SMART TAG LIBRARY

EL-SADAT STEM SCHOOL

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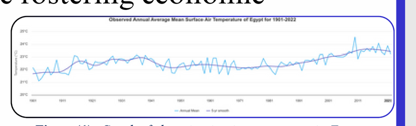
ABSTRACT

Egypt, recognizing the urgent need to address pressing challenges in waste management, technological advancement, climate change, and economic growth, has embarked on a sustainable development journey. A steadfast commitment to combatting climate change is demonstrated through strategic investments such as the construction of solar labs in Qaraman Island, Sohag, this was done while fostering economic prosperity. In line with this vision, the Smart Library is emerged as a modern and efficient solution to library management, integrating a suite of sensors, actuators, and modules. These include touch, temperature, smoke (MQ-2), and motion (PIR) sensors, servo motors, an RFID module, and a mini SIM800L, enabling enhanced security, safety, and efficient book borrowing. When key solution requirements are met -through meticulous design requirements, such as temperature regulation that the difference between in and out temperature reached 11.2 celcius degrees in day time, security measures, safety protocols, and efficient book borrowing processes-, the Smart Library ensures a seamless user experience while prioritizing sustainability. These design choices, combined with the library's construction use white sandstone for passive temperature regulation. Furthermore, the incorporation of a green roof augments insulation capacities, thereby improving the library's sustainable footprint and advancing sustainability. The efficiency of the solar panel is calculated to be 16.71%

INTRODUCTION

Egypt has long grappled with life-threatening challenges spanning waste management, technological advancement, climate change, and economic growth. In response, a sustainable development journey has been embarked on, aligning with SDGs and emphasizing a green economy. Notably, strategic investments, such as the construction of solar labs in Qaraman Island, Sohag, reflect Egypt's commitment to combating climate change while fostering economic prosperity. After analyzing previous solutions such as the Tianjin Binhai Library, China, the HVAC system, and Verde Vista, Germany, four challenges were addressed. The Tianjin Binhai Library in China is featured to be a striking green roof design atop its modern architecture, offering benefits like improved thermal insulation and environmental sustainability. While its smart system for auto-borrowing enhances user experience, challenges include maintenance requirements and potential leaks. HVAC systems, while offering better air quality and constant temperature management, can adversely affect the environment and are expensive to install and operate. Additionally, the framework for smart building networks employs machine learning to optimize heating systems, though issues persist with accuracy and reliance on complete data. Verde Vista, situated in Berlin, Germany, features an extensive green roof on a commercial office building. Pros encompass improved air quality, energy efficiency, and habitat creation. Yet, challenges include initial investment and potential structural load concerns.


Figure(22); Graph of changing in air temperature in Egypt.

The Smart Library is conceived as a modern and efficient approach to library management, integrating various sensors, actuators, and modules. Incorporating touch, temperature, smoke (MQ-2), and motion (PIR) sensors, alongside servo motors, an RFID module, and a mini SIM800L, this system offers advantages over traditional libraries, including increased security, safety, and efficient book borrowing.

To ensure a successful Smart Library system, several key solution requirements must be met, including a suitable sensor setup, appropriate actuator mechanisms, and a reliable method for monitoring and controlling various aspects of the library. These requirements give rise to a variety of design considerations.

1-Temperature regulation, for instance, necessitates the monitoring of both internal and external temperatures, with the servo motor automatically opening the window if the temperature difference is less than 3 degrees, ensuring user comfort.

2-Regarding security, a motion sensor is installed in the warehouse to detect any suspected motion. Failure to complete a specific pattern on the touch sensor results in door closure, effectively locking the intruder inside and triggering a message to the library owner via the mini SIM800L, safeguarding against theft.

3-Safety measures include the activation of a humidifier upon smoke detection by the smoke sensor, extinguishing fires promptly, and alerting the library owner to potential hazards.

4-Automation: The automatic borrowing system consists of an RFID sensor. A card will be put in the book with its information on it, and scanned on the RFID module to record the book to the borrowed list on the computer. This ensures an efficient and reliable book-borrowing system.

These design requirements, chosen based on solution needs, aim to guarantee the Smart Library's security, safety, and efficiency for all users. Incorporating various sensors and actuators, alongside communication capabilities like the mini SIM800L, ensures effective monitoring and control. Additionally, the library's construction using white sandstone contributes to temperature regulation. These design choices are instrumental in meeting solution requirements and ensuring the project's success.

MATERIALS

TOTAL COST: 2702 L.E

METHODS

Suitable construction materials for the smart library were identified initially. Sandstone and synthetic resin (Bulbond) were chosen due to their strength, lightweight nature, natural availability, and thermal insulation properties. Alternative options were dismissed due to various limitations, such as low strength (clay mixture), use of non-natural materials (ceramic paste), high cost (natural resin), or ineffectiveness (glue with sandstone).

For the construction and Building of the smart library prototype, some steps should be followed:

1. **Construction of Walls:** Sandstone was cut into 70 blocks of 10*20*2 cm dimensions and assembled using synthetic resin (Bulbond) to form the walls of the smart library.
2. **Roof Installation:** The green roof structure was installed using palm petioles, soil, and grass. (as shown in Fig. 23).
3. **Sensor Placement:** Sensors for monitoring temperature and humidity, motion, and smoke were strategically positioned throughout the building. The sensors were connected to a microcontroller, programmed to adjust the system based on the data collected. (as shown in Fig.24).
4. **Coding:** For more information about system's coding, scan the QR code.

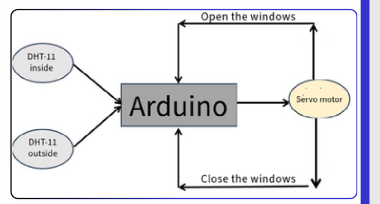

Figure(23); Our Smart Tag library prototype

Codes && Wirings!

QR code; Scan for more details about project's coding and wiring

The feedback system for temperature monitoring:

The temperature control system in our smart library project employs a feedback loop to maintain optimal temperature conditions. Using DHT-11 sensors, it continuously monitors the temperature. If the temperature deviates from the set threshold, the system activates a servo motor to adjust window openings for ventilation. Once the temperature returns to the desired range, the servo motor resets, ensuring a consistent and comfortable environment for library patrons.



Figure(24); Temperature feedback system

Voltage divider and the diode trick:

The diode in this setup is indeed used to further decrease the voltage at the junction of the resistors from 3.3V to approximately 2.6V. This is achieved because a diode has a forward voltage drop, which in this case subtracts about 0.7V from the 3.3V, resulting in a safe voltage level of around 2.6V for the SIM800L RX pin. This ensures that the voltage levels are within the acceptable range for the SIM800L module, thereby preventing any potential damage. This setup is a clever way to ensure safe and effective communication between the Arduino and the SIM800L module.

Safety precautions: Personal protective equipment and caution were employed when handling materials and working with electricity. All electrical components were connected to a circuit breaker for added safety. The project prioritized performance and safety. The use of appropriate materials and safety measures ensured the success of the smart library prototype construction.

TEST PLAN

The test plan details the methodology for evaluating prototype functionality, performance, and safety. Despite numerous attempts, certain tests yielded unsuccessful results, such as the ineffectiveness of bricks made from Aswan clay, gravel, and sand. (as shown in fig. 25)


Figure(25); Aswan clay bricks

In the test plan for the smart library project, each system will undergo rigorous evaluation to ensure compliance with the designated design requirements.

1. **Temperature Regulation:** Dual DHT-11 sensors will continuously monitor temperature variations inside and outside the library, with testing focusing on validating sensor accuracy through diverse temperature simulations. The servo motor's performance in responding to temperature fluctuations, and controlling window operations, and the humidifier's efficacy in adjusting humidity levels will be assessed.
2. **Safety Protocols:** Comprehensive assessments will involve testing the smoke sensor's ability to detect smoke and trigger the humidifier during controlled simulations of fire scenarios, ensuring reliable responses across varying fire intensities.
3. **Security Measures:** Testing will encompass the Touch and PIR sensors' capacity to detect unauthorized access attempts and integrate them with the locking mechanism to thwart intrusion effectively.
4. **Automation Testing:** Evaluation will focus on the RFID-powered borrowing and returning system's precision in identifying users and books, ensuring seamless synchronization with the library database for accurate recording and processing of borrowing transactions.


Figure(26); Our library prototype

The way of sending data by SIM800L to the laptop: To send temperature and humidity data from Arduino to the laptop via the SIM800L module, the Arduino collects sensor readings and sends them to the SIM800L module using serial communication. The SIM800L module, acting as a GSM modem, establishes a connection to the internet or a cellular network. It then sends the data to a server or an online platform using HTTP POST requests or other communication protocols. The laptop can access this server or platform to retrieve the data sent by the SIM800L module.

RESULTS

The positive result that was concluded from the project is that the temperature difference was achieving its desired design requirement. The negative results of the project that is the humidifier took too much time to get 80% of the humidity and lacked the efficiency of the turning off fire system.

The feedback system in the smart library project activates a humidifier based on monitored temperature and humidity levels. For instance, at 10:45 AM, the inside temperature was 34.5°C. After the humidifier's operation, by 8:00 PM, the temperature dropped to 31.5°C. Similarly, the humidity rose from 10% to 16%. This indicates the system's efficiency in dynamically maintaining a comfortable environment by effectively controlling the temperature.

Trial Time (hours)	Temperature Inside (Before) (°C)	Temperature Inside (After) (°C)	Humidity Inside (Before) (%)	Humidity Inside (After) (%)	Time to Reach Target (estimated) (minutes)
10:45 AM	34.5	[illegible]	10	[illegible]	4.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.1

Table(1); The effect of feedback system on the temperature along day time

From table(2), the maximum and minimum temperature differences during the day are approximately 11.20°C and 9.20°C respectively. So, the range or "error" for the daytime temperature difference is about 2.00°C (11.20°C - 9.20°C). Similarly, for the nighttime, the maximum and minimum temperature differences are approximately 7.00°C and 5.20°C respectively. Therefore, the range or "error" for the nighttime temperature difference is about 1.80°C (7.00°C - 5.20°C).

Trial Number	Temp. Inside (Day) (°C)	Temp. Outside (Day) (°C)	Temp. Difference (Day) (°C)	Temp. Inside (Night) (°C)	Temp. Outside (Night) (°C)	Temp. Difference (Night) (°C)
[illegible]	29.30	40.50	+11.20	[illegible]	[illegible]	6.60
[illegible]	29.40	[illegible]	+9.40	[illegible]	[illegible]	5.20
[illegible]	30.00	[illegible]	+9.80	[illegible]	[illegible]	7.00
[illegible]	29.80	[illegible]	+10.20	[illegible]	[illegible]	5.80
[illegible]	29.50	[illegible]	[illegible]	[illegible]	[illegible]	6.70

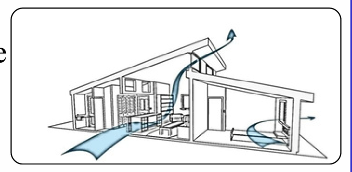
Table(2); Difference of temperature along day and night

ANALYSIS

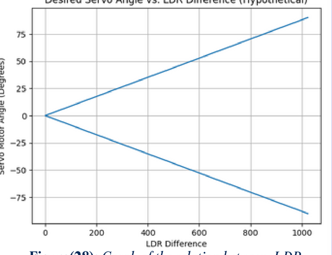
Smart building technology represents an innovative sustainable approach to modern architectural projects. Its design depends on the natural ventilation that the fresh air enters the building from a low window and then exits from the opposite higher ones. (as shown in Fig.27). The goal of this project was to design and build a library with enhanced security measures and fire safety features, along with an automated book-borrowing system. Automation was given priority in the building's design to reduce the need for manual intervention and provide the best possible indoor environment for residents.

The implementation of our SmartTag library was guided by specific design requirements:

- keeping the indoor temperature at least 3°C lower than the outside ambient temperature.
- supplying a strong safety system to prevent fires.
- raising the security to a point where it discourages possible theft.
- utilizing renewable energy sources to promote sustainability.

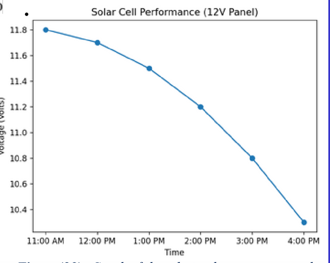

Figure(27); Design of cross Natural ventilation

An Arduino microcontroller was used to manage a variety of sensors and actuators to meet these requirements. By monitoring the temperature both inside and outside the building, the DHT sensor made it easier to control the temperature by opening windows and turning on humidifiers. Smoke sensors were integrated to enable fire detection, which in turn activated the humidifier to dampen fires. Motion sensors were used to detect human presence, and in the event of unauthorized access, doors would immediately close and alerts would ring. Furthermore, an RFID sensor made the process of borrowing books easier by giving pertinent information about the books and authors. In addition, building materials and natural ventilation design principles were used to achieve temperature regulation goals. The library was mostly powered by solar energy, with solar panels that were outfitted with a solar tracking system to maximize energy production. A solar cell is a device that converts sunlight into electricity through the photovoltaic effect. It's made of semiconductor materials, like silicon, that absorb photons and release electrons, creating an electric current. (shown in Fig.28).



Figure(28); Graph of the relation between LDR difference and servo motor angle

$$effeciency\ solar\ panel\ (\%) = \frac{power\ output\ in\ Watts}{solar\ irridance * Area\ of\ solar\ panel\ in\ m^2} * 10(\frac{2}{800 \times 0.01496} x100\% = 16.71\%$$

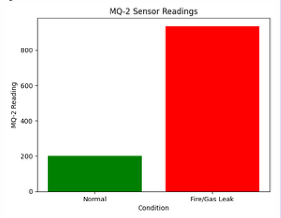


Figure(29); Graph of the relation between time and voltages produced by solar cell.

From the **positive outcomes** of the project were achieving the temperature difference requirement, while encountering **negative outcomes** with the humidifier's slow response to reach 80% humidity and the inefficiency of the fire suppression system.

The prototype is constructed of various structural components. Sandstones are the main materials used in building wall construction because of their durability, lightweight, and excellent temperature insulation. While synthetic resin is used as an adhesive material. By utilizing a green roof design that includes mats, grass, and palm petioles, heat flow and energy usage are greatly reduced. Plywood is used to create doors and windows because it is inexpensive and easy to shape. The main power source of the building is solar energy, which is made possible by solar panels that have a solar tracking system installed for increased efficiency. Sandstones are the main materials used in building wall construction because of their durability, lightweight, and excellent temperature insulation. While synthetic resin is used as an adhesive material. By utilizing a green roof design that includes mats, grass, and palm petioles, heat flow and energy usage are greatly reduced. Plywood is used to create doors and windows because it is inexpensive and easy to shape. The main power source of the building is solar energy, which is made possible by solar panels that have a solar tracking system installed for increased efficiency.

For calculating the inner volume = (area of cross section*height) = ((0.35*0.52)+(0.18*0.30)+(0.5*0.15*0.52)+(0.5*0.18*0.08)) * 0.50 = 0.2822*0.50 = 0.1411m^3 (MA.1.03).



Figure(30); Reading of MQ-2 gas sensor.

The SmartTag library project utilizes an Arduino microcontroller to coordinate various sensors and actuators for automation. Sensors like the DHT-11 monitor temperature and humidity, while the SIM800L module enables SMS communication for alerts. Motion and RFID sensors enhance security and streamline book borrowing processes. Actuators such as the servo motor SG90 and relay modules control environmental parameters and activate devices like humidifiers and alarms. The MQ-2 gas sensor enhances safety by sensors and actuators for automation. Sensors like the DHT-11 monitor temperature and humidity, while the SIM800L module enables SMS communication for alerts. Motion and RFID sensors enhance security and streamline book borrowing processes. Actuators such as the servo motor SG90 and relay modules control environmental parameters and activate devices like humidifiers and alarms. The MQ-2 gas sensor enhances safety by detecting gas leaks. (as shown in Fig. 30). This integrated system prioritizes user comfort, safety, and operational efficiency within the library environment.

Most important sensor and actuator: The DHT-11 sensor operates on a thermistor, measuring temperature by detecting changes in electrical resistance as temperature varies. It also includes a humidity-sensing component. This sensor contributes crucial data for maintaining optimal environmental conditions within the smart library, enabling precise temperature regulation and humidity control. The spray ultrasonic humidifier utilizes high-frequency vibrations to produce a fine mist of water, effectively increasing humidity levels as required.

Sensor feedback system leveraged by the smart library for both temperature control and book management. Temperature sensors trigger adjustments like window opening with servo motors based on temperature differences. Scanning RFID tags on users and books instantly identifies them, automating borrowing and returns. This feedback loop updates a central database, streamlining the process and providing valuable circulation data.

The **voltage divider** circuit is utilized to step down the voltage from the Arduino TX pin to the SIM800L RX pin, ensuring compatibility between the two components. It consists of a 10K resistor connected in series with the TX pin and a 20K resistor connected between the RX pin and ground. Additionally, a **diode trick** is employed to reduce the voltage from 3.3V (at the junction of the resistors) to 2.6V for the SIM800L RX pin, enhancing signal stability and preventing damage to the module.

Power supply: The Smart Library system operates at a total voltage of 7.4V, derived from the highest voltage source in the system. The power consumption, approximately 22.8W, is calculated by summing the product of voltage and current for each component: 14.8W (7.4V * 2A) for the Arduino and 8W (4V * 2A) for the SIM800L module (ME.2.06). Optimizing power usage involves efficient component selection and power management strategies.

Humidity affects the temperature in smart library projects utilizing a feedback system that increases humidity to effectively regulate temperature. As the humidity rose from 10% to 16%, the temperature notably dropped from 34.5°C to 31.5°C. This phenomenon is attributed to evaporative cooling, where the process of water vaporization absorbs heat, thereby reducing the ambient temperature.

In a **lithium-ion battery**, during charging, lithium ions move from the positive electrode to the negative electrode through the electrolyte, represented by the equation: $LiC_6 \rightarrow Li^+ + 6C + e^-$. Conversely, during discharging, the lithium ions move back from the negative electrode to the positive electrode, represented by the equation: $Li^+ + CoO_2 + e^- \rightarrow LiCoO_2$. (CH.2.09)

LEARNING TRANSFER

ME.2.06	Studying power will help us in determining the amount of energy transferred to the machines used in the industrial processes and the rate at which that energy is transferred (power)
ES.1.05	Sandstone is the main building material of our library.
CS.2.05	We have studied the concept of loops (feedback) in programming languages, where a certain action is repeated as long as a certain condition is true.
PH.2.11	We used a step down and step up transformers to control the volt entering different devices
MA.1.03	Learning about calculating volume of regular shapes so we could calculate the volume of our house
CH.2.09	The building depends on lithium-ion batteries that is rechargeable to store the electric energy of the solar cell.

CONCLUSION

Our integrated library and warehouse system combines comfort, safety, and sustainability. Sandstone walls maintain a cozy indoor climate while access to the warehouse is controlled through capacitive touch switches for enhanced safety. A gas sensor swiftly identifies fire hazards, triggering a water spray system for prompt extinguishing. Our solar panel tracking system, using two light dependent resistors (LDRs), maximizes energy generation by adjusting panel position according to the sun's movement. Additionally, we've incorporated a green roof, further enhancing sustainability by reducing heat absorption and stormwater runoff. An RFID system at the library entrance facilitates automatic book borrowing, ensuring accurate record-keeping and security. Overall, our system offers a safe, comfortable, and environmentally conscious space, fulfilling modernity and sustainability goals.

RECOMMENDATION

As there is no perfect person, there isn't a perfect project. We recommend that every organization or team who wants to improve this prototype to follow some recommendations that we couldn't do due to lack of time and materials, we recommend

- **Integration of Camera Module for Enhanced Security:** Incorporating facial recognition technology via a camera module boosts security by precisely identifying individuals entering the warehouse, dissuading unauthorized access, and offering proactive surveillance capabilities.
- **Soil moisture sensor:** Consider integrating a smart irrigation system with soil moisture sensors for the green roof, ensuring optimal plant health and water conservation.
- **Isolated Materials for Roofing:** Utilizing thermoplastic polyolefin (TPO) roofing under soil or grass offers superior insulation and durability, promoting energy efficiency and long-term cost savings while also contributing to environmental sustainability.
- **Using The Raspberry Pi:** The Raspberry Pi is a tiny but potent computer perfect for education and hobby projects. Its credit card size hides powerful capabilities, from learning programming to DIY electronics. Affordable and versatile, it's beloved by students, hobbyists, and pros alike.
- **Robust Cellular Connectivity:** Smart library placement requires strong cellular signals to support SIM800L module operations, enabling seamless communication between Arduino and the central processing unit.

LITERATURE CITED

Fedkin, M., & Dutton, J. A. (n.d.). 1.2 Efficiency of Conversion | EME 812: Utility solar power and concentration. PennState College Earth and Mineral Sciences. https://www.e-education.psu.edu/eme812/node/4

Francis, L. F. M., & Jensen, M. B. (2017). Benefits of green roofs: A systematic review of the evidence for three ecosystem services. *Urban Forestry & Urban Greening, 28*, 167–176. https://doi.org/10.1016/j.ufug.2017.10.015

Giancoli, D. C. (2015). *Physics: Principles with applications* (7th ed., Vol. 1). Pearson Education.

Louis, L. (2016). Working Principle of Arduino and Using it as a Tool for Study and Research. *International Journal of Control, Automation, Communication and Systems, 1*(2), 21–29. https://doi.org/10.5121/ijcacs.2016.1203

Qisti, Q. N., Abdullah, N., & Ahmad, K. A. (2023). Enhanced solar tracking system using Internet of things technology. *Platform journal* 7(4), 2. https://doi.org/10.61762/pajevol7iss4art25232

Yang, T., & Clements–Croome, D. (2018). Natural ventilation in built environment. *Sustainable Built Environments* (pp. 431–464). Springer. https://doi.org/10.1007/978-1-0716-0684-1_488

FOR FURTHER INFORMATION

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