Unified Measurement Cup for the Food Industry

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Abstract

In the present scenario, there exists various instruments in the food industry to measure weight and volume of multiple ingredients used in certain specific sustenance that we consume. To fulfil a product recipe, serving size or quantity and quality requirements of the food served, these ingredients should be measured. These various ingredients in the food should be measured with extreme care and accuracy as it ensures that they are equally distributed in the food product, and the end flavor of all of them remains the same. At home, when mother's bake cakes or desserts, they measure each ingredient properly to make the food taste appetizing. Multiple digitized instruments are out there in the market, but none perform multiple tasks together and also none measure temperature of the ingredients or food being prepared. Hence, in this research paper, we aim to design and develop an All-in-One measurement cup using an Arduino, force transducer and IR temperature sensors that not only saves money but also space by not investing on multiple kitchen instruments and keeping the efficiency and accuracy of the measurements precise.

Keywords: Arduino, digitized instruments, efficiency, force transducer, food industry, IR temperature sensor.

I. INTRODUCTION

There exists a certain amount of redundancy between these two commonly used equipment: a digital scale and a measuring cup. Despite the fact that they are both used to measure and specify the amount of an ingredient or properties like temperature, volume and density, when considered specifically in a culinary setting, they have always been treated and utilized as independent items. The measurements that we usually perform with the help of a digital scale or a measuring cup include weight, volume, and temperature of an item or ingredient. There are devices that can measure these quantities independently, such as weighing machines for weight, liquid measuring cups for volume, and thermometers for measuring the temperature of the food items, but there exists no device that can simultaneously measure the weight, volume, and temperature of a substance. Therefore, these two individual items (a digital scale and a measuring cup) can be combined to create a single product - that can perform the functions of both, save time, preserve counter space, and provide a new unique user experience.

Culinary is an art that every individual should experiment with and to be able to prepare delicacies with the perfect mouth-watering taste, all of the cooking ingredients should be mixed in the right proportions; by weight or by volume. The significance of temperature monitoring in food preparation and processing is self-evident. Traditional devices such as thermocouples or platinum resistance thermometers can always be used to measure the temperature up to a certain range and predominantly through contact itself. A non-contact type temperature measurement instrument is required for things with higher temperature readings or those that cannot be monitored using contact-type instruments, such as cakes in the oven or chocolate mold during coating.

The All-In-One Measurement Cup is an attempt to combine multiple measurement instruments such as temperature sensors, load cells, etc. into a single cup. It has been designed to measure not only the weight or the quantity of ingredients or liquid inside the cup but can also be used to measure the temperature of food products both outside and inside the cup, such as oil, cakes in the oven, and much more. A continuous digital reading of these measures is acquired and displayed on an OLED screen built into the handle of the cup for quick measurements. A multifunctional cup like this one can simplify liquid and solid measurements by replacing other basic measuring devices and performing multiple tasks at once that would otherwise be performed separately. It saves time in businesses, industries and kitchens where extreme control over liquids, solids and the proportion of food ingredients is required during the preparation of food so that it tastes the same in every batch. Hence, along with precision, portion control is equally important. Our digital measuring cup ensures that we get the exact amount of food we desire.

A contactless infrared (IR) temperature sensor – MLX90614 – is used in this cup for the temperature measurement. A 5kg beam-type load cell along with the HX711 load cell amplifier module is employed to measure the weight of any type of food product or ingredient. For the liquid level measurement, weight is converted to volume using the mass-volume relationship. Hence, it can automatically convert the weight of any of these pre-set ingredients - flour, milk, water, oil, sugar, and chocolate syrup into volume. A mode button is provided to choose between any of these ingredients, depending on the type of ingredient poured into the cup, and the OLED display will continuously display the values with the current volume.

II. RELATED WORK

A measurement cup is certainly one of the necessities in a kitchen or a culinary environment, where perfection in the end product is a requisite. Not only this, but also a measurement cup or any digital scale device, that gives out readings for temperature, weight or volume, generally makes the process easier for the person who is cooking. Hence works related to such innovations have been explored and reviewed along with the works that involve the utilization of the transducers and sensors (specifically in a setting that deals with edible items.), that are used in the All-In-One Measurement Cup.

For the measurement of temperature in food production and processing industries, majorly two types of instruments are used, namely, force temperature devices and electrical temperature devices. The force temperature devices include- Bimetallic Strip Thermometer, which works on the principle that various metals expand at different rates as they are heated; Filled Thermal Systems, that employ liquids filled in a bulb attached to a graduated capillary tube to give a direct readout of the temperature measured; and Liquid Spring Thermometers indicate the temperature by utilizing the volumetric expansion of a liquid produced by temperature variations to operates the pressure spring that moves on a dial readout or is connected to some other signal conditioning circuit. The electrical temperature devices that are of importance to the food industry are- RTDs (Pt100), that utilize the effect of temperature change on resistance of metals to deduce the temperature; and Thermocouples, that use the EMF generated in a circuit due to the difference in temperature at the two ends of a bimetallic strip to deduce temperature. The force temperature devices do not warrant for accurate temperature measurements whereas the electrical temperature devices are all contact type measurement devices. Infra-Red thermometry is also employed in temperature measurement, which is non-contact type and mostly produces accurate results [1].

A digital measuring cup is a must-have item in any modern kitchen. One such measuring cup for the visually impaired has also been constructed [2]. This paper focuses on measuring the volume of the liquid present in the cup and converting it into speech, i.e., this device speaks the volume of the liquid out loud to the user. The volume of liquid in the cup was measured using two concentric cylinders that act as a capacitor when the liquid is allowed to rise between them. The change in capacitance of the plates then determines the height and thus the volume of the liquid. A second set of plates at the bottom of the cup measures the liquid's dielectric constant, allowing volume to be calculated independently of the liquid's dielectric constant. This method was accurate up to 4% of the reading and repeatable to 2% and runs for 200 hours on six “D” cells.

There are several ways for measuring liquid level, including sensors based on Load Cell and an enclosing Floating pipe to monitor water levels, this study primarily uses the Archimedes principle, easily accessible PVC pipes, and the load cell. In this method, the buoyant force acts on the floating body as it comes into contact with the water, pushing the load cell vertically. Furthermore, the buoyant force is proportional to the density of the water as well as the distance between the water level and the bottom of the enclosing floating pipe. As a result, the water level may be estimated by using the load cell to measure the buoyant force [3].

Another such measurement system employs a 1kg load cell in conjugation with an HX711 module to determine the density of Pertmax and water by weighing the mass of the liquid to be tested using a load cell as a sensor, and is also equipped with a DS18B20 waterproof temperature sensor to read the temperature of the liquid. Both of these are interfaced with an Arduino Uno R3 [4]. According to the data sheet, the DS18B20 sensor can measure temperatures from - 55°C to 125°C, but the range of temperature measured, recorded by the author during experimentation, is 13°C to 60°C. The average inaccuracy of the Pertamax is 0.17 percent, the diesel is 0.37 percent, and the water is 0.54 percent, according to the Liquid Arduino-based density meter, which uses Pycnometer equations to calculate density.

The DS18B20 waterproof temperature sensor is found to be quite erroneous and has a mean error of ± 3.00 % [5] and needs to be calibrated, in order to obtain accurate results, with the help of an ASTM 117C mercury thermometer, in order to reduce and achieve a mean error of ± 0.85 % in measurements.

The portable "Digital Weight Measurement" device devised by V.G Nandawar et. all [6], is capable of displaying the weight of grains as well as the price of the selected grain, on an LCD display; it is built small, cheap and light in weight. It can measure weights up to 3kg and uses a load cell along with HX711 interfaced with an Arduino mini pro board. It uses a strain gauge type load cell that works on the principle of Wheatstone Bridge Network.

III. METHODOLOGY

A. Strain Gauge based weight measurement system

We'll need a weight measurement system to determine the weight of the object or the liquid in the cup. A 5kg load cell and a HX711 load cell amplifier module is required for the design of a weight measurement system. The Arduino Uno will handle all of the system's operations, which will then be displayed on a 16x2 LCD.

1. Strain Gauge

A common strain gauge is made up of very tiny wire or foil laid out in a grid pattern in such a way that when strain is applied along one axis, the resistance changes linearly. Strain gauges are sensors that are used to measure a wide range of physical parameters. When they are stretched or compressed, their resistance changes. Because of this property, strain gauges are often bonded to a solid surface and used to measure acceleration, pressure, tension, and force. It converts all the above-mentioned parameters into a change in electrical resistance which can then be measured. The measurement of tension can be used to determine the weight applied to the load cell.

2. Load Cell

Load cells are specifically force transducers that transform force or pressure into electrical signals. The magnitude of the electrical signal is directly proportional to the applied force. Based on the output signal, there are three fundamental load cell types: hydraulic, pneumatic, and strain gauge. In our project we use the strain gauge type load cell which usually consists of two or four strain gauges in a Wheatstone bridge configuration.

When a load is applied, the load cell's body deforms slightly. Strain gauges attached to the load cell change shape in response to variations in shape. This creates a change in the strain gauge's electrical resistance, which can subsequently be detected as a voltage change with the help of the Wheatstone bridge configuration that converts the change in strain/resistance to voltage. As the change in output is proportional to the amount of weight applied, the weight of the object may be calculated using the voltage change.

3. HX711 load cell amplifier

The electrical impulses created by the load cell are only a few millivolts. Hence, they must be amplified further by an amplifier, which is where the HX711 Weighing Sensor comes in. The Hx711 Load cell amplifier module is a 24 high-precision analogue to digital converter that amplifies low electric output from load cells, amplifies and transforms the low electric output of the load cell and converts it to digital form. To measure the weight, the digital form is sent to the Arduino uno microprocessor. When the load cell amplifier is linked to the microcontroller, the microcontroller will read changes in the load cell's resistance after some calibrations. This results in extremely precise weight measurements.

The HX711 is connected to load cells through a four-wire Wheatstone bridge. RED, BLK, WHT, GRN, and YLW are common colors seen in Fig. 1.

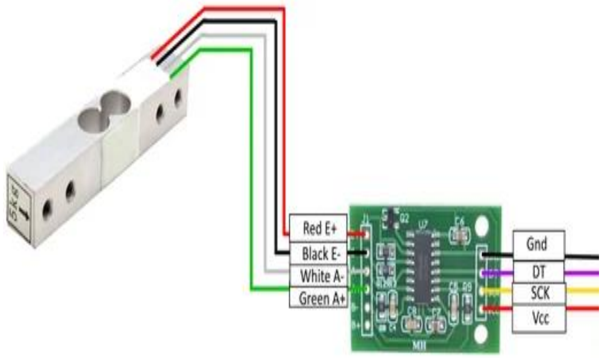

Fig. 1. Load cell connections to amplifier

B. Liquid level measurement system

In order to measure the level using our digital measurement cup we decided to utilise the same setup we used for measuring weight by simply converting the mass of the liquid into volume using the mass-volume relationship.

$V = m/ \rho$

Where,

m is mass in kg or g

V is volume in L or mL

ρ is density in kg/L or g/mL

We opted to use the measuring cup solely for very commonly used liquids/fluids in our daily life such as water, milk, oil, chocolate syrup, sugar syrup etc. because different liquids have varied densities and feeding information for all of them is not possible. With just a small conversion we can get the level of the liquid in the container which will directly be reflected in the LCD.

We could have used a non-contact capacitive sensor for liquid level measurement, but we chose this since it is cost-effective and takes up less space because just one measuring device is utilised for both weight and level measurement.

IV. CONSTRUCTION

A. Experimental Setup

The setup in Fig. 2 shows the simulation of the 5kg loadcell which is used to calculate weight. It is connected to the HX711 load cell amplifier and the output i.e.; the measured weight is displayed in the LCD. The load cell sensor had an inaccurate designation at first, so the readings had to be corrected by weighing objects of known mass and then calibrating with the Arduino application.

Fig. 2. Weight measurement using HX711 load cell

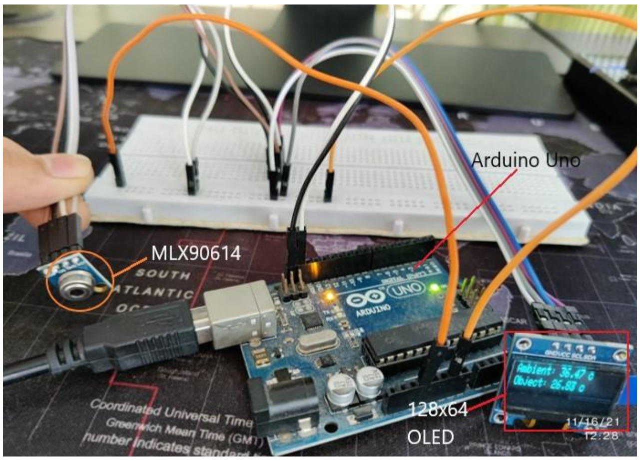

Fig. 3. Temperature measurement using MLX90614

The simulation of the temperature sensor MLX90614 is shown in Fig. 3, and the output is displayed in the OLED screen, showing both the ambient and object temperatures in degree Celsius. The microcontroller - Arduino Uno - will handle all operations and simulations in accordance with the instructions given to it.

B. Final Prototype

The final prototype was implemented plastic measuring jar with a volume of 500ml, integrating both weight measurement and level measurement system onto it. At first, the load cell was placed inside the measuring cup with equal heights from both the bottom and top of the load cell which can be seen in the Fig. 4.

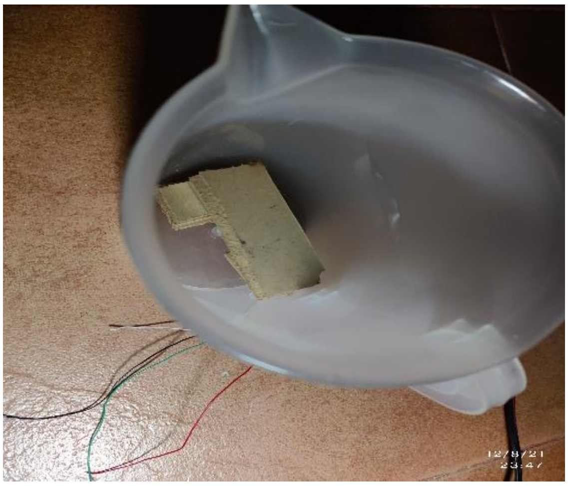

Fig. 4. Load cell placed inside the measuring jar

Fig. 5 depicts the IR based temperature sensor and the OLED screen for displaying values which were drilled and placed on the handle of the measuring jar. Finally, all the sensors were integrated to the Arduino Uno.

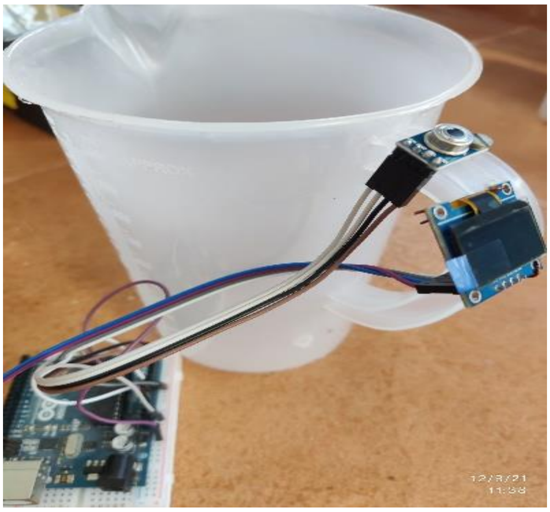

Fig. 5. Integration of MLX90614 and OLED on cup

The interior view of the measuring jar can be seen in Fig. 6. The bottom of the jar was finally covered with a plastic material so that it does not allow the solid or the liquid food product to be measured seep below to the space where the load cell is placed.

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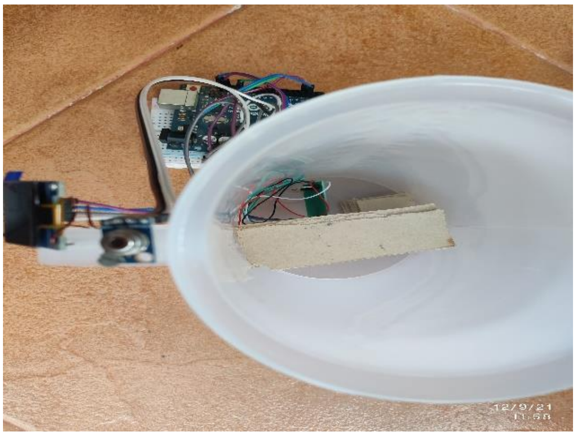

Fig. 6. Interior view of the measuring cup system

V. RESULTS AND DISCUSSION

Two different 190ml water bottles bought from a store were placed into the jar at first one after another. Beforehand, the weight of this bottles was measured using a standard digital weighing scale from the market and the obtained weight was 190g. So, we considered 1ml = 1g for calibration of the load cell and the result is depicted in Fig. 7 and Fig. 8.

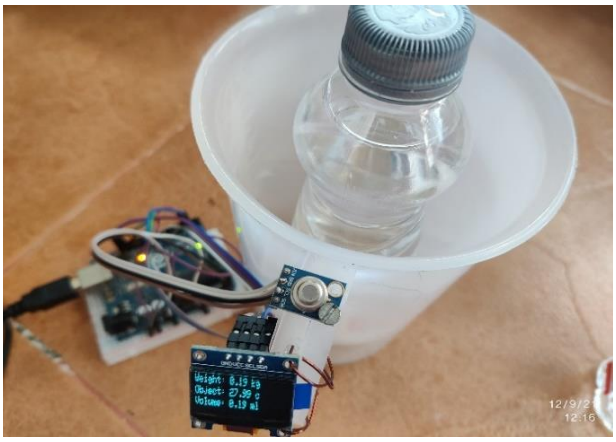

Fig. 7. Weight and volume measurement of a water bottle 1

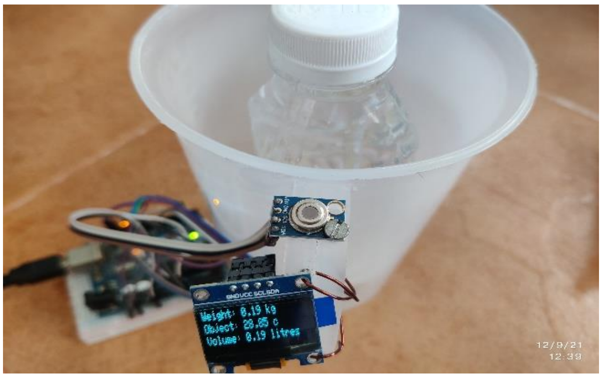

Fig. 8. Weight and volume measurement of a water bottle 2

Simultaneously, the temperature of the object is also been displayed on the OLED screen. Temperature of other food quantities can be measured by pointing the temperature sensor towards the food product like boiling water, heating oil, cake in an over or anything else with a distance of 20cm between the sensor and the food.

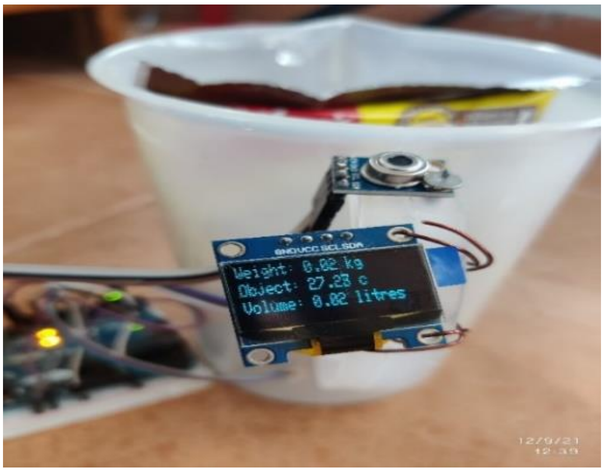

Fig. 9. Weight measurement of snack packet after calibration

Fig. 9 depicts the weight of a snack packet. The measured weight of the packet using a standard weighing scale was 20g and the load cell displays the weight to be 0.02kg (200g) after calibration.

Comparing the actual weight of the product and the weight by the load cell seen in, we obtain the accuracy of the weight and volume measurement of our device to be exact at 100% as seen in Table I.

TABLE I. COMPARISON OF ACTUAL AND OBTAINED WEIGHTS AND VOLUME

Sl. No.	**Food Product**	**Actual weight/ volume of the product**	**Obtained weight/volume of the product after calibration**	**Accuracy**
1.	Water	190g/190ml	190g/190ml	100%
2.	Snack Packet	20g	20g	100%
3.	Rice	500g	500g	100%
4.	Flour	200g	200g	100%
5.	Juice	150ml	150ml	100%

- ⇨ Actual weight of the snack packet = 20g
- ⇨ Obtained weight = 20g
- ⇨ Therefore, Accuracy = 100%
- ⇨ Actual weight of the water bottle= 190g
- ⇨ Actual volume of the water(according to label) = 190ml

- ⇨ Obtained weight = 190g
- ⇨ Obtained volume = 190ml
- ⇨ Therefore, Accuracy = 100%

VI. CONCLUSION

The proposed system of an All-in-One Measurement Cup using various sensors such as HX711 Load Cell, Temperature Sensor (MLX90614 IR Sensor) was developed to provide a solution for the foods industry for reducing the use of different measuring instruments for different measurements to one single portable measuring system.

The beam type load cell we have used can be replaced with a smaller button type force transducer to save more space due to its compact size.

We did discover various errors such as the bulkiness of load cell, weight of the cup itself being added to the measurements which were corrected. There were loose connections in the wires with various components and also placement of the sensors on the cup which was a tedious task. We believe that further research will help in solving these problems and will help various food industries to accurately obtain values of each ingredient being used.

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