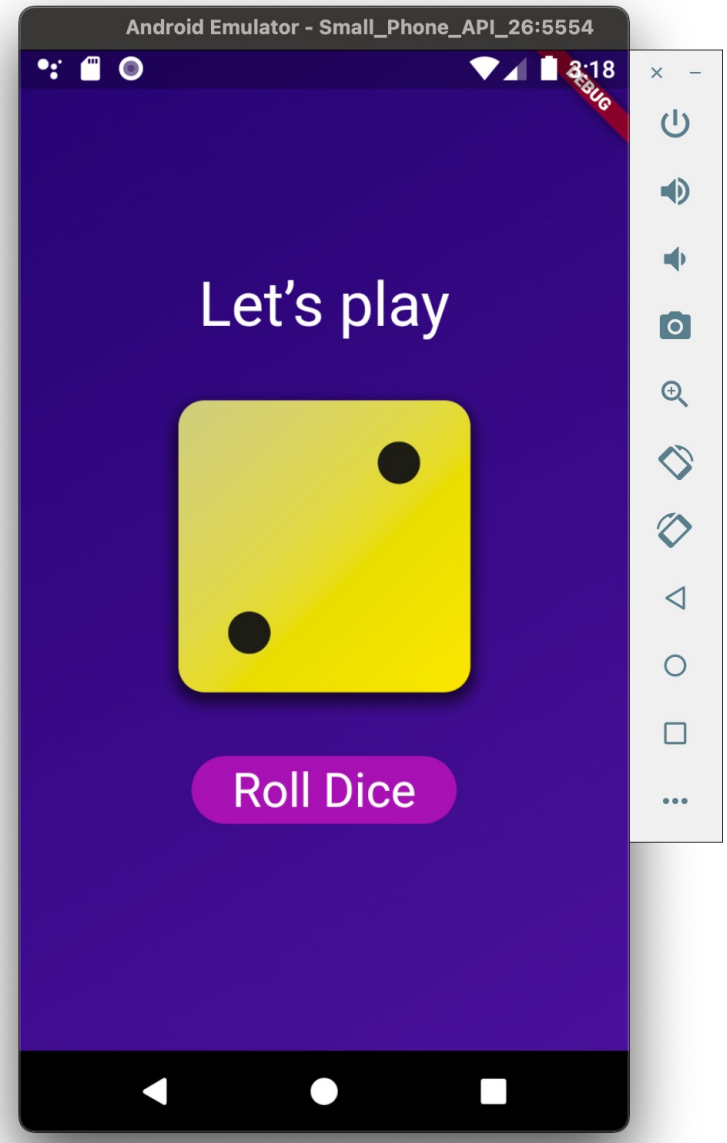
Basics of Dart & Flutter: Part I

Shan-Hung Wu
CS, NTHU

Let’s Roll Dice

- Today’s topics:
- Dart language
- Flutter app overview
- Stateless vs stateful widgets



Evolution of Dart

- Dart 1.0 (Nov 2013)
  - Initially introduced as an alternative to JavaScript
  - Pub package manager
- Dart 2.0 (Aug 2018)
  - Strong type system
  - Sound null safety
  - Supports Flutter!
- Dart 3.0 (May 2023)
  - Null Safety by default
  - Unified dev workflow across different platforms

Dart Features

- Platform-independent (Windows, Mac, Linux, and Web)
  - Just-In-Time (JIT) compilation in development
    - Runs in VM; offering ***hot reload***
  - Ahead-Of-Time (AOT) compilation in production
    - Native code or JavaScript; high performance
- Auto memory management with ***Garbage Collection*** (GC)
- ***Function as first-class citizen***
- ***Sound null safety***
- ***Object-oriented***
  - Supports encapsulation, inheritance, polymorphism, interface, extension, etc.
- ***Async, await, and concurrency*** (Isolates)
- Foreign Function Interface (FFI)
- Free and open-source

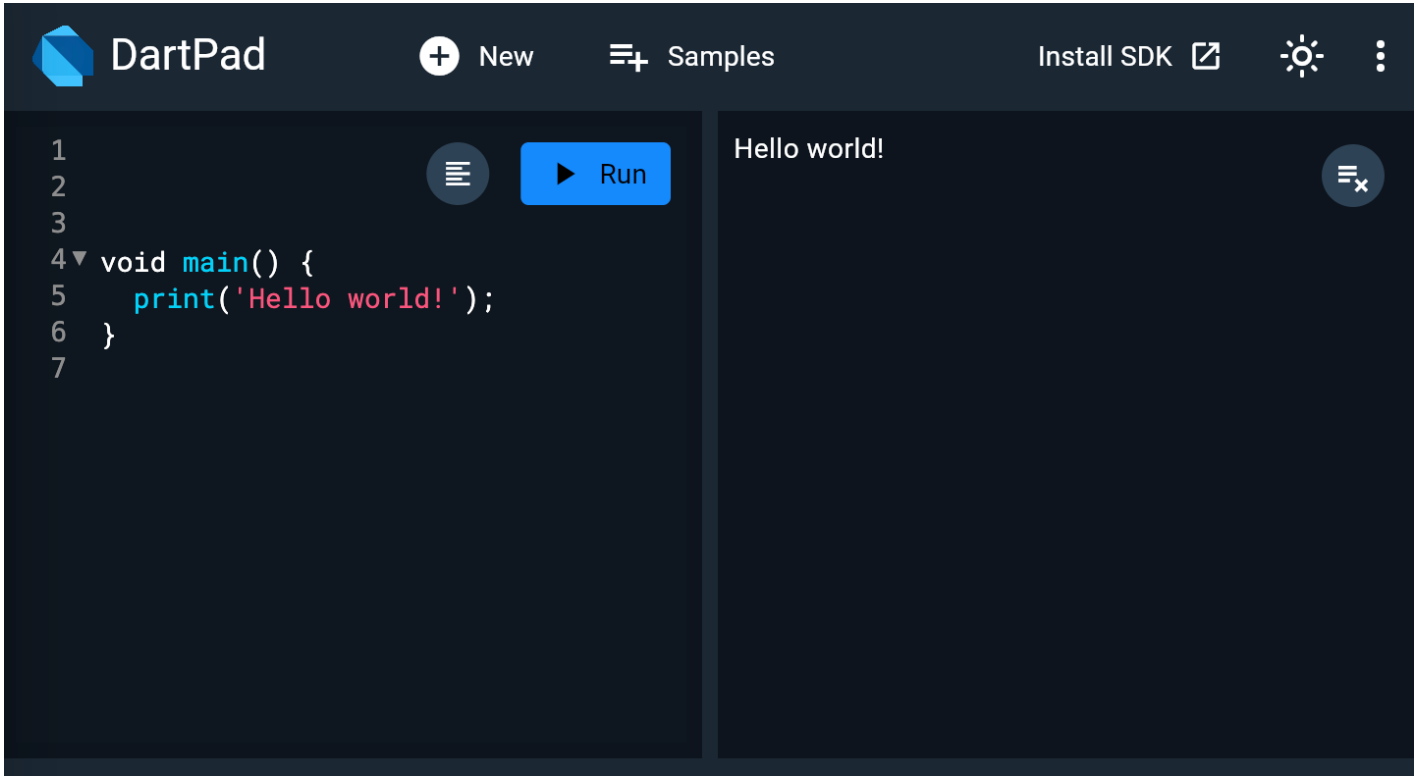
Warm up:

What’s the difference between statements & expressions?

Terms Revisited

- ***Statement***: command that ends with ";"
  - `print('Hello world!');`
- ***Expression***: command evaluated to a single value
  - `'Hello ' + 'world!'`
- ***Keyword***: word reserved for compiler
  - `int`, `String`, `if`, `for`, `static`, `final`, etc.
- ***Identifier***: name of variable, function, class, etc.
  - `int age;`
- ***Literal***: value directly written in source code
  - `double pi = 3.14;`

Hello World!



- Let's run it on DartPad (Dart → JavaScript):

Variables

```
void main() {
  String firstName = 'John';
  var lastName = 'Smith';
  String address = 'USA';
  int age = 20;
  double height = 5.9;
  bool isMarried = false;

  print('Name is $firstName $lastName');
  print('Address is $address');
  print('Age is $age');
  print('Height is $height');
  print('Married status is $isMarried');
}
```

- Use `var` with type inference
- Use `final` or `const` to declare fixed values:

```
const pi = 3.14159;
```

User Input

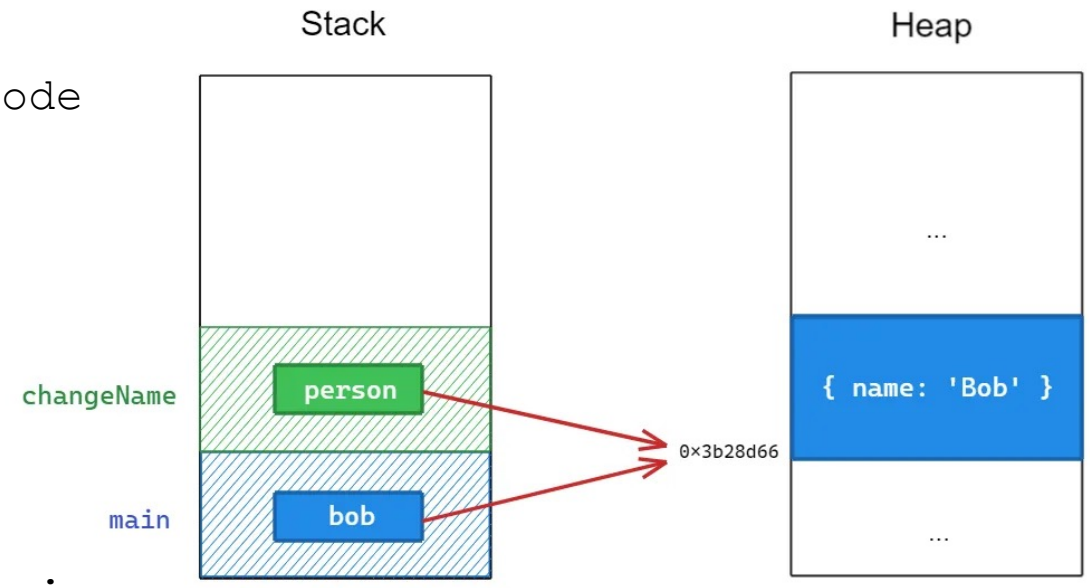
```
import 'dart:io';

void main() {
  print('Enter your name:');
  String? name  = stdin.readLineSync();
  if (name != null) {
    print('Hello ${name}');
  }
}
```

- Package `dart:io` provided by Dart
- Only runs in command line via `dart run`
- `String?` means `name` could be `null`
  - We will discuss this feature later

Built-in Data Types

```
bool
int
double
num // int or double
runs // String's Unicode
String
List
Set
Map
Function
```

- All types are ***object types***
  - Extending `Object` class
- Passed “by reference”, not “by value”




```
void main() {
  var bob = ...;
  changeName(bob);
}
void changeName(Map person) { ... }
```

Immutable Types

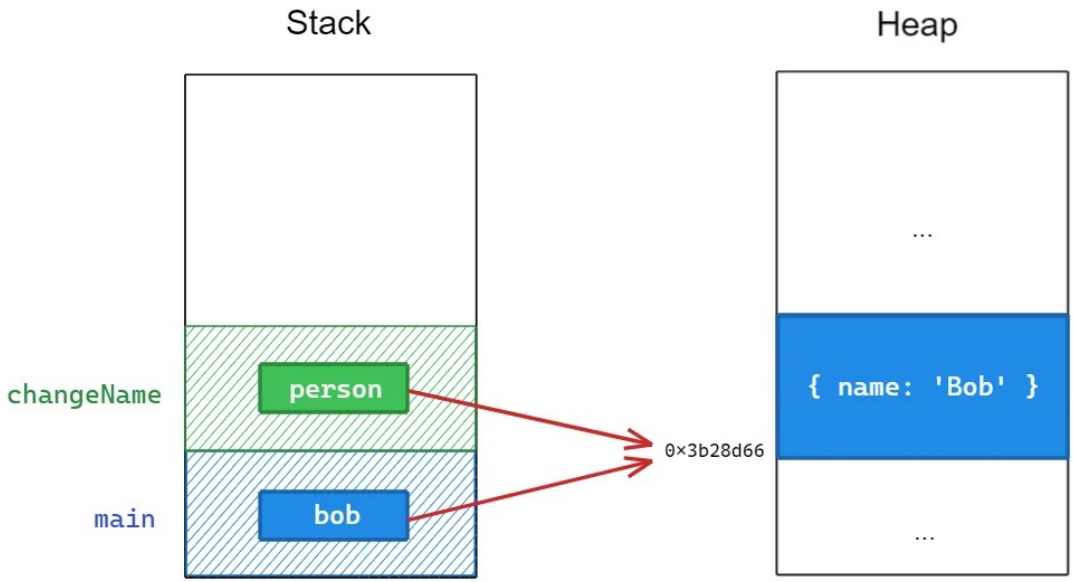
- `bool`, `int`, `double` and `String` types are ***immutable***
- `'Hello ' + 'world!'` creates new `String` object

- In effect, these types ***behave like value types*** in other languages

- Why not just use value types?
- Object types can have methods:

```
const pi = 3.14159;
print('Pi is ${pi.toStringAsFixed(2)}');
```

Memory Management



- In Dart, the ***garbage collector*** periodically finds "unused" objects in heap and frees their memory
  - No need to call `free()` as in C
- What "unused" objects?
- Those not referenced by variables in stack

Lists, Maps, and Generics

- List (array):

```
List<int> myList = [1, 2, 3];
myList.add(4); // Adds 4 to the end
myList[0] = 10;
myList.removeAt(0);
print(myList[0]); // Prints what?
```

- Map:

```
Map<String, String> myMap = {
  'lang': 'Dart',
  'client': 'Flutter',
  'server': 'Firebase'
};
myMap['store'] = 'Google Play';
myMap['lang'] = 'Dart language';
myMap.remove('server');
print(myMap['lang']); // Prints what?
```

Iterating Lists & Maps

- List:

```
for (var e in myList) {
  print(e);
}
```

- Map:

```
for (var e in myMap.entries) {
  print('${e.key}: ${e.value}');
}

for (var k in myMap.keys) {
  print(k);
}

for (var v in myMap.values) {
  print(v);
}
```

Functions

```
void add(num num1, num num2){
  // num1 and num2 are parameters
  num sum = num1 + num2;
  print('The sum is $sum');
}

void main(){
  // 10 and 20 are arguments
  add(10, 20);
}
```

Parameters & Default Values

```
// Optional positional parameters
void sayMessage(String message, [String? author]) {
  print("$message — ${author ?? 'Anonymous'}");
}

// Named parameters & default values
void setDimensions({int width = 10, int height = 10}) {
  print("Width: $width, Height: $height");
}

void main() {
  sayMessage('Hello, Dart!');
  setDimensions(height: 20, width: 30);
}
```

- Named param is optional by default
  - Use `required` to make it mandatory

Generics in Functions

```
// Returns the first element of any list
T firstElement<T>(List<T> list) {
  if (list.isEmpty) {
    throw Exception('The list is empty');
  }
  return list.first;
}

// Returns the larger argument
T maxValue<T extends Comparable>(T a, T b) {
  return a.compareTo(b) > 0 ? a : b;
}
```

- Helps ensure type safety

Multiple Return Values

```
final json = <String, dynamic>{ // "dynamic" means "any type"
  'name': 'Dash',
  'age': 10,
  'color': 'blue',
};

// Returns multiple values in a record:
(String, int) userInfo(Map<String, dynamic> json) {
  return (json['name'] as String, json['age'] as int);
}

// Destructures using a record pattern:
var (name, age) = userInfo(json);
```

Arrow Functions

- If a function consists of just one line of code that returns a value, it has simpler syntax:

```
// Normal function
int add(int a, int b) { return a + b; }

// Arrow function
int add(int a, int b) => a + b;
```

- Don’t use arrow if function doesn’t return anything

Functions as First-Class Citizens

```
// Basic operations
int add(int a, int b) => a + b;
int multiply(int a, int b) => a * b;

// Higher-order function that accepts functions as params
void printOPResult(int a, int b, Function(int, int) op) {
  var result = op(a, b);
  print('Result: $result');
}

void main() {
  // Assigning functions to variables
  Function(int, int) op = add;
  printOPResult(4, 2, op);
  op = multiply;
  printOPResult(4, 2, op);
}
```

- Functions can be assigned to variables and passed around

Anonymous Functions

- E.g., list manipulation:

```
for (int e in myList) {
  print(e);
}

myList.forEach((e) {
  print(e);
});

// Multiply each el by 2
var myList2 = myList.map(
  (e) => e * 2
).toList();
```

- E.g., map manipulation:

```
for (var k in myMap.keys) {
  print(k);
}

myMap.keys.forEach((k) {
  print(k);
});

var entries = myMap.map(
  (k, v) =>
      MapEntry(..., ...)
);
var myMap2 = Map<..., ...>
      .fromEntries(entries);
```

Variables are Block-scoped

```
void outerFunction() {
  var outerStr = "I'm outside!";

  void innerFunction() {
    var innerStr = "I'm inside!";
    print(outerStr); // Accessible in nested func!
  }

  // print(innerStr); // Error: undefined 'innerStr'
}
```

- Lexical scoping: variable's scope is determined at compile time, not at runtime (dynamic scoping)

Closures & Captured Variables

```
Function makeAdder(int base) {
  return (int i) => base + i; // return func
}

void main() {
  var addFrom2 = makeAdder(2);
  var addFrom3 = makeAdder(3);
  print(addFrom2(10)); // Output: 12
  print(addFrom3(10)); // Output: 13
}
```

- ***Closures*** are functions that capture and retain variables from their lexical scope
- ***Capture variables*** stay in memory even after the outer function executes

No Bad Closures in Loops

```
List<Function> createCounters() {
  var counters = <Function>[];
  for (var i = 0; i < 3; i++) {
    counters.add(() => i);
  }
  return counters;
}

void main() {
  var counters = createCounters();
  for (var counter in counters) {
    print(counter()); // Prints 0, 1, 2
  }
}
```

- JavaScript prints “3, 3, 3” (bad closure)
- Dart prints “0, 1, 2”
  - Each closure in loop captures its own copy of `i`

Classes & Custom Types

- Class as the blueprint (type) of your custom objects

```
class Person {
  // Instance variables
  String name;
  int age;

  // Constructor
  Person({required this.name, required this.age});

  // Method
  void displayInfo() {
    print('Name: $name, Age: $age');
  }
}
void main() {
  var alice = Person('name': 'Alice', age': 20); // Instance
  alice.displayInfo(); // Output: Name: Alice, Age: 20
  var bob = Person('name': 'Bob', age': 21); // Instance
  bob.displayInfo(); // Output: Name: Bob, Age: 21

  assert(alice is Person); // No AssertionError thrown
}
```

Named Constructors

```
class Person {
  String name;
  int age;

  // Constructor
  Person({required this.name, required this.age});

  // Named constructor
  Person.fromMap(Map<String, dynamic> data)
      : name = data['name'],
        age = data['age'];
  ...
}

void main() {
  var map = {'name': 'Dave', 'age': 25};
  var person = Person.fromMap(map);
  person.displayInfo();
}
```

Inheritance (1/3)

```
class Student extends Person {
  String university;

  Student({
    required super.name,
    required super.age,
    required this.university
  });

  Student.fromMap(Map<String, dynamic> data)
      : university = data['university'],
        super.fromMap(data);

  @override
  void displayInfo() {
    super.displayInfo();
    print('University: $university');
  }

  void study() { ... } // custom method
}
```

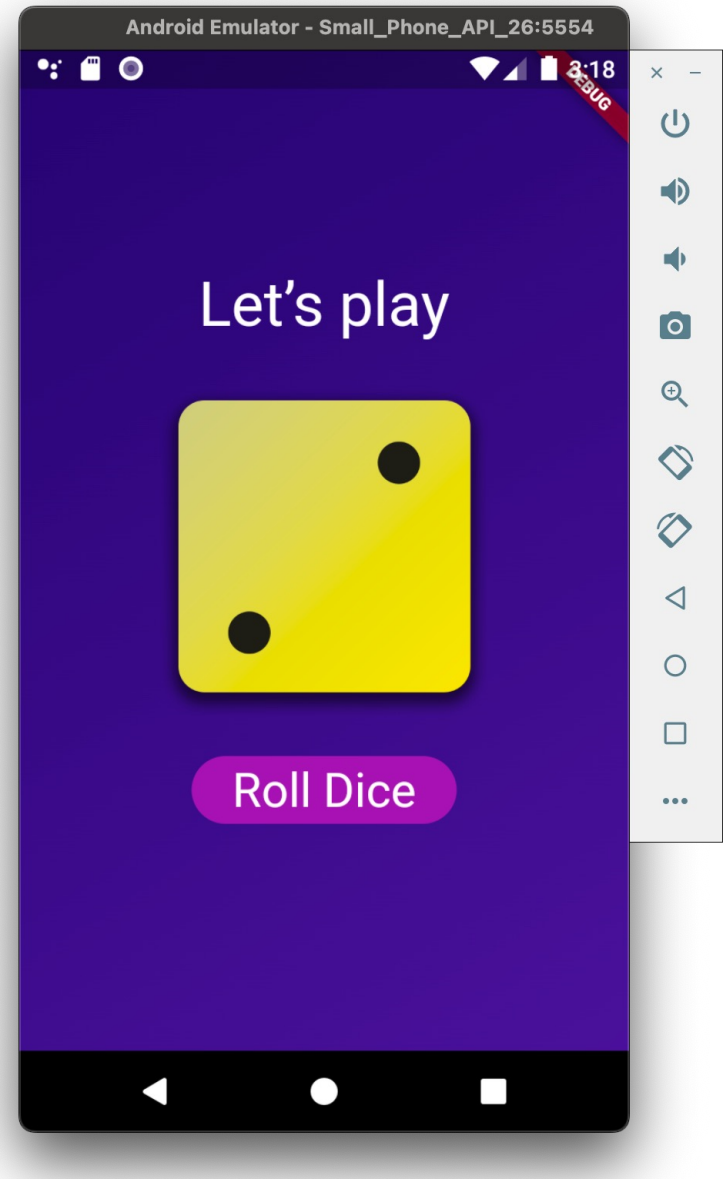
Inheritance (2/3)

```
class Employee extends Person {
  String company;

  Student({
    required super.name,
    required super.age,
    required this.company
  });

  Student.fromMap(Map<String, dynamic> data)
      : company = data['company'],
        super.fromMap(data);

  @override
  void displayInfo() {
    super.displayInfo();
    print(Company: $company');
  }

  void work() { ... } // custom method
}
```

Inheritance (3/3)

```
void main() {
  Person alice = Student(..., university: ...);
  alice.displayInfo(); // with "University: ..."

  assert(alice is Person);
  assert(alice is Student);
  assert(alice is! Employee);

  print(alice.runtimeType); // Output: 'Student'

  var studentAlice = alice as Student;
  studentAlice.study();
}
```

Entering Flutter



Final vs. Const

```
void main() {
  final date = DateTime.now(); // OK
  const date = DateTime.now(); // Error

  const pi = 3.14; // OK
  final gravity; // Error: must be initialized
  final gravity = Gravity();
  gravity.setForce(...) // OK
}
```

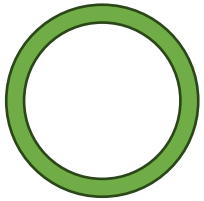
- A `final` variable can only be set once
  - Referenced object can still be mutable
- A `const` variable is a compile-time constant
  - ***Canonicalized***: only one copy in memory
  - `Const` widgets can be rebuilt faster in Flutter

Immutable Class

```
class ImmutablePoint {
  final double x; // or any immutable type
  final double y;

  // Const constructor
  const ImmutablePoint(this.x, this.y);
}

void main() {
  const point1 = ImmutablePoint(2, 3);
  const point2 = ImmutablePoint(2, 3);
  print(point1 == point2); // Outputs: true
  print(identical(point1, point2)); // Outputs: true

  final point3 = ImmutablePoint(2, 3);
  final point4 = ImmutablePoint(2, 3);
  print(point1 == point2); // Depends on if "==" is overridden
  print(identical(point1, point2)); // Outputs: false
}
```

- Try `const` Widget yourself

Composite over Inheritance



```
class StyledText extends StatelessWidget {
  final String text;
  final TextStyle style;

  const StyledTextComposition(this.text, {
    super.key,
    required this.style,
  });

  @override
  Widget build(BuildContext context) {
    return Text(text, style: style);
  }
}
```

- Composition allows widgets to remain loosely coupled, promoting reusability

```
class StyledText extends Text {
  ...
}
```

Stateless vs. Stateful Widgets

```
class CounterWidget extends StatefulWidget {
  const CounterWidget({super.key});

  @override
  _CounterWidgetState createState() => _CounterWidgetState();
}
class _CounterWidgetState extends State<CounterWidget> {
  int _counter = 0; // Initial counter value

  void _incrementCounter() {
    setState(() {
      _counter++;
    });
  }

  @override
  Widget build(BuildContext context) {
    return Text('Counter: $_counter');
  }
}
```

- `setState()` tells Flutter to rerun `build()`

References

- Introduction to Dart