

A Smart Stove System for Cooking Food: A Study

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Abstract

Traditional cooking methods often suffer from inconsistencies, safety concerns, and a lack of real-time feedback, leading to suboptimal culinary results, potential hazards, and inefficient energy consumption. This paper introduces the design and implementation of an innovative smart stove system engineered to address these challenges comprehensively. Leveraging Internet of Things (IoT) principles, the system integrates an array of precise sensors (e.g., temperature, flame/gas detection, weight) with a sophisticated microcontroller, smart actuators (e.g., automated gas shut-off), and a user-friendly mobile application. This robust architecture enables automated, precision temperature regulation, real-time monitoring of cooking parameters, and proactive safety protocols such as automatic gas supply cut-off in case of leaks or unattended operation. Key features include remote monitoring and control, personalized recipe guidance with adaptive cooking adjustments, and energy consumption optimization. The proposed smart stove system aims to transform the culinary experience by ensuring consistent, perfectly cooked meals while drastically enhancing kitchen safety, reducing food waste, and improving energy efficiency, heralding a new era of intelligent and convenient home cooking.

Keywords: Smart stove, cooking, food, sensors, energy efficiency, internet of things (IoT)

INTRODUCTION

For decades, the stove has been a stubborn analog bottleneck in an increasingly digital kitchen. While refrigerators catalog our groceries and ovens connected to Wi-Fi for preheating, the cooktop—the heart of daily culinary creation—has largely remained a brute-force device, relying primarily on intuition, guesswork, and the highly subjective adjustment of a knob.

However, this era ends rapidly. The rise of the “smart stove system” is proving to be far more than a simple integration of Wi-Fi and Bluetooth; it is a fundamental transformation of cooking, turning the unpredictable art into a precise, repeatable science, guided by an invisible sous chef that never tires, and never burns the butter [1–3].

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The Death of Guesswork: Precision at the Molecular Level

The core innovation of a smart stove is its precision control. Traditional gas or electric burners are prone to thermal lag and hot spots, requiring a chef (amateur or professional) to constantly monitor and manually adjust. Smart cooktops, typically leveraging advanced induction technology paired with integrated thermal sensors, eliminate this chaos. Imagine setting a stove not to “medium-high,” but to 180°F, held consistently for exactly 12 min.

These systems use dynamic heat mapping across the cooking surface, allowing millisecond

adjustments to the power output based on real-time feedback from the pan. This enables domestic cooks to achieve professional techniques effortlessly.

- *Perfect poaching*: Water is held at the delicate simmer point, ensuring that eggs are poached without breaking up from a rolling boil.
- *Sous vide on the stovetop*: By using a deep pan and smart temperature probe, the cooktop can maintain the precise thermal environment required for vacuum-sealed cooking, making sophisticated meals accessible without dedicated equipment.
- *Melting chocolate without a double boiler*: Set the temperature to the exact melting point (approximately 90°F), and the smart stove ensures that direct heat never scorches the delicate ingredient.

The result is not just convenient, but also the elevation of flavor profiles previously lost to overheating or undercooking.

Your Culinary Co-Pilot: Guidance and Adaptation

The truly engaging element of the smart stove system is its cognitive ability: the way it moves beyond being a simple heat source and becomes a genuinely intelligent guide.

Forget cookbooks: The new system integrates connected recipe platforms, turning the cooktop screen (or a projected visual interface) into a step-by-step assistant. It does not just display the instructions; it also executes them.

When the recipe calls for sautéing onions for five minutes at medium heat, the stove automatically sets the temperature, starts the timer, and provides visual queues when it is time to proceed to the next step. If you pause the process of chopping more vegetables, the heat goes into a customized holding pattern, ensuring that the food does not overcook while you catch up [4–7].

Smoke alarms are relics of poor cooking habits. Smart stoves incorporate sophisticated smoke and moisture sensors, often paired with thermal cameras, to anticipate failures. If the pan oil approaches its smoke point, the system instantly lowers the temperature and sends a critical alert to the smartphone or kitchen hub of the user. For busy parents or novice cooks, this feature transforms stovetop cooking from a high-stakes vigilance task into a safe guided process.

The Connected Kitchen Ecosystem

A smart stove is not an island; it is the central processing unit of the modern food preparation ecosystem. Their intelligence is compounded by their ability to communicate seamlessly with other appliances.

- *Inventory management*: Connected through a refrigerator and pantry scanner, the stove can suggest recipes based on the ingredients available to date. “You have chicken breast, broccoli, and soy sauce. Would you like to cook the Thai Sesame Stir-Fry?”
- *Ventilation sync*: As soon as the stove is switched on and detects steam or smoke (especially in high-heat searing), the connected range hood automatically adjusts the fan speed and lighting, thereby optimizing the air quality without manual interaction.
- *Personalized profiles*: Each family member has a personalized culinary profile. When Dad logs into the app, the stove defaults to his preferred medium-rare setting for a steak. When the teenager uses the stove, high-heat deep-frying functions are restricted unless safety oversight is enabled.

The smart stove system is doing what the smartphone does for communication—it is democratizing access to complex skills. This lowers the barrier to entry for beginners, providing a reliable co-pilot that guarantees success. Experienced chefs eliminate tedious monitoring tasks, freeing up the cognitive space for creativity, plating, and experimentation.

As these systems become standard, the anxiety associated with perfectly searing a scallop or flawlessly simmering a reduction fades. The future kitchen will not just be smart—it will be profoundly competent, ensuring that every meal prepared on a smart stove is a success, turning novice cooks into confident culinary artists, one perfectly precise degree at a time [8, 9].

FRAMEWORK FOR A SMART STOVE SYSTEM

Introduction: Imagine a kitchen where your stove is not just a heat source but also an intelligent culinary partner. It anticipates your needs, perfects your dishes, ensures safety, and helps you learn. This is the vision for a smart stove system, a sophisticated blend of hardware, software, artificial intelligence (AI), and connectivity, designed to revolutionize the way we cook. This framework outlines the architecture, core components, and operational principles of such a system, transforming the mundane task of cooking into an effortless, precise, and delightful experience [10, 11].

Core Principles Guiding the Framework

- *Safety first*: Proactive hazard detection and prevention (gas leaks, fire, and overheating).
- *Precision and consistency*: Achieving perfect doneness, temperature, and timing every time.
- *Efficiency and sustainability*: Optimized energy usage, reduced food waste.
- *User-centricity*: Intuitive interfaces, personalized experiences, and accessible controls.
- *Connectivity and integration*: Seamless interaction with smart home ecosystems, external services, and user devices.
- *Intelligence and adaptability*: Learning from user habits, recipes, and environmental factors.

The system can be conceptualized in four interconnected layers as follows.

Hardware Layer (The Physical Stove and Sensors)

This layer comprises the physical components responsible for heat generation, sensing, and mechanical actions.

Cooking Surfaces

- *Induction burners (primary)*: Preferred for precise temperature control, rapid heating, energy efficiency, and inherent safety (no open flame) from Figure 1.
- *Gas burners (optional/hybrid)*: Users who prefer flame cooking with smart gas flow control.
- *Integrated warming zones*: For keeping food at optimal serving temperatures.

Sensor Array

Temperature sensors

- *Surface temperature*: Under each burner.
 - *Ambient temperature*: Within the kitchen environment.
 - *Internal food probes*: Retractable or wireless probes for precise internal food temperature monitoring (e.g., meat doneness).
 - *Infrared/thermal imaging*: Detection of hot spots, browning levels, or overheating.
 - *Gas/smoke/CO sensors*: For the immediate detection of leaks or combustion byproducts. Vision Sensors (Embedded Cameras)
 - *Overhead camera*: To monitor food state (browning, boiling intensity, spill detection). AI vision can identify the ingredients or stages of cooking.
 - *Internal oven camera*: To monitor baking/roasting progress without opening the door.
 - *Weight sensors (integrated onto burners)*: To detect the presence of cookware, measure ingredients, or monitor liquid evaporation.
 - *Humidity sensors*: To assess moisture levels for baking or slow cooking.
 - *Proximity/motion sensors*: To detect user presence and prevent accidental activation.
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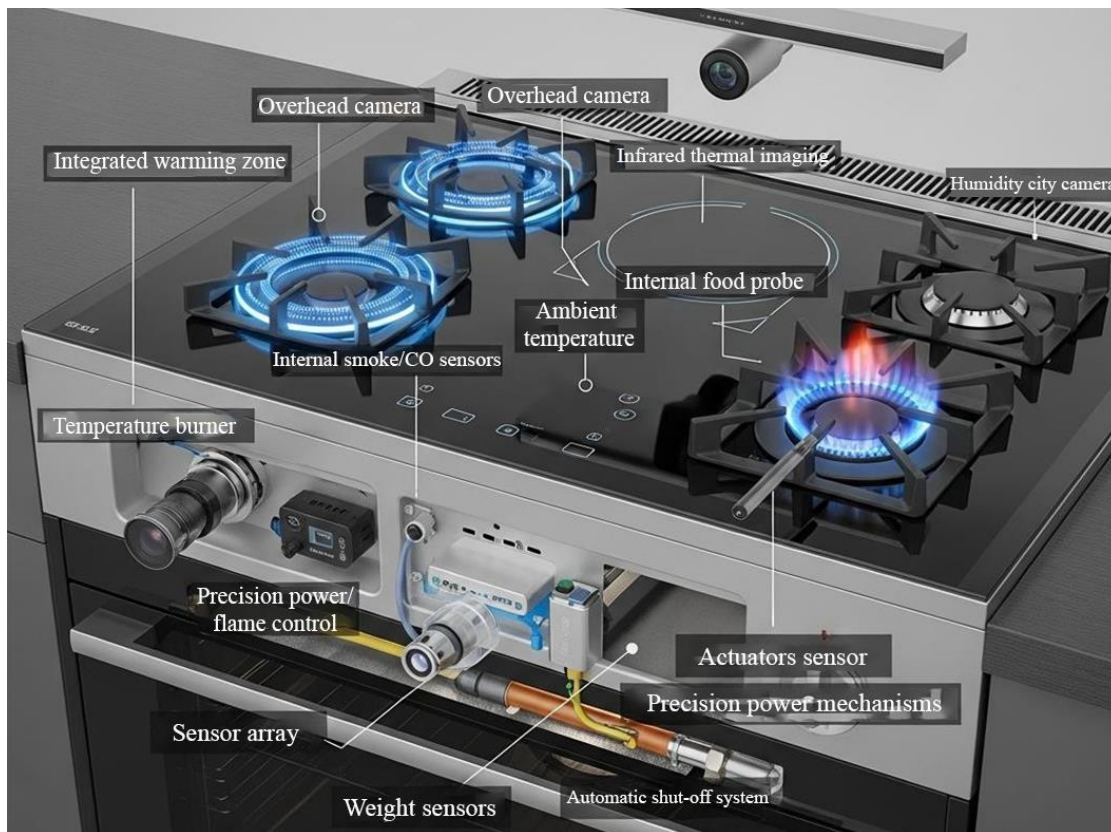


Figure 1. Hardware setup for a smart stove for cooking.



Figure 2. Sensor array in the proposed system.

Actuators and Control Mechanisms

- *Precision power/flame control*: Microadjustments to the induction coil power or gas valve opening.
- *Automatic shut-off valves*: For gas lines triggered by the safety protocols shown in Figure 2.
- *Integrated ventilation system*: Smart range hood control, adjusting fan speed based on cooking intensity, or smoke detection.
- *Motorized stirrers/lifting mechanisms (advanced)*: For hands-free stirring or preventing boil over.

User Interface Hardware

- *High-resolution capacitive touchscreen*: integrated into the stove/hood for recipe display, manual controls, and status updates.
- *Haptic feedback elements*: For tactile confirmation of controls.
- *LED indicator lights*: For burner status, warnings, or cooking progress.

Software Layer (The Brain of the Stove)

This layer encompasses the embedded operating system, control algorithms, AI, and communication protocols.

Real-Time Operating System (RTOS)

- Manages sensor data and actuator commands and ensures precise low-latency control.

Core Control Algorithms

- *Pid controllers*: Maintain precise temperature setpoints (e.g., sous vide functions).
- *Recipe execution engine*: Interprets recipe steps, manages timers, and orchestrates heating profiles.
- *Dynamic power adjustment*: Based on sensor feedback (e.g., reducing heat as the liquid boils down).

Artificial Intelligence (AI) and Machine Learning (ML) Modules

- *Food recognition and state estimation*: Using camera vision, ingredients, and cooked state (raw, simmering, browning, burnt) are identified.
- *Predictive cooking analytics*: Estimates the remaining cooking time and anticipates potential issues (e.g., “Food likely to burn in 2 minutes”).
- *Personalization engine*: Learns user preferences (e.g., how well a steak is preferred, favorite recipes, cooking styles).
- *Adaptive cooking*: Adjusts recipes based on actual ingredients, pan type, and environmental factors.
- *Self-diagnosis and maintenance*: Monitors component health, predicts potential failures, and schedules maintenance alerts.

Connectivity and Communication Module

- *Wi-Fi and bluetooth*: Connect to home networks, mobile devices, and other smart appliances.
- *Zigbee/Z-wave (Optional)*: For broader smart home interoperability.
- *API Gateway*: For secure communication with cloud services and third-party applications.

Security and Privacy Module

- Data encryption (at rest and in transit).
- User authentication for remote access.
- Secure boot and firmware updates.
- Privacy controls for sensor data (e.g., camera footage).

User Interface (UI) Layer

This layer defines how users interact with and receive information from the system.

On-Stove Touchscreen Display

- *Recipe guidance:* Step-by-step instructions, ingredient lists, and instructional videos.
- *Manual controls:* Intuitive sliders and buttons for setting temperature, power, and timers.
- *Status and alerts:* Real-time cooking progress, safety warnings, and notifications.
- *Personalized dashboards:* Quick access to saved recipes and cooking history.

Mobile Application (iOS/Android)

- *Remote control:* Preheating, starting/stopping cooking cycles, and adjusting settings.
- *Monitoring and notifications:* Real-time updates on cooking progress and safety alerts (e.g., “Gas leak detected at home!”), and reminders.
- *Recipe database and management:* Browse, save, create, and share recipes. Sync ingredients with smart grocery lists.
- *Personalization and analytics:* View cooking history, nutritional insights, and energy consumption reports.
- *Video feed (optional):* Live stream from integrated cameras.

Voice Assistant Integration

- Hands-free control via popular assistants (e.g., Amazon alexa and google assistant).
- “Alexa, start the pasta recipe.” “Hey Google, what’s the internal temperature of the steak?”

Haptic and Audio Feedback

- Subtle vibrations for button presses.
- Audible alerts for timers, warnings, or recipe steps.

Cloud and Data Layer

This layer provides scalable data storage, advanced processing, and external integrations.

Data Storage and Management

- *User profiles and preferences:* Securely stored user settings, dietary restrictions, and cooking history.
- *Recipe database:* Vast library of recipes, constantly updated, and scalable.
- *Sensor data logs:* Historical data for AI training, predictive maintenance, and troubleshooting (Figure 3).
- *Energy consumption data:* For efficiency tracking.

Cloud-Based AI and ML Processing

- *Collective learning:* Aggregates anonymous cooking data from multiple users to refine the recipes and AI models.
- *Complex recipe optimization:* Analyzes ingredients, user feedback, and cooking methods to suggest improvements.
- *Nutritional analysis:* integrates food databases to provide real-time nutritional information for cooked dishes.

Third-Party Integrations

- *Smart home ecosystems:* Control lighting, ventilation, and other appliances based on cooking activities.
- *Grocery delivery services:* Generate shopping lists directly from recipes and order ingredients.
- *Food and health tracking apps:* Sync cooked meal data for dietary management.
- *Recipe sharing platforms:* Connect with communities of cooks.

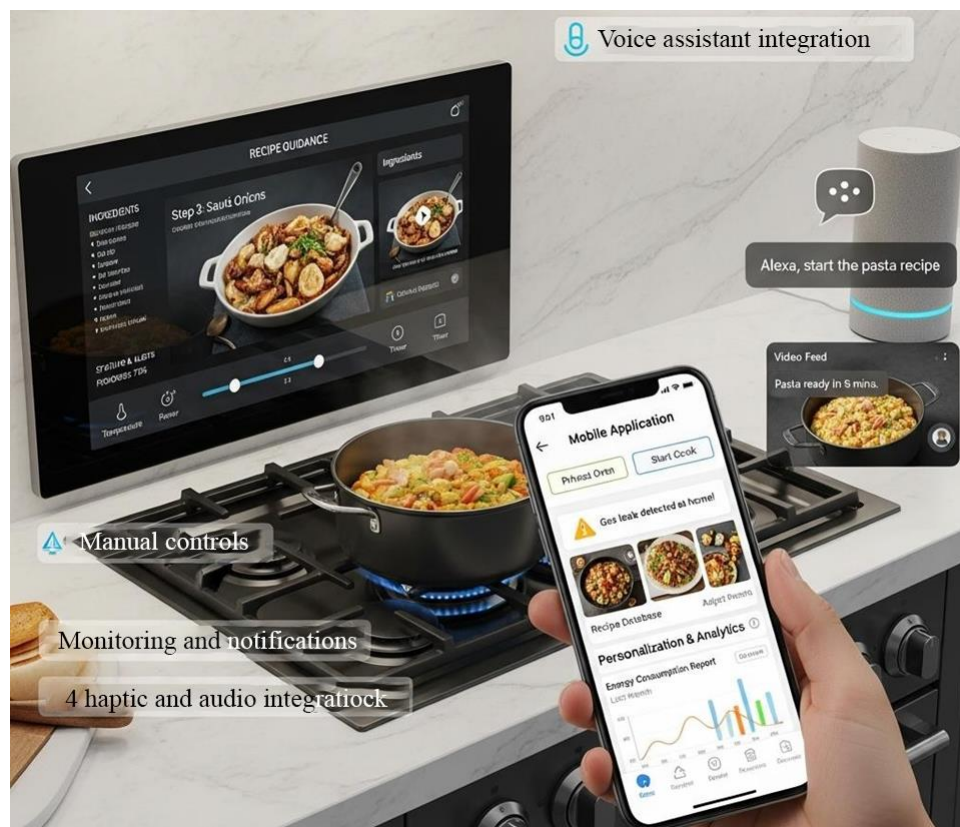


Figure 3. User interface.

Firmware Over-The-Air (FOTA) Updates

Ensuring that the stove's software remains up-to-date with new features, security patches, and performance improvements.

- *Guided recipe execution:* User selects a recipe from the app/touchscreen.
 - The stove identifies ingredients (via camera/weight sensors) and guides the user through preparation.
 - Heats the burner to a precise temperature, monitors food state (e.g., browning, boiling point), and adjusts heat automatically.
 - Notify the user for each step (e.g., “Add onions,” “Flip steak”).
 - Monitors internal food temperature for perfect doneness.
 - Automatically transitions to a warming mode once cooked.
- *Safety protocol—gas leak detection (hybrid model)*
 - The gas sensor detects a leak.
 - The system immediately triggers an audible alarm on the stove and sends a critical notification to the mobile app.
 - The automatic gas shut-off valve activates, cutting off the gas supply.
 - The integrated ventilation system activates at maximum power.
 - Stove display visually warns user and advises on safety steps.
- *Remote monitoring and control*
 - Users away from home check the status of cooking via the mobile app.
 - Receives alerts about cooking progress or potential issues.
 - “Forgot to turn off the burner?”—The user can remotely shut down all burners using a tap.

A smart stove system is more than an appliance upgrade; it is an intelligent kitchen cornerstone. By integrating advanced sensing, AI-driven intelligence, and seamless connectivity, this framework lays the foundation for a cooking experience that is safe, precise, efficient, and user-friendly. It evolves

with the user, learns their preferences, and ultimately empowers everyone to become a more confident and adventurous home chef, transforming the kitchen into a hub of innovation and culinary delight [12].

DISCUSSION

For centuries, the stove has been the unchallenged centerpiece of the home, a silent analog dictator ruling over heat and flame. It demanded mastery, rewarding the patient chef, and mercilessly punishing the distracted amateur. Today, this dynamic is changing fundamentally. The advent of the smart stove system—an interconnected platform of precision heating, integrated sensors, and cloud-based intelligence—is transforming the act of cooking from an intuitive art reliant on guesswork to a dependable, repeatable science. This is not just a stove with Wi-Fi; it is the operating system for the domestic kitchen.

Precision: The Death of the Guessing Game

The most profound impact of a smart stove lies in its ability to achieve and maintain hyperspecific temperatures. Traditional stoves, even high-end gas or electric models, rely on broad subjective settings (Low, Medium, High). However, a smart induction stove integrates sophisticated sensors that communicate directly with the control panel to establish a digital feedback loop.

- *Degree-level control:* Chefs can set temperatures down to a single degree (e.g., 141°F for perfectly medium-rare steak), ensuring that searing heat is maintained or that a gentle simmer never turns into a boil over. This level of precision, previously reserved for expensive laboratory equipment or specialized sous vide setups, is now the standard.
- *Automatic adjustment:* If a large volume of cold stock is added to a simmering pot, the smart system recognizes the temperature drop and intelligently spikes the energy output long enough to restore the target heat, guaranteeing consistent performance without user intervention.
- *The power of consistency:* For home bakers, making candy or preparing delicate emulsifications, this reliability removes the margin of error that often leads to culinary catastrophe. The smart stove transforms ambition into a guaranteed outcome.

The Built-in Sous Chef: Guided Cooking

The second major pillar of the smart stove system is its role as an integrated instruction device. For novice cooks overwhelmed by complex recipes, the stove takes on the persona of a patient sous chef, guiding them through every step.

- *Recipe synchronization:* Users select a recipe from a platform (often displayed on a built-in screen or synced tablet). The stove automatically presets the temperature, duration, and specific burner required for each stage of the recipe.
- *Visual monitoring and feedback:* Many systems include internal cameras or specialized sensors that analyze the condition of food, such as monitoring browning, recognizing boiling points, or measuring core temperature. If a pot is about to boil over, the system can send an alert or automatically reduce the heat.
- *“Hands-free” optimization:* Imagine a system that knows exactly how long different ingredients take to cook. The smart stove can optimize the timing of multiple dishes across different burners and oven zones, ensuring that the mashed potatoes, gravy, and roasted chicken finish cooking simultaneously.

Safety, Sustainability, and Integration

Beyond culinary performance, smart stove systems offer significant practical advantages that appeal to mainstream consumers and environmentalists.

Enhanced Safety

A forgotten pot on a traditional burner is at risk of fire. Smart stoves can address this problem through proactive monitoring.

- *Presence detection:* Motion sensors can be utilized to determine whether a human is standing near a stove. If a burner is left high for 30 min with no detected human presence, the system can automatically shut down, preventing tragedy.
- *Ventilation synchronization:* Many models communicate directly with smart ventilation hoods. When a burner is activated, the hood automatically powers up and adjusts its fan speed based on the intensity of the heat or smoke detected.

Energy Efficiency

Smart induction stoves are inherently more efficient than traditional gas and radiant electric cooktops. They heated the pan directly via electromagnetic energy, thereby minimizing the wasted heat. Furthermore, precise control prevents burners from running unnecessarily hot, reducing overall energy consumption and shrinking the kitchen's carbon footprint.

Navigating the Challenges

While the promise of the digital hearth is vast, its widespread adoption faces several hurdles.

- *Cost barrier:* Smart stoves are significantly more expensive than their traditional counterparts, placing them primarily in the luxury appliance bracket.
- *The learning curve:* For cooks accustomed to the visceral feedback of a gas flame, relying on preset profiles and digital interfaces can feel alienating. There is a psychological barrier to trusting an algorithm based on one's intuition.
- *Dependence on connectivity:* Like all IoT devices, functionality depends on reliable Wi-Fi and the long-term support of proprietary software platforms. If a manufacturer discontinues support for a specific recipe platform, the core "smart" functionality of the expensive appliance is diminished.
- *The over-automated kitchen:* Some culinary purists argue that automating the process removes the joy and necessary skill development inherent in cooking, turning the chef into a mere button-pusher.

The current generation of smart stoves is merely a precursor to a fully integrated kitchen operating system. In the near future, we anticipate stoves that actively communicate with other appliances.

- *AI and predictive cooking:* The stove learn user habits, dietary preferences, and even ingredient inventory (via smart fridge integration). It could suggest recipes based on what needs to be used and automatically preheat the oven based on traffic patterns that indicate when the user is arriving home.
- *Health monitoring:* Integrated sensors might analyze the nutritional content of the prepared meal by adjusting cooking times or ingredients to meet specific caloric goals.
- *Haptic feedback:* Control surfaces may move beyond standard touchscreens by incorporating haptic feedback that feels like turning a physical dial while maintaining digital precision.

The smart stove system is not just an appliance upgrade; it represents a profound shift in how we interact with food preparation. By replacing guesswork with precision and anxiety with guidance, the digital hearth makes high-quality, consistent cooking accessible to everyone, ensuring that the future kitchen is both safer and more delicious.

CONCLUSION

In summary, a conventional kitchen environment presents several challenges related to consistent cooking quality, operational safety, energy consumption, and user convenience. A smart stove system was conceived and developed to directly address these issues, bringing a new level of intelligence and automation to meal preparation. Through the successful integration of advanced sensor technology, IoT connectivity, and intuitive user interfaces, the system demonstrated its capability of delivering precise temperature control, providing proactive safety alerts and automatic hazard mitigation, enabling remote management, and offering personalized culinary guidance. Its successful deployment promises a significant reduction in culinary errors and food waste, improved energy efficiency

through optimized heating cycles, and a substantially more enjoyable and safer cooking experience for users of all skill levels.

The intelligent automation offered by smart stove systems represents a substantial leap forward in kitchen technology, moving beyond mere convenience to foster a genuinely smarter, safer, and more sustainable home environment. While the current iteration establishes a robust foundation, future enhancements could explore deeper machine learning integration for truly adaptive cooking algorithms that learn user preferences and food characteristics, real-time food recognition and automated doneness assessment, seamless integration with broader smart home ecosystems, and the development of advanced material science for even greater efficiency and ease of cleaning. Ultimately, the smart stove system is poised to redefine the act of cooking, empowering users with unprecedented control, confidence, and creativity in the kitchen.

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