Planquarium: A Context-Aware Rule-Based Indoor Kitchen Garden

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Abstract. Planquarium is a context-aware indoor kitchen garden system, where a user can grow fresh plants and vegetables without prior knowledge. Further, the Planquarium will take care of the plants that are inside it using a Rule-Based Context-Aware environment, that is capable to monitor different aspects of the plant and can provide an ideal environment for the plant inside. Different plants have different requirements therefore, we have integrated profiling systems so that a person can select a plant and the Planquarium will adjust itself accordingly. Initially, we have deployed temperature, humidity, moisture, water and light(Artificial sunlight full spectrum) sensors to monitor the plants. In the future, we can further add soil quality monitors to optimum growth. Planquarium is suitable for congested smart cities, smart homes and for people who care for organic food.

Keywords: Context-aware · Rule-base · Indoor kitchen garden

1 Introduction

Context-aware systems are based on the notion that a device is capable to perceive its environment and then react to the changes. These changes can be in different form e.g, reaction to emergency scenario [1] or collection of a different scenario to provide an assisted living for elder people [2]. The context-aware systems are widely used in smart cities, where different devices are connected with each other and provides a smart space for a user in different locations and scenarios. In smart cities, all included domains are supposed to be smart e.g., hospital, office and market to name some. Where a user is assisted in his daily life with the help of technology. Smart homes are emerging from concept towards implementation where the lights, electronic equipments are connected with a user and act on behalf of a user according to some rules specified by the user or on a self-learning technology. Rules are favourable in the case where

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expert knowledge is required to be encoded into a computer system. A minute amount of knowledge can be represented in a single rule, and the collection of such rule is called a knowledge base. In the context of smart cities and smart homes, one ignored domain is smart gardening, considering the limitation of land in congested cities, people are living in technologically equipped small and smart homes. This paper addresses the issue of planting plants and vegetables in a controlled context-aware rule-based device, which will not be able to grow without sunlight and outdoor environment otherwise. Planquarium, on one hand, will provide fresh vegetables to a user without any expert knowledge, while it will also provide fresh and clean air to a user by recycling the indoor air and produce Oxygen. Initially, this concept will be implemented on a small scale with few and essential sensors attached to check the quality of vegetables grown inside. Further, it can be used to grow more plants or fruits, with soil checking capability to fully automate the system. This paper is distributed as follow Sect. 2 provides the motivation which drive us to carry out this research work. Section 3 define the preliminaries in detail from very basic. Related work is discussed in Sect. 4 followed by our proposed model. Section 5 is about the conclusion and future work.

2 Motivation and Preliminaries

The motivation for this paper comes from the technologically complex world of smart cities and connected technologies where the aspect of natural living is demising slowly. The concept of green living is kept in mind in this research work. In smart cities, we have observed the technology has overcome different life aspect, for example, smart laundry management system in congested buildings, smart parking systems, smart environment, smart elder care but unfortunately, when we think of smart gardening we find that the existing systems are not automated as discussed in the Section Related Work. This motivates us to develop a conceptual model and a prototype to assist the user in promoting indoor gardening for keeping the air clean and have fresh vegetables. With the help of having a smart indoor garden, the concept of a smart home will be completed. In order to make it perceive its environment, the system has to be designed on the paradigm of context-aware systems, where the context will monitored using sensors. When enough is gathered, it is understood that the context will be processed by some mechanism and must produce some output or deduce some output. The output can be in terms of controlling sensor e.g., temperature adjustment or deducting new context. The deduction or the reasoning capacity is generated using a rule-engine. A rule engine will have set of rules and it will match the context in terms of facts with the rules and if a rule match is found it will process it accordingly. In order to completely understand the rule-engine working mechanism in context of context-aware system, the following study is recommended [3].

3 Related Work

In this section, we discuss the latest technology that is related to smart gardening. We tried to study the latest literature to find out the latest trends in indoor smart gardening. The article [4] discusses smart gardening with IoT perspective. However, the paper has not discussed any technical infrastructure. The author has connected all the sensors in a manner so that it can send the sensor values to the user and the user has to take some action. By implementing such a system the automation is not achieved as it is merely sending the details to the application that a user should have, and then the user has to decide the matter. The concept of smart technology is not purely implemented. In article [5] shares our argument that lack of space for gardening and apartment lifestyle have an impact on indoor gardening techniques. The system although looks quite mature in terms of technology but still it lacks the context-awareness and no such technique is there to automate the growth of the plant. In this system, sensors are attached near the plant to measure different aspects such as temperature, humidity and soil moisture to name some. This data is then sent to the user mobile application which can then make changes accordingly. In both [4,5] the problem is that if the user does not check the data on time or ignore it for a while, it can be damaging for the plant. Some automation can be seen in the research work [6]. In this system, the base on the soil moisture the watering of soil is carried out. It can check if the soil is under moisture or overmoisture and then it can start or stop watering of the soil. The system is mainly used for the garden purpose and does not entertain many sensors, instead, it only has light and moisture sensor. The same concept is discussed in the [7], for terrace gardening. It also has the only temperature and moisture sensor installed. Apart from these, there are commercially available indoor gardens (*CLICK and GROW*, *OGarden Smart, TreGren, Postscapes* which also claim to be fully automatic, however, there is no research work behind these models to support their claims. After the study of recent literature work and to the best of our knowledge, there is no such system available which is fully automatic, context-aware and is rule-based that can make the indoor gardening a really automatic without user intervention at all in terms of maintaining the environment.

4 Proposed Model

In this section, we define in detail the working mechanism of the Planquarium, its different components and how profiling can be used effectively. In this paper, we are combing the power or RBS with the CA computing paradigm. By fusing both, we can actually make a system that can act like a human expert. The CA system will provide context relative to a plant in a raw form, which will be transformed into a high-level context and made ready to be processed by the RBS as a fact. The context related to a plant can be temperature around the plant, humidity, light, moisture, water level to name some. These contexts can be utilized by the RBS to provide an ideal plant growing environment indoor.

4.1 Physical Properties and Sensors Used

The modal is made of transparent box shape which contains the plant and soil. Different sensors are attached for monitoring the plant. A water tank is externally attached to the box, which contains water. The water tank is used to water the plant whenever required. Another external device is the regulator, which is the brain of the whole system and programmed in a way to perform the reasoning on the available context and accordingly regulate the plant environment. The sensors and controller used are briefly defined in the next section.

Arduino Uno. It is an open-source, Microchip ATmega328P microcontroller based microcontroller board. Arduino Uno and its variants are developed by Arduino.cc. It has both digital (14 pins) and analogue (6 pins) I/O pins, which can be connected with different sensors and shield or even boards. The programming is carried out in Arduino IDE and uses type B USB cable for connectivity. It can be powered with a USB cable or a 9-V adapter. Arduino Uno can accommodate a variety of sensors, but we will discuss sensors which are relevant to our research work.

Water Level Sensor. The water level sensor (ICSG001A)[1] indicates the level of liquid. It can be deployed in the water tank which is attached externally to the plant box. This will monitor the water level and inform the user in case the water level drop beyond a certain threshold. The sensor is shown in the Fig. 1. It needs an initial calibration to fetch values, after which it can detect values from the container and programmed accordingly.

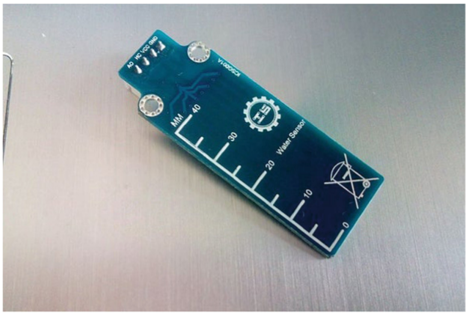

Fig. 1. Water level sensor

[1] https://www.instructables.com/id/How-to-use-a-Water-Level-Sensor-Arduino-Tutorial/.

Humidity Sensor

Humidity and Temperature Sensor. The humidity and temperature sensors (DHT11 or DHT22) are available as a single unit which can be connected to the Arduino board to get values. The sensor DHT11 and DHT22 both have the same function but with more reliable results with DHT22. Both are considered sluggish as it cannot provide data more than once a second. The image of the sensor is provided in Fig. 2.

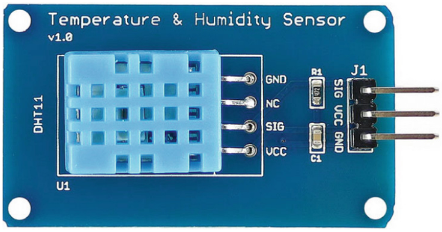

Fig. 2. Temperature and humidity sensor

Moisture Sensor. Moisture sensor (SEN-13322) is installed in the soil to detect and regulate the moisture level of the soil. The sensor must be installed near the roots for optimum results. The image sensor is provided in Fig. 3. Since all of these sensors can check on most of the vital requirements of the plant which needs to be controlled for better growth of the plant. The most important factor for the growth of any plant is sunlight. The natural sunlight has its own properties for plant growth. However, since the proposed model is based on the concept of an indoor kitchen garden, it is always possible that the natural light may not be available. Therefore, artificial sunlight has to be maintained in order to make the system a complete working prototype. The artificial sung-light is discussed in the next section.

4.2 Artificial Sunlight

Sunlight is a universal and balanced source of wavelengths necessary for plant growth. However, artificial light can also provide the necessary light requirements. Depending upon the nature of plants, different light wavelengths are necessary e.g., according to the author [8] Foliage growth requires blue wavelength light. Flowering and fruiting plants require red wavelength light. The green wavelength lights are used less and therefore the wavelengths are reflected which gives the leaves green colour. There are various types of artificial lights, some require to be near the plants as they emit cool light such as fluorescent lights. Fluorescent lights are more economical, and release blue wavelengths, and are good for foliage growth. However, they do not provide a full spectrum

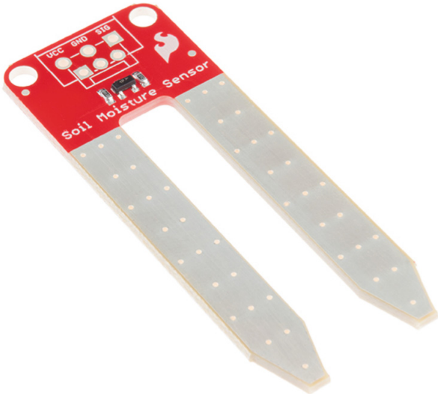

Fig. 3. Moisture sensor

of wavelengths. Normally they are mixed with Incandescent lights. Incandescent lights emit more heat and are required to be installed far from plants, but they release more of the red wavelengths. Depending on the plant nature, the lights can be combined together to provide well-balanced lights. LED lights are customizable and some people prefer to install customized LED bulbs, LED lights are economical and very cheap to maintain. For the full spectrum light, Halogen lights can be used. The drawback of halogen lights is that they produce a lot of heat and less energy efficient. Especially designed horticultural grow lights are available now for indoor use. They provide a full spectrum of wavelengths and are widely used in research and growing of hybrid plants.

4.3 Sensors Integration and Working Mechanism

In Fig. 4 the sensors mentioned earlier are installed. Each sensor has to be installed at a specific position to provide optimum results. In our system, Water level sensor is submerged in the water tank. The water sensor checks the level of the water and it can provide two mechanisms. If the tank is connected with a water source, it can pump water to the tank and fill itself. Alternative, if the water source is not connected with the tank and the water level drops, then it can alert the user to fill the tank. The moisture sensor is installed within the soil near the roots if a single plant is intended to grow. It checks the soil moisture and detects if the plant needs more water or not. If the water is required, the regulator release water according to the requirements. The humidity sensor is installed to check for the humid air, if the air is too humid the regulator turns the fan on to let the humidity reduce. The temperature sensors also utilize the fan to control the temperature. The integration of all the sensors with the controller ensures that the plant has all the requirements within the ideal growing environment. The artificial sunlight is also controlled with the regulator and it can mimic the pattern of sunlight intensity according to the time of the day.

Since the planquarium is designed in a fashion that it can change according to the plant inside. This adaption is carried out by the profiling system. Profiling system has data for different plants. A user just needs to change the plant type in case if he changed the plant inside. The profile management then regulates the regulator according to the new type. We intend to host the database of different plants so that user can simply update their planquarium and the newly available profile will be available for usage. The profile for one simple plant is provided in the next section.

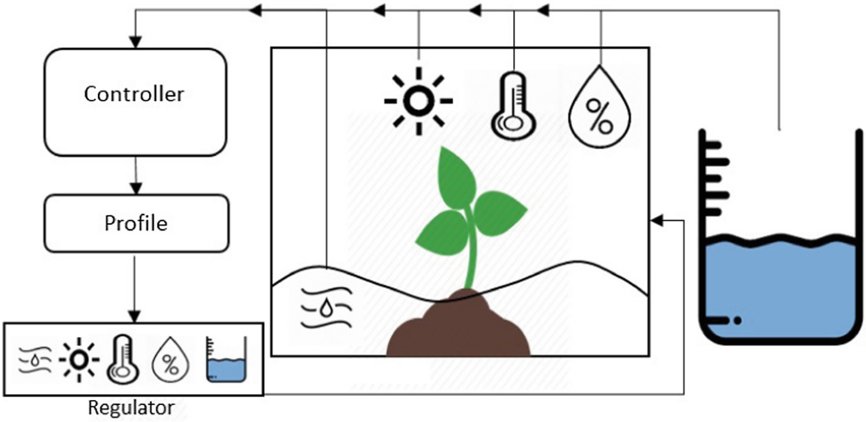

Fig. 4. Planquarium architecture

4.4 Sample Profile

In Table 1, we have defined in the first column, the rule. The rule has variables that are replaced with the facts when received from the sensors. The second column shows the consequent or the actions that will be taken based on the rules defined in the first column. The third column shows which plant the rule belongs to. As different plants have different requirements so we can not generalize the rules instead we have to define rules for every plant that we want to grow inside the planquarium and then differentiate them from each other based on the profile system. In this Table, which is a sample from a big table, we have P2, P3, P4 and P5. This shows that within that sample different rules are shows when we want to grow P2. We will enable the P2 rules, which will apply all the rules on planquarium which belong to Plant 2 or P2. To demonstrate let us assume the following statements separated by commas to make it as close to the rule

we have planquarium named ?p, there is a water tank ?wt, plaquarium ?p has water tank ?wt, water sensor has id ?id, planquarium has water sensor id ?id, water level is ?wl, if planquarium has water level less then 11 then refill the water tank ?wt.

The resultant rule will be as shown below

Planq(?P), watertank(?wt), haswatertank(?p,?wt), wsensorID(?id), hasWSensorId(?p,?id), waterlevel(?wl), hasWaterLevelLessThen(?p,11) with action to take refill(?wt)

Table 1. Profiling rules for different plants

Rule	Consequent	Profile
Planq(?P), watertank(?wt), haswatertank(?p,?wt), wsensorID(?id), hasWSensorId(?p,?id), waterlevel(?wl), hasWaterLevelLessThen(?p,11)	refill(?wt)	P3
Planq(?P), watertank(?wt), haswatertank(?p,?wt), wsensorID(?id), hasWSensorId(?p,?id), waterlevel(?wl), hasWaterLevelGreaterThen(?p,90)	Stoprefill(?wt)	P3
Planq(?P), TemperatureSensor(?id), hasTempSensor(?p,?id), temp(?temp), hasTempGreaterThen(?p,45)	StartFan(?fan)	P5
Planq(?P), TemperatureSensor(?id), hasTempSensor(?p,?id), temp(?temp), hasTempLessThen(?p,30)	StopFan(?fan)	P5
Planq(?P), HumiditySensor(?id), hasHumiditySensor(?p,?id), humidity(?h), hasHumidityLessThen(?p,60)	StartSpray(?spray)	P3
Planq(?P), HumiditySensor(?id), hasHumiditySensor(?p,?id), humidity(?h), hasHumiditygreaterThen(?p,90)	StopSpray(?spray)	P4
Planq(?P), MoistureSensor(?id), hasMoistureSensor(?p,?id), Moisture(?m), hasMoisturegreaterThen(?p,55)	StopWater(?wtr)	P2
Planq(?P), MoistureSensor(?id), hasMoistureSensor(?p,?id), Moisture(?m), hasMoistureLessThen(?p,25)	StartWater(?wtr)	P2

5 Conclusion and Future Work

In this paper, we have demonstrated the concept and early experiment of our Planquarium, which is an intelligent context-aware rule-based indoor kitchen garden growing system. All the user need is to plug in the planquarium and let the plants grow inside by selecting the profile of the plant from the controller menu. The Planquarium is in line with the smart cities concept, and we have tried to connect a simple plant with the smart cities. It is equally beneficial for users who have limited space and they want to grow fresh plants inside their homes. In the future, we will further add a mechanism for effective profiling, as in the future we see the size of the rule-base might be huge due to many profiles stored in single rule-base. Furthermore, the soil quality tester sensor will be deployed which will check if the soil the Planquairum is suited for the plant inside or not. If not then how do we restore the soil to match the quality requirements of the soil. Moreover, we also want to take the experiment to the level of small fruit trees. In this way, we can develop a big Planquarium with more sensors and larger space and an effective cooling/heating mechanism to grow a plant of approximately 2 meters in length so that indoor fruit garden can also be deployed.

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