Senior Design Proposal: PIXEL

1 Introduction

Digital cameras have shown a resurgence in popularity in recent years, capturing the interest of photographers and hobbyists alike. Smartphones have mostly replaced consumer cameras in today's market due to their convenience. However, smartphone cameras are often missing features found in standalone digital cameras. Furthermore, even current digital cameras face limitations in usability and image management. Team PIXEL is addressing these challenges with an innovative digital camera design. Our project focuses on optimizing the functionality, efficiency, and user experience of a digital camera, leveraging modern technologies to deliver smarter image capturing and sharing capabilities.

Our solution is a digital camera powered by an ESP32 camera module, capable of automatically uploading captured images to a shared album over Wi-Fi. By integrating AI-based facial recognition, the system ensures that only relevant photos are shared with individuals present in the pictures, saving users the hassle of sorting through large, generic albums. With an onboard microSD card for local storage and a color OLED display for real-time previews, our camera offers an all-in-one solution for modern photography enthusiasts. This project not only simplifies the photo-sharing process but also enhances the quality and creativity of digital camera photography.

2 Problem Description

Digital cameras are making a comeback, valued for their image quality and nostalgic charm, but they still face significant limitations that hinder their usability in today's fast-paced, interconnected world. One of the main challenges is the lack of accessibility of the images once they are captured. Unlike modern smartphones, which seamlessly integrate with cloud services for instant photo backup and sharing, digital cameras often require manual intervention to transfer images. It can be a burden to upload all of your photos after an event or trip and add them to a massive shared album, individually inviting each person you have taken a picture of. Additionally, the reliance on proprietary or outdated connectors and cables adds to the inconvenience of downloading and sharing images from a digital camera. Many users lose the original cords needed to connect their cameras to laptops or find that these cords are incompatible with newer devices. This forces users to either buy new accessories or rely on external card readers, which adds cost and complexity. For casual users, this technical barrier can lead to frustration, while for professionals, it can slow down workflows and delay the delivery of images to clients. Similarly, digital cameras often have a very limited memory, so only a fixed number of images can be stored on the device. This limitation means that to take new pictures, old ones must be deleted, or pictures must be downloaded off the device and stored on external memory every time it is used. These difficulties of uploading and saving images create a significant usability gap that limits the potential of digital cameras in a world in which immediate, cloud-based solutions exist.

It is also difficult to set up a self-timer photo with just a digital camera and also know that everyone is in frame, especially given that no one is actually holding the camera. When you set up a camera on a bookshelf or ledge so that everyone can be in the photo, you often have to go through several iterations of starting the timer, getting into position, waiting, and then checking to see if the photo turned out well. The taker of the photo also has to rush to push down the timer button and then get into frame, which can be chaotic, resulting in a lower quality photo. Even if the correct framing is obtained, the images are often still low quality because of too bright or dull lighting.

3 Proposed Solution

To address the limitations of traditional digital cameras, we propose developing a smart, Wi-Fi-enabled digital camera that not only takes high-quality images but also integrates seamlessly with cloud services and provides enhanced usability features. Our solution is designed to eliminate the need for extensive manual intervention in photo transfers, simplify group photography, and solve lighting challenges.

1. **Instant Image Upload and Sharing** - This solution employs the ESP32 camera module and Wi-Fi to take images and automatically upload them to a cloud integration platform, such as Google Drive or a custom website. As part of this uploading process, an AI facial recognition algorithm developed using OpenCV will be used to recognize who is in each picture and create individual pages of the website or albums for each person. Then, everyone will not have to sort through all the pictures in the entire collection and can easily find the ones relevant to their use. In the event that the camera is not connected to Wi-Fi, there will also be a microSD card onto which the images can be saved so that the internal ESP32 memory is not instantly filled and the images are not lost forever if a connection is not available. This solution eliminates the need for individually downloading and sharing each image, external cords or accessories, and the limited memories of current digital cameras.

2. **Self-Timer and Framing** - The proposed solution for the difficulties of taking a self-timer photo and correctly framing the group in a shot will be addressed with a separate button clicker and laser levels. A small, handheld, wireless device that is separate from the camera will have a button that is connected to the camera ESP32 over bluetooth that someone can click and the photo will be taken. They will be able to be in the camera shot without having to directly press the button on the camera and then run to be in the picture. Additionally, four laser line levels will be used to project a rectangular outline from the camera. This box will represent the frame that is actually being captured by the camera. This way, even though there is not someone holding the camera and looking through the viewfinder, the group can ensure that they are properly positioned in the shot.

3. **Adjustable Flash Brightness** - To address the fact that many digital camera images are overexposed due to the flash being too bright or too dark due to the lack of a flash, an adjustable flash system is proposed. A potentiometer will be used to adjust the brightness for a camera flash LED driver. The user can turn the dial on the potentiometer based on if they want the full flash brightness, no flash, or variable levels in between. This solution will allow bright images or objects to not become washed out and dark images and spaces to clearly, effectively be photographed.

4 Demonstrated Features

This list of features attempts to address the three main solution areas: image capture/sharing, self-timer/framing, and lighting. Image capture and sharing requires the use of a viewfinder, actually taking the photo, and finally uploading it over Wi-Fi. When images are shared, they will also have an associated location based on GPS data. Self-timer and framing requires a remote button to take the photo and lasers to outline the field of view, and improved lighting is achieved with an adjustable flash.

1. The primary feature of this project is the ability to take a photo when a button on the camera is pressed. The photo will be captured in a digital color format.

2. The second objective is to be able to automatically share and upload images, which addresses the inaccessibility problem. Once a photo is taken, it will be sent over Wi-Fi to a shared album or website that anyone can access.

3. In addition to being able to take a photo with a button on the camera itself, there will be a separate remote control to capture an image. This will allow someone to take a photo without actually holding the camera. The remote control has the same functionality as the take button on the camera. This feature replaces the need to have a timer function. The user can set up the camera, walk away into the field of view, and remotely take the photo.

4. The camera will utilize lasers to indicate the outline of the field of view. Similar to a laser level, the lasers would show the edges of the frame so that users can ensure the desired image is actually captured. This is especially relevant when using the remote control feature in (3) so that users can tell where the field of view is without looking at the device itself.

5. Once the images have been uploaded, the album/website will employ AI facial recognition to group together images of the same person. With enough photos of the same people, an algorithm would be able to classify who is who and create collections of each person’s photos.

6. The camera will have an LED to function as the flash when the photo is taken. To address the fact that digital camera images sometimes suffer from poor lighting, the flash brightness will be controlled by an adjustable knob.

7. There will be an OLED screen to preview the field of view before the photo is taken, serving as a live viewfinder. Once the photo is taken, the screen will display the image and the user will use it to decide whether to delete or upload the image, and this decision will be made with the push of a button.

8. The camera will have GPS technology. When a photo is taken, the camera will save the location, time, and date from the GPS coordinates, and this information will be available with the photo once it is uploaded.

5 Available Technologies

To address the requirements of our senior design project, we have researched several technologies and components that we will need to apply to achieve the desired functionality and demonstrate the identified features. Included links are to possible technologies to purchase/use.

For **wireless communication**, we have determined that the technology of the ESP32-S3-WROOM-1-N4R8 microncontroller is best suited for our needs. It has built-in Wi-Fi and Bluetooth capabilities. It eliminates the need for additional wireless modules, reducing costs and simplifying the design. It can handle data transmission and control operations efficiently and only costs around $5.

For **image capture**, we are planning on utilizing the Arducam OV2640 Camera Module which has easy integration with the ESP32 via an I2C or SPI interface. It seems to offer adequate image resolution and is also well-documented on their website for more straightforward integration. It costs around $7.

For our **user interface**, we will include a color OLED display which has SPI-based communication and allows for real-time feedback and mode indication. Users will be able to preview their photos and monitor device status easily. It will cost around $20.

For our **power supply**, we plan on using a 5V LiPo Battery with a charging circuit for a portable, rechargeable power source. This reliable battery source will ensure uninterrupted operation in a variety of environments. We estimate the cost to be around $10-$20.

We will also include push buttons for **user input** (taking photos and selecting options), LEDs for **mode indication**, and a potentiometer or dial to **control the brightness of the flash**. These parts are in lab stock and widely available.

For the actual **camera flash**, we plan on using a Dual LED Flash Driver with Boost Converter which provides high-intensity light for low-light conditions. It will cost around $5-$10.

For the **enclosure for the camera**, to ensure its protection, we will custom 3D print a case in the EIH. It will provide a durable, lightweight housing for components. This will most likely be free from the EIH with the curriculum code.

We will need to implement **cloud integration**, which we are thinking about doing through Google Drive or a custom website to support image upload and remote post-processing. It will be free to develop.

For the **image post-processing**, we will use OpenCV, an open-source computer vision library, which provides advanced image processing functions, including filtering, enhancing, and object detection. It is free and highly adaptable for use with ESP32 or external platforms for local or cloud-based processing.

For the **built-in GPS,** the system will utilize a GPS receiver module, such as the NEO-6M, which is suitable for capturing data in real time. The GPS module will communicate with the ESP32 over a UART serial interface. The ESP32 will parse the GPS data strings to extract the required location and time information. The cost will be around $30.

The **circuit board** itself will be a custom PCB and integrate the microcontroller, peripheral connections, etc. and will cost around $50.

For our **laser outline framing feature**, we will implement a low-power laser module (either class 2 or class 3R laser module) with adjustable beam focus, with GPIO control for turning on and off. It can be integrated with the ESP32 for timed operation and user control and will be eye-safe under normal use conditions. The cost is projected to be around $10.

For the **remote control button** to take a picture from far away, we plan on using a prebuilt bluetooth key fob button to communicate over bluetooth with the ESP32. We will pair the bluetooth key fob with the ESP32 using its Bluetooth low energy capabilities, program the ESP32 to listen for and interpret the key fob's button-press signal and then once received, trigger the ESP32 to activate the camera module to capture an image. These buttons are widely available online. The CamKix camera shutter remote control with bluetooth wireless technology is one such button. This will cost around $10.

6 Engineering Content

The engineering content includes the steps required to design, build, and test our digital camera.

- Design: Plan how each subsystem will interact to solve the problem.
    - User Interface:
        - User uses either a button on the camera or the wireless controller to take a photo.
        - User interacts with a dial next to the display to adjust flash brightness.
        - User can press a button on the camera to cancel a picture's auto upload to the cloud.
        - For all of the above (except the controller), the buttons are connected to the microcontroller, likely via GPIO pins.
    - Remote Control

    - This is a pre-built bluetooth controller. The ESP32 must be programmed to receive a signal when the controller button is pressed.
- Laser Outline
    - Four laser lines are aligned with the dimensions of the to-be captured image by shining outward from the camera at the appropriate angles. These angles will need to be determined by taking into account the focal length of the camera lens.
    - The laser outline is either on or off depending on the user's preference (this setting is chosen in the user interface).
- Wi-Fi Connection
    - Wi-Fi capabilities are built into the chosen microcontroller.
    - Connecting to Wi-Fi must be a user-friendly process.
    - Connecting to Wi-Fi is only done directly after taking a photo and it then disconnects after. This is both to save some power and ensure that the ESP32 can still communicate with the bluetooth controller.
- Cloud Upload
    - The microcontroller automatically uploads to a website and/or shared album. The images are sent to this location from the microcontroller.
    - If there is no Wi-Fi connection, the image is stored in the device's memory card and automatically uploaded later.
    - The images are sorted using AI facial recognition. Some photo enhancement options are to be available. This must be executed on the website and not the microcontroller. One possible framework is OpenCV.
- Flash
    - This flash must be powered from the camera power supply.
    - The flash brightness is adjustable. The microcontroller, depending on the user-set brightness, must change flash intensity.
- Memory
    - Removable micro SD card is used for storing images when Wi-Fi connection is unreliable.
    - The SD card must interface with the microcontroller.
- Power Supply
    - In-camera power supply must provide adequate power to the microcontroller and all the peripherals.
    - Power supply is a rechargeable battery. This involves designing an appropriate system to prevent overcharge.
- GPS
    - The GPS module will record a photo's capture timestamp and location data.
    - The GPS module is connected to the ESP32 via UART serial communication.
- Decide on components.
    - Components must be compatible with the chosen microcontroller.
    - Determine the appropriate number and values of resistors and capacitors.

- Build:
  - Create board
    - Design Schematic
    - Design PCB
    - Order and build the board
  - Programming
    - ESP32 is programmed to transmit and receive data and power to and from peripherals.
  - Assemble the camera
    - Camera and all the parts are placed into an enclosure.
    - Ensure the camera system is user friendly. The enclosure should be compact and comfortable to hold.
    - The user interface must be designed in a way that feels intuitive and convenient for the user.
- Testing:
  - Check that each peripheral is behaving as expected (e.g., all the buttons work, light from flash is adjustable, photos are uploaded online, etc.). This can be done with the use of header pins connected in parallel with the peripherals used. Testing pads can be included on the board for testing power and ground connections.
  - Test the edge cases (e.g., what happens when the user holds down buttons, what happens when out of on-board memory storage space, etc.).
  - Fix any problems that arise. After ensuring that the board itself works, code will likely need to be adjusted to improve performance.
  - Have outside parties test using the camera. Make any necessary adjustments to improve user experience.

Shown below and on the next page, Figures 1 and 2 visualize the engineering process and the camera system, respectively. The engineering process summarizes the above description, broken into design, build, and test sections. The camera system overview provides a block diagram of the project. It highlights all of the peripherals and their connections with the ESP32 microcontroller.

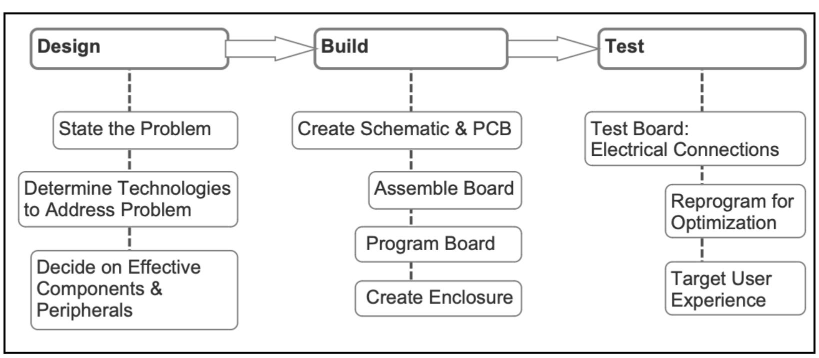

Figure 1. Engineering Process

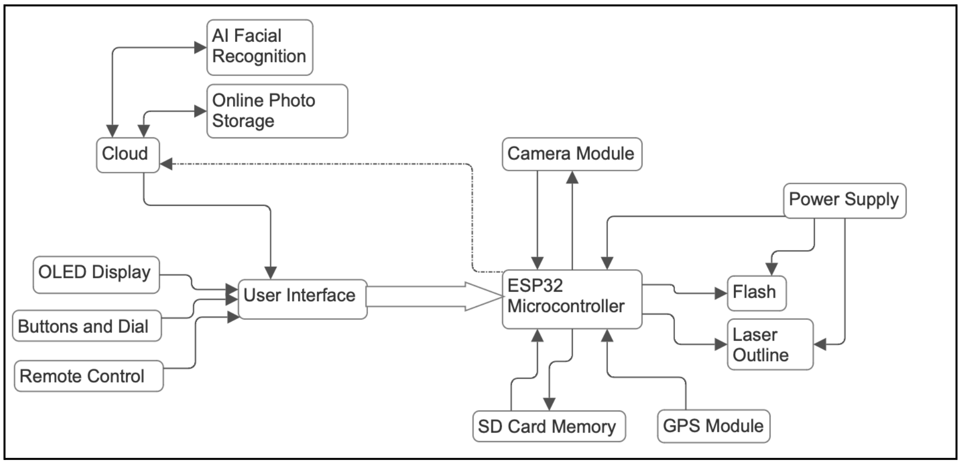

Figure 2. Camera System

7 Conclusions

Our project seeks to modernize and enhance the functionality of digital cameras by addressing common limitations such as inconvenient image sharing, limited memory, and poor lighting conditions. By leveraging the ESP32 microcontroller and integrating AI facial recognition, real-time Wi-Fi photo uploads, and intuitive user controls, our design offers a seamless photography experience. Features like a laser outline for framing, remote-controlled photography, and an adjustable flash brightness provide innovative solutions that simplify and elevate the user experience.

This smart camera design is important because it bridges the gap between the nostalgic appeal of digital cameras and the convenience of modern, interconnected devices. By automating tedious tasks such as photo uploads and organization, and by providing tools for improving the user experience, our camera not only enhances usability but also empowers users to capture and share memories effortlessly. With its innovative features, robust engineering design, and focus on solving real-world problems, this project demonstrates the potential to make a meaningful impact in the field of photography and personal technology.