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Mobile App for Tours & Travels with AR/VR

Submitted by: Wei Haoran
Matriculation Number: U1822972L

Supervisor:
Assoc Prof Wei Lei

School of Electrical & Electronic Engineering

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Abstract

Rising technology has created new chances for tourism in Singapore under the pandemic. This paper will showcase *HiSG*, a new travel smartphone app that blends augmented reality technology and virtual reality photography to improve users' experience and increase their passion for traveling in Singapore.

The app is built with the Flutter user interface framework, and the Wikitude SDK offers geographical information based augmented reality functionalities. Google Cloud Platform hosts the backend authentication, database, and storage services. The Google Maps Platform and the Tourism Information & Service Hub application programming interfaces are used to support some of the data and functionality in this project.

This report discusses the project's objectives, literature review, and the design and implementation of the technology stack and the application functionalities. Finally, an analysis of the learning outcomes and project management is presented.

Acknowledgement

I would like to thank Assoc Prof Wei Lei, this project’s supervisor, for providing me with this excellent opportunity to study and practice mobile application development skills through this project “Mobile App for Tours & Travels with AR/VR.”

Dr Penny de Byl of Holistic 3D, the instructor of the Udemy course “A Beginner’s Guide to Augmented Reality with Unity”, deserves special thanks. Her education introduced me to the realm of augmented reality application creation.

I would like to express my gratitude to the Wikitude community for answering my questions and making valuable suggestions regarding the Wikitude Flutter plugin.

It is critical to acknowledge the Tourism Information & Services Hub (TIH) and its partner, the National Communications System (NCS) Group, for their assistance. In addition, I want to express my gratitude to Mr Chua Saw Cheng Andreas from NCS, who allowed me to use TIH resources and helped troubleshoot access issues.

Finally, I would like to express my heartfelt gratitude to my friends. Their ideas and suggestions have been influential in leading me through this project.

Acronyms

AWS	Amazon Web Services
API	Application Programming Interface
AR	Augmented Reality
ATM	Automated Teller Machine
CSS	Cascading Style Sheets
CSP	Cloud Service Provider
CDN	Content Delivery Network
COVID-19	Coronavirus Disease 2019
DMS	Database Migration Service
DSLR	Digital Single-lens Reflex
EC2	Elastic Compute Cloud
ECS	Elastic Container Service
XML	Extensible Markup Language
GPS	Global Positioning System
GCP	Google Cloud Platform
GUI	Graphical User Interface
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
IaaS	Infrastructure as a Service
IDE	Integrated Development Environment
JSON	JavaScript Object Notation
LRT	Light Rail Transit
MRT	Metro Rail Transit
NCS	National Career Service
No-SQL	Not Only SQL
OS	Operating System
PaaS	Platform as a Service
POI	Point of Interest
RDS	Relational Database Service

S3	Simple Storage Service
SaaS	Software as a Service
SDK	Software Development Kit
SDLC	Software Development Life Cycle
SQL	Structured Query Language
3D	Three Dimensional
TIH	Tourism Information & Services Hub
2D	Two Dimensional
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
UX	User experience
UI	User Interface
VM	Virtual Machine
VPS	Visual Positioning Service
VR	Virtual Reality

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Chapter 1

Introduction

This chapter includes the project's background, motivation, objectives, and scope, "Mobile App for Tours & Travels with AR/VR.".

1.1 Background and Motivation

Whether looking for new flavours or exploring new territories, Singapore is always one of the top destinations for international travellers. With the world's biggest indoor waterfall, most extensive orchid garden, and first night-time zoo [1], Singapore's tourism receipt reached S$27.6 billion for 2019. [2]

Then, the year 2020 came. Due to the threat of the COVID-19 pandemic and increased border control measures, the number of overseas visitors to Singapore has decreased by nearly 85% compared to 19.2 million in 2019 [3, 4]. The tourist industry in Singapore is facing unprecedented problems. Increasing local travel demand becomes an essential workaround.

Opportunities for tourism hide in technology. With the rise and popularity of mobile devices, 88.43% of the population in Singapore lived with smartphones as of 2020. [5] New technologies such as augmented reality (AR) and virtual reality (VR) may be an excellent way to make daily experiences more appealing [6]. To restore the prosperity of tourism in Singapore by way of integrating AR and VR into a mobile application is the main idea of this project.

1.2 Objective and Scope

Building a tourism guide mobile application designed for visitors and residents in Singapore is the primary goal of this project. VR and AR technologies will provide a more enjoyable and immersive experience to the application's users. Other application features include itinerary planning, itinerary recommendation, and point-of-interest searching.

The deliverable of this project is an Android application called *HiSG*. This application's tourism resources and guides are customized for people interested in travelling in Singapore only, not for other countries worldwide.

Chapter 2

Literature Review

2.1 Mobile Application Development

This section includes the basic knowledge about modern mobile application development, including types of mobile applications and the life cycle of software development.

2.1.1 Types of Mobile Apps

There are three types of mobile applications [7]: native apps, hybrid apps and web apps.

2.1.1.1 Native Apps

Native apps are applications people usually refer to when talking about mobile applications available in app stores. The term “native” means the app is built for a specific platform, whether iOS, Android, or others. Native apps can work more swiftly and naturally because it was created exclusively for the platform.

2.1.1.2 Web Apps

Web apps are built on a website, and they can be accessed from mobile devices of different operating systems with a web browser. To fit a variety of screen sizes, responsive and adaptive website design techniques are usually adopted. [8] Web apps cannot be downloaded from the app store and installed permanently on a device. Compared with native apps, web apps have less control of the devices’ hardware. [7]

2.1.1.3 Hybrid Apps

As its name implies, a hybrid app is a hybrid of native and web applications. Hybrid apps are web apps wrapped in the shell of native software. HTML5 is often the primary programming language. Hybrid apps are popular among developers because they save time writing code for various systems. [9]

2.1.2 Software Development Life Cycle (SDLC)

The Software Development Life Cycle (SDLC) is introduced for creating high-quality software with well-defined procedures. According to the SDLC methodology, there are six phases of software development: Requirement analysis, planning, architectural design, development, testing and deployment. [10]

SDLC can achieve a high management control and documentation level if implemented correctly. All stakeholders and developers clearly understand the plan, goal and process of developing the products. Agile is one of the popular modern approaches to ensure that SDLC is adopted efficiently in a development team. [11]

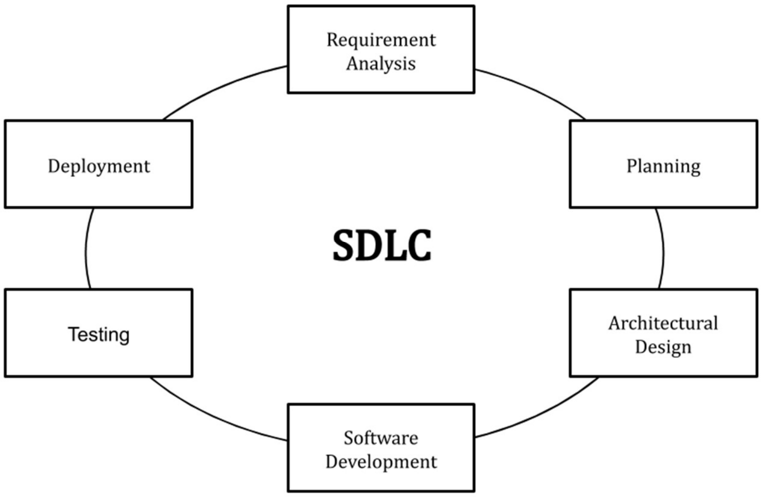


Figure 1. Graphic illustration of Software Development Life Cycle
Source: Adapted from [11]

2.2 Application Development Framework

This section describes the definition of an application framework and lists two examples of popular development frameworks: React Native and Flutter.

2.2.1 Introduction to Application Development Framework

A software library that offers a fundamental structure to facilitate the development of applications for a particular environment is known as an application framework. An application framework serves as the backbone of an application. [12]

The invention of application frameworks aims to lessen the difficulties during the development process. The main objective of an application framework is to share reusable code among several modules of an application.

Application frameworks are utilized to develop graphical user interfaces (GUIs) and web-based applications.

2.2.2 Popular Mobile Application Frameworks

In a survey of 2021, the top 5 favoured cross-platform mobile application frameworks [13] were: Flutter by Google, React Native by Meta (formally called Facebook), Apache Cordova [14], Ionic [15] and Xamarin by Microsoft [16].

This section will dive into the top 2 frameworks, i.e., Flutter and React Native.

2.2.2.1 React Native (17-20)

React Native is a mobile app development framework for creating Android and iOS applications. [17] Before introducing how React Native works, we should first talk about React.

React (or React JS) is an open-source JavaScript library to create user interface (UI) components. [18] A React component can be a simple component or a stateful component. Either a simple or stateful component can display UI components according to the data input, but a stateful component has its internal state variables. [19] The UI display will refresh if the value of a state variable is changed.

React Native is the framework that makes the development and maintenance more efficient. With one code base of JavaScript to build React UI components, React Native renders it into native iOS and Android UI in a declarative way [20]. The primary React component is called a view.

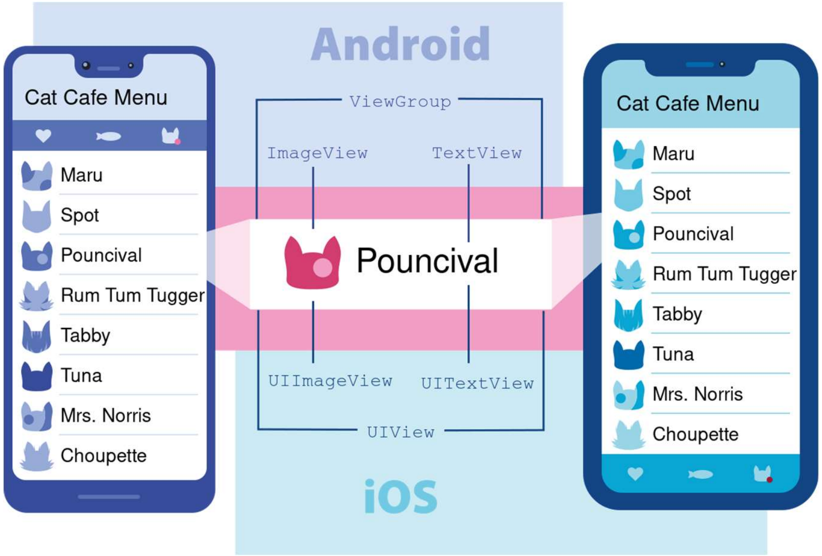


Figure 2. Example of a React view group in iOS and Android apps
Source: Adapted from [20]

2.2.2.2 Flutter

Flutter is a user interface (UI) toolkit that allows developers to construct native apps for mobile, web, desktop, and embedded devices using a single code base. [21] Dart is the programming language for the Flutter framework. [22]

A widget is a UI block in Flutter. Similar to React Native's simple and stateful components, Flutter has stateless and stateful widgets [23]. A Flutter app can adopt Material or Cupertino design styles. A Material app can be rendered natively to any platform, while a Cupertino app is specifically designed according to Apple's Human Interface Guidelines for iOS [24].

2.3 Application Integration and Data Collection

This section lists two ways to utilize valuable resources from other applications: Application Programming Interface (API) and Software Development Kit (SDK). This section also includes a way to collect data from public websites, which is web scraping.

2.3.1 Application Programming Interface (API)

Application Programming Interface (API) is an intermediary that enables data transmission between two programs. With API, an application can send structured remote requests and then receives the responses from another application. [25] By analogy, we might think of API as a waiter in a restaurant. A party of the communication, which is the customer, tells the waiter what he wants for a meal. Then the waiter sends the customer's order to the other party, the kitchen. When the food is ready, the waiter returns to the customer with the food, which is the response. [26]

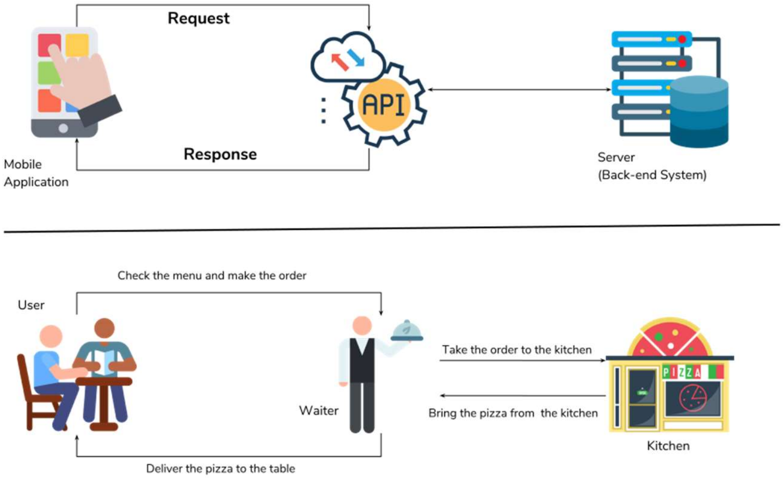

Request
API
Mobile
Application
Response
Server
(Back-end System)
Check the menu and make the order
User
Waiter
Take the order to the kitchen
Bring the pizza from the kitchen
PIZZA
Kitchen
Deliver the pizza to the table

Figure 3. How an API works with an example
Source: Adapted from [26]

API makes the development of applications easier and faster. Developers can gather helpful resources and integrate new components swiftly through an API so that the companies can focus more on their business goals.

API facilitates the cooperation between technology companies. There are three release policies of API: private, partner, and public, which indicates the scope of usage of the API release. [27]

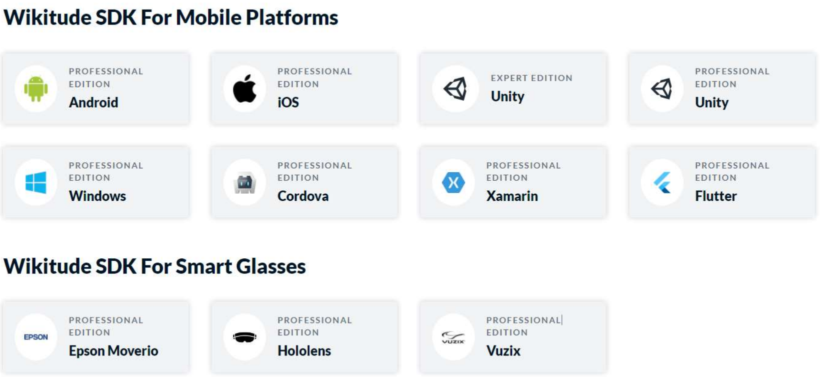
2.3.2 Software Development Kit (SDK)

A software development kit (SDK) is a toolkit to help programmers develop applications for a specific platform, programming language, or operating system (OS). Applications created with SDK can connect to another program and directly use the pre-built functionalities from the SDK. [28]

A typical SDK may include a compiler, a debugger, IDE, code libraries, code samples and documentation. Multiple APIs are often included in the SDK. [29]

Some mobile apps downloaded from the app store display advertisements from Google to earn profits, which is a use case of Google Mobile Ads SDK. [30]

Manufacturers of platforms or services often offer SDKs for different developing frameworks, OS, and programming languages. For example, Wikitude, an augmented reality (AR) development platform, provides SDKs for different OS frameworks and different smart glasses brands [31].



Wikitude SDK For Mobile Platforms

PROFESSIONAL EDITION Android	PROFESSIONAL EDITION iOS	EXPERT EDITION Unity	PROFESSIONAL EDITION Unity
PROFESSIONAL EDITION Windows	PROFESSIONAL EDITION Cordova	PROFESSIONAL EDITION Xamarin	PROFESSIONAL EDITION Flutter

Wikitude SDK For Smart Glasses

PROFESSIONAL EDITION Epson Moverio	PROFESSIONAL EDITION Hololens	PROFESSIONAL EDITION Vuzix

Figure 4. SDK provided by Wikitude
Source: Adapted from [31]

2.3.3 Website Data Scraping

2.3.3.1 Introduction to Web Scraping

Website data scraping is a common technique to gather data of interest by people or organizations for analytics or decision-making purposes [32].

The process of website data scraping generally consists of two steps: extracting public data from a vast number of websites and then storing it in a structured format, usually JSON [33] or XML [34].

Although most data extracted from websites are publicly accessed, it may become offensive or even illegal if individuals or companies use it to steal personal information from users or engage in unfair competition [35].

2.3.3.1 Web Scraping with Python

Python is a preferred language to implement the process of web scraping [36] because of its dynamic-typed variable, compact and scripting-based coding style and various libraries for data processing, aggregation and visualization, such as Numpy [37], Matplotlib [38] and Pandas [39]. Requests, Beautiful Soup and Selenium are popular Python libraries for web scraping.

Requests

Requests is a Python library to send HTTP/1.1 requests to a website's server [40]. POST, GET or PUT method requests [41] can be executed with headers, parameters, and request body specified in the code. After the website server handles the request, a response is returned with a status code and body content containing valuable data.

Beautiful Soup

Beautiful Soup is a Python package for parsing HTML and XML files and extracting data. [42] It can deal with the HTML body from the raw response of an HTTP request. Information such as inner text, attributes, and hyperlinks can be easily extracted from raw HTML elements by the Beautiful Soup library.

Selenium

Selenium is a library initially designed for testing web applications, while nowadays, it is also commonly used for web browser automation and web data extraction [43]. Unlike Requests and Beautiful Soup, Selenium simulates human activities on a web page via a web driver [44]. When running a program with Selenium, a web browser controlled by code is opened, and human-like actions are performed, such as scrolling down the window or clicking on a button. It searches and manipulates web elements better than Beautiful Soup on dynamic or anti-scraping websites.

2.4 Development with Augmented Reality (AR)

This chapter will define the concept of augmented reality (AR), list AR SDK's major features with examples of existing AR integrated applications and introduce three examples of AR development tools: ARKit, ARCore, and Wikitude.

2.4.1 Definition of Augmented Reality

Augmented reality (AR) is a technology that allows designers to add computer-generated input to sections of a user's actual surroundings. Designers build digital material inputs that adapt instantaneously to changes in the user's environment, such as geographical location and heading direction, ranging from audio and video to graphics and GPS overlays [45].

Unlike virtual reality (VR), which isolates users from the real-world view, AR is just an add-on interface to users' physical surroundings [46].

2.4.2 AR Features and Examples

2.4.2.1 Image Tracking

Image tracking is an AR feature detecting and tracking 2D pictures based on the image recognition technology in computer vision [47]. The multiple target feature means the app can track multiple images simultaneously [48]. The 2D picture input is a marker or trackable. 2D or 3D objects on the marker are called overlays [49].

Cloud recognition enables the hosting of thousands of markers for tracking with metadata information to retrieve from the cloud upon recognition of images [50]. Cloud recognition significantly reduces the local storage size and benefits applications with an extensive collection of markers.

An example of the image tracking feature is Disney's colouring book. It allows real-time augmented display of 3D cartoon characters with painted colour and texture on its colouring book [51].

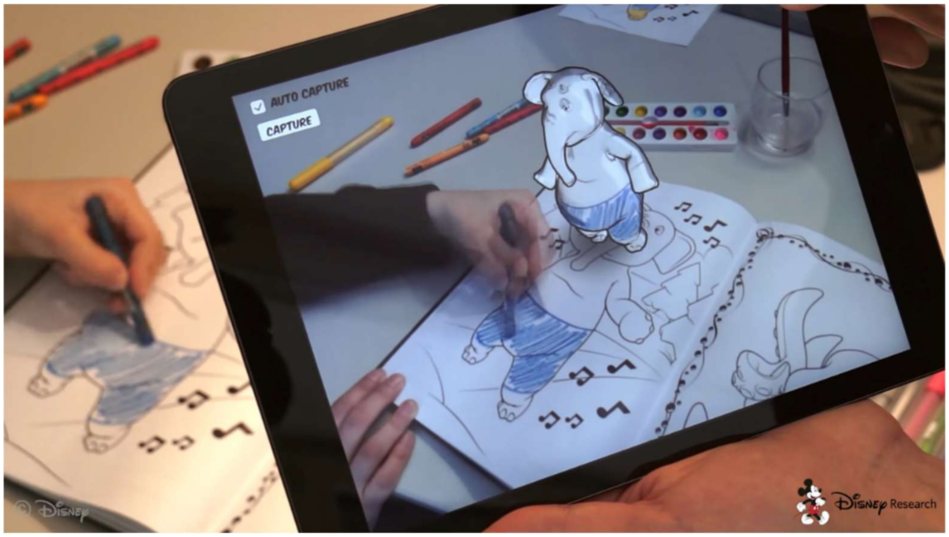


Figure 5. Demonstration of Disney's colouring book with AR
Source: Adapted from [51]

2.4.2.2 3D Object Tracking

3D object tracking is an AR feature based on deep learning, which allows tracking an object with the camera and the object moving. An estimated bounding box is generated to fit the moving object, and a segmentation mask indicates the object's actual shape projected in the camera view [52].

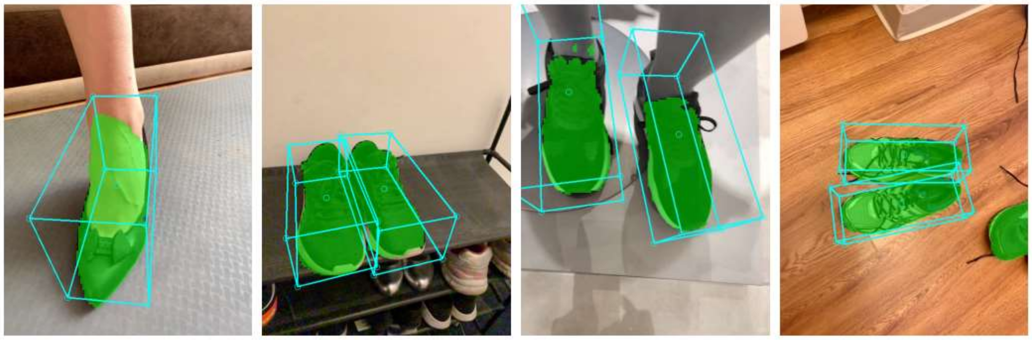


Figure 6. Demonstration of 3D object tracking principle
Source: Adapted from [52]

In 2019, YouTube announced its new AR feature for virtually try-on to facilitate the sales of make-up products [53].

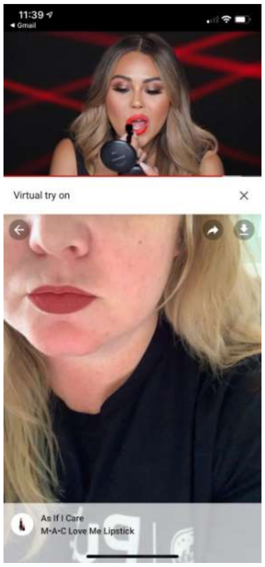


Figure 7. Screenshot of YouTube's make-up try-on AR feature
Source: Adapted from [54]

2.4.2.3 Scene and Plane Recognition

When hanging out in a furniture shop, people usually have no idea what these products look like in their homes. The IKEA Place AR app provides an innovative solution to this problem [55]. With the new AR app, customers can step into their living room, switch on the camera, and see which sofa fits the best in the background.

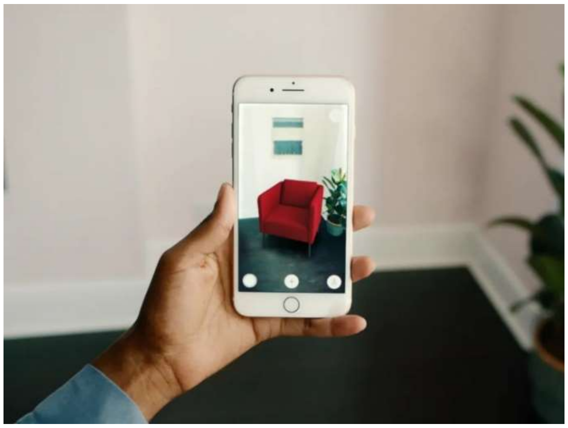


Figure 8. Fitting a sofa in the room with the IKEA Place AR app
Source: Adapted from [55]

Scene and plane recognition is the AR feature that makes this happen. A pre-scanned map of the scene is required to configure the AR experience. Taking pictures of different angles and constructing a 3D model are common ways to load the scene preset [56].

After placing a 3D object in the scene, the user can change its position and angle. Multiple objects can be present in the same scene simultaneously [57].

2.4.2.4 Geo AR

Geo AR, also known as location-based AR, renders markers with geographical location information into the AR view. Geo-based AR apps make a difference in many sectors, such as tourism, real estate, sales, gaming and entertainment [58].

Nintendo's Pokémon GO mobile application, released in 2016, shows the unpredictable potential of AR integrated applications to the world. With pokemon markers pinpointed to the world map, Pokémon lovers can catch and collect Pokémon near their location.

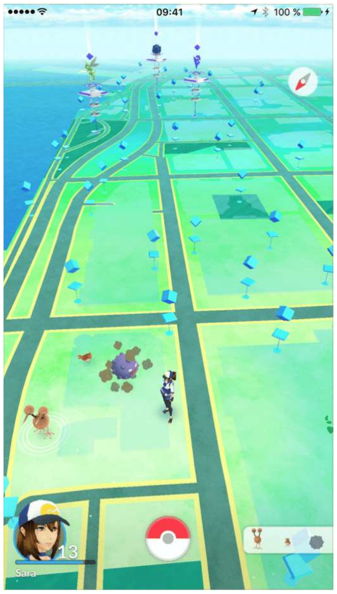


Figure 9. Screenshot of Pokémon map in the Pokémon GO app
Source: Adapted from [59]

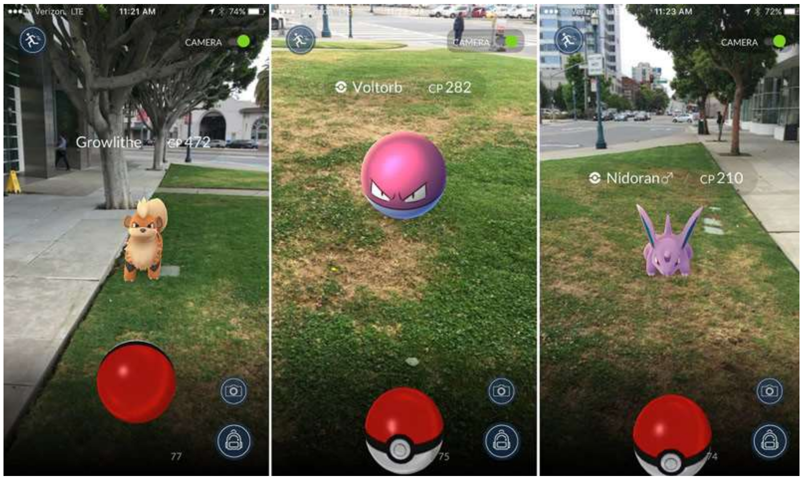


Figure 10. Catching Pokémon map in the Pokémon GO app
Source: Adapted from [60]

2.4.3 AR Development Tools

This section will introduce three tools for AR development: ARKit, ARCore, and Wikitude.

2.4.3.1 ARKit

ARKit is Apple's framework for AR applications on iOS devices only. [61]

ARKit supports AR features such as tracking, scene analytics and rendering 2D or 3D models [61]. From ARKit 5 launched in Jun 2021, ARKit integrated Location Anchors for location-based AR experiences [62].

2.4.3.2 ARCore

ARCore is Google's AR platform [63]. ARCore is available to a wide range of Android devices and can also support iOS devices compatible with ARKit [64].

To build customized AR experiences with ARCore, developers must use platform-specific languages as the primary language for their applications. For example, Java or Kotlin should be used if expecting an Android app with ARCore features [65].

2.4.3.3 Wikitude

Since 2008, Wikitude has been a developing platform that provides cross-platform AR services. Object and scene tracking, Geo AR, cloud recognition and multiple object tracking are some core AR features supported by Wikitude. [66]

Native API, Plugin API and JavaScript API are the three main Wikitude APIs. [67] Many SDKs and plugins are developed to support different OS and frameworks based on these three APIs. For example, Wikitude Flutter SDK is built on its JavaScript API, allowing Flutter apps to use JavaScript language and ArchitectWidget [68] to implement AR features.

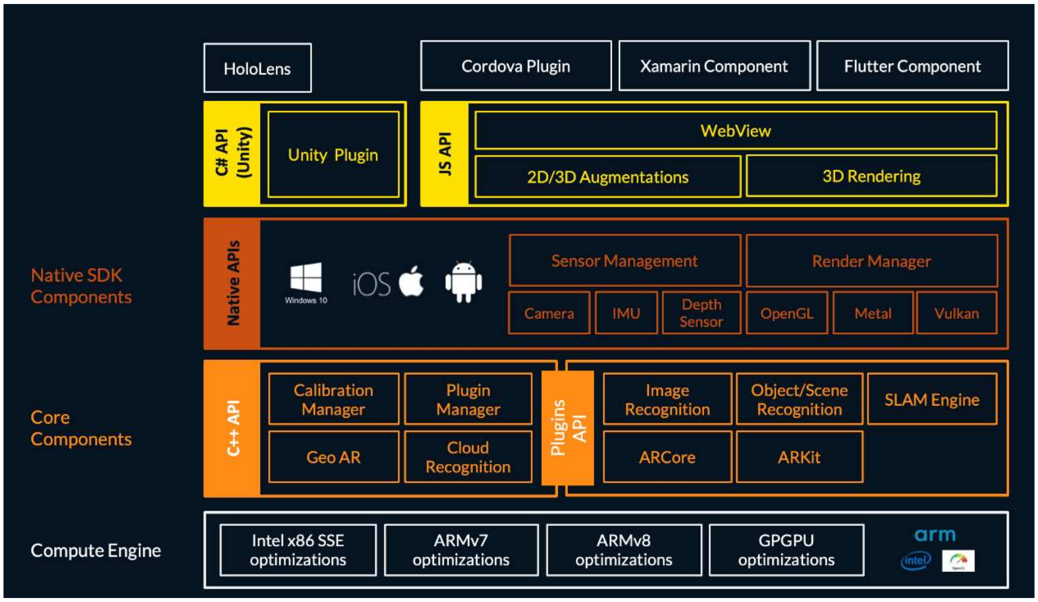


Figure 11. The architecture of Wikitude SDK
Source: Adapted from [67]

2.5 Virtual-reality (VR) photography

360 VR photography, also known as 360 panoramic photography, is the type of photography that captures the entire surroundings from a single viewpoint [69].

360 VR photos or videos can be viewed online via scrollable and zoomable panorama viewers [70]. YouTube's VR channel [71], available to headsets, cardboards [72], phones, and desktops, allows users to immerse themselves in 360 videos.

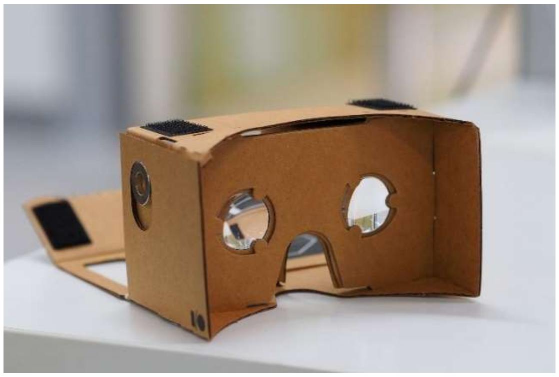


Figure 12. Google VR Cardboard
Source: Adapted from [73]

The equipment required for shooting a 360 photo is a digital single-lens reflex (DSLR) camera sitting on a tripod with a panoramic head [74].

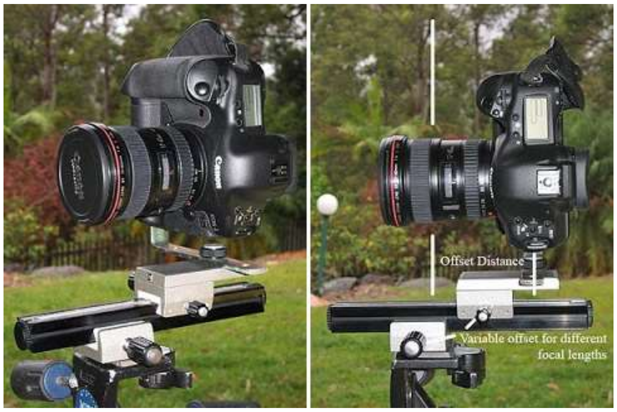


Figure 13. DSLR camera on a panoramic tripod head
Source: Adapted from [74]

2.6 Cloud Service

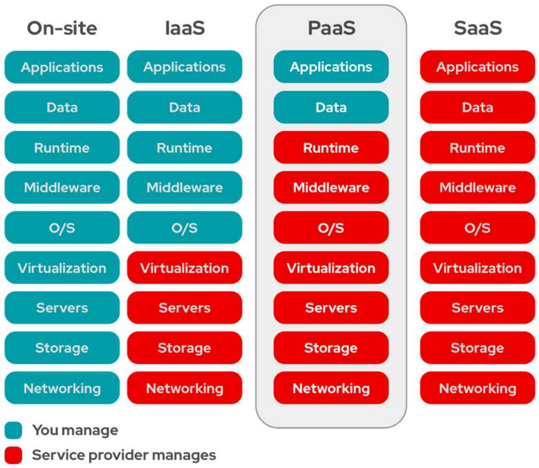
This chapter introduces cloud computing services and lists the highlights of Amazon Web Services (AWS) and Google Cloud Platform (GCP).

2.6.1 Introduction to Cloud Computing

Cloud computing is the distribution of a series of cloud services, including servers, databases, storage, networking, and applications [75]. Cloud computing is a cost-saving and innovative option for enterprises and developers. It helps reduce time in maintaining infrastructures and ensures high availability and security.

Upon the ownership of cloud services, cloud computing can be divided into three categories to satisfy different use cases. The public cloud, which belongs to the cloud service provider (CSP), is where users rent the usage of cloud services. A private cloud is often owned by an organization or a company to keep the infrastructure and services private to only internal users. A hybrid cloud mixes private and public clouds, providing a flexible option for companies that would like to integrate their existing system [75].

The services of the cloud can be categorized as infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) [76].



On-site	IaaS	PaaS	SaaS
🟦 Applications	🟦 Applications	🟦 Applications	🟥 Applications
🟦 Data	🟦 Data	🟦 Data	🟥 Data
🟦 Runtime	🟦 Runtime	🟥 Runtime	🟥 Runtime
🟦 Middleware	🟦 Middleware	🟥 Middleware	🟥 Middleware
🟦 O/S	🟦 O/S	🟥 O/S	🟥 O/S
🟦 Virtualization	🟥 Virtualization	🟥 Virtualization	🟥 Virtualization
🟦 Servers	🟥 Servers	🟥 Servers	🟥 Servers
🟦 Storage	🟥 Storage	🟥 Storage	🟥 Storage
🟦 Networking	🟥 Networking	🟥 Networking	🟥 Networking

🟦 You manage
🟥 Service provider manages

Figure 14. Compare on-site, IaaS, PaaS and SaaS
Source: Adapted from [80]

SaaS provides services to customers, and CSP is responsible for all the data and applications. Examples of SaaS include Dropbox and Google Workspace [76].

PaaS gives users the responsibility to handle their data and applications, but all the other infrastructure and networking are maintained by CSP [77]. Examples of PaaS are AWS Lambda [78] and Red Hat OpenShift [79].

IaaS, such as servers and virtual machines (VMs), gives cloud users more flexibility. Users can choose their preferred OS to use and should make efforts to keep their system running safely. Examples of IaaS include AWS EC2 [84] and Google Cloud's Compute Engine [93].

2.6.2 Amazon Web Services (AWS)

Amazon Web Services (AWS) is one of the leading cloud service providers worldwide [81]. Its pay-as-you-go pricing scheme offers flexible usage scenarios of cloud services to individual and enterprise customers. Compute, storage, networking, and database are the four core services of AWS [82].

2.6.2.1 Compute

Amazon Elastic Container Service (Amazon ECS) [83] and Amazon Elastic Compute Cloud (Amazon EC2) [84] are core IaaS for cloud computing services. Users can create and utilize EC2 instances as virtual machines (VM). Amazon ECS provides a container orchestration service fully managed by AWS.

2.6.2.2 Storage

Amazon Simple Storage Service (Amazon S3) is the primary storage service of AWS. S3 storages and secures unlimited objects for users with high availability, scalability, and performance [85].

2.6.2.3 Networking and Content Delivery Network (CDN)

AWS deploys services, applications, and data globally to different regions [86]. With edge networking services such as Amazon CloudFront [87], users of cloud-based applications can access websites, applications, and content near their geographical locations to enjoy a faster and smoother user experience.

2.6.2.4 Database

The relational database in AWS is handled by Amazon Relational Database Service (RDS) [88], while DynamoDB [89] is a popular solution for the No-SQL database. Database Migration Service (DMS) [90] is offered for enterprise users to migrate their server-based databases to the cloud.

2.6.3 Google Cloud Platform (GCP)

2.6.3.1 Cloud Foundations

Google Cloud Platform (GCP) [91] is a suite of cloud computing services provided by Google. It covers almost all cloud services that AWS has. [92] Regarding the four core services of AWS, GCP has Compute Engine [93] as its virtual machine (VM) product, Cloud Storage [94] to store objects, Cloud SQL and Firestore as relational and object-oriented database [95] solutions [96], and Cloud CDN [97] for content delivery.

2.6.3.2 Google Maps Platform

Alongside the essential cloud services mentioned above, Google Maps Platform [98] provides rich resources of APIs, including static and dynamic maps, Direction API [99] for route navigation, Places Search and Details API to search for a place worldwide and get detailed information about it.

2.6.3.3 Firebase

Firebase is Google’s development platform for building, deploying, and releasing mobile or web applications. Firebase services include authentication [100], Firestore database, Realtime database, storage, hosting, functions, and machine learning.

Developers can efficiently utilize these services via Firebase SDKs with an application linked to a Firebase project [101].

There are three cloud products shared between Firebase and GCP: Cloud Firestore, Cloud Functions, and Cloud Storage, which support the No-SQL database, serverless computing, and object storage, respectively. Firebase and GCP share their projects, the billing system, accounts, and access controls [101].

Chapter 3
High-level Design

This chapter shows the blueprint of *HiSG*: technology stack and the app’s functions.

3.1 Technology Stack

Technology stack refers to all technical components that a program is built on, such as programming languages, development frameworks, APIs, SDKs, and any cloud service providers. This project’s deliverable, *HiSG*, can be split into two parts:

1. Main application.

The main application is a native app built with the Flutter UI framework. Firebase and Google Cloud Platform offer database, storage, and authentication services for the main application.

2. Augment Reality (AR) Component.

The Wikitude Flutter SDK contributes to the AR components of *HiSG*. As the Wikitude SDK for Flutter is developed based on its JavaScript SDK, it works as a hybrid app embedded in the main application indeed. The programming languages for Wikitude SDK are HTML, CSS, and JavaScript. Google Maps Platforms APIs provide essential location data.

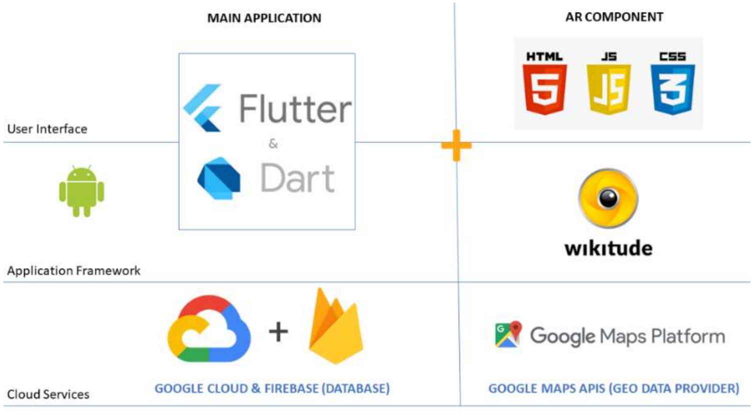


Figure 15. Technology Stack of the application HiSG

3.2 Features

This part, in tabular form, provides a list of features that the application should have, the expectations of each feature, and the corresponding section that describes how it is implemented.

Feature Name	*Expectations*	*Implementations*
Search	The app should have a search function to present rich tourism resources.	4.1.3.2 Discover and Search Pages 4.1.3.3 Search Result Detail Pages 4.3.3 Search
Navigation	The app should be able to guide the user's journey from one point to another point.	4.1.3.5 AR Feature Pages 4.3.2 AR Walking Navigation
AR-based Features	The app should integrate Geo-AR or marker-based AR technology.	4.1.3.5 AR Feature Pages 4.3.1 AR Search Nearby 4.3.2 AR Walking Navigation
Account and User Management	The app should allow user registration, login, and save the user's in-app activities.	4.1.3.7 Authentication Pages 4.3.4 Authentication and User Service 4.3.5 User's Favourite List
360 Experiences	The app should be able to display VR photography, such as 360-degree images and videos.	4.1.3.4 VR Photos and Videos
Itinerary Planning	The app show allows the user to plan their trip in Singapore. The app may provide customized suggestions.	4.1.3.6 Itinerary Plan Pages 4.3.6 Itinerary Planning and Recommendation

Table 1. HiSG app features

Chapter 4

Implementation

This chapter shows the implementation of the program's functionalities, user interface (UI) and User Experience (UX).

4.1 User Interface (UI)

People interact with applications, websites, or embedded systems through the user interface (UI) [102]. A good design of Graphics User Interface (GUI) makes users enjoy interacting with the application.

This section shows the implementation of UI in the *HiSG* app.

4.1.1 Sitemap

A sitemap shows how pages are linked together in an application. *Figure 16* shows the sitemap of the *HiSG* app.

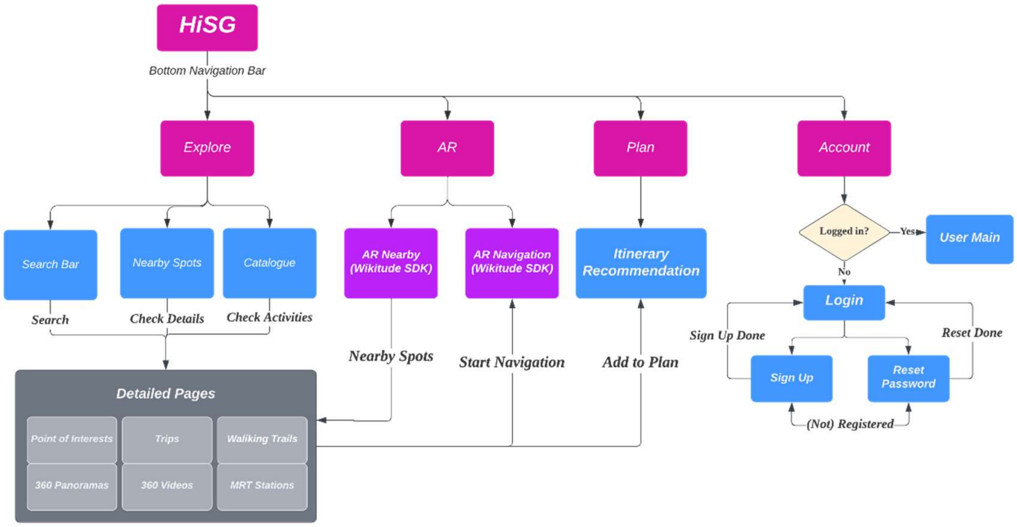


Figure 16. Sitemap of HiSG.

4.1.2 Logo and Splash Screen

Figure 17 shows the logo of *HiSG*. A splash screen looks like *Figure 17 (c)* will show up when opening the application.

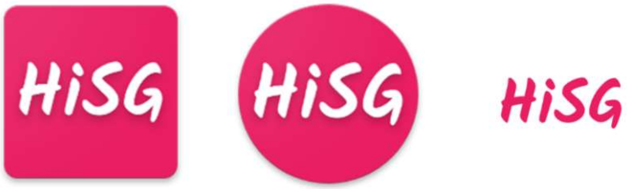


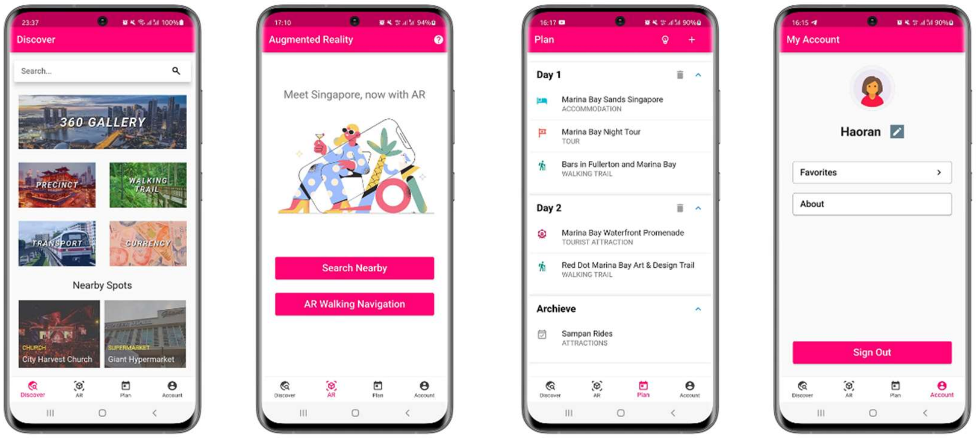
Figure 17. Logo (left), Rounded Logo (middle), and Splash Screen Icon (right)

4.1.3 Pages

This section includes screenshots of all the pages in the *HiSG* app. The demonstration phone model is Samsung S20, with a resolution of 1440 x 3200 pixels.

4.1.3.1 Main Pages

After the application is initialized, *HiSG* displays a top app bar, a bottom navigation bar, and the main content in between. There are four tabs in the bottom navigation bar: Discover, AR, Plan and Account, as shown in *Figure 18*.

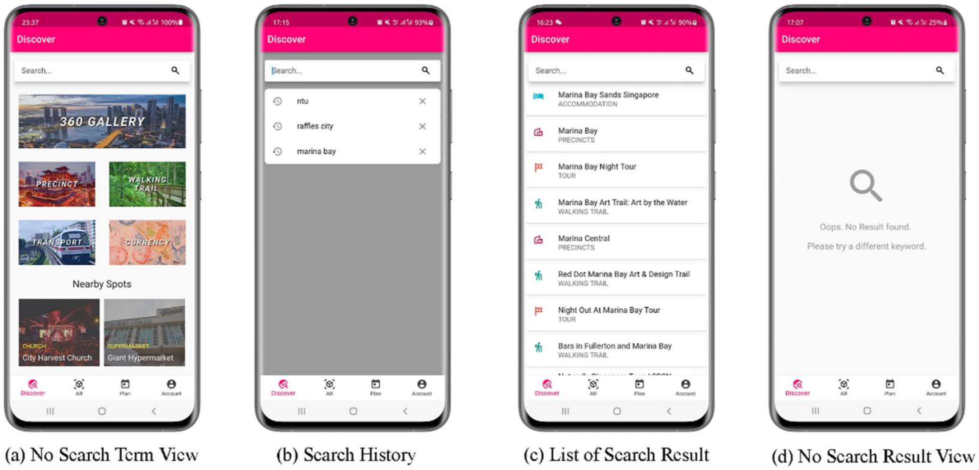


(a) Discover Page (b) AR Page (c) Itineary Plan Page (d) User Main Page

Figure 18. Screenshots of four main pages.

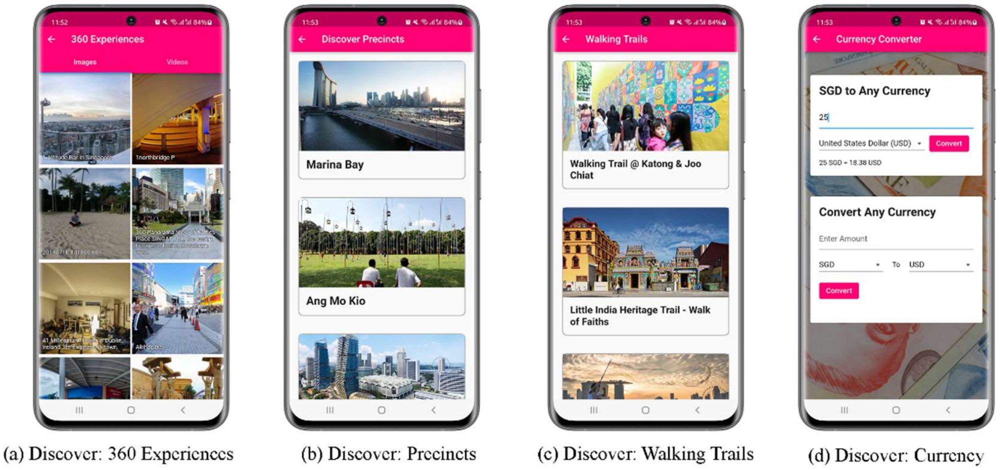
4.1.3.2 Discover and Search Pages

On the discover page (*Figure 19*), there are banners for categorized page navigation (Figure 20), a search bar, and a scrollable list of nearby spots based on the user's current location.



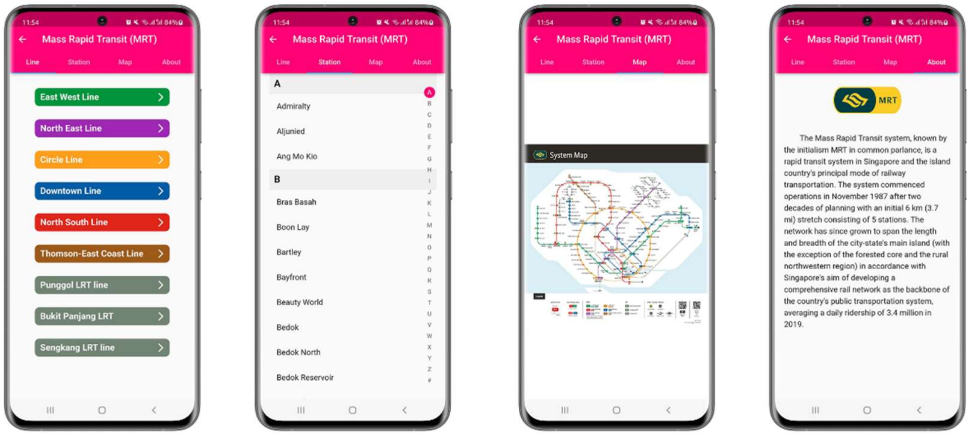
(a) No Search Term View (b) Search History (c) List of Search Result (d) No Search Result View

Figure 19. Screenshots of discover and search pages



(a) Discover: 360 Experiences (b) Discover: Precincts (c) Discover: Walking Trails (d) Discover: Currency

Figure 20. Catalogue pages for resources of different categories



The Mass Rapid Transit system, known by the initialism MRT in common parlance, is a rapid transit system in Singapore and the island country's principal mode of railway transportation. The system commenced operations in November 1987 after two decades of planning with an initial 6 km (3.7 mi) stretch consisting of 5 stations. The network has since grown to span the length and breadth of the city-state's main island (with the exception of the forested core and the rural northwestern region) in accordance with Singapore's aim of developing a comprehensive rail network as the backbone of the country's public transportation system, averaging a daily ridership of 3.4 million in 2019.

(a) Discover: MRT Lines (b) Discover: MRT Stations (c) Discover: MRT Map (d) Discover: About MRT

Figure 21. Catalogue page for MRT

Catalogue pages, as shown in *Figure 20* and *Figure 21*, show a list of various types of resources available to the user. There are five catalogue pages accessible from the discover main page: 360 experiences (*Figure 20a*), precincts (*Figure 20b*), walking trails (*Figure 20c*), MRT (*Figure 21*), and a currency converter (*Figure 20d*).

A search history list will be displayed if the user clicks on the search bar, as shown in *Figure 19 (b)*. After the user key in any keyword they are interested in, the app's search function is activated, with a list view of search results is displayed to the user, as shown in *Figure 19 (c)*. If no search result is found, a message that looks like *Figure 19 (d)* is displayed.

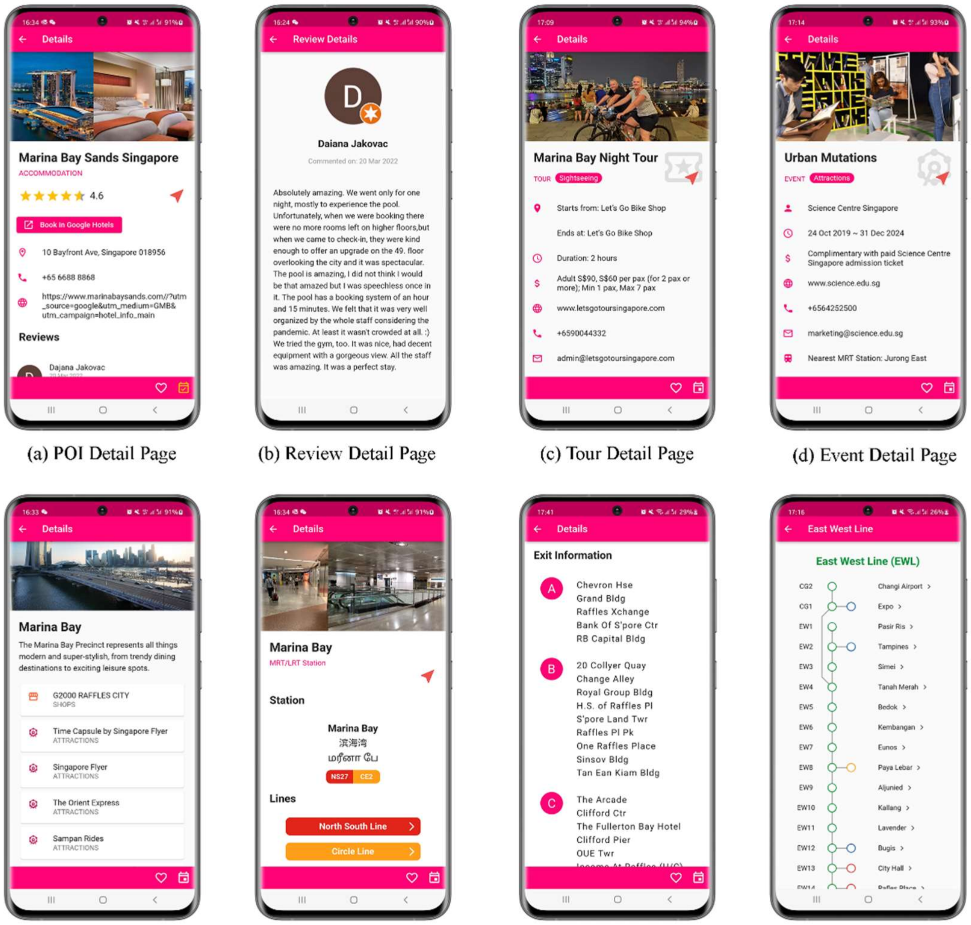
4.1.3.3 Search Result Detail Pages

A search result may be classified as a point of interest (POI), a tour, an event, or a precinct. Clicking on a search result card takes the user to a detailed page with further information.

As shown in *Figure 22*, two icon buttons are on the bottom bar of a detailed page, corresponding to the "add to favourite" and "add to plan" functions. According to the type of search result, different information will be displayed as the main body.

A typical detailed page of POI, tour or event contains the images, name, category, address, and contact information. For a POI, a list of reviews for the place is displayed. *Figure 22 (b)* shows the detailed page of a review.

Customized information is included if the POI is a transit station or a lodging place. The train line and exit information for MRT or LRT stations are shown in *Figure 22 (f - h)*. A hotel booking link button is displayed for hotels, as shown in *Figure 22 (a)*.



16:34

Details

Marina Bay Sands Singapore

ACCOMMODATION

★★★★★ 4.6

Book in Google Hotels

10 Bayfront Ave, Singapore 018956

+65 6688 8868

https://www.marinabaysands.com//?utm_source=google&utm_medium=GMB&utm_campaign=hotel_info_main

Reviews

Dajana Jakovac

(a) POI Detail Page

16:24

Review Details

Daiana Jakovac

Commented on: 20 Mar 2022

Absolutely amazing. We went only for one night, mostly to experience the pool. Unfortunately, when we were booking there were no more rooms left on higher floors,but when we came to check-in, they were kind enough to offer an upgrade on the 49. floor overlooking the city and it was spectacular. The pool is amazing, I did not think I would be that amazed but I was speechless once in it. The pool has a booking system of an hour and 15 minutes. We felt that it was very well organized by the whole staff considering the pandemic. At least it wasn't crowded at all. :) We tried the gym, too. It was nice, had decent equipment with a gorgeous view. All the staff was amazing. It was a perfect stay.

(b) Review Detail Page

17:09

Details

Marina Bay Night Tour

TOUR Sightseeing

Starts from: Let's Go Bike Shop

Ends at: Let's Go Bike Shop

Duration: 2 hours

Adult S$90, S$60 per pax (for 2 pax or more); Min 1 pax, Max 7 pax

www.letsgotoursingapore.com

+6590044332

admin@letsgotoursingapore.com

(c) Tour Detail Page

17:14

Details

Urban Mutations

EVENT Attractions

Science Centre Singapore

24 Oct 2019 ~ 31 Dec 2024

Complimentary with paid Science Centre Singapore admission ticket

www.science.edu.sg

+6564252500

marketing@science.edu.sg

Nearest MRT Station: Jurong East

(d) Event Detail Page

16:33

Details

Marina Bay

The Marina Bay Precinct represents all things modern and super-stylish, from trendy dining destinations to exciting leisure spots.

G2000 RAFFLES CITY
SHOPS

Time Capsule by Singapore Flyer
ATTRACTIONS

Singapore Flyer
ATTRACTIONS

The Orient Express
ATTRACTIONS

Sampan Rides
ATTRACTIONS

(e) Precinct

16:34

Details

Marina Bay

MRT/LRT Station

Station

Marina Bay
滨海湾
மரீனா பே
NS27 CE2

Lines

North South Line

Circle Line

(f) MRT Station: Name and Lines

17:41

Details

Exit Information

A
Chevron Hse
Grand Bldg
Raffles Xchange
Bank Of S'pore Ctr
RB Capital Bldg

B
20 Collyer Quay
Change Alley
Royal Group Bldg
H.S. of Raffles Pl
S'pore Land Twr
Raffles Pl Pk
One Raffles Place
Sinsov Bldg
Tan Ean Kiam Bldg

C
The Arcade
Clifford Ctr
The Fullerton Bay Hotel
Clifford Pier
OUE Twr

(g) MRT Station: Exits

17:16

East West Line

East West Line (EWL)

CG2	Changi Airport >
CG1	Expo >
EW1	Pasir Ris >
EW2	Tampines >
EW3	Simei >
EW4	Tanah Merah >
EW5	Bedok >
EW6	Kembangan >
EW7	Eunos >
EW8	Paya Lebar >
EW9	Aljunied >
EW10	Kallang >
EW11	Lavender >
EW12	Bugis >
EW13	City Hall >
EW14	Raffles Place >

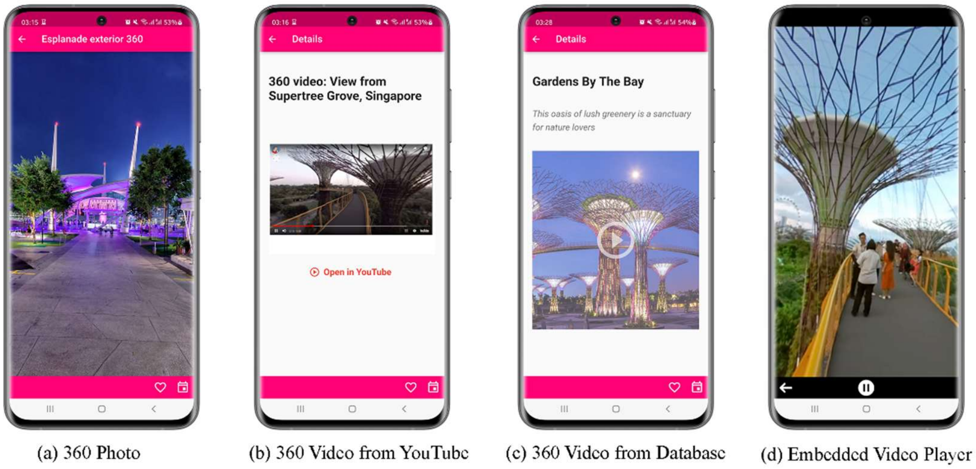
(h) MRT Line

Figure 22. Screenshots of detailed pages

As shown in *Figure 19 (e)*, a precinct detail page contains the area's image, name, and description, with a list of places located in this precinct.

4.1.3.4 VR Photos and Videos

360-degree VR photos and videos can also be searched by the search bar on the discover page (*Figure 19*). GUI for VR photos varies by their data source, as shown in *Figure 23*.



360 video: View from Supertree Grove, Singapore

Gardens By The Bay

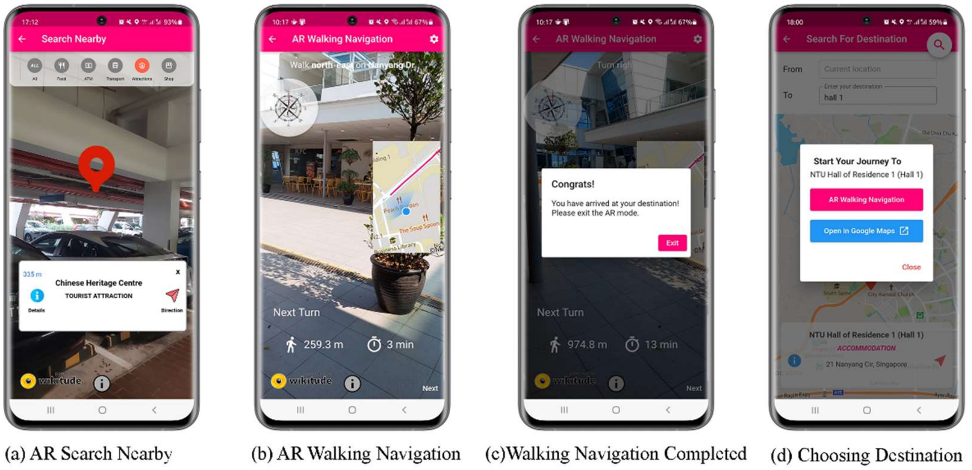
This oasis of lush greenery is a sanctuary for nature lovers

(a) 360 Photo (b) 360 Video from YouTube (c) 360 Video from Database (d) Embedded Video Player

Figure 23. Screenshots of 360 VR experiences

4.1.3.5 AR Feature Pages

There are two AR features in the AR tab: AR search nearby and AR walking navigation, as shown in *Figure 24*.



Congrats!

You have arrived at your destination! Please exit the AR mode.

Start Your Journey To
NTU Hall of Residence 1 (Hall 1)

(a) AR Search Nearby (b) AR Walking Navigation (c)Walking Navigation Completed (d) Choosing Destination

Figure 24. Screenshots of AR pages

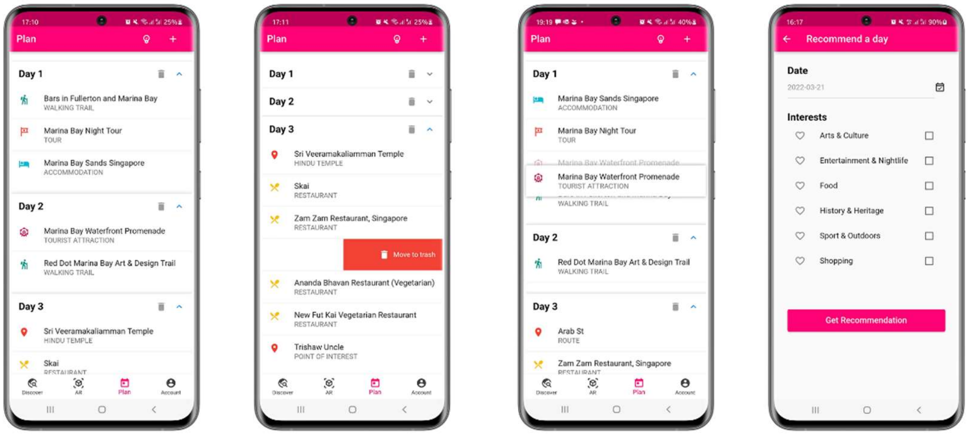
AR Search Nearby page will show the view of the back camera and POI markers near the user's location. A panel pops out to display the place name, category, and distance to the user if a marker is selected, as shown in *Figure 24 (a)*. A filter on the top allows users to see markers for selected categories.

When the user clicks the "AR Walking Navigation" button, the destination picker page shows up in *Figure 24 (d)*, allowing the user to search for their destination. The user can swipe left and right on the bottom panel to choose among different search results. The centre of the map changes according to the place selected.

After choosing the destination, navigation starts in *Figure 24 (b)*. A marker on top of the camera view indicates the location of the next turning point. The route instruction is shown on the top, and the distance and time to the next turning point are shown in the middle. A map and a compass are also displayed to guide the user. A dialogue pops out when the user arrives at his destination to let the user exit the navigation mode, as shown in *Figure 24 (c)*.

4.1.3.6 Itinerary Plan Pages

From the "plan" tab on the bottom navigation bar, the itinerary plan page allows users to add, delete, and reorder their desired destinations. A plan consists of one or more days, with saved places planned for each day, as shown in *Figure 25*.



(a) Itinerary Plan (b) Collapsible and Dismissible (c) Drag and Drop Items (d) Itinerary Recomendation

Figure 25. Screenshots of the itinerary plan and recommendation pages

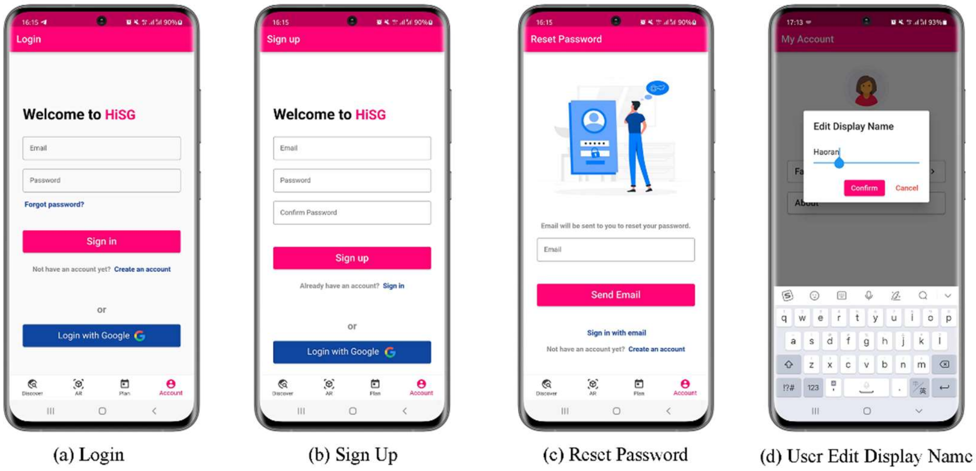
Cards of saved places are dismissible, which will be deleted from the list on swipe, as shown in *Figure 25 (b)*. A long tap on the card will activate the "drag and drop" feature, as shown in *Figure 25 (c)*, which allows the user to reorder the plan list.

Figure 25 (d) shows the itinerary recommendation page. The page pops out if the user taps on the bulb icon on the top app bar. After selecting the date and user's interest, the recommendation engine will add a new day with recommended places to the existing plan.

4.1.3.7 Authentication Pages

Pages related to authentication are shown in *Figure 26*, including the login page in *(a)*, the sign up in *(b)*, and the reset password page in *(c)*.

The user can check his information if the login is successful, as shown in *Figure 18 (d)*. The user can edit their display name on this page, as shown in *Figure 26 (d)*.



Not have an account yet? Create an account

Already have an account? Sign in

Email will be sent to you to reset your password.

Not have an account yet? Create an account

(a) Login (b) Sign Up (c) Reset Password (d) User Edit Display Name

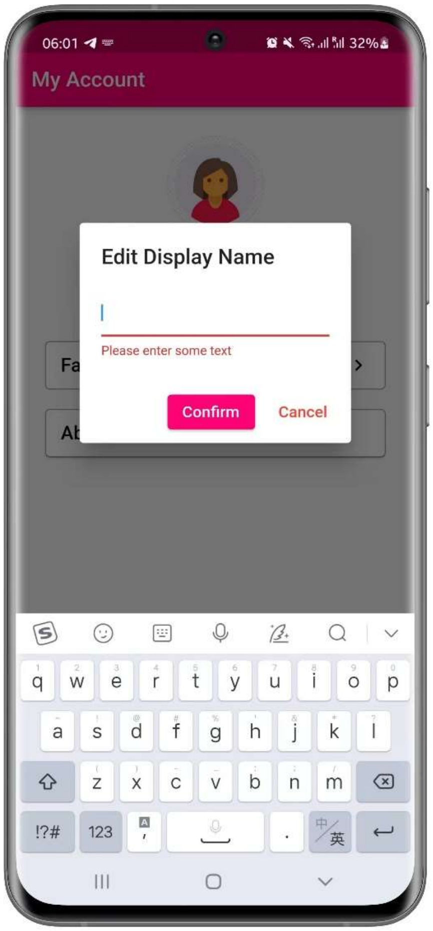
Figure 26. Screenshots of authentication pages

4.2 User Experience (UX)

This section includes a series of techniques and UI components used to enhance the user experience of application interaction.

4.2.1 Form Validation

Hints are displayed next to the input field when there is a validation rule violation. *Figure 27* is an example of empty input when editing the display name for the user.



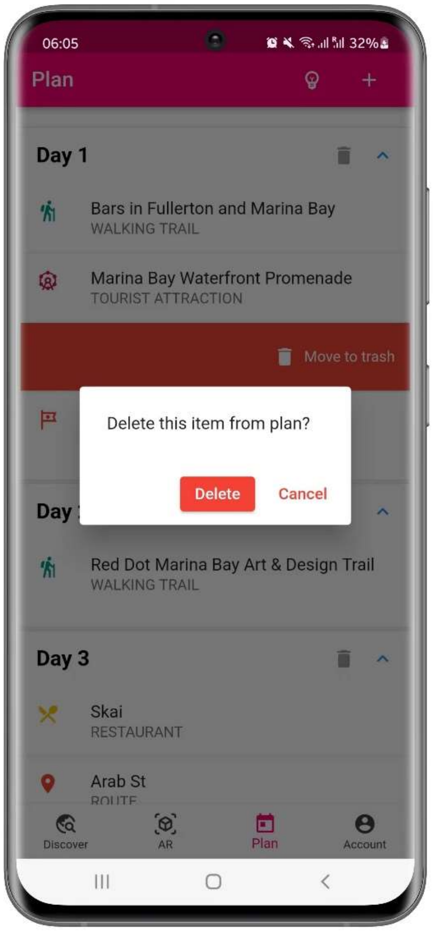
Edit Display Name

Please enter some text

Figure 27. Screenshot of a form validation hint

4.2.2 Confirmation Window

The itinerary plan page detects multiple gestures, such as swiping left and right, dragging and dropping, and expanding and collapsing. A confirmation window will pop out to the user to avoid any accident actions to confirm the action performed. *Figure 28* shows the confirmation window for an itinerary activity deletion.

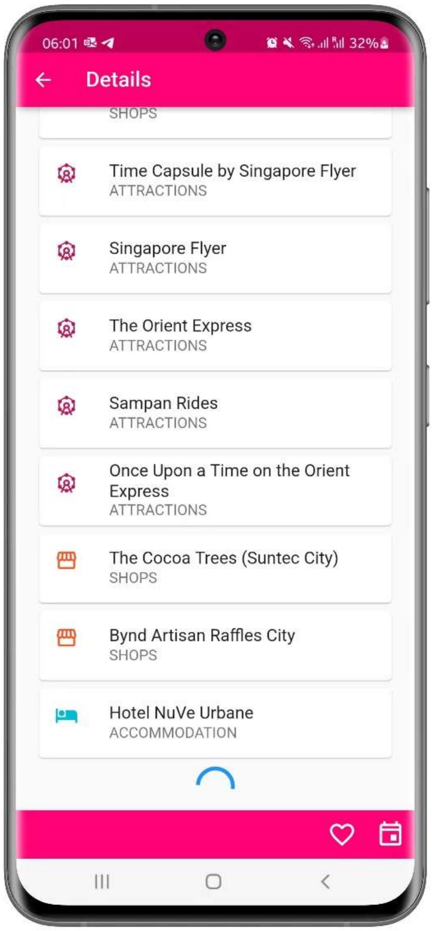


Delete this item from plan?

Figure 28. Screenshot of a confirmation window

4.2.3 Circular Progress Indicator

Fetching data from API or database requires time. When waiting for the response, a circular progress indicator is helpful to inform the user that their interested information is loading and will be ready soon. *Figure 29* shows a circular progress bar when the app is requesting more data from the API.



SHOPS

Time Capsule by Singapore Flyer
ATTRACTIONS

Singapore Flyer
ATTRACTIONS

The Orient Express
ATTRACTIONS

Sampan Rides
ATTRACTIONS

Once Upon a Time on the Orient Express
ATTRACTIONS

The Cocoa Trees (Suntec City)
SHOPS

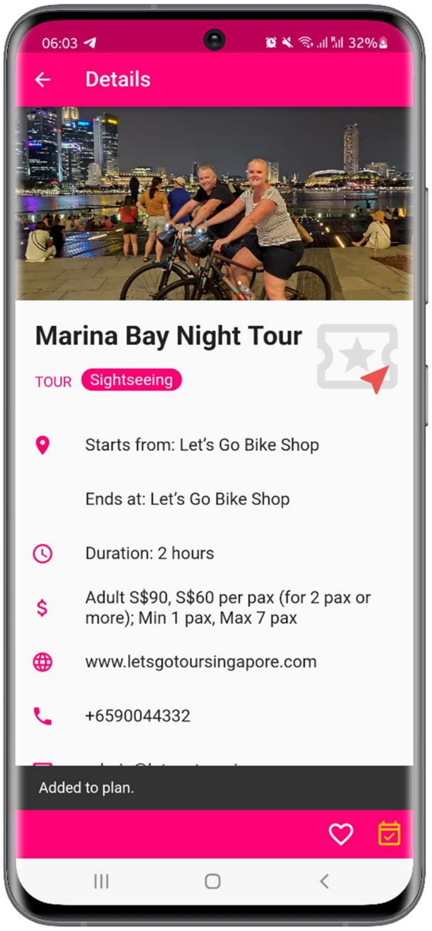
Bynd Artisan Raffles City
SHOPS

Hotel NuVe Urbane
ACCOMMODATION

Figure 29. Screenshot of a circular progress indicator

4.2.4 Snackbar Messager

A snackbar is a floating message container that usually appears at the top or the bottom of a page to indicate to the user whether the action just performed is successful [103]. *Figure 30* shows an example of the snackbar message when the user adds an activity to his itinerary plan.



06:03 32%

Details

Marina Bay Night Tour

TOUR Sightseeing

Starts from: Let's Go Bike Shop

Ends at: Let's Go Bike Shop

Duration: 2 hours

Adult S$90, S$60 per pax (for 2 pax or more); Min 1 pax, Max 7 pax

www.letsgotoursingapore.com

+6590044332

Added to plan.

Figure 30. Screenshot of a snackbar message

4.2.5 URI launcher

Uniform Resource Identifier (URI) is a unique identifier for a resource. A URI can refer to any object, not just a website. In the *HiSG* app, the URI launcher is used to open a website in the browser or launch external applications to enable coordination among applications.

On a detailed page, the “mailto” scheme is used to send an email, and the “tel” scheme is used to dial a phone number.

Some websites support opening the corresponding mobile app when the URI is launched. For example, a launch of *https://www.youtube.com/watch?v=$video_id* in the *HiSG* app can automatically open the YouTube app on the same device if it is installed.

4.3 Functions

This section explains how the features are implemented in the *HiSG* app.

4.3.1 AR Search Nearby

When the AR view is first launched with the Wikitude SDK, the program requests the user's current location. Requests are sent to Google Places API to get a list of nearby places' information. The application will process the data and display POI markers to the AR view based on the location of the POI. The marker list is cached in the application.

A typical Places API request URL includes two parameters: location and radius. The location parameter is a string containing altitude and longitude, connected by a comma. The radius parameter is the maximum distance to the location in the meter.

Categories of POI available are food, ATM, transit station, tourist attraction, and shop. If the user chooses categories to filter the markers, the app will only display markers from those categories.

A panel with POI information will appear if the user selects any markers in the display, as shown in *Figure 24(a)*. The left-hand info button will lead the user to the POI's detailed page. The arrow button on the right will start the navigation process.

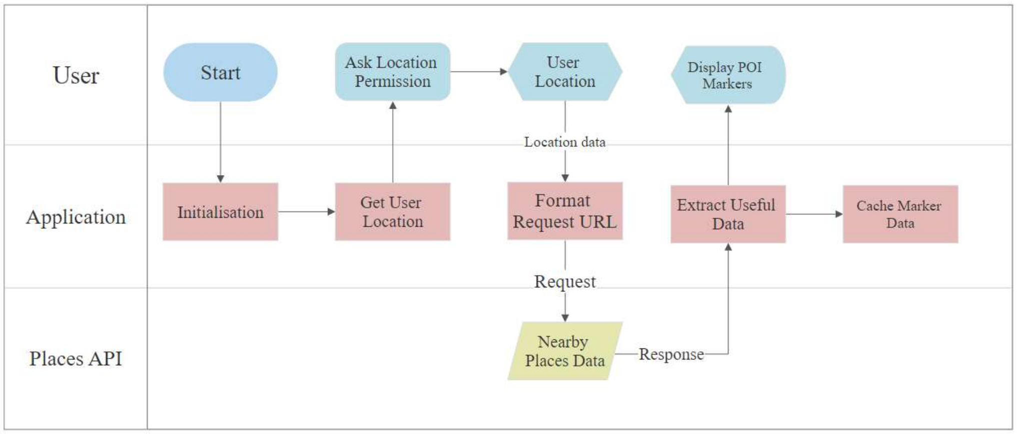


Figure 31. Flowchart of AR search nearby feature

4.3.2 AR Walking Navigation

A navigation process requires two key parameters: the origin and destination locations. Hence, the AR walking navigation feature is divided into two sections: selecting a destination and the AR navigation process. The first section is a native page in Flutter, while the second is supported by the Wikitude SDK.

The first stage is shown in *Figure 32*. The app displays a page for the user to choose a destination before rendering the AR view, as shown in *Figure 24*. After capturing the destination input, the app creates the request URL and sends it to Google Places API. After receiving a response from the API, the app displays a list of search results from which the user can select. When the user selects a destination from the displayed search results, the app sends the user's current location as the original location and the selected place's location as the destination location to the second stage to initialize the AR view.

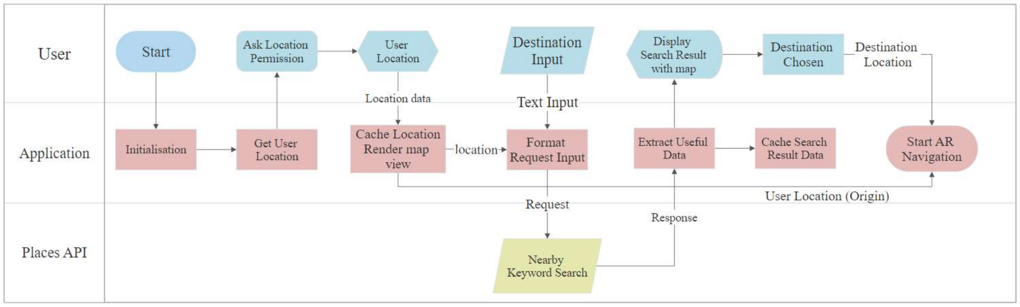


Figure 32. Flowchart of the first stage of AR walking navigation

Figure 33 illustrates the second stage. The app first initializes the AR view using the back camera. Meanwhile, a route request with the origin and destination locations is sent to Google Directions API. When the app receives the answer, it extracts the routing directions, duration, and distance and shows it to the user. The navigation process starts.

During the AR navigation, the app periodically retrieves the user's position and changes the time, distance, and instruction in the AR display.

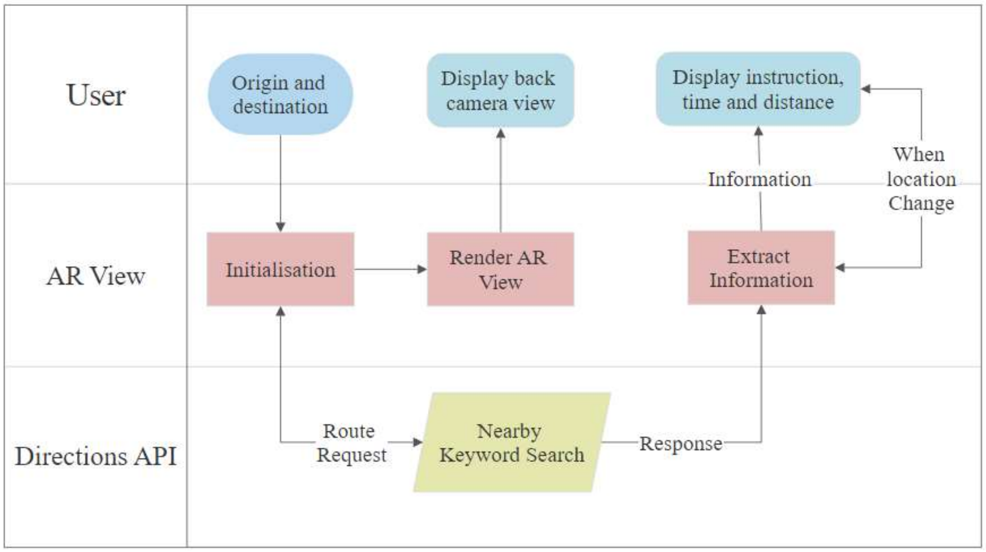


Figure 33. The second stage of AR walking navigation

4.3.3 Search

The search function is critical in *HiSG*. It presents rich resources to the user, including places, tours, events, precincts, 360-degree images and 360-degree videos.

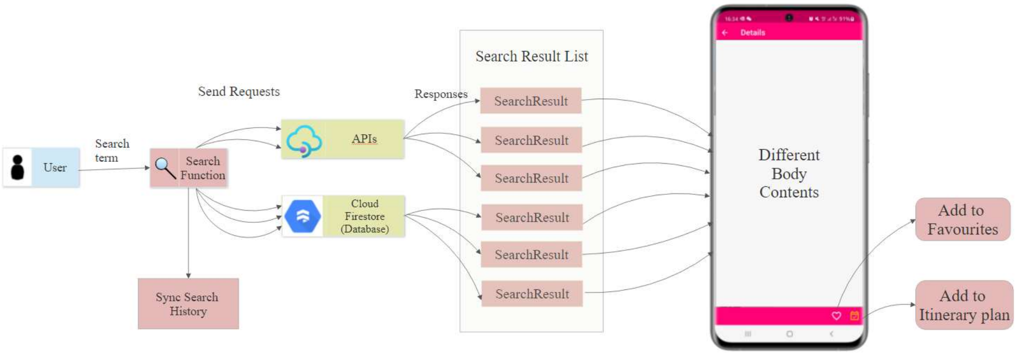


Figure 34. Flowchart of the search function

If the user is logged in, a search history list is queried from the user database and displayed to the user as options, as shown in *Figure 19(c)*.

After the user inputs the text to be searched, requests are sent to various APIs and the cloud database for the material of different categories. The response data from sources is combined into a single class called *SearchResult*. As indicated in *Figure 34*, the user is presented with a list of search results. A detailed page is presented to the user when any search result card is clicked (*Figure 22*).

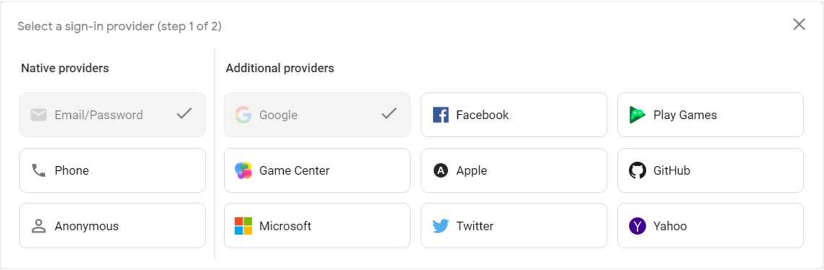
The top and bottom bars on detailed pages serve as a container for the search result. Depending on the source of the *SearchResult*, which is listed in *Table 2*, different body contents are displayed. The user can add the search result to the favourite list or add it to the itinerary plan on the bottom bar.

Search Result Type	*Data Source*	*Detail Page Body Content*
Point of interest	Google Places API	Images, Name, Type, Address, Contact Information, Reviews, {Hotel booking link}
Point of interest (MRT or LRT Station)	Cloud Firestore Google Places API	Images, Station Name in four languages, Train lines,
Tour, Event	TIH Content API	Image, Name, Type, Address, Contact Information, Description, Details
Precinct	TIH Content API	Image, Name, Description, List of places in the precinct
360 Images	Cloud Firestore	Web View of 360 Image
360 Videos	Cloud Firestore	Video Name, Description, 360 Video Player
360 Videos	Cloud Firestore YouTube	Video Name, Embedded Video, link to the YouTube app

Table 2. Type and detailed page contents of search results from different sources

4.3.4 Authentication and User Service

Firebase provides a fully managed authentication service for developers [100]. *Figure 35* shows a list of sign-in providers that Firebase Authentication supports. *HiSG* allows users to sign in using a Google account or email address. Firebase provides user login, registration, and password resetting features.



Select a sign-in provider (step 1 of 2)

Native providers

- Email/Password ✓
- Phone
- Anonymous

Additional providers

- Google ✓
- Facebook
- Play Games
- Game Center
- Apple
- GitHub
- Microsoft
- Twitter
- Yahoo

Figure 35. Screenshots of Firebase Authentication sign-in providers

A uid is generated when a user is registered. A user's display name, avatar picture, and search history are all kept in JSON format in the user database, with uid as the document reference [104]. Favourite and planned items are stored as sub-collections.

A class named User Service is developed to speed up UI response and decrease the number of database requests. The user service class acts as a connector between user and database, allowing for asynchronous database updates, as shown in *Figure 36*.

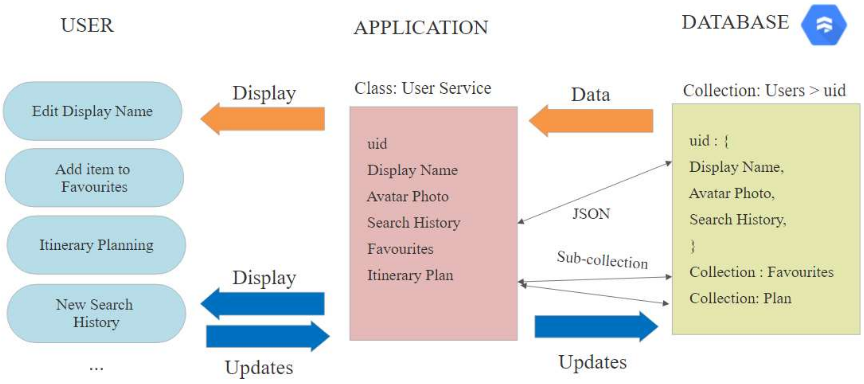


Figure 36. Illustration of the User Service class

4.3.5 User’s Favourite List

Figure 37 illustrates adding or deleting a search result from the favourite collection. Functions of the search result class enable the transformation between a JSON and a search result instance, as shown in *Figure 38*.

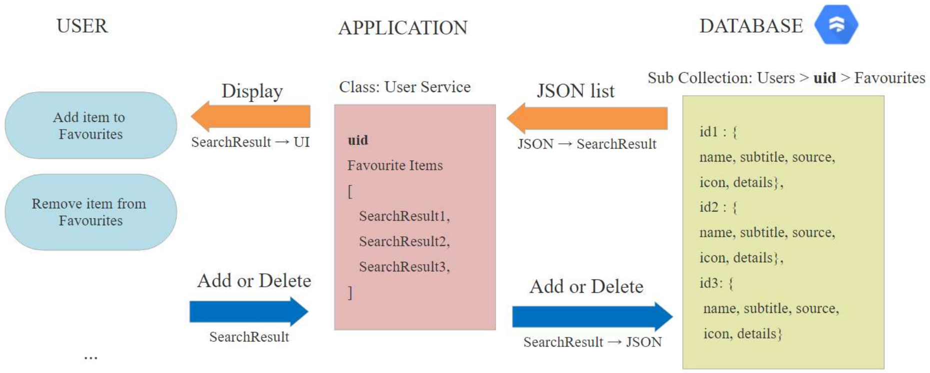
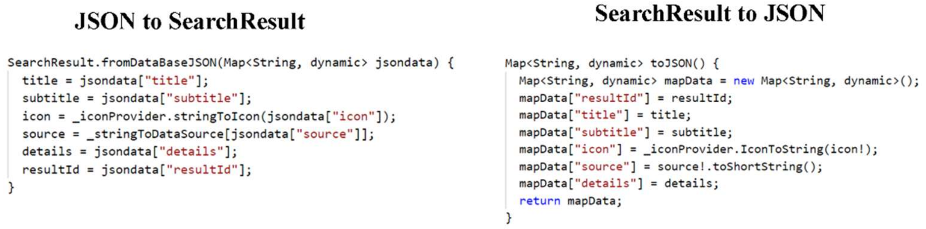


Figure 37. Illustration of adding and deleting items from the favourite list



JSON to SearchResult

```
SearchResult.fromDataBaseJSON(Map<String, dynamic> jsondata) {
  title = jsondata["title"];
  subtitle = jsondata["subtitle"];
  icon = _iconProvider.stringToIcon(jsondata["icon"]);
  source = _stringToDataSource[jsondata["source"]];
  details = jsondata["details"];
  resultId = jsondata["resultId"];
}
```

SearchResult to JSON

```
Map<String, dynamic> toJSON() {
  Map<String, dynamic> mapData = new Map<String, dynamic>();
  mapData["resultId"] = resultId;
  mapData["title"] = title;
  mapData["subtitle"] = subtitle;
  mapData["icon"] = _iconProvider.IconToString(icon!);
  mapData["source"] = source!.toShortString();
  mapData["details"] = details;
  return mapData;
}
```

Figure 38. Screenshots of function code to convert JSON to SearchResult and vice versa

When a user adds a search result instance to his favourite list, it is first added to the user service class’s favourite item list. The search result is displayed as “added” on the UI page. Meanwhile, the instance is converted to JSON, and a JSON document is added to the user’s Favourite database sub-collection.

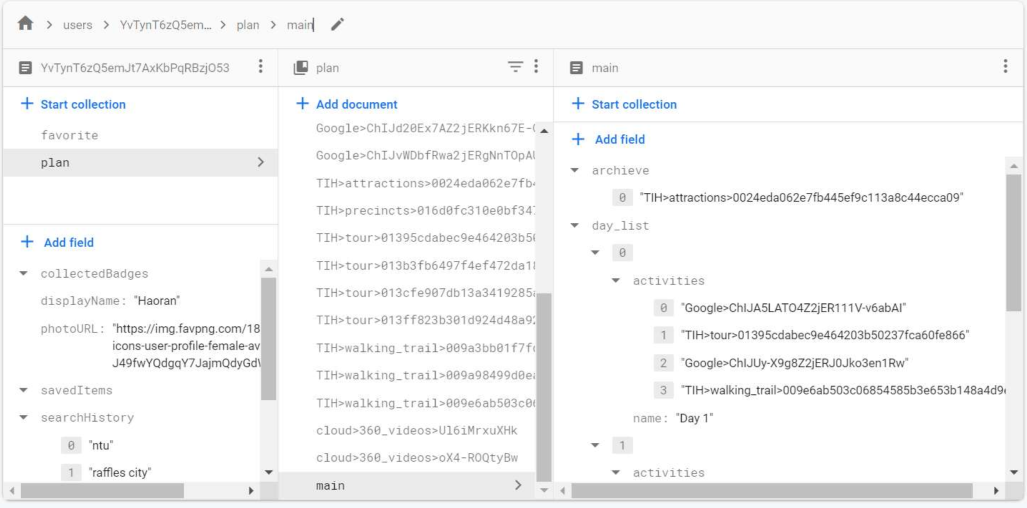
When a user removes a search result instance from his favourite list, it is removed first from the user service class’s favourite item list. The search result is seen as “deleted” by the user. Meanwhile, the instance id is obtained, and the document associated with it is removed from the database.

4.3.6 Itinerary Planning and Recommendation

The user interface of the itinerary planning page, as indicated earlier in *Section 4.1.3.6* Itinerary Plan Pages, allows the user to add, delete, and reorganize search results in days. The plan page is only accessible when the user has logged in. Otherwise, the user is prompted to sign in.

When a user clicks the "add to plan" button on a detailed page, the search result is added to a list named *archive*. The *archive* is used to temporarily store objects that are not allocated to a specific day.

The adding and deleting feature of itinerary planning is mainly similar to the User's Favourite List feature, but one significant difference is the introduction of a "main JSON".



```
favorite
plan

collectedBadges
displayName: "Haoran"
photoURL: "https://img.favpng.com/18
           icons-user-profile-female-av
           J49fwYQdgqY7JajmQdyGd\
savedItems
searchHistory
    0 "ntu"
    1 "raffles city"
```

```
Google>ChIJd20Ex7AZ2jERKkn67E-(
Google>ChIJvWDbfRwa2jERgNnTOpA(
TIH>attractions>0024eda062e7fb
TIH>precincts>016d0fc310e0bf34
TIH>tour>01395cdabec9e464203b5(
TIH>tour>013b3fb6497f4ef472da1
TIH>tour>013cfe907db13a3419285
TIH>tour>013ff823b301d924d48a9
TIH>walking_trail>009a3bb01f7f
TIH>walking_trail>009a98499d0e
TIH>walking_trail>009e6ab503c0
cloud>360_videos>Ul6iMrxuXHk
cloud>360_videos>oX4-ROQtyBw
main
```

```
archieve
    0 "TIH>attractions>0024eda062e7fb445ef9c113a8c44ecca09"
day_list
    0
        activities
            0 "Google>ChIJA5LATO4Z2jER111V-v6abAI"
            1 "TIH>tour>01395cdabec9e464203b50237fca60fe866"
            2 "Google>ChIJUy-X9g8Z2jERJ0Jko3en1Rw"
            3 "TIH>walking_trail>009e6ab503c06854585b3e653b148a4d9
        name: "Day 1"
    1
        activities
```

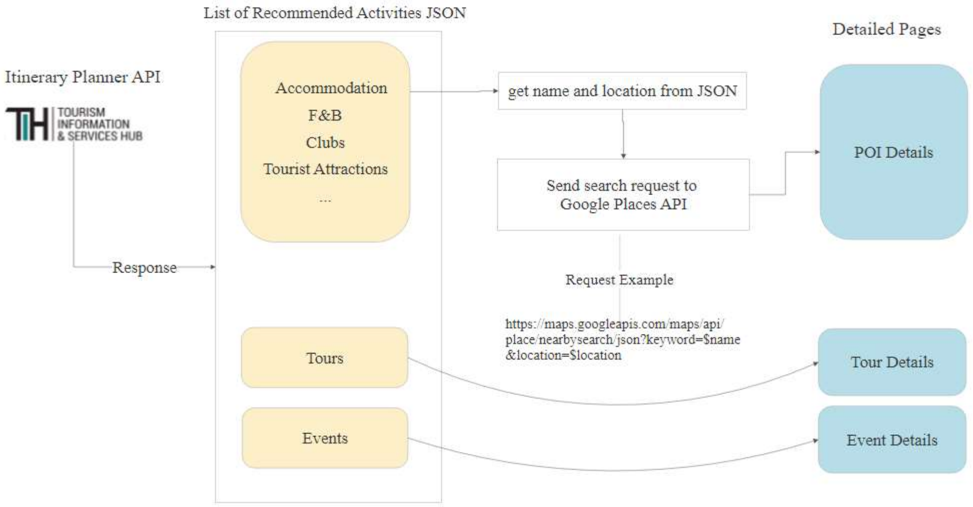
Figure 39. Screenshot of plan sub-collection with the main JSON on Firebase console

The main JSON for itinerary planning is designed to group the planned search result into days and keep the ordering of days and activities. Fields in the main JSON include the archive and a day list. A day in the day list includes its name and a list of activities arranged on that day.

When an addition is made to the plan, the main JSON and the relevant document are updated. However, when activities are deleted or reordered, just the primary JSON is changed.

The itinerary recommendation feature uses the *recommendItineraies* method of TIH's Itinerary Planner API [105]. The start date and the user's interests are the parameters that apply in the recommendation feature.

The app will call the TIH API once the user registers the date and interests. Several suggested activities include food and beverage, tourist sites, clubs, lodging, excursions, and events. To tackle the issue of only tours and events having their detailed page UI, an additional request to the Google Place API is made for each proposed POI item to populate the main body of the detailed page.



```
https://maps.googleapis.com/maps/api/
place/nearbysearch/json?keyword=$name
&location=$location
```

Figure 40. Flowchart of itinerary recommendation engine

A window will pop out to show a list of formatted recommended activities. Once the user hits the "OK" button, a new day containing all the activities will be appended to the end of the day list. Then the main JSON is updated, and the activity documents are created in the plan sub-collection.

Chapter 5 Application Testing

This chapter includes the necessary test cases for the *HiSG* app by functionality.

5.1 Test Cases for Authentication

Test Suite 1: Email Registration				
#	Test Case	Steps	Expected Result	Status
1	Email Registration Smoke Test	1. Enter an email address. 2. Enter a password. 3. Confirm password. 4. Click “Sign up”.	1. A snackbar notification pops out to indicate that the sign-in operation is successful. 2. The new user profile is created in the database. 3. The user is redirected to the sign-in page.	Pass
2	Confirm Password Wrong	1. Enter an email address. 2. Enter a password. 3. Confirm with a password different from the password entered. 4. Click “Sign up”.	A snackbar notification appears, indicating that the password and confirm password cannot match.	Pass
3	Invalid Email	1. Enter an email address. without the “@” symbol 2. Enter and confirm the password. 3. Click “Sign up”.	A hint text appears under the email input field, showing the email is not valid.	Pass

4	Weak Password	1. Enter an email address. 2. Enter a password of fewer than six characters. 3. Confirm password. 4. Click “Sign up”.	A snackbar notification pops out, showing that the password is weak.	Pass
5	Email already existed	1. Enter an email address that has already registered. 2. Enter the password. 3, Confirm the password 4. Click “Sign up”.	A snackbar notification indicates that the email has already been registered.	Pass
Test Suite 2: Email Login				
#	Test Case	Steps	Expected Result	Status
6	Email Login Smoke Test	1. Enter the email address registered. 2. Enter the correct password 3. Click “Sign in”.	It is signed in successfully. The application is refreshed.	Pass
7	Wrong Password	1. Enter the email address registered. 2. Enter a wrong password 3. Click “Sign in”.	A snackbar notification pops out to indicate that the password is wrong.	Pass
8	Invalid Email	1. Enter an email address without the “@” symbol. 2. Enter the password. 3. Click on the “Sign in” button.	A hint text appears under the email input field, showing the email is not valid.	Pass

<table>
<tr><td colspan="5"><b><i>Test Suite 3: Google Login</i></b></td></tr>
<tr><td>#</td><td>Test Case</td><td>Steps</td><td>Expected Result</td><td>Status</td></tr>
<tr><td>9</td><td>Google Login Smoke Test</td><td>Click “Login with Google”.</td><td>The Google login window opens for the user to choose which Google account to sign in to.</td><td>Pass</td></tr>
<tr><td colspan="5"><b><i>Test Suite 4: Reset Password</i></b></td></tr>
<tr><td>#</td><td>Test Case</td><td>Steps</td><td>Expected Result</td><td>Status</td></tr>
<tr><td>10</td><td>Reset Password Smoke Test</td><td>1. Click “Forgot password?”.
2. Enter the email registered.
3. Click “Send Email”.</td><td>1. A snackbar notification pops out to indicate that the password reset email has been sent.
2. The user can receive the email and reset the password.</td><td>Pass</td></tr>
<tr><td>11</td><td>Email not registered</td><td>1. Click “Forgot password?”.
2. Enter an email not registered.
3. Click “Send Email”.</td><td>A snackbar notification indicates that the email has not been registered.</td><td>Pass</td></tr>
<tr><td colspan="5"><b><i>Test Suite 5: User Data Synchronization</i></b></td></tr>
<tr><td>12</td><td>Edit Name</td><td>1. Login.
2. Click on the pencil icon on the user’s main page.
3. Edit the name and click on “Confirm”.</td><td>The user’s display name is changed.</td><td>Pass</td></tr>
</table>

13	Data Synchronization	1. Login. 2. Edit the user's display name. 3. Add more favourited items. 4. Make changes to the user's itinerary plan. 5. Search any terms on the discover page. 6. Sign out. 7. Sign in with the same account.	After signing in again, the user's display name, favourite list, itinerary plan and search history are consistent with the last signed out version.	Pass

Table 3. Test cases for authentication

5.2 Test Cases for Discover and Search

Test Suite 1: Discover Main Page

#	Test Case	Steps	Expected Result	Status
1	Discover Main Page Smoke Test	Switch to the tab "Discover".	The components are displayed correctly.	Pass
2	Nearby Spots	Switch to the tab "Discover".	1. A scrollable view of nearby spots is displayed. 2. Each spot item can be clicked and redirect the user to a detailed page.	Pass

Test Suite 2: Catalogue Pages

#	Test Case	Steps	Expected Result	Status
3	360 Experiences: Images	1. Switch to the tab "Discover". 2. Click on "360 Gallery". 3. Switch to the tab "Images".	1. A gallery view of 360 images is displayed. 2. Each image item can be clicked and show the corresponding image.	Pass
4	360 Experiences: Videos	1. Switch to the tab "Discover". 2. Click on "360 Gallery". 3. Switch to the tab "Videos".	1. A gallery view of 360 videos is displayed. 2. Each video item can be clicked and show the corresponding video.	Pass

5	Precincts	1. Switch to the tab “Discover”. 2. Click on “Precincts”.	1. A list view of precincts is displayed. 2. Each precinct item can be clicked and show the corresponding details.	Pass
6	Walking Trails	1. Switch to the tab “Discover”. 2. Click on “Walking Trails”.	1. A list view of walking trails is displayed. 2. Each walking trail item can be clicked and show the corresponding walking trail details.	Pass
7	Transport: MRT/LRT lines	1. Switch to the tab “Discover”. 2. Click on “Transport”. 3. Switch to the tab “Line”.	1. A list view of MRT lines is displayed. 2. Each train line item can be clicked and show the corresponding line map.	Pass
8	Transport: MRT/LRT station	1. Switch to the tab “Discover”. 2. Click on “Transport”. 3. Switch to the tab “Station”.	1. A list view of MRT stations is displayed. 2. The list can be navigated by its first letter. 3. Each station item can be clicked and show the corresponding station details.	Pass
9	Transport: MRT/LRT map	1. Switch to the tab “Discover”. 2. Click on “Transport”. 3. Switch to the tab “Map”.	1. An image of the MRT map is displayed. 2. The map is zoomable and controllable.	Pass

10	Transport: MRT/LRT about	1. Switch to the tab "Discover". 2. Click on "Transport". 3. Switch to the tab "About".	A description of the MRT in Singapore is displayed.	Pass
11	Currency Converter	1. Switch to the tab "Discover". 2. Click on "Currency". 3. Calculate 25 SGD to USD. 4. Calculate 25 USD to TWD.	1. The currency converter page is displayed. 2. The calculation result is the same as the latest currency	Pass
Test Suite 3: Search				
#	Test Case	Steps	Expected Result	Status
12	Search Smoke Test	1. Click on the search bar. 2. Enter "Marina Bay". 3. Click on the search icon.	A list of search results is displayed. Each search result item is clickable and will redirect to the detailed page.	Pass
13	Search history	1. User login. 2. Click on the search bar.	A list of search history is displayed.	Pass
14	No Search Result	1. Click on the search bar. 2. Enter "abcdefghijklmn". 3. Click on the search icon.	An image shows no search result is displayed.	Pass

Table 4. Test cases for discover and search

5.3 Test Cases for Detailed Pages

Test Suite 1: Content Display				
#	Test Case	Steps	Expected Result	Status
1	POI Display	1. Open any POI page 2. Scroll the images 3. Click on the review 4. Click on the arrow icon	1. Details of POI are displayed correctly. 2. The images are scrollable. 3. A review detail page can be opened when clicking on the review. 4. A navigation window can be opened when clicking on the arrow icon.	Pass
2	Event and Tour Display	1. Open any event or tour page. 2. Click on the phone number. 3. Long tap the phone number. 4. Click on the website link. 5. Long tap on the website link. 6. Click on the email address. 7. Long tap on the email address. 8. Click on the arrow icon.	1. Details of the event are displayed correctly. 2. A click on the resource opens the URI (if any). 3. A long tap on the resource copies the text (if any). 4. A navigation window can be opened when clicking on the arrow icon.	Pass

3	MRT/LRT Station	1. Open any station page. 2. Click on the arrow icon. 3. Click on the line bar. 4. Click on any other station on the line page.	1. Details of the station are displayed correctly. 2. A navigation window can be opened when clicking on the arrow icon. 3. The line bar can redirect the user to the line page, where more station pages can be accessed.	Pass
4	Precinct	1. Open any precinct page. 2. Click on all the items in the precinct. 3. Click on the "Load More" button.	1. Details of the precinct and a list of places in the precinct are displayed correctly. 2. All items on the precinct page are accessible. 3. More items are loaded when clicking on the "Load More" button.	Pass
5	Walking Trail	1. Open any walking trail page. 2. Switch to the "Map" tab. 3. Tap on any red marker point on the map. 4. Click on the arrow button. 5. Switch to the "Description" tab.	1. Details of the walking trail are displayed correctly. 2. The "map" tab shows a map of the walking trail with points. Clicking on the point will show its name and address. A click on the arrow button will open the navigation option window. 3. The "description" tab shows a description of the walking trail.	Pass

6	360 Image	Open any 360 image page.	The selected 360-degree image is displayed. A scroll on the image or a change in device facing direction changes the viewpoint of the image.	Pass
7	360 Video	1. Open any 360 video page. 2. Click on the video preview image. 3. Click on the "Open in YouTube App" button, if any.	1. The 360 video description is displayed. 2. Clicking on the video preview image will start playing the video. 3. If the 360 video is from YouTube, it can be opened in the YouTube app.	Pass
Test Suite 2: Add to favourite or plan				
8	Add to Favourite or Plan	1. Login. 2. Open any detailed page. 3. Click on the heart icon or the calendar icon. 4. Check the user's favourite list page or the plan page.	1. The icon turns yellow. 2. A snackbar notification pops out to indicate that the adding action is successful. 3. The item appears in the user's favourite list or the plan page.	Pass
9	Add to Favourite or Plan when not logged in	1. Sign out if logged in. 2. Open any detailed page. 3. Click on the heart icon or the calendar icon.	A snackbar notification appears, indicating that the adding action is unsuccessful because the user is not logged in.	Pass

Table 5. Test cases for detailed pages

5.4 Test Cases for Itinerary Planning

Test Suite 1: Plan Main Page UI				
#	Test Case	Steps	Expected Result	Status
1	Itinerary plan display	1. Login. 2. Switch to the “Plan” tab.	A list of the saved itinerary plan is displayed.	Pass
2	Collapse and expand	1. Click on the down arrow button. 2. Click it again.	The day selected can be collapsed and expanded.	Pass
3	Drag and drop	1. Long tap on any item on the plan page. 2. Drag it to another day. 3. Release.	The item appears in the new position and is deleted from the old position.	Pass
4	Add to the archive	1. Swipe any item to the right. 2. Click on “Cancel” on the pop-out window. 3. Swipe another item to the right. 4. Click on “Confirm” in the pop-out window.	The first item remains at the previous position. The second item is removed from the previous day and appears in the archive list.	Pass
5	Delete from plan	1. Swipe any item to the left. 2. Click on “Cancel” on the pop-out window. 3. Swipe another item to the left. 4. Click on “Delete” in the pop-out window.	The first item remains at the previous position. The second item is removed from the previous day.	Pass

6	Add a new day	1. Click on the plus button in the top right corner. 2. Click on “Confirm” in the pop-out window.	A new day with no activity appears in the plan.	Pass
7	Delete an existing day	1. Click on the bin button of a day. 2. Click on “Delete” in the pop-out window.	The day is deleted from the plan. All activities are moved to the archive. The list of days is re-indexed.	Pass
Test Suite 2: Itinerary Recommendation				
8	Itinerary Recommendation	1. Click on the light bulb icon in the top right corner. 2. Click on “Get Recommendation”. 3. Check several interest options. 4. Click on “Get Recommendation”. 5. Wait and click on “Add” when the recommended result is ready.	When no interest is selected, a snackbar notification displays. When any interest is selected, a loading indicator shows up. After a while, a list of recommended items is displayed. Clicking on “Add” will add these items to the main plan page.	Pass

Table 6. Test cases for itinerary planning

5.4 Test Cases for AR Features

Test Suite 1: AR Search Nearby				
#	Test Case	Steps	Expected Result	Status
1	Marker Rendered	1. Switch to the “AR” tab 2. Click on the “Search Nearby” button 3. Hold the device and look around	Markers are shown on the screen at different locations nearby.	Pass
2	Marker Filtering	1. Enter “Search Nearby” mode 2. Click on different categories on the top panel	Markers of selected categories are left on the screen.	Pass
3	Marker Selection	1. Enter “Search Nearby” mode. 2. Click on any marker	A panel pops out, showing the name and type of the place selected.	Pass
5	Detailed Page Redirection	Click on the “details” button on the marker detail panel	The use will be redirected to the place detailed page.	Pass
6	Navigation Dialogue	1. Click on the “direction” button on the marker detail panel 2. Click on the “Open in Google Maps” button 3. Click on the “AR Walking Navigation” button	A navigation dialogue pops out for the user to select the option for navigation. Google maps app or walking navigation mode is opened for the navigation process.	Pass

Test Suite 2: AR Walking Navigation				
9	AR Walking Navigation Initialization	1. Switch to the “AR” tab 2. Click on the “AR Walking Navigation” button 3. Hold the device and walk around	The walking instruction, distance and time left to the next turning point are shown on the screen. A map and a compass are shown on the screen.	Pass
10	Display Setting Switches	1. Enter the “AR Walking Navigation” mode 2. Click on the setting icon on the top app bar 3. Toggle the switch for showing the map 4. Toggle the switch for showing the compass 5. Toggle the switch for the text colour	The user can toggle the switches to show or hide the map and the compass on the screen or change the displayed text’s text colour.	Pass
11	Instruction Update	1. Enter the “AR Walking Navigation” mode 2. Click on the “Next” button several times	The instruction, distance and time display are switched for the next turning point. Finally, a dialogue pops out, indicating the user has arrived at the desired destination.	Pass

Table 7. Test cases for AR Features

Conclusion

This chapter summarises the learning outcomes obtained through the project, an objective evaluation of the project management and future work of the project.

Learning Outcomes Obtained

This project is my first time designing and developing a mobile application. I divide the learning outcomes into two main categories: technical and behavioural.

Technical

Technical outcomes learnt from this project include:

1. How to write code in Dart language and create a Flutter app.

2. How to integrate Google Cloud Platform and Firebase as a cloud service provider.

3. How to implement object-oriented programming in a project to make the code more readable.

4. How to gather resources through web scraping with Python.

5. How to make use of an API.

Behavioural

Behavioural outcomes learnt from this project include:

1. How to seek technical support from the platform and resource providers.

2. How to get inspiration from communication with friends and peers.

3. How to manage a mobile application development project.

Project Management Evaluation

This section is an objective evaluation of the project management process. The whole process is divided into four phases: research, planning, execution, and finalization.

There are three criteria for the evaluation: timeliness, quality, and effectiveness. A score is given to each criterion, with a total score of five.

Research Phase

Criterion	Timeliness	Quality	Effectiveness
Score	5	4	5

Table 8. Evaluation of the research phase in project management

The research phase started in mid-August and ended in mid-September of 2021. The main task of the research phase was to determine the technology stack of the application. Most of the technology stack was decided, except the adaption of cloud service.

Planning Phase

Criterion	Timeliness	Quality	Effectiveness
Score	4	3.5	5

Table 9. Evaluation of the planning phase in project management

The planning phase is mid-September of 2021. A strategic plan was made, including the timeline of the execution stage. However, the time required for most of the work was underestimated in this plan.

Executions Phase

Criterion	Timeliness	Quality	Effectiveness
Score	3.5	4	4

Table 10. Evaluation of the execution phase in project management

The execution phase starts in early October of 2021 and will last until mid-April 2022. Due to assignments and exams, the project execution in 2021 was slow, but the UI design and AR nearby search feature were mainly completed. Most of the work was accomplished in the January of 2022.

The main issue with execution is priority management. Much time was consumed in data collection, leaving little time for function development and enhancement. Although project management solutions such as the Notion board view provide a good representation of progress, project task prioritization is inadequate. Many activities share the same priority, and the execution order is not strictly according to the priority. Fortunately, most of the work can still be completed before the deadline.

Finalization Phase

Criterion	Timeliness	Quality	Effectiveness
Score	4	3.5	4

Table 11. Evaluation of the Finalization phase in project management

The finalization phase includes the application testing, report writing and project demonstration. This phase will be ended in mid-May.

The application function testing is included in Chapter 5, which ensures the app functions are running without error. The report writing took around two weeks from mid-March. An extra demonstration video is created to provide everyone with an intuitive view of the application.

Future Work

This section covers the future work for *HiSG*, which includes enhancement to the existing AR features, possible new features that can be added and new platforms that can be deployed.

Existing AR Feature Enhancement

The existing AR navigation is solely dependent on the geo-location of the user. Considering the limited precision of the location from Wi-Fi or the Global Positioning System (GPS), a combination with scene recognition may be the way to improve the accuracy of navigation information.

Google Maps Live View is an AR navigation feature embedded in the Google Maps app. It uses the global localization technology, a combination of Street View, Visual Positioning Service (VPS) and machine learning, to improve the navigation behaviour [106]. With VPS, the location of the user is determined by comparison between the camera view and the pre-defined imagery from Google Street View, instead of GPS signals.

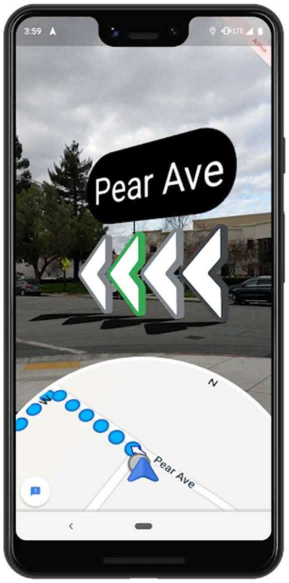


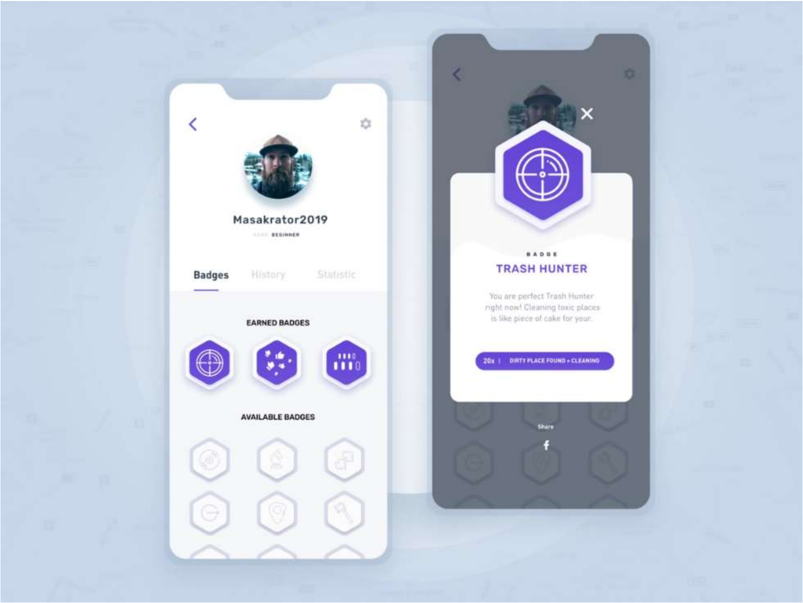
Figure 41. Screenshot of Google Maps Live View.
Source: Adapted from [106]

New Feature

Badge Collection

Imagine a tourist visiting Singapore and using our app to make vacation plans. A badge-collection system will allow him to keep track of where he has travelled, what resources he has browsed, and how many journeys the application has taken him on.

The badges available and collected may be displayed on the user's main page. *Figure 42* shows an example of the possible UI for this badge collection feature.

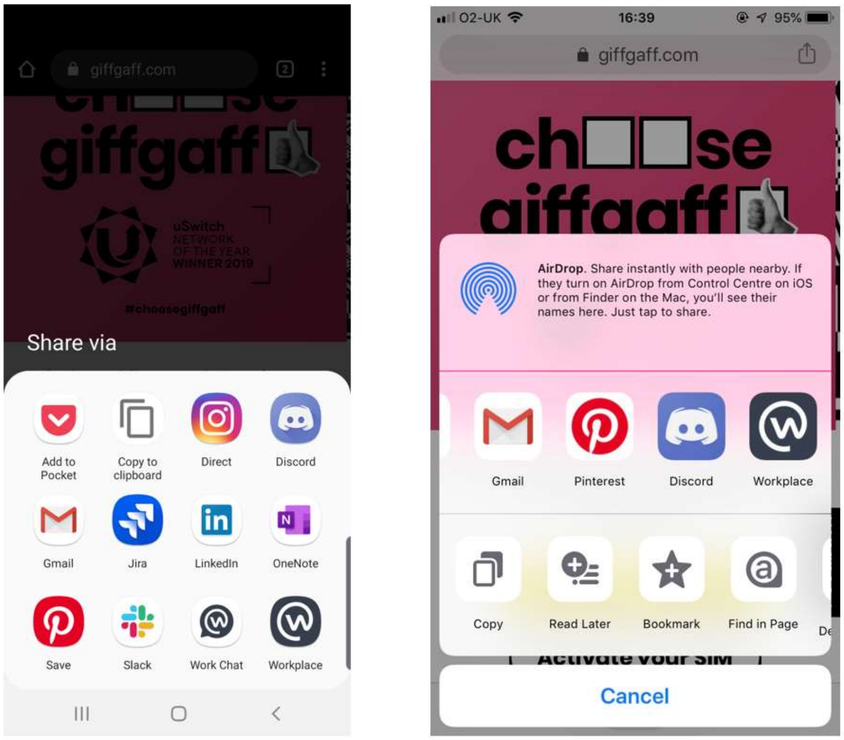


You are perfect Trash Hunter right now! Cleaning toxic places is like piece of cake for your.

Figure 42. Possible user interface pages for the badge collection feature.
Source: Adapted from [107]

Content Sharing

Most applications allow their users to share content with their friends through social media. For *HiSG*, the content shared may be the detailed information for an exciting tour, a day planned in the itinerary, or a wonderful 360 VR image. The sharing function also encourages people to download and try the *HiSG* app.



AirDrop. Share instantly with people nearby. If they turn on AirDrop from Control Centre on iOS or from Finder on the Mac, you'll see their names here. Just tap to share.

Figure 43. Native share dialogue on Android (left) and iOS (right).
Source: Adapted from [108]

New Platform

HiSG is an Android app created using Flutter, a cross-platform development tool. *HiSG*'s next stage might be integrating the app into the iOS system and benefiting Apple users. The native configuration on iOS and functional compatible testing are the last activities before deploying to the iOS system.

Since *HiSG* has AR and VR features, making the application compatible with smart headsets and glasses can also improve the user's interaction experience.

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Appendix A - Source Code

The source code for the *HiSG* app is available on the website below, excluding secret keys to APIs:

https://github.com/Haoran101/FYP-HiSG

Open-Source Code References

Name	***Author***	***URL***	***Type***
Wikitude Flutter Example App	Wikitude	https://github.com/Wikitude/wikitude-flutter-plugin-examples	GitHub Repository
Flutter Exchange Rate App	akmadan	https://github.com/akmadan/currency_flutter_webapp	GitHub Repository
Flutter Firebase Social Login App	Coding Cafe	https://www.youtube.com/playlist?list=PLxefhmF0pcPmTIE0yl7wNw7JqUceYuL_L	YouTube Tutorial
Flutter Drag and Drop List View	Johannes Milke	https://www.youtube.com/watch?v=HmiaGyf55ZM	YouTube Tutorial
Search Bar in Flutter	Reso Coder	https://resocoder.com/flutter-search-bar	Blog Article

Appendix B - List of APIs used

Name	***Resource URL***
Google Maps Nearby Search	https://maps.googleapis.com/maps/api/place/nearbysearch/output?parameters
Google Place Details	https://maps.googleapis.com/maps/api/place/details/output?parameters
Google Place Photos	https://maps.googleapis.com/maps/api/place/photo?parameters
TIH Content API	https://tih-api.stb.gov.sg/content/v1/search/all
TIH Media API	https://tih-api.stb.gov.sg/media/v1/media/uuid/
TIH Map API	https://tih-api.stb.gov.sg/map/v1/place/
TIH OAuth API (test environment)	https://api-test.stb.gov.sg/oauth/accesstoken
TIH Recommendation Engine API (test environment)	https://api-test.stb.gov.sg/service/v1/content/recommendations
Open Exchange Rate Latest	https://openexchangerates.org/api/latest.json
Open Exchange Rate Currencies	https://openexchangerates.org/api/currencies.json
Google Direction Service JavaScript API	https://developers.google.com/maps/documentation/javascript/directions

Appendix C - List of dependencies used

All the Flutter packages with versions are listed below.

The “^” mark means any version later than or equivalent.

Package	***Version***
location	^4.1.1
path_provider	^2.0.1
wakelock	^0.5.1
material_floating_search_bar	^0.2.6
augmented_reality_plugin_wikitude	9.9.0
http	^0.13.3
flutter_html	^2.1.5
firebase_core	^1.11.0
firebase_auth	^3.3.5
google_sign_in	^5.2.2
cloud_firestore	^3.1.6
video_player_360	^0.1.5
panorama	^0.4.1
fuzzywuzzy	^0.1.7
flutter_rating_bar	^4.0.0
url_launcher	^6.0.18
drag_and_drop_lists	^0.3.2+2
date_format	^2.0.5
geolocator	^8.0.5
basic_utils	^3.9.0
flutter_map	^0.14.0
flutter_map_marker_popup	^2.1.2
cached_network_image	^3.2.0
azlistview	^2.0.0
photo_view	^0.13.0
provider	^6.0.2
flutter_compass	^0.7.0
permission_handler	^9.2.0
flutter_polyline_points	^1.0.0
flutter_map_location_marker	^3.1.0

Appendix D - List of public web data used

Usage	*URL*
360-degree VR photos	https://www.360cities.net/
360-degree VR videos	https://www.visitsingapore.com/en/
360-degree VR videos (YouTube)	https://www.youtube.com/channel/UCN027-rS7Z7QmmR336HJA1Q
MRT station and line information	https://www.lta.gov.sg/content/ltagov/en/map/train.html#
Hotel information	https://www.google.com/travel/hotels