Acid-Carousel

Water quality monitoring with automatic instruments
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People living in the city are prone to the environmental impact of human activity. Rivers, lakes, canals are sometime subject to the effects of accidental or deliberate discharge of substances that are toxic to water plants and animals, as well as to people. The competent authorities are often unable to implement continuous and thorough monitoring of the water quality. In fact, if we exclude drinking water for home use, open waters are subject to sporadic checks, often only after contamination has occurred. For those who live in Milan, it is important to remember the incident when polluted waste was discharged in the Lambro river by a factory on its bank.

People, like the author, who live near the Martesana, a canal close to Milan and rich in water fauna, feel the responsibility to help to monitor the water quality in those areas. Water monitoring often cannot be accomplished by visual checks alone. What are actually needed are instruments that measure several symptomatic water quality parameters. So that when acceptable thresholds are exceeded, warning messages will be issued automatically.

One parameter is the acidity/basicity, namely, the concentration of hydrogen ions called pH. Other substances, such as chlorine, nitrates, and hydrocarbides can also pollute the water.

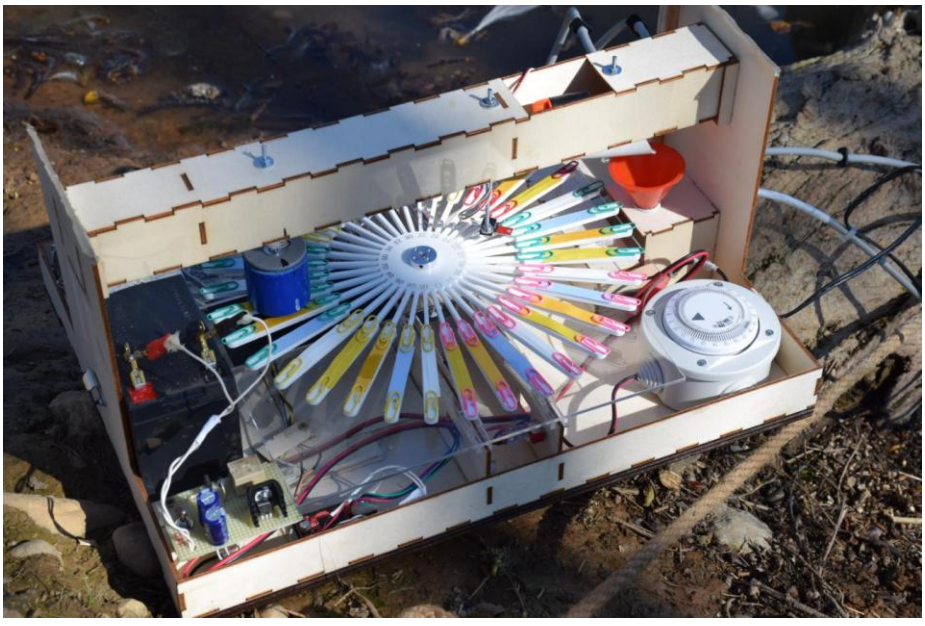

Fig. 1 – The ACID-Carousel

Fig. 2 – Examples of test paper

In order to measure the acidity of a particular substance, or other components in the water, there exist electronic instruments and manual laboratory procedures. But a very simple method is based on test-paper, that change color, depending on the pH values or the concentration of other substances, there are many types of them. Normally, the measurements are performed in the lab on water samples taken from areas suspected of being polluted. However, when it is necessary to continuously monitor a body of water, it is not practical to leave an expensive and fragile electronic instrument on the banks of the river, or have someone checking the water twice daily with test paper. Additionally, such instruments require continuous recalibration and/or comparisons with reference sample.

Test paper (Fig. 2), inexpensive and reliable long-term, is largely used, not just to measure the pH, but also to identify the presence of other substances in the water, such as hydrocarbons, hydrogen sulfur, and nitrates. Depending on the color of the test paper submerged in the water, it is possible to go back to the concentration of those substances, by comparing them to a table provided by the manufacturer and included in the package. The test-paper method is not so precise as laboratory analysis, but can be enough for our purposes.

Thus, if one would want to change the manual measuring method with test paper

into an automatic one, one would need to have a sensor capable of detecting the color of the paper, and compare it to a color/value table. This type of sensor is available and returns, for each color it reads, three numeric values, directly linked to the intensity of each of the three basic colors: red, green and blue (RGB).

The basic idea of the **Acid-Carousel** (Fig. 1) is an automatic system for:

- wetting the test paper,
- moving the paper strip under a color sensor,
- measuring the color and compares it with a color/value table,
- transmitting data to an Internet server.

This can be done directly on the bank of a river or lake with a frequency chosen by the user. A system like Acid-Carousel is able of handing several type of test paper simultaneously.

The sample and wetting system

The system is designed to take the water directly from a river or lake, run it through the tubes and the dripper for a sufficient amount of time, with the purpose of removing all trace of the previous sample testing, and then have a few drop fall onto the test paper. A small, continuously running electricity pump (Fig.5), like the one used to irrigate house plants, is submerged in the water to be tested, pumps the water into a tube that leads to the dripper (Fig. 4). The dripper too is like the ones used to irrigate our gardens. The drops fall for a selected amount of time onto a gutter obtained by a PVC used for electrical circuit properly shaped that will discharge them via a funnel (Fig. 3). This way the dripper is “cleaned” of the previous water. Then the servo engine twirls the gutter so that a few drops drip onto the test paper. An Arduino UNO board activates the pump and the servo according to a specific timing set in the software. The same Arduino manage all the other features of ACID Carousel.

Fig. 3 – The gutter and the funnel

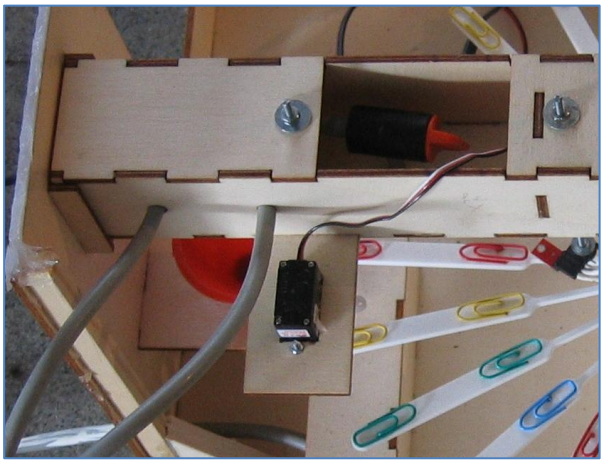

Fig. 4 – The dripper and the servo moving the gutter

Fig. 5 – The 12 Vcc pump

Fig. 6 – The box

How does the Carousel move?

The Carousel itself is made of a wheel of approximately 30 cm diameter, with 36 “arms”, each of which holds a strip of test paper of about 0.7 x 6 cm (Fig. 7). The wheel is cut from a sheet of white opaque 4 mm thick Plexiglass (Polymethyl Methacrylate), by a laser cutting machine. Each “arm” holds two clips to keep the paper strip in place**.**

A stepper motor moves the wheel, while the dripping mechanism and the gutter are moved by the servo. The Arduino manages all these devices.

The color sensor (the blue cylinder) is situated to the right , above the wheel. Under the wheel is the card with the electronics and the lead rechargeable battery (Fig 1).

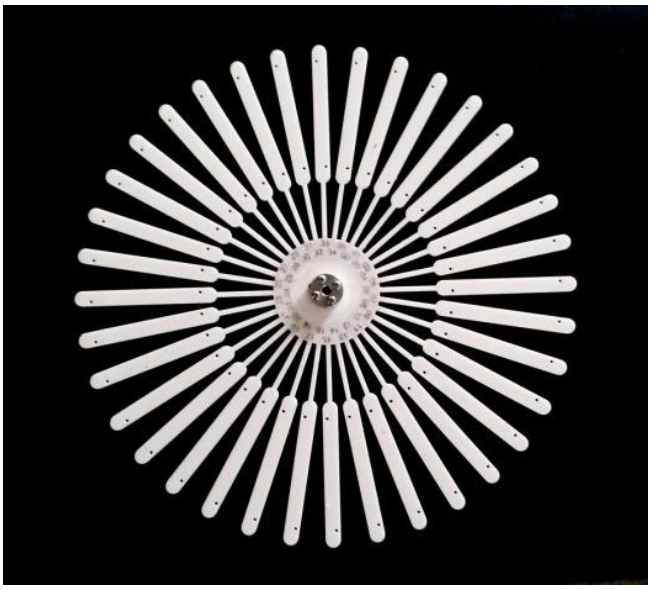

Fig. 7– The Plexiglass wheel just cut by the laser machine, with the flange for the motor shaft

The stepper motor is able of 1600 micro step depending on the pulses emitted by the driver board connected to Arduino. The motor is a bipolar stepper NEMA-14 guided by a Sparkfun EasyDriver Version 4.3 card.

Arduino UNO moves the Carousel so that the selected “arm” will be exactly under the dripping system, at first, then under the color sensor. This is obtained by an IR ranging sensor (Fig. 8).

The movement has a rapid modality, based on the number of steps that exist between one “arm” and another, and subsequently, with an end modality, based on optimizing the response of the sensor with small back and forth movements of the Carousel.

As soon as the color sensor reads the strip, the stepper rotates the Carousel so that the arm immediately following will be positioned under the dripper for the next sampling.

The Sensors (Fig. 8)

The position sensor QTR-1RC is made of a couple LED/foto transistors, by Pololu. The color sensor RGB, TCS34725, by Adafruit, is made from a white LED that has the function of a light source, and four photodiodes that measure the reflected light. Three of them are sensitive to the three base colors, while the fourth is sensitive to all the light spectrum.

The exit signals are already digital, and represent the following values:

- Color Temperature - measured in Kelvin (calculated)
- Lux - or Lumens per Square Meter (calculate)
- Red, Green and Blue (filtered) values
- Clear (unfiltered) value

The Measurements

Each of the three RGB values generated by the sensor is relatable to the value of "clear" so that errors caused by small variations of the LED light, or by the outside light are minimized. Arduino reads the 4 values, executes the 3 ratios and compares them with a table of 3 x n reference value obtained by a calibration done with the used test paper (n represents the number of the values that the paper test is able to measure). The result of the analysis will be the table value nearest to the one measured. This value can be memorized onto an SD, or transmitted by a GSM system, or other systems. To build the reference table, relating, for example to the strip measuring the pH, one must use solutions with a different pH, and make a note of the response given by the color sensor. It is not necessary to have solutions with the whole range of 14 pH levels, because since the near pH colors are also similar, some of the values can be obtained via interpolation. We need a table for every kind of test paper.

The box

The Acid-Carousel's container is built from 3 mm thick plywood. It is painted with a waxy adherent. It includes the base, on which all other components are mounted, and a cover with a handle (Fig. 6). Two tubes are attached to the base where the water flows in and out, as well as the water from the dripper.
The block with the dripper, gutter and the color sensor, can be lifted in order to easy dismount the wheel and change the paper strips when they are finished.
The whole container is built from pieces cut with a laser cut. The same container can be built in methacrylate (Plexiglass) by using the same design than the one made from plywood.

Fig. 8 – The QTR-1RC Reflectance Sensor (Pololu) and the TCS34725 (Adafruit).

Software

Several Arduino sketches are available to run the Acid Crousel. Some are suitable for lab use to maintain and calibrate, and others are for field work.

The automatic operation program performs the following functions:

1. When launched, the stepper aligns the nearest arm to the right of the position sensor, under the dripper. The position of the “gutter” is straight onto the unloading funnel.

2. Then, the pump starts to work after a pre-set time between two measurement cycles, and keeps running for a sufficient period necessary to clear all traces of the prior sampling water from all the hydraulic cycle. The drops fall onto the gutter that are discharged into the funnel.

3. The servo turns the gutter into a tilted position that allows one or two drops of water to fall onto the test card. After a set time, the gutter goes back to the previous position.

4. The stepper engine moves the Carousel so that the wet strip is positioned under the color sensor.

5. The color sensor lights up the card and reads the three RGB + C values, and the results R/C, G/C e B/C are calculated.

6. The three values thus obtained are compared to the reference table for that particular test card.

7. The stepper engine rotates the carousel to bring the next strip under the dripper for the next analysis.

The Floating Pump

When using the ACID-Carousel to identify the presence of hydrocarbons that notoriously float on the water surface, the ACID-Carousel pump can be fitted with a floater like the one in polystyrene shown in Fig 6.

Fig. 9 – The floating pump