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Mobile applications State Management in Flutter

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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

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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

...

1.3. BLoc

...a

1.4. MobX

...

1.5.GetX

...

2 | The Todo app

In this section I'm going to present the development of a Todo management mobile app using a series of State Management solutions and collect some measurements. In particular for every solution implementation three development processes will be done. First basic functionalities of the app will be implemented the. Then I will measure how much effort/code is required to add other new functionalities. In the last part some optimization will be made to the code in terms of UI renders (and memory consumption).

2.1. General overview

In this section the the development processes are explained more in details.

2.1.1. Base functionalities

This part of the development process aims to realize the skeleton of the app. The output app offers the possibility to visualize and partially handle todos. It is composed of a single page: the HomePage. The HomePage is composed by an AppBar and two tabs:*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)
- Not Completed (visualize pending todos)

The elements that compose the list of todos are called TodoItems. TodoItems visualize the todo's name and description using a Text widget and completion using a Checkbox. It is possible to use the checkbox to mark a Todo as completed or to mark it as pending. In the *stats* Tab instead 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

Once basic functionalities got implemented a few more will be added. This part of the development process is divided into two subpart. Both of them aims to add a single new feature.

The Add todo Feature

The first subpart of the features addition process aims to add the possibility to create new Todos. This feature will utilize the `FloatingActionButton` already present in the skeleton of the app in the bottom right corner to push the `AddTodoPage`. In the `AddTodoPage` will be possible to compile some `TextField` widget and use a `TextButton` to actually create the new todo.

The Update feature

The second subpart of the features addition process aims to add the possibility to tap on a specific `TodoItem` to navigate to the `UpdateTodoPage` where two `TextFields` and a `TextButton` button will show. Once inserted a new name and/or a new description for the todo, clicking on the confirm button the `UpdateTodoPage` route will be popped and the todo will be updated.

2.1.3. Renders optimization

In this part some optimization for the widget's rendering will be made. In particular the aim of this development process is to use the least renders possible or in other words to call the least *build* execution possible. The focus will be on the `TodoView` and `TodoItems`. We want the `TodoView` to be rendered again only when a structure change in the *filteredTodos* list happens and not when a single `TodoItem`'s internal aspects change. When Todos are modified through tapping the `TodoItem`'s `Checkbox` or using the update feature only the corresponding `TodoItem` should be rendered again leaving the rest of the application the same.

2.2. Implementation

in this section the development process with different State Management solutions will be presented.

2.2.1. Shared project structure and files

In this subsection will be presented the implementation of the shared files between different solutions. The project will have the folder structure shown in figure 2.1 Indeed some parts of the code will be shared/reused between solutions. The complete structure of the app's UI will be the same for every implementation such as the repository used to fetch Todos.

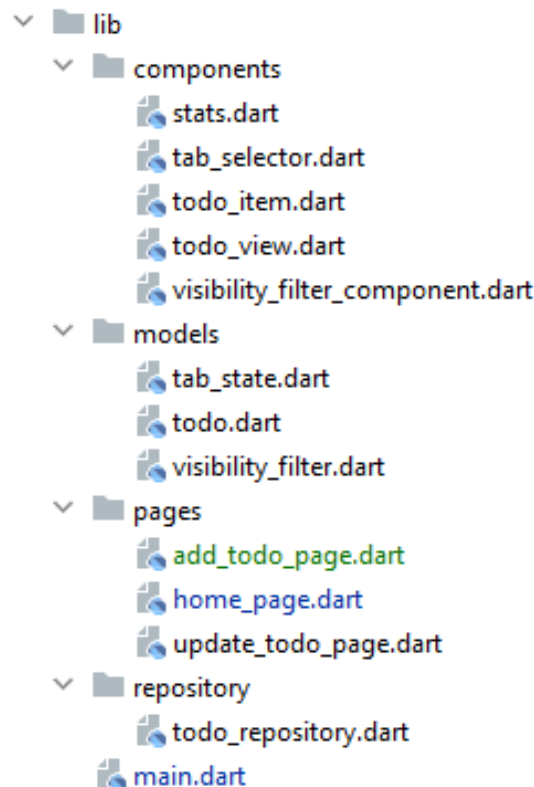


Figure 2.1: Folders structure of the skeleton of the Todos app.

ThenMain

The main function will run the root widget of the application called MyApp. It is a stateful widget composed by a MaterialApp. Inside the MaterialApp three roots are defined. The HomePage, the UpdateTodoPage and the AddTodoPage. The initialRoute is set to the HomePage.

```

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

First model presented is the `TabState` model. It models the tabs visualized in the Home-Page. `TabState` are only two : *todos* and *stats*. In the *todos* tab todos are visualized instead in the *stats* tab some numerical recap of the todos is visualized.

```

enum TabState{
    todos,stats
}

```

Possible filters for the *filteredTodos* list are modelled by the `VisibilityFilter` enumeration.

```

enum VisibilityFilter{
    completed,notCompleted,all
}

```

For what concerns the Todo model is not possible to give a common implementation for every solution. Todo model will change in different implementations. The general

structure of the Todo model is presented below. (It is presented here as an immutable class but in some implementation it will be changed to mutable)

```
@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;
}
```

TodoRepository models a repository that simulates the todos fetching from a Database. It has two static functions. Those functions are async functions with a duration of 2 seconds to give the impression of a real async operation.

```

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* to *stats* tab using the BottomNavigationBar TabSelecto widget. An empty FloatingActionButton is 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 StatelessWidget in other implementations.).

```

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 composed by a Column with

inside two TextFields and a TextButton. The TextButton is left empty for future implementation.

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

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

```

        child: const Text("Confirm"))
      ],
    ));
  }

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

```

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

```

class AddTodoPage extends StatefulWidget {

  final void Function(String,String) addTodoCallback;

  const AddTodoPage({Key? key, required this.addTodoCallback}) : 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: () {},
          , child: const Text("Create"))
      ],
    ));
}

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

```

Components

TodoView component uses a ListView. *itemCount* and *itemBuilder* fields are left empty for future implementation.

```

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 stateless widget. Uses two Text widgets to display the Todo 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 empty for future 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");  
      },  
      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 uses a `BottomNavigationBar` with as many `BottomNavigationBarItems` as `TabState.values` (in our case two). Function fields are left empty for future implementation.

```

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.

```
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 is a Stateless widget composed by Text widget showing stats value.

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

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

    return 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 *InheritedWidget* 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 App

To use `InheritedWidgets` we create a class where the state, or part of the state, will be contained and extend it to `InheritedWidget`. For our purpose a single class will be enough to contain all the state information. This class will be called `TodoInheritedData`.

```
class TodoInheritedData extends InheritedWidget{
```

Data that should be accessible down the tree must be placed inside it. In our case the only data needed is : a list of `Todos`, a `VisibilityFilter` , a `Int` for the stats (for conciseness it will represent the number of completed todos) and another list of `Todos` that will contain the todos matching the filter. Inside the constructor final variables are initialized with the corresponding arguments and *stats* and *filteredTodos* variables are computed. *filterTodos* function is just a function that takes the full list of todos and a filter and returns the filtered list. Important to notice is the fact that a *child* widget must be also passed in the constructor. This is because our `TodoInheritedData` is nothing else than a widget itself that wraps the data and make them accessible in the child tree.

```
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);
```

```
}
```

Is important to understand that `TodoInheritedData` widget is stateless. It cannot be changed (every value is final) but instead a new `TodoInheritedData` widget must be provided when a data change occurs. The `updateShouldNotify` function must be overridden inside `TodoInheritedData`. This function help to avoid ui rebuilding when a new state without actual data changes occurs. Once a `TodoInheritedData` element is replaced with a new one this new element will take care to call the `updateShouldNotify` function to decide whether is necessary or not to notify changes in the subtree. If the function returns `true` the subtree is rebuilt, if return `false` instead is not.

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

In our case the `listEquals` function takes as parameters the old `filteredTodos` list and the new one and compare them element by element checking if changes were made. In the particular case no changes were performed it returns `true` and will lead the `updateShouldNotify` function to return `false` and not to rebuild the entire subtree. At this point our `TodoInheritedData` can be used it in a stateful widget.

```
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 as convention. We add also an *init* method to fetch the data from the repository on widget's creation.

```

@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. We need to declare also the *of* static method to retrieve our `TodoInheritedData` down the tree. This method just extracts the nearest `TodoInheritedData` element up in the tree using *dependOnInheritedWidgetOfExactType* method. In case it does not find one it will cause a runtime error.

```

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

```

At this point our `TodoProvider` widget can be incorporated as a parent of the `Scaffold` widget in the `HomePage`. The usage of the `Builder` widget is due to the fact that data is accessible only in a context where a `TodoProvider` is already present. In other word `TodoProvider`'s data cannot be used 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 a `TodoProvider` widget.

```

@override
Widget build(BuildContext context) {

```

```

return TodoProvider(
  child: Builder(
    builder: (context) {
      return Scaffold();
    }
  );
}

```

At this point the `TodoView` component can be populated. It is a stateless widget that will look up for the *filteredTodos* list in the `TodoInheritedData` inside the *build* method and create a `ListView` dynamically with it. The `ListView` will be composed by `TodoItem` widgets.

```

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),
        );
      },
    );
  }
}

```

`TodoItem` widget is stateless widget that take as parameter a `Todo` and take care of displaying it with as defined in 2.2.1.

```

class TodoItem extends StatelessWidget {
  final Todo todo;

```

```

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

@override
Widget build(BuildContext context) {
  return 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) {
        })),
    ],
  );
}
}

```

At this point we got a single page (Homepage) that contains a `TodoView` showing *filteredTodos* list's todos contained in the `TodoInheritedData` inside a `TodoProvider` widget. When the application starts we first see an empty page (todos are empty at the beginning) and then after few seconds a list of todos with their names, descriptions and completions appears. The list of filtered todos can be visualized but is not interactable yet. In the app `HomePage`'s `AppBar` we already set up a `VisibilityFilterComponent` that is nothing else than a stateless widget. In its *build* method a `DropDownButton`'s `value` field is set up looking up for the *filter* values in the `TodoInheritedData`. Then the *items* field is filled with a list of `DropDownMenuItem` that comes from the mapping of all possible `VisibilityFilter` values to `DropDownMenuItems`.

```

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) {

        },
    );
}
}

```

For what concerns the *onChanged* field a function that takes as single parameter a filter value must be provided. In particular we want this function to change the state contained in the *TodoInheritedData* (the *filter* variable) and to fire a rebuild of the *TodoInheritedData* subtree. As we mentioned above *TodoInheritedData* contains only final fields and should never be modified. Instead, a new *TodoInheritedData* element should be created in the *TodoProvider* *build* method with the modified data. In the *to* *TodoProvider* stateful widget a function called *onChangeFilter* is added. This function takes the new *filter* values as parameter and changes the value of the *filter* in the stateful widget calling *setState*. Doing so the *build* function is called again with the new filter value and a new *TodoInheritedData* widget is created.

```

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

```

The *onChangeFilter* function must be provided to the *TodoInheritedData* to make it accessible in the widget's subtree. To do so a new parameter is added in the *TodoIn-*

heritedData as follow.

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

class TodoInheritedData extends InheritedModel<int> {
  {...}
  final void Function(VisibilityFilter) onChangeFilter;
  {...}
}
```

Now that the *onChangeFilter* function is accessible down in the tree it can be called in the *onChange* field we provide inside the VisibilityFilterComponent DropdownButton.

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

The *filteredTodos* list can now be changed applying different filters. However, the Check-box inside every *TodoItem* is just showing if the particular todo is completed or pending but its *onChange* function is still empty and does nothing when tapped. When a tap on the CheckBox occurs a change in the corresponding *Todo*'s *completed* field should be fired and a rebuild of the *TodoItems* performed. (for the moment we don't care if the *TodoItem* only or the entire *TodoView* is rebuilt). To do so *TodInheritedData* should provide also a function down the tree that allow to perform this change. Going back again to the *TodoProvider* stateful widget a *onSetCompleted* function is added . This function takes as parameter the id of the *Todo* to be changed and the new value for the *completed* field.

```
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();
});
}

```

The *todos* list is scanned using a map. Once the todo with the corresponding id is found its *completed* value is changed 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*. All the elements of the *TodoInheritedData* subtree are rebuilt too.

At this point is possible to visualize the *filteredTodos* list, change the filter and update *Todo*'s *completed* field. To implement the *stats* tab the *Stats* component must be connected to the corresponding data and the *TabSelector*'s logic defined. First, the *stats* value is retrieved in the *Stats* component widget using the *of* method and visualized in the *Ui*.

```

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

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

        return Text(TodoInheritedData.of(context).stats.toString());
    }
}

```

Then a new *TabState* variable is created in the *HomePage* called *tab* and set as *TabState.todos* by default. A function called *onTabChange* will call the *setState* method modifying the *tab* value and causing the *build* method to run again.

```
TabState tab = TabState.todos;
```

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

tab value and *onTabChange* function are now passed to the *TabSelector* component as parameters and used to populate the *BottomNavigationBar* widget.

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

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

At this point all the basic functionalities have been implemented.

Down below some images taken from an execution of the application. Six todos are randomly created and only two of them are marked as completed.

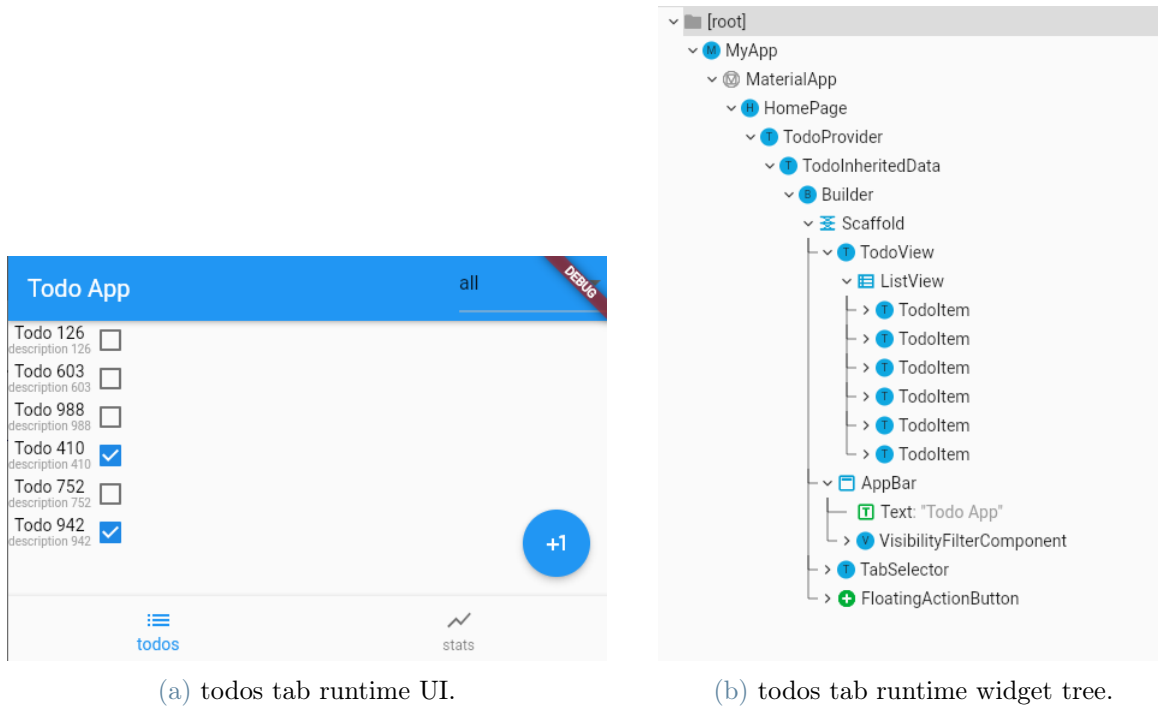


Figure 2.2: Show the runtime Widget's tree and UI when visualizing todos tab.

Figure 2.2a shows how the application UI looks like after few seconds from the start. Figure 2.2b show the widgets tree related with the run.



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

Figure 2.2a shows how the application UI looks like after the user taps on the TabSe-

lector's stats button. Figure 2.2b 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 2.4.

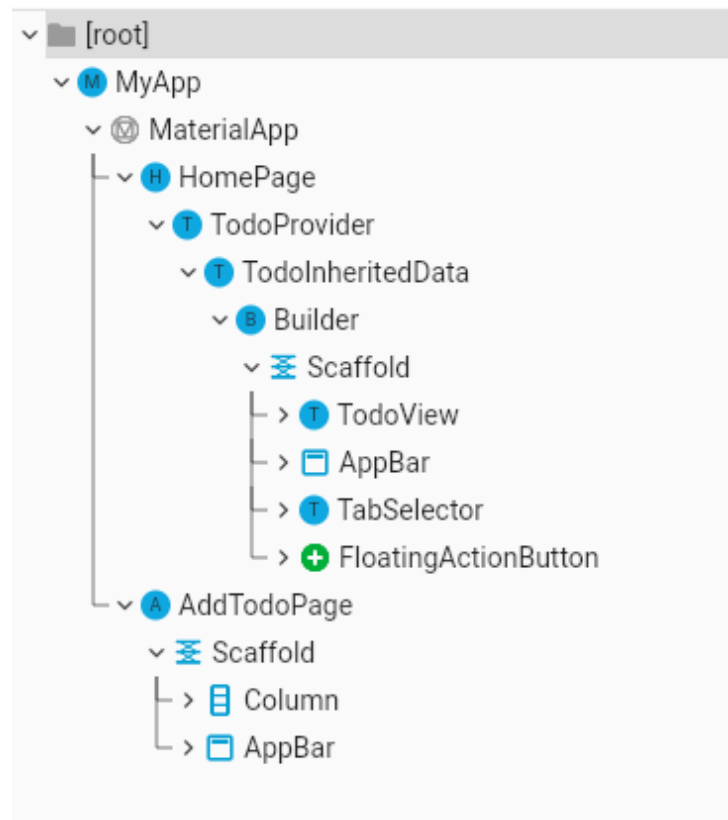


Figure 2.4: Show the tree structure after the FloatingActionButton in the HomePage is tapped.

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. Moreover, 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 *updateShouldNotifyDependent* 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 caused 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. It 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 it. The problem was generated 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 different state management solutions

4 | Comparisons

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

5 | Conslusions

Conclusions

Bibliography

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.

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List of Tables

List of Symbols

| Variable | Description | SI unit |
|--------------------|--------------------|---------|
| \boldsymbol{u} | solid displacement | m |
| \boldsymbol{u}_f | fluid displacement | m |

Acknowledgements

Here you might want to acknowledge someone.

