CIS 450 Final Project

Technical Documentation:

In this project, we enhanced the functionality of the ESP32-C3-LCDKit by integrating a voice announcement feature into the lighting control system. Starting with the Knob Panel Example as the base, we extended the "Lighting" case to provide auditory feedback whenever the brightness level was adjusted using the knob. This voice feedback aimed to improve user interaction and accessibility by announcing the current lighting level, creating a more intuitive and user-friendly experience. Throughout the project, we employed multitasking principles to ensure that the voice announcement task operated independently of the lighting control functionality, maintaining the system's responsiveness and reliability.

To achieve concurrency, we utilized FreeRTOS, implementing separate tasks for lighting control and voice announcements using xTaskCreate. We leveraged synchronization mechanisms such as xEventGroupWaitBits and xEventGroupSetBits to safely share and update the lighting level data between tasks. These mechanisms ensured that the tasks worked in harmony without conflicts or delays, demonstrating effective concurrency control. Additionally, mutexes were used to protect shared resources, ensuring data consistency and system stability even under simultaneous operations.

Additionally, we introduced a bonus feature that allowed for scheduled lighting adjustments. This feature, running in its own task, provided users with the ability to set predefined times for automatic lighting changes, further enhancing the system’s utility. This demonstrated our understanding of multitasking and showcased how additional functionalities could seamlessly integrate into the existing system while adhering to concurrency principles.

Throughout the project, we followed a modular development approach, implementing and testing each feature independently before integration. This allowed us to identify and resolve issues early in the process, ensuring a polished final system. Documentation was maintained at every stage, detailing system architecture, concurrency control mechanisms, and user instructions. By combining technical expertise with creative problem-solving, we successfully delivered a responsive and innovative lighting control system with voice feedback, reflecting the core principles and concepts learned in the course.

One of the significant challenges we faced during this project was implementing effective concurrency control to ensure seamless operation of the voice announcement feature alongside the lighting control system. Since both features required access to shared data, such as the current brightness level, we encountered initial difficulties with task synchronization. Without proper safeguards, conflicts arose where the voice announcement task would sometimes announce outdated or incorrect brightness levels. To address this, we had to delve deeper into FreeRTOS event groups and mutexes, refining our understanding of these tools to protect shared resources and coordinate task execution effectively. Debugging these synchronization issues was time-consuming, as subtle timing conflicts often caused unpredictable system behavior.

Another struggle involved the integration of the audio output for the voice announcements. Setting up the hardware components, such as the speaker, and configuring the audio playback libraries on the ESP32-C3 platform proved more complex than anticipated. We encountered issues with inconsistent audio quality and delays in playback, which disrupted the overall user experience. Troubleshooting required us to optimize the audio processing task, including managing its priority and ensuring it didn’t interfere with the responsiveness of the lighting control. Additionally, understanding the nuances of the provided base code was a steep learning curve, as we had to navigate and adapt existing implementations to accommodate our enhancements. Despite these challenges, persistence and incremental testing allowed us to overcome these obstacles and achieve a fully functional system.

Through this project, we gained a deeper understanding of multitasking and concurrency control in embedded systems, particularly using FreeRTOS. We learned how to effectively manage multiple tasks running simultaneously and ensure safe access to shared resources using synchronization mechanisms like event groups and mutexes. Additionally, we developed practical skills in debugging timing and synchronization issues, which are critical for creating responsive and reliable systems. Implementing the voice announcement feature also taught us the importance of hardware-software integration, from configuring audio components to optimizing task priorities for seamless operation. Overall, this project reinforced key concepts of embedded systems design while enhancing our problem-solving and technical skills.

Github: <https://github.com/requieeeeem/CIS_450_Final_Project>

Youtube: <https://youtube.com/shorts/r20iox0m_S8?feature=share>