AUTOMATED WATER ICE SERVING SYSTEM (AS)
(AQUASERVE)
BEKO

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Abstract. With the rise of smart appliances, no automatic water/ice dispenser has yet been integrated into refrigerators. This project introduces an innovative, hands-free dispenser designed for global use, starting with Beko refrigerators. The system uses proximity sensors for glass detection, IR sensors for height measurement, Time-of-Flight sensors for water level tracking, and radar sensors for gesture recognition. All sensor data is processed by an STM32F407 microcontroller to ensure accurate operation. The filling process is fully automated, stopping once the desired water level is reached. The design emphasizes cost-effectiveness, user-friendliness, and compatibility with various glass sizes. The system has been successfully simulated, tested, and integrated into a refrigerator prototype.

PROJECT DESCRIPTION

Our project focuses on designing a fully automatic water/ice dispenser system to be integrated into Beko refrigerators. The main problem our company wants us to solve is the enhancing the user experience in the use of these dispensaries. The outcome of our project is a touchless, sensor-driven system that automates the entire dispensing process from detecting the glass to determining its height and water level ensuring a seamless and safe experience for users.

The motivation behind the project is rooted in enhancing the user experience and bringing innovation to a standard household appliance. While some premium refrigerators in the market offer autofill features, such as those by GE Appliances, Bertazzoni, and Café, these solutions often come with high costs, limited glass compatibility, and lack features like gesture control. Their systems typically require standard-shaped glasses and have accuracy limitations, which can lead to overfilling or underfilling. Additionally, the high-end models can cost over $7,000–$11,000 [1][2], making them inaccessible to many consumers. Our aim is to address these shortcomings by creating a more affordable, adaptable, and intuitive alternative.

Our project proposes a novel solution that combines multiple sensing technologies into one cohesive system. By integrating proximity sensors for glass detection, IR sensors for height measurement, a Time-of-Flight sensor for precise water level tracking, and a radar sensor for gesture recognition, we provide a smart, hands-free dispensing system. Unlike existing products, our design supports glasses of various shapes and sizes without compromising accuracy. The inclusion of gesture control, which is currently absent in all existing dispensers, adds a unique layer of user interaction. This innovation not only improves accessibility but also positions our design as a highly competitive, next-generation product in the market.

In terms of design and performance specifications, our system is built around the STM32F407 microcontroller, which handles real-time processing of all sensor data. The proximity sensors detect glass placement within ±2mm, and IR sensors measure glass height with a ±10mm tolerance. The Time-of-Flight sensor used for tracking water levels operates within a 0–200 cm range and ±3mm accuracy, with a sampling interval below 50 ms. Gesture recognition is enabled through the XENSIV BGT60TR13C radar sensor, detecting gestures within 10–30cm and with an error margin under 15 percent. The system operates at 12V DC and has a total power consumption of 300 mA. Designed with safety and ergonomics in mind, the dispenser also meets various global standards (CE, UL, RoHS, REACH), ensuring it is ready for mass production and global deployment [3][4][5][6].

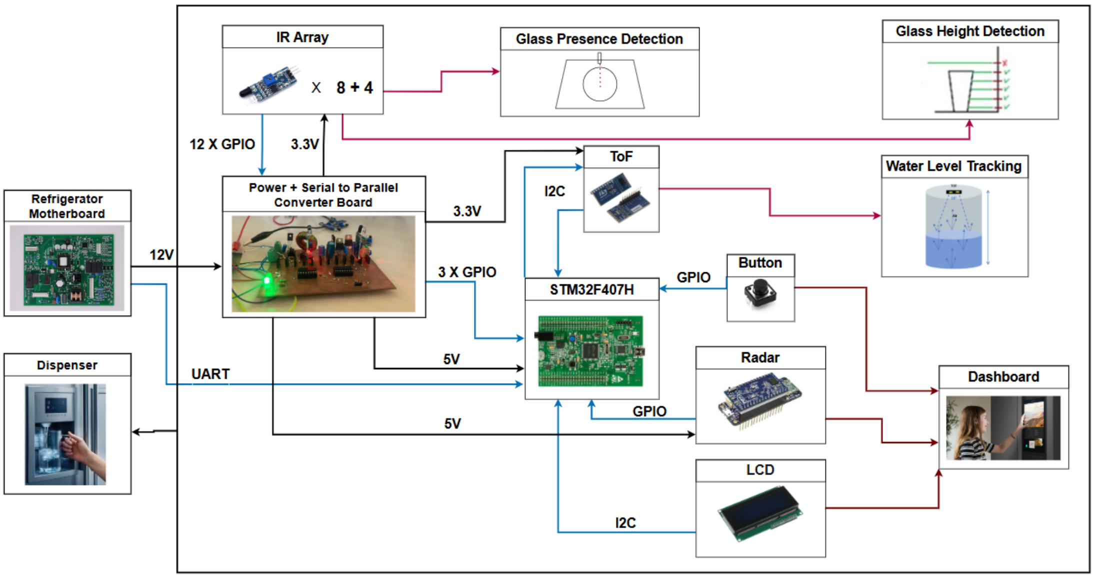

Figure 1: Big Picture

MILESTONES

Our project includes four key milestones that guided the development of the automatic water/ice dispenser system.

The first milestone marks the successful implementation of glass presence and height detection. After completing the glass placement and height detection stages, both sensors were integrated into a subsystem. The proximity sensors ensure the glass is correctly positioned, while the IR sensors determine its height. The system verifies correct placement by blinking an LED and then displays the measured height on a terminal. The milestone is achieved when this sequence operates reliably, preventing unnecessary calculations when no glass is present.

The second milestone involves real-time water level tracking using a Time-of-Flight sensor. After integrating this with the previously developed subsystem, the system can monitor rising water levels and compare them to the measured glass height. When the water level reaches the desired point, an LED lights up to simulate valve deactivation. The milestone is successfully met when the system reliably stops the simulated water flow at the correct fill level using accurate sensor data.

The third milestone focuses on gesture recognition functionality. After implementing gesture control with a radar sensor, the system is able to recognize specific user gestures such as ’water’, ’ice’, ’autonomous’, and ’manual’. The selections will be displayed in LED. This milestone is considered complete when the system accurately interprets all gestures with minimal error and responds.

The final milestone signifies the full integration of all components of the system into a single functional unit. All subsystems are embedded into the refrigerator’s dispenser area and thoroughly tested for real-world performance. The milestone is achieved when the complete system operates seamlessly and demonstrates readiness for deployment as a production-ready solution.

DESIGN DESCRIPTION

We adopted a modular solution strategy that evolved through distinct development phases and milestones. Each milestones tackled a critical subsystem of the dispenser. Each step verified by simulation and hardware tests. This ensured both flexibility in development and robustness in system performance.

For glass detection, we used an IR sensor due to its low cost and simplicity. It was mounted near the dispenser base and monitored via GPIO pins to detect glass presence. Once detected, the system moved to the height detection phase, using vertically aligned IR sensors to estimate height based on triggered sensors. A shift register reduced cable clutter by converting parallel data into a serial stream for the microcontroller.

For water level tracking, we used the VL53L5CX Time-of-Flight (ToF) sensor, which was interfaced using the I²C protocol. Once the water level matched the measured glass height, the system automatically simulated closing the water valve.

The gesture recognition phase used the XENSIV BGT60TR13C radar sensor for contactless control. Gestures for mode selection were programmed using two GPIO signals. The radar's API translated gestures into digital outputs, which were read by the STM32F407 to trigger actions like indicator LEDs.

The final system combined all subsystems into a compact, 3D-printed housing that fits a standard Beko fridge compartment. A custom power card converted 12V from the mainboard to 5V and 3.3V for sensors and the microcontroller, with analog switching for efficient power control. Components were arranged to reduce wiring and support communication via GPIO, I2C, and serial interfaces. The power card schematic is shown in Figure 2, and the integrated version appears in Figure 3.

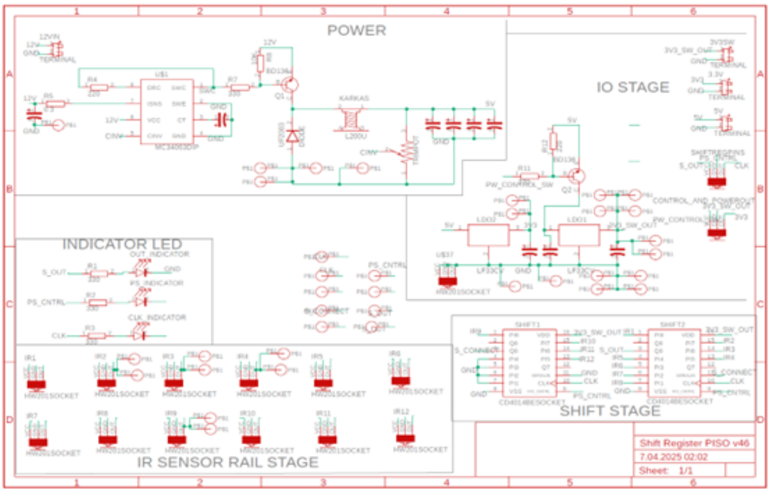

Figure 2: Schematic of the Power Card

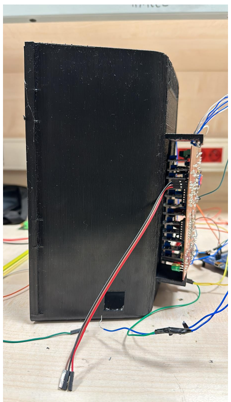

Figure 3: Integrated Power Card

Figure 4: Last Version of the Prototype

In terms of tools and equipment, the project primarily relied on the STM32F407 microcontroller, HW-201 IR sensors, VL53L5CX ToF sensor, and XENSIV radar module. We also used a multimeter and oscilloscope for power and signal validation, and an electronic pump for testing actual water flow. Our simulation and experimentation phases confirmed the functionality of each module before final integration, ensuring a robust and reliable design. All of the components were integrated into the prototype successfully and it can be seen in Figure 3.

RESULTS AND PERFORMANCE EVALUATION

To validate the functionality and performance of the automatic water/ice dispenser system, both simulation-based and experimental tests were conducted on the finalized prototype. These tests assessed sensor reliability, responsiveness, and overall system accuracy under various real-world conditions, including different glass shapes, heights, and surface properties.

The IR sensors demonstrated fast and reliable glass placement detection within one second of insertion. As shown in Figure 4A, the system immediately triggers the filling process. In contrast, Figure 4B illustrates that misaligned or absent glasses do not activate the system, effectively preventing unintended operation.

Figure 4A: Glass detected, filling continues

Figure 4B: Glass not detected, filling stopped

Height detection was performed using a vertical array of IR sensors, with results displayed on a terminal. The system achieved a measurement accuracy of approximately ±10mm, regardless of the glass shape or transparency. This resolution proved sufficient for calculating safe fill levels while accommodating slight variances in placement.

The VL53L5CX ToF sensor enabled reliable real-time water level tracking, unaffected by reflections or noise. As shown in Figure 5A, filling continued below the target level and stopped at the threshold (Figure 5B), with a consistent ±25mm tolerance. This minor offset met domestic standards and prevented overfilling.

Figure 5A: Glass detected, not enough water, filling continues

Figure 5B: Glass detected, enough water, filling stopped with a small error

The XENSIV BGT60TR13C radar sensor recognized user gestures with an average latency below 1 second and an error rate under 15%. During tests, four gestures—mod and output selection—were linked to distinct colored LEDs for indication. The user can select the mode (up and down) and output (left and right) with the radar sensor.

The final prototype successfully integrated all modules into a 3D-printed housing designed to fit within a Beko refrigerator compartment. The custom power card supplied stable 5V and 3.3V outputs from a 12V DC input. Multimeter and oscilloscope tests confirmed the system's average power consumption at 300mA, in line with the initial nonfunctional requirements. No voltage drops or resets were observed during the operation, demonstrating electrical reliability.

When compared to commercial alternatives, our system performed competitively. Existing models often require specific glass sizes and lack gesture control. Many cost between $2,300 and $11,000 [1][2][7][8]. In contrast, our system supports various glass sizes, includes gesture control, and costs under $100. This affordable design offers unique, yet-to-be-commercialized features.

While our prototype met all functional requirements, minor limitations were observed. Inconsistent output values could be read from the sensors. When we placed the sensors better and more stably to prevent this, the problem was gone.

CONCLUSIONS AND FUTURE DIRECTIONS

In this project, we successfully designed, implemented, and tested an innovative automatic water/ice dispenser system to be integrated into Beko refrigerators. By leveraging a combination of cost-effective and reliable sensors—including IR sensors for glass detection and height measurement, a Time-of-Flight sensor for real-time water level tracking, and a radar sensor for gesture-based control—we created a fully touchless, user-friendly solution. The system was embedded into a 3D-printed dispenser setup and integrated with a custom-designed power distribution circuit, meeting both functional and non-functional requirements such as accuracy, power efficiency, safety, and affordability.

Our final prototype met all milestones successfully. Gesture control enhanced user convenience and set our design apart from existing products. It offers better adaptability and interaction at a much lower cost, making it a strong candidate for commercialization.

Future work includes improving performance with more precise sensors and resolving minor mechanical issues. Enhancements like better enclosure design, modular sensor placement, and waterproofing can boost reliability. Adding gesture functions would expand usability. With further development, the system has strong potential for real-world use and could inspire a new generation of smart appliances.

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BEHIND THE SCENES