

Automatic Page-Turning Photocopier

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1. Introduction

1.1 Objective and Background

- **Goals:** This project aims to address inefficiency in traditional photocopiers designed for bound materials, which require human intervention for page turning. Additionally, this project can minimize human error caused by fatigue during repetitive turning-page tasks.
- **Functions:**
 - Automated Page Handling: A robotic arm with multi-linkage structure turns pages precisely and adaptive gripping mechanism accommodates varying paper thicknesses and textures.
 - High-Fidelity Document Capture: Using high-resolution camera to capture text/images without distortion and computer vision detects page edges and adjusts alignment dynamically.
 - Intelligent Environment Adaptation: Adjustable LED lighting compensates for shadows, glare, or uneven paper surfaces
 - User-Centric Control: A UI platform is designed for setting page ranges, scan resolution, output formats and showing real-time progress via display screen.
- **Benefits:** This project would significantly reduce manual effort and save time for scanning tasks. This automatic page-turning photocopier is available for a wide range of materials from fragile antique books to industrial blueprints. It also reduces the risk of wear-and-tear on delicate materials through gentle robotic handling.
- **Features:** This automatic page-turning photocopier is more compact and cost-effective compared to existing similar products. It is capable of capturing images of text and converting them into digital documents.

1.2 High-Level Requirements List

- The system must complete a single page-turning cycle within 20 seconds. This is measured from the moment a page is detected to the successful completion of the page flip. The efficiency of the automatic page-turning photocopier will be evaluated by averaging the time taken over 100 consecutive operations.
- This photocopier is required to produce scanned images with no significant shadows or reflections. This will be assessed by evaluating the page area affected by such artifacts under standard testing conditions.
- The robotic arm must be capable of handling documents with varying binding types and thicknesses (ranging from 0.05 to 0.5 mm per sheet). Its performance will be validated by ensuring successful handling of $\geq 95\%$ of bound materials without causing tearing or misalignment during operation.

2. Design

2.1 Diagrams

2.1.1 Physical Diagram

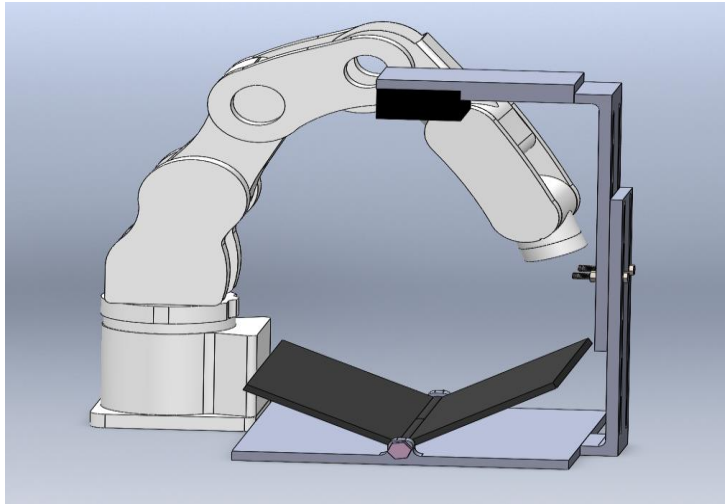


Figure 1. CAD1

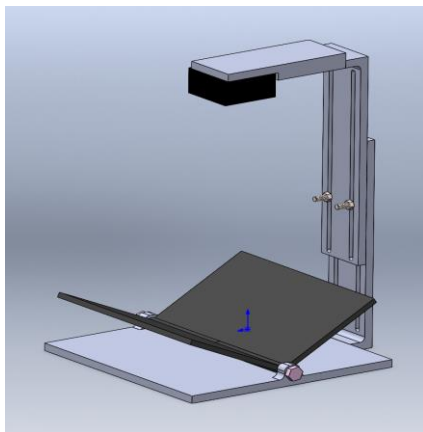


Figure 2. CAD2

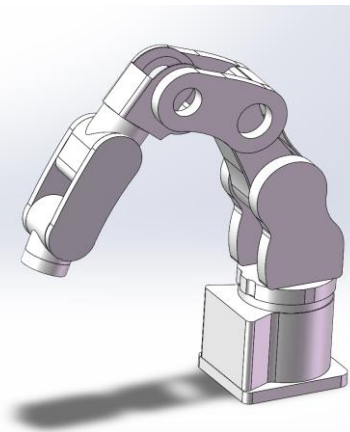


Figure 3. CAD3

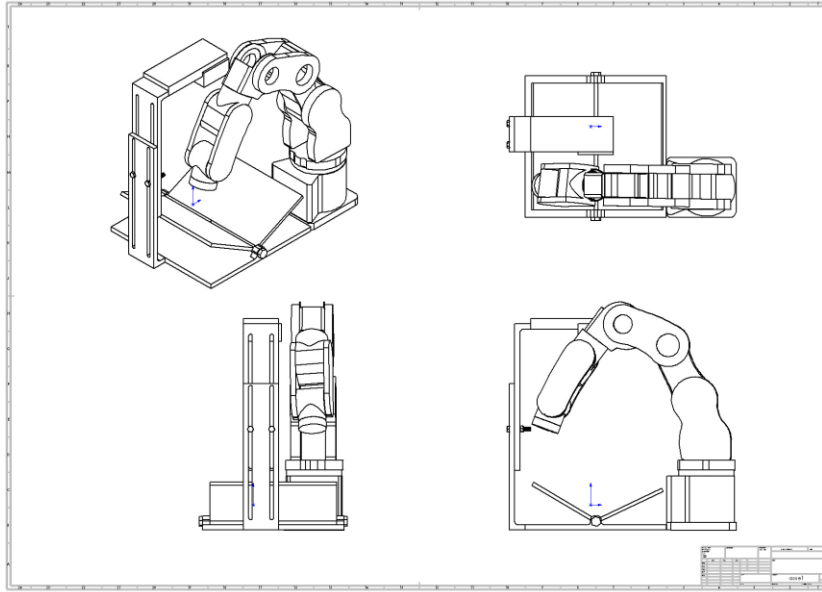


Figure 4. CAD 4

2.1.2 Block Diagram

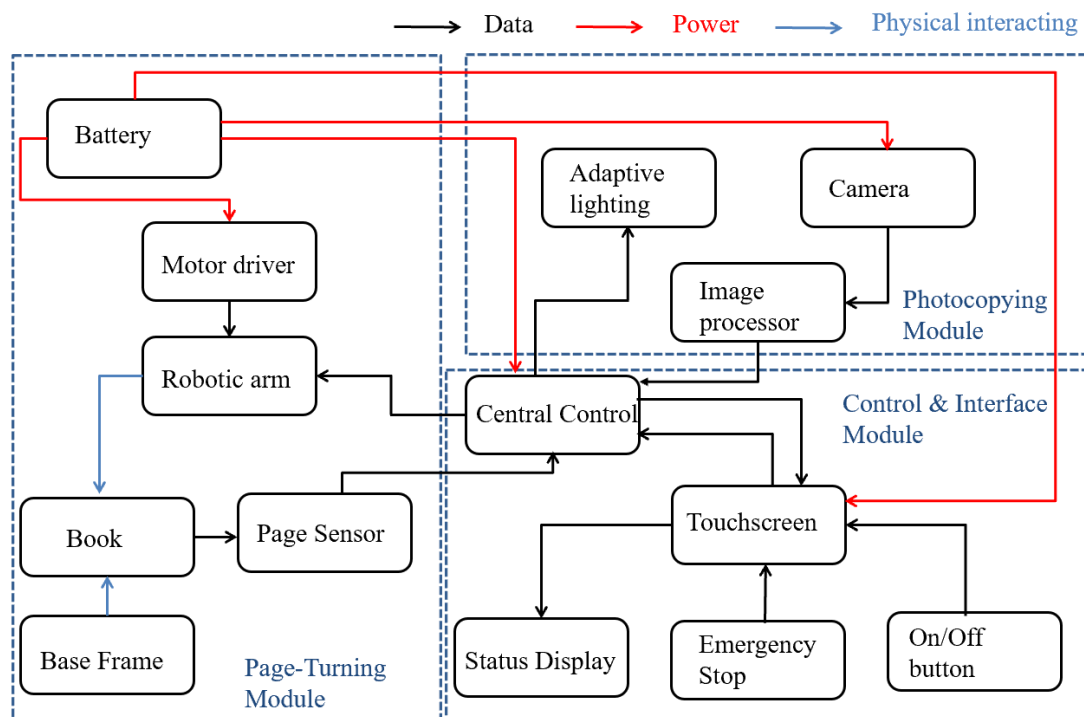


Figure 5. Block Diagram

2.2 Block Descriptions

This system automates photocopying with a Robotic Arm and Page-Turning Module, guided by a Page Sensor and Motor Driver. It includes a Camera and Image Processor for image capture, a Photocopying Module for copying, and a Touchscreen for user interaction. Safety features like an Emergency

Stop and Adaptive Lighting enhance functionality, all powered by a Battery and controlled via an On/Off button.

2.2.1 Page-Turning Module

The page turning module aims to physically turn one page of the book at one time by controlling robotic arm and mechanical frames through communication with the control & interface module. A battery power is used to power the motor which drives the revolution joint on robotic arm in this module. The robotic arm has six degrees of freedom so that it can reach the target position with various poses. When robotic arm receives signals sent from central controller, the robotic arm will move to the target position and the suction machine at the end of robotic arm would grasp one page and this page move with robotic arm to realize paging turning. The page sensor is installed in the base to detect the edge of the book and send signals to help the central controller improve image processing. The base, which is used to support books, is designed to be an inclined plane to make the page turning process easier.

- **Requirement 1:** The robot arm should finish every round within 6 seconds.
- **Requirement 2:** Only one page can be motivated at one time

2.2.2 Photocopying Module

The Photocopying Module is responsible for accurately reproducing the content of pages by capturing high-resolution images, processing them for clarity, and sending the final output. It communicates with the Control & Interface Module to coordinate the copying process and receives power from the Battery to operate the camera, image processor, and photocopying mechanism. The Camera captures the image of the page, which is then enhanced by the Image Processor to ensure clarity and accuracy. The processed image is sent to the Central Control, which then send the image to the screen for display. This module ensures that the copied document matches the original in quality and detail, contributing to the overall functionality of the automatic page-turning photocopier by providing a reliable and efficient copying process.

- **Requirement 1:** The camera must capture images with a resolution of at least 300 DPI.
- **Requirement 2:** The image processor should enhance images within 10 seconds.
- **Requirement 3:** The image processor must produce images with consistent quality and without smudging or misalignment.

2.2.3 Control & Interface Module

The Control & Interface Module serves as the central hub for managing and coordinating the operations of the automatic page-turning photocopier. This module consists of two submodules: the control module and the interface module. The control module processes user inputs from the Touchscreen and sends commands to the Motor Driver, Camera, and Image Processor to execute tasks such as page turning,

image capture, and showing results. It is powered by the power supply, and will disable the circuit if the battery voltage reaches critical levels. It is expected to draw approximately 50-80mA during operation. The interface module monitors system status and displays real-time information on the Status Display. By integrating user interaction and system control, the Control & Interface Module ensures the photocopier operates efficiently and responds accurately to user commands, contributing to the overall functionality by providing a user-friendly and coordinated experience.

Microcontroller

The microcontroller executes system logic and ensures seamless communication between different components. It interacts with the touchscreen interface via SPI to process user inputs and update display content in real time. It also communicates with the status display to provide feedback on the scanning process and system health. Additionally, to ensure safe operation, the emergency stop button and ON/OFF switch are connected to the microcontroller via GPIO pins, allowing immediate shutdown of system functions within 10ms.

- **Requirement 1:** This microcontroller should be chosen for its affordability and SPI clock speed of 12.5 MHz.
- **Requirement 2:** The microcontroller should communicate over UART and SPI simultaneously at speeds exceeding 4.5Mbps(each).
- **Requirement 3:** The GPIO pins should be capable of sinking or sourcing 10mA $\pm 5\%$ per pin at 3.3V $\pm 5\%$.
- **Requirement 4:** The module should provide real-time status updates on the Status Display with delay no longer than 1s.

2.3 Risk Analysis

The Page-Turning Module, specifically the robotic arm, is the most critical part of our project. The robotic arm poses the greatest risk due to its need for precise control and adaptability to various book sizes and page thicknesses. Any malfunction in the robotic arm can lead to page damage or misalignment, disrupting the entire process. Risks include:

- **Mechanical Complexity:** Precision is required to avoid damaging pages.
- **Synchronization:** Must be perfectly timed with the Camera and Photocopying Module.
- **Sensor Accuracy:** Page Sensor must detect page edges correctly.

Acceptable Tolerances:

- **Positioning Accuracy:** ± 1 mm.
- **Operation Speed:** ≤ 6 seconds per page turn.
- **Success Rate:** $\geq 95\%$.

Relate to High-Level Requirements:

- **Reliability:** Ensures automated page turning works consistently.
- **Efficiency:** Maintains system speed and synchronization.

- **Flexibility:** Handles various book sizes and page types.

3. Ethics and Safety

3.1 Ethics

Privacy and responsible use are key ethical considerations for our automatic page-turning photocopier. The system captures images of documents, which may include sensitive or copyrighted material. We will ensure that no images are stored or transmitted without explicit user consent and will implement safeguards to prevent unauthorized copying. Our team is committed to adhering to the *IEEE Code of Ethics*[1] and *ACM Code of Ethics*[2], which emphasize honesty, accountability, and the prioritization of public welfare. We will also consider the environmental impact of our design, particularly in terms of energy efficiency and material sustainability.

3.2 Safety

The automatic page-turning photocopier uses electrical and mechanical components that interact with users and books. The Battery and Motor Driver are electrical parts that must be carefully insulated to prevent shocks or overheating. The Robotic Arm moves to turn pages, so it must be designed to avoid pinching fingers or damaging books. The system includes an Emergency Stop button to quickly stop all operations if something goes wrong. In the lab, we will follow safety rules like wearing gloves and goggles when handling tools and keeping the workspace clean to avoid accidents.

References

- [1] *IEEE Code of Ethics*. (n.d.). <https://www.ieee.org/about/corporate/governance/p7-8.html>
- [2] *ACM Code of Ethics*. (n.d.-b). <https://www.acm.org/code-of-ethics>