Smart Water Bowl For Pets
IoT Exam Project

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***Abstract*—In this work I am going to present my implementation of a smart water bowl for pets. In particular the system has been designed to monitor the water level and send an alarm when it results under a given, user configurable, threshold. As for the hardware, the project has been developed with the ESP32 VROOM board connected to two sensors: an ultrasonic ranging sensor (HC-SR04) and an temperature/humidity sensor (DHT22). The implemented data pipeline is based on the HTTP protocol to send sensor data to a *Data Proxy* that save the collected information in an InfluxDB and proceed to forcast the expected water lever using two different prediction models.**

The complete code developed for the project is available on GitHub.

I. Introduction

Pet owners faces many challenges to assure that their furry friends live a happy life. One of these challenges is providing fresh water to the animal(S), especially during the hot summer season, during the day. For these reason, the Smart Water Bowl would offer an helping hand by providing constant information about the remaining water in the bowl and the statistics of relevant data, like temperature, humidity and average water level during the day.
The full system architecture, discussed in details in Sec. III, is based on the ESP32 VROOM which controls two sensors: an ultrasonic raging sensor to measure the water level and a temperature/humidity sensor to also account for the water evaporation during the day and the extra water consumption during hot days.
The data pipeline described in Sec. II consists in two modules, using different protocols to collect the sensors data in a database and to allow the user to change some setting on the boards. Additionally, the collected data are also used by two forecast models that predicts the water level based on different input data.
The whole project has been developed using Python and the ArduinoIDE(C++), the complete code and an explanation on how to run the system can be found on this project GitHub repository.

II. Data Pipeline

In order to develop the required system, two communication protocols have been implemented. In particular, MQTT has been used to allow the user to tune some parameters, while the collected data are being managed by HTTP in order to be sent to the *Data Proxy* running on a laptop.

A. MQTT - Parameters Tuning

The MQTT protocol has been implemented to allow the user to change the following parameters on the the ESP32 board while the system is running:

- **Base water level (calibration)**: the user can specify the starting water level, i.e. the distance between the ranging sensor and the water in the bowl. This way the user is not forced to fill the bowl till a precise point and can adapt the amount of water, for example, based on water consumption.
- **Threshold**: this value specify the threshold level after which an alarm level is triggered. In particular, the threshold represent the maximum accepted value for the for the difference between the observed water level and the starting base water level, as summarize in eq. 1.

$$threshold = max\{observedLevel - baseLevel\} \quad (1)$$

- **Sampling rate**: this value allow the user to control the sampling rate of the data collection. The default value is 10s, and it can be changed to any desired time interval even if values lower than 2s can create some overheating problems in the DHT22 sensor.
- **Alarm Counter**: this values let the user decide how many alarm events are actually required before sending an alert for the low water level.

On the ESP32, the MQTT communication has been implemented using the *PubSubClient.h* library for *Arduino*. Once the board is connected to the WiFi, it tries to establish a connection to an MQTT Broker service; if the connection succeeds the MQTT client proceeds to subscribe to four topics, one for each tunable parameter, otherwise a new try is attempted every 5 seconds.
As broker the for the publish/subscribe protocol, I decided to use *Eclipse Mosquitto* because it was easy to run, supported by Windows and free to use.
On the laptop, I have also installed *MQTT Explorer* in order to simulate a remote controller that allows to change the paramenters by publish the desired valued on the relative topic.

B. HTTP - Data Acquisition

The data collected by the sensors needs to be saved in a database, for data visualization and monitoring, and made

available to the forecasting models to generate the expected water level. I have opted for HTTP over Coap because this protocol is easier to implement, has more available libraries that offer a variety of functions and still performed in the desired times even being an ”heavier” protocol.
To expose the **endpoint** needed to the board to establish a connection, I created an HTTP server, that runs on the laptop, by means of *Fast API* and *Uvicorn*.
On the ESP32, the Arduino library *HTTPClient.h* allows to create an HTTP client that performs a **post** request sending a Json file with the following data: sensor name, measured temperature and humidity, observed water level, starting water level, alert status, WiFi receiver signal strength (RSSI) and time.

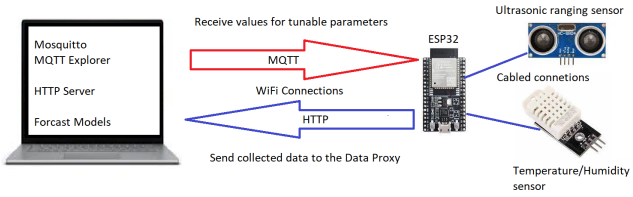

Fig. 1. Summary scheme of the implemented system architecture

III. System Architecture

A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
- Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.
- Do not mix complete spellings and abbreviations of units: “Wb/m^2” or “webers per square meter”, not “webers/m^2”. Spell out units when they appear in text: “. . . a few henries”, not “. . . a few H”.
- Use a zero before decimal points: “0.25”, not “.25”. Use “cm^3”, not “cc”.)

C. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \tag{2}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(2)”, not “Eq. (2)” or “equation (2)”, except at the beginning of a sentence: “Equation (2) is . . .”

D. LaTeX-Specific Advice

Please use “soft” (e.g., `\eqref{Eq}`) cross references instead of “hard” references (e.g., `(1)`). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don’t use the `{eqnarray}` equation environment. Use `{align}` or `{IEEEeqnarray}` instead. The `{eqnarray}` environment leaves unsightly spaces around relation symbols.

Please note that the `{subequations}` environment in LaTeX will increment the main equation counter even when there are no equation numbers displayed. If you forget that, you might write an article in which the equation numbers skip from (17) to (20), causing the copy editors to wonder if you’ve discovered a new method of counting.

BibTeX does not work by magic. It doesn’t get the bibliographic data from thin air but from .bib files. If you use BibTeX to produce a bibliography you must send the .bib files.

LaTeX can’t read your mind. If you assign the same label to a subsubsection and a table, you might find that Table I has been cross referenced as Table IV-B3.

LaTeX does not have precognitive abilities. If you put a `\label` command before the command that updates the counter it’s supposed to be using, the label will pick up the last counter to be cross referenced instead. In particular, a `\label` command should not go before the caption of a figure or a table.

Do not use `\nonumber` inside the `{array}` environment. It will not stop equation numbers inside `{array}` (there won’t be any anyway) and it might stop a wanted equation number in the surrounding equation.

E. Some Common Mistakes

- The word “data” is plural, not singular.
- The subscript for the permeability of vacuum μ_0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement

at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
- A graph within a graph is an "inset", not an "insert". The word alternatively is preferred to the word "alternately" (unless you really mean something that alternates).
- Do not use the word "essentially" to mean "approximately" or "effectively".
- In your paper title, if the words "that uses" can accurately replace the word "using", capitalize the "u"; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones "affect" and "effect", "complement" and "compliment", "discreet" and "discrete", "principal" and "principle".
- Do not confuse "imply" and "infer".
- The prefix "non" is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the "et" in the Latin abbreviation "et al.".
- The abbreviation "i.e." means "that is", and the abbreviation "e.g." means "for example".

An excellent style manual for science writers is [7].

F. Authors and Affiliations

The class file is designed for, but not limited to, six authors. A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

G. Identify the Headings

Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is "Heading 5". Use "figure caption" for your Figure captions, and "table head" for your table title. Run-in heads, such as "Abstract", will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced.

H. Figures and Tables

a) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation "Fig. 1", even at the beginning of a sentence.

TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
	Table column subhead	***Subhead***	***Subhead***
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[a]Sample of a Table footnote.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization {A[m(1)]}", not just "A/m". Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)", not "Temperature/K".

ACKNOWLEDGMENT

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression "one of us (R. B. G.) thanks ...". Instead, try "R. B. G. thanks...". Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

Please number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] was the first ..."

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors' names; do not use "et al.". Papers that have not been published, even if they have been submitted for publication, should be cited as "unpublished" [4]. Papers that have been accepted for publication should be cited as "in press" [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

REFERENCES

[1] G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.

[2] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[3] I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[4] K. Elissa, “Title of paper if known,” unpublished.

[5] R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.

[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7] M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.