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UAV and smartphone-based 3D modeling integration with augmented reality (AR) animation

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Abstract

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, have increasingly become an essential tool in various domains, from agriculture to entertainment. One of their most transformative applications lies in the realm of 3D modeling. By utilizing high-resolution cameras and state-of-the-art sensors, smartphone and UAVs can capture spatial data from the environment, facilitating the generation of detailed 3D models of landscapes, structures, and objects. These models, in turn, can be seamlessly integrated into the domain of Augmented Reality (AR) to offer an immersive and interactive experience. This fusion of UAV-based 3D modeling with AR technology is not only pushing the boundaries of what's possible in various industries but also reshaping the way we interact with the digital and physical worlds. Also, UAVs can soar over regions that are either inaccessible or difficult for humans to reach, capturing a myriad of perspectives and angles. This ability ensures that the resultant 3D models are comprehensive, accurate, and rich in detail. On the other hand, AR technology superimposes digital information onto the real world, through devices such as smartphones, tablets, or AR glasses. When these precise 3D models generated by UAVs are embedded into AR environments, users can virtually explore, analyze, or manipulate these models within a real-world context. The symbiotic relationship between smartphone and UAV-based 3D modeling and AR holds promise for a multitude of applications. Whether it's for urban planning, entertainment, historical site preservation, or education, the merging of these two groundbreaking technologies is paving the way for innovative solutions and captivating experiences. This journey will delve into the intricacies of how smartphone and UAVs create 3D models and how these models find their application in the captivating world of AR. In this study, human 3D model was animated with different motions on building 3D model.

1. Introduction

In recent years, the capacity to generate accurate 3D models has been significantly enhanced by the rapid advancements in both smartphone technology and Unmanned Aerial Vehicles (UAVs). These two platforms, representing both ground-level and aerial viewpoints, have ushered in a new era of spatial representation and data acquisition. UAVs, colloquially known as drones, are equipped with sophisticated sensors and cameras, making them ideal for aerial surveys and capturing expansive terrains from above [1]. These devices can map vast areas swiftly, providing detailed images that, when processed using specialized software, yield intricate 3D models of landscapes, infrastructures, and more [2]. Simultaneously, the omnipresence and ever-advancing capabilities of smartphones present an opportunity at the ground level. Modern smartphones, empowered by advanced camera systems, depth sensors, and potent computational capacities, have morphed into potent devices for 3D data capture [3]. Their ubiquity ensures that a significant portion of the global population has access to a device capable of creating detailed 3D models of objects, interiors, and immediate surroundings. When these two platforms' capabilities are combined, they offer a holistic view of spaces, from expansive aerial views to detailed ground-level nuances, paving the way for a myriad of applications across various domains, including urban planning, environmental monitoring, and heritage conservation [4-7]. This paper delves into the technical intricacies and methodologies associated with 3D modeling using both phones and UAVs, illustrating the transformative potential that their integration brings to modern spatial analysis and representation.

UAVs, equipped with sophisticated sensors and cameras, have the ability to soar over vast terrains, capturing detailed images from vantage points that were previously challenging to achieve [8]. These images, when processed using advanced software, form intricate 3D models of landscapes, structures, and more. Concurrently, the ubiquity and technological prowess of smartphones allow for the detailed modeling of objects and spaces from a ground perspective. Innovations in smartphone camera technology, depth sensing, and computational capabilities have made them potent tools for 3D data capture [9]. Smartphones can be used for modeling objects and land surfaces in a cost-effective and rapid manner compared to measurement devices. In addition to workflows similar to UAV or terrestrial photogrammetry techniques, smartphones equipped with LiDAR systems can also directly generate 3D models [10, 11]. While it is evident that phones and UAVs are used for the purpose of generating 3D models in various industrial fields, it is also noticeable that there are not many sectors where these data are brought together [12].

No longer tethered to resource-intensive, standalone software suites, today's designers, engineers, educators, and hobbyists are turning to cloud-based platforms to craft, collaborate on, and share their 3D productions. These online applications, combining the scalability of cloud computing with the versatility of modern web technologies, have broken down barriers previously set by hefty licensing costs and specialized hardware requirements [13]. Their user-centric interfaces, complemented by an array of tools ranging from basic to advanced, cater to both newcomers and seasoned professionals [14, 15]. The real-time collaborative potential of these platforms introduces a paradigm shift, enabling teams to co-create and iterate on projects seamlessly, irrespective of geographic boundaries [16].

When these UAV and smartphone-derived 3D models are integrated into the domain of Augmented Reality (AR), a new dimension of immersive experience emerges. AR, a technology that superimposes digital content onto the real world, finds a compelling use case in the integration of these models. Users can virtually engage with, analyze, or even modify these models in a real-world context, leading to applications ranging from urban development and architectural visualization to interactive gaming and education [17].

The study aims to present the integration of 3D models produced with two different devices, each having distinct details. It has been demonstrated that UAV-based 3D models can be used in an Augmented Reality (AR) environment, integrated with simpler 3D models, and serve as a foundation for AR animations. The amalgamation of UAV and smartphone-based 3D modeling with AR technology is redefining boundaries across industries. This paper will explore the techniques of 3D data capture from both platforms, their convergence, and the transformative potential they hold in the AR ecosystem. The study involved the integration of models produced within the scope of the work in an Augmented Reality (AR) environment. Motion was applied to a 3D human model on the UAV-generated 3D library model, leading to the execution of an AR animation.

2. Study Objects and Method

The study integrated terrestrial and aerial photographs obtained using two different devices into an online platform for the production of 3D data. In order to create a human 3D model, photographs of the individual were taken with a smartphone. For the purpose of building modeling, an unmanned aerial vehicle was used. The smartphone and unmanned aerial vehicle (UAV), which were the iPhone 13 smartphone and DJI Phantom 3 Pro UAV, were equipped with a 12MP camera and integrated positioning systems, and consecutive photos of objects were obtained with these devices. To produce a human 3D model, photographs were taken by circling around the person with the phone, obtaining terrestrial images. For the purpose of creating a building 3D model, aerial photographs were acquired by conducting a photogrammetric UAV flight at a height of 100 meters. Flights were conducted using a DJI Phantom 3 Pro model unmanned aerial vehicle (UAV) equipped with an integrated camera with a 12MP resolution and approximately 23 minutes of flight time, aiming to produce a library 3D model. Despite weighing approximately 1.5 kg, the UAV enables the preparation and execution of photogrammetric flight plans through integrated GPS positioning systems. The overlap ratios of the aerial photographs to be obtained during photogrammetric flights with the UAV were determined in flight planning software. UAV flight plans were prepared and executed based on flight altitude, camera focal length, overlap ratios, and flight durations depending on the spatial sampling interval of the data. In the study, 100 terrestrial photos obtained with the smartphone and 99 aerial photos acquired with the UAV were used. The terrestrial photo of human model and aerial photo of building are shown in Figure 1.

To produce a 3D model, a computer with a powerful processor and graphics card, as well as software, is required. However, today, many online platforms can generate 3D models using photographs obtained from UAVs and smartphones. In photogrammetry studies, the production of high-resolution 3D models can be achieved using overlapping aerial and terrestrial photographs. In both types of photographs, the positions and orientations of overlapping images are utilized to match the photos. Once their orientations and positions are determined, the objects' surfaces in the photos are matched with key points. The matched points on the objects are then used to create sparse point clouds and dense point clouds sequentially, and by combining these points, a mesh model is generated [18, 19]. Online platforms facilitate quick and easy data production. Thus, by providing conveniences that will benefit every user, they enable the production of 3D models for all kinds of objects. Users can obtain applications and, based on their existing devices, enable various projects or visualizations for hobby purposes. For the purpose of producing a 3D model, the online platform, which is "3D ProBox" was utilized [20]. The online platform facilitates the production of 3D data using consecutively taken aerial and terrestrial photographs. For the study, separate projects were created on the platform for both models. Aerial and terrestrial photographs were uploaded to these projects, and in a short time, human and building model production was accomplished without the required for a computer or software. The projects of human 3D model and building 3D model on online platform are shown in Figure 2. On the online platform, one can navigate through the 3D model, and it can be presented in various projects for promotional purposes. Additionally, these platforms allow the produced data to be downloaded in 3D model formats and shared for various purposes.

Figure 1. Terrestrial photo of human model and aerial photo of building.

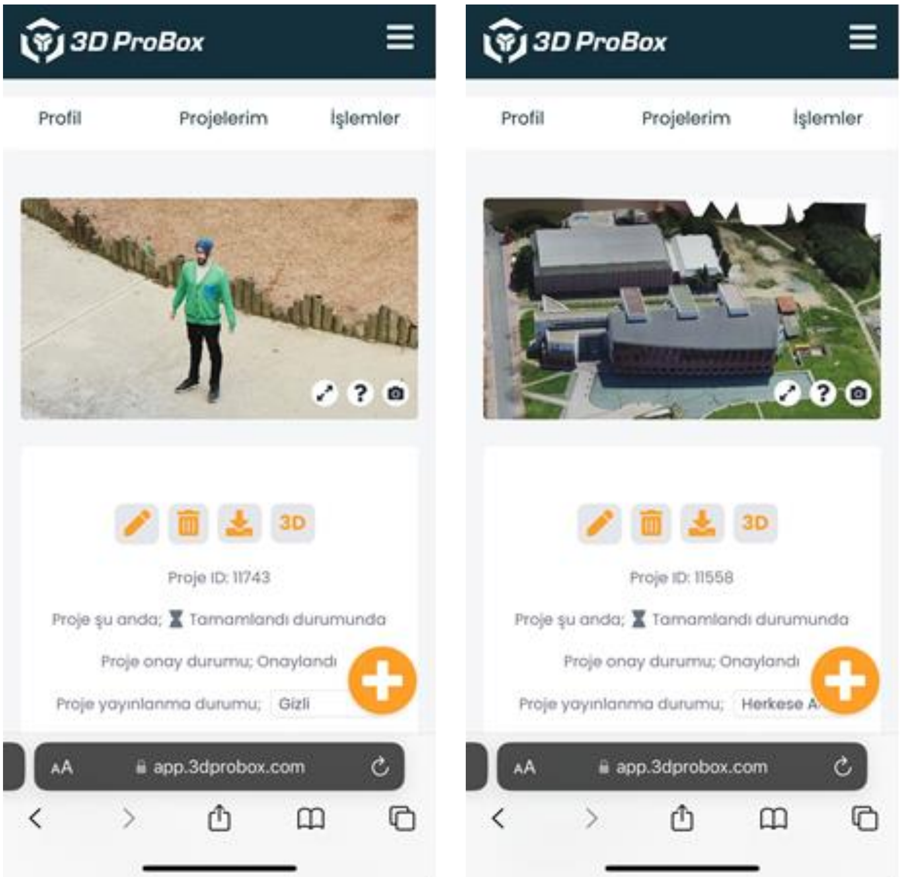

Figure 2. Human 3D model and building 3D model on online platform.

Online platform allows for the export of produced 3D models for use in different applications. Animating objects with mobility is typically done by experts using computer-based software. However, some online platforms can provide certain movements to human 3D models. As in this study, these models can either be produced from different devices or be modelled by an expert. Online platforms and software are used to animate human 3D models for applications such as films, animations, advertisements, etc. The human and building 3D models have been exported for use in virtual reality and for the purpose of producing animations in this study. The Mixamo platform allows for the application of various human movements to 3D human models produced online and facilitates their integration into augmented reality applications [21]. After human motions were applied to the 3D human model in the Mixamo platform, the animated 3D models were imported to the Adobe Aero platform (Figure 3). The Adobe Aero platform, which is online AR animation platform, allows for both animated and static 3D models to be presented separately or together in AR [22] (Figure 4).

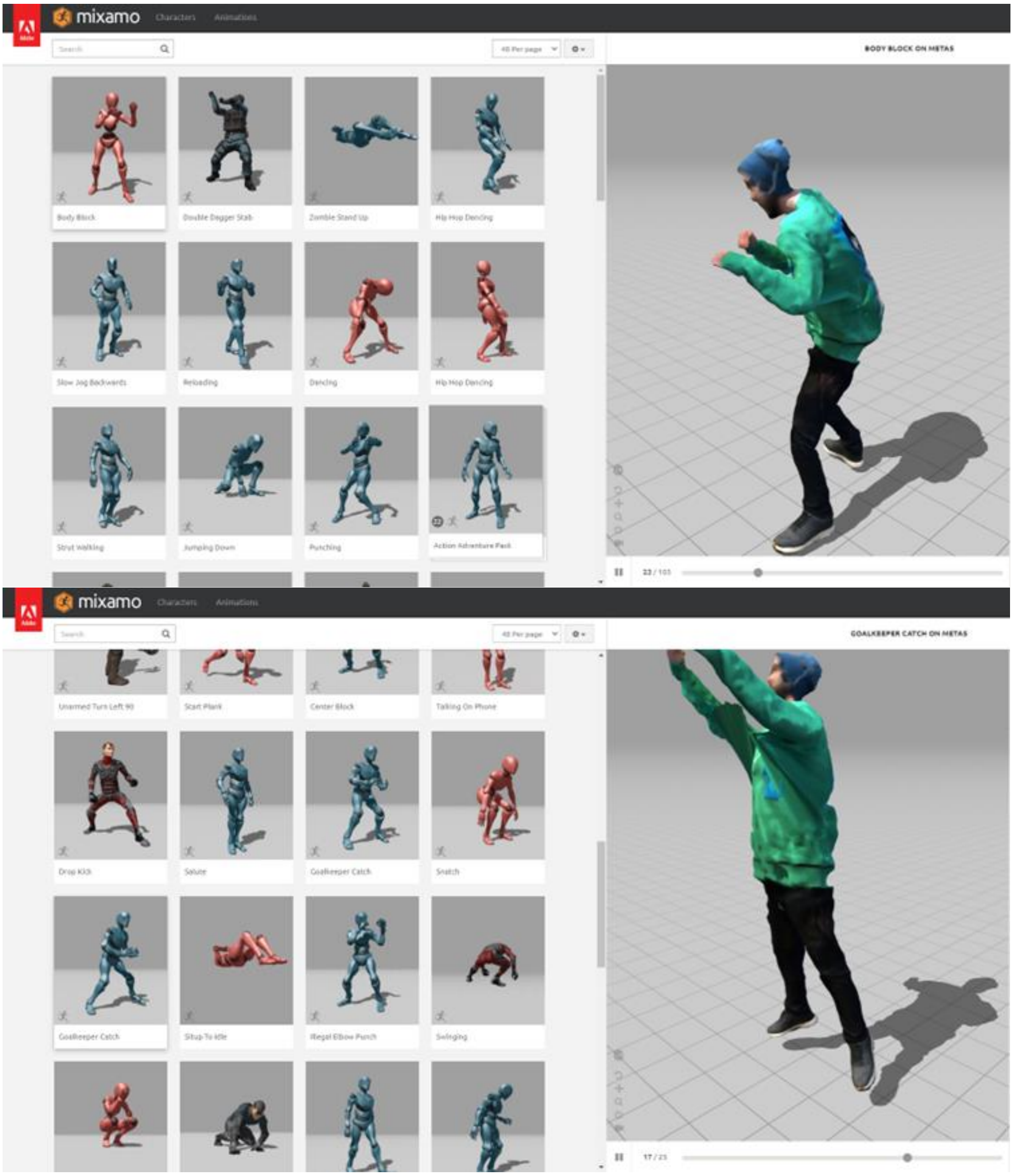

Figure 3. Human 3D model animation on the Mixamo platform.

Typically, many AR platforms only allow the presentation of a single model. Presenting 3D models of different objects together is not achievable on many platforms. A separate project presentation must be created for each model. Especially, AR platforms can both pose a data size problem and fail to bring different models together.

However, the platform used in this study can combine both different models and models with different features produced on different devices. Furthermore, these platforms do not permit the 3D model to be displayed as an animation. The AR platform used in the study allows for the presentation of 3D models from distinct objects in AR and permits animated human 3D models to navigate around a fixed 3D model. Therefore, it can be observed that 3D models produced by smartphone or UAV can be utilized in various applications. Figure 5 shows the animation of human 3D model animation and building 3D model in the AR. In the study, walking, talking on the smartphone, and dancing movements have been integrated into the human model. Upon examining the human 3D model in motion and within the AR platform, it was observed that the movements were executed seamlessly. However, since the person who took the photos during the human modeling process was not a professional, there were observed issues with the movements in the produced model.

Figure 4. Human 3D model with motions and building 3D model on Adobe Aero platform for AR animation.

Figure 5. Human 3D model with different motions and building 3D model on Adobe Aero platform for AR animation.

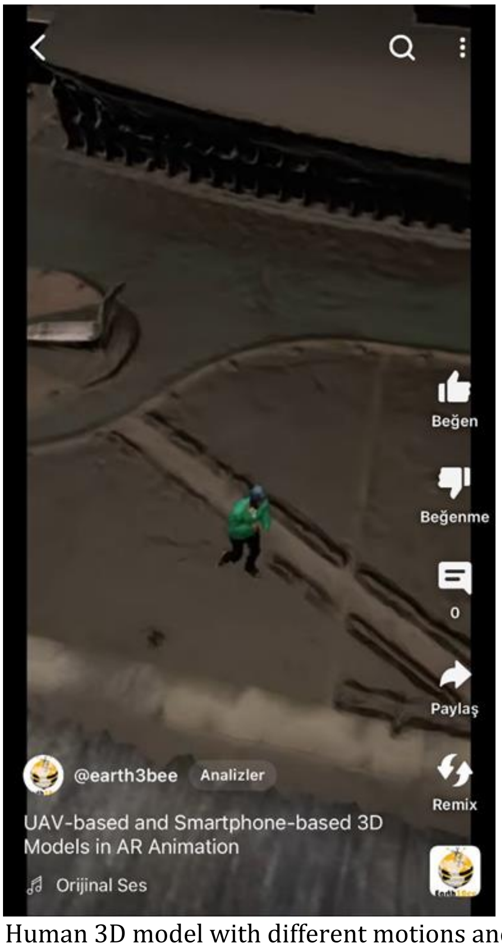

Figure 6. Human 3D model with different motions and building 3D model on Adobe Aero platform for AR animation.

The 3D models integrated into the AR environment are recorded as videos and used in various projects for advertising and promotional purposes. In the study, the produced human and building 3D models were opened on the AR platform and presented to users. Since the human 3D model has various movements, users can see the animated human model over the building model in real-time, and also, its presentation is facilitated through video recording on the platform. In Figure 6, it can be seen that the 3D models displayed in AR are presented online as videos. By scanning the QR code in Figure 6, access to the AR animation can be obtained.

3. Results

With the advancement of technology today, UAVs are preferred for modeling and mapping studies. The cameras and LiDAR systems of smartphones are also used in modeling studies. The progression of technology now allows every user to produce high-quality data of different objects. Instead of traditional photogrammetry methods, it is observed that smartphones and UAVs are used to obtain data with the desired accuracy. In the scope of the study, overlapping images were obtained with UAV and smartphone, and the presentation of these data in the AR environment was realized with different online platforms. Photos obtained with a smartphone and UAV can be produced directly with online platforms instead of computer-assisted software. With the quick uploading of obtained photos to the online platform, platforms produce data quickly and easily. In the study, 3D models are produced by integrating objects photographed with different tools into the same platform. Therefore, data procurement and data production processes are now easily accessible to every user. It is observed that a better-quality data production will be ensured if the photographing of the human model is carried out better or if the person taking the photograph is professional. It is observed that the quality of the 3D model produced with photos obtained by UAV with the photogrammetric method may be related to camera resolution and overlap rate. Thus, it is observed that models to be produced from photographs obtained with the photogrammetric method are of better quality. In the study, it was observed that the use of 3D models of different objects in the AR environment could become more widespread by combining human and building 3d models. In the study, it was observed that the human model was given 3 different movements and the human 3D models made the desired movements seamlessly over the building 3D model. The study initially presents a foundational UAV-based 3D model. Subsequently, a 3D human model generated using a different device is added to the presented model. The research demonstrates the ability to merge large objects produced through UAVs with smaller, dynamically created objects produced using smartphones, all while being scalable. Additionally, human 3D models have been enriched with movements that reflect human characteristics, facilitating their presentation in Augmented Reality (AR) environments. Since human movements can vary, the study also illustrates the integration of different human motions into the same 3D model. This presentation showcases how 3D models representing living beings can be realistically presented in a virtual environment. The study has also shown that the data obtained especially with UAV can be a basis for many different studies. It was observed that movements could be given to different objects by moving the 3D human model. With the study, human movements were animated around a real building. Also, models created online using UAVs and smartphones can be rapidly put into use. These models find applications in various industries such as advertising, promotion, cinema, gaming, and animation.

4. Discussion and Conclusion

It is seen that all kinds of tools used in 3D model production can be used together and different sectors can benefit from these studies. Especially, it is observed that animation or video studies produced with computer-aided studies are also provided at the smartphone level. It is observed that the integration of modeling studies into AR platforms has improved and animations can be presented to users. Furthermore, this study demonstrates the possibility of generating 3D models using images obtained from various data sources and the potential for integrating these 3D models. Typically, 3D designers often manually create human and terrain models. However, this study reveals the production of both region-specific and human-related 3D models using regular phones and smartphones. It's observed that the process of imparting motion to human 3D models can be applied to 3D models generated with smartphones in an online environment. Moreover, with advancing technology, these tasks can be rapidly performed within smartphone applications and can be readily accessible to everyone in an AR environment

The biggest problem that can be encountered in the AR environment is seen as data size, but the use of different models together shows that all kinds of data can be shown virtually in the future. In addition, with the movement of objects, it can be commented that the popularity of studies such as games and promotions can also increase. It is seen that solutions will be produced for different sectors as well as academic research with UAV-based models. Furthermore, it is thought that in the future, many data produced with different tools will be used more easily when brought together. In the future, it is anticipated that UAV and smartphone-based 3D models will be used in many different studies, and the realistic representations will likely impress users.

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Author contributions

Semih Sami Akay: Conceptualization, Methodology, Software, Data curation, Writing-Original draft preparation.
Orkan Özcan: Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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