Chapter 80
Electronic Sustainability in Libraries With Microcontrollers: Applications

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ABSTRACT

Electronic sustainability can be achieved using simple microcontrollers by saving energy, time, and manpower and safeguarding the resources from accidental or intentional loss. Implementation of such an electronic framework does not require huge investments or special skills but will save a lot on automating simple tasks basically micro-computers that can be programmed to control operations with endless day-to-day applications. Arduino microcontroller is used widely in making mini projects that can be effectively connected to systems for better electronic governance in libraries like avoiding theft, saving electricity, saving water, data streaming, live system allocation, automatic system shut down, scheduler, etc. Their applications can be broadened by our own creativity. Electronic components in the form of switches, buttons, sensors, etc. work as input devices. Motors, lights, buzzers, display boards, etc. can be used as visual and sound output devices. All the software is available from Arduino DLE free library, and the components are easily customizable and connectable.

1. INTRODUCTION

Arduino Uno microcontrollers are compact and easily programmable, offering a wealth of freely available software codes within the Arduino Community. These codes are customizable to suit individual needs. The controllers are both cost-effective and reprogrammable, providing a replaceable solution with versatile functionalities that seamlessly integrate into various projects. One notable feature is their multiplatform compatibility, distinguishing them from other controllers.

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Given that most modern computers lack serial ports, Arduino Uno's adaptability stands out. Even beginners can program it through a USB cable, eliminating the need for a dedicated serial port. This adaptability extends to customization, as controllers can be tailored and operated using open-source software, complemented by downloadable circuit diagrams.

The use of basic and inexpensive components, coupled with essential tools and a touch of creativity, allows for the execution of simple projects. This not only fosters experimentation but also enhances library efficiency. The affordability and replaceability of components further contribute to the accessibility and popularity of Arduino Uno.

The Arduino project goes beyond traditional compiler tool chains, offering users an integrated development environment (IDE) for a user-friendly coding experience. Additionally, a command line tool developed in Go provides an alternative for those who prefer command-line interfaces or seek automation in their projects (Arduino Playground - DHTLib, n.d.; Team, n.d.).

2. BACKGROUND

Libraries, being user and service centric, has lot of commitments at different levels of skills. Many slight skilled work like turning on and off lights, computers, printers, internet connectivity, sensors, cameras etc. Few regular jobs like watering plants, adjusting the moisture control, air conditioning, allotting systems to users etc. which are too labourious still very simple tasks. These labourious tasks do not need any sill set but claims time and labour. Therefore, automating these simple tasks with systems that are too easy to handle, especially without any help of a professional body will save time and energy which has direct impact on economic and efficient use of human and other resources.

3. WHAT CAN ARDUINO DO IN LIBRARIES?

Arduino can be used in libraries in:

1. Theft detection and control
2. Live system access time management
3. Automatic on and off lights
4. Flood alarm
5. Fire alarm
6. Intruder alert and alarm (Kalpana et al., 2022)
7. Auto watering system for plants
8. Air conditioner - Automatic on and off with Moisture control
9. Automatic temperature monitor
10. Solar panel data streamer
11. Parking lot management

4. DEVICES

Arduino Microcontroller boards are available in different types and versions according to its functionality and purpose.

- Arduino Uno
- Arduino Pro
- Arduino 101
- Arduino Mega 2560
- Arduino Zero
- Arduino Due
- Arduino Gemma
- Lilypad Arduino, etc. (50 cool arduino projects for February, 2023; Team, n.d.)

5. POWER SOURCES

1. USB cables
2. Batteries
3. External power supply with an adapter

6. ARDUINO LIBRARIES: IDE INTERFACE

Software requirements are just a click away.

Step No. 1. Plug the USB cable to micro-computer
Step No. 2. Select the program according to the requirement
Step No. 3. Copy the software coding from the libraries. Software patches/packages can be downloaded from www.Arduino.cc for free or from the link https://playground.Arduino.cc/Main/DHTLib/ (Cloud, 2023)
Step No. 4. Customize according to requirement, if any.

7. BASIC COMPONENTS WITH DEFINITIONS

7.1 Bread Board

Breadboards are flat plastic-framed boards employed for connecting electrical components such as capacitors, resistors, buzzers, LED lamps, and more. They eliminate the need for permanent soldering, utilizing numerous small sockets that are electrically interconnected and organized on the board.

7.2 Jumper Wires

Jumper wires consist of simple connecting wires with connector pins at each end. They play a crucial role in establishing connectivity, linking Arduino board header pins to a breadboard or directly to output devices. The use of jumper wires reduces the reliance on bulky cables, saving time in multiple connections and soldering processes. These wires are versatile and can be employed to connect various electrical components such as motors, switches, and electrical circuits.

There is a variety of jumper wires available, categorized by connector ends, including male-male pins, male to female pins, and female to female pins. This diversity facilitates adaptation to different connecting components. The male connectors are commonly known as plugs, while the female connector pins are referred to as jacks. Some jumper wires are equipped with both plug and alligator clip ends in certain situations. Additionally, square head and round head connector pins are options to be considered and chosen based on specific requirements or suitability for a given application.

7.3 USB Wire for Data Transfer and Power Source

USB pins serve the purpose of transferring data from the system to the Arduino board, along with providing regulated power. Typically, type A/B pins are predominantly utilized for this function. However, in more recent editions, type C pins have also been incorporated for these tasks.

8. ACCESSORIES AND UTILITIES

8.1 Input Devices

Arduino receives data from various input devices, which is then processed through the chip. Inputs, such as gestures, moisture, heat, sound, movement, etc., play a crucial role in the information processing, ultimately leading to the generation of the desired output.

1. Motion sensor

Passive Infrared sensors are employed for detecting live movement, particularly from objects like humans and animals that emit infrared radiation. The sensitivity, range, and size of motion sensors vary based on the manufacturer, adaptability, and specific requirements. Typically, these sensors are equipped with two potentiometers to fine-tune delay time and sensitivity. It's important to note that they may not detect moving toys or robots, only responding to humans or animals in motion.

Certain areas in libraries, such as the reference section, stack area, and restrooms, experience less frequent use and lower foot traffic compared to academic sections or maker spaces. In these underutilized spaces, inefficient energy consumption occurs with continuous operation of lighting and air conditioning. To address this, it becomes imperative to turn off electronic fixtures when not in use. However, regular manual monitoring by library staff proves challenging. The strategic installation of motion sensors in areas with lower traffic, such as staircases, toilet entries, and less frequently visited spaces, facilitates the automatic activation and deactivation of fixtures as needed. This not only conserves electricity but also reduces the need for manual intervention, resulting in energy savings and increased operational efficiency.

Within the library context, certain floors, such as the reference section and stack area, witness frequent use in contrast to sections like hot reads, new arrivals, or academic spaces. The manual management of lighting and air-conditioning in these well-utilized areas remains a common practice. To optimize energy usage and relieve library staff of unnecessary tasks, the introduction of motion sensors in less frequented areas, including staircases, proves beneficial in conserving electricity.

Another aspect to consider is the energy consumption of computers, even when in sleep mode. To prevent electrical wastage, it is recommended to power off computers when not in use, where feasible. Additionally, sensors can be employed to automatically switch off other electrical equipment, such as printers and computers, during prolonged periods of inactivity. While users can contribute by manually performing these actions, effective monitoring by library staff ensures the sustained success of these energy-saving measures (Kalpana et al., 2022).

2. Moisture sensor

The moisture sensor finds practical application in the maintenance of indoor plants and gardens within the library setting, offering a solution to reduce manual labor and prevent water spillage during watering activities. This sensor gauges the water content in the soil using two sensing probes, measuring moisture through variations in resistance between the probes. As moisture levels rise, conductivity decreases, and vice versa. Green roofing, walls and indoor planting monitoring can be done with arduino moisture sensor system for automating the water supply to the plants installed in building's roof as part of a green roof, sometimes referred to as a living roof, vertical gardens are small pots arranged vertically parallel to walls with small plants, small potted plants that can thrive with limited light, water and maintenance. There are many advantages to integrating a green setting in libraries, both in terms of the ambience, environment and functionality.

Setting a green roof, vertical garden and potted plants in library will enhance the ambience, air quality and soothing climate. But maintaining such infrastrucres are quite labourious and automating it with arduino controllers with moisture and air quality sensors, it minimizes the labour. Moreover, water saved from rain water harvesting system can be connected to this moisture sensor system which automatically waters the plant when needed.

3. Intrusion sensor

Libraries may have areas with camera blind spots, windows, and doors that are challenging to monitor manually, creating potential opportunities for intrusion by animals like monkeys, unauthorized individuals, or theft of resources. To enhance security, implementing an Arduino intrusion alert system in these vulnerable locations can provide an alarm when tampered with. This proactive approach helps prevent intrusion, and the accompanying buzzers act as a deterrent to ward off potential threats (Chris, 2021).

4. Heat, smoke or flame sensor

Depending on the installation site, particularly in libraries, the deployment of these sensors becomes crucial. Heat, smoke, and flame detectors play a pivotal role by interrupting the circuit, triggering alerts, and sounding alarms within the system to prevent physical damages or the loss of resources, especially

in unmanned environments. Fire accidents can result in the significant loss of valuable materials and resources.

5. Flood or water sensor

It is crucial to safeguard important areas in libraries, such as those housing stacks, rare resources, and computer peripherals, from water seepage or flooding. Beyond rainfall, flooding in buildings can occur due to seepage or ruptures in water supply lines, common occurrences in daily life. To prevent potential accidents, water sensors activate alarms within the system when they come into contact with a specified or predetermined water level. This proactive measure helps mitigate the risk of water-related incidents.

6. Moisture sensor for air conditioning

Libraries and museums, equipped with humidifiers and air conditioners, necessitate manual adjustments corresponding to weather, humidity, and climatic changes. In regions prone to frequent climatic fluctuations, these institutions require vigilant monitoring and hands-on intervention. This is vital because atmospheric moisture variations can adversely affect printed resources, paintings, and artifacts, impacting their quality and longevity.

To tackle this challenge, moisture sensors offer real-time information on atmospheric moisture levels, triggering system alerts and adjusting components accordingly. The system also issues alarms based on predefined parameters. The implementation of an Arduino moisture sensor system proves advantageous by minimizing the need for manual oversight and avoiding costly or complex installations. The DHT-22 (also referred to as AM2302) is a noteworthy digital output sensor that measures relative humidity and temperature. It employs a capacitive humidity sensor and a thermistor to assess the surrounding air, transmitting a digital signal to the data pin. (7)

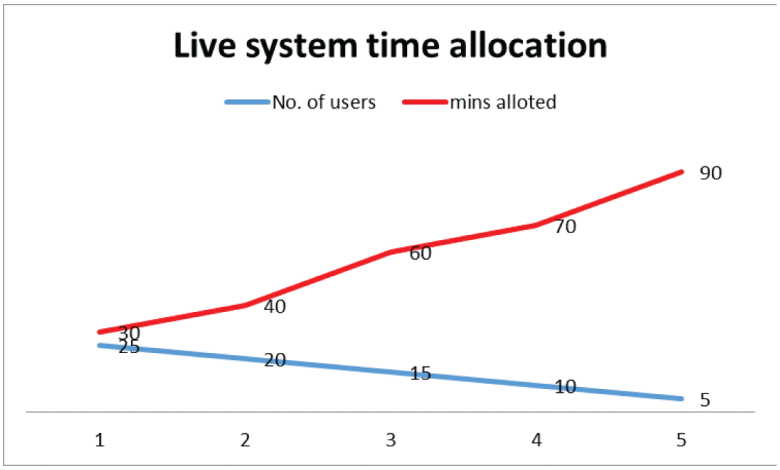
The serial monitor prints the room temperature and humidity. Relative humidity is the ratio of water vapor in the air to the saturation point of water vapor. At the saturation point, water vapor begins to condense, forming dew on surfaces. The saturation point varies with air temperature. Colder air has a lower capacity for holding water vapor before saturation, while hotter air can accommodate more water vapor. This concept can be scaled up for a weather monitoring system, measuring temperature and moisture in specific and larger landscapes, especially in the context of museums.

7. Real time Timer

Libraries provide computer systems for users to access electronic resources, emails, references, etc. Policy decisions are typically based on fixed access times determined by the ratio of available systems to the number of users. When users reach their allocated time limit, the system alerts them to conclude their work. However, in practical scenarios, not all computers may be in use throughout the access period. Formulating policies based on the fixed ratio of systems to the student population may not be effective. Policies need to be dynamic, adjusting to the current demand.

To address this, real-time information about computer availability can be communicated to users through online library portals. This allows users to plan their work more efficiently. Installing sensors in library sections such as computer areas, maker spaces, and reference sections facilitates the collection of real-time data on user entry and resource availability. This information empowers the library

Figure 1. Proportional live timing allotment according to no. of user's request



management team to allocate computers and other resources in real-time, with the flexibility to extend usage during non-peak hours and vice versa.

8. Parking Slot management

Upon entering the library parking area, a system equipped with object sensors can showcase real-time parking space availability on a display board. When a parking spot is occupied, the corresponding slot will be highlighted on the board, aiding drivers in locating an available space. The system is in the process of incorporating image processing for enhanced guidance. Additionally, ongoing efforts include the development of a payment management system and route guidance features for a more comprehensive parking experience at the library (Nandyal et al., 2017; Tarun et al., 2019).

9. Data streamer

Microsoft Excel proves to be an advantageous tool for data visualization and analysis. With the incorporation of the Data Streamer add-in, users gain the capability to import, view, and analyze real-time data sourced from external devices, such as the Arduino microcontroller. This feature enhances the accessibility, affordability, and user-friendliness of gathering data from sensors, catering to a diverse range of applications. The Data Streamer, available at no cost with Office 365, retrieves values from your computer's serial port, utilizing the same method employed by the Arduino IDE Serial Monitor for data printing. Enabling Microsoft Excel O365 with Data Streamer is essential for leveraging these functionalities (Tarun et al., 2019; Team, n.d.).

Analyzing data from solar panel control provides insights into power generation capacity, utilization, grid connectivity, and NET meter usage. This information is instrumental in monitoring, planning, cleaning, and maintaining the entire solar system, including its components and peripherals. Furthermore, the generated solar power can be seamlessly integrated into the grid, offering redemption for energy utilization and delivering direct economic benefits. The implementation of Arduino-based monitoring

and alerting systems for solar panels aids in effectively managing the infrastructure and optimizing overall efficiency (50 cool arduino projects for February, 2023).

10. Air Quality Monitor

Air Quality monitor can be installed in libraries which enables to check and monitor the air quality especially presence of unsafe levels of gas like carbon monoxide. MQ7, Mega versions of arduino sensors are used as air quality sensors as libraries are prone to have chemical pollution in air from the printing ink and binding materials used in book binding and furnitures (Harsha et al., 2023).

11. Rain water harvesting and waste water recycle monitoring

The process of gathering and storing rainwater that flows off of buildings, roadways, parks, and open spaces is known as rainwater harvesting. It is possible to store or restore the groundwater via this runoff of water and align with the environmental conservation initiatives. Several applications of water collected from rainwater harvesting systems are toilet flushes, watering plants in green roof, indoor plants etc., condensing system in air conditioning systems, used as potable water for drinking by connecting to water purifier systems.

8.2 Output Devices

Input devices in libraries primarily consist of sensors and data streamers. On the other hand, output mechanisms predominantly involve LED lights with distinct colors for various indications, buzzers offering customization options, and the widespread utilization of data streamers. Alerts and alarms play a critical role in physical applications, serving to prevent accidents or losses. Concurrently, data collected through data streamers are formatted into Excel sheets, facilitating the monitoring and regulation of library resources.

9. RECENT ADVANCEMENTS

1. Wi-fi access control

The Arduino Wi-Fi access control system facilitates connectivity to a Wi-Fi router through a network of sensors, a clock, and power supply components. This allows for the collection of data directly onto your cellphone. The access data proves valuable for effectively managing the power supply of the Wi-Fi router, enabling automatic shutdown based on predetermined timings. Additionally, it serves as a protective measure against short circuits, electrical accidents, intrusion, and hacking when the router is not in active use.

2. RSS reader

The RSS reader retrieves feeds and showcases them on LCD panels powered by an Arduino Nano RP2040 Connect equipped with onboard Wi-Fi. Customizing features such as emails, web pages, etc.,

requires a level of understanding and programming expertise for effective utilization of this module (Ayyub, 2012).

3. Smart bin

Many libraries feature RFID-enabled smart bins. In contrast to RFID technology, Arduino projects are simpler, more cost-effective, and can perform similar functions. With advanced chips and software, Arduino projects can seamlessly integrate into existing RFID infrastructure coding.

4. Voice detection and control

In recent advancements, Internet and communication technologies are increasingly exploring the integration of Arduino for voice recognition in detecting verbal commands. Research and updates in this area are currently trending as experts seek to enhance and optimize the utilization of Arduino (Rajkanna et al., 2014; Vanitha et al., 2021).

5. Automated book handling system

The control system is enacted using a physical device, typically grounded in mathematical logic to achieve the desired counts. In this project, Arduino Mega is employed to establish the necessary control, leveraging RFID technology. A CAD design is created, and the essential robot for automation is constructed. Consequently, by developing an autonomous robot, the time needed for book handling is minimized, ensuring the safe management of books. This approach also leads to a reduction in material handling costs with a decrease in manpower requirements (Kalpana et al., 2022; Vadivel Vivek et al., 2020; Kalpana et al., 2023).

10. OPERATION CONTROLS

Arduino systems can be controlled through the following:

1. Gesture control

Gesture-controlled systems interpret hand movements, such as the stop gesture, as controls. Rather than relying on traditional input devices like a keyboard, mouse, or joystick, hand gestures can be employed to command specific functions on a computer. This includes actions like playing/pausing a video, navigating left/right in a photo slideshow, scrolling up/down on a web page, and various other functionalities (Agrawal & Gupta, 2016; Kashif, 1969; Margolis, 2011; Sriskanthan et al., 2002).

2. Cell phone control

In Smart Home projects, the Internet of Things (IoT) is predominantly utilized, with Arduino controllers embedded in standalone devices such as refrigerators, air conditioners, microwave ovens, etc. These

installations are interconnected via Bluetooth, integrated, and controlled through Android applications on smartphones (Margolis, 2011; Nandyal et al., 2017; Nayyar & Puri, 2016).

3. Clock control

Automated control of electrical fittings such as lights, fans, air conditioners, and class timing buzzers can be achieved by integrating Arduino chips with a clock programmed with fixed timings. This automation proves highly beneficial in minimizing the need for manual checks on lights floor-wise, reducing the likelihood of manual errors, and preventing potential short circuits during holidays.

11. ADVANTAGES OF ARDUINO MICRO-CONTROLLERS

1. Easy to learn and use

Arduino projects are highly popular in school assignments, primarily because they are easily approachable for beginners without requiring any prerequisites or advanced technical skills. Arduino boards are user-friendly and can be utilized with minimal programming knowledge. They use a simplified version of the C/C++ language, making it easily comprehensible for customization. This makes Arduino an ideal platform for beginners, as all programs are available in a plug-and-play model. Novices simply need to grasp the project concept and select the desired program from the library.

2. Inexpensive Hardware

The fundamental Arduino board, along with accessories like jumper wires and a breadboard, does not necessitate sophisticated tools for connection and is available at a low cost. In contrast, employing similar technologies through professional service providers incurs higher expenses in terms of equipment, installation, and annual maintenance. Recent Arduino boards come equipped with Wi-Fi and GSM for connectivity, enabling the sharing of instant alerts and messages for prompt action.

3. CommunityBased Software

The Arduino user community serves as a comprehensive resource for addressing nearly all issues, challenges, and adaptability concerns. With numerous researchers consistently contributing to its development, a wealth of information and solutions is readily available. Consequently, when a problem is reported, guidance or solutions can be easily obtained instantly, and this assistance comes without any financial commitment.

4. Cross Platform Support

Arduino boards are compatible with various platforms, including Linux, Mac OS, and Windows. The selection of board versions and the appropriate programs, along with their components, should be undertaken with care and a thorough understanding of the requirements.

5. Tons of Libraries

Arduino boards are versatile enough to handle complex projects where multiple programs are interconnected. However, to link numerous projects together, some programming knowledge is essential to comprehend the guidance provided by the Arduino community (Nayyar & Puri, 2016).

12. BARRIERS

While Arduino boards have a lot to offer, they are not always the optimal choice, as they come with certain drawbacks. Here's a brief description of a few limitations associated with Arduino:

1. Lack of Multitasking

Multi-tasking remains a challenge in Arduino as it tends to slow down the overall process. Each input and output must be processed through all lines of code when engaging in multi-tasking. While this hurdle can be addressed by implementing program loops, it does require a certain level of programming knowledge. In comparison to boards like Raspberry Pi and other similar platforms, Arduino exhibits slower multi-tasking capabilities.

2. Not Optimized for Performance

Power efficiency poses a challenge when using Arduino boards, but this can be addressed by implementing optimized power-saver mode programs.

3. Limited Support for Programming Languages

Arduino boards are primarily programmed in the C or C++ language, and it lacks inherent support for cross-programming languages. While Arduino doesn't directly support Python with its integrated development environment (IDE), it can still be programmed using open-source libraries such as pySerial (Kashif, 1969).

4. Less Memory Storage Capacity

Handling complex data involving images or engaging in big data tasks with image processing, particularly in robotics or large-scale industrial projects like automating production processes, is considered a sophisticated undertaking. Arduino faces limitations in memory storage, making it challenging to manage such intricate programs effectively. The Arduino UNO, for instance, offers only 2kb of SRAM and 32kb of flash memory, capable of storing sketches with a limited number of coding lines. This constraint restricts Arduino's applicability in projects with demanding functionalities (Chris, 2021).

According to Foley & Rodger (2023), nine waves of SC sustainability have been identified in the context of zero-point entropy. These waves encompass leadership, reporting, energy conservation, certification, SC management integrity, guiding design development, economic principles, political principles, and

Figure 2. Sustainable technologies and its integration with Arduino in Libraries

social principles, all serving as drivers of zero-point energies within the supply chain (Kalpana et al., 2023). A statistical analysis considering factors such as energy requirements, energy production, actual usage, installation costs, economic maintenance vis-à-vis the lifespan of installations, and environmental impact can contribute to the integration of sustainable technologies.

13. INTEGRATION OF ARDUINO INTO LIBRARY FUNCTIONS, COUPLED WITH NATURAL RESOURCES AND SUSTAINABLE TECHNOLOGIES

1. Utilizing solar panels as a power source connected to Arduino allows for real-time monitoring of solar panel data and simultaneous power supply to Arduino systems. Energy generated can be stored in batteries for future use or directly utilized for electrified devices.
2. Arduino's capability to control water levels in indoor plants facilitates efficient water usage, especially when harvested from rainwater harvesting systems.
3. Indoor air quality can be improved by employing indoor plants to naturally cleanse the air from printing and binding chemicals emitted by books. Selecting plant species that thrive with limited sunlight serves both ornamental and functional purposes.
4. Implementing Arduino controllers in indoor water pools, water plants, and fountains offers a luxurious and functional environment, with water level monitoring and automatic watering systems enhancing efficiency.
5. Arduino chip installations can effectively monitor green roofing, vertical and hanging gardens, minimizing hardware, installation, and maintenance costs associated with air-conditioners.
6. Rainwater harvested from civil structures can be stored, recycled, and repurposed for watering plants, toilet flushes, and other applications.
7. Light shelves synchronized with the sun's orbit bring in natural light, reducing the need for electricity-based lighting during the daytime.
8. Glass panels, controlled by sun blinds, enhance natural lighting in reading areas, providing users with adjustable illumination.

9. Integration of entry and live system allocation, linked to the library website, allows users to check the availability of individual systems in real-time, facilitating better planning based on system numbers and time availability.
10. Automating day-to-day operations, such as turning on and off fixtures, alarms, and printers through motion sensors, significantly reduces energy consumption and labor requirements, freeing skilled manpower for more essential library tasks.
11. Flood and fire alarms, powered by solar energy and monitored by Arduino, enhance library resource protection.

14. INTEGRATION OF PRACTICALLY FEASIBLE AND SIMPLE TECHNOLOGIES

- Save from allotted budgets
- Create a pictorial and healthy ambience
- Calm and soothing environment brings in more users and thus justifies its physical existence as a place of community well-being
- Can mark a positive footprint against global warming and carbon emission

15. IMPACT OF ARDUINO IN LIBRARY SUSTAINABILITY

A library serves as a space where knowledge is not only created but also shared and utilized. Such environments must align with the user's needs, fostering productivity through comfort, ample resources, flexibility, and a human touch. However, in recent years, there has been a shortage of resources such as skilled and well-trained staff, and libraries are increasingly expected to generate their own resources.

Given this scenario, it becomes crucial for libraries to focus on sustaining resources like electricity, water, and skilled manpower to enhance efficiency. The challenge is to overcome fund limitations that may otherwise impede resource availability. Implementing sustainable measures, such as automating simple tasks using low-budget infrastructures, can contribute significantly to environmental conservation and mitigate the impact of global warming.

In addition, the introduction of automated vigilant monitoring systems and supervision plays a key role in maintaining discipline and managing resources efficiently. These systems provide enhanced protection against accidents, intrusion, and losses, ensuring a secure and well-managed library environment.

16. CONCLUSION

In conclusion, the library, burdened with substantial manual tasks that consume time and skilled labor, can benefit significantly from cost-effective automation techniques. Implementing such strategies not only enhances library services but also optimizes the utilization of human and material resources. Beyond being a space for academic knowledge, the library serves a broader purpose of resource sustainability, experimentation, and contributing to nature through efficient resource usage, conservation, and maximizing allotted resources.

Looking forward, Arduino boards present an exciting prospect for libraries, offering connectivity, security, and multitasking capabilities, especially in handling big data. This opens avenues for intensive research, creativity, and innovative applications within library operations. While some libraries have individually adopted nature-friendly technologies, the integration of multiple technologies requires special care in monitoring and maintenance. Arduino's implementation allows for the seamless integration of nature-friendly and resource-efficient practices, thereby enhancing managerial economies in libraries.

17. FUTURE RESEARCH DIRECTIONS

1. Evaluation of labour cost efficiency in terms of currencies on pre and post implementation of arduino control systems for intrusion sensing, motion sensing and automating the on and off of electrical devices.
2. Comparison of sustainable technologies that can economically develop the library with energy efficiency, water management, intrusion alert etc.
3. Evaluating the user experience in pre and post implementation of greenery in libraries in terms of energy efficiency, labour management, resource management and sustainability with automated arduino sensors.

REFERENCES

50 cool arduino projects for February. (2023). All3DP. Retrieved April 29, 2023, from https://all3dp.com/1/best-cool-Arduino-projects/

Agrawal, R., & Gupta, N. (2016). Real time hand gesture recognition for Human Computer Interaction. *IEEE 6th International Conference on Advanced Computing (IACC).* 10.1109/IACC.2016.93

Al Ahasan, M. A., Roy, S., Saim, A. H. M., Akter, R., & Hossain, M. Z. (2018). Arduino-Based Real Time Air Quality and Pollution Monitoring System. *International Journal of Innovative Research in Computer and Communication Engineering*, *6*(4), 81–86. doi:10.21276/ijircst.2018.6.4.8

Arduino Playground - DHTLib. (n.d.). Retrieved April 29, 2023, from https://playground.arduino.cc/Main/DHTLib/

Ayyub, P. B. I. (2012). *Gmail and RSS notifiers using the Arduino*. ATMega32 AVR. Retrieved April 29, 2023, from https://atmega32-avr.com/gmail-and-rss-notifiers-using-the-Arduino/

Chris. (2021). 8 advantages of Arduino over raspberry pi. *Chip Wired.* Retrieved April 29, 2023, from https://chipwired.com/Arduino-advantages-over-raspberry-pi/

Cloud, A. (2023). Retrieved April 29, 2023, from https://create.arduino.cc/

Das, L., Kumar, A., Singh, S., Ashar, A. R., & Jangu, R. (2021). IoT Based Weather Monitoring System Using Arduino-UNO. *2nd International Conference on Computation, Automation and Knowledge Management (ICCAKM)*, 260-264. 10.1109/ICCAKM50778.2021.9357748

Foley, B., & James, R. (2023). A Bayes Estimate Density Fuzzy Modular function for improving supply chain sustainability through blockchain entropy prediction. *Supply Chain Analytics, 4*. https://www.sciencedirect.com/science/article/pii/S2949863523000456 doi:10.1016/j.sca.2023.100046

Harsha, Naik, V, & M. (2023). Monitoring System for Safe Environment Air Quality. *IEEE North Karnataka Subsection Flagship International Conference (NKCon)*, 1-6.

Kalpana, T. M., Sivakumar, R., & Gopalakrishnan, S. (2022). Arduino Micro-controllers in Library Sustainability. *RRRLF sponsored SALIS 2022. National Conference on Transformation of Learning Resource Centre in Digital Era*, 204-208.

Kalpana, T. M., V, S., Jadhav, M., Satpathy, K., & S, G. (2023). Library Automation Sustainment With Arduino Micro Controllers. In D. Kar (Ed.), New and innovative libraries in digital era: Services and practices (pp. 419–429). Bookwell.

Kashif. (1969, May 1). *What are advantages and disadvantages of Arduino*. Retrieved April 29, 2023, from https://linuxhint.com/advantages-and-disadvantages-arduino/

Margolis, M. (2011). *Arduino Cook Book*. O'Reilly Media Inc.

Nandyal, S., Sultana, S., & Anjum, S. (2017). Smart Car Parking System using Arduino UNO. *International Journal of Computer Applications*, *169*(1), 13–18. doi:10.5120/ijca2017914425

Nayyar, A., & Puri, V. (2016). A review of Arduino board's, Lilypad's & Arduino shields. *2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom),* 1485-1492.

Rajkanna, U., Mathankumar, M., & Gunasekaran, K. (2014). Hand gesture based mobile robot control using PIC microcontroller. *2014 International Conference on Circuits, Power and Computing Technologies (ICCPCT-2014)*. 10.1109/ICCPCT.2014.7054886

Sriskanthan, N., Tan, F., & Karande, A. (2002). Bluetooth based home automation system. *Microprocessors and Microsystems*, *26*(6), 281–289. doi:10.1016/S0141-9331(02)00039-X

Tarun, P., Pradeep Chandra, T., Anil Kumar, G., & Yadav, S. (2019). Microcontroller rooted collaborative functioning system in vehicles. *2019 International Conference on Communication and Electronics Systems (ICCES)*. 10.1109/ICCES45898.2019.9002240

Team, T. A. (n.d.). *Getting started with Arduino*. Arduino Documentation. Retrieved April 29, 2023, from https://docs.arduino.cc/learn/starting-guide/getting-started-arduino/

Vadivel Vivek, V., Pradeesh, E. L., Natarajan, N., Pravin, M. C., & Raghavendra Prabhu, S. (2020). Development of a system to assist in library to automate the book handling process. *IOP Conference Series. Materials Science and Engineering*, *995*, 012018. doi:10.1088/1757-899X/995/1/012018

Vanitha, C. N., Sridhar, K. L., & Dhivakar, R. (2021). Automation of Noise Detection Using Internet of Things. *2021 6th International Conference on Inventive Computation Technologies (ICICT),* 184-189. 10.1109/ICICT50816.2021.9358628

ADDITIONAL READING

Kalpana, T., & Gopalakrishnan, S. (2014). Energy Sustainability through Renewable Sources in Libraries – A Study. *ScieXplore: International Journal Of Research In Science*, *1*(1), 58–63. doi:10.15613/sijrs/2014/v1i1/53856

Kalpana, T. M., & Gopalakrishnan, S. (2013). Self-Sustainability in Academic Libraries in the Digital Era. In S. Thanuskodi (Ed.), *Challenges of Academic Library Management in Developing Countries* (pp. 47–67). IGI Global. doi:10.4018/978-1-4666-4070-2.ch004