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DIFFERENT APPROACHES TO CREATION OF DIGITAL TWINS FOR USE IN AR/VR GALLERIES

Abstract. The article analyzes different ways and technologies that can be used to create a so-called “digital twin” (digital copy) of a physical real-life art object and assesses their suitability for AR/VR applications, based on existing examples of digitized items that are considered to be part of cultural heritage, either local or global. One of primary issues for any digitisation process is that of faithful recreation of the original, which can be achieved in multiple ways ranging by price, complexity and quality of the result. Some approaches discussed in this article, can be utilized almost universally, with little regard to the type of the object to be scanned, while others have limitations arising from equipment’s capabilities, properties of the material the art piece is made of or even considerations about possible damage to the scanning equipment. In some cases we would need to combine several different techniques to receive the result that satisfies our project’s requirements and/or goals. However, before choosing our work process, we also have to take into consideration the application or in other words - the desired use case of our digital copies. As such, the primary concern for the purpose of this article is on the analysis of the available tools and techniques, from the standpoint of balanced cost/quality ratio in relation to fairly constrained use cases of

virtual gallery spaces, both offline and online. VR/AR technologies place yet another restriction on our review, because it is highly not advised to use highest quality assets when creating experiences intended to be experienced with the aid of VR or AR and especially standalone headsets (meaning they do not need external processing equipment). This review also is limited to technologies known to be capable of producing results with consistent and repeatable quality levels as getting good results early on in the project's life cycle allows us more room for any edits.

Key words: virtual reality, augmented reality, virtual gallery, digital preservation, digital art heritage.

Introduction. Any virtual space, be it an environment used in computer game or simulated historic building usually needs to have some 2D or 3D assets as building blocks. Virtual galleries are no different than above examples but have much more straightforward requirements, which in turn leads to easier adherence to them: artworks have to be displayed in a form as close to original as possible, taking into account available resources and funding.

Problem statement. Compared to instruments and tech available just 20 years prior, we have a wide range of potential approaches to the problem of high resolution digitization of art objects. Not all of them will be suitable for a specific purpose, much less will produce material that is ready for use in a virtual environment "out of the box". Choosing a solution relies on careful consideration of different factors and compromises: end use of the digital "duplicate", desired detalization level, available funds, etc.

Analysis of recent research and publications. Talking strictly about sources currently available in free access, which mostly consist of scientific or commercial articles (usually published for marketing purposes) we can conclude that most of

them will come from areas fairly unconnected to artistic and cultural research, such as electronics engineering, structural engineering or material sciences. This does not diminish their usefulness for us and sometimes could lead us onto new research paths. For example a way of non-invasive defect detection in timber could help us preserve carved wood sculptures. Analysis of pavement cracks can help with detection of similar defects on cultural heritage objects made of concrete and similar materials. As useful previous papers could be for use in artistic domain, most fitting to our work would be articles, for example, providing comparative analysis of 3D-scans and photogrammetry. This one, in particular, is a much needed experimentally proven answer to a question of what would be more precise and accurate 3D digitization method (given a set of reasonably good equipment), when choosing between photogrammetry and laser or structured light scanner. However, there are little, if any, works using already established products and repositories as proofs of the level of quality, achievable using currently available digitization techniques, this approach being fairly useful as during the creation of digital copy of an object for the VR/AR gallery, primary consideration will be given to established technologies and equipment, possibly with commercial support available.

As such **the purpose of this article** is to provide a concise comparative overview of different scanning technologies, suitable for use in the art industry, with the respect to expected result quality and effort involved in achieving it. Specifically we are concerned with professional solutions suitable for use in online or offline virtual galleries.

Presentation of the main research material. *2D scanning techniques.* Digital 2D duplicate is created after a fairly straightforward process that usually falls into one of the two categories: photography or scanning. While achieving high-resolution photos by the means of film photography is very

much possible [12], the resulting analog image has yet to be transformed into digital, usually by the means of scanning developed film or source material. As such, applications of film for digitization purposes are left out of this article, in large part because, as it was just noted – film itself has to be digitized.

Digital photography is in a way the most versatile and easy to use tool at our disposal. It is also very cost-efficient as given a suitably good camera and a tripod, our images likely will look reasonably good for use in a virtual environment. By choosing this approach we can make use of DSLR, mirrorless, light field cameras or iPhone (not recommended, however in recent years they started replacing professional equipment as a more compact "on the go" alternative). Theoretical and practical sides of the question are seldom the same in creative industries, this being not the exception. There are two immediate challenges present: shape distortion and inadequate color capture of textured items. First point is well illustrated by the photo of my own graduate linocut with dimensions of 100x70 centimeters [23] that was hard to capture in one shot with a good level of detail and without introducing warping of geometry in corners, which was almost unavoidable due to lens curvature. Accurate color capture however was of no immediate concern. To demonstrate the second issue, we can use yet another work, this time a linocut print on aluminum foil [24], image used as an example was captured from a slight angle to offset lamp glare.

When we talk about scanning of flat items, we usually refer to office flatbed scanners or devices similar to WideTEK 36 ART-600 (Image Access, n.d.), with both satisfying different requirements. Examples of what such scanners are capable of are fairly easy to find as they are one of most recommended ways of DIY ("do it yourself") digitization for any image-based product and particularly artworks. This approach is perfect for any item smaller than A3 sheet of paper, [22] with most of the

office or home equipment being limited to A4 / Letter sizes. Professional machines, like above mentioned WideTEK can work with items up to 2.2 m in length and 0.9 m in width, which opens much more possibilities for digitization of the items to be showcased. Additional improvement over photography is that we are not particularly concerned about lighting setup or medium chosen by the artist. This equipment can also offer highly textured scans, capable of capturing not only an image, but highlighting the artist's technique and brush strokes. This makes employing scanning services a highly desirable option, but one requiring fairly high upfront investment if we want to have such ability in-house.

Both outlined techniques offer us good options with acceptable price ranges and can produce materials ready for use in a virtual gallery environment, with file size being of no immediate concern as editing an image in programs like Gimp [6] or Paint.net [2] is always a possibility.

3D scanning techniques. 3D scanning is a more involved process that can result in very accurate digital copies of real-life objects. This quality comes at the cost of extra equipment that usually goes well above what regular individuals can afford or at the very least high-end precision scanners are. We can focus on two more common techniques that give us more precise results: laser triangulation and structured light.

Laser triangulation works on a principle of deriving distance to an object from angles of two sides of an imaginary triangle, formed by laser beam [8; 9; 14; 15] This distance is then being recorded as point in space relative to the scanner's position, with corrections made to account for rotation of the scanned object. Such points, collectively called “point cloud”, then become vertices of our 3D model, which in most cases needs some manual verification and simplification, however this is much less work than would be involved in making the whole model by hand from the start. One of main advantages of

this technique is its simplicity, as all that is needed (assuming simplest possible setup is used) are a camera and a laser, with any cheap items being sufficient for achieving good enough quality of results or serving as a learning setup for students.

Structured light method relies on multiple shots of an object with a light pattern projected onto it. Common patterns used are linear and sinusoidal, with linear providing coarse object position and shape data and sinusoidal – detailed. [3; 8; 9; 17]. Distortions in the pattern are used to identify surface shape of an object, which then are converted into a detailed 3D model. Main drawback of this technique however is its poor performance in shadowed areas with non-uniform lighting, which is usually the case when working in situ on large historic artifacts or works of art.

Conclusions. Viability of discussed above techniques for use in cultural heritage preservation and preparation of digital copies for virtual galleries is in a way a subjective assessment, as each author would have differing opinions about what quality of assets they prefer to be used in their work. Thankfully, we can utilize existing repositories mostly comprised from corporation-led projects such as Google Arts & Culture (*Search — Google Arts & Culture*, n.d.), museum-submitted catalogs of public domain items (AD&D 4D Association for the Documentation and Diffusion 4D, n.d.; Full Collection | Scan the World, n.d.; Nationalmuseum, n.d.; Smithsonian 3D Digitization, n.d.; SMK – Statens Museum for Kunst, n.d.) and individual contributions(Flynn, n.d.), which sometimes are directly supported by other businesses in the form of curated collections or “newly introduced” licenses, such as the case with Sketchfab’s CC0 dedication [16; 19]. These projects usually showcase best quality scans available pretty much anywhere on the Internet and, provided they stay accessible and available in the future, are a good indication of

what is achievable if we wanted to showcase works of art in ways most true to original.

Taking into account our stated use case, any optimizations specific to online content presentation are to be done later, after sufficiently good digitization is completed. The better the source material, the higher will be the quality of the result as for example retopology of a 3D model is much easier when we need to simplify the shape rather than introducing new elements. As such, from methods discussed in this article, 2D scanning by the means of an ordinary flatbed scanner provides excellent cost to quality ratio, good ease of use and versatility. When it comes to 3D objects, it would be best to utilize laser triangulation scanners, combined with photography. In this case primary shape data will be received from the scanner, with photos used as a basis for texturing work and manual shape editing.

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РІЗНІ ПІДХОДИ ДО СТВОРЕННЯ ЦИФРОВИХ ДВІЙНИКІВ ДЛЯ ВИКОРИСТАННЯ В AR/VR ГАЛЕРЕЯХ

Анотація. У статті проаналізовано різні способи і технології, які можуть бути використані для створення так званого «цифрового двійника» (цифрової копії) фізичного оригіналу мистецького об'єкта, оцінено їхню придатність для застосування в AR/VR на основі існуючих прикладів оцифрованих об'єктів, які вважаються частиною культурної спадщини місцевого чи світового значення. Одним із головних завдань будь-якого процесу оцифрування є точне відтворення оригіналу, якого можна досягти різними способами, що відрізняються за ціною, складністю та якістю результату. Деякі підходи, розглянуті в цій статті, можна використовувати майже універсально, незалежно від типу об'єкта, що сканується, тоді як інші мають обмеження, пов'язані з можливостями обладнання, властивостями матеріалу, з якого виготовлено твір мистецтва, або навіть із міркуваннями про можливе пошкодження скануючого обладнання. У деяких випадках доведеться комбінувати кілька різних методів, щоб отримати результат, який задовольняє потреби та/або цілі нашого проєкту. Перед обранням того чи іншого способу виконання поставленого завдання, маємо врахувати бажаний спосіб використання цифрових копій. Таким чином, основна увага в цій статті зосереджена на аналізі доступних інструментів і технік із

точки зору збалансованого співвідношення ціни та якості стосовно досить вимогливих продуктів, таких як віртуальні галереї. Технології доповненої і віртуальної реальності накладають ще одне обмеження, на наш огляд, оскільки не рекомендується використовувати ресурси найвищої якості при створенні контенту, призначеного для сприйняття за допомогою VR або AR, а особливо автономних гарнітур (тобто таких, що не потребують додаткового обладнання для обробки зображень). Цей огляд також обмежується технологіями, які завідомо здатні створювати результати з однаковим та повторюваним рівнем якості, оскільки отримання хороших результатів на ранній стадії проєкту дає нам більше можливостей для будь-яких змін, якщо в них є потреба.

Ключові слова: віртуальна реальність, доповнена реальність, віртуальна галерея, цифрове архівування, цифрова художня спадщина.

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