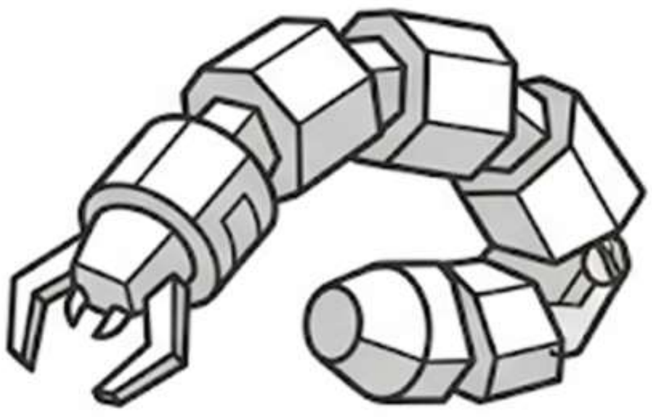


Smart Baby Monitoring Cradle

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Problem Statement

Parents need an intelligent, autonomous baby cradle to provide safe, smart, and timely infant care, because existing baby monitors can only offer passive surveillance but lack immediate response to anomalies.

Needs

- An intelligent identification system to detect real-time infant status.
- An automated mechanical structure to provide safe oscillation.
- A remote alert application to deliver instant notifications and real-time streaming for parents.

Design Description

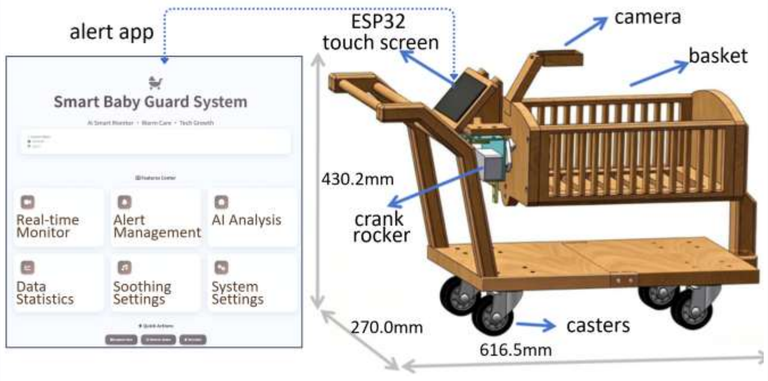


Fig. 1 Prototype of the cradle with integrated mobile app

The project can be separated into three parts: an intelligent monitoring system, an automated soothing cradle, and a remote alert app. The monitoring system deploys a dual-channel “OR” logic on an ESP32-S3 module: the audio channel evaluates environmental sounds RMS, while the vision channel processes local frame differences and selectively triggers the cloud GLM-4V model for precise motion detection. Upon detection, the Arduino commands the motor to drive a crank-rocker linkage mechanism[1] to initiate small-amplitude cradle oscillation and broadcast customized music. The app serves as the control hub, providing parents with real-time video streams, instant alert notifications, and remote control of the cradle.

Significance of Solution

Our design uses a motor-driven crank-rocker to isolate the sleeping platform from sudden motor acceleration, providing a smooth, gentle, soothing experience.

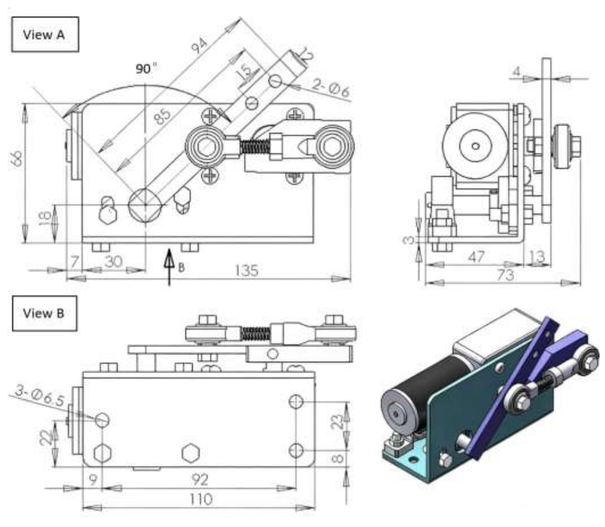


Fig. 2 Crank-rocker linkage structure

As illustrated in Figure 2, the core unit consists of a driving crank, a connecting rod, and a rocker to convert $360°$ rotation of the short crank to a small-amplitude oscillation of the cradle. Two physical limit bolts are installed on the base to constrain swing angles to prevent tipping.

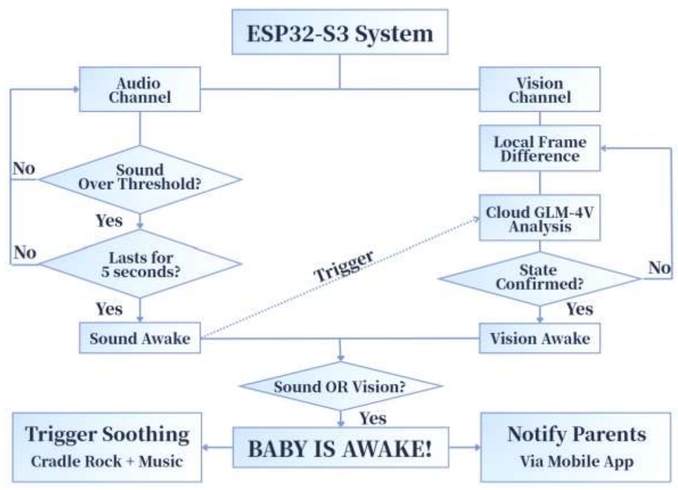


Fig. 3 Logic flow of the monitoring system

As shown in Figure 3, the system processes data through an edge-cloud collaborative network to balance detection accuracy and cloud costs. The intelligent monitoring module executes dual-channel “OR” logic locally, then triggers the GLM-4V model only when anomalies are detected, minimizing API calls while maintaining high sensitivity. Once the infant’s awakening is confirmed, the system immediately initiates safe soothing while sending a notification to parents via the alert app.

Validation

Two main functions are tested:

1. Event Triggering System

- ✓ By developing edge algorithms on the ESP32-S3, the audio channel achieves a 64ms response loop for local RMS energy calculation.
- ✓ In full-system loop tests, the total latency from initial edge trigger to final mobile notification is measured to be under 3 seconds.
- ✓ Compared to continuous photo analysis (720 cloud calls/day), the on-demand strategy drops cloud invocations to about 10 calls/day, reducing API costs by 98%.

2. Oscillation Soothing

- ✓ By installing two limit bolts on the base, the actual swing angle of the rocker is constrained within $45°$ safe arc to ensure infant safety.

Conclusion

Integrating an optimized crank-rocker mechanism, a high-efficiency edge-cloud VLM architecture, and a remote alert application, this smart cradle provides real-time, safe, and automated monitoring and comforting for infants. By bridging the gap between advanced technology and empathic care, this human-centered project highlights how intelligent engineering can profoundly transform modern parenting, thus enhancing domestic well-being.

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Reference

[1] Norton, R. L., *Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines*, 2nd ed., New York: McGraw-Hill, 2001.