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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

This chapter is devoted to the implementation of a mobile application. The application manages a list of todos. It is developed using the state management 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 an 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. It 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 it 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 possible 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 explains how models, pages, components and the repository are implemented.

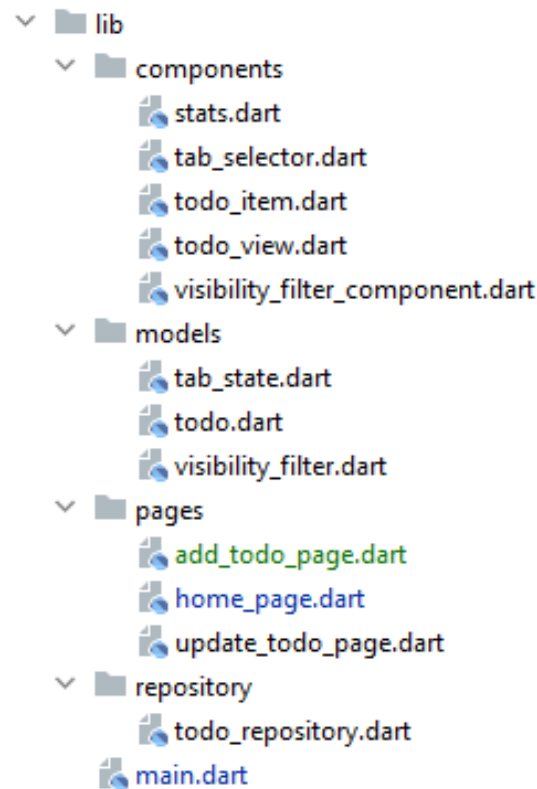


Figure 2.1: Todos app skeleton's folders structure.

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 *inicialRoute* 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);
            }
        }
        return Future.value(todos);
    }
}

```

```

    }
  }
  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 BottomNavigationBar (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 implemen-

tation.

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: 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 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 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. This new class will contain the state ,or part of it. For our purpose a single class will be enough to contain all the state. This new class is called *TodoInheritedData*.

Source code 2.14: Todo app - extension to InheritedWidget

```
class TodoInheritedData extends InheritedWidget{
```

The accessible 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 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 provided in the constructor. This is because TodoInheritedData is nothing else than a widget itself that wraps data and make it accessible down the tree.

Source code 2.15: Todo app - TodoInherited data 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);
}

```

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 TodoInheritedData class. This function belongs to the InheritedWidget class and its reimplementaion 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 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 takes as parameters the old *filteredTodos* list ,contained in the *old-Widget* argument, and the new *filteredTodos* list and compare them element by element checking if changes occurs. In case no changes were performed it returns *true* and leads the *updateShouldNotify* function to return *false*. In this way the entire subtree is not rebuilt.

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 instantiating 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 *dependOnInheritedWidgetOfEx-*

actType provided by the framework. In case no `TodoInheritedData` instance is found it raises an error.

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

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

`TodoInheritedData` widget 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 instance 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, an empty page appears (todos are empty at the beginning) and then, after a 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 *TodoInheritedData* 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 it, will generate an error at compile time (final variable cannot be set outside constructor). A completely 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 practice, 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 consequence the `TodoInheritedData` widget, present in the tree, is replaced with the new one. However, widgets access the state through the `TodoInheritedWidget`. 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.

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

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

```

    {...}
    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. It takes as parameter a `Todo` and takes care of displaying it 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) {
        }
      ),
    ],
  );
}

```

However, the Checkbox 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 TodoIhneritedData 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.

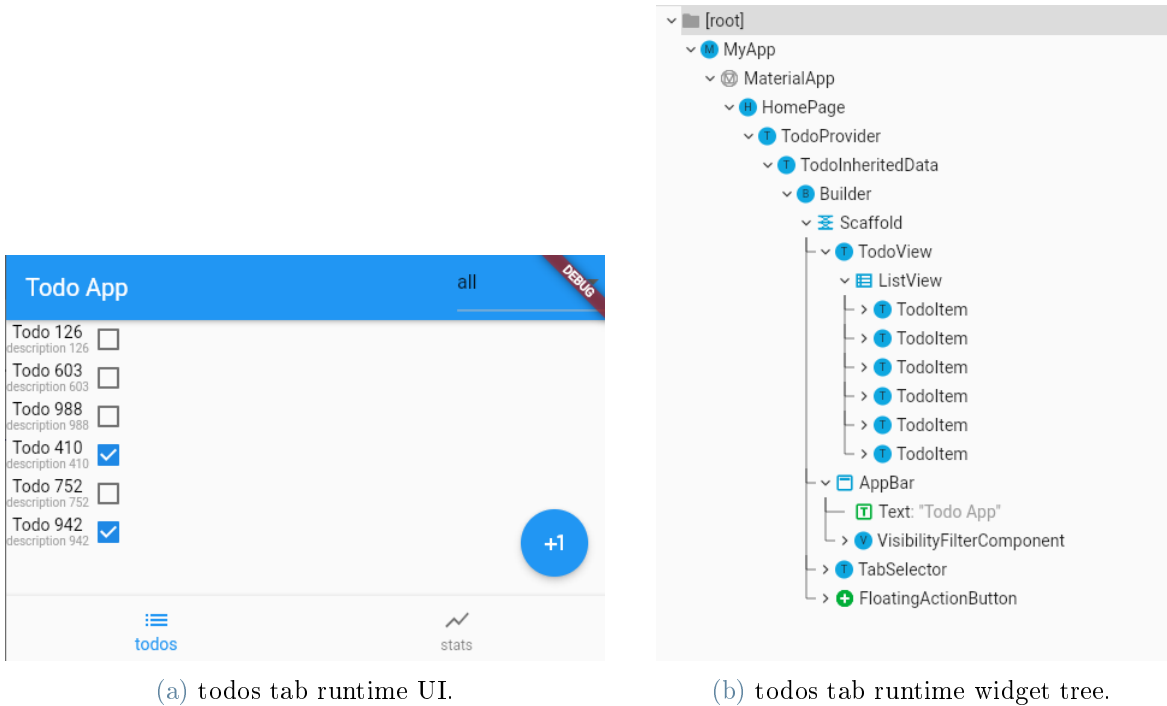


Figure 2.2: Show the runtime Widget’s tree and UI when visualizing todos tab.

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



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

Figure ?? shows how the application UI looks like after the user taps on the TabSelector’s

stats button. Figure ?? 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 ??.

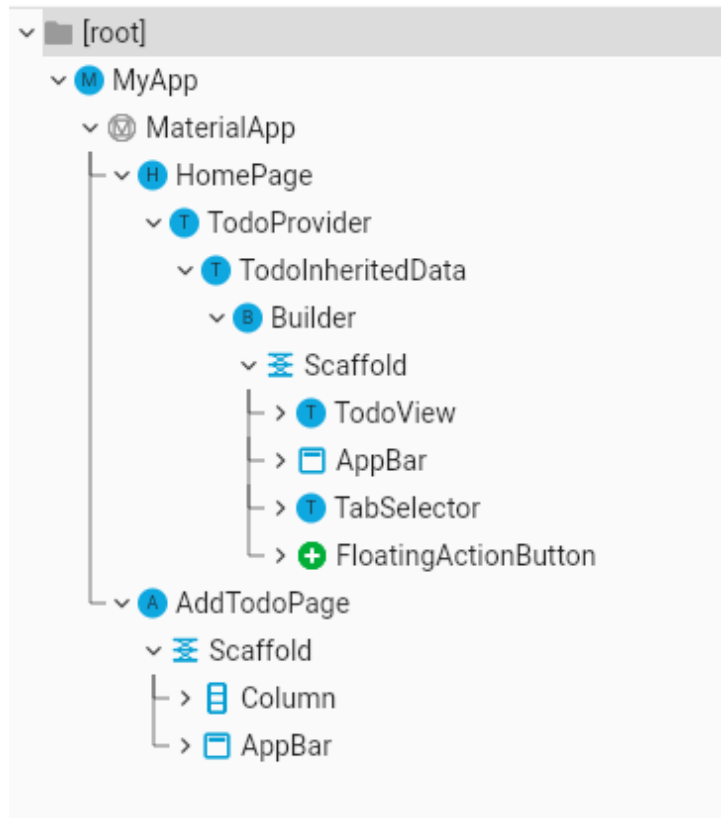


Figure 2.4: Show the tree structure after the FloatingActionButton in the HomePage is tapped.

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. 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 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.

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