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Deep Reinforcement Learning Based Weather Monitoring Systemusing Arduino for Smart Environment

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Abstract: ***Weather forecasting is an essential predictive challenge that has depended primarily on model-based methods. Collection of data about the different weather parameters is needed a smart environment. Recent developments in machine learning (ML) made possible to collect the data. The data from input sensors is then read by Arduino, which acts as server. The sensors collect the data of various environmental parameters and provide it to Arduino, which act as a base station. It then transmits the data using WIFI and the processed data will be displayed on laptop through accessing the server that is on the receiver side. In this paper, new directions are explored with forecasting weather as a data intensive challenge that involves inferences across space and time. Machine Learningmakes predictions through a unique hybrid approach that combines discriminatively trained predictive models and a deep neural network. The Deep Learning algorithm utilized here is Value-Based – Temporal Difference Algorithm. This in turnmodels the joint statistics of a set of weather-related variables. It is shown that the base model can be enhanced with spatial interpolation that uses learned long-range spatial dependencies. An efficient learning and inference procedure is also devised, that allows for large scale optimization of the model parameters. The methods are evaluated with experiments on real-world meteorological data that highlight the promise of the approach.***

Key Words: Machine Learning, Arduino, WIFI, DRL (DeepReinforcement Learning) Algorithms, Temporal difference (TD) Algorithm

I. INTRODUCTION

Weather forecasting is forecasting the states of atmosphere, of a specific given territory or area. Accurate climate forecast is important to seek after every day exercises. All Living and non-living things are dependent on climate. Indeed, the climate industry in India is still in its budding stage, confronting numerous snags.

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One of the main deterrents that weather forecasting faces is the subjective and ill-suited desires from the nature. An automated weather station is a gadget that can be utilized to gauge and record the known parameters of atmosphere without association of people [1][2].

The climatic conditions are required to be checked to keep up agricultural developments and to guarantee the protected workplace in enterprises, and so forth. Due to technological development, the way towards reading the natural parameters wound up less challenging contrasted with the past days. The sensors are down scaled to electronic gadgets used to gauge the physical and ecological parameters. By making use of these sensors for checking the weather conditions, the outcomes will be exact and the whole framework will be efficient and less power consuming. The framework proposed in this paper portrays the executed stream of the weather monitoring station. This incorporates the wireless technology IEEE 802.11 b/g (Wi-Fi) for communication. This framework screens the weather circumstances and periodically updates the data to the remote database. The objective of sending the information to a remote database is that the weather conditions of a specific place can be known from anyplace on the planet. The framework comprises of amount of rain fall, temperature, humidity and pressure sensors. Each of these sensors measures the corresponding weather parameters. The framework is planned to be used in extensive residential buildings and manufacturing firms. Machine learning has the capacity learn without being expressly customized. It enables machines to find concealed patterns and insights. In supervised learning, a model is assembled in view of training information. The model is then utilized for mapping new illustrations. In view of the watched weather patterns from the past, a model can be constructed and used to predict the weather. Time Series Analysis and Decision Tree models are mostly used prediction models. Mostly, these models take the present weather conditions and process it to build a model for predicting the weather. This research work centers on comprehending the weather prediction inconsistencies and in-proficiency in light of linear regression algorithms and time series model. The significant commitment of this examination work is to formulate a productive weather prediction model based on Decision Tree and Time Series Analysis.

II. MACHINE LEARNING

An ML model highlights spatiotemporal dependencies among weather variables induced by atmospheric process.

The data drawn from a continental scale weather corpus composed of data captured via balloons is used for experimental purpose. In particular, the IGRA dataset consisting of balloon observations are considered. These balloons transmit observations on wind velocity and direction, temperature, geopotential height, dew point, and other related variables. These observations are officially published in real time by the NOAA and later by the National Climatic Data Center following preprocessing. The data is integrated into the IGRA dataset which is updated periodically and has historical weather data spanning decades compiled from eleven source datasets. Any information added to the archive undergoes a cycle of quality assurance to resolve potential inconsistencies among variables [4, 5]. Formally, four weather variables are considered in the model: wind velocity, v; pressure, p; temperature, t and dew point, d. The wind observations are represented by using a two-dimensional vector, v = [vx, vy] while all other weather variables are scalars. The weather stations are represented (where the balloons are released) as SL = {s1,..., sNs } where Ns is the total number of weather stations. For all these stations, we have historical weather data logged at a frequency of approximately five hours over several years. The approach followed to build the weather model was governed by the following guidelines:

1. Temporal mining: The model should be able to identify and learn from recurring weather patterns over time.
2. Spatial interpolation: The dynamic influence of atmospheric laws on weather phenomena need to be accounted for in our predictions.

Inter-variable interactions: The interdependencies that are local between weather variables should be captured by our model. Accordingly our model can be viewed as having three main components. The first component is a set of individual predictors for the weather variables that are trained using historical data. A variety of off-the-shelf machine learning procedures can be applied to the recorded data to build these individual predictors. The second component works to refine inferences produced by the separate predictors by constraining the output to be spatially smooth and aligned with constraints imposed by physical laws. The interplay of these constraints is dynamic and hence, we develop a data-centric approach. The third component has a deep belief network which obviously leads to a preference to solutions that respect the expected joint statistics of the weather variables. We describe the three key components in detail below and finally conclude this section with an integrated graphical model of our framework. Data is streamed continually, which is the key to reliably feed real- time business processes and to extract timely insights.

III. EXISTING SYSTEM

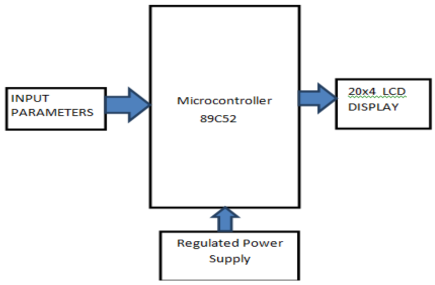

Fig 1 AConventional Weather Monitoring System

There are several systems available today for measuring and monitoring the climatic changes that take place throughout the day.The present –day In-use systems although produce results, it is found that they are produced on a less accurate and on a time-delayed output.The prediction level of the weather forecast was also on a satisfactory level only. The conventional weather monitoring system indicated above is the most basic and cost-effective system that prevailed a decade ago. The conventional system provides a less accurate output, which disables the user from predicting the prevalent weather conditions at all times.

IV. PROPOSED SYTEM

In order to overcome the above shortcomings, we propose a highly effective weather monitoring system, implemented through deep learning algorithms and techniques. The system proposed here is designed with a view to give accurate results within a very short span of time. The implementation of the system with Arduino UNO (SMD R3) as the primary component enables us to achieve higher precision results within a stipulated period. Thus, the system aids the user to easily predict or forecast weather and warn us of any drastic climatic changes that could occur in near future.

V. BLOCK DIAGRAM

The entire proposed system is concisely depicted as a block diagram for easy understanding and analysis. Arduino UNO (SMD R3) forms the heart of the proposed system. It is conveniently interfaced to various other transducers to sense climatic changes.

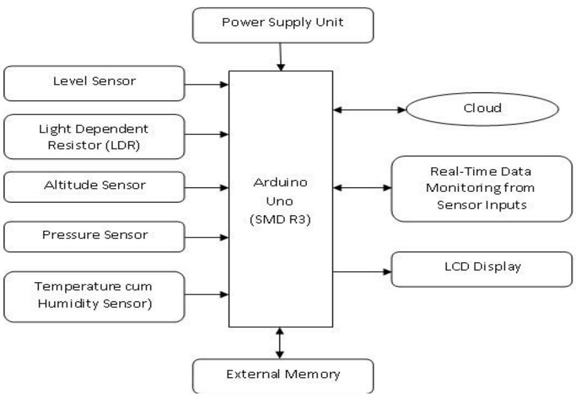

Fig. 2. Block diagram of Weather Monitoring System

Since, Arduino is the latest wireless technology, it willimmediately visualizeandstorevariousweather parameters as given above with the help of sensors interfaced. The procured data is then sent and stored in the memorycard.Thenattheoutput sideLCDisinterfacedfordisplayingtheresult.On/Off relays are alternatively involved for serveraccess.Also5V,1ApowersupplyisgiventotheArduinoboardthroughmicroUSBslot.AnSDcardof8GBisused to store the operating system as well as all programs and files needed for this project. Keyboard and mouse is connected to the Arduino board through USB ports. Monitor is connected to the Arduino board through HDMIportusingHDMItoVGAcable.Ethernetportisusedto giveinternetconnectiontothesystemviaLAN.The Fig.1 istheArduino Processor Board,revision2.0, whichhas512MBofRAM,anEthernetport,HDMIoutput, RCAcompositevideooutput,audiooutput,twoUSBports, and closelyspacedpinsthat gives accesstogeneralpurpose inputsandoutputs (GPIO).TheArduinorequiresanexternal memory such as an SD card with an operating system on it. The Arduinoisvery familiar,with many exampleprojects and information availableonline.

A. HARDWAREDESCRIPTION

Arduino board was invented at Interaction Design Institute Ivrea (IDII) situated in ivera, Italy.It was designed by Massimo Banzi and Casey Reas along with Ben Fry. It isacardsizedARMpoweredLinuxcomputerdevelopmentboard.TherearedifferenttypesofArduino Boards with variousspecifications. Fortheproposed WeatherforecastingsystemArduino Uno (SMD R3) boardmodelisusedasthemaindevelopmentboardwhichisshowninFig. 2The Arduino Uno SMD R3 is derived from ATmega328 microcontroller board. It comprises of 14 digital I/O pins. Six Pins are employed for extracting PWM outputs andremaining for analog inputs.In addition a 16 MHz crystal oscillator, a USB Port, a power port, an ICSP header, and a reset button are also available in the Board. Thus it can easily support the microcontroller and it can be easily interfaced to the PC via a USB cable. It can be powered up it with a AC-to-DC adapter or battery to get started.

Fig. 3. Arduino Uno (SMD R3) Board

B. SOFTWAREDETAILS

Arduino Integrated Development Environment (IDE) is available as open-source software program in the cloud. This enables the users to write, modify and upload code at their will, that too in a real-time work environment. This code can then be sent to the cloud which can be utilized by anyone connected to the internet. This provides an extra level of redundancy to the user. The highest advantage of this IDE is that it is compatibility free and can be used with any Arduino Version Board with any restriction.

All Arduino versions are open sourced and can be freely downloaded using any browser. The most attractive feature of the Arduino IDE is that it can be used on Windows, Linux (both 32 and 64 bits), and Mac OS X.

This makes the Arduino Board platform independent, making it very compatible to users of different platforms. The IDE software is designed uniquely such that it make users to write, edit and upload codes with ease. This enables all beginners to self-learn and develop code on their own without any prior knowledge or assistance. Hence this software forms the primary platform to code and produce outputs that can be stored or retrieved from or to the cloud.

Thus, lining-up some of the unique features of a Arduino IDE, we have

1. Arduino Builder that is a pure command line tool for solving any complex code and can also be used as a stand-alone in an IDE environment
2. The core software can always be upgraded through the pluggable USB port, and the modular architecture enables the libraries update automatically

Arduino Specifications

Developer Arduino Foundation

- OS family: Linux, Windows,MACOs
- Source model: Open source
- Latestrelease:Arduino Uno Wi-Fi rev 2/ATMEGA4809, NINA-W132 Wi-Fi module from u-blox, ECC608 crypto device
- Marketing target: Arduino
- Update method: upload .hex method
- Package manager:ESP82866
- Platforms: Any
- Kernel type: Intel Math Kernel
- License: Creative Commons Attribution Share-Alike license

VI. FUNCTIONALITY

The high quality precision sensors/transducer interfaced to the Arduino provides us with immediate results as their sensitivities are exceptionally high. The DR detects the amount of ambient light that is available at a time. The Level, altitude and pressure sensors work together in synchronization to provide us with intricate details such as height at which the reading is taken, the air pressure at that altitude. Furthermore the temperature cum humidity sensor provides us with the amount of moisture content prevalent in the surrounding air.With the help of DRL Algorithms such as a Value based algorithms, complex computation with the obtained data is performed thus,providing us with real-time data monitoring. The obtained resultant data can be transferred either to any external storage device or can be uploaded on to any cloud space. Thus, uploading on to cloud enables us to monitor the weather condition of any remote location right from our laptop or desk top computers. To know the current weather status at remote location, the user can to login into web browser by entering user name and password given for particular server by the user. Web application is enabled after security check and with that the output graphical representation is also obtained.

Arduino processed data is updated continuously oncloud server &the user will get to know the stored data on both an hourly and daily basis.

VII. TEMPORAL DIFFERENCE ALGORITHM

Generally,Reinforcement Algorithms are presented as a group of computational procedures, which specify a strategy to collect interaction experiences.From the group of interaction experiences obtained, an optimization policy is finalized upon, which is employed through mathematical models to obtain the optimal result.The four classes of RL algorithms are Meta-heuristics, policy gradient, value-based and Model-based. Our proposed model extensively uses the Value-Based Algorithm for procuring very precise and timely results.Value-Base algorithm constructs an optimal policy implicitly by iterative approximation method and the final result is an Optimal Q-Function.Value-based algorithm has several variants such as Temporal Difference Learning, Deep-Q Learning (DQN),Double DQN,DuelingDQN,NoisyDQN,Multi-Step DQN and Prioritized Experience Replay.The Arduino based weather monitoring system utilizes the temporal difference learning algorithm to produce good resultsTemporal Difference (TD) learning algorithm chosen and extensively employed here as it is the simplest and lucid of all methodologies available. The employability of the temporal algorithm is presented as a step-wise procedure for easy understandability.

Step 1: Search for the optimal function Q, which is generally obtained by solving a system of recursive equations. The resultant equation is termed as “Bellman Equation”, which generally satisfies our deigned optimal policy.

$$Q(s.a)$$

Step 2: The argument of the equation is noted down and the next iteration is performed and the result obtained

$$a = \text{argmax } Q(s, a)$$

Step3: The “Temporal Difference” between the arguments is noted down, viz., the transition between successive values is noted.

Observe transition (s, a,r,s’,done)

Step 4: The newly obtained values are updated in the transition table.

$$Q(s, a) \leftarrow Q(s, a) + \text{argmax } Q(s, a)$$

Step5: Iteratively repeating steps 1 to 4 provides us with the best optimal result.

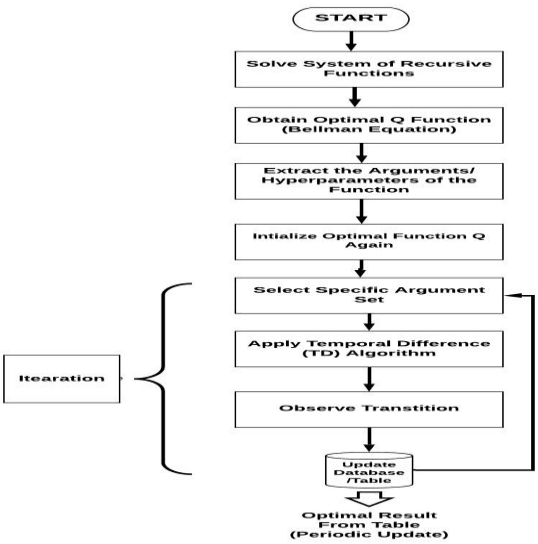

Fig 4. Temporal Difference Algorithm

Several are the merits of our proposed system. The maximum utility of the system is obtained through the ardent combination of an Arduino processor embedded with Deep Learning Value Based Algorithm – The Temporal Difference (TD) Algorithm.The primary advantage on employing this algorithm being, all the set of equations can be solved using the Basic Point Iteration Method. This straight forward method, ensures that each iteration is expected to fully pass across all transition probabilities, thereby providing the guarantee of providing a correct answer.The hardware too contributes greatly towards the systems merit factors. The simplicity of design, availability of the Arduino processor at an economical and affordable cost makes it all the more easier for us to design the entire system. In addition, The Arduino also provides us with a plug-n-play interface, via which all the sensors are directly connected to the main processor. The end results can be stored onto any kind of external storage device with ease. This highlights the fact that the proposed system does not have any hardware or software compatibility issues.

VIII. FUTURE SCOPE

Exporting the data onto a cloud storage, enables anybody to monitor the weather conditions via the internet. Further, it enables any user to monitor the weather condition of any remote, inaccessible location from any locality and effectively forecast and predict the weather condition for the near future too.

VIII. GRAPHICAL RESULTS

Table 1 indicates the various weather parameters measured over a period of 1 week. The graphical results are indicated below the table to show the transitions that were observed after the application of the Temporal Difference Algorithm.

Date	TEMPERATURE (In Deg)		Humidity (In %)		r Pressure (In Milli B	
	Predicted	Actual	Predicted	Actual	Predicted	Actual
11-Oct-19	35	34	81	79	1013	1012
12-Oct-19	33.8	34	82	85	1011	1010
13-Oct-19	32.6	33	80	76	1010	1010
14-Oct-19	33.4	34	71	68	1011	1009
15-Oct-19	32.7	33	65	69	1009	1011
16-Oct-19	31.2	30	69	73	1014	1011
17-Oct-19	29	28	74	79	1011	1009

Table 1. A Weather Monitoring Table

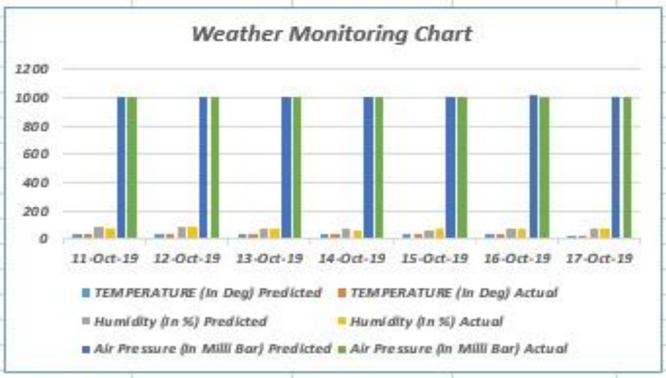

Fig 5. Weather Monitoring Chart

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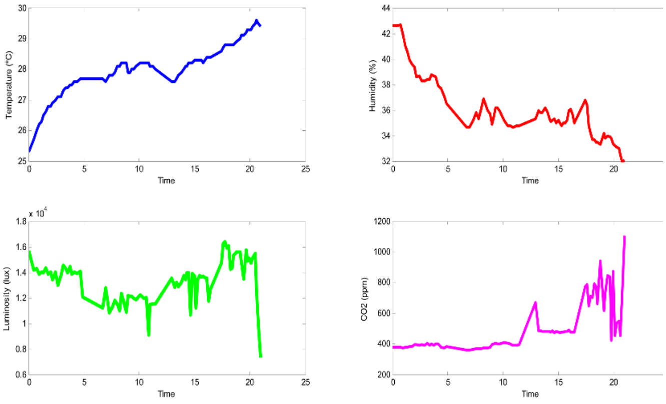

Fig 6. Temperature, humidity, luminosity and air pressure graphs

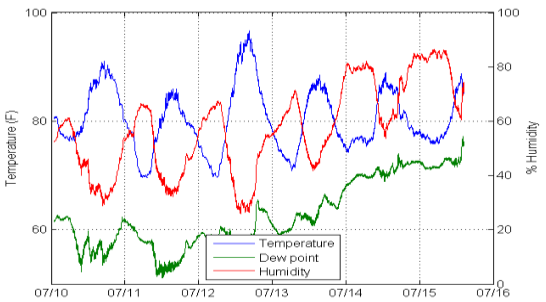

Fig 7. Consolidated data

IX. CONCLUSION

Weatherpredictionisavery primary factor,which forecasts the climate and its possible changes in a region,based upon weather parameter values.The calculated results obtained can be used to predict or forecasttheweatherofa specified localityforaparticular periodoftime.EmployingArduino inthe model enables us to send SMS alertmessagesore-mails to a prescribed mobile number. High alert indication is also intimated to the user when the parameters changes are drastic. Due to upgradation of technology on a daily basis and for immediate, accurate obtainment of results, sensorsforairtemperature,airhumidity,light,soilmoisture, and rain detection are employed in combination with Arduino. Data from the sensors is transmittedtoserver, storing it in the cloud, from whereitcanbeviewedglobally and accessed easilyby all. Finally, we have designed a Deep-Reinforcement System that performs a real-time monitoring of environmentalparameters, without the need of any additional hardware or costly servers. The forecasted weather is primarily aimed for providing advanced information to farmers and related people, so as to enable them to devise short-term and long-term plans and get maximum benefit.

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