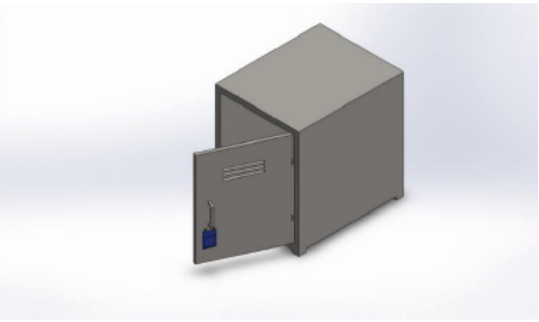
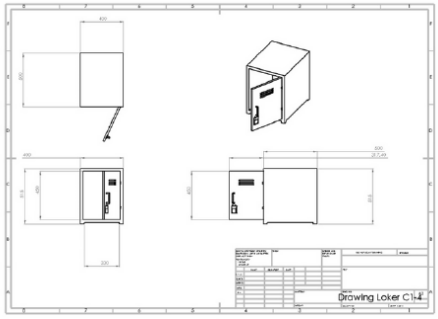
The Intellilock System: Revolutionizing Security and Convenience

In an increasingly automated world, I identified a crucial need for enhanced security and convenience in everyday infrastructure. Traditional lockers, common in educational settings like Parahyangan Catholic University's Building 8, often house valuable personal belongings. However, conventional metal locks pose significant vulnerabilities: they are prone to damage, easily duplicated, and lack real-time monitoring, leading to risks of theft and unauthorized access. This outdated system compromises security, creates inconvenience, and fosters frustration.

Driven by a passion for practical innovation, I spearheaded the development of **Intellilock**, a smart locker system designed to deliver superior security and user experience. This initiative transcended mere device construction; it involved leveraging cutting-edge IoT principles to create a tangible improvement in daily life, ensuring peace of mind for users and showcasing the profound benefits of smart manufacturing systems in a real-world context. The core objective was to overcome the limitations of traditional keys and provide a more secure, efficient, and user-friendly storage solution.**Intellilock: From Concept to Implementation**

The Intellilock project focused on utilizing and implementing a smart locker locking system powered by RFID technology. We aimed to evaluate how RFID, integrated with actuators like solenoids and indicators like LEDs, could effectively enhance security and efficiency in locker management within an educational environment. Furthermore, the project sought to demonstrate the seamless integration of these components to create a solution that is both secure and convenient for users, representing a significant advancement in security technology with strong potential for broader application.





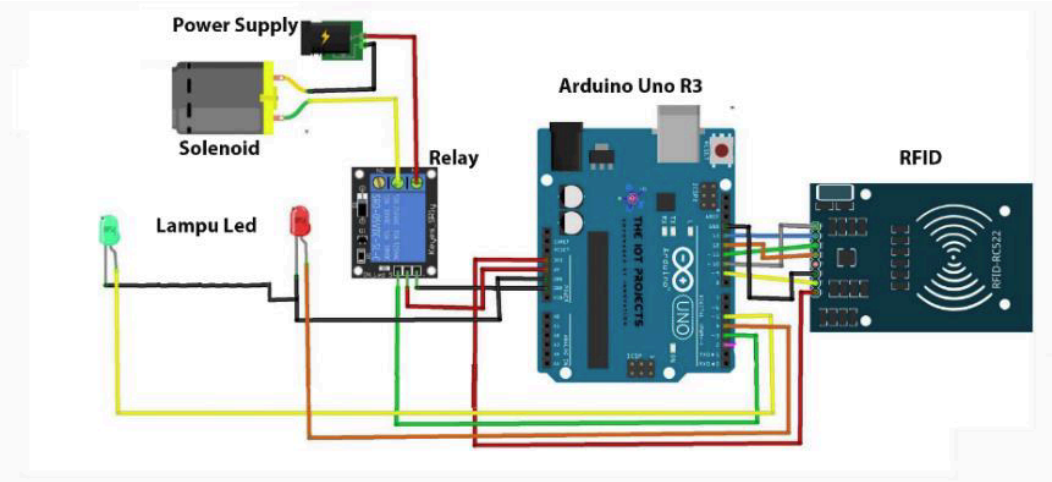
My process commenced with meticulous **product design**. Using **SolidWorks**, I developed the Computer-Aided Design (CAD) for Intellilock, ensuring precise dimensions for seamless assembly and component integration. This virtual blueprint was essential for visualizing the final physical product and its utility.

The Intellilock system comprises several interconnected components, each playing a vital role:

- **RFID Sensor (RFID-RC522):** Serving as the primary input, this sensor identifies users via radio frequency. The passive RFID tag, embedded in user cards, provides a unique, non-duplicable ID, significantly enhancing security over conventional keys. Its benefits include integration with existing ID cards (e.g., student/faculty cards), reducing the need for physical keys, and providing traceable data logs of locker access.
- **Actuators:**
    - **Light Emitting Diodes (LEDs):** These LEDs visually indicate the locker's status. A red LED signifies a locked locker, while a green LED illuminates when the locker is open or unlocked, aiding users in confirming the locker's state and preventing forced entry.
    - **Solenoid:** This electromagnetic component converts electrical energy into linear motion. Upon an authorized RFID card tap, the solenoid acts as an automatic lock, retracting to unlock the door and re-engaging to lock it when pushed shut.
- **Control Unit (Arduino Uno R3 Microcontroller):** The Arduino Uno R3 served as the central microcontroller, the "brain" of the Intellilock system. It processes programmed logic, manages sensor-actuator interactions, and controls all operations within the smart locker circuit.
- **Relay:** As an electromechanical switch, the relay enabled the low-voltage Arduino to control the higher-voltage solenoid, ensuring safe and effective power delivery.
- **Other Materials:** The prototype locker was constructed from wood, utilizing recycled furniture material to minimize costs during prototyping. Various tools such as screwdrivers, scissors, electrical tape, solder, tin, duct tape, screws, hinges, locker handles, and lock hooks were used for assembly. Cables and jumper cables facilitated electrical connections, along with resistors for current regulation. An LCD 16x2 was integrated to display the user's name.

The functional design was brought to life through a meticulously designed electrical circuit, visualizing the intricate connections between the Arduino and all components.

Intellilock System Circuit Diagram



The virtual circuit design facilitated the physical assembly. Crucially, Intellilock's entire functionality was driven by the **custom code I designed and implemented in the Arduino IDE**. This code acted as the central intelligence, orchestrating every action:

The code structure was organized into key sections:

- **Library Includes and Pin Declarations:** This section involved incorporating necessary libraries such as `SPI.h` and `MFRC522.h` for RFID communication, and `WiFi.h` and `HTTPClient.h` for network connectivity and data transmission. Pins for RFID, LEDs (green and red), relay, and a buzzer were defined. Constants for access/denial delays were also set.
- **Setup Function:** Here, initial hardware configurations were performed. This included starting serial communication, initializing SPI and the MFRC522 module, setting pin modes for LEDs and the relay as outputs, ensuring the relay was initially inactive, and establishing a **Wi-Fi connection**. This Wi-Fi capability was foundational for the IoT aspect of the project.
- **Loop Function:** This continuous loop served as the operational core. It constantly checked for new RFID card presentations, read the card's Unique ID (UID), and processed it. A critical part of this function was the **IoT integration**: the Arduino connected to a **Google Script URL** (e.g., `mainLinkForSpr`) to send the RFID UID and terminal name. It then handled HTTP GET requests and redirects to fetch access type and user names from the Google Sheets backend. Based on the response, it would activate the green LED and relay (if authorized) or the red LED (if denied). This allowed for real-time user validation and access logging in the cloud. The code also incorporated

Over-The-Air (OTA) updates, enabling remote firmware upgrades.

The **working mechanism** of Intellilock is straightforward yet robust: When a user taps their RFID card onto the reader, the RFID module sends the unique ID to the Arduino microcontroller. The microcontroller processes this ID based on the programmed logic. If the ID is authorized, the solenoid is triggered, automatically unlocking the locker. Simultaneously, the green LED illuminates, and the LCD displays the user's name, providing clear visual and textual feedback. If the ID is unauthorized, the solenoid remains locked, and the red LED illuminates, indicating denied access. The solenoid automatically relocks the door when it is pushed shut.

During prototyping and assembly, I encountered several practical challenges:

- **Product Exterior:** Integrating numerous cables from the Arduino resulted in a cluttered internal appearance, requiring meticulous routing to conceal power supply cables for a cleaner aesthetic. The chosen wood for the door also proved too thick, necessitating additional cutting.
- **Circuit Assembly:** The delicate pins of the LEDs were prone to breaking during assembly, and thin anode/cathode wires frequently detached from cables. Electrical tape was used to secure connections. The solenoid initially lacked sufficient power from batteries, requiring a constant 12-volt power adapter for stable operation. Jumper cables of varying head sizes also caused connection issues due to loose fittings, leading to frequent errors during testing. Furthermore, the narrow spacing of digital pins on the Arduino often led to incorrect pin insertions.
- **Coding:** While the code was designed to be modular (library includes, setup, loop), ensuring seamless Wi-Fi connectivity and stable HTTP requests to the Google Script required careful debugging, especially concerning SSL certificates and potential authorization issues with Google's API.

Project Conclusion: Tangible Impact and Developed Competencies

The Intellilock project concludes that it **provides enhanced security and convenience over conventional lockers by leveraging an integrated system of RFID, solenoid, and LED components. It represents a practical application of smart manufacturing principles that can significantly improve daily operations in educational institutions.**

From this project, I gained and honed the following skills:

- **Embedded System Design & Prototyping:** Gained hands-on experience in designing and building a functional smart device from concept to a working prototype.
- **Microcontroller Programming (Arduino):** Developed strong proficiency in C++ for Arduino, encompassing logical flow design, handling sensor inputs, controlling actuator outputs, and implementing communication protocols.
- **RFID Technology Implementation:** Acquired practical experience in implementing RFID modules for secure access control and user identification.
- **IoT System Integration & Cloud Connectivity:** Gained valuable experience in connecting hardware to cloud services (via Google Sheets/Scripts) for real-time data logging, user access management, and exploring remote management capabilities, demonstrating a foundational understanding of IoT principles.
- **Circuit Design & Assembly:** Enhanced practical skills in wiring electronic components, troubleshooting connectivity issues, ensuring stable power supply, and managing complex internal cabling.
- **CAD Design (SolidWorks):** Utilized SolidWorks to design the physical product, ensuring dimensional accuracy and facilitating the integration of all components.
- **Problem Solving & Troubleshooting:** Developed robust analytical skills in identifying and resolving various hardware and software issues encountered during development, from fragile components to communication errors.
- **Hardware-Software Integration:** Gained expertise in ensuring seamless communication and interaction between physical components (sensors, actuators, microcontroller) and the control program.

This project is not merely an academic accomplishment but also an invaluable practical experience in applying smart manufacturing principles and IoT concepts to solve real-world problems. It underscores my dedication to operational excellence and my capability to deliver impactful solutions that benefit users and organizations alike.