

**Touch Display: Main Unit**

**Internship**

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Following hints and remarks to your report:

- please check your abstract and don't use "I" --> it is not scientific writing

- Wikipedia is not a reference for science

- delete 4.1.1 because 4.1.2 is missing --> same by 4.3.1.

- all references listed needs to be used within the written text

- a chapter with results and evaluation is missing

- the plagiarism value is too high --> see attached

Please improve your report!

Abstract

Since years, Graphical User Interface (GUI) has been playing an important role in most applications. Not very long ago, users were relying mostly on command line as the main tool of interacting with their application such as entering the inputs and reading the outputs, this has changed. In 1973 a personal computer was developed at Xerox PARC which used the concept of a Desktop and a mouse as an input tool [1]. In 1984 the Apple Lisa and Macintosh teams released a computer called Lisa which is known as the first successful commercially used computer that uses the concept of windows, panels and mouse-driven control [2]. Software developers after this date started to focus more on integrating a GUI for their released applications since it offers the user a simple way to interact with the software and also it serves as an attractive mean to help draw the attention of new users. Nowadays, this kind of inputs has developed even further, a new input method that doesn’t depend on a mouse-driven interaction, but on a simple finger touches directly applied on the screen. This paper explains the concept and the implementation the was developed for creating a GUI that runs on the official Raspberry Touchscreen, at first a comparison of different available technologies to implement the GUI is presented, then a detailed explanation of the Application architecture, and finally the implementation techniques and methods are layed out to help in showing the link between the architecture of the Application and the decisions made regarding the design and implementation followed by the results and outcomes.

**Keywords: GUI, User, Design, Event, Touchscreen**

Content

[Abstract 1](#_Toc525482253)

[Content 2](#_Toc525482254)

[List of Figures 3](#_Toc525482255)

[List of Abbreviations 4](#_Toc525482256)

[1 Introduction 5](#_Toc525482257)

[2 Development options 6](#_Toc525482258)

[2.1 TKinter 6](#_Toc525482259)

[2.2 QT 7](#_Toc525482260)

[2.3 Kivy 8](#_Toc525482261)

[2.4 Web App 9](#_Toc525482262)

[3 Application structure 11](#_Toc525482263)

[4 Application parts 12](#_Toc525482264)

[4.1 Main menu 12](#_Toc525482265)

[4.1.1 Turning off the Raspberry Pi 14](#_Toc525482266)

[4.2 Detection Window 15](#_Toc525482267)

[4.3 Speed and Sensors 15](#_Toc525482268)

[4.3.1 Displaying Engine Power 16](#_Toc525482269)

[4.4 ASE-Protocol 17](#_Toc525482270)

[4.5 Overall Module 17](#_Toc525482271)

[5 Sending and Receiving information 18](#_Toc525482272)

[5.1 The implementation of the shared interface 20](#_Toc525482273)

[5.2 Interval value 22](#_Toc525482274)

[6 Conclusion 24](#_Toc525482275)

[Bibliography 25](#_Toc525482276)

**List of Figures**

[Figure 1: Overall structure. 11](#_Toc455056942)

**List of Abbreviations**

|  |  |  |  |
| --- | --- | --- | --- |
| **GUI** | Graphical User Interface |  |  |
| **ECU** | Electronic Control Unit |  |  |
| **HTML** | Hyper Text Markup Language |  |  |
| **CSS** | Cascading Style Sheets |  |  |
| **PHP** | Hypertext Preprocessor |  |  |
| **JSON** | JavaScript Object Notation |  |  |
| **UI** | User Interface |  |  |
| **Tkinter** | TK Interface |  |  |
| **OS** | Operating System |  |  |
| **GCC** | GNU Compiler Collection |  |  |
| **XML** | Extensible Markup Language |  |  |
| **IoT** | Internet of Things |  |  |
| **QML** | QT Modeling Language |  |  |
| **API** | Application Programming Interface |  |  |
| **AJAX** | Asynchronous JavaScript And XML |  |  |

# Introduction

Creating a Graphical User Interface (GUI) is an important part of every application that offers a form of interaction with the user. This part of the software is the only part that the user can see. When not presented well, some users may not be happy about the application on their hands no matter how efficient or fast it is and regardless of all the efforts that were spent creating the underlying parts of the program, after all, one can think of the GUI as the connection point between the user and the device.

There are many tools and technologies available to create interesting GUIs, choosing the right tools (frameworks, libraries, compiler toolchain,…etc.) is the first step in creating something with good quality, but unlike other parts of the software, GUIs don’t just need to have good performance and be practical but also, responsive, user-friendly, where it takes into account the age class of its main users base, for example, the GUI components should be presented differently if the application is going to be used by people with older age rather than younger users, and also attractive since in this time users also expect their applications to have a good design and styling with suitable colors and graphics.

Web technologies were chosen to help in creating the GUI that will run on the official Raspberry Pi Touchscreen, this decision is widely practiced by many developers all over the world when creating User Interfaces (UIs) for their applications to run on the Touchscreen. This, of course, is not the only possible choice as there are many different tools, libraries and frameworks that can also help developers to create GUIs for the Touchscreen, but this options has some advantages that are not available in other tools while at the same time offers almost all the main features that are supported by the other technologies.

# Development options

There are many options for developing a Graphical User Interface (GUI) to run on the Raspberry Pi, The search for the tools to be used for implementation was narrowed to the following options:

* TKinter
* Kivy
* QT
* GUI as a Web application (Web technologies)

Those four options are very popular when developing applications for Raspberry Pi that involved graphics, the reasons why those four options are the most popular tools for developing graphics application on this platform are numerous and each tool comes with its advantages and disadvantages.

## TKinter

The name of TKinter is derived from the two words TK and interface since TKinter is a Python binding for the TK GUI framework. The very first thing to notice about TKinter is that it is a Python Library, programs written with TKinter use Python programing language. TKinter comes already pre-installed on the Raspbian Operating System (OS) and the user doesn't need to install any libraries, it is already there and the developer can start focusing on the program on hands right from the very beginning.

TKinter is not dependent on Raspbian, on the contrary it is a platform independent, and the developer can use it to write programs which can work on many platforms.  The biggest reason behind the popularity of TKinter is that it is a very fast library in term of the development, it has a quick and clear development route so the developer can easily layout the different GUI components, this way the programmer can focus more on the functionality that's required to be implemented. On the other hand programs developed with TKinter have performance issues where unfortunately TKinter may not perform as fast as desirable [3], thus making it unfavorable choice when thinking about creating programs with quick responses.

On the other hand, this library is also known for its old outdated look, usually its look feels a bit old and not suitable for the current changes and improvements happening for GUI frameworks, nevertheless some attempts for changing this reputation took place when issuing TKinter 8.5, unfortunately, these changes were not enough to make programs developed with TKinter look more modern and up-to-date with their appearance. Offering the user a good and up-to-date GUI is one of the tasks a developer should think about. Providing the look and feel of old GUI styles makes TKinter look unattractive for many developers concerned with creating software that has some sort of graphics involved.

## QT

QT is programing framework, developed to help in creating applications that need to provide some form of graphical user interface for is users, QT supports many platforms and can run on most Desktop applications, a considerable support for embedded systems as well as Mobile platforms. Programs developed with QT have a natural or native look making it an attractive choice for many programmers, beside the support for GUI, QT can be used to create command-line applications and many interesting projects were developed using QT [4].

QT also supports a wide range of toolsets and compilers, it supports the famous Linux GCC compiler and Microsoft Visual Studio toolsets, another interesting feature available in QT is that it offers the possibility of writing the logic with JavaScript, QT offers QT Quick that provides what's known as a declarative scripting language QT Modeling Language (QML) which is a declarative language where inline JavaScript is allowed to handle the logic. Moreover, QT offers support for parsing XML documents and processing JSON files, both XML and JSON technologies are widely used in machine-to-machine interactions and web services hence making QT suitable for applications that need to interact with other machines directly and exchange messages and process them without the need for adding an external tool.

Qt performance has been proven to be good in general although some questions were raised when performing under Raspberry Pi, sometimes the graphics don't render smoothly and some lagging is observed, in such case and especially if the main part of the program that’s being developed is the graphics then the developer might need to make compromises between good performance and good-looking User Interfaces.

Concerning working with Raspberry Pi, QT can offer many desired features as mentioned above but it first needs to be configured and installed properly, one way of installing QT is by creating a cross-compiler for Raspbian, unfortunately, such action is not easily achieved and many developers decide to not consider QT once they fail in creating the cross-compiler, QT online community is already saturated with negative experiences and wasted times of developers trying to setup the cross-compilers to eventually fail after wasting a considerable precious times.

QT isn‘t the best choice, although it offers many interesting features but there are some serious concerns when running the developed graphics on Raspberry Pi, and the fear that using QT for developing the GUI could result in slow unresponsive user interfaces makes QT unattractive for this scenario.

## Kivy

Kivy Is also another Python supported graphics library, it is open source and platform-independent, it can run on Windows, Linux and Android, it is developed by Kivy Organization. One of the strongest point of Kivy is that it supports touch-screens naturally without the need of installing or adding external features, moreover, it supports Raspberry Pi. Kivy is equipped with most of the required features for developing applications, it offers great support for handling user inputs such as mouse, keyboard and as mentioned above for touch events, this becomes quite useful when developing an app for Android. Its graphics are created based on the famous OpenGL library, making it quite flexible and powerful [5]. Kivy also offers what’s known as KV language which is an intermediate language that the developer might need when creating more sophisticated applications.

The downsides of Kivy are not many but they exists, one of them is that Python itself may not be enough to develop a fully functioning application, especially when this application gets bigger, at this point the developer might need to use KV language and the problem with this that KV is only used for Kivy, hence learning it could become costly since time and resources should be spent learning a new programing language and eventually it’ll only be used for creating applications using Kivy.

Although it supports Raspberry Pi, Kivy doesn’t come pre-installed on Raspbian and the developer has to take care of this, the problem here that installing Kivy on Raspbian is not a straightforward process, sometimes trying to install Kivy and getting all the dependencies to work together is not an easy task that could easily end up in frustration and precious wasted times [6].

Up to this point, Kivy has demonstrated that it is a reliable library, programs developed with Kivy showed great degree of efficiency and behaved as expected with the expected response time, while this might be true for small projects, the same can’t be said about big projects. Hence more research needs to be carried on. Kivy still has some work ahead of it when it comes to large-scale projects.

## Web App

The fourth popular option for developing Raspberry Pi applications with GUI is creating the Application as a Web App. This way the application will run inside the browser and can be created with many available technologies such as HTML, CSS, JavaScript, jQuery, and maybe using additional frameworks like Bootstrap, moreover developers also use PHP, Python, or JavaScript (Node.js) when they need back-end technologies, in such cases a web server should be installed, examples for such servers are Node.js or Apache.

Many Internet of Things (IoT) applications developers have created their programs as a web app, there’re even platforms such as Node-Red by IBM that will help the developer to create an IoT app while the workflow and the outcome is all in-browser [7]. Creating the Application as a Web App, and in this case the GUI, enables the developer to take advantages of the big capabilities offered by HTML and CSS for creating a fast and attractive User Interfaces (UI).

Program created as a Web App will be able to enjoy using all the features available in those mentioned technologies to run fast and smooth, the reason behind this is that, currently websites are accessed from Mobile devices more than traditional Desktop platforms, and some of those Mobile devices are very old running on old software but still perform as expected and are just as responsive.

Web technologies always try to keep compatible with old devices for as long as they can have a running browser in such a way enabling many old slow devices to keep running web apps with acceptable performance and speed and also with attractive UI, such concerns for performance, speed and compatibility make creating applications for Raspberry Pi using web technologies a suitable choice.

The look of the GUI units can be changed and adjusted as much as desired, the reason behind this is that the great flexibility those mentioned technologies offer, when creating a web App the user can expect his app to be accessed from many different devices running on completely different platforms, such challenge was a good point in pushing web development technologies to become more modular and flexible.

Since Web apps can run on most devices equipped with a browser, this means it is even possible to have our application running not just only on Raspberry Pi but also on a Desktop, Mobile devices or even on a Tablet. Such goal could become an important concern for the future and it can be achieved easily, hence it makes developing the Application as a Web App a good choice when thinking about portability features of the App itself.

Graphics created with Web technologies can be developed to become interesting, attractive and user-friendly, such technologies offer many features and possibilities for the developers to create nice, interactive, modular and even animated widgets. One example for such capabilities are the animation feature in CSS [8], with this feature the developer can create and fine-tone very interesting animated widgets that interacts with the user and respond in an interesting and attractive way to any form of inputs.

Another feature of web technologies is that their ability to handle different forms of user inputs, such as mouse, keyboard and finger touches, while handling multi-touch events is an important feature for smartphones and Tablet applications, it is not an important one when the application running on Raspberry Pi using the official Touchscreen since this screen simulates mouse clicks as finger prints and in this case the application only needs to handle traditional user inputs such as events coming from the mouse or the keyboard. Despite this, this feature could play an important role once there's a need to port the Application to other devices such as a Tablet or a Mobile.

One interesting feature when creating web applications that is usually the developer doesn't need to install any additional software or libraries, a mere of a text editor is enough to get the developer ready, on top most of the framework or libraries don't need any installation and can be added by simply adding one line of code to reference them. Such point can save the user hours or even long days of tries to install the right library or bundling different technologies together.

While having many interesting and positive features, web technologies also have their own drawbacks, one of the most obvious one is that any app can only run inside a web browser and if the user doesn’t have an installed web browser then the app can't run, yet this draw back can be overcome, there are currently few available frameworks that helps the developer create applications using web technologies and then producing the final result as a stand-alone app, whether this is for Desktop platforms or for smartphones.

The developed solution will run inside the browser but Raspberry Pi will boot and run it immediately without any intervention from the user, also the Application will be running in full-screen mode, this feature is known as Kiosk mode.

# Application structure

The Application can be developed and structured in many different ways, the connection between the Front-End (GUI) and the Back-End can be established using many different techniques, the used technique is chosen based on performance at first, where the GUI has to show the values sent by the Back-End in real-time then based as well as on other factors such as portability and usability. The options for connecting the GUI with the Back-End include:

* Web socket and a log file.
* Database.
* Using the file system.
* Using JSON technology.

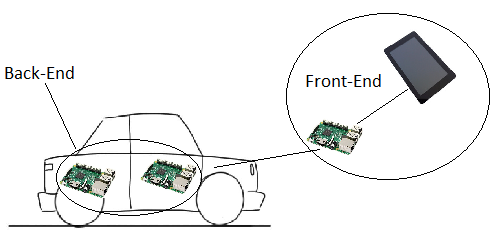


Figure 1: Overall structure

Figure1 shows the overall structure of the System, in this paper the two terms: Front-End and Back-End indicates the following: The Front-End refers to what the user is able to see and interact with, while the Back-End refers to all other Raspberry Pis, ECUs (Electronic Control Units), their connections and software

.

There are also other options that doesn’t include any middleware between the two parts of the System but having no middleware can create some problems and also could lead to a data lose. In this case the Front-End and the Back-End would interact by direct Application Programming Interface (API) calling, those APIs would be an interface that was agreed upon and it represents a contract for interaction between the Front-End and the Back-End.

Two cases can exist in this scenario:

* The Back-End will signal the Front-End whenever a new data is available to be read.
* The Front-End will periodically call specific APIs to get the desired values and check to see if they are ready to be read.

# Application parts

Internally, the Application depends on many features of HTML/CSS and JavaScript, the following pages present a short description of the various parts of the application from the point of view of the actual implementation and what kind of technologies were used.

The Application consists of five windows in total. They are divided as follows:

* Main menu
* Detection window
* Speed and Sensors window
* ASE\_Protocol window
* Overall status window

Those five windows collaborate together to offer the user the possibility to monitor the values coming from the different sensors in the car such as the speed of the car, the orientation, the engine power, the sensors on the front side as well as the back side of the car, furthermore, the Application shows any data detection sent from the Back-End of the System.

## Main menu

When lunching the Application, the first window that will appear is the Main menu, in this window the user can decide one of four options:

* Detection window.
* Speed and Sensor window.
* Overall status of the car window.
* ASE\_Protocol window.

When performing one click over any of them, the icon will get bigger, then a text will replace the icon after few fractions of a second, the way the text replace the icon is carried on as if a curtain starts covering the icon with top-down approach.

To change the size of an item in the menu and make it a little bit bigger, the property “transform” is used as follows [9]:

transform: scale(1.2);

Simply, increasing the size of the icon by 20%. Such increase is also timed and happens over 0.2 seconds, this is indicated in the CSS properties of the icon container as follows:

transition: transform .2s;

To achieve the effect of having the text appearing over the icon in a top-down approach attention must be given to the text and its container, first all properties should be set depending on how the text and its container are desired to appear, such as text color, background color, the size of the text and so on…then this effect should be added to the icon whenever the user touches the icon. The timing of such event is handled in the CSS properties of the text container, this time takes place over 0.5 seconds.

Once the user leaves the icon, basically, putting the mouse/finger anywhere outside the icon space, the text and its background will withdraw in a reverse order to the way they were introduced, they’ll move in a bottom-top approach and then the icon will go back to its normal size.

Another option for the user is to choose more than one window, the application offers the user the possibility to combine two windows at the same time so the user can monitor two different reading of the car at the same time. Next to the right corner and at the top of the main menu window there are two buttons next to each other, one represents having the screen showing only one module, while the other represents splitting the screen in half and having it showing two modules next to each other depending on user‘s selection. Both buttons can’t be pressed together at the same time, thus the user has to choose one of them, when one option is selected the other option is automatically deselected.

In case the user wants to see only one module, he can immediately choose that window, where having only one module showing in the window is the default option. Once a module is selected the application will lunch the selected module. On the other hand, if the user wants to have two modules showing at the same time, the two-module button must be active and it has to be selected first then the user can choose two modules of the available modules. With every module getting selected a green line appears underneath the selected module to indicate the selection, when the second module is selected the application will lunch the new window with having the screen split into two parts and one modules of the previously selected ones appears in each parts of the screen.

The following example shows how the mechanism for the two-option selections. The Application detects which option the user has chosen based on the opacity of each button, since the selected button will have a full opacity while the other will have a 50% opacity.

Once an option is selected, a variable is used to keep the count of how many modules the user selected so far, the reason behind such action is we need to know exactly when the user chooses the second module because once the second module is selected the application will launch a new screen containing both modules:

$("#sas").click(function(){

if( $("#twosr").css('opacity') == '1')

{  
 $("#firsts").css('display','block');  
 number\_selection++;

The above code explains what happens when the user press on “Speed and Sensor” module, jQuery is used to help locating which component the user is interacting with [10]. When this module is selected the code first checks to see what options of viewing the user has selected, is it one window or tow windows, this is done based on the opacity of each button, if two-window selection is chosen then, at first the application draws a line underneath the “Speed and Sensor” module then increase the counter that keeps track of how many selections.

Later the application checks if this counter equals 2, in this case two modules have already been selected and all the application has to do is to see which two modules those are and then lunches them in one window. Whenever the user makes a selection the application keeps whatever the user has selected in a variable, hence two variables are needed, one for the first module and the other for the second module.

If the user has only selected to see one module each time, then the application will simply lunch a window with the selected module [11] as follows:

window.open('sas.html', '\_self');

The above code, lunches “Speed and Sensor” window, for example, once the user seletcs it after having selected to show the module in full screen.

Another feature of the main menu is the possibility to turn off Raspberry Pi from the Application itself. At the top next to the right corner of the main menu window there’s a small button to turn off/shut down the Raspberry Pi, once this button is double clicked a message will appear to ask the user to confirm the turning off of the Raspberry pi, an answer with yes to the confirmation message will cause the Raspberry Pi to turn off.

This functionality is achieved via PHP, PHP is a server side language and its script can’t be run without installing a server on the Raspberry Pi, so the first step to achieve this functionality is by installing a web server such as Apache, once apache is installed, the next step is to install PHP itself. Both can be installed easily from the terminal.

Now everything is ready and installed, a small PHP script can drive the Raspberry Pi to shutdown via the following line of code:

system('sudo /sbin/shutdown -h now');

Basically, what the function *system* does, is executing an external command/program and outputting the results afterwards, here there are no results. Once this line of code is executed the Raspberry Pi will shut down immediately.

In order to make this code executable/successful, few configurations for the Raspberry Pi has to be made, those configurations can be adjusted from the terminal and for one time only. One of those configurations, for example, is giving Apache (the web server) the permission to shut down the Raspberry Pi.

Rebooting is implemented similarly but with few alternations.

## Detection Window

The point of the detection window is to show a video containing the detected item as well as the sign of the item itself and some information about it. The Detection window uses HTML5 element called “video” to show the video of the detection [12].

The video element is very simple and can be used with rather few options and properties, the most important one is the path to the video that’s supposed to be played. Besides that, one can specify the width and height for the video element itself using the width and height properties as follows:

<video width="320" height="240" controls>

<source src="movie.mp4" type="video/mp4">

</video>

Here the playing video is called “movie.mp4” located in the very same folder as the source code file, the height is set to 240 pixels and the width is set to 320 pixels.

## Speed and Sensors

Speed and sensor module has three goals:

* Displaying the power of engine, in percentage.
* Displaying the current speed.
* Displaying the sensor data obtained from six sensors located on the front and back of the car.

The Speed and sensor module is divided into two parts, the first part will display the engine power, while the second part displays the current speed and values obtained from the sensors.

The displaying of the engine power is done via a circle that has its border as an indicator for the range of the current power of the engine, the way it is shown is by having the border highlighted depending on the actual power range. For example: if the engine is working at 60% of its power, then the circle will has a full border, but only 60% of this border is highlighted and bolded with a different color to the actual color of the boarder. Secondly, the percentage of the engine power is written clearly in the middle of the circle.

Drawing the circle is done mostly in JavaScript, the only thing that needed to be done in html is to have a place holder for the engine power gauge to be drawn at, and this is achieved by using the html canvas element. Canvas by itself can’t draw, it has no functions or properties to help plotting dots or shapes on screen, the developer using Canvas should use as well JavaScript to draw the graphics [13].

Once the Canvas element has been placed in the html source code, a reference to it in the JavaScript function must be created, and this is achieved using:

var enginepower = document.getElementById("carengine");

var ctx = enginepower.getContext("2d");

The variable “ctx” has a reference now to the Canvas element in the html document and now it can be used to place graphics in the Canvas. The next thing should be done is clearing the area of drawing, this is achieved using *clearRect* function. The area that’s to be cleared has the shape of a rectangle, so regardless of the shape of the actual drawing the *clearRect* function will clear a rectangular area. Now the focus can be shifted towards drawing the gauge border, the arc or the boarder of the circle can be drawn using the *context.arc* function.

The next step is to fill the range of the value that the arc is supposed to show, so far the full border has been built and now attention should be on drawing the value that indicates the current power of the engine, this is achieved again with the same function which is *context.arc.*

## ASE-Protocol

This module consists of three parts:

* 10 LEDs showing status of 10 bits sent by the Back-End.
* Two switches and a slider.
* Four buttons.

The LED buttons will change their statues from glowing to not glowing depending on the respective bits, there are 10 bits that’re set by the Back-End and each bit corresponds to an LED, where a value of 1 means glowing and a value of 0 means not glowing. To help create the LEDs and make them glowing, CSS animation was used among other CSS properties [11].

The two switches have two values for each one, either on or off depending on the status of the switch. On the other hand the slider has a value range from 1 to 100.

The four buttons have different behavior, two of them respond to long presses while the other two respond to a normal press.

## Overall Module

This module presents a place for displaying the overall situation of the car, in addition to displaying a chart that helps in having a better understanding of the condition of the car. This module could play an important role when trying to debug any malfunctions, damages, or faults happening to the car. Moreover, the module is very easy to adapt and additional information can be added to the car or different types of chart can be presented once required and once the Back-End can present more information regarding the overall situation of the car. This module will show the following:

* Number of total KMs run by the car so far.
* Last time the car was operating.
* Any warning to be displayed.
* A chart which currently showing the working hours each day over a year.

The chart is drawn using canvasJS library, which offers a free trial version.

The code is very adaptable and different libraries can be used depending on the specific requirements at hands.

# Sending and Receiving information

The way the Application deals with data and the messages exchanged between the Back-End and the Front-End is achieved via different types of technologies, those are: PHP, JavaScript, jQuery, AJAX and JSON [14]. As mentioned above, there are many good advantages of using a shared buffer, and this is the solution that’s being implemented for the System.

At the root directory of the Front-End, there exists a file *data.json*, this file contains JSON array that has all the information that’s exchanged between the Application (the Front-End) and the Back-End of the System. The Back-End will write any data that should be sent to this array and the Front-End will present this data to the user.

Having a JSON array as a buffer between the Front-End and the Back-End of the application offers many advantages, the most important one is to have the Front-End completely independent of the Back-End. Whatever technology is used to develop the Back-End of the whole System, it can probably work with minimum efforts and interfaces properly with JSON [15]. The job of this array is simple, it’ll basically act as an interface between the two parts of the System, the Back-End and the Front-End.

When new data arises and needs to be presented to the user, all the Back-End has to do is passing this data to the JSON array, this way the Back-End of the System does not have to care about how the Front-End will handle this data.

How can the Front-End know about the new data that just arrived? There are two approaches to solve this problem:

* Having the Back-End signaling the Front-End to indicate that there is new data and the one that’s showing is old and need to be updated.
* Having the Front-End periodically checks for new data and either shows whatever it finds in the JSON array or compares the data in the JSON array with the data it has, if the data is different or even part of it is different, then an update is needed.

Both approaches can, of course, be used, either the first one or the second one, but there are some design principles must be taken into account when deciding which solution is the best one.

Most importantly, the System must present the data in real time, so the focus should be on choosing the fastest option as well. When we design the Front-End in such a way that it needs to be notified to check for any changes in the data, then we are creating another link between the Front-End and the Back-End. Using such design is not a wise decision because we are creating more reasons for reducing the decoupling between the two parts of the System, moreover, such design approach means the designers of the Back-End need to think of a way to send messages and notifications to the other part of the System, that’s the Front-End, and this part must be designed to accommodate and receive those signals, thus both designers must agree on a way to design the System although the Front-End is being designed separately and there’s no direct connection or knowledge of the how the System is going to send messages to the Front-End.

Choosing this option, means the Front-End is going to suggest a way of how it wants to receive signals that’re coming from the other part of the System, whatever technology is chosen to resolve this matter it may not be the right one or the most practical one for the Back-End. Furthermore, there’s the problem of presenting the data to the user in real time. Right now, the Front-End can’t tell which method is going to be used by the Back-End and thus it can’t guarantee that it’ll be able to show data in real-time to the user.

The other option of showing the data coming from the Back-End is having the Front-End itself to do periodic checks to bring data from JSON array and present it to the user. With this option there are also two options to choose from: When reading new data from JSON array, should the Front-End compare the new data with the data that’s already presented and only shows this data when there’s a difference between the two? Or should the Front-End simply show the data that it has just acquired from the JSON array without doing any kind of comparison?

When the Front-End needs to compare the newly read data with the old one the following steps will be followed:

1. Read the data present in the JSON array each X amount of time
2. Read the data that’s currently presented to the user (the old data), since the Front-End doesn’t have a storage mechanism
3. Make a comparison between the two to check for any changes
4. Two cases:
   * + - There’s no change in data, do nothing
       - There’s a change in data between the two readings and the new changes will be presented to the user

On the other hand, When the Front-End simply reads the data available in the JSON array and present it back to the user, the following steps will be followed:

1. Read the data present in the JSON array each X amount of time.
2. Present this newly read data back to the user.

The solution to be used is the later one, where the Front-End has to do the minimal possible operations, so it adheres to the real-time requirements as close as possible.

When using such solution, the user will not notice any difference when the Front-End pushes the newly read data in case this data is not different from the old one, the user will notice changes only when the newly read data is different from the data that was showing previously.

## The shared interface

The way to access JSON array is achieved via PHP, at first the PHP script must know where the array is stored, so it needs the path of the array, then JSON content of the file must be decoded, and finally each element in the array can be reached using its key. As mentioned above JSON array is stored in a file called *data.json* and since JavaScript can’t reach the file system, then a different technology must be used, in this case PHP was chosen.

The reasons behind such decision are because PHP is a Back-End technology and thus is able to reach the file system, PHP has simple and very user-friendly methods for accessing and handling JSON arrays [16], and PHP is already being used in the Application when turning off/rebooting the Raspberry Pi, thus using PHP means there’s no need to introduce new technologies to the Application and avoid any complications that could results with such action. The following code illustrates the process:

$url = 'data.json';

$data = file\_get\_contents($url);

$readings = json\_decode($data);

*file\_get\_contents* is the function that will locate the file containing the JSON array, then *json\_decode* will extracts the JSON array from the file. Now for example if we would like to access the speed element, we can do it via the following:

$readings[0]->engine;

To show the speed of the car in the info bar, we need to call this PHP script that handles the JSON array and then redirect the returned value to the HTML file that’s showing the info bar.

At this point, it should be first specified which part of the HTML document is responsible for presenting the speed, once this is done, a call is made to the PHP script which returns the speed that’s being read from the JSON array. The calling of the PHP script is being indirect and through another function called *setInterval*, this function will keep calling the function that’s passed to it as its first parameter, in this case the calling of the PHP script, and will keep repeating the calling according to the interval that’s passed to it as its second parameter, the second parameter in this case is *x amount of time* this value is measured in milliseconds and will have the function *setInterval* to repeat the calling of its first parameter every *x amount of time* [11].

Getting the orientation data of the car from JSON array is done a little bit differently, the reason for this is with the speed, the called PHP script could simply print the speed directly into the responsible HTML file, while with the orientation, we want the PHP script to return the read value from JSON array and JavaScript will have to alter the CSS attributes of the parts of the HTML that’s showing the orientation of the car, since we need to rotate the arrow that points to the direction of the car and this rotation can be done with CSS.

The function *setInterval* is used again [11], with two parameters, the first is the AJAX script that will call the PHP script which will return the orientation value from the JSON array, and the second parameter is the *x amount of time*, meaning that the function *setInterval* will call the included AJAX script every x amount of time. The difference is in the AJAX script, as shown in the following code snippet:

$.ajax({

type: "GET",

url: 'orientation.php',

success: function(data){

$(".orientation").css("transform", "rotate("+data+"deg)");

}

})

Here AJAX script is making a GET request to the PHP server that’s running the PHP script, the request is directed to the page *orientation.php* and the returned value after calling the PHP is passed to the variable *data,* the code that’s inside the function will be executed once the PHP script return with a status of success from its call.

Since the orientation value that’s read from the JSON array is now stored in the variable called *data* we can now use this value inside the function that’s called in the AJAX script to alter the HTML part that’s showing the orientation of the car according to the value *data*.

Since the arrow that’s showing the orientation of the car can be modified using CSS, we can simply alter its CSS properties accordingly, we do this using jQuery. First the arrow must be located, using *$(“.orientation”)* then we specify which attribute we want to alter, and then we pass the value, in this case we are modifying the transform property, and applying a rotation with a *data* (data is the orientation value obtained from the JSON array) degree.

## Interval value

What is the right interval that should be used to make a call for the PHP scripts to obtain the required values from the JSON array? The answer to this question can partially be derived from experience, among other factors, where this value should not be set arbitrarily.

When the Application doesn’t make enough calls to obtain the new values then the Application is missing many important values and not doing a good job of showing data in real-time to the user. On the other hand, when the Application is doing many additional unnecessary calls, it is then overwhelming itself which will lead to many performance issues that could make the experience of the user unpleasant.

Fortunately, this value can easily be changed and set, it is hardcoded because there’s no reason to set such a sensitive value as a choice for the user. Having the value as an option where the user can enter this value in a textbox, for example, could put the Application under many risks, since the user doesn’t have any idea about the underlying of the code and the architecture of the Application.

The nature of the Application allows for great performance even when this value is set very low, the reason behind this is there are no threads running in the background, and the only running part of the program is what the user can see on the screen, so at any given time there will be only one page loaded and running and the Application will be trying to make calls for the JSON array only for the data related to this specific page, any data that’s presented in other pages and needs to be obtained from the JSON array will not be called unless it is in the active page itself.

Another important point to be noticed here, is that this interval value can be different from one part of the Application to another, where some values that’s sent from the Back-End and saved into the JSON array don’t have a sensitive nature where it can change every few milliseconds of time, thus the interval between each call for such values shouldn’t be very small and should be set according to the sensitivity of the obtained values/data.

# Results and Evolution

The implemented solution performs well on Raspberry Pi, this small computer is not considered a device with strong processing powers, yet the developed Application shows good responsivity. The user can easily interact with the Application, moves from one module to another, have two modules running at the same time, all of this while showing data in real time, that’s brought from the shared buffer with the Back-End at high speed rates. The user can’t notice that the Application is updating the data that’s being read from the shared buffer, it can only be noticed when some change in the presented data takes place that’s when the shared buffer has different data to the previous one. Some readings from the buffer happen at a very high speed rates (many times each second), yet the Application doesn’t show any latencies nor does it exhibit any delays in responding to the user’s orders and interactions.

Another important observation, the Application has shown a great degree of flexibility, many modifications happened during the course of the development, at first two modules were developed and integrated into the Application but then they had to be highly modified. One of them was completely removed and replaced by a newly created module while the other had to be modified where new components had to be added while removing few existing components. These modifications and changes show that the Application is adaptable and can be easily manipulated however it is required. Removing a full module was possible, and integrating a new module at a late stage of the development was possible too, hence showing good degree of flexibility.

On the other hand, the Application requires more development regarding the usability, more work needs to be done to make the experience of the user better and smother. So far, the Application still sometimes confuses one or two events with each other, this confusion leads to having the application behaving in an undesirable way, which could cause some degree of annoyance to the user. Capturing and eliminating this kind of behavior was not an easy task, many libraries were tested in the hope of showing a positive actions when dealing with those events, unfortunately, most of those libraries failed in detecting and eliminating the unwanted events. Those unwanted events resulted from the browser realizing that it is operating under a Touchscreen and trying to respond to evens such as swipes while the touchscreen itself accepts touch events by simulating each touch as a mouse click. This situation resulted basically because the app was running inside the browser and not directly under Raspbian OS. This of course resulted in more work and time spent trying to solve this unwanted behavior.

Choosing web technologies as the main development tools gave the Application the possibility to have lightweight yet modern graphics. The Application also enjoys using a wide range of libraries and frameworks hence making it able to present the data in any possible form and however it is required, this is because web technologies are very flexible and can integrate many tools working together in harmony.

The Application now can be extended to look good on any screen size all that’s needed is little effort to change the layout of the GUI components so they are organized differently under each screen and will appear that way automatically each time the Application is run on different screen sizes.

# Conclusion

The Application that’s has been implemented serves its goals and purposes, it is responsive and offers the user a good experience. One of the strongest points of implementing the GUI using web technologies is to have the application easily ported to any platform, after all, the only requirement for the host device is to have a web browser. In future, when the Application is needed to run on a PC (Windows or Linux), Mac, IPhone, an Android device, or an IPad it can easily run.

Currently, the Application components and UI is designed to look good on the Official Raspberry Touchscreen, and they’ll not adjust well for any different screen size but once needed it can be ported to look well on all the mentioned devices with not much efforts. One reason for not having the Application to automatically adjust to any screen size as it is now is having the focus on creating something suitable for the Touchscreen first and for most, as having it to run on every device is not a current requirement.

On the other side, the provided Touchscreen simulates mouse clicks when getting touch inputs, this approach doesn’t work well on the browser which causes some unwanted behavior sometimes for example when the Touchscreen mistakes a swipe with a long press assuming that a long press from the user is intended to be a swipe, hence extra work needed to capture such misunderstanding and take measures to eliminate unwanted behavior.

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