Mobile Applications

4. Storing data in Android

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1. Introduction

- **Persistent storage** refers to the mechanisms used to save data permanently on a device, ensuring that the data remains available even after the app is closed or the device is restarted
- Android provides several options for persistent storage, such as:
  - Local database: using **SQLlite**, a lightweight relational database integrated in Android
  - Internal storage: to store private files directly on the device's file system
  - External storage: for storing files that can be shared with other apps
  - DataStore: key-value pairs (e.g., for user preferences)
  - Cloud storage: un this unit, we study **Cloud Firestore**, a cloud-hosted NoSQL document database provided by **Firebase** (Google)

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2. Firebase

- **Firebase** is a set of backend cloud computing services and application development platforms provided by Google
  - It provides a range of services and tools to assist developers in building, improving, and scaling mobile and web applications
  - It is sometimes called a *backend as a service*
- **Google Cloud** a suite of cloud computing services that provides for data storage, analytics, machine learning, etc.
  - Firebase is considered to be a part of Google Cloud
    - Firebase was initially an independent startup that Google acquired in 2014
    - Firebase has been integrated into the broader Google Cloud ecosystem

https://cloud.google.com/

https://firebase.google.com/

2. Firebase

- Some key components of Firebase are the following:
  - Cloud Firestore: a cloud-hosted NoSQL document database
  - Authentication: support service for various authentication methods, including email/password, social media logins (Google, Facebook, Twitter), and more
  - Cloud Functions: serverless computing, allowing to run backend code in response to HTTPS requests and events triggered by Firebase
  - Cloud Storage: scalable and secure cloud storage for user-generated content like images, videos, and other files
  - Analytics: statistics about user engagement, retention, and conversion rates

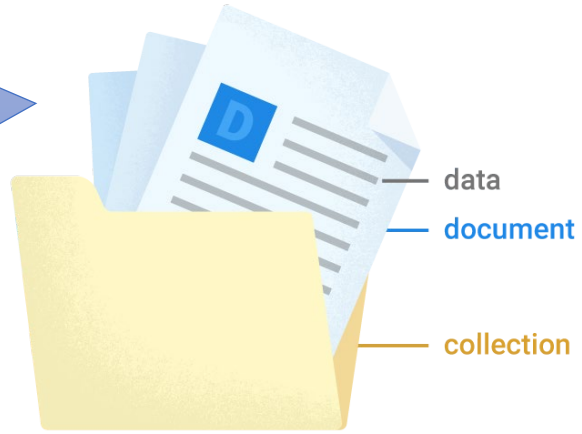
Most Firebase services have quotas and pricing based on the usage

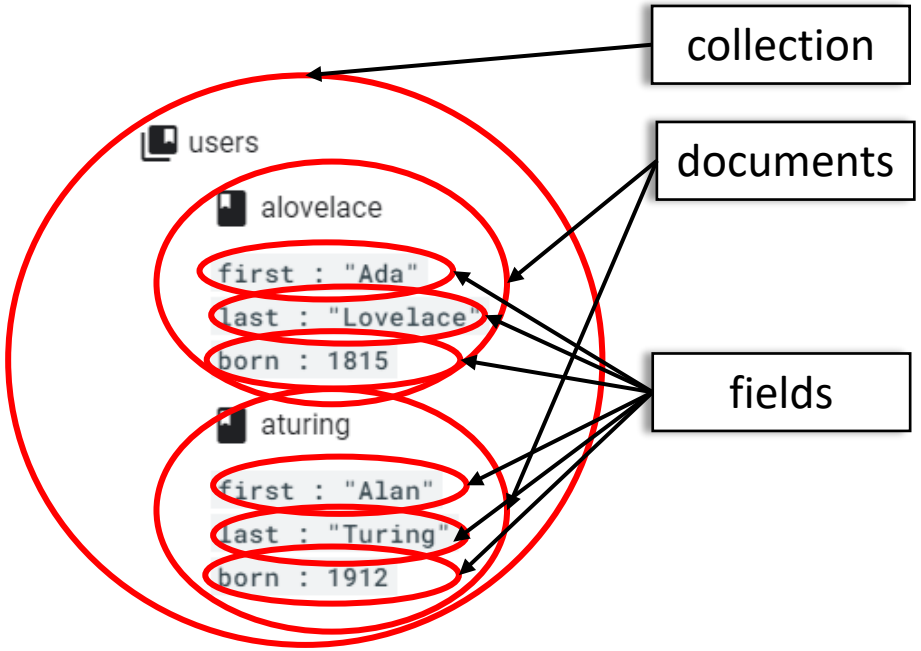
https://firebase.google.com/docs/

2. Firebase - Cloud Firestore

- In Cloud Firestore, the basic unit of storage is the **document**
  - A document is a lightweight record that contains **fields**, which map to values
  - Documents live in **collections**, which are simply containers for documents

Each document is uniquely identified by an automatically generated or user-defined id

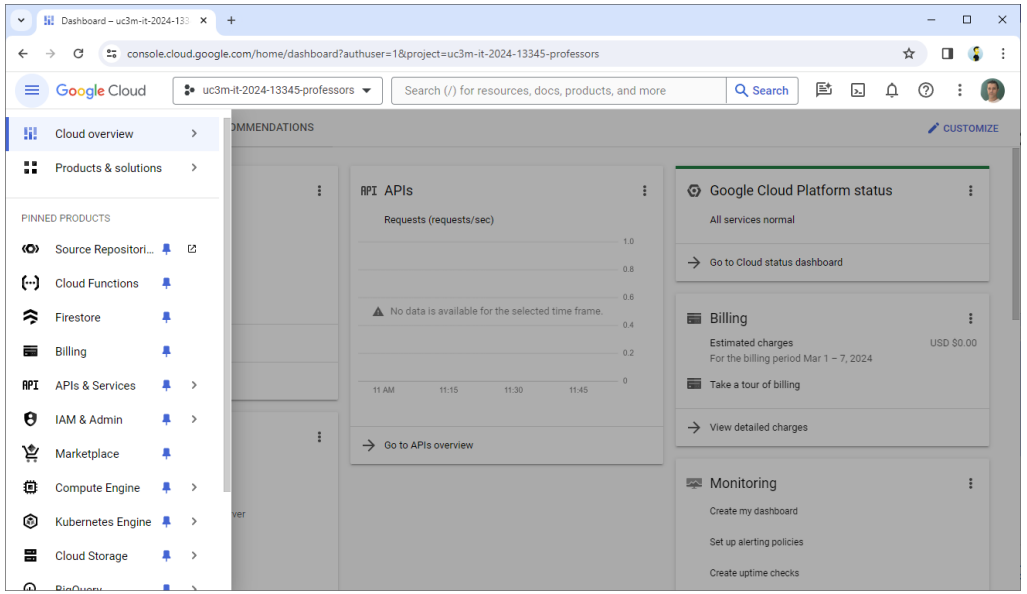




https://firebase.google.com/docs/firestore/data-model

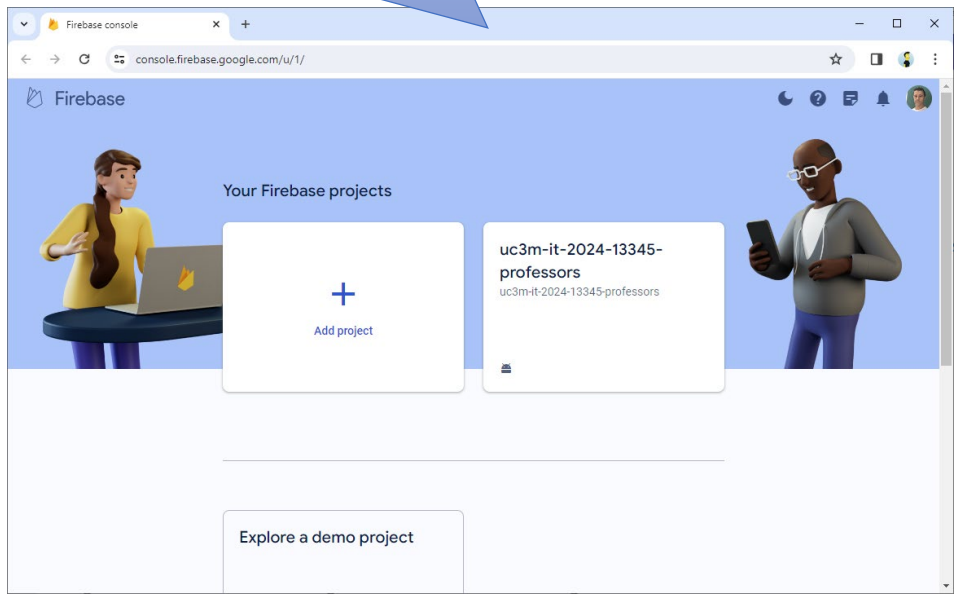
2. Firebase - Cloud Firestore

- Some of the Firebase services are also available through the Google Cloud console, for example, Cloud Firestore, Cloud Functions, or Cloud Storage



https://console.cloud.google.com/

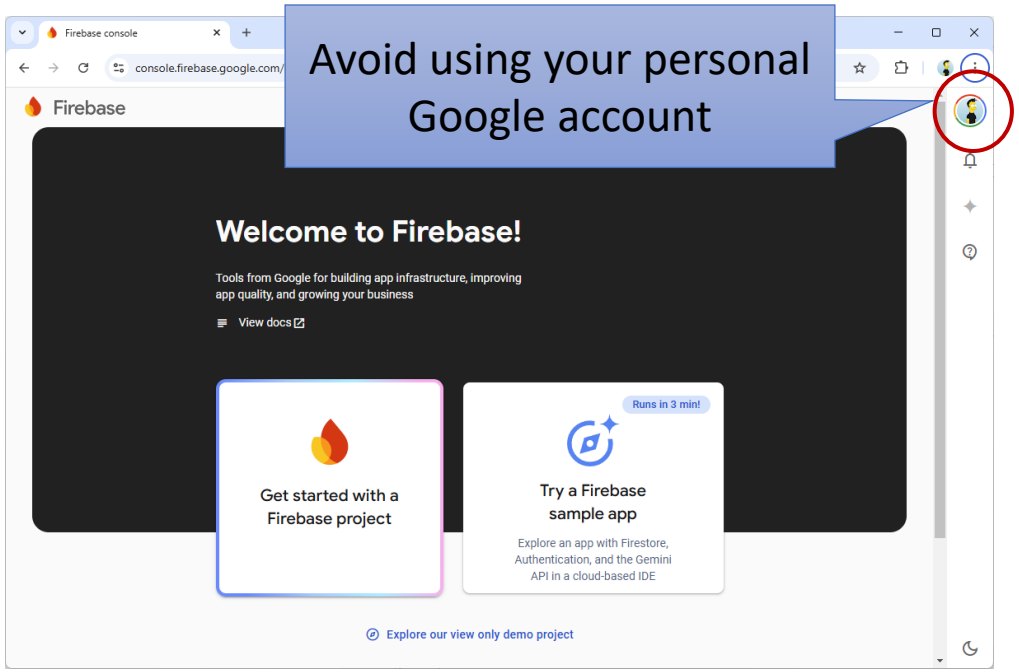
We use the Firebase console in this unit

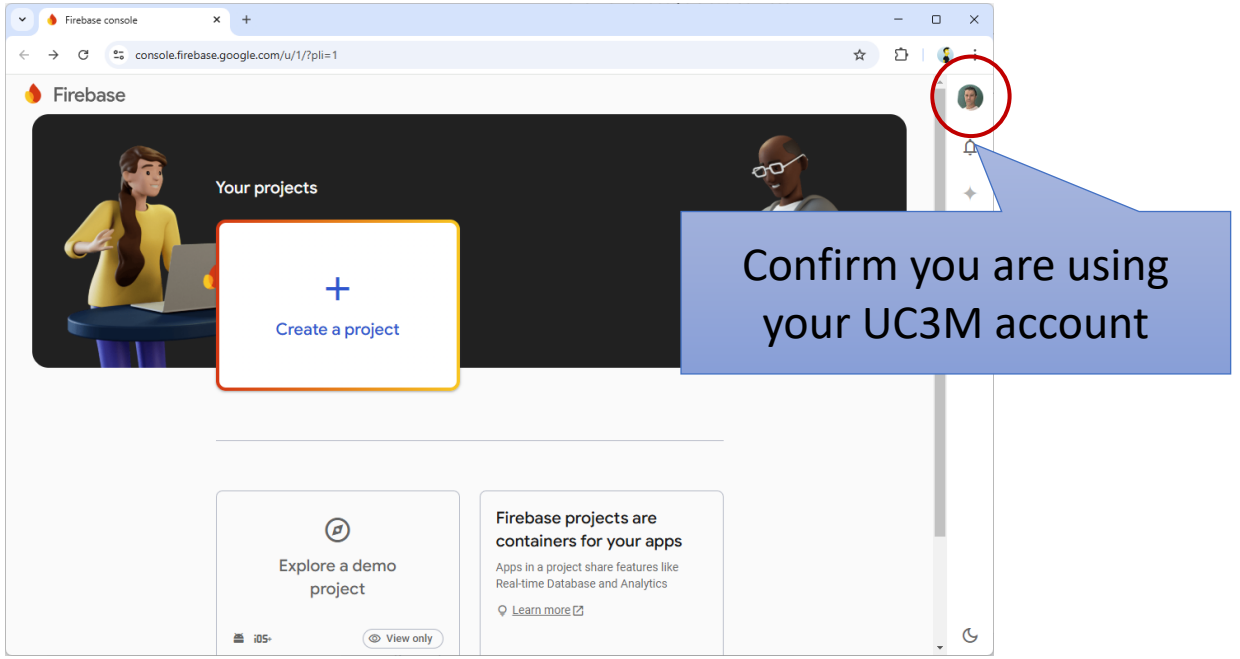


https://console.firebase.google.com/

2. Firebase - Cloud Firestore

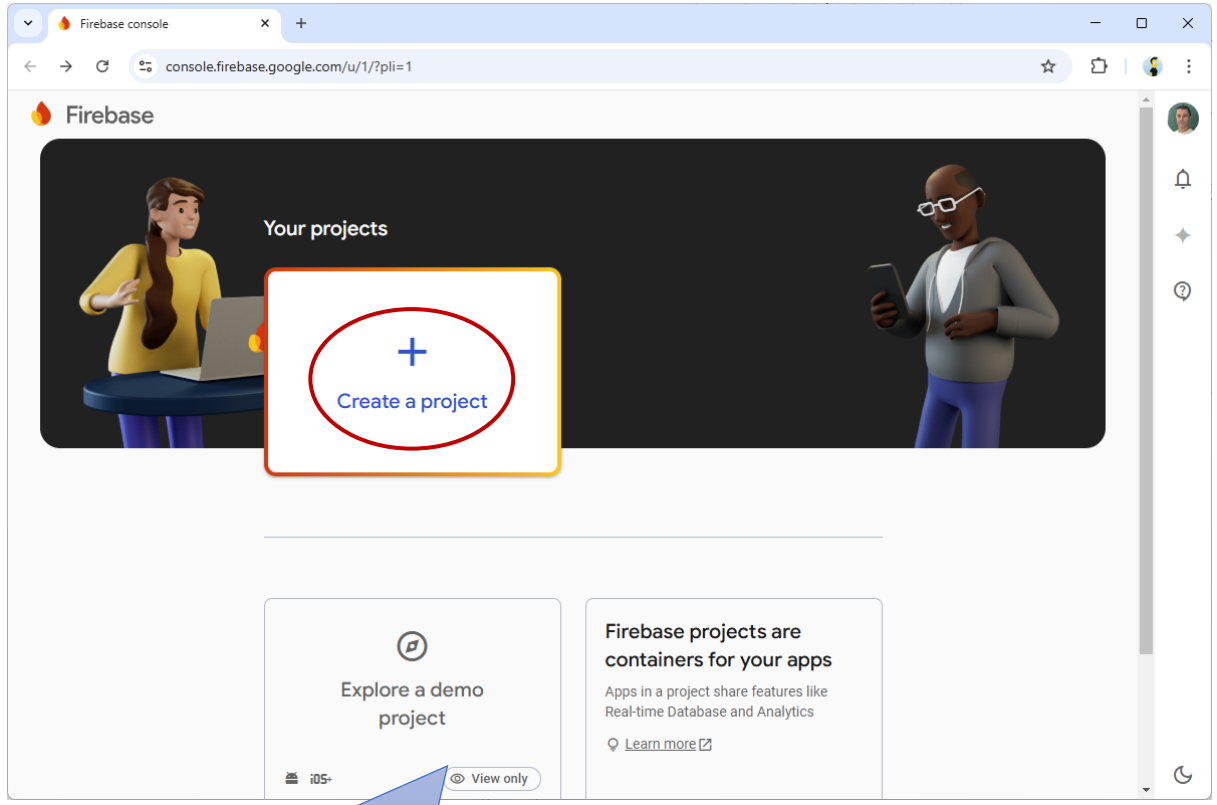
- To use Firebase, first we need a Google account
  - In this course, we should use our UC3M account (e.g. xxxxxxxxx@alumnos.uc3m.es)



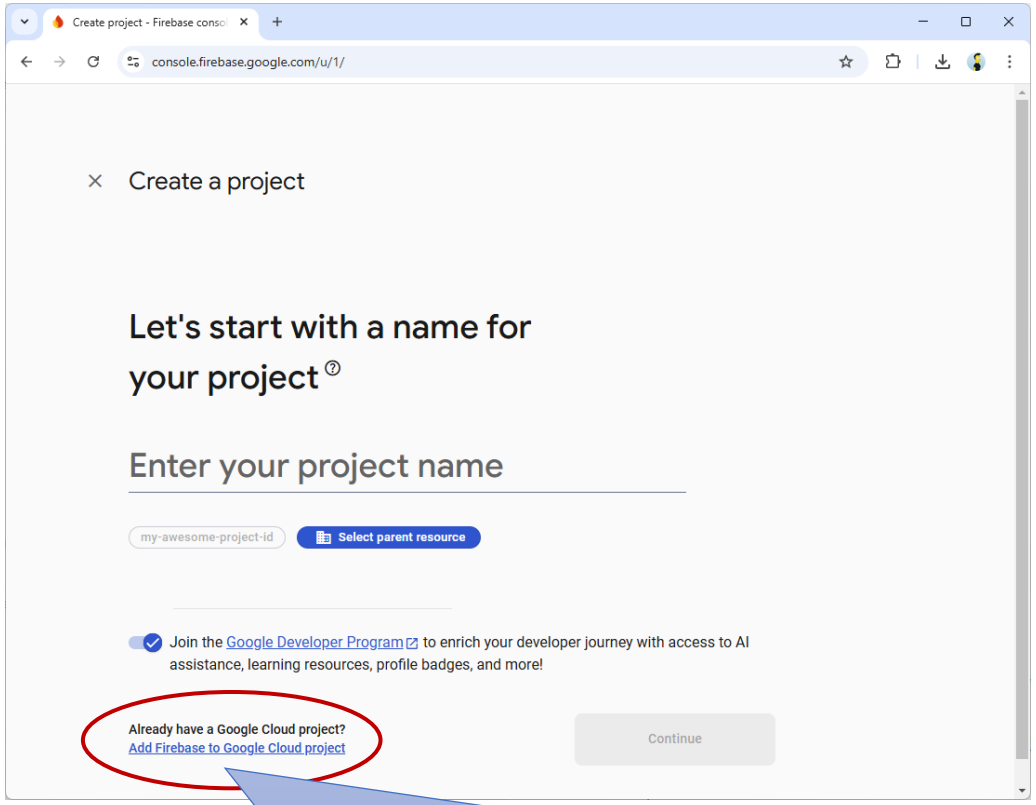


https://console.firebase.google.com/

2. Firebase - Cloud Firestore

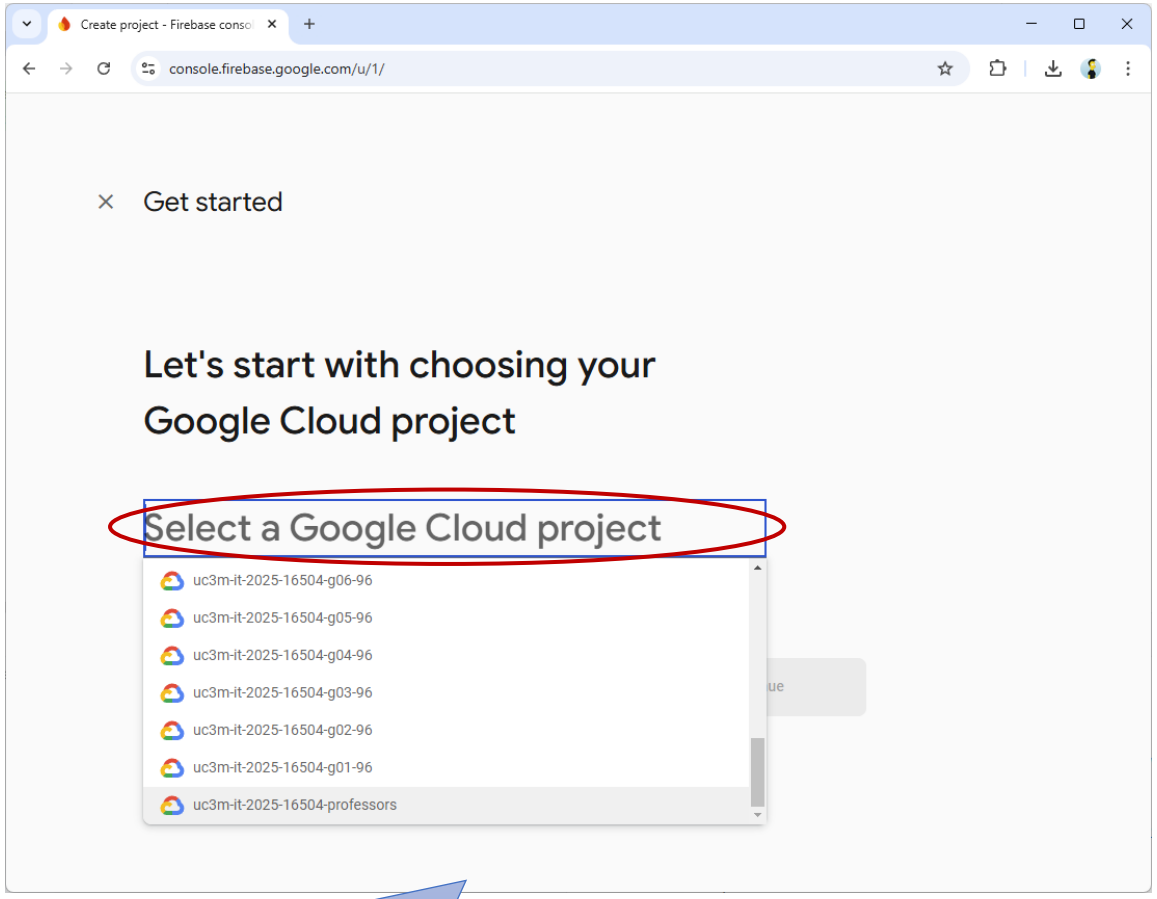


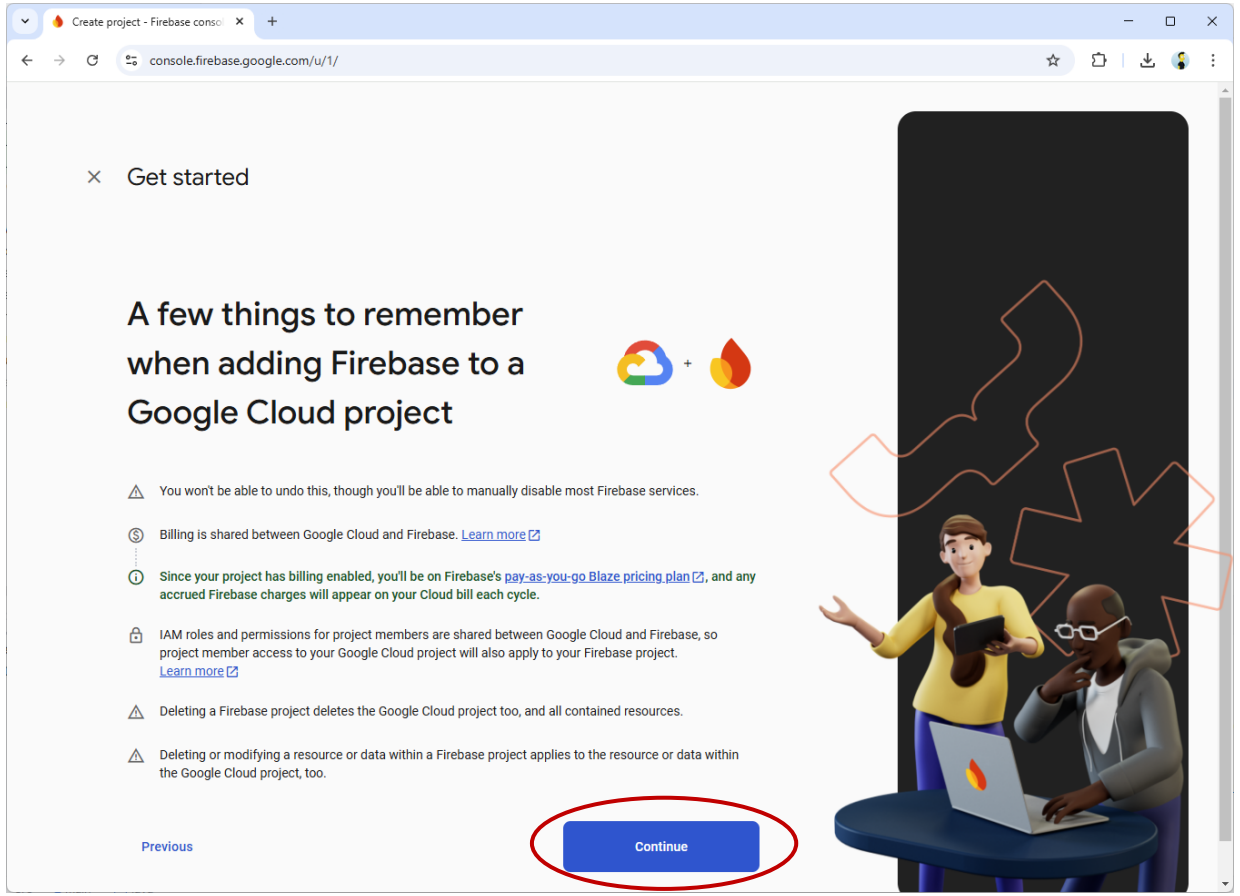
The first step to use Cloud Firestore is to add a project in the console



We need to use the Google cloud project already created (**uc3m-it-2025-16504-g**-lab**), in which you should have redeemed your educational Google coupon ($50) on the lab session on 7 March

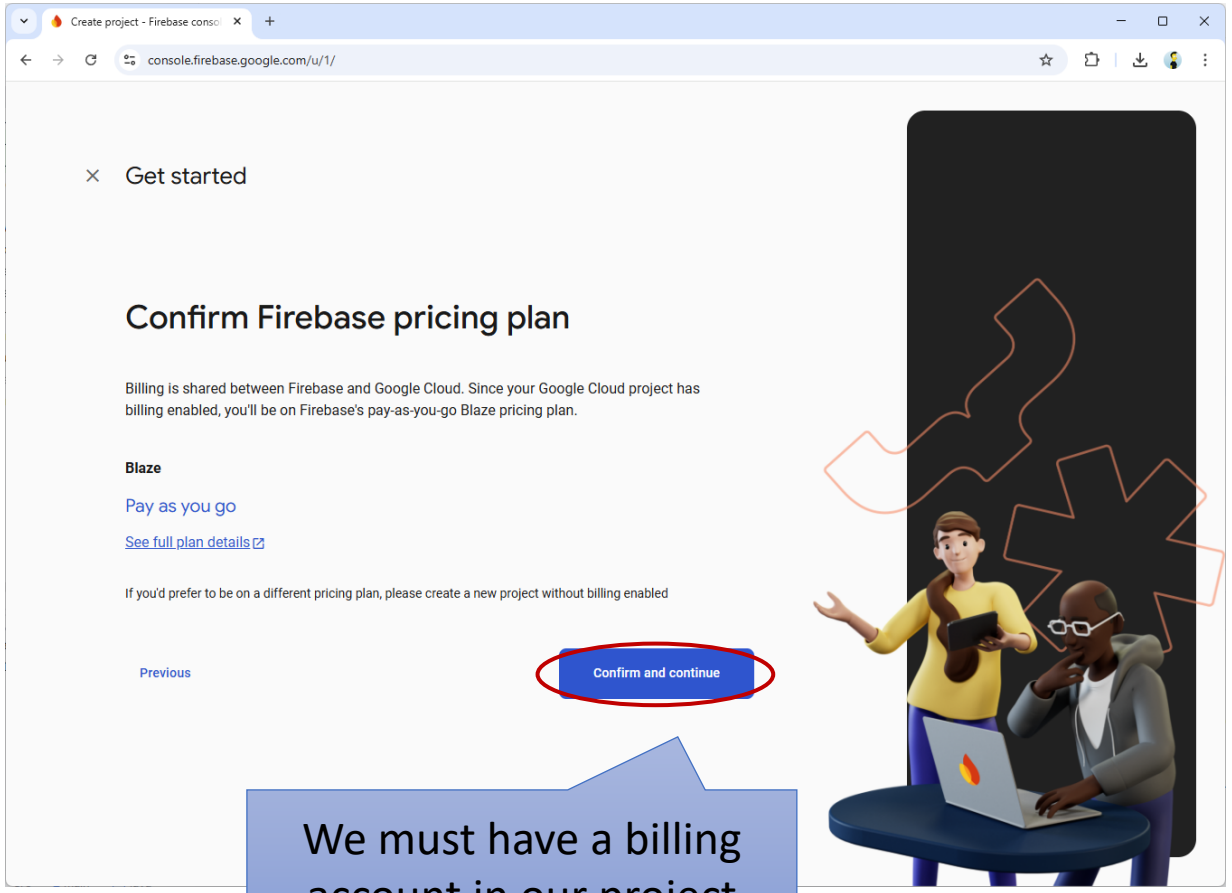
2. Firebase - Cloud Firestore



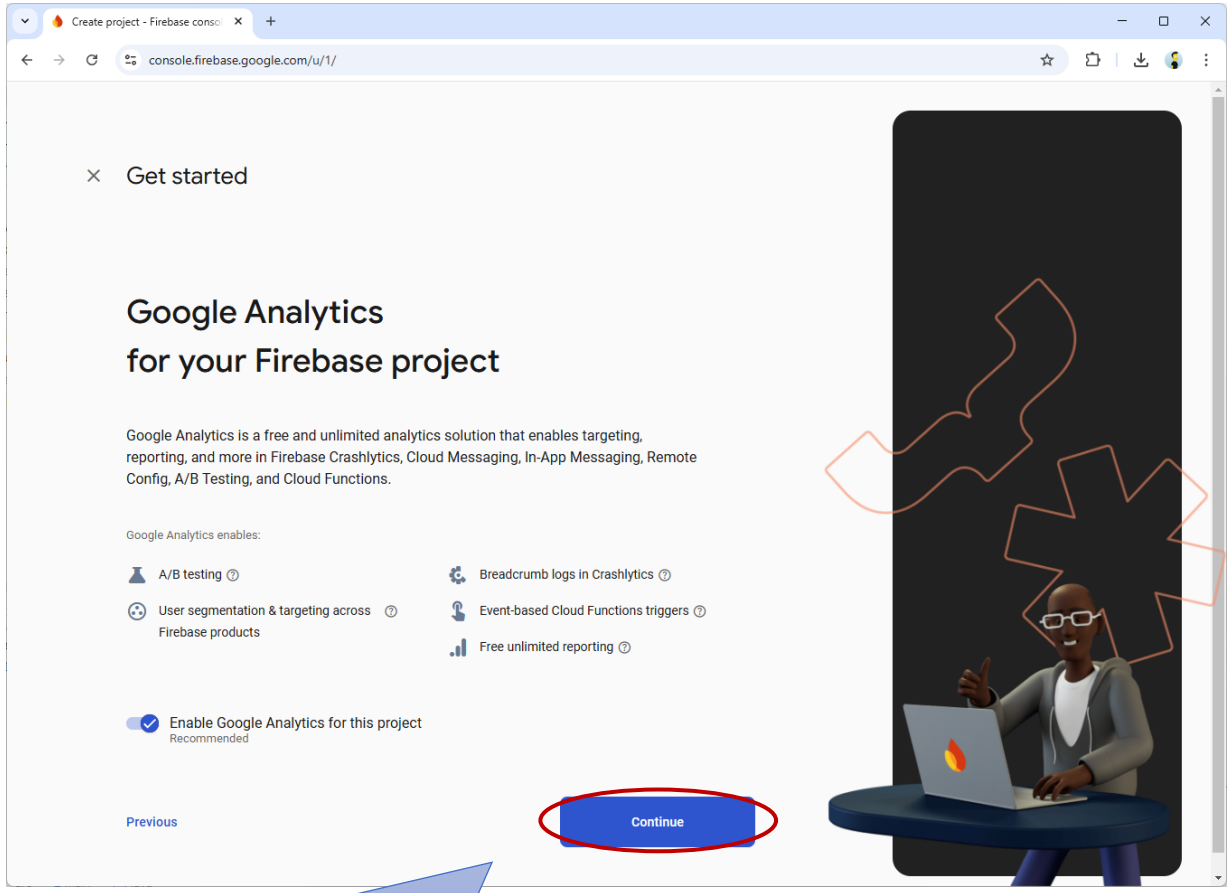


Select your project here and follow the instructions

2. Firebase - Cloud Firestore

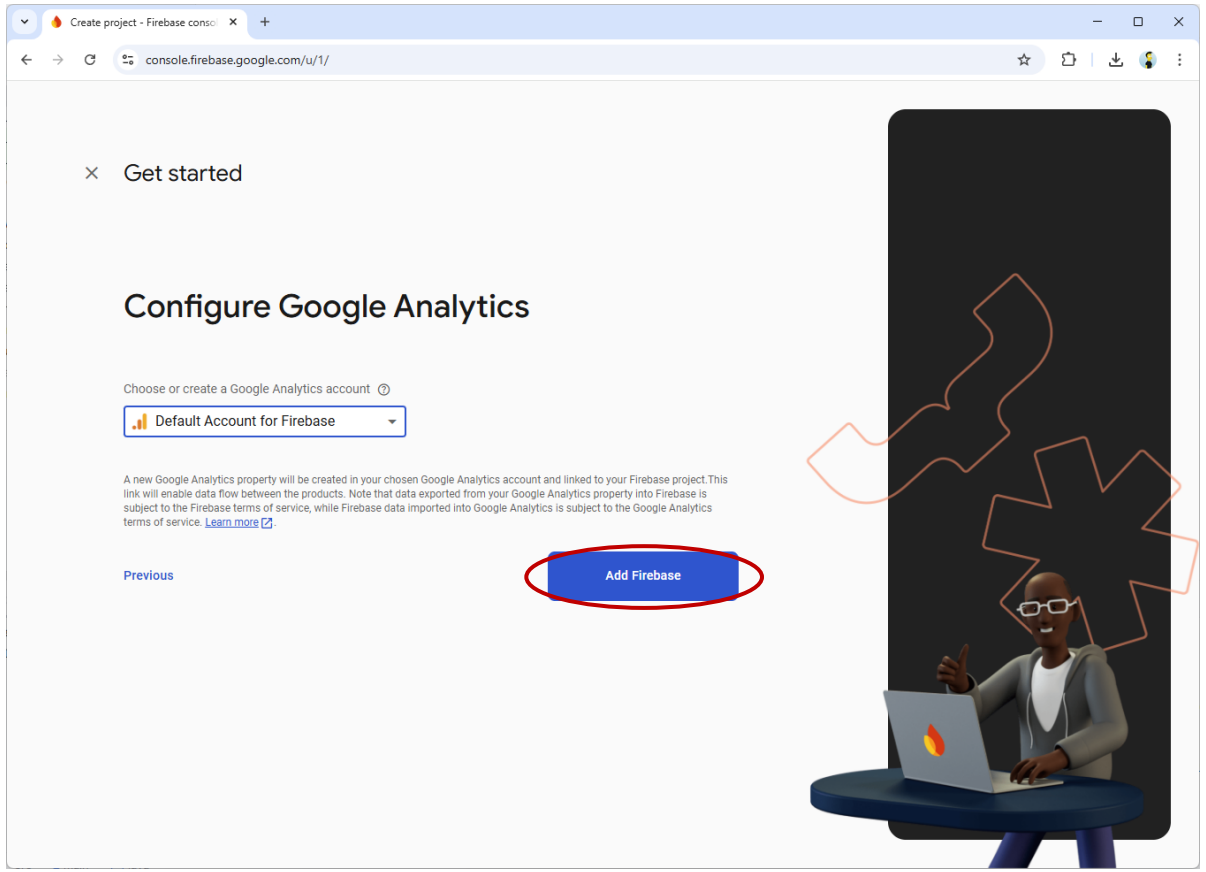


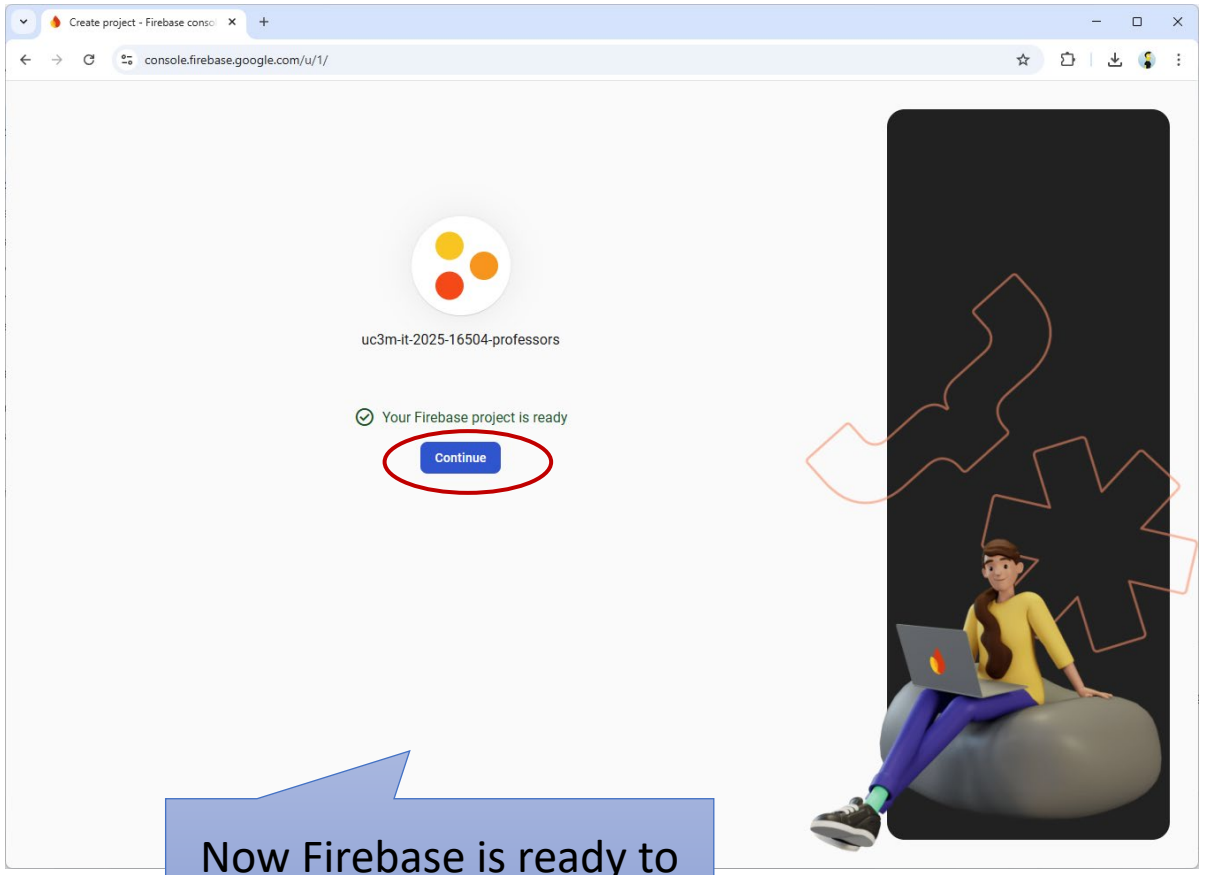
We must have a billing account in our project



Analytics is optional

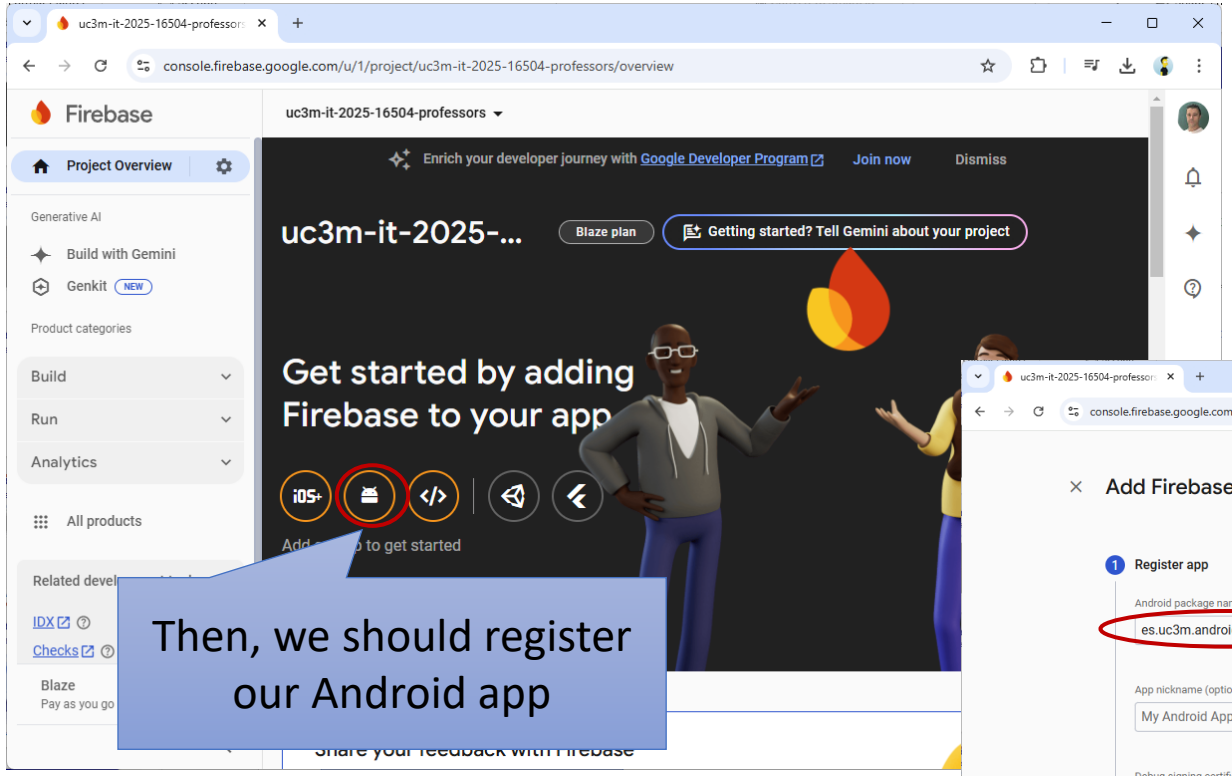
2. Firebase - Cloud Firestore



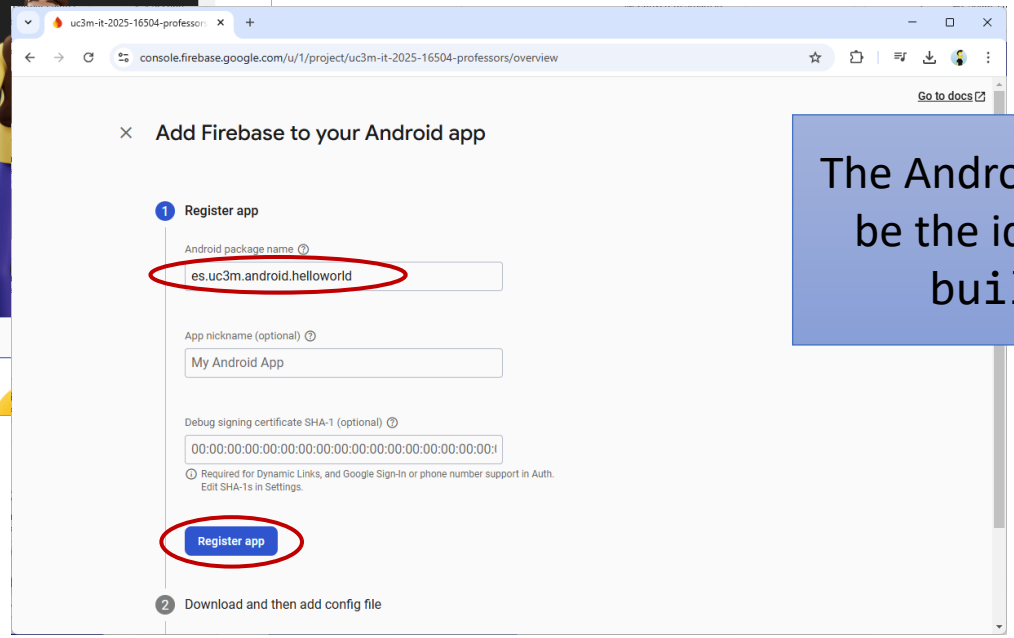


Now Firebase is ready to be used

2. Firebase - Cloud Firestore



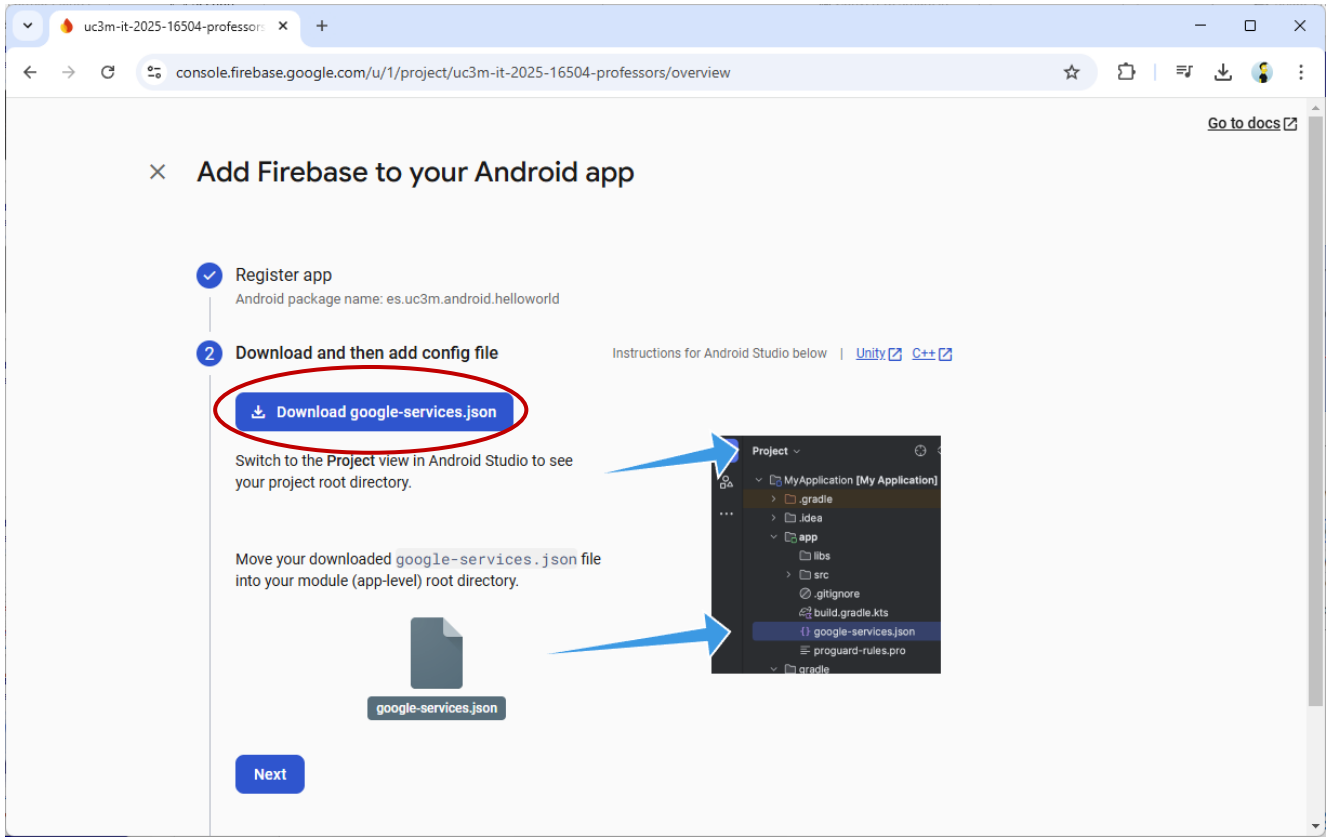

```
android {
    namespace = "es.uc3m.android.firebase"
    compileSdk = 35

    defaultConfig {
        applicationId = "es.uc3m.android.firebase"
        minSdk = 24
        targetSdk = 35
        versionCode = 1
        versionName = "1.0"

        testInstrumentationRunner = "androidx.test.runner.AndroidJUnitRunner"
    }
```



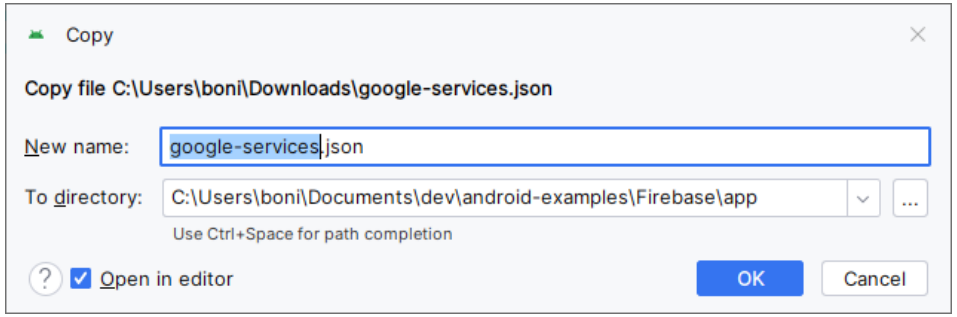
The Android package name must be the id defined in our app's `build.gradle.kts`

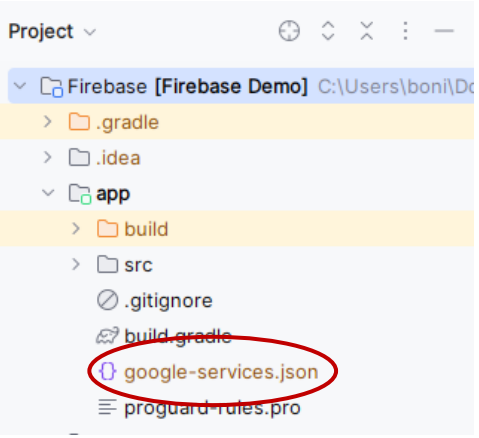
https://firebase.google.com/docs/android/setup

2. Firebase - Cloud Firestore



Then we need to download a configuration file called **`google-services.json`** and copy it to the app folder of our Android project





https://developers.google.com/android/guides/google-services-plugin

2. Firebase - Cloud Firestore

- For security reasons, it is not recommended to publish **`google-services.json`** on open repositories (e.g., in GitHub)
  - As the doc says:

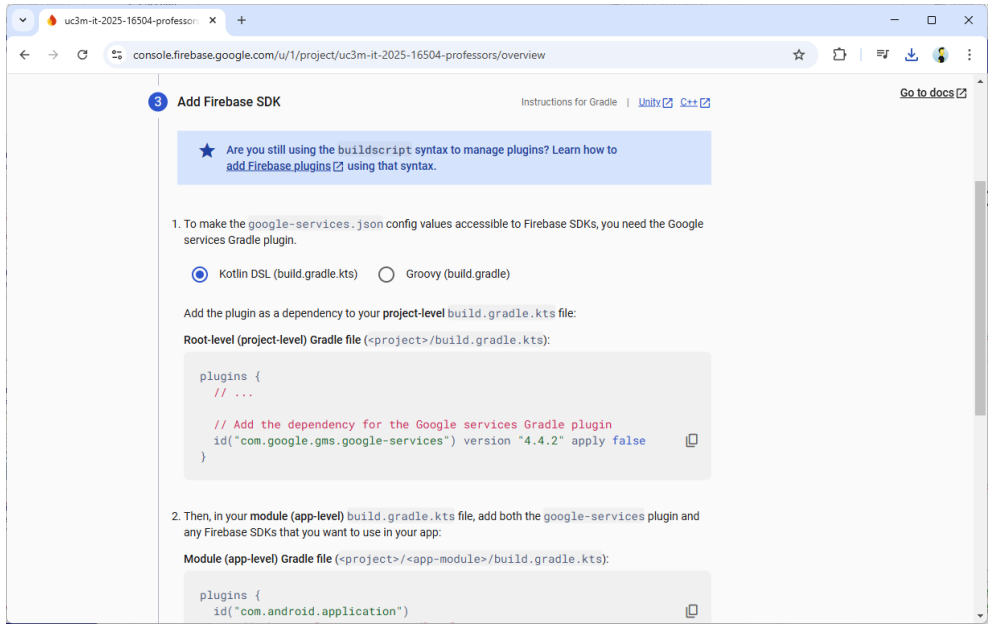
> *For open source projects, we generally do not recommend including the app's Firebase config file or object in source control because, in most cases, your users should create their own Firebase projects and point their apps to their own Firebase resources (via their own Firebase config file or object).*

https://firebase.google.com/docs/projects/learn-more#config-files-objects

So, it you are using an open GitHub repository, a good practice is to include this file name in `.gitignore`

2. Firebase - Cloud Firestore

- Then, we need to configure our Android project to use Firebase:



build.gradle.kts (project)

```
plugins {
    alias(libs.plugins.google.services) apply false
}
```

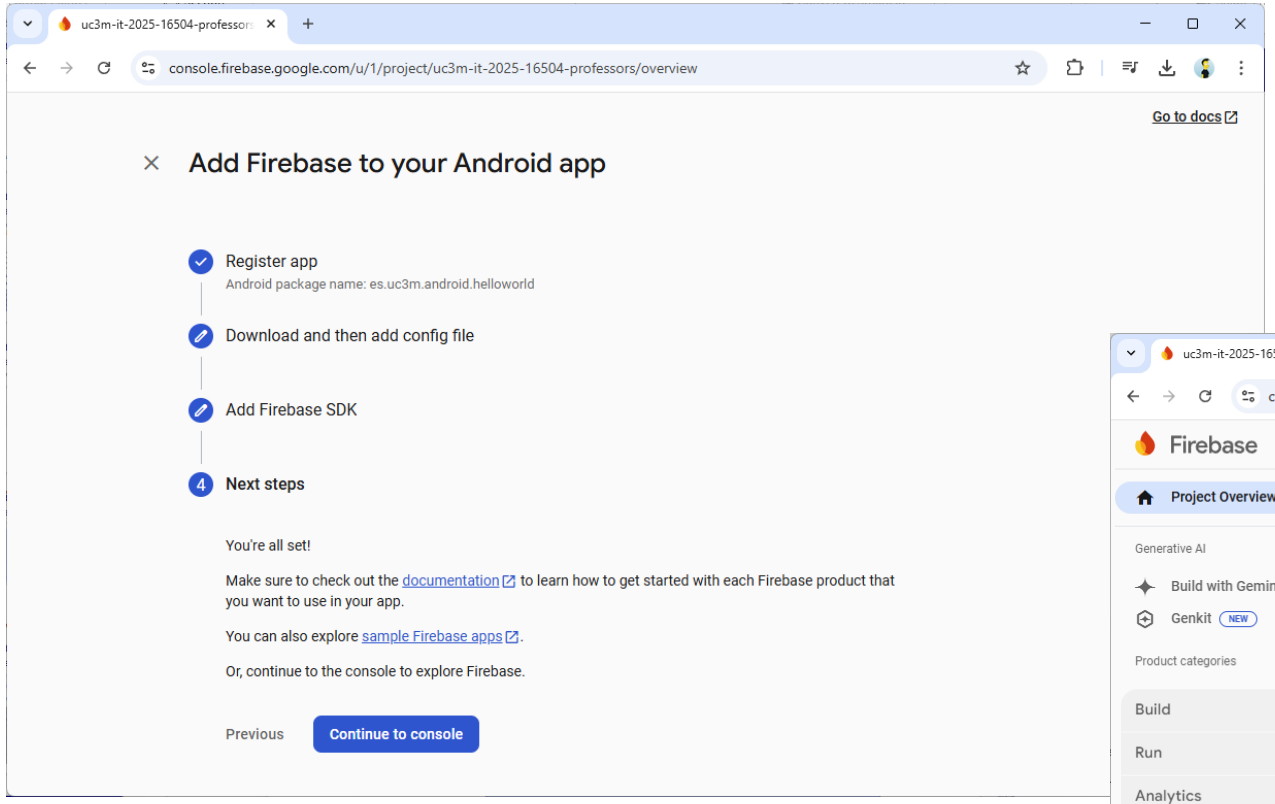
build.gradle.kts (app)

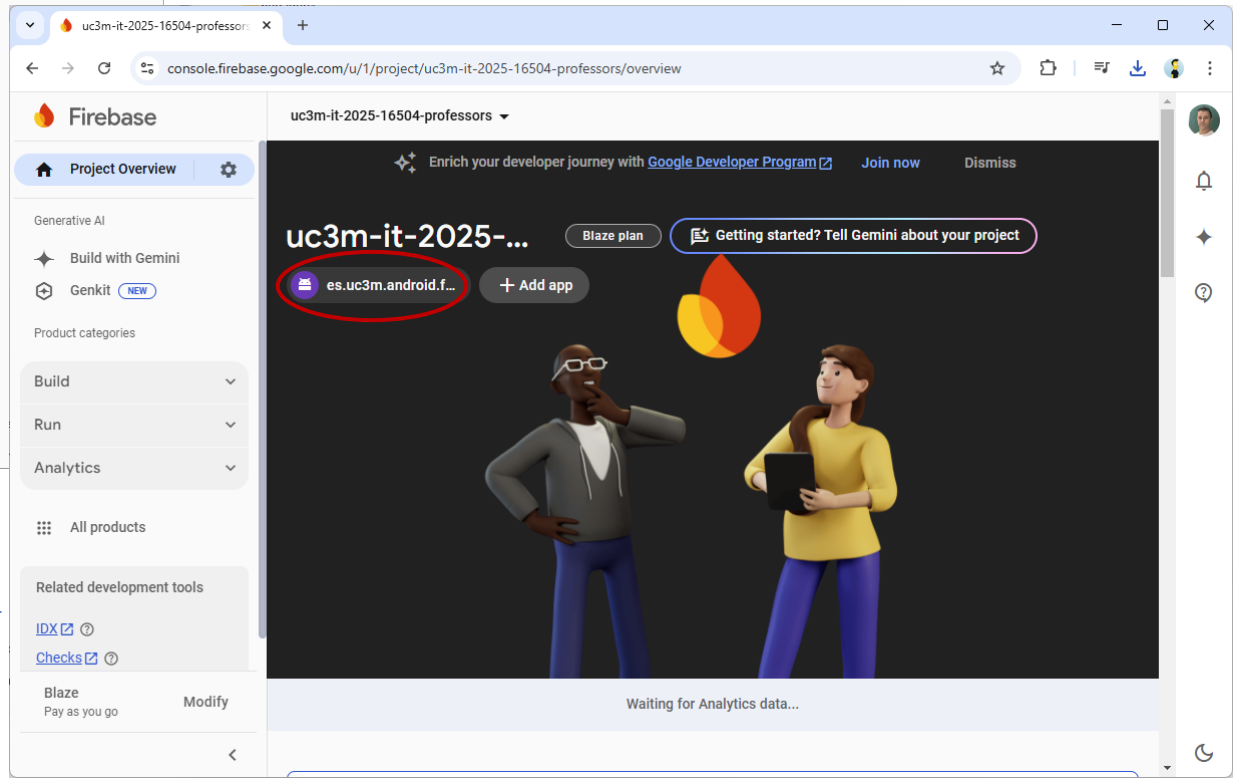
```
plugins {
    alias(libs.plugins.google.services)
}

dependencies {
    implementation(platform(libs.firebase.bom))
    implementation(libs.firebase.firestore)
    implementation(libs.firebase.auth)
}
```

libs.version.toml

```
[versions]
google-services = "4.4.2"
firebaseBom = "33.10.0"

[libraries]
firebase-firestore = { module = "com.google.firebase:firebase-firestore" }
firebase-bom = { module = "com.google.firebase:firebase-bom", version.ref = "firebaseBom" }
firebase-auth = { module = "com.google.firebase:firebase-auth" }

[plugins]
google-services = { id = "com.google.gms.google-services", version.ref = "google-services" }
```

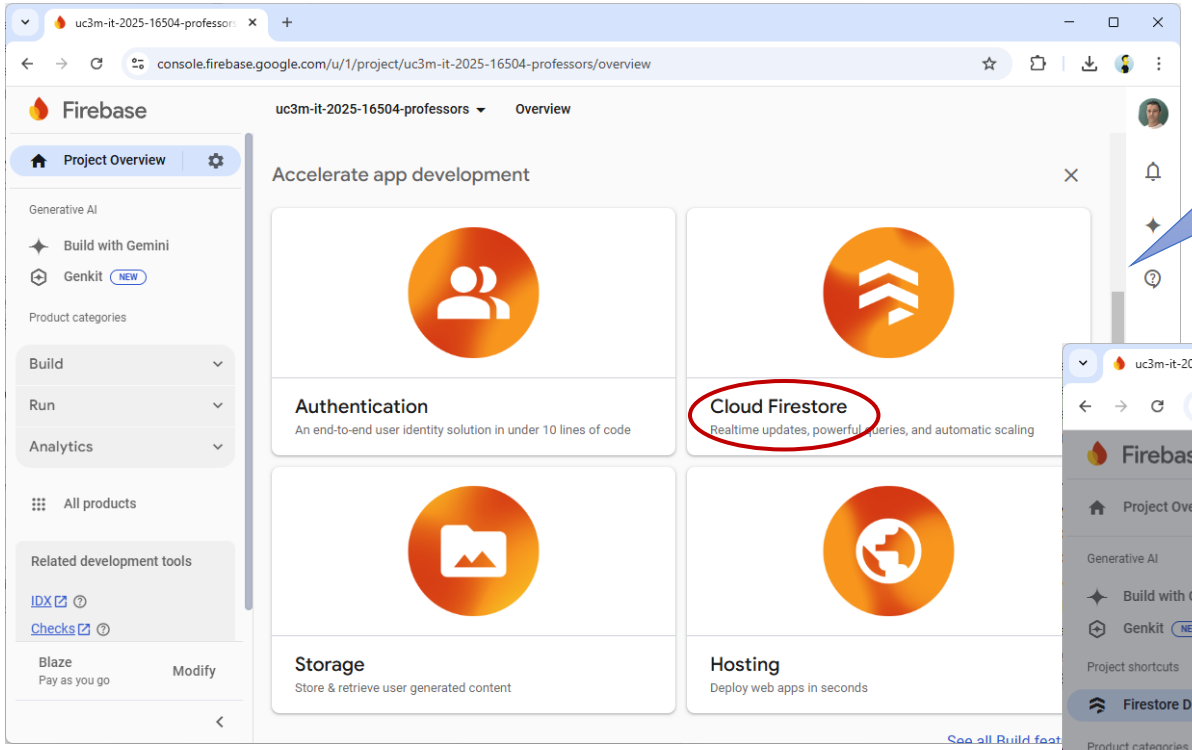
2. Firebase - Cloud Firestore



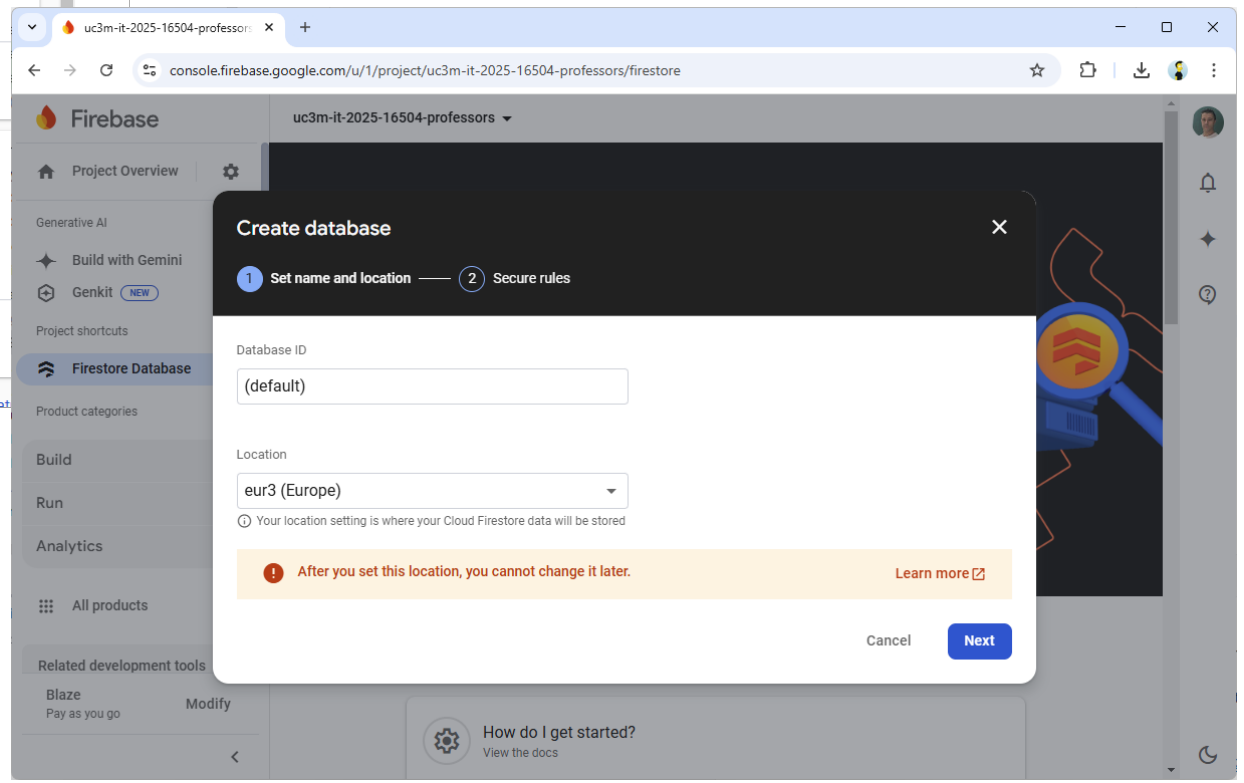


At the end, you can see your app in the Firebase console

2. Firebase - Cloud Firestore

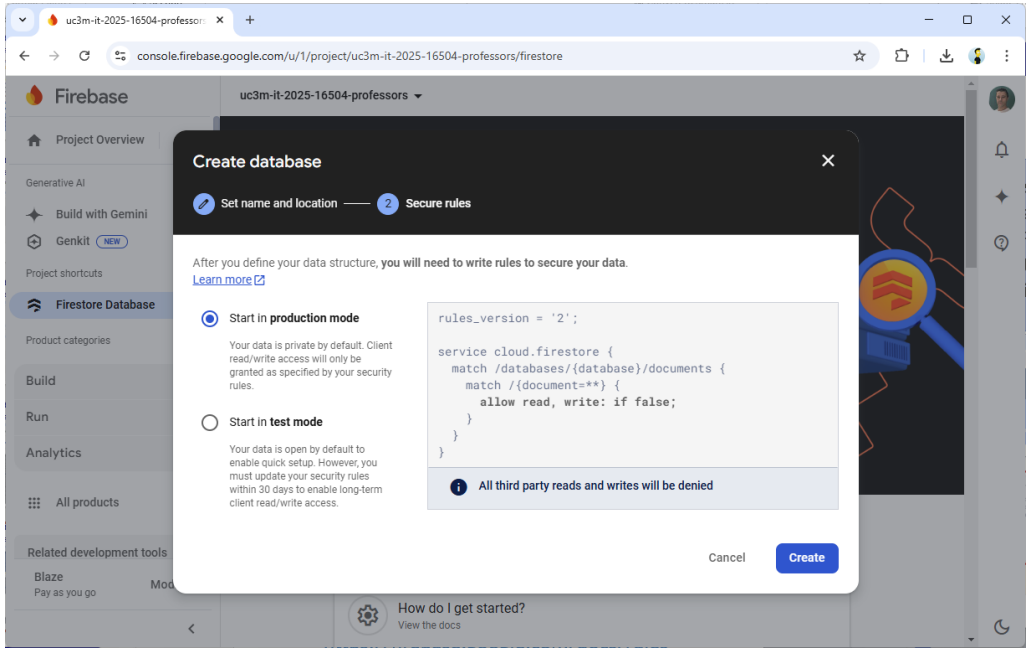


Scroll down an click on "Cloud Firestore"



Then, we should create a database, specifying a name (can be just "default") and a location

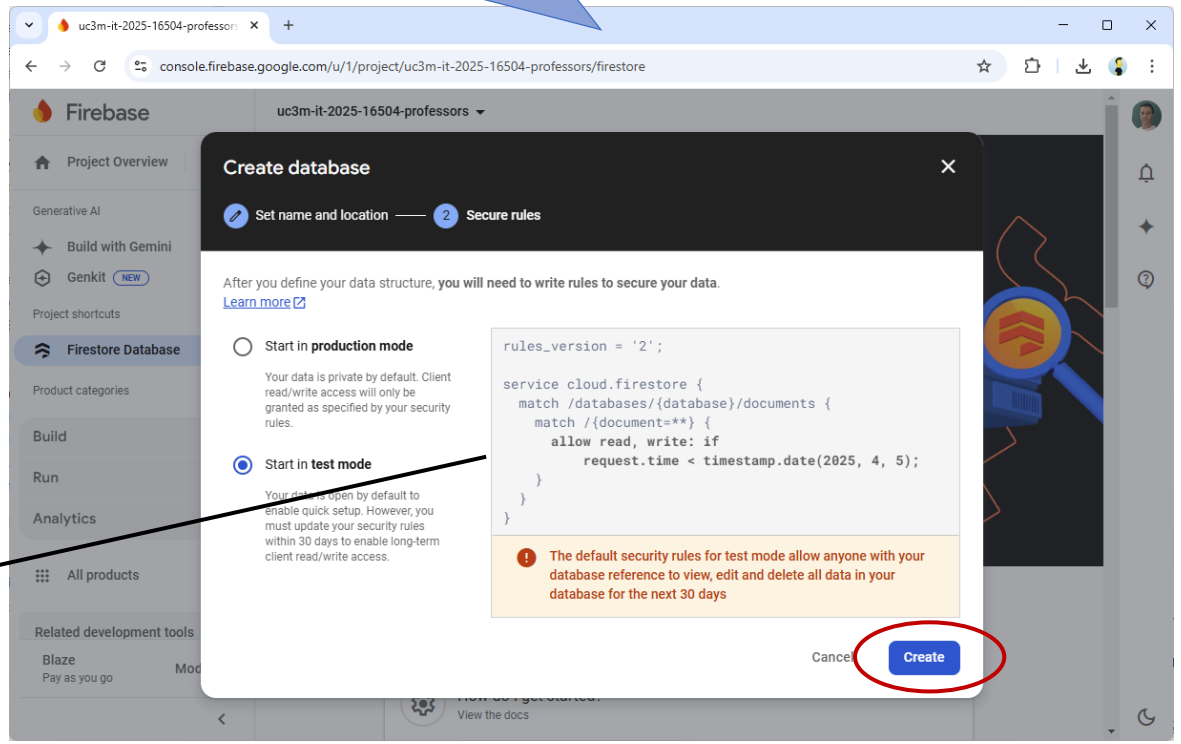
2. Firebase - Cloud Firestore




```
rules_version = '2';

service cloud.firestore {
  match /databases/{database}/documents {
    match /{document=**} {
      allow read, write: if
          request.time < timestamp.date(2025, 4, 5);
    }
  }
}
```

https://firebase.google.com/docs/rules

Then, we need to specify the **Security Rules**, which are a set of declarative statements that define how Firestore should handle read and write operations. We can start in test mode, although this should be changed in the future



2. Firebase - Cloud Firestore

- The Security Rules is a feature in Firestore that allows us to control access to our database
  - These rules determine who can read, write, update, or delete data in your Firestore collections and documents
  - They are organized hierarchically and follow this structure:

This line specifies the database and documents to which the rules apply

This line defines rules for a specific collection or document

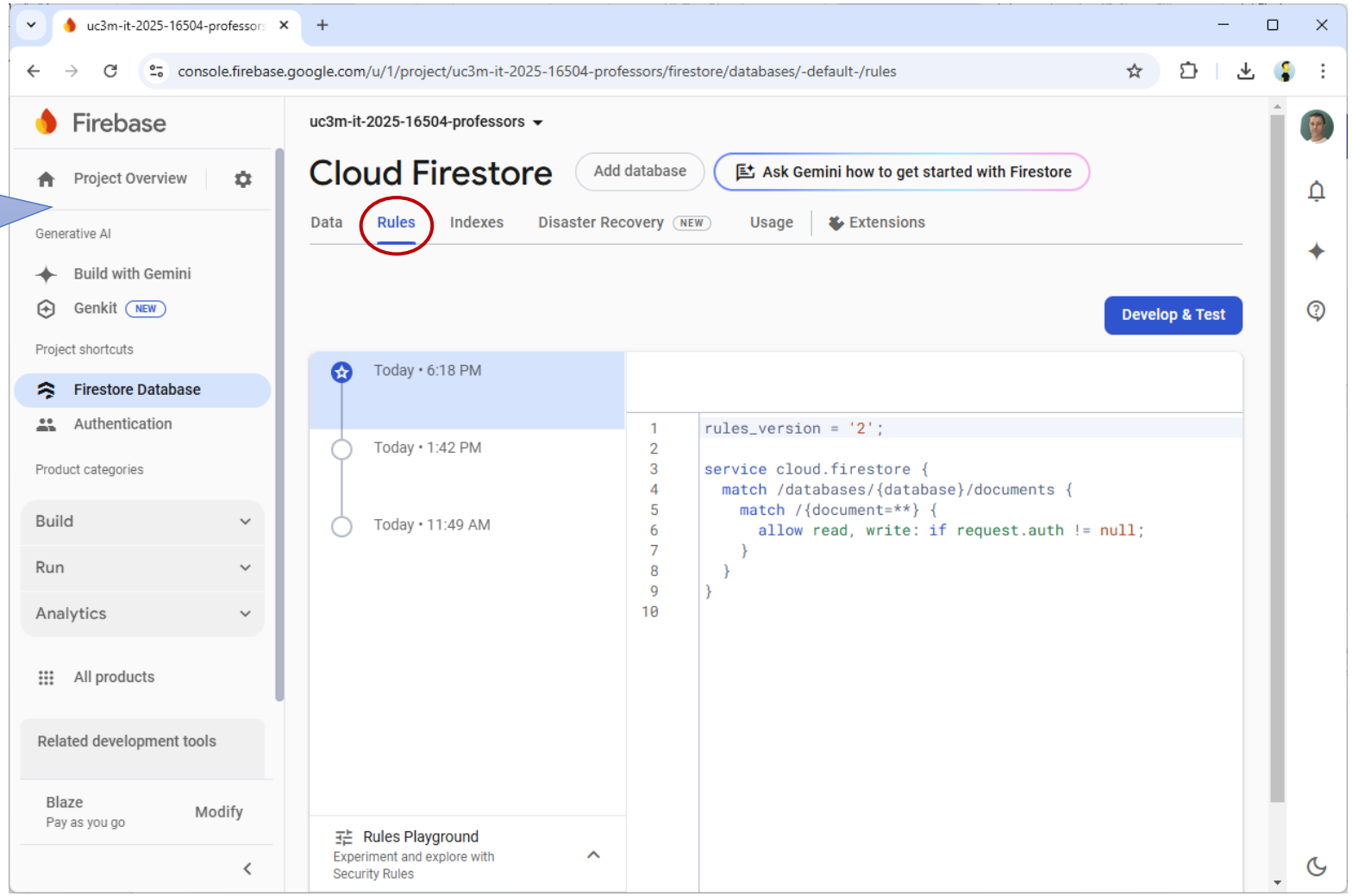
```
rules_version = '2';

service cloud.firestore {
  match /databases/{database}/documents {
    // Define rules for specific collections or documents
    match /collection/{document} {
      allow read, write: if <condition>;
    }
  }
}
```

This line specifies the operations (read, write, create, update, delete) allowed under certain conditions

https://firebase.google.com/docs/firestore/security/get-started

2. Firebase - Cloud Firestore

We can change the security rules in this part of the Firebase console



2. Firebase - Cloud Firestore

- Some examples of basic security rules are as follows:

```
rules_version = '2';

service cloud.firestore {
  match /databases/{database}/documents {
    match /{document=**} {
      allow read, write: if
          request.time < timestamp.date(2025, 4, 5);
    }
  }
}
```

Test mode: open access in our database for a limited period (usually 30 days)

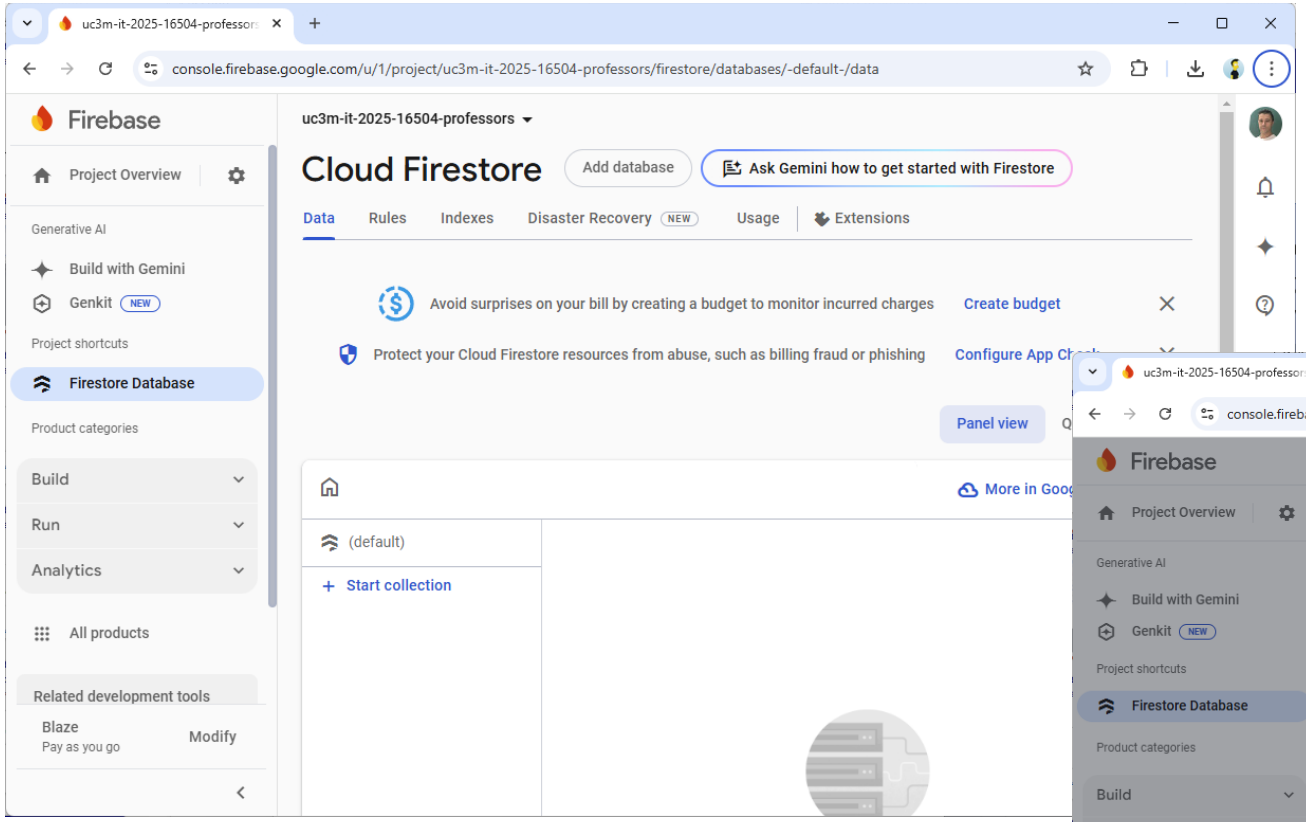
```
rules_version = '2';

service cloud.firestore {
  match /databases/{database}/documents {
    match /{document=**} {
      allow read, write: if true;
    }
  }
}
```

Unlimited open access. This approach is not recommended since it completely disables security

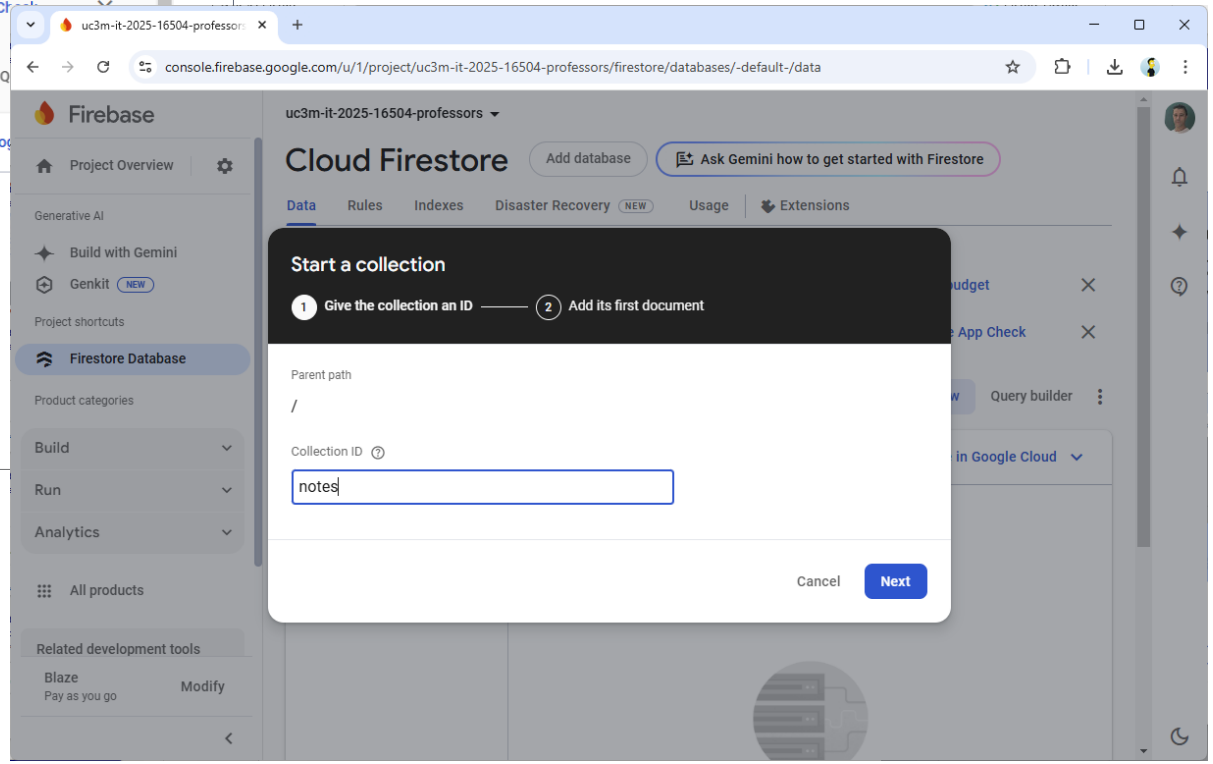
Authenticated users: only allow access to users who are logged in

```
rules_version = '2';

service cloud.firestore {
  match /databases/{database}/documents {
    match /{document=**} {
      allow read, write: if request.auth != null;
    }
  }
}
```

2. Firebase - Cloud Firestore



After provisioning the database, we can manage the documents in the database manually, although our objective is to do it programmatically from our Android app



2. Firebase - Cloud Firestore

- For handling Cloud Firestore programmatically, we need some form of **asynchronous programming**
  - Asynchronous programming is a paradigm that allows tasks to be executed concurrently, without blocking the execution of the main program
  - This is particularly useful for tasks that may take a significant amount of time to complete, such as network requests
- Using **Kotlin Coroutines** can simplify asynchronous programming in Android app
  - Coroutines are functions that can be paused and resumed without blocking the thread, making it ideal for long-running tasks like network operations or database access
  - Coroutines allow us to write asynchronous code in a sequential style, making it easier to read and maintain

https://developer.android.com/kotlin/coroutines

2. Firebase - Cloud Firestore

For managing complex state that survives configuration changes, we can use an instance of `ViewModel`

The `ViewModel` in this example expose a notes list (`notes`) and functions to handle it with CRUD operations

```
class MyViewModel : ViewModel() {
    private val _notes = MutableStateFlow<List<Note>>(emptyList())
    val notes: StateFlow<List<Note>> get() = _notes

    private val _toastMessage = MutableStateFlow<String?>(null)
    val toastMessage: StateFlow<String?> get() = _toastMessage

    private val firestore = FirebaseFirestore.getInstance()

     // ...

}
```

The `ViewModel` should remain UI-agnostic, therefore we expose a message (`toastMessage`) to be displayed in the UI in case of errors

build.gradle.kts (app)

```
dependencies {
    implementation(libs.androidx.runtime.livedata)
}
```

libs.version.toml

```
[versions]
runtimeLivedata = "1.7.8"

[libraries]
androidx-runtime-livedata = { module =
"androidx.compose.runtime:runtime-livedata",
 version.ref = "runtimeLivedata" }
```

We *observe* changes in the `ViewModel` using the library `LiveData`

2. Firebase - Cloud Firestore

Fork me on GitHub

Read data. We can use the `get()` method to retrieve an entire collection

```
private fun fetchNotes() {
    viewModelScope.launch {
        firestore.collection(NOTES_COLLECTION).get()
            .addOnSuccessListener { result ->
                val noteList = result.map { document ->
                    document.toObject<Note>().copy(id = document.id)
                }
                _notes.value = noteList
            }
            .addOnFailureListener { exception ->
                _toastMessage.value = exception.message
            }
    }
}
```

Using *viewModelScope* is a way to manage coroutines in a `ViewModel`. When the `ViewModel` is cleared (e.g., when the associated Activity is destroyed), the *viewModelScope* is automatically canceled, ensuring that no coroutines run unnecessarily

Add data. We use the `add()` method to add a document in a collection

```
fun addNote(title: String, body: String) {
    viewModelScope.launch {
        val note = Note(title = title, body = body)
        firestore.collection(NOTES_COLLECTION)
            .add(note)
            .addOnSuccessListener {
                fetchNotes() // Refresh the list after adding
            }
            .addOnFailureListener { exception ->
                _toastMessage.value = exception.message
            }
    }
}
```

Firestore creates collections and documents implicitly the first time we add data to the document

https://firebase.google.com/docs/firestore/quickstart#java_1

2. Firebase - Cloud Firestore

Update data. We can use the `update()` method to modify a document. We should know the document id (typically autogenerated)

```
fun updateNote(id: String, title: String, body: String) {
    viewModelScope.launch {
        val updatedNote = Note(title = title, body = body)
        firestore.collection(NOTES_COLLECTION).document(id)
            .set(updatedNote)
            .addOnSuccessListener {
                fetchNotes() // Refresh the list after updating
            }
            .addOnFailureListener { exception ->
                _toastMessage.value = exception.message
            }
    }
}
```

Delete data. We can use the `delete()` method to modify a document. We should also know the document id

```
fun deleteNote(id: String) {
    viewModelScope.launch {
        firestore.collection(NOTES_COLLECTION).document(id)
            .delete()
            .addOnSuccessListener {
                fetchNotes() // Refresh the list after deleting
            }
            .addOnFailureListener { exception ->
                _toastMessage.value = exception.message
            }
    }
}
```

2. Firebase - Cloud Firestore

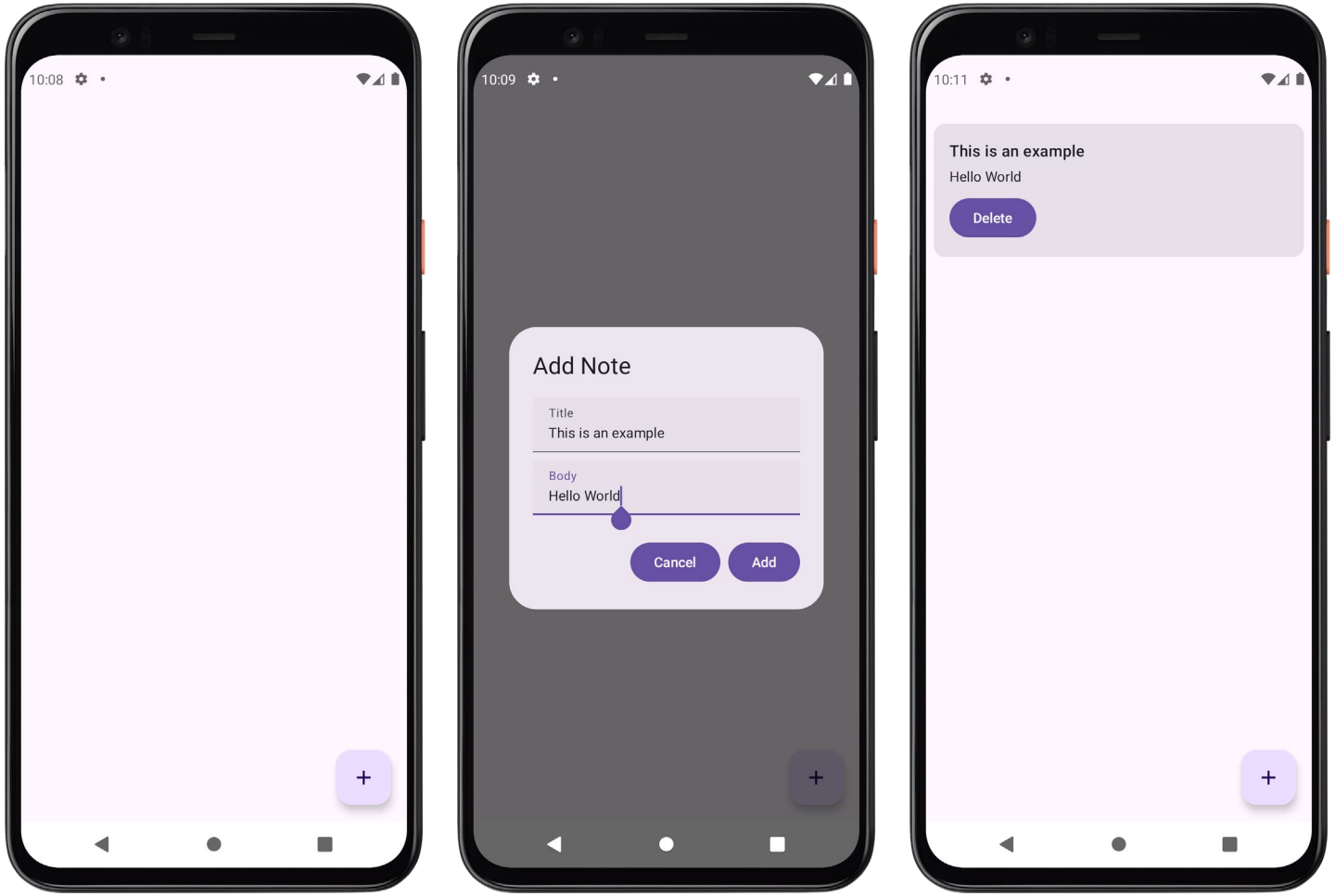

```
@Composable
fun MainScreen(viewModel: MyViewModel = viewModel()) {
    var showAddNoteDialog by remember { mutableStateOf(false) }
    var noteToEdit by remember { mutableStateOf<Note?>(null) }
    val context = LocalContext.current
    val notes by viewModel.notes.collectAsState()
    val toastMessage by viewModel.toastMessage.collectAsState()

    Scaffold(
        floatingActionButton = {
            FloatingActionButton(onClick = { showAddNoteDialog = true }) {
                Icon(Icons.Default.Add, contentDescription = stringResource(R.string.add_note))
            }
        }
    ) { padding ->
        Column(modifier = Modifier.padding(padding)) {
            LazyColumn {
                items(notes) { note ->
                    NoteItem(
                        note = note,
                        onNoteClick = { noteToEdit = it },
                        onDeleteClick = { viewModel.deleteNote(it.id!!) }
                    )
                }
            }
        }
    }
```

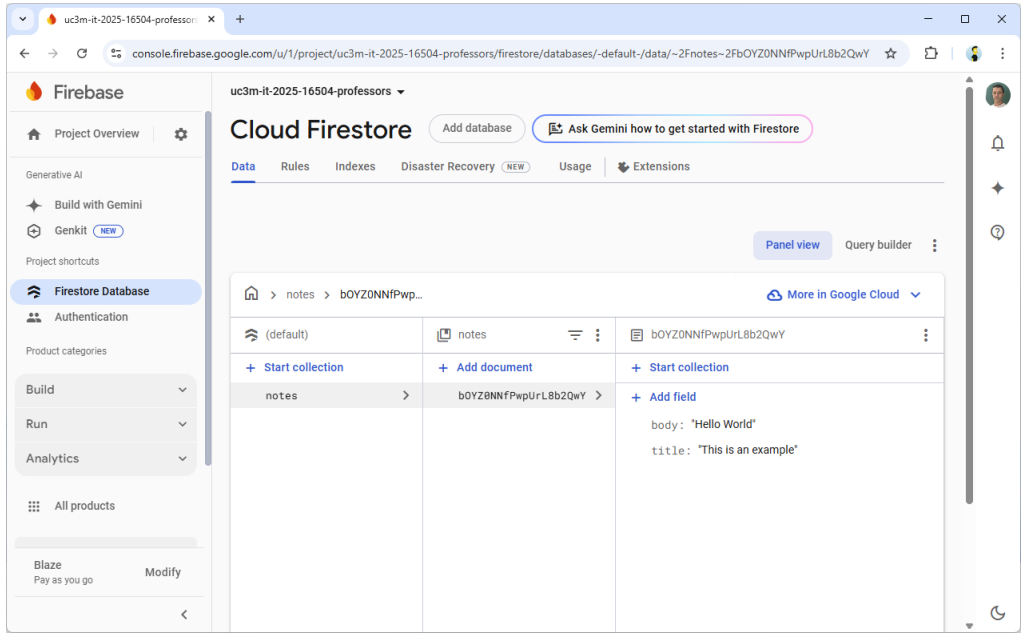
We observe changes in `notes` and `toastMessage` from the `ViewModel`

```
    if (showAddNoteDialog) {
        AddNoteDialog(
            onDismiss = { showAddNoteDialog = false },
            onAddNote = { title, body ->
                viewModel.addNote(title, body)
                showAddNoteDialog = false
            }
        )
    }

    noteToEdit?.let { note ->
        EditNoteDialog(
            note = note,
            onDismiss = { noteToEdit = null },
            onUpdateNote = { title, body ->
                viewModel.updateNote(note.id!!, title, body)
                noteToEdit = null
            }
        )
    }

  LaunchedEffect(toastMessage) {
        toastMessage?.let { message ->
            Toast.makeText(context, message, Toast.LENGTH_LONG).show()
            // Reset message to avoid showing it repeatedly (e.g., config changes)
            viewModel.showToast(null)
        }
    }

}
```

`LaunchedEffect` is a helper composable that allows us to run background tasks (like fetching data, waiting for something, or listening for updates) safely (i.e., without blocking the UI)

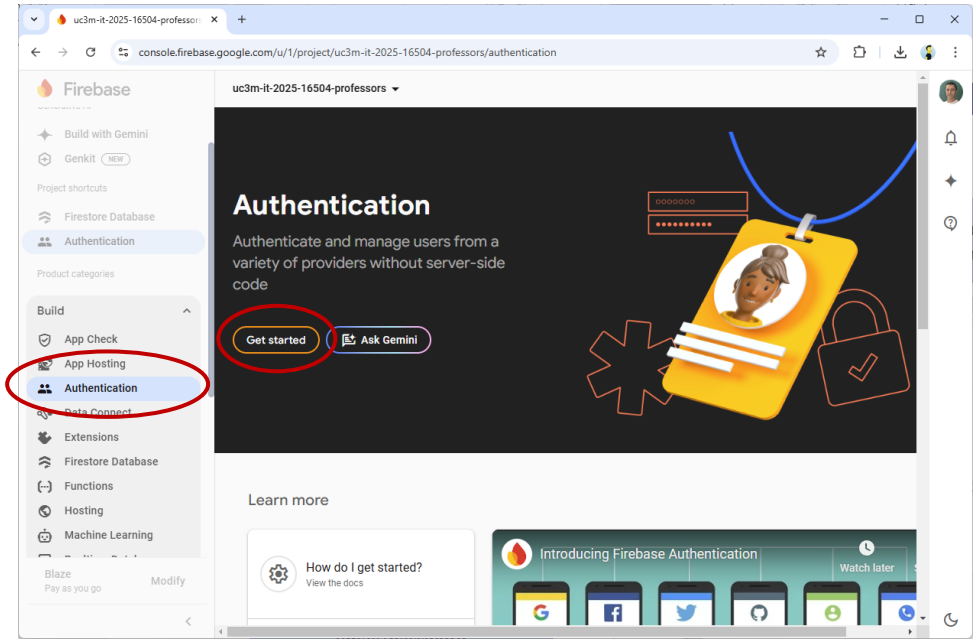
2. Firebase - Cloud Firestore

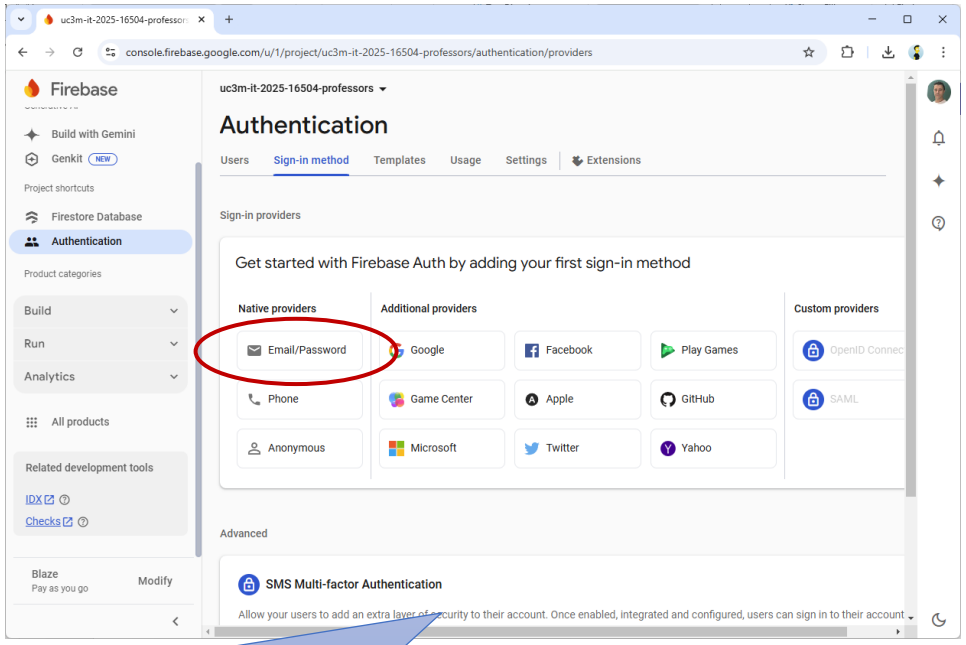




2. Firebase - Authentication

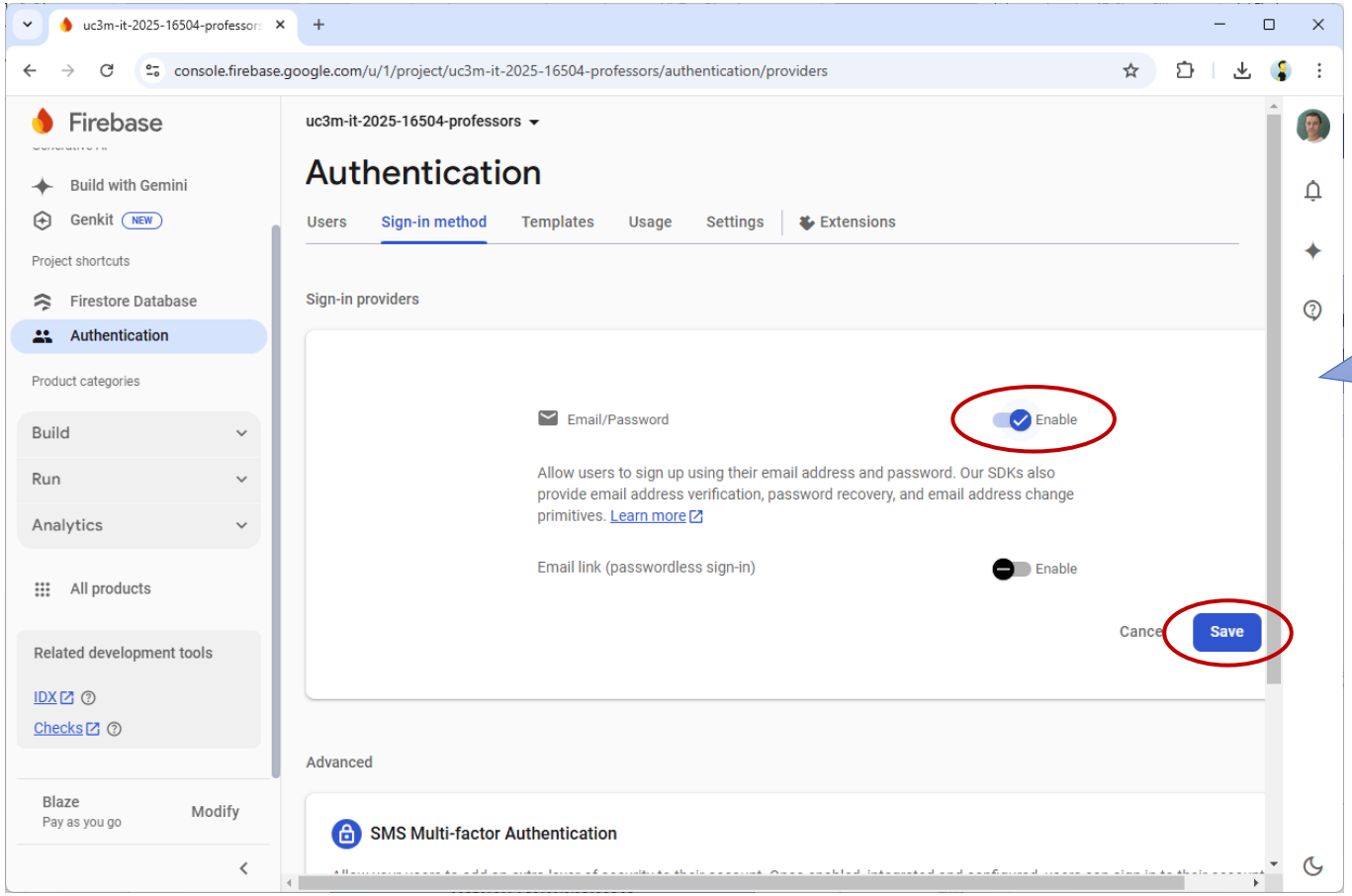
- Authentication in Firebase is a service that allows users to sign in using various methods, such as email/password, phone numbers, or social media accounts, among others





We need to select one or more sign-in providers (email/password, phone, social ids, etc.). In the following example, we use email/password

2. Firebase - Authentication



We need to enable authentication with email/password here

2. Firebase - Authentication

- In the Java/Kotlin logic, we implement the logic for creating users (sing up) and authenticating existing users (log in):

Sing up

```
fun signUp(email: String, password: String) {
    viewModelScope.launch {
        try {
            auth.createUserWithEmailAndPassword(email, password).await()
            _route.value = NavGraph.Home.route

        } catch (e: Exception) {
            _toastMessage.value = e.message
        }
    }
}
```

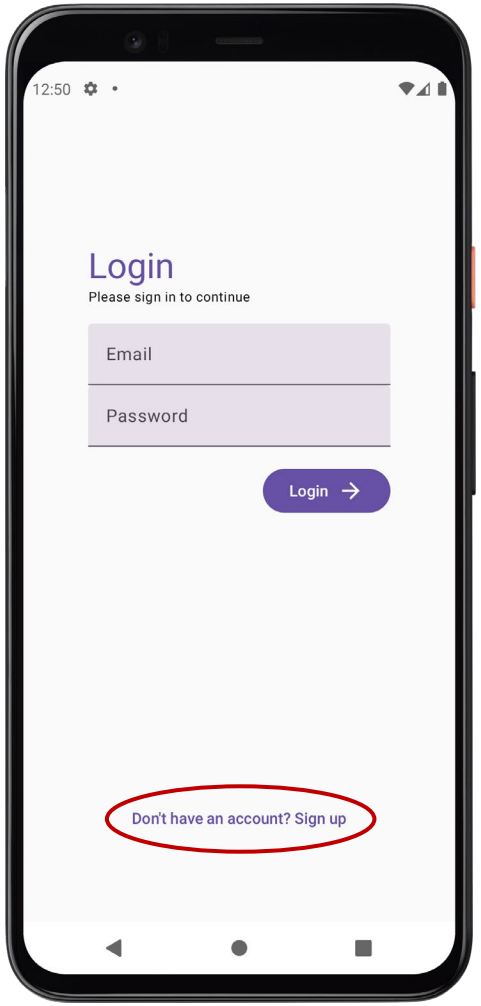
Login

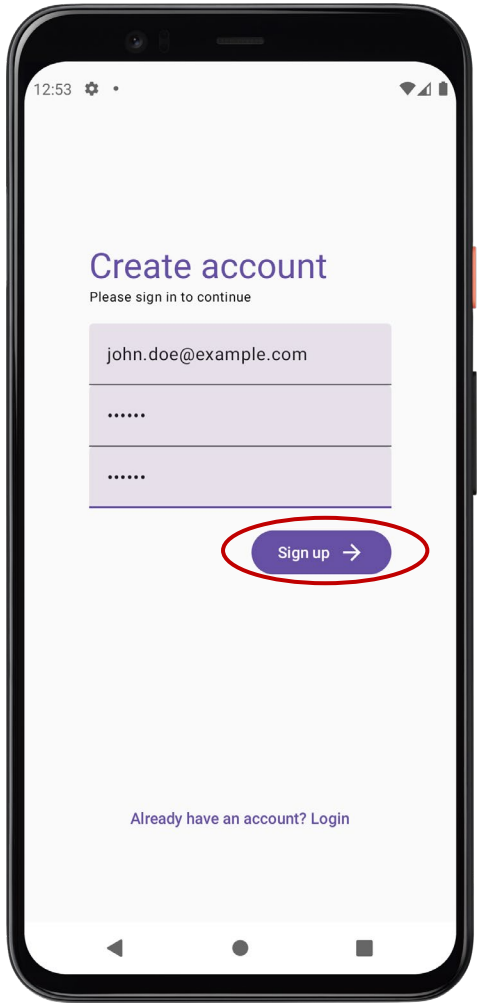
```
fun login(email: String, password: String) {
    viewModelScope.launch {
        try {
            auth.signInWithEmailAndPassword(email, password).await()
            _route.value = NavGraph.Home.route

        } catch (e: Exception) {
            _toastMessage.value = e.message
        }
    }
}
```

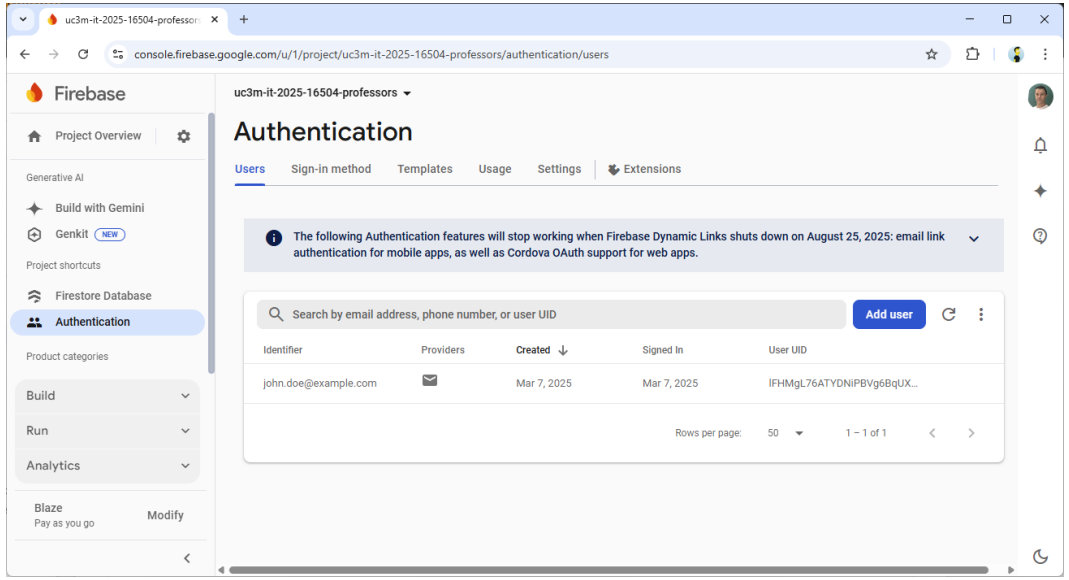
In both cases, the strings `email` and `password` have been read from the UI

https://firebase.google.com/docs/auth/android/start

2. Firebase - Authentication







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3. DataStore

- DataStore is a modern solution introduced by Android Jetpack to provides an efficient way to store **key-value** pairs
  - It is designed to address the limitations of `SharedPreferences` (used in the legacy Android View system)
- The advantages of DataStore are the following:
  - Asynchronous API: Uses Kotlin coroutines for asynchronous operations, avoiding blocking the main thread
  - Type safety: Reduces runtime errors by leveraging Kotlin's type system
  - Data consistency: Ensures atomicity for read-write operations
  - Modern architecture: designed to work seamlessly with Jetpack components like `ViewModel` and `LiveData`

https://developer.android.com/topic/libraries/architecture/datastore

3. DataStore

The following example stores two values (and `String` and `Boolean`) in a data store called `"settings"`

The keyword `suspend` indicates that the function is a coroutine, so it can be paused and resumed, allowing it to perform asynchronous operations without blocking the main thread

```
const val DATASTORE_NAME = "settings"
val USER_NAME_KEY = stringPreferencesKey("user_name")
val IS_ENABLED_KEY = booleanPreferencesKey("enabled")

val Context.dataStore: DataStore<Preferences> by preferencesDataStore(name = DATASTORE_NAME)

class DataStoreHelper(private val context: Context) {

    suspend fun saveUserName(name: String) {
        context.dataStore.edit { preferences ->
            preferences[USER_NAME_KEY] = name
        }
    }

    val userName: Flow<String> = context.dataStore.data
        .map { preferences ->
            preferences[USER_NAME_KEY] ?: ""
        }

    suspend fun saveEnabled(enabled: Boolean) {
        context.dataStore.edit { preferences ->
            preferences[IS_ENABLED_KEY] = enabled
        }
    }

    val enabled: Flow<Boolean> = context.dataStore.data
        .map { preferences ->
            preferences[IS_ENABLED_KEY] ?: false
        }
}
```

3. DataStore

We use a `ViewModel` to interact with the previous `DataStoreHelper` to manage and persist user settings. It uses Kotlin's `StateFlow` to expose these settings to the UI in a reactive way

```
class SettingsViewModel(private val dataStoreHelper: DataStoreHelper) : ViewModel() {

    private val _userName = MutableStateFlow("")
    val userName: StateFlow<String> get() = _userName

    private val _isEnabled = MutableStateFlow(false)
    val isEnabled: StateFlow<Boolean> get() = _isEnabled

    init {
        // Observe DataStore changes
        viewModelScope.launch {
            dataStoreHelper.userName.collectLatest { name ->
                _userName.value = name
            }
        }
        viewModelScope.launch {
            dataStoreHelper.enabled.collectLatest { enabled ->
                _isEnabled.value = enabled
            }
        }
    }

    fun saveUserName(name: String) {
        viewModelScope.launch {
            dataStoreHelper.saveUserName(name)
        }
    }

    fun saveEnabled(enabled: Boolean) {
        viewModelScope.launch {
            dataStoreHelper.saveEnabled(enabled)
        }
    }
}
```

When a `ViewModel` has dependencies (e.g., `dataStoreHelper`), we need a way to pass those dependencies to the `ViewModel` during its creation

3. DataStore

A way to provide ViewModel dependencies (e.g. `dataStoreHelper` in this example) is through a `ViewModelProvider.Factory` to customize the creation of `ViewModel` instances

```
class SettingsViewModelFactory(
    private val dataStoreHelper: DataStoreHelper
) : ViewModelProvider.Factory {
    override fun <T : ViewModel> create(modelClass: Class<T>): T {
        if (modelClass.isAssignableFrom(SettingsViewModel::class.java)) {
            @Suppress("UNCHECKED_CAST")
            return SettingsViewModel(dataStoreHelper) as T
        }
        throw IllegalArgumentException("Unknown ViewModel class")
    }
}
```

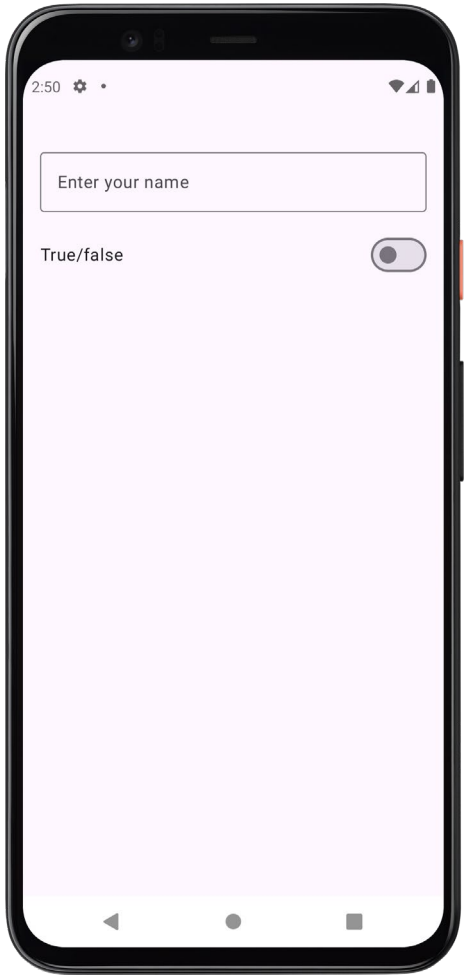
- While custom factories work, they can become verbose when having many ViewModel classes with dependencies. Modern alternatives include:
  - Hilt: A dependency injection library that simplifies ViewModel creation
  - Koin: A lightweight dependency injection framework for Kotlin

3. DataStore


```
@Composable
fun SettingsScreen(
    modifier: Modifier = Modifier, viewModel: SettingsViewModel = viewModel(
        factory = SettingsViewModelFactory(
            DataStoreHelper(LocalContext.current)
        )
    )
) {
    val userName by viewModel.userName.collectAsState()
    val enabled by viewModel.isEnabled.collectAsState()

    Column(
        modifier = modifier
            .fillMaxSize()
            .padding(16.dp)
    ) {
        OutlinedTextField(
            value = userName,
            onValueChange = { viewModel.saveUserName(it) },
            label = { Text(stringResource(R.string.enter_name)) },
            modifier = Modifier.fillMaxWidth()
        )
        Spacer(modifier = Modifier.height(16.dp))
        Row(
            verticalAlignment = Alignment.CenterVertically, modifier = Modifier.fillMaxWidth()
        ) {
            Text(text = stringResource(R.string.enabled), modifier = Modifier.weight(1f))
            Switch(
                checked = enabled, onCheckedChange = { viewModel.saveEnabled(it) })
        }
    }
}
```

Finally, we use the ViewModel in our UI



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4. Files

- Managing files in Android using Kotlin and Jetpack Compose involves interacting with the Android file system to read and write files
- Android provides different APIs for file management, such as:

1. **Internal storage**: private to the app
2. **External storage**: shared storage accessible by other apps (requires permissions)

https://developer.android.com/training/data-storage

4. Files - Internal storage

- For each app, the Android system provides directories within internal storage where an app can organize its files:
  - One directory is designed for our app's persistent files
  - Other directory contains our app's temporal files (cache)
- In either case, the app doesn't require any system permissions to read and write to files in these directories
- There are different ways to manage files in the internal storage:
  - Using the `File` API
  - Using context methods (e.g., `openFileInput()` to read, `openFileOutput()` to write, etc.)

https://developer.android.com/training/data-storage/app-specific

4. Files - Internal storage

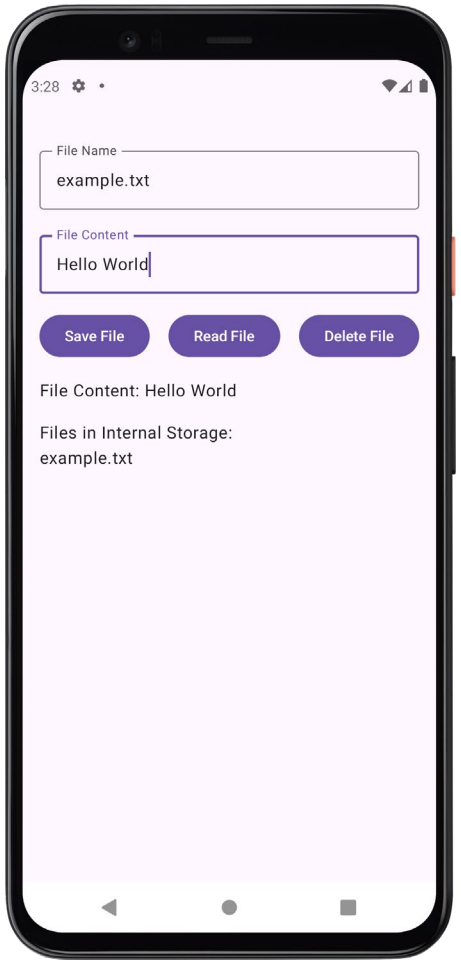

```
class FileHelper(private val context: Context) {

    // Write to a file in internal storage
    fun writeToFile(fileName: String, content: String): Boolean {
        return try {
            context.openFileOutput(fileName, Context.MODE_PRIVATE).use { stream ->
                stream.write(content.toByteArray())
            }
            true
        } catch (e: IOException) {
            Toast.makeText(context, e.message, Toast.LENGTH_LONG).show()
            false
        }
    }

    // Read from a file in internal storage
    fun readFromFile(fileName: String): String {
        return try {
            context.openFileInput(fileName).bufferedReader().use { reader ->
                reader.readText()
            }
        } catch (e: IOException) {
            Toast.makeText(context, e.message, Toast.LENGTH_LONG).show()
            ""
        }
    }

    // List all files in internal storage
    fun listFiles(): Array<String> {
        return context.fileList()
    }

    // Delete a file in internal storage
    fun deleteFile(fileName: String): Boolean {
        return context.deleteFile(fileName)
    }
}
```

This example encapsulates the access to the internal storage in a helper class

4. Files - Internal storage

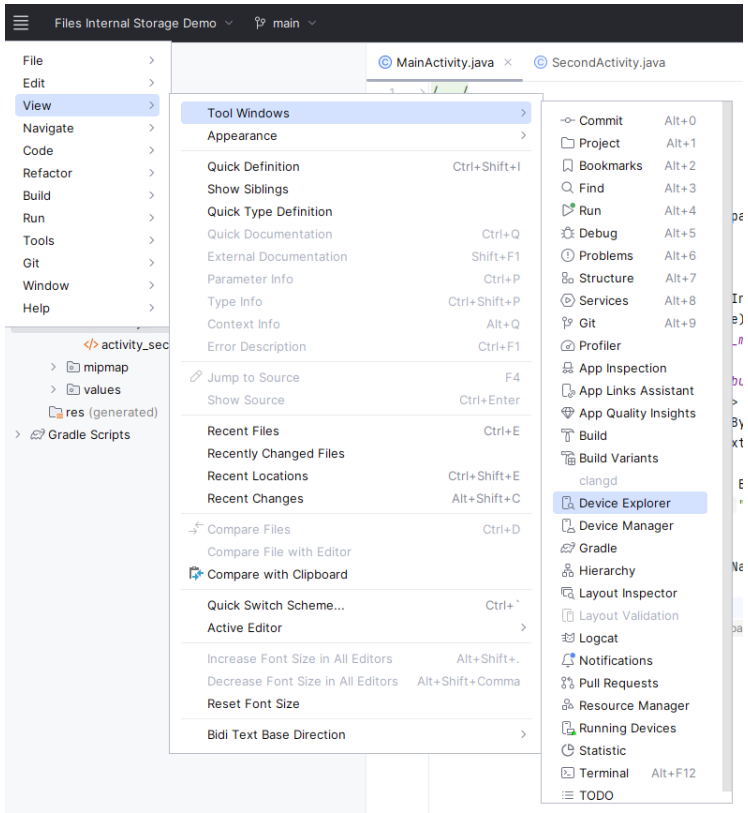
The helper class is used in a ViewModel, which is then observed in the UI

```
class FileViewModel(private val fileHelper: FileHelper) : ViewModel() {

    private val _fileContent = MutableStateFlow("")
    val fileContent: StateFlow<String> get() = _fileContent

    private val _fileList = MutableStateFlow<List<String>>(emptyList())
    val fileList: StateFlow<List<String>> get() = _fileList

    fun writeToFile(fileName: String, content: String) {
        viewModelScope.launch {
            val success = fileHelper.writeToFile(fileName, content)
            if (success) {
                refreshFileList()
            }
        }
    }

    fun readFromFile(fileName: String) {
        viewModelScope.launch {
            _fileContent.value = fileHelper.readFromFile(fileName)
        }
    }

    fun refreshFileList() {
        viewModelScope.launch {
            _fileList.value = fileHelper.listFiles().toList()
        }
    }

    fun deleteFile(fileName: String) {
        viewModelScope.launch {
            val success = fileHelper.deleteFile(fileName)
            if (success) {
                refreshFileList()
            }
        }
    }
}
```



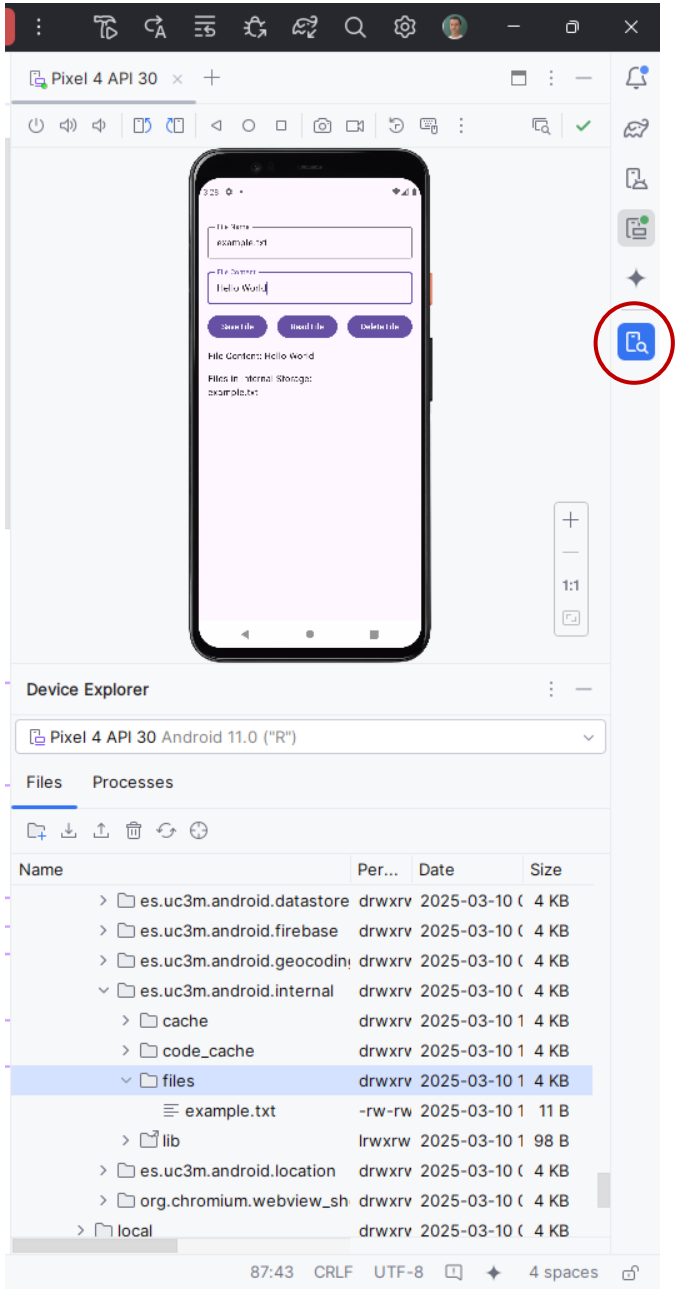
4. Files - Internal storage

- The path for storing files in the internal storage is: `/data/data/<app_id>/files`



We can use the integrated **Device Explorer** in Android Studio to browser these files

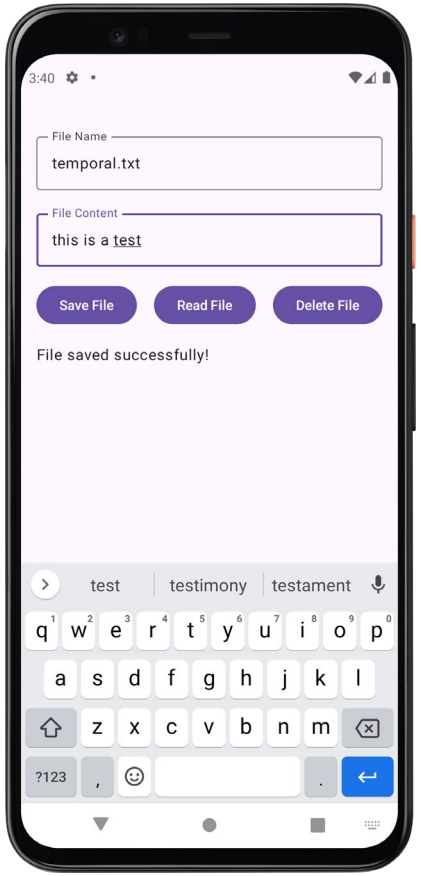
This explorer can be opened using View→Tool Windows→Device Explorer



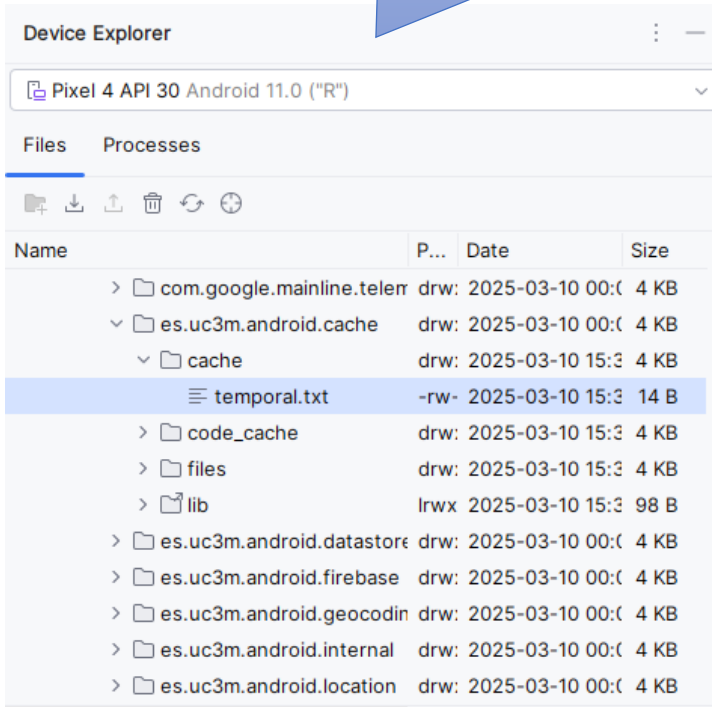
4. Files - Internal storage


```
class CacheFileHelper(private val context: Context) {

    // Write to a file in the cache directory
    fun writeToCache(fileName: String, content: String): Boolean {
        return try {
            val file = File(context.cacheDir, fileName)
            FileOutputStream(file).use { stream ->
                stream.write(content.toByteArray())
            }
            true
        } catch (e: IOException) {
            e.printStackTrace()
            false
        }
    }

    // Read from a file in the cache directory
    fun readFromCache(fileName: String): String {
        return try {
            val file = File(context.cacheDir, fileName)
            file.bufferedReader().use { reader ->
                reader.readText()
            }
        } catch (e: IOException) {
            e.printStackTrace()
            ""
        }
    }

    // Delete a file from the cache directory
    fun deleteFromCache(fileName: String): Boolean {
        val file = File(context.cacheDir, fileName)
        return file.delete()
    }
}
```

In the examples repository, you can find another app that uses the temporal internal storage (cache)



The path for storing temporal files is: `/data/data/<app_id>/cache`



4. Files - External storage

- For reading/writing in the external storage of an Android device, the first thing we need to do in our app project is to specify a system permission that the user must grant
- This is done using the tag `uses-permission` in the manifest file:

```
<uses-permission
    android:name="android.permission.READ_EXTERNAL_STORAGE"
    android:maxSdkVersion="32" />
<uses-permission
    android:name="android.permission.WRITE_EXTERNAL_STORAGE"
    android:maxSdkVersion="32"
    tools:ignore="ScopedStorage" />
```

Starting from Android 13 (API level 33), these permissions are no longer required for accessing shared files due to the introduction of scoped storage and more granular permissions

https://developer.android.com/training/data-storage/shared

4. Files - External storage

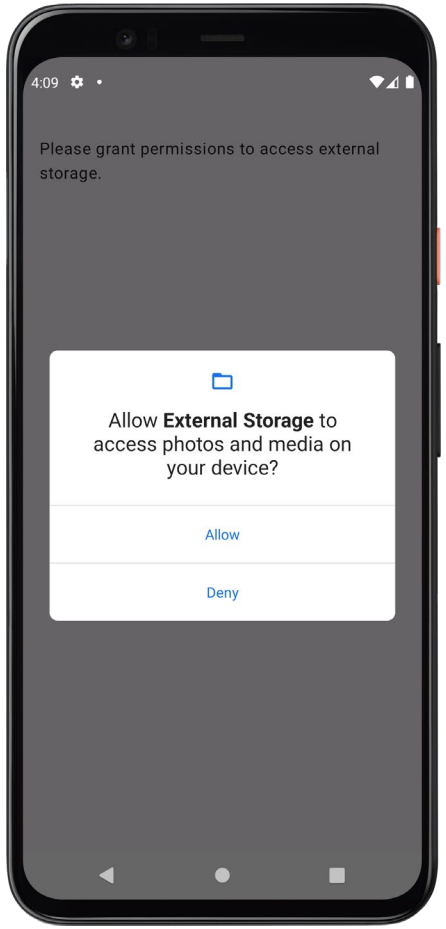

```
class ExternalStorageHelper(private val context: Context) {

    // Get the public documents directory
    fun getPublicDocumentsDir(): File? {
        return Environment.getExternalStoragePublicDirectory(Environment.DIRECTORY_DOCUMENTS)
    }

    // Write to a file in external storage
    fun writeToExternalStorage(fileName: String, content: String): Boolean {
        return try {
            val documentsDir = getPublicDocumentsDir()
            if ((documentsDir != null) && !documentsDir.exists()) {
                documentsDir.mkdirs()
            }
            val file = File(documentsDir, fileName)
            FileOutputStream(file).use { stream ->
                stream.write(content.toByteArray())
            }
            true
        } catch (e: IOException) {
            Toast.makeText(context, e.message, Toast.LENGTH_LONG).show()
            false
        }
    }

    // Read from a file in external storage
    fun readFromExternalStorage(fileName: String): String {
        return try {
            val documentsDir = getPublicDocumentsDir()
            val file = File(documentsDir, fileName)
            Toast.makeText(context, file.absolutePath, Toast.LENGTH_LONG).show()
            file.bufferedReader().use { reader ->
                reader.readText()
            }
        } catch (e: IOException) {
            Toast.makeText(context, e.message, Toast.LENGTH_LONG).show()
            ""
        }
    }
}
```

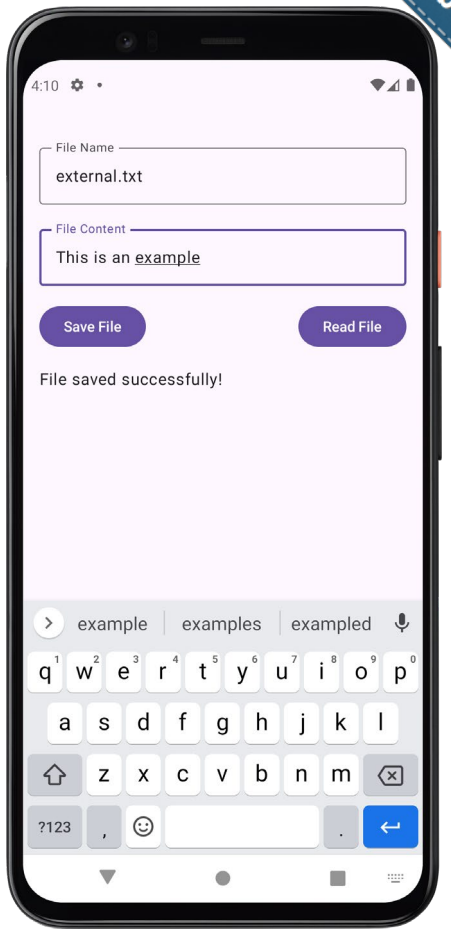
In this example, we use another helper class to encapsulate all the access to the external storage

4. Files - External storage


```
@Composable
fun RequestPermissions(
    onPermissionsGranted: () -> Unit, onPermissionsDenied: () -> Unit
) {
    val permissions = if (Build.VERSION.SDK_INT >= Build.VERSION_CODES.TIRAMISU) {
        arrayOf(Manifest.permission.READ_MEDIA_IMAGES, Manifest.permission.READ_MEDIA_VIDEO)
    } else {
        arrayOf(
            Manifest.permission.READ_EXTERNAL_STORAGE, Manifest.permission.WRITE_EXTERNAL_STORAGE
        )
    }

    val launcher = rememberLauncherForActivityResult(
        contract = ActivityResultContracts.RequestMultiplePermissions()
    ) { permissionsMap ->
        val allGranted = permissionsMap.values.all { it }
        if (allGranted) {
            onPermissionsGranted()
        } else {
            onPermissionsDenied()
        }
    }

    LaunchedEffect(Unit) {
        launcher.launch(permissions)
    }
}
```

We need to implement the permissions grant in our composable logic

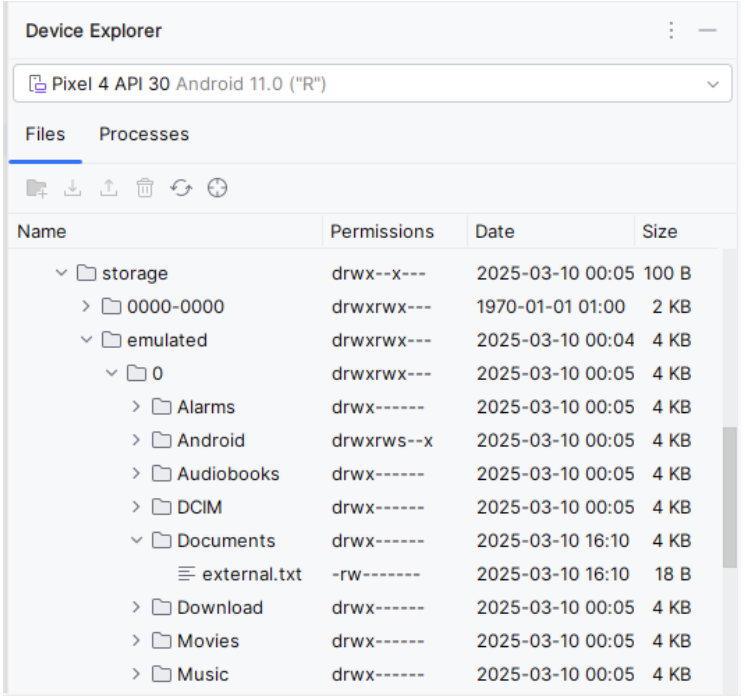




4. Files - External storage

- The paths for public directories are standardized and can be accessed using the `Environment` class:

Directory	Path
Downloads	`/storage/emulated/0/Download`
Pictures	`/storage/emulated/0/Pictures`
Music	`/storage/emulated/0/Music`
Movies	`/storage/emulated/0/Movies`
Documents	`/storage/emulated/0/Documents`
Camera	`/storage/emulated/0/DCIM`



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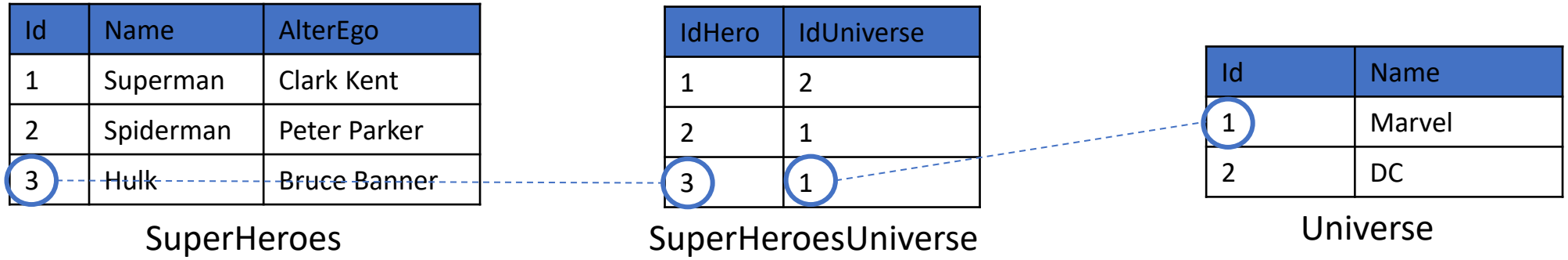
5. Local database - Relational databases

- A relational database (RDBMS) stores data as a set of **tables** with columns and rows following the relational model (RM), which was postulated in 1970 by Edgar Frank Codd at IBM laboratories:
  - Tables store information about the objects being represented
  - Each column of a table stores a certain type of data
  - The rows (or record) of the table represent a collection of related values of an object or entity
  - A field stores the value of a row and column
  - Each row in a table usually have a unique identifier called a primary key
  - Rows from different tables can be related to foreign keys



5. Local database - Relational databases

- **SQL** (Standard Query Language) is a standard language that allows us managing a DBMS
- SQL commands fall into two categories:
  - Data Manipulation Language (DML). Allows performing basic operations on data (CRUD = create, read, update, delete): `SELECT`, `INSERT`, `DELETE`, `UPDATE`
  - Data Definition Language (DDL). Allows you to create, delete and modify tables, users, views, or indexes: `CREATE TABLE`, `DROP TABLE`, `ALTER TABLE`

5. Local database - SQLite

- **SQLite** is a lightweight open-source relational database written in C
  - SQLite is included by default in Android devices
- As usual in RDBMS, we use SQL to manage the data and data definition in SQLite
- Each SQLite database is stored as a single binary file. In Android, these files are store in the following path:

  `/data/data/<package_name>/databases`
- There are two main ways to manage SQLite databases in Android
  - Low-level: Through the class `SQLiteOpenHelper`
  - High-level: Through the **Room API**

https://www.sqlite.org/

5. Local database - Room persistence library

- A convenient way to manage SQLite databases from Android apps is through the **Room persistence library**
- This library provides different benefits, such as:
  - Compile-time verification of SQL queries
  - Custom annotations to map tables to Java
  - Improved support for database migration and preloaded databases

https://developer.android.com/training/data-storage/room

5. Local database - Room persistence library

- There are three major components in Room:

1. Data **entities** that represent tables in the database
   - Classes annotated with `@Entity` , containing attributes annotated with `@PrimaryKey` (for setting the primary key), `@ForeignKey` (for specifying foreign keys), and `@ColumnInfo` (for further columns)
2. **Data Access Objects (DAOs)** that provide methods that an app can use to query, update, insert, and delete data in the database
   - Interfaces annotated with `@Dao`, containing methods annotated with `@Query` (for reading data), `@Insert` (for inserting data), `@Update` (for updating data), and `@Delete` (for deleting)
3. The **database class** that serves as the main access point with the local database
   - A single Java/Kotlin class annotated with `@Database`

5. Local database - Room persistence library

- The **entity class** used in the Room demo is as follows:

```
@Entity(tableName = "notes")
data class Note(
    @PrimaryKey(autoGenerate = true) val id: Int = 0, // Auto-generated ID
    val title: String,
    val body: String
)
```

This entity will be used to manage a SQLite table like this

id	title	body

5. Local database - Room persistence library

- The **DAO interface** used in this demo is as follows:

```
@Dao
interface NoteDao {
    @Insert(onConflict = OnConflictStrategy.REPLACE)
    suspend fun insert(note: Note)

    @Update
    suspend fun update(note: Note)

    @Query("DELETE FROM notes WHERE id = :id")
    suspend fun delete(id: Int)

    @Query("SELECT * FROM notes ORDER BY id DESC")
    fun getAllNotes(): LiveData<List<Note>>
}
```

5. Local database - Room persistence library

- The database class used this demo is as follows:

We need specify all the entities (Kotlin classes)

We need specify abstract method using the DAO interfaces

```
@Database(entities = [Note::class], version = 1, exportSchema = false)
abstract class NoteDatabase : RoomDatabase() {
    abstract fun noteDao(): NoteDao

    companion object {
        @Volatile
        private var INSTANCE: NoteDatabase? = null

        fun getDatabase(context: Context): NoteDatabase {
            return INSTANCE ?: synchronized(this) {
                val instance = Room.databaseBuilder(
                    context.applicationContext,
                    NoteDatabase::class.java,
                    "note_database.db"
                ).build()
                INSTANCE = instance
                instance
            }
        }
    }
}
```

We need to extend RoomDatabase

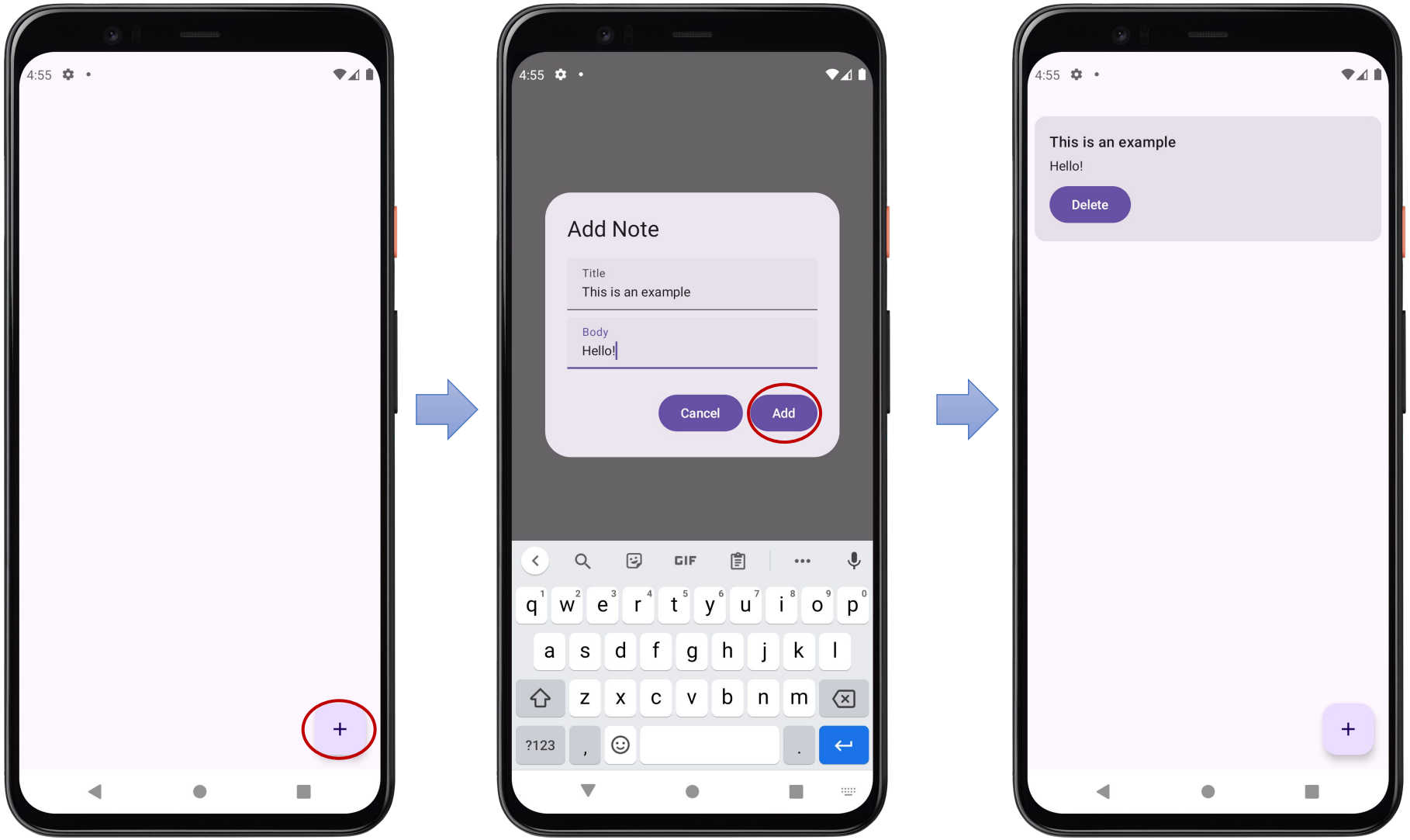
Creation of connection to the database using Room

5. Local database - Room persistence library


```
class NoteViewModel(application: Application) : AndroidViewModel(application) {
    private val noteDao = NoteDatabase.getDatabase(application).noteDao()
    val allNotes: LiveData<List<Note>> = noteDao.getAllNotes()

    fun addNote(title: String, body: String) {
        viewModelScope.launch {
            val note = Note(title = title, body = body)
            noteDao.insert(note)
        }
    }

    fun updateNote(id: Int, title: String, body: String) {
        viewModelScope.launch {
            val note = Note(id = id, title = title, body = body)
            noteDao.update(note)
        }
    }

    fun deleteNote(id: Int) {
        viewModelScope.launch {
            noteDao.delete(id)
        }
    }
}
```

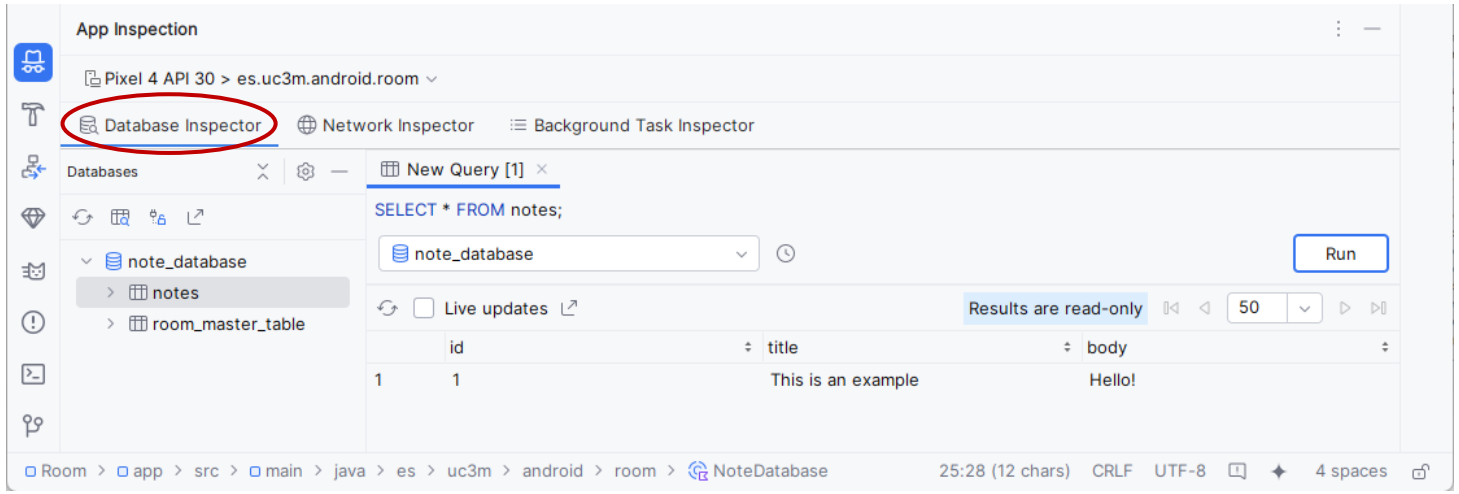
Finally, we access the database in our Kotlin logic (typically in a `ViewModel` class), invoking the DAO methods to manage the data

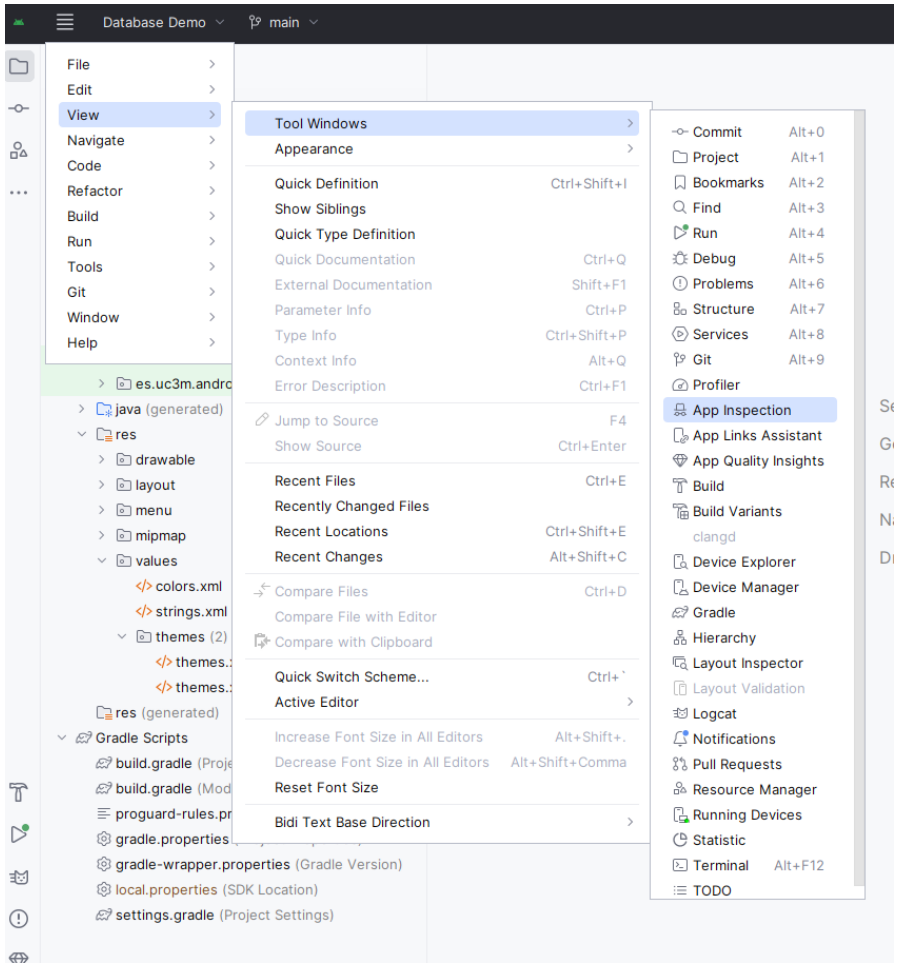
5. Local database - Room persistence library



5. Local database - Database inspector

- It is possible to browse the database using an integrated database inspector available in Android Studio (View → Tool Windows → App Inspection)
  - App Inspection → Database inspector





5. Local database - Preloaded database

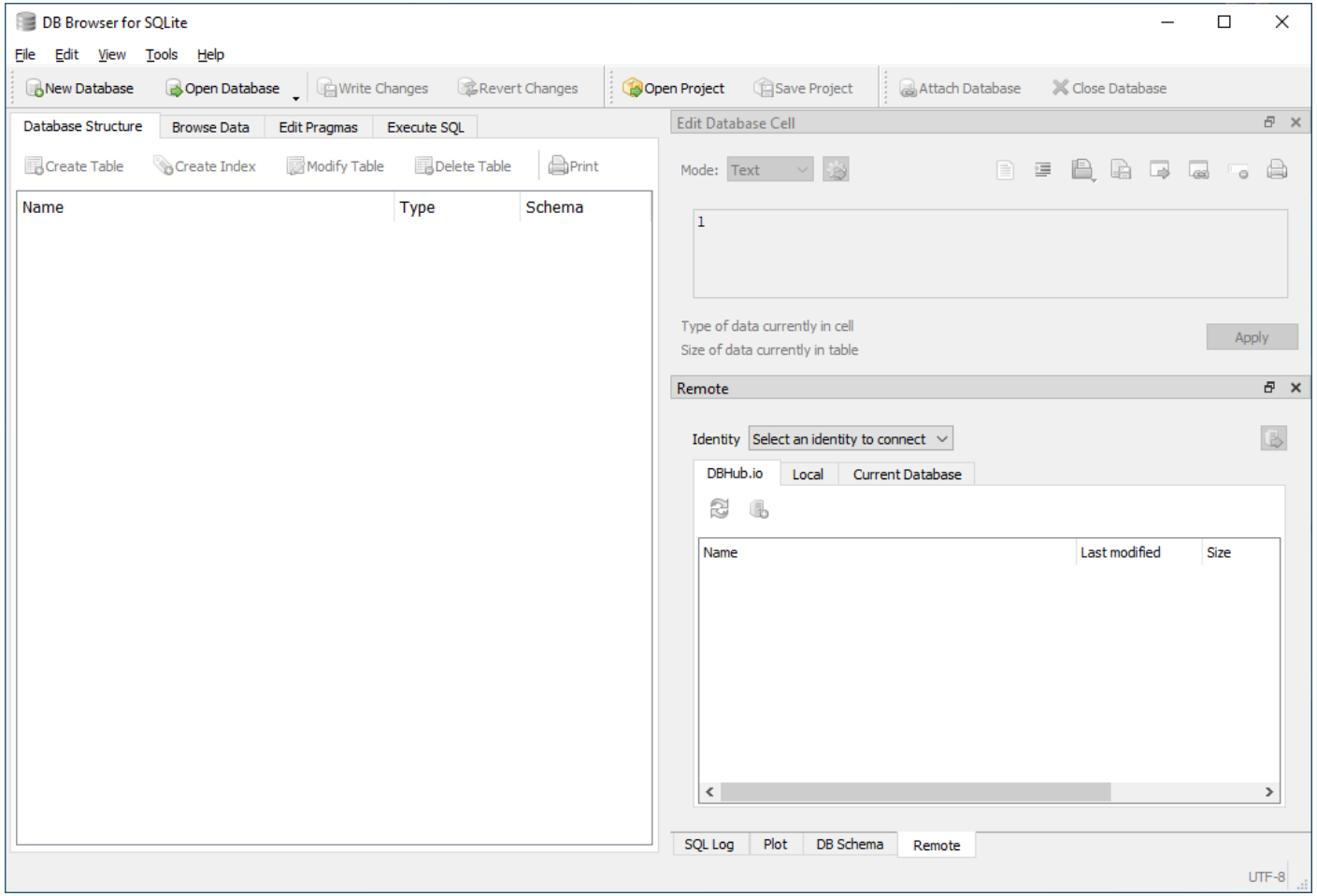
- It is possible to create a SQLite database using an external tool and copy it to our Android app
  - This option can be interesting for having preloaded data in our apps, for example for the final project app
- The procedure to use this preloaded database can be as follows:
  1. Create SQLite database. For instance, using DB Browser for SQLite

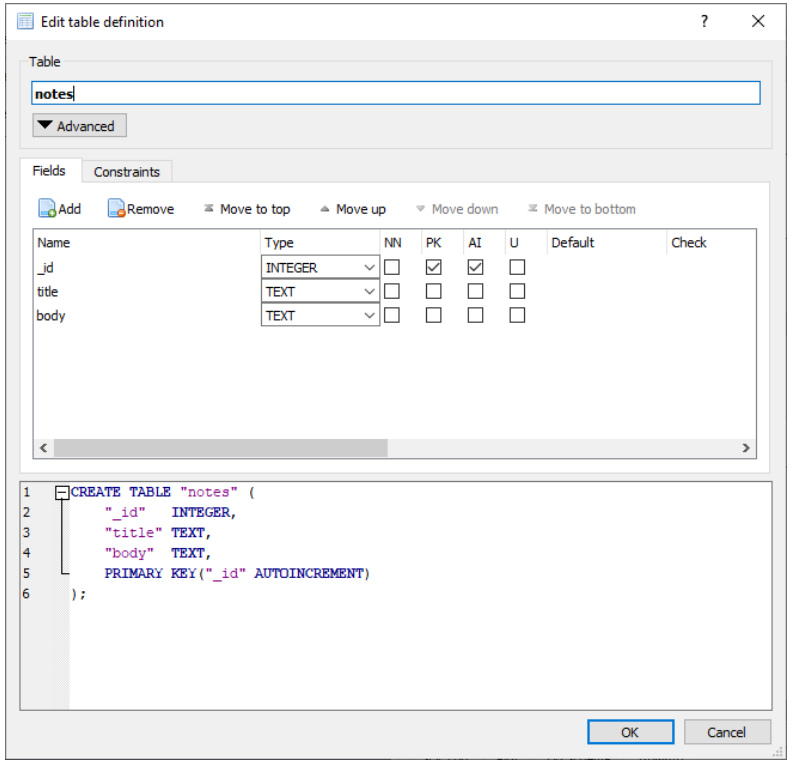
https://sqlitebrowser.org/

  2. Copy the SQLite database in an assets folder
  3. Load database in our project (we can use shared preferences to do it only one time)

5. Local database - Preloaded database

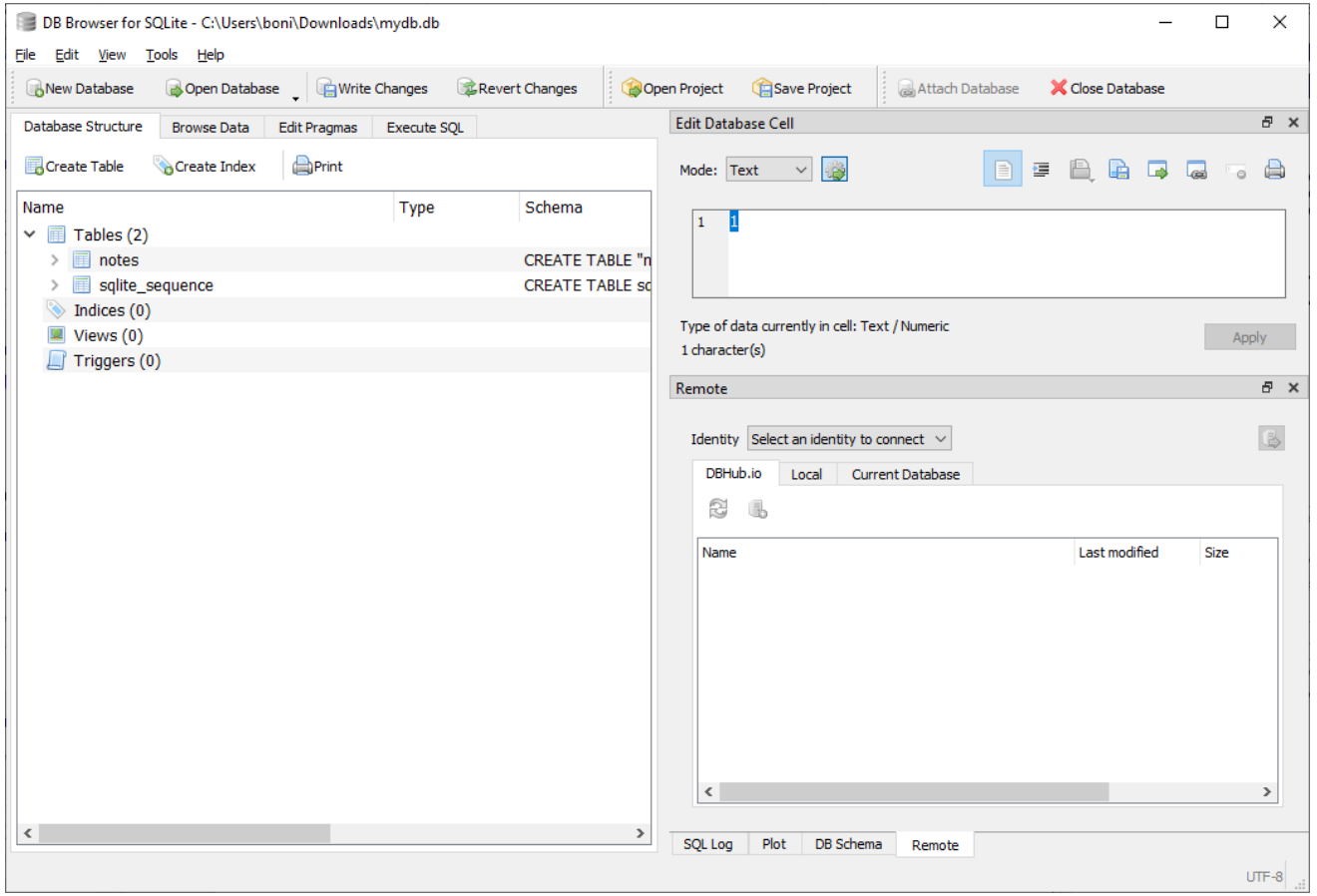
1. Create SQLite database. For instance, using DB Browser for SQLite:

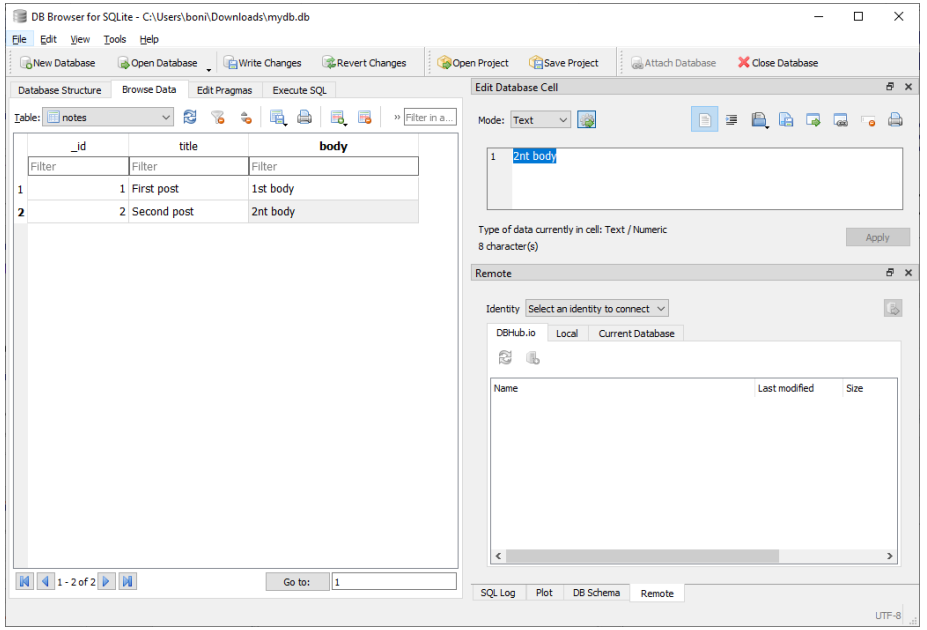




5. Local database - Preloaded database

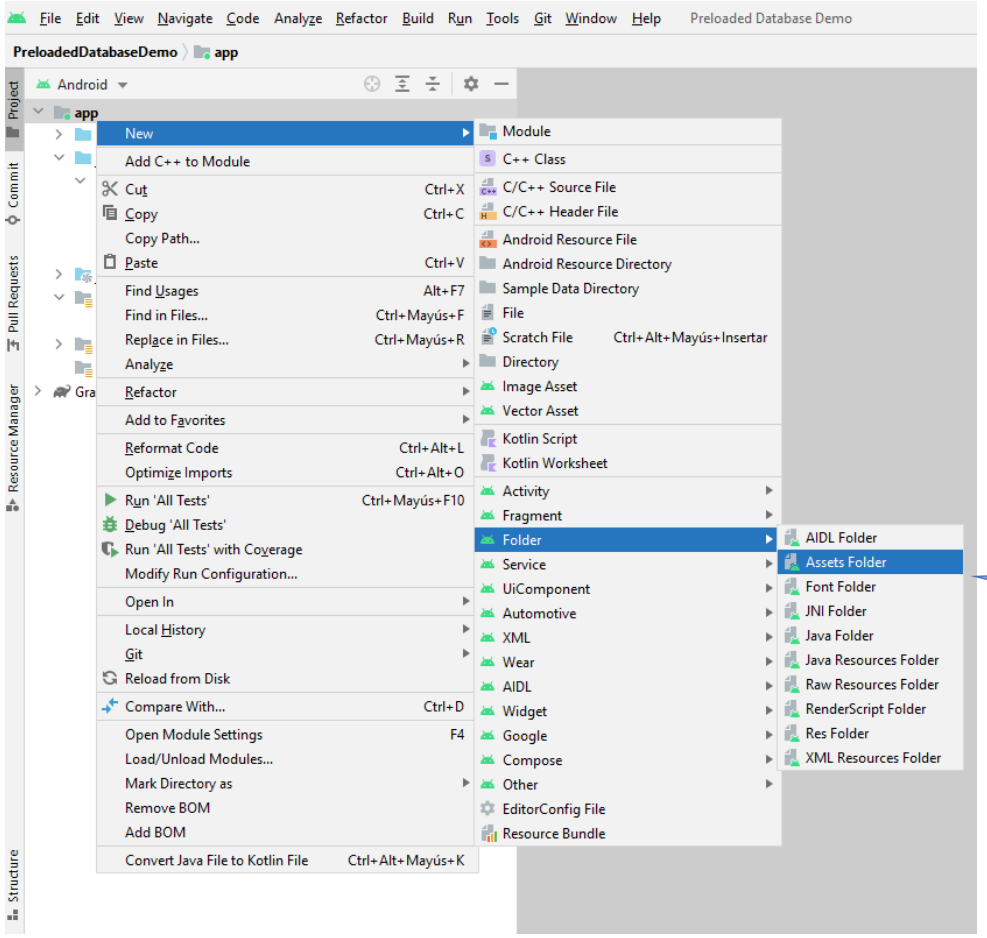
1. Create SQLite database. For instance, using DB Browser for SQLite:





5. Local database - Preloaded database

2. Copy the SQLite database in an assets folder



We can use the Android Studio wizard New→Folder→Assets folder

5. Local database - Preloaded database

3. Load database in our project
   - The room library eases the manipulation of a preloaded databases
   - We need to put the preloaded database in the assets folder and invoke the method `createFromAsset` in the database class

```
@Database(entities = [Note::class], version = 1, exportSchema = false)
abstract class NoteDatabase : RoomDatabase() {
    abstract fun noteDao(): NoteDao

    companion object {
        @Volatile
        private var INSTANCE: NoteDatabase? = null

        fun getDatabase(context: Context): NoteDatabase {
            return INSTANCE ?: synchronized(this) {
                val instance = Room.databaseBuilder(
                    context.applicationContext,
                    NoteDatabase::class.java,
                    "note_database.db"
                ).createFromAsset("preloaded_notes.db")
                    .build()
                INSTANCE = instance
                instance
            }
        }
    }
}
```

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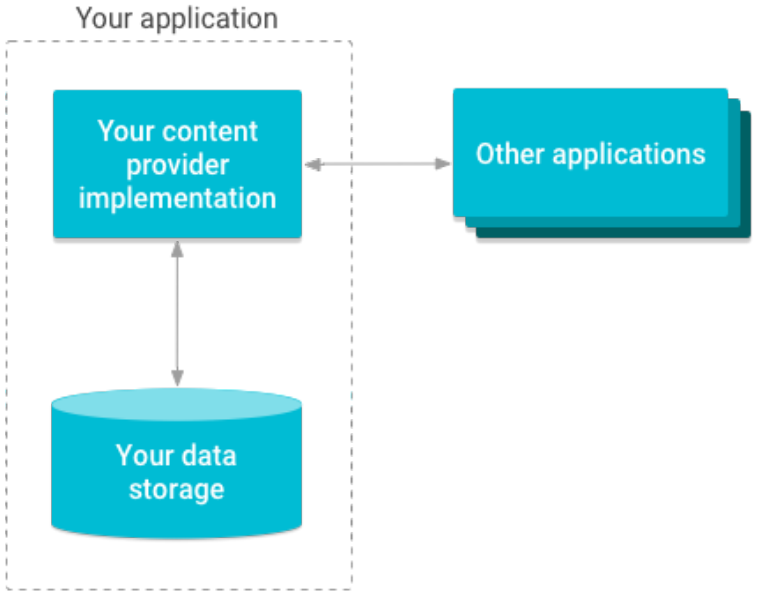
6. Content providers

- A content provider is type of app component in Android (together with activities, broadcast receivers, and services) aimed to share data between different apps



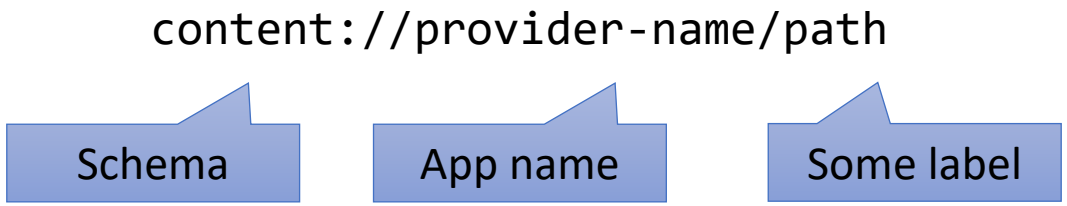
https://developer.android.com/guide/topics/providers/content-providers

6. Content providers

- A content provider behaves like a distributed database where other apos can carry out CRUD (create, read, update, and delete) operations
  - Using the methods: `insert()`, `query()`, `update()`, and `delete()`
- To create a content provider in Android, we need:
  1. Create a subclass of `ContentProvider`
  2. Register it in the Manifest (using the tag **`provider`**)
- The demo app ContentProvider provides a basic example using a content provider
  - It is an app that exposed CRUD operations on a basic table through a content provider

6. Content providers

- A content provider is identified in Android using a content **URI** (*Uniform Resource Identifier*)
  - An URI is a unique sequence of characters that identifies a logical or physical resource
  - URL (Uniform Resource Locators) is subsets of URIs aimed to identify web resources
- The structure of a content URI in Android is as follows:



6. Content providers

Fork me on GitHub

Method to initialize the provider

Method to **read** data from the provider

Method to **write** data into the provider

Method to **update** data from the provider

Method to **delete** data from the provider

Method to return the MIME type corresponding to a content URI

```
class MyContentProvider : ContentProvider() {

    private lateinit var dbHelper: MyDatabaseHelper

    override fun onCreate(): Boolean {
        dbHelper = MyDatabaseHelper(context!!)
        return true
    }

    override fun query(
        uri: Uri,
        projection: Array<String>?,
        selection: String?,
        selectionArgs: Array<String>?,
        sortOrder: String?
    ): Cursor {
        val db = dbHelper.readableDatabase
        return db.query(TABLE_NAME, projection, selection, selectionArgs, null, null, sortOrder)
    }

    override fun insert(uri: Uri, values: ContentValues?): Uri {
        val db = dbHelper.writableDatabase
        val id = db.insert(TABLE_NAME, null, values)
        return ContentUris.withAppendedId(uri, id)
    }

    override fun update(
        uri: Uri, values: ContentValues?, selection: String?, selectionArgs: Array<String>?
    ): Int {
        val db = dbHelper.writableDatabase
        return db.update(TABLE_NAME, values, selection, selectionArgs)
    }

    override fun delete(uri: Uri, selection: String?, selectionArgs: Array<String>?): Int {
        val db = dbHelper.writableDatabase
        return db.delete(TABLE_NAME, selection, selectionArgs)
    }

    override fun getType(uri: Uri): String {
        return "vnd.android.cursor.dir/vnd.com.example.provider.${TABLE_NAME}"
    }
}
```

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7. Takeaways

- Firebase is a set of backend cloud computing services provided by Google
  - Cloud Firestore is a cloud-hosted NoSQL document database within Firebase
  - Firebase Authentication is a Firebase service provided that simplifies the process of adding user authentication to apps
- DataStore is lightweight mechanism for storing name/value data
- Also, we can use regular files for writing and reading persistent data in the internal or external storage
  - The user must grant permissions to access the external storage
- Android provides access to SQLite, which is a lightweight open-source relational database
  - The Room persistence library eases the management of SQLite for Android
  - We can use an external tool (like DB Browser for SQLite) to create a preloaded database to be included in our Android app project
- Content providers is a type of app component which allows to share data between different apps