INSS Press

Journal of Intelligent and Sustainable Systems

Article

Designing Responsible Agentic AI for Smart Homes: A Hybrid Intelligent Service Ecosystem Perspective

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Abstract

Agentic artificial intelligence is transforming smart homes from reactive automation systems into increasingly autonomous environments capable of reasoning, coordination, and adaptive decision-making. While this shift promises greater efficiency and personalization, it also raises critical challenges related to accountability, transparency, and ethical governance. Existing smart home designs largely conceptualize autonomy as a technical capability rather than a governed socio-technical phenomenon. Drawing on Service-Dominant Logic and the Hybrid Intelligent Service Ecosystem framework, this study proposes the Agentic AI Home System (AAIHS) as a design artifact for responsible agentic smart homes. The architecture integrates three design mechanisms, configured agency, computable institutions, and reflexive learning, to enable appropriate autonomy, institutional alignment, and accountable adaptation in domestic AI environments. Adopting a Design Science Research approach, the study presents a layered system architecture and human–AI interaction design that balance machine initiative with human oversight while ensuring transparency and institutional governance. The study contributes to research on agentic information systems by operationalizing ecosystem-level governance mechanisms for autonomous systems and provides design guidance for developing responsible, transparent, and collaborative smart home technologies.

Keywords: Agentic AI; Smart Homes; Hybrid Intelligent Service Ecosystems; Design Science Research; Responsible AI; Human–AI Collaboration

1. Introduction

Artificial intelligence is entering a phase in which systems no longer merely automate predefined tasks but increasingly act as autonomous agents capable of reasoning, planning, and adapting to context (Baird & Maruping, 2021; Kumar et al., 2026). Smart home technologies are rapidly evolving from reactive automation tools into increasingly autonomous systems that act on users' behalf (Owens et al., 2025; Yu et al., 2024). Advances in agentic artificial intelligence (AI) enable smart home systems to interpret context, pursue goals, and coordinate actions across multiple devices without continuous human instruction (Hughes et al., 2025; Murugesan, 2025; Rivera et al., 2025). Rather than merely executing predefined commands, agentic AI systems increasingly reason about goals, interpret situational context, coordinate actions across subsystems, and learn from ongoing interaction (Hofmann et al., 2024; Holldack et al., 2026; Piccialli et al., 2025). Thermostats autonomously adjust temperature, security systems lock doors in response to perceived threats, and energy managers optimize consumption based on predicted demand (Bonenberger et al., 2025). While such capabilities promise convenience and efficiency, they also introduce a fundamental challenge: how can autonomous systems act appropriately in domestic environments where decisions are value-laden, contested, and continuously evolving?

Unlike industrial or enterprise settings, the home is a deeply social and normative space (Yu et al., 2024). Domestic decisions, such as when to lower heating, activate security measures, or collect sensor data, are rarely purely technical (Owens et al., 2025). They involve competing preferences among household members, situational judgments about comfort and safety, and implicit norms around privacy and authority. As smart homes become more autonomous, users increasingly experience moments of discomfort or loss of control when systems act without explanation, override preferences, or adapt in ways that no longer reflect household values (Bonenberger et al., 2025). For example, a thermostat may lower nighttime temperatures in the name of efficiency without considering health conditions, a security system may initiate intrusive actions based on misclassified signals, or a learning system may drift from user preferences without offering opportunities for correction. These breakdowns reflect not technical failure but a mismatch between system autonomy and domestic meaning.

Existing smart home systems remain ill-equipped to address this problem (Owens et al., 2025). Most commercial designs conceptualize automation as a unidirectional process in which systems optimize predefined objectives and users adapt to system behavior (Murugesan, 2025). In this view, autonomy is treated as a property of the artifact rather than a relational capability negotiated between humans and machines (Murugesan, 2025). As a result, current systems often lack mechanisms for determining when autonomous action is appropriate, how decisions should be justified, and how evolving household norms can be incorporated into ongoing operation. Prior research has documented this techno-centric orientation, showing that smart home scholarship and practice privilege sensing, connectivity, and efficiency while marginalizing human interpretation, ethical negotiation, and institutional governance.

Addressing these limitations requires rethinking the smart home not as a collection of intelligent devices but as a hybrid socio-technical ecosystem in which humans, AI agents, and institutional norms jointly shape action and value. Drawing on the Hybrid Intelligent Service Ecosystem (HISE) framework (Bartelheimer et al., 2025) and Service-Dominant Logic (SDL) (Vargo & Lusch, 2004), we conceptualize smart homes as environments where value emerges through continuous interaction, negotiation, and resource integration among heterogeneous actors. From this perspective, autonomy is not absolute but configured, meaning that decision authority shifts dynamically based on context, risk, competence, and user preference. Similarly, responsible autonomy requires systems to recognize and respect domestic institutions, such as consent, roles, privacy expectations, and safety norms, that govern everyday life (Rivera et al., 2025).

To operationalize this perspective, we introduce the *Agentic AI Home System (AAIHS)*, a design-science artifact that demonstrates how agentic smart homes can be designed to support appropriate autonomy. The AAIHS integrates three core design mechanisms. First, configured agency enables dynamic negotiation of control between humans and AI, allowing systems to act autonomously when appropriate while deferring or seeking confirmation in sensitive contexts. Second, computable institutions encode household norms and external regulations as machine-interpretable policies that constrain and guide system behavior. Third, reflexive learning ensures that adaptation remains accountable and correctable by incorporating user feedback and institutional updates into both decision logic and learning processes. The AAIHS is instantiated through a layered architecture that integrates sensing, reasoning, orchestration, interaction, governance, and learning, and through a user-facing interface that makes autonomy visible, explainable, and negotiable. Rather than treating the interface as a control panel, the design positions it as a governance surface through which users participate in configuring autonomy, interpreting system actions, and shaping future behavior. Accordingly, this study addresses the following research question:

RQ: How can agentic smart home systems be designed to support appropriate autonomy through hybrid intelligence and institutional reflexivity?

This paper makes three contributions. First, it identifies *appropriate autonomy* as a central design challenge for agentic smart homes and articulates its domain-specific characteristics. Second, it translates HISE and SDL into actionable design mechanisms, configured agency, computable institutions, and reflexive learning, grounded in the realities of domestic environments. Third, it presents the AAIHS as a concrete design artifact demonstrating how responsible agentic AI can be embedded into smart home architectures and interaction design.

The remainder of the paper is structured as follows. Section 2 derives domain-specific design requirements and theoretical foundations for responsible agentic smart homes. Section 3 presents the AAIHS architecture and explains how the proposed mechanisms are instantiated. Section 4 examines the user interface as a site of human–AI co-creation and governance. Section 5 discusses implications for design science research and future intelligent service ecosystems.

2. Design Requirements and Theoretical Foundations

2.1. Problem Space: Why Agentic Smart Homes Require New Design Logics

As smart homes adopt agentic AI capabilities, they increasingly operate without continuous human input. Systems can now infer intent, plan actions, and coordinate across devices, enabling proactive security, energy optimization, and environmental control (Owens et al., 2025). However, autonomy in domestic environments differs fundamentally from autonomy in organizational or industrial settings (Sequeiros et al., 2021; Yu et al., 2024). Homes are socially dense, normatively rich, and continuously evolving spaces in which actions carry personal, ethical, and relational consequences (Rivera et al., 2025).

Three domain-specific challenges recur across smart home contexts. First, autonomy without situational appropriateness leads to overreach. Smart systems may act decisively in low-confidence or high-stakes situations, such as locking doors, disabling devices, or altering environmental conditions, without assessing whether human confirmation is warranted. These actions may be technically defensible yet socially inappropriate, undermining trust and comfort. Second, optimization without normative grounding produces misalignment. Smart homes frequently optimize abstract objectives such as energy efficiency, security, or convenience while overlooking contextual factors including health conditions, shared household roles, or privacy expectations. Without explicit representations of domestic norms, systems lack a basis for resolving value conflicts (Shukla, 2026). Third, learning without accountability results in opaque adaptation. While machine learning enables personalization over time, adaptation often occurs invisibly. Users may experience gradual drift away from preferences without understanding why changes occurred or how to intervene. In domestic contexts, such opacity erodes confidence and discourages sustained engagement.

These challenges are not isolated usability issues; they reflect a deeper limitation in how smart home autonomy is conceptualized (Owens et al., 2025). Most systems treat intelligence as embedded within individual devices and position users as external controllers (Owens et al., 2025). What is missing is a design logic that supports shared agency, institutional awareness, and reflexive adaptation suited to everyday domestic life.

Despite growing interest in intelligent and connected home technologies, existing research offers limited guidance on how autonomy should be designed in domestic environments (Owens et al., 2025). Much of the literature focuses on device capabilities, sensing infrastructures, and automation efficiency, while paying comparatively little attention to how autonomous decisions should be governed, justified, or aligned with household norms. As smart homes evolve into agentic environments capable of independent reasoning and coordination, this gap becomes increasingly consequential. Designing autonomy in such settings therefore requires new design logics that account for shared agency, institutional constraints, and reflexive adaptation.

From this problem space, three design requirements emerge: (1) smart homes must support appropriate autonomy, rather than maximal autonomy; (2) smart homes must operationalize domestic norms and rules, not merely optimize technical objectives; and (3) smart homes must enable transparent and correctable learning, rather than silent adaptation.

2.2. From Agentic AI to Configured Agency in Domestic Contexts

Agentic AI extends traditional automation by enabling systems to pursue goals, reason under uncertainty, and adapt behavior over time (Baird & Maruping, 2021; Hofmann et al., 2024; Hughes et al., 2025). Prior research highlights benefits such as increased efficiency, personalization, and proactive service delivery. However, much of this work implicitly assumes that greater autonomy is inherently desirable.

In domestic environments, this assumption does not hold. Homes are characterized by heterogeneous actors, including adults, children, guests, and pets, whose preferences, authority, and vulnerabilities differ. Decisions such as adjusting heating, activating cameras, or restricting access often require contextual judgment rather than optimization. Consequently, absolute autonomy becomes problematic.

This motivates the concept of configured agency, which reframes autonomy as a variable and negotiable property of the system (Bartelheimer et al., 2025; Rivera et al., 2025). Configured agency refers to the dynamic allocation of decision authority between humans and AI based on situational risk, confidence, ethical sensitivity, and user preference. Rather than asking whether a system can act autonomously, configured agency asks when it should, under what constraints, and with what level of human involvement.

In smart homes, configured agency allows systems to act independently in routine, low-risk situations while deferring to human judgment in ambiguous or high-stakes contexts. Importantly, it also requires systems to justify their actions and accept correction. Autonomy thus becomes a relational design choice rather than a purely technical capability, grounded in domestic practices and expectations. Configured agency therefore serves as the first core design mechanism, directly addressing the problem of autonomy without appropriateness.

2.3. Institutional Reflexivity and the Need for Computable Institutions

While configured agency determines who should decide, it does not specify how decisions should be evaluated. Domestic actions are governed by a dense web of institutions, including shared norms, household rules, role expectations, and external regulations. These institutions define what is acceptable, appropriate, and legitimate.

Current smart home systems largely ignore this institutional layer (Owens et al., 2025; Yu et al., 2024). Rules are often implicit, fragmented, or hard-coded, making them difficult to adapt, contest, or explain. As a result, systems lack the capacity to reason about privacy, authority, or safety beyond simplistic thresholds.

To address this gap, this study introduces the notion of computable institutions. Computable institutions are machine-interpretable representations of social and ethical rules that constrain and guide system behavior. They translate abstract expectations, such as "bedrooms are private," "parents have override authority," or "comfort takes precedence over efficiency when health is at risk," into executable policies. In domestic contexts, computable institutions enable systems to: (1) enforce privacy zones regardless of optimization goals; (2) differentiate authority among household members; and (3) resolve conflicts between competing values such as comfort, safety, and sustainability.

By embedding institutional rules into the system's reasoning and orchestration layers, smart homes become institutionally aware actors rather than purely technical optimizers. This directly addresses the problem of optimization without normative grounding.

2.4. Reflexive Learning and Accountability in Smart Home Adaptation

Learning is central to intelligent systems, particularly in environments where preferences evolve. However, in smart homes, learning must be both adaptive and accountable. Prior research on adaptive AI, explainable systems, and agentic intelligence suggests that conventional reinforcement or preference-learning approaches often prioritize performance improvement while obscuring the learning process from users (Kumar et al., 2026).

This creates two risks. First, users may be unable to understand why system behavior changes over time. Second, incorrect or outdated preferences may persist due to the absence of structured mechanisms for correction.

Reflexive learning addresses these risks by embedding learning within a feedback loop that includes explanation, evaluation, and revision. Reflexive learning treats user responses—not only explicit feedback but also overrides and adjustments—as signals that update both algorithmic models and governing rules. Learning thus becomes socially situated rather than purely statistical.

In smart homes, reflexive learning ensures that adaptation remains aligned with household values and evolving circumstances. It transforms learning from a background process into a visible and negotiable aspect of interaction, addressing the problem of opaque adaptation. Reflexive learning therefore aligns with emerging research on human-in-the-loop AI and explainable adaptive systems, which emphasize transparency and user participation in AI learning processes.

2.5. Hybrid Intelligent Service Ecosystems and Service-Dominant Logic

The three design mechanisms, i.e., configured agency, computable institutions, and reflexive learning, require a theoretical framework capable of capturing distributed intelligence and co-creation. The Hybrid Intelligent Service Ecosystem (HISE) framework (Bartelheimer et al., 2025) provides such a lens.

HISE conceptualizes intelligence as emerging from interaction among human, artificial, and hybrid actors rather than residing in a single artifact. It emphasizes reflexivity, institutional embedding, and value co-creation, making it particularly suitable for domestic environments.

Service-Dominant Logic (SDL) (Vargo & Lusch, 2004) complements HISE by grounding value in resource integration rather than technological output. From an SDL perspective, smart homes do not deliver value autonomously; value emerges through ongoing interaction between users, AI systems, and institutional arrangements.

HISE and SDL justify a shift from device-centric automation to ecosystem-level design. They provide the theoretical foundation for treating smart homes as sites of negotiated autonomy, institutional governance, and shared learning.

2.6. Toward Responsible and Reflexive Agentic Smart Homes

Synthesizing these perspectives, this study argues that responsible agentic smart homes require three interdependent design mechanisms. Configured agency governs how decision authority is dynamically shared between humans and AI (Bartelheimer et al., 2025). Computable institutions ensure that autonomous behavior is constrained by social and ethical norms (Malik et al., 2026; Rivera et al., 2025). Reflexive learning enables systems to adapt both their models and governing rules over time (Kumar et al., 2026).

These mechanisms shift the design focus from isolated automation to the responsible orchestration of hybrid intelligence. Rather than asking how intelligent a smart home can become, the central question becomes how intelligence can remain accountable, interpretable, and aligned with evolving domestic practices. The following section translates this theoretical foundation into a concrete design architecture that operationalizes hybrid intelligent service ecosystems in smart homes.

3. Design Architecture and Rationale

3.1. Design Objectives and Principles

Based on the limitations of current smart home systems identified in Section 2, the design of the Agentic AI Home System (AAIHS) is guided by three interrelated objectives: (1) enabling autonomy without relinquishing human control, (2) embedding ethical and social norms directly into system behavior, and (3) supporting adaptive learning that remains transparent and correctable over time. These objectives are operationalized through three design principles derived from the Hybrid Intelligent Service Ecosystem (HISE) framework and Service-Dominant Logic: configured agency, computable institutions, and reflexive learning.

Configured agency addresses the problem of unconditional automation by ensuring that decision authority is dynamically allocated between human users and AI agents according to contextual risk, competence, and user preference. Rather than treating autonomy as a fixed system attribute, the AAIHS conceptualizes agency as situational and adjustable.

Computable institutions address the absence of social and ethical grounding in existing smart home systems. Household norms, consent arrangements, role hierarchies, and regulatory constraints are translated into machine-interpretable policies that actively govern system behavior rather than remaining external or implicit guidelines.

Reflexive learning addresses the opacity and drift commonly associated with adaptive systems. Learning processes are explicitly linked to user feedback, institutional updates, and auditability, ensuring that adaptation remains accountable rather than autonomous in isolation. These principles establish the foundation for a smart home system that functions as a hybrid intelligent service ecosystem rather than merely a collection of automated devices.

In sum, these design principles translate the requirements identified in Section 2 into implementable system capabilities. Configured agency operationalizes appropriate autonomy, computable institutions operationalize institutional alignment, and reflexive learning operationalizes transparent and correctable adaptation.

3.2. Conceptual Architecture of the AAIHS

The design artifact proposed in this study is the Agentic AI Home System (AAIHS) architecture, conceptualized as a socio-technical ecosystem in which human, artificial, and institutional actors integrate resources to co-create value-in-use. Figure 1 presents the conceptual architecture, illustrating how sensing, reasoning, orchestration, interaction, governance, and learning are organized around the three design principles.

Unlike traditional smart home architectures that prioritize device-level automation or workflow efficiency, the AAIHS centers on responsible orchestration. Decision-making is not localized within individual devices but coordinated through an agentic core that is constrained by institutional rules and continuously shaped by user interaction. This conceptual architecture establishes the foundation for a layered implementation described below.

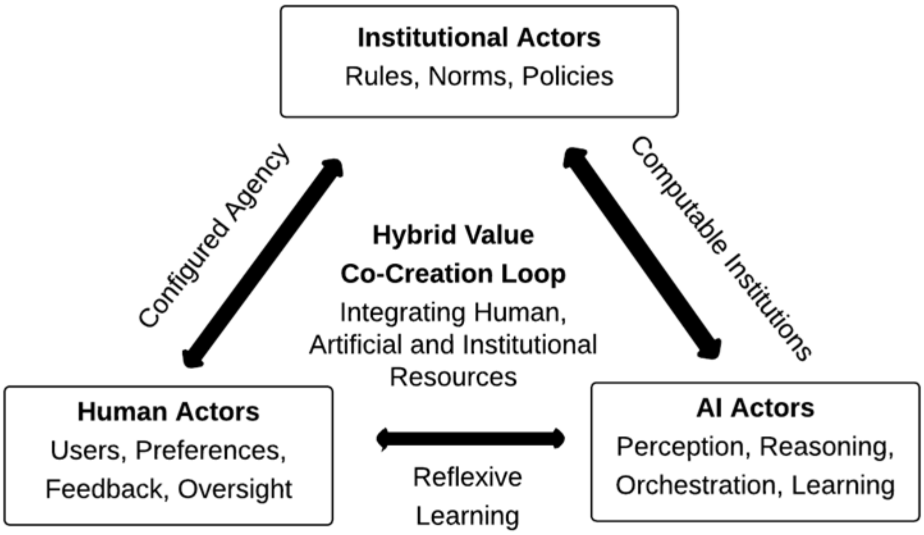

Figure 1. Conceptual Architecture of the Agentic AI Home System (AAIHS)

3.3. Integrated Layered Architecture

To translate the conceptual architecture into a realizable artifact, the AAIHS adopts a six-layer structure in which each layer fulfills a distinct functional role while remaining interdependent with the others (Figure 2).

The sensing and perception layer captures contextual data from distributed IoT devices using lightweight, event-driven communication. Importantly, institutional constraints such as consent, privacy boundaries, and data minimization are enforced at this stage, ensuring that responsibility is embedded at the point of data acquisition.

The semantic reasoning layer interprets contextual inputs using ontological representations, probabilistic inference, and language-model–based reasoning. This layer evaluates situational uncertainty and ethical sensitivity to determine whether an action can be executed autonomously or requires human confirmation, thereby enacting configured agency.

The agentic orchestration layer coordinates actions across subsystems such as HVAC, lighting, security, and energy management. Rather than optimizing isolated device performance, orchestration decisions are constrained by institutional policies and user-defined priorities, ensuring legitimacy and alignment with household values.

The human–AI interaction layer provides mechanisms through which users engage with system behavior. It exposes decision rationales, autonomy settings, and override options, enabling users to actively participate in shaping system outcomes rather than merely issuing commands.

The institutional governance layer encodes household norms, role distinctions, consent rules, and external regulations as machine-interpretable policies. These computable institutions guide reasoning and orchestration processes and are subject to revision through user interaction and feedback.

Finally, the learning and reflexivity layer integrates reinforcement signals, user feedback, and audit data to update both algorithmic models and institutional rules. Learning is thus treated as a governed and inspectable process rather than an opaque optimization routine.

These layers form a closed loop in which perception informs reasoning, reasoning guides action, action is mediated through interaction and governance, and feedback drives accountable adaptation.

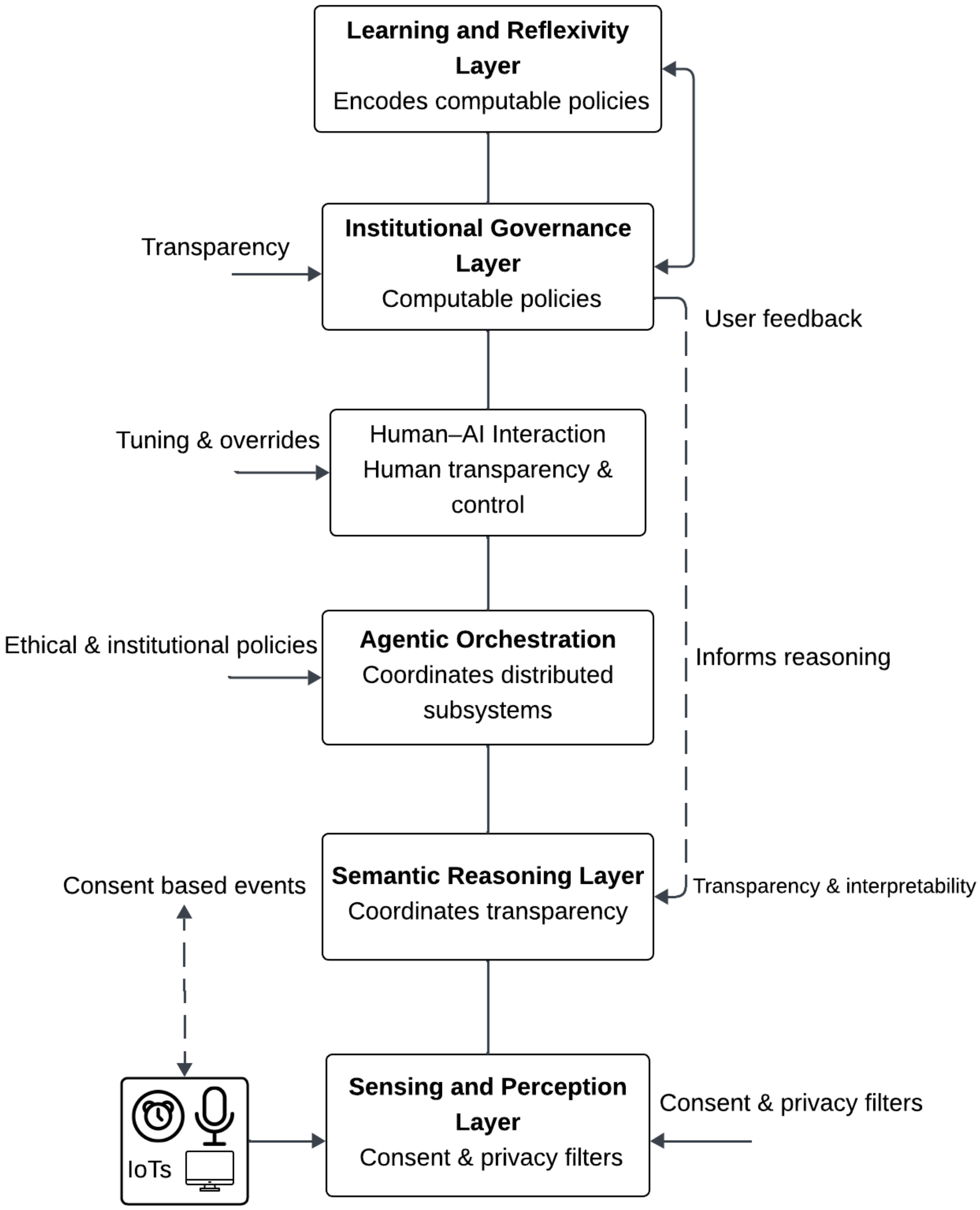

Figure 2. Integrated Layered Architecture of the AAIHS

3.4. Operational Architecture and System Flow

Figure 3 illustrates the operational instantiation of the AAIHS within a secure, distributed infrastructure. Contextual data from edge devices are transmitted via encrypted MQTT channels to an AI agent hosting the reasoning and orchestration components. External services and cloud-based APIs are accessed through authenticated protocols, ensuring traceability, access control, and data integrity.
Human interaction occurs through voice interfaces and mobile dashboards, where users can inspect decisions, manage consent, and override automation. System behavior follows a reflexive operational cycle, reason and plan, act, evaluate, and recontextualize, ensuring that outcomes continuously inform subsequent decisions. Audit logs and feedback channels connect operational behavior to the institutional governance and learning layers, enabling ethical recalibration over time.

This operational architecture demonstrates how abstract design principles are translated into concrete mechanisms, providing a replicable blueprint for responsible agentic smart home systems.

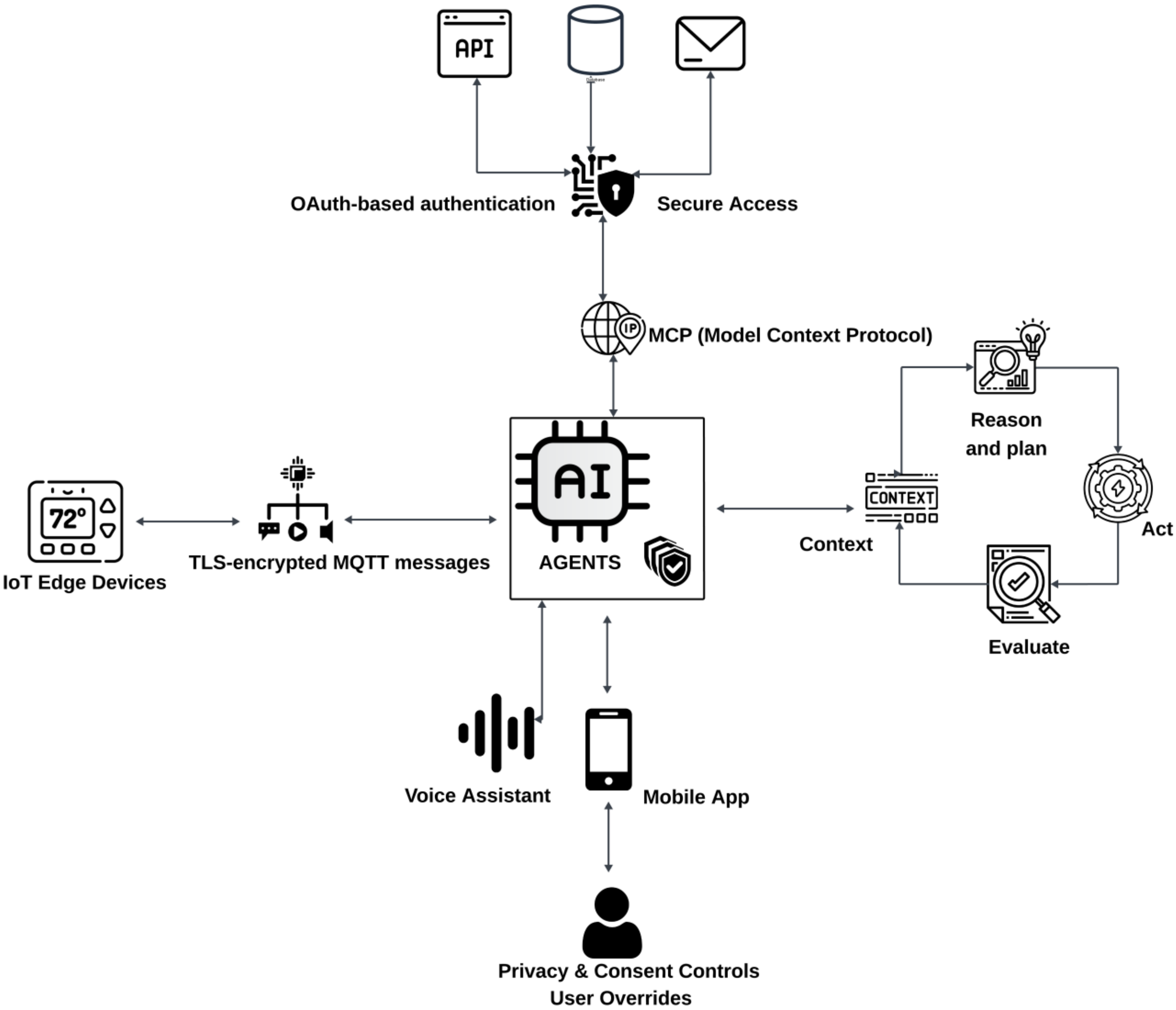

Figure 3. Technical Architecture and Operational Flow of the AAIHS

By explicitly linking architectural layers, governance mechanisms, and learning processes, the AAIHS provides a reusable design blueprint that can guide the development of responsible agentic systems in smart homes and related service environments.

4. User Interface and Human–AI Co-Creation

4.1. Interface as a Mechanism for Configured Agency

In the Agentic AI Home System (AAIHS), the user interface is not merely a control surface but a central mechanism through which configured agency is enacted. As agentic systems increasingly operate with a degree of autonomy, the interface becomes the primary site where humans and AI negotiate authority, responsibility, and meaning. Rather than supporting one-directional command execution, the AAIHS interface is designed to facilitate dialog-based interaction, enabling users to understand, influence, and recalibrate system behavior in context (Figure 4).

This design departs from conventional smart home dashboards that emphasize device status and manual overrides. Instead, the AAIHS interface operationalizes hybrid intelligence by making autonomy transparent, adjustable, and contestable. Users are not positioned as supervisors who intervene only when automation fails, but as co-creators who continuously shape how and when the system acts.

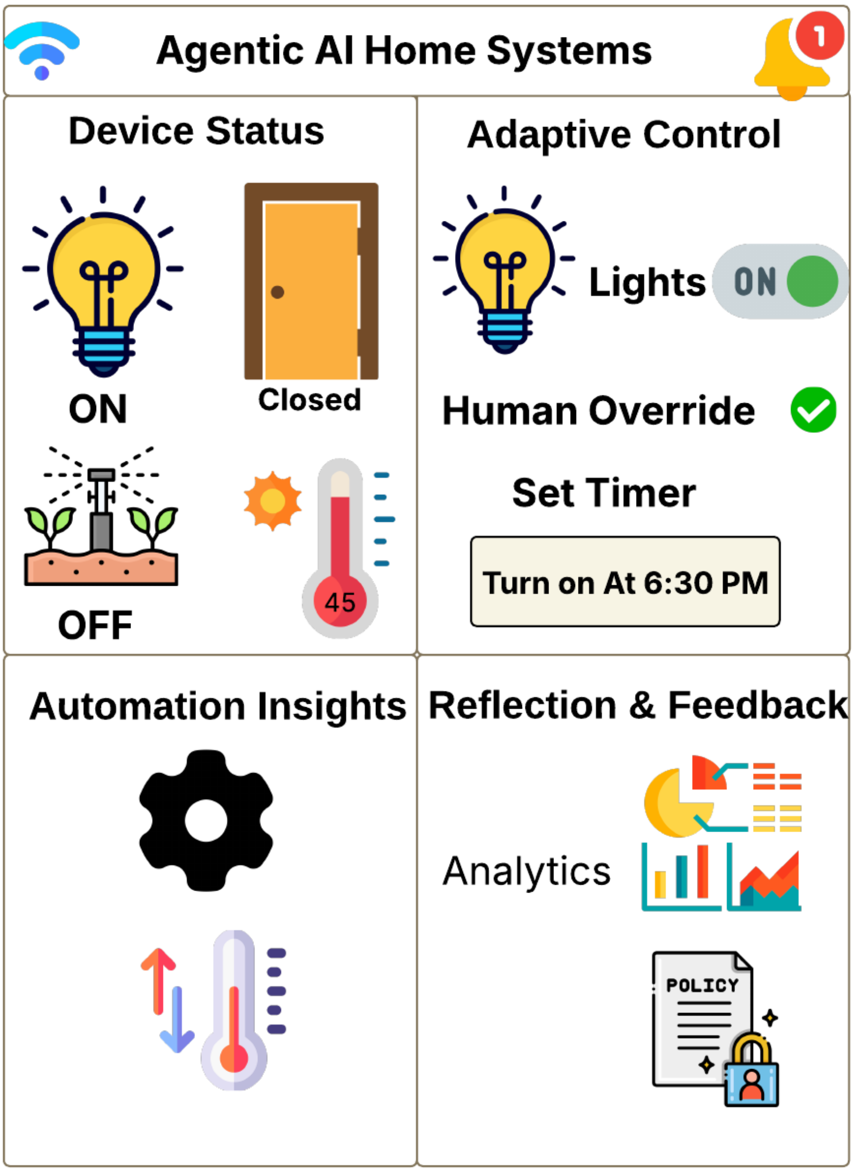

Figure 4. User Dashboard for Hybrid Co-Creation, Transparency, and Human Override

In this way, the interface operationalizes the three core design mechanisms of the AAIHS: configured agency through adjustable autonomy and human override, computable institutions through the visibility of governing rules and constraints, and reflexive learning through continuous feedback integration.

4.2. Integration with Orchestration and Institutional Governance

The interface is tightly coupled with the agentic orchestration, institutional governance, and reflexive learning layers described in Section 3. Real-time telemetry from connected devices flows through the orchestration layer and is rendered intelligible at the interface level. Each automated action, such as adjusting temperature, activating security measures, or optimizing lighting, is presented alongside its rationale, confidence level, and relevant institutional constraints.
These explanations are not static annotations but dynamically generated representations of the system's reasoning process. By exposing why an action was taken and under which conditions, the interface supports interpretability and accountability without overwhelming users with technical detail.

Crucially, user responses to system actions, such as acceptance, modification, or override, are treated as first-class inputs rather than exceptional interventions. Acceptance reinforces current configurations, modification initiates a negotiation process in which alternative priorities are evaluated, and override actions are recorded within the institutional governance layer. In this way, the interface functions as an active learning channel that directly links human judgment to system adaptation.

4.3. Interface Modules Supporting Transparency and Control

The AAIHS interface is organized around four interdependent modules that collectively support transparency, agency, and reflexivity.

The contextual state module provides a synthesized view of household conditions, such as temperature, energy consumption, and security status. Information is rendered through natural language summaries rather than raw sensor data, enabling users to comprehend system state without technical interpretation. The direct intervention module enables users to intervene in or override automated behavior. Rather than treating overrides as isolated corrections, this module records the intent and context of each intervention, ensuring that manual actions contribute to institutional learning.

The automation insight module visualizes the logic underlying system behavior. It explains which data sources informed a decision, which institutional rules were applied, and how competing objectives were resolved. By making reasoning explicit, this module operationalizes explainability as a core design property rather than a post hoc feature.

The reflection and notification module supports meta-level interaction by prompting users to review outcomes, adjust autonomy thresholds, or revise ethical preferences. These prompts encourage users to engage with the system as a co-evolving partner rather than a background utility. These modules ensure that decision-making processes remain visible, revisable, and discussable over time.

4.4. Human–AI Co-Creation in Everyday Interaction

Human–AI co-creation in the AAIHS emerges through repeated, low-friction interactions rather than explicit configuration tasks. For example, when the system recommends lowering blinds to conserve energy, users may accept the suggestion, modify its parameters, or reject it entirely. Each response generates a distinct learning signal for the system: acceptance reinforces the current model, modification initiates a negotiation of priorities, and rejection prompts updates to institutional rules governing similar situations.

Over time, these micro-level interactions accumulate into institutional learning. Preferences, ethical boundaries, and situational sensitivities become embedded within the system's operational logic. The home thus evolves as a hybrid service ecosystem in which human values and algorithmic capabilities are continuously aligned through everyday use.

4.5. Interface as Ethical Infrastructure

Beyond usability and interaction efficiency, the AAIHS interface functions as ethical infrastructure. Decision pathways, audit trails, and explanation traces remain persistently accessible, ensuring that autonomy is always contextualized within social and institutional norms. This visibility reinforces co-accountability, positioning both human and artificial actors as responsible participants in the ecosystem. By rendering autonomy explainable, negotiable, and correctable, the interface transforms domestic automation into a form of responsible collaboration. Rather than obscuring intelligence behind seamless execution, the AAIHS interface foregrounds the ethical dimensions of agentic behavior, enabling trust, learning, and shared responsibility to emerge organically.

This design demonstrates how user interfaces can function as governance infrastructures in agentic service systems, enabling transparency, negotiation, and institutional learning across human–AI collaborations.

5. Discussion, Design Evaluation, and Contributions

This study advances research on smart homes and agentic AI by conceptualizing the Agentic AI Home System (AAIHS) as a Hybrid Intelligent Service Ecosystem (HISE) and articulating how responsible agency can be designed, governed, and experienced in domestic environments. Rather than treating autonomy as a binary system property, the paper reframes intelligent homes as socio-technical ecosystems in which agency, value, and accountability emerge through continuous interaction among human, artificial, and institutional actors.

5.1. Design Evaluation: Validating Appropriate Autonomy

This study adopts a Design Science Research (DSR) approach (Hevner et al., 2004; Rivera et al., 2025), in which the Agentic AI Home System (AAIHS) constitutes a prescriptive artifact designed to address a clearly articulated problem space: how to enable appropriate autonomy in agentic smart homes. In accordance with Design Science Research principles, the artifact is evaluated through ex-ante analytical validation, including requirement–artifact traceability, scenario-based walkthroughs, and theoretical consistency assessment.

5.1.1. Requirement–Artifact Alignment

Section 2 identified three recurring domestic challenges in agentic smart homes: (1) autonomy without situational appropriateness, (2) optimization without normative grounding, and (3) learning without accountability. The AAIHS directly addresses these challenges through three interdependent design mechanisms (Table 1).

Table 1: Design Requirements Traceability and Artifact Instantiation

Identified Challenge	Design Requirement	AAIHS Mechanism
Autonomy without appropriateness	Appropriate autonomy	Configured agency in reasoning layer + adjustable autonomy thresholds
Optimization without normative grounding	Institutional alignment	Computable institutions in governance layer
Learning without accountability	Transparent and correctable learning	Reflexive learning + visible feedback loops

First, configured agency addresses the problem of autonomy overreach by dynamically allocating decision authority between humans and AI according to contextual risk, uncertainty, and ethical sensitivity. Rather than maximizing automation, the system embeds conditional autonomy thresholds within its reasoning layer, ensuring that high-stakes or ambiguous situations trigger human confirmation. Second, computable institutions address misalignment by embedding household norms, role hierarchies, and regulatory constraints into machine-interpretable policies. This prevents orchestration processes from optimizing abstract goals (e.g., energy efficiency) in ways that violate domestic meaning (e.g., health, privacy, authority). Third, reflexive learning mitigates opaque adaptation by integrating user feedback and institutional revision into the learning process. Overrides, adjustments, and contextual responses update not only predictive models but also governing rules, ensuring that learning remains transparent and correctable. This traceability analysis demonstrates that each design mechanism is structurally aligned with a specific domestic autonomy failure, satisfying the DSR criterion that artifacts must respond explicitly to the problem space from which they are derived.

5.1.2. Scenario-Based Validation

To further assess adequacy, the artifact was evaluated against representative domestic breakdown scenarios. In overreach situations (e.g., misclassified security threats), configured agency enables autonomy throttling through risk-sensitive reasoning, preventing inappropriate high-stakes action. In misalignment situations (e.g., energy optimization conflicting with occupant health), computable institutions constrain orchestration decisions, ensuring that normative rules override narrow optimization. In learning-drift situations (e.g., personalization diverging from preferences), reflexive learning and interface transparency allow users to inspect, revise, and recalibrate adaptation trajectories.

Across these scenarios, the AAIHS demonstrates robustness in balancing autonomy with accountability. Importantly, the evaluation demonstrates that appropriate autonomy is not achieved through a single mechanism but through coordinated interaction among architecture, governance, and interface layers. These scenario walkthroughs serve as analytical demonstrations that the proposed design mechanisms logically address recurring autonomy failures in domestic environments, consistent with ex-ante artifact evaluation in design science research.

5.1.3. Theoretical Coherence

Beyond functional adequacy, the artifact was assessed for theoretical alignment. The AAIHS operationalizes the Hybrid Intelligent Service Ecosystem (HISE) framework by distributing intelligence across human, artificial, and institutional actors rather than localizing it within devices. Reflexivity is instantiated through feedback loops spanning reasoning, governance, and learning layers. Institutional embedding is achieved through computable policy enforcement mechanisms.

Similarly, the artifact extends Service-Dominant Logic (SDL) by embedding institutional arrangements directly into computational processes. Value in the smart home does not reside in optimized temperature or reduced energy consumption alone; it emerges through negotiated resource integration shaped by institutional constraints. By translating institutional arrangements into machine-interpretable rules, the AAIHS bridges service theory and agentic system design.

5.2. Theoretical Contributions

First, this study contributes to the emerging literature on agentic AI by reconceptualizing agency as configured, relational, and distributed rather than embedded solely within an AI artifact. Prior work on agentic systems has largely emphasized technical autonomy or cognitive capability. In contrast, the AAIHS demonstrates that meaningful autonomy in domestic contexts depends on how decision authority is dynamically allocated, negotiated, and justified across actors. By operationalizing configured agency, the study provides a theoretically grounded mechanism for explaining when and why AI systems should act independently, defer to human judgment, or engage in collaborative decision-making.

Second, the paper extends the Hybrid Intelligent Service Ecosystem (HISE) framework by grounding it in the smart home domain and specifying concrete design mechanisms through which hybrid intelligence emerges. While HISE has primarily been articulated at a conceptual level, this study shows how its core principles—co-creation, reflexivity, and institutional embedding—can be instantiated through layered architecture, orchestration logic, and interaction design. In doing so, the paper responds directly to calls for domain-specific elaboration of HISE propositions and clarifies how hybrid intelligence unfolds in everyday, non-organizational settings.

Third, the study advances Service-Dominant Logic (SDL) by introducing computable institutions as a bridge between institutional theory and agentic system design. SDL emphasizes that value co-creation is governed by institutional arrangements, yet offers limited guidance on how such arrangements operate within computational systems. By conceptualizing institutions as machine-interpretable policies—such as consent rules, role-based authority, and contextual constraints—the paper extends SDL into the design of intelligent services that must reason ethically and contextually in real time.

5.3. Design Contributions

From a design science perspective, the AAIHS constitutes a coherent design artifact that integrates architecture, governance, and interaction into a unified system logic. The study demonstrates how responsible AI principles—such as transparency, accountability, and user control—can be embedded directly into system architecture rather than treated as external guidelines or post hoc explanations.

A key design contribution lies in conceptualizing the user interface as a governance mechanism rather than a peripheral control tool. By positioning the interface as the primary site of human–AI co-creation, the AAIHS illustrates how interpretability, override, and feedback can be designed to support institutional learning and ethical reflexivity. This reframing challenges dominant smart home designs that prioritize seamless automation at the expense of user understanding and agency.

In addition, the layered architecture presented in this study offers a reusable design logic for other agentic service systems. The separation of sensing, reasoning, orchestration, interaction, institutional governance, and reflexive learning provides a modular yet interdependent structure that designers can adapt to domains beyond the home, such as healthcare, mobility, or energy management.

In sum, these insights contribute design knowledge that extends beyond the specific artifact by articulating generalizable principles for designing accountable agentic service systems.

5.4. Practical Implications

For designers and developers of smart home technologies, this study highlights the risks of pursuing autonomy without governance. Systems that optimize efficiency without transparency or institutional grounding may undermine trust, adoption, and long-term value creation. The AAIHS illustrates how incorporating configured agency and computable institutions can mitigate these risks by aligning automation with user values, household norms, and situational ethics.

For users and households, the proposed design reframes the smart home as a collaborative partner rather than an opaque controller. By making system reasoning visible and negotiable, users gain the ability to shape not only outcomes but also the logic by which decisions are made. This shift supports sustained engagement and reduces the cognitive and ethical burden often associated with autonomous systems.

For policymakers and platform providers, the study underscores the importance of embedding governance mechanisms at the system level. As domestic AI systems increasingly rely on external platforms, APIs, and cloud-based services, institutional reflexivity becomes critical for ensuring compliance, accountability, and responsible data use across organizational boundaries.

5.5. Limitations and Future Research

This study is conceptual and design-oriented, focusing on architectural and interaction principles rather than empirical evaluation. Future research could validate the AAIHS through prototyping, user studies, or field deployments to examine how configured agency and reflexive interfaces affect trust, satisfaction, and long-term adaptation. Comparative studies could further explore how different institutional configurations influence outcomes across households with diverse values, compositions, and cultural contexts.

Additionally, the effectiveness of the proposed architecture may depend on contextual factors such as household size, cultural norms, and platform interoperability constraints, suggesting important boundary conditions for the applicability of the framework.

Another important limitation concerns the level of user participation assumed in the proposed design. The AAIHS framework emphasizes human–AI co-creation through feedback, overrides, and interpretive interaction. However, users may vary substantially in their willingness or ability to actively engage with smart home systems. Differences in technical literacy, trust in automation, and motivation may influence how frequently users interact with system explanations or modify system behavior. In practice, many users may prefer minimal interaction and expect automated systems to operate largely in the background. Future research should therefore examine how agentic smart home architectures can accommodate both high-engagement and low-engagement users, exploring interface designs and adaptive interaction models that support passive as well as active forms of human–AI collaboration.

More broadly, future work may extend the concept of computable institutions to multi-household or platform-level ecosystems, where governance spans multiple stakeholders and regulatory regimes. Such extensions would further illuminate how hybrid intelligence can be responsibly governed and scaled across interconnected service ecosystems.

6. Conclusion

This study reconceptualizes smart homes as Hybrid Intelligent Service Ecosystems in which responsible intelligence emerges through collaboration among human, artificial, and institutional actors. By identifying appropriate autonomy as a central design challenge for agentic smart homes, the paper introduces the Agentic AI Home System (AAIHS) as a design artifact that demonstrates how autonomous behavior can be responsibly designed rather than assumed as an inherent property of intelligent systems.

The proposed architecture operationalizes this perspective through three interdependent mechanisms: configured agency, computable institutions, and reflexive learning. Together, these mechanisms enable smart home systems to dynamically negotiate decision authority, align automated actions with household norms and institutional rules, and support accountable learning through user interaction and feedback. Through its layered architecture and reflexive user interface, the AAIHS illustrates how intelligent environments can remain adaptive while preserving human oversight, transparency, and ethical accountability.

More broadly, this work highlights that agency in intelligent environments must be situated, governed, and continuously recalibrated, particularly in socially and ethically complex contexts such as the home. By translating ecosystem-oriented service theory into actionable design mechanisms and architectural principles, this study contributes design knowledge for developing trustworthy, transparent, and human-aligned agentic systems. The design logic articulated here extends beyond domestic settings and may inform the development of responsible agentic systems in other intelligent service ecosystems, including healthcare, mobility, and energy management. As agentic AI systems continue to expand across everyday environments, ensuring that autonomy remains accountable, transparent, and aligned with human values will become an increasingly central design challenge.

Funding
This research received no external funding.

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