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PRESERVING CULTURAL AND HISTORICAL HERITAGE USING DRONES

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ABSTRACT

The purpose of this study is to determine the role of drones in the process of preserving cultural and historical heritage. For this research, the DJI Air 2S More Combo unmanned aerial vehicle was employed in combination with photogrammetry and supporting software products such as 3ds Max, Blender, and KOMPAS-3D. The main outcomes include the creation of high-quality digital models of 16 cultural and historical sites in Northern Kazakhstan, the development of new methodologies for assessing structural wear and cultural value, and the acquisition of copyright certificates for these methods. Results demonstrate the significant potential of UAVs in enhancing heritage preservation, improving accuracy, and contributing to global accessibility.

KEYWORDS: Drones, Heritage Preservation, Three-Dimensional Technologies, UAV Photogrammetry, Cultural Monuments.

1. INTRODUCTION

The preservation of cultural and historical heritage has become increasingly urgent due to industrialization, environmental changes, and human activity. In Kazakhstan, with its vast territory and rich cultural memory, ensuring the survival of mazars, settlements, and traditional architectural structures is of national importance. Digital technologies now provide a realistic opportunity to document, preserve, and make this heritage accessible to global audiences.

1.2. UAV Development in Historical Context

The first UAV concepts can be traced to Nikola Tesla (1898) and early 20th-century experimental aircraft. Since then, UAVs evolved from military reconnaissance to multifunctional civil tools. Modern quadcopters, with their high-resolution cameras and intelligent flight systems, have become indispensable in archaeology and heritage preservation.

1.3. Research Objectives

This study aims to explore the role of UAVs in

- Digitally documenting cultural heritage objects in Kazakhstan.
- Creating accurate three-dimensional models.
- Developing methodologies for structural wear assessment.
- Contributing to open-access digital archives.

2. LITERATURE REVIEW

The integration of UAVs into archaeology has been transformative. UAVs provide lower-altitude, high-resolution imaging capabilities superior to satellite imagery. In Italy, drones identified Roman settlements in the Apennines, while in the UK they revealed underground structures at Silchester. In Kazakhstan, projects like IRN AP19676333 highlight the national importance of 3D digitization in heritage preservation. Scholars such as Ian Hodder have emphasized the role of UAVs in providing data for settlement reconstructions, further underlining their archaeological value.

3. MATERIALS AND METHODS

The Project analyzed the best software products for drones: Nira, Agisoft Metashape, Bentley iTwin Capture Modeller, Trendspek. It is the latter that ideally performs work according to the photogrammetry method and creates quickly and efficiently three-dimensional models directly ready for three-dimensional printing.

The right software with the help of unmanned aerial vehicles can significantly increase the efficiency of photogrammetry, optimize workflows and make informed decisions in the process of preserving cultural and historical heritage. The advantages of using drones in archaeological research are, first of all, the speed of obtaining information. In the past, aerial photography was practiced, but it is much more expensive and less effective than unmanned equipment. The drone, in addition, provides very high quality recording, therefore, diagnostics and three-dimensional digitalization of objects is facilitated.

The Project used a multifunctional professional DJI Air 2S More Com with high resolution for high-quality shooting of large-scale objects. The drones are equipped with advanced RTK technology, which allows it to achieve high-precision positioning with an accuracy of 1 cm + 1 ppm. RTK V3 features a completely new RTK module that provides centimeter-level positioning data in real time and supports post-processing kinematics (PPK). The aircraft can record raw satellite observation data, camera exposure parameters, and more. The positioning system supports an RTK base station and an NTRIP RTK network, which help achieve accurate and stable data collection in difficult operating conditions.

In Kazakhstan, flights of unmanned aerial vehicles are regulated by the rules for the operation of UAVs in the airspace of the Republic of Kazakhstan. They are developed in accordance with the provisions of the Law of the Republic of Kazakhstan "On the Use of the Airspace of the Republic of Kazakhstan and Aviation Activities" and determine the procedure for the operation of unmanned aerial vehicles in the airspace of Kazakhstan.

The materials obtained from the drone are processed using the photogrammetry method. Photogrammetry involves obtaining several superimposed photographs of an object from different angles. The software then compares each photo and determines the geometry of the object. **In handheld 3D scanning, photogrammetry can be used for two reasons**

- First, to improve accuracy: This can use markers, the photogrammetry module determines the location of each marker to create a kind of "skeleton", which is then filled in using laser scanning or structured light scanning.
- Second, to capture colors: Photogrammetry cameras on handheld 3D scanners are often used to capture colors, also called "textures".

The software creates a texture map that it traces around the 3D model.

The following steps will help you use drones effectively for photogrammetry

1. Choose the right drone
- High-resolution camera: Find a drone with a great camera to take quality photos.
- GPS capabilities: It is important to make sure the drone has GPS so you can mark its location and track its movements.
- Stability and flight time: Choose a drone that remains stable and has a long flight time to cover the entire area.

2. Prepare for the flight
- Familiarize yourself with the batteries: Charge your drone batteries and also bring extra ones in case you need them.
- Camera settings: As mentioned above, adjust your camera settings to help you take clearer photos; sharpness and brightness levels are examples of these settings.
- Weather conditions: Always check the weather forecast to avoid flying during strong winds or rain.

3. Plan Your Drone Flight
- Coverage Area: Decide where you want to make a map, then create a plan for how the drone will fly over all of those locations.
- Overlap: Make sure there is 60-80% overlap between the images you take, which will help with stitching them together later.
- Altitude: The drone's altitude should remain constant so that all of the images you take are the same size.

4. Control Your Drone
- Launching the drone: For example, taking off along a planned flight path at the same altitude and speed.
- Flight Control: Ground control software is used to control the drone's flight and make adjustments as needed.
- Images should also be taken in such a way that there is 60-80% overlap in each new image.

What is Image Overlap! Image overlap refers to the degree to which a particular image occupies the same space as the next image in a series of images. This overlap plays a key role in helping the photogrammetry software combine the images and create a complete map or model.

Types of Overlaps

Frontlap

Meaning: The total area between photos taken one after the other along the same flight path.

Overall percentage Typically ranges from 60% to 80%.

Reason Ensures that each point on the ground is visible in multiple photos, which helps the alignment process.

Sidelap

Meaning The total area between photos taken along adjacent flight paths.

Overall percentage Often ranges from 60% to 80%.

Reason Ensures that the edges of flight paths are visible in multiple photos, which helps create smooth maps or models.

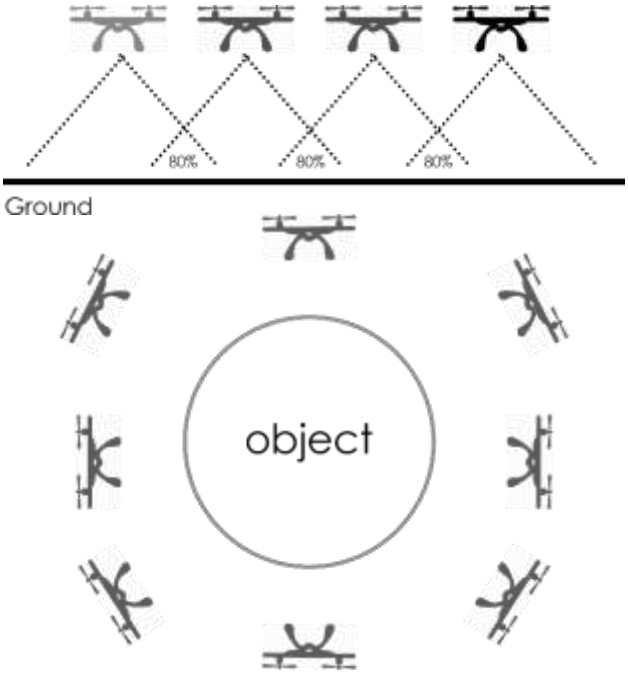

Figure 1: Overlapping Footage at Different Drone Positions.

Accuracy

Positioning With significant overlap, the photogrammetry software can find the correspondences between the pixels contained in the two images that are needed to match them (Figure 1).

Fine detail A high overlap range results in more data points, which means the final model will have fine detail and close estimates.

Backup

Error reduction Overlapping between images gives you more information that minimizes errors caused by image distortion or other strange events.

Consistency This ensures that even if some images are not perfect, the entire model will remain accurate.

3D Modelling

Depth information Overlap is essential for 3D models. It allows for multiple perspectives of the

same location. With this method, the software can determine depth and create a 3D image.

Ways to Achieve Good Overlap

Flight Planning

Software Choose a flight planning software that will help you map out your path with the right amount of overlap.

Altitude For consistent overlaps, maintain the same altitude.

Camera Settings

Trigger Set the camera to shoot at a predetermined time based on how fast and high the drone is flying. This way, you will get the overlap you expect.

Monitoring

Real-Time Changes Watch your journey as it happens. Make adjustments as needed to avoid losing overlaps.

On your laptop, it is important to organize your drone images efficiently for smooth processing and restoration. **Here's how to do it**

1. Main Project Folder
- Name the folder: A good name that describes the folder is important, such as Drone_Photos_Project_X.
- Location: Place this folder in an easily accessible location, such as your desktop or a dedicated project directory.
2. Subfolders for Different Stages
- Raw Images: Create a subfolder called Raw_Images where all the unedited photos from the drone will be stored.
- Processed Images: Create another section and call it Processed_Images; this will contain the photos that have been edited or modified.
- Backup: You should have a backup section where you will store important photos or data sets.
3. Organize by Date and Flight
- Date-based folders: Inside the Raw_Images folder, create smaller compartments based on dates (e.g. 2024-08-17) so that you don't lose information about when these photos were taken.
- Flight-based folders: If you fly multiple times in one day, create another subfolder inside the date-based folder (e.g. Flight_1, Flight_2).
4. Naming Conventions

Images should have a similar naming convention, such as ProjectX_2024-08-17_Flight1_001.jpg. This will make them easy to identify and sort.
- Metadata: When processing images, it is often useful to save data such as date, time, and GPS coordinates.

5. Tags and Keywording
- Tags: Label your images by their specific characteristics or areas of interest using tags or keywords (e.g. Building, Vegetation, Water).
- Software: Use photo management software such as Adobe Lightroom or even the built-in tools in your operating system to add tags.
6. Backup and Sync
- Cloud Storage: Use cloud storage services such as Google Drive, Dropbox, or OneDrive to back up your images and access them from anywhere.
- External Drives: Save them to an external hard drive for safekeeping.

Now let's move on to our software to create a 3D model from our photos

We will be using the reality capture software.

1. Open RealityCapture
2. Launch the software: Launch RealityCapture on your computer.

New Project: Click the main application icon in the upper left corner and select New or press CTRL+N to start a new project.

3. Import Photos

Add Images: There are several ways to add images:

Drag and Drop Simply drag and drop photos into the RealityCapture window. The plus symbol will indicate when the selection can be accepted1.

Input Button Click the Input button located under 1. Add Image in the Workflow tab to select one or more images from a single folder2.

Folder Button Use the Folder button to add all images from a designated directory2.

Keyboard shortcuts Use CTRL+ENTER to add selected images or use CTRL+SHIFT+ENTER to include all images in a folder2.

4. Organize and Review

Viewing Images

Figure 2: Museum-Reserve.

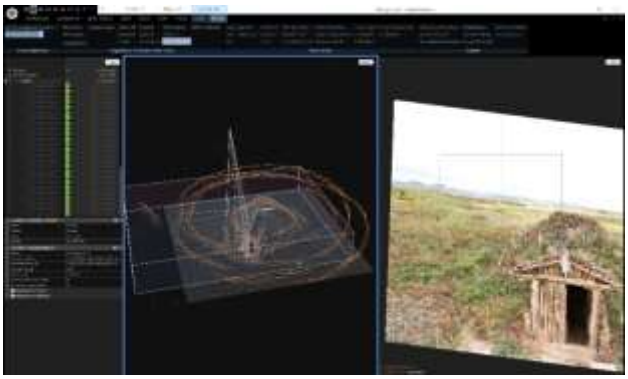

Figure 3: Initial Stage of Model Creation.

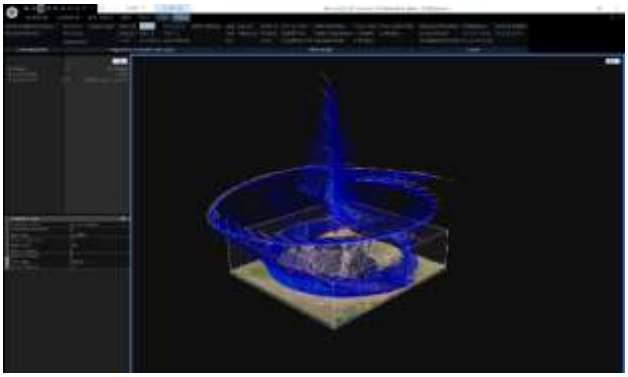

Figure 4: Initial Model Processing.

Point clouds and fusion components are concepts that need to be understood before you begin the RealityCapture process. Here are some details:

In simple terms, a point cloud is a cluster of data points arranged in a 3D coordinate system. The outer surface of an object or scene is represented by these points, which are captured using 3D scanning technologies such as LiDAR and photogrammetry. Each point in the collection consists of X, Y, and Z coordinates, and sometimes other parameters such as color or intensity.

Figure 5: Research Team.

Merge Two Components When working with multiple point clouds, you may need to merge them into one complete data set. This is especially useful when different parts of an object or scene were captured separately. The process of merging two components in RealityCapture involves the following steps:

Align Components We make sure that both point clouds have been correctly aligned. This means that the corresponding points in each cloud must be matched so that they overlap accurately. RealityCapture has manual and automatic alignment tools that can help you.

Merge Point Clouds

Select Components In the software, select the components (point clouds) you want to merge.

Merge Use the merge function on the selected components, such as point clouds, to merge them into a single point cloud. This process combines the data points from the two clouds and ensures the accuracy of the overlapping areas.

Inspect the merged cloud After merging, inspect the resulting point cloud for inconsistencies or artifacts. If necessary, you can improve the merged cloud by removing duplicate points or even adjusting its alignment.

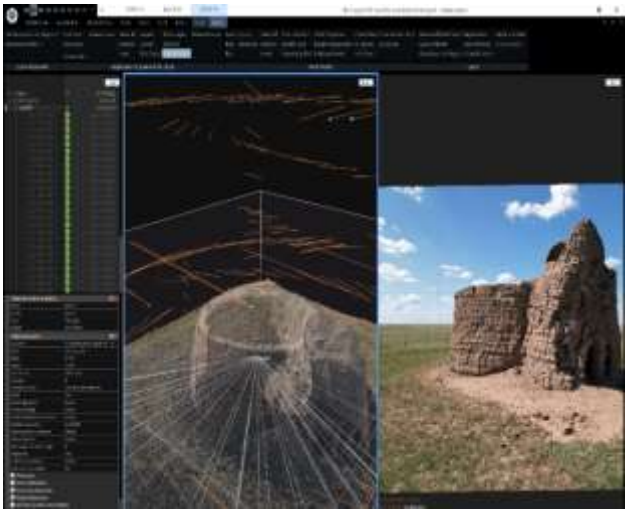

Figure 6: Merge Point Clouds.

Let's dive into the RealityCapture reconstruction process. The reconstruction process is a method for converting aligned photographs and point clouds into reality. Here are the main steps

1. Create a Dense Point Cloud

Once the photographs are aligned and all the necessary components are merged, create a dense point cloud. This involves creating a high-resolution point cloud from the sparse point cloud that was created during the alignment step.

The Process

- Select the Reconstruction tab.
- Depending on your needs, select Normal Detail or High Detail. Using higher detail settings creates more points, but they take longer to process and are more computationally intensive.
- Click Calculate to begin the process.
- Output: A dense point cloud with millions of points that represent the surfaces of the scanned objects or scenes.

2. Create a Mesh

- Once you have a dense point cloud, the next step is to create a mesh. A mesh is basically a 3D surface made up of vertices, edges, and faces that define the shape of an object.

Process

- In the Reconstruction tab, click Calculate Model.
- Choose a level of detail appropriate for your mesh. Models created with higher detail settings will be more accurate, but will take longer to process.
- Click OK to begin generating the mesh.

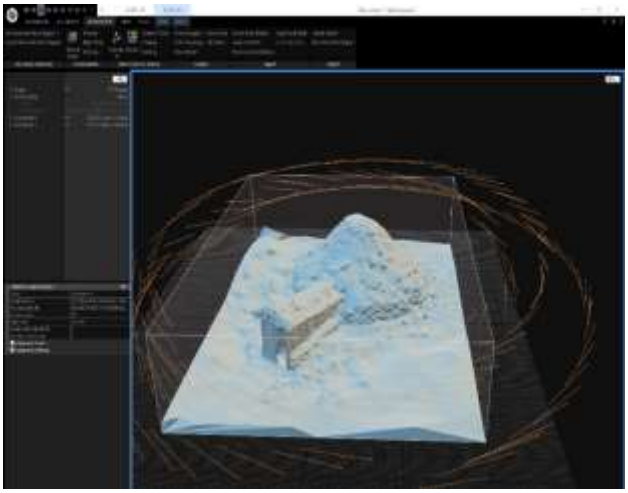

Figure 4: The Reconstruction Process.

Output: A 3D mesh representing the surface geometry of the object. This mesh can be viewed and modified in RealityCapture.

This step of 3D reconstruction is important because it applies the original photographs to the mesh, thereby adding realism to your 3D model. Here's how texturing works in RealityCapture:

The Texturing Process

Preparation:

Make sure your 3D mesh is clean and free of artifacts. Mesh issues can affect the quality of the texture.

All of your photographs should be well-aligned, and a dense point cloud should represent the object or scene you want to capture.

Texturing settings:

In RealityCapture, click the Texturing tab.

Click Texture to access the texturing options.

Choose your preferred texture settings, including resolution and blending options. Higher resolution textures will provide more detail, but will require more processing power and disk space.

Texture Calculation

Click OK to begin the texturing process. This software will project color information from photographs onto a 3D mesh.

This application is capable of using complex algorithms to accurately display textures even where multiple images overlap.

Inspect and Edit

Once the texturing process is complete, inspect the textured model in the 3D view.

Inspect for any issues such as offsets in the texture or seams or color inconsistencies. Adjust the texture settings and reapply if necessary.

Enhance

Enhancements are made to the textures using the tools found in RealityCapture. Brightness, contrast, or color balance can be adjusted to ensure a consistent and realistic look.

External software such as Photoshop can also be used to manually edit individual parts of the textures if needed.

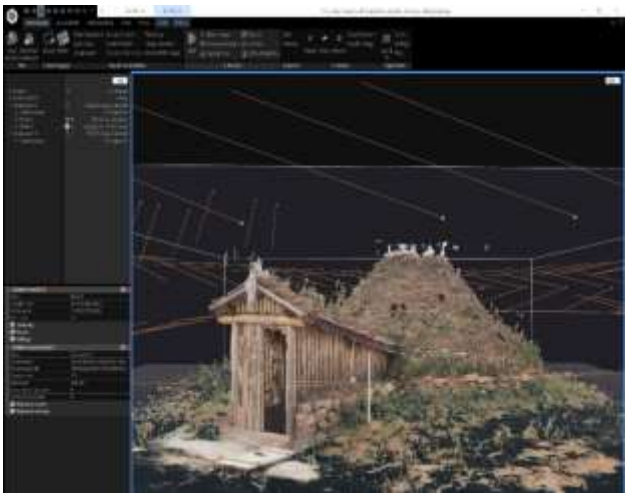

Figure 6: Editing the Model.

Exporting and distributing your 3D model is the final step in the RealityCapture workflow.

This allows you to use your model in other applications, share it with collaborators, or publish it online. **Here is a detailed overview of the export and distribution options**

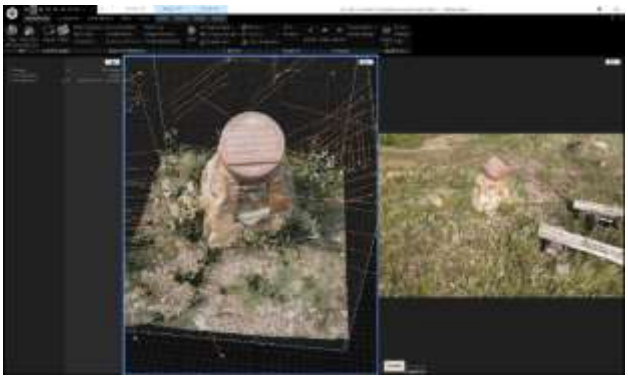

Figure 7: Exporting a 3D Model.

Choose an export format

Go to the Export tab in RealityCapture.

Choose the format you want here

OBJ: This is one of the most common formats used in 3D modeling and animation software.

FBX (Filmbox): Mostly used in game engines and animation software.

STL (Positive Spatially Only)-used for printing

PLY: For storing 3D data with color information.

Configure your export settings:

Scale: Determine how big or small your model will be relative to its intended use.

Coordinate System: Depending on what software you plan to use, choose the appropriate coordinate system (Y-up or Z-up).

Texture Maps: If you want to maintain the visual quality of your model during export, make sure textures such as diffuse, normal, and specular are included in your export settings.

Export Model:

Click Export after selecting a destination folder for your files.

RealityCapture will create all the necessary files and save them to the selected path.

Sharing Alternatives

Direct Sharing

Email: You can send the exported files directly to your team members via email. But if they are large, make sure these files are compressed into ZIP folders.

Cloud Storage: Instead of sending them via email, upload the files to Google Drive, Dropbox, or OneDrive and give others a link.

Online Platforms: There are many platforms for uploading and sharing 3D models.

Sketchfab: This is one of the most popular platforms for sharing 3D models. Sketchfab allows you to upload your model, which can then be viewed and interacted with in the browser.

Thingiverse: This is best for sharing 3D printed projects only. Other people must upload and print your STL files on the Thingiverse platform.

3D Warehouse: Also used primarily for sharing 3D prints made in SketchUp software integration tools other than its own, such as Autodesk Revit

Integration with other software:

Game engines: Use your model in interactive applications or games by importing it into game engines such as Unity or Unreal Engine

3D modeling software such as Blender, Maya or 3ds Max can also be used to further refine your model or even animate it.

4. RESULTS

The practical significance of using digital technologies in historical research, as well as in the reconstruction and recreation of monuments, is to combine the efforts of computer technology specialists, historians, archaeologists, museologists, architects, restorers, builders, and history buffs in preserving cultural heritage. The significance of research on the IRN Project AP19676333 "Three-dimensional technologies in the process of preserving the cultural and historical heritage of Northern Kazakhstan" is obvious.

As a result of work on the Project, digital models of 16 cultural and historical sites of the Akmola region were obtained and posted on the website https://sketchfab.com.

Thanks to digital three-dimensional models, a methodology was developed for determining the value of cultural and historical sites using weighting factors for each of the three selected criteria. The assessment is a mathematical intersection of three functions - the level of historical significance, physical condition and integrity of the object. The methodology made it possible to rank the selected objects. An author's certificate was received for the scientific work "Methodology for determining the value of a cultural and historical heritage object", author - PhD Mukhamadeeva R.M., No. 47283 dated 11.06.2024. As a result of comparing the obtained digital models of cultural and historical heritage objects with the variants of the original forms obtained in the KOMPAS 3D program, a method for determining the degree of wear was developed. Wear is determined by subtracting the obtained volume of the digitized modern model from the original volume of the historical object. An author's certificate "Method for determining the degree of wear of cultural heritage objects using digital technologies" was also received, author - PhD in History. Mukhamadeeva I.A., No. 48764 dated August 1, 2024

As a result of the analysis, we can conclude that it is necessary to restore two objects in the Korgalzhyn

district: Mazar "Bespakyr" (Fig.), the degree of wear is 37% and Mazar Alyptomar (Fig.), the degree of wear is 35%.

5. DISCUSSION

The objectives set in this study have not been fully resolved. Three-dimensional models of a fisherman's hut, a ruler's hut, and a kumys hut obtained using a drone are unique models. Familiarization with these models allows us to tell about the lifestyle and culture of the tribes of Northern Kazakhstan in the Eneolithic era. To give an idea of the way of life, traditions, and level of civilization in 3700-3100 BC.

A disadvantage of the studies performed can be considered the impossibility of visiting these objects from the inside and working in them from the inside. The reason is the labor intensity of the photogrammetric method, when it is necessary to take a large number of high-quality photographs. It is also not possible to use a laser three-dimensional scanner, which must have a power source and good lighting for the scanning process.

Obtaining a three-dimensional digital interior space of the objects of the historical monument - the settlement of Botai is possible. To do this, first of all, the problem of providing an asphalt road and connecting communications (electricity and security system) must be solved. Once approval is received to continue the Project, work on obtaining a three-dimensional internal digital space can continue.

6. CONCLUSION

It should be noted that the rapid pace of development of new technological capabilities makes it possible to envisage the rapid introduction of even more advanced technology for archaeological research and the processes of preserving cultural and historical heritage.

The restoration of monuments contributes to the revival of historical memory and national pride. The purpose of this study was to determine the contribution of information obtaine by drones to the process of digitalization of cultural and historical heritage. The goal has been achieved, but there are still enough objects for research. To date, the database of digital objects for Northern Kazakhstan, created using drones, is the only such collection.

It is obvious that drones will not replace traditional archeology, a lot of interesting things are hidden directly in the depths underground. Underground ruins cannot always be seen from the air. There are many factors affecting the "visibility" of cultural and historical objects, so the described digitization method should be recommended in combination with other fundamental methods, such as field research methods and geophysics. Additionally, equipping near-infrared cameras that allow us to “see” the fine details of archaeological sites should be the future of drone technology.

The intersection of technology and heritage preservation offers exciting opportunities to preserve our past. From digital archiving to virtual reality, crowdsourcing to artificial intelligence, each tool offers a unique way to document, preserve, and share the richness of our history.

Using new technologies, we can ensure that all the achievements and lessons of our ancestors do not disappear without a trace, but are available for future generations to understand, be proud of, and learn from.

REFERENCES

Akgul, M., Yurtseven, M., Gulci, S., & Akay, A. E. (2018). UAV and GNSS-based DEM estimation for earthworks volume. *Arabian Journal for Science and Engineering, 43*(4), 1893–1909. https://doi.org/10.1007/S13369-017-2811-9

Alkafafi, A., Mukhamadeyeva, R., & Mukhamadeyeva, I. (2024). Method for determining the degree of deterioration of cultural heritage objects using digital technologies. In *Proceedings of the 7th International Scientific Conference “World Scientific Reports” (August 22–23, 2024)*. Paris, France. https://ojs.publisher.agency/index.php/WSR/article/view/4093

Balazhik, V., Tot, Z., & Abdurakhmanov, I. (2021). Analysis of the accuracy of data collection using UAVs. *International Journal of Geoinformatics, 17*(1), 1–10. https://doi.org/10.52939/ijg.v17i1.1697

Carvajal-Ramírez, F., Navarro-Ortega, A. D., Agüera-Vega, F., & Martínez-Carricondo, P. (2019). UAV photogrammetry and 3D modeling applied to virtual reconstruction of an archaeological site. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W15*, 279–284. https://doi.org/10.5194/isprs-archives-XLII-2-W15-279-2019

Erdelyi, J., Kopacik, A., & Kyrinovic, P. (2018). Construction control and documentation of facade elements using terrestrial laser scanning. *Applied Geomatics, 10*(2), 113–121. https://doi.org/10.1007/s12518-018-0208-4

FARo Laser Scanner Focus M70. (2024). https://www.g2metric.co.il/product/faro-laser-scanner-focus-m70/ (Accessed May 30, 2024).

Fiz, J. I., Martín, P. M., Cuesta, R., Subías, E., Codina, D., & Cartes, A. (2022). Examples and results of aerial photogrammetry in archaeology with UAV. *Drones, 6*(3), 59. https://doi.org/10.3390/drones6030059

Grossman, L., Smikt, O., & Smilansky, U. (2008). On the application of 3D scanning technology for documentation and typology of stone artifacts. *Journal of Archaeological Science, 35*, 3101–3110.

Hassan, A. T., & Fritsch, D. (2019). Integration of laser scanning and photogrammetry in 3D/4D cultural heritage conservation: A review. *International Journal of Applied Science and Technology, 9*(4), 9–16. https://doi.org/10.30845/ijast.v9n4p9

Heritage conservation: Tech tools for documenting and preserving the past. (2024). https://countrysquire.co.uk/2024/03/04/heritage

Jaafar, H. A., Meng, X., Sowter, A., & Bryan, P. (2017). A new approach to monitoring historic and heritage buildings using terrestrial laser scanning and generalized Procrustes analysis. *Structural Control and Health Monitoring, 24*(11). https://doi.org/10.1002/stc.1987

Karachaliou, E., Georgiou, E., Psaltis, D., & Stylianidis, E. (2019). UAV mapping of historic buildings: From 3D modeling to BIM. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W9*, 397–402. https://doi.org/10.5194/isprs-archives-XLII-2-W9-397-2019

Kwoczynska, B., Piech, I., Polewany, P., & Gora, K. (2018). Modeling of sacred sites based on airborne and terrestrial laser scanning. In *Baltic Geodetic Congress* (pp. 275–282). https://doi.org/10.1109/BGC-Geomatics.2018.00059

Lingua, A., Martino, A., Sammartano, G., Maschio, P., Reali, E., & Tonghini, C. (2023). UAV-based archaeological 3D monitoring: A ruralscape case in Iraqi Kurdistan. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLVIII-M-2*, 935–942. https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-935-2023

Lis-Maffei, G. (2024). Illustration and heritage: Rachel Emily Taylor. *International Journal of Heritage Studies, 30*(8), 992–994. https://doi.org/10.1080/13527258.2024.2358220

Logothetis, S., Delinasiou, A., & Stylianidis, E. (2015). Building information modeling for cultural heritage: A review. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, II-5/W3*, 177–183. https://doi.org/10.5194/isprsannals-II-5-W3-177-2015

Mohammadi, M., Rashidi, M., Mousavi, V., Karami, A., Yu, Y., & Samali, B. (2021). Quality assessment of digital twins created based on UAV photogrammetry and TLS: A case study of a bridge. *Remote Sensing, 13*(17), 3499. https://doi.org/10.3390/rs13173499

Moon, D., Chung, S., Kwon, S., Seo, J., & Shin, J. (2019). Comparison and utilization of photogrammetry and laser scanning point clouds: A 3D world model for intelligent heavy equipment planning. *Automation in Construction, 98*, 322–331. https://doi.org/10.1016/j.autcon.2018.07.020

Mulakala, J. (2015). Measurement accuracy of DJI Phantom 4 RTK and photogrammetry. https://www.gim-international.com/files/23b0ad77f81a0aa56e8c83f8c4300270.pdf (Accessed October 28, 2023).

Mukhamadeyeva, R., & Mukhamadeyeva, I. (2024). Digitalization in the process of preserving the historical heritage of Kazakhstan. In *Proceedings of the IX International Scientific Conference "Innovative Scientific Research"* (pp. 40–46). Toronto, Canada. https://conference-w.com/

Pompeiano, F. (2020). From national to cultural monuments: A review of architectural heritage protection in Albania (1912–1992). *Journal of Architectural Conservation, 26*(1), 55–70. https://doi.org/10.1080/13556207.2019.1684021

Pritchard, D., Sperner, J., Hoepner, S., & Tenschert, R. (2017). Terrestrial laser scanning for heritage conservation: The Cologne Cathedral documentation project. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, IV-2/W2*, 213–220. https://doi.org/10.5194/isprs-annals-IV-2-W2-213-2017

Qubaa, A. R., Thannoun, R. G., & Mohammed, R. M. (2022). UAVs for photogrammetry in archaeological documentation. *World Journal of Advanced Research and Reviews, 14*(3), 358–368. https://doi.org/10.30574/wjarr.2022.14.3.0539

Remondino, F. (2011). Heritage recording and 3D modeling with photogrammetry and 3D scanning. *Remote Sensing, 3*(6), 1104–1138. https://doi.org/10.3390/rs3061104

Remondino, F., & Campana, S. (2014). *3D recording and modelling in archaeology and cultural heritage.* Archaeopress.

Rodriguez-González, P., Jiménez Fernández-Palacios, B., Muñoz-Nieto, A. L., Arias-Sánchez, P., & González-Aguilera, D. (2017). Mobile LiDAR: New possibilities for documentation and dissemination of large cultural heritage sites. *Remote Sensing, 9*(2), 189.

Samadzadegan, F., Dadrass Javan, F., & Zeynalpoor Asl, M. (2023). Architectural heritage 3D modelling using unmanned aerial vehicles multi-view imaging. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLVIII-M-2*, 1395–1402. https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1395-2023

Themistocleous, K. (2019). The use of UAVs for cultural heritage and archaeology. In *Remote Sensing for Archaeology and Cultural Landscapes* (pp. 241–269). Springer. https://doi.org/10.1007/978-3-030-10979-0_14

Wang, Y., Chen, Q., Zhu, L., Liu, L., & Zheng, L. (2019). A review of mobile laser scanning applications and key techniques in urban areas. *Remote Sensing, 11*(13), 1540. https://doi.org/10.3390/rs11131540

Xing, Y., Yang, S., Fahy, C., Harwood, T., & Shell, J. (2025). Capturing the past, shaping the future: A scoping review of photogrammetry in cultural building heritage. *Electronics, 14*(18), 3666. https://doi.org/10.3390/electronics14183666