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Global Reporting Format (GRF) Application Automation for Runway Surface Conditions in West Africa

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Abstract

This paper aims to design an automated Global Reporting Format's (GRF) application in order to reduce time of manual application (on a runway) of the Global Reporting Format developed by International Civil Aviation Organization (ICAO). A method has been used to measure and generate Runway Condition Report (RCR) automatically. The developed computing model is an autonomous and automatic application implemented specially for West Africa (and can be extended to any rainy area). It uses Arduino materials and computing code developed by the authors. Results obtained show that using that method to retrieve the Runway Condition Report (RCR) is fast, so human presence on the runway is reduced. Even though the results obtained using this model are slightly different from those expected, the actual runway conditions are not too much affected.

Keywords

Climate Change, Global Reporting Format, Runway Surface Condition, Measurements Duration, West Africa, ICAO

1. Introduction

The World has been experiencing the climate change for many years ago. This climate change is globally due to greenhouse gas emissions increasing [1] [2], including that of aircraft. However, it is not only aviation that impacts the climate through the emission of greenhouse gases, but also climate change has considerable influences on aviation [3]. The effects of climate change such as rising temperatures; strong winds; heavy, brutal and/or long-lasting rainfall affect aeronautical operations in terms of timing, aerodynamic and directional control. In addition, everywhere in the world we observe incidents (aircraft go-around, runway excursion, etc.) and aircraft accidents generally in rainy weather [4]. That's why many airdromes have implemented their own systems to assess and report runway surface conditions to the pilots in order to help them take off and land safely. However, with the expansion of international flights, the lack of uniformity from one country to another creates difficulties for the development of airline operational procedures and for the training of flight crews. Therefore, ICAO has introduced the Global Reporting Format (GRF) which is a globally harmonized methodology that is intended to be the only reporting format for international aviation, with the objective of reducing runway excursions [5] [6] [7] [8] [9]. The current methods which are simple and proven, are however far from meeting the new international requirements for real-time monitoring of runway conditions. The significant growth in traffic increases runway occupation time which must be minimized by human inspections. So, Cerema Laboratory and its partners in Europe are currently working to automate the Global Reporting Format (GRF) application but it is not yet finished [10] [11]. Regions' climate characteristics are different from each other, so that, engineering rules established from studies carried out in a given area cannot necessarily be transposed to another. Thus, we are in parallel proposing a method. In this work, we are interested in making the Global Reporting Format (GRF) application easier and almost totally automatic in West Africa. According to the weather in that area we have chosen to work in the case of WET surface, a surface with STANDING WATER and a DRY surface.

Different electronic materials are used and a computer code is developed to automate water depth estimation on runway and to generate also automatically a Runway Condition Report (RCR). Materials and methods are presented in Section 2. Section 3 and Section 4 concern respectively Results and discussions, and Conclusion.

2. Materials and Methods

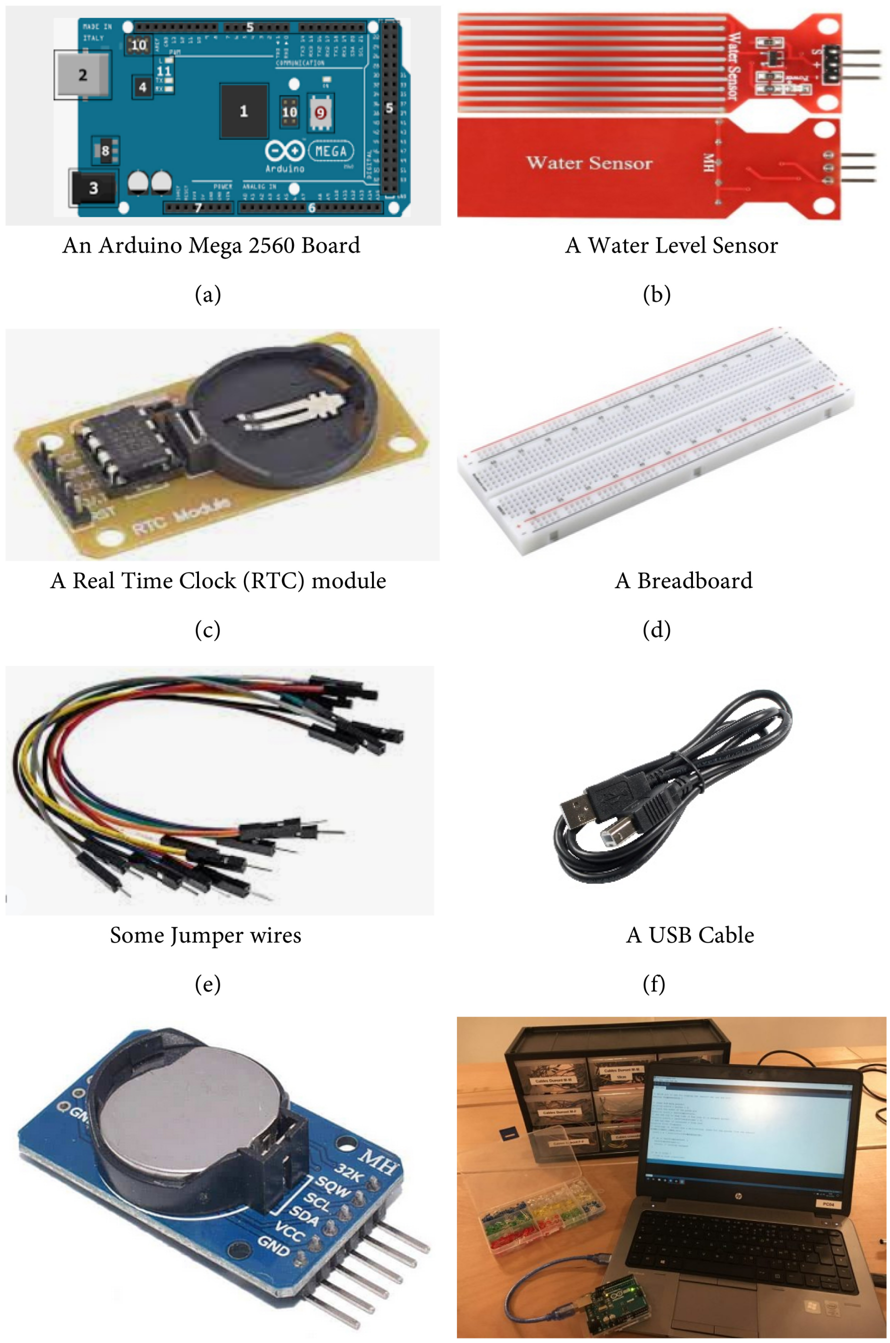
2.1. Equipment Components

This paper aims to generate automatically the RCR at Ouagadougou airport by reporting automatically water level. Materials used to retrieve water level on a surface in order to generate RCR automatically are various. On one hand, there are electronic equipment components [9] [12] [13]. On the other hand, software including a computer code is needed to generate RCR automatically [14].

Some of those hardware materials are presented in **Figure 1** and they are described below:

1) *Arduino Mega* 2560 *Board* (see **Figure 1**, panel "a") is an electronic device designed for automation project like ours;

2) *Water Level Sensor* (*WLS*) (**Figure 1**, panel "b") is a device that measures



An Arduino Mega 2560 Board (a)

A Water Level Sensor (b)

A Real Time Clock (RTC) module (c)

A Breadboard (d)

Some Jumper wires (e)

A USB Cable (f)

A battery (g)

An Hp laptop (computer) and a glass box (h)

Figure 1. Equipment components [5] [6] [7] [8].

water high or low level in a fixed vessel. Here water level must be converted into millimeters;

3) *Real Time Clock* (*RTC*) *module* (**Figure 1**, panel "c") is an electronic device designed in the form of an integrated circuit to measure the passage of real-time. Real-time clocks maintain accurate time measurements within an embedded system even when the main power is off. It counts hours, minutes, seconds,

months, days, and even years. We need it here to retrieve the beginning time of the runway inspection;

4) *Breadboard* (**Figure 1**, panel "d") is used to connect the electronic devices;

5) *Jumper wires* (**Figure 1**, panel "e") are used to connect two points in a circuit without soldering;

6) *USB Cable* (**Figure 1**, panel "f") is used to connect the Arduino board to a computer;

7) *Battery* (**Figure 1**, panel "g") is used to keep providing electrical power to the Real Time Clock (RTC) module during off mode;

8) *Hp laptop* (*computer*) (**Figure 1**, panel "h") is used to write and run the code.

2.2. Runway Condition Report (RCR) Determination Process

Water level on landing runway is retrieved by using a water level sensor which has three pins: VCC, GND and OUT as described below:

1) *VCC* is the power supply pin that can be connected to a 5 V supply;

2) *GND* is the board ground pin and it should be connected to the Arduino device ground pin;

3) *OUT* is the board Analog output pin used to send out an analog signal between VCC and GND pins.

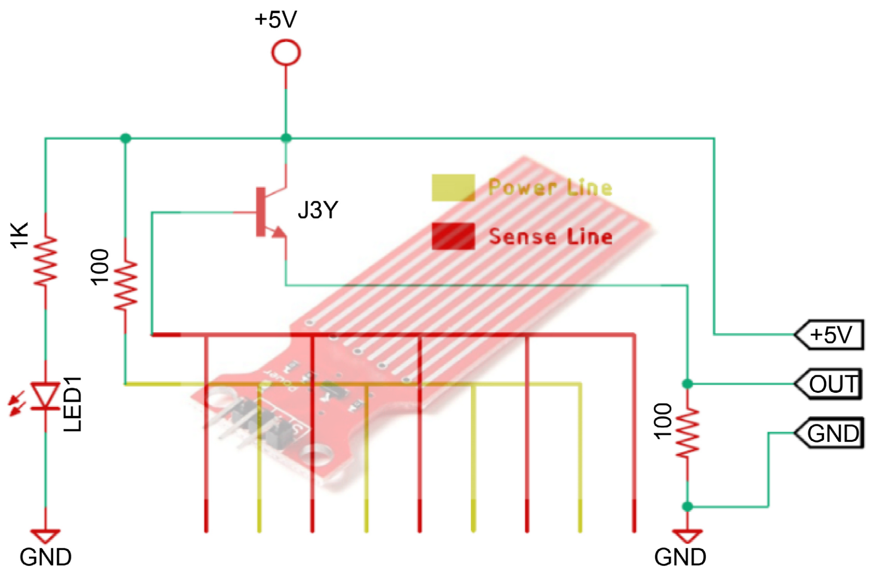
To be working the water level sensor, it must be connected to the Arduino MEGA board (see **Figure 2**). When the sensor runs on 5 V power, it gives out data in analog format. Panel "a" of **Figure 2** shows that the transistor's collector is connected to a 5 V power supply, and its emitter is connected to the ground with a 100 Ohms resistor. In the module, a set of 5 conducting plates are connected with the VCC in series with a 100 Ohms resistor and the other 5 sets are connected to the base of the NPN transistor. Now when the water touches these conducting palates, currents start flowing from the 5 V supply to the base of the transistor, and the transistor turns on. The more submerged the sensor is, the more output voltage it will generate [13]. The analog value is then converted into voltage using Equation (1):

$$\text{Voltage} = 5 \times (\text{Analog Value})/1023 \quad [12] \tag{1}$$

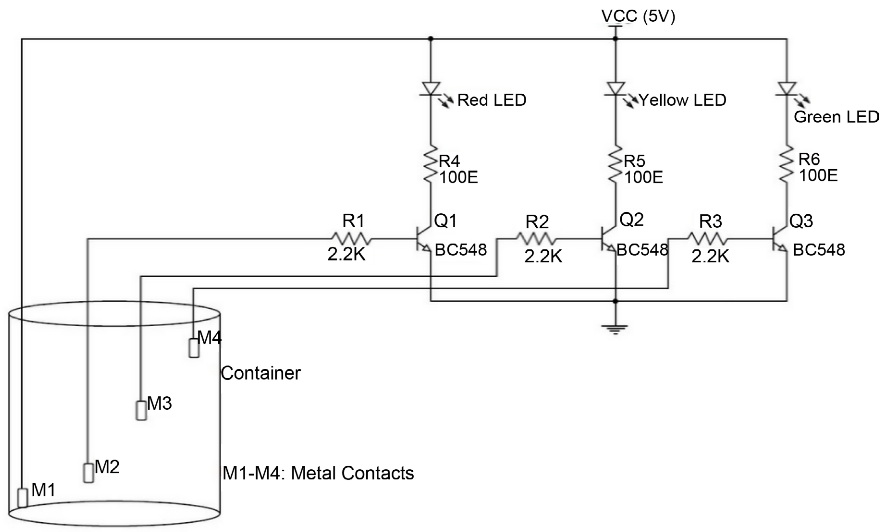
The voltage is now converted in water level (depth) in millimeters (mm). The process is to carefully find the voltage values corresponding to each depth of the water. The depth is considered from 0 mm to 15 mm according to ICAO method of retrieving the Runway Condition Report (RCR) [5] [6] [7] [8]. Using these water levels measured for tree parts of the Runway, we compute the accurate Runway Condition Report (RCR) thanks to the Arduino code that we have developed.

A Real Time Clock (RTC) module is added in order to retrieve the runway inspection beginning time.

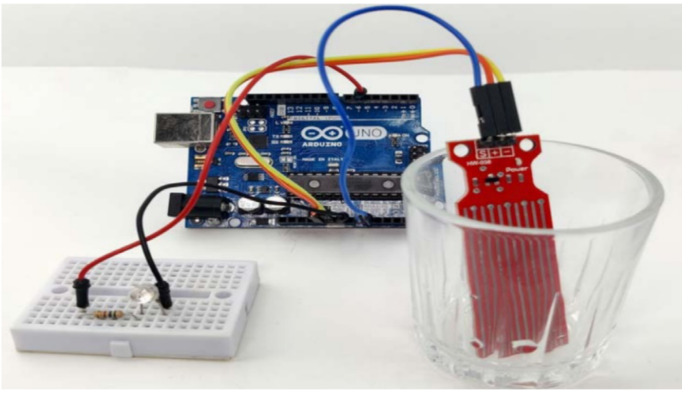
To retrieve an accurate RCR, the Runway Condition Assessment Matrix (RCAM) showed in **Table 1** has been used in the code: It gives the relationship



(a)



(b)



(c)

Figure 2. Functional assembly of the water level sensor with the Arduino device. (a) Schematic diagram of the water level sensor (real image in background) [13]. (b) Simple representation of water level indicator using Arduino [15]. (c) Arduino water level sensor circuit—connection image [13].

Table 1. Runway Condition Assessment Matrix (RCAM) [16]. RCAM-WET and DRY only (based on PANS–Aerodromes (doc 9981)).

RUNWAY CONDITION ASSESSMENT MATRIX (RCAM)			
Assessment criteria		Downgrade assessment criteria	
Runway Condition Code (RWYCC)	**Runway surface description**	**Aeroplane deceleration or directional control observation**	**Pilot report of runway braking action**
6	• DRY	---	---
5	• WET (The runway surface is covered by any visible dampness or water up to and including 3 mm depth	Braking deceleration is normal for wheel braking effort applied AND directional control is normal	GOOD
4		Braking deceleration OR directional control is between Good and medium	GOOD TO MEDIUM
3	• WET (slippery wet runway)	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced	MEDIUM
2	More than 3 mm depth of water: • STANDING WATER	Braking deceleration OR directional control is between Medium and Poor	MEDIUM TO POOR
1		Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced	POOR
0		Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain	LESS THAN POOR

Note. –An RWYCC 5, 4, 3 or 2 cannot be upgraded.

between the Runway Condition Code (RWYCC) and the Runway surface description.

The runway surface is WET if it is covered by any visible dampness or water up to and including 3 mm depth; there is STANDING WATER on the runway surface if more than 3 mm depth of water is on it. When it remains less than 25% visible moisture on the runway surface, it is considered as a DRY surface (ASECNA).

2.3. Method of Comparison of the Results

Based on the definition of proportions and variations as defined by Roussillon [17] and the equilibrium composition of a plasma in the low-voltage air circuit breaker as defined by Banouga *et al.* [18], the accuracy of the model-determined RCR is evaluated by Equation (2).

$$\Delta_{\text{depth}}(\%) = \frac{\left|\text{depth}_{\text{in-situ}} - \text{depth}_{\text{model}}\right|}{\text{depth}_{\text{in-situ}}} \times 100 \quad (2)$$

where Δ_{depth} is the difference depth measurements between in-situ measurements ($\text{depth}_{\text{in-situ}}$) and those from computing model ($\text{depth}_{\text{model}}$).

Then based on the definition of proportions and variations as defined by Roussillon [17], the difference in term of Runway Condition Code (RWYCC) (Δ_{RWYCC}) has also been computed by using Equation (3):

$$\Delta_{\text{code}} = \left|\text{code}_{\text{in-situ,depth}} - \text{code}_{\text{model,depth}}\right| \quad (3)$$

where $\text{RWYCC}_{\text{in-situ,depth}}$ and $\text{RWYCC}_{\text{model,depth}}$ denote Runway Condition Code from in-situ depths measurements and computing model depths respectively.

3. Results, Analyzes, and Discussions

3.1. Results

The RCR's automation estimating method reliability is being checked by running the code in the case of WET surface, a surface with STANDING WATER and a DRY surface. Experience is done in laboratory by using Ouagadougou airport location indicator (DFFD) [19] and the Runway number (04) in the RCR message as default data. Three (03) displayed messages obtained the 25$^{\text{th}}$ of June 2022 are shown in **Table 2**.

In these three messages, the acronym DFFD means that measurements are made at Ouagadougou airport. The 8 digits that follow indicate the day and time at which measurements were made. For example, in the case of RCR 1 (06252239), the measurements were recorded on June 25 at 10:39 p.m (22:39). The next digits (04) represent the recorded runway number. The remaining digits and letters in the message highlight the runway status code (RWYCC) in all three parts and the level of dry or wet status of the runway. For example, in RCR 1 and RCR 2, the runway is respectively entirely wet and with standing water in all three parts with respectively a maximum water depth of 3 mm in RCR 1 case and 4 mm, 4 mm and 5 mm for RCR 2. Especially in the case of RCR 2 there is a situational awareness alert message (RWY POOR. STAND 4 WITH OIL) which means that braking on the runway is poor and there is some oil on the Stand number 4 of the apron. The RCR 3 reveals that the runway is dry (DRY) everywhere by 11:59 p.m.

Table 2. Three displayed RCR messages of the 25$^{\text{th}}$ June 2022.

RCR number	Message displayed
RCR 1	DFFD 06252239 04 5/5/5 100/100/100 NR/NR/NR WET/WET/WET
RCR 2	DFFD 06252250 04 2/2/2 100/100/100 04/04/05 STANDING WATER/STANDING WATER/STANDING WATER RWY POOR. STAND 4 WITH OIL.
RCR 3	DFFD 06252359 04 6/6/6 NR/NR/NR NR/NR/NR DRY/DRY/DRY

3.2. Analyses and Discussions

The RCR estimated by the computing model is assessed by comparing the results obtained to water level measured using the sensor graduation. Some differences of ±1 mm are observed between the computing model data and (reading) measurements values. Results presented in **Table 3** show that the model is reliable and robust.

Differences between computing model estimation and graduated sensor's measurements can be explained on the one hand by the measurement's errors due either to the sensor accuracy or to the reading errors, and on the other hand by the computing model accuracy.

Anyway, these errors do not affect the runway retrieving conditions because a water level higher than 3 mm is considered as STANDING WATER, and it's noticed that the differences between sensor reading measurements and computing model start from 5 mm.

Figure 3 shows that the differences between sensor (reading) measurements and computing model values are very slight. Therefore, the computing code to retrieve the Runway Conditions Report can be considered as a proper application for an easier and faster Global Report Format (GRF).

The equipment has to measure nine (9) times and each one lasts about 15 seconds (according to computing model). The time to travel from one point to the next one is around one (1) minute (according to the inspectors Chief). And we have 8 intervals of travel between the nine (9) consecutive points;

Therefore, the runway occupation time during measurements ($T_{\text{measurements}}$) is:

$$T_{\text{measurements}} = \frac{15 \times 9 + 60 \times 8}{60} = 10 \text{ minutes } 15 \text{ secondes}$$

In fact, computing model will help the runway inspectors take a short time to evaluate the RCR. So, they won't last on the runway which is usually used because of the traffic growth [10]. The inspectors will have around 10 minutes to

Table 3. Comparison of computing model data and graduated sensor's measurements.

Methods	Water depth (mm)							
Graduated Sensor's readings	**0**	**3**	**4**	**5**	**8**	**10**	**13**	**15**
Computing model values	**0**	**3**	**4**	**4**	**7**	**11**	**13**	**14**
RWYCC for reading and computing measurement (without caoutchouc)	5	5	2	2	2	2	2	2
RWYCC for reading and computing measurement (with caoutchouc)	3	3	2	2	2	2	2	2
Difference in Depth measurement (%)	0%	0%	0%	20%	12.5%	10%	0%	6.67%
Difference in RWYCC	0	0	0	0	0	0	0	0

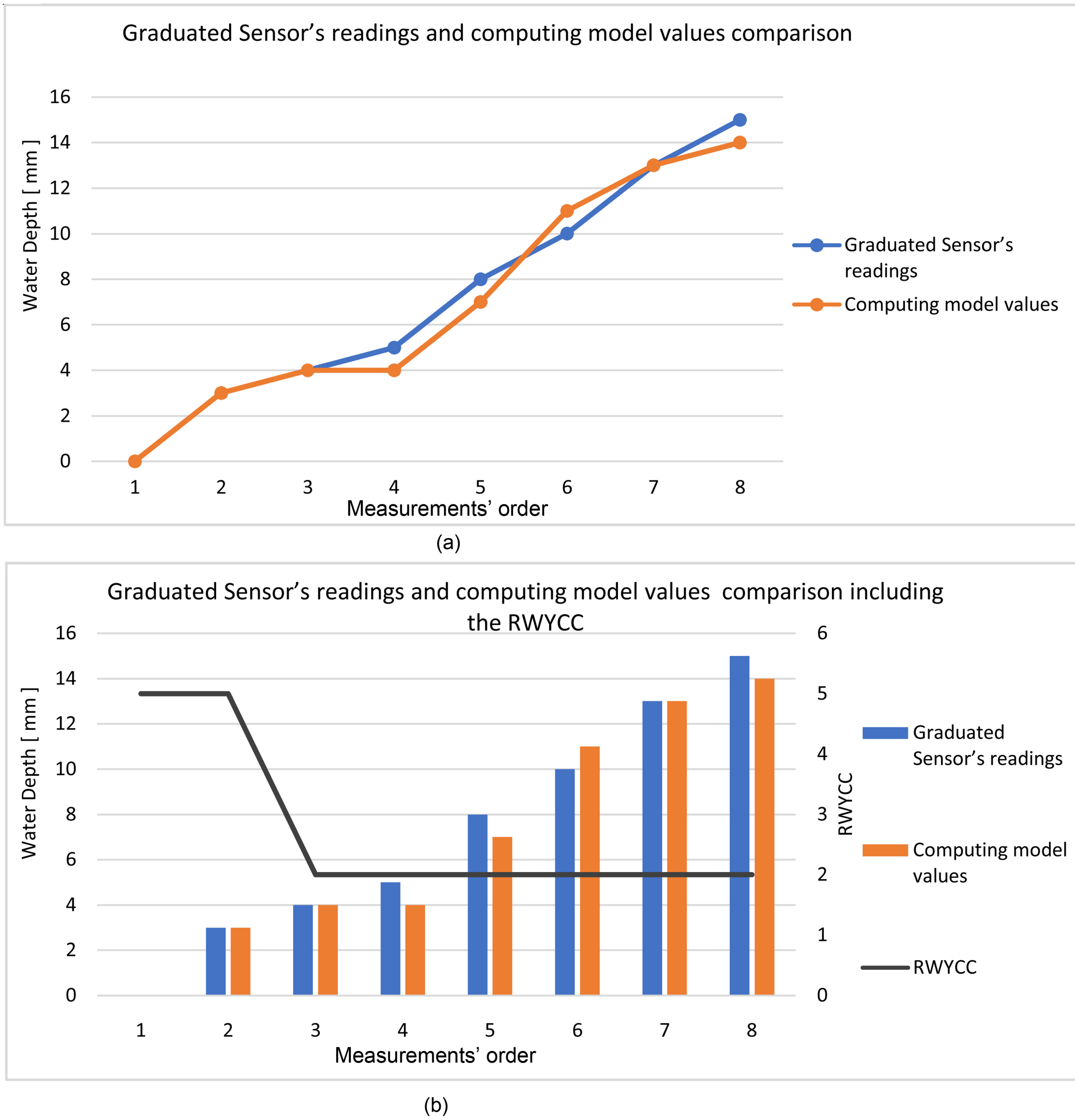


Figure 3. Comparison of reading and computing results (a) and with RWYCC (b).

stay on the runway of 3000 m against around 20 minutes they currently spend on it.

In addition, the developed computing model method is easy to use because it works autonomously. Inspector will only have to run it.

Using this computing model will also protect inspectors from rain because they won't have to get out from vehicle for the different measurements. As it is automatic, there will be no making mistakes risk while writing the RCR, because after making itself the measurements, it will generate the RCR automatically.

4. Conclusion

The developed computing model is an autonomous and automatic application implemented specially for West Africa. It uses Arduino materials and computing code developed by the authors. This code put in application a water level sensor and Runway Condition Report (RCR) determination ways defined by ICAO. Results obtained show that using that method to retrieve the Runway Condition Report (RCR) is fast, so human presence on the runway is reduced. Even though the results obtained using this model are slightly different from those expected, the actual runway conditions are not too much affected. This method can therefore be taken into account and one can try to improve it with, for example, a more accurate water level sensor or any other suggestion.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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