Flutter internalsBlog

September 30, 2019

How does Flutter actually work, internally?

What are Widgets, Elements, BuildContext, RenderOject, Bindings...

Difficulty: *Beginner*

Introduction

When I started up my journey into the fabulous world of Flutter last year, very little documentation could be found on Internet compared to what exists today. Despite the number of articles that have been written, very few talk about how Flutter actually works.

What are finally the Widgets, the Elements, the BuildContext ? Why is Flutter fast and why does it sometimes work differently than expected? What are the trees?

When you are writing an application, in 95% of the cases, you will only deal with *Widgets* to either display something or interact with the screen. But haven't you ever wondered how all this magic actually works? How does the system know when to update the screen and which parts need to be updated?

Part 1: The background

This first part of the article introduces some key concepts that will be then used to better understand the second part of this post.

Back to the device

For once, let's start from the end and let's get back to the basics.

When you look at your device, or more specifically at your application running on your device, you only see a screen.

In fact, all what you see is a series of pixels, which together compose a flat image (2 dimensions) and when you are touching the screen with your finger, the device only recognizes the position of your finger on the glass.

All the magic of the application (from a visual perspective) consists in having that flat image updated based on, most of the time, interactions with:

- the device screen (e.g. finger on the glass)
- the network (e.g. communication with a server)
- the time (e.g. animations)
- other external sensors

The rendering of the image on the screen is ensured by the **hardware** (*display device*), which at regular interval (usually 60 times per second), refreshes the display. This refresh frequency is also called "**refresh rate**" and is expressed in **Hz** (Hertz).

The *display device* receives the information to be displayed on the screen from the **GPU** (*Graphics Processing Unit*), which is a specialized electronic circuit, optimized and designed to rapidly generate an image from some data (polygons and textures). The number of times per second the *GPU* is able to generate the "*image*" (=*frame buffer*) to be displayed and to send it to the *hardware* is called the **frame rate**. This is measured with the **fps** unit (e.g. 60 frames per second or 60 fps).

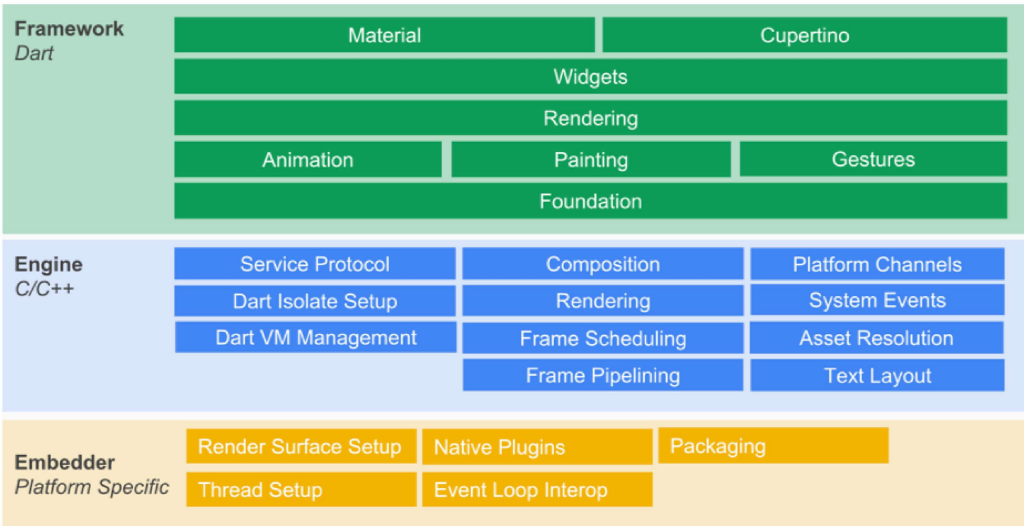
You will maybe ask me why did I start this article with the notions of 2-dimension flat image rendered by the GPU/hardware and the physical glass sensor... and what is the relationship with the usual Flutter Widgets?

Simply because one of the main objectives of a Flutter application is to compose that 2-dimensional flat image and to make it possible to interact with it, I think it might be easier to understand how Flutter actually works if we look at it from that perspective.

...but also because in Flutter, believe it or not, almost everything is driven by the needs of having to refresh the screen... quickly and at the right moment !

Interface between the code and the physical device

One day or another, everyone interested in Flutter already saw the following picture which describes the Flutter high-level architecture.



When we are writing an Flutter application, using Dart, we remain at the level of the *Flutter Framework* (in green).

The *Flutter Framework* interacts with the *Flutter Engine* (in blue), via an abstraction layer, called Window. This abstraction layer exposes a series of APIs to communicate, indirectly, with the device.

This is also via this abstraction layer that the *Flutter Engine* notifies the *Flutter Framework* when, among others:

- an event of interest happens at the device level (orientation change, settings changes, memory issue, application running state...)
- some event happens at the glass level (= gesture)
- the platform channel sends some data
- but also and mainly, when the **Flutter Engine is ready to render a new frame**

Flutter Framework is driven by the Flutter Engine frame rendering

This statement is quite hard to believe, but it is the truth.

Except in some cases (see below), no Flutter Framework code is executed without having been triggered by the Flutter Engine frame rendering.

These exceptions are:

- *Gesture* (= an event on the glass)
- *Platform* messages (= messages that are emitted by the device, e.g. GPS)
- *Device* messages (= messages that refer to a variation to the device state, e.g. orientation, application sent to background, memory warnings, device settings...)
- *Future* or *http responses*

> The Flutter Framework will **not** apply any visual changes without having been requested by the Flutter Engine frame rendering.

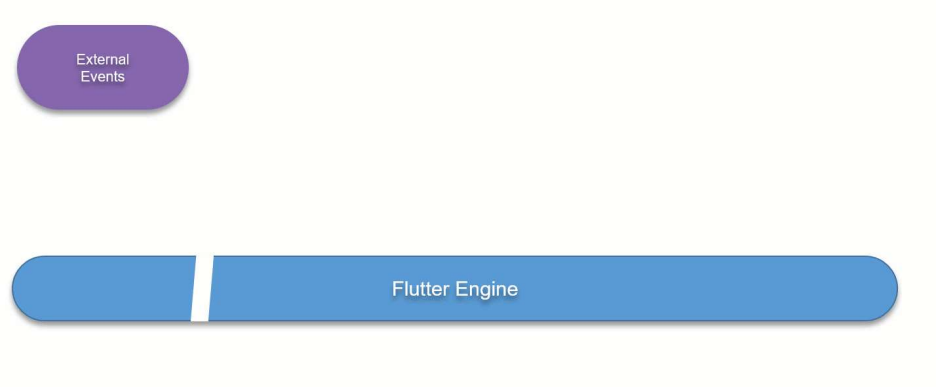
*(between us, it is however possible to apply a visual change without having been invited by the Flutter Engine, but this is really **not advised** to do so)*

But you will ask me, if some code related to the *gesture* is executed and causes a visual change to happen, or if I am using a *timer* to rythm some task, which leads to visual changes (such as an animation, for example), how does this work then?

> If you want a visual change to happen, or if you want some code to be executed based on a timer, you need to **tell the Flutter Engine** that something needs to be rendered.
>
> Usually, at next *refresh*, the Flutter Engine will **then** request the Flutter Framework to run some code and eventually provide the new scene to render.

Therefore, the big question is how does Flutter Engine orchestrate the whole application behavior, based on the rendering?

To give you a flavor of the internal mechanisms, have a look at the following animation...



Internals flow

Short explanation (further details will come later):

- Some external events (gesture, http responses, ...) or even *futures*, can launch some tasks which lead to having to update the rendering. A message is sent to the *Flutter Engine* to notify it (= *Schedule Frame*)
- When the *Flutter Engine* is ready to proceed with the rendering update, it emits a *Begin Frame* request
- This *Begin Frame* request is intercepted by the *Flutter Framework*, which runs any task mainly related to *Tickers* (such as Animations, e.g.)
- These tasks could re-emit a request for a later frame rendering... (example: an animation is not complete and to move forward, it will need to receive another *Begin frame* at a later stage)
- Then, the *Flutter Engine* emits a *Draw Frame*.
- This *Draw Frame* is intercepted by the *Flutter Framework*, which will look for any tasks linked to updating the layout in terms of structure and size.
- Once all these tasks are done, it goes on with the tasks related to updating the layout in terms of painting.
- If there is something to be drawn on the screen, it then sends the new *Scene* to be rendered to the *Flutter Engine* which will update the screen.
- Then, the *Flutter Framework* executes all tasks to be run after the rendering is complete (= *PostFrame callbacks*) and any other sub-sequent other tasks not rendering related.
- ... and this flow starts again and again.

RenderView and RenderObject

Before going into the details related to the flow of actions, it is the right time to introduce the notion of *Rendering Tree*.

As previously said, everything eventually turns out to become a series of pixels to be displayed on the screen and the *Flutter Framework* converts the *Widgets* we are using to develop the application into visual parts which will be rendered on the screen.

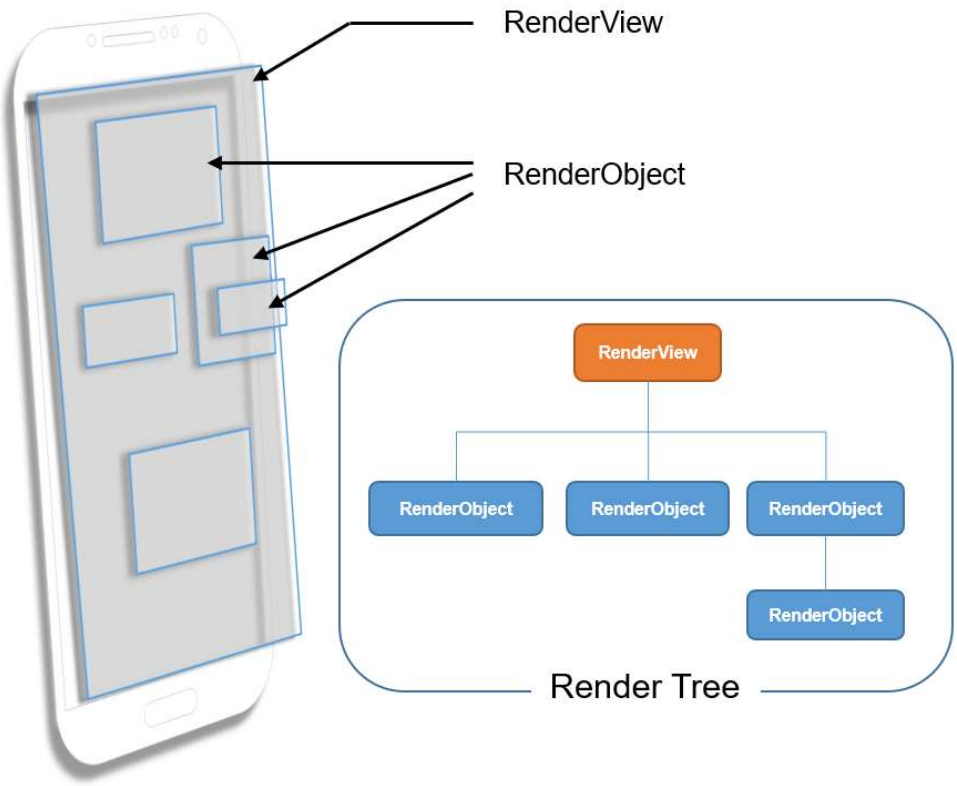
These visual parts which are rendered on the screen correspond to objects, called RenderObjects, which are used to:

- define some area of the screen in terms of dimensions, position, geometry but also in terms of "*rendered content*"
- identify zones of the screen potentially impacted by the gestures (= *finger*)

The set of all the *RenderObject* forms a tree, called *Render Tree*. At the top of that tree (= *root*), we find a RenderView.

The *RenderView* represents the total output surface of the *Render Tree* and is itself a special version of a *RenderObject*.

Visually speaking we could represent all this as follows:



The relationship between Widgets and RenderObjects will be discussed later in this article.

It is now time to go a bit deeper...

First things first - initialization of the bindings

When you start a Flutter application, the system invokes the *main()* method which will eventually call the **runApp(Widget app)** method.

During that call to the *runApp()* method, Flutter Framework initializes the interfaces between the *Flutter Framework* and the *Flutter Engine*. These interfaces are called **bindings**.

The Bindings - Introduction

The **bindings** are meant to be some kind of glue between the *Flutter Engine* and the *Flutter Framework*. It is only through these *bindings* that data can be exchanged between the two Flutter parts (Engine and Framework).
(There is only one exception to this rule: the *RenderView* but we will see this later).

Each **Binding** is responsible for handling a set of specific tasks, actions, events, regrouped by domain of activities.

At time of writing this article, *Flutter Framework* counts 8 bindings.

Below, the 4 ones that will be discussed in this article:

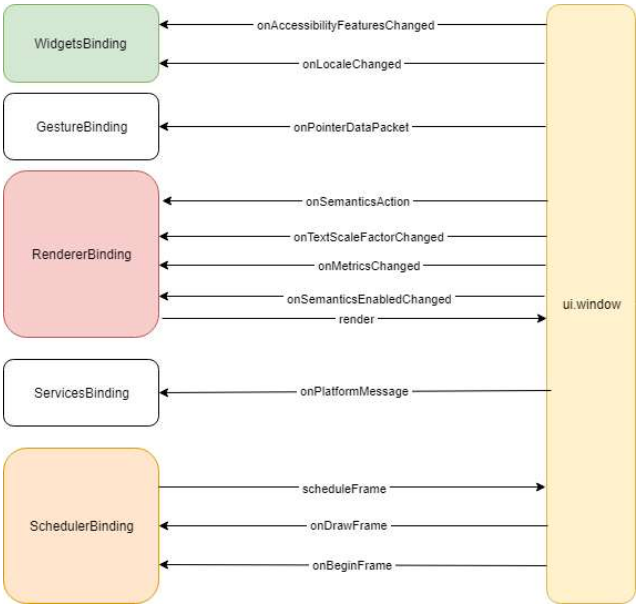
- *SchedulerBinding*
- *GestureBinding*
- *RendererBinding*
- *WidgetsBinding*

For sake of completeness, the last 4 ones (which will not be addressed in this article):

- *ServicesBinding*: responsible for handling messages sent by the *platform* channel
- *PaintingBinding*: responsible for handling the image cache
- *SemanticsBinding*: reserved for later implementation of everything related to *Semantics*
- *TestWidgetsFlutterBinding*: used by widgets tests library

I could also mention the *WidgetsFlutterBinding* but the latter is not really a binding but rather some kind of "*binding initializer*".

The following diagram shows the interactions between the bindings I am going to cover a bit later in this article and the *Flutter Engine*.



Let's have a look at each of these "main" bindings.

SchedulerBinding

This *binding* has 2 main responsibilities:

- the first one is to tell the *Flutter Engine*: "*Hey! next time you are not busy, wake me up so that I can work a bit and tell you either what to render or if I need you to call me again later...*";
- the second one is to listen and react to such "*wake up calls*" (see later)

When does the SchedulerBinding request for a *wake-up call*?

- When a *Ticker* needs to *tick*
  For example, suppose you have an animation and you start it. An animation is cadenced by a *Ticker*, which at regular interval (= *tick*) is called to run a *callback*. To run such *callback*, we need to tell the *Flutter Engine* to wake up us at next refresh (= *Begin Frame*). This will invoke the *ticker* callback to perform its task. At the end of that task, if the *ticker* still needs to move forward, it will call the *SchedulerBinding* to schedule another frame.

- When a change applies to the layout
  When for example, you are responding to an event that leads to a visual change (e.g. updating the color of a part of the screen, scrolling, adding/removing something to/from the screen), we need to take the necessary steps to eventually render it on the screen. In this case, when such change happens, the *Flutter Framework* will invoke the *SchedulerBinding* to schedule another frame with the *Flutter Engine*. (we will see later how it actually works)

GestureBinding

This *binding* listens to interactions with the Engine in terms of "*finger*" (= *gesture*).

In particular, it is responsible for accepting data related to the *finger* and to determine which part(s) of the screen is/are impacted by the gestures. It then notifies this/these parts accordingly.

RendererBinding

This *binding* is the glue between the *Flutter Engine* and the *Render Tree*. It has 2 distinct responsibilities:

- the first one is to listen to events, emitted by the Engine, to inform about changes applied by the user via the device settings, which impact the visuals and/or the *semantics*
- the second one is to provide the Engine with the modifications to be applied to the display.

In order to provide the modifications to be rendered on the screen, this *Binding* is responsible for driving the PipelineOwner and initializing the **RenderView**.

The **PipelineOwner** is a kind of *orchestrator* that knows which *RenderObject*'s need to do something in relation with the layout and coordinates these actions.

WidgetsBinding

This *binding* listens to changes applied by the user via the device settings, which impact the language (= *locale*) and the *semantics*.

> Side note
>
> At a later stage, I suppose that all events related to the *Semantics* will be migrated to the *SemanticsBinding* but at time of writing this article, this is not yet the case.

Besides this, the *WidgetsBinding* is the glue between the Widgets and the *Flutter Engine*. It has 2 distinct main responsibilities:

- the first main one is to drive the process in charge of handling the Widgets structure changes
- the second one is to trigger the rendering

The handling of the Widgets Structure changes is done via the BuildOwner.

The *BuildOwner* tracks which Widgets need rebuilding, and handles other tasks that apply to widget structures as a whole.

Part 2: from Widgets to pixels

Now that we have introduced the basics of the internal mechanics, it is time to talk about *Widgets*.

In all *Flutter* documentation, you will read that *everything is Widgets*.

Well, it is almost correct but in order to be a bit more precise, I would rather say:

> From a **Developer perspective**, everything related to the User Interface in terms of layout and interaction, is done via Widgets.

Why this precision? Because a *Widget* allows a developer to define a part of the screen in terms of dimensions, content, layout and interaction **BUT** there is so much more. So what is a Widget, actually?

Immutable Configuration

When you read the *Flutter* source code, you will notice the following definition of the *Widget* class.

```
@immutable
abstract class Widget extends DiagnosticableTree {
  const Widget({ this.key });

  final Key key;

  ...
}
```

What does this mean?

The annotation "**@immutable**" is very important and tells us that **any variable in a Widget class has to be FINAL**, in other words: "*is defined and assigned **ONCE FOR ALL***". So, once instantiated, the *Widget* will no longer be able to adapt its *inner variables*.

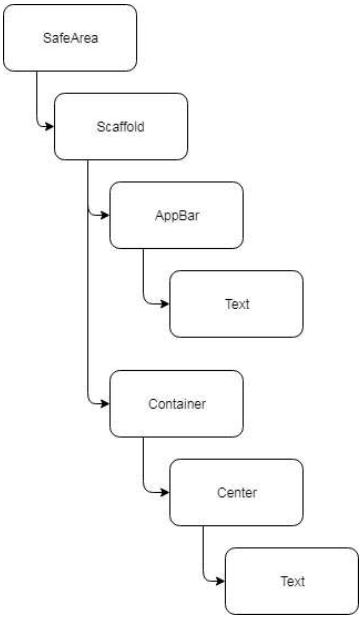
> A Widget is a kind of constant configuration since it is **IMMUTABLE**

The Widgets hierarchical structure

When you develop with *Flutter*, you define the structure of your screen(s), using *Widgets*... Something like:

```
Widget build(BuildContext context){
    return SafeArea(
        child: Scaffold(
            appBar: AppBar(
                title: Text('My title'),
            ),
            body: Container(
                child: Center(
                    child: Text('Centered Text'),
                ),
            ),
        ),
    );
}
```

This sample uses 7 Widgets, which together form a hierarchical structure. The *very simplified* structure, based on the code, is the following:



As you can see, this looks like a tree, where the *SafeArea* is the root of the tree.

The forest behind the tree

As a you already know, a *Widget* may itself be an aggregation of other *Widgets*. As an example, I could have written the previous code the following way:

```
Widget build(BuildContext context){
    return MyOwnWidget();
}
```

This assumes that the widget "*MyOwnWidget*" would itself render the SafeArea, Scaffold... but the most important with this example is that

> a Widget maybe a leaf, a node in a tree, even a tree itself or why not a forest of trees...

The notion of Element in the tree

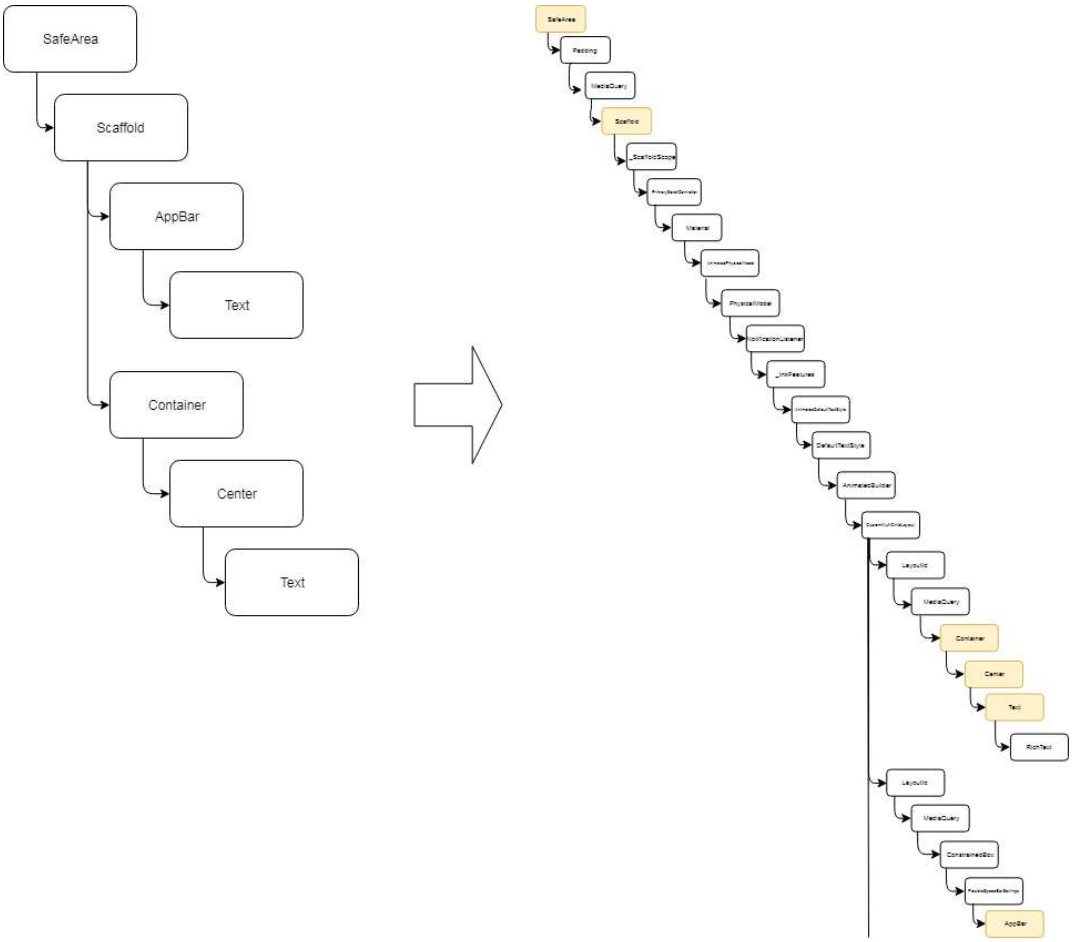
Why did I mention this?

As we will see later how, in order to be able to generate the pixels that compose the image to be rendered on the device, *Flutter* needs to know in details all the little parts that compose the screen and, to determine all the parts, it will request to **inflate** all the *Widgets*.

In order to illustrate this, consider the russian dolls principle: closed you only see 1 doll but the latter contains another one which in turn contains another one and so on...

When *Flutter* will have inflated all the *widgets*, part of the screen, it will be similar to obtaining all the different russian dolls, part of the whole.

The following diagram shows **a part** of the final Widget hierarchical structure that corresponds to the previous code. In yellow, I have highlighted the Widgets that were mentioned in the code so that you can spot them in the resulting partial widgets tree.



Important clarification

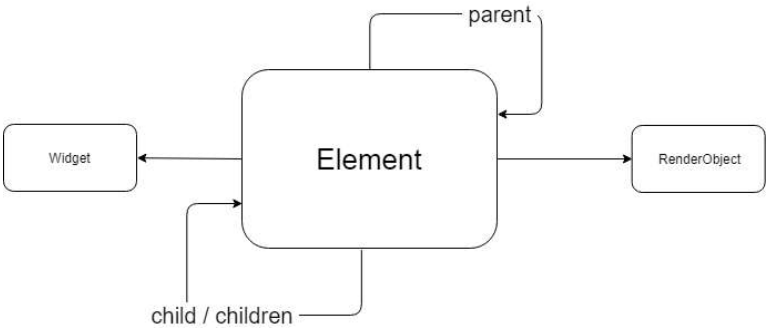
The wording "Widget tree" only exists for sake of making it easier to understand since programmers are using Widgets but, in Flutter there is NO Widget tree!

In fact, to be correct, we should rather say: "**tree of Elements**"

It is now time to introduce the notion of Element...

To **each** widget corresponds **one** element. Elements are linked to each other and form a tree. Therefore an **element** is a reference of something in the tree.

At first, think of an **element** as a node which has a *parent* and potentially a *child*. Linked together via the *parent* relationship, we obtain a tree structure.



As you can see in the picture above, the *Element* **points to** one *Widget* and **may** also point to a *RenderObject*.

Even better... the Element points to the Widget which **created the** element !

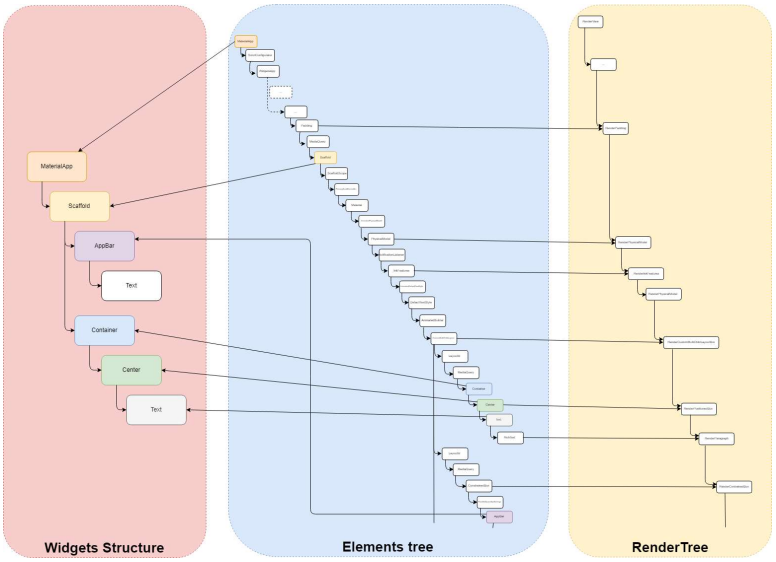
Let me recap...

- there is no Widgets tree but a tree of Elements
- Elements are created by the Widgets
- an Element references the Widget that created it
- Elements are linked together with the *parent* relationship

- Elements could have a child or children
- Elements could also point to a *RenderObject*

> **Elements** define how parts of the visuals are linked to each other

In order to better visualize where the notion of *element* fits, let's consider the following visual representation:



The 3 trees

As you can see the **elements tree** is the actual link between the *Widgets* and the *RenderObjects*.

But, why does the Widget create the Element?

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3 main categories of Widgets

In *Flutter*, Widgets are split into 3 main categories, I personally call these categories:
(but this is only my way of categorizing them)

- the proxies

  The main role of these Widgets is to hold some piece of information which needs to be made available to the *Widgets*, part of the tree structure, rooted by the *proxies*. A typical example of such *Widgets* is the **InheritedWidget** or **LayoutId**.

  These *Widgets* do not directly take part of the User Interface but are used by others to fetch the information they can provide.

- the renderers

  These *Widgets* have a **direct** involvement with the layout of the screen as they define (or are used to infer) either:

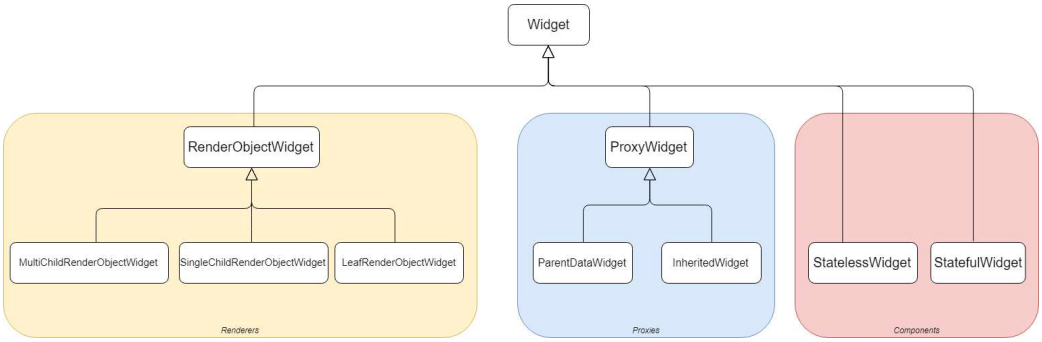
  - the dimensions;
  - the position;
  - the layout, rendering.

  Typical examples are: **Row**, **Column**, **Stack** but also **Padding**, **Align**, **Opacity**, **RawImage**...

- the components.

  These are the other *Widgets* which are not directly providing the **final** information related to dimensions, positions, look but rather data (or *hint*) which will be used to obtain the final information. These *Widgets* are commonly named **components**.

  Examples are: **RaisedButton**, **Scaffold**, **Text**, **GestureDetector**, **Container**...



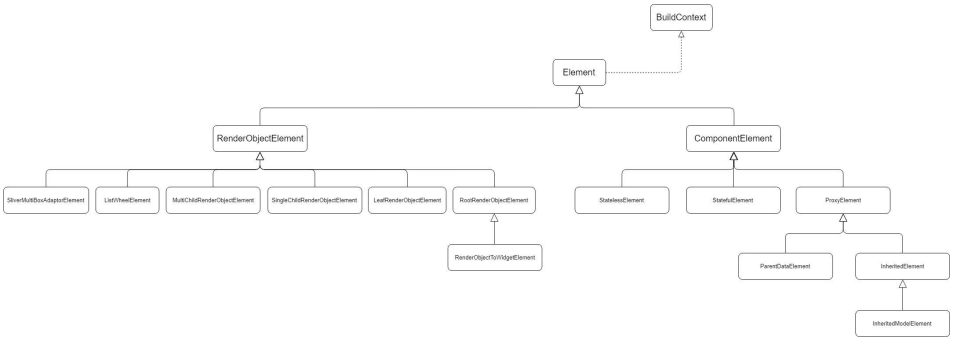
Widgets Categories

The following PDF lists most of the Widgets, regrouped by categories.

Why is that split important? Because depending on the Widget category, a corresponding *Element* type is associated...

The Element types

Here are the different *element types*:



Internals Element Types

As you can see in the picture above, **Elements** are split into 2 main types:

- ComponentElement

  These elements do not **directly** correspond to any visual rendering part.

- RenderObjectElement

  These elements correspond to a part of the rendered screen.

Great! Lots of information so far but how is everything linked together and why was it interesting to introduce all this?

How do Widgets and Elements work together?

> In *Flutter*, the whole mechanics relies on **invalidating** either an *element* or a *renderObject*.

Invalidating an *element* can be done in different ways:

- by using **setState**, which invalidates the whole **StatefulElement** (notice that I am intentionally not saying *StatefulWidget*)
- via *notifications*, handled by other **proxyElement** (such as *InheritedWidget*, for example), which invalidates any *element* that depends on that *proxyElement*

The outcome of an *invalidation* is that the corresponding *element(s)* is/are referenced in a list of **dirty** elements.

Invalidating a *renderObject* means that no changes are applied to the structure of the *elements* but a modification at the level of a *renderObject* happens, such as

- changes to its dimensions, position, geometry...
- needs to be repainted, for example when you simply change the background color, the font style...

The outcome of such invalidation is that the corresponding *renderObject* is referenced in a list of renderObjects that need to be rebuilt or repainted.

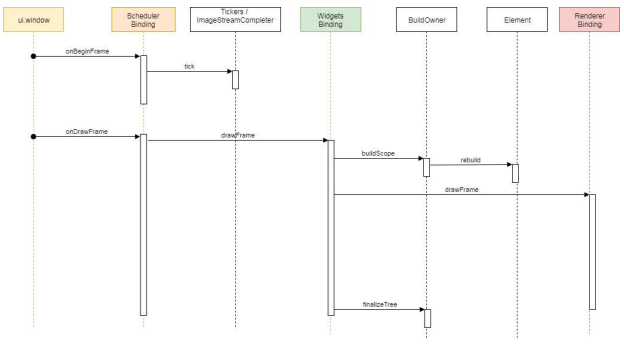
Whatever the type of invalidation, when this happens, the **SchedulerBinding** (remember it?) is requested to ask the **Flutter Engine** to schedule a new **frame**.

It is when the *Flutter Engine* wakes up the *SchedulerBinding* that all the magics happens...

onDrawFrame()

Earlier in this article, we mentioned that the *SchedulerBinding* had 2 main responsibilities, one of which was to be ready to handle requests emitted by the *Flutter Engine*, related to frame rebuild. This is the perfect moment to focus on this now...

The partial sequence diagram below shows what happens when the *SchedulerBinding* receives a request *onDrawFrame()* from the *Flutter Engine*.



Internals onDrawFrame() - Elements

Step 1: the elements

The *WidgetsBinding* is invoked and the latter first considers the changes related to the *elements*.

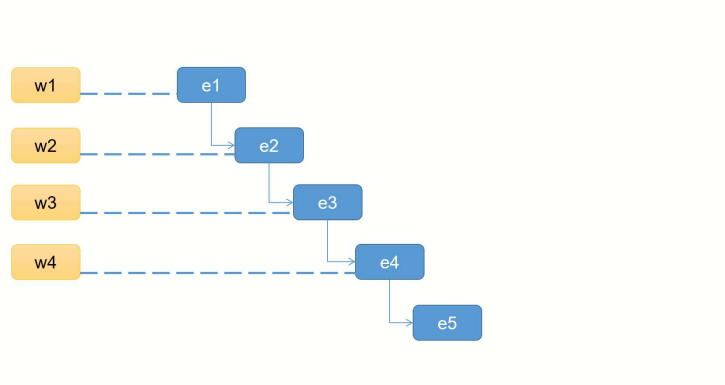
As the **BuildOwner** is responsible for handling the *elements tree*, the *WidgetsBinding* invokes the *buildScope* method of the *buildOwner*.

This method iterates the list of *invalidated elements* (= dirty) and requests them to **rebuild**.

The main principles of this *rebuild()* method are:

1. request the element to *rebuild()* which leads to most of the time, invoking the **build()** method of the widget referenced by that *element* (= method *Widget build(BuildContext context){...}*). This *build()* method returns a new widget.
2. if the element has no child, the new widget is inflated (see just after), otherwise
3. the new widget is compared to the one referenced by the child of the element.
    - If they could be exchanged (=*same widget type and key*), the update is made, the child element is kept.
    - If they could not be exchanged, the child element is unmounted (~ *discarded*) and the new widget is inflated.
4. The inflating of the widget leads to creating a new element, which is mounted as new child of the element. (*mounted* = inserted into the elements tree)

The following animation tries to make this explanation a bit more visual.



onDrawFrame() - Elements

Note on Widget inflating

When the widget is inflated, it is requested to create a new *element* of a certain type, defined by the *widget* category.

Therefore,

- an *InheritedWidget* will generate an *InheritedElement*
- a *StatefulWidget* will generate a *StatefulElement*
- a *StatelessWidget* will generate a *StatelessElement*
- an *InheritedModel* will generate an *InheritedModelElement*
- an *InheritedNotifier* will generate an *InheritedNotifierElement*
- a *LeafRenderObjectWidget* will generate a *LeafRenderObjectElement*
- a *SingleChildRenderObjectWidget* will generate a *SingleChildRenderObjectElement*
- a *MultiChildRenderObjectWidget* will generate a *MultiChildRenderObjectElement*
- a *ParentDataWidget* will generate a *ParentDataElement*

Each of these *element* types has a distinct behavior.

For example

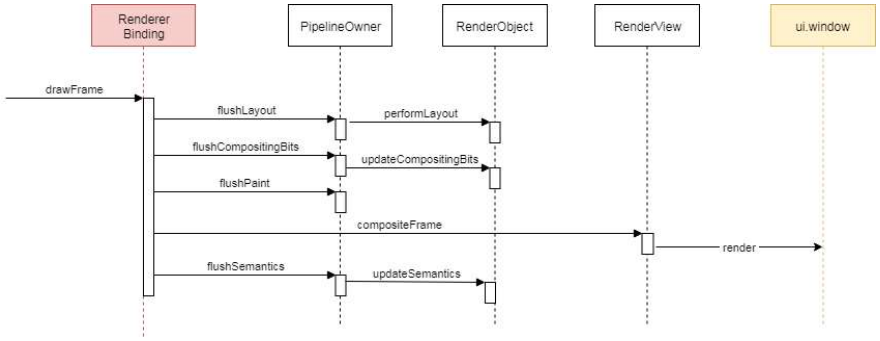
- a *StatefulElement* will invoke the *widget.createState()* method at initialization, which will create the *State* and link it to the *element*
- a *RenderObjectElement* type will create a *RenderObject* when the element will be mounted, this *renderObject* will be added to the *render tree* and linked to the *element*.

Step 2: the renderObjects

Once all actions related to *dirty* elements have been completed, the *elements tree* is now stable and it is time to consider the *rendering* process.

As the **RendererBinding** is responsible for handling the *rendering tree*, the *WidgetsBinding* invokes the *drawFrame* method of the *RendererBinding*.

The partial diagram below shows the sequence of actions performed during a *drawFrame()* request.



Internals onDrawFrame() - RenderObjects

During this step, the following activities are performed:

- each *renderObject* marked as *dirty* is requested to perform its layout (meaning calculating its dimensions and geometry)
- each *renderObject* marked as *needs paint* is repainted, using the *renderObject's layer*.
- the resulting **scene** is built and sent to the *Flutter Engine* so that the latter transmits it to the device screen.
- finally the *Semantics* is also updated and sent to the *Flutter Engine*

At the end of this flow of actions, the device screen is updated.

Part 3: Gesture handling

The gestures (= events related to the finger on the glass) is handled by the **GestureBinding**.

When the *Flutter Engine* sends information related to a gesture-related event, through the *window.onPointerDataPacket* API, the **GestureBinding** intercepts it, proceeds with some buffering and:

1. converts the coordinates emitted by the *Flutter Engine* to match the device pixel ratio, then
2. requests the **renderView** to provide a list of **ALL** *RenderObjects* which cover a part of screen containing the coordinates of the event
3. then iterates that list of *renderObjects* and dispatches the related event to each of them.
4. when a *renderObject* is waiting for this kind of event, it processes it.

From this explanation, we directly see how important *renderObjects* are...

Part 4: Animations

This last part of the article focuses on the notion of **Animations** and more specifically on the notion of **Ticker**.

When you initiate an animation, you generally use an AnimationController or any similar Widget or component.

In *Flutter*, everything which is related to animation refers to the notion of Ticker.

A **Ticker** does only one thing, when active: "*it requests the **SchedulerBinding** to register a callback and ask the Flutter Engine to wake it up when next available*".

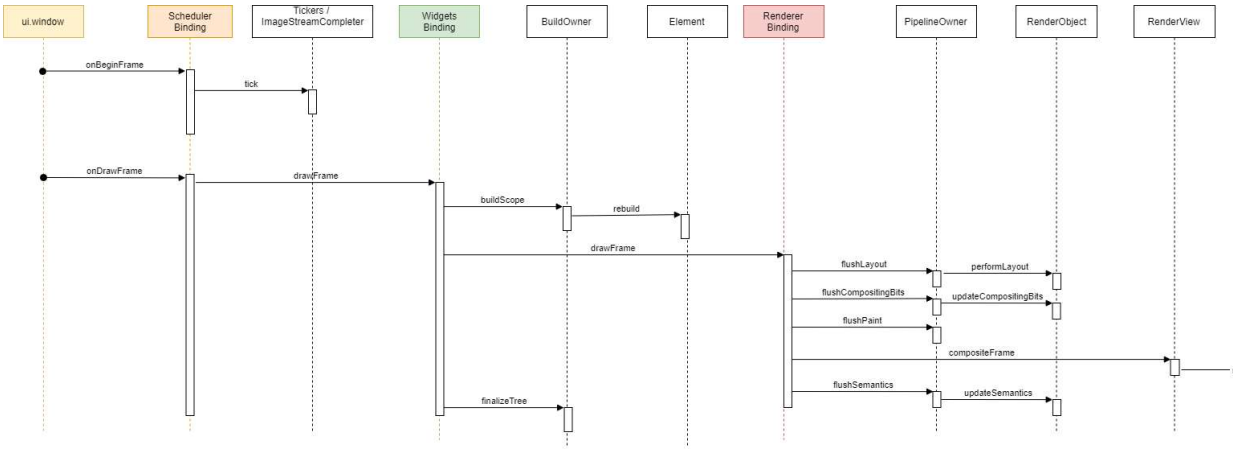
When the *Flutter Engine* is ready, it then invokes the *SchedulerBinding* via a request: "*onBeginFrame*".

The *SchedulerBinding* intercepts this request then iterates the list of ticker callbacks and invokes each of them.

Each ticker tick is intercepted by any controller interested in this event to process it. If the animation is complete, the ticker is "*disabled*", otherwise, the ticker requests the *SchedulerBinding* to schedule another callback. And so on...

Global Picture

Now that we have seen how the *Flutter internals* work, here is the global picture:



Internals Big Picture

BuildContext

Final word...

If you recall the diagram that shows the different *element types*, you most probably noticed the signature of the base *Element*:

```
abstract class Element extends DiagnosticableTree implements BuildContext {
    ...
}
```

Here is the famous BuildContext.

What is a *BuildContext*?

The **BuildContext** is an **interface** that defines a series of **getters** and **methods** that could be implemented by an **element**, in an harmonized manner.

In particular, the **BuildContext** is mainly used in the *build()* method of a **StatelessWidget** and **StatefulWidget** or in a *StatefulWidget* **State** object.

> The **BuildContext** is nothing else but the **Element** itself which corresponds to
>
> - the *Widget* being rebuilt (inside the build or builder methods)
> - the *StatefulWidget* linked to the **State** where you are referencing the **context** variable.

This means that most developers are constantly handling *elements* even without knowing it.

How useful the BuildContext can be?

As the *BuildContext* corresponds to the *element* related to the *widget* but also to a location of the widget in the tree, this *BuildContext* is very useful to:

- obtain the reference of the *RenderObject* that corresponds to the *widget* (or if the *widget* is not a *renderer*, the *descendant widget*)
- obtain the size of the *RenderObject*
- visit the tree. This is actually used by all the Widgets which usually implement the **of** method (e.g. *MediaQuery.of(context), Theme.of(context)*...)

Just for the fun...

Now that we have understood that the *BuildContext* is the *element*, for the fun I wanted to show you another way of using it...

The following **totally useless** code makes possible for a *StatelessWidget* to update itself (as if it was a *StatefulWidget* but without using any *setState()*), by using the *BuildContext* ...

> **WARNING**
>
> **Please do not use this code!**
>
> Its sole purpose is to demonstrate that a StatelessWidget is able to request to be rebuilt.
>
> If you need to consider some state with a Widget, please use a StatefulWidget

```dart
void main(){
    runApp(MaterialApp(home: TestPage(),));
}

class TestPage extends StatelessWidget {
    // final because a Widget is immutable (remember?)
    final bag = {"first": true};

    @override
    Widget build(BuildContext context){
        return Scaffold(
            appBar: AppBar(title: Text('Stateless ??')),
            body: Container(
                child: Center(
                    child: GestureDetector(
                        child: Container(
                            width: 50.0,
                            height: 50.0,
                            color: bag["first"] ? Colors.red : Colors.blue,
                        ),
                        onTap: (){
                            bag["first"] = !bag["first"];
                            //
                            // This is the trick
                            //
                            (context as Element).markNeedsBuild();
                        }
                    ),
                ),
            ),
        );
    }
}
```

Between us, when you are invoking the **setState()** method, the latter ends up doing the very same thing: _element.markNeedsBuild().

Conclusions

Yet another long article, will you tell me.

I thought it could be interesting to know how *Flutter* has been architectured and to remind that everything has been designed to be efficient, scalable and open to future extensions.

Also, key concepts such as *Widget*, *Element*, *BuildContext*, *RenderObject* are not always obvious to apprehend.

I hope that this article might have been useful.

Stay tuned for new articles, soon. Meanwhile, let me wish you a happy coding.

Tushar Kale • a year ago

What a fantastic article!
I have been searching for such information for so long. Thank you for publishing this.
Google should include the link to this article in the official Flutter documentation!

2 ▲ | ▼ • Reply • Share ›

Jorge Granada • 6 months ago • edited

Just came to this article and must say I'm complettely dissapointed..... on how short it is.. I'd love to keep studying every piece presented here in much further detail. This is an amazing presentation from a stand point that really resonates to me (just "copying and pasting" guide code is not may way of learning software programming). Didier, thanks a lot for your generosity of sharing this article. I hope to see a "full" version of this..perhaps as a book???. This approach to me (engineer) is the perfect way to learn (I mean explaining why x is there..and why it has that specific shape...from the purposse as opposed to a recipie to be followed) Congratulations. !

▲ | ▼ • Reply • Share ›

> **boeledi** Mod ➚ Jorge Granada • 6 months ago
>
> Hi Jorge,
> So many thanks for your feedback. Stay tuned for new articles, shortly.
>
> ▲ | ▼ • Reply • Share ›

balajiramadoss10 • 7 months ago • edited

Thats a great article, Can you please also provide an article about how flutter generates apk, ipa internally?

Because In documentation, they just simply wrote in 2 lines
The engine's C and C++ code are compiled with Android's NDK. The Dart code (both the SDK's and yours) are ahead-of-time (AOT) compiled into native, ARM, and x86 libraries. Those libraries are included in a "runner" Android project, and the whole thing is built into an .apk.

It would be nice if you write an article about it

▲ | ▼ • Reply • Share ›

rukkumani n • a year ago

Thank you very much

▲ | ▼ • Reply • Share ›

Matheus Lino • a year ago

Thank you for the article, very usefull, cleared much some concepts.

▲ | ▼ • Reply • Share ›

童虎 • a year ago

Hello, The window link has 404. It seems like flutter remove the Window. Bring the https://api.flutter.dev/flu...

▲ | ▼ • Reply • Share ›

> **boeledi** Mod ➚ 童虎 • a year ago
>
> Hi. Thanks for spotting it. I have updated to the new link.
>
> ▲ | ▼ • Reply • Share ›

Graham Dickinson • 2 years ago

Great article, very informative.

May I ask what tool you use to draw your diagrams? I would like that kind of quality for my app documentation. Thanks.

▲ | ▼ • Reply • Share ›

> **boeledi** Mod ➚ Graham Dickinson • 2 years ago
>
> Hi Graham,
>
> Thanks for the feedback. For the diagrams, I am using draw.io
>
> 1 ▲ | ▼ • Reply • Share ›
>
> > **Graham Dickinson** ➚ boeledi • 2 years ago
> >
> > Thanks for getting back to me so quickly and for the info, I will check it out. Only just discovered your blog, sadly. Really liked your Medium article on Widget State and have seen a couple more yours. Keep up the great work :-)
> >
> > Krgrds, Graham
> >
> > +27 84 798 6450
> >
> > ▲ | ▼ • Reply • Share ›

聂超群 • 2 years ago

Awesome Article!!!

▲ | ▼ • Reply • Share ›

Minh Nguyen • 2 years ago

Thank you for yout great article. I read this sentence in Flutter in Action: "`Elements` are what are actually displayed on your device at any given moment when

running a Flutter app". So, What we see on the screen is `RenderObjects` or `Elements`?

Reply • Share ›

boeledi Mod ➚ Minh Nguyen • 2 years ago

Thanks for your comment.

To answer your question, everything part of the screen is a RenderObject

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The Vinh Luong • 2 years ago • edited

Thank you for yout great article. I am a little confuse about the notion of **scene** you are using. Is **scene** and **frame** of the same meaning in your article?

Reply • Share ›

Milind Kumthekar • 2 years ago

I congratulate you for drafting such an excellent article om internals.

Reply • Share ›

boeledi Mod ➚ Milind Kumthekar • 2 years ago

thank you

Reply • Share ›

Mayur Soni • 2 years ago

Really impressed with the detailed explanation on how Flutter internally work..! Thank you.

Reply • Share ›

boeledi Mod ➚ Mayur Soni • 2 years ago

thank you for your feedback

Reply • Share ›

Jorge Carbonell • 2 years ago

Great article! I do appreciate the time and effort you've put on this.

Reply • Share ›

Krrish Raj • 2 years ago

This is what I was looking for. Thanks a lot.

Reply • Share ›

ych • 2 years ago

I am just curious. How did you dig all this information? Reading the code or their some magic "Low-level Flutter" book exist? 😊

Reply • Share ›

boeledi Mod ➚ ych • 2 years ago

Hi Ych,

By reading the code and debugging, line by line... :)

1 Reply • Share ›

聂超群 ➚ boeledi • 2 years ago

cool

Reply • Share ›

ych ➚ boeledi • 2 years ago

Uh, you have done a tremendous amount of work. Thank you very much.

Reply • Share ›

Hakem Kadem • 2 years ago

Many thanks for your valuable efforts to explain flutter framework. Just I would be asking about the references or something else helping to dive deeper in this framework.

Reply • Share ›

abinash • 3 years ago

I loved this article ...I have to read it again n again to fully understand it

Reply • Share ›

김정태 • 3 years ago

Thank you for good post!
and I want to translate Korea language this post.
please Let me know Can I translate this

Reply • Share ›

boeledi Mod ➚ 김정태 • 3 years ago

Thanks for your feedback. Yes of course you can translate this page in Korean. Simply, do not forget to mention me as the author and put a link to this original article.

Kind Regards,

Didier

1 Reply • Share ›

Leo van der Hoek • 3 years ago

Thank you for this clear explanation of the inside of Futter/Dart. Although I am a beginner in flutter I am still overwhelmed. This is something that helps understand all those properties and methods a little bit better.

Reply • Share ›

Frank Treacy • 3 years ago

What an insightful article, Didier! For some reason I kept trying to draw analogies to the DOM while I was reading. I missed a lot of stuff, but some stuck for sure. The "BuildContext is an element" was a nice surprise and totally makes sense

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mail@didierboelens.com