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Design and Experimental Prototyping of an ESP32-Based Digital Device for Weight Acquisition and Monitoring of Hand Luggage Bags

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ABSTRACT

This research paper presents an ESP32-Based instrument to be used as an embedded electronic hardware part of hand luggage bags. Its consists of low cost and size electronic parts including a weight sensor, alerting buzzer, a LCD monitor and an ESP32 microcontroller core, with integrated digital instrumentation and data processing resources. The schematic diagram of the proposed digital electronic instrument is designed, then a prototyping realization is done and well tested. Furthermore, the experimental data obtained are exported into Matlab CFtool framework, in order to compute the LSE (least square estimates) model within the class of third order polynomial shapes. This resulting optimal model with analytical structure shows the feasibility and high quality of the proposed low cost instrumentation device, for weight monitoring to be embedded into hand luggage bags.

Key words: ESP32, Digital Device, Weight Acquisition, Hand Luggage Bags

1. INTRODUCTION

The electronic-textile engineering is a modern emerging discipline, devoted to the design and manufacturing of textile products involving embedded control electronic parts. Unlike classic textile objects, an electronic-textile product is a composite communicative or interactive (i.e. sensitive and reactive) with its using ambient medium. In addition, its interactive virtue becomes really smart if it involves a useful behavior which is quite similar to that of a human expert under the same operating context. Nowadays, the electronic-textile applications vary from wearable smart objects to a class of IoT devices. However, the great emphasis of this paper is on the electronic part of existing smart hand luggage bags. The next paragraphs of this introductive section, deal with a critical survey on weaknesses of smart handbags models available in electronic-textile literature. Two relevant weaknesses to be considered further are the building hardware constraints (e.g. size and cost) and the involved service types.

A sample of published research works are helpful for a better understanding of building hardware constraints of the electronic part of smart existing bags. In [1], a PIC16F886 microcontroller is used as the electronic core of a basic *smart bag* model, with reinforcement by a number of hardware building modules with great size. Then, a Raspberry Pi is used as microcontroller core in [1], [3] and [4], for *smart bag*, *smart backpack for students* and *smart school bag* models respectively. In [5] and [6], the Arduino Uno microcontroller is used as digital control core. It is worth noting at this point that, all the microcontrollers mentioned until this point, don't involve embedded Wifi and Bluetooth. As a weakness, many external hardware modules are required for implementing remote communication media, at the expense of greedy cost and seize of the overall electronic part, with higher size of the smart bag. Thus, the ESP32 microchip with embedded real time application, can be used as in [7] and [8], in other to optimize the overall building cost and performance.

On the other hand, involved popular services encountered in main electronic device parts for smart bags are: buzzer-based event alert, IoT (Internet of Thinks) technologies including GPS [9] and [10]. However, a few specific electronic part for smart bags involve *finger printing sensor* [6], [11]. However, for hand luggage bags to be used for the market and even for the air flight and more, a real time knowledge of the admissible weight range appears to be a relevant impact factor to be considered by the designers and manufacturers.

Following the preceding brief review of most relevant electronic parts for smart handbag models encountered in many human activities (e.g. travelling, school furniture transporting, and more), and given a few weaknesses above related in most cases to their high hardware size and cost, as well as to the lack of weight tracking service, the relevant aim of this paper is to study a ESP32-based multifunction electronic control device for more novating models of smart hand luggage bags.

As a scientific research work to be presented in deph, the next sections of this paper are organized as follows:

- Material and method in section 2;
- Results and discussions in section 3;
- Conclusion in Section 4;

2. TOOLS AND METHOD

Design tools of the proposed electronic control part for smart hand luggage bags are: block diagram, hardware specification diagram, schematic scheme and resulting flow chart. Indeed, in applied science and engineering, these design tools bring easier architectural description, better understanding of involved signals (nature, processing sources/receivers), as well as the overall operating constraints and involve services.

The block diagram of the proposed electronic hardware part for smart hand luggage bag is presented in in Fig. 1. It consists of a microchip core equipped with numerous types of embedded resources, each of which being dedicated to a target task, e.g. instrumentation, data acquisition, digital control, digital signal processing, data and program memory, WiFi server/client, Bluetooth/BLE server/client, and more.

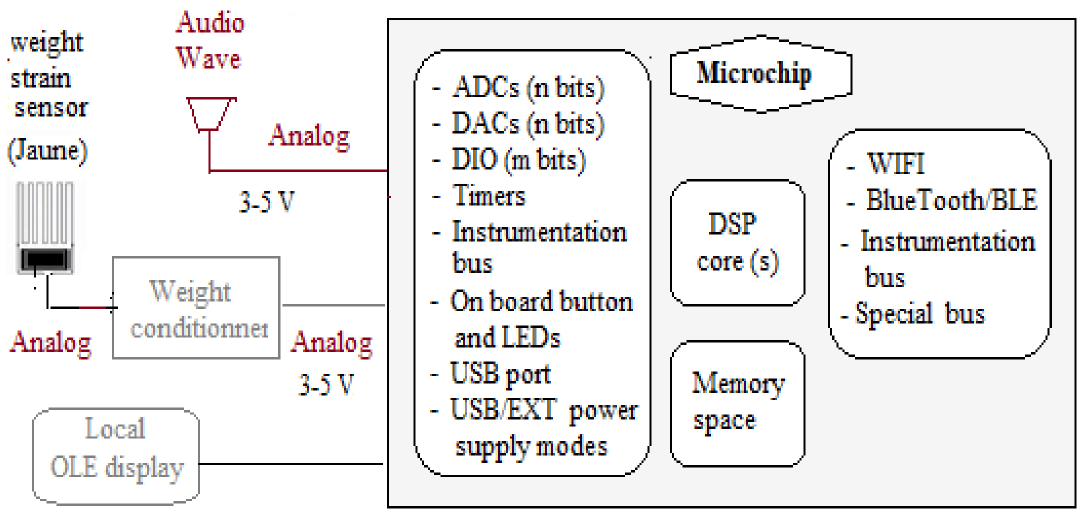

Fig. 1 Block diagram of the proposed instrumentation device

In addition to the inventory of required tasks and signal types, a suitable choice of hardware parts is necessary in order to satisfy numerous constraints, including technical specifications, operating range, overall cost and size. Fig. 2 shown the hardware specification scheme associated with the related Block described as depicted on Fig. 1.

At this point, it is useful to point out a few prerequisites about signal processing techniques, which are involved for better operating conditions of hardware specification scheme shown in Fig. 2. For the Weight sensor module, Fig. 3 shows a basic scheme based on a strain gauge probe the weight sensor operating according to Wheatstone Bridge technique.

The basic scheme of a weight sensor module presented in Fig. 3, consists of two main parts :

- An ideal Wheatstone bridge in Fig. 3a, containing a piece of strain gauge with electric resistance Rg (ψ), ψ being the weight impact of the bag;
- A difference amplifier in Fig. 3b, with inputs dictated by outputs Va and Vb.

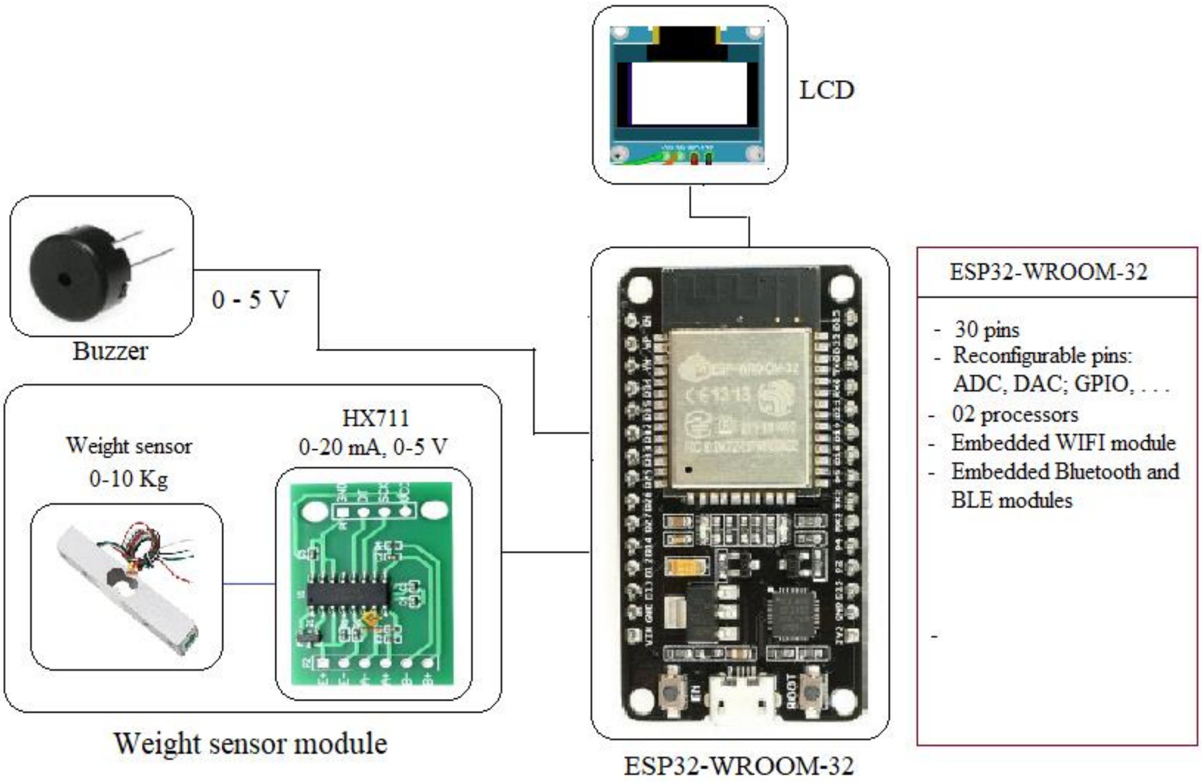

Fig. 2 Hardware specifications scheme of the proposed electronic control device

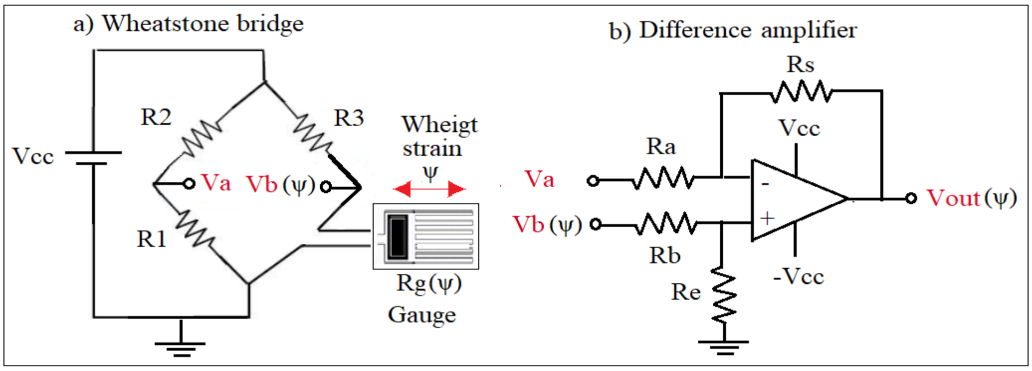

Fig. 3 Basic scheme of a wheigt sensor module

Straightforward analysis steps, show that the Wheatstone bridge in Fig. 3a, is governed by equations (1a, 1b), whereas the input-output behavior of the difference amplifier is given by Equation (2).

$$\text{a)} \begin{cases} V_a = \dfrac{R_1}{R_1 + R_2} V_{cc} \\ V_b(\psi) = \dfrac{R_g(\psi)}{R_g(\psi) + R_3} V_{cc} \end{cases} \qquad \text{b)}\ V_b(\psi) - V_a = \left(\dfrac{R_g(\psi)}{R_g(\psi) + R_3} - \dfrac{R_1}{R_1 + R_2} \right) V_{cc} \tag{1}$$

$$V_{out}(\psi) = \left(\frac{R_e + R_s}{R_e} \right) \left(\frac{R_e}{R_e + R_b} V_b(\psi) - \frac{R_s}{R_a + R_s} V_a \right) \tag{2}$$

If the descriptive parameters Re, Rs, Ra and Rb of equation (2), are chosen according to the design constraint equation (3) Where K is single aggregated parameter, then Equation (2) would be transformed into Equation (4), which is structurally a more ingenious characteristics of overall the overall instrumentation circuit illustrated in Fig. 3, for a basic weight acquisition module.

$$\frac{R_s}{R_a} = \frac{R_e}{R_b} = K \tag{3}$$

$$V_{out}(\psi) = K\ V_{cc}\left(\frac{R_g(\psi)}{R_g(\psi) + R_3} - \frac{R_1}{R_1 + R_2}\right) \tag{4}$$

As a direct implication, the reverse characteristic $\psi(V_{out})$ of equation (4), can be experimentally calibrated from a suitable choice of N sequential data to be provided according to equation (5). In addition, a rigorous analytic model of $\psi(V_{out})$ can be computed from the experimental sequence (5), according to an optimal estimation technique, in order to be called at real time from a software driver for rigorous digital weight acquisition.

$$\{(\psi(n), (V_{out}(n))\} \text{ for } n = 1, 2, \ldots, N \tag{5}$$

Table 1 shows the main relevant software tools used for the implementations needs of the Application program to be embedded after compilation into the ESP32 target.

Table -1 Technical specifications of software tools

No.	Software tools and specifications
1	Proteus software
2	ESP32 driver for Proteus
3	ESP32 driver for window, CP210x USB to UART bridge
4	Arduino C++ IDE, 1.8.10 version
5	Bluethooth Library for ESP32, BluetoothSerial.h
6	HX711 library, HX711.h
7	ESP32 driver For Arduino IDE, Package_esp32_index.json from Espressif
8	OLE Display Library, Adafruit-GFX-Library-master.zip

The electronic instrumentation scheme presented in Fig. 4 has been drawn using Proteus software. It is useful for a better understanding of pins connection of the ESP32-based electronic device. In Fig. 4, it is worth noting that the key functions of the ESP32-WROOM-32 are as follow: a) Acquiring the weight detected by the sensor and conditioned into voltage using HX711 module; b) Decoding the real weight value (kg unit) to be transmitted the local LCD display; c) Displaying on an LCD the weight value.

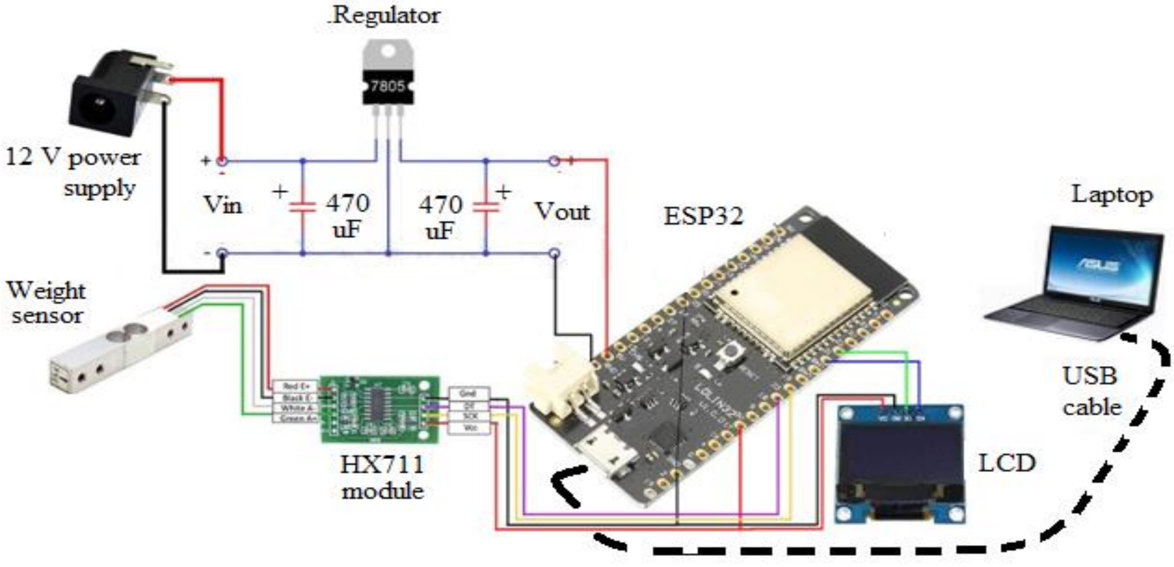

Fig. 4 Electronic instrumentation scheme

The flowchart of the main application software is depicted on Fig. 5. Then, the implementation works are conducted under Arduino IDE C++, followed by compiling and uploading the compiled application into the ESP32 microcontroller. In addition, the local ESP32 control system is tested using co-hardware simulation technique, on the Arduino virtual USB graphical monitor. Fig. 6 shows a screenshot of a portion of C++ application program under Arduino IDE C++. However, the image of the overall C++ sketch cannot be provided here.

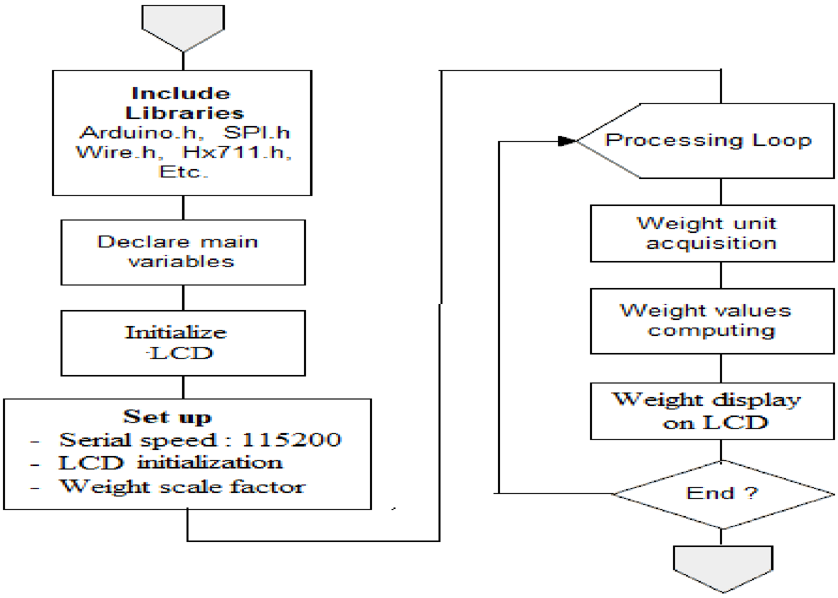

Fig. 5 Flowchart of the application software

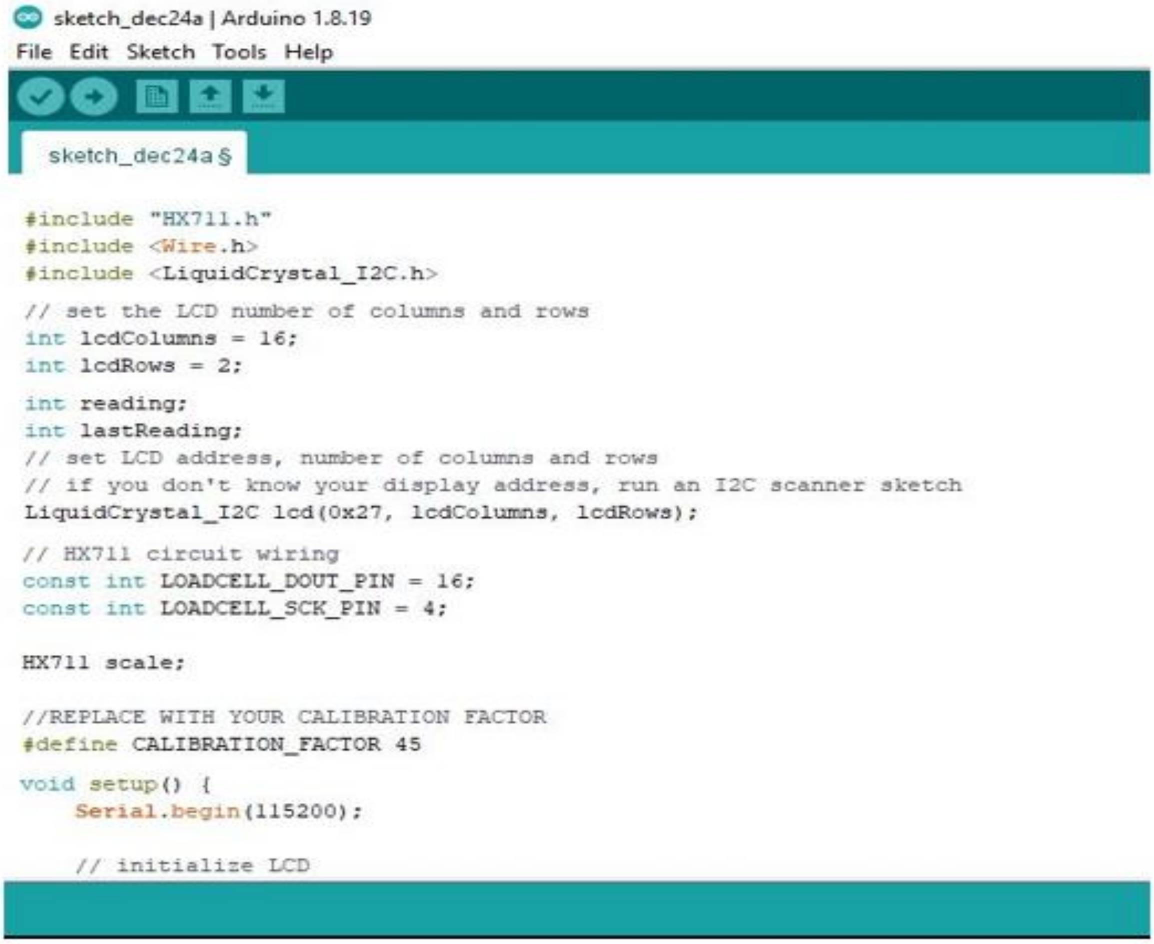

Fig. 6 Screenshot part of the application program under Arduino IDE/C++

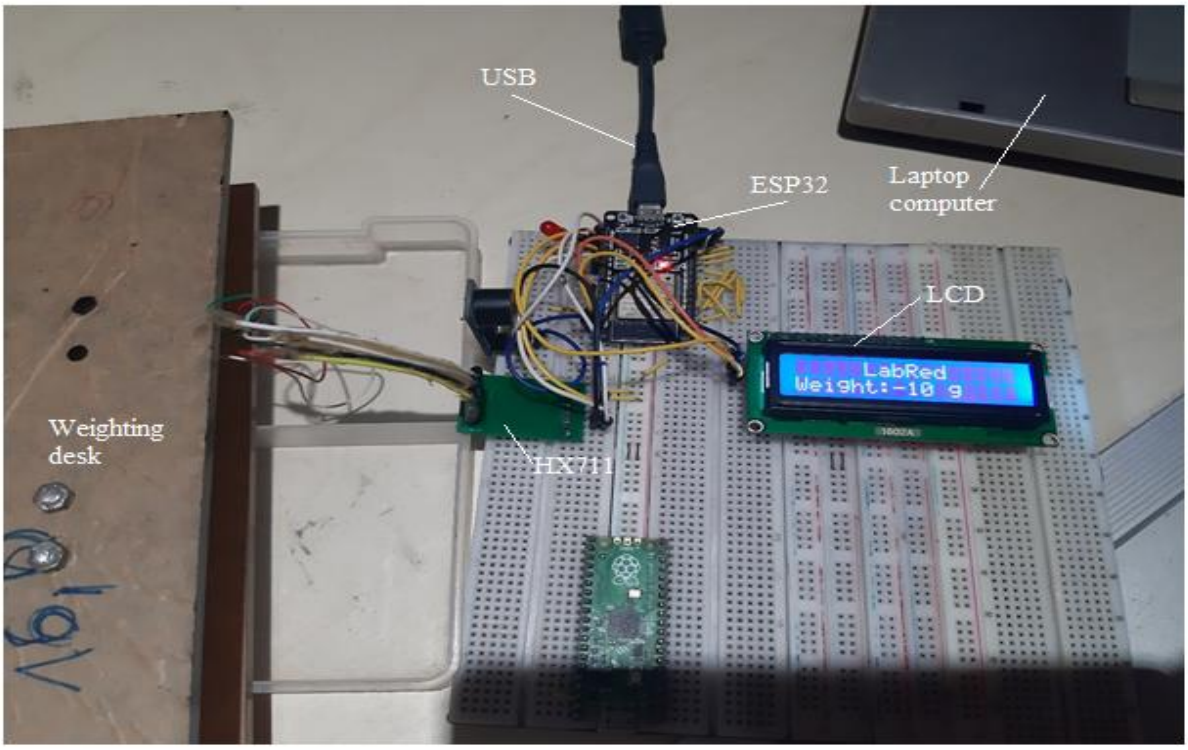

Fig. 7 Prototyping experimental workbench

The prototyping experimental workbench built for conducting real time tests is presented in Fig. 7, where the main parts are identified by corresponding labels. It is worth noting that the USB communication link between the ESP32 processing core and a Laptop computer, is only useful offline under specific operating needs, e.g.:

- Uploading the compiled application program into ESP32 for real time use;
- ESP32-based execution of the embedded application program, with serial transmission of resulting instantaneous data to an active Arduino framework, for possible virtual monitoring on a target Laptop screen.;

These operating modes have been used to obtain experimental results to be presented in this section. A few input weight samples of known values, have been used on the sensor plate for the calibration purpose of the proposed digital instrument.

Fig. 8 LCD monitoring value 6 Kg weight input

In Fig. 8, the real input weight of 0.01 kg is displayed on the LCD. Then, in Fig. 8 the response for an input weight of 6 kg is 6.262 kg as visualized on the LCD screen. Many additional weight samples with known values, have been tested in order to build the experimental input-output characteristics of the proposed digital instrument as it will be seen in section 3.

3. RESULTS AND DISCUSSIONS

Fig. 9 stands for the experimental input-output characteristics of the proposed ESP32-Based instrumentation device of weights. The graphical representation of experimental data and their numerical analysis processes, were implemented within Matlab/CFtool framework.

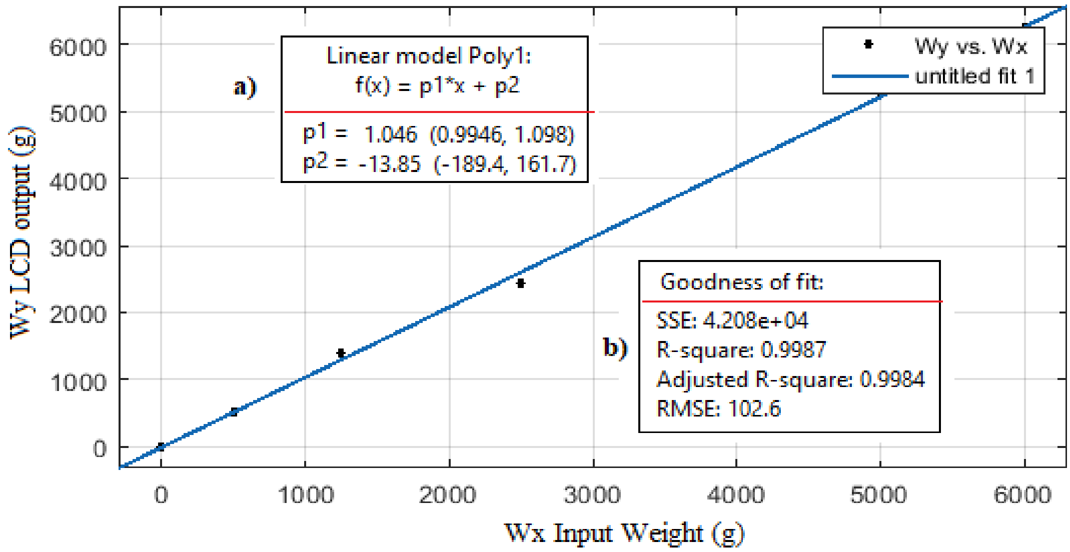

Fig. 9 Experimental input-output characteristics of the proposed instrumentation device.

Fig. 9a shows the parameters of the linear model, whereas Fig.9b presents the corresponding optimal characteristics, i.e. SSE (Sum of Squares Error), Adjusted R-Square and RMSE (Root mean Square Error).

4. CONCLUSION

.This paper has shown the feasibility of an ESP32-based instrumentation device for accurate weight digital acquisition with real time monitoring on local LCD. Experimental tests and resulting data analysis have outlined good technical characteristics of a first prototyping realization of the proposed instrumentation device. However, this first instrument is just a part of a more ambitious scientific research product. Indeed, a complete ESP32-based device needs to be embedded into hand luggage bags as a smart part devoted to automatic weight monitoring and alerting. In addition, extending its local LCD monitoring module to a wireless (Bluetooth or BLE) virtual terminal such as a smartphone, could be a relevant impact factor for the manufacturing of the commercial model of new smart electronic-textile luggage bags. All these relevant improvements will be considered in our future research works.

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