SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Mobile applications State Management in Flutter

Tesi di Laurea Magistrale in
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Abstract

Abstract

Keywords: here, the keywords, of your thesis

Abstract in lingua italiana

Qui va l'Abstract in lingua italiana della tesi seguito dalla lista di parole chiave.

Parole chiave: qui, vanno, le parole chiave, della tesi

Contents

Introduction

Introduction

1 | State management solutions

here i will present some main concepts and functionalities of the state management solutions proposed. This chapter will be filled with the information contained in the other word file i sent you.

1.1. SetState and InheritedWidget/InheritedModel

...

1.2. Redux

...

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...

2 | The Todo app

This chapter is devoted to the implementation of a mobile application. The application manages a list of todos. It is developed using the state managemenent solutions proposed in Chapter 1. For every solution, three different development processes are taken. Moreover, a series of measurements ,concerning the volume of the code and the effort, are collected.

2.1. General overview

This section explains in details the three development processes. These processes concern the implementation of the main functionalities, the addition of new ones and the performance optimization.

2.1.1. Base functionalities

This part of the development process aims to realize the skeleton of the app and the main functionalities. The output of the process will be and application that offers the possibility to visualize and partially handle todos. It is made of a single page: the HomePage. The HomePage is composed by an AppBar and two tabs: the *todo* tab and the *stats* tab. In the *todo* tab the list of todos is visualized. Is possible to filter todos using a DropdownButton in the top right corner inside the AppBar. The available filter values are:

- All (visualize completed and pending todos)
- Completed (visualize completed todo only)
- Not Completed (visualize pending todos only)

The list of todos is visualized using a TodoView component. The elements that compose the list of todos are called TodoItems. TodoItems visualize the todo's name and description using two Text widgets and completion using a Checkbox widget. It is possible to use the checkbox to mark a Todo as completed or to mark it as pending depending on its current state. In the *stats* tab is possible to visualize the number of completed todos through a Text widget. In the lower part a TabSelector allow to switch from tabs.

2.1.2. Adding new features

This part of the development process aims to add two new features to the output application of the previous process. This process is divided into two subparts. Both of them aims to add a single new feature.

The Add todo Feature

The first subpart adds the possibility to create new todos. It utilizes the FloatingActionButton , already present in the skeleton of the app in the bottom right corner, to push a new page called: AddTodoPage. In the AddTodoPage is possible to compile two TextField widget and use a TextButton widget to pop the page and create the new todo.

The Update feature

The second subpart adds the possibility to update existing todos. Tapping on a specific TodoItem the application navigates to a new page : the UpdateTodoPage. In the UpdateTodoPage is possible to compile two TextFields widgets and use a TextButton widget to pop the page and apply the modification.

2.1.3. Renders optimization

This part of the development process aims to perform some optimizations in terms of UI rendering and memory consumption. In particular, the code will be refactored in order to use the least UI renders possible and ,in other words, to call the least *build* methods possible. The focus is on the TodoView and TodoItem widgets. The TodoView widget should be rendered again only after a structural change in the *filteredTodos* list. A structural change is intended as a mutation of the length of the list or a substitution of its internal elements. Basically, a structural change occurs when a new todo is added or removed from the list or when the filter changes. If the change concerns a single todo (e.g. when its internal state is changed using the checkbox or the update feature)it is considered a non-structural change. The main difference is that, a structural change, needs to rebuild the entire TodoView ,instead, a non-structural change can rebuild only a subpart (the particular TodoItem). This because , when a structural change occurs, more than one TodoItem is affected and ,the most convinient way to mutate them all consistently ,is to rebuild the entire TodoView widget. Moreover, addind , deleting and substituting a TodoItem (and consequently add/delete/substitute a child to the TodoView tree node) is only possible by the parent widget and not by widgets on the same tree level. A non-structural change ,instead, affects only a specific TodoItem/child and so, it is possibile to rebuild the single element only. Those optimizations are not really necessary in this scenario. The implemented application is ,indeed, very simple and do not need this kind of improvements at all. This is just an experiment in order to define which solution performs better at handling optimizations and to give an adjunctive prospective in the final comparison.

2.2. Implementation

This section contains the implementation of the application presented in the Section 2.1.

2.2.1. Shared project structure and files

In order to make comparisons even more fair , the code about the application's core and UI is shared between different solution's implementations. This subsection presents the shared code in details. Some parts of the shared code can change from one implementation to another in order to adapt to the solution. However, changes to this structure are kept minimal. And the same is for the UI. It uses the least widget and visual features possible. In the Figure 2.1 the shared folder's and file's structure is shown. Subsequent paragraphs exaplains how models, pages, components and the repository are implemented.

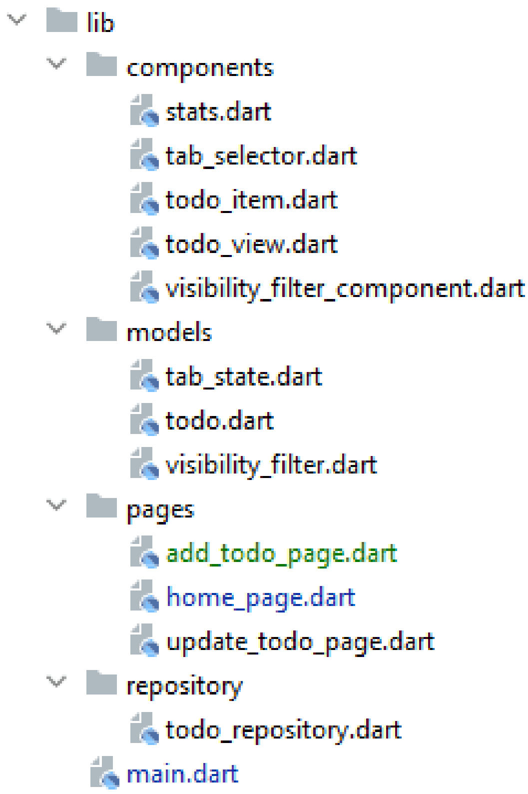


Figure 2.1: Todos app skeleton's folders structure.

The application's Root

The root widget of the application is called MyApp. It is a stateful widget composed by a MaterialApp. Inside the MaterialApp, three routes are defined : the HomePage , the UpdateTodoPage and the AddTodoPage. The *inizialRoute* is set to the HomePage as deafult. Inside the *main* function the MyApp widget is passed to the *runApp* method at the application's start.

Source Code 2.1: Todo app - MaterialApp and main function definition

```
void main() {
  runApp(const MyApp());
}

class MyApp extends StatefulWidget {
  const MyApp({Key? key}) : super(key: key);
```

```
  @override
  State<MyApp> createState() => _MyAppState();
}

class _MyAppState extends State<MyApp> {

  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      initialRoute: "/",
      routes: {
        "/": (context) => const HomePage(),
        "/updateTodo": (context) => UpdateTodoPage(),
        "/addTodo": (context) => AddTodoPage(),

      },
    );
  }
}
```

Models and Repository

as show in code **??** HomePage's tabs are only two : *todos* and *stats*. In the *todos* tab todos are visualized. In the *stats* tab ,instead, some numerical recap of the todos is visualized. They are defined using an enumeration for simplicity.

Source Code 2.2: Todo app - TabState model definition

```
enum TabState{
 todos,stats
}
```

Filters for the *filteredTodos* list are modelled by an enumeration too. They can take three values: *all, notCompleted, completed.*

Source Code 2.3: Todo app - VisibilityFilter model definition

```
enum VisibilityFilter{
 completed,notCompleted,all
}
```

It's not possible to give a common implementation of the Todo model matching every solution. Todo model ,indeed, change in different implementations. The sharable structure of the model ,however, can defined as below RIFERIMENTO. (

Source Code 2.4: Todo app - Todo model definition

```
@immutable
class Todo {
  final int id;
  final String name;
  final String description;
  final bool completed;

  const Todo(
      {required this.id,
      required this.name,
      required this.description,
      required this.completed});

  @override
```

```
    bool operator ==(Object other) {
      return (other is Todo) &&
          other.description == description &&
          other.name == name &&
          other.id == id &&
          other.completed == completed;
    }

    @override
    String toString() {
      return "{ id: $id  completed: $completed}";
    }

    @override
    // TODO: implement hashCode
    int get hashCode => super.hashCode;
  }
```

The TodoRepository class simulate todos's fetching from a Database. It has two static methods. These methods are asynchronous and have a duration of 2 seconds to give the impression of a real asynchronous operation. The method *loadTodos* , in particular , populate a list with six new todos after the generation of their unique ID's. Subsequently, after 2 seconds, returns it to the caller.

Source Code 2.5: Todo app - TodoRepository definition

```
  class TodoRepository {
    static Future<List<Todo>> loadTodos() async {
      Random rand = Random();
      List<Todo> todos = [];
      List<int> ids = [];
      while (ids.length < 6) {
```

```
        int newInt = rand.nextInt(1000)+2;
        if (!ids.contains(newInt)) {
          ids.add(newInt);
        }
      }
      todos = ids
          .map((number) => Todo(
              id: number,
              name: "Todo " + number.toString(),
              description: "description " + number.toString(),
              completed: rand.nextBool()))
          .toList();

      await Future.delayed(const Duration(seconds: 2));
      return todos;
    }

    static Future<void> saveTodos(List<Todo> todos) async {
      await Future.delayed(const Duration(seconds: 2));
    }
  }
```

Pages

Homepage uses a simple Scaffold widget. The AppBar contains a VisibilityFilterComponent only when the tab is set to *todos*. The body can change from *todos* tab to *stats* tab using the BottomNaviagationBar (the TabSelector). An empty FloatingActionButton is also present for future implementation. (note: some small pieces could change in different solution's implementation. in the above example the tab changing is implemented through setState but it will not be always the case. Also ,the HomePage, can be muted to Stateless widget in other implementations.).

Source Code 2.6: Todo app - HomePage definition

```
class HomePage extends StatefulWidget {
  const HomePage({Key? key}) : super(key: key);

  @override
  State<HomePage> createState() => _HomePageState();
}

class _HomePageState extends State<HomePage> {
  TabState tab = TabState.todos;

  @override
  Widget build(BuildContext context) {
    return Scaffold(
          appBar: AppBar(
            actions: [
              tab == TabState.todos
                  ? const VisibilityFilterComponent()
                  : Container()
            ],
            title: const Text("Todo App"),
          ),
          body: tab == TabState.todos ? const TodoView() : const Stats(),
          bottomNavigationBar: TabSelector(
            currTab: tab,
            onTabChange:,
          ),
          floatingActionButton: tab == TabState.todos
              ? FloatingActionButton(
                  child: const Icon(Icons.plus_one),
            onPressed: () {},
          ) : null,
        )
    );
  }
}
```

The UpdateTodoPage uses a Scaffold widget. The body is filled with a Column with two TextFields and a TextButton inside. The TextButton is left empty for future implementation.

Source Code 2.7: Todo app - UpdatePage definition

```
class UpdateTodoPage extends StatefulWidget {
  final Todo todo;
  final void Function(String,String) callback;

  const UpdateTodoPage({Key? key, required this.todo,required this.callback}) :

  @override
  State<UpdateTodoPage> createState() => _UpdateTodoPageState();
}

class _UpdateTodoPageState extends State<UpdateTodoPage> {
  final textControllerName = TextEditingController();
  final textControllerDesc = TextEditingController();

  @override
  Widget build(BuildContext context) {

    return Scaffold(
        appBar: AppBar(
          title: Text("Update Todo"+widget.todo.name),
        ),
        body: Column(
          children: [
            TextField(
              controller: textControllerName,
              decoration: const InputDecoration(
```

```
                border: OutlineInputBorder(), hintText: 'Enter a new name
            ),
            TextField(
              controller: textControllerDesc,
              decoration: const InputDecoration(
                border: OutlineInputBorder(), hintText: 'Enter a new desc
            ),
            TextButton(onPressed: () {},
            child: const Text("Confirm"))
          ],
        ));
  }

  @override
  void dispose() {
    textControllerName.dispose();
    textControllerDesc.dispose();
    super.dispose();
  }
}
```

The AddTodoPage uses a Scaffold widget. The body is filled with Column with two TextField widgets and a TextButton widget inside. The TextButton is left empty for future implementation.

Source Code 2.8: Todo app - AddTodoPage definition

```
class AddTodoPage extends StatefulWidget {

  final void Function(String,String) addTodoCallback;

  const AddTodoPage({Key? key, required this.addTodoCallback}) : super(key:
```

```
  @override
  State<AddTodoPage> createState() => _AddTodoPageState();
}

class _AddTodoPageState extends State<AddTodoPage> {
  final textControllerName = TextEditingController();
  final textControllerDesc = TextEditingController();

  @override
  Widget build(BuildContext context) {

    return Scaffold(
        appBar: AppBar(
          title: const Text("Add Todo"),
        ),
        body: Column(
          children: [
            TextField(
              controller: textControllerName,
              decoration: const InputDecoration(
                  border: OutlineInputBorder(), hintText: 'Enter a name'),
            ),
            TextField(
              controller: textControllerDesc,
              decoration: const InputDecoration(
                  border: OutlineInputBorder(), hintText: 'Enter a description')
            ),
            TextButton(onPressed: () {}
            , child: const Text("Create"))
          ],
        ));
  }

  @override
  void dispose() {
    textControllerName.dispose();
```

```
    textControllerDesc.dispose();
    super.dispose();
  }
}
```

Components

Components are widgets created with a specific aims. TodoView component take care to visualize a list of todos. Todos are accessed in different ways depending on the implementation. TodoView uses a ListView widget. *itemCount* and *itemBuilder* fields are left empty for future implementation.

Source Code 2.9: Todo app - TodoView definition

```
class TodoView extends StatelessWidget {

  const TodoView({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building TodoView");


    return ListView.builder(
      itemCount:,
      itemBuilder: (context, index) {
        return TodoItem(

        );
      },
    );
  }
}
```

TodoItem is a component that take care to visualize a specific todo. TodoItem is a stateless widget. It uses two Text widgets to display the todo's information and a Checkbox to change the todo's completion. It is wrapped in a InkWell widget to make is responsive to taps. Functions are left empty for future implementation.

Source Code 2.10: Todo app - TodoItem definition

```
class TodoItem extends StatelessWidget {
  final Todo todo;

  const TodoItem({Key? key, required this.id}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Todo Item \$todo");

    return InkWell(
      onTap: () {
        Navigator.pushNamed(context, "/updateTodo");
      },
      child: Row(
        children: [
          Column(
            children: [
              Text(todo.name,
                  style: const TextStyle(fontSize: 14, color: Colors.black)),
              Text(todo.description,
                  style: const TextStyle(fontSize: 10, color: Colors.grey)),
            ],
          ),
          Checkbox(
              value: todo.completed,
              onChanged: (value) {}),
        ],
```

```
      ),
    );
  }
}
```

TabSelector component provides a way to switch from tabs. Tabselector uses a BottomNavigationBar with as many BottomNavigationBarItems as TabState.values (in our case two). Functions's fields are left empty for future implementation.

Source Code 2.11: Todo app - TabSelector definition

```
class TabSelector extends StatelessWidget {


  const TabSelector(
      {Key? Key})
      : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Tab Selector");

    return BottomNavigationBar(
      currentIndex: ,
      onTap: (){},
      items: TabState.values
          .map((tab) => BottomNavigationBarItem(
                label: describeEnum(tab),
                icon: Icon(
                  tab == TabState.todos ? Icons.list : Icons.show_chart,
                ),
              ))
          .toList(),
```

```
    );
  }
}
```

VisibilityFilterComponent uses a DropdownButton with as many DropdownMenuItems as VisibilityFilter.values (in our case three). Function fields are left empty for future implementation.

Source Code 2.12: Todo app - VisibilityFilterSelector definition

```
class VisibilityFilterComponent extends StatelessWidget {

  const VisibilityFilterComponent(
      {Key? key})
      : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Visibility filter");
    return DropdownButton<VisibilityFilter>(
      value:,
      items: VisibilityFilter.values.map((filter) {
        return DropdownMenuItem<VisibilityFilter>(
            child: Text(describeEnum(filter)), value: filter);
      }).toList(),
      onChanged: (filter) {

      },
    );
  }
}
```

Stats component takes care to visualize some numerical representation of the list of todos.

Stats component is a Stateless widget composed by Text widget showing stats value.

Source Code 2.13: Todo app - Stats definition

```
      class Stats extends StatelessWidget {
  const Stats({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Stats");

    return Center(
        child: Text());
  }
}
```

2.2.2. Inherited widget/model and SetState implementation

In this section Todo app will be implemented using two standard tools Flutter's framework provides to handle state: **InheritedWidget** (or the more advanced **InheritedModel**) and **setState**.

State management solution's introduction

setState method notify the framework that the internal state of this object has changed. Whenever you change the internal state of a State object, make the change in a function that you pass to *setState*.

```
setState(() { _myState = newValue; });
```

The provided callback is immediately called synchronously. It must not return a future (the callback cannot be async), since then it would be unclear when the state was actually being set.

Calling *setState* notifies the framework that the internal state of this object has changed

in a way that might impact the user interface in this subtree, which causes the framework to schedule a build for this State object.
If you just change the state directly without calling *setState*, the framework might not schedule a build and the user interface for this subtree might not be updated to reflect the new state.
Inherited widget are a base class for widgets that efficiently propagate information down the tree. To obtain the nearest instance of a particular type of inherited widget from a build context, use *BuildContext.dependOnInheritedWidgetOfExactType*. Inherited widgets, when referenced in this way, will cause the consumer to rebuild when the inherited widget itself changes state. The convention is to provide a static method *of* on the InheritedWidget which does the call to *BuildContext.dependOnInheritedWidgetOfExactType*. This allows the class to define its own fallback logic in case there isn't a widget in scope. An InheritedWidgets is not intended to be used as the base class for models whose dependents may only depend on one part or "*aspect*" of the overall state. Indeed inherited widget's dependents are unconditionally rebuilt when the inherited widget changes.

InheritedModel widget is similar except that dependents aren't rebuilt unconditionally. Widgets that depend on an InheritedModel qualify their dependence with a value that indicates what "*aspect*" of the model they depend on. When the model is rebuilt, dependents will also be rebuilt, but only if there was a change in the model that corresponds to the aspect they provided.

Base functionalities

Here starts the implementation of the base functionalities exposed in Subsection 2.1.1.

Core state

In order to use InheritedWidget's functionalities, a new class must be defined and extended with InheritedWidget class. For our purpose ,a single class will be enough to contain all the application's state. This new class is called *TodoInheritedData*.

Source Code 2.14: Todo app - InheritedWidget - extension to InheritedWidget

```
class TodoInheritedData extends InheritedWidget{
```

The application's state is composed by: a list of Todos, a VisibilityFilter , a Int for the stats (for conciseness it will represent the number of completed todos) and filtered list of todos that will contain the todos matching the filter. Inside the constructor, final variables are initialized with their corresponding arguments and, *stats* and *filteredTodos* variables, are computed.

Source Code 2.15: Todo app - InheritedWidget- TodoInheritedData implementation

```
class TodoInheritedData extends InheritedWidget{
  final List<Todo> todos;
 final List<Todo> filteredTodos;
 final VisibilityFilter filter;
 final int stats;

TodoInheritedData(
    {
    Key? key,
    required this.todos,
    required this.filter,
    required Widget child})
    : stats = todos.length,
      filteredTodos = filterTodo(todos, filter),
      super(child: child, key: key);
}
```

filterTodos function is just a function that takes the full list of todos and a filter and returns the filtered list. Important to notice the fact that a *child* widget must be also provided in the constructor. This is because TodoInheritedData is nothing else than a widget itself that wraps data and makes it accessible down the tree.

TodoInheritedData widget is stateless. It cannot be changed (every value is final) ,instead , a new TodoInheritedData widget must be provided when a data change occurs. The *updateShouldNotify* function must be overridden inside the TodoInheritedData class. This function belongs to the InheritedWidget class and its override is mandatory. It helps to avoid useless UI rebuilding when a new state ,without actual data changes , occurs. Once a TodoInheritedData element is replaced with a new one, the new element takes care to call the *updateShouldNotify* method and to decide whether is necessary to notify changes in the subtree. If the method returns *true* ,the subtree is rebuilt, if it returns *false* ,instead, it is not.

Source Code 2.16: Todo app - InheritedWidget -updateShouldNotify method override

```
@override
bool updateShouldNotify(TodoInheritedData oldWidget) {
  return !listEquals(oldWidget.filteredTodos, filteredTodos);
}
```

listEquals function is provided by Dart language. It takes two lists and compares them element by element, returning true if all are the same. In the code above, it takes as parameters the old *filteredTodos* list (the one belonging to the old widget) and the new filteredTodos list and compares them. In case no changes were performed it returns *true* and leads the *updateShouldNotify* function to return *false* leaving the subtree unchanged.

InheritedWidget class requires also the *of* method override. The *of* method makes the instance of the TodoInheritedData class accessible down the tree. It is a static method that can be called without istantiating any TodoInheritedData object and returns the instance of the nearest TodoInheritedData widget up in the tree. It extracts the instance from the current *context* object using the method called *dependOnInheritedWidgetOfExactType* provided by the framework. In case no TodoInheritedData instance (of the provided type) is found it raises a runtime error.

Source Code 2.17: Todo app - InheritedWidget - TodoInheritedData of method override

```
static TodoInheritedData? of(BuildContext context) {
 final TodoInheritedData? result =
  context.dependOnInheritedWidgetOfExactType<TodoInheritedData>();
assert(result != null, 'No TodoInheritedData found in context');
return result;
}
```

TodoInheritedData widget is now ready to be used. In the overall it is a container for our state. It makes the state accessible in the subtree but ,is not clear yet who is really filling it with the correct informations. TodoInheritedData widget represents the state of the appplication in a given moment. It cannot change its internal values neither substitute itself with another instance. In practice , what happends, is that a stateful widget is created. This stateful widget will contain the state and will bother to create a new instance of the TodoInheritedData widget containing it. Everytime its internal state is changed (using *setState*) a new instance of TodoInheritedData widget is produced and substituted with the old one. In this way ,changes are reported to the subtree. The subtree sees a different image of the state and reacts to it. Personally, I did not appreciate this approach InheritedWidget uses. On one way it is simple and works really well for its purpose , on the other it introduces a new level of data caching. The concept of data caching will be explained a bit more in details later but ,for the moment ,we can say that the application's state is not exactly unique. What is seen by the subtree is a screenshot of the state and not the state itself. The real state is contained in the stateful widget. It is important , though, that the real state and the screenshot provided in the subtree are well syncronized. A bad syncronization can produce inconsistency in what is visualized and the information contained in the internal state. More in general, it can be said , that the more data caching level are introduced the harder it gets to efficiently syncronize them. It is clear that ,in our scenario ,this problem does not really show up. Or better, it will in the optimization part but ,in that case ,InheritedWidget tool will be used with a purpose that goes behoind its real usage. Anyway, it is possible that different widgets sees different screenshots of the data and the bigger the application grow the higher will be the probability that this happends. Now that the background is a bit clearer the implementation process can continue. As mentioned above a new stateful widget must be created. This new stateful widget is called *TodoProvider*. It has two variables representing the state: a list of todos and a filter. (the rest of the state is computed at TodoInheritedData creation)

Source Code 2.18: Todo app - InheritedWidget - TodoProvider implementation

```
class TodoProvider extends StatefulWidget {
  const TodoProvider({Key? key, required this.child}) : super(key: key);

  final Widget child;

  @override
  _TodoProviderState createState() => _TodoProviderState();
```

```
}

class _TodoProviderState extends State<TodoProvider> {
  List<Todo> todos = [];
  VisibilityFilter filter = VisibilityFilter.all;

@override
Widget build(BuildContext context) {
  return TodoInheritedData(
    todos: todos,
    filter: filter,
    child: widget.child,
  );
}
```

Note that the VisibilityFilter ,*filter*, is set as *all* by default. In the statefull widget's *init* method , todos are fetched from the repository and pushed inside the *todos* variable using the *setState* method.

Source Code 2.19: Todo app - InheritedWidget - TodoProvider 's init method implementation

```
@override
void initState() {
  TodoRepository.loadTodos().then((todos) {
    setState(() {
      this.todos = todos;
    });
  });
  super.initState();
}
```

loadTodos is a TodoRepository's async function that simulate the retrieval of the todos from a database as defined in the paragraph 2.2.1.

At this point our TodoProvider widget can be incorporated as the parent of the Scaffold widget in the HomePage. The usage of the Builder widget is due to the fact that the instante of TodoInheritedData is accessible only in a context where a TodoProvider is already present. In other word TodoProvider's data cannot be accessed in the same *build* method where it was instantiated into. Two options are possible; creating a separated file where to put our Scaffold ,or use a Builder widget that takes the current context and creates another with the TodoProvider widget.

Source Code 2.20: Todo app - InheritedWidget - data's injection in the tree

```
@override
Widget build(BuildContext context) {
  return TodoProvider(
    child: Builder(
      builder: (context) {
        return Scaffold();      }
  );
}
```

The TodoView component

TodoView component can now be populated. Its implementation can be found in paragraph 2.2.1 in subsection 2.2.1. It is a stateless widget that looks up for the *filteredTodos* list, contained in the TodoInheritedData widget. It uses the *of* method ,defined here RIFERIMENTO, to access the nearest TodoInheritedData instance. Then, it uses the list to populate the ListView widget.

Source Code 2.21: Todo app - InheritedWidget - TodoView implementation

```
class TodoView extends StatelessWidget {

  const TodoView({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building TodoView");

    final List<Todo> filteredTodos = TodoInheritedData.of(context).filteredTodos;
```

```
    return ListView.builder(
      itemCount: filteredTodos.length,
      itemBuilder: (context, index) {
        return TodoItem(
          todo: filteredTodos.elementAt(index),
        );
      },
    );
  }
}
```

The VisibilityFilterSelector component

At this point we got a single page (Homepage) that uses a TodoView widget to show the *filteredTodos* list contained in the TodoInheritedData widget. When the application starts , and empty page appears (todo are empty at the beginning) and then ,after few seconds , a list of todos, with their names, descriptions and completions, is shown. The list of filtered todos can be visualized , but is not interactable yet. In the HomePage's AppBar, a VisibilityFilterComponent is ready to be used as defined RIFERIMENTO. Its DropdownButton's *value* field is filled looking up for the *filter* value in the TodoInherited-Data widget. Then , the *items* field is filled with a list of DropdownMenuItem widgets that comes from the mapping of all possible VisibilityFilter values to DropdownMenuItem widgets.

Source Code 2.22: Todo app - InheritedWidget - VisibilityFilterComponent implementation

```
class VisibilityFilterComponent extends StatelessWidget {

  const VisibilityFilterComponent(
      {Key? key})
      : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Visibility filter");
    VisibilityFilter filter= TodoInheritedData.of(context).filter;
```

```
    return DropdownButton<VisibilityFilter>(
      value: filter,
      items: VisibilityFilter.values.map((filter) {
        return DropdownMenuItem<VisibilityFilter>(
            child: Text(describeEnum(filter)), value: filter);
      }).toList(),
      onChanged: (filter) {

      },
    );
  }
}
```

The *onChanged* field must be populated with a function that takes as single argument a VisibilityFilter value. This function is called when a DropdownMenuItem is tapped by the user. It contains ,in its argument, the tapped DropdownMenuItem's filter value. We want this function to change the state contained in the TodoInheritedData widget (the *filter* variable) when fired. In order to do so , a state changing function must be provided by the TodoInheritedData widget to be accessed ,and called, by other widgets. As we mentioned earlier, TodoInheritedData widget contains only final fields and should never be modified. It is not possible ,indeed, to directly change the values inside the TodoInheritedData widget. For this reason , just adding a new function inside the TodoInheritedData widget ,to perform the change, is not a solution. Indeed, trying to change a part of the state, inside this ipotetic function, will generate an error at compile time (final variable cannot be set outside constructor). A completly new TodoInheritedData widget ,indeed, should be created. The TodoInheritedData widget is created in the TodoProvider widget, when the *build* method runs, using its local variables *todos* and *filter*. In order to generate a new TodoInheritedData widget, is sufficient to change the TodoProvider widget's local state ,using the *setState* method. This will cause the *build* method to run again with the new values and generate a new TodoInheritedData widget. At this point should be clear that the state changing function comes from the TodoProvider widget. This function , once called, changes the local state of the TodoProvider stateful widget generating a new state for the application.
In pratice ,a new function ,called *onChangeFilter*, is added inside the TodoProvider widget. This function takes a VisibilityFilter value as parameter and set the value of TodoProvider's *filter* variable using *setState* method.

Source Code 2.23: Todo app - InheritedWidget - TodoProvider's onChangeFilter implementation

```
void onChangeFilter(VisibilityFilter filter) {
  setState(() {
    this.filter = filter;
  });
}
```

Once called, being the state (the part concerning the filter) changed, another run of the *build* method is performed. As a conseguence the TodoInheritedData widget ,present in the tree, is replaced with the new one. However, widgets access the state through the TodoInheritedData widget and not through the TodoProvider widget. For this reason, the *onChangeFilter* function must be provided to the TodoInheritedData widget to make it accessible in the subtree. A new parameter is added in the TodoInheritedData class, tough.

Source Code 2.24: Todo app - InheritedWidget - TodoInheritedData widget expansion

```
class TodoInheritedData extends InheritedWidget {
  {...}
  final void Function(VisibilityFilter) onChangeFilter;
  {...}
```

The *onChangeFilter* function is then passed to the TodoInheritedData widget on its creation.

Source Code 2.25: Todo app - InheritedWidget -onChangeFilter function injection into TodoInheritedData widget

```
@override
Widget build(BuildContext context) {
  return TodoInheritedData(
    todos: todos,
    onChangeFilter: onChangeFilter,
    filter: filter,
    child: widget.child,
  );
}
```

Now that the *onChangeFilter* function is accessible down in the tree, it can be called in the *onChange* field of the DropdownButton widget, inside the VisibilityFilterSelector component.

Source Code 2.26: Todo app - InheritedWidget - DropdownButton's onChanged field implementation

```
onChanged: (filter) {
  TodoInheritedData.of(context).onChangeFilter(filter!);
},
```

It is now possible to apply different filters to the list of todos in the Homepage.

The TodoItem component

TodoItem widget is stateless at the moment. It that take as paramenter a Todo instance and takes care of displaing it as defined in source code 2.4. TodoItem does not read the state. The todo to be displayed is ,indeed, passed by the parent widget (the TodoView). However, the TodoItem widget needs to "write" the state, once the checkbox is tapped. For the moment the Checkbox widget ,inside every TodoItem, is just showing their todo's completion. Its *onChange* function is still empty and ,for this reason, it does nothing when tapped. When the CheckBox is tapped a change in the corresponding Todo's *completed* field should be fired and a rebuild of the TodoItems performed. In order to do so, TodoIhneritedData widget should provide a state changing function that allow to perform this change. The process to be followed and the reasoning is the same exposed in the previous paragraph 2.2.2 when we spoke about the VisibilityFilterSelector widget. Going back to the TodoProvider stateful widget a function ,called *onSetCompleted* , is added . This function takes as parameter the *id* of the todo to be changed and the new value for the *completed* field.

Source Code 2.27: Todo app - InheritedWidget - TodoProvider widget *onSetCompleted* function implementation

```
void onSetCompleted(int id, bool completed) {
  assert(todoExists(id) != null, 'No todo with id : \$id');

  setState(() {
    todos = todos.map((e) {
      if (e.id == id) {
        return Todo(
            id: id,
            name: e.name,
            description: e.description,
            completed: completed);
      } else {
        return e;
      }
    }).toList();
  });
}
```

In the *onSetCompleted* function , *todos* list is scanned using the *map* method. Once the todo, with the corresponding id ,is found, its *completed* value is updated to the new value. Calling the *onChangeFilter* method on the TodoProvider stateful widget will cause the *build* method to run again and to create another TodoInheritedData widget. As usual , the function is passed from the TodoProvider widget to the TodoInheritedData widget ,on its creation. In this way, the function is accessible down the tree. It is now possible to call it inside the onChanged method of the TodoItem's Checkbox.

Source Code 2.28: Todo app - InheritedWidget - TodoItem's Checkbox *onChanged* field implementation

```
Checkbox(
value: todo.completed,
    onChanged: (value) {
            TodoInheritedData.of(context).onSetCompleted(todo.id, value!);
}),
```

At this point is possible to visualize the *filteredTodos* list, change the filter and update Todo's *completed* field.

The Stats component

Stats widget is stateless. It just needs to read the state, the part concerning the stats. The nearest instance of the TodoInheritedData widget is retrieved using the *of* method and used to fill the Text widget.

Source Code 2.29: Todo app - InheritedWidget - Stats component implementation

```
class Stats extends StatelessWidget {
  const Stats({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Stats");

    return Center(
        child: Text(TodoInheritedData.of(context).stats.toString()));
  }
}
```

The TabSelector component

The part of the state concerning the tab includes just one variable and is related to the HomePage only. The fact that a state management solution is being used, to handle the application's state, does not mean that it has to be the first choice to handle everything. An important aspect of the state management in medium-large applications is that , the core objective , still remains to handle things in the easiest way possible, as long as it works fine. There is no meaning in overcomplicating procedures that are easy to implement and do the job well. Sometimes, indeed, for the parts of the state that can be refered as "local" ,meaning that are relative to a small part of the application only, is not necessary to use complicated state management solutions. It is better to keep things simple and use the tools that most adapt to the specific scenario. For example, in our case, there are two ways to implement the TabSelector widget: use *setState* and stateful widgets or use InheritedWidgets. The simpler one is to use setState as proposed RIFERIMENTO for more than one aspect. First, it is a good practice to keep the global state of the application as small and clean as possible. The bigger and the more complicated it gets the messier becomes to avoid bugs. Second, it is simpler , in pratice, to create a local variable and hadle it with *setState* and stateful widgets instead of adding a new variable to the TodoInheritedData widget , handle it using the to TodoProvider widget and access it in the HomePage. The HomePage is already a stateful widget and is built using the *tab* variable. It is sufficient to add a new function ,in order to change the tab value, to implement the feature. This new function ,called *onTabChange*, takes a int value as parameter and uses the *setState* method to update the *tab* variabile. (it takes as argument a int ,and not a TabState ,because the *onTap* field of the BottomNavigationBar, in the TabSelector component ,provides an int. This int value refers to the index of the tapped element inside the list of BottomNavigationBarItem widgets we provided to the *items* field.

Source Code 2.30: Todo app - InheritedWidget - HomePage's onTabChange function implementation

```
TabState tab = TabState.todos;

void onTabChange(int index) {
 setState(() {
   tab = TabState.values.elementAt(index);
 });
}
```

However, the function *onTabChange* ,needs to be called in the TabSelector widget (and not in the HomePage). The easiest way is to pass the function ,to the TabSelector widget ,as parameter and use it in the BottomNavigationBar's *onTap* field.

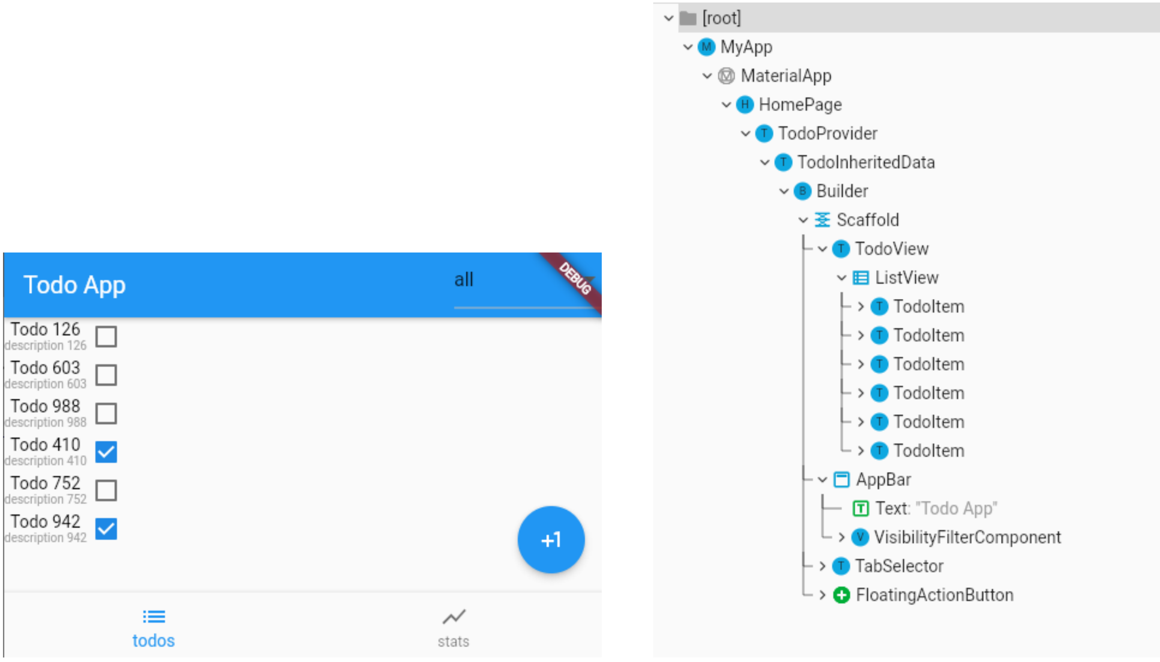
Source Code 2.31: Todo app - InheritedWidget - TabSelector component implementation

```
class TabSelector extends StatelessWidget {
  final TabState currTab;
  final Function(int) onTabChange; // new parameter

  const TabSelector(
      {Key? key, required this.currTab, required this.onTabChange})
      : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Tab Selector");

    return BottomNavigationBar(
      currentIndex: TabState.values.indexOf(currTab),
      onTap: onTabChange, //used here
      items: TabState.values
          .map((tab) => BottomNavigationBarItem(
                label: describeEnum(tab),
                icon: Icon(
                  tab == TabState.todos ? Icons.list : Icons.show_chart,
                ),
              ))
          .toList(),
    );
  }
}
```

It is now possible to switch from tabs.

Summary

The whole process was fast and straight forward. Down below some images taken from an execution of the application. In this execution ,six todos are randomly created and only two of them are marked as completed.

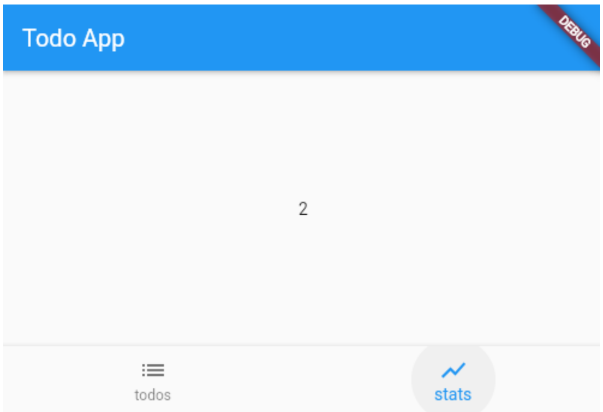


(a) todos tab runtime UI.

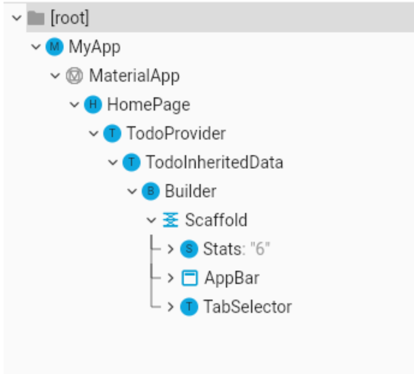
(b) todos tab runtime widget tree.

Figure 2.2: Show the runtime Widget's tree and UI when visualizing todos tab.

Figure 2.2a shows how the application's UI looks like after few seconds from the start. Figure 2.2b show the widget's tree related with the run. Notice the TodoInheritedData widget as a child of the HomePage widget,it provides the state to the subtree.



(a) stats tab runtime UI.



(b) stats tab runtime widget tree.

Figure 2.3: Show the runtime Widget's tree and UI when visualizing stats tab.

Figure 2.3a shows how the application UI looks like after the user taps on the TabSelector's stats button. Figure 2.3b show the widgets tree related with the run after the button is clicked.

Time spent: 2-3 hours
Lines of code written/updated: 86
Classes/widget created: 2 (TodoInheritedData class and TodoProvider widget)

Features addition

Here stats the development process where the todo-addition feature and the todo-update feature are implemented.

Todo addition feature

First thing first, TodoInheritedData widget must provide a function to add todos. A new function is created in the TodoProvider widget and passed to the TodoInheritedData widget. This new function will be called *onAddTodo* and will take two parameters (name and description).

Source Code 2.32: Todo app - InheritedWidget - TodoProvider *onAddTodo* function implementation

```
void onAddTodo(String name, String desc) {
  Random rand = Random();
```

```
  List<int> ids = todos.map((e) => e.id).toList();
  int newId = rand.nextInt(1000) + 2;
  while (ids.contains(newId)) {
    newId = rand.nextInt(1000) + 2;
  }
  Todo newTodo = Todo(
      id: newId,
      name: name,
      description: desc+ " " + newId.toString(),
      completed: false);
  List<Todo> newList = List.from(todos);
  newList.add(newTodo);
  setState(() {
       todos = newList;
  });
}
```

After generating a new unique id ,it creates a new Todo object called *newTodo* with the *completed* field set to *false* . Adding the new Todo ,to the TodoProvider's state *todos* list , requires a bit of workaround. The state of a stateful widget is immutable. Yes, it is a bit counterintuitive but ,as we already said , in functional programming, is generally better to create new instances instead of mutating existing one. Indeed, stateful widget's state can only be changed by the *setState* method. Unfortunately, the method *add* for lists, dart languege provides, is of type void and do not return a new list but add the new value to the existing list's instance. For this reason ,directly calling the *add* method to the TodoProvider's local lists *todos* will have no effect. That list is immutable and cannot be changed. TodoProvider's *todos* list must be completely replaced with a new list containing also the new todo. First ,a new temporary list ,called *newList*, is created and populated with the elements present in the *todos* list. Then, the *newTodo* is added to this new list. At this point, is sufficient to replace the *todos* list with the new one inside the *setState* method.
To make the *onAddTodo* function accessible down the tree ,is sufficient to add a new field in the TodoInheritedData widget and pass the function to it, on its creation.

Source Code 2.33: Todo app - InheritedWidget - onAddTodo function propagation
mbox

```
class TodoInheritedData extends InheritedWidget {
  {...}
  final void Function(String,String) onAddTodo;

  {...}

@override
Widget build(BuildContext context) {
  return TodoInheritedData(
    todos: todos,
    onChangeFilter: onChangeFilter,
    onAddTodo: onAddTodo,
    onSetCompleted: onSetCompleted,
    filter: filter,
    child: widget.child,
  );
}
```

mbox

In the AddTodoPage ,a TextButton widget has been already set up and is ready to call the *onAddTodo* function once tapped. However, there is a small inconvenient. The AddTodoPage is accessed by pushing on top of the HomePage another route as shown in figure 2.4. The AddTodoPage is added as a child of the MaterialApp widget.

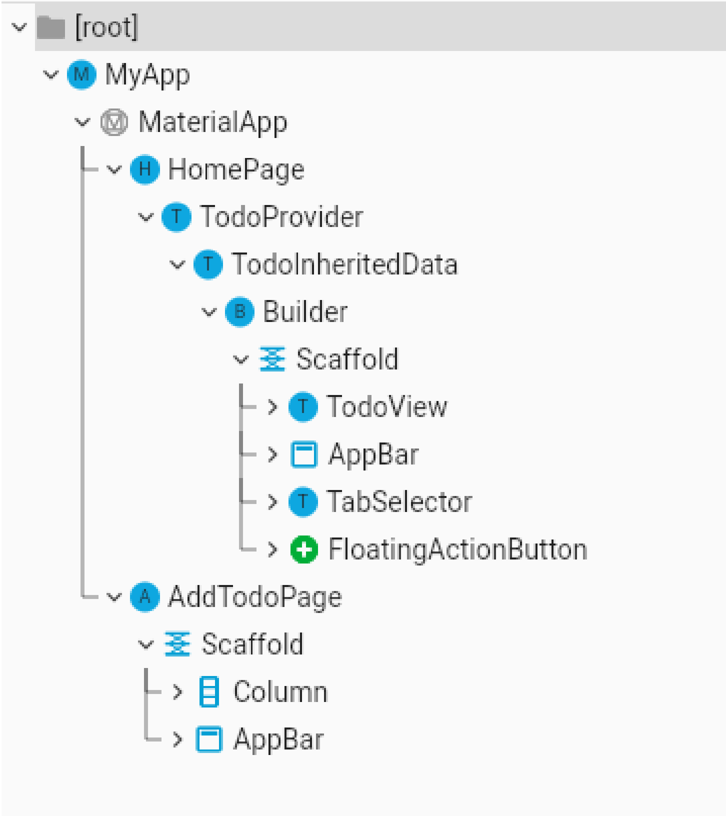


Figure 2.4: Show the tree structure after the FloatingActionButton in the HomePage is tapped.

The AddTodoPage is not a part of the subtree of the HomePage but is a standalone tree. There is no instance of TodoProvider widget as ancestor of the Scaffold widget present in the AddTodoPage. Tt is not possible, touogh, to call the *of* method as we did before. Indeed ,calling the *of* method in a context where a TodoProvider widget is not present will cause the line,

```
assert(result != null, 'No TodoInheritedData found in context');
```

inside its implementation, to return *false* and rise a runtime error. The easiest method to proceed is to pass the *onAddTodo* function as a parameter to the AddTodoPage when it is pushed on top of the HomePage. A new parameter, called *addTodoCallback* , is added to the AddTodoPage .

Source Code 2.34: Todo app - InheritedWidget - AddTodoPage's callback function parameter creation

```
class AddTodoPage extends StatefulWidget {

  final void Function(String,String) addTodoCallback;
    {. . .}
```

mbox

Then, the MaterialApp is notified about the necessity of this new argument at the AddTodoPage creation. It will find the argument inside the context, in a specific variable called *arguments*.

Source Code 2.35: Todo app - InheritedWidget - MaterialApp AddTodoPage route ridefinition

```
routes: {
{. . .}
  "/addTodo": (context) => AddTodoPage(
      addTodoCallback: ModalRoute.of(context)!.settings.arguments
          as Function(String, String)),
},
```

The only part to fill in, in the AddTodoPage, is the *onPressed* field of the TextButton. The callback function in then used, inside it, to add the new todo to the list, then, the AddTodoPage is popped.

Source Code 2.36: Todo app - InheritedWidget - AddTodoPage TextButton onPressed field implementation

```
TextButton(onPressed: () {
  widget.addTodoCallback(textControllerName.text,textControllerDesc.text);
  Navigator.pop(context);
}
```

When the AddTodoPage is popped, the new Todo is added and the HomePage is rebuilt.

Time spent: 20-30 minutes
Lines of code written/updated: 24
Classes/widget created: 0

Todo updating feature
A new function must be implemented ,in the TodoProvider widget ,and passed to the TodoInheritedData widget. This new function will be called *onUpdateTodo* and takes three arguments: the *id* of the todo to be updated, the *newName* that should be set and the *newDesc*.

Source Code 2.37: Todo app - InheritedWidget - todoProvider's onUpdateTodo function implementation

```
void onUpdateTodo(int id, String newName,String newDesc) {
  assert(todoExists(id) != null, 'No todo with id : \$id');
  List<Todo> newTodosList = todos.map((element) {
    if (element.id == id) {
      return Todo(
          completed: element.completed,
          description: newDesc,
          name: newName,
          id: element.id);
    } else {
      return element;
    }
  }).toList();
  setState(() {
    todos = newTodosList;
  });
}
```

onUpdateTodo function first checks if a todo matching the id exists. Then, for the same immutability concept we dealt with in paragraph 2.29, a *newTodosList* is created and populated with the elements inside the *todos* list. Moreover, the todo with the corresponding id is updated with the new name and the new description. Finally, the *todos* list in the TodoProvider stateful widget is replaced with the *newTodosList* using the *setState* method. This new *onUpdateTodo* method is then made accessible down the tree adding a field to the TodoInheritedData widget and passing the method to id.

Source Code 2.38: Todo app - InheritedWidget - onUpdateTodo function propagation

```
class TodoInheritedData extends InheritedWidget {
  ...
  final void Function(int, String,String) onUpdateTodo;
  ...


@override
Widget build(BuildContext context) {
  return TodoInheritedData(
    todos: todos,
    onChangeFilter: onChangeFilter,
    onAddTodo: onAddTodo,
    onSetCompleted: onSetCompleted,
    onUpdateTodo: onUpdateTodo,
    filter: filter,
    child: widget.child,
  );
}
```

For the same problem faced during the implementation of the todo addition feature ,also in this case, the *onUpdateTodo* function must be passed to the new route (no TodoProvider present in this context) as parameter. A new variable is added to the UpdateTodoPage ,beside the already existent one, called *callback* . This new variable will be of type Function taking two Strings as arguments (the id will be already set up by the calling page).

Source Code 2.39: Todo app - InheritedWidget - UpdateTodoPage callback variable creation

```
class UpdateTodoPage extends StatefulWidget {
  final Todo todo;
  final void Function(String,String) callback;
```

All is ready now to push the UpdateTodoPage on top of the Homepage when the InkWell widget (inside the TodoItem widget) is tapped. However, there is a small extra step to perform before proceeding. Flutter Navigator ,indeed, allows to pass only a single object ,as argument ,between routes. In this case not only the *onUpdateTodo* function but also a instance of the Todo must be passed to the UpdateTodoPage. For this reason a wrapper class is created with the name *UpdateTodoPageArguments* .

Source Code 2.40: Todo app - InheritedWidget - onUpdateTodo function propagation

```
class UpdateTodoPageArguments {
  final Todo todo;
  final void Function(String ,String) updateState;

  UpdateTodoPageArguments({required this.todo, required this.updateState});
}
```

Inside the InkWell's *onTap* function ,the corresponding todo and the *onUpdate* function are wrapped into an object of type UpdateTodoPageArguments. This object is then passed to the new route.

Source Code 2.41: Todo app - InheritedWidget - onUpdateTodo function propagation

```
Navigator.pushNamed(context, "/updateTodo",
    arguments: UpdateTodoPageArguments(
        todo: todo,
        updateState: (String newName,String newDesc) {
          TodoInheritedData.of(context, aspect: 0)
```

```
              .onUpdateTodo(todo.id, newName,newDesc);
        }));
```

It is necessary to specify to the MaterialApp widget where, the two parameter (necessary for the UpdateTodoPage creation), will be situated. As before , they are putted in a specific variable, inside the context object, called *arguments*.

Source Code 2.42: Todo app - InheritedWidget - onUpdateTodo function propagation

```
routes: {
  "/": (context) => const HomePage(),
  "/updateTodo": (context) => UpdateTodoPage(
        todo: (ModalRoute.of(context)!.settings.arguments
                as UpdateTodoPageArguments)
            .todo,
        callback: (ModalRoute.of(context)!.settings.arguments
                as UpdateTodoPageArguments)
            .updateState,
      ),
```

Now that the *onUpdateTodo* function is set up and passed to the UpdateTodoPage is time to call it inside the TextButton *onPressed* field.

Source Code 2.43: Todo app - InheritedWidget - onUpdateTodo function propagation

```
TextButton(onPressed: () {

  widget.callback(textControllerName.text,textControllerDesc.text);
  Navigator.pop(context);
},
```

At this point, once the user taps the confirm button the page pops, the corresponding todo updates and the HomePage rebuilds.

Time spent: 20-30 minutes
Lines of code written/updated: 43
Classes/widget created: 1 for arguments between routes

Render optimizations

The optimizations performed in this part are explained more in details in paragrph RIFERIMENTO RENDERS OPTIMIZATION. I spent some hours trying to figure out how to make the single TodoItem widget rebuild only, after a non -structural change occurs. When a non-structural change occurs ,may be instresting ,tough, to limitate the tree rebuilding to widgets affected by the mutation only. For example, when the Checkbox inside a TodoItem is tapped, would be nice to rebuild the TodoItem widget only, and not the entire TodoView widget. After some attempts, I realized that it was just not feasible using InheritedWidgets. InheritedWidget ,indeed ,do not offer this possibility at all. Every widget that access the state ,in the TodoProvider's subtree , using the *of* method ,is registered as *listener* for state changes. Once a state change occurs ,there are only two possibilities: notify all listeners and rebuild them or notify none. In other words when a state change occurs ,and it must be visualized , the entire TodoProvider's subtree must be rebuilt unconditionally. Flutter framework ,however, offers a particular widget ,called InheritedModel, to handle this kind of scenario. InheritedModel works as InheritedWidget except for the fact that, when a widget access the state ,(calling the *of* method) it must provide also a new additional parameter, called *aspect*. The *aspect* parameter can be whatever object. For example a String or a Int, but also a more complex data structure. The *aspect* parameter identifies which part (or parts) of the state the widget is registering to. With this new additional tool is possible to achive the partial rendering we were looking for. Indeed, with InheritedModel , widgets are rebuilt based on the changed aspect of the state. If a particular widget registered for a particular aspect and a state mutation not affecting that aspect, occurs, the widget is not rebuilt. However, the entire logic defining which aspect of the data changed (when a state transition occurs) must be implemented by the programmer.
Proceeding with the optimization process, first thing to do is to substitute the extension to InheritedWidget with the InheritedModel one, in the TodoInheritedData class.

Source Code 2.44: Todo app - InheritedModel - extension to InheritedModel

```
class TodoInheritedData extends InheritedModel<int> {
```

I decided to use Ints in order to identify aspects. In particular, widgets that need to rebuild on *filteredTodos* list structural change, will register to the aspect identified with the number 0. Widgets that do never need to rebuild will register to the aspect identified with number 1. Widgets that need to rebuild when a non-structural change occurs affecting the specific Todo with id n will register to the aspect identified with the number n.

(no Todos will have id with value 0 or 1. This is a convention I used to keep things simple. Other ,more complex structure , could be used to avoid this behaviour). At this point the method *of*, in the TodoInheritedData widget, should be updated taking into account the aspect parameter. Morevover, the *result* variable should be populated with the static *inheritedFrom* method belonging to the InheritedModel class, instead of the *dependOnInheritedWidgetOfExactType* method belonging to InheritedWidget class.

Source Code 2.45: Todo app - InheritedModel - of method implementation

```
static TodoInheritedData of(BuildContext context, {required int aspect}) {
  final TodoInheritedData? result =
      InheritedModel.inheritFrom<TodoInheritedData>(context, aspect: aspect);
  assert(result != null, 'No TodoInheritedData found in context');
  return result!;
}
```

All the lines of code that access the state with the *of* method must now be changed taking into account the new implementation and the new *aspect* argument.

```
TodoInheritedData.of(context, aspect: aspect)
```

In particular, the TodoView widget will pass as aspect argument the number 0 declaring that should be notified (and rebuild) only when a structural change occurs. Instead, TodoItem widgets will pass the corresponding Todo's *id* in the aspect parameter. Now that every widget is registered to the desired aspect of the data only, is necessary to "teach", the TodoInheritedData widget ,how to recognize aspects changes. To do so, InheritedModel provides a method called *updateShouldNotifyDepenedent* that is just like the InheritedWidget's one, *updateShouldNotify* , but takes as argument also a Set of ints called *dependencies* (aspects). This method is called once for every widget that registered to state changes. The *dependencies* variable will contain all aspects the widgets registered to (only one for widget in our case).

Source Code 2.46: Todo app - InheritedModel - updateShouldNotifyDepented method implementation

```
@override
```

```
bool updateShouldNotifyDependent(
    TodoInheritedData oldWidget, Set<int> dependencies) {
  int currLen = filteredTodos.length;
  int prevLen = oldWidget.filteredTodos.length;
  bool structureRebuildlen = (dependencies.contains(0) && currLen != prevLen);
  if (structureRebuildlen == true) {
    return true;
  } else {
    List<int> currIds = filteredTodos.map((todo) => todo.id).toList();
    List<int> prevIds =
        oldWidget.filteredTodos.map((todo) => todo.id).toList();
    bool sameIds = listEquals(currIds, prevIds);
    bool structureRebuildcomp = (dependencies.contains(0) && !sameIds);
    if (structureRebuildcomp == true) {
      return true;
    } else {
      List<bool> components = [];
      for (var element in filteredTodos) {
        components.add(dependencies.contains(element.id) &&
            !oldWidget.filteredTodos.contains(element));
      }
      bool res = components.fold(false,
          (bool previousValue, bool element) => previousValue || element);
      return res;
    }
  }
}
```

This method was tough to code. The method's pseudocode is presented down below.

Source Code 2.47: Todo app - InheritedModel - updateShouldNotifyDepented method pseudocode

```
if( widgetRegisteredForStructuralChange && strucuturalChangeOccured){
        return true;
    }else{
        if( widgetRegisteredForSpecificTodoChange && thatTodoChanged){
```

```
            return true;
            }else{
                return false;
    }
}
```

At this point , when the TodoItem's checkbox is tapped the single TodoItem widget is rebuilt. However, no visual changes are shown. The widget rebuilds with the same information as before . This is due to the fact that the *build* method populates its internal widgets based on a local *todo* variable. This variable is populated on the TodoItem widget's creation with a Todo instance provided by the parent widget(TodoView). Indeed, when the TodoView widget instantiates TodoItems in its ListView, it creates a copy of the corresponding Todo before passing it to the constructor. Even if we changed the information contained in the TodoInheritedData widget, the TodoItem widget do not see any difference. Its local todo variable , indeed, did not change. The fact that ,before the optimization, TodoItem widgets rebuilt correctly comes from the fact that the transition of the state caused the entire TodoView widget to rebuild. The conseguence was that TodoItems were detroyed and created again using new copies of the data coming from the TodoInheritedData widget.
To recap, the performance optimization we were looking for were achieved succesfully but an issue ,regarding the syncronization of the data, arised. The TodoItems widget sees a screenshot of the state different from the one seen by the rest of the application. This is a really bad behavior and is caused by the fact that ,sometimes, during programming , more than one level of information caching is required or used to avoid effort in coding and performance issues. In other words, a local copy of the data is kept and referred to in case of data access in order to optimize the accesses in the main storage that can become quite expensive in large scenarios. A great example of that is the local copy of the database's data used in many applications. Is more effective to fetch data from the database, save them locally, manipulate this local copy and only in case of real necessity access again the database to store them or retrieve other data. In large applications (but also in small ones like in this cases) more than one level of data caching is used. Particular attention is required to handle those levels to avoid inconsistency in what is visualized and the real data. In this case the *filteredTodos* list actually changed but the UI did not reflect this change. The problem was generate by the fact that a local copy of the real Todo instance was passed to the TodoItem widget. Instead , the "correct" way of handling this scenario is to pass the id of the Todo in the constructor and then use this id to look up for the Todo instance in the centralized state (the TodoInheritedData). This of course

will require more computational effort but will guarantee also a lot more stability and robustness. Therefore, TodoItem widget's local variable of type Todo is replaced with a new int variable called *id* that represents the id of the Todo the widget is visualizing. In the *build* method, then, the corresponding Todo is looked up.

Source Code 2.48: Todo app - InheritedModel - TodoItem widget todo look up

```
class TodoItem extends StatelessWidget {
  final int id;

  const TodoItem({Key? key, required this.id}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    final Todo todo = TodoInheritedData.of(context, aspect: id)
        .todos
        .where((element) => element.id == id)
        .first;
```

At this point the application is working as intentioned and the renders optimization was successfully accomplished.

Time spent: 8-10 hours
Lines of code written/updated: 49
Classes/widget created: 0

2.2.3. Redux implementation

2.2.4. BloC implementation

In this section the state management solution called Bloc is used to implemented the todo application. The bloc overview can be found here RIFERIMENTO.

States

The application state is decomposed in four smaller states: the state of the list of todos, the state of the filtered list of todos and the filter, the state of the statistics and the state of the tab. The state of the list of todos contains the whole list of todos. The state of the filtered list of todos and of the filter contains a filter ,of type VisibilityFilter ,and a list of todos matching the filter value. The state of the stats contains an int number indicating the number of completed todos. Lastly, the state of the tab contains the value of the HomePage's active tab. The state of the list of todos and the state of the tab are independent. The state of the filter and the state of the stats , instead, are directly linked to the state of the list of todos. They will , indeed, react to the changes in the state of the list of todos and update consequently.

The states of the list of todos

First of all we start defining and naming the possible states of the list of todos. These states are only two: TodosLoadingState and TodoLoadedState. The Loading state indicates that the list of todos is still loading. The loaded state ,instead, indicates that the list of todos has been successfully fetched from the database and is available. In order to define these two states a new abstract class is created. It is called TodosState. It must extend the class Equatable. The Equatable class is useful to define equality between states without the need to override the equality operator in every state class. The TodosLoadingState does not contains any other information. The TodosLoadedState contains ,instead, a list filled with todos.

Source Code 2.49: Todo app – Bloc - states definition for the list of todos

```
abstract class TodosState extends Equatable{
  const TodosState();

  @override
  List<Object> get props => [];
}
class TodosLoadingState extends TodosState{
  @override
  String toString() => 'TodosState - TodosLoadingState';
}
class TodosLoadedState extends TodosState{
   final List<Todo> todos;
   const TodosLoadedState(this.todos);

   @override
```

```
  List<Object> get props => [todos];

  @override
  String toString() => 'TodosState - TodosLoadedState';
}
```

The state of the filtered list and the filter

Also in this case there are only two possible states: FilteredTodosLoadingState and FilteredTodosLoadedState. The loading state identifies the fact that the filtered list hasn't been computed (or todos fetched) yet. The Loaded state, instead, identifies the fact that the list of todos has been successfully fetched and the list of filtered todos computed. It contains two variables: a VisibilityFilter and a List of todos. An abstract class , called FilteredTodosState, must be created and extended with Equatable class. All the others state classes ,belonging to the state relative to the filtered list and the filter, will extend the FilteredTodosState abstract class. Someone can notice that , the state of the filtered list and the filter ,contains two different aspects of the application state: the filter and the filtered list precisely. In this case it is possible to further split the state and create two separated blocs ,handling respectively the filter and the filtered list. From a general point of view ,the state should be divided in the more possible pieces to keep things well separated and clean , like we do for classes and methods. However, the bloc pattern do not specify how granular should be the state fragmentation and , theoretically, we could decide to use a single bloc to handle the whole application ‘s state , like in Redux. In this particular case , I decided to implement a trade of and keep the filter and the filtered list in the same bloc. They concern , indeed, two similar aspects of the data and ,splitting them , would require the bloc of the filtered todos to depend on the bloc of the filter also, making its dependencies going from one bloc to two blocs (the bloc of the todos and the bloc of the filter).

Source Code 2.50: Todo app - Bloc - states definition for the filtered list of todos and the filter

```
abstract class FilteredTodoState extends Equatable {
  const FilteredTodoState();

  @override
```

```
  List<Object> get props => [];
}

class FilteredTodoLoadingState extends FilteredTodoState {
  @override
  String toString() => 'FilteredTodoState - FilteredTodoLoadingState';
}

class FilteredTodoLoadedState extends FilteredTodoState {
  final List<Todo> todos;
  final VisibilityFilter filter;

  const FilteredTodoLoadedState(this.todos, this.filter);

  @override
  List<Object> get props => [todos, filter];

  @override
  String toString() => 'FilteredTodoState - FilteredTodoLoadedState';
}
```

the state of the stats

Also in this case there only two possible states: StatsLoadingState and StatsLoadedState. The first identifies the fact that stats hasn't been computed yet and do not contains any additional information . The second identifies the fact that stats are available and contains an int variable inside , *completed* that represents the actual stats.

Source Code 2.51: Todo app - Bloc - states definition for the stats

```
abstract class StatsState extends Equatable {
  const StatsState();

  @override
  List<Object> get props => [];
}
```

```
class StatsLoadingState extends StatsState {
  @override
  String toString() {
    return 'StatsState - StatsLoadingState';
  }
}

class StatsLoadedState extends StatsState {
  final int completed;

  const StatsLoadedState(this.completed);

  @override
  List<Object> get props => [completed];

  @override
  String toString() {
    return 'StatsState - StatsLoadedState : {completed: \$completed}';
  }
}
```

The state of the tab

In order to define the states of the tab ,the enumeration presented HERE RIFERIMENTO is enough.

Source Code 2.52: Todo app - Bloc - state definition for the tab

```
enum TabState{
 todos,stats
}
```

Events

Now that states for every possible part of the application have been defined, it's the turn of Events. Events are just classes. They can represent a specific actions the user can perform or also internal changes. They enable the states to mutate creating transitions.

Events of the list of todos

For the moment is sufficient to define two events only. One identifies the action of fetching todos from the database and is called LoadTodosEvent. It do not contains any other information. The other identifies the action of changing the *completed* field of a specific todo and is called SetCompletedTodoEvent. It contains two informations, the *id* of the specific todo to be modified and the new value for the *completed* field. Also in this case, a new abstract class is defined and extended with Equatable class. It is called TodosEvent. All other event classes , concerning the state of the list of todo ,are extended with this abstract class.

Source Code 2.53: Todo app - Bloc - event definition for the list of todos

```
abstract class TodosEvent extends Equatable {
  const TodosEvent();

  @override
  List<Object> get props => [];
}

class LoadTodosEvent extends TodosEvent {
  @override
  String toString() => 'TodosEvent - LoadTodosEvent';
}

class SetCompletedTodoEvent extends TodosEvent {
  final int id;
  final bool completed;

  const SetCompletedTodoEvent(this.id, this.completed);

  @override
  String toString() => 'TodosEvent - SetCompletedTodoEvent';
```

```
}
```

Events for the filtered list and the filter

Two events are enough to define all possible transition for the state of the filtered list and the filter. One is called FilteredTodoChangeFilterEvent and is used to change the state of the filter. It contains , indeed, a VisibilityFilter variable that indicates the new value for the filter. The other event is called TodosUpdatedEvent . It informs the part of the state concerning the filtered list that the list of todo has changed. A new filtered list must be computed ,tough, and a new FilteredTodosLoadedState emitted. It contains internally a variable providing the changed list of todos.
Also in this case ,all event classes extend a shared abstract class called FilteredTodoEvent which , in turn, extends the Equatable class.

Source Code 2.54: Todo app - Bloc - events definition for the filtered list of todos and the filter

```
abstract class FilteredTodoEvent extends Equatable {
  const FilteredTodoEvent();

  @override
  List<Object> get props => [];
}

class FilteredTodoChangeFilterEvent extends FilteredTodoEvent {
  final VisibilityFilter filter;

  const FilteredTodoChangeFilterEvent(this.filter);

  @override
  List<Object> get props => [filter];

  @override
  String toString() => 'FilteredTodoEvent - FilteredTodoChangeFilterEvent {filter: \$fil
}
```

```
class TodoUpdatedEvent extends FilteredTodoEvent {
  final List<Todo> todos;

  @override
  List<Object> get props => [todos];

  const TodoUpdatedEvent(this.todos);

  @override
  String toString() => 'FilteredTodoEvent - TodoUpdatedEvent';
}
```

Events for the stat's and tab's state

Both the state of the tab and the state of the stats require just one event. The event concerning the state of the tab is called ChangeTabEvent and contains internally a variable of type TabState indicating the value of the new tab. The event concerning the state of the stats is called StatsUpdatedEvent and is generated after the fetching or the updating of the list of todos in the TodoBloc. Precisely it is generated once a new state of type TodosLoadedState is emitted in the TodoBloc. It contains internally the new list of todos of the emitted state.
Also in this case , both the event for the stats and the event for the tab extends respectively the abstact classes TabEvent and StatsEvent.

Source Code 2.55: Todo app - Bloc - events definition for the stats and the tab

```
abstract class StatsEvent extends Equatable{
  const StatsEvent();

}
class StatsUpdatedEvent extends StatsEvent{

  final List<Todo> todos;
  const StatsUpdatedEvent(this.todos);
```

```
  @override
  List<Object> get props => [todos];

  @override
  String toString() => 'StatsEvent - StatsUpdatedEvent';
}

abstract class TabEvent extends Equatable{

  const TabEvent();

}

class ChangeTabEvent extends TabEvent{
  final TabState tab;

  const ChangeTabEvent(this.tab);

  @override
  List<Object> get props => [tab];

  @override
  String toString() => 'TabUpdated { tab: \$tab }';

}
```

The Blocs

At this point ,both the events and the states necessary to implement di base functionalities of the application have been defined. Is possible ,then, to implement the classes, called *blocs*, that are going to define the way in which new states are emitted in relation to the received events.

The bloc for the list of todos

To define the bloc for the list of todos is necessary to create a new class, we name TodoBloc, and make it extends the Bloc class, provided by the flutter_bloc package. Moreover, it is necessary to provide , in the extension, also the type of events and states the bloc will manage. In our case , the ToboBloc class handles events of type TodosEvent and states of type TodosState, previously defined. A constructor must be defined where the bloc is initialized with a initial state. The initial state for the TodoBloc is of type TodoLoadingState by the fact that, at the application start, todos are still to be fetched from the database. The Bloc class ,provided by the solution ,requires to override the *mapEventToState* method . The *mapEventToState* method is ,indeed, annoted with the @override notation meaning that the implementation we are giving substitutes the one of the Bloc class. The override is mandatory. The method *mapEventToState* takes as argument an event of type TodosEvent and returns a Stream of TodosStates. It is asynchronous (indicated by the async* annotation after the arguments) and do not terminate during the entire execution of the application. It keeps listening for new events, tough. Inside its implementation , a series of nested *if-else* statement have the task of identifing the type of the received event and to emit the consequent state. Indeed, the received event is always of the abstract type TodosEvent but can be of the subtype LoadTodosEvent or SetCompletedTodoEvent. Once the subtype is defined ,the event logic is processed and the new state emitted. The syntax *yield** Is used , instead of the classic syntax *return*,because it allows to emit a new state, in the Stream , without terminating di *mapEventToState* method execution. If the *return* syntax is used , indeed, the new state is emitted correctly but the method terminates and the application become unresponsive. For code readability, the logic to be executed when a LoadTodoEvent or a SetCompletedTodoEvent is received has been moved to two other private methods ,called respectively *mapLoadTodoToState* and *mapSetCompletedToState*. This kind of practice is used also in the subsequence blocs implementation. The *mapLoadTodoToState* method takes as single argument an event of type LoadTodosEvent (not a generic TodosEvent anymore) and bothers to fetch the todos from the database using the TodoRepository class. In case it successfully gets the list of todos, it emits a new state of type LoadedTodoState containing it. In case of failure ,instead, the TodosLoadingState is emitted. The *mapSetCompletedToState* method takes as single argument an event of type SetCompletedTodoEvent. After checking that the current state is of type TodosLoadedState (in case it is not is meaningless to update the todo not having an actual list) a new list of todo is created containing the same todos as before except for the one with the id matching the value contained in the event. That todo, indeed, is replaced with a new one with the *completed* field set to the completed value contained in the event. Notice that a new instance of the list must be created and provided to the new state. If we just mutate the list present in the previous state the Equatable class do not identify any difference between the previous state and the new emitted one, and consequently, do not notify any listener.

Source Code 2.56: Todo app - Bloc - TodoBloc implementation

```
class TodoBloc extends Bloc<TodosEvent, TodosState> {
  TodoBloc() : super(TodosLoadingState());

  @override
  Stream<TodosState> mapEventToState(TodosEvent event) async* {
    if (event is LoadTodosEvent) {
      yield* _mapLoadTodosToState(event);
    } else if (event is SetCompletedTodoEvent) {
      yield* _mapSetCompletedToState(event);
    }
  }

  Stream<TodosState> _mapLoadTodosToState(LoadTodosEvent event) async* {
    try {
      final List<Todo> todos = await TodoRepository.loadTodos();
      yield TodosLoadedState(todos);
    } catch (e) {
      yield TodoLoadingState();
    }
  }

Stream<TodosState> _mapSetCompletedToState(
    SetCompletedTodoEvent event) async* {
  if (state is TodosLoadedState) {
    List<Todo> newList = (state as TodosLoadedState)
        .todos
        .map((todo) => todo.id == event.id
            ? Todo(
                name: todo.name,
                description: todo.description,
                id: todo.id,
```

```
                completed: event.completed)
            : todo)
        .toList();
    yield TodosLoadedState(newList);
  }
}

}
```

The bloc for the filtered list and the filter

The procedure is the same utilized for the todo bloc. A new class ,called FilteredTodos-Bloc ,is created and extended with the Bloc class. This new class handles the events of type FilteredTodosEvent and the states of type FilteredTodosState. Being the bloc of the filtered list of todos dependent from the bloc of the list of todos, an instance of this second one is passed inside the constructor at the initialization and used to listen for changes. The instance of the bloc of the todos is saved in a local variable of type TodoBloc. In this case the constructor is a bit more articulated with respect to the TodoBLoc's one. It emits the initial state based on the state of TodoBloc. If the state is of type loaded , the constructor computes ,and then emits , a state of type FilteredtodosLoadedState using a filter of type *all*. If the state is of type loading, the constructor emits a state of type FilteredLoadingState.

Source Code 2.57: Todo app - Bloc - FilteredTodoBloc initial state definition

```
class FilteredTodoBloc extends Bloc<FilteredTodoEvent, FilteredTodoState> {
  final TodoBloc todoBloc;

  FilteredTodoBloc({required this.todoBloc})
      : super(
          todoBloc.state is TodosLoadedState
              ? FilteredTodoLoadedState(
                  (todoBloc.state as TodosLoadedState).todos,
                  VisibilityFilter.all,
                )
              : FilteredTodoLoadingState(),
```

```
        )
}
```

In addition, the constructor must register the bloc to the changes in the TodoBLoc. To do so , a particular variable of the TodoBloc instance , called *stream*, is used. The variable *stream* is present because the TodoBloc extends the Bloc class. It is , indeed, the variable where the *mapEventToState* method emits new states. We can register to its output using the method *listen*. Inside the *listen* method's call, a function must be provided. This function Is called everytime the steam emits a new state. Inside this function the new emitted state can be accessed and used to implement some logic. Actually , we won't implement the logic there ,instead, we emit a new event that will be handled by the *mapEventToState* method ,defined later. Once a new state is emitted in the TodoBloc the function checks if the state is of type TodoLoadedState. In case it is, it means that a new list of todos is available. It can be the case that the list of todos has been just fetched or some todos have been updated. In both cases , the bloc of the filtered list must compute a new filtered list and emit a new state containing it. A specific event ,called TodoUpdatedEvent ,has been defined for this situation HERE RIFERIMENTo where the events related to the bloc of the filtered list have been implemented.

Source Code 2.58: Todo app - Bloc - FilteredTodoBloc subscription to TodoBloc stream

```
class FilteredTodoBloc extends Bloc<FilteredTodoEvent, FilteredTodoState> {
  final TodoBloc todoBloc;
  late StreamSubscription todoSubscription;

  FilteredTodoBloc({required this.todoBloc})
      : super(
          todoBloc.state is TodosLoadedState
              ? FilteredTodoLoadedState(
                  (todoBloc.state as TodosLoadedState).todos,
                  VisibilityFilter.all,
                )
              : FilteredTodoLoadingState(),
        ) {
    todoSubscription = todoBloc.stream.listen((state) {
      if (state is TodosLoadedState) {
        add(TodoUpdatedEvent((todoBloc.state as TodosLoadedState).todos));
```

```
      }
    });
  }
```

The *mapEventToState* method is overriden now defining the logic used to emit new state based on the received event. Like in the TodoBloc, also in this case, the method is asynchrounous and returns a stream of FilteredTodosStates. The method takes as argument a single event of the generic abstract type FilteredTodosEvent. Inside the method, two nested *if-else* statement defines the type of the received event. The event can be of type FilteredTodosChangeFilterEvent or TodosUpdatedEvent. In the first case the private method *mapTodoChangeFilterEventToState* is called. In the second case the private method *mapTodosUpdatedEventToState* is called.

Source Code 2.59: Todo app - Bloc - FilteredTodoBloc *mapEventToState* method implementatio

```
@override
Stream<FilteredTodoState> mapEventToState(FilteredTodoEvent event) async* {
  if (event is FilteredTodoChangeFilterEvent) {
    yield* _mapTodoChangeFilterEventToState(event);
  } else if (event is TodoUpdatedEvent) {
    yield* _mapTodoUpdatedEventToState(event);
  }
}
```

The *mapTodoChangeFilterEventToState* method checks that the state of the TodoBloc is of type TodosLoadedState (in case it is not changing the filter is useless) and ,then ,it emits a new state of type FilteredTodosLoadedState containing the new filter and the new computed list of filtered todos.

Source Code 2.60: Todo app - Bloc - FilteredTodoBloc *_mapTodoChangeFilterEventToState*method implementation

```
Stream<FilteredTodoState> _mapTodoChangeFilterEventToState(
    FilteredTodoChangeFilterEvent event) async* {
```

```
  if (todoBloc.state is TodosLoadedState) {
    yield FilteredTodoLoadedState(
        filterTodos((todoBloc.state as TodosLoadedState).todos, event.filter),
        event.filter);
  }
}
```

The method *mapTodoUpdatedEventToState* checks that the TodoBloc's state is of type TodosLoadedState and then emits a new state of type FilteredTodosLoadedState. The emitted state uses and contains the current filter ,if it is set, otherwise used the filter of type *all*.

Source Code 2.61: Todo app - Bloc - FilteredTodoBloc _ *mapTodoUpdatedEventToState* method implementatio

```
Stream<FilteredTodoState> _mapTodoUpdatedEventToState(
    TodoUpdatedEvent event) async* {
  final filter = (state is FilteredTodoLoadedState)
      ? (state as FilteredTodoLoadedState).filter
      : VisibilityFilter.all;
  if (todoBloc.state is TodosLoadedState) {
    yield FilteredTodoLoadedState(
        filterTodos((todoBloc.state as TodosLoadedState).todos, filter),
        filter);
  }
}
```

The last thing to do is to ensure that the subscription to the todoBloc is disposed when the current bloc terminates.

Source Code 2.62: Todo app - Bloc - FilteredTodoBloc *close* method implementation

```
@override
Future<void> close() {
  todoSubscription.cancel();
  return super.close();
```

}

The bloc for the stats

This bloc is similar to the previous one , it has to deal with one event only, tough : the StatsUpdatedEvent. As usual, the class StatsBloc is defined an extended with the Bloc class. The StatsBloc class handles events of the type StatEvent and states of the type StatsState. Also in this case, the bloc depends on the bloc of the list of todo. For this reason, a variable of type TodoBloc is added and required in the constructor. In the constructor, a new initial state of type StatsLoadeingState is emitted. The subscription to the state's stream of the TodoBloc is perfomed passing a function ,called *onTodosStateChanged*, that check if the TodoBloc's state is of type TodoLoadedState and , in case it is ,emits a event of type StatsUpdatedEvent. This event will be handled by the *mapEventToState* method implemented later. The function *onTodosStateChanged* is called also once in the constructor to update the stats in case the TodoBloc is already of type TodosLoadedState on StatsBloc's creation.

Source Code 2.63: Todo app - Bloc - StatsBloc constructor implementation

```
class StatsBloc extends Bloc<StatsEvent, StatsState> {
  final TodoBloc todoBloc;
  late StreamSubscription todoSubscription;

  StatsBloc({required this.todoBloc}) : super(StatsLoadingState()) {
    void onTodosStateChanged(state) {
      if (state is TodosLoadedState) {
        add(StatsUpdatedEvent(state.todos));
      }
    }

    onTodosStateChanged(todoBloc.state);

    todoSubscription = todoBloc.stream.listen(onTodosStateChanged);
  }
```

The *mapEventToState* method requires a single *if-else* statement because the only event it has to handle is the StatsUpdatedEvent. When received, the list of todos it contains is used to compute the stats and ,then, a new StatsLoadedState is emitted. In the *close* method the subscription to the TodoBloc is terminated.

Source Code 2.64: Todo app - Bloc - StatsBloc *matEventToState* and *close* methods implementation

```
@override
  Stream<StatsState> mapEventToState(StatsEvent event) async* {
    if (event is StatsUpdatedEvent) {
      final numCompleted =
          event.todos.where((todo) => todo.completed).toList().length;
      yield StatsLoadedState(numCompleted);
    }
  }

  @override
  Future<void> close() {
    todoSubscription.cancel();
    return super.close();
  }
}
```

The bloc for the tab

The procedure is the same as before. This time the bloc is really simple. After creating the class TabBloc and extending it to the Bloc class,the states and events to be handled are specified. In the contructor, the initial state is initialized and set to the TabState.todos value. The *mapEventToState* method is overridden connecting the only event with the emission of a state corresponding to the event's TabState internal value.

Source Code 2.65: Todo app - Bloc - TabBloc implementation

```
class TabBloc extends Bloc<TabEvent,TabState>{
  TabBloc() : super(TabState.todos);

  @override
  Stream<TabState> mapEventToState(TabEvent event)async*{
    if(event is ChangeTabEvent){
      yield event.tab;
    }
  }

}
```

Observe blocs

Terminates here the definition of the application's state. All states ,events and blocs have been defined. It is possible to start testing the logic of the application, in the main function for example, initializing an object of type TodoBloc and trying to emit new events using the *add* method offered by the Bloc package.

Source Code 2.66: Todo app - Bloc - example of TodoBloc usage

```
void main()  {

  TodoBloc todoBloc= TodoBloc();
  todoBloc.add(LoadTodosEvent());

}
```

The fact that it is possible to test the logic of the application without the need of writing a single widget explains how powerful the bloc package is. It is , indeed, really easy to split the logic layer from the presentation layer without dealing with complicated external dependencies. Moreover, it is possible to use an additional tool that helps the debugging and testing process; the BlocObserver. This component allows to intercept events, transitions and errors during the usage of the blocs and to execute arbitrary code when they occur. To use this component is necessary to define another class , that we call AppBlocObserver, and extend it with the BlocObserver class from the Bloc package. Inside the AppBlocObserver class, it is possible to override three methods: *onEvent*, *onTransition* and *onError*. *onEvent* is called everytime a new event is emitted in a bloc and provides, in its implementation ,the emitted event and the intrested bloc. *onTransition* is called everytime a state transition occurs, inside a bloc. It offers two elements inside its implementation: the corresponding bloc and a object of type Transition. An object of type Transition is composed by two states and one event. The states are the ones preceeding and postponing the the event's execution. (note: not always the emission of a event produces a state transition. Some events may not generate a new state or may be ignored). Lastly, the method *onError* is called when an unexpected behaviour occurs and provides , in its implementation, the corresponding bloc where the error occured and an object of type StackTrace that reports the stack situation when the error occurred. In our case the corresponding event, transition and error are displayed only but other, more articolated , implementation can be provided.

Source Code 2.67: Todo app - Bloc - AppBlocObserver implementation

```
class AppBlocObserver extends BlocObserver{
  @override
  void onEvent(Bloc bloc, Object? event) {
    super.onEvent(bloc, event);
    print("Event : " +event.toString());
  }

  @override
  void onTransition(Bloc bloc, Transition transition) {
    super.onTransition(bloc, transition);
    print( transition.toString());
  }
  @override
  void onError(BlocBase bloc, Object error, StackTrace stackTrace) {
    print(error);
    super.onError(bloc, error, stackTrace);
  }
}
```

Before running the application with the *runApp* method ,the AppBlocObserver ,we just created , is set as the default observer for the blocs.

Source Code 2.68: Todo app - Bloc - application's observer setting

```
void main() async {

  Bloc.observer = AppBlocObserver();
}
```

Making the state accessible

Similarly to the implementation with Redux and Inheritedwidget , also in this case, a particular widget called BlocProvider must be used to make the state , or part of it, accessible in the subtree. Since the information regarding the list of todos needs to be accessible by the entire application its BlocProvider is situated in the root. In the *main* function , the first widget to be passed to the *runApp* method is indeed a BlocProvider widget. A BlocProvider widget is a typed widget , meaning that, the type of the bloc it makes accessible ,must be provided. In our case it needs to provide a bloc of type TodoBloc. Inside the BlocProvider widget , two fields must be filled: *create* and *child*. In the *create* field, a function taking as single argument the context and returning a bloc of the previously specified type ,must be provided. This function is executed on the BlocProvider initialization. However, the initialization of the BlocProviders is lazy. This means that it is performed when the BlocProvider is accessed the first time and not when it is inserted in the widget tree. This type of procedure is used to postpone heavy methods execution as lately as possible to avoid, in case they are never accessed, to perform useless computation and waste time. It is possible to set the lazy flag to false in case of the *create* function needs to be run instantly after the widget build. A function that instantiates a TodoBloc and emits the first event of the application, the LoadTodoEvent, is provided in the *create* field. In order to emit new events the method *add*, provided by the extension to Bloc class, is used. Moreover , the *cascade* notation ,offered by Dart language , is used to increase de readability of the code. It allows to concatenate more actions using the ".." notation. The *child* field is populated with the MyApp widget as usual.

Source Code 2.69: Todo app - Bloc - make the TodoBloc accessible

```
void main() async {
  Bloc.observer = AppBlocObserver();
  runApp( BlocProvider<TodoBloc>(create:(context)=>
   TodoBloc()..add(LoadTodosEvent()),child: const MyApp()));
}
```

Beyond the TodoBloc, also the other blocs previously defined need to be made accessible. They are required in the HomePage only because the information they provide is not used by the other pages. This time a MultiBlocProvider is used to wrap the HomePage. A MultiBlocProvider is nothing else that a widget itself that contains a field called *providers* where a list of BlocProvider widgets is inserted. It is the same as nesting a series of BlocProviders widge but it has the advantage of making the code more readable. In the *providers* field, a list with three BlocProvider widgets is inserted. The first is of type TabBloc, the second is of type StatsBloc and the third is of type FilteredTodoBloc. The last two BlocProvider widgets need to be initialized passing a TodoBloc in the constructor. In order to retrieve the TodoBloc, the *of* method ,provided by the BlocProvider widget ,is used. The *of* method is called indicating the type of bloc to be searched and looks for the bloc in the current context. It rises an error in case a bloc of the specified type is not found in the context. Fortunately , we already set a BlocProvider of type TodoBloc in the parent widget ,and so , the *of* method successfully finds it. The reason because the TodoBloc is positioned in an higher level with respect to the other blocs it that ,it is a good practice, to limitate the access to the state to the few parts of the application possible. This allows the state to be modified by the parts that has access to it only and , in case of problems, it is easier to understand which part of the code caused it.

Source Code 2.70: Todo app - Bloc - make other blocs accessible

```
class MyApp extends StatelessWidget {
  const MyApp({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("building: MATERIAL-APP");
    return MaterialApp(
      initialRoute: "/",
```

```
      routes: {
        "/": (context) => MultiBlocProvider(providers: [
              BlocProvider<TabBloc>(create: (context) => TabBloc()),
              BlocProvider<StatsBloc>(
                  create: (context) =>
                      StatsBloc(todoBloc: BlocProvider.of<TodoBloc>(context))),
              BlocProvider<FilteredTodoBloc>(
                  create: (context) =>
                      FilteredTodoBloc(todoBloc:
                       BlocProvider.of<TodoBloc>(context))),
            ], child: const HomePage()),
        "/addTodo": (context) => const AddTodoPage(),
        "/updateTodo" : (context) => UpdateTodoPage(todo:
         (ModalRoute.of(context)!.settings.arguments as Todo)),
      },
    );
  }
}
```

Integrazione dello stato all'interno dell'UI

Now that the application's state has been defined and also made accessible in the interested part of the widgets trees is the moment to connect it with the UI.

La Home Page

The Scaffold widget is wrapped into a BlocBuilder widget. The BlocBuilder widget is used to access the state concerning the tab. Indeed, almost the entire HomePage is build on top of the tab value. The entire HomePage creation is moved inside the *builder* field of the BlocBuilder widget. Moreover, the type of the bloc and the type of states the BlocBuilder has to manage are specified in its declaration. Inside the function provided in the *builder* field ,indeed, we have access to the state in the form of an object of the type previously provided, in addition to the current context.

Source Code 2.71: Todo app - Bloc - wrapping the HomePage into a BlocBuilder

```
class HomePage extends StatelessWidget {
  const HomePage({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("building: HomePage");

    return BlocBuilder<TabBloc, TabState>(builder: (context, tabState) {
          });
  }
}
```

Inside the function is possible to access the state of the tab through the variable *tabState* of type TabState and use it to build the Scaffold consequently.

Source Code 2.72: Todo app - Bloc - HomePage's Scaffold based on the tab

```
builder: (context, tabState) {
  return Scaffold(
    appBar: AppBar(
      title: const Text("TodoApp"),
      actions: [tabState == TabState.todos?  VisibilityFilterComponent():Container()],
    ),
    body: tabState == TabState.todos ? const TodoView() : const Stats(),
    bottomNavigationBar: const TabSelector(),
    floatingActionButton:
        tabState == TabState.todos
          ? FloatingActionButton(
              child: const Icon(Icons.plus_one),
              onPressed: () {
                Navigator.pushNamed(context, "/addTodo");
              })
          : Container()

  );
}
```

Il componente TodoView

The TodoView component needs to access the state of the filtered list and the filter only. The ListView widget is wrapped in a BlocBuilder widget . We define ,using the <> notation ,that it will handle the bloc of type FilteredTodosBloc and its internal state (of type FilteredTodosState). In the function passed in the *builder* field , the state is accessible using the variable called *filteredTodosState*. The actual type of the state is defined using an *if-else* statement. In case the state is of type FilteredTodosLoadingState a CircularProgressIndication widget is returned. In case the state is of type FilteredTodosLoadedState a variable containing the list of todos will be available inside the filteredTodosState object and can be used to populated the ListView widget.

Source Code 2.73: Todo app - Bloc - TodoView implementation

```
class TodoView extends StatelessWidget {
  const TodoView({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    return BlocBuilder<FilteredTodoBloc, FilteredTodoState>(
        builder: (context, filteredTodoState) {
      print("building: TodoView");

      if (filteredTodoState is FilteredTodoLoadedState) {
        return ListView.builder(
            itemCount: filteredTodoState.todos.length,
            itemBuilder: (context, index) {
              return TodoItem(

                  todo: filteredTodoState.todos.elementAt(index));
            });
      } else if (filteredTodoState is FilteredTodoLoadingState) {
        return const Center(child: CircularProgressIndicator());
      } else {
        return const Center(child: CircularProgressIndicator());
      }
    });
```

```
  }
}
```

Il componente TodoItem

Since this part of the development process do not consider any type of optimization, the TodoItem component does not need to be modified with respect to the implementation defined in RIFERIMENTO. The todo instance to be visualized is passed as argument in the constructor from the ancestor widget (TodoView). However, even if the TodoItem component does not access the state to read any value it needs to access the state to emit an event. Once the checkbox is tapped ,indeed, the list of todos should be modified. Emitting an event is easier than reading the state. It can be considered a constant action meaning that the widget should not be notified when the state changes. For this reason there is no need to use any BlocBuilder widget. It is sufficient to access the bloc ,in which the event must be emitted ,using the BlocProvider's *of* method , and emit the event. The Checkbox widget's *onChanged* function provides a Boolean variable (called *completed* in our case) that represents the value the Checkbox will take after being clicked. A new event of type SetCompletedTodoEvent is created , using this variable and the *id* of the todo passed by the parent ,and emitted in the TodoBloc.

Source Code 2.74: Todo app - Bloc - onChanged field implementation inside a TodoItem's Checkbox

```
onChanged: (completed) {
  BlocProvider.of<TodoBloc>(context)
      .add(SetCompletedTodoEvent(id, completed!));
}),
```

Summarizing ; once the Checkbox is pressed, inside a TodoItem , a new event in the bloc of the list of todos is generated. This event causes a state transition in the TodoBloc passing from the current state to a new state where the corresponding todo has been modified. Then, the bloc of the filtered list and the bloc of the stats, listening for changes in the TodoBloc, react emitting a new internal event (respectively of type TodoUpdatedEvent and StatsUpdatedEvent) . This event causes a state transition of the questioned blocs to a new state where the filtered list and the stats are computed using the new TodoBloc's state. As a conseguence of the change in the FilteredTodosBloc state , the TodoView component is notified and rebuilt showing the modification.

Il componente VisibilityFilterSelector

The VisiblityFilterSelector component depends only by the bloc of the filtered list and the filter. It just need to visualize the current filter and to update the state with a new filter in case a DropdownMenuItem is tapped. The DropdownButton is wrapped inside a BlocBuilder widget. The BlocBuilder widget is informed ,with the <> notation , it will handle the bloc of type FilteredTodosBloc and the states of type FilteredTodoState.

Source Code 2.75: Todo app - Bloc - wrapping the VisibilityFilterSelector component into a BlocBuilder

```
return BlocBuilder<FilteredTodoBloc, FilteredTodoState>(
    builder: (context, filteredTodoState) {
```

Inside the *builder* field, a new variable of type VisibilityFilter is created and initialized based on the state of the FilteredTodosBloc. In case the state is of type loaded the variable is initialized with the current filter value. In case the state is of type loading the variable is initialized with the value *all*.

Source Code 2.76: Todo app - Bloc - populating a filter variable based of the current state

```
final VisibilityFilter filter= filteredTodoState is FilteredTodoLoadedState? filter
```

The DropdownButton is populated with the created filter variable. Notice that ,the function provided in the *onChenge* field of every DropdownMenuItem widget, uses its internal filter value to create ,and emit, a new event in the FilteredTodoBloc of the type FilteredTodoChangeFilterEvent.

Source Code 2.77: Todo app - Bloc - DropdownMenuItem's onChange field implementation

```
onChanged: (filter) {
 BlocProvider.of<FilteredTodoBloc>(context).add(FilteredTodoChangeFilterEvent(filte
```

```
},
```

The TabSelector component

The entire component depends only on the state of the tab. It needs to read and write the state. The BottomNavigatorBar widget is wrapped inside a BlocBuilder widget. the BlocBuilder widget will handle the bloc of type TabBloc and the states of type TabState.

Source Code 2.78: Todo app - Bloc - wrapping the BottomNavigationBar into a BlocBuilder

```
return BlocBuilder<TabBloc, TabState>(
  builder: (context, currTab) {
    return BottomNavigationBar(
      currentIndex: TabState.values.indexOf(currTab),
```

TheBottomNavigationBar's *onTap* field is populated with a function that emits a new event of the type ChangeTabEvent ,inside the TabBloc, after the user taps the BottomNavigationBarItem.

Source Code 2.79: Todo app - Bloc - BottomNavigationBar's *onTap* field implementation

```
onTap: (index)=>BlocProvider.of<TabBloc>(context).add(ChangeTabEvent(TabState.values.ele
```

The Stats component

Also in this case, the only dependency the Stats component has is about the part of the state concerning the stats. The component is, therefore, wrapped into a BlocBuilder widget. The Blocbuilder widget will handle the bloc of type StatsBloc and the states of type StatsState. Inside the function provided into the *builder* field the type of the current state is checked. In case the state is of type StatsLoadedState , a widget of type Text is returned and populated using the *completed* variable contained inside the state object. In case the state is of type StatsLoadingState a CircularProgressIndicator widget is returned ,indicating that the stats still need to be computed.

Source Code 2.80: Todo app – Bloc - Stats component implementation

```
return BlocBuilder<StatsBloc, StatsState>(
  builder: (context, statsState) {
    return statsState is StatsLoadedState ?Center(
      child: Text(
          statsState.completed.toString()),
    ) : Center(child: const CircularProgressIndicator());
  },
);
```

Conclusions

All the base functionalities of the application have been implemented and work fine. In the overall the development process did not face big issues. The only hard part was to create the two blocs of the filter and the stats. Being them dependend by an external bloc, they required a little bit more attention to be handled correctly with respect to the rest of the application. Although the process was linear it required a lot of lines of code and a lot of boilerplate. In the follow some summarizing data are reported.

Time spent: 10-12 hours
Lines of code written/updated: 367
Classes/widget created: 24
Created files: 12

2.2.5. MobX implementation

2.2.6. GetX implementation

3 | The Other app

Another app developed using same state managemnts solutions

4 | Comparisons

Some comparisons involving the data i kept and the other word file i have sent to you before

5 | Conslusions

Conclusions

A | Appendix A

If you need to include an appendix to support the research in your thesis, you can place it at the end of the manuscript. An appendix contains supplementary material (figures, tables, data, codes, mathematical proofs, surveys, . . .) which supplement the main results contained in the previous chapters.

B | Appendix B

It may be necessary to include another appendix to better organize the presentation of supplementary material.

List of Figures

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Acknowledgements

Here you might want to acknowledge someone.