketching and Computer Aided Sketching.

4.3.1.1. Digital Freehand Sketching for Cultural Heritage

Freehand sketching is a basic method used by archaeologists and architects, and it has also gone digital. Needless to say, the same advantages that are attained by digital handwriting are also available when sketching. Use of uncountable pens, brushes, line types, line widths, colors, textures, geometric shapes and figures, libraries of figures, scale, rulers, ability to cut, paste and merge graphics with images and other drawings, repetition, copying, integration with cameras and extracts from web sites and other drawings and visual resources, and the most amazing capabilities with editing when using hand gestures for moving and resizing elements you draw, giving a very different user experience that is far superior to anything that can be done manually. Add to that sharing capabilities with email and other programs. It is very difficult to justify NOT using digital freehand sketching.

Hardware needed is the same as for digital handwriting: tablet with pen stylus, or notebook/desktop with digitizing table with stylus, or touchscreen notebook with stylus (see above). It must be noted that the use of the IPAD Pro/Apple Pen combination with the myriads of packages offered for sketching may offer a better user experience for sketching, especially with the integration of the IPAD camera input in all applications. From my own limited experience, such integration is still unavailable in the software packages under Windows. Furthermore, with the IPAD, you have built in 4G mobile network integration for communication. With Windows based machines, you must add a USB Internet device or connect via a WIFI network to achieve the communication integration. However, as mentioned before, such preferences are purely subjective, and will depend on the budget and personal preferences of the user.

There are two types of available software for Digital Freehand sketching: Pixel based programs and Vector based programs, as categorized above. Which one you choose will depend on your preferences, however, most probably

you will use both, depending on the task at hand. For digital sketching for architecture and archaeology, we actually need a combination of both pixel and vector graphics capabilities that is offering the ability to create vector graphics and use paint brushes in the same time. Free hand sketching capabilities must be available with precise entity creation, and whatever package can provide both will offer a better user experience. It is a matter of personal preference which package to use, since all pixel based packages can be used for digital sketching, but some are more capable than others.

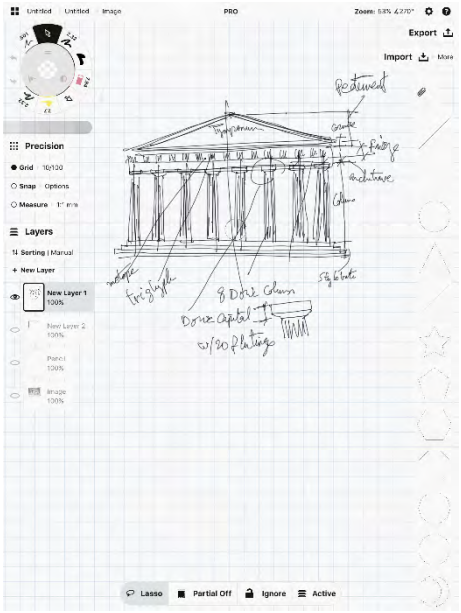

Figure 22. Freehand Sketching using Ipad and CONCEPT Software (Author)

4.3.1.2. Pixel Based Software for Digital Freehand Sketching

For cultural heritage sketching, some examples of Pixel based packages that are excellent for sketching are: Autocad Sketchbook and Morpholio Trace. High end industry standard Adobe Photoshop naturally can be used, however, it has a steep learning curve and many capabilities that will not be used in sketching, yet some prefer using it as an all-purpose sketching application. Most software is available for all operating system platforms

4.3.1.3. Vector Based Software for Digital Freehand Sketching

For sketching architectural details and artifacts, I believe that vector based software is far superior to pixel based software. The capability to manipulate whole entities (lines, shapes or nodes) or parts of entities provides great flexibility, however, as mentioned above, this is purely a subjective choice and will vary from person to person. Vector based packages must have some tools for freehand sketching. There are many software products on the market that can offer both capabilities. Some software packages are available on all platforms, while others offer definite advantages under IOS. To mention some excellent examples: Sketchpad, INKSCAPE (open source), iVectorlite, VectorIllustration, ConceptDraw PRO, TopHatch Inc. Concepts, to mention but a few. Some may feel comfortable in sketching using presentation software like Microsoft Powerpoint, and the public domain free programs: Libreoffice Impress and Libreoffice Draw, which are still viable alternatives. At the end of the day, whatever tool you are comfortable and productive with, use it.

4.3.1.4. Digitizing Tablets and Computers with Tablets.

The use of digitizing tablets with desktop computers or notebooks without touch screen has become a standard interface for artists. It may be useful for some archaeologists and architects. With the introduction of Autocad for the Ipad or Autocad Mobile, Autodesk has created a new paradigm for CAD, giving a new user experience that I

believe is to become standard within the near future. The use of a stylus or pen with CAD offers great flexibility in drawing and an enhanced user experience unlike traditional input methods for CAD. It is now used mostly for revisions and reviews, but I believe that the trend will be towards complete integration and capabilities in the CAD process.

4.3.1.5. Computer Aided Sketching (CAS)

Computer Aided Sketching (CAS) can be defined as using software for sketching ideas, conceptual design, investigating design alternatives, solutions, reconstructions, by the creation of CAD based 2D or 3D digital models that are not necessarily accurate or that can be used as a final product. Post-processing for the output of digital sketches is usually required. Traditionally, sketching using manual media is an important part in the design or creative process for engineers and artist. Integration of sketching in the computer process is relatively new. With adoption and development of CAD and computers in the design and artistic creativity processes, a relatively new breed or category of software has appeared that is CAD based but offers relative ease of use and a relatively easy learning curve, compared to the industry standard CAD packages. Those programs are mostly available on the two basic dominant PC platforms: Windows and iOS, however, some versions are also offered for Android systems. The programs offer integration with other more expensive CAD and 3D modelling software such as 3D Max, Autocad, Revit or other software.

Perhaps the most well-known sketching program is Trimble's Sketchup software, which claims 35 *million* users worldwide (SketchUp Community, 2016). Another program is Autodesk's Formit, which is a 3D modeler with direct integration with Revit. Shapr3D is a solid modeler on the iPad designed for the Apple pencil, however, this is marketed as a true solid modeler.

4.3.1.6. 2D CAD Modelling for Cultural Heritage

Computer Aided Design (CAD) systems and software are used in cultural heritage for 2D Drafting (plans, elevations, sections, sketches…etc.), 3D Modeling for quick visualization, detailed colored realistic renderings, for conservation and reconstruction of archaeological buildings and artifacts, for reconstructions of past periods, for 3D Modeling of Archaeological artifacts, mixing 2D and 3D CAD with images and maps and numerous other applications. Using computers for graphics is faster than manual methods, more accurate, once a 3D model is created, you can generate plans, elevations, sections and perspective, it is easier in editing and revisions, you can add intelligence and information to the model then extract it, you can interface with other systems for faster decisions like simulation and analysis software, CAD is digital and allows for quick data translation into manufacturing via 2D or 3D formats for example DXF (2D) STEP, IGES(3D), and CAD saves money by reviewing digital prototypes before creating physical prototypes for samples, exhibits or reconstructions.

2D CAD models are usually created by one of two methods:

- Data entry of exact measurements are obtained from actual measurements of the building or artifact, which is the most common method. This entails fieldwork and actual measurements taken from the site..
- Tracing of a picture of the model and interpolating its scale. Older documents may be scanned or pictures are taken from the site with an item of known measurements which will be used to determine the correct scale. It is a very useful tool to have a graded staff that is included in your photographs as a scale reference. This may be considered a type of Photogrammetry, which encompasses all methods of obtaining measurements from photographs.

4.3.1.7. Drafting Versus Modelling

Drafting is simply the graphic recording of buildings/artefacts/details. Traditionally, for describing any building/object universally accepted norms have been agreed upon for description of that building/object through projections, resulting in plans, elevations, sections and details in universally agreed upon standards and norms. For

cultural heritage disciplines, architects, archaeologists and art/architectural historians traditionally followed those norms. With the use of computers, and the introduction of Computer Aided Design (CAD) systems and software, architecture, archaeology and related disciplines saw a real revolution in terms of interaction with the cultural heritage information.

4.3.1.7.1. Drafting:

Using computers to re-produce sets of drawings is what has been called Computer Aided Design (CAD) and Computer Aided Design and Drafting (CADD), with computers being used instead of manual methods. In digital drafting, when CAD is used as a replacement of manual methods, you get just that, drawings at the scale it was originally drafted in.

4.3.1.7.2. Modelling:

With the increase of software and hardware capabilities another concept was introduced, that of the digital Modelling, or CAD Modelling. In 2D CAD models, projections are created in true 1:1 scale of the projection. For a 2D model with a correct layering scheme, one can also generate all necessary scaled details of those specific 2D projections. For example, after creating a 2D model for a plan of a building you can immediately generate and extract from that model any other plans or details at any required scale, since all was "modeled" only once at the correct 1:1 scale. This is different from drafting, which will require a redrawing for the different scales or details

Figure 23. Logo's of some CAD Software Packages

4.3.1.8. 3D Cad Modelling

For 3D models, the 3rd dimension, that of height is added, so one can also extract volumetric information and also generate all types of views and projections: 2D (orthographic projections: plans, elevations, sections and details) and 3D projections (axonometric, isometric or perspective). One can also further use the 3D model for animation and visualization by "rendering" the model, opening up a world of other possibilities: 3D rendering in different visualization methods, photo-realistic still images and photo-realistic animations and fly around/walk through, Virtual Reality interaction and Augmented Reality use, immersive and interactive visits and so much more. Thus the 3D model gives us a level of interaction with subjects under study way beyond what drafting or manual methods were ever capable of doing.

The 3D CAD software market is dominated by Autodesk's Autocad and 3D Studio Max. Other software vendors for fully fledge professional packages include Dessault Systems who have high end CAD software which most probably would be too much for digital heritage use such as CATIA and Solidworks, but they also have Draftsight (free software) and Draftsight Pro that are suitable for 2D uses. Archicad and Bentley's Microstation are popular fully capable 3D CAD software for Modeling, Documentation, and Visualization,

and many others. Other packages include: Sketchup, Openscad, FreeCAD, DsignSpark and many others. Sketchup Make is a free 3D sketching program, however it has a paid upgrade called SKetchup Pro.

Another type of CAD software is what is referred to as CAD Modelers and Visualization packages, those are geared for creation and rendering of 3D CAD models with photorealistic visualization and inclusion of animation and cinematic effects and capabilities. Those sophisticated packages push us to the realm of artistic creations with the 3D models, and they are the packages used by the film and animation industry and special effects providing life-like modelling of anything the artist can think of. The most popular may be Autodesk's 3ds Max, with other software like Blender, Cinema 4D, Mudbox, Maya, Rhino3D, Inventor, Cinema 4D, Houdini, Poser and many

Figure 24. 3DCAD Model Example, using Archicad and Cinema 4D (KBD Architecture, 2019)

others packages.

Figure 25. .Logo's for some 3D Rendering, Animation and Visualization Software

All of the abovementioned packages overlap in capabilities, and can be used for cultural heritage and architecture, however, depending on the modelling/visualization/animation task at hand then each will have its own advantages and disadvantages. For example, Poser specialized in modelling and movement of human figures, so can be very useful in statues of cultural heritage of humans, and can thus be used for animation and recreation of those figures in reconstructions of historical eras. 3DS Max is more of a general purpose program that can give excellent results from initial 3D modelling to animation and effects if required. The bottleneck BEFORE you can use any of those packages capabilities will be to create the initial 3D model, which is the first step in the work flow.

Types of 3D Models

3D models can be created in several ways: Entity based wire frame models, 3D mesh modles, surface based models and solid based models. This will depend on the capabilities of the software. Today, most 3D CAD software packages can create solid models. Entity based models are created from primitives (basic lines, arcs, circles, curves) that are used to generate the 3D models, kind of using a wire frame model then filling in the area between the wires. This is the most limited type of 3D model construction methods and many shapes simply can't be created using those simple primitives, require a higher level of modelling, especially with curved surfaces and b-splines and other curves. Such models are most suitable of simple structures and artifacts with no details or space curves. For example, modelling a statue of the head of Nerfertiti would be quite difficult using such a model.

The Surface Based models use surfaces to create the geometry. A modeler with such capability can usually generate most if not all possible surfaces. Difficult surfaces like NURBS (Non uniform b-spline surfaces) are non-standard

curves that were not available in most CAD software, but are now common with most high end modellers. Models with surfaces have a hollow inner core, thus the model is bounded by surfaces only. However, surface modellers with NURBS allow the creation of almost any shape from nature.

This leads us to true Solid Modellers, the high end of the spectrum of 3D modelling. Software with these capabilities use actual “solids” in construction of the compound shapes. The system can create and use primitives of cubes, balls, torus, pipes..etc and other solids then can generate compound forms using Boolean operations (subtraction, addition, intersection) generating in the end a solid model that behaves and looks like a true model in real life. Cross sections of such models will show a solid object being dissected.

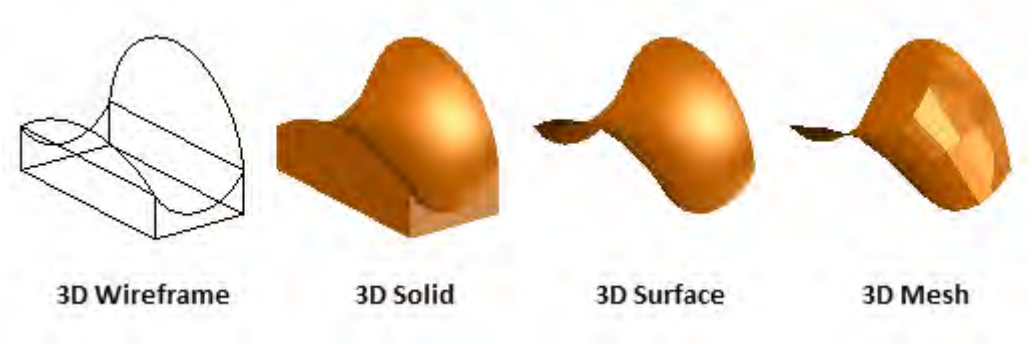

Figure 26. Types of CAD Models. (Autodesk, 2018)

Figure 27. Project Soane, Example of a complete model with renderings and visualizations. AndrewMilburn, GAJ Architects, UAE (Gaj Architects, 2017).

For most cultural heritage work, all 3D model types may come into use, with the 3D solid model being the most useful. So, the problem now that is facing anyone recording cultural heritage artefact or building would be how to create the geometry for the 3D model. For that, there are generally three methods: Direct Input, camera based and scanner based. The forthcoming sections will explain each method.

4.3.1.8.1. Direct Input Modelling

In this method the necessary commands and specific measurements to directly create the geometry of model are used in the CAD software program being used. The creation of a CAD model using direct input of the measured information of the heritage model is a long process, to say the least, depending on the complexity of the model, the capabilities of the software and the proficiency of the user. You MUST have all measurements ready and available BEFORE you start modelling on any of the above mentioned CAD/Modelling packages. The more complex the geometry, the more time it takes. To get professional results required a steep learning curve and training. Some 3D software package may be unable to completely model the item accurately either for limitations in the software itself or lack of geometric information collected.

Figure 28. . Direct modelling of a Doric column in Autocad(Author).

Figure 29. Project Soane of theBank of England Digital Reconstruction (Porject Soane, 2017).

4.3.1.8.2. Scanner Based Modelling

There are generally three types of scanning solutions for creation of 3D models, depending on the technology, format and portability: LiDar 3D Laser scanners, low cost desktop 3D laser scanners and portable hand held 3D scanners. LiDAR (Light Detection and Ranging) technology laser scanners allow the creation 3D models from the

scanned data, by forming “clouds” of coordinates that describe the complex geometry, called “point clouds”. Those coordinates are then processed using special software to generate the 3D model. LiDar Scanners that are mounted on drones are called LiDar UAV (Unmanned Aerial Vehicle). Today it is standard practice to use a mixture of LiDar Scanners with Photomodelling, since both techniques complement each other for the final creation of the 3D model (Meschini, Petrucci, Rossi, & Sicuranza, 2014). LiDAR 3D laser scanners use specialized integrated software and are used usually for large elements like facades of buildings, whole buildings and large structures (see figs. Below). Standard desktop 3D scanners are used for small objects that can be fit within the limitation of the 3D scanner. There are hand held 3D scanners which also are limited by the size of the object you can manipulate and scan. The systems are now small and portable, produce very high accuracy and are fast. It is quite common now for certain projects to use a combination of both photo-modelling (see below) and laser scanning (Factum Foundation, 2018) both technologies complement each other for the final creation of the 3D model (Meschini, Petrucci, Rossi, & Sicuranza, 2014).

Figure 30. 3D Point Cloud of Buddhhist Temple in Bagan,Myanmar. (CapturingReality Bagan, 2018)

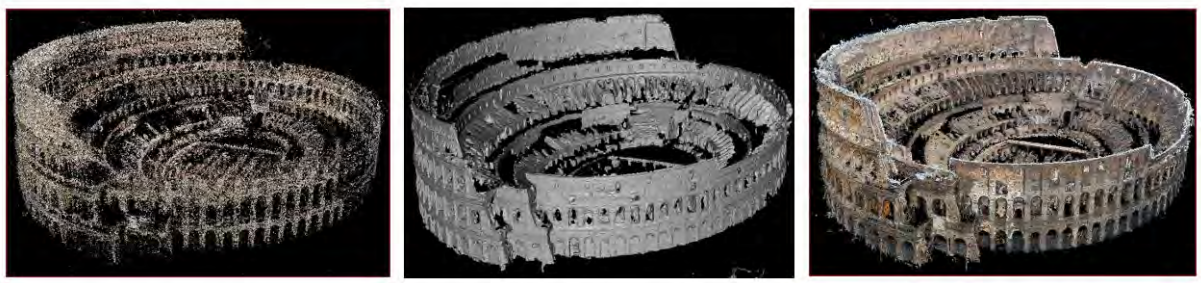

Figure 31. PointCloud then Mesh model then 3D textured model (Grail Lab, n.d.).

LiDAR Laser Scanners: LiDAR laser scanners are expensive but accurate, very fast, and require training to use them. There are many laser scanner manufacturers in the market, offering excellent solutions like: Leica, Faro, Artec, Paracosm, Zeiss and others.

Low Cost Handheld 3D Scanners: Low cost hand held 3D scanners can be used for generation of a 3D model of the item being scanned. This is most useful for small artifacts. The accuracy differs between the different models. There are several “desktop” models, in addition to the hand held types.

4.3.1.8.3. Camera Based Modellin (Photomodelling)

Photogrammetry is the taking of measurements from photographs (Dictionary.com, 2019). Once it was closely linked to aerial photography (Merriam Webster, 2018), but now the term has been extended to encompass all types

Figure 32. From left toright: Faro Focus X30 (Faro, 2019), Leica 3D Disto (Leica, 2019) , Leica BLK360 (Leica BLK, 2019),Artec Ray (Artec Ray, 2019).

Figure 33. Left:EinScanSE Shining 3D Desktop 3D Scanner, Right: Matter & Form V2 3D Scanner (P., 2018)

Figure 34. Left: GoScan 3D (Goscan, 2019), Center: ARtec EvaLite, Right: EinScan Pro +, (P., 2018)

of photographs. (Photogrammetry, 2019). Thus many uses and techniques fall under this term, one of them would be Photomodelling, which is the use of camera images to create a 3D model that can be used by a CAD system or that can be viewed interactively in a special 3D viewer. Photomodelling is one of the fastest and most effective methods of creating a 3D model of complex objects. The 3D model is automatically constructed by acquiring the geometric and textural information from a series of overlapping images taken by the camera. A series of coordinates (called cloud points) are created that accurately describe the model, those can be used by any CAD program to create a 3D model.

3D Photomodelling using Digital Cameras: Any digital camera can be used to create a 3D model, even simple Point and Shoot cameras and Smartphone cameras. Naturally, some cameras will give better results than others. Ideally a DSLR camera in manual mode will give the best results. It must be noted that the end result will depend on the quality of the photographs and being able to capture all the details from different angles so that the software can properly triangulate and create the 3D model. The idea is to take a series of overlapping pictures of the artifact being modelled by from all possible angles. What will not be photographed will not be modelled. Buildings or building details can also be modelled in the same way, except that you don't necessarily have to take pictures in a

full circle. Care should be taken to set the exposure settings to be manually fixed to avoid automatic adjustment of the exposure by the camera, so that lighting will be uniform throughout the picture taking. At the end, the series of pictures is interpolated by special software that generates a 3D model of the item pictured. The accuracy and details of the model will depend on the number of pictures taken, the quality of the pictures, and the presence or lack of interference or clutter from elements surrounding your target subject. Some pre-processing may be necessary to get good results. Some objects give better results than others. Small artefacts that you can easily get around and photograph from all angles, are not too shiny and are well illuminated from all angles will give excellent results. Same for buildings, it is preferable to have direct sunshine or too many shadows. Working in an overcast day with no direct sunshine is ideal. There are several software packages for processing the images: Agisoft Photoscan, Photomodeler, Autodesk Recap Pro, ARC 3D Webservice, Pix4dMapper, Reality Capture and others. There are also several web sites that publish those 3D models, and offer them for sale, perhaps the most famous is Sketchfab. 3D models can be used for 3D printing, CAD, and for VR and AR presentations. The construction industry relies on this technology to create as-built drawings that are a necessity for renovation projects. It is also necessary for built cultural heritage for any restoration project to record the current state prior to restoration. Museums are amongst the heaviest users of such technology, especially the Smithsonian Institute with their 3D Digitization Program ((Smithsonian x3D, 2018)) and the British Museum.

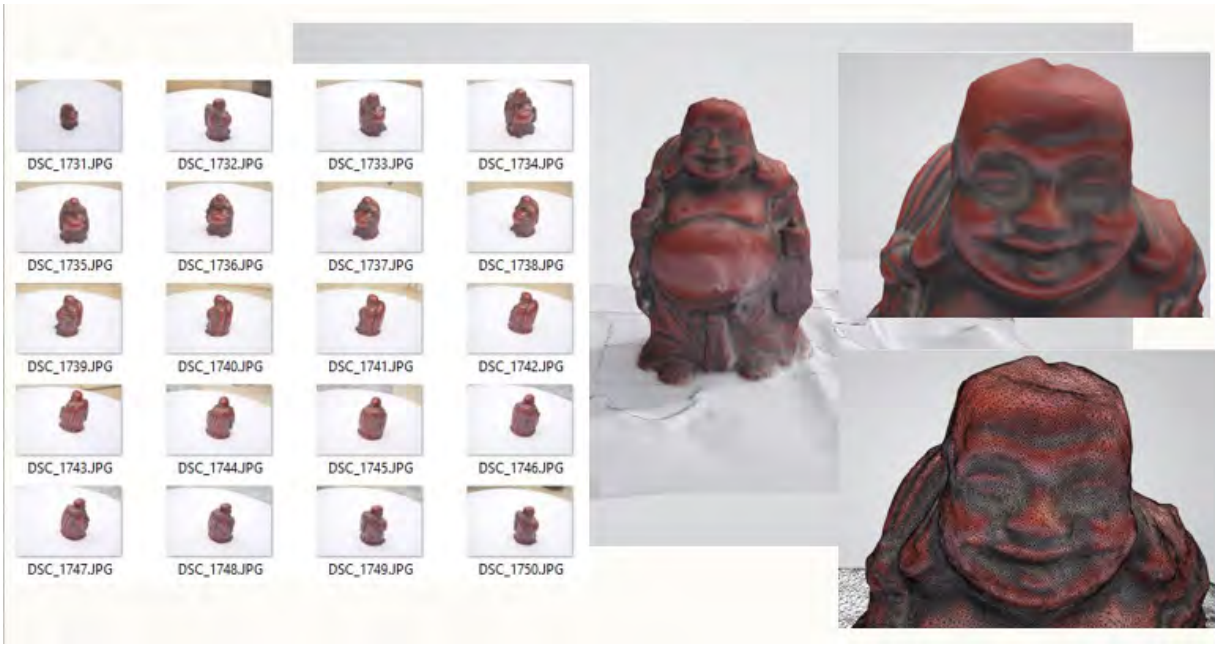

Figure 35. Photomodellingusing Autodesk Recap Photo (Author).

Figure 36. DifferentSketchfab 3D Models, Left : Castel Saint Angeolo, Rome, (Sketchfab - Castel Saint'Angelo, 2016), Center:Al KhamisMosque Gravestone, Kingdom of Bahrain (Sketchfab - Khamis, 2018), Right: EgyptianFunerary Mask, Egypt, (Sketchfab - Mask, 2018)

3D Model Creation Using Special Cameras: There are several solutions to automatically generate 3D models

using specialized cameras or scanners. One such solution is a scanner add on to Apple's Ipad Canvas by Occipital: this is a solution combining an IPad, a scanner called a Structure Sensor, and Canvas software. There result is that you can scan any room to your CAD program directly, at an accuracy of 1-2%. Several rooms can be combined to create a whole layout (CANVAS, 2018). The current use of this solution is for architecture, design and build, interior modelling and other architecturally related solutions and has yet to be tested for cultural heritage. But considering its price, this is an excellent solution to quickly model build cultural heritage.

Figure 37. Left : Canvaswith Structure Sensor (CANVAS, 2018) Right : Matterport 3D Camera (Matterport, 2019) .

Matterport is another company that provides a complete solution that includes a propriety 3D camera and the images are uploaded to their web based software and processed on their cloud, then the finished 3D interactive panorama is published on their site (Matterport, 2019). This is one of the most complete solutions to record spaces, however, one must note that I have not seen it used in a cultural heritage recording.

Aerial Drones (UAV's).: Small Aerial Drones, also known as UAV's (Unmanned Aerial Vehicles), is an "unmanned aircraft or ship that is guided remotely or autonomously" (UAV Surveying, 2018) .Some types referred to as Quadcopters which have four propellers, and multicopters which have more than four, are used in taking aerial photographs and videos. Applications for such a technology covers just about anything: surveying, mapping, construction, architecture, engineering, entertainment and of course cultural heritage. They are most useful in cultural heritage for taking photographs of structures from the air to provide more images for 3D Photomodelling or for LiDAR scanning (Meschini, Petrucci, Rossi, & Sicuranza, 2014). Numerous types are available on the market (Toptenselect, 2018), ranging from small and cheap (eg. Dromida Omnibus, see below) to professional and heavy. They have become an indispensable tool in recording large sites, coming a standard part of the equipment in many cultural heritage recording projects (CapturingReality Bagan, 2018).

Figure 38. Aerial Drone with mounted cameras. Left: DJIPhantom 3 Professional, Center: DJI T600 , Right: Dromida Omnibus. (Toptenselect, 2018)

2D Images and 3D CAD Photomodelling: Still images can be integrated in a CAD model to generate a realistic 3D model. Sketchup and 3Ds Max have been used successfully for this purpose. The idea is to use a 2D picture and "map" it on a 3D model, instead of having to recreate the details of the picture digitally. It is very useful for flat walls with many details, such as paintings or writing, since a good picture of the wall can be easily mapped on a 3D model of the wall, and you eventually have a very detailed 3D model.

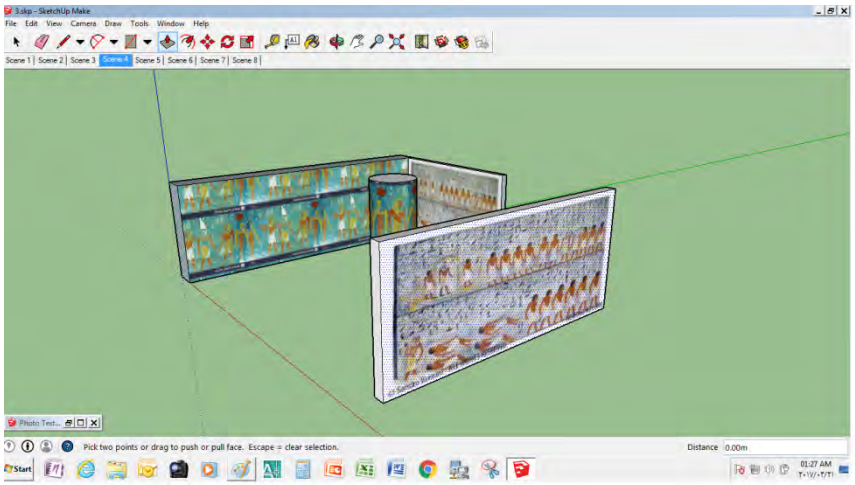

Figure 39. Sketchup modelling in 3D CAD using 2D images(Author)

4.3.2. BIM for Heritage Sites: Historical Building Information Modelling (HBIM).

Specific information can be also added to 2D or 3D models, giving us “intelligent” models that can act as repository of data and information about the building/artifact itself. Such intelligence can be used by other programs or applications for more processing. With 2D models, GIS applications that add statistical data, demographics and land use data are among the most popular. For 3D models, material takeoffs and structural analysis, simulation or other applications. Thus the trend has been going onto creating 3D models for architectural and heritage information, for all objects, from whole towns to small shards of pottery or jewelry.‘

The Building Information Modelling (BIM) paradigm is a step further in 3D intelligent modelling, in which the model is created with 3D intelligent components. Originally developed and applied for the building industry for AEC (Architecture, Engineering and Construction) disciplines. This is quite different from CAD modelling, since the items used behave as real-life elements. Today BIM in architecture and engineering is an accepted standard, however, it is still being introduced to cultural heritage, and is being slowly adopted also as a standard. Historical Building Information Modelling is BIM with an added layer of cultural heritage information and data [(MOLA Team, 2015) ; (Antonopoulou & Bryan, 2017), (Chiabrando, Donato, & Santagati, 2018)]. The aim is integrating 3D archaeological models with all relevant information and databases to create an intelligent model with all information related to the site is contained in it. Once a BIM model is built, one can get all the advantages of 3D modelling, plus intelligence, information, materials, volumes, areas, finishes…etc. plus full portrayal of all projections, 3D perspectives, animation (walkthroughs, fly-over), Virtual Reality visits and different levels of rendering and visualization of the model (Garabnani, 2017). Possibilities are endless. This is especially useful for conservation projects, HBIM ensures that all information related to the heritage site is contained in one model, from which all involved in the project will have one source of information, while conforming to the building “industry standards.” (Wessex Archaeology, 2019). (Scianna, Gristina, & Paliaga, 2014). For conservation and operation of archaeological sites, HBIM becomes an indispensable tool to ensure the continuity and upkeep of the site and monitoring any degradation and ensure continuous and consistent upkeep. Several limitations are immediately apparent when using standard commercial BIM software for complex heritage sites and buildings, since numerous cultural heritage buildings don’t necessary follow or use standard architectural components. Open Source BIM software or dedicated HBIM software is not readily available, with obvious limitations and unfulfilled needs of archaeologists, and the need for programmable BIM packages to add any new functionality. I believe that eventually specialized HBIM software will appear that is modified to cater for the complexities of archaeological buildings. (Logothetis & Stylianidis, 2016).

As for BIM software, there are numerous software packages that are designed for the AEC industry, with Autodesk Revit being the market leader. There are many other BIM packages like: Graphicsoft Archicad, NEMETSCHEK Vectorworks, Navisworks, Dessault Systemes BIM, Bentley Microstation, Edificius, IDEA Architecture, Allplan

Figure 40. HBIM Case Study of Valentino Castel in Turin,Hall of Columns (Chiabrando,, Sammartano, & Spano, 2016).

Architecture and many others. No dedicated HBIM software is available yet on the market.

Using BIM will also allow architects/archaeologists to use the four different immersive technologies (Autodesk, 2019) that are available now for the AEC industry in cultural heritage. Those technologies are: Virtual Reality, Immersive Visualization, Augmented Reality and Mixed Reality. It is no longer an option to use those technologies, it is a must for cultural heritage.

4.3.3. Google Earth, Google Street View, Architecture and Built Cultural Heritage.

One of the most interesting web sites for cultural heritage is Google Earth, which has 3D models of numerous cultural heritage sites in 3D and with panoramic pictures of the site. Most of the well visited European Cultural Heritage sites has been already modeled in 3D and are well documented with images and panoramic virtual visits, but in the Middle East generally, numerous cultural heritage buildings and sites have not yet been modeled in 3D.

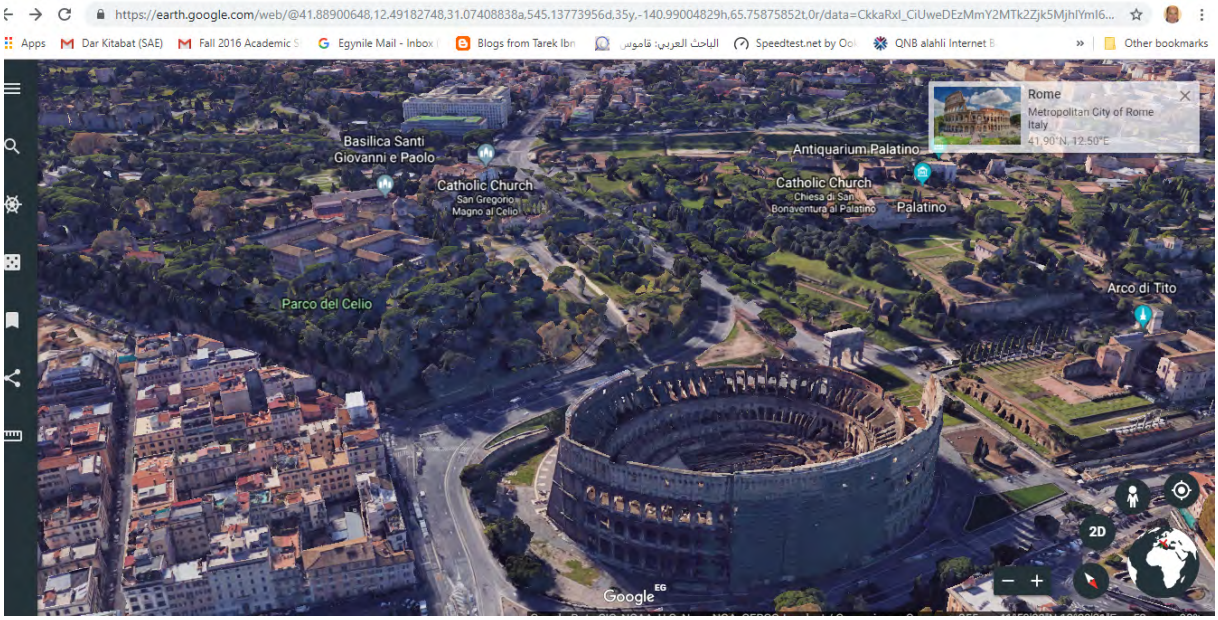

Figure 41. Google Earth, 3D view of the Coliseum in Rome. (Google Earth, 2019)

On Google Street View, you can upload 360^o panoramas of sites, which is the best next thing to actually being there, and is a necessary asset for any researcher in cultural heritage. Numerous sites in the Middle East have not yet been documented. All you need is your camera phone, an internet connection on your phone, and you are ready to upload those panoramas.

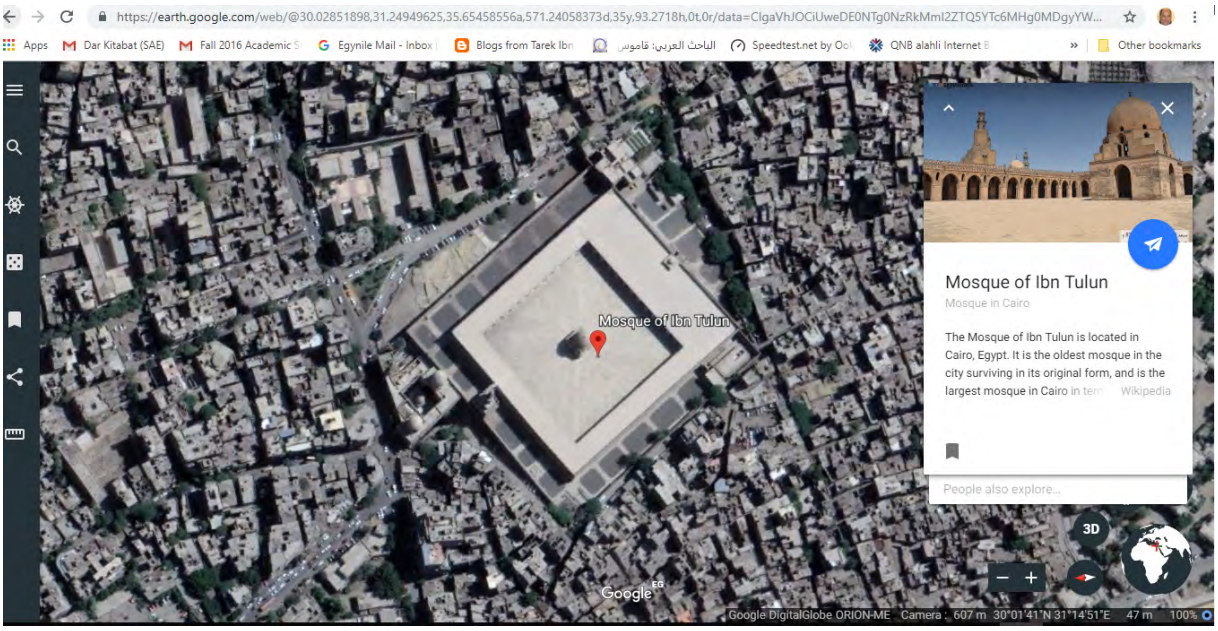

Figure 42. Mosque of Ibn Tulun, Cairo. No 3D model or panoramas. (Google Earth - Ibn Tulun, 2019)

4.3.4. Smart Phones as a Digital Measurement Tool.

Smart phones are now a necessary gadget with all of us, so it is not strange that more and more packages are offered to provide functionality that may not be available to its larger brothers. Smart phones, whether with a stylus or not, can handle most of the applications available for IOS and Android for graphics and video. Several software packages are available that are limited to Smartphones. Of great use for cultural heritage are measurement software packages by which you can take the physical dimensions of an item, room, building or distances. Some even allow you to record the measurement by drawing a dimensioned scaled sketch using the phone and its camera as a measurement sensor. On the Iphone the following packages are available: My Measures +, Easy Measure, Tape Measure AR, Ruler App+AR Tape, Ruler, CamToPlan – AR, Magicplan, Smart Measure, CamMeasure Lite, Photo Measures Lite. . . and many more. For Android Smartphones there are also many offering like: Google AR Meaure App, GPS Fields Area Measure, Ruler, Imagemeter, Smart Measure, Easy Measure and many more.

4.4. Future Technologies

4.4.1. Microsoft Hololens and Holograms.

Borrowing from the construction industry, with Microsoft's introduction of its Hololens 2 wearable viewer this has opened up new ways to interact and visualize buildings in a mixed reality environment. Coupled with Trimble's Sketchup Viewer for Hololens, or with Trimble' XR10 customized hat with the built in Hololens 2 (Jackson, Tom, 2019), mixed reality has become closer to archaeologists in a manner never possible before. We are yet to see applications in archaeology. This will usher in a "New Paradigm" of experiencing cultural heritage buildings (Trimble, 2016).

4.5. Conclusion

Computers in cultural heritage have become an integral part of the discipline. Changes in the technology are constantly happening, and archaeologists must keep up with those changes and developments. This puts great pressure on the practice of the profession and on educators of Archaeological curricula in the different schools of Archaeology. The nature of the profession and variety of skills needed requires inter-disciplinary experience in standard desktop applications, 2D and 3D CAD, photography, use of multiple equipment and instruments and

integrate all for recording the data for archaeological purposes. This first step in the workflow of cultural heritage makes using computers and having excellent digital skills a necessity to complete the other steps of the workflow for archiving, analysis, visualization, presentation and publication of cultural heritage.

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