ARAŞTIRMA MAKALESİ (Research Article)

AUGMENTED REALITY APPLICATIONS ON QUARRIES AND MINES

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ABSTRACT

Augmented reality (AR) is, relatively, one of the newest techniques in visualization technologies, which began to be developed in the 1990s. AR can be expressed as positioning models in natural life environments by taking them out of the computer. A well-known and common approach is modeling in the computer environment and making applications. There are various software developed for this purpose. In augmented reality, it is possible to create these models in the same space with life, participate in these models, and intervene. The other connected issue is the excellent value of 3D visualization for the earth sciences because seeing provides a better understanding. In this study, augmented reality applications were implemented using photogrammetric models prepared for quarries and open pit and underground mines located in different world regions to enhance the visualization perception and interaction. Spatial and dimensional unity, an advanced level, and quality in visualization were provided for the models of quarries and mines with the mobile application technique. The applications also contribute to and are samples of the digital transformation concept.

Keywords: *Augmented Reality (AR), Mobil Applications of AR, Earth Sciences, Quarry, Open Pit Mine, Underground Mine*

MADEN VE TAŞ OCAKLARININ GÖRÜNTÜLENMESİNDE ARTIRILMIŞ GERÇEKLİK

ÖZ

Artırılmış gerçeklik, 1990'larda geliştirilmeye başlanan, görüntüleme teknolojileri içinde göreceli olarak en genç tekniklerden biridir. Görüntülerin bilgisayardan çıkarak hayatın içinde konumlandırılması olarak ifade etmek mümkündür. Bilgisayar ortamında modelleme ve bunların üzerinden uygulamalar yapmak yaygın bir yaklaşımdır. Bu amaçla geliştirilmiş dünya çapında yazılımlar mevcuttur. Artırılmış gerçeklikte, bu modellerin hayatla eş mekânda oluşturulması, bu modellerin içinde yer almak ve müdahale etmek mümkündür. Bir diğer husus, yer bilimlerinde 3B görüntülemenin mühendislik değeri yüksektir. Zira görmek daha iyi anlamaya katkı sağlamaktadır. Bu çalışmada, daha geliştirilmiş bir görüntüleme seviyesi elde etmek için, dünyanın değişik bölgelerindeki gerçek taş ocağı, açık ve yeraltı maden ocakları için geliştirilen fotogrametrik modeller kullanılarak artırılmış gerçeklik uygulamaları yapılmıştır. Mobil uygulama tekniği ile taş ocağı ve maden ocaklarının görüntülerinde mekânsal ve boyutsal birliktelik, daha üst düzey ve kalitede bir

görüntüleme imkânı sağlanmıştır. Uygulamalar, dijital dönüşüm kavramına katkıda bulunmakta ve örnek teşkil etmektedir.

Anahtar kelimeler: *Artırılmış Gerçeklik (AG), AG ile Mobil Uygulamalar, Yer Bilimleri, Taşocağı, Açık Ocak Madenleri, Yeraltı Madenleri*

1. INTRODUCTION

1.1 Augmented Reality (AR)
While augmented reality (AR) technology has improved in the last ten years, its potential for cognitive education and power for better understanding the third dimension has been studied and examined in detail [1-5]. Today's developments show that AR will cover all areas of life with similarities that we can see in fictional science movies. The disciplines such as economy, commerce, education, military, social communication, tourism, various industrial fields, etc., are in the scope of AR [6-7]. Yılmaz and Göktaş [8] give a detailed review of AR applications in education which is also related to all others.

Various elements such as two-dimensional (2D) and three-dimensional (3D) visualization, sounds, texts, video, animation, navigation, web access, communication, holographic environments can be embedded and utilized in AR technology [9-10]. With its cross-platform feature, the software developed in this area can switch to computer, internet, virtual reality, augmented reality, and mobile application environments [11-12].

1.2 AR Usage Areas
The enhanced technological features of AR show that it has and will have a sustainable and scalable character. Due to these properties, it is understood that it has the potential to be used in almost every field of daily life and will have an increasing economic volume. [13].

In earth sciences and mining, the visualization of resources that are unseen assets is of great importance. Modeling both underground models and production processes is an application area for augmented reality technology [14-15].

1.3. Photogrammetry
Photogrammetry is another approach that has recently increased use in 3D modeling technology. Its simple definition is to process successive photographs and obtain photorealistic models of objects, land, and whatever the asset is [16]. It has a wide application field, including topographic mapping [17], mining [18], and geology [32]. Data cloud is obtained by successive photographs taken in a brief period and from different angles. Drones equipped with high-quality optical objectives are utilized for photo-scanning the area which is the subject of the process. Satellites, heights, angles, distances, correlation stations are critical components of the process, which is highly complicated [19-23].

1.4. Computer Software for Augmented Reality
The augmented reality process requires a couple of software use. The initial work is to prepare the 3D model of the object. This stage is carried out by photogrammetry or 3D modeling software. The next step is realized by implementing some engines like Unity 3D [24] or Unreal Engine [33]. Unity 3D, one of the two most popular augmented reality software, is relatively practical and suitable for most

computers, while Unreal Engine requires more robust configurations. Besides, some software such as Vuforia has special utilities for augmented reality applications and cooperates with Unity 3D and Unreal Engine. AutoCAD, 3D Studio Max, Maya, Blender, Z-Brush, Photoshop, Illustrator, etc., are the software, especially for material, animation, and object preparation.

1.4.1 Software for the photogrammetric modeling
According to the object's size or land, scanning instruments from smartphones to drones can be used. A group of photographs, in other terms, data cloud, needs special software for complex computations and long processing times to produce a 3D model that can be visualized in a computer environment. Pix4D, AgiSoft, MicMac, Meshroom, 3DF Zephyr, Carlson, Photo Capture, etc., are some software to obtain photogrammetric models.

1.4.2 Software for augmented reality
Major software for augmented reality are Unity 3D and Unreal Engine, also known as game engines. These engines are the most popular and used AR and virtual reality (VR) platforms. The primary advantage and feature is the ability to switch applications to different platforms, which makes them cross-platform software. This means that any application can be adapted to PC, Web, mobile, VR, AR, or game station platforms (Fig.1). VR and AR applications need related equipment such as VR and AR glasses, and mobile applications are implemented on mobile phones or tablet computers.
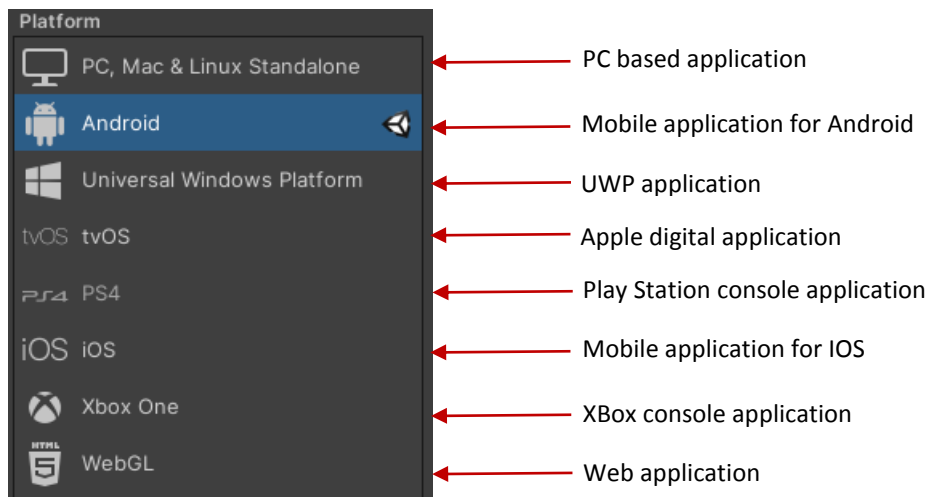

Figure 1. Cross-platforms included in Unity 3D.

Although Unity and Unreal Engine have their AR packages, specialized software such as Vuforia can also be considered to obtain an AR visualization.

This study has developed AR applications before earth sciences and mines. The photogrammetric models of quarries and open and underground mines from different countries are used for augmented

reality applications. The mobile phone is the instrument used to have photo-realistic models and visualize them in the same natural environment.

2. AUGMENTED REALITY APPLICATION ON QUARRIES AND MINES

In this study, photogrammetric 3D models of 2 quarries, one open-pit mine and one underground mine from different geographies of the world, have been utilized for augmented reality applications. The models are obtained from Sketchfab assets, which are the output of drone scans. Some of the file types of the models are OBJ, FBX, DAE, GLB. Unity 3D [24] has been utilized to obtain augmented reality applications. AR Core, AR Foundation, or software such as Vuforia could be employed at this stage. Here, Vuforia is being used for AR applications for simplicity and practicality.

2.1. Photogrammetric models

Photogrammetry has a rising usage trend for 3D modeling. The method provides photo-realistic models using drone camera scanning/searching specific patterns (Fig.2).
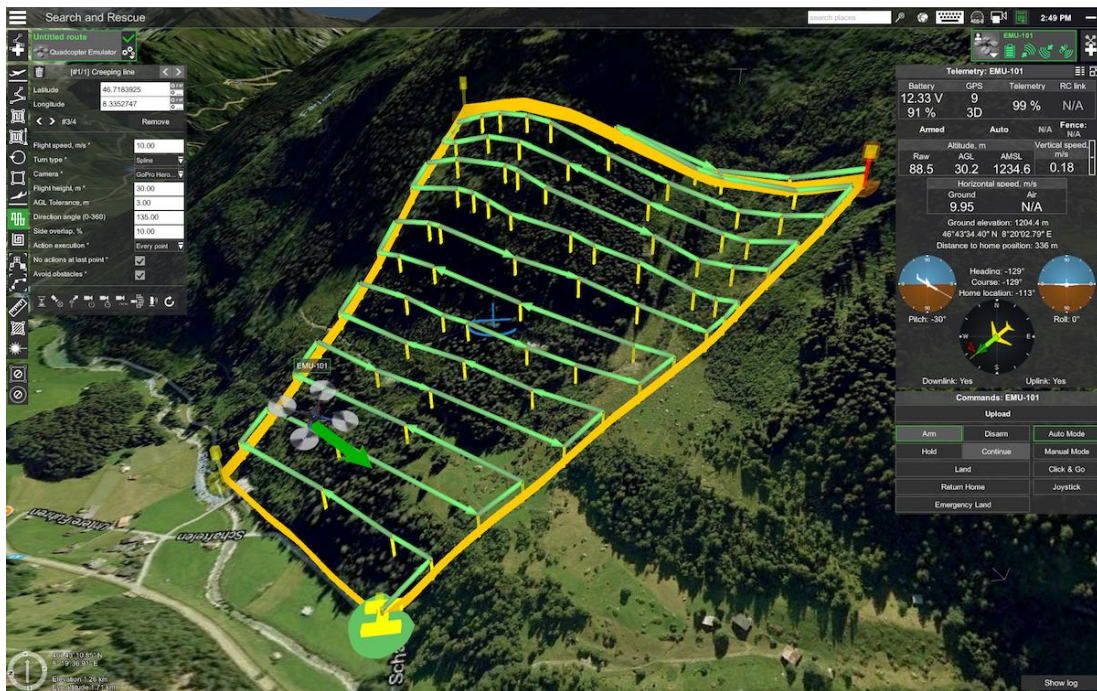

Figure 2. Drone search pattern [25].

Consecutive photographs are processed in software such as Pix4D, AgiSoft, MicMac, Meshroom, 3DF Zephyr, Carlson, Photo Capture, etc., to have data cloud and 3D model.

2.2. Vuforia

One of the most advanced and widely used augmented reality software is Vuforia of PTC [26]. The software is compatible with Unity 3D and cooperates with it. 3D models are transported from the

computer screen to an image that acts like a QR-code. Besides a natural environment independent of any image marker, the model can also be visualized on the ground plane.

3. AR APPLICATIONS FOR QUARRIES AND MINES

In the study, one open-pit mine, one underground mine, and two quarries are utilized for AR applications. The AR instantiations are taken in the university department hall. Photogrammetric models are obtained from Sketchfab [27], and augmented reality is realized by Unity 3D and Vuforia. The underground mine is Grube Theresia, Morshausen, Germany, the open-pit mine is Rawang Mine, Malaysia, and the quarries are Lyttleton, New Zealand, and PPC's KGale, Botswana.

3.1. Grube Theresia, Morshausen, Germany

The photogrammetric model, including underground gallery design, has been utilized with Unity 3D and Vuforia combinations [28]. The topography takes place in the model, and additionally, the underground mine design is added (Fig. 3-4).

Figure 3. AR application in the department hall for Grube Theresia Mine terrain [28].

3.2. Rawang Quarry Mine, Malaysia

The photogrammetric model is provided by Aerial-Craft [29]. Mobile AR application enables observing the mine outside the computer (Fig. 5-6).

3.3. Lyttleton Quarry, New Zeland

The third application is carried out for Lyttelton Quarry, New Zealand [30]. The quarry AR application provided a better visualization on the ground (Fig. 7-8).

3.4. PPC KGale, Botswana

An active quarry in Botswana is provided by Premier Mapping again [31]. The AR model is obtained similarly; Unity 3D and Vuforia (Fig. 9-10).
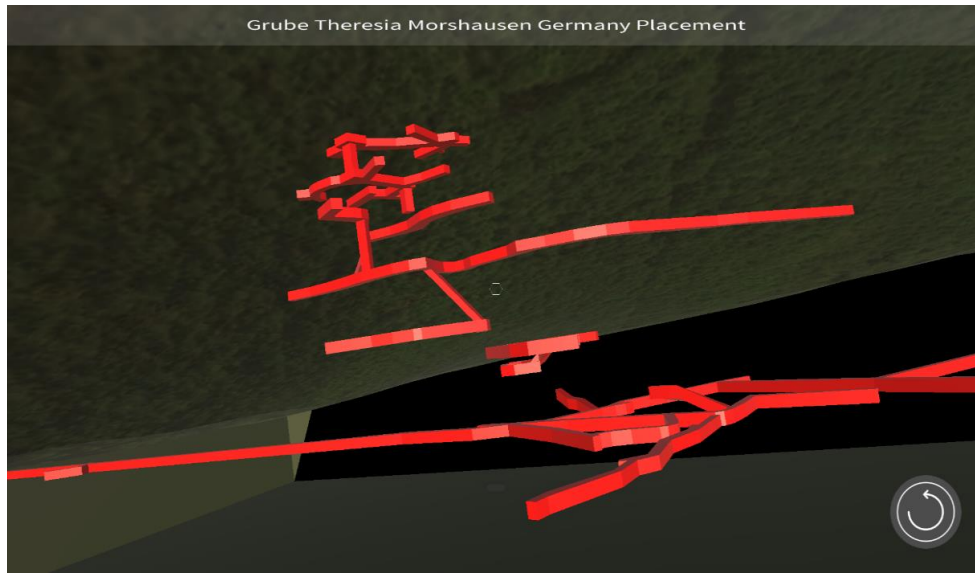

Figure 4. AR app for Grube Theresia underground mine galleries, Morshausen, Germany [28].
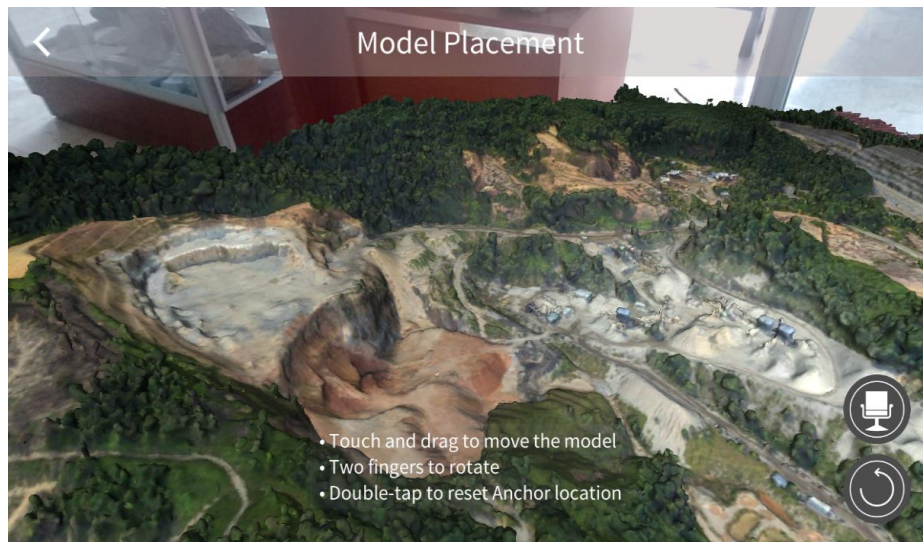

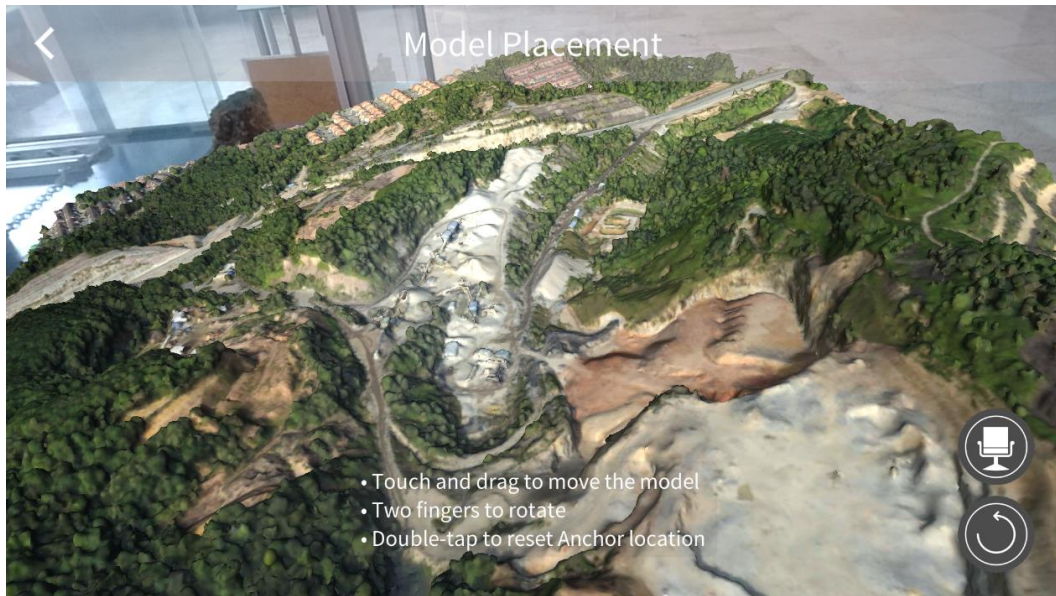**Figure 5.** AR app in the department hall for Rawang open pit, Malaysia [29].

Figure 6. AR app for Rawang open pit quarry, Malaysia [29].
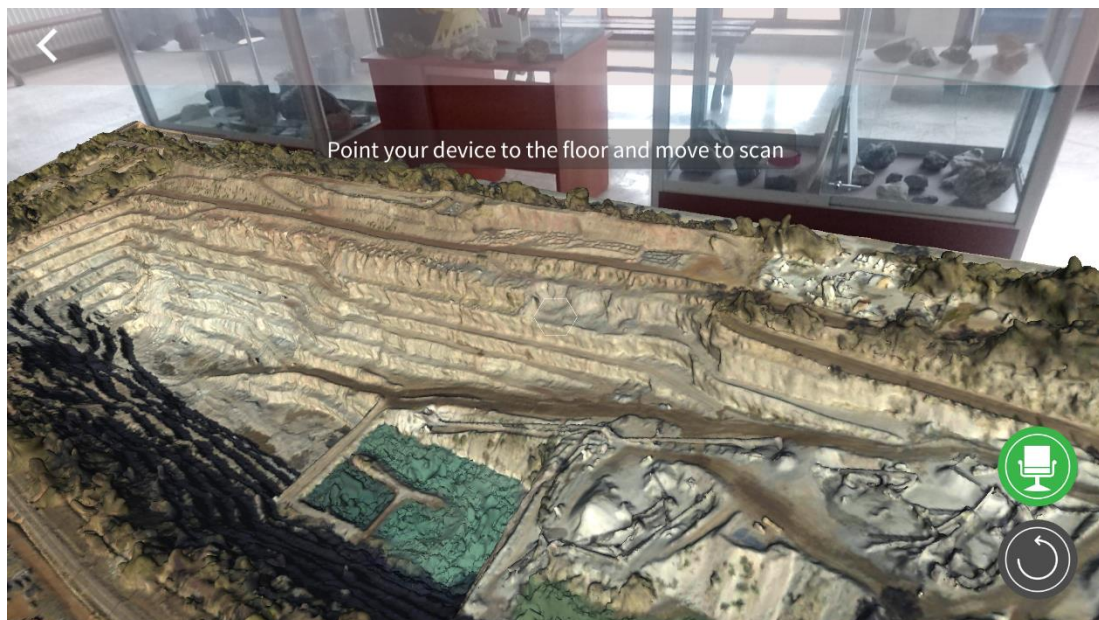
Figure 7. AR app in the department hall for Lyttleton Quarry, New Zealand [30].
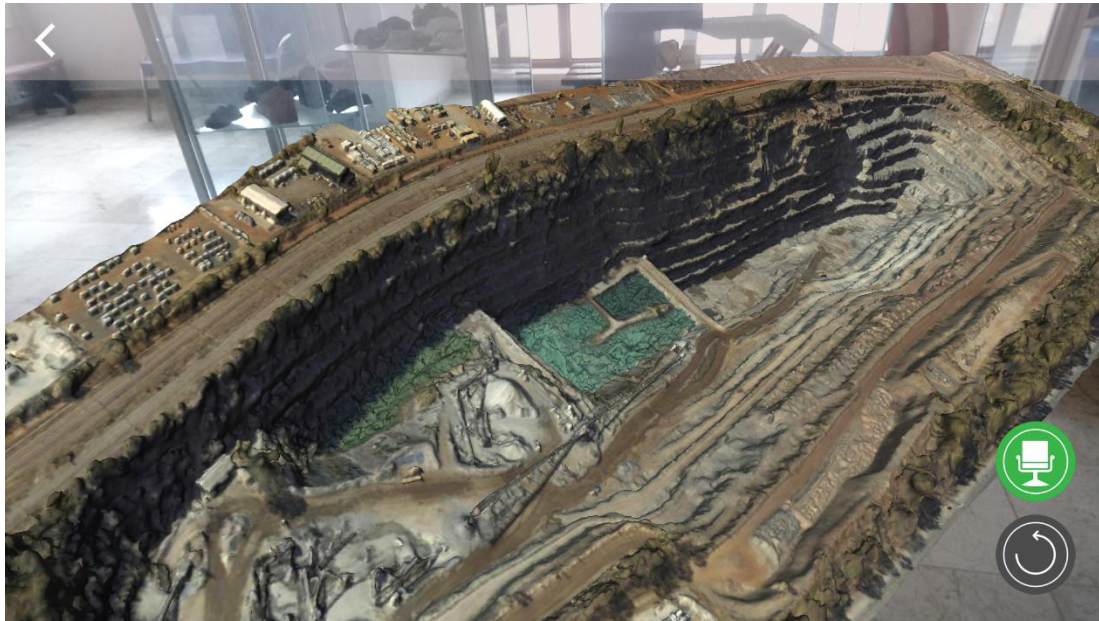
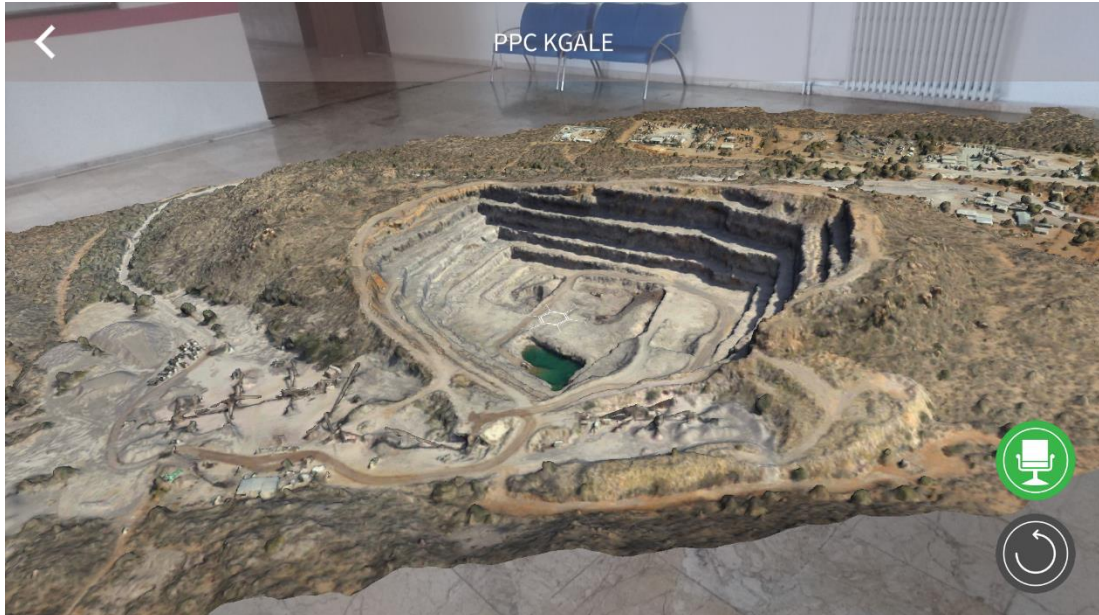**Figure 8.** AR app for Lyttleton Quarry in New Zealand [30].

Figure 9. AR app in the department hall for PPC's KGale Quarry, Botswana, Africa [31].

Figure 10. ARR app for PPC's KGale Quarry in Botswana, Africa [31].

All applications have the utility to control the models by fingers. Rotation, scaling, and dragging actions are performed on mobile instruments. They can appear on any ground with their photo-realistic existence and are manipulated to observe from different directions and with different sizes.

4. DISCUSSION

Augmented reality is a qualified tool for observing computer-aided digital designs in the environment we live in. The fact that visual models go out of the computer screen, and that 3D objects can be examined in our environment, distinguishes it from other methods. There may be difficulties in understanding and comprehending some mine sites partially or as a whole, due to their size and complex structure, in 3D. It is seen that AR application for academic studies, modelling and project development processes will serve both in education and technical evaluations in the course of better understanding and cognitive education. In this study, photogrammetric models of four mines and quarries were used with AR applications. The results obtained in the faculty environment have shown that it is possible to take part in the application areas, to wander around, and to examine them from different dimensions and angles with AR models. The study reveals that AR applications can contribute and underpin better understanding complex structures and serve cognitive training.

5. CONCLUSION

In this study, augmented reality, a relatively younger visualization technology, has been utilized to obtain more realistic 3D visuals for the quarries and the mines from Germany, New Zealand, Malaysia, and Botswana. The photogrammetric models of real mines and quarries have been used in the applications by implementing Unity 3D and Vuforia software. The mobile phone has been employed as an instrument to produce 3D AR outputs. Besides visualization, interaction with the

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models to rotate, drag, and scale is also possible. All the visual results have been obtained in the university environment.

The study provides an application sample enhancing the level of visualization for earth sciences and the mining industry. It contributes to the digital transformation in the visualization aspect. The results reveal that AR with photogrammetry provide a better and more qualified visual output which is important for earth sciences and mining as 3D thinking and observation are crucial.

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REFERENCES

[1] Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., & Peire, J. (2011). New technology trends in education: Seven years of forecasts and convergence. Computers and Education, 57(3), 1893-1906

[2] Kesim, M. & Özarslan, Y. (2012). Augmented reality in education: current technologies and the potential for education. Procedia - Social and Behavioral Sciences, 47, 297-302.

[3] Zhou, Z., Cheok, A.D., Pan, J., & Li, Y. (2004). Magic story cube: An interactive tangible interface for storytelling. Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology, 364-365. DOI: 10.1145/1067343.1067404.

[4] Cheng, K.H. and Tsai, C.C. (2012). Affordances of augmented reality in science learning: Suggestions for future research. Journal of Science Education and Technology, 22, 449-462. DOI: 10.1007/s10956-012-9405-9

[5] Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., and Peire, J. (2011). New technology trends in education: Seven years of forecasts and convergence. Computers and Education, 57 (3), 1893-1906

[6] Rice, R. (2009). The augmented reality hype cycle. http://www.sprxmobile.com/the-augmented-reality-hype-cycle /2014.

[7] Wang, X., Kim, M.J., Love, P.E.D., and Kang, S.C. (2013). Augmented Reality in built environment: Classification and implications for future research. Automation in Construction, 32, 1–13.

[8] Yılmaz, M.R., Göktaş, Y. (2018). Using Augmented Reality Technology in Education. Journal of Çukurova University Education Faculty, 47(2), 510-537.

[9] Azuma, R.T., (1997). A survey of augmented reality. Presence: Teleoperators and Virtual Environments, 6(4), 355-385.

[10] Wang, D., He, L., & Dou, K. (2013). StoryCube: supporting children's storytelling with a tangible tool. The Journal of Supercomputing. DOI: 10.1007/s11227-012-0855.

[11] Wojciechowski, R., Walczak, K., White, M., & Cellary, W. (2004). Building virtual and augmented reality museum exhibitions. Proceedings of 9th international conference on 3D web technology (Web3D 2004), 135-144.

[12] Kirner, T.G., Reis, F.M.V., & Kirner, C. (2012). Development of an interactive book with Augmented Reality for teaching and learning geometric shapes. Information Systems and Technologies (CISTI), 1-6.

[13] Pine, J. 2018. 10 Real Use Cases for Augmented Reality AR is set to have a big impact on major industries. https://www.inc.com/james-paine/10-real-use-cases-for-augmented-reality.html

[14] Stothard, P.M., Squelch, A.P., Van Wyk, E.A., Schofield, D., Fowle, K., Caris, C., Kizil, M., & Schmid, M. (2008). Taxonomy of Interactive Computer-based Visualisation Systems and Content for theMining Industry - Part 1. Proceedings of the AUSIMM Future Mining Conference 2008, Sydney.

[15] Van Krevelen, D.W.F. & Poelman, R. (2010). A Survey of Augmented Reality Technologies, Applications and Limitations. The International Journal of Virtual Reality, 9(2):1-20.

[16] American Society for Photogrammetry and Remote Sensing (2019). What is ASPRS?. Available online at: https://www.asprs.org/organization/what-is-asprs.html (accessed November 27, 2019)

[17] Fonstad, M. A., Dietrich, J. T., Courville, B. C., Jensen, J. L., and Carbonneau, P. E. (2013). Topographic structure from motion: a new development in photogrammetric measurement. Earth Surf. Process. Landforms 38, 421–430. DOI: 10.1002/esp.3366

[18] Abbaszadeh, S., and Rastiveis, H. (2017). "A comparison of close-range photogrammetry using a non-professional camerawith field surveying for volume estimation," in ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-4/W4, (Heipke: International Society for Photogrammetry and Remote Sensing), 1–4. DOI: 10.5194/isprs-archives-XLII-4-W4-1-2017

[19] Vangorp, P., Laurijssen, J., and Dutré, P. (2007). The influence of shape on the perception of material reflectance. ACM Trans. Graphics 26:77. DOI: 10.1145/1239451.1239528

[20] Ahn, J., Ahn, E., Min, S., Choi, H., Kim, H., and Kim, G. J. (2019). "Size perception of augmented objects by different AR displays," in HCI International 2019—Posters, Vol. 1033, ed. C. Stephanidis (London: Intech Open), 337–344. DOI: 10.1007/978-3-030-23528-4_46

[21] Smallman, H. S., and St John, M. (2005). Naive realism: misplaced faith in realistic displays. Ergon. Design Q. Hum. Fact. Appl. 13, 6–13. DOI: 10.1177/106480460501300303

[22] Kunz, B. R., Wouters, L., Smith, D., Thompson, W. B., and Creem-Regehr, S. H. (2009). Revisiting the effect of quality of graphics on distance judgments in virtual environments: a comparison of verbal reports and blind walking. Atten. Percept. Psychophys. 71, 1284–1293. DOI: 10.3758/APP.71.6.1284

[23] El Jamiy, F., and Marsh, R. (2019). Survey on depth perception in head mounted displays: distance estimation in virtual reality, augmented reality, and mixed reality. IET Image Process. 13, 707–712. DOI: 10.1049/iet-ipr.2018.5920

[24] Unity 3D (2022). Unity Technologies Inc. https://unity.com

[25] SPH Engineering, Riga, Latvia (2022). Retrieved from https://www.ugcs.com/news-entry/announcing-release-of-ugcs-update-with-added-search-patterns-for-sar-operations

[26] PTC Inc. https://www.ptc.com/en/products/vuforia

[27] Sketchfab Inc. https://sketchfab.com

[28] Outcropwizard, Bonn, Germany (2022). Grube Theresia, Morshausen, Germany. Retrieved from https://sketchfab.com/3d-models/ppc-kgale-2016-09-08-677a883d45ea48fbb974a0470f98a2ed

[29] Aerial-Craft (2022). Rawang Mine Quarry, Malaysia. Retrieved from https://sketchfab.com/3d-models/rawang-quarry-2a-11jan17-malaysia-f3eae47abe694f36a9a98578315acc1e

[30] Premier Mapping, Cullinan, South Africa. Lyttleton Quarry, New Zealand. Retrieved from https://sketchfab.com/3d-models/2016-09-01-lyttelton-05612c2bc3844d249b905a21f05aa594

[31] Premier Mapping, Cullinan, South Africa. PPC KGale Quarry, Botswana, Retrieved from https://sketchfab.com/3d-models/ppc-kgale-2016-09-08-677a883d45ea48fbb974a0470f98a2ed

[32] Gül, Y (2019). Açık Maden İşletmelerinde İnsansız Hava Aracı (İHA) Uygulamaları. Jeoloji Bülteni. Cilt 62, Sayı 1, 99 - 112, 01.01.2019. https://doi.org/10.25288/tjb.519506.

[33] Unreal Engine (2022). Epic Games Inc. https://www.unrealengine.com/en-US/