POLITECNICO MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE

Mobile applications State Management in Flutter

Tesi di Laurea Magistrale in Computer Science - Ingegneria Informatica

Author: **Lorenzo Ventura**

Student ID: 906003
Advisor: Prof. Luciano Baresi
Co-advisors:
Academic Year: 2021-2022

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

0.1. General Background

input./Sections/GeneralBackground.tex

0.2. The experiment the model

input./Sections/GeneralOverview.tex

1 | State management solutions

1.1. Inventor and core concepts

InheritedWidgets

Redux

BLoC

MobX

1.2. State management and UI integration

InheritedWidgets

Redux

BLoC

MobX

1.3. Handling asynchronous actions

InheritedWidgets

Redux

BLoC

MobX

1.4. Tracing the state and optimize renderings

InheritedWidgets

Redux

BLoC

MobX

1.5. Installation and dependencies

InheritedWidgets

Redux

BLoC

MobX

1.6. Community and support

InheritedWidgets

Redux

BLoC

MobX

2 | The Todo app

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

2.1. General overview

This section explains in details the three development processes and the resulting application.

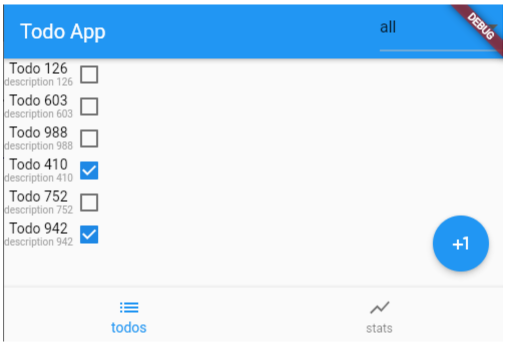
2.1.1. Base functionalities

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

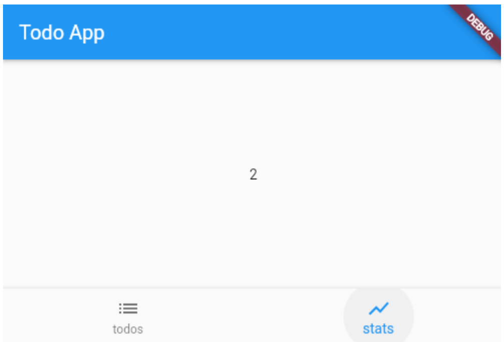
- All (visualizes completed and pending todos)
- Completed (visualizes completed todo only)
- Not Completed (visualizes pending todos only)

The list of todos is visualized using a TodoView component widget. The elements contained in the TodoView component are called TodoItems. TodoItem widgets visualize the name, the description and the completion of a specific todo using two Text widgets and a Checkbox widget. It is possible to use the checkbox in order to mark a todo as completed

or to mark it as pending depending on its current state.
The *stats* tab visualizes the number of completed todos through a Text widget. In the lower part, a TabSelector widget allow to switch from tabs.



(a) *todos* tab runtime UI



(b) *stats* tab runtime UI.

Figure 2.1: Shows the HomePage's UI

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 step. This process is divided into two subprocesses. Both of them aims to add a single new feature.

The Add todo Feature - The first subprocess adds the possibility to create new todos. It utilizes the FloatingActionButton widget, already present in the bottom right corner of the application, to push a new page called AddTodoPage. In the AddTodoPage is possible to compile two TextField widgets and tap on a TextButton widget to return to the HomePage creating the new todo.

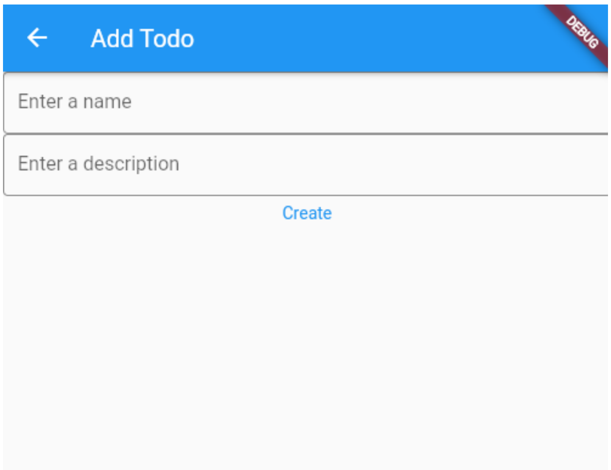


Figure 2.2: Shows the AddTodoPage's UI

The Update feature - The second subprocess aims to add the possibility to update existing todos. Tapping on a specific TodoItem widget allows to navigate to a new page called UpdateTodoPage. In the UpdateTodoPage is possible to compile two TextFields widgets and tap on a TextButton widget to return to the HomePage modifing the corresponding todo.

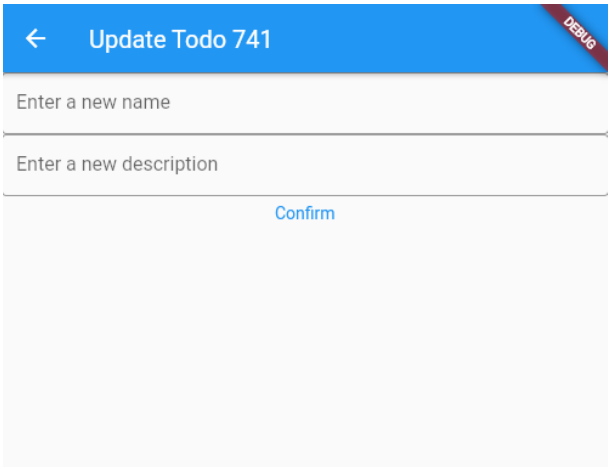


Figure 2.3: Shows the UpdateTodoPage's UI for the todo with id 741

2.1.3. Renders optimization

This part of the development process aims to perform some optimizations in terms of UI renderings and memory consumption. In particular, the code will be refactored in order to use the least UI renders possible or, in other words, to call the least *build* method's runs possible. The focus is on the TodoView widget and TodoItem widgets. The TodoView widget should be rendered again only after a structural change in the *filteredTodos* list. The *filteredTodos* list represent the list containing the todos matching the current filter. 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 and/or when the filter changes. If the *filteredTodos* list's 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 widget ,instead , a non-structural change can rebuild only a subpart (the particular TodoItem widget). When a structural change occurs, more than one TodoItem widget is affected by the change. The most convinient way to mutate all the TodoItem widgets consistently is to rebuild the entire TodoView widget. Moreover, adding , deleting and substituting a TodoItem (and consequently add/delete/substitute a child to the TodoView tree's node) is only feasible 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 Section 2.1 using the state management solutions proposend in Chapter RIFERIMENTO.

2.2.1. Shared project structure and files

In order to make comparisons even fairer , the code about the application's core and about the UI is shared between different solution. In this way , measurements are taken considering only the parts of the code added by each solution's implementation. This subsection presents the shared parts in details. Some parts of the code can change from one implementation to another in order to adapt to the solution's pattern. However, changes to the structure are kept minimal and the same is for the UI. It uses the least widgets and visual elements possible. In Figure 2.4 the shared folder's and file's structure is shown. Subsequent paragraphs exaplain how models, pages, components and the repository are implemented.

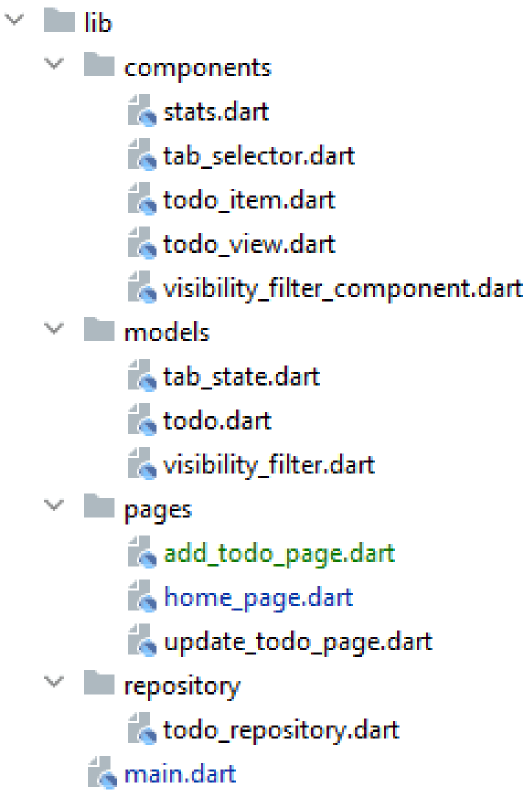


Figure 2.4: Shows Todos app's shared files structure

The application's Root - The root widget of the application is called MyApp. It is a stateless widget composed by a MaterialApp widget. Inside the MaterialApp widget, three routes are defined : the HomePage , the UpdateTodoPage and the AddTodoPage. The *inizialRoute* is set to the HomePage as deafult. The UpdateTodoPage takes a Todo instance as argument. Inside the *main* function the MyApp widget is passed to the *runApp* method in order to start the application.

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

```
void main() {
  //launching the application
  runApp(const MyApp());
}

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

  @override
```

```
  Widget build(BuildContext context) {
    return MaterialApp(
      initialRoute: "/", //setting initial route to the HomePage
      routes: { //defining possible routes
        "/": (context) => const HomePage(),
        "/updateTodo": (context) => UpdateTodoPage(
              todo: (ModalRoute.of(context)!.settings.arguments
                      as Todo),
        "/addTodo": (context) => AddTodoPage(),
      },
    );
  }
}
```

Models - The model for the HomePage's tabs is implemented using an enumeration.

Source Code 2.2: Todo app - TabState model implementation

```
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 implementation

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

It's not possible to give a common implementation for the Todo model matching every solution. Todo model, indeed, can change in different implementations. The sharable structure of the model, however, can defined as shown in Source Code 2.4

Source Code 2.4: Todo app - Todo model implementation

```
@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;
}
```

Repository and utilities - Some useful functions are shared between different implementations. They are contained in the utility.dart file. *generateId* function takes a list of todos and generate a new unique id. *todoExists* function takes a list of todos and a id and checks if a todo with that id exists.

Source Code 2.5: Todo app - Utility functions implementation

```
int generateId(List<Todo> todos) {
  Random rand = Random();
  int newInt = rand.nextInt(1000) + 2;
  List<int> ids = todos.map((todo) => todo.id).toList();
  while (ids.contains(newInt)) {
    newInt = rand.nextInt(1000) + 2;
  }
  return newInt;
}

bool todoExists(List<Todo> todos, int id) {
  List<Todo> result = todos.where((todo) => todo.id == id).toList();
  return result.isNotEmpty ? true : false;
}
```

The TodoRepository class simulates the todos's fetching process 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, populates a list with six new todo instances, using the *generateId* function for the generation of their unique IDs. Subsequently, 2 seconds later, it returns the list to the caller.

Source Code 2.6: Todo app - TodoRepository implementation

```
class TodoRepository {
  //generate 6 unique todos
  static Future<List<Todo>> loadTodos() async {
    List<Todo> todos = [];
    Random rand = Random();
    while (todos.length < 6) {
      int newInt = generateId(todos);
      todos.add(Todo(
          id: newInt,
          name: "Todo " + newInt.toString(),
```

```
          description: "description " + newInt.toString(),
          completed: rand.nextBool()));
    }
//waiting 2 seconds before returning the list
    await Future.delayed(const Duration(seconds: 2));
    return todos;
  }

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

Components - Components are widgets created with a specific task. They provide some sort of indipendent functionality. TodoView widget component, for example, takes care of visualizing a list of todos. Todos are accessed in different ways depending on the implementation. TodoView widget uses a ListView widget filled with TodoItem widgets. *itemCount* and *itemBuilder* fields are left empty for future implementation.

Source Code 2.7: Todo app - TodoView component implementation

```
        class TodoView extends StatelessWidget {

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

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

            return ListView.builder(
              itemCount: //to be filled,
              itemBuilder: (context, index) {
                return TodoItem(
                todo: //to be filled
                );
              },
```

```
        );
      }
    }
```

TodoItem widget component takes care of visualizing a specific todo. TodoItem widget is a stateless. It uses two Text widgets in order to display the todo's informations and a Checkbox widget to allow changing the todo's *completed* field. The entire TodoItem widget is wrapped into an InkWell widget to make it responsive to taps. Functions fields are left empty for future implementation.

Source Code 2.8: Todo app - TodoItem component implementation

```
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" , arguments: todo);
      },
      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) {
              //to be filled
              }),
        ],
      ),
    );
  }
}
```

TabSelector component allows to switch from tabs. It uses a BottomNavigationBar widget. Its *items* field is populated with a list of BottomNavigationBarItem widgets that comes from the mapping of all possible TabState values to BottomNavigationBarItem widgets. Function fields are left empty for future implementation. Functions fields are left empty for future implementation.

Source Code 2.9: Todo app - TabSelector component implementation

```
class TabSelector extends StatelessWidget {

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

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

    return BottomNavigationBar(
      currentIndex: //to be filled ,
      onTap: (){
      //to be filled
      },
```

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

VisibilityFilterSelector component uses a DropdownButton widget. Its *items* field is populated with a list of DropdownMenuItem widgets that comes from the mapping of all possible VisibilityFilter values to DropdownMenuItem widgets. Function fields are left empty for future implementation.

Source Code 2.10: Todo app - VisibilityFilterSelector component implementation

```
class VisibilityFilterSelector extends StatelessWidget {

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

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

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

```
      //to be filled
     },
   );
 }
}
```

Stats component takes care of visualizing some numerical representation regarding the list of todos. Stats component is a stateless widget composed by a Text widget, showing the stats value, wrapped into a Center widget.

Source Code 2.11: Todo app - 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(
        // to be filled
        ));
  }
}
```

Pages - The HomePage can be a statefull widget or a stateless widget depending on the utilized solution. In both cases it uses a simple Scaffold widget. The AppBar widget contains a VisibilityFilterSelector component only when the tab is set to *todos*. The *body* is filled with a TodoView component if the tab is set to *todos* and with a Stats component if the tab is set to *stats*. The *body* can change from *todos* tab to *stats* tab using the BottomNaviagationBar (filled with the TabSelector widget). An empty FloatingActionButton widget is also present for future implementation. (note: some small pieces could change in different solution's implementation. In the above example the tab value is contained in the HomePage but it will not be always the case).

Source Code 2.12: Todo app - HomePage implementation

```
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; //example of tab handling

  @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(),
          floatingActionButton: tab == TabState.todos
              ? FloatingActionButton(
                  child: const Icon(Icons.plus_one),
            onPressed: () {
              Navigator.pushNamed(context, "/addTodo");

            },
          ) : Container(),
        );
  }
```

```
}
```

The UpdateTodoPage is statefull and uses a Scaffold widget too. The reason why it is implemented with a statefull widget is that it uses TextEditingController objects which need a statefull widget to work properly. The *body* is filled with a Column widget containing two TextField widgets and a TextButton widget. The TextButton widget *onPressed* field is left empty for future implementation.

Source Code 2.13: Todo app - UpdateTodoPage implementation

```
class UpdateTodoPage extends StatefulWidget {
  final Todo todo;

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

  @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 description'),
          ),
          TextButton(
              onPressed: () {
                //to be filled
              },
              child: const Text("Confirm"))
        ],
      ));
  }

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

The AddTodoPage is statefull and uses a Scaffold widget. The *body* field is filled with a Column widget containing two TextField widgets and a TextButton widget. The TextButton *onChanged* field is left empty for future implementation.

Source Code 2.14: Todo app - AddTodoPage implementation

```
class AddTodoPage extends StatefulWidget {

  const AddTodoPage({Key? key, required})
      : super(key: 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: () {
                  //to be filled
                },
                child: const Text("Create"))
          ],
        ));
  }

  @override
```

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

Here ends the implementation of the shared code.

2.2.2. InheritedWidget/Model and SetState implementation

This section implements the Todo application using two standard tools the Flutter framework provides in order to handle the state. These tools are InheritedWidgets and InheritedModels plus the usual *setState* function.

Base functionalities

The 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 2.15: Todo app - InheritedWidget - extension to InheritedWidget

```
class TodoInheritedData extends InheritedWidget{
```

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

Source Code 2.16: 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, //computing stats
      filteredTodos = filterTodo(todos, filter),//computing filtered list
      super(child: child, key: key);
}
```

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

TodoInheritedData widget is stateless. It cannot be changed (every value is final) and a new TodoInheritedData widget must be provided when a data change occurs. The *updateShouldNotify* method must be overridden inside the TodoInheritedData class. This method belongs to the InheritedWidget class and its override is mandatory. It helps avoiding useless UI rebuilding when a new state, without actual data changes, occurs. Once a TodoInheritedData widget is replaced with a new one, the new widget takes care of calling the *updateShouldNotify* method and deciding 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 2.17: Todo app - InheritedWidget - TodoInheritedData's *updateShouldNotify* method override

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

```
}
```

listEquals function is provided by the Dart language. It takes two lists and compares them element by element, returning true if all elements are equal. In the Source Code 2.17, 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 (it 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 Flutter framework. In case no TodoInheritedData widget is found it raises a runtime error.

Source Code 2.18: 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 contains the state and bothers to create a new instance of the TodoInheritedData widget every time the state changes. Everytime its internal state is changed (using *setState*), indeed, a new instance of TodoInheritedData widget is produced and substituted with the old one. In this way, changes are reported to the subtree which sees a different image of the state and rebuild with it. I personally did not appreciate this adjunctive data cache layer InheritedWidget introduces. On one way it is simple and works really well for its purpose , on the other hand 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 atomic/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 levels 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 is 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 grows the higher will be the probability that this scenario show up. 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 each TodoInheritedData creation)

Source Code 2.19: Todo app - InheritedWidget - TodoProvider widget 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 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 2.20: Todo app - InheritedWidget - TodoProvider 's *init* method implementation

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

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 only accessible in a context where a TodoProvider is already present. In other words, 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 one containing the TodoProvider widget.

Source Code 2.21: Todo app - InheritedWidget - Data injection in the HomePage's subtree

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

  @override
  Widget build(BuildContext context) {
    return TodoProvider(// new TodoProvider widget
      child: Builder(// new Builder widget
      builder: (context) {
        return Scaffold(...) // the rest of the HomePage;
        }
      ),
    );
  }
}
```

The TodoView component - TodoView component can now be populated. It is a stateless widget that looks up for the *filteredTodos* list, contained in the TodoInherited-Data widget. It uses the *of* method, defined in Source Code 2.18, to access the nearest TodoInheritedData instance. Then, it uses the list to populate the ListView widget.

Source Code 2.22: Todo app - InheritedWidget - TodoView component implementation

```
class TodoView extends StatelessWidget {

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

  @override
  Widget build(BuildContext context) {
    print("Building TodoView");
    //retrieving the filtered list from the state
    final List<Todo> filteredTodos =
     TodoInheritedData.of(context).filteredTodos;

    return ListView.builder(
      itemCount: filteredTodos.length,// to use it here
```

```
      itemBuilder: (context, index) {
        return TodoItem(
          todo: filteredTodos.elementAt(index),// and here
        );
      },
    );
  }
}
```

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 VisibilityFilterSelector component is ready to be used as defined in Source Code 2.10 . Its current DropdownButton's *value* field is filled looking up for the *filter* value in the TodoInheritedData widget.

Source Code 2.23: Todo app - InheritedWidget - VisibilityFilterSelector component implementation

```
class VisibilityFilterSelector extends StatelessWidget {

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

  @override
  Widget build(BuildContext context) {
    print("Building Visibility filter");
    // retrieving the visibility filter from the state
    VisibilityFilter filter= TodoInheritedData.of(context).filter;
    return DropdownButton<VisibilityFilter>(
      value: filter, // use it here
      items: VisibilityFilter.values.map((filter) {
```

```
        return DropdownMenuItem<VisibilityFilter>(
            child: Text(describeEnum(filter)), value: filter);
      }).toList(),
      onChanged: (filter) {
        //to be implemented
      },
    );
  }
}
```

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 ,as 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 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 to 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 sets the value of TodoProvider's *filter* variable using the *setState* method.

Source Code 2.24: Todo app - InheritedWidget - TodoProvider's *onChangeFilter* field 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, an instance of the *onChangeFilter* function must be provided to the TodoInheritedData widget to make it accessible in the subtree. A new parameter is added, tough , in the TodoInheritedData class.

Source Code 2.25: Todo app - InheritedWidget - TodoInheritedData widget expansion

```
class TodoInheritedData extends InheritedWidget {
  final List<Todo> todos;
  final List<Todo> filteredTodos;
  final void Function(VisibilityFilter) onChangeFilter; //new variable
  final int stats;
  final VisibilityFilter filter;
```

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

Source Code 2.26: Todo app - InheritedWidget - *onChangeFilter* function injection into TodoInheritedData widget

```
@override
Widget build(BuildContext context) {
  return TodoInheritedData(
    todos: todos,
    onChangeFilter: onChangeFilter,//new argument
```

```
    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 2.27: 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 for the moment. It takes as paramenter a Todo instance and takes care of displaing it. TodoItem widget does not access the state. The todo to be displayed is, indeed, passed by the parent widget (the TodoView). However, TodoItem widget needs to write the state once the checkbox is tapped. For the moment, the Checkbox widget is just showing the value of the completed field and Its *onChange* function is still empty. When the checkbox is tapped, a change into the corresponding Todo's *completed* field should be fired and a rebuild of the TodoItem widget performed. In order to do so, TodoIhneritedData widget should provide a state changing function for the *completed* field. The process to be done is the same exposed in the previous paragraph. Into the TodoProvider stateful widget a new function ,called *onSetCompleted* , is created. This function takes as parameter the *id* of the todo to be changed and the new value for the *completed* field.

Source Code 2.28: Todo app - InheritedWidget - TodoProvider widget *onSetCompleted* function implementation

```
void onSetCompleted(int id, bool completed) {
    //control the todo's existance
    assert(todoExists(todos, id) == true, 'No todo with id : \$id');
    //change the state
    setState(() {
      todos = todos.map((todo) {
        if (todo.id == id) {
          return Todo(
              id: id,
              name: todo.name,
              description: todo.description,
              completed: completed);
        } else {
          return todo;
        }
      }).toList();
    });
  }
```

In the *onSetCompleted* function , *todos* list is scanned using the *map* method. Once the searched todo is found, its *completed* value is updated. Calling the *onSetCompleted* method on the TodoProvider stateful widget causes the *build* method to run again and to substitute the current TodoInheritedData widget with a new , updated, one. As before, the function is passed from the TodoProvider widget to the TodoInheritedData widget ,on its creation. In this way, the function is made accessible down the tree. It is now possible to call *onSetCompleted* function inside the *onChanged* field of the TodoItem's Checkbox.

Source Code 2.29: Todo app - InheritedWidget - TodoItem's Checkbox *onChanged* field implementation

```
Checkbox(
value: todo.completed,
    onChanged: (value) {
    //call the onSetCompleted method
```

```
    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 part of the state concerning the stats. The nearest instance of the TodoInheritedData widget is retrieved using the *of* method and used to fill in the Text widget.

Source Code 2.30: 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:
        //retrive the value of the stats
        Text(TodoInheritedData.of(context).stats.toString()));
  }
}
```

The TabSelector component - The part of the state concerning the tab just includes one variable and is related to the HomePage only. The fact that a state management solution is being used does not mean that it has to be adopted 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. Sometimes, indeed, for the parts of the state that can be refered as "local" ,meaning that they 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. 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 in Source Code 2.31 for more than one aspect. Firstly, 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. Secondly, it is simpler , in pratice, to create a local variable and to hamdle it with *setState* and stateful widgets instead of adding a new variable to the TodoInheritedData widget , manage 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 tab changing function to accomplish the task. This new function, called *onTabChange*, takes a int value as parameter and uses the *setState* method to update the *tab* variabile. This int value refers to the index of the tapped element inside the list of BottomNavigationBarItem widgets provided to the *items* field.

Source Code 2.31: Todo app - InheritedWidget - HomePage's *onTabChange* function implementation

```
TabState tab = TabState.todos; // new variable inserted in the HomePage

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 it, togheter with the tab variable, as parameter and use it in the BottomNavigationBar's *onTap* field.

Source Code 2.32: Todo app - InheritedWidget - TabSelector component implementation

```
class TabSelector extends StatelessWidget {
  final TabState currTab; // new parameter
  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), //used here
      onTap: onTabChange, //used here
      items: (...)
    );
  }
}
```

It is now possible to switch from tabs. All the base functionalities were implemented. The whole process was fast and straight forward.

Features addition

Here stats the development process described in subsection 2.1.2.

Todo addition feature - TodoInheritedData widget must provide a way of adding todos to the list. A new function is created, in the TodoProvider widget, and passed to the TodoInheritedData widget as parameter. This new function is called *onAddTodo* and takes two parameters (*name* and *description*).

Source Code 2.33: Todo app - InheritedWidget - TodoProvider's *onAddTodo* function implementation

```
  void onAddTodo(String name, String desc) {
    //generate a new unique id
    int newId = generateId(todos);
    //create the new todo
    Todo newTodo = Todo(
```

```
        id: newId,
        name: name,
        description: desc + " " + newId.toString(),
        completed: false);
    //perform the state change
    List<Todo> newList = List.from(todos);
    newList.add(newTodo);
    setState(() {
      todos = newList;
    });
  }
```

After generating a new unique id, it creates a new Todo instance, called *newTodo*, with the *completed* field set to *false* . Adding the *newTodo* to the TodoProvider's *todos* list requires a bit of workaround. The state of a stateful widget is immutable. It is a bit counterintuitive but, as we already discussed, in functional programming is generally easier to create new instances instead of mutating existing ones. Stateful widget's state can only be changed by the *setState* method. Unfortunately, the *add* method for lists, dart languege provides, is of type void just adds the new value to the existing list's instance without returning anything. For this reason, directly calling the *add* method to the TodoProvider's local *todos* list would have no effect. The *todos* list is immutable and cannot be changed. TodoProvider's *todos* list must be completely replaced with a new instance containing the new todo. Firstly, 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 *onAddTodo* function to it, on its creation.

Source Code 2.34: Todo app - InheritedWidget - *onAddTodo* function propagation

```
class TodoInheritedData extends InheritedWidget {

  final void Function(String,String) onAddTodo; // new variable
```

```
  final List<Todo> todos;
  final List<Todo> filteredTodos;
  final void Function(VisibilityFilter) onChangeFilter;
  final int stats;
  final VisibilityFilter filter;

  (...)

class TodoProvider extends StatefulWidget {
@override
Widget build(BuildContext context) {
  return TodoInheritedData(
    todos: todos,
    onChangeFilter: onChangeFilter,
    onAddTodo: onAddTodo, // passing the onAddTodo function
    onSetCompleted: onSetCompleted,
    filter: filter,
    child: widget.child,
  );
}
```

In the AddTodoPage, a TextButton widget has been already set up 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 2.5. The AddTodoPage is added as a child of the MaterialApp widget.

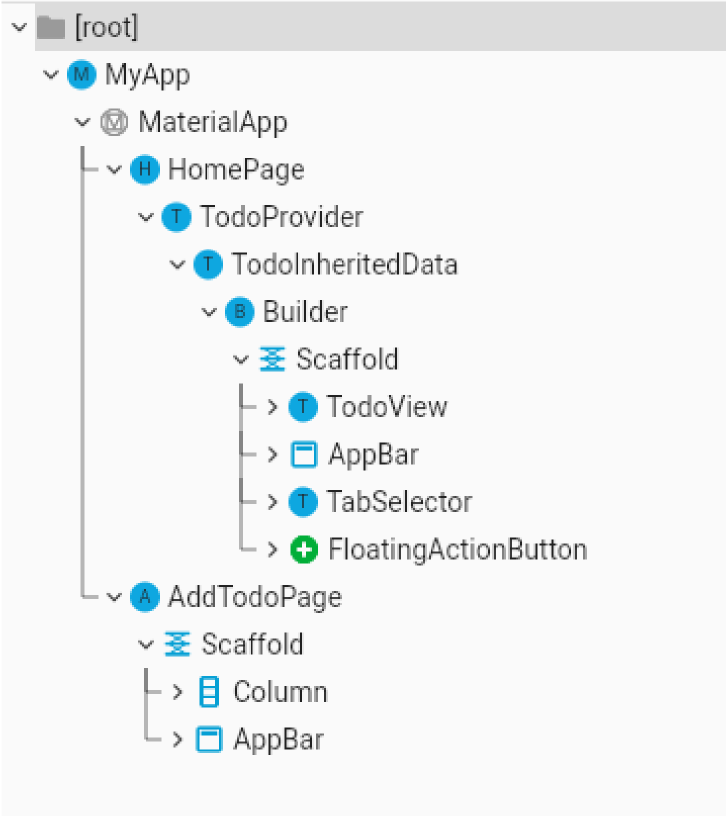


Figure 2.5: Shows the widgets tree structure in the AddTodoPage

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. It is not possible, tough, to call the *of* method as we did before. Indeed, calling the *of* method in a context where a TodoProvider widget is not present causes the assertion line (the one below) in Source Code 2.18 to return *false* and to rise a runtime error.

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

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 2.35: Todo app - InheritedWidget - AddTodoPage's callback function parameter creation

```
class AddTodoPage extends StatefulWidget {
  final void Function(String, String) addTodoCallback; // new parameter

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

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

Source Code 2.36: Todo app - InheritedWidget - "*addTodo*" route parameters redefinition

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

The *addTodoCallback* function is then used in the *onPressed* field of the TextButton widget in the AddTodoPage. Once the TextButton is tapped, the new todo is added to the list and the AddTodoPage is popped returning to the HomePage. Being the state changed the HomePage is rebuilt.

Source Code 2.37: Todo app - InheritedWidget - AddTodoPage *onPressed* field implementation

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

Raising the TodoProvider widget above the MaterialApp widget would not be a good solution. The higher the TodoProvider widget resides in the tree the more widgets are rebuilt on state changes. In this case it is easier to pass the callback function as parameter to the AddTodoPage.

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

Source Code 2.38: Todo app - InheritedWidget - TodoProvider's *onUpdateTodo* function implementation

```
void onUpdateTodo(int id, String newName, String newDesc) {
  //control the todo's existance
  assert(todoExists(todos, id) == true, 'No todo with id : \$id');
  //create a new list with the updated todo
  List<Todo> newTodosList = todos.map((todo) {
    if (todo.id == id) {
      return Todo(
          completed: todo.completed,
          description: newDesc,
          name: newName,
          id: todo.id);
    } else {
      return todo;
    }
  }).toList();
  //update the state
  setState(() {
    todos = newTodosList;
  });
}
```

The *onUpdateTodo* function checks if a todo matching the id exists. Then, for the same immutability concept we dealt with in the previous paragraph 2.30, a *newTodosList* is created and populated with the elements of 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.

Source Code 2.39: Todo app - InheritedWidget - *onUpdateTodo* function propagation

```
class TodoInheritedData extends InheritedWidget {

  final void Function(int, String,String) onUpdateTodo; // new variable
  final void Function(String,String) onAddTodo;
  final List<Todo> todos;
  final List<Todo> filteredTodos;
  final void Function(VisibilityFilter) onChangeFilter;
  final int stats;
  final VisibilityFilter filter;

  (...)

class TodoProvider extends StatefulWidget {

@override
Widget build(BuildContext context) {
  return TodoInheritedData(
    todos: todos,
    onChangeFilter: onChangeFilter,
    onAddTodo: onAddTodo,
    onSetCompleted: onSetCompleted,
    onUpdateTodo: onUpdateTodo, // passing the onUpdateTodo function
    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 is of type Function taking two Strings as arguments (the id will be already set up by the calling page).

Source Code 2.40: Todo app - InheritedWidget - UpdateTodoPage callback function parameter creation

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

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

 (...)
```

We are 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 a single object as argument between routes. In this case, besides the *onUpdateTodo* function also a todo instance must be passed to the UpdateTodoPage. For this reason, a wrapper class is created with the name *UpdateTodoPageArguments* .

Source Code 2.41: Todo app - InheritedWidget - UpdateTodoPageArguments class implementation

```
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 2.42: Todo app - InheritedWidget - Using a UpdateTodoPageArguments instance to pass argument between routes

```
Navigator.pushNamed(context, "/updateTodo",
//passing the the state changing function using a wrapper class
    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 parameters (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 2.43: Todo app - InheritedWidget - "*updateTodo*" route re-definition

```
routes: {
  "/": (context) => const HomePage(),
  "/updateTodo": (context) => UpdateTodoPage(
        todo: (ModalRoute.of(context)!.settings.arguments
                as UpdateTodoPageArguments)
            .todo,
        callback:
//access the wrapper class to populate the callback parameter
         (ModalRoute.of(context)!.settings.arguments
                as UpdateTodoPageArguments)
            .updateState,
      ),
```

Now that the *onUpdateTodo* function is accessible in the UpdateTodoPage it is time to call it inside the TextButton *onPressed* field.

Source Code 2.44: Todo app - InheritedWidget - UpdateTodoPage *onPressed* field implementation

```
TextButton(onPressed: () {
  //call the onUpdateTodo function
  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.

Rendering optimizations

I spent some hours trying to figure out how to make the single TodoItem widget rebuild, 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 widget 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 alone. InheritedWidgets, indeed, do not offer this possibility at all. Every time a widget accesses the state in the TodoProvider's subtree, using the *of* method, it 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 is 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 accesses 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 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. The extension to InheritedWidget is substituted with the extension to the InheritedModel, in the TodoInheritedData class.

Source Code 2.45: 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, register to the aspect identified with the number 0. Widgets that do always need to rebuild register to the aspect identified with number 1. Widgets that need to rebuild when a non-structural change, affecting the specific Todo with id n, occurs 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 *of* method, contained in the TodoInheritedData widget, should be updated taking into account the *aspect* parameter. Morevover, the *result* variable should be populated with the *inheritedFrom* static method belonging to the InheritedModel class, instead of the *dependOnInheritedWidgetOfExactType* static method belonging to InheritedWidget class.

Source Code 2.46: Todo app - InheritedModel - TodoInheritedData's *of* method implementation

```
//add the aspect argument
static TodoInheritedData of(BuildContext context, {required int aspect})
 {
  final TodoInheritedData? result =
  //calling the inheritFrom method using the aspect parameter
```

```
      InheritedModel.inheritFrom<TodoInheritedData>(context,
       aspect: aspect);
  assert(result != null, 'No TodoInheritedData found in context');
  return result!;
}
```

All the lines of code accessing 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, it is necessary to "teach" the TodoInheritedData widget to recognize aspects' changes. To do so, InheritedModel provides a method called *updateShouldNotifyDepenedent* that is similar to the InheritedWidget's one, *updateShouldNotify* , but takes as argument also a Set of ints called *dependencies* (aspects). Once a transition occurs this method is called once for every widget that registered to state's changes. The *dependencies* variable will contain all the *aspects* the widget registered to (only one for every widget in our case). Before proceeding with the *updateShouldNotifyDepenedent* method's implementation we define a function called *_checkStructuralChange* that check if two lists have strctural differences.

Source Code 2.47: Todo app - InheritedModel - TodoInheritedData's *updateShouldNotifyDepented* method implementation

```
bool _checkStructuralChange(List<Todo> before, List<Todo> current) {
   //calculate the length of the current filtered list
   int currLen = current.length;
   //calculate the length of the previous filtered list
   int prevLen = before.length;

   bool structureRebuildLen = (currLen != prevLen);
```

```
    //check if the two lengths differ
    if (structureRebuildLen) {
      // if they differ a structural change occured
      return true;
    } else {
      //map the current list to a list containing the ids only
      List<int> currIds = current.map((todo) => todo.id).toList();
      //map the previous list to a list containing the ids only
      List<int> prevIds = before.map((todo) => todo.id).toList();
      //check they are the same
      bool sameIds = listEquals(currIds, prevIds);
      if (!sameIds) {
        //if they differ a structural change uccurred
        return true;
      } else {
        // no structural change occured
        return false;
      }
    }
  }
  @override
  bool updateShouldNotifyDependent(
      TodoInheritedData oldWidget, Set<int> dependencies) {
    if (dependencies.contains(1)) {
    // the widget do always need to rebuild
      return true;
    }
    if (dependencies.contains(0)) {
    //widget registered for structural changes
      bool structuralChange =
          _checkStructuralChange(oldWidget.filteredTodos, filteredTodos);
      if (structuralChange) {
      //in case structural changes occurred
        return true;
      } else {
        return false;
```

```
      }
    }
    //if this point is reached the widget registered
    //for a particular todo's changes
    //check if that todo changed
    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 2.48: Todo app - InheritedModel - TodoInheritedData's *updateShouldNotifyDepented* method pseudocode

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

I propose now two pratical examples to clearify a bit the *updateShouldNotifyDepenedent* behaviour.

Pratical example 1 - Suppose to have a list of todos containing two todo instances, one with id 38 and one with id 121. In the HomePage there is a TodoView widget containing two TodoItem widgets. TodoView widget calls the *of* method in order to access the state passing the int value 0 as parameter. The two TodoItem widgets call the *of* method in order to access the state passing their todo's id value as parameter. Suppose now to add a new todo in the list using the AddTodoPage. The *updateShouldNotifyDepented* method is called once for every widget that access the state. Note that also the TabSelector and the VisibilityFilterSelector widgets access the state using the *of* method but their are not considered in this example. So, the *updateShouldNotifyDepenedent* method is called once for the TodoView widget, with dependencies value equal to 0. It is also called once for every TodoItem widget with dependencies value equal to 38, in one case, and equal to 121, in the other. Before actually rebuilding any widget the framework executes all the *updateShouldNotifyDepenedent* method calls. We start analizing the call for the TodoItem widget with id 38 with reference to the pseudocode defined in Source Code 2.49. In this case a structural change occured (we added a todo) but the widget did not registered for structural changes (dependencies do not contains 0). Moreover, the widget registered for changes in the todo with id 38 but no changes occured in that todo. The function returns false and the widget is not rebuilt. The same happens for the *updateShouldNotifyDepenedent* methods execution of the TodoItem widget with id 121. In the *updateShouldNotifyDepenedent* method execution for the TodoView widget, instead, the dependencies list contains the value 0(and only that). In this case the TodoView widget registered for structural changes and a structural change occured (the new list is longer than the old one). The *updateShouldNotifyDepenedent* method returns true and the widget is rebuilt creating a new TodoView widget composed by three TodoItem widgets this time.

Pratical example 2 - Suppose to have a list of todos containing two todo instances as before, one with id 38 and one with id 121. In the HomePage there is a TodoView widget containing two TodoItem widgets. TodoView widget calls the *of* method in order to access the state passing the int value 0 as parameter. The two TodoItem widgets call the *of* method in order to access the state passing their corresponding todo's id value as parameter. Suppose now to tap on the TodoItem widget's checkbox with id 38 in order to change its *completed* value. As before the *updateShouldNotifyDepenedent* method is called once for every widget that access the state. The *updateShouldNotifyDepenedent* method execution regarding the TodoView widget returns false because the second if in the Source Code 2.49 evaluates to false due to the fact that the widget did not registered for specific todo's changes. The TodoView widget is not rebuilt then. In the *updateShouldNotify-Depenedent* method execution regarding the TodoItem widget with id 121 the part that leads the entire method to return false is the second expression in the second if statement.

Indeed, the todo with id 121 did not changed with respect to the one contained in the previous state. The TodoItem widget with is 121 is consequently not rebuilt. The execution of the *updateShouldNotifyDepenedent* method concerning the TodoItem with id 38, instead, return true. The second condition is, indeed, satisfied by the fact that the widget registered for a specific todo's change and also that todo changed. The todo with id 38 is, indeed, changed with respect to the todo with id 38 in the previous state. This leads the TodoItem widget with id 38 to rebuild leaving all the other widgets unchanged.

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 optimizations, TodoItem widgets rebuilt correctly comes from the fact that every 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 2.49: Todo app - InheritedModel - accesing the state into TodoItem component

```
class TodoItem extends StatelessWidget {
  final int id; // Todo variable replaced with a int one

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

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

At this point I also suggest to generate a new unique Key, in the TodoView widget, and pass it to the TodoItem widget. I indeed faced a "strange" bug/behaviour before providing a unique key to every TodoItem widgets. This bug showed up performing multiple filter changes and subsequently performing a todo update regarding the *completed* field (but also in case of other updates I suppose). In that case not only the interested TodoItem widget rebuilt but also other, apparently random, ones. Investigating a bit I discovered that some TodoItem widgets turned out to be registered for more than one aspect after the filter changes. This was clearly not possible because every TodoItem widget registers for a single aspect by construction. The only reason I could think of was that some of them were reused by the framework to avoid discarding them and rebuilding them from scratch. Indeed, when the TodoView is rebuilt multiple times in a single execution the Flutter framework tries to minimize the creation of TodoItem widgets. I did not understood in depth where this bug was generated but it was solved right after I added a unique key to every TodoItem widget. Providing a unique key blocks the framework from reusing TodoItem instances. After this adjunctive passage the application is working as intentioned and the rendering optimizations were successfully accomplished.

Conclusions

Table 2.1 reports some measurements taken from the InheritedWidget's implementation process. The *lines of code* column represents the lines of code added or updated with respect to the shared project structure proposed in subsection 2.2.1. The *time* column represents the time spent in order to implement the corresponding subprocess. The unit of measure **h** stands for hours and **m** stands for minutes. The *lines-time ratio* column represents the average number of lines written in a minute. The *classes* column represents the number of created classes in each subprocess.

Measurement for InheritedWidget process

	lines of code	time	lines/time ratio	classes
base functionalities	100	2-3 h	0.66 l/m	2
feature addition	58	20-30 m	2.32 l/m	1
rendering optimization	45	8-10 h	0.084 l/m	0

Table 2.1: InheritedWidget measurements table

Figure 2.6 represents a pie chart showing the percentage of lines of code written in each implementation's process, including the one regarding the shared structure. The whole process is quite balanced in term of lines of code. The 64% of the code is used to produce the presentation layer and the remaining 36% is used to manage the state and its optimizations. Considering the fact that the UI is kept minimal truncating the necessary lines of code accentuates even more the fact that the state management took less than a half of the entire written code.

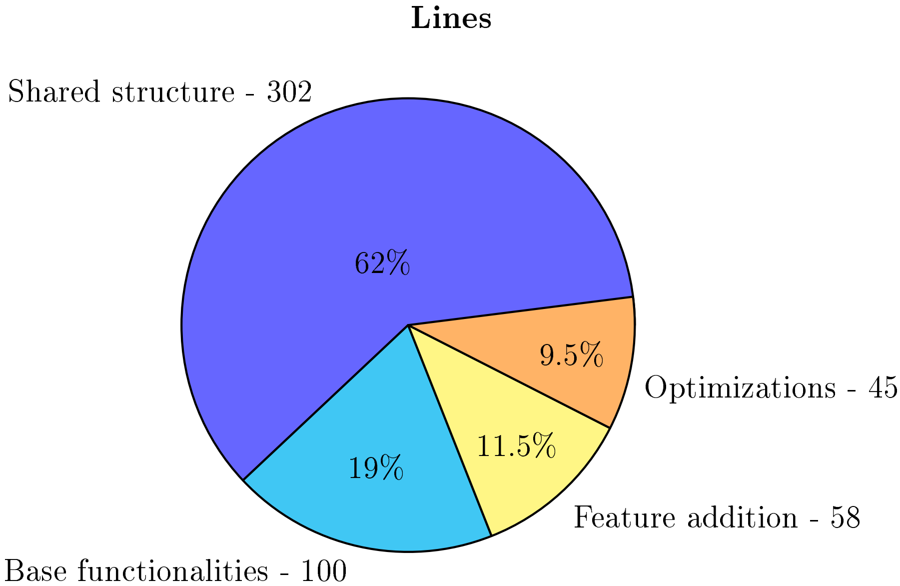


Figure 2.6: Shows the pie chart regarding the lines of code spent in each subprocess for the InheritedWidget implementation

Figure 2.7 represents a pie chart showing the percentage of time spent in each implementation's process. Notice that the optimizations process took more than the 75% of the entire time.

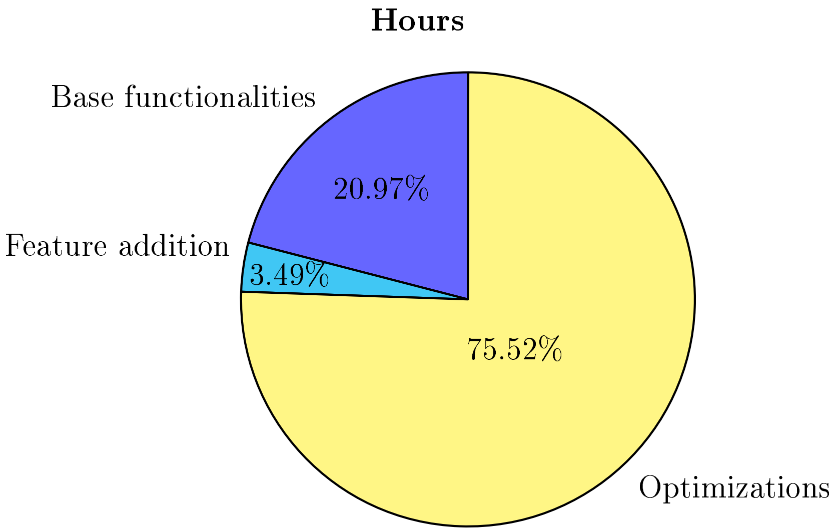


Figure 2.7: Shows the pie chart regarding the hours spent in each subprocess for the InheritedWidget implementation

Figure 2.8 shows the final folders structure for the InheritedWidget implementation. The only file added to the original folders structure is the todo_provider.dart file.

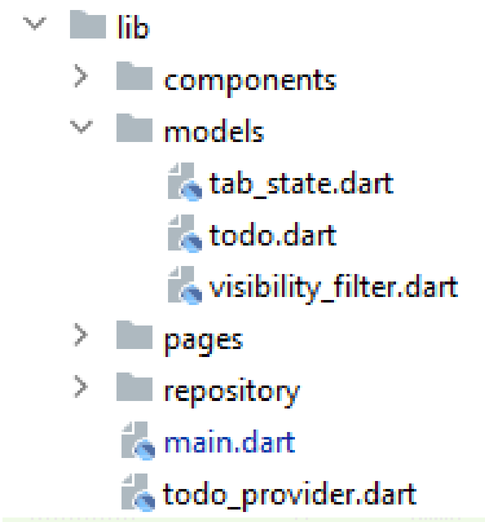
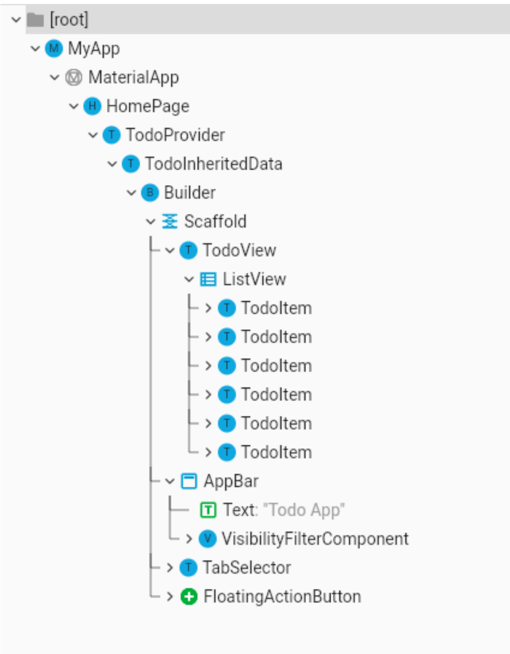
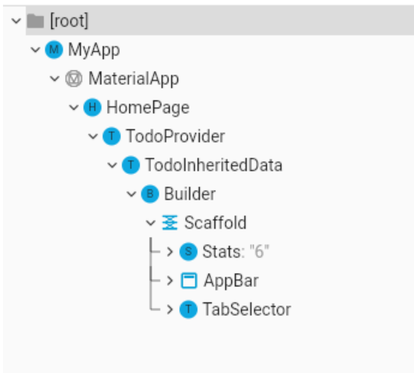


Figure 2.8: Shows the final folders structure for the InheritedWidget implementation of the Todos app

Figure 2.9 represents the widget's tree structure for the InheritedWidget final application. Notice the TodoProvider widget, situated below the HomePage, providing an instance of the TodoInheritedData to the subtree.



(a) Widgets tree structure *todos* tab



(b) Widgets tree structure *stats* tab

Figure 2.9: Shows the widgets tree structure for InhritedWidget Todos app

2.2.3. Redux implementation

This section implements the Todo application using the Redux package in order to handle the state.

Base funtionalities

The AppState - Redux solution requires the state to be centrilized in a unique location. A model for this centrilized component must be defined in order to group up all the subparts. Subparts of the state regarding the filter and the tab have been already modelled in the implementation of the shared parts in paragraph 2.2.1 in Source Code 2.2 and 2.3. They are used now to compose a new class, called AppState, that groups all the subparts in a unique place throughout the entire application.

Source Code 2.50: Todo app - Redux - AppState model implementation

```
class AppState {

  VisibilityFilter visibilityFilter;
  List<Todo> todos;
  TabState tabState;

  AppState({this.todos=const [],
  this.tabState= TabState.todos,
  this.visibilityFilter= VisibilityFilter.all});
}
```

Notice that the list of filtered todos is not contained in the AppState model. When the Redux solution is used, indeed, the centralized state is kept as simple as possible and the parts of the state that can be computed or derived should be omitted. The filtered list of todo will be computed in the presentation layer when needed. This approach, however, can introduce reduntant computations due to the fact that the filtered list is calculated at every widget's build. This is where Selectors come into play; they propose a mechanism based on the memoization techinque in order to reuse precomputed values. This aspect will be deeper investigated later.

The actions - In order to mutate the state is necessary to define *actions*. Actions are processed by reducers to produce new states. Actions are just instances of predeclared classes. We start defining the action's classes needed to change the state regarding the list of todos. As usual, the first two features to be implemented are the fetching process and the setting of the *completed* field of a specific todo. Due to the way Redux works, asynchronous actions are handled by Middlewares. Reducers, indeed, are pure functions and are not suited for handling asynchronous code. Two actions are defined just for the fetching process. One is called *LoadTodoAction* and will be intercepted by the middleware which takes care of fetching todos from the database. The second is called *LoadTodoSuccededAction* and carries the list of fetched todos. When the fetching process in the middleware terminates, a new *LoadTodoSuccededAction* is emited and handled by the AppState's reducers.

Source Code 2.51: Todo app - Redux - actions implementation for the fetching process

```
class LoadTodoAction{
  @override
  String toString(){
    return "LoadTodoAction";
  }
}
class LoadTodoSucceededAction{
  List<Todo> todos;
   LoadTodoSucceededAction(this.todos);

   @override
  String toString(){
    return "LoadTodoSucceededAction";
  }
}
```

Another action class is created in order to handle the setting o the *completed* field. In this case the action is synchronous and is directly handled by reducers. This new action is called *SetCompletedAction* and contains the id of the todo to be changed and the new value for the *completed* field.

Source Code 2.52: Todo app - Redux - SetCompletedTodoAction implementation

```
class SetCompletedTodoAction {
  final int id;
  final bool completed;

  SetCompletedTodoAction(this.id, this.completed);

   @override
  String toString(){
    return "SetCompletedTodoAction";
  }
}
```

Two more actions are needed in order to handle the tab's and the visibility filter's changes. They are called respectively *SetTabAction* and *SetVisibilityFilterAction*. They contains the new *tab* value and the new *filter* value to be set.

Source Code 2.53: Todo app - Redux - SetTabAction and SetVisibilityFilterAction implementation

```
class SetTabAction{
  final TabState newtab;

  SetTabAction(this.newtab);

   @override
  String toString(){
    return "SetTabAction";
  }
}

class SetVisibilityFilterAction{
  VisibilityFilter filter;
```

```
  SetVisibilityFilterAction(this.filter);

    @override
  String toString(){
    return "SetVisibilityFilterAction";
  }
}
```

Reducers - Is the turn now for reducers's definition. They link actions with new states. Even if the usage of the Redux state management solution requires the centralization of the state in a unique component, the state's logic can be in any case split up in subparts. It is like a tree with a single root where the root is represented by the AppState's reducer. It can split up in many sub-reducers and every one of them can further split up into other sub-reducers. Therefore, the state is stored in single place, but its pieces can still be segmented and managed separately and independently. During the reasoning process it is easier to break the whole state into smaller pieces step by step using a top-down approach. However, in the implementation process, a bottom-up approach is usually taken. This is due to the fact that, during the implementation process, smaller bricks are required to build bigger components. In this presentation, for example, is not possible to define directly the AppState's reducer even if, logically, it should be the first reducer to be implemented. The AppState's reducer is composed by multiple sub reducers, in our case three. There is a reducer for the list of todos, a reducers for the filter and a reducer for the tab.

The todoReducer - The reducer for the list of todos needs to handle two actions, the *LoadTodoSuccedeedAction* and the *SetCompletedTodoAction*. The *todoReducer* is a combination of two subreducers both handling a specific action. As we already said, reducers are pure functions. They take the previous state and an action and return the next state. The reducer for the *LoadTodoSuccedeedAction* is called *setLoadedTodo* and just returns the list contained in the received action.

Source Code 2.54: Todo app - Redux - LoadTodoSuccedeedAction reducer implementation

```
List<Todo> _setLoadedTodo(List<Todo> todos,
 LoadTodoSucceededAction action) {
  return action.todos;
}
```

The reducer for the *SetCompletedTodoAction* is called *setCompletedTodo* and takes care of searching in the current list of todos the todo matching the id contained in the action. Once found, it is updated and a new instance of the whole list is created and returned. The necessity to create another instance for the list comes from the fact that, in order to recognize a state change, Redux needs to identify differences between the current state and the previous one. If we just update the list it would result to be equal to the previous one and the transition would not be recognised.

Source Code 2.55: Todo app - Redux - SetCompletedTodoAction reducer

```
List<Todo> _setCompletedTodo(List<Todo> todos,
 SetCompletedTodoAction action) {
  List<Todo> newList= todos.map((todo) => todo.id == action.id
      ? Todo(
          id: action.id,
          name: todo.name,
          description: todo.description,
          completed: action.completed)
      : todo).toList();

  return List.from(newList);
}
```

Now that all reducers related to the list of todos have been implemented we use some tools, the Redux package provides, in order to combine them in a single one binding the received actions to the correct sub-reducer. These tools are the *combineReducers* function and the *TypedReducer* class. The *TypedReducer* class is, indeed, a typed class that helps avoiding nested if-else structures which can generate lot of boilerplate and code unreadability. It binds a specific action to a reducer. *combineReducers* , instead, is a function that creates a new reducer composing sub-reducers provided in the form of *TypedReducers*. The two previously defined reducers are now merged into a single one called *todosReducer*.

Source Code 2.56: Todo app - Redux - todoReducer implementation using *combineReducers* function

```
final todoReducer = combineReducers<List<Todo>>([
  TypedReducer<List<Todo>, LoadTodoSucceededAction>(_setLoadedTodo),
  TypedReducer<List<Todo>, SetCompletedTodoAction>(_setCompletedTodo),
]);
```

The alternative would have been to write the *todosReducer* as presented in Source Code 2.57. The output is the same but the code is clearly less readable.

Source Code 2.57: Todo app - Redux - todoReducer implementation using the traditional way

```
final todosReducer = (List<Todo> todos, action) {
  if (action is LoadTodoSucceededAction) {
    return _setLoadedTodo(todos,action);
  } else if (action is SetCompletedTodoAction) {
    return _setCompletedTodo(todos, action);
  } else {
    return state;
  }
};
```

The tab's reducer and the visibility filter's reducer - The process is the same as before. Two reducers, called *setTabState* and *setVisibilityFilter*, are created in order to handle the actions of type *SetTabAction* and *SetVisibilityFilterAction* respectively. In both cases the value contained in the action is used to produce a new state. Both of them are used to create two other reducers called *tabReducer* and *visibilityFilterReducer* using the *combineReducers* function introduced earlier. In this case the usage of the *combineReducers* function wasn't really necessary by the fact that it combines only one reducer. However, in case new actions are introduced it gets handy.

Source Code 2.58: Todo app - Redux - tabReducer and visibilityFilterReducer implementation

```
//reducer for the tab
TabState _setTabState(TabState state, SetTabAction action){
   return action.newtab;
}
//combineReducers for the tab
final tabReducer= combineReducers<TabState>([
  TypedReducer<TabState, SetTabAction>(_setTabState),

]);
//reducer for the filter
VisibilityFilter _setVisibilityFilter(
    VisibilityFilter oldState, SetVisibilityFilterAction action) {
  return action.filter;
}
//combineReducers for the filter
final visibilityFilterReducer = combineReducers<VisibilityFilter>([
  TypedReducer<VisibilityFilter, SetVisibilityFilterAction>(
      _setVisibilityFilter)
]);
```

The AppState reducer - All the basic bricks have been implemented and can be used now to create the biggest reducer; the AppState's reducer. It is a function that takes the current *AppState* and an action. It then creates a new AppState instance using the sub-reducers it is composed of. Every sub-reducer processes the received action in order to investigate the necessity of perfom a transition in the part of the state it handles.

Source Code 2.59: Todo app - Redux - appStateReducer implementation

```
AppState appStateReducer(AppState appState, action) {
  return AppState(
      todos: todoReducer(appState.todos, action),
      tabState: tabReducer(appState.tabState, action),
      visibilityFilter: visibilityFilterReducer(appState.visibilityFilter,
      action));
}
```

The Middleware - All the necessary elements in order to start accessing the state in the presentation layer are settled up but the way in which todos are fetched from the database is not clear yet. Two actions were set up for this purpose but only one has been handled by a reducer. The process of fetching todos from the database is not immediate. It is asynchronous with respect to the application workflow. Reducers are not suited for handling asynchronous code, they need to be pure and as simple as possible. There are many ways, in practice, to deal with asynchronous code using Redux but, the most correct one (and also the one proposed in the documentation) is to use Middlewares. Middlewares has been introduce HERE RIEFERIMENTO. They act as a sort of proxy between actions and reducers. One or more middlewares can be set to be executed on actions' emission. They are used to handle asynchronous code but also side effects generated by actions. In our case, an action of type *LoadTodoAction* has been defined but is not handled by any reducer yet and it is ignored once received. However, it will pass through one or more middlewares before reaching the reducers. It is necessary to set up a middleware that intercepts it and starts the fetching process. A middleware is just a function that takes three parameters: the *store*, an *action* and the *next* dispatcher. It processes the action, probably accessing the store, and then passes the action to the next middleware. A new middleware function is defined and called *loadTodoMiddleware*. It checks if the dispatched action if of type *LoadTodoAction* and, in case it is, starts to load the todos from the database. Once the fetching process is completed it dispatches an action of type *LoadTodoSuccededAction* that contains the list of fetched todos. We previously set up a specific reducer in order to handle this type of action in the AppState reducer.

Source Code 2.60: Todo app - Redux - loadTodosMiddleware middleware implementation

```
void loadTodosMiddleware(Store<AppState> store, action,
 NextDispatcher next) {

  if (action is LoadTodoAction) {
    TodoRepository.loadTodos().then((todos)
     {store.dispatch(LoadTodoSucceededAction(todos));} );
  }
  next(action);
}
```

All the ingredients are now available to start composing our UI.

Making the state accessible - Redux solution uses Provider widgets to make the state accessible down the widgets tree. The state is unique and, therefore, should be placed in the root of the widgets tree, otherwise, some parts of the tree would not be covered by its accessibility. To do so, a StoreProvider widget is positioned at the root of app, right below the MyApp widget. An object of type Store must be provided to the StoreProvider widget, in the *store* field. The typed class Store is provided by the Redux package. In our case, the global state is modelled by the AppState class. The Store class constructor takes three parameters. The reducer for the AppState, an AppState instance that identifies the initial state and a list of middlewares. In our case a single middleware is used. In order to fetch todos at the application start we will use the *init* method of stateful widgets. The HomePage is already stateful and its *init* method is used in order to dispatch the first action : the *LoadTodosAction*. For simplicity the function to be executed in the *init* method is passed from the MyApp widget, where the store is already available, to the HomePage using a newly created parameter.

Source Code 2.61: Todo a pp - Redux - makes the Store accessible using a StoreProvider widget

```
void main() {
  WidgetsFlutterBinding.ensureInitialized();
  runApp(MyApp(
      store: Store<AppState>(appStateReducer,//pass the AppState's reducer
          initialState: AppState(), middleware: [loadTodosMiddleware]));
```

```
}

class MyApp extends StatelessWidget {
  final Store<AppState> store; //new parameter

  const MyApp({Key? key, required this.store}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    print("Building Material App");
    return StoreProvider(// use a StoreProvider widget
      store: store, //use the new parameter here
      child: MaterialApp(initialRoute: "/",
        routes: {
          //pass the todos's fetching action to the HomePage
          "/": (context) => HomePage(onInit: (){
            store.dispatch(LoadTodoAction());
            },),
            (...)
          },
      ),
    );
  }
}
```

Inside the HomePage, the *initState* method is set up in order to dispatch a *LoadTodoAction* using the function passed as parameter by the MaterialApp widget. In order to access the store, a StoreConnector widget is used. A StoreConnector widget takes two functions in its *converter* and *builder* fields. The *converter* function takes the state and creates a viewmodel containing the minimal information necessary to build the widget. The *builder* function actually uses the viewmodel in order to create the widget. The viewmodel is really important because idenfies the prospective from which, the widget, is looking at the centralized state. If the viewmodel changes the widget is rebuilt. Not always a state change produces a viewmodel change. The StoreConnector widget is a typed widget and takes two types in its definition: the store's type (the AppState) and the viewmodel's type (in this case just a TabState object). The HomePage only needs the part of the state related to the tab and, for this reason, it is not necessary to create an ad hoc viewmodel. The model of the TabState defined in Source Code 2.2 is enough to contain the necessary part of the state for the HomePage creation. In the *converter* field a function is provided which manipulates the state returning the current TabState value. The *builder* field is populated with a function that returns the usual Scaffold widget. Inside this function, the current *context* and the object returned from the *converter* function can be used. This last one is used to populate the Scaffold widget as usual.

Source Code 2.62: Todo app - Redux - HomePage implementation

```
class HomePage extends StatefulWidget {
  final void Function() onInit; //new parameter

  const HomePage({Key? key, required this.onInit}) : super(key: key);

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

class _HomePageState extends State<HomePage> {
  @override
  void initState() {
   //using the new function parameter to start the fetching process
    widget.onInit();
    super.initState();
  }

  @override
  Widget build(BuildContext context) {
    print("Building HomePage");
  //use a StoreConnector widget to access the state
    return StoreConnector<AppState, TabState>(
      //scan the store to retrive the current tab value
      converter: (store) => store.state.tabState,
      builder: (context, currTab) {
        return Scaffold(
```

```
            appBar: AppBar(
              title: const Text("Todo App"),
              actions:  [
                currTab == TabState.todos //use it here
                    ? const VisibilityFilterSelector()
                    : Container()
              ],
            ),//use it here
            body: currTab == TabState.todos ? const
             TodoView() : const Stats(),
            bottomNavigationBar: const TabSelector(),
            floatingActionButton: currTab == TabState.todos //use it here
                ? FloatingActionButton(...)
                : Container());
      },
    );
  }
}
```

We can now start implementing the component widgets but, first, a short digression about Selectors is taken.

Selectors - They are introduced hereRIFERIMENTO . Selectors are used to compute those parts of the state that entirely depends on other parts. In our case, for example, the filtered list entirely depends on the list of todos and the visibility filter. It is not included in the AppState with the idea of computing it in the presentation layer. This decision also comes from the fact that, if situated in the centralized state, would be hard to syncornize it with the changes in the todos list and in the visibility filter. The easiest way to deal with the filtered list is to compute it in the presentation layer before building the TodoView widget. However, this way of doing can become soon quite heavy by the fact that the computation of the filtered list is perfomed every time the widget is rebuilt. In this scenario Selectors come into play to memoize the previously computed values and to reuse them once accessed. Selectors are just functions that take as input the state an return an element composed using it. All the memorization part is perfomed by a third party package called *Reselect*. In order to use this package it must be included in the pubspec.yaml file under the *dependencies* field. It provides some functions called *createSelector* that take care of memoizing precomputed values and understanding when is necessary to recompute them. Selectors can be simple or composed. For example, two simple selectors can be implemented in our case. One takes the state and returns the visibility filter and the other takes the state and returns the list of todos.

Source Code 2.63: Todo app - Redux - first level Selectors implementation

```
final todosSelector = (AppState state) => state.todos;

final filterSelector = (AppState state) => state.visibilityFilter;
```

Selectors can be composed with other selectors to create articulated objects. Selectors are composed using the *createSelector* function followed by a number. For example, a selector computing the list of completed todos can be built using the *todosSelector* and the *createSelector1* function. The same con be done to compute the list of pending todos. Another Selector is created to finally compute the filtered list. It uses the four other selectors we just implemented and the *createSelector4* function. Besides of making the code more readable, selectors, allow to optimize the application's performances.

Source Code 2.64: Todo app - Redux - composed Selectors implementation

```
//computer the list of completed todos
final completedTodosSelector = createSelector1(
    todosSelector,
    (List<Todo> todos) =>
        todos.where((todo) => todo.completed == true).toList());

//compute the list of pending todos
final pendingTodosSelector = createSelector1(
    todosSelector,
    (List<Todo> todos) =>
        todos.where((todo) => todo.completed == false).toList());

//compute the filtered list
final filteredTodosSelector = createSelector4(
```

```
    todosSelector, filterSelector,
     completedTodosSelector, pendingTodosSelector,
    (List<Todo> todos, VisibilityFilter filter, List<Todo> completed,
        List<Todo> pending) {
  switch (filter) {
    case VisibilityFilter.completed:
      return completed;
    case VisibilityFilter.notCompleted:
      return pending;
    case VisibilityFilter.all:
      return todos;
  }
});
```

The TodoView component - After this short digression about selectors, we are ready to set up the TodoView component. Its internal ListView widget is wrapped into a StoreConnector widget typed with the AppState type and the List<Todo> type. The TodoView component just needs to access the part of the state concerning the filtered list of todos that is representable with an object of type List<Todo>. The list of filtered todos is not directly available in the AppState but selectors can be used to compute it. In the *converter* field of the StoreConnector widget, a function is provided which takes the store and returns the filtered list using the *filteredTodosSelector* defined Source Code 2.64. The *converter* function's output is available inside the *builder* field's function and is used to populate the ListView widget as usual.

Source Code 2.65: Todo app - Redux - TodoView component implementation

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

  @override
  Widget build(BuildContext context) {
    //use the StoreConnector widget to access the state
    return StoreConnector<AppState, List<Todo> >(
```

```
        builder: (context, todos) {
          print("Building TodoView");
          return ListView.builder(
            itemCount: todos.length, //use it here
            itemBuilder: (context, index) {
              return TodoItem(
                todo: todos.elementAt(index), //use it here
              );
            },
          );
        },
        converter: (store) {
          //use the selector
          return filteredTodosSelector(store.state);
        });
  }
}
```

The TodoItem component - The TodoItem component does not require any modification with respect to the implementation proposed in Source Code 2.8. It just receives a todo from the parent widget and exposes it to the user. The only missing part is the *onChanged* field of the Checkbox widget which is still empty. Inside the *onChanged* field, a function must be provided which updates the *completed* field of the visualized todo. The store is accessed using the *of* method of the StoreProvider widget (the *of* method gets the nearest instance of provided type, in our case AppState). The store is then used to dispatch an action of type *SetCompletedTodoAction* created using the id, of the visualized todo, and the *completed* Boolean value provided by the *onChanged* function.

Source Code 2.66: Todo app - Redux - TodoItem component's *onChanged* field implementation

```
Checkbox(
    value: todo.completed,
    onChanged: (completed) {
```

```
      StoreProvider.of<AppState>(context).dispatch(
          SetCompletedTodoAction(todo.id, completed!));
    }),
```

The VisibilityFilterSelector component - The VisibilityFilterSelector component only accesses the part of the state concerning the filter. The entire DropdownButton widget is wrapped into a StoreConnector widget. The StoreConnector's *converter* field is filled with a function taking the store and returning the current filter value. To do so, it uses the *filterSelector* selector implemented earlier in Source Code 2.63. The output of the *converter* function is accessed in the *builder* field function and used to populate the DropdownButton widget. The function used in the *onChanged* field of the DropdownMenuItem widgets gets an instance of the store using the StoreProvider widget's *of* method and dispatches an action of type *SetVisibilityFilterAction* using the DropdownMenuItem 's *filter* value.

Source Code 2.67: Todo app - Redux - VisibilityFilterSelector component implementation

```
@override
Widget build(BuildContext context) {
  //using a StoreConnector widget to access the state
  return StoreConnector<AppState, VisibilityFilter>(
    //scan the store to retrive the filter value
    converter: (store) => filterSelector(store.state),
    builder: (context, activeFilter) {
      print("Building Visibility filter");

      return DropdownButton<VisibilityFilter>(
        value: activeFilter, //use it here
        items: (...),
        onChanged: (filter) {
          //dispatch an action of type SetVisibilityFilterAction
          StoreProvider.of<AppState>(context)
              .dispatch(SetVisibilityFilterAction(filter!));
```

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

The TabSelector component - Also in this case, the TabSelector component requires to read and also write the AppState. A StoreConnector widget is used to wrap the BottomNavigationBar widget and to connect it to the state. The view-model to be returned by the *converter* function is just an object of type TabState. An arrow function returning the current AppState's *tab* value is provided to the *converter* field. The function's output is then used in the *builder* field's function to populate the BottomNavigationBar widget. The *onTap* field of the BottomNavigatioBar widget is filled with a function that dispatches an action of type *SetTabAction* when fired.

Source Code 2.68: Todo app - Redux - TabSelector component implementation

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

  @override
  Widget build(BuildContext context) {
    //use a StoreConnector widget to access the state
    return StoreConnector<AppState, TabState>(
      //scan the store to retrive the tab value
      converter:(store)=>store.state.tabState,
      builder: (context, currTab) {
        print("Building Tab Selector");

        return BottomNavigationBar(
          //use it here
          currentIndex: TabState.values.indexOf(currTab),
          onTap: // dispatch an action of type SetTabAction
           (index)=>StoreProvider.of<AppState>(context)
           .dispatch(SetTabAction(TabState.values.elementAt(index))),
```

```
          items: (...)
        );
      },
    );
  }
}
```

The Stats component - The stats component only requires to read the state. The Center widget is wrapped into a StoreConnector widget. In the *converter* field's function the *completedTodoSelector* defined in Source Code 2.64 selector is used to access the list of completed todos. In this case the viewmodel to be outputted is just an int value representing the number of completed todos.

Source Code 2.69: Todo app - Redux - Stats component implementation

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

  @override
  Widget build(BuildContext context) {
    //use the StoreConnector widget to access the state
    return StoreConnector<AppState, int>(
      builder: (context, completed) {
        print("Building Stats");
        //use it here
        return Center(child: Text(completed.toString()));
      },
      converter: (store) {
        // use the selector
        return completedTodosSelector(store.state).length;
      },
    );
  }
}
```

At this point all the base functionalities have been implemented and are working fine.

Features addition

The first thing to do is to make the state provide a way of adding and updating todos. For this purpose two new actions are created with the name *AddTodoAction* and *UpdateTodoAction* respectively. The *AddTodoAction* contains the name and the description for the todo to be create. The *UpdateTodoAction*, besides the new name and description, also contains the id of the todo to be modified.

Source Code 2.70: Todo app - Redux - AddTodoAction and UpdateTodoAction implementation

```
class AddTodoAction {
  final String name;
  final String desc;

  AddTodoAction(this.name, this.desc);
}

class UpdateTodoAction{
  final String name;
  final String desc;
  final int id;

  UpdateTodoAction(this.name,this.desc,this.id);
}
```

Two new reducers are created in order to handle these new actions. They are called respectively *addTodo* and *updateTodo*. The *addTodo* reducer creates a new todo using the information contained in the *AddTodoAction* instace and a newly generated unique id. Then, it creates a new list instace and populates it with the elements of the old list plus the new todo.

Source Code 2.71: Todo app - Redux - addTodo reducer implementation

```
List<Todo> _addTodo(List<Todo> todos, AddTodoAction action) {
  //generate new unique id
  int newId = generateId(todos);
  //create a new todo instance
  Todo newTodo = Todo(
      id: newId,
      name: action.name,
      description: action.desc + " " + newId.toString(),
      completed: false);

  return List.from(todos)..add(newTodo);
}
```

The *updateTodo* reducer modifies the todo with the id matching the one contained in the action. Then, it generates a new list and fills it with the element contained in the current one.

Source Code 2.72: Todo app - Redux - updateTodo reducer implementation

```
List<Todo> _updateTodo(List<Todo> todos, UpdateTodoAction action){

  List<Todo> newList= todos.map((todo) => todo.id == action.id
      ? Todo(
      id: action.id,
      name: action.name,
      description: action.desc,
      completed: todo.completed)
      : todo).toList();

  return List.from(newList);
}
```

These new reducers are then combined with the already existing ones in the *com-*

bineReducers function and linked with the corresponding action using the typed class *TypedReducer*.

Source Code 2.73: Todo app - Redux - adding addTodo reducer and updateTodo reducer to the todoReducer

```
final todoReducer = combineReducers<List<Todo>>([
  TypedReducer<List<Todo>, AddTodoAction>(_addTodo), //new reducer
  TypedReducer<List<Todo>, LoadTodoSucceededAction>(_setLoadedTodo),
  TypedReducer<List<Todo>, SetCompletedTodoAction>(_setCompletedTodo),
  TypedReducer<List<Todo>, UpdateTodoAction>(_updateTodo), //new reducer
]);
```

The AppState can now handle actions of type *AddTodoAction* and *UpdateTodoAction*. These new functionalities can now be used in the AddTodoPage and in the UpdateTodoPage. The StoreProvider widget has been positioned in the root of the application to be available in all the subtrees. Is sufficient, tough, to access the store in the AddTodoPage and dispatch an action of type *AddTodoAction*, when the TextButton widget is tapped.

Source Code 2.74: Todo app - Redux - AddTodoPage *onPressed* field implementation

```
TextButton(
    onPressed: () {
      //create a new action
      final AddTodoAction action= AddTodoAction(textControllerName.text,
       textControllerDesc.text);
          //dispatch it
      StoreProvider.of<AppState>(context).dispatch(action);
      Navigator.pop(context);
    },
```

The same is done in the UpdateTodoPage. Once the TextButton widget is tapped an action of type *UpdateTodoAction* is dispatched.

Source Code 2.75: Todo app - Redux - UpdateTodoPage *onPressed* field implementation

```
TextButton(
    onPressed: () {
      //create an action
      final UpdateTodoAction action=
       UpdateTodoAction(textControllerName.text,textControllerDesc.text,widget.todo.id)
          //dispatch it
      StoreProvider.of<AppState>(context).dispatch(action);
      Navigator.pop(context);
    },
```

All the features have been successfully added.

Rendering optimization

In order to perform the rendering optimizations we will leverage on the fact that, the StoreConnector widget, only rebuilds when the viewmodel, it relies on, changes. Or better, this happens when a specific field of the StoreConnector widget, called *distinct*, is set to true. This feature, the Redux package provides, makes the optimization process really easy. We just need to define the correct viewmodel and provide it with the correct equality operator. Some changes must be done in the TodoView widget and in the TodoItem widget. Firstly, the TodoItem widget needs to interact with the state in order to understand when a change regarding its todo is performed. For the moment, indeed, the TodoItem widget just receives a todo instance from the parent widget and exposes it to the user. A StoreConnector widget is used to read the state in the TodoItem widget. The complete instance of the todo to be visualized is not necessary anymore but the id only is enough. Using the id, the corresponding todo is searched in the store by the *converter* field's function and passed to the *builder* field. The widget returned by the *builder* function remains the same with the only exception that it uses the todo instance got from the store instead of the one passed by the parent widget.

Source Code 2.76: Todo app - Redux - accessing the state into TodoItem component

```
class TodoItem extends StatelessWidget {
  final int id; //todo variable substituted with a int one

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

  @override
  Widget build(BuildContext context) {
    //use a StoreConnector widget to access the state
    return StoreConnector<AppState, Todo>(
      //set the distinct value to true enabling
      //comparison between viewmodels
      distinct: true,
        converter: (store) =>
          //retrive the corresponding todo scanning the store
            store.state.todos.firstWhere((element) => element.id == id),
        builder: (context, todo) {
          print("building: Todo Item \$id ");
          //the remaining part remains the same
          return InkWell(. . .);
        });
  }
}
```

Now that the TodoItem widget listens for its own todo changes, the optimization process concerning the TodoItem widget is automatically performed. We said, indeed, that the StoreConnector widget is rebuilt every time its viewmodel changes and we set the viewmodel as the corresponding todo instance in the AppStore. Once a state change occurs, the StoreConnector widget compares the current todo with the new one and, in case they differ, it rebuilds. To notice that this mechanism works because we redefined the equality operator between objects of type Todo in Source Code 2.4. An object of type Todo is equal to another one if all their internal values match. This equality differs from the traditional one by the fact that does not check for the entity's equality. Indeed, if it would, the two todos would appear to be different everytime even if their internal values match. This because, once a new state is emitted, the list of todos is recreated from scratch and its internal todos are replaced with new instances. In the dart language two distinct objects end to be different also if their internal values are exactly the same. This way of handling object already showed up numerous times in this overview and will show up even more in the next implementations. Going back to the to the TodoItem component, it already uses the correct equality operator to compare different viewmodels and so is capable to understand when to rebuild autonomously. The same process must be done in the TodoView widget. It already uses a StoreConnector widget to derive the list of filtered todos from the store. However, as we just said, two different plain lists appear to be always different by default also if their internal aspects matches, leading to unconditioned rebuilds. Furthermore, it is not possible to redefine the equality operator for lists and, even if it were, it would not be a good idea. A simple way to handle this scenario is to create an ad hoc viewmodel and redefine its equality operator in order to match our own rebuilding logic. To do so, a local class is created and called ViewModel. This local class just contains a list of todos.

Source Code 2.77: Todo app - Redux - TodoView component ad hoc ViewModel implementation

```
class _ViewModel {
  final List<Todo> todos;

  _ViewModel({required this.todos});

}
```

Inside the ViewModel class the equality operator is overridden making two ViewModel instances equal when their length matches and their internal ids match too. In this way the TodoView widget is rebuild only in case the filtered list has reported a structural change. (structural and not structural changes are exaplained in paragraph 2.1.3).

Source Code 2.78: Todo app - Redux - ViewModel's equality operator override

```
  //redefine the == operator to detect structural changes
  @override
  bool operator ==(Object other) {
```

```
    return ((other is _ViewModel) &&
        todos.length == other.todos.length &&
        todos.every(
            (todo) => other.todos.any((element) =>
             todo.id  == element.id)));
  }

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

After setting the *distinct* field to true and modifying the *converter* function to return a ViewModel instead of a plain List the optimizations are basically done.

Source Code 2.79: Todo app - Redux - TodoView component renders optimization

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

  @override
  Widget build(BuildContext context) {
    return StoreConnector<AppState, _ViewModel>(
        distinct: true, //set the distinc field to true
        builder: (context, vm) {
          print("Building TodoView");
          return ListView.builder(
            itemCount: vm.todos.length, //use the viewmodel
            itemBuilder: (context, index) {
              return TodoItem(
                id: vm.todos.elementAt(index).id, //use the viewmodel
              );
            },
          );
        },
        converter: (store) { //return a ViewModel instead of a plain list
```

```
      return _ViewModel(todos: filteredTodosSelector(store.state));
    });
  }
}
```

To put the the icing on the cake we set the *distinct* field to true also in the VisibilityFilterSelector component and in the TabSelector component. In this way they are rebuilt only in case their prospective of the state changes and not at every state transition.

Conclusions

Table 2.2 reports some measurements taken from the InheritedWidget's implementation process. The *lines of code* column represents the lines of code added or updated with respect to the shared project structure proposed in subsection 2.2.1. The *time* column represents the time spent in order to implement the corresponding subprocess. The unit of measure **h** stands for hours and **m** stands for minutes. The *lines-time ratio* column represents the average number of lines written in a minute. The *classes* column represents the number of created classes in each subprocess.

Recap

	lines of code	time	lines/time ratio	classes
base functionalities	175	9-11 h	0.3 l/m	6
feature addition	42	15-20 m	2.1 l/m	2
rendering optimization	26	1 h	0.43 l/m	1

Table 2.2: Redux measurement table

Figure 2.10 represents a pie chart showing the percentage of lines of code written in each implementation's process, including the one regarding the shared structure. The whole process is quite balanced in term of lines of code. The state management code covers less than the 45% of the entire code.

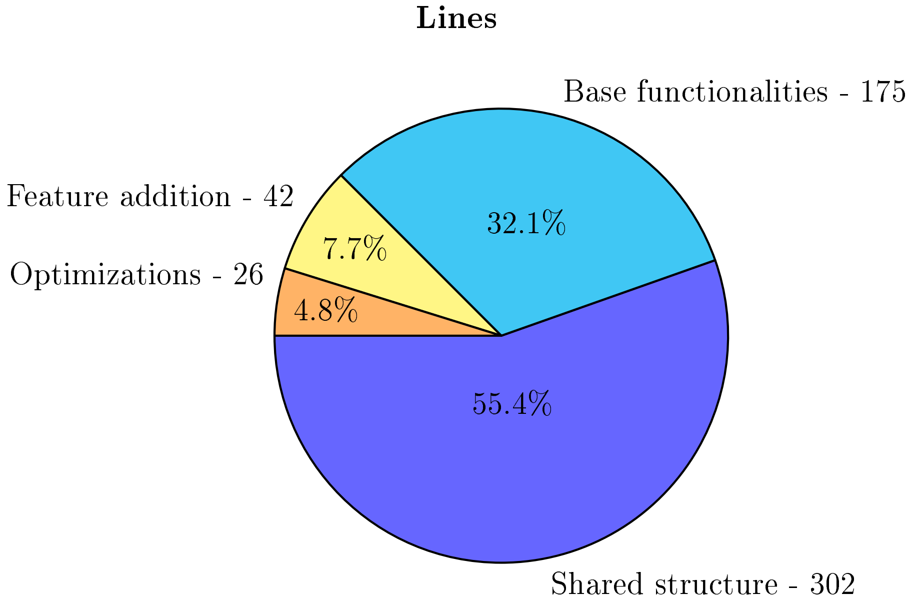


Figure 2.10: Shows the pie chart regarding the lines of code spent in each subprocess for the Redux implementation

Figure 2.11 represents a pie chart showing the percentage of time spent in each implementation's process. Notice that the learning process and the implementation of the base functionalities took more than the 85% of the entire time. It means that the optimization process and the feature addition process were pretty fast and also that the solution requires a bit of time to get learned digested.

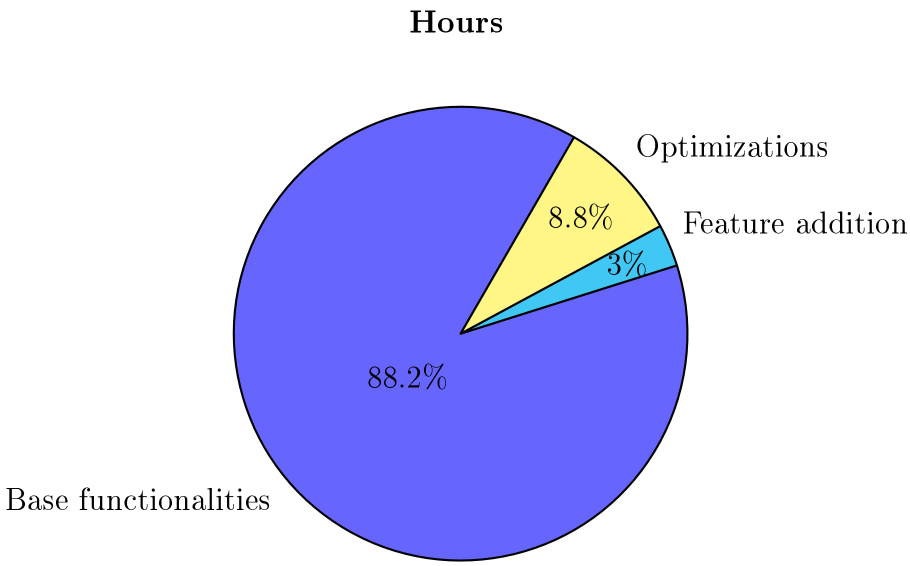


Figure 2.11: Shows the pie chart regarding the hours spent in each subprocess for the Redux implementation

Figure 2.12 shows the final folders structure for the Redux implementation. It is clearly more articulated with respect to the InheritedWidgets one shown in figure 2.8.

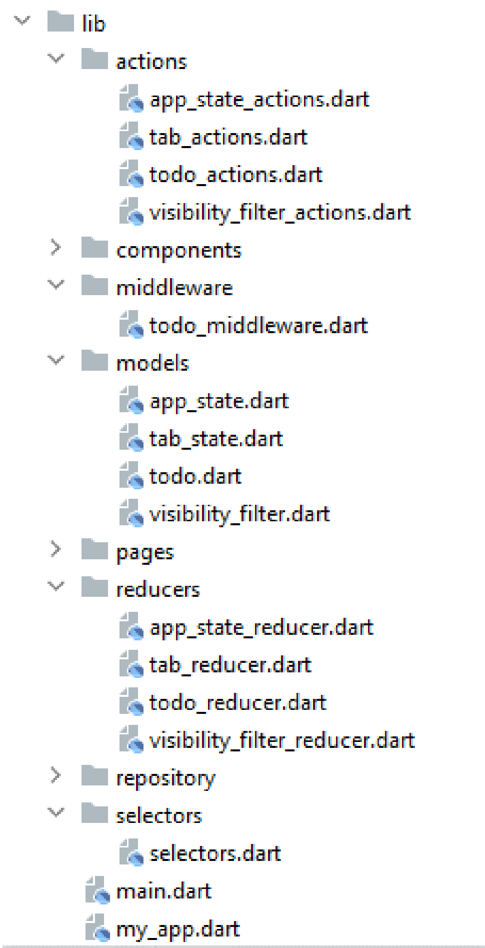
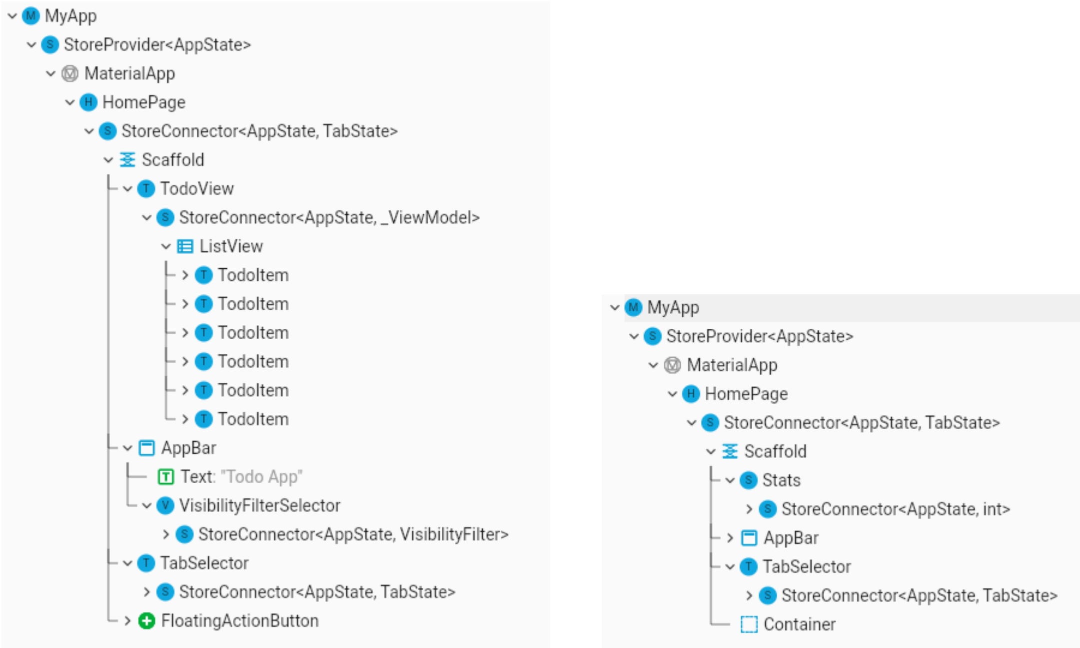


Figure 2.12: Shows the final folders structure for the Redux implementation of the Todos app

Figure 2.13 represents the widget's tree structure for the Redux final application. Notice the StoreProvider widget, situated above the HomePage, providing an instance of the store to the subtree. Also notice all the StoreConnector widgets accessing the state using their corresponding viewmodel.



(a) Widgets tree structure *todos* tab (b) Widgets tree structure *stats* tab

Figure 2.13: Shows the widgets tree structure for Redux implementation of the Todos app

2.2.4. BloC implementation

This section implements the Todo application using the BLoC package in order to handle the state.

Base funtionalities

States - The application state is decomposed in four smaller states: the state of the list, the state of the filtered list, the state of the statistics and the state of the tab. The state of the list contains the whole list of todos. The state of the filtered list contains a filter, of type VisibilityFilter, and a list of todos matching that 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 and the state of the tab are independent. The state of the filtered list and the state of the stats, instead, are directly linked to the state of the list. They will, indeed, react to the changes in the state of the list 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 *TodosLoadingState* state indicates that the list of todos is still loading. The *TodoLoadedState* 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 Equatable class. 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 instances.

Source Code 2.80: 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

FilteredTodosLoadingState state identifies the fact that the filtered list hasn't been computed (or todos fetched) yet. The *FilteredTodosLoadedState* state, instead, identifies the fact that the list of todos has been successfully fetched and the filtered list 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 other state classes, belonging to the state relative to the filtered list, will extend the *FilteredTodosState* abstract class. Someone can notice that, the state of the filtered list, contains two different aspects of the application's state: the filter and the filtered list. In this case it is possible to further split the state creating two separated blocs, handling respectively the filter and the filtered list. From a general point of view, the state should be divided into as many pieces as possible to keep things clean and well separated, like we do for classes and methods. However, the BLoC pattern does not specify how granular should the state fragmentation be 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-off keeping the filter and the filtered list in the same bloc. They concern, indeed, two similar aspects of the data. Splitting them, would require the bloc of the filtered list to depend on the bloc of the filter also, raising its dependencies from one bloc to two blocs (the bloc of the todos and the bloc of the filter).

Source Code 2.81: 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 one identifies the fact that the stats hasn't been computed yet and do not contains any additional information . The second identifies the fact that the stats are available and contains an int variable, called *completed*.

Source Code 2.82: 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 regarding the tab, the enumeration presented Source Code 2.2 is enough.

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

Events of the list of todos - For the moment it is sufficient to define two events only. One identifies the action of fetching todos from the database and is called *LoadTodosEvent*. It does not contain 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, are extended with this abstract class.

Source Code 2.83: Todo app - Bloc - events 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 the possible events 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 a VisibilityFilter variable which 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 and contains the new list. Consequently a new filtered list must be computed and a new *FilteredTodosLoadedState* emitted.
Also in this case, all event classes extend a shared abstract class called *FilteredTodoEvent* which, in turn, extends the Equatable class.

Source Code 2.84: 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: \$filter}';
}

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 state and tab's state - Both the state of the tab and the state of the stats require one single event. The event concerning the state of the tab is called *ChangeTabEvent* and contains a variable of type TabState indicating the value of

the new tab. The event concerning the state of the stats is called *StatsUpdatedEvent*. It is generated once a new state of type *TodosLoadedState* is emitted in the state of the list and contains the new list of todos.
Also in this case, both the events for the stats and the events for the tab extend respectively the abstact classes *TabEvent* and *StatsEvent*.

Source Code 2.85: 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 the base functionalities have been defined. Is possible now 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 and make it extends the Bloc class, provided by the flutter_bloc package. This new class is called *TodoBloc*. Moreover, it is necessary to provide, in the extension, also the type of the events and the states the bloc manages. 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 BLoC package, requires the *mapEventToState* method to be overridden. 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 does not terminate during the entire execution of the application. It keeps listening for new events. 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 different subtypes. Once the subtype is defined, the event logic is processed and the new state emitted. The syntax *yield** Is used, instead of the classic *return* syntax,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. In order to increase the 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 subsequent 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, a *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* (otherwise 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 updated *completed* field. Notice that, a new instance of the list must be created and provided to the new state. If we just mutate the list contained in the previous state, the Equatable class does not recognize any difference between the previous state and the new emitted one, and consequently, do not notify any listener.

Source Code 2.86: Todo app - Bloc - TodoBloc implementation

```
class TodoBloc extends Bloc<TodosEvent, TodosState> {
  //initialize the bloc's state at creation
  TodoBloc() : super(TodosLoadingState());

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

  Stream<TodosState> _mapLoadTodosToState(LoadTodosEvent event) async* {
    try {
```

```
    //fetch todos
      final List<Todo> todos = await TodoRepository.loadTodos();
      yield TodosLoadedState(todos);
    } catch (e) {
      yield TodoLoadingState();
    }
  }

Stream<TodosState> _mapSetCompletedToState(
    SetCompletedTodoEvent event) async* {
  if (state is TodosLoadedState) {// create a new updated list
    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 used for the *TodoBloc*. A new class, called *FilteredTodosBloc*, 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 dependent on the bloc of the list, an instance of the *TodoBloc* is passed inside the constructor. The instance of the TodoBloc 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 the TodoBloc. If the state is of type *TodosLoadedState*, the constructor computes, and then emits, a state of type *FilteredtodosLoadedState* using a filter of type *all*. If the state is of type *TodosLoadingState*, the constructor emits a state of type

FilteredLoadingState.

Source Code 2.87: Todo app - Bloc - FilteredTodoBloc initialization

```
class FilteredTodoBloc extends Bloc<FilteredTodoEvent, FilteredTodoState> {
  //this variable is used to listen for changes in the todoBloc
  final TodoBloc todoBloc;

  FilteredTodoBloc({required this.todoBloc})
      : super(
      //initialize the state based on the todoBloc's state
          todoBloc.state is TodosLoadedState
              ? FilteredTodoLoadedState(
                (todoBloc.state as TodosLoadedState).todos,
                VisibilityFilter.all,
              )
              : FilteredTodoLoadingState(),
        )
}
```

In addition, the constructor must register the FilteredTodoBloc to changes in the TodoBloc. To do so, a particular variable of the TodoBloc instance, called *stream*, is used. The variable *stream* exists 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 *listen* method. Inside the *listen* method's call, a function must be provided. This function is called everytime the stream emits a new state and allows to access the state in order to implement arbitrary logic. We provide to the *listen* method a function that checks if the new emitted state is of type *TodoLoadedState*. In case it is, it means that a new list of todos is available and that the FilteredTodoBloc has to compute a new filtered list and emit a new state. Instead of encapsulating the above logic into the function provided to the *listen* method we emit an event that will be managed in the *mapEventToState* method. A specific event, called *TodoUpdatedEvent*, has been defined for this situation in Source Code 2.84 where the events related to the bloc of the filtered list have been implemented.

Source Code 2.88: Todo app - Bloc - FilteredTodoBloc subscription to TodoBloc stream

```
class FilteredTodoBloc extends Bloc<FilteredTodoEvent, FilteredTodoState> {
  final TodoBloc todoBloc;
  //the todoSubscription variable is marked as late
  // because it is initialized after the constructor's execution
  late StreamSubscription todoSubscription;

  FilteredTodoBloc({required this.todoBloc})
      : super(
          todoBloc.state is TodosLoadedState
              ? FilteredTodoLoadedState(
                  (todoBloc.state as TodosLoadedState).todos,
                  VisibilityFilter.all,
                )
              : FilteredTodoLoadingState(),
        ) {
        //subscription to the todoBloc's state changes
    todoSubscription = todoBloc.stream.listen((state) {
    //in case a new state of type Loaded is emitted
      if (state is TodosLoadedState) {
      //an internal event of type TodoUpdatedEvent is emitted
        add(TodoUpdatedEvent((todoBloc.state as TodosLoadedState).todos));
      }
    });
  }
```

The *mapEventToState* method is overriden defining the logic used to emit new states based on the received event. As we did for the TodoBloc, also in this case, the method is asynchrounous and returns a stream of *FilteredTodosStates*. The method takes as single argument an event of the generic abstract type *FilteredTodosEvent*.The method contains two nested *if-else* statements which define 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 2.89: Todo app - Bloc - FilteredTodoBloc *mapEventToState* method override

```
@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 TodoBloc's state is of type *TodosLoadedState* (otherwise 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 2.90: 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 uses the filter of type *all*.

Source Code 2.91: Todo app - Bloc - FilteredTodoBloc *_mapTodoUpdatedEventToState* method implementation

```
Stream<FilteredTodoState> _mapTodoUpdatedEventToState(
    TodoUpdatedEvent event) async* {
    // populate a filter value bases on the todoBloc's state
  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 2.92: Todo app - Bloc - FilteredTodoBloc *close* method implementation

```
@override
Future<void> close() {
// cancel the subscription
  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 : the StatsUpdatedEvent. As usual, the *StatsBloc* class is defined and 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 *TodoBloc*. 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 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 2.93: Todo app - Bloc - StatsBloc constructor implementation

```
class StatsBloc extends Bloc<StatsEvent, StatsState> {
  final TodoBloc todoBloc;
  //marked as late because it initialized after constructor exectuion
  late StreamSubscription todoSubscription;

  StatsBloc({required this.todoBloc}) : super(StatsLoadingState()) {
  // wrap the code into a function to reuse it
    void onTodosStateChanged(state) {
      if (state is TodosLoadedState) {
        add(StatsUpdatedEvent(state.todos));
      }
    }

    onTodosStateChanged(todoBloc.state);
         // if a new event is emitted in the todoBloc
         // execute the onTodosStateChanged function
    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, its internal *computed* field is used to compute the stats before emitting a new *StatsLoadedState*. In the *close* method the subscription to the *TodoBloc* is terminated.

Source Code 2.94: Todo app - Bloc - StatsBloc *mapEventToState* and *close* methods implementation

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

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

The bloc for the tab - The procedure is the same as before. This time the bloc is really simple. The *TabBloc* class is created and extended to the Bloc class. Moreover, the states and the events it handles are specified in its declaration. In the contructor, the initial state is 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 *tab* internal value.

Source Code 2.95: 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;
    }
  }
}
```

Observing the blocs - Terminates here the implementation 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 2.96: Todo app - Bloc - example of TodoBloc usage

```
void main()  {
  //create a new bloc
  TodoBloc todoBloc= TodoBloc();
  //dispatch an event
  todoBloc.add(LoadTodosEvent());

}
```

The fact that it is possible to test the application's logic without the need of writing a single widget indicates how powerful the BLoC package is. It is, indeed, really easy to divide the logic layer from the presentation layer without dealing with complicated external dependencies. Moreover, it is possible to use an additional tool which 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. In order to use this component is necessary to define another class, that we call *AppBlocObserver*, and to 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 2.97: 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 is set as the default observer for the blocs.

Source Code 2.98: Todo app - Bloc - setting the application's observer

```
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, the BlocProvider widget is situated at the root. The first widget to be passed to the *runApp* method is indeed a BlocProvider widget. A BlocProvider widget is a typed widget. This means it needs additional information to work properly. In particular, the type of the bloc it makes accessible is required. In our case it needs to provide a bloc of type TodoBloc. Inside the BlocProvider widget, two fields must be filled; the *create* field and the *child* field. The *create* field is populated with a function taking as single argument the *context* and returning a bloc of the previously specified type. This function is executed on the BlocProvider widget's initialization. The initialization of the BlocProvider widget is lazy by default. This means that it is performed when the BlocProvider widget is accessed for 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 performing useless computation and wasting time in case they are never accessed. It is possible to set the *lazy* flag to false in case the *create* function needs to be run immediatetly. The *create* field is populated with a function which instantiates a TodoBloc and emits the first event of the application, the *LoadTodosEvent*. The *add* method, provided by the extension to Bloc class, is used in order to emit new events. 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 2.99: Todo app - Bloc - make the TodoBloc accessible using a BlocProvider widget

```
void main() async {
//set the  observer
  Bloc.observer = AppBlocObserver();
```

```
  //run di application and fetch todos
  runApp( BlocProvider<TodoBloc>(create:(context)=>
   TodoBloc()..add(LoadTodosEvent()),child: const MyApp()));
}
```

Beyond the TodoBloc, all 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. A MultiBlocProvider is used to wrap the HomePage. A MultiBlocProvider is nothing else that a widget that contains a field called *providers* where a list of BlocProvider widgets is inserted. It is the same as nesting a series of BlocProvider widgets 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. We already set a BlocProvider widgetof type TodoBloc in the current context, and so, the *of* method successfully retrieve the TodoBloc instance. The reason why the TodoBloc is positioned in an higher level with respect to the other blocs is because it needs to be accessible also in the other pages. The reason why the other blocs are pushed down the tree is because 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 find out which part of the code caused it.

Source Code 2.100: Todo app - Bloc - make other blocs accessible using a MultiBlocProvider widget

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

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

```
      initialRoute: "/",
      routes: {
      // usage of MultiBlocProvider
        "/": (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)),
      },
    );
  }
}
```

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

The HomePage - 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. Within the function, provided in the *builder* field 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 2.101: 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>( //use a BlocBuilder
    builder: (context, tabState) {
            return Scaffold(...);
          });
  }
}
```

The *tabState* variable is used to build the Scaffold widget as usual.

Source Code 2.102: Todo app - Bloc - HomePage implementation

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

  );
```

```
}
```

The TodoView component - The TodoView component needs to access the state regarding the filtered list and the filter only. The ListView widget is wrapped into a BlocBuilder widget in order to access the state. The BlocBuilder widget will handle a bloc of type *FilteredTodosBloc* and its internal states (of type *FilteredTodosState*). Within 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* we can use its internal *todos* variable, containing the list of todos, to populate and return the ListView widget.

Source Code 2.103: Todo app - Bloc - TodoView implementation

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

  @override
  Widget build(BuildContext context) {
    //using a BlocBuilder widget
    return BlocBuilder<FilteredTodoBloc, FilteredTodoState>(
        builder: (context, filteredTodoState) {
      print("building: TodoView");
        //dependeing on the current state
      if (filteredTodoState is FilteredTodoLoadedState) {
        return ListView.builder(
            itemCount: filteredTodoState.todos.length,//access it here
            itemBuilder: (context, index) {
              return TodoItem(
                  todo: filteredTodoState.todos.elementAt(index)); //here
            });
      } else if (filteredTodoState is FilteredTodoLoadingState) {
        return const Center(child: CircularProgressIndicator());
      } else {
```

```
        return const Center(child: CircularProgressIndicator());
      }
    });
  }
}
```

The TodoItem component - Since this part of the development process does not consider any type of optimization, the TodoItem component does not need to be modified with respect to the implementation defined in Source Code 2.8. 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 in order to read any value it needs to access the state to emit a new event. Once the checkbox is tapped, indeed, the list of todos should be modified. Emitting an event is easier than reading the state by the fact the "conversation" is one-sided. It can be considered a constant action meaning that the widget should not be notified when the state changes. Therefore there is no need to use any BlocBuilder widget. It is sufficient to access the corresponding bloc 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 with it and emitted in the TodoBloc.

Source Code 2.104: Todo app - Bloc - TodoItem component *onChanged* field implementation

```
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 one 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.

The VisibilityFilterSelector component - The VisiblityFilterSelector component depends only on 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 value in case a DropdownMenuItem is tapped. The DropdownButton widget is wrapped inside a BlocBuilder widget. The BlocBuilder widget will handle a bloc of type *FilteredTodosBloc* and its internal states of type *FilteredTodoState*.

Source Code 2.105: Todo app - Bloc - VisibilityFilterSelector component implementation

```
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 *FilteredTodoLoadedState* the variable is initialized with the current filter value. In case the state is of type *FilteredTodoLoadingState* the variable is initialized with the value *all*.

Source Code 2.106: Todo app - Bloc - populating a filter variable based of the current state in the VisibilityFilterSelector component

```
final VisibilityFilter filter= filteredTodoState is
 FilteredTodoLoadedState? filteredTodoState.filter:
  VisibilityFilter.all;
```

The DropdownButton widget 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 2.107: Todo app - Bloc - VisibilityFilterSelector component *onChange* field implementation

```
onChanged: (filter) {
 BlocProvider.of<FilteredTodoBloc>(context)
 .add(FilteredTodoChangeFilterEvent(filter!));
},
```

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 a bloc of type *TabBloc* and the states of type *TabState*.

Source Code 2.108: Todo app - Bloc - TabSelector component implementation

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

TheBottomNavigationBar widget's *onTap* field is populated with a function that emits a new event of the type *ChangeTabEvent*, inside the *TabBloc*,once fired.

Source Code 2.109: Todo app - Bloc - TabSelector component's *onTap* field implementation

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

The Stats component - Also in this case, the only dependency the Stats component has refers to the part of the state concerning the stats. The entire component is, therefore, wrapped into a BlocBuilder widget. The Blocbuilder widget will handle a bloc of type *StatsBloc* and its internal states of type *StatsState*. Within 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 are being computed.

Source Code 2.110: Todo app – Bloc - Stats component implementation

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

Features addition

New events - The first thing to do is to make the state provide a way of adding and updating todos. Two new events are created and called *AddTodoEvent* and *UpdateTodoEvent* respectively. The *AddTodoEvent* contains the name and the description to be used in the creation of the new todo instance. The id is set during the actual todo's addition in order to be generated uniquely. The *completed* field is set to false by default (the new todo is obviously pending at its creation). The *UpdateTodoEvent* contains the id of the todo to be modified and the new name and description. Both the *AddTodoEvent* and the *UpdateTodoEvent* are extended with the *TodosEvent* abstract class in order to be manageable by the TodoBloc.

Source Code 2.111: Todo app - Bloc - AddTodoEvent and UpdateTodoEvent definition

```
class AddTodoEvent extends TodosEvent {
  final String name;
  final String desc;

  const AddTodoEvent(this.name, this.desc);

  @override
  String toString() => 'TodosEvent - AddTodoEvent';
}

class UpdateTodoEvent extends TodosEvent {
  final int id;
  final String newName;
  final String newDesc;

  const UpdateTodoEvent(this.id, this.newName, this.newDesc);

  @override
  List<Object> get props => [id, newName, newDesc];

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

TodoBloc update - It necessary now to "teach" the TodoBloc to handle these new events. The workflow is the following: when the *AddTodoEvent* is received in the TodoBloc, a new instance of the list of todos, contained in the current state, is generated . A new todo is created using the name and description contained in the event. The new todo is added to new instance of the list. The new list is then used to creted a new state of the type *TodosLoadedState* before emitting it in the TodoBloc. When the *UpdateTodoEvent* is received a new instance of the list contained in the current state is created. The todo with the id matching the one contained in the event is modified using the new name and and the new description. Lastly, a state of type *TodosLoadedState* is emitted with the new list. There is one more thing to do, adding to the TodoBloc's *mapEventToState* method two new *if-else* branches that check if the received event is of type *AddTodoEvent* of *UpdateTodoEvent*. In the first case, the private method *mapTodoAddedToState* is called. In the second case, the private method *mapTodoUpdatedToState* is called.

Source Code 2.112: Todo app - Bloc - TodoBloc *mapEventToState* extension for new events

```
@override
Stream<TodosState> mapEventToState(TodosEvent event) async* {
  if (event is LoadTodosEvent) {
    yield* _mapLoadTodosToState(event);
  } else if (event is AddTodoEvent) {//new branch
    yield* _mapTodoAddedToState(event);
  } else if (event is UpdateTodoEvent) {// new branch
    yield* _mapTodoUpdatedToState(event);
  } else if (event is SetCompletedTodoEvent) {
    yield* _mapSetCompletedToState(event);
  }
}
```

The *mapTodoAddedToState* method performs the procedure described above. It checks if the current state is of type *TodosLoadedState*(otherwise is meaningless to perform any addition), then, it generates a unique id and a new instance of the list contained in the current state. It then creates a new todo instance and adds it to the new list. Lastly, a new *TodosLoadedState* is created with the new list and emitted.

Source Code 2.113: Todo app - Bloc - TodoBloc's *mapTodoAddedToState* method implementation

```
Stream<TodosState> _mapTodoAddedToState(AddTodoEvent event) async* {
    if (state is TodosLoadedState) {
    //generate new unique id
      int newId = generateId((state as TodosLoadedState).todos);
      //create new todo
      Todo newTodo = Todo(
```

```
        id: newId,
        name: event.name,
        description: event.desc + " " + newId.toString(),
        completed: false);
        //add it to a new list instance
    final List<Todo> updatedTodos =
        List.from((state as TodosLoadedState).todos)..add(newTodo);
    yield TodosLoadedState(updatedTodos);
  }
}
```

The *mapTodoUpdatedToState* method checks if the current state is of type *TodosLoadedState* (otherwise it is meaningless to perform any modification), then, it creates a new instance of the list contained in the current state and modifies instrested todo. Lastly, a *TodosLoadedState* is created using the new list and emitted.

Source Code 2.114: Todo app - Bloc - TodoBloc's *mapTodoUpdatedToState* method implementation

```
Stream<TodosState> _mapTodoUpdatedToState(UpdateTodoEvent event) async* {
  if (state is TodosLoadedState) {
  //replace the list with a new updated one
    List<Todo> newTodos = (state as TodosLoadedState)
        .todos
        .map((todo) => todo.id == event.id
            ? Todo(
                id: event.id,
                name: event.newName,
                description: event.newDesc,
                completed: false)
            : todo)
        .toList();
    yield TodosLoadedState(newTodos);
  }
}
```

Access new feature in the UI - The state is capable now to handle the new functionalities. Thanks to the fact that the TodoBloc were situated on top of the widgets tree it is possible to access the state in the *AddTodoPage* and in the *UpdateTodoPage* easily. An instance of the TodoBloc exists in the current *context* and can be accessed using the *of* method. In case the TodoBloc was located in a lower level with respect to the MaterialApp widget (from where routes start) it would have had to be passed by argument to the corresponding page.
The AddTodoPage implementation is reported Source Code 2.146. The only part to be changed is the *onPressed* field of the TextButton widget. The provided function retrives the TodoBloc instance using the *of* method and emitts a new *AddTodoEvent* . Moreover, it pops the AddTodoPage bringin back the application in the HomePage where the TodoView is rebuilt due to the change in the state of the TodoBloc.

Source Code 2.115: Todo app - Bloc - emitting an AddTodoEvent in the AddTodoPage

```
TextButton(
    onPressed: () {
      BlocProvider.of<TodoBloc>(context).add(AddTodoEvent(
          textControllerName.text, textControllerDesc.text));
      Navigator.pop(context);
    },
    child: const Text("Create"))
```

The same process is done to implement the UpdateTodoPage. A function is provided to the *onPressed* field. This function uses the TextField widgets' parameters to create and emit an event of type *UpdateTodoEvent*. The UpdateTodoPage is then popped and the HomePage rebuilds due to the TodoBloc state change.

Source Code 2.116: Todo app - Bloc - emitting an UpdateTodoEvent in the UpdateTodoPage

```
TextButton(
    onPressed: () {
      BlocProvider.of<TodoBloc>(context).add(UpdateTodoEvent(
          widget.todo.id,
          textControllerName.text,
          textControllerDesc.text));
      Navigator.pop(context);
    },
    child: const Text("Confirm"))
```

Rendering optimizations

Optimizations using the *buildWhen* field - To achieve the desired partial rendering is necessary to work on the TodoView widget and the TodoItem widget only. We leverage on a specific field of the BlocBuilder widget called *buildWhen*. This field is fillable with a Boolean function in order to determine whether or not to rebuild the BlocBuilder widget on a state transition. If the *buildWhen* function returns true, the widget is rebuilt otherwise it is not. Inside this function, the previous state and the next state can be accessed. For the moment, when a state change occurs, the TodoView widget destroys all the children widgets and rebuilds them using the data contained in the new state. Well, actually it is not precisely like this. Flutter indeed uses some articulated mechanisms in order to rebuild the few parts of the widget tree possible. From our perspective, however, TodoItem widgets are destroyed and recreated at every transition, also in case a single TodoItem changed. To make the TodoItem widget self-rebuild, is necessary to make it sensible to changes in the state. For the moment, the TodoItem widget does not use any BlocBuilder widget at all. Indeed, it just visualize the todo instance passed by the parent widget without actually accessing the state. The first thing to do is to wrap it inside a BlocBuilder widget making it listen for changes in the TodoBloc. Instead of receiving, from the TodoView parent widget, a copy of the todo instance is enough, now, to receive the id only and use it to obtain the instance of the entire todo through the state. Within the *builder* function the todo is looked up and used to create the TodoItem widget.

Source Code 2.117: Todo app - Bloc - accessing the state into TodoItem component

```
class TodoItem extends StatelessWidget {
  final int id; //todo variable replaced with int one

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

@override
Widget build(BuildContext context) {
//new BlocBuilder widget
  return BlocBuilder<TodoBloc, TodosState>(
   builder: (context, state) {
   print("building: Todo Item \$id " + key.toString());

   if (state is TodosLoadedState) {
    //retrieve the instance of the todo from the state using the id
    Todo t = (state).todos.firstWhere((element) => element.id == id);
    //use it in the InkWell widget as usual
    return InkWell(. . .);
        } else {
    return Row(
      children: const [
        Text("ERROR"),
      ],
    );
  }
});
```

At this point, both the TodoView widget and the TodoItem widget listen for changes in the state. The *buildWhen* field, introduced above, is used to "teach" them when to rebuild. Starting from the TodoView widget, we provide a function in the *buildWhen* field that checks the types of the previous and the next states. If they differ there is no point in proceeding further and a true value is returned. If they match, the function checks if the length of the previous filtered list and the length of the new one coincide. If they differs the change was structural and is necessary to rebuild the entire TodoView widget. In case they match, the function proceeds checking further for structural changes. If the elements contained in the first list are exactly the ones contained in the second one no structural change occures. (note: it checks the ids only because we are interested in structural changes) If all elements are the same there is no need to rebuild the TodoView widget and the function terminates returning false.

Source Code 2.118: Todo app - Bloc - using the *buildWhen* field to perform exclusive rebuild in te TodoView component

```
return BlocBuilder<FilteredTodoBloc, FilteredTodoState>(
    buildWhen: (previous, next) {
  return !((previous is FilteredTodoLoadedState) &&
      (next is FilteredTodoLoadedState) &&
      //check if structural change occured
      previous.todos.length == next.todos.length &&
      listEquals(next.todos.map((todo) => todo.id).toList(),
          previous.todos.map((todo) => todo.id).toList()));
},
```

The same must be done in the TodoItem widget. The TodoItem widget needs to rebuild when a non-structural change occurs. A function is provided in the *buildWhen* field that checks if the previous and the next states are both of type *FilteredTodoLoadedState*. In case they aren't the only possibility is that the new state is of type *FilteredTodosLoadingState* and the old one is of type *FilteredTodosLoadedState*. At the contrary, indeed, no TodoItem widgets could be present in the HomePage and the *buildWhen* function wouldn't be called at all. (*FilteredTodosLoading* state does not produce any TodoView widget). So, there is no need to rebuild the TodoItem widget because, if states differs, the new state is necessary of type *FilteredTodosLoadingState* and TodoItem widgets are going to be destroyed in any case. In case states match, the function checks if the new state contains the corresponding todo. Otherwise is useless to rebuild the TodoItem widget because a structural change occured and all the TodoItem widgets are going to be detroyed. In case it contains the corresponding todo, the function checks if the todo has undergone any changes with respect to the previous state. In case it does, the function returns true and the TodoItem is rebuilt.

Source Code 2.119: Todo app - Bloc - using the *buildWhen* field to perform exclusive rebuilding in the TodoItem component

```
buildWhen: (previous, next) {
      if (next is TodosLoadedState &&
          previous is TodosLoadedState &&
          next.todos.map((todo) => todo.id).contains(id) &&
          previous.todos.firstWhere((element) => element.id == id) !=
              next.todos.firstWhere((element) => element.id == id)) {
        return true;
      } else {
        return false;
      }
    }
```

Optimizations using BlocSelector widget - I propose now another way to perform the questioned rendering optimizations. After I got them implemented using the *builde-When* field I found out that a particular widget, called BlocSelector, is provided by the BLoC package exactly for this specific scenario. The BlocSelector widget behaves as the StoreConnector widget does in the Redux solution. It takes a mandatory function, in its *selector* field, which exstrapolates a viewmodel from the state and uses it to construct the widget. The viewmodel is also used to determine whether to rebuild the widget or not. If the viewmodel differs from the previous one the widget is rebuilt. Would be nice, then, to extrapolate two viewmodels from the state, one for the TodoView widget and one for the TodoItem widget, and use them to determine wheter to rebuild the entire TodoView widget or just a single TodoItem widget (as we did in the Redux optimization part). The viewmodel for the TodoView widget will be a list of todos, in particular the filtered list. We want also this list to apper different from a subsequent one only when it goes through a structural change. To do so we define an ad hoc viewmodel class and override its equality operator to obtain the desired behaviour.

Source Code 2.120: Todo app - Bloc - using the *buildWhen* field to perform exclusive rebuild in te TodoItem component

```
class _ViewModel {
  final List<Todo> todos;
```

```
  _ViewModel({required this.todos});

  @override
  bool operator ==(Object other) {
    return ((other is _ViewModel) &&
          todos.length == other.todos.length &&
          todos.every(
              (todo) => other.todos.any((element) => todo.id == element.id)));
  }

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

The viewmodel for the TodoItem widget will be instead a todo instance. It is obtained searching in the state's list of todos the one matching the TodoItem widget's id. In this way, once the corresponding todo instance is updated, the difference is seen by the BlocSlector widget and a rebuild is triggered. The equality operator for todos instances has been already defined HERE RIFERIMENTO making two todo instances equal when all their internal values match. Until now what we did was pretty basilar and similar to what we have done for the implementation with Redux. In this case, however, there is a small inconvenient. In the way we defined states they are not always suited for extracting a viewmodel. Just think at the viewmodel for the TodoView widget, it needs to extract a list of todos from the current state but, in some situations, we don't even have a proper list, for example in the case of a LoadingState. In Redux this problem did not arise by the fact that there were no distinction between a loading state and a loaded state, or better, the loading state was indicated only by the fact that the list was empty. The distinction the BLoC pattern does between state's typologies is, in my opinion, very powerfull and adaptive. It is able to define complex hierarchies between them and to fit a large number of situations. In some cases, however, like in this one, it tends to overfit and to cause an excessive needs of specificity overcomplicating even simple actions. The mechanism used in Redux which derives a viewmodel from the state to determine which part is observed by the widget does not apply so good in the BLoC pattern. It is implementable but it is not straigh forward like in Redux. First we need to be sure to use the BlocSelector widget in a situation where a list is available. To do so it is sufficient to use the BlocBuilder widget already present in both the TodoView widget and the TodoItem widget. The *builder* function will take care, as usual, of differentiating possible state's types. In the case of a Loaded state we can now return a BlocSelector widget instead of the plain component. This allows us not to define the logic through which components are going to be rebuilt. All the work is done by the BlocSlector with the help of the equality operator we previously defined.

Source Code 2.121: Todo app - Bloc - using the *buildWhen* field to perform exclusive rebuilding in the TodoItem component

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

  @override
  Widget build(BuildContext context) {
    return BlocBuilder<FilteredTodoBloc, FilteredTodoState>(
       builder: (context, filteredTodoState) {
      //check that the state is of type Loaded
      //to be sure a list exists
      if (filteredTodoState is FilteredTodoLoadedState) {
        //use the BlocSelector widget to perform the optimizations
        return BlocSelector<FilteredTodoBloc, FilteredTodoState,
         _ViewModel>(
            //use the ad hoc viewmodel to contain the selected filtered list
            selector: (state) =>
                _ViewModel(todos:
                (state as FilteredTodoLoadedState).todos),
            builder: (context, filteredList) {
              print("building: TodoView");
              return ListView.builder(...);
            });
      } else {
        return const Center(child: CircularProgressIndicator());
       }
      }
    );
  }
}
```

The same can be done in the TodoItem widget. the BlocBuilder widget is used to determine the type of the state and, in case of a loading state, a BlocSelector is returned.

Source Code 2.122: Todo app - Bloc - using the *buildWhen* field to perform exclusive rebuilding in the TodoItem component

```
class TodoItemSelector extends StatelessWidget {
  final int id;
  const TodoItemSelector({Key? key, required this.id}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    return BlocBuilder<TodoBloc, TodosState>(
       builder: (context, state) {
      //check if state is of type Loaded
      //to be sure to have a list of todos
      if (state is TodosLoadedState) {
        //return a BlocSelector to perform the optimizations
        return BlocSelector<TodoBloc, TodosState, Todo>(
            //select the corresponding todo from the state
            selector: (state) {
          return (state as TodosLoadedState)
          .todos.firstWhere((element) => element.id==id);
        }, builder: (context, todo) {
          //return the usual InkWell without any change
          print("building: Todo Item \$id " + key.toString());

          return InkWell(...);
          }); //end of BlocSelector
      } else {
        return Row(...);
      }
    });
  }
}
```

We almost done but there is another small brick to add to the picture. Currently, the optimizations we tried to achive (with not small effort and boilerplate) still do not work. The issue is that we wrapped both the BlocSelector widgets inside a BlocBuilder widget. This procedure was mandatory otherwise we would have run into a runtime error when tring to select a list (or a todo) from a loading state which does not contain any information. However, in this way, every time a state transition occurs both BlocBuilder widgets are rebuilt unconditionally leading BlocSelector widgets to rebuild with them and making the achived optimizations useless. We want the external BlocBuilder widget to rebuild only when the state passes from a loaded state to a loading state and viceversa. We can use its *buildWhen* field to determine the type of change the sstate went through. Basically if the state did not change its type is not necessary to rebuild the BlocBuilder widget. The previous and current state types are checked.

Source Code 2.123: Todo app - Bloc - using the *buildWhen* field to perform exclusive rebuilding in the TodoItem component

```
buildWhen: (previous, next) {
 return previous.runtimeType != next.runtimeType;
}
```

However, unlike Redux, the BLoC architecture is not really suitable for this kind of optimization mechanism. The following considerations are taken from my own experience with the solution by the fact I did not found any interesting material about BlocSelector widget's usage and neither about the problem I'm going to present. There is a small obstacle with the concept of selector/converter widgets. They filter the state to obtain the needed information and use viewmodels to wrap and compare states. Every time a state transition occurs all the conversion/selectors are computed before actually running any widget rebuilding. This mechanism does not take into account the fact that, some conversions, can lead the entire subtree to rebuild making the computation of all the other conversions not only useless but also potentially dangerous. It can appear a bit abstract until now but I'm going to propose and example to clarify a bit the entire picture. In our case,

Conclusions

Table 2.3 reports some measurements taken from the BLoC's implementation process. The *lines of code* column represents the lines of code added or updated with respect to the shared project structure proposed in subsection 2.2.1. The *time* column represents the time spent in order to implement the corresponding subprocess. The unit of measure **h** stands for hours and **m** stands for minutes. The *lines-time ratio* column represents the average number of lines written in a minute. The *classes* column represents the number of created classes in each subprocess.

Measurement for Bloc process

	lines of code	**time**	**lines/time ratio**	**classes**
base functionalities	314	10-12 h	0.47 l/m	24
feature addition	53	15-20 m	2.65 l/m	2
rendering optimization	28	6-8 h	0.066 l/m	0

Table 2.3: BLoC measurements table

Figure 2.14 represents a pie chart showing the percentage of lines of code written in each implementation's process, including the one regarding the shared structure. Notice that the state management took about the 60% of the overall written lines of code. This underlines the massive amount of boilerplate the BLoC solution requires. More than an half of the application's code were written for the state management.

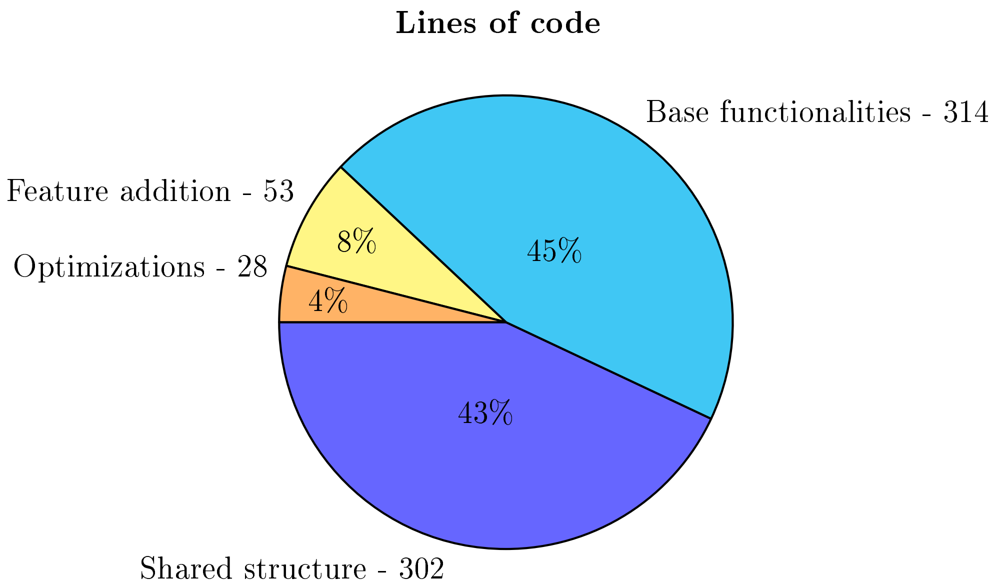


Figure 2.14: Shows the pie chart regarding the lines of code spent in each subprocess for the BLoC implementation

Figure 2.15 represents a pie chart showing the percentage of time spent in each implementation's process. Notice that the feature addition process took small time considering it has the higher number of lines of code with respect to the previous solutions.

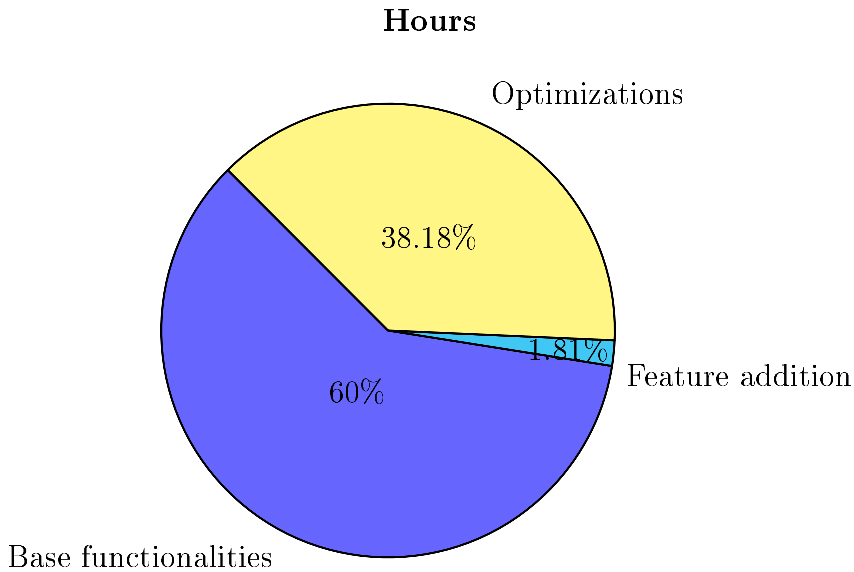


Figure 2.15: Shows the pie chart of the hours spent in each process for the BLoC implementation

Figure 2.16 shows the final folders structure for the BLoC implementation. Like in the Redux solution also in case the folders structure is pretty articulated. A lot of files have been added to the original structure.

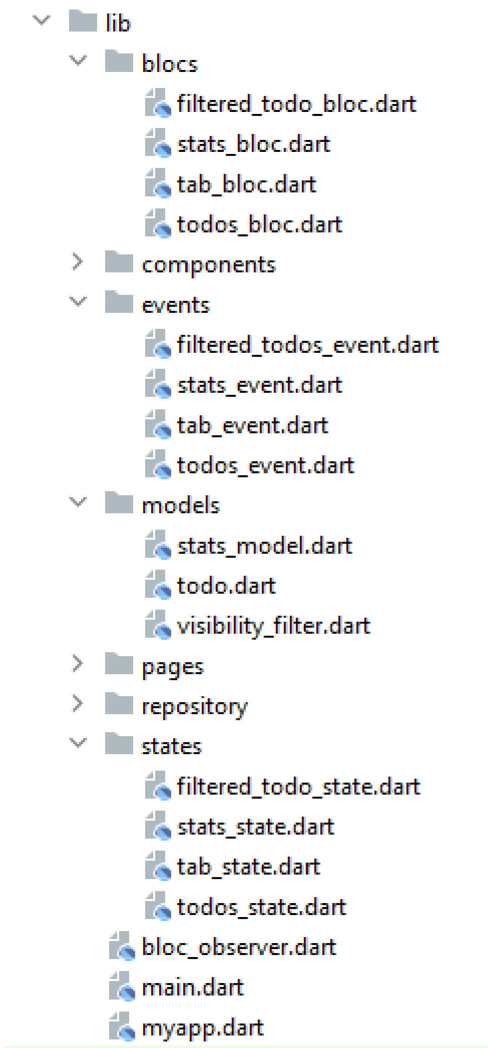
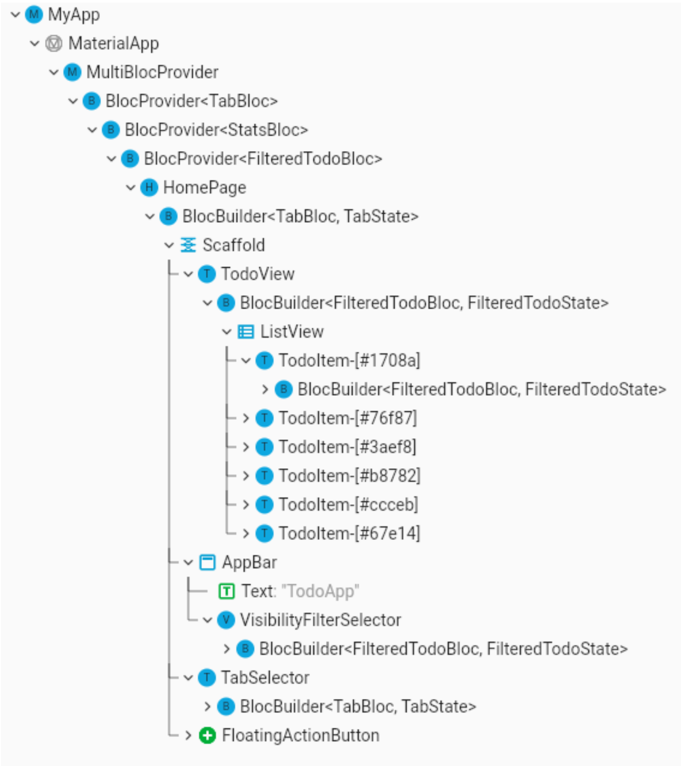
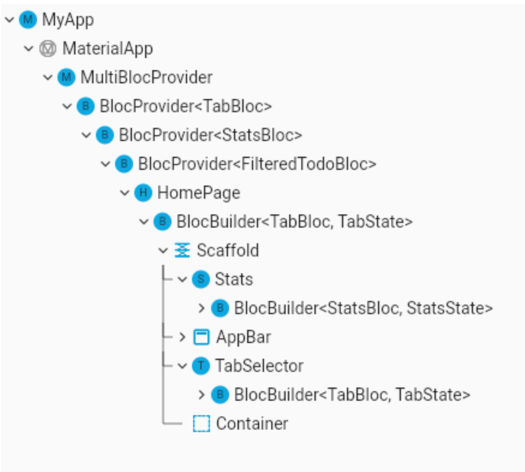


Figure 2.16: Shows the final folders structure for the BLoC implementation of the Todos app

Figure 2.17 represents the widget's tree structure for the BLoC final application.



(a) Widgets tree structure *todos* tab



(b) Widgets tree structure *stats* tab

Figure 2.17: Shows the widgets tree structure for BLoC Todos app

2.2.5. MobX implementation

This section implements the Todo application using the MobX package in order to handle the state.

Base funtionalities

As mentioned in Chapter XX RIFERIMENTO the MobX package makes one or more parts of the state Observable and uses a particular widget, called Observer, to keep track of changes in the observed variables. To be able to define observables is necessary to extend the intrested class with the Store class offedered by the MobX package. Moreover, the container class must be made abstract. The usual definition of the Todo class is used momentarily remembering that no rendering optimizations are kept into account. The parts of the state to be made observable are: the list of todos, the filter and the tab value. The whole application, indeed, relies on them to track changes and update correspondingly.

The observable state - A new abstract class is created and called _TodoStore. It contains the list of todos and the filter. A separate observable variable will be used to implement the state of the tab. This design choice allows to present two different approaches the MobX package provides and divides the information regarding the todos from the information regarding the tab value. (the filter value is in some way connected with the list of todo). This new abstract class is extended with the Store class. A list of todos and a visibility filter are created inside it and annoted with the @observable syntax. The @observable annotation informs the code generator that those variables need to be made observable, moreover, the code generator automatically creates a getter and a setter action for them.

Source Code 2.124: Todo app - MobX- TodoStore abstract class implementation

```
//extend with the Store mixin to allow annotations
abstract class _TodoStore with Store {
  @observable
  List<Todo> todos = [];

  @observable
  VisibilityFilter filter = VisibilityFilter.all;
}
```

Actions - In this implementation the strict mode is set to "always". This choice reflects the common usage of the pattern. It is indeed a common choice to allow state mutations only through actions. This behavior comes with a lot of advantages that make it the correct choice for the major of the cases. This subject will be deeper investigated in the latter sections but, for the moment, it is worth noting that the MobX package also provides the possibility to configure the strict mode to "never" allowing the direct change of the state without passing through an action. A bunch of new methods are now added to the TodoStore class and marked with the @action annotation. The simplest one is the *changeFilter* method that allows to change the current filter.

Source Code 2.125: Todo app - MobX - TodoStore's *changeFilter* action implementation

```
@action
 void changeFilter(VisibilityFilter filter) {
   this.filter = filter;
 }
```

A method to set the *completed* field of a particular todo is also required. This method is called *setCompleted* and takes the id of the todo to be changed and its new completed value. As usual, a new list is created, after modifying the todo, in order to allow MobX to recognize the change in the list of todos.

Source Code 2.126: Todo app - MobX - TodoStore's *setCompleted* action implementation

```
@action
  void setCompleted(int id, bool completed) {
    //check the todo's existance
    assert(todoExists(todos,id) ==true, 'No todo with id : \$id');
    todos.where((element) => element.id==id).first.completed=completed;
  }
```

The two usual methods to fetch and save todos into the DataBase/repository are implemented and annotated with the @action annotation too.

Source Code 2.127: Todo app - MobX - TodoStore's *fetchTodos* and *saveTodos* actions implementation

```
@action
Future<void> fetchTodos() async {
  todos = await TodoRepository.loadTodos();
}

@action
Future<void> saveTodos() async {
  await TodoRepository.saveTodos(todos);
}
```

Computed fields - computed fields are the part of the state that can be derived from other parts of the state. They are pivotal in the MobX state management solution because the package is able to smartly compute them and to perform lot of optimizations under the hood using memoization technique to prevent useless computations. They are a similar concept with respect to selector in Redux. The list of completed todos is well suited to demonstrate the power of the computed field. A new getter function is created and called *completedTodos*. It computes the list of completed todos and returns it. The @computed annotation is positioned right above the method to let the code generator know how to implement it in order to perform the optimizations discussed earlier. During the application lifecycle the *completedTodos* method will be accessed numerous times and automatically recomputed in case a part of the state, it depends on, changes. Moreover, its value is memoized and reused in case multiple accesses are necessary. Another method is created in the same way in ordert to compute the *pendingTodos*.

Source Code 2.128: Todo app - MobX - TodoStore's *completedTodos* and *pendingTodos* computed values implementation

```
@computed
List<Todo> get completedTodos =>
    todos.where((element) => element.completed).toList();
```

```
@computed
List<Todo> get pendingTodos =>
    todos.where((element) => !element.completed).toList();
```

pendingTodos and *completedTodos* methods are then used to implement other computed values: the *filteredTodos*, the number of completed todos and the number of pending todos. The *filteredTodos* method returns the list of todos that match the visibility filter. It is composed using the computed values defined before. Also the *stats* value can be obtained using the computed feature.

Source Code 2.129: Todo app - MobX - *filteredTodos* and *stats* computed value implementation

```
@computed //compute todos list length
int get len => todos.length;

@computed //compute the completed todos
int get completed => completedTodos.length;

@computed //compute the pending todos
int get pending => pendingTodos.length;

@computed //compute the filtered list
List<Todo> get filteredTodos {
  switch (filter) {
    case VisibilityFilter.all:
      return todos;
    case VisibilityFilter.completed:
      return completedTodos;
    case VisibilityFilter.notCompleted:
      return pendingTodos;
  }
}
```

```
@computed //compute stats
String get stats {
  return completed.toString();
}
```

The code generation - The _TodoStore class won't be directly used in the code but its actual implementation will. The _TodoStore is, indeed, an abstract class and is used by the code generator to implement the TodoStore class. A particular line of code must be placed just below the imports to allow the code generator to recognize the abstract class to be implement. This line of code uses the *part* directive followed by the name of the file to be generated. The generated code will be putted inside a file called *counter.g.dart* which is included with the *part* directive right below the imports. Without this line, the code generator will not produce any output. The generated file contains the _$TodoStore mixin. It is combined with the _TodoStore abstract class to finally implement the TodoStore class.

Source Code 2.130: Todo app - MobX - TodoStore code generation

```
//allow the code generator to create the todo_store.g.dart file
part 'todo_store.g.dart';
//use the generater file
class TodoStore = _TodoStore with _\$TodoStore;
```

In order to use the code generator and generate the code, a series of directives can be inserted into the terminal. For the sake of simplicity, the following line of code will be always used to generate code.

Source Code 2.131: Todo app - MobX - directive for code generation

```
flutter pub run build_runner watch --delete-conflicting-outputs
```

It automatically generates the code and handles all the possible conflicts that can arise.

For example, in case a file named todo_store.g.dart already exists it first deletes the file and then computes it again. With this line of code, the code generation process is made really easy. The drawback is that every time the code is modified the generated code is re-created from scratch. In our case this does not represent a big deal because the application is contained and the code generator only takes about 12-13 seconds to execute and create the entire code. In a more spread scenario other directives can be used to make the code generation process lighter. I decided not to show the generated code because it is quite long and hard to read.

The spy feature - in order to enable the spy feature a new configuration for the *mainContext* must be provided before running the application, in the main function. After cloning the default *mainContext* the *isSpyEnabled* field is set to true and the *writePolicy* field is set to always in order to enable the strict-mode for every state change. Moreover, a function must be passed to the spy feature. The code inside this function is executed every time an action occurs. In our case is enough to print the event name when an event of type *action* occurs to have a clear picture of what is going on.

Source Code 2.132: Todo app - MobX - spy feature attachment

```
//create a new configuration with strict mode set to "always"
mainContext.config = mainContext.config
    .clone(isSpyEnabled: true, writePolicy: ReactiveWritePolicy.always);
//provide a function to the spy feature
mainContext.spy((event) {
  if (event.type == "action") {
    print("event name : " + event.name);
  }
});
```

And that's basically all we need in order to implement the application's state. At this point is already possible to test the state logic.

Making the state accessible - MobX, like every other solution used so far, uses a Provider widget to supply the state to the subtree. In this case the mobx package do not self-implement the provider widget, instead it relies on and external package called *Provider* which offers this feature. The procedure is the usual one, the MaterialApp widget is wrapped into a Provider widget of type TodoStore which supplies the instance of the TodoStore to the subtree. It has a *create* field where the TodoStore can be initialized and where the fetching of todos can take place.

Source Code 2.133: Todo app - MobX - making the state accessible using the Provider widget

```
//wrap the material app into a Provider widget
return Provider<TodoStore>(
    create: (_) => TodoStore()..fetchTodos(), //fetch todos at creation
    child: MaterialApp(. . .),
    }));
```

The HomePage and the TabSelector component - The HomePage is almost entirely built using the state's part regarding the tab. The first thing to do is to create an observable variable of type TabState to represent it. This time, a different approach with respect to the one used to implement the state of the todos and the filter, is used. We are not creating an abstract class neither generating any code. Moreover, no Provider widget is used because the tab value needs to be accessed only in a couple of widgets and passing it between them is way easier. The tab value is wrapped into an observable object of type TabState. The entire object is managed by the MobX package and the only difference with respect to a normal variables usage is that, in order to access the TabState value, we need to further dig into the *value* field instead of just using the tab variable as it is. Both the body and the VisibilityFilterSelector widget as well as the TabSelector widget depends on the tab value so the entire Scaffold widget is wrapped into a Observer widget. Once a change in the *tab* variable occurs, the Observer widget automatically determine which parts of the Scaffold widget should be rebuilt. In our case all components depends on the tab value and then are rebuilt once a tab change occurs. In cases independent components are wrapped into the Observer widget they would not be rebuilt. The entire Scaffold widget is populated using the tab variable as usual. The only part that differs is the TabSelector component. Beside depending on the tab value it also needs to change it. There are two equivalent options : passing the tab variable to the TabSelector component or passing a closure function. The first solution is used.

Source Code 2.134: Todo app - MobX - HomePage implementation

```
class HomePage extends StatelessWidget {
  HomePage({Key? key}) : super(key: key);
  //new observable variable
  final _tab = Observable<TabState>(TabState.todos);

 @override
  Widget build(BuildContext context) {
    print("building HomePage");
    return Observer(//wrap the HomePage into a Observer widget
      builder: (context) {
        return Scaffold(
          appBar: AppBar(
            title: const Text("Todo App"),
            actions: [
             _tab.value == TabState.todos //access the state here
                    ? const VisibilityFilterSelector()
                    : Container()

            ],
          ),
          //access the state here
          body: _tab.value == TabState.todos ? const TodoView() :
           const Stats(),
          bottomNavigationBar: TabSelector(),
          floatingActionButton:  _tab.value == //access the state here
           TabState.todos
                ? FloatingActionButton(...)
                : Container()

        );
      }
    );
  }
}
```

A new variable is added to the TabSelector widget and populated in the constructor. It is used in the *onTap* field's function to mutate the tab value once the user taps on one specific BottomNavigationBarItem widget. Notice that the state change is wrapped into a *runInAction* object. This because if we change the tab value directly, a run time error would arise alerting that observable values cannot be changed outside actions. This is due to the strict mode previously set to "always". *runInAction* creates a throwaway action we can use directly in the code. This approach is made necessary because we used a stand alone Observable variable. If we included the tab variable into the TodoStore class the code generator would had automatically create its getter and setter actions.

Source Code 2.135: Todo app - MobX - TabSelector component implementation

```
class TabSelector extends StatelessWidget {
  //new variable passes from the HomePage
  final Observable<TabState> tab;

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

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

      return BottomNavigationBar(
        //use it here
        currentIndex: TabState.values.indexOf(tab.value),
        onTap: (index) {
          //use a runInAction necessary for the strict mode
          runInAction(() => tab.value = TabState.values.elementAt(index));
        },
        items: (...),
      );
  }
}
```

The VisibilityFilterSelector component - It entirely depends on the value of the filter in the TodoStore. To obtain the instance of the TodoStore we use the static *of* method of the Provider widget specifying the type of the instance we are looking for. This procedure will be frequently used from now on and is usually performed at the beginning of the *build* method.

Source Code 2.136: Todo app - MobX - retrieving the TodoStore

```
final store = Provider.of<TodoStore>(context);
```

The entire VisibilityFilterSelector component is then populated using the filter variable contained in the TodoStore as usual and wrapped into an Observer widget to make is responsive to filter changes. In the *onChanged* field of the DropdownMenuItem widgets the *changeFilter* action previously defined is used to set the filter value to the tapped one.

Source Code 2.137: Todo app - MobX - VisibilityFilterSelector component implementation

```
return Observer( //wrap the VisibilityFilterSelector into a Observer widget
  builder: (context) {
    print("building Visibilityfilter");

    return DropdownButton<VisibilityFilter>(
      value: store.filter, //use the state here
      items: (...),
      onChanged: (tappedValue) {
        //change the state here
        store.changeFilter(tappedValue!);
      },
    );
  },
);
```

Notice that we could omit the usage of the *changeFilter* action and set the value of the filter directly. This because a setter and a getter action are automatically created by the code generator for every observable field. This implies that the *changeFilter* action could also be omitted in the definition of the TodoStore abstract class.

Source Code 2.138: Todo app - MobX - changing the state in the VisibilityFilterSelector without predefined action

```
onChanged: (tappedValue) {
        //another way of changing the state
        store.filter = tappedValue!;
      },
```

I personally dislike this feature MobX package offers in the Flutter framework. I investigated a bit in the usage of MobX with React and JS finding out that, in that case, it behaves as expected raising a warning in case a field is directly changed. (violating the strict mode) I find the way for changing the filter value proposed in the Source Code 2.137 a lot more elegant with respect to the one proposed in the Source Code 2.138. Explicitly using predefined actions, indeed, brings way more meaning for the reader and prevents programmers to accidentally mutate the state in the implementation process. Even if I prefer the first approach, in the end, both approaches pass though actions in order to change the state and this respects the MobX's rules. Actions are, indeed, really important to the correct functioning of the application because using them allows the MobX package to generate atomic state transitions. Suppose a simple action, like the one we just used, produces reactions of different types and those reactions affects different parts of the state and the UI. Suppose now that the strict mode is disabled and set to "never". In that case, the various reactions can be completed/fired in different interval of time because their carried computation is heavier of lighter with respect of the others. Consequently the entire state of the application is not well synchronized and the UI could reflect this inconsistency bringing to a bad situations. MobX package ensure that actions, and consequent reactions, are performed atomically without leaking any intermediate values as long as actions are used.

The Stats component - this component is really simple. It just needs to access the TodoStore to get the *stats* value. The procedure shown in the Source Code 2.136 is used as usual to get an instance of the TodoStore and, consequently, of the *stats* value. The entire widget is then wrapped into an Observer widget .

Source Code 2.139: Todo app - MobX - Stats component implementation

```
//retrive the state
final store = Provider.of<TodoStore>(context);
return Observer(//wrap the Stats component into an Observer widget
  builder: (context) {
          //access the state
          return Center(child: Text(store.stats));
  },
);
```

The TodoView component and the TodoItem component - These two components represent the core of the UI development process. Remember now that no optimizations are considered for the moment. The TodoView widget needs to access the state and to re-render once a change in the *filteredtodos* list occurs. In this scenario, the MobX pattern really shines. It is sufficient to wrap the entire TodoView widget inside a Observer widget and access the filtered list contained in the TodoStore to allow the MobX package to automatically detect a change in the filtered list. Once the list of todos or the filter is updated, the *filteredTodos* list is automatically re-computed. As usual the TodoItem widget just acts as a visualizer for the corresponding todo and consequently takes as argument the todo instance to be visualized.

Source Code 2.140: Todo app - MobX - TodoView component implementation

```
//retrieve the state
final store = Provider.of<TodoStore>(context);
return Observer( //wrap the TodoView inside an Observer widget
  builder: (_) {
    print("building TodoView");

    return ListView.builder(
      itemCount: store.filteredTodos.length, //access the state here
      itemBuilder: (context, index) {
```

```
        return TodoItem( //access the state here
          todo: store.filteredTodos.elementAt(index),
        );
      },
    );
  },
);
```

The TodoItem widget implementation is the same presented 2.8 except for the *onChanged* field of the TextButton widget that needs to be filled up. The provided function retrieves the store using the Provider widget and fires the *setCompleted* action using the todo's id and the new value for the *completed* field. Notice, that also in this case, the *completed* field could be changed directly without any error.

Source Code 2.141: Todo app - MobX - changing the state in the TodoItem component's Checkbox

```
onChanged: (value) {
  //retrieve the state
  final store = Provider.of<TodoStore>(context);
  //change it
  store.setCompleted(todo.id, value!);
  // the state could also be changed using
  // todo.completed = value!;
}),
```

All the base functionalities are now working fine.

Features addition

In order to add and update todos its necessary to define two new actions. Also in this case the creation of these two new actions could be avoided because setter and getter methods already exists for the list of todos. However, actions carry a lot more meaning and enable to avoid code duplication. Two new methods are added to the TodoStore class and annoted with the @action syntax. The functioning is the usual one, in the *addTodo* method a new todo instance is created with an unique id and added to the list of todos. In the *updateTodo* method the id argument is used to search for the corresponding todo and the *name* and *desc* arguments are used to update it. Both methods need to substitute the todo's list with a new instance to allow the MobX package to recognize the change. Subsequently the code is generated again using the line of code presented in Source Code 2.131.

Source Code 2.142: Todo app - MobX - *updateTodo* action and *addTodo* action definition

```
@action
void updateTodo(int id, String name, String desc) {
  //check the todo existance
  assert(todoExists(todos,id) != null, 'No todo with id : \$id');
  //update the todo
  Todo todo=todos.where((element) => element.id==id).first;
  todo.name=name;
  todo.description=desc;
}

@action
void addTodo(String name, String desc) {
  //generate a new id
  int newId = generateId(todos);
  //create a new todo instance
  Todo newTodo = Todo(
      id: newId,
      name: name,
      description: desc + " " + newId.toString(),
      completed: false);
   todos.add(newTodo);
  todos = todos.toList();
}
```

Accessing these new actions in the UpdateTodoPage and in the AddTodoPage is simple by the fact that the Provider widget has been positioned as parent of the MaterialApp widget (from where different routes generate). In the *onPressed* field of the TextButton, situated in the AddTodoPage, the store is retrieved using the Provider's *of* method and used to fire a action of type addTodo.

Source Code 2.143: Todo app - MobX - AddTodoPage's *onPressed* field implementation

```
onPressed: () {
  //retrieve the state
  final store =
      Provider.of<TodoStore>(context, listen: false);
  //add the todo
  store.addTodo(
      textControllerName.text, textControllerDesc.text);
  Navigator.pop(context);
}
```

The same is done for the *onPressed* field of the TextButton in the UpdateTodoPage.

Source Code 2.144: Todo app - MobX - UpdateTodoPage's *onPressed* field implementation

```
onPressed: () {
  //retrieve the state
  final store =
      Provider.of<TodoStore>(context, listen: false);
  //update the todo
  store.updateTodo(widget.todo.id, textControllerName.text,
      textControllerDesc.text);
  Navigator.pop(context);
},
```

Rendering optimizations

Mobx package allows to perform the desired optimizations in an easy and direct way. All the effort is taken by the packages itself and the only thing to be cared about is to fragment the state in the most suited granularity for the purpose. In other words it is sufficient to make the state observable in the right points and wrap the corresponding UI elements into Observer widgets to get the job done. In the implementation provided so far, for the list of todos, the only observable part was the list itself. The list is observed by the package and by the Observer widget contained in the TodoView. There is no concept of observability in the single todos yet and, once a todo instance is change, what is seen by the package is just a completely new list. Consequently, every Observer widget listening for changes in the todo list is rebuilt. The smallest observable element the package sees is the list itself. Said that, the first thing to do in order to optimize the renderings is to increase the granularity of the observed state. Not only the list but also every contained todo needs to be made observable. It is necessary to redefine the todo model. This necessity arises with the usage of the MobX package and has not been faced in the other state management solutions used so far. The MobX solution introduces a dependency in the data layer and in the model definitions beside the usual dependency introduced in the business logic layer. In some scenarios this could represent an untoward drawback, for example in the porting processes. In some other cases this does not represent an obstacle.
The Todo model class needs to be made abstract an to implement the Store behaviour as we did for the TodoStore. It is possible now to annotate its internal fields with the @action syntax. All the fields except for the id are made observable. Moreover, the *final* attribute must be removed to all the observed variables. It is indeed meaningless to observe a variable that cannot be mutated.

Source Code 2.145: Todo app - MobX - Todo model redefinition

```
//allow the code generation to create the todo.g.dart file
part 'todo.g.dart';

//use the generated file
class Todo = _Todo with _\$Todo;
```

```
abstract class _Todo with Store{

   final int id;
  @observable
   String name;
  @observable
   String description;
  @observable
   bool completed;

 //the rest of the class is unchanged
 (...)
}
```

The *todo.g.dart* file is generated using the line of code presented in Source Code 2.131. The TodoItem widget is "stateless" for the moment. It receives a copy of the corresponding todo instance from the parent. We need to retrieve the instance directly from the store if we want the Observer widget to rebuild correctly and react to changes. Instead of receiving the entire todo from the parent the id is enough. It is used then in the *build* method to access the corresponding todo instance in the store using the Provider widget. The remaining TodoItem code remains the same except for the fact that it is wrapped into an Observer widget.

Source Code 2.146: Todo app - MobX - access the state into TodoItem component

```
class TodoItem extends StatelessWidget {
  final int id; //todo variable is substituted with an int one

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

  @override
  Widget build(BuildContext context) {
    //retrieve the state
    final store = Provider.of<TodoStore>(context, listen: false);
    //retrieve the todo matching the id
```

```
    final todo = store.todos.where((element) => element.id == id).first;
    return Observer(builder: (_) { //wrap the TodoItem into an Observer widget
      print("building TodoItem \${todo.id}");

      return InkWell(...);
    });
  }
}
```

Conclusions

Table 2.4 reports some measurements taken from the MobX's implementation process. The *lines of code* column represents the lines of code added or updated with respect to the shared project structure proposed in subsection 2.2.1. The *time* column represents the time spent in order to implement the corresponding subprocess. The unit of measure **h** stands for hours and **m** stands for minutes. The *lines-time ratio* column represents the average number of lines written in a minute. The *classes* column represents the number of created classes in each subprocess.

Measurement for MobX process

	lines of code	time	lines/time ratio	classes
base functionalities	91 (+110)	5-6 h	0.275 l/m	2 (+1)
feature addition	26 (+20)	10-15 m	1.73 l/m	0
rendering optimization	15 (+ 47)	30 m	0.5 l/m	1 (+1)

Table 2.4: MobX measurements table

Figure 2.18 represents a pie chart showing the percentage of lines of code written in each implementation's process, including the one regarding the shared structure. The state management code is really contained with respect to the shared structure's one.

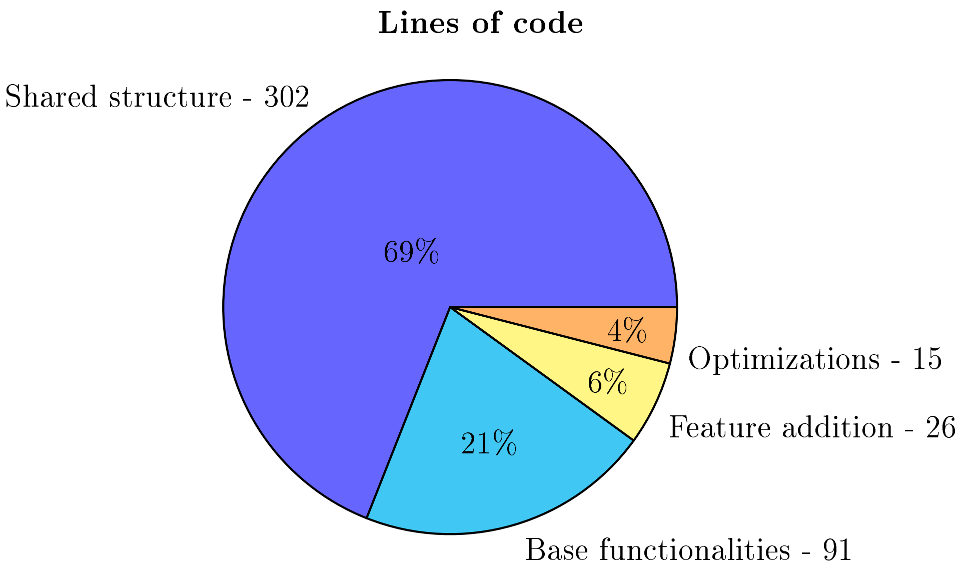


Figure 2.18: Shows the pie chart regarding the lines of code spent in each subprocess for the MobX implementation

Figure 2.19 represents a pie chart showing the percentage of time spent in each implementation's process. Notice that the most of the time has been spent understaing the solution and implementing the base functionalities.

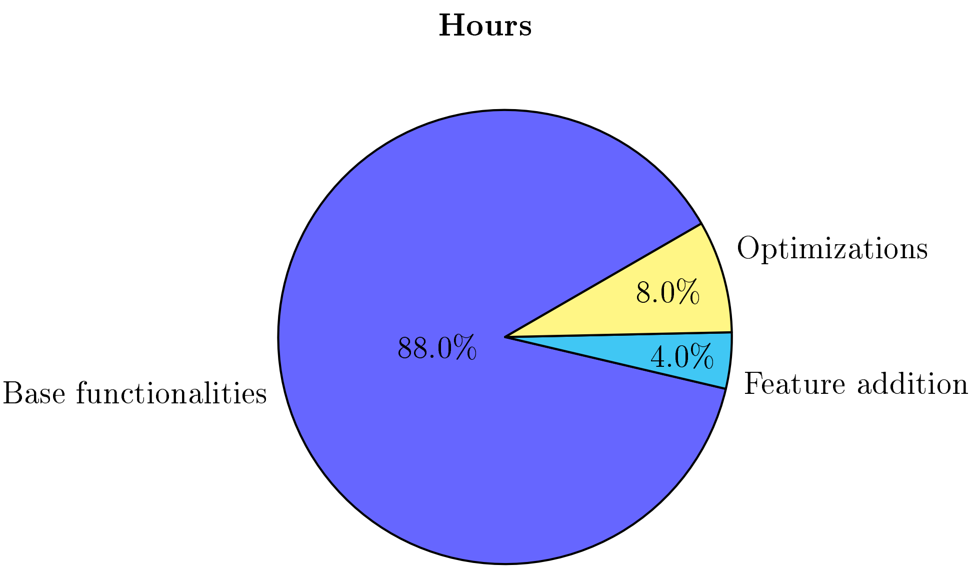


Figure 2.19: Shows the pie chart regarding the hours spent in each process for the MobX implementation

Figure 2.20 shows the final folders structure for the MobX implementation process. The only added files are the *todo_store.dart* file plus the two generated files.

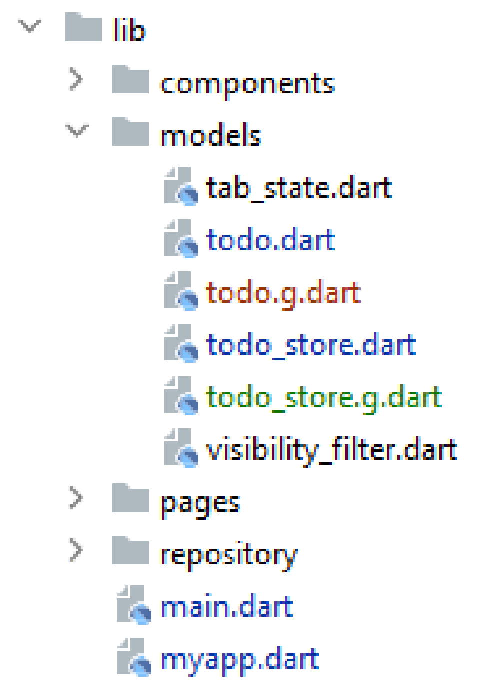


Figure 2.20: Shows the final folders structure for the MobX implementation of the Todos app

Figure 2.21 represents the widget's tree structure for the MobX final application.

(a) Widgets tree structure *todos* tab

(b) Widgets tree structure *stats* tab

Figure 2.21: Shows the widgets tree structure for MobX Todos app

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

List of Tables

List of source codes

Acknowledgements

Here you might want to acknowledge someone.