



Augmented Reality Technology to Display Infrastructure Data in the Field Work

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Abstract

Urbanization, which took place in parallel with technological development, has increased rapidly throughout the world. In order to increase the welfare level of the societies living in cities, infrastructure studies have been given importance in the design of cities. It ensures that infrastructure services such as electricity, drinking water, sewerage, natural gas, telecommunications and Internet services are provided for the benefit of people. In order to provide infrastructure services in a sound manner, it is important to keep track of the infrastructure inventory and carry out regular maintenance and repairs, in addition to urban planning. In terms of providing infrastructure services, ensuring that existing infrastructure data is displayed during field studies will increase the efficiency of work. In our study, the visualization of the water and wastewater infrastructure was done in an augmented reality environment. The pilot study conducted in Şanlıurfa, Karaköprü District, Maşuk Region, aimed to increase the efficiency of infrastructure services.

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1. Introduction

People have contributed to the advancement of technology by passing on the knowledge they have learned and applied to future generations, from the past to the present. With the increase in the development of technology, we are witnessing that our lives are changing at a very fast pace. People can easily access and analyze the data they want in the age of technology. Today, in parallel with the proliferation of mobile phones, wearable technologies, and Internet of Things technologies, an incredible cloud of data has been created. It has become important to be able to use data at the right time and in the right place when we do not have a data problem. Augmented reality technology aims to make our lives easier by presenting the data you need in real time and in the physical world (Azuma et al., 2011). We constantly interact with the world and objects in our social lives. Our interaction with the real world and objects in our lives is enhanced by Augmented Reality technology. AR is a technology that makes it possible for computer-generated sounds and images to be used in the real world (Arth et al., 2015).

This technology gives us an advantage. It shows us images that we cannot see in the physical world under normal conditions. In many fields such as marketing, construction, architecture, museums, medicine, and education, augmented reality technology has been applied. Marketing techniques have been developed by the increase of customer interaction with augmented reality applications in the field of marketing. In the construction industry, the use of augmented reality technology for construction inspection will be a cost and time saving measure (Behzadan and Kamat, 2009). In education, the use of augmented reality has paved the way for a more permanent and fluid educational application (Azuma, 1997).

There have been developments in mobile augmented reality applications as a result of developments in mobile communications technology (Kengne, 2014). The benefits of mobile augmented reality technologies have been enhanced by the development of the network infrastructure in mobile communication devices, the improvement of location sensitivity, and the improvement of the image quality of mobile cameras (Ortman and Swedlund, 2012). It is well known that when augmented reality technology first emerged, mobile communication technology was not as widespread as it is today.

The creation of sustainable and livable cities has become increasingly important as urbanization increases. The quality of life of future generations should be considered when designing cities (Ekin and Çabuk A., 2011). It is important to remember that people's quality of life is directly affected by the design of infrastructure and superstructure projects. Technical infrastructure services, such as drinking water, natural gas, Internet, telecommunications and electricity, are provided to meet people's essential needs (Bayraktar, 2019).

It is well known that these infrastructure services are indispensable to human life. Efforts are being made by relevant institutions and organizations to provide infrastructure services without interruption. It is important to prevent accidents that may occur during excavation work by conducting excavation work in a controlled manner. In our country, infrastructure coordination centers have been established with the "Regulation on Metropolitan Municipalities Coordination Centers" published in the Resmi Gazete on 15.06.2006, in order to discipline and coordinate infrastructure works.

The aim of the Infrastructure Coordination Center is to prevent material and moral damages that may occur during excavation works by issuing licenses for excavation works. Aykome units provide coordination between all companies and related organizations operating in the city. The most important point in providing infrastructure services is to ensure service continuity.

Nowadays, infrastructure services have become indispensable. Accidents occur during excavations. This is especially true because the inventory of underground infrastructure in the excavated area is not clearly known during excavation (Schall et al., 2014). Accidents are a cause of loss of time and money. The existence of an infrastructure inventory by the institutions, organizations or individuals in charge of the excavation can be a preventive measure against possible accidents.

The aim of this study is to present the infrastructure data in a coordinated way with augmented reality technology and to use it in field studies. With the use of augmented reality technology in field studies, it will be possible to have information about the underground works in the field easily.

2. Literature Review

Sherman and Craig (2019) emphasized the effective use of virtual reality as a communication tool. They talked about the necessary components for designing virtual reality applications, why virtual reality technology is needed, and the areas that can be used in the future. As a result of cheaper software development costs in parallel with technological developments, virtual reality technology has been used as a communication tool in many fields.

Keskin Mustafa and Yilmaz (2014) stated that it is important to design and implement the infrastructure information system, which is included in the city information system, by authorized institutions and organizations in order to provide infrastructure services in a healthy way. Researchers studied drinking water and sewerage services from infrastructure services in terms of infrastructure information system. They explained the importance of the infrastructure information system so that local governments can bequeath a healthy infrastructure service to future generations, and so that infrastructure services can be carried out in a planned manner without loss of cost.

In the research on augmented reality, Tekin (2019) has observed that location-based augmented reality applications are relatively less among mobile augmented reality applications. He has worked on displaying infrastructure data in a location-based augmented reality application. In the study, which used water and wastewater pipes in Yıldız Technical University Davutpaşa Campus, geographic data was arranged using Autocad and Netcad and transferred to Mapbox map service (MAPBOX, 2021). Android based application designed with Unity 3D. In the designed application, it was found that the position sensitivity in the display of linear data was not at the desired level. The application designed using open source software is open to development.

By examining the studies on augmented reality, it is believed that augmented reality is still open to development and will be mentioned very often in the future. Bayraktar (2019) stated that the need for technical infrastructure has increased with the increase in urban population, and more importance should be given to technical infrastructure over time. Occupational accidents that occur in technical infrastructure works can cause loss of life, as well as loss of cost and time.

The researcher, who mentioned the accessibility and accuracy of the data in the studies to be conducted, aimed to establish an infrastructure information system in the infrastructure coordination center with the infrastructure data. The researcher emphasized the diversity of companies providing technical infrastructure services and the differences in the data of these companies, as well as the problems in the accuracy of the data, and emphasized that the infrastructure information system should be created with the data of all companies and institutions with high accuracy data. In the study, the technology of geographic information systems was examined and the standards of geographic information systems were mentioned, and the importance of the infrastructure information system for Trabzon Metropolitan Municipality Aykome Directorate was stated.

Uluğ (2020) stated that museums need to renew themselves over time and explained that innovations in museums have emerged in the light of new technological developments. The researcher stated that the promotion and protection of works is the most important issue in museology, and explained the advantages that augmented reality applications can provide at this point. By examining the mobile augmented reality application of Sakıp SABANCI Museum, the researcher made suggestions on what should be considered when designing augmented reality applications in the museum industry.

3. Materials and Methods

In the study, a region located in Seyrantepé neighborhood of Karaköprü district of Şanlıurfa was selected as the study area. An android-based mobile augmented reality application was prepared by using the data of drinking water and sewerage networks in our study area (Fig. 1).

3.1 Platforms Used

We used the Unity platform for our AR application. Unity provides simulation and video game development for computers, consoles and mobile devices. Our application is developed using C# programming language through Unity Platform. Mapbox Unity SDK, developed by Mapbox, helps to use the data stored in Mapbox on the Unity platform via web service.

The World Alignment Kit included in the Mapbox Unity SDK enables augmented reality applications on the Unity Platform. The World Alignment Kit enables the visualization of personalized geospatial data in Mapbox Studio on the Unity Platform via web services and the display of physical geospatial data at world scale. ARCore software provides geolocation and access to spatial information. Since the ARCore software supports Android 7.0 (Level 24) and higher, the minimum Android version is 7.0 (Level 24). The application prepared accordingly can be installed on all devices with Android operating system compatible with ARCore. In our study, the Redmi Note 8 (2017) device manufactured by Xiaomi was used as a test device.

3.2 Preparation of Data

The data of drinking water and wastewater networks in our study area were in .ncz file format. It was used by converting the data to geojson format to be used as a web service with the help of geographic information system platforms. The prepared data was transferred to Mapbox Studio to be published through the Mapbox web service. The data is published as a service through the `tile_set_editor` via Mapbox Studio.

3.3 Designing the Mobile Application

Unity Software version 2018.3.1 was used in the design process of the mobile AR application. A new project was created in Unity Software and this project was organized as an Android-based mobile application (Fig. 2).

- Scene Panel: Provides a 3D vision of the playground.
- Hierarchy Panel: It is the panel where all objects in the scene are listed.
- Inspector Panel: It is the panel that contains detailed information about the selected objects.
- Project Panel: All resource files that you can use in your game are located here.

To use the geospatial data in the Unity environment, the geospatial data is arranged through Mapbox Studio and published as a `tile_set` and style so that it can be used in Unity through the web service. Geographic data can also be edited using Mapbox Studio (Fig. 3).

The Unity SDK was designed by Mapbox to make it easy to bring geographic data to the Unity platform and build location-based mobile applications. When the Mapbox Unity SDK is opened in Unity, many sample applications appear. A World Scale AR sample has been prepared by Mapbox for world-scale AR applications. The Mapbox Unity SDK version 2.1.0 was used to build the application for this study.

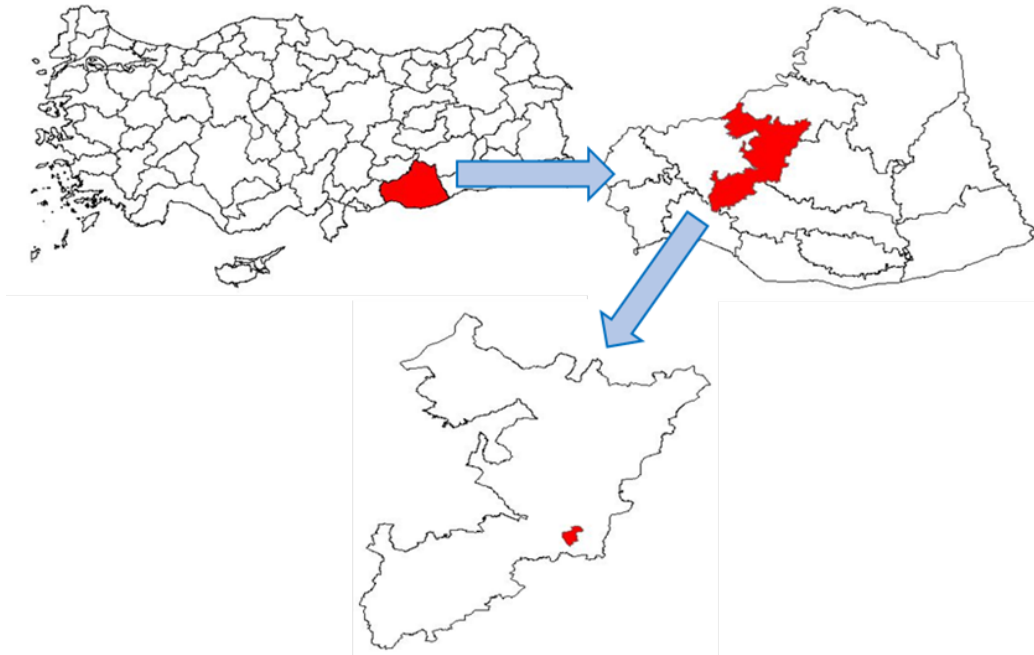


Figure 1. Study Area

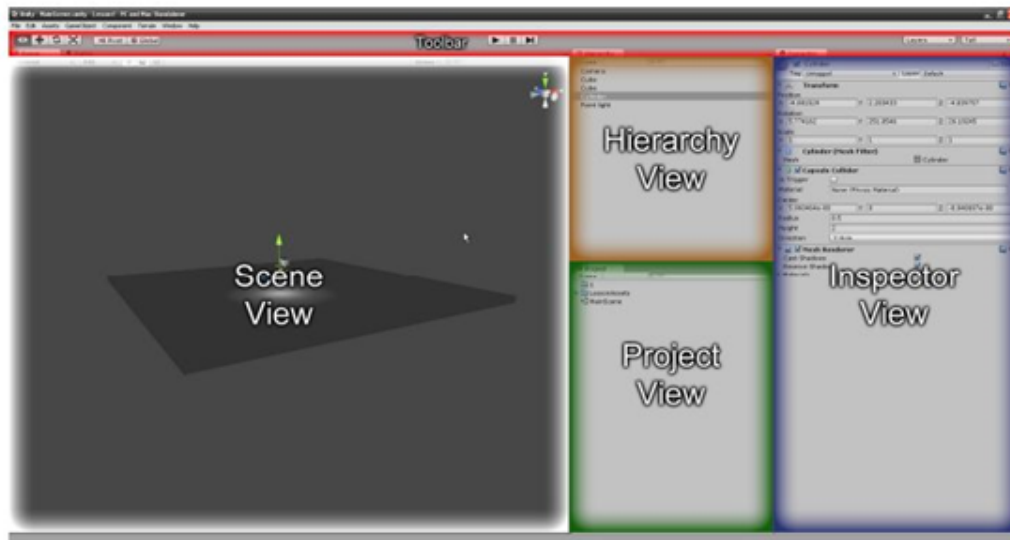


Figure 2. Unity Workbench (MapBox, 2021)

The application design began by importing the Mapbox Unity SDK 2.1.0, created by Mapbox, into the Unity platform. The Mapbox Unity SDK transferred to the Unity environment contributes to the design of location-based games and augmented reality applications (Fig. 4).

In the application created using the Mapbox Unity SDK, there are five game_objects taken from the Mapbox SDK. Using these game_objects, Mapbox created a personalized application that visualizes geographic data and turns it into an AR application. In the Mapbox World_Alignment_Kit;

- **AR_Root:** The Unity interface prefab for building cross-platform AR applications.
- **Map_Camera:** A top-down view of the map, used to display GPS tracks, AR position, and current map orientation. View in play mode with the map checkbox.
- **AR_Aligned_Map:** The map aligned to AR Root using your device's location services. Renders orange debug buildings by default.

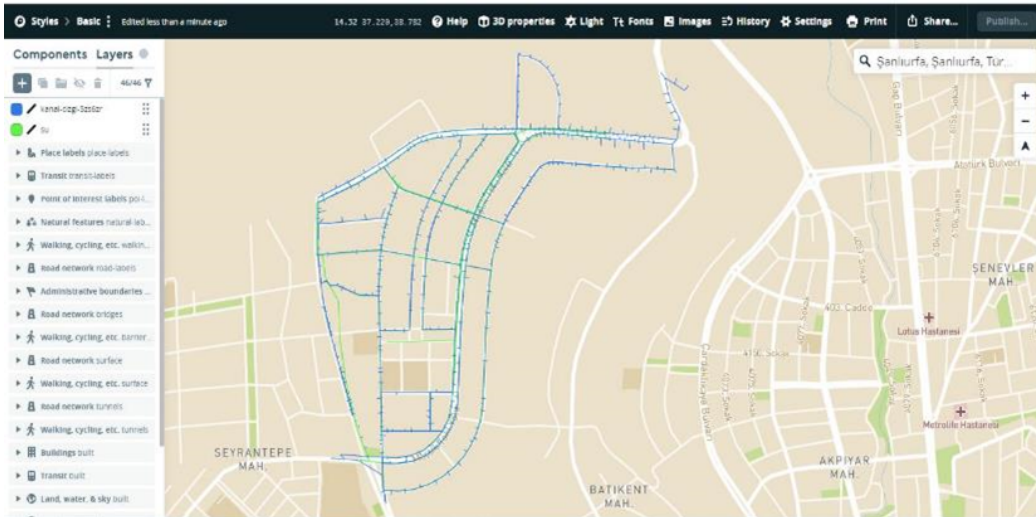


Figure 3. Screenshot of Mapbox Studio

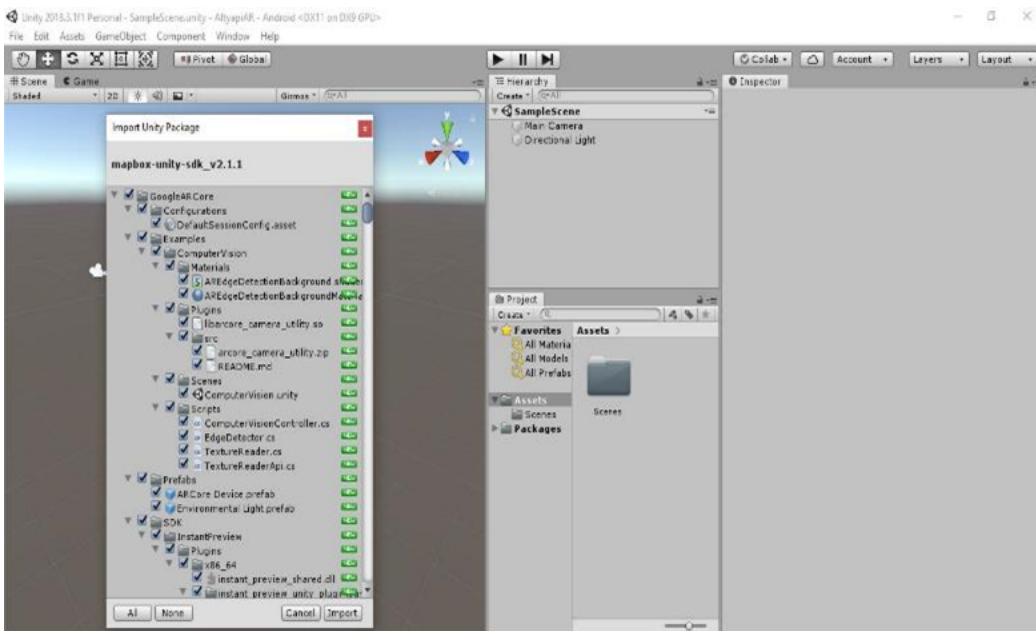


Figure 4. Screenshot of Mapbox Unity SDK

- **Debug_Canvas:** A detailed debug log of location services and AR activity, viewable by pressing the 'LOG' icon in play mode and on devices. This is included as a unified UI element to make location debugging easier.
- **Location Provider:** Provides GPS data to the map and spoofs data for testing in the editor. (UNITY, 2005).

These services provided by Mapbox are free up to a certain usage level, after which a fee is charged. In the application we have built, we have taken care to use free software.

Because the Mapbox Unity SDK is imported into the Unity environment, access token information is requested. Mapbox users will be able to create tokens in their Mapbox accounts for the application they are building, and access statistical information about those tokens (Fig. 5).

When designing applications using Unity software, it is possible to visualize with desired icons by uploading images in .png format to the buttons on the main screen. When designing our application, care was taken to create an understandable design by using images suitable for the buttons on the main screen (Fig. 6).

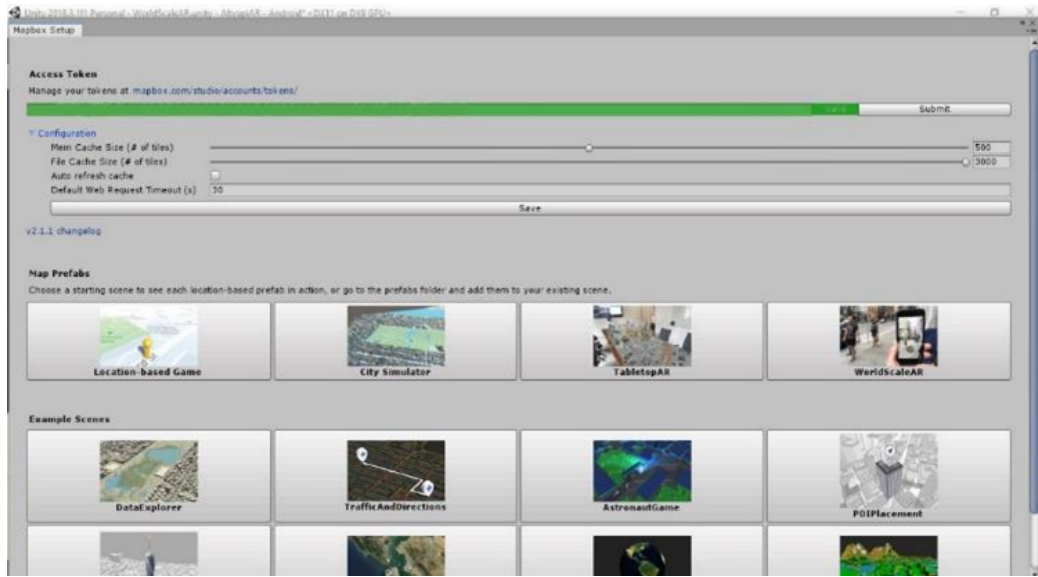


Figure 5. Mapbox Unity SDK



Figure 6. Main Screen Design of AR Application

By using 7 buttons in the home screen design, we enabled operations on the application with the help of these buttons. Buttons we created;

1. The button we have shown as the Settings icon allows manual adjustments of the direction of the data displayed in the augmented reality environment where the position sensitivities are insufficient. When this button is pressed, the direction buttons 7 are opened and manual adjustments are made using the direction buttons.

2. With the help of the button we have shown with the GPS icon, when the user of the application is on the move, it provides the data to be updated again according to the GPS position, in case the updating of the data is insufficient due to the position sensitivity. With the help of this button, the data visible on the ground will be updated and displayed again.
3. Button 3, marked with the LOG icon, is where the GPS records are stored. It allows us to see GPS sensitivities and actual GPS values.
4. Compass helps to determine the direction of the user using the application.
5. The Map button displays a map on the screen with streets and important buildings, as well as our geographical data. This map was created in Mapbox Studio using Mapbox Basemaps.
6. The button we call AR enables the use of the Augmented Reality platform, where the phone's camera is turned on and geographic data is placed on the phone's screen according to your location.
7. These buttons with directional arrows allow you to make the manual adjustments mentioned in button 1.

It is possible to customize the appearance of geographic data in the application on the Unity platform, which we have enabled to be displayed in Unity through the Mapbox web service. The AR_Aligned_Map object is used for all adjustments related to geographic data. The visualization of 3 different data related to the visualization of geographic data in Unity has been arranged.

The part we call Image provides the visualization of the map with our geographical data, roads and important buildings. The Terrain part is used to model the land surface. Map layers are used to arrange the data that will be displayed in augmented reality. The AR_Aligned_Map object, for which we created map and augmented reality arrangements, uses tileset and studio data from Mapbox Studio. An ID is created for each piece of data we create in Mapbox Studio. It is possible to make adjustments by entering the ID information in the Unity environment (Fig. 7).

In the AR_Aligned_Map object, we have two geographic data layers that we have set up in map layers; drinking water data and waste water data. After our geographic data layers are opened in unity with their id information, the visualization of this data is adjusted from the Data Layers section. With Mapbox Geographic Services, the data opened in unity can also be visualized on the unity platform (Fig. 8).

In the application we designed, the synchronization of geographic data is done automatically. In the tests we have made with the geographic data that we have created the visualization; directional problems have occurred in the linear geographic data. We have added a manual adjustment feature for editing the directional problems. We made functional definitions for the buttons by making changes in the codes on the AR_Controller in order to manually edit the data with the help of buttons (Fig. 9).

On mobile phones, it takes time for GPS accuracy to recover after the user moves. In the application we developed, a function was added to update the map using a GPS button. In the first tests we conducted, it was observed that the data on the map could not be accurately positioned after the application was moved for a while. Functionality was added to the GPS button by making an adjustment in AR_Aligned_Map_Object (Fig. 10).

We designed the AR application, which we created by making the necessary arrangements through the Unity platform, to work in harmony with Android operating system 7.0 and above mobile devices. In our application, which also includes Google ARCORE support, the infrastructure data is visualized in an augmented reality environment.

The Xiaomi Redmi Note 8 device was used for testing the mobile AR application. The technical specifications of the device are shown in Table 1.

Table 1. Technical specifications of the used device

MONITOR	
Display Technology:	IPS LCD
Screen Size:	6.3 inch
Aspect Ratio:	19,5:9
Screen Resolution:	1080 x 2340 pixels
Pixel Density:	409 ppi
Colour Depth:	16 million colours, 24-bit
Screen to Body Ratio:	82%
Screen Refresh Rate:	60 Hz
HARDWARE / SOFTWARE FEATURES	
Operation System (OS):	Android 9.0 Pie
User Interface (UI):	MIUI V10
Chipset:	Qualcomm Snapdragon 665
Number of CPU Cores:	8
CPU:	4x 2.0 GHz Kryo 260, 4x 1.8 GHz Kryo 260
CPU Manufacturing Technology:	11 nm
CPU Design:	64-bit
GPU:	Qualcomm Adreno 610
CONNECTION FEATURES	
Wi-Fi:	802.11a (IEEE 802.11a-1999)
USB Connection Type:	USB Type-C
Bluetooth Version:	4.2
Navigation:	GPS, A-GPS, GLONASS, BDS (BeiDou)
Other Connection Types:	Infrared port VoLTE

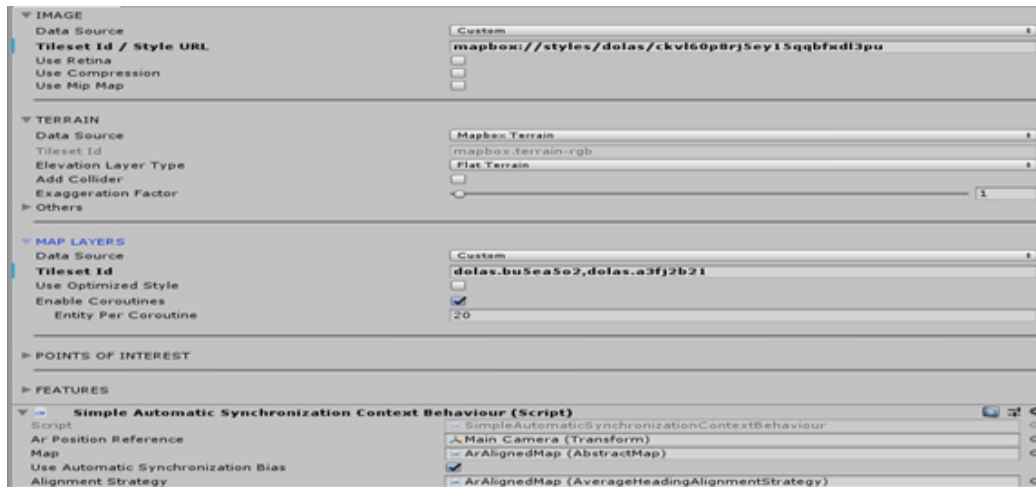


Figure 7. AR Aligned Map Object

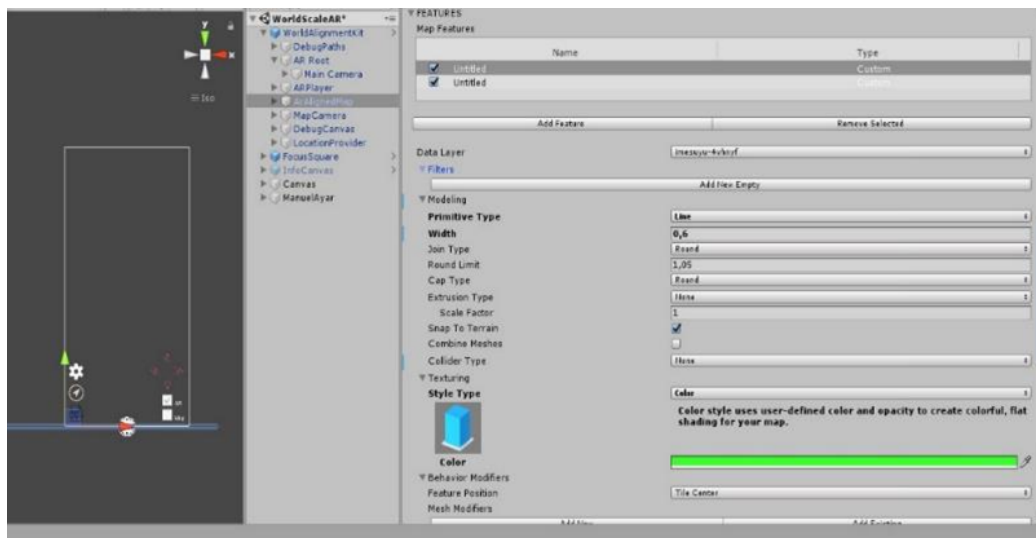


Figure 8. Screenshot of Map Features

4. Findings and Discussion

In the AR application we designed, linear geographic data belonging to infrastructure networks is used. We have seen that the direction of linear data cannot be accurately positioned in mobile AR applications. It has been observed that positioning in AR applications using point data is more sensitive than linear data.

In mobile applications designed for more precise positioning of linear data, manual adjustment buttons can be added to the data to provide movement capability. In mobile AR applications that are designed with manual adjustment buttons, known fixed points in the workspace are needed for precise positioning of lines in the real world. Using known landmarks, it is possible to position the lines according to the landmarks.

To determine the positional accuracy of the prepared application, coordinate readings were taken using the ground control points determined from the geographic data and the images of the AR application in the field. Coordinate readings on the ground were performed using both a Continuously Operating Reference Stations-Turkey (CORS-TR) supported Global Navigation Satellite System (GNSS) receiver and a mobile application.

The line seen in the mobile AR application and the coordinates collected over land were compared. Since the line directions on land were matched to the infrastructure data by manual corrections in the mobile AR application, the location information obtained from the mobile AR application was not trusted and was not used as a validation criterion. In the study, the UTM coordinate system in WGS84 datum was used as the coordinate system.

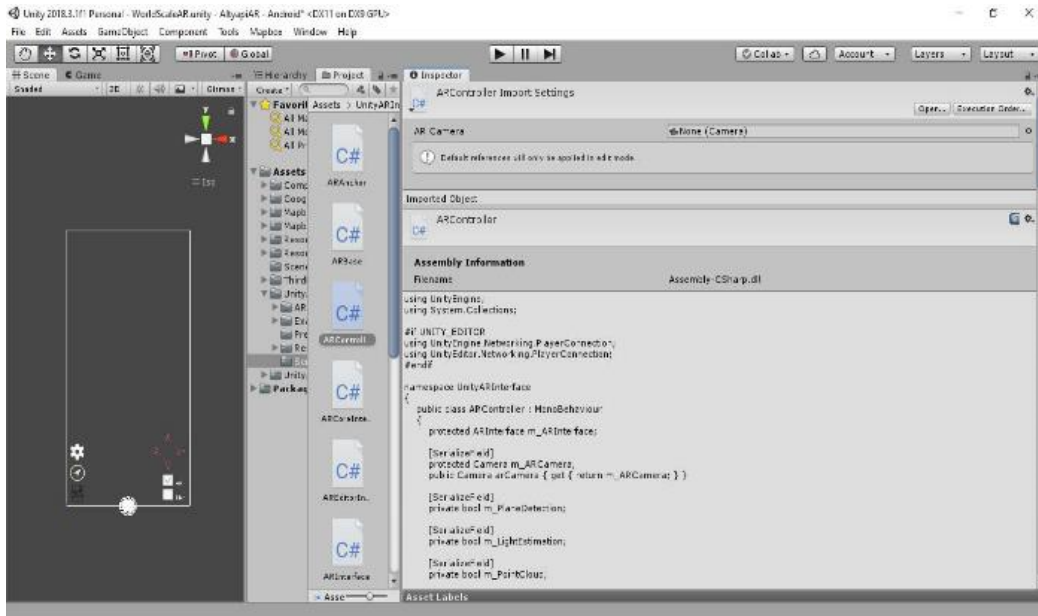


Figure 9. AR Controller

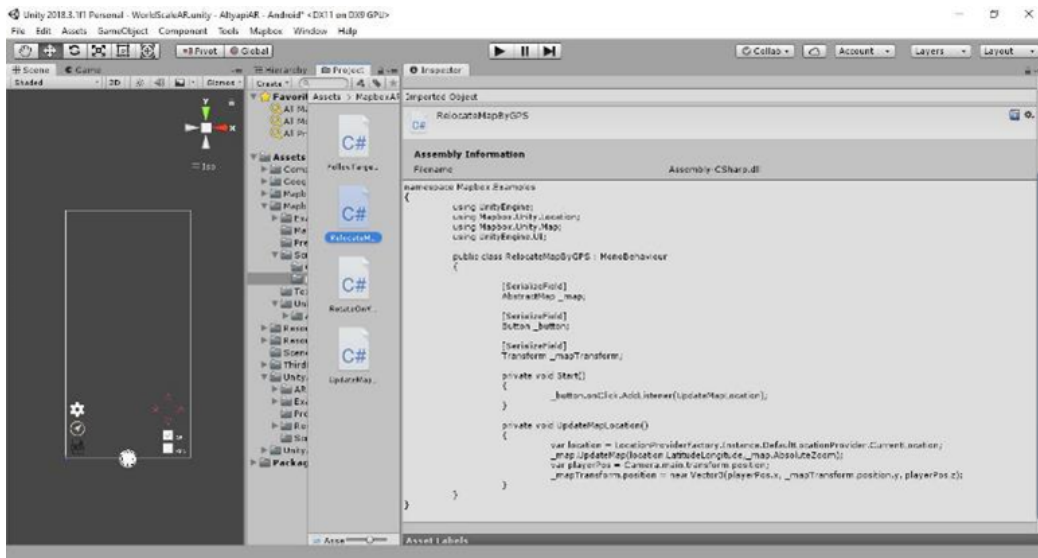


Figure 10. Settings of GPS Button

The location accuracy of the mobile AR application was tested by collecting coordinate information from the geographic data and the field from the ground control points by markers in the field of view of the mobile device. The Root Mean Square Error (RMSE) was obtained by using the double measurement method in the error theory.

Direction problems in field data, coordinate information was collected after manual settings were made in AR application. Therefore, the coordinates of field data could be collected more accurately with the help of CORS-TR supported GNSS receiver (Table 2).

Table 2 shows the UTM coordinates collected from the pilot region. By subtracting the land and CORS-TR coordinates; *de* presents for the easting and *dn* for the northing difference calculations in centimetres (Equations 1 and 2).

$$de = (y_{LK} - y_{AR}) * 100 \tag{1}$$

$$dn = (x_{LK} - x_{AR}) * 100 \tag{2}$$

Here, x_{LK} , y_{LK} and x_{AR} , y_{AR} are the coordinates from the land and CORS-TR supported augmented reality application, respectively (Table 3).

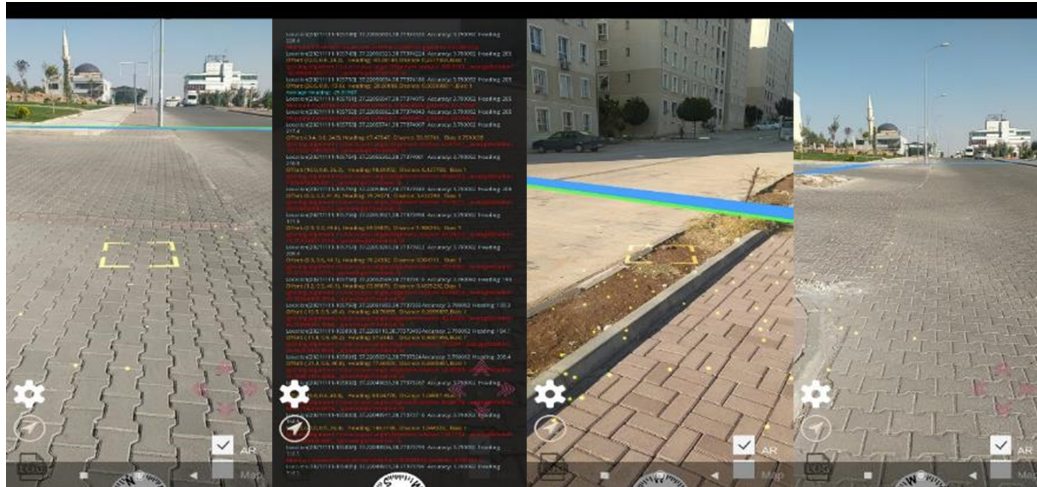


Figure 11. Screenshots of Mobile AR Application

Table 2. Land coordinates collected for control purposes

Point	Land Coordinates		CORS Coordinates	
	East (m)	North (m)	East (m)	North (m)
1	479811,89	4119162,92	479811,88	4119162,62
2	479817,90	4119163,24	479817,91	4119163,03
3	479825,41	4119163,14	479825,60	4119162,98
4	479833,04	4119163,42	479833,05	4119163,53
5	479844,21	4119163,38	479844,39	4119163,56
6	479861,33	4119163,72	479861,52	4119164,16
7	479890,48	4119164,16	479890,86	4119164,87
8	479926,85	4119164,72	479926,91	4119164,99
9	479958,71	4119165,20	479958,83	4119164,96
10	479994,48	4119165,77	479994,49	4119165,58
11	480021,53	4119166,18	480021,61	4119165,90
12	480057,50	4119166,73	480057,69	4119166,23
13	480090,05	4119167,28	480090,01	4119167,22
14	480093,48	4119167,14	480093,18	4119166,76
15	480097,57	4119167,30	480097,28	4119167,32
16	480100,04	4119171,66	480100,10	4119171,14
17	480100,41	4119177,03	480100,27	4119176,85
18	480100,97	4119189,94	480100,84	4119189,75
19	480101,39	4119197,07	480101,29	4119196,83
20	480102,72	4119209,65	480102,55	4119209,85
21	480105,96	4119231,95	480105,76	4119231,79

Table 3. Coordinate differences between land and CORS-TR

Point	Coordinate Differences	
	de (cm)	dn (cm)
1	1	30
2	1	21
3	19	16
4	1	11
5	18	18
6	19	44
7	38	71
8	6	27
9	12	24
10	1	19
11	8	28
12	19	50
13	4	6
14	30	38
15	29	2
16	6	52
17	14	18
18	13	19
19	10	24
20	17	20
21	20	16

Using the calculated dn and de values; northing, easting and resultant mean error calculations were calculated with the mean error formula by using the Eq. (3).

$$RMSE = \pm \sqrt{\frac{[d_i d_i]}{2 * n}} \quad (3)$$

Here, d_i is the differences between the northing and easting land coordinates of each pair of measures and the coordinates taken by the AR application with CORS-TR; n represents the number of control points collected. The mean error value for the easting is $\pm 11.9cm$, for the northing is $\pm 21.8cm$, and the resultant mean error value is $\pm 24.9cm$.

AR technology will continue to evolve with improvements in software and hardware. Location-based AR applications are affected by position sensitivities so that spatial data can be accurately placed on the real world. In AR applications created with geographic data, applications created with point data can give more successful results. It can be seen that the directions of the lines cannot be used accurately when using linear data in AR applications, where spatial sensitivities are observed to be better in point data. AR applications designed with linear data need to be manually adjusted with ground control points on the land.

In order to carry out infrastructure works in a healthy way, it is necessary to consider the opinions and suggestions of all stakeholders involved in infrastructure management. Infrastructure management, which includes both public institutions and infrastructure companies, should be carried out on a common denominator. Geographical data related to infrastructure should be collected by involving all stakeholders, and this data should be used by all stakeholders. All infrastructure networks can be protected in multi-stakeholder studies.

Since the location sensitivity of the smartphones used cannot reach the desired precise location sensitivity without the use of additional equipment, external location information should be verified with geodetic GNSS instruments in these applications.

5. Conclusion

Augmented reality (AR) technology services offered by companies that produce geographic information system (GIS) software are becoming more widespread. By using GIS software, people and institutions that host their geographic data on a geographic server can see their data in an AR application. The design of spatial AR applications becomes easier with the development of AR application design in free and open source software.

In order to extend the designed mobile application, it is necessary to eliminate the directional problems in linear data. It is possible to eliminate this problem, which is often encountered in the design process of AR applications, by using additional hardware. By adding manual adjustment buttons to AR applications designed for use on mobile devices, direction corrections can be made using these buttons. Known landmarks in the field are required for manual fine-tuning. Ensuring that known fixed points in the field are displayed with point symbols in AR applications will facilitate manual adjustments. Although it is easy to use such a method in an area covering a few streets, many more fixed points will be needed for a study covering many streets. It is known that the directional problems can be solved with the hardware developments in AR applications.

As a result of the comparison between the coordinate values obtained from the geographic data and the field data, an average error of $\pm 24.9cm$ was obtained. The use of the AR application that we have prepared near the study area in excavations to be carried out in field studies with the calculated average error will provide great advantages in terms of carrying out the process.

Acknowledgments

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