AUGMENTED REALITY TECHNOLOGY MOBILE APPLICATION HUMAN HEART ANATOMY

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Abstract

Apabila teknologi maju, augmented reality (AR) meningkatkan visualisasi data, termasuk ramalan cuaca. Aplikasi tradisional sering membentangkan data yang kompleks dalam format statik, menjadikan tafsiran sukar, terutamanya di kawasan dengan perubahan cuaca yang kerap. Projek ini menggunakan teknologi ar untuk mencipta aplikasi ramalan cuaca yang intuitif dan interaktif. Tumpuan projek ini adalah untuk menggabungkan data dan teknologi ar untuk membangunkan aplikasi ramalan cuaca untuk jumlah pengguna hololens. Saya akan menyelidik beberapa perisian ramalan cuaca yang terkenal atau serupa di pasaran dan membandingkan kekuatan dan kelemahan mereka dengan menganalisis dan menunjukkan mereka serta menambah baik dan menyelesaikan projek saya dengan membandingkan kekuatan dan kelemahan aplikasi sebelumnya. Objektif utama adalah untuk menyediakan data cuaca masa nyata yang mudah ditafsirkan, mengubah data kompleks menjadi graf yang mudah difahami. Kajian terdahulu telah menyerlahkan kelebihan ar dalam meningkatkan penglibatan pengguna dan pemahaman data yang kompleks, terutamanya dalam persekitaran yang kaya dengan data seperti ramalan cuaca. Aplikasi ini menyepadukan sambungan apis cuaca pihak ketiga atau bluetooth ke peranti lain, memastikan pengumpulan data cuaca yang tepat dan terkini, yang dipaparkan dalam antara muka intuitif dengan carta interaktif dan isyarat visual. Pengguna boleh mengawal apl dengan isyarat, ini akan membantu mereka memahami dengan lebih baik data yang telah mereka visualisasikan. Ini sejajar dengan penemuan mengenai kepentingan visualisasi data intuitif dalam meningkatkan penglibatan pengguna dan penarikan balik maklumat. Proses pembangunan akan mengambil pendekatan struktur pecahan kerja (WBS), dengan maklum balas pengguna pada setiap peringkat untuk memastikan reka bentuk dan fungsi memenuhi keperluan khusus khalayak sasaran. Visualisasi data ialah aspek utama projek ini, menawarkan cerapan tentang perubahan suhu, kelembapan, kelajuan angin dan penunjuk utama lain yang dibentangkan dalam grafik dan animasi carta yang menarik secara visual. Kaedah persembahan data cuaca yang dipermudahkan ini sejajar dengan penyelidikan terdahulu yang menunjukkan bahawa data visualisasi boleh menyokong membuat keputusan tepat pada masanya dalam konteks harian dan kecemasan. Dengan mengubah data cuaca yang kompleks kepada format yang mudah dan boleh diakses, aplikasi ini membolehkan pengguna membuat keputusan yang termaklum tentang kecemasan berkaitan cuaca dan perancangan harian. Projek ini akan menunjukkan peranan kritikal visualisasi data dalam meningkatkan penglibatan pengguna dan menyampaikan keadaan cuaca masa nyata melalui AR.

Abstract

As technology advances, augmented reality (AR) enhances data visualization, including weather forecasts. Traditional applications often present complex data in a static format, making interpretation difficult, especially in areas with frequent weather changes. This project utilizes AR technology to create an intuitive and interactive weather forecasting application. The focus of this project is to combine data and AR technology to develop a weather forecasting application for HoloLens user volume. I will research several well-known or similar weather forecasting software on the market and compare their strengths and weaknesses by analyzing and demonstrating them and improving and completing my project by comparing the strengths and weaknesses of previous applications. The main objective is to provide real-time weather data that is easy to interpret, turning complex data into easy-to-understand graphs. Prior studies have highlighted the advantages of AR in improving user engagement and comprehension of complex data, particularly in data-rich environments like weather forecasting. The application integrates third-party whether APIs or Bluetooth connectivity to other devices, ensuring the collection of accurate, up-to-date weather data, which is displayed in an intuitive interface with interactive charts and visual cues. Users can control the app with gestures; this will help them to better understand the data they have visualized. This aligns with findings from on the importance of intuitive data visualization in enhancing user engagement and information recall. The development process will take a Work Breakdown Structure (WBS) approach, with user feedback at each stage to ensure that design and functionality meet the specific needs of the target audience. Data visualization is a central aspect of this project, offering insights into temperature changes, humidity, wind speed, and other key indicators presented in visually appealing chart graphics and animations. This method of simplified weather data presentation aligns with previous research showing that visualized data can support timely decision-making in daily and emergency contexts. By transforming complex weather data into simple, accessible formats, the application enables users to make informed decisions about weather related emergencies and everyday planning. This project will demonstrate the critical role of data visualization in increasing user engagement and communicating real-time weather conditions through AR.

Keywords: Augmented Reality, Data Visualization, Hololens

1.0 INTRODUCTION

Technological advancements in the 21st century have revolutionized how people interact with digital information. Augmented reality (AR) and virtual reality (VR) are increasingly utilized in fields such as education, healthcare, and meteorology to provide interactive and immersive data visualization (Craig, 2013). In meteorology, AR holds significant potential for enhancing weather forecasting, which is crucial for travel planning, disaster preparedness, and agricultural decision-making. However, existing weather applications rely heavily on static text or 2D visuals, making it difficult for users unfamiliar with meteorological data to interpret (Chen, L, 2023).

This challenge is particularly prominent in Malaysia, a country characterized by its tropical climate and unpredictable weather patterns. Research highlights the challenges posed by sudden weather changes, which complicate planning for travelers, farmers, and city dwellers (Tang, 2018). Additionally, traditional weather applications often lack localized, real-time updates, limiting their usability (Tang, 2018).

To address these issues, advancements in AR technology present a promising solution. Research demonstrates that AR enhances data comprehension and user engagement by overlaying real-time information onto the real world (Dargan et al, 2023). By integrating AR into weather forecasting systems, users can gain dynamic, real-time insights into weather data, improving accessibility and decision-making.

This project aims to develop an AR-based weather forecasting application tailored for Malaysian users, leveraging Microsoft HoloLens to present localized, real-time weather data through interactive AR visualizations. The system will utilize third-party APIs like OpenWeatherMap to deliver accurate and timely weather updates (Malaysian Meteorological Department, 2022). This approach ensures that users, ranging from outdoor workers to farmers, can make informed decisions effectively and efficiently.

By integrating cutting-edge AR technology with real-time meteorological data, this project seeks to overcome the limitations of traditional weather applications and provide Malaysian users with a dynamic, immersive, and practical tool for weather forecasting.

2.0 LITERATURE REVIEW

Augmented Reality Weather Forecast Application

Augmented reality (AR) technology has increasingly been applied in mobile and wearable systems to enhance the visualization of real-time data, including weather information. By overlaying digital content onto the physical environment, AR allows users to intuitively interact with dynamic forecasts, improving understanding and engagement. Studies have shown that effective weather data visualization in AR requires not only accurate real-time data integration but also well-designed interaction models and visual clarity (Dargan et al., 2023; Jérémy Lacoche et al., 2022). However, challenges persist, particularly in systems running on resource-constrained devices like HoloLens, where high computational demands can affect performance and usability (Fang et al., 2023). To address these limitations, researchers have explored improvements in UX design, gesture-based controls, and the use of simplified 3D elements to reduce cognitive load. Incorporating feedback mechanisms and optimizing system responsiveness have also been identified as key to enhancing user satisfaction and ensuring broader adoption of AR in data-driven applications.

3.0 METHODOLOGY

This project follows the waterfall model of the Software Development Life Cycle (SDLC). The waterfall model is a linear and phased approach that ensures that each phase is completed before moving on to the next. The main phases are requirements analysis, design, development and testing.

3.1 Needs Analysis

In developing the AR-based weather visualization system on HoloLens, gathering and understanding user requirements is crucial to ensure that the system meets practical needs. The requirements were derived through interface sketches, test prototypes, and user interviews.

To start, a low-fidelity prototype was designed in Unity, including key elements such as the weather dashboard, UV index ring, wind speed chart, and region-switching panel like Figure 1 displays. This early prototype was shown to a small group of potential users—mainly students and travelers—who provided feedback on usability and interface clarity. Based on this feedback, several refinements were made, such as increasing the contrast of weather text, simplifying chart layouts, and improving gesture recognition.

Figure 1 Weather Dashboard

Additionally, existing weather applications (e.g., AccuWeather, Windy, and HoloMaps) were analyzed to identify strengths and weaknesses like Table 1 shows.

Table 1 Comparison Table of existing systems

Function	AccuWeather	Weather Channel	Apple Weather	Windy	HoloMaps
Real-Time Updates	have	have	have	have	have
Short-Term Forecast	have(120min)	have	have(minute)		
Radar/Maps	have	have	have	have	have
Safety Alerts		have	have		
Augmented Reality					have
Gesture Control					
Data Visualization	have(simple charts)	have(videos)	have(simple graph)	have (Detailed Maps)	have

Personalized Alerts	have	have	have (Custom Layers)	have

Users highlighted that traditional 2D apps often feel static and less intuitive, while AR-based visualization can provide more immersive and informative weather data. Insights gained from these apps helped shape core features like dynamic weather-based backgrounds, gesture-based navigation, and interactive 7-day forecasts.

The main user requirements identified are:

- Real-time weather updates with clear visualization of temperature, humidity, UV index, and wind speed.
- Interactive AR experience through HoloLens hand gestures (tap, swipe, pinch).
- Region switching to view weather data for different cities.
- Dynamic backgrounds and animations to reflect weather conditions.
- Instruction panel to guide first-time users.

3.2 Conceptual Model Design

The conceptual model defines the key components and interactions of the AR-based weather system:

- Weather Data Module: Retrieves real-time data (temperature, humidity, wind, UV index) from OpenWeatherMap API and parses it into Unity for visualization.
- Visualization Module: Displays data using interactive 3D charts, rings, and panels. Dynamic elements like moving clouds or sun animations reflect real-time conditions.
- Gesture Interaction Module: Enables control via HoloLens gestures, allowing users to switch regions, zoom into data, or open panels.

- Region Dashboard: Presents weather information for different locations in a clean and structured layout.

The system follows an MVC (Model-View-Controller) structure to keep the data flow organized. The Model handles API data, the View manages 3D UI elements, and the Controller interprets gesture inputs to update the interface. The interface like Figure 2 and Figure 3 displays.

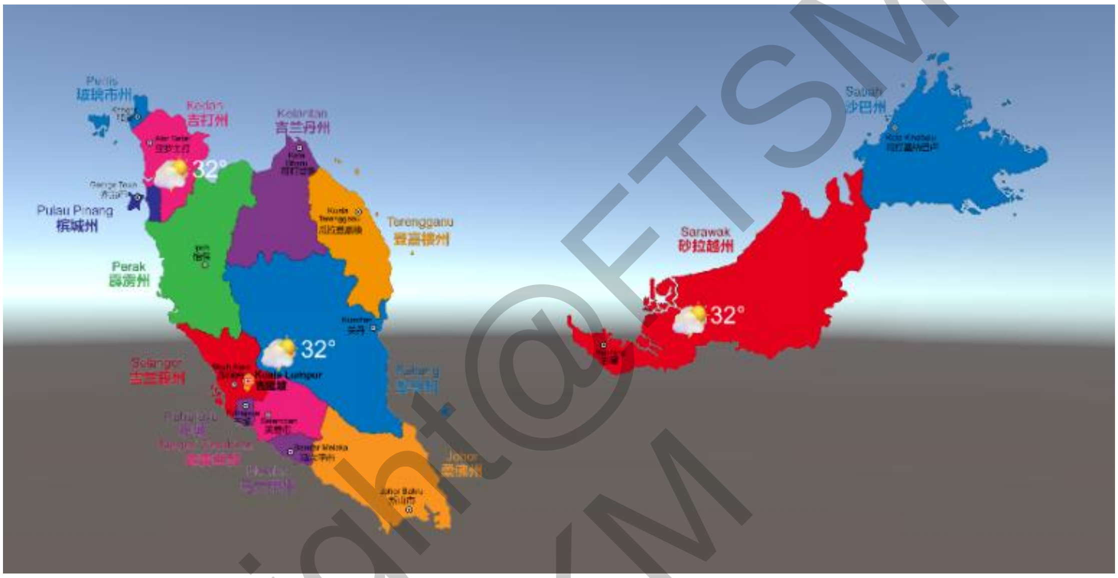


Figure 2 Main interface

Figure 3 Weather Dashboard interface

4.0 RESULTS

4.1 Application Development

Main Interface

The main interface of the system features a 3D interactive map of Malaysia, displaying real-time weather conditions for each state like Figure 4 displays. Users can view the current temperature and weather icons directly on the map, with state names display in both English and Chinese. By clicking on a state, the system navigates to a detailed weather page for that region, offering more in-depth data such as humidity, wind speed, and forecasts. This interface is designed using Unity and MRTK, combining spatial mapping with user-friendly interaction to enhance weather visualization.

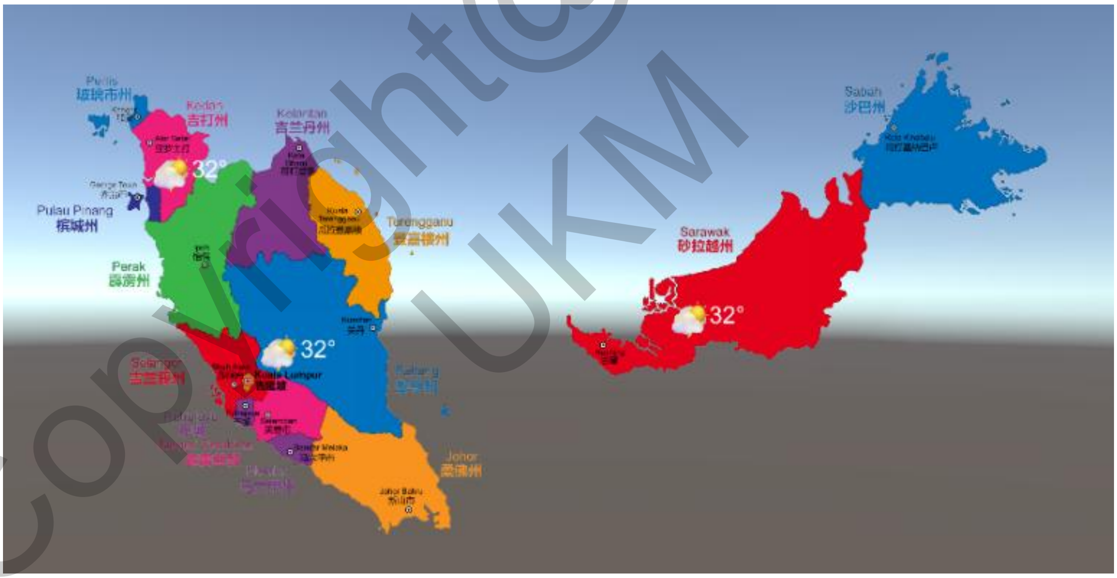


Figure 4 Main interface

Region Weather Dashboard

The Detailed Weather View presents localized weather information for the selected region, such as Kuala Lumpur. It displays the current date, time, temperature, and weather condition with a clear visual icon like Figure 5 shows. The interface includes a 7-day forecast panel, a daily suggestion message, and essential metrics such as humidity, UV index, rainfall, visibility, and "feels like" temperature. Sunrise and sunset times are also provided. The layout uses modern card-based design, making weather data easy to interpret briefly and enhancing user experience in an immersive AR environment.

Figure 5 Region Weather Dashboard

Dynamic Background Module

To enhance user experience and realism, the Detailed Weather View dynamically changes its background based on the current weather condition like Figure 6 shows. For example, on a sunny day, the interface features a bright and clear background with sunlight filtering through trees, while on a rainy day, it switches to a darker background with raindrop textures and stormy ambiance. This visual adaptation provides immediate contextual feedback, helping users intuitively feel the weather conditions beyond just numbers and icons.

Figure 6 Dynamic Background Module

Data visualization module

The Weather Metrics Visualization Module displays key environmental indicators using intuitive graphical elements like Figure 7 displays. Wind speed is shown with a combination of line and bar charts, allowing users to observe variations over time. The UV Index is visualized using a semi-circular gauge for quick risk assessment. Additionally, the Sunrise & Sunset panel offers a visual arc to illustrate daylight duration. These visualizations enhance user comprehension by transforming raw weather data into easy-to-read graphical insights within the regional weather view.

Figure 7 Data visualization module

Static Weather Info Module

The Static Weather Info Module presents key non-dynamic metrics to complement the real-time data like Figure 8 displays. It includes humidity percentage along with dew point information, visibility range with qualitative remarks, and "feels like" temperature that considers humidity effects. These static indicators provide users with a broader understanding of environmental comfort and safety, helping to interpret how weather conditions may physically feel beyond temperature alone.

Figure 8 Static Weather Info Module

7-Day Forecast Pane

The 7-Day Forecast Panel provides users with a quick overview of upcoming weather trends Figure 9 indicated. It lists daily high and low temperatures alongside corresponding weather icons for easy interpretation. Dates and weekdays are clearly displayed to help users plan ahead. This module enhances the application's utility by extending the weather insights beyond the current day, offering a concise yet informative long-term outlook.

Figure 9 7-Day Forecast Panel

4.2 Application Evaluation

The application was evaluated through a two-part testing process: functional testing and usability evaluation. Functional testing ensured that all core features, including real-time weather data display, gesture-based interactions, region switching, and background animations—performed as intended without critical errors. Each function was tested in multiple conditions on the HoloLens device to verify stability and responsiveness.

For usability evaluation, a group of users—including students, lecturers, and frequent weather app users—were invited to test the system. Participants interacted with features such as the instruction panel, UV index ring, wind chart, and city selection interface. A structured questionnaire was used to collect feedback on clarity, ease of use, responsiveness, and perceived usefulness.

The results indicated high level of user satisfaction, with all measured usability factors scoring above 4.5 out of 5. Users particularly appreciated the immersive design, clean data presentation, and smooth gesture interactions. Open-ended feedback highlighted suggestions such as improving text size, adding offline mode, and enhancing response time. These findings confirm that the system is both technically functional and well received by its target users.

i. Functional Testing

Region Switching

State Transition Testing (STT) is used to test the region switching function (Function ID: F002). This function allows the user to click on a specific region (e.g., “Selangor”) on the main weather map and navigate to a detailed weather view for that region. The system must update the view and data context accordingly. The state transition diagram (Figure 10) illustrates this behaviour, while Table 2 outlines the test coverage for this feature.

Table 2 Test Coverage for Region Switching (F002)

Test Coverage ID	Current State	Event	Action	Next State	Result
TCOV-02-001	Main View	User clicks on a region	Load selected region	Region Detail View	Pass

		button	weather data		
TCOV-02-002	Region Detail View	User clicks "Back to main"	Return to map view with all states	Main View	Pass
TCOV-02-003	Main View	User clicks invalid region	Nothing happened	Main View (unchanged)	Pass

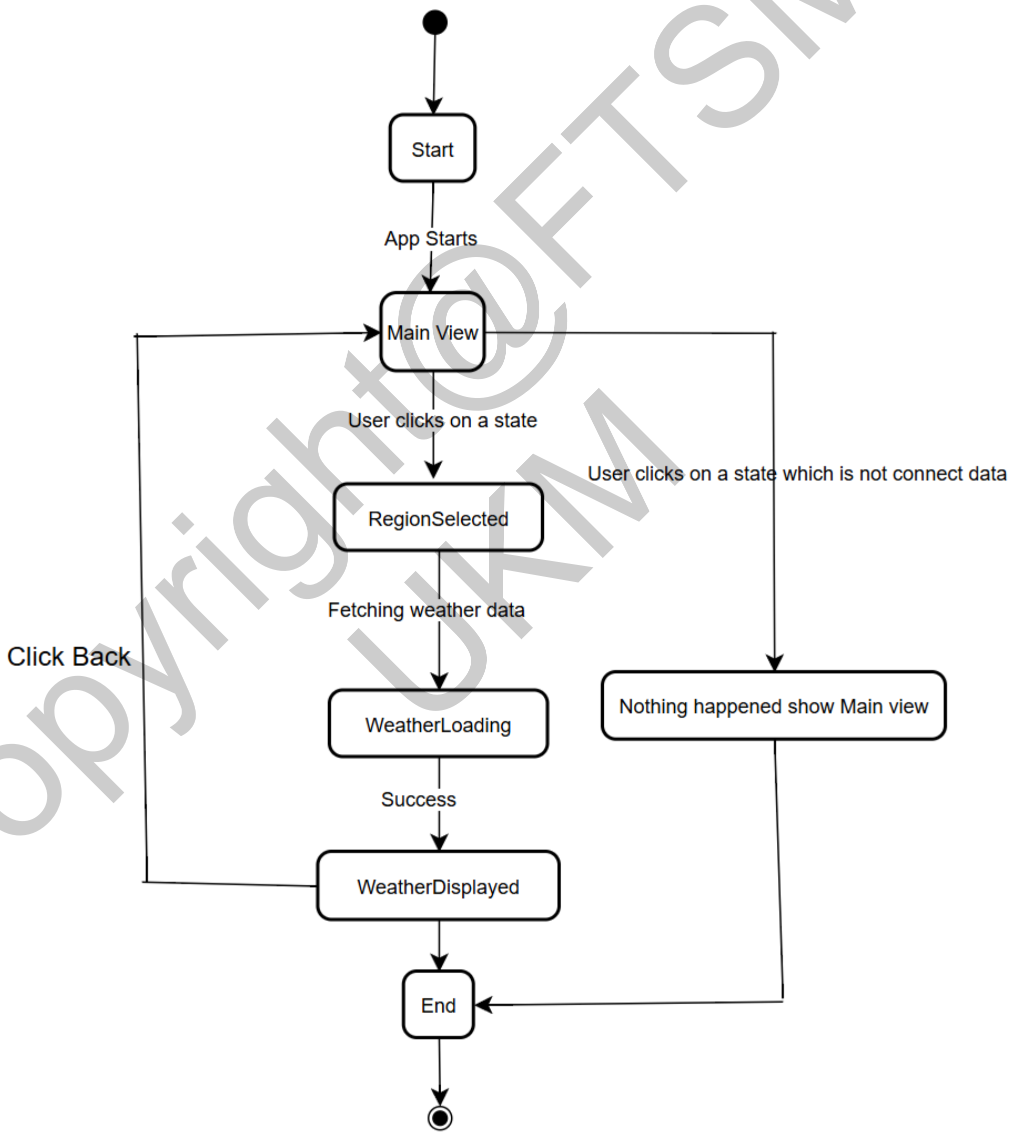


Figure 10 State Transition Diagram for Region Switching Function (F002)

Weather-Based Background Switching

This test verifies the system's ability to switch background visuals based on real-time weather data. Different weather conditions such as "Rain" or "Sunny" trigger changes in the displayed background. The following Figure 11 and Table 3 illustrate the state transitions and test coverage for this feature.

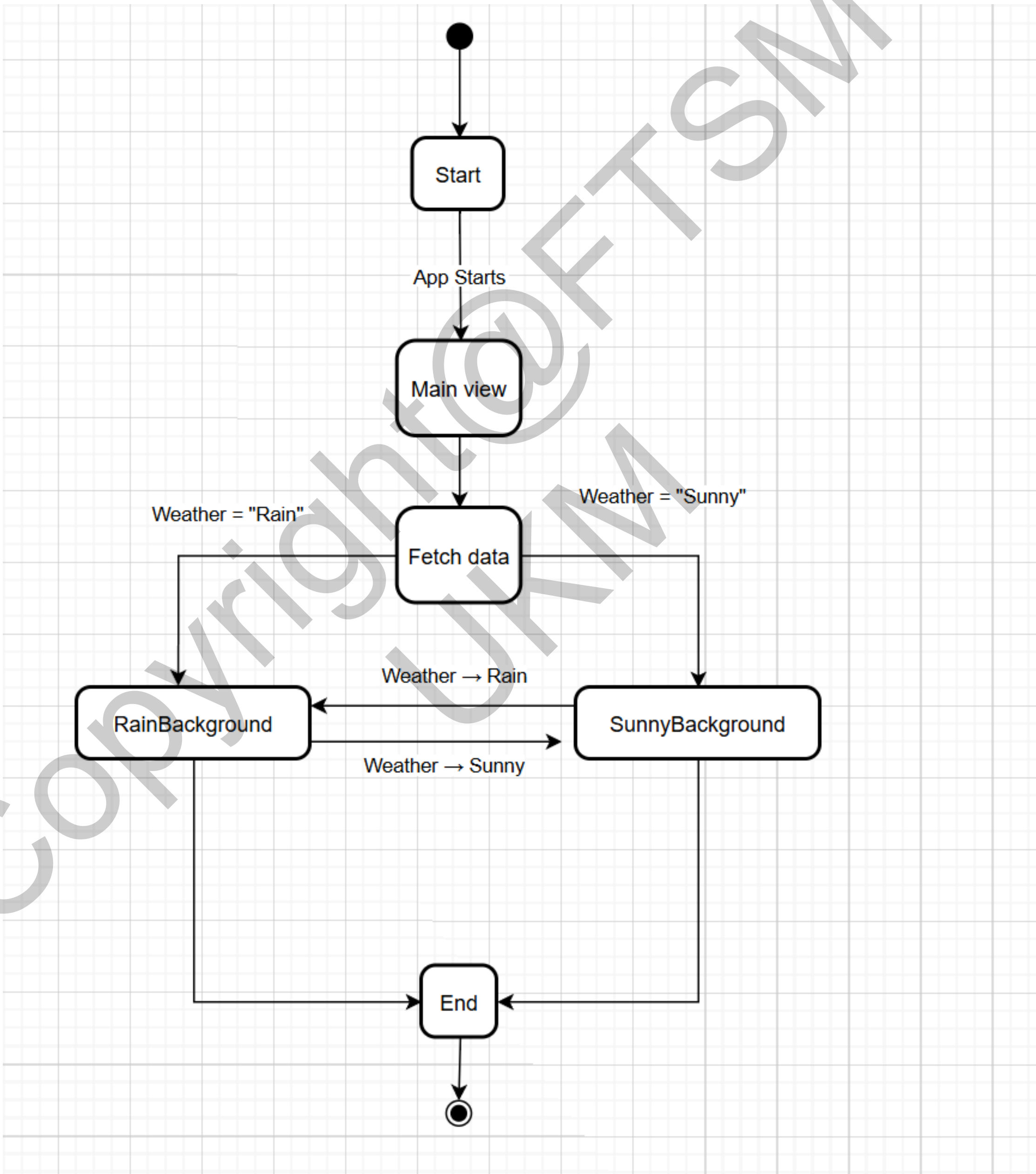


Figure 11 Background switch

Table 3 Test Coverage for Background Switching (F003)

Test Coverage ID	Current State	Event	Action	Next State	Result
TCOV-03-001	MainView	Weather = "Sunny"	Display sunny background video	SunnyBackground	Pass
TCOV-03-002	MainView	Weather = "Rain"	Display rain background video	RainBackground	Pass
TCOV-03-003	SunnyBackground	Weather changes to "Rain"	Switch from sunny to rain background	RainBackground	Pass
TCOV-03-004	RainBackground	Weather changes to "Clear"	Switch from rain to sunny background	SunnyBackground	Pass

Wind Speed Chart Visualization

This test verifies the wind speed chart's accuracy and stability like Table 4 showed. The system visualizes hourly wind data as vertical bars, highlighting the current hour to help users understand daily wind patterns.

Table 4 Wind speed chart(F006)

Test Coverage ID	Input Condition	Action	Expected Output	Result
TCOV-06-001	Valid wind data (e.g., [2,4,6])	Draw chart bars using fillAmount = wind/10	Bars drawn correctly relative to wind values	Pass
TCOV-06-002	Wind speed = 0	Try to draw with height = 0	Bar at 0 height, still visible	Pass
TCOV-06-003	Wind speed = 10	Draw chart with max fill	Bar fills to maximum height	Pass
TCOV-06-004	Current hour = 14	Highlight bar at index 14	Bar at 14 is brighter / colored differently	Pass
TCOV-06-005	User returns from another	Refresh chart	Chart reloads with updated	Pass

state	data

UV Index Ring

This test and Table5 verify that the UV index ring accurately reflects the data received from the weather API. The circular indicator should fill proportionally based on the UV value and handle edge cases such as missing or extreme data.

Table 5 UV Index Ring(F007)

Test Coverage ID	Input Condition	Action	Expected Output	Result
TCOV-07-001	UV Index = 0	Fill ring with 0%	Empty ring or minimal fill	Pass
TCOV-07-002	UV Index = 5	Fill ring to 50%	Ring half-filled	Pass
TCOV-07-003	UV Index = 10	Fill ring to 100%	Fully filled ring	Pass
TCOV-07-004	UV Index > 10	cap at max value	Ring capped at 100%	Pass
TCOV-07-005	UV Index data is missing	Invalid data	Ring updates with correct fill on re-entry	Pass

Weather Dashboard Display

This test verifies that the weather dashboard correctly aggregates and displays multiple weather indicators (temperature, UV index, wind speed, humidity) in a unified view. The dashboard should load all relevant modules successfully and update based on real-time data like Table 6 displayed.

Table 6 Test Coverage for Weather Dashboard

Test Coverage ID	Input Condition	Action	Expected Output	Result
TCOV-04-003	Valid API data	Load dashboard with multiple data	Dashboard modules load and display data	Pass
TCOV-04-004	One module fails load	Partial data shown	Display UI images	Pass

Non-Functional Testing (Performance & Usability)

This section covers non-functional aspects of the Weather Visualization System like Table 7 shows. Performance and usability are critical to user satisfaction and system reliability, especially when deployed on devices like HoloLens. The test verifies that key tasks are responsive and intuitive under normal usage.

Table 7 Test Coverage for Non-Functional Requirements

Test Coverage ID	Requirement	Input Scenario	Expected Behaviour	Result
TCOV-NF-001	Performance	User clicks a region on main map	Target view loads within 3 seconds	Pass
TCOV-NF-002	Usability	First-time user navigates UI	User completes task without guidance	Pass
TCOV-NF-003	Visual Responsiveness	Weather = "Rain"	Rain background and related UI display smoothly	Pass

TEST CASE SPECIFICATION

This section presents the key test cases for the Weather Visualization System, including inputs, expected outputs, and pass/fail criteria to ensure that all main features work as intended.

Environment

Tests were conducted on the Weather Visualization System using real-time and simulated data. The system was deployed and tested on HoloLens 2 and standard PC platforms. The specifications are listed below.

Table 8 Software & Hardware Specifications

Category	Specification
Operating Systems	Windows 10 (PC), HoloLens 2 (Windows Holographic)

Development Platform	Unity 2019.4.30 + MRTK
Weather API	OpenWeatherMap API, VisualCrossing API, Open-meteo API
Test Devices	PC (Mouse/Keyboard), HoloLens (Gesture Input)

Test Case

This section lists the test cases based on the test coverage defined earlier. Table 9 listed each test case includes the input, expected result, and the interface or module being tested to verify the system's functionality.

Table 9 Test Cases for Weather Visualization System

Test Case ID	Input	Expected Result	Interface / Module
TC-02-001	User clicks "Selangor" on main map	Navigate to Selangor weather page	Region Switching (F002)
TC-03-001	Weather = "Rain"	Rain background video plays, other visuals hidden	Background Display (F003)
TC-04-001	Wind data = [3,5, 7,…] (24h)	24 bar segments rendered, height relative to wind values	Wind Chart (F004)
TC-04-002	Wind data = [0, 0,…]	All bars at zero height, still visible	Wind Chart (F004)
TC-04-003	Real-time data	Dashboard shows wind, UV, temperature, humidity	Dashboard View (F004)
TC-05-001	UV Index = 7	Circular ring filled 70%	UV Index Display (F005)
TC-05-002	UV Index = null	Fill 0%	UV Index Display (F005)
TC-06-001	API returns valid data	Weather info displayed correctly	Data Fetch (F006)
TC-NF-001	User clicks region	Page loads within 3 seconds	System Performance
TC-NF-002	New user interacts with interface	Navigation is completed without external help	GUI Usability
TC-NF-003	API returns weather = "Rain"	Rain background shows smoothly, no glitches	Visual Display

TEST SUMMARY

This section summarises the testing of the Weather Visualization System. All 11 planned test cases covering key features like region switching, background updates, and data visualization were executed successfully with no major issues like Table 10 showed.

Table 10 Test Summary

Test Cases Planned	Test Cases Executed	Test Cases Passed	Test Cases Fai
11	11	11	**0**

ii. Usability Testing

PARTICIPANTS

The usability testing involved a total of seven participants like Table 11 shows, comprising six males and one female. Among these participants, five were students from the Multimedia program, while two were from the Information Science program. Additionally, five of them had prior experience with Augmented Reality and Virtual Reality (AR/VR) technologies, which provided more in-depth insights into the functionality of the developed application. One of the respondents was an academic staff member, while the remaining six were students.

The involvement of participants from both academic and technical backgrounds contributed valuable feedback, especially in evaluating the usability and effectiveness of the application not only in an educational setting but also in terms of its technical robustness, user interface design, and potential for future similar application.

Table 11 Participants

Gender/Experienced	Frequent	Proportion
Male	6	85%
Female	1	15%
Have AR/VR experiences	5	71%
Fresh of AR/VR	2	29%

INSTRUMENTS

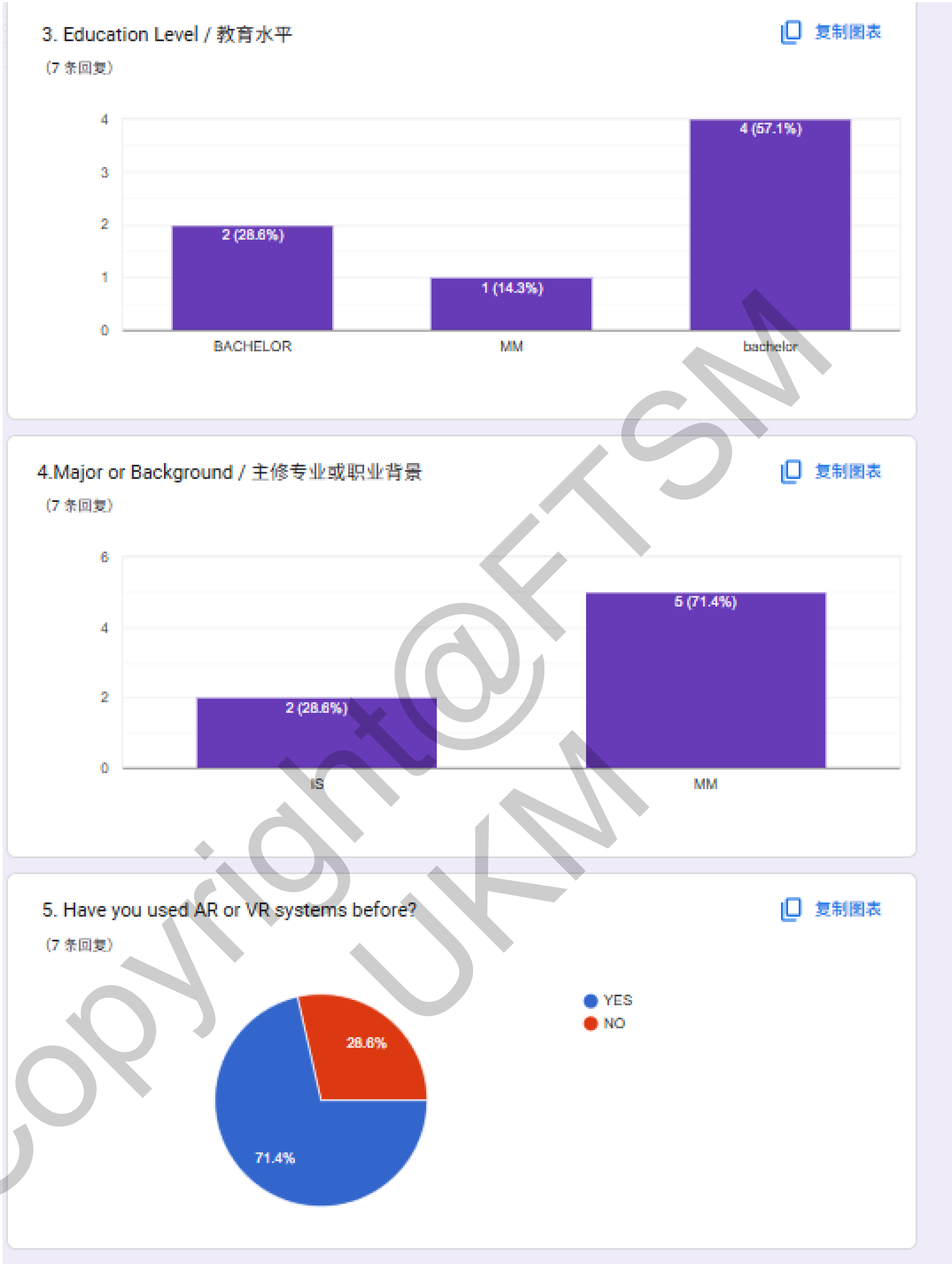
The research instrument consisted of a post-use questionnaire comprising eleven main questions like Figure 12, Figure 13, Figure 14, Figure15 show. These questions were designed to assess various aspects of application usability, including users' confidence in using the application, understanding of weather-related content, the effectiveness of the system in visualizing dynamic environmental data, and the users' willingness to continue using and recommending the application to others.

The questionnaire used a 5-point Likert scale: Totally Disagree, Disagree, Neutral, Agree, and Totally Agree. To measure changes in perception and user confidence toward the system, the questionnaire was administered twice — before and after the session of using the application.

All items in the questionnaire were developed with reference to validated usability evaluation frameworks and supported by credible sources (Lacoche et al., 2022; Craig, 2013; R Manimegalai et al., 2023) to ensure that the instrument was grounded in recognized usability assessment principles and methods.


Section A: Participant Information
1.Gender / 性别
复制图表
(7 条回复)
6
4
2
0
5 (71.4%)
1 (14.3%)
1 (14.3%)
FEMALE
MALE
male
2.Age / 年龄
复制图表
(7 条回复)
3
2
1
0
3 (42.9%)
1 (14.3%)
1 (14.3%)
1 (14.3%)
1 (14.3%)
21
22
23
34
IS

Figure 12


3. Education Level / 教育水平
(7 条回复)
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3
2
1
0
2 (28.6%)
1 (14.3%)
4 (57.1%)
BACHELOR
MM
bachelor
4.Major or Background / 主修专业或职业背景
(7 条回复)
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2 (28.6%)
5 (71.4%)
IS
MM
5. Have you used AR or VR systems before?
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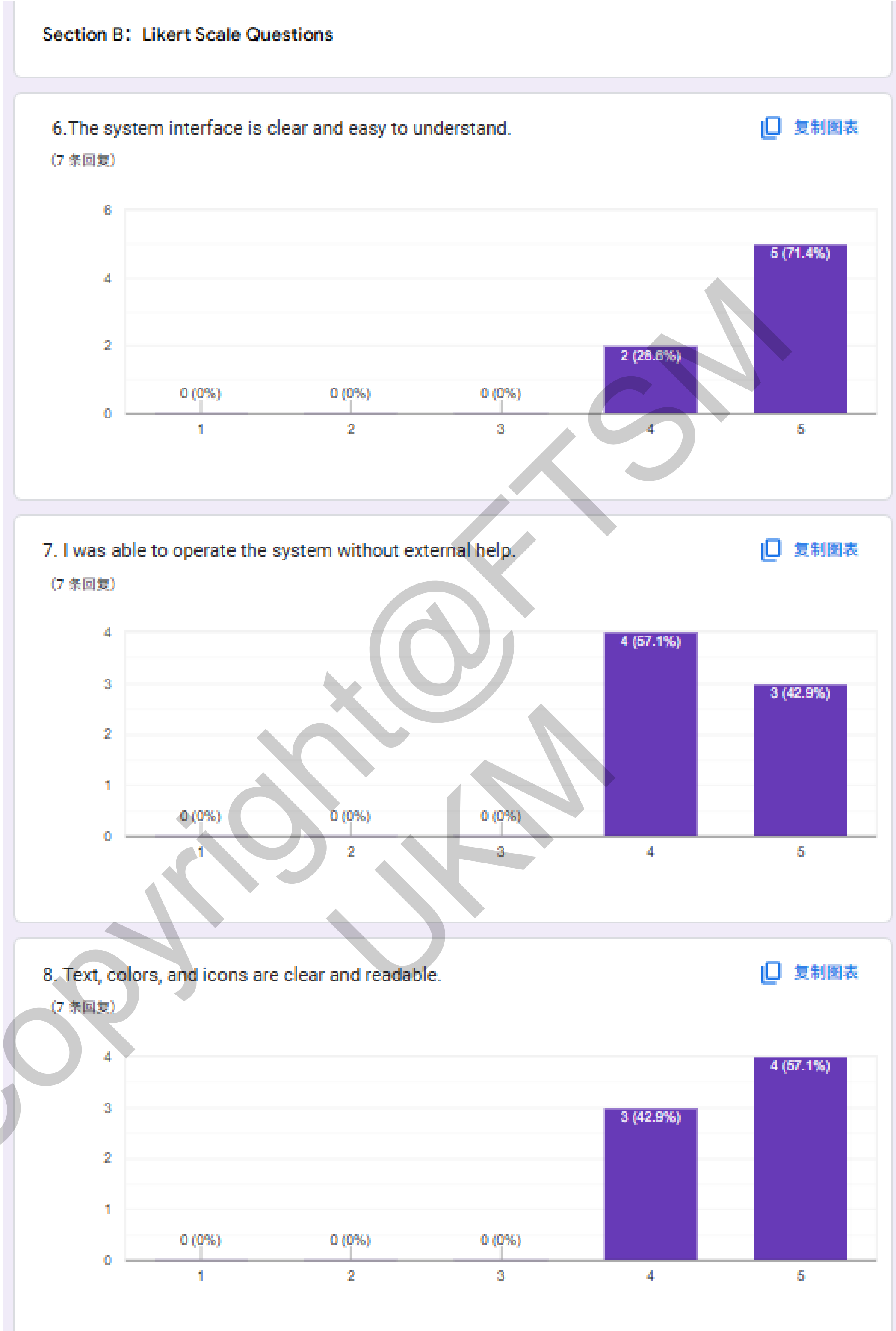
YES
NO
28.6%
71.4%

Figure 13


Section B: Likert Scale Questions
6.The system interface is clear and easy to understand.
(7 条回复)
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0 (0%)
0 (0%)
0 (0%)
2 (28.6%)
5 (71.4%)
1
2
3
4
5
7. I was able to operate the system without external help.
(7 条回复)
复制图表
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3
2
1
0
0 (0%)
0 (0%)
0 (0%)
4 (57.1%)
3 (42.9%)
1
2
3
4
5
8. Text, colors, and icons are clear and readable.
(7 条回复)
复制图表
4
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0 (0%)
3 (42.9%)
4 (57.1%)
1
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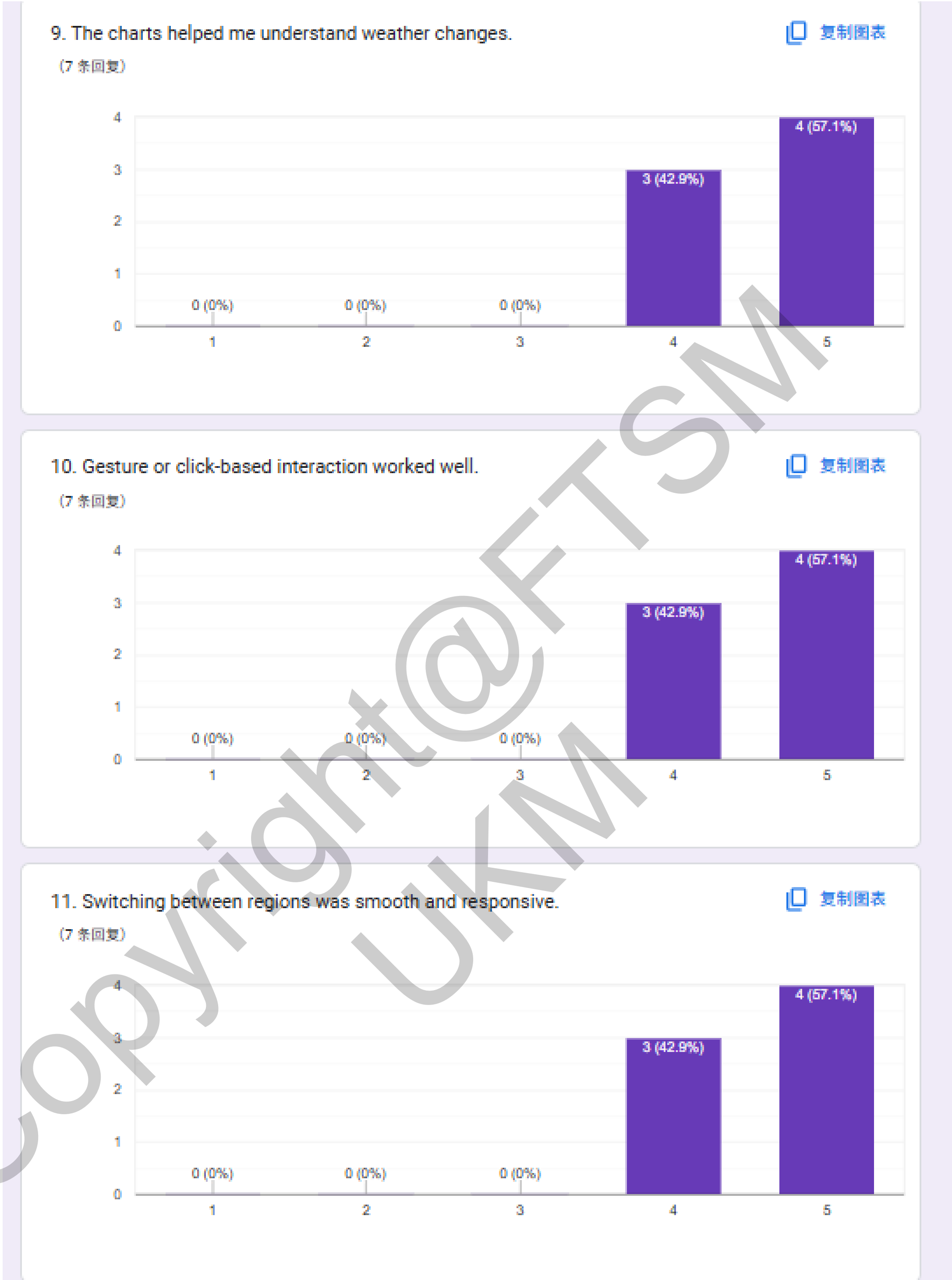
5

Figure 14


9. The charts helped me understand weather changes.
复制图表
(7 条回复)
4
3
2
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0
0 (0%)
0 (0%)
0 (0%)
3 (42.9%)
4 (57.1%)
1
2
3
4
5
10. Gesture or click-based interaction worked well.
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4
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0
0 (0%)
0 (0%)
0 (0%)
3 (42.9%)
4 (57.1%)
1
2
3
4
5
11. Switching between regions was smooth and responsive.
复制图表
(7 条回复)
4
3
2
1
0
0 (0%)
0 (0%)
0 (0%)
3 (42.9%)
4 (57.1%)
1
2
3
4
5

Figure 15

TESTING PROCEDURE

The usability testing was carried out at MyXLab, Faculty of Information Science and Technology (FTSM), Universiti Kebangsaan Malaysia (UKM). The session followed a structured process aimed at evaluating the usability and effectiveness of the AR-based Weather Forecast Application developed for Microsoft HoloLens.

At the start of the session, participants were given a brief overview of the study objectives and a demonstration of the key features of the application, including gesture-based interaction, weather data visualization in 3D, and user navigation in the HoloLens environment. Participants were also shown how to operate the device using hand gestures, gaze, and voice commands.

After the briefing, participants were asked to explore and interact with the application. During this hands-on session, they completed several tasks such as:

- Viewing current and forecasted weather data in AR
- Observing visual elements like temperature, wind speed, and UV index
- Observing dynamic background effects based on real-time weather conditions
- Navigating through multi-day forecasts using gesture input

Upon completing the interaction tasks, participants were required to complete a post-use questionnaire. This instrument was designed to capture their feedback on usability, interface clarity, confidence in using the system, and their overall experience with the application.

The session concluded with a brief open-ended discussion, where participants shared additional comments and suggestions regarding the strengths and potential improvements for the AR weather forecasting system.

USABILITY TESTING (BASED ON QUESTIONAIRE)

Table 12 shows strong user satisfaction based on questionnaire in the appendix A, with all usability factors scoring above 4.5. The highest-rated item was useful weather insights (4.9±0.31), and all standard deviations were low, indicating consistent feedback.

Table 12 Usability evaluation results

Factor	Mean±SD
The system interface is clear and easy to understand.	4.5±0.55
I was able to operate the system without external help.	4.8±0.41
Text, colours, and icons are clear and readable.	4.5±0.55
The charts helped me understand weather changes.	4.5±0.55
Gesture or click-based interaction worked well.	4.7±0.52
Switching between regions was smooth and responsive.	4.5±0.55
The system felt immersive and realistic.	4.7±0.52
Weather-based background changes enhanced the experience.	4.7±0.52
Weather data (temperature, humidity, etc.) was displayed accurately.	4.7±0.55
The system gave me useful and relevant weather insights.	4.8±0.41

To complement the quantitative evaluation, users were asked three open-ended questions to provide qualitative feedback. Table 13,Figure 16,Figure 17,Figure 18. summarize their responses, highlighting commonly praised features such as real-time alerts and data visualization, as well as challenges like occasional slow loading and difficulties with HoloLens usability. Users also suggested improvements including offline mode, faster responsiveness, and additional 3D or interactive elements to enhance the experience.

Table 13 Summary of Open-Ended User Feedback

Question	Key Themes from User Responses
Which feature did you like the most? Why?	- Real-time weather alerts and background visuals - Sunrise and UV index display - Wind speed column (useful for outdoor users) - Data visualization (charts and interaction)
Did you face any problems while using the system?	- Long loading times (overall and background-specific) - Some buttons respond slowly - Difficulty using HoloLens for first-time users - One user reported no issues
Any suggestions for improvement?	- Add more visualization elements and 3D models - Improve system response time - Include more regional options - Provide offline mode for poor connectivity areas

Section C：Open-ended Questions

16.Which feature did you like the most? Why?

（7 条回复）

The real-time weather alerts and background,they can remind me the weather

the data visualiztion,it is very visual

the background it looks cool

The UV index display it looks like fuels

The wind speed column it is useful for outdoor sports.

visualization part,it is interesting

the visualization way especially the sunrise

Figure 16

17.Did you face any problems while using the system?

（7 条回复）

no

sometimes load too long

the background sometimes upload too long

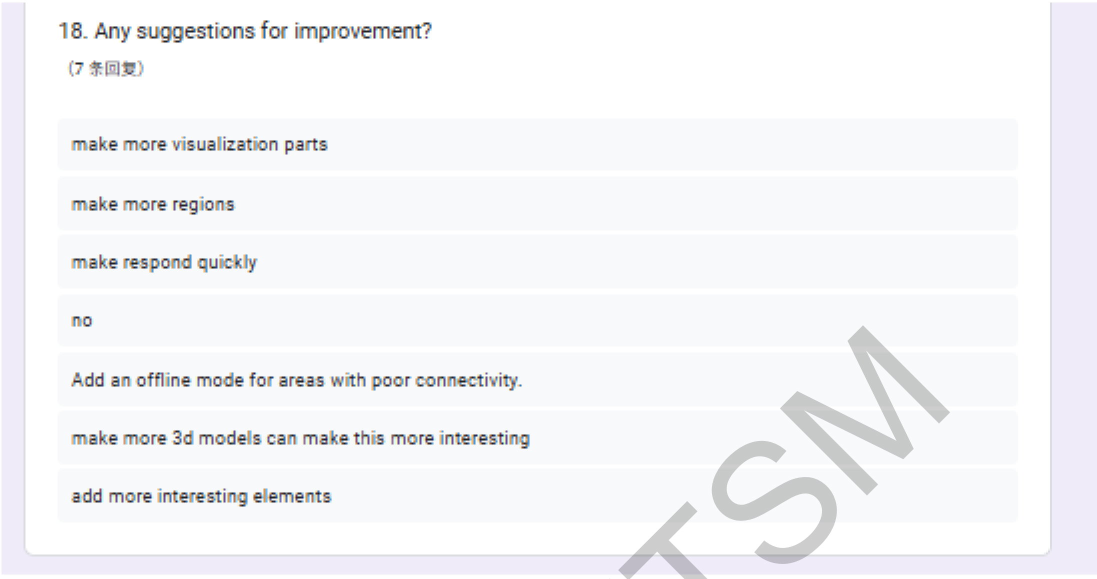
sometimes click load too long

sometimes the button respond slowly

hololens is hard to use for fresh

sometimes the hololens is hard to use

Figure 17


18. Any suggestions for improvement?
(7 条回复)

make more visualization parts

make more regions

make respond quickly

no

Add an offline mode for areas with poor connectivity.

make more 3d models can make this more interesting

add more interesting elements

. Figure 18

5.0 CONCLUSION

The Weather Visualization System successfully demonstrates the integration of augmented reality and immersive interface design to enhance user understanding of real-time weather data. Through comprehensive system-level testing, the application proved stable, accurate, and user-friendly across multiple key features, including region switching, dynamic background adaptation, and environmental data visualization. Functional testing confirmed the technical reliability of weather indicators such as UV index, wind speed, and 7-day forecasts, while usability testing revealed high user satisfaction, with average ratings exceeding 4.5 on all evaluated factors.

The application's design is supported by recent research which highlights the importance of AR in improving the accessibility and comprehension of environmental data (R Manimegalai et al., 2023; Dargan et al., 2023). Users found the system immersive and effective for daily weather interpretation, validating findings from studies that emphasize the potential of AR for real-time, data-driven visual communication (Lacoche et al., 2022; Craig, 2013). Moreover, incorporating weather APIs and gesture-based interaction through HoloLens aligns with current trends in human-centric AR systems (Fang et al., 2023; Lee et al., 2022).

The challenges of localized weather forecasting in Malaysia—such as short-term variability and urban microclimates—further reinforce the need for intuitive and dynamic visual systems like this (Amira, 2022; Tang, 2019). By leveraging augmented reality to visualize climate risks (Mora et al., 2017) and enhance awareness, the system also holds promise for use in education, tourism, public safety, and smart city management.

Overall, this project validates the potential of immersive AR applications in delivering real-time weather data through intuitive and interactive platforms, reflecting both technological innovation and practical utility.

6.0 APPRECIATION

FACULTY INFORMATION SCIENCE AND TECHNOLOGY and MyXLab.

7.0 REFERENCES

amira. (2022). *The Challenges of Weather Forecasting in Malaysia | IBNU SINA INSTITUTE*. Research.utm.my. https://research.utm.my/isi-sir/the-challenges-of-weather-forecasting-in-malaysia

Chen, L., Han, B., Wang, X., Zhao, J., Yang, W., & Yang, Z. (2023). Machine Learning Methods in Weather and Climate Applications: A Survey. *Applied Sciences*, *13*(21), 12019. https://doi.org/10.3390/app132112019

Fang, W., Zhang, T., Chen, L., & Hu, H. (2023). A survey on HoloLens AR in support of human-centric intelligent manufacturing. *Journal of Intelligent Manufacturing*. https://doi.org/10.1007/s10845-023-02247-5

Huang, R., Fang, C., Qiu, K., Cui, L., Dong, Z., Zhu, S., & Tan, P. (2021). AR Mapping: Accurate and Efficient Mapping for Augmented Reality. *ArXiv:2103.14846 [Cs]*. https://arxiv.org/abs/2103.14846

Kieran Healy, K. (2019). Data visualization: A practical introduction. Princeton University Press. https://press.princeton.edu/books/hardcover/9780691181615/data-visualization

Lee, R., Park, S., Jung, S., & Kim, J. (2022). *Quality-Aware Real-Time Augmented Reality Visualization under Delay Constraints*. ArXiv.org. https://arxiv.org/abs/2205.00407?utm_source

Mora, C., Dousset, B., Caldwell, I. R., Powell, F. E., Geronimo, R. C., Bielecki, Coral R., Counsell, C. W. W., Dietrich, B. S., Johnston, E. T., Louis, L. V., Lucas, M. P., McKenzie, M. M., Shea, A. G., Tseng, H., Giambelluca, T. W., Leon, L. R., Hawkins, E., & Trauernicht, C. (2017). Global risk of deadly heat. *Nature Climate Change*, *7*(7), 501–506. https://doi.org/10.1038/nclimate3322

Nama, P., Bhoyar, M., & Chinta, S. (2024). AI-powered edge computing in cloud ecosystems: Enhancing latency reduction and real-time decision-making in distributed networks.

Well Testing Journal, 33(S2), 45–62. https://welltestingjournal.com/index.php/WT/article/view/109

R Manimegalai, S Arawind, G V Sri Rajiv Jegan, & B Gomathi. (2023). *ARWeather: Weather Forecasting and Visualization using Augmented Reality*. 585–590. https://doi.org/10.1109/iciscois56541.2023.10100520

Ramaseri Chandra, A. N., El Jamiy, F., & Reza, H. (2019). Augmented Reality for Big Data Visualization: A Review. *2019 International Conference on Computational Science and Computational Intelligence (CSCI)*. https://doi.org/10.1109/csci49370.2019.00238

Tang, K. H. D. (2019). Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. *Science of the Total Environment*, *650*(2), 1858–1871. https://doi.org/10.1016/j.scitotenv.2018.09.316

Tang, K. H. D. (2019). Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. *Science of the Total Environment*, *650*(2), 1858–1871. https://doi.org/10.1016/j.scitotenv.2018.09.316

Yip Weng Sang, Diong Jeong Yik, Nursalleh K. Chang @ bin Kassim, Muhammad Firdaus Ammar bin Abdullah, Fadila Jasmin binti Fakaruddin, Woo Wang Chun and Wong Wai Kin Malaysian Meteorological Department. (2022). Radar Integrated Nowcasting System (RaINS): Advancements and limitations. Retrieved from https://www.met.gov.my/data/research/researchpapers/2023/TN02_2023.pdf

Craig, A. (2013). Understanding Augmented Reality : Concepts and Applications. Elsevier Science.

Dargan, M. S., Kumar, G., & Balakrishnan, R. (2023). Augmented reality for smart environments: Trends, challenges, and future prospects. Springer Journal of Advanced Computational Sciences, 45(1), 23–37. https://link.springer.com/article/10.1007/s11831-022-09831-7

Lacoche, J., Villain, E., & Foulonneau, A. (2022). Evaluating Usability and User Experience of AR Applications in VR Simulation. Frontiers in Virtual Reality, 3. https://doi.org/10.3389/frvir.2022.881318

Laman Web Rasmi Jabatan Meteorologi Malaysia. (n.d.). www.met.gov.my. https://www.met.gov.my

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