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World Bulletin of Education and Learning (WBEL)

ISSN (E): 3072-175X | Volume 2, Issue 9, September 2026
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DATABASE-DRIVEN CONTROL ALGORITHM FOR A SMART HOME SYSTEM THAT ADAPTS TO USER HABITS

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Abstract

This article proposes a database-driven control algorithm for a smart home system that adapts to user habits. The proposed approach integrates historical sensor readings, device operating records, environmental conditions, and explicit user preferences into a structured framework for household automation. Its objective is to support a balance between occupant comfort, energy efficiency, and user control through decisions informed by recurring patterns of household activity. The algorithm combines time-dependent occupancy estimates, preference profiles, and rule-based safety constraints to generate device control actions. A feedback mechanism records manual overrides and uses them to update preference estimates while distinguishing recurring choices from temporary exceptions. The database supports both operational decision-making and the traceability of automated actions. The framework is considered in the residential context of Uzbekistan, with attention to seasonal variation, household diversity, internet interruptions, and the feasibility of local data processing. An evaluation methodology is outlined using comfort deviations, energy consumption, override frequency, response latency, and system availability as performance indicators. The article presents a conceptual design and a proposed evaluation framework rather than experimentally validated performance improvements. Its contribution is an explicit connection between persistent household data, adaptive decision-making, and user supervision, providing a foundation for subsequent implementation and empirical assessment.

Keywords: Smart home, adaptive control, database-driven systems, user habits, occupancy prediction, energy management, Internet of Things, user preferences.

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Introduction

MA’LUMOTLAR BAZASI ASOSIDA FOYDALANUVCHI ODATLARIGA MOSLASHUVCHI AQLLI UY TIZIMINI BOSHQARISH ALGORITMI

Xushvaqova Shohsanam Jo'ra qizi
Matematik modellashtirish. Sonli usullar
Dasturlar majmui yo’nalishi mustaqil tadqiqotchisi
O’zbekiston Respublikasi

Annotatsiya:
Ushbu maqolada foydalanuvchi odatlariga moslashuvchi aqlli uy tizimini boshqarish uchun ma’lumotlar bazasiga asoslangan algoritm taklif etiladi. Taklif etilayotgan yondashuv sensorlarning tarixiy ko‘rsatkichlari, qurilmalarning ishlash qaydlari, muhit sharoitlari va foydalanuvchi tomonidan aniq belgilangan afzalliklarni uy jarayonlarini avtomatlashtirishning yagona tuzilmasiga birlashtiradi. Uning maqsadi xonadon faoliyatining takrorlanuvchi qonuniyatlariga asoslangan qarorlar orqali yashovchilar qulayligi, energiya samaradorligi va foydalanuvchi nazorati o‘rtasidagi muvozanatni ta’minlashga ko‘maklashishdir. Algoritm qurilmalarni boshqarish amallarini shakllantirishda vaqtga bog‘liq bandlik baholari, foydalanuvchi afzalliklari profillari va qoidalarga asoslangan xavfsizlik cheklovlarini uyg‘unlashtiradi. Qayta aloqa mexanizmi foydalanuvchining avtomatik boshqaruvga qo‘lda kiritgan o‘zgartirishlarini qayd etib, takrorlanuvchi tanlovlarni vaqtinchalik istisnolardan ajratgan holda afzalliklar bahosini yangilaydi. Ma’lumotlar bazasi tezkor qaror qabul qilishni hamda avtomatik amallarning sabablarini kuzatish imkoniyatini qo‘llab-quvvatlaydi. Mazkur yondashuv O‘zbekiston turar joylari sharoitida mavsumiy o‘zgarishlar, xonadonlar tarkibining xilma-xilligi, internet uzilishlari va ma’lumotlarni mahalliy qayta ishlash imkoniyatlarini hisobga olgan holda ko‘rib chiqiladi. Baholash mezonlari sifatida qulaylik ko‘rsatkichlarining belgilangan chegaralardan og‘ishi, energiya sarfi, qo‘lda o‘zgartirishlar chastotasi, javob berish kechikishi va tizimning ishlashga tayyorligi taklif etiladi. Maqolada tajribada tasdiqlangan samaradorlik natijalari emas, balki konseptual loyiha va uni baholash tuzilmasi taqdim etiladi. Ishning asosiy

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hissasi xonadon ma’lumotlarini saqlash, moslashuvchan qaror qabul qilish va foydalanuvchi nazoratini o‘zaro bog‘lab, keyingi dasturiy amalga oshirish hamda empirik baholash uchun asos yaratishdan iborat.

Kalit so‘zlar: aqlli uy, moslashuvchan boshqaruv, ma’lumotlar bazasiga asoslangan tizimlar, foydalanuvchi odatlari, bandlikni bashorat qilish, energiyani boshqarish, buyumlar interneti, foydalanuvchi afzalliklari.

Introduction

Smart home automation connects sensing, computation, and device control within domestic environments. Its practical value depends on whether automated actions reflect the needs of residents rather than merely execute predefined schedules. Lighting that switches off while someone remains seated, or cooling that operates in an empty room, illustrates the limitations of decisions based on isolated measurements. A system that adapts to user habits therefore requires both reliable information about present conditions and a structured memory of previous interactions. This study addresses that requirement through a proposed control algorithm in which a database supports learning, decision-making, feedback, and operational accountability.

Research on adaptive residential environments provides a foundation for this approach. Rashidi and Cook describe how the CASAS system discovers patterns in daily activities and adjusts automation policies using resident feedback. Their work demonstrates the importance of treating routines as changeable rather than permanently fixed. However, the present article does not claim to introduce habit adaptation itself. Instead, it develops a design that explicitly connects stored household observations with preference updates, constrained control actions, and records explaining why those actions were selected. The intended contribution lies in the integration and specification of these components for an implementable household management framework.

A database has a broader function here than retaining sensor histories. It can associate observations with timestamps, rooms, device states, consent settings, and manual interventions. These relationships help distinguish repeated preferences from occasional exceptions. For example, a temporary temperature

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adjustment during a family gathering should not automatically replace the usual evening preference. Likewise, missing sensor readings should not be interpreted as evidence that a room is unoccupied. The proposed architecture therefore includes data quality checks, confidence estimates, and conservative fallback rules. Adaptation is treated as a controlled process whose recommendations remain subordinate to explicit user choices and safety requirements.

For application in Uzbekistan, the design considers household circumstances as variables to be investigated rather than assuming a uniform residential setting. Relevant deployment questions include which appliances permit automated control, whether several residents share a room, how seasonal requirements change, and what happens when internet access becomes unavailable. Local processing is proposed to preserve essential functionality during connectivity interruptions. Multilingual interfaces and straightforward preference settings are also considered as implementation options. These design choices require subsequent assessment with participating households; they are not presented as established characteristics or preferences of the entire population.

The research objective is to specify a database-driven algorithm that coordinates habit recognition, user feedback, and device control while making its decisions traceable. Three questions guide the proposed investigation: how historical records should inform current actions, how preference changes should be distinguished from temporary deviations, and how adaptation should operate under incomplete information. Evaluation is planned around energy consumption, comfort deviations, manual override frequency, response latency, and availability, using clearly defined comparison conditions. Because no deployment dataset or experimental measurements are supplied, the article develops a conceptual architecture and evaluation protocol. Any expected benefits remain hypotheses to be tested through simulation and subsequent household trials under documented operating conditions.

Methods

The proposed study follows a design and evaluation methodology combining database modelling, algorithm specification, simulation, and prospective household testing. Its initial scope covers lighting and temperature control in

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individually monitored rooms. Appliances requiring specialised safety certification remain outside autonomous control. Before any household deployment, participants would receive an explanation of collected information, retention periods, access permissions, and withdrawal procedures. Household identifiers would be pseudonymous, and identifiable occupancy histories would remain on a local gateway wherever feasible. The methodology specifies planned procedures; it does not imply that recruitment, implementation, or experimental testing has already occurred.

The relational database would contain linked records for rooms, devices, observations, preferences, control actions, and feedback. Each observation would include an event timestamp, source identifier, measured value, unit, and quality flag. Control records would preserve the selected action, its justification, the applicable preference version, and device acknowledgement. Ingestion would reject duplicate records, flag implausible readings, and distinguish missing values from measured absence. Device timestamps would be normalised to a shared clock. Retention rules would remove detailed histories after an agreed period while preserving aggregated statistics needed for adaptation. Access would follow explicitly assigned household permissions.

Habit estimation would use thirty-minute intervals, separating weekdays from weekends. For each room and interval, the algorithm would estimate occupancy probability from valid observations collected during a rolling twenty-eight-day window. These settings are initial design parameters requiring sensitivity analysis. Recent observations would receive greater weight through exponential decay. Temperature and lighting preferences would be estimated from explicitly accepted settings and repeated manual adjustments under comparable conditions. A single override would trigger immediate compliance where safe but would not permanently redefine a preference. Persistent updates would require repeated evidence across separate days or direct user confirmation.

At each decision cycle, the controller would retrieve current measurements, occupancy estimates, applicable preferences, and device constraints. It would evaluate a finite set of permissible actions using a weighted objective incorporating estimated energy demand, deviation from preferred conditions, and switching frequency. Objective components would be normalised before

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weighting, and household preferences would guide comfort priorities. Safety limits, active manual overrides, and minimum switching intervals would act as hard constraints. Insufficient confidence would trigger predefined conservative operation. Every command would be logged, and missing acknowledgements would prevent the system from assuming successful execution.

Evaluation would compare the adaptive controller with fixed schedules and a rule-based controller under identical simulated conditions. Chronological data partitions would separate parameter development from testing, preventing future observations from influencing earlier decisions. Scenarios would include routine changes, sensor outages, conflicting preferences, and interrupted connectivity. Measures would include energy use, occupied-room comfort deviations, overrides per occupied hour, command latency, and successful decision-cycle completion. Ablation experiments would disable habit learning or feedback updates separately. Repeated simulation runs would report uncertainty intervals and paired differences against baselines. Subsequent household trials would use counterbalanced controller periods, subject to consent and feasibility, with weather and occupancy documented as potential confounders. No performance advantage would be asserted unless supported by these comparative observations and transparently reported analytical assumptions and limitations.

Results

The outcome of the conceptual analysis is a specified control architecture linking household observations, preference estimation, constrained decision-making, and feedback storage. This constitutes a design result rather than evidence of operational performance. The architecture defines how information should move from sensor acquisition to command acknowledgement and subsequent evaluation. Its central feature is the separation of observations, inferred habits, explicit preferences, and executed actions. Consequently, an inferred routine cannot silently replace a direct user instruction. The resulting specification provides a basis for implementation while leaving energy savings, comfort improvements, and prediction accuracy unresolved until comparative testing is completed.

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The database design establishes traceability between each proposed control action and the information available when it was selected. An action record would reference its observation window, preference version, confidence estimate, and applicable constraints. This arrangement enables retrospective examination of whether an inappropriate action originated from inaccurate sensing, outdated preferences, or decision logic. Importantly, a transmitted command and an acknowledged device response remain separate records. Their separation prevents communication attempts from being counted automatically as successful physical changes. However, acknowledgement alone cannot verify environmental effects; independent measurements would still be required to confirm that room conditions changed as intended.

The adaptation specification distinguishes immediate user control from long-term preference revision. A manual adjustment would take precedence within permitted operating limits, while permanent changes to the preference profile would require repeated evidence or explicit confirmation. Under the proposed logic, an unusual evening gathering could therefore change current lighting without necessarily altering subsequent weekday settings. Conversely, repeated adjustments across comparable days would become candidates for profile updates. These examples describe intended decision pathways, not observed household responses. The unresolved design issue is the evidence threshold: excessive sensitivity could produce unstable preferences, whereas excessive conservatism could delay adaptation to genuine routine changes.

The failure-handling specification identifies different responses to uncertainty, missing observations, and interrupted communication. Missing occupancy data would be marked as unknown rather than converted into vacancy. Reduced confidence would activate conservative rules, while unavailable remote connectivity would leave locally supported functions eligible to operate. Local operation nevertheless depends on gateway power, functioning sensors, and accessible devices; it does not guarantee availability during every outage. Conflicting preferences among occupants also remain explicit inputs requiring a household-approved resolution policy. The design therefore identifies boundaries of autonomous operation instead of assuming that historical behaviour always supplies an acceptable decision.

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The evaluation framework produces a set of testable comparisons rather than numerical findings. Energy consumption must be assessed alongside occupied-room comfort deviations because reduced consumption alone could reflect inadequate service. Override frequency must be interpreted with user engagement, since fewer interventions do not necessarily indicate satisfaction. Latency and availability measurements must distinguish controller decisions from successful device execution. Chronological testing and component ablation would help examine whether habit estimation and feedback contribute beyond fixed schedules or simple rules. At this stage, no dataset, effect size, statistical significance, or validated benefit is available. The reported outcomes are architectural decisions, operational safeguards, and measurable criteria for subsequent empirical investigation in households.

Discussion

The proposed architecture places the database within the control process rather than treating it solely as an archive. This choice makes the relationship between historical behaviour and current actions explicit. Nevertheless, storing more observations does not automatically produce better decisions. Historical records may contain sensor errors, temporary disruptions, or preferences expressed by different occupants. Their usefulness depends on contextual interpretation and appropriate retention. The design therefore assigns importance to provenance, quality flags, and preference versions. These elements support investigation of unexpected actions, although their practical value must be assessed against storage requirements, maintenance effort, and the capabilities of affordable gateways.

A central trade-off concerns adaptation speed and behavioural stability. Rapid updates could follow changing routines but might also encode temporary exceptions as enduring preferences. Slower updates reduce this risk while potentially prolonging unsuitable automation. The proposed requirement for repeated evidence offers an initial compromise, not an established optimum. Similarly, the twenty-eight-day observation window and thirty-minute intervals require empirical justification. Shift work, holidays, and irregular household schedules may challenge these settings. Comparing alternative windows, decay

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rates, and confidence thresholds would clarify whether one configuration serves diverse households or whether parameter selection should itself become part of the personalisation process.

Another issue is the distinction between inferred occupancy and inferred preference. Knowing that a room is occupied does not establish which temperature or lighting level its occupants want. Furthermore, silence after an automated action cannot reliably be interpreted as approval. Residents might tolerate inconvenience, overlook a setting, or lack convenient access to controls. Explicit feedback therefore remains important, but frequent confirmation requests could undermine usability. The interface should allow correction without demanding continuous supervision. Where several residents share spaces, preference conflicts require agreed procedures, such as shared acceptable ranges, rather than assuming that the most frequent user represents everyone.

Application in Uzbekistan requires evaluation across actual housing and household conditions. The framework should be tested with different appliance configurations, building characteristics, household sizes, and seasonal operating requirements. These factors could influence both achievable energy reductions and acceptable comfort boundaries. Local processing may reduce dependence on external connectivity, but it introduces responsibilities for gateway maintenance, software updates, and secure storage. Language options should be selected with participating residents, while controls should remain understandable to users with varying technical experience. Such considerations frame deployment questions; the current design cannot establish national suitability without geographically and socially diverse evidence from fieldwork.

The proposed evaluation also requires careful interpretation. A controller could reduce energy consumption simply by delivering less heating, cooling, or illumination, so comparisons must document equivalent service expectations. Likewise, improved occupancy prediction does not necessarily translate into useful control if devices respond slowly or preferences remain inaccurate. Simulation can isolate mechanisms but depends on assumptions about buildings, equipment, and behaviour. Household trials introduce stronger realism alongside confounding effects from weather, novelty, and changing routines.

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Combining measured outcomes with participant explanations would help distinguish effective adaptation from apparent numerical improvement. These limitations define the evidence needed before recommending deployment beyond carefully supervised experimental settings in homes.

Conclusion

This article has developed a framework for a database-driven smart home control algorithm that adapts to user habits. The proposed system connects historical observations, current environmental conditions, explicit preferences, and user feedback within a traceable decision process. Its principal contribution is the specification of relationships between these components rather than a claim of superior predictive accuracy or measured energy savings. By separating observed behaviour from inferred preferences and confirmed instructions, the framework establishes a basis for personalisation that remains subject to user authority. Whether this design delivers practical advantages must be determined through implementation and controlled comparative evaluation.

The database is central to this framework because it preserves the context required to interpret household activity. Sensor values alone provide limited guidance unless their timing, location, reliability, and relationship to previous actions are available. Recording preference versions and command acknowledgements also makes it possible to examine why an action was selected and whether its execution was reported. Nevertheless, traceability should not justify unlimited collection. The proposed system requires retention periods, restricted access, and transparent information about stored records. Detailed histories should be retained only where their contribution to operation or evaluation warrants the associated storage and privacy implications.

Adaptation is understood as a gradual, reversible process rather than unrestricted learning from every interaction. Immediate manual control and persistent preference updates serve different purposes and should remain distinct. Repeated evidence or direct confirmation can support lasting changes, while temporary adjustments can address exceptional circumstances without rewriting established routines. Uncertain occupancy estimates, missing measurements, and communication failures require explicit fallback behaviour. Shared spaces

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additionally require household-approved procedures for resolving conflicting preferences. These principles provide operational boundaries for the algorithm, but their usability remains an empirical question. Future implementation must examine whether residents understand, accept, and can conveniently modify these boundaries.

For Uzbekistan, the framework offers a starting point for locally informed experimentation rather than a universally applicable deployment model. Testing should account for differences in buildings, controllable equipment, household composition, connectivity, and seasonal requirements. Interface language and interaction methods should be selected with participating residents instead of being inferred from geographic location. Local processing may support continuity during internet interruptions, provided that power, gateway operation, and device communication remain available. Affordability must also include installation, maintenance, replacement, and support costs. Assessing these conditions would help determine which household settings can benefit from the proposed architecture and which require alternative arrangements.

The next research stage should implement a prototype and evaluate it against fixed schedules and rule-based control under comparable conditions. Chronological testing, sensitivity analysis, and component ablation should examine the contribution of historical learning and feedback separately. Energy measurements must be interpreted alongside comfort, reliability, and user experience, with uncertainty and unsuccessful cases reported openly. Subsequent household trials should assess sustained operation after initial novelty has diminished. Until such evidence exists, expected improvements remain hypotheses. The framework therefore establishes a research direction in which household data support accountable automation, while demonstrated usefulness, user acceptance, and dependable operation remain the criteria for practical adoption.

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