

# Human-Machine Interfaces for Socially Connected Devices: From Smart Households to Smart Cities



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**Abstract** This chapter defines a smart community as a set of smart homes, commercial buildings, public spaces, and transportation with boundaries based on walking distance, located in a physical region. This smart community uses social products and provides community public services, smart water management, smart mobility management to promote social interaction. The communication uses a tailored Human Machine Interface (HMI) within a gamification structure that provides feedback and adjustments based on user profiles and behavior to teach, motivate, and engage end-users in achieving specific goals, such as energy reduction. Hence, gamification builds strategies to make engaging applications by triggering internal and external motivations in end-users. A smart home gathers and analyzes data from its sensors, then delivers analytics and predictions to end-users and service provides as well as strives to improve the management of its various subsystems through social products. In that regard, the multi-sensor system allows experts to know more about the needs of homes to propose actions that reduce energy consumption and improve the home and community quality of life by galvanizing individuals to read, analyze, and act upon their energy consumption through sensor profile patterns. Thus, this chapter discusses the use of an adaptive neural network fuzzy inference and a fuzzy logic decision system to evaluate the level of energy consumption in households and the type of environmental home.

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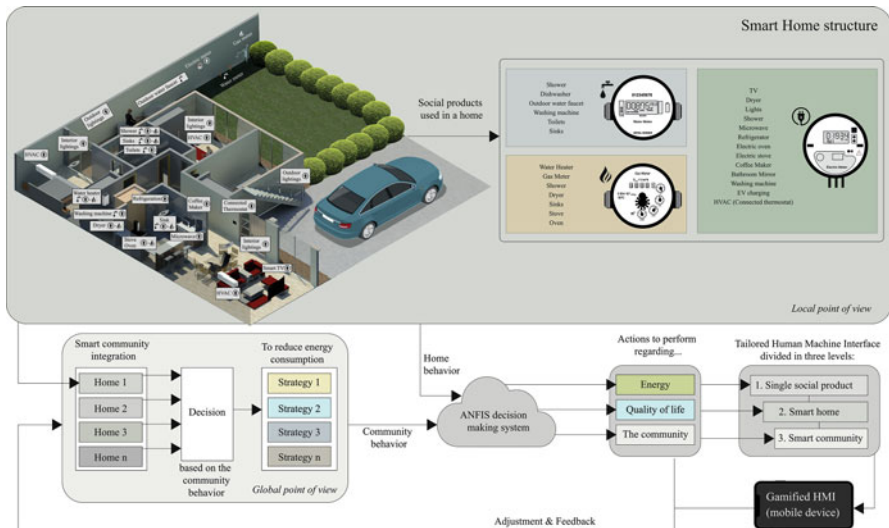
These decision systems give insights to propose an interactive and tailored HMI for each kind of home and community interaction. Finally, this chapter discusses improving the quality of life of people who are elderly using connected devices that transmit and receive information inside households or public spaces via an HMI.

**Keywords** Smart community · Smart home · Social products · Socially connected products · Multi-sensor system · ANFIS · Gamification · HMI

# 1 Introduction

This chapter introduces a multi-sensor system for use in a smart home environment composed of a set of smart homes, commercial buildings, public spaces, and transportation with boundaries based on the walking distance, located in the same geographical space. This multi-sensor system enables connectivity of sensors in a smart home toward understanding the neighborhoods' requirements, specifically, for promoting pro-environmental attitudes among neighbors to achieve a reduction in energy consumption and improve quality of life.

Figure 1 shows the proposed multi-sensor structure focused on decision fusion where the home behavior (local point of view) and the community behavior (global point of view) provide information into the system throughout the social products. The adaptive neural network fuzzy inference (ANFIS) analyzes and evaluates this information to propose actions to perform regarding energy, quality of life, and the



**Fig. 1** General proposal for data fusion and HMI in smart homes and the smart community

community. Finally, a Human Machine Interface (HMI) uses a gamification strategy with a fuzzy logic decision system to run on a tailored interface in three levels:

1. A single social product, for instance, a connected thermostat,
2. The smart home, which is the set of social products within the home,
3. The smart community.

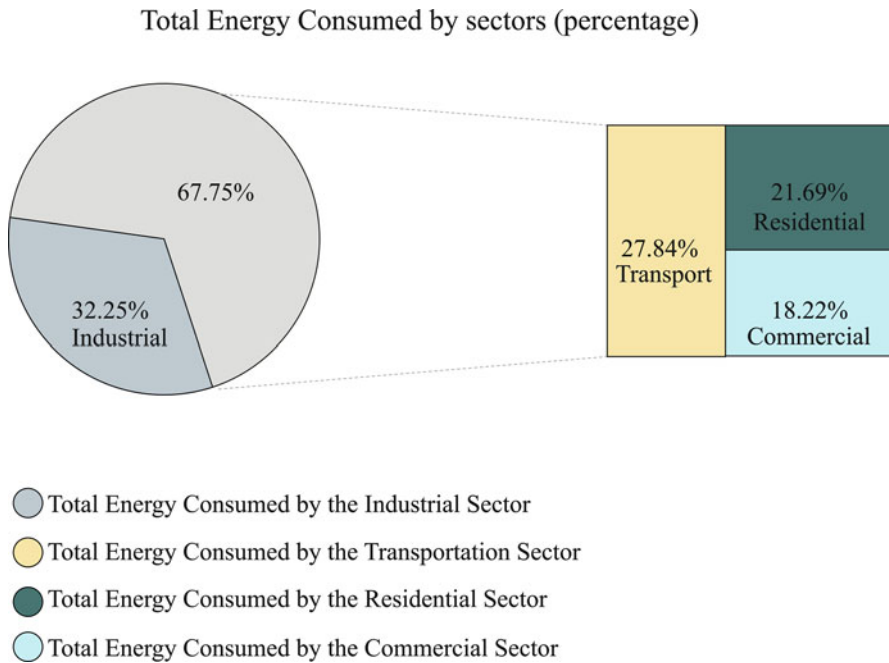
### 1.1 *Smart Community*

Although the concept of a smart community is nascent, it is still not yet well defined as there is no clear separation between a smart community and a smart city. This section considers that it is necessary to determine the single concept of a community first without considering its smartness. Thus, in [24], Łucka believes that a community should have these characteristics:

- Be self-sustaining and dense to enable residents short commutes by bicycle or walking rather than by automobile.
- Layout should support a normal walking distance, which is typically a radius of 0.25–0.5 miles.
- Be organized around public transportation.
- Promote social relationships by interconnected networks of streets and public spaces.
- Be safe by making strangers feel noticed and potentially unwelcomed if they plan to commit a crime. This safety is provided by promoting “eyes on the street” in the neighborhoods.
- Besides housing, there are places of work, leisure, and shopping near the community.

Thus, a community in terms of energy is composed of not only residential sectors, but also industrial, commercial, and transport sectors. Figure 2 depicts the total energy consumption by sector in the U.S. from January 2019 to February 2020 obtained from the database *Energy consumption estimates by sector* of the U.S. Energy Information Administration [11]. According to this information, residential buildings, commercial sectors, and transportation represent 21.69%, 18.22%, and 27.84%, respectively. Communities therefore belong to 67.75% of the total U.S. energy consumption in the last year. An essential task for communities is to promote a reduction in energy consumption without being obtrusive or losing the quality of life by transitioning the community into a smart community. An essential task for smart communities is to promote pro-environmental attitudes.

Several authors have defined their concept of the Smart Community. Li et al. [21] describe it as a set of smart homes, amenities, and green areas where residents have social interaction and relationships with their neighborhoods. Homes are virtually connected in the same geographic region by powerline communication, wireless



**Fig. 2** Total energy consumed by industrial, transportation, residential and commercial sector in percentage from January 2019 to February 2020 [11]

communication, such as Bluetooth or Wi-Fi, phone line communication, and/or technologies that require dedicated wiring such as Ethernet.

Eltoweissy et al. [12], indicate that a smart community has four key characteristics:

- **Sustainability:** the community is self-sufficient regarding services offered and the resources needed to enable those services.
- **Resilience:** the community changes dynamically; for instance, the smart community can react in a precise and timely way in response to incipient emergencies.
- **Empathy-driven proactive intelligence:** the community can predict future needs using artificial intelligence algorithms within smart products.
- **Emergent behavior:** the community evolves based on current needs as profiled by smart products.

Wang [48] emphasizes that the smart community should use smart products, a management method, and a community philosophy featured with multinetwork integration. He mentions that there is a lack of standardization due to a miss in the unified local region. This author describes three development stages for a smart community:

- Initial stage: community uses smart products and provides management, e-commerce services, and health services within the smart community and the smart home.
- Development stage: A smart platform application reaches the community. This application gathers multiple mobile apps to enhance the community.
- Improvement stage: A standardized service system should be initiated for the smart community. This stage focuses on continuous improvement and development.

London [49], Oslo [52], and Copenhagen [16] have launched smart community initiatives where there is a continuous interaction between the citizen and the communities (government, agency, company, and institutions) and user-centered designs by encouraging the digital engagement of the populace. A key component for a smart community is the smart home. There is an interaction between the building, user, and the software and hardware technology within the smart home through smart household appliances, or social products. Ponce et al. [40] define a social product as a product that modifies the behavior of the end-user by observing, registering, and analyzing her or his consumption patterns. This product can adapt its characteristics online or offline to improve its performance and acceptability. Thus, a smart product, or an intelligent household appliance, can be considered a social product for tracking and understanding users [8, 14, 29].

Social interaction plays a primary role in understanding users' patterns [30, 31]. A way to shape occupants' habits is by sending stimuli through gamification strategies [29–32, 39, 40]. Gamification, in this context, is defined as a process to improve services through gameful experiences to augment value creation for users [15].

We therefore define smart community as a creative community located in a physical region by a set of smart homes, commercial buildings, public spaces, and transportation with boundaries based on walking distance. A smart community uses social products to provide community public services, smart water management, and smart mobility management to promote social interaction. Communication uses a tailored HMI within a gamification structure that includes feedback and adjustments based on user profiles and behavior to teach, motivate, and engage end-users to perform specific tasks and achieve certain goals, as energy reduction (Fig. 3). For this chapter, the set of homes is used as a fundamental part of smart community integration.

Currently, the *IESE Cities in Motion Index* [5] presented a report on 147 cities' smartness. Figure 4 shows the top 10 smart cities around the world based on nine dimensions described below. Note that each of the top cities has strengths and weakness based on these dimensions.

- Economy: this dimension measures 13 indicators that promote the economic development of a territory: productivity, the time required to start a business, ease of starting a business, headquarters, motivation to start early-stage entrepreneurial activity, estimated annual GDP growth, GDP in millions of dol-



**Fig. 3** Smart community integration

lars, GDP per capita, mortgage, Glovo and Uber services, salary, and purchasing power.

- Human capital: this dimension measures 10 indicators to promote education accessibility at different levels, as well as promote arts and recreation activities.
- Social cohesion: this dimension measures 16 indicators to determine how happy citizens are and how much equality exists among city’s population; also how other factors may alter these levels, such as crime, death, homicide, terrorism, and suicide rates.
- Environment: this dimension measures 11 indicators that take into account the amount of pollution a city produces, such as air pollution, garbage or emissions, as well as environmental performance, future climate estimations, and public water access.

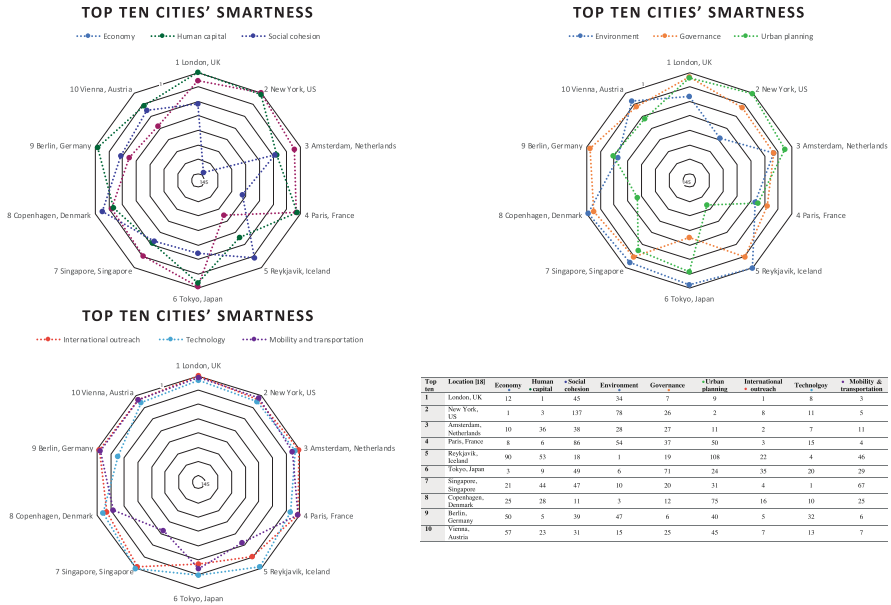


Fig. 4 Top 10 smart cities around the world and their place regarding each dimension [5]

- **Governance:** this dimension measures 12 indicators to determine how well prepared a city is to confront economic problems, incentivize investments, legal strength, international presence, democracy, corruption rankings, and how inclusive a government is to its citizens.
- **Urban planning:** this dimension measures five indicators that take into account the number of bicycle rental or sharing points, percentage of urban population with access to private sanitation services, number of people per household, percentage of high rise buildings, and number of completed buildings, including high rises.
- **International outreach:** this dimension measures six indicators to assess how prepared a city is to receive outside visitors; this means the number of passengers per airport, number of hotels and restaurants, and how attractive a city is, taking into account the number of international businesses implemented in the city, and the number of photos taken in city locations.
- **Technology:** this dimension measures 11 indicators to assess how proficient the population is with technology by use of the internet and social networks, also internet quality, and cell phone accessibility.
- **Mobility and transportation:** this dimension measures 10 indicators that determine the efficiency of the city by means of transportation, either private cars or public transportation, as well as bicycle accessibility.

### 1.2 Smart Home

A smart home gathers and analyzes data from its sensors, then delivers analytics and predictions to end-users and service providers as well as strives to improve the management of its various subsystems through social products [2]. The system controls home electronics and appliances such as HVAC, telecommunications, A/V, security, lighting, and sprinklers, and provides residents with analytics such as how much electricity they have consumed on specific appliances or system. Moreover, utilities are capable of reading meters from a distance [14]. Furthermore, a smart home interface with a gamification structure provides interactions that make users feel comfortable; for instance, in [29], a gamified smart home structure was proposed that uses social products to promote ecological-saving and money-saving activities to promote energy-saving behavior in end-users (Fig. 5).

Also, a smart home requires an Energy Management System between the home and the household products to track and monitor users' activities to generate profiles [6]. Artificial intelligence enables communication between homes by monitoring and enriching services to end-users, from entertainment, to security, to lighting and temperature access and optimization [44].

There are four categories of smart homes based on the types of services they offer [27]:

1. Assistive homes: this home assists occupants based on their daily actions, providing care for everyone from children to the elderly. These homes are mostly used for healthcare.
2. Detection and multimedia information gathering: this home collects photos and videos of the occupants.
3. Surveillance home: This home processes data that alert users of upcoming natural disasters or invasions of security.
4. Ecological home: this type of home promotes environmental sustainability by providing occupants with capabilities to manage energy supply versus demand.

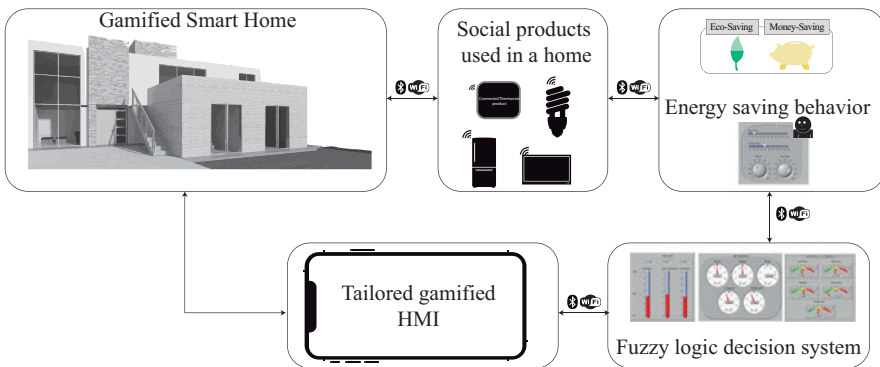


Fig. 5 Examples of a gamified smart home structure presented in [29]



Smart home services can be added to homes by transitioning from a traditional home to a smart home. Thus, smart homes have the potential to improve the quality of living for many families.

### 1.3 Socially Connected Products

In [34], the S<sup>3</sup> product development reference framework was proposed to implement sensing, smart, and sustainable products:

- *Sensing* is the ability of a system to detect events, obtain information, and measure changes utilizing sensors for observing physical and/or environmental conditions.
- *Smart* is the complementary consolidation of physical parts, components, and connectivity to make a product intelligent and accessible to interface with other gadgets.
- *Sustainable* incorporates social, environmental, and economic elements to produce balanced and optimized performance.

Social products can be promoted by knowing the types of behavior and usability problems in the use of connected devices and involving residential energy users in planning, implementing, and monitoring energy usage.

Figure 6 displays the social products of a smart home, divided by the type of utility consumption (water, gas, and electricity) and needs to be satisfied within the smart community environment to provide safety, transportation, and healthcare. Those elements working together provide a more in-depth insight into the improvement of energy behavior. For instance, if the homeowner knows the weather, the individual could determine the type of clothes to wear; hence, when he or she returns home, with the appropriate outfit, the individual would not need

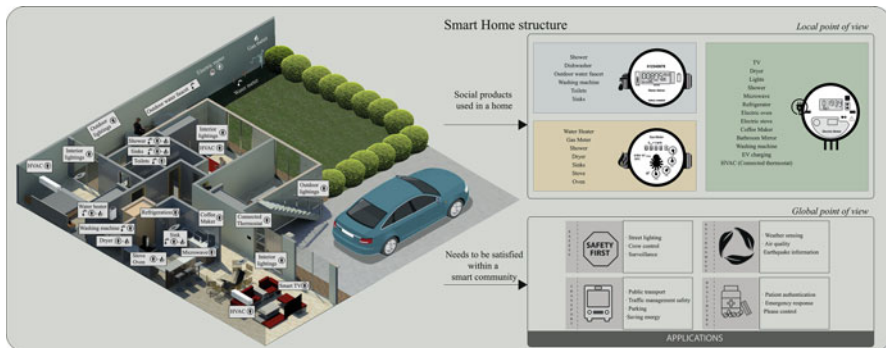


Fig. 6 Social products divided by the type of utility

to increase or decrease the indoor temperature. Thus, the individual could avoid consuming extra electricity as she or he is thermally comfortable.

Social products acceptability has the following characteristics [13]:

- Users know that when they buy a connected product, they can exploit advantages.
- Products fit with the user's current and changing lifestyles.
- Appliances and devices are quick and cheap to obtain.
- Products demonstrate reduced or eliminated physical demands in operation.
- Neither a high degree of background knowledge, nor routine interventions by professionals, is needed for installation, use, and/or maintenance.
- The usability of the product considers end-user skills; the product does not fail or act unpredictably.
- Products interpret user requirements.
- Products have privacy and security features, so users' information is secure and safe.

## 1.4 Gamification

Several authors have defined gamification:

- For Terrill [50], gamification takes game mechanics and uses them in web properties to increase engagement.
- For Huotari and Hamari [15], gamification is a process to improve services through gameful experiences to augment value creation for users.
- For Deterding et al. [9], it is the employment of game design and elements within non-gaming contexts.
- For Chou [7], it is the art of designing fun, engaging elements found traditionally in games, and employing these features in real-world activities.

For environmental purposes, gamification has the following addresses and considerations:

- Albertalli et al. [1], defined energy gamified applications as traditional software targeting an environmental goal using serious game features.
- An analysis of 25 gamified energy applications suggests three best practices for sustainable applications [43]:
  1. Sustainability should be rewarding and fun.
  2. Leverage positive peer pressure.
  3. Use gamification to galvanize useful action.
- In [3], a variety of game design elements were explored to enhance the engagement of end-users in energy saving and optimization applications. Examples of game design elements ranged from incentives such as discounts and prizes, to competitive aspects such as leaderboards and badges.

### 1.4.1 Energy Adapted Octalysis Framework

The Octalysis framework proposed by Chou [7] analyzes and builds strategies to make engaging applications. This framework considers extrinsic and intrinsic motivations, among other elements:

- Extrinsic motivation: motivation stems from the desire to attain something for outer recognition or monetary prizes. Encompasses a variety of factors from identification to external regulation.
- Intrinsic motivation: motivation stemming from a source that is rewarding or of value wholly on its own in the absence of a particular objective to accomplish. Following [19], this motivation considers three elements applicable for an energy purpose:
  - Autonomy through customization and independence including control of goals and tasks. Contributes to familiar routines, improved performance, reinforced success, responsibility, and internalized rewards.
  - Competence can relate to task complexity/understanding, execution challenge, and memory, and may be categorized as performance, achievement or engagement based.
  - Relatedness pertains to preferences, sharing, relationships and their interactions. Contributes to forging social relationships, disseminating achievements and milestones, sharing experiences, enhancing empathy, setting examples, exchanging suggestions and feedback, and validation.

In previous research [39], an adaptation for the Octalysis framework was proposed. This adaptation includes the game design elements offered in [3], the Hexad gamified user, the role player, and the end-user in the energy segment and the target group proposed in [4, 7, 26, 36, 38, 45]. Table 1 shows the extrinsic and intrinsic motivations regarding energy applications [3].

**Table 1** Gamification elements for extrinsic and intrinsic motivations

| Extrinsic motivation        | Intrinsic motivation |
|-----------------------------|----------------------|
| Offers, coupons             | Notifications        |
| Bill discounts              | Messages             |
| Challenges                  | Tips                 |
| Levels                      | Energy community     |
| Dashboard                   | Collaboration        |
| Statistics                  | Control over peers   |
| Degree of control           | Social comparison    |
| Points, badges, leaderboard | Competition          |

## 2 Multisystem: Data Fusion

When multiple sensors collect information, data fusion is often useful for making more robust inferences compared to single modalities, especially when a reference framework is utilized to map attribute or property values to quantitative measurements in a way that is both predictable and consistent. The utility of a multi-sensor data fusion framework is attractive for its functions of information processing, integration, communication, and compensation [18, 23, 47].

Multi-sensor data fusion is a concept based on animals' and humans' fundamental ability to integrate redundant and complementary information across modalities to improve the chance of survival. The primary functions are:

- Compensation: diagnose, calibrate, and adapt in response to environmental variations.
- Information processing: attention, event recognition, and decision-making.
- Communication: standard inference protocol for conveying perceptions and interpretations of sensor data to the external world.
- Integration: seamlessly coupled sensing, processing, and actuator subsystems.
- Decision-making: analyze and make predictions from sensed data to inform decisions.

While data fusion is not novel, we are now able to realize higher performance and more robust systems for data fusion through advancements in sensors, artificial intelligence, digital systems, information processing techniques, and embedded systems.

### 2.1 ANFIS: Adaptive Neuro-Fuzzy Inference Systems

In the presence of uncertain or vague information, conventional modeling techniques may face challenges. The IF-THEN linguistic rules of fuzzy systems employ human-like reasoning without complete or precise information. The issue arises in transferring human knowledge to that of fuzzy logic systems, and tuning these systems. Many approaches have been proposed, including of fusing fuzzy systems with artificial neural networks (ANNs), which can adapt and learn based on experience. One example is the adaptive neuro-fuzzy inference system (ANFIS) by Jang [18], which automatically produces fuzzy membership functions and IF-THEN rule bases. ANFIS uses adaptive networks, which are a superset of the feed-forward type ANNs [18, 37], in a directionally-connected topology of nodes. Learning takes place through rules that minimize an error criterion as connection parameters are updated. A common learning rule is gradient descent although Jang introduced a hybrid learning rule using least squares estimation. The ANFIS topology [18] is depicted in Fig. 7.

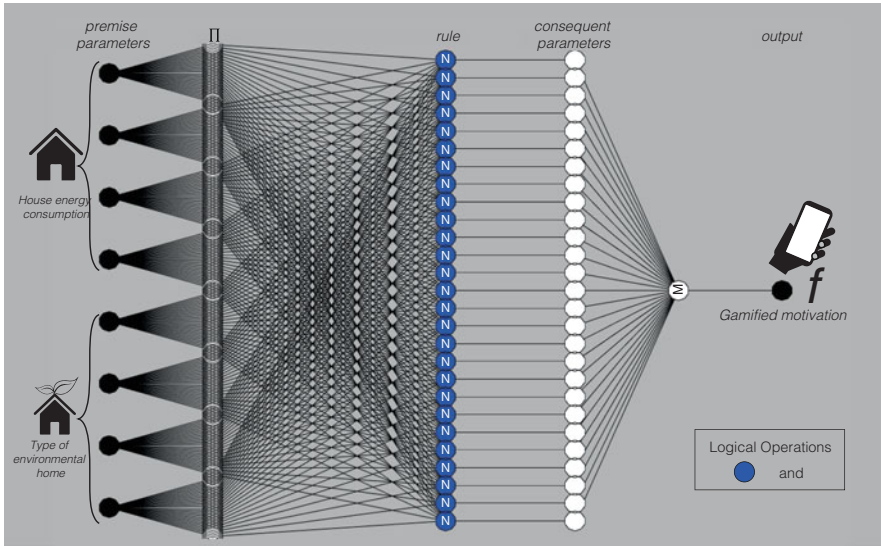


Fig. 7 ANFIS topology

## 2.2 Topology Proposed: Detection of Gamified Motivation at Home for Saving Energy

The proposed system is based on two elements: the level of household energy consumption and the type of ecological behavior.

### 2.3 Input 1: Level of Energy Consumption

The level of energy consumption was obtained from the 2015 Residential Energy Consumption Survey public database [10]. Table 2 depicts the code and characteristics selected to meet the following criteria:

- Single-family house detached from any other home.
- No basement in the housing unit.
- No attic in the housing unit.
- One story.
- Owned by someone in the household.
- 10–15 windows in heated areas.
- Household is responsible for paying incurred electricity costs.
- Members of household are home most weekdays.
- Square footage ranges from 1100 sq. ft. to 1800 sq. ft.
- Located in the Bay Area (California).

**Table 2** Code selected from the Residential Energy Consumption Survey public database [10]

| CODE               | Description   | Information   |
|--------------------|---|---|
| TYPEHUQ            | Type of housing unit  | 2 – single-family house detached from any other house                         |
| CELLAR             | Basement in the housing unit  | 0 – no  |
| ATTIC              | Attic in the housing unit   | 0 – no  |
| STORIES            | Number of stories in a single-family home   | 10 – one story  |
| KOWNRENT           | A housing unit is owned, rented, or occupied without payment of rent  | 1 – owned by someone in the household   |
| WINDOWS            | Number of windows in heated areas   | 41 – 10 to 15   |
| ELPAY              | Who pays the electricity used in the home?  | 1 – household is responsible for paying for all electricity used in this home |
| ATHOME             | How many weekdays is someone at home most or all of the day?  | 5 – 5 days  |
| TOTSQFT_EN         | Total square footage (includes heated/cooled garages, all basements, and finished/heated/cooled attics). Used for EIA data tables | The range used between 1100 sq. ft. and 1800 sq. ft.                          |
| CLIMATE_REGION_PUB | Building America Climate Region (collapsed for public file)   | 5 – marine  |
| IECC_CLIMATE_PUB   | International Energy Conservation Code (IECC) climate zone (collapsed for public file)  | 3C IECCC climate zone 3C (California, Bay Area)                               |

Once the kWh energy consumption is obtained during the year, we may estimate the 30-day energy consumption from each type of home to profile the households using (1),

$$\begin{aligned}
 & \text{Monthly house energy consumption} \left( \frac{kWh}{\text{month}} \right) \\
 &= \frac{kWh}{\text{year}} \cdot \frac{\text{year}}{8760 \text{ hours}} \cdot \frac{24 \text{ hours}}{1 \text{ day}} \cdot \frac{30 \text{ days}}{1 \text{ month}}
 \end{aligned} \tag{1}$$

The house is then profiled, and a 30-day table is generated with random values where the limit value is the monthly house energy consumption. As the database does not present information about months, this calculation has the premise that the total monthly hours should be at least under the monthly average of the household

energy consumption reference. Next, from the 30-day table, the following data is obtained:

- The complete set of types of homes.
- The minimum value of the set.
- The maximum value of the set.
- Mean.
- Standard Deviation.
- House low consumption: Mean – Standard Deviation.
- House high consumption: Mean + Standard Deviation.

Finally, these values are normalized using (2),

$$X1 = \frac{X - (\text{Min}_{set} - 5)}{(\text{Max}_{set} + 5) - (\text{Min}_{set} - 5)} \quad (2)$$

where,

$X1$  = normalized value.

$X$  = value to be normalized.

$\text{Min}_{set}$  = Minimum value of the set.

$\text{Max}_{set}$  = Maximum value of the set.

$+/-5$  = This value is used to avoid having a maximum normalized number of 1 and a minimum normalized number of 0.

## 2.4 Input 2: Type of Environmental Home

The type of pro-environmental user is related to the level of energy consumption: *It is assumed that based on the criteria selected from Table 2, there is similar home behavior. Hence, there is a lower limit for a home that consumes less energy than the other houses, an average energy consumption, and an upper limit for a home that consumes more power than the other houses.*

A pro-environmental home can be designed a lower limit home as this type of house demonstrates awareness for energy consumption; an average environmental home can be designated for average energy consumption; and a disengaged-environmental home can be designated an upper limit energy consumer, i.e., a lack of awareness for energy consumption. Thus, each type of home is associated with a value from 0 to 1:

- Pro-environmental home: 0.2
- Average environmental home: 0.4
- Disengaged-environmental home: 0.6

A new database was created and associated with the type of pro-environmental home by considering these premises (3),

$$\text{Type of home} \begin{cases} \frac{x}{0.20} & \text{if } x_2 > x \rightarrow \text{pro - environmental home} \\ \frac{x}{0.60} & \text{if } x_3 < x \rightarrow \text{disengaged - environmental home} \\ \frac{x}{0.40} & \text{if } x_2 > x < x_3. \rightarrow \text{Average environmental home} \end{cases} \quad (3)$$

Finally, these values are normalized using (2).

## 2.5 Output: Gamified Motivation (Local Point of View)

Gamified motivation considers intrinsic and/or extrinsic motivators: *The disengaged-environmental home and the home that consumes more kWh requires extrinsic motivation as they are moved by outer recognition and external rewards. The pro-environmental home and the home that consumes less kWh can be related to intrinsic motivation as the house is using less kWh than others in similar conditions due to this activity being rewarding on its own. On the other hand, the average home in either environmental type and kWh consumed use both motivations as this type of home may be motivated by external recognition or by autonomy, competence, and relatedness elements.*

Thus, a Sugeno Fuzzy Inference System is employed where the input variables are Input 1: Level of energy consumption and Input 2: Type of environmental home, and the output values are the gamified motivators (see Fig. 8).

### 2.5.1 Community Gamified motivation's Detection (Global Point of View)

Obtaining the output values for each type of home, we may then calculate the mean value of the four output values from each household to get the average. Then, these values are used to create the ANFIS system using backpropagation as an optimization method and subclustering to generate the Fuzzy Inference System.

## 3 Proposal

From a representational sample of 118,208,250 households around the country, 55,727 houses represented in four groups met the criteria established in Table 2. Table 3 depicts the four types of homes with their characteristics and their household appliances, according to [10]. The ranges of energy consumption are from a house the consumed 4159 kWh to a house that consumed 10,674 kWh. Surprisingly, the second biggest home (home type 3) consumed the most energy during the year,



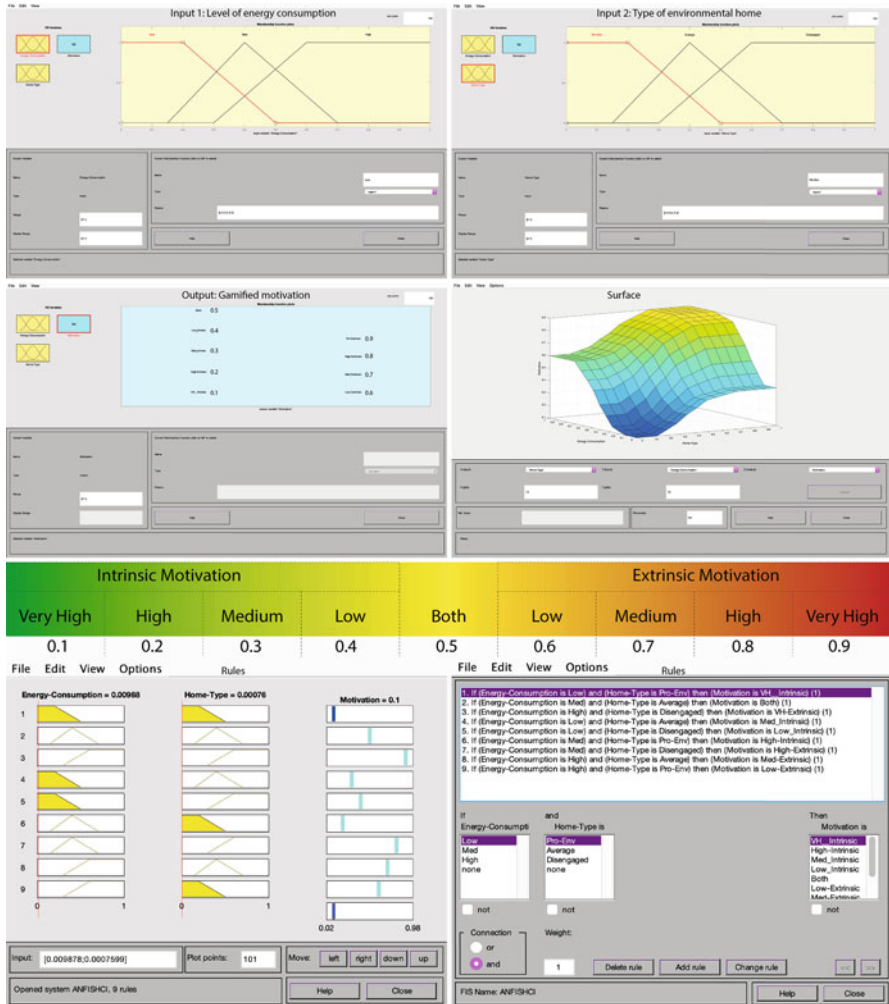


Fig. 8 Sugeno fuzzy logic inference system

likely due to the number of refrigerators (three), and that this home, when compared to home type 4, does not have a smart meter.

### 3.1 Input 1: Level of Energy Consumption

Based on (1), Table 4 shows the daily kWh consumption per home, and Table 5 depicts the estimated 30-day kWh consumption per household and their normalized values.

**Table 3** Four types of households

| CODE                          | Description  | Home type 1                | Home type 2                | Home type 3                | Home type 4                |
|-------------------------------|--|----------------------------|----------------------------|----------------------------|----------------------------|
| DOEID                         | Unique identifier for each respondent                                | 11,106                     | 12,192                     | 12,834                     | 15,114                     |
| NWEIGHT                       | Final simple weight  | 17,076                     | 13,385                     | 11,678                     | 13,588                     |
| TOTSQFT_EN                    | Total square footage   | 1125 (104 m <sup>2</sup> ) | 1550 (144 m <sup>2</sup> ) | 1652 (153 m <sup>2</sup> ) | 1793 (166 m <sup>2</sup> ) |
| KWH                           | Total site electricity usage per household over a year               | 4159.13 kWh                | 8920.06 kWh                | 10,674.33 kWh              | 6371.80 kWh                |
| HHAGE                         | Age of the survey responder  | 36                         | 76                         | 50                         | 79                         |
| NHSLDMEM                      | Number of household members  | 3                          | 2                          | 4                          | 6                          |
| NUMADULT<br>18 years or older | A housing unit is owned, rented, or occupied without payment of rent | 2                          | 2                          | 4                          | 4                          |
| NUMCHILD<br>0–17 years old    | Number of windows in heated areas                                    | 1                          | 0                          | 0                          | 2                          |
| SMARTMETER<br>0 No<br>1 Yes   | Does your home have a “smart meter”?                                 | 1                          | 1                          | 0                          | 1                          |
| NUMFRIG                       | Number of refrigerators used   | 1                          | 2                          | 3                          | 1                          |
| MICRO                         | How many microwaves are in your home?                                | 1                          | 1                          | 2                          | 1                          |
| TOAST<br>0 No<br>1 Yes        | Is the toaster used at least once a week in your home?               | 1                          | 1                          | 0                          | 1                          |
| COFFEE<br>0 No<br>1 Yes       | Coffee maker used  | 1                          | 1                          | 0                          | 1                          |
| DISHWASH<br>0 No<br>1 Yes     | Dishwasher used  | 1                          | 1                          | 1                          | 0                          |
| CWASHER<br>0 No<br>1 Yes      | Clothes washer used in home  | 1                          | 1                          | 1                          | 1                          |
| DRYER<br>0 No<br>1 Yes        | Clothes dryer used in home   | 1                          | 1                          | 1                          | 1                          |
| TVCOLOR                       | Number of televisions used   | 5                          | 3                          | 1                          | 3                          |

**Table 4** Daily energy consumption per house

| Home        | kWh/year  | Year/8760 h | 24 h/day |
|-------------|-----------|-------------|----------|
| Home type 1 | 4159.13   | 0.47        | 11.39    |
| Home type 2 | 8920.06   | 1.02        | 24.44    |
| Home type 3 | 10,674.33 | 1.22        | 29.24    |
| Home type 4 | 6371.80   | 0.73        | 17.46    |
| Average     | 7531.33   | 0.86        | 20.63    |

**Table 5** Estimated monthly house energy consumption per home

| Min set                                   | 10.29  | Deviation                |        |        | 6.844             |        |        |        |
|---|--------|--------------------------|--------|--------|-------------------|--------|--------|--------|
| Max set                                   | 29.75  | House low consumption <  |        |        | 13.46             |        |        |        |
| Average                                   | 20.31  | House high consumption > |        |        | 27.15             |        |        |        |
| Monthly house energy consumption per home |        |                          |        |        | Normalized values |        |        |        |
| Day                                       | Home 1 | Home 2                   | Home 3 | Home 4 | Home 1            | Home 2 | Home 3 | Home 4 |
| 1   | 10.93  | 23.3                     | 29.75  | 16.88  | 0.21              | 0.68   | 0.92   | 0.44   |
| 2   | 10.29  | 24.68                    | 29.36  | 16.13  | 0.19              | 0.73   | 0.91   | 0.41   |
| 3   | 10.87  | 24.35                    | 29.03  | 17.38  | 0.21              | 0.72   | 0.90   | 0.46   |
| 4   | 10.87  | 23.93                    | 28.4   | 17.17  | 0.21              | 0.70   | 0.87   | 0.45   |
| 5   | 10.33  | 24.29                    | 29.08  | 16.26  | 0.19              | 0.72   | 0.90   | 0.41   |
| 6   | 11.7   | 23.5                     | 29.29  | 17.71  | 0.24              | 0.69   | 0.91   | 0.47   |
| 7   | 11.1   | 24.32                    | 28.57  | 17.03  | 0.22              | 0.72   | 0.88   | 0.44   |
| 8   | 11.56  | 23.42                    | 29.67  | 16.91  | 0.24              | 0.69   | 0.92   | 0.44   |
| 9   | 11.41  | 23.58                    | 28.89  | 17.83  | 0.23              | 0.69   | 0.89   | 0.47   |
| 10  | 11.61  | 23.94                    | 28.18  | 17.38  | 0.24              | 0.70   | 0.87   | 0.46   |
| 11  | 10.91  | 23.87                    | 258    | 16.92  | 0.21              | 0.70   | 0.92   | 0.44   |
| 12  | 11.2   | 23.94                    | 29.49  | 17.03  | 0.22              | 0.70   | 0.91   | 0.44   |
| 13  | 10.67  | 23.15                    | 29.33  | 16.66  | 0.20              | 0.67   | 0.91   | 0.43   |
| 14  | 11.27  | 23.63                    | 29     | 17.19  | 0.23              | 0.69   | 0.90   | 0.45   |
| 15  | 11.67  | 24                       | 29.32  | 17.24  | 0.24              | 0.71   | 0.91   | 0.45   |
| 16  | 11.57  | 24.23                    | 28.82  | 16.6   | 0.24              | 0.72   | 0.89   | 0.43   |
| 17  | 11.27  | 24.17                    | 28.94  | 16.56  | 0.23              | 0.71   | 0.89   | 0.43   |
| 18  | 11.34  | 23.52                    | 29.65  | 17.04  | 0.23              | 0.69   | 0.92   | 0.44   |
| 19  | 10.99  | 23.79                    | 28.83  | 17.06  | 0.22              | 0.70   | 0.89   | 0.44   |
| 20  | 10.37  | 23.46                    | 29.31  | 17.24  | 0.19              | 0.69   | 0.91   | 0.45   |
| 21  | 11.63  | 24.24                    | 28.75  | 17.31  | 0.24              | 0.72   | 0.89   | 0.45   |
| 22  | 11.52  | 23.88                    | 29.6   | 16.78  | 0.24              | 0.70   | 0.92   | 0.43   |
| 23  | 11.44  | 24.43                    | 29.46  | 17.27  | 0.23              | 0.72   | 0.91   | 0.45   |
| 24  | 11.36  | 24.29                    | 28.41  | 16.97  | 0.23              | 0.72   | 0.87   | 0.44   |
| 25  | 11.14  | 23.94                    | 29.4   | 16.42  | 0.22              | 0.70   | 0.91   | 0.42   |
| 26  | 10.95  | 24.05                    | 29.01  | 17.39  | 0.21              | 0.71   | 0.90   | 0.46   |
| 27  | 10.87  | 24.25                    | 28.96  | 17.24  | 0.21              | 0.72   | 0.89   | 0.45   |
| 28  | 11.66  | 24.38                    | 28.99  | 16.31  | 0.24              | 0.72   | 0.90   | 0.42   |
| 29  | 11.21  | 24.86                    | 28.48  | 17.49  | 0.22              | 0.74   | 0.88   | 0.46   |
| 30  | 10.76  | 23.87                    | 28.95  | 17.15  | 0.21              | 0.70   | 0.89   | 0.45   |

**Table 6** Type of environmental home

| Monthly type of environmental home |        |        |        |        | Normalized values |        |        |        |
|------------------------------------|--------|--------|--------|--------|-------------------|--------|--------|--------|
| Day                                | Home 1 | Home 2 | Home 3 | Home 4 | Home 1            | Home 2 | Home 3 | Home 4 |
| 1                                  | 2.19   | 9.32   | 17.85  | 6.75   | 0.22              | 0.54   | 0.91   | 0.43   |
| 2                                  | 2.06   | 9.87   | 17.62  | 6.45   | 0.22              | 0.56   | 0.90   | 0.41   |
| 3                                  | 2.17   | 9.74   | 17.42  | 6.95   | 0.22              | 0.56   | 0.89   | 0.43   |
| 4                                  | 2.17   | 9.57   | 17.04  | 6.87   | 0.22              | 0.55   | 0.88   | 0.43   |
| 5                                  | 2.07   | 9.72   | 17.45  | 6.50   | 0.22              | 0.56   | 0.89   | 0.41   |
| 6                                  | 2.34   | 9.40   | 17.57  | 7.08   | 0.23              | 0.54   | 0.90   | 0.44   |
| 7                                  | 2.22   | 9.73   | 17.14  | 6.81   | 0.23              | 0.56   | 0.88   | 0.43   |
| 8                                  | 2.31   | 9.37   | 17.80  | 6.76   | 0.23              | 0.54   | 0.91   | 0.43   |
| 9                                  | 2.28   | 9.43   | 17.33  | 7.13   | 0.23              | 0.54   | 0.89   | 0.44   |
| 10                                 | 2.32   | 9.58   | 16.91  | 6.95   | 0.23              | 0.55   | 0.87   | 0.43   |
| 11                                 | 2.18   | 9.55   | 17.75  | 6.77   | 0.22              | 0.55   | 0.91   | 0.43   |
| 12                                 | 2.24   | 9.58   | 17.69  | 6.81   | 0.23              | 0.55   | 0.91   | 0.43   |
| 13                                 | 2.13   | 9.26   | 17.60  | 6.66   | 0.22              | 0.54   | 0.90   | 0.42   |
| 14                                 | 2.25   | 9.45   | 17.40  | 6.88   | 0.23              | 0.54   | 0.89   | 0.43   |
| 15                                 | 2.33   | 9.60   | 17.59  | 6.90   | 0.23              | 0.55   | 0.90   | 0.43   |
| 16                                 | 2.31   | 9.69   | 17.29  | 6.64   | 0.23              | 0.55   | 0.89   | 0.42   |
| 17                                 | 2.25   | 9.67   | 17.36  | 6.62   | 0.23              | 0.55   | 0.89   | 0.42   |
| 18                                 | 2.27   | 9.41   | 17.79  | 6.82   | 0.23              | 0.54   | 0.91   | 0.43   |
| 19                                 | 2.20   | 9.52   | 17.30  | 6.82   | 0.23              | 0.55   | 0.89   | 0.43   |
| 20                                 | 2.07   | 9.38   | 17.59  | 6.90   | 0.22              | 0.54   | 0.90   | 0.43   |
| 21                                 | 2.33   | 9.70   | 17.25  | 6.92   | 0.23              | 0.55   | 0.89   | 0.43   |
| 22                                 | 2.30   | 9.55   | 17.76  | 6.71   | 0.23              | 0.55   | 0.91   | 0.42   |
| 23                                 | 2.29   | 9.77   | 17.68  | 6.91   | 0.23              | 0.56   | 0.90   | 0.43   |
| 24                                 | 2.27   | 9.72   | 17.05  | 6.79   | 0.23              | 0.56   | 0.88   | 0.43   |
| 25                                 | 2.23   | 9.58   | 17.64  | 6.57   | 0.23              | 0.55   | 0.90   | 0.42   |
| 26                                 | 2.19   | 9.62   | 17.41  | 6.96   | 0.23              | 0.55   | 0.89   | 0.43   |
| 27                                 | 2.17   | 9.70   | 17.38  | 6.90   | 0.22              | 0.55   | 0.89   | 0.43   |
| 28                                 | 2.33   | 9.75   | 17.39  | 6.52   | 0.23              | 0.56   | 0.89   | 0.42   |
| 29                                 | 2.24   | 9.94   | 17.09  | 7.00   | 0.23              | 0.57   | 0.88   | 0.44   |
| 30                                 | 2.15   | 9.55   | 17.37  | 6.86   | 0.22              | 0.55   | 0.89   | 0.43   |

### 3.2 *Input 2: Type of Environmental Home*

Table 6 shows the type of environmental home values per home and their normalized values.

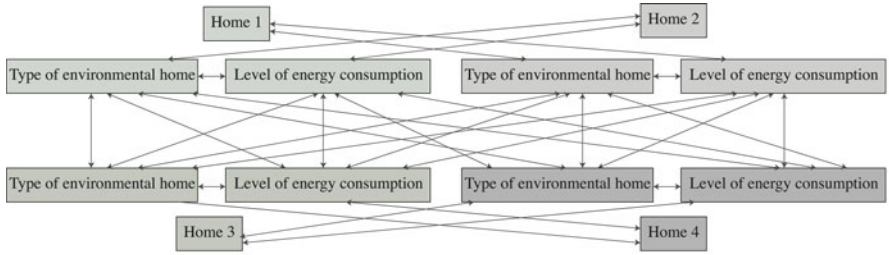
### 3.3 *Output: Gamified Motivation (Local Point of View)*

Table 7 displays the type of gamified motivation values per home.

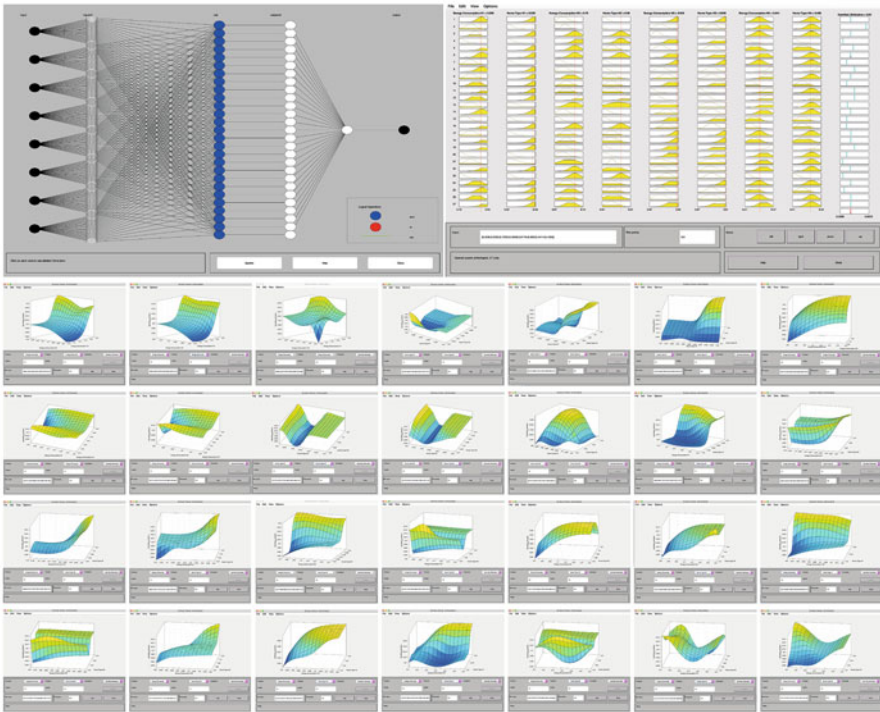
**Table 7** The gamified motivation for each home

| Gamified motivation by home |        |        |        |        |      |
|-----------------------------|--------|--------|--------|--------|------|
| Day                         | Home 1 | Home 2 | Home 3 | Home 4 | Mean |
| 1                           | 0.17   | 0.81   | 0.90   | 0.57   | 0.61 |
| 2                           | 0.16   | 0.83   | 0.90   | 0.52   | 0.60 |
| 3                           | 0.17   | 0.83   | 0.90   | 0.59   | 0.62 |
| 4                           | 0.17   | 0.83   | 0.90   | 0.55   | 0.61 |
| 5                           | 0.16   | 0.83   | 0.90   | 0.52   | 0.60 |
| 6                           | 0.19   | 0.82   | 0.90   | 0.61   | 0.63 |
| 7                           | 0.18   | 0.83   | 0.90   | 0.57   | 0.62 |
| 8                           | 0.19   | 0.82   | 0.90   | 0.57   | 0.62 |
| 9                           | 0.19   | 0.82   | 0.90   | 0.61   | 0.63 |
| 10                          | 0.19   | 0.83   | 0.90   | 0.59   | 0.63 |
| 11                          | 0.17   | 0.83   | 0.90   | 0.57   | 0.62 |
| 12                          | 0.18   | 0.83   | 0.90   | 0.57   | 0.62 |
| 13                          | 0.17   | 0.81   | 0.90   | 0.55   | 0.61 |
| 14                          | 0.19   | 0.82   | 0.90   | 0.58   | 0.62 |
| 15                          | 0.19   | 0.83   | 0.90   | 0.55   | 0.62 |
| 16                          | 0.19   | 0.83   | 0.90   | 0.55   | 0.62 |
| 17                          | 0.19   | 0.83   | 0.90   | 0.55   | 0.61 |
| 18                          | 0.19   | 0.82   | 0.90   | 0.57   | 0.62 |
| 19                          | 0.18   | 0.83   | 0.90   | 0.57   | 0.62 |
| 20                          | 0.16   | 0.82   | 0.90   | 0.57   | 0.61 |
| 21                          | 0.19   | 0.83   | 0.90   | 0.55   | 0.62 |
| 22                          | 0.19   | 0.83   | 0.90   | 0.55   | 0.62 |
| 23                          | 0.19   | 0.83   | 0.90   | 0.58   | 0.62 |
| 24                          | 0.19   | 0.83   | 0.90   | 0.57   | 0.62 |
| 25                          | 0.18   | 0.83   | 0.90   | 0.54   | 0.61 |
| 26                          | 0.18   | 0.83   | 0.90   | 0.59   | 0.62 |
| 27                          | 0.17   | 0.83   | 0.90   | 0.55   | 0.61 |
| 28                          | 0.19   | 0.83   | 0.90   | 0.54   | 0.61 |
| 29                          | 0.18   | 0.84   | 0.90   | 0.60   | 0.63 |
| 30                          | 0.17   | 0.83   | 0.90   | 0.55   | 0.61 |

Figure 9 presents the ANFIS system for the global community point of view. Figure 9a shows the relationship between each home and its interaction with the other dwellings regarding its level of energy consumption and type of environmental home. Figure 9b displays the ANFIS system structure, the rules, and the surfaces of the community interaction.



(a) Relationship between homes.

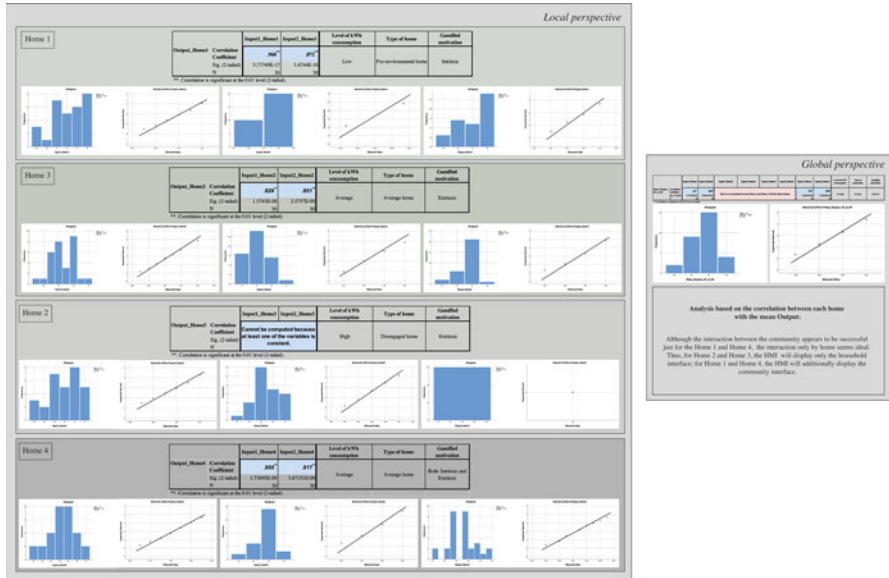


(b) ANFIS structure, rules, and community interaction

**Fig. 9** ANFIS system for the global point of view (set of homes). (a) Relationship between homes. (b) ANFIS structure, rules, and community interaction

## 4 Results

From the local point of view, a correlation between the input and output can be seen. From the global point of view, a relationship between the data and the mean output is shown. Figure 10 displays these correlations; for the local location of view, home 1, 2 and 4 have a strong relationship; home 3 shows no correlation due to output values of 0.9, representing a constant value. However, either the fuzzy system or the ANFIS



**Fig. 10** Correlations between input and output for each home (local point of view) and the community (global point of view)

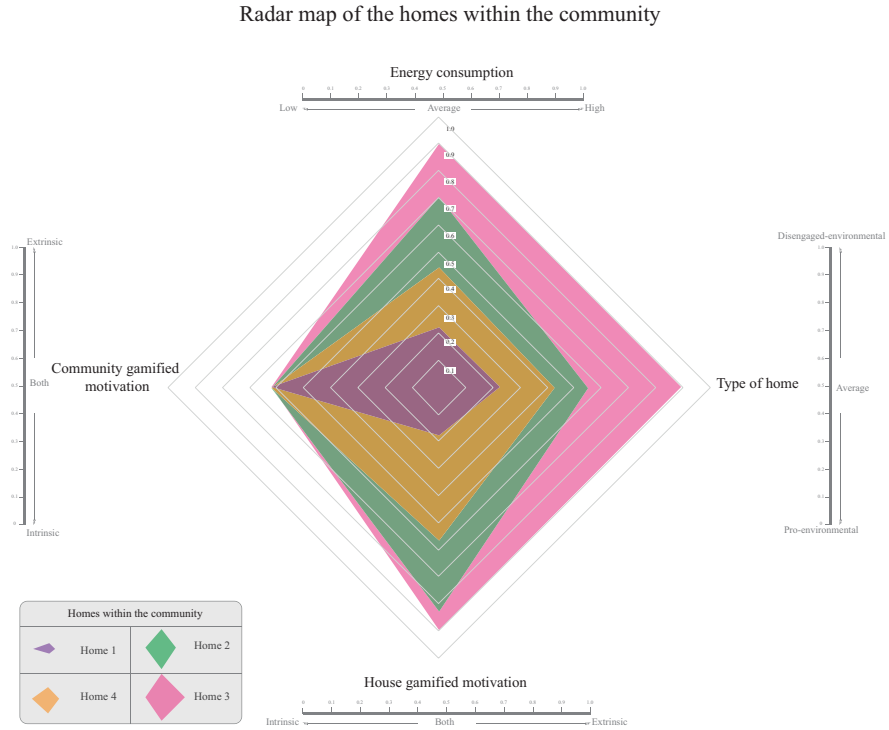
system demonstrates that home 3 is the home that consumes more electricity than the other houses and is cataloged as a disengaged home. This home should display in the interface extrinsic gamified motivation.

The global point of view presents a strong correlation between on home 1 and 4, and the mean output values because home 2 and 3, in a local point of view, require high to very high extrinsic gamified motivation. Therefore, both houses need extrinsic motivation to interact with the community and promote energy reduction; the ANFIS system depicts this interaction between each pair of homes.

Thereby, Figure 11 shows a radar map of the level of energy consumption, type of home, and gamified motivation:

- Home 1: Energy consumption = Low; Type of home = Pro-environmental home; and Motivation: Intrinsic.
- Home 2: Energy consumption = Average; Type of home = Disengaged-environmental home; and Motivation: Extrinsic.
- Home 3: Energy consumption = High; Type of home = Disengaged-environmental home; and Motivation: Extrinsic.
- Home 4: Energy consumption = Average; Type of home = Average home; and Motivation: Intrinsic and Extrinsic (Both).

Thus, considering the gamification elements regarding energy applications and the type of motivation:

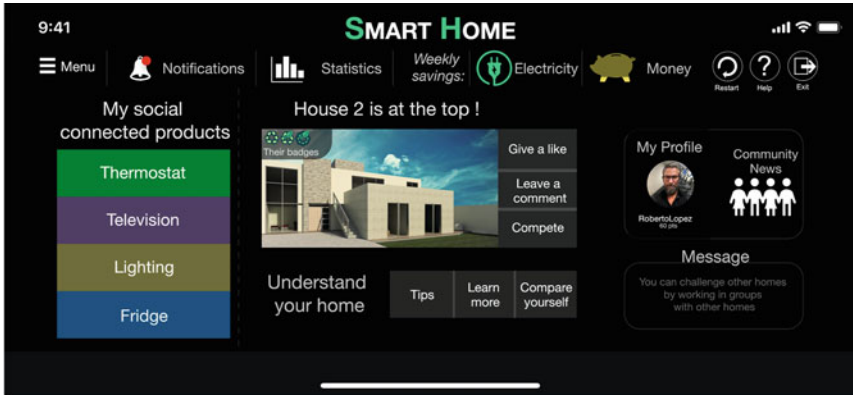


**Fig. 11** Level of energy consumption, type of home, and gamified motivation for each home

- Intrinsic motivation: energy community, collaboration, control over peers, social comparison, competition; additional elements from the Octalysis framework are mentorship, community progress.
- Extrinsic motivation: offers, coupons, bill discounts, challenges, levels, dashboards, statistics, degree of control, additional elements to consider are points, badges, progress bar, and leaderboard.
- Therefore, an application with both motivation types should consider gamification elements from the extrinsic and intrinsic motivation.

Figure 12 displays the type of HMI for all home types. Figure 12a is the interface for home 1; this home is considered a pro-environmental home with less consumption. This interface emphasizes the community side by adding the community news, ability to comments and discuss, and compete to reduce energy consumption. Figure 12b is for house 3, the disengaged- environmental home, and the home that consumes more energy. This interface is focused on showing the rewards elements: coupons, prizes and bill discounts; although extrinsic motivation is not interested in challenges, it is included to subtly promote social interaction. HMI changes weekly savings to weekly expenses as a method to push the user to reduce consumption if they are visualizing a loss instead of a win. Figure 12c shows





(a) Human-Machine Interface for Home 1.



(b) Human-Machine Interface for Home 3.



(c) Human-Machine Interface for Home 2 and Home 4.

**Fig. 12** Human machine interfaces (HMIs) for each type of home from a local point of view. (a) Human-machine interface for home 1. (b) Human-machine interface for home 3. (c) Human-machine interface for home 2 and home 4

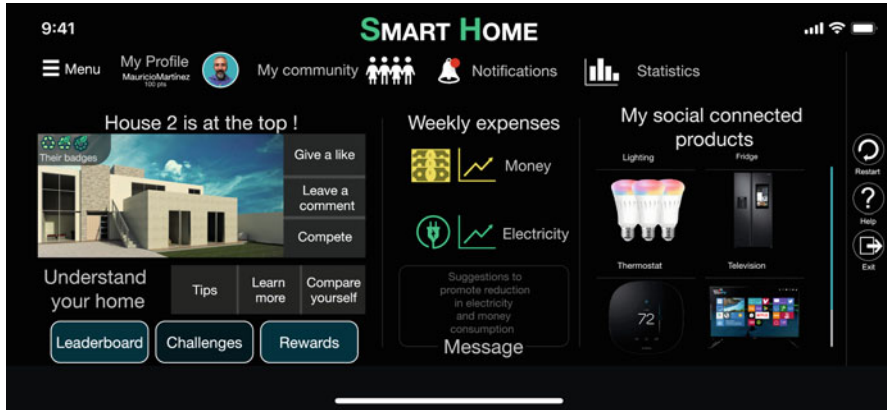


Fig. 13 Human-machine interface for the community from a global point of view

the interface for home 2 and 4, the average home, as this type of home can be motivated either by extrinsic or intrinsic triggers; this first iteration displays both motivational insights to track which of these elements interest the end-user. Finally, Fig. 13 shows the HMI for Home 1 and Home 4 at a global point of view, in smart community integration. Home 2 and Home 3 do not have a tailored global interface. According to the correlation presented from Fig. 10, they may not be interested in interacting with other homes, which is also strongly related to extrinsic motivation.

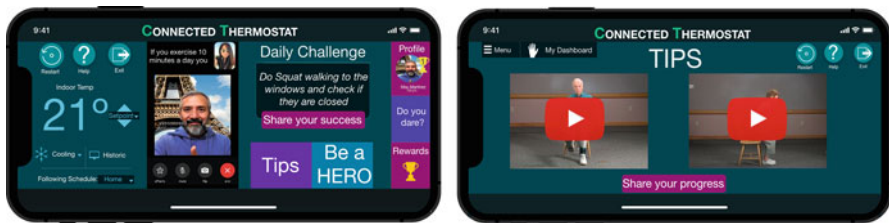
## 5 HMI to Improve the Quality of Life of Older People Using the Proposed Structure

Householders from Home type 2 and Home type 4 represent a type of elderly occupant. People who are older can be viewed as individuals who have a wealth of experience and knowledge, along with desires and interests, but also losses and limitations [42]. The aging process consists of biological changes including sensory, physical, and cognitive deterioration as well as social changes, e.g., social isolation and/or loss of loved ones, and potentially psychosocial variations to confidence, purpose, or value [20, 28]. Table 8 depicts the percentage of the elderly population that lives alone in Mexico, the United States, and around the world, and the 10 most common causes of death in each country and worldwide. Understanding the most common causes of death in each country, a tailored HMI can tackle specific needs [17, 41, 51].

Losing autonomy is a challenge for many as they age, often resulting in changes to living situations and environments. Social inclusion aims to provide a channel for social participation and engagement via local services, relationships, civic activities, and financial resources [46]. It is well known that healthy social relationships, and

**Table 8** Percentage of older people that live alone and common diseases

| Country                           | Mexico                      | United States               | World                       |
|-----------------------------------|-----------------------------|-----------------------------|-----------------------------|
| Live alone (% in 2018)            | 11% [17]                    | 27% [51]                    | 16% [51]                    |
| Most common diseases in 2017 [41] | Cardiovascular              | Cancer                      | Cardiovascular              |
|                                   | Cancer                      | Cardiovascular              | Cancer                      |
|                                   | Kidney                      | Digestive                   | Respiratory                 |
|                                   | Digestive                   | Respiratory                 | Digestive                   |
|                                   | Liver                       | Liver                       | Liver                       |
|                                   | Respiratory                 | Drug disorder               | Tuberculosis                |
|                                   | Homicide                    | Kidney                      | Lower respiratory infection |
|                                   | Lower respiratory infection | Lower respiratory infection | Kidney                      |
|                                   | Road accidents              | Suicide                     | Road accidents              |
|                                   | Alcohol disorder            | Road accidents              | Diarrheal                   |

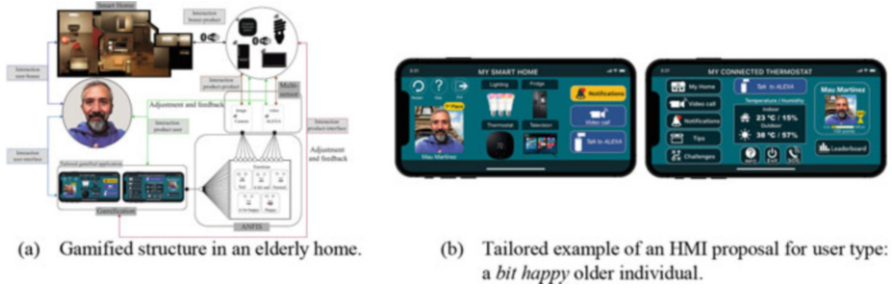


**Fig. 14** Tailored HMI presented in [30] for an elderly user. This interface is designed to promote social interaction and physical activity seen at a level 1 social connected product of the local point of view

feelings of belonging and connectedness, reduce stress and promote health and well-being. Nowadays, many older adults use technology within their social context, but psychosocial aspects, such as negative or positive evaluation and opinions of technological solutions, influence use. Gamification is a useful technique for enriching enjoyment, encouraging healthcare, and promoting social participation among the elderly [25]. As rapid advancements in technology and medicine increase our life spans, there is a pronounced and timely need to design novel personalized solutions for older adults that enhance healthcare, cultivate independence, and facilitate social inclusion.

Previous research focused on the elderly using gamified interfaces include the following:

- In [30], a novel tailored gamified HMI is proposed for helping older people (Fig. 14). This interface considers the personality trait of the end-user to choose gamification elements for physical activity guidance.



**Fig. 15** Gamified structure and tailored HMI for end-users from a local point of view [31]. (a) Gamified structure in an elderly home. (b) Tailored example of an HMI proposal for user type: a *bit happy* older individual

- In [31], the inclusion of Alexa and cameras is proposed to track end-users to monitor daily mood and status toward enriching quality of life by encouraging physical activity and social participation. Physical characteristics are identified through the use of the smart home's multi-sensor system. Algorithms for face and voice detection run on the ANFIS system to select and recommend personalized gamification elements that operate on user type-specific HMIs. Figure 15a displays the gamified structure within the local point of view in a home, where Alexa and a camera track the user's mood, and Fig. 15b displays the tailored HMI.

Both proposals aim to change how we use products such that we may leverage household appliances to increase social engagement and participation. Using multi-sensor systems and data fusion techniques, we may leverage sensors and smart household appliances to detect, analyze, and predict end-user behavior, patterns, trends, and propose personalized applications that align well with users.

A limitation of the proposed approach is that individuals who are older as well as their caregivers and family members must adopt and accept automated monitoring in the house. Further, the type of mobile device available to the end-user may be limited or noncompatible due to socioeconomic levels. It is also required that end-users use voice assistants, such as Alexa, as an initial channel of interaction. Another possible limitation is face detection and emotion recognition. Emotions are complex and multilayered, and therefore susceptible to misclassification in certain circumstances, especially in the wild and in situations of limited training data. But technology is becoming more ubiquitous and machine learning models are evolving and developing robustness as data collection efforts ramp up.

With this local perspective and by tackling end-user needs, it is feasible to interact with the community through continuous feedback where end-users needs are satisfied, and the business sector is either in the community or the city. Supportive and fundamental technologies can improve the satisfaction of the individual, community, and city needs. Table 9 shows the characteristics of supportive

**Table 9** Supportive and fundamental technologies and their interaction at smart homes, smart community, and smart city

|  |   |   |
|--|---|---|
| Supportive technologies  | Customer journey, 3D printing, energy technology, gamification, voice assistants, health technology, geospatial technology, clean technology, collaborative technology, advanced materials  |   |
| Fundamental technologies   | Human-computer interaction, artificial intelligence, internet of things, cloud computing, nanotechnology, mobile internet, automation, big data, robots   |   |
| <b>Smart home</b>  | <b>Smart community</b>  | <b>Smart city</b>   |
| <p>Healthcare: socially connected products track end-user biometrics to detect or track heart attacks, pneumonia, falls, seizures, anxiety attacks, psychosis, respiratory diseases, hearing loss, insulin status, and dementia. These products display medicament schedules, missing pills, and/or fall frequency</p> <p>Environment: during natural disasters, such as earthquakes, detect if all users are safe, e.g., outside the home. Avoid fires by identifying lit candles, or provide weather sensing to promote social interaction and physical activities</p> <p>Groceries: detect missing food or food shortages</p> <p>Household appliances: detect and foresee missing supplies</p> <p>Face-to-face virtual interaction: promote social relationships with other homes, and when possible, promote public interaction at parks</p> | <p>Healthcare: receive from a house its requirements, for instance, assistance with elderly occupants. Schedule medical appointments. If an accident occurs, send an ambulance to the house</p> <p>Environment: provide weather forecasts to inform end-users to support daily planning, such as going outside or staying in. During a pandemic, provide information on how many infected people are near the end-user</p> <p>Groceries: provisioning food to the home</p> <p>Transport: monitoring parking spaces and transportation; managing traffic; and ensuring public transportation is accessible. Establish connection with groceries to supply food to the home</p> | <p>The interactions between communities allow the smart city to track citizens' behavior, understand the trends, and provide accurate feedback, security, and information to the populace</p> <p>Participatory sensing [33]: The end-user through a smartphone becomes a sensor that shares and extracts information to monitor the environment, transportation, mobility, and energy waste</p> |

techniques and necessary technologies, and examples of interactions at the three levels: smart home, smart community, and smart city.

## 6 From Citizen to Smart City: A Future Vision

The *IESE Cities in Motion Index* report [5] gives a clear picture of the elements required to have a transition toward a smart city. The future of smart cities tends to integrate not only the technological aspects of life but also how they combine with and develop the rest of the indicators. Therefore, converging into a city that sees participation from all inhabitants may reduce stress from traffic, legal problems, crime and suicide rates. This may seem Utopian, however with the right planning, partnerships, and public's help, the integration of technology to achieve this ideal is a matter of time.

With the global pandemic COVID-19, at least five areas that artificial intelligence could have contributed to within a smart city were identified [22]:

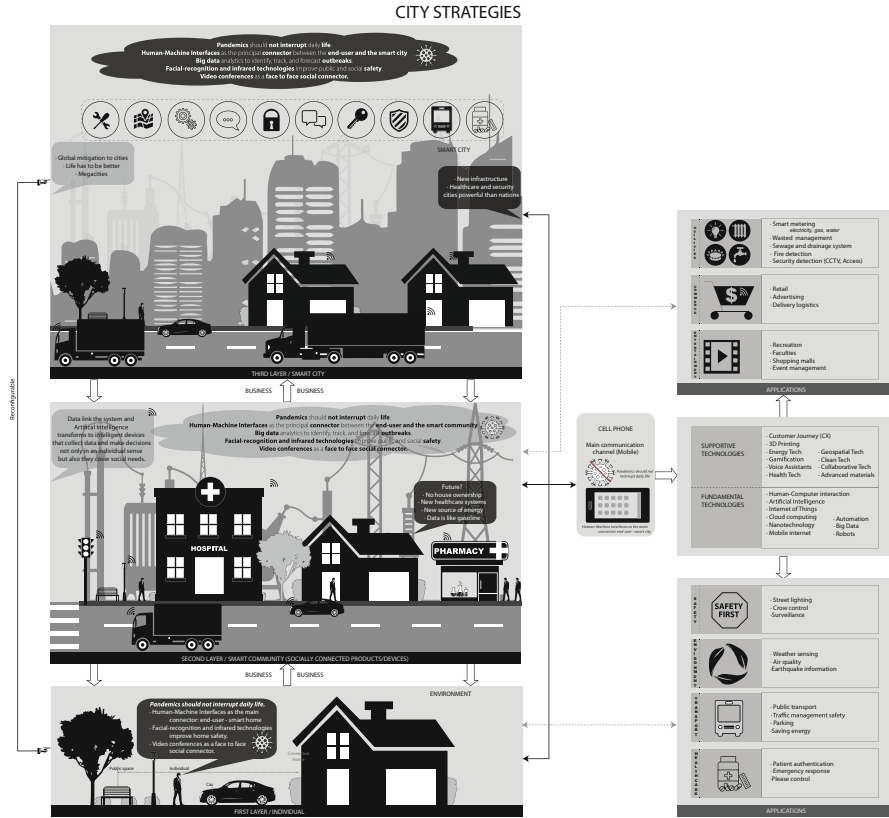
- Detecting, tracking, and predicting outbreaks using big data.
- Use of face recognition and infrared-based technologies to improve public safety and security.
- Surveillance, sterilization, and supply delivery via drones and autonomous robots.
- Innovations in virus understanding, diagnostics, and treatments.
- Novel tele-communication devices and platforms to promote togetherness and connectedness during times when physical contact must be limited for safety.

Thus, in times of social distancing, the role of the HMIs takes a suitable place as they serve as a social connector between the end-user and the entire community or smart city. It is a new paradigm where end-users partake in a new type of social interaction, leveraging the internet of things, social media, and e-commerce to make a new life.

### 6.1 Smart City Vision in a COVID-19 Context

Figure 16 depicts a third-layer structure to achieve a smart city. A new concept considered in this roadmap is the COVID-19 global pandemic. With technology and network communications, it is feasible to continue living in a new normal and with new methods of communication where HMIs take the central role as a social connector and interactor between the end-user and the community and smart city. The three-layer topology considers the following:

- The first layer is the individual segment. The home takes advantage of the socially connected products and devices to interact with the house. Some applications



**Fig. 16** Smart city vision from an individual layer into a connected smart city

consider healthcare, transportation, environment, and safety in interactions with the smart community and the smart city. HMIs connect with the home to provide new forms of social interaction and foresee if a family member is becoming ill, for instance, with cameras and communication via Alexa by detecting if the user is having fever and presenting COVID-19 symptoms. The smart fridge can identify, based on a dietary list, any food shortages, and contact the market to request provisions.

- The second layer is the smart community. This layer imagines new healthcare systems, new sources of energy, no home ownership, and data is like gasoline in the future. The data link the system, and artificial intelligence transforms devices that collect data and make decisions not only in a personal sense but also from the perspective of social needs. This layer considers applications for utilities, commerce, and entertainment. The HMIs and big data analytics bring new information to identify, track, and forecast outbreaks. The surveillance cameras and infrared technologies can detect users with erratic behavior or with fever to improve public and social safety. Video conferences allow new manners of

business; for instance, physicians assist infected users and avoid physical contact to help prevent the spread of viruses.

- The third layer deepens the smart city concept. It considers that life should be better, with new developments and improvements to infrastructure, healthcare, and security. Cities should be powerful, connected, responsive, and adaptive. The safest and most reliable and convenient way to interact will be through HMIs, video conferencing, conventional calls, or mails; however, new dynamics will be implemented for social and physical interactions, e.g., access to information about a specific location and how many nearby people are infected so that a user can take precaution.

Therefore, considering the elderly sector, by taking advantage of HMIs, smart devices, and household products in the home, the elderly can receive more attention from their family, interact with friends, and monitor their health. For instance, as proposed in [31], the home can track an end-user's mood, and avoid social isolation through interaction. In this way, an elderly user can engage with Alexa through conversation. On the other hand, implementing social connectors such as video conferences in the HMIs could encourage the elderly to be more in touch with friends and family.

## 7 Discussion

This chapter presented socially connected products within a smart home, and proposed a tailored interface to improve the quality of life of users and the community by promoting a reduction in energy consumption. A Sugeno Fuzzy Logic decision system was used to classify the type of home based on energy consumption level and type of environmental home to propose a gamified structure that runs in a customized HMI. The proposed interface is oriented based on the preferred motivation. Although the level of energy consumption was classified based on the 2015 Residential Energy Consumption Survey public database [10], the fuzzy decision system is designed to organize the level of energy consumption from the household appliances.

This classification uses the following scale: low consumption, average consumption, and high consumption. The average value range comes from the database, by using the standard deviation; the higher consumption comes from the addition of the average value plus the standard deviation. Whereas the lower consumption comes from the subtraction of the average value minus the standard deviation. The type of energy home is classified as either a pro-environmental home, average home, or disengaged-environmental home. The type of home is related to the level of energy consumption of the house. Finally, the gamified motivation is classified in three varieties: intrinsic motivation (Low, Medium, High, and Very High); extrinsic motivation (Low, Medium, High, and Very High); or both motivation types. This interaction is included within the local point of view (see Fig. 1).



Once the decision system classifies the type of home and provides a personalized gamification interface, the multi-sensor system may be utilized inside the smart home setting to detect the level of energy consumption and the environmental type of the home to promote social interaction and energy reduction to improve the quality of life in the community. This interaction is included within the global point of view (see Fig. 1). Therefore, the ANFIS system is designed to propose the type of gamification motivation based on community behavior and a tailored community gamified interface.

Hence, a Human Machine Interface for each type of home is proposed and considers three levels:

- For a single social product, e.g., a connected thermostat. Several approaches to this type of social product have been published in [30, 39].
- For the smart home, which is the set of social products within the home. In [29, 31], saving energy in smart homes was empowered using gamification techniques.
- And lastly, for the smart community. Although there is no limitation, this interface should be included and considered based on the correlation and interaction between homes and the gamified community motivation.

This general proposal is limited in that the home should have a level of automatization and connectivity to provide real-time monitoring and feedback, as well as enable user profile creation to provide personalized interfaces. Moreover, once the community interaction is classified, if there are homes that a community structure will not allow to reduce energy consumption, then perhaps other interactions may be explored. For example, interaction between pairs of homes or groups of three homes may be proposed to offer more types of community awareness and engagement to improve quality of life.

Considering Nielsen's heuristics within the interface may increase the impact for and engagement of the end-user. These heuristics take into account [35]: the visibility of a system's current status; whether the real world matches the system; users' freedom and control; standards and consistency; error prevention; recognition (as opposed to recall); efficiency of use as well as flexibility; minimalist and aesthetic design; error recovery; and user support.

This proposal looks for a change in how connected/social products are used and how a community could interact to enhance social inclusion. It aims to produce new forms of social interaction between users and their homes. This first approach considers only the interaction between homes and the household products within the smart home; nevertheless, with further research, this interaction could include the transportation and commercial sector by taking advantage of the associated communications and promoting more connected community interaction. With a multi-sensor system, we may leverage connected smart home appliances to develop a profile of a house, and propose tailored applications triggered by intrinsic and/or extrinsic motivations that best fit the type of home.

## 8 Conclusion

In this chapter, a multi-sensor system for improving the quality of life by reducing energy consumption was proposed. A gamification structure triggered by outcome motivations within an HMI for a community was presented based on each home's characteristics. This strategy considers each home's interaction by profiling the level of energy consumption and type of environmental home within a fuzzy logic decision system. Then the interaction between homes to set the community was proposed through an ANFIS system that provides which gamified motivation is required to engage the home in having a reduction in energy consumption and improvement of quality of life in the community. The proposed approach aims to develop a profile of the home and improve our understanding of the type of home and the interaction of the houses in the community toward an accurate application that improves quality of life while promoting energy reduction. This HMI introduces an opportunity to create an ecosystem enabling connected products and homes to interact with the community to help residents feel included.

An example of the relevance of HMIs is the COVID-19 pandemic. HMIs tackle social distancing by taking advantage of social products and connectors such as video conferences, calls, blogs, and social media. Thus, individuals interact with others without concerns of infection; for instance, this interaction works for social relationships, work, healthcare, schools, and religious groups. As Fig. 16 indicates, HMIs work as a critical connector between each smart home, smart community, and smart city with the end-user, where the user provides information and consumption and behavior patterns to each level, improving their quality of life and fostering social synergy with other users.

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