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Research article

Development of an Interactive Augmented Reality-Based Weather Forecast Simulation with Automated BMKG Data for Enhanced TV Broadcasting

Moh. Zikky [a,], Robby Alexander[b], Zakha Maisat Eka Darmawan[c], Fitrah Maharani Humaira[d], Laily Asna Safira[e]*

[a,b,c] *Department of Multimedia Creative Technology, Politeknik Elektronika Negeri Surabaya, Jl. Raya ITS Sukolilo, Surabaya 60111, Indonesia*
[d,] *Department of Informatics and Computer Engineering, Politeknik Elektronika Negeri Surabaya, Jl. Raya ITS Sukolilo, Surabaya 60111, Indonesia*
[e] *Electrical Engineering Department, Diponegoro University, Jl. Prof. Soedarto, SH, Tembalang, Semarang 50275, Indonesia*
email: [a,*]*zikky@pens.ac.id*, [b] *robyalexander571@gmail.com*, [c] *zakha@pens.ac.id*, [d] *fitrah@pens.ac.id*, [e] *lailyasnasafira2@lecturer.undip.ac.id*
* *Correspondence*

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ABSTRACT

The weather has a significant impact on human activities. Weather data are used in various industries. Recently, Augmented Reality (AR) technology has been widely used to enhance content representation through multidimensional visualization. Television stations utilize AR to capture viewers' attention in the programs they broadcast; AR has the potential to enhance communication between viewers and the content. Our research on developing an AR application for an engaging immersive reality implementation aims to simulate a virtual stage in TV broadcasts, displaying real-time weather data from the Indonesian Meteorology, Climatology, and Geophysics Agency (BMKG) using the latest SQL database. The implementation of the AR system as a multimedia mode in delivering weather information increases the attractiveness and engagement of viewers. This system operates by translating weather data from SQL into key parameters for pre-built 3D visualizations, which appear at marked coordinates. This application runs on the Windows platform and can be managed via Android, allowing presenters to convey engaging scenarios. Research on East Java BMKG data showed that the design function to transform BMKG data into a virtual weather animation data was significantly successful in both synchronizations.

1. Introduction

Digitalization systems, adaptive artificial intelligence, metaverse technology, and any sustainable technology have increased along with the advancement of computer technology. This is considered among the top 10 Gartner strategic technology trends of 2023 [1]. Alternative reality (XR) technologies, including physical, augmented, hybrid, and virtual reality, need to be given concern [2][3]. Today, there are numerous studies focusing on this advancement. 3D AR learning objects have been used in the sciences to make representations of multidimensional natural phenomena more accessible in classroom settings, and they offer the promise of enhancing communication about weather [4].

One of the developed research areas in this field is immersive reality, which is known as metaverse technology. Immersive technology could be represented by Virtual Reality (VR), Augmented Reality (AR), or even Mixed Reality (MR). This technology has shown considerable growth, especially with the development of interactive computer technology and 3D modeling packages. The term

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Immersive Reality itself refers to a technology that combines computer-generated virtual objects and surrounding information in the real environment to augment the contextual perception of the user. VR has a positive impact on learning and conveying information to the user, making the knowledge acquisition process more efficient [2][5][6][7][8].

This method becomes feasible in different areas of disciplines, such as game development, reality simulation, research in medicine, in the context of education or entertainment, and many other sectors [4][8][9][10][11]. The research conducted by [4] developed an AR visualization of the lifecycle of a single-cell thunderstorm [4]. One of the interesting immersive reality implementations is to simulate virtual stages in TV broadcasting, especially for the Weather Forecasting Channel. The delivery of weather forecasts on television today mostly does not make much use of interactive or even immersive technology. The anchor only presents the news by explaining the video or slides being played without interacting directly with the virtual content and enhancing it with attractive weather simulations. Therefore, this research will present a virtual stage concept with attractive metaverse simulations, either for presenting attractive simulations, and for further development in the field of cloud service, real-time data presentation, and various things that support multimedia presentations that present more attractive and more immersive experiences for the audience [12][13][6]. Research development by IBM created Max reality, which uses advanced augmented reality (AR) technology to create 3D visuals of storms and atmospheric events dynamically that can make even ordinary weather look intriguing [14]. AR Simulator design in an AR application registers an AR image target and generates the visualization based on the position of the image target. A particle system was used to develop volumetric visualization and make the thunderstorm clouds and precipitation visually realistic. Tactile or physical control over a virtual object can improve interactivity and accessibility to virtual content [15][7][5][6].

The weather plays a huge role in defining human activities. Weather information is used in various sectors such as transportation, agriculture, infrastructure, tourism, event organizing, disasters mitigation, and others. Weather is defined as the air condition in an area at a certain temperature for a short period. Weather parameters include air temperature, air humidity, air pressure, wind direction, and speed [15]. The use of the internet of things has also been implemented in the Automatic Weather Station (AWS). Data obtained from AWS can be connected in one network to facilitate the processing of weather data. AWS is divided into two categories, an offline AWS and real-time AWS. Offline AWS is an AWS that can only collect data and store it in storage media such as SD cards, flashcards, and the internal memory of data loggers. Operators must download data obtained from the data logger to view the values of weather parameters. Real-time AWS is an AWS that can send data in real-time through communication media. BMKG recently uses the FTP protocol for AWS data communications. FTP-based data transmission has a disadvantage if the number of AWS sites is very large, as there is a buildup of data on the FTP server, so that the data arrives late on the FTP server. The FTP protocol also has lower power consumption efficiency compared with the HTTP protocol. In this case, HTTP can be used to display real-time AWS data using a web browser [15].

So, in this research plan, a weather forecast broadcast platform will be developed using interactive AR/MR with data automatization from BMKG (the Indonesian Meteorological, Climatological, and Geophysical Agency). AR/MR or metaverse media will be offered as a platform which presents Indonesia's territorial map and its several forecast data results within attractive animation based on those BMKG's city data. From a simple mechanism perspective, this system will start by downloading weather data from the BMKG website, then reading its real-time file, and inserting it into an SQL Database [15]. This data will be used as a variable in the game engine (e.g., Unity or Unreal Engine). Thus, virtual objects will be displayed based on the variables obtained. In this research, immersive reality technology will be presented on the stage of a TV anchor with attractive weather forecasting simulation and animation. Thus, the anchor should interact with those virtual animation objects directly, either using an AR/MR headset such as Microsoft HoloLens or other hologram devices. The animation may be presented by Augmented Reality (AR) or even the Mixed Reality (MR) concept where its system crawls data from BMKG (the Indonesian Meteorological, Climatological, and Geophysical Agency) as the base resources. Furthermore, the application will also be equipped with a Weather History feature that works to store weather data from previous days for further analysis or replay of its simulation. As a prototype examination, it will be examined in East Java territory in

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Indonesia as the first attempt. Thus, if the system has been established well, it may be developed for all Indonesian territories or even cities worldwide [15].

This project constitutes a series of processes that utilize image or video segmentation to understand reality and its surroundings. Based on this data, the surface area is determined to become the stage of this interactive immersive multimedia interaction. Thus, the other challenging part is how to present the real-time data from BMKG and provide it in attractive AR with 3D animation assets simulation. On this part, we will develop a plugin framework for the game engine which can be synchronized with BMKG real-time XML data. The last process is how to blend the virtual 3D animation with the news anchor. In conclusion, with this concept we can conclude that immersion is not only produced by visual realism but by semantic consistency between real-world data and virtual representations. Real-time BMKG data dynamically convert virtual meteorological objects to contextualized data visualization. This semantic abstraction enables data-driven, context-aware weather simulations within immersive reality systems.

2. Materials and Methods

In this study, we developed an Augmented Reality (AR) application based on markers [9][10] with input from BMKG meteorological data. The AR application is used for TV station weather forecast broadcasts. Data visualization utilizing AR is projected to improve interaction between the presenter and the news being given. This application runs on a Windows PC owned by a TV broadcaster. The system's output is a 3D object displaying weather changes and includes supporting data. This research resulted in three primary aspects of the program. The first is the Data Downloader Program, which retrieves BMKG XML data. The second is an API to access the database. The final application is an augmented reality application that displays data from the database. Figure 1 depicts the main diagram for the overall system.

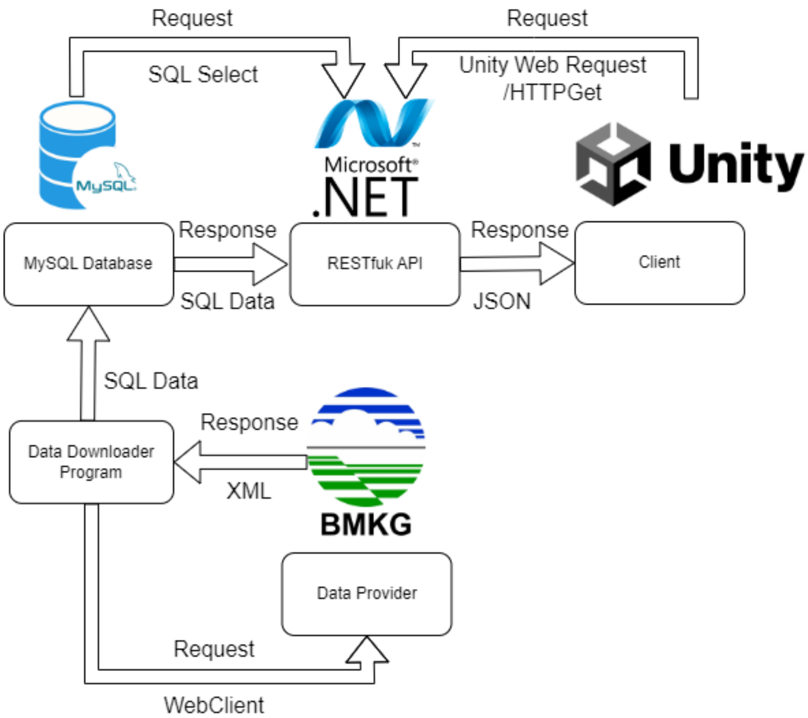

Fig. 1. Main Diagram

The workflow used in this study is shown in Figure 2, with the database being prepared first, followed by the creation of a data downloader application from BMKG. The API requires the software to retrieve the necessary data from the database. Then, an AR model is created for showing weather forecast data. The remote application as a controller is an additional feature that enhances the interaction between the weather prediction presenter and the data displayed.

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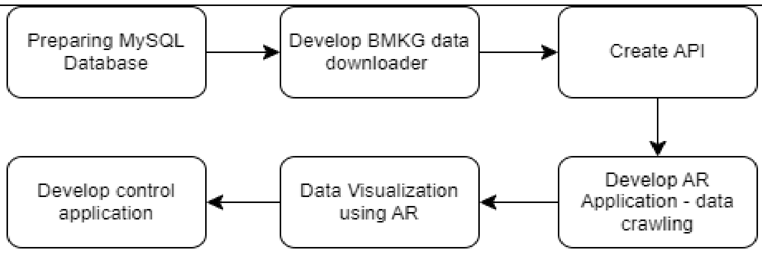

Fig. 2. Workflow used on this study

2.1 Database

A MySQL database is used to store data in this research. The database will store BMKG XML data, and the column name convention in the database will be the same as in the XML file. The data types used in the table are all VARCHAR, sometimes known as strings. To make it easier to read and retrieve data via the API, the database design employs the same data type.

The Indonesian Meteorological, Climatological, and Geophysical Agency (BMKG) provides open data on weather and disasters. This study uses weather forecast data obtained from https://data.bmkg.go.id/prakiraan-cuaca/. This study specifically uses meteorological data from the East Java region; this is due to the implementation carried out at the local TV station JTV, which focuses on East Java news. The data is in XML (Extensible Markup Language) format, which may be opened with Microsoft Visual Studio or comparable tools. The elements in the XML file are organized into nodes. The BMKG XML data structure is shown in the node shown in Figure 3 below. East Java has 39 "area" nodes, which store meteorological information for the region.

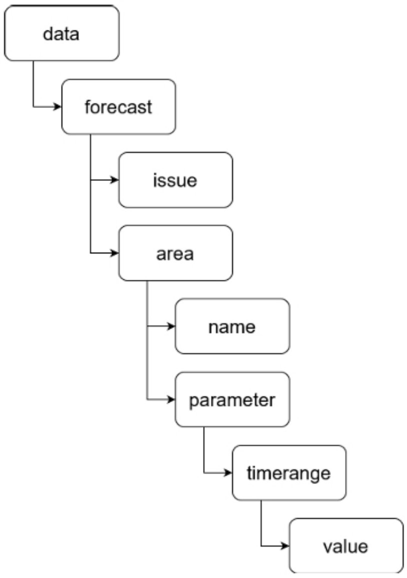

Fig. 3. The XML data structure of BMKG

2.2 Data Crawling

The downloader and parsing application were created using Microsoft Visual Studio and the C# programming language. The following libraries were used in the downloader development process: System.Net to access the BMKG URL; System.ComponentModel to determine whether the data was successfully downloaded; System.Xml, to access XML data reading functionalities; MySql.Data.MySqlClient to connect the data downloader program to the database; and System.IO to save XML data to local files.

Figure 4 shows the data reading flow from BMKG XML data. To read data, the software must first retrieve local data (information stored on the computer). To connect the software to the database, a Connection String must be prepared. The Connection String contains account information as well as the database table to which we are attempting to connect. The data entered in the array will be saved to the database after the connection is established. To protect security and save memory, the connection will be disconnected once the data has been entered. At this point, the API is constructed to serve as a link between the database and the AR application designed for data display.

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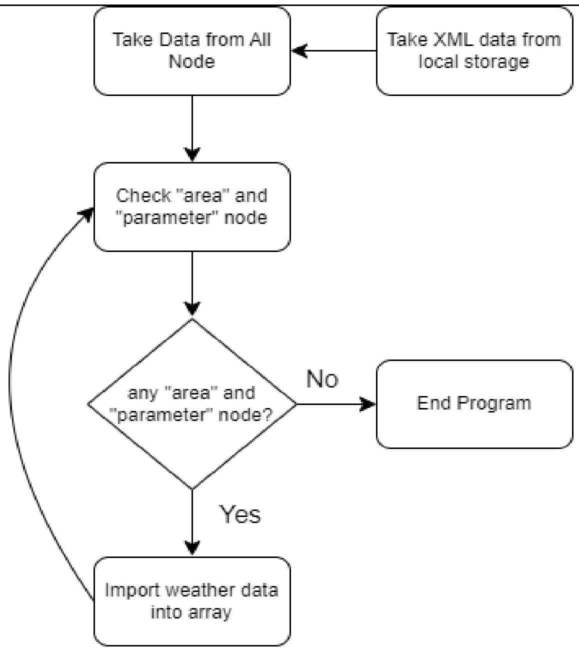

Fig. 4. The process of XML data reading on BMKG official website

2.3 Application Design

2.3.1 Augmented Reality Model

The AR application in this study was created with Unity version 2020. To retrieve data from the API, the Unity project must have a class that can handle data in the same format as the model in the API. The API sends class data that is translated (serialized) into JSON, which Unity must then convert (deserialize) back into a class. The Augmented Reality (AR) SDK used in this study is the Vuforia SDK. This study only uses three Vuforia features, which are: (1) Camera Device, which allows users to change Unity's main camera to an AR camera, (2) The Image/Object Tracker component is a marker. The marker used in this project is a deer doll, and (3) The Frame Player displays photos obtained by the camera.

This study includes two primary objects: a 3D pillar model and 3D weather as data visualization media. The first primary object, a 3D model displayed above the marker, is a pillar created with Blender software. To save resources (storage and performance), this study built a 3D low-poly (basic) object. The data received will be used to display a weather model at the top of the pillar. Text will be presented at the front, along with other data such as the region name, weather name, temperature, and humidity; an example of the visualization is shown in Figure 5. in the experimental test, we used a deer doll as a marker.

Figure 5. AR Visualization

The second important component is the weather representation visual object, which is displayed above the pillar and was made using Unity's Particle System. In addition to the Particle System, the Universal Render Pipeline (URP) module adds a bloom effect (shine) to make the sun object more

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visually appealing. The 3D weather model depicts sunny weather, partly cloudy, cloudy, heavily cloudy, fog, smoke, hazy air, light rain, moderate rain, heavy rain, local rain, and thunderstorms.

2.3.2 Application

A remote-control application was developed to increase the connection between the weather prediction presenter and the data being given. In this study, the SDK Mirror is used to handle communication between the host and the remote. The host in this context refers to a Windows PC or other device capable of showing AR. The remote is another gadget that the presenter can carry and use to control the AR display. The host and client (remote application) will interact using IP addresses. The host will offer an IP address, and the client will only need to enter the one listed. After the connection is established, the remote application can be operated using the provided buttons. The following diagram shows the communication flow between the host and client in the application communication.

3. Results and discussion

System testing in this study was done in stages. The goal of this staged testing is to test each component of the software under development, beginning with the BMKG XML Data Downloader Program, Web API, and AR Application. The tests conducted included the following tests: (1) Database Creation Testing; (2) Data Crawling Performance Testing; (3) Application Testing.

Create a database.

The ability of the downloader program to download XML data from BMKG and save it to a local computer is evaluated during testing. Testing is done by launching a downloader program that already has an application file type (.exe). During this testing stage, it was discovered that the downloader program could connect to the BMKG website and display the message "File Downloaded," indicating that the data download from BMKG was successful. The program can connect to the BMKG website and store the information gathered. When the device is not connected to the internet, the program displays a System.Net error message and must be manually closed.

Data Crawling Performance Testing

API testing is performed on the database and data access transfer by accessing the URL generated by the framework. When the API is performed with the dotnet run command, the framework returns a message indicating which URLs can be accessed. This API includes three functions. The first, GET, presents the region name data (list name list). The second GET returns a timestamp (date of data publishing). The last GET returns data depending on the region name and time.

Application testing.

Application testing involves running two programs on various platforms (Windows PC and Android). Both devices are linked to the same Wi-Fi network, allowing a connection to be created. Some of the things tested include the following: (1) The host can display the device's IP; (2) The remote can enter the IP address displayed on the host; (3) The host can identify when the remote is connected; (4) The host can identify local data; (5) The host can obtain weather data through the API; (6) The host can spawn (display) UI buttons based on the acquired data; (7) The remote can show UI buttons based on data from the host; (8) The host can recognize markers with the camera; (9) The remote buttons can show and remove 3D objects.

The Inbox WI-1 camera detects markers for computer input, which is used in testing. Experiments in application testing are repeated multiple times to demonstrate that the application system's performance can be consistent and reliable. The user performs a series of application trial processes that include the following steps.

First, the first experiment evaluates the "Latest Data Update" functionality by testing all application operations, including the Web API for database access. When the host starts a session, it checks if the folder contains a NameList.txt file. If not, the system uses the first GET function to retrieve the region name data. When the "Yes" button on the "Download the latest data?" option is hit, the system invokes another GET function to obtain weather data for each region. To determine whether the data was correctly downloaded, the system displays the data date (timestamp) included in the WeatherDetails.txt file.

Second, functionality Testing: the second experiment tests the "Use Old Data" functionality, which is then followed by all of the application's functions. In this experiment, the WeatherList.txt file was not erased to see if the system could detect it. The test results showed that all application

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functionalities were working properly, indicating that the first step of the experiment had been successfully stored and that the host application could recognize it. When the local file was successfully discovered, the application displayed the message "There is local weather data in this device" along with the date of detection.

Third, data conformity test, the third experiment involves a data conformance test. To determine whether the displayed data is appropriate, JSON data from the API is compared to 3D visualization results for each location. The data conformity test results reveal that the data acquired from the database via the API corresponds exactly to the data displayed by the 3D visualization. With a good data match, the information delivered to the audience is more accurate. Matching data assists the presentation team in validating the data.

4. Conclusions

Based on the findings of the research and testing, it is reasonable to conclude that the system established in this study performed satisfactorily from the database to host-client communication. The Data Downloader Program can be executed when the device is connected to the internet for testing purposes. If the internet connection is lost, the program cannot be run, and an error notice appears. The API for retrieving data from the database was successfully developed, as indicated by the data compatibility test results. The remote application produced with Unity and the Mirror SDK can execute if both devices are connected to the same local network. All buttons on the remote application correctly transfer commands to the host as long as both are connected and not disconnected during the session. The evaluation of the UI display on the host and remote applications remains unclear, and the use of marker-based AR is not always detectable by the camera.

Author Contributions

M. Zikky: Conceptualization, methodology, supervision, and writing – review & editing. R. Alexander: Data curation and visualization. Z. M. E. Darmawan: Investigation, software, and writing – original draft. F. M. Humaira: Formal analysis, funding acquisition, and validation. L. A. Safira:Project administration and resources.

Declaration of Competing Interest

We declare that we have no conflict of interest.

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