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Model to Identify the Smartness of a Home

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ABSTRACT : This study has as its main purpose to establish the degree of intelligence of a home taking into account several properties established according to existing studies at the level of published articles with weights depending on their importance at the overall level. The model starts from 6 established categories, these having subcategories that apply to both rural and urban homes. It is desired that after applying the model, traditional homes will be clearly delimited from semi-smart and smart ones.

Keywords: - evaluation**,** IoT, model, security, smart home

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1. INTRODUCTION

This paper aims to develop a model that will classify both urban and rural homes into one of the traditional, semi-smart and smart categories based on several characteristics obtained from analyzing the existing state of the art in published works. The model tracks certain properties for each category, the last of which represents the actions carried out by residents in the smart home.

All the properties tracked aim to fit into the main themes that define a home as smart, namely the degree of automation, the degree of security, the type of devices used in the home, but also the location of the home, in the village or in the city.

At the end, a score from 1 to 100 is established that determines which category the home falls into in terms of intelligence. Existing studies focus more on identifying the characteristics that determine the degree of intelligence of the home and less on calculating a score from which this degree results.

Considering the era of technology that advances daily, more and more homes are starting to use increasingly advanced applications and devices to make daily activities easier and to increase the degree of comfort and quality of life.

This model has as its main purpose the very clear delimitation of the 3 possible categories of homes starting from the traditional ones to the most modern and intelligent ones.

2. LITERATURE REVIEW

The article [1] compares smart homes with traditional ones, highlighting the differences in terms of technology, energy efficiency, security and costs.

A smart home uses advanced technologies to automate various functions, allowing remote control of lighting, temperature, security systems and home appliances via smartphones or voice commands. The integration of artificial intelligence allows these systems to learn user behaviors, optimizing operation over time.

Traditional homes rely on manual control and conventional infrastructure, without the integration of modern technologies. They offer simplicity and familiarity but lack the automation and energy efficiency of smart homes.

Advantages of smart homes:

- Energy efficiency: Smart thermostats and automated lighting systems reduce energy consumption and associated costs.
- Increased security: Surveillance cameras, motion sensors and smart locks allow monitoring and control of home security remotely.
- Convenient automation: The ability to program functions such as turning on the coffee maker or turning off the lights via voice commands or mobile apps.

Disadvantages of smart homes

- Vulnerability to cyberattacks: Without adequate security measures, systems can be susceptible to unauthorized access.
- High initial costs: The purchase and installation of smart technologies can involve significant investments.
- Dependence on technology: Malfunctioning systems can affect the comfort and functionality of the home.

Advantages of traditional homes

- Simplicity and familiarity: The lack of complex technologies provides a straightforward and manageable living experience.
- Lower initial costs: Construction and maintenance are generally more affordable.
- Independence from technology: The operation of the home does not depend on electronic systems or internet connections.

Disadvantages of traditional homes

- Lack of automation: Requires manual intervention for most domestic functions.
- Low energy efficiency: Conventional systems can consume more energy.
- Limited security: Requires additional investment to implement modern security systems.

It is possible to upgrade traditional homes by adding smart devices, such as thermostats, lighting systems, or surveillance cameras, to benefit from the benefits of automation without rebuilding the entire home.

Although smart homes can reduce energy consumption, the production and disposal of electronic components can contribute to an increase in e-waste.

The collection of data about residents' behavior by smart devices raises concerns about privacy and security of personal information.

The choice between a smart home and a traditional home depends on individual preferences, budget, and lifestyle. Smart homes offer convenience and efficiency, but they involve costs and technological risks. Traditional homes offer simplicity and low costs, but they may lack modern amenities. A hybrid solution, combining elements of both types, can be a balanced option for many homeowners.

The article [2] proposes a conceptual framework for assessing the level of intelligence of smart homes. The authors define this level as the extent to which smart devices in a home can improve the comfort and health of users through automation and adaptation to their needs.

The main goal of the study is to provide a systematic tool for assessing the intelligence capacity of smart homes, thus facilitating the development and implementation of more efficient and personalized solutions.

The proposed framework includes several essential dimensions:

- Automation: The ability of the system to perform tasks without human intervention.
- Adaptability: The ability to adjust according to changes in the environment and user preferences.
- Interoperability: The compatibility and integration between different devices and platforms.
- User interaction: The ways in which users can communicate and control the system.
- Machine learning: The ability of the system to learn from users' behaviors and preferences to provide personalized services.

The framework can be used by developers, researchers and end users to:

- Evaluate and compare different smart home solutions.
- Identify areas for improvement in the design and implementation of smart systems.

- Guide investments and strategic decisions in the field of smart home technologies.

The study provides a valuable tool for understanding and evaluating the complexity and efficiency of smart homes, emphasizing the importance of a holistic approach that includes both technical aspects and user experience.

3. RESEARCH METODOLOGY

1. Automation and remote control (20 points)

Home automation is the integration of technologies that allow the control and monitoring of various aspects of the home remotely, via a mobile application or a voice assistant. This offers considerable comfort and much greater control over the environment we live in. It is important that this criterion is evaluated correctly, given the significant impact it can have on energy efficiency and security.

- Light control via app or voice assistant. Smart lighting systems allow light control through a mobile app or voice commands, which can improve not only comfort but also energy efficiency, adjusting light intensity depending on the time of day or the user's needs.
- Smart sockets and switches. These devices allow the user to turn electrical appliances on or off remotely. For example, a user can turn off an air conditioner that was left on when they were away from home, saving energy and reducing costs.

Automation and remote control are an essential element of a modern smart home. This not only improves the comfort of the home, but also contributes to reducing energy consumption, while ensuring a safer living environment.

2. Security and surveillance (20 points)

Home security is one of the main concerns of any homeowner. Smart security solutions allow for continuous monitoring of the home and rapid intervention in case of unforeseen events. These systems not only enhance safety but can be integrated with other smart solutions to create a holistic protection system.

- Remote access surveillance camera. Smart surveillance cameras allow for real-time viewing of the home, regardless of the user's location, via an app or browser. This type of technology is essential for protecting the home from intruders and providing a sense of security.
- Motion, smoke, water, gas sensors. These devices can detect anomalies, such as the presence of an intruder or water or gas leaks and alert the user immediately. In the event of a fire, smoke sensors can automatically activate an alert system, reducing the user's reaction time and providing better protection.

Security is a crucial factor for any home, and integrating smart surveillance technologies can make the difference between preventing a problem and an unfortunate incident. These systems help reduce risks and can save lives or property.

3. Energy efficiency (20 points)

An energy-efficient home not only reduces utility costs but also helps protect the environment by reducing your carbon footprint. Smart technologies can optimize energy consumption, automatically adjusting settings to ensure the best balance between comfort and savings.

- Smart thermostat. A smart thermostat learns the habits of its occupants and can adjust the temperature based on their presence in the home. For example, if no one is home, the thermostat can lower the temperature to save energy, and when someone returns, it can automatically adjust the temperature to the desired level.
- Solar panels with smart monitoring (for smart homes in villages). Smart solar panels allow for real-time performance monitoring. They can adjust energy production based on weather conditions and provide insights into system efficiency. In addition, their integration with other smart technologies helps manage energy consumption more efficiently.
- Smart Grid Integration (for smart homes in cities). Connects the home's energy system to the local grid, enabling real-time adjustments to energy consumption based on grid demand. This helps optimize energy use during peak times and may lead to lower costs and a more sustainable energy ecosystem.

- Smart appliances. IoT technology has also reached the field of home appliances. Smart refrigerators, washing machines or ovens can be programmed to operate only when needed, thus reducing energy consumption.

Energy efficiency is becoming increasingly important as natural resources become increasingly limited. Smart homes that integrate energy-efficient technologies not only save money but also help protect the environment.

4. Integration with voice assistants (10 points)

Voice assistant technology has revolutionized the way we interact with smart devices in our homes. These assistants allow voice control of various systems, bringing added convenience and ease of use.

- Google Assistant, Amazon Alexa, Apple Siri. These platforms allow for the integration of various smart devices, from lights and thermostats to security and entertainment systems, controlled through simple voice commands. This type of integration adds an extra level of convenience, allowing users to control their home without using apps or physical buttons.

Integration with voice assistants makes using smart technologies much more intuitive and accessible, even for people who are not familiar with technology.

5. Other smart systems and devices (10 points)

In addition to basic technologies, there is a wide range of smart devices that can transform a house into a "smart home." These include devices that are not necessarily essential, but that add value and improve the overall comfort of the home.

- Smart TV with IoT integration. Smart TVs can be connected to the internet and communicate with other devices in the home, allowing for personalization of the viewing experience and integration with other entertainment systems.
- Multi-room audio system. These systems allow music to be played simultaneously in multiple rooms of the house, everything being controlled remotely via an app or voice assistant.
- Smart cleaning robots. Robotic vacuum cleaners or mops can clean the house at set intervals or when dirt is detected, without human intervention.
- Automatic irrigation systems (for smart homes in villages). These systems can adjust garden watering based on weather conditions, saving water and ensuring plant health.
- Smart water management systems (for smart homes in cities). Systems that monitor and optimize water consumption by adjusting water usage based on weather forecasts and providing insights into water usage trends. This could help conserve water and lower utility bills, which is particularly beneficial in urban settings where water is a valuable resource.

These devices are optional, but they contribute significantly to creating a comfortable and efficient environment.

6. Human behavior in using smart applications and devices (20 points)

The adoption of a smart home depends not only on the technology used, but also on the behavior of the users. This is an essential criterion for understanding how technologies are integrated and used in everyday life.

How the user integrates into smart systems and how much they are used can significantly influence their effectiveness. Users who actively use the apps and settings will benefit from better control over their home.

A. Notation

C_i: The i-th category in the system's taxonomy, where i = 1, 2, ..., N.

w_i: The weight assigned to category C_i, reflecting its relative importance in the overall scoring model.

F_{ij}: The j-th feature within category C_i, where j = 1, 2, ..., M_i, and M_i is the total number of features in C_i.

$x_{ij} \in \{0, 1\}$: A binary indicator representing the presence (1) or absence (0) of feature F_{ij}.

p_{ij}: The proportional score contribution of feature F_{ij} within category C_i, typically normalized to account for the number and weights of active features.

H(u): A human behavior engagement function that maps raw or aggregated feature data to a score component, capturing user interaction or participation levels.

S_i: The score of category C_i, computed as a function of its features, weights, and engagement values.

S: The total smartness score, obtained by normalizing the sum of all category scores.

B. Category Weighting

$$\sum_{n=1}^{6} \mathbf{wi} = 1$$

Based on max scores:

- $w_1 = w_2 = w_3 = w_6 = 0.2$
- $w_4 = w_5 = 0.1$

C. Category Scoring Functions

$$S_1 = (x_{11} * p_{11} + x_{12} * p_{12}) * w_1$$

- Light control: $p_{11} = 0.5$
- Smart sockets/switches: $p_{12} = 0.5$

$$S_2 = (x_{21} * p_{21} + x_{22} * p_{22}) * w_2$$

- Surveillance camera: $p_{21} = 0.5$
- Sensors: $p_{22} = 0.5$

$$S_3 = (x_{31} * p_{31} + x_{32} * p_{32} + x_{33} * p_{33}) * w_3$$

- Smart thermostat: $p_{31} = 0.3$
- Solar panels/smart grid integration: $p_{32} = 0.4$
- Smart appliances: $p_{33} = 0.3$

$$S_4 = x_{41} * w_4$$

- One or more assistants: $x_{41} = 1$ if present

$$S_5 = (x_{51} + x_{52} + x_{53} + x_{54}) * 0.025$$

- 4 features each contribute 2.5 points (scaled)

$$S_6 = H(u) * w_6$$

- H(u): Derived from device usage frequency, app usage logs, automation script engagement.

D. Total Smartness Score

$S = S_1 + S_2 + S_3 + S_4 + S_5 + S_6$

To convert into a 100-point scale: $S_{scaled} = S * 100$.

E. Smartness Classification

- HomeType(S_{scaled}) = Traditional home, if $S_{scaled} \leq 40$
- HomeType(S_{scaled}) = Semi-smart home, if $41 \leq S_{scaled} \leq 70$
- HomeType(S_{scaled}) = Smart home, if $S_{scaled} > 70$

F. Application Examples

Example 1: Traditional Home
This home has few smart devices. It only has a smart TV and a smart lighting system, with no security or advanced automation.

Example 2: Semi-Smart Home
This includes a smart security system, smart thermostat, and IoT-enabled appliances. However, user interaction is low and integration with voice assistants is limited.

Example 3: Smart Home
This home has lighting, security, climate control, audio devices, and smart appliances, all integrated and controlled by voice assistants. The user has a high level of interaction with smart systems.

Example 4: Smart Home
This includes all automation and security features, only smart thermostat, voice assistant and smart TV, behavior score: 0.8.
S = 0.2 + 0.2 + 0.06 + 0.1 + 0.05 + 0.16 = 0.77 =>77/100 => **Smart Home**.

4. FUTURE WORK

As future work, incorporating AI/ML-based dynamic weight adjustments could enhance the adaptability and performance of energy systems in real-time. Integration with smart grid data would enable better coordination between smart homes and the grid, optimizing energy distribution and consumption. Additionally, cross-validation with market data and energy savings could improve the accuracy of energy models, ensuring more reliable and measurable efficiency gains.

5. CONCLUSIONS

This 6-factor weighted model provides a structured, quantitative, and scalable approach for identifying home smartness. It can support smart home planning, real estate evaluation, or smart city integration frameworks.
Binary scoring simplifies complex or nuanced setups by providing clear, yes/no assessments. Human behavior quantification can be subjective, making it difficult to measure accurately. Feature overlaps may occur across categories, leading to redundancies or confusion in classification. This approach streamlines the process but may sacrifice some precision or detail.

6. REFERENCES

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