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Mobile applications State Management in Flutter

Tesi di Laurea Magistrale in
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Abstract

Abstract

Keywords: here, the keywords, of your thesis

Abstract in lingua italiana

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

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

Contents

Introduction

Introduction

1 | State management solutions

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

1.1. SetState and InheritedWidget/InheritedModel

...

1.2. Redux

...

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2 | The Todo app

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

2.1. General overview

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

2.1.1. Base functionalities

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

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

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

2.1.2. Adding new features

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

The Add todo Feature

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

The Update feature

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

2.1.3. Renders optimization

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

2.2. Implementation

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

2.2.1. Shared project structure and files

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

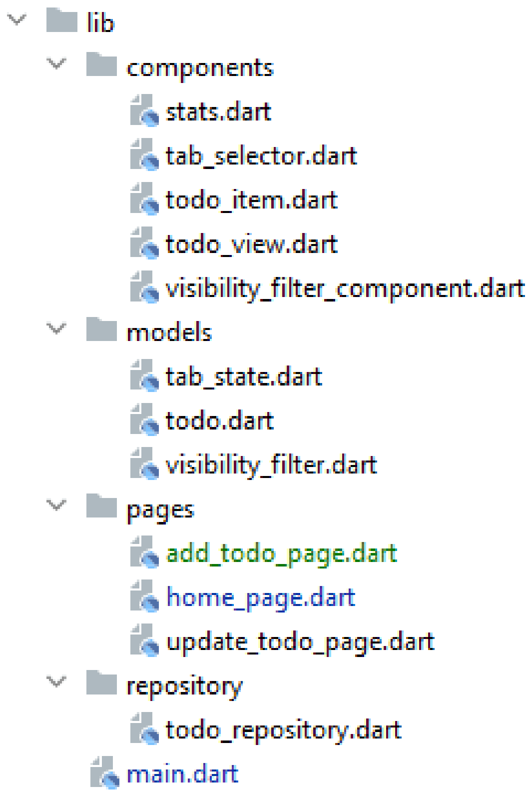


Figure 2.1: Todos app skeleton's folders structure.

The application's Root

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

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

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

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

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

class _MyAppState extends State<MyApp> {

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

      },
    );
  }
}
```

Models and Repository

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

Source code 2.2: Todo app - TabState model definition

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

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

Source code 2.3: Todo app - VisibilityFilter model definition

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

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

Source code 2.4: Todo app - Todo model definitio

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

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

  @override
  bool operator ==(Object other) {
```

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

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

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

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

Source code 2.5: Todo app - TodoRepository definition

```
  class TodoRepository {
    static Future<List<Todo>> loadTodos() async {
      Random rand = Random();
      List<Todo> todos = [];
      List<int> ids = [];
      while (ids.length < 6) {
        int newInt = rand.nextInt(1000)+2;
        if (!ids.contains(newInt)) {
          ids.add(newInt);
```

```
        }
      }
      todos = ids
          .map((number) => Todo(
              id: number,
              name: "Todo " + number.toString(),
              description: "description " + number.toString(),
              completed: rand.nextBool()))
          .toList();

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

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

Pages

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

Source code 2.6: Todo app - HomePage definition

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

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

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

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

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

Source code 2.7: Todo app - UpdatePage definition

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

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

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

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

  @override
  Widget build(BuildContext context) {

    return Scaffold(
        appBar: AppBar(
          title: Text("Update Todo"+widget.todo.name),
        ),
        body: Column(
          children: [
            TextField(
              controller: textControllerName,
              decoration: const InputDecoration(
                  border: OutlineInputBorder(), hintText: 'Enter a new name'),
            ),
            TextField(
              controller: textControllerDesc,
              decoration: const InputDecoration(
```

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

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

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

Source code 2.8: Todo app - AddTodoPage definition

```
class AddTodoPage extends StatefulWidget {

  final void Function(String,String) addTodoCallback;

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

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

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

```
  final textControllerDesc = TextEditingController();

  @override
  Widget build(BuildContext context) {

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

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

Components

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

Source code 2.9: Todo app - TodoView definition

```
class TodoView extends StatelessWidget {

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

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


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

        );
      },
    );
  }
}
```

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

Source code 2.10: Todo app - TodoItem definition

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

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

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

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

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

Source code 2.11: Todo app - TabSelector definition

```
class TabSelector extends StatelessWidget {


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

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

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

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

Source code 2.12: Todo app - VisibilityFilterSelector definition

```
class VisibilityFilterComponent extends StatelessWidget {

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

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

      },
    );
  }
}
```

Stats component takes care to visualize some numerical representation of the list of todos. Stats component is a Stateless widget composed by Text widget showing stats value.

Source code 2.13: Todo app - Stats definition

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

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

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

2.2.2. Inherited widget/model and SetState implementation

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

State management solution's introduction

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

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

The provided callback is immediately called synchronously. It must not return a future (the callback cannot be async), since then it would be unclear when the state was actually being set.
Calling *setState* notifies the framework that the internal state of this object has changed in a way that might impact the user interface in this subtree, which causes the framework to schedule a build for this State object.
If you just change the state directly without calling *setState*, the framework might not schedule a build and the user interface for this subtree might not be updated to reflect the new state.
Inherited widget are a base class for widgets that efficiently propagate information down the tree. To obtain the nearest instance of a particular type of inherited widget from a build context, use *BuildContext.dependOnInheritedWidgetOfExactType*. Inherited widgets, when referenced in this way, will cause the consumer to rebuild when the inherited widget itself changes state. The convention is to provide a static method *of* on the InheritedWidget which does the call to *BuildContext.dependOnInheritedWidgetOfExactType*. This allows the class to define its own fallback logic in case there isn't a widget in scope. An InheritedWidgets is not intended to be used as the base class for models whose dependents may only depend on one part or "*aspect*" of the overall state. Indeed

inherited widget's dependents are unconditionally rebuilt when the inherited widget changes.

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

Base functionalities

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

Core state

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

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

```
class TodoInheritedData extends InheritedWidget{
```

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

Source code 2.15: Todo app - InheritedWidget- TodoInheritedData implementation

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

TodoInheritedData(
    {
```

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

filterTodos function is just a function that takes the full list of todos and a filter and returns the filtered list. Important to notice the fact that a *child* widget must be also provided in the constructor. This is because TodoInheritedData is nothing else than a widget itself that wraps data and makes it accessible down the tree.
TodoInheritedData widget is stateless. It cannot be changed (every value is final) ,instead , a new TodoInheritedData widget must be provided when a data change occurs. The *updateShouldNotify* function must be overridden inside the TodoInheritedData class. This function belongs to the InheritedWidget class and its override is mandatory. It helps to avoid useless UI rebuilding when a new state ,without actual data changes , occurs. Once a TodoInheritedData element is replaced with a new one, the new element takes care to call the *updateShouldNotify* method and to decide whether is necessary to notify changes in the subtree. If the method returns *true* ,the subtree is rebuilt, if it returns *false* ,instead, it is not.

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

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

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

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

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

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

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

Source code 2.18: Todo app - InheritedWidget - TodoProvider implementation

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

  final Widget child;

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

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

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

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

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

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

loadTodos is a TodoRepository's async function that simulate the retrieval of the todos from a database as defined in the paragraph 2.1.

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

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

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

The TodoView component

TodoView component can now be populated. Its implementation can be found in paragraph 2.8 in subsection 2.2.1. It is a stateless widget that looks up for the *filteredTodos* list, contained in the TodoInheritedData widget. It uses the *of* method ,defined here

RIFERIMENTO, to access the nearest TodoInheritedData instance. Then, it uses the list to populate the ListView widget.

Source code 2.21: Todo app - InheritedWidget - TodoView implementation

```
class TodoView extends StatelessWidget {

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

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

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

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

The VisibilityFilterSelector component

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

Source code 2.22: Todo app - InheritedWidget - VisibilityFilterComponent implementation

```
class VisibilityFilterComponent extends StatelessWidget {

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

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

      },
    );
  }
}
```

The *onChanged* field must be populated with a function that takes as single argument a VisibilityFilter value. This function is called when a DropdownMenuItem is tapped by the user. It contains ,in its argument, the tapped DropdownMenuItem's filter value. We want this function to change the state contained in the TodoInheritedData widget (the *filter* variable) when fired. In order to do so , a state changing function must be provided by the TodoInheritedData widget to be accessed ,and called, by other widgets. As we mentioned earlier, TodoInheritedData widget contains only final fields and should never be modified. It is not possible ,indeed, to directly change the values inside the TodoInheritedData widget. For this reason , just adding a new function inside the TodoInheritedData widget ,to perform the change, is not a solution. Indeed, trying to change a part of the state, inside this ipotetic function, will generate an error at compile time (final variable cannot

be set outside constructor). A completly new TodoInheritedData widget ,indeed, should be created. The TodoInheritedData widget is created in the TodoProvider widget, when the *build* method runs, using its local variables *todos* and *filter*. In order to generate a new TodoInheritedData widget, is sufficient to change the TodoProvider widget's local state ,using the *setState* method. This will cause the *build* method to run again with the new values and generate a new TodoInheritedData widget. At this point should be clear that the state changing function comes from the TodoProvider widget. This function , once called, changes the local state of the TodoProvider stateful widget generating a new state for the application.
In pratice ,a new function ,called *onChangeFilter*, is added inside the TodoProvider widget. This function takes a VisibilityFilter value as parameter and set the value of TodoProvider's *filter* variable using *setState* method.

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

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

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

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

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

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

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

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

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

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

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

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

The TodoItem component

TodoItem widget is stateless for the moment. It that take as paramenter a Todo and takes care of displaing it as defined in 2.2.1. TodoItem does not really access the state to read values. The todo to be displayed is ,indeed, passed by the parent widget (the TodoView). However, the TodoItem widget needs to "write" the state, once the checkbox is tapped. For the moment the Checkbox widget ,inside every TodoItem, is just showing their todo's completion but its *onChange* function is still empty and does nothing when tapped. When the CheckBox is tapped a change in the corresponding Todo's *completed* field should be fired and a rebuild of the TodoItems performed. In order to do so, TodoIhneritedData should provide a state changing function, down the tree, that allow to perform this change. The process to be performed and the reasoning is the same exposed in the previous paragraph: paragraph 2.21 . Going back again to the TodoProvider stateful widget a function ,called *onSetCompleted* , is added . This function takes as parameter the id of the todo to be changed and the new value for the *completed* field.

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

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

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

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

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

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

```
            TodoInheritedData.of(context).onSetCompleted(todo.id, value!);
}),
```

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

The Stats component

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

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

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

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

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

The TabSelector component

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

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

```
TabState tab = TabState.todos;

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

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

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

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

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

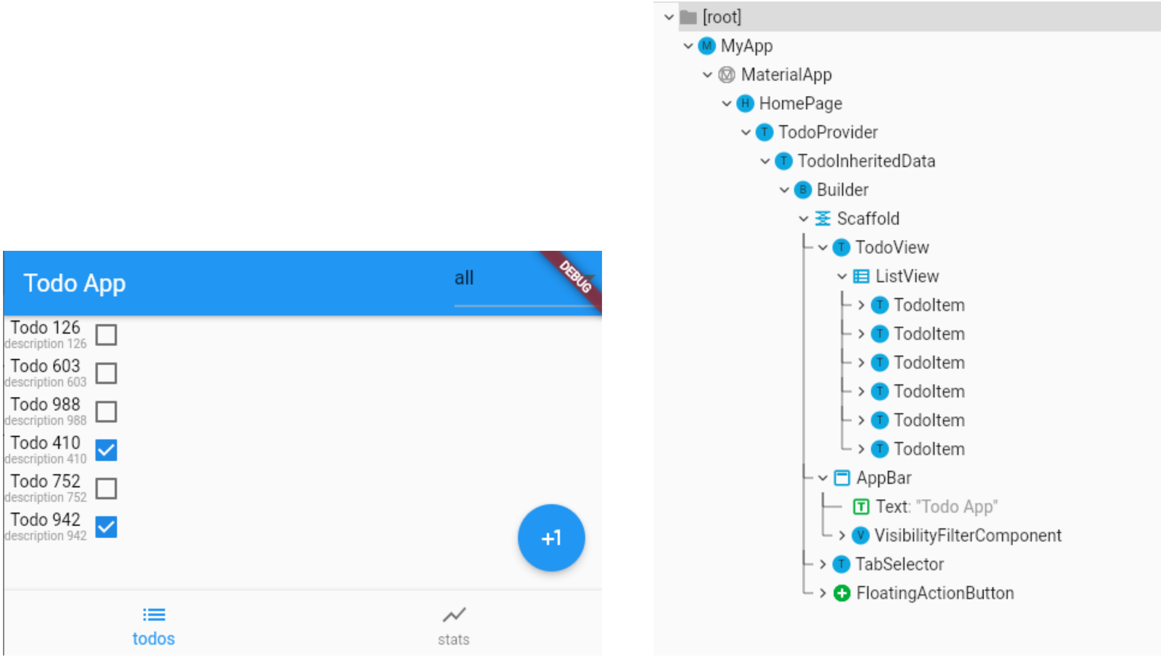
```
  @override
  Widget build(BuildContext context) {
    print("Building Tab Selector");

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

It is now possible to switch from tabs.

Summary

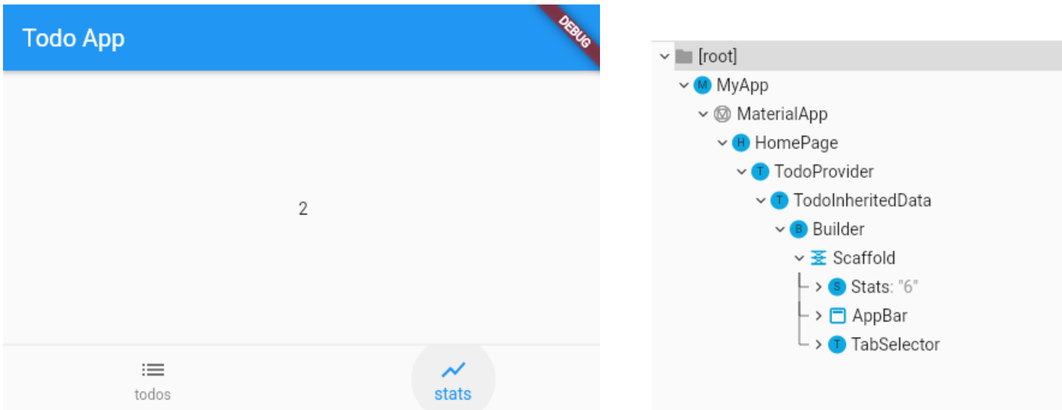
The whole process was fast and straight forward. Down below some images taken from an execution of the application. In this execution ,six todos are randomly created and only two of them are marked as completed.



(a) todos tab runtime UI. (b) todos tab runtime widget tree.

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

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



(a) stats tab runtime UI. (b) stats tab runtime widget tree.

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

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

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

Features addition

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

Todo addition feature

A new function must be implemented in the TodoProvider widget and passed to the TodoInheritedData widget. This new function will be called *onAddTodo* and will take two parameters (name and description).

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

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

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

  {...}

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

In the AddTodoPage a TextButton has been already set up and is ready to call this 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 **??**.

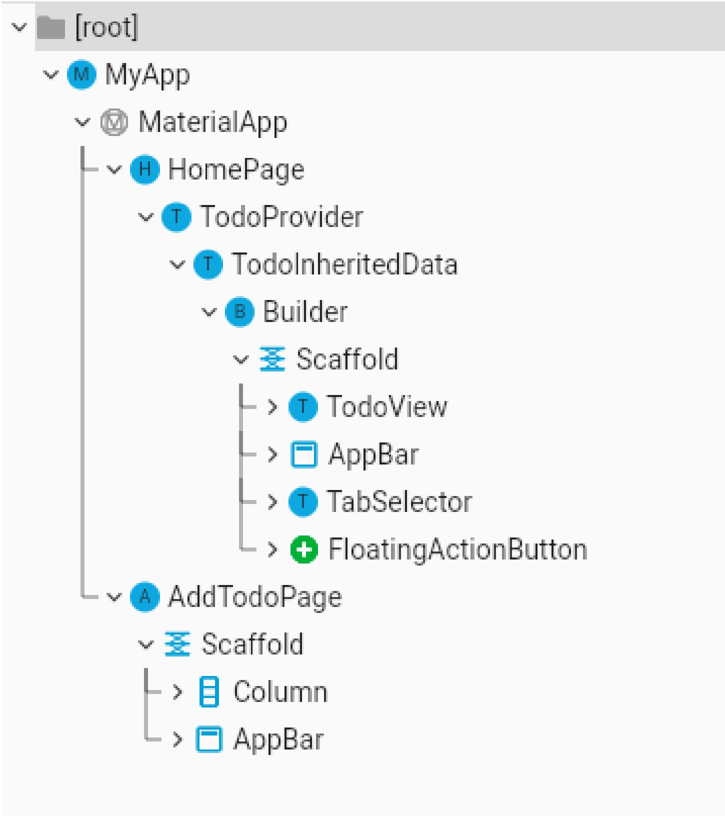


Figure 2.4: Show the tree structure after the FloatingActionButton in the HomePage is tapped.

In this new scope the Scaffold widget inside the AddTodoPage become the root of the tree of the current route. In other words, the AddTodoPage is not a part of the subtree of the HomePage but is a standalone tree instead. There is no instance of TodoProvider as ancestor of the AddTodoPage Scaffold widget and so it is not possible to call the *of* method as before. Indeed calling the *of* method in a context where a TodoProvider is not present will cause the line

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

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

```
class AddTodoPage extends StatefulWidget {

  final void Function(String,String) addTodoCallback;
```

```
  {. . .}
```

And the material app is notified about the necessity of this new argument in the AddTodoPage creation.

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

At this point the *onChange* function of the TextButton inside the AddTodoPage can finally be populated as follow

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

The current route (AddTodoPage) is also popped after the todo creation, and the HomePage is rebuilt (by the fact the TodoInheritedData changed).

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

Todo updating feature

First thing is to create and make the *onUpdateTodo* feature/function accessible down the tree. A new function must be implemented in the TodoProvider widget and passed to the TodoInheritedData widget. This new function will be called *onUpdateTodo* and takes three arguments: the id of the todo to be updated, the *newName* that should be set and the *newDesc*.

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

```
      return Todo(
          completed: element.completed,
          description: newDesc,
          name: newName,
          id: element.id);
    } else {
      return element;
    }
  }).toList();
  setState(() {
    todos = newTodosList;
  });
}
```

It first checks if a todo matching the id exists. Then, for the same immutability concept we dealt with when we spoke about the *onAddTodo* feature, a *newTodosList* is created and populated with the elements inside the *todos* list. Moreover, the todo with the corresponding id is update with the new name and new description. Finally, the *todos* list in the TodoProvider stateful widget is overridden with the *newTodosList* using the *setState* method. This new *onUpdateTodo* method is then made accessible down the tree adding it to the TodoInheritedData.

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


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

```
  );
}
```

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

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

Inside the *onTap* function of the TodoItem's InkWell widget the route UpdateTodoPage will be pushed but first a container for arguments must be set up. Indeed, Flutter Navigator allows to pass only a single object as argument between routes. In this case not only the *onUpdateTodo* function must be passed to the new route but also some information about the Todo itself. For this reason a wrapper class is created with the name *UpdateTodoPageArguments* .

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

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

and inside the InkWell's *onTap* function will be used to create a container for the arguments.

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

A further change must be done in the MaterialApp's "/updateTodo" route to populate the field of the UpdateTodoPage correctly.

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

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

```
TextButton(onPressed: () {

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

Once pressed the UpdateTodoPage will be popped, and the HomePage rebuilt to show the actual changes in the *todos* list.

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

Render optimizations

This was a pretty hard task. I spent some hour trying to figure out how make , when a single todo update occurs, rebuild the TodoItem only instead of the entire TodoView. Then I realized that it was just not feasible using InheritedWidgets. InheritedWidget indeed do not offer this possibility at all. Every widget in the TodoProvider's subtree that access the state is registered as listener for state changes and once a state change occurs there are only two possibilities: notify all those widgets and rebuild them or not. In other words when a state change occurs and must be visualized the entire TodoProvider's subtree must be rebuilt unconditionally. Flutter framework however offers a particular widget called InheritedModel to handle this scenario. InheritedModel

work as InheritedWidget except for the fact that when a widget access the state (calling the *of* method) it must provide also a new additional parameter called *aspect*. *Aspect* can be whatever object, for example a String or a Int, but also a more complex data structure. The *aspect* parameter identifies on which part (or parts) of the state the widget is registering to.
First thing to do is to substitute the extension to InheritedWidget with InheritedModel in the TodoInheritedData class (in the todo_provider.dart file).

```
class TodoInheritedData extends InheritedWidget {
```

to

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

I decided to use Ints to identify aspects. In particular, widgets that need to rebuild on *filteredTodos* list structure change will register to aspect identified with the number 0. Widgets that do never need to rebuild will register to aspect identified with number 1. Widgets that need to rebuild when a change in a specific Todo with id n occurs will register to the aspect identified with the number n. (no Todos will have id with value 0 or 1. This is a convention I used to keep things simple. Other more complex structure could be used to avoid this behaviour). With *filteredTodos* structure I mean the length of the list. TodoView indeed should be entirely rebuilt only when a Todo is added or removed from the list changing its length. No todos replacement is considered by the fact that a replacement should be split into two separated actions ; a deletion and an insertion. At this point the method *of* should be updated taking into account also the aspect parameter. Morevover, the *result* variable should be populated with the *inheritedFrom* static method belonging to the InheritedModel class instead of the *dependOnInheritedWidgetOfExactType* method belonging to InheritedWidget class.

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

Now all the lines of code that access the state with the *of* method must be changed taking into account the new implementation and the new *aspect* argument in this way

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

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

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

```
    }
  }
}
```

This was tough to code but in the end worked well for the purpose. The method's pseudocode is presented down below.

```
if( widgetRegisteredForStructureChange && strucutureChangeOccured){
        return true;
    }else{
        if( widgetRegisteredForSpecificTodoChange && thatTodoChanged){
            return true;
            }else{
                return false;
    }
}
```

At this point the TodoItem's checkbox is tapped just the TodoItem is rebuilt. No visual changes are shown, however. The widget will rebuild with the same information as before and this is due to the fact that the *build* method refers to the local TodoItem's Todo variable. This variable is populated on the TodoItem creation and cannot be changed. Indeed, a Todo is passed as argument in the constructor method from the TodoView and from that moment on will remain the same. No visual changes are shown because this local Todo indeed did not change. It is a copy of the actual Todo present in the *filteredTodos* list and for this reason is not affected by changes. This is a really bad behavior and is cause by the fact that sometimes, during programming , more than one level of information caching is required/used to avoid effort in coding or 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 reflected it. The problem was generate by the fact that a copy of the real Todo was passed to the TodoItem widget instead of the id of the Todo and then use this id to look up for the Todo in the centralized state (the TodoInheritedData). This of course will require more computational effort but also will guarantee a lot more stability and robustness. Saying that the TodoItem's local variable

Todo is replaced with a new int variable called *id* that represents the id of the Todo that the widget is visualizing. Then in the *build* method the corresponding Todo is looked up.

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

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

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

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

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

2.2.3. Redux implementation

2.2.4. BloC implementation

2.2.5. MobX implementation

2.2.6. GetX implementation

3 | The Other app

Another app developed using same state managemnts solutions

4 | Comparisons

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

5 | Conslusions

Conclusions

A | Appendix A

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

B | Appendix B

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

List of Figures

List of Tables

List of source codes

Acknowledgements

Here you might want to acknowledge someone.