Study and Comparison of Technologies in Home And Building Electronic Systems by Fuzzy Logic

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Abstract. Nowadays, there exist in market many systems of automation, energy management and security for housings and buildings (domotics systems). In many occasions the engineer find difficult to decide what system to choose due to the multiple factors that have to be taken into account in the decision. This work considers the most outstanding factors for the decision taking, which constitutes the input variables of a Fuzzy model developed in order to help in that decision, where the output variables measure the grade of adaptation of the system to the home. A high number of rules are defined to develop the inference and to generate the appropriate output values. The proposed model is developed with the Fuzzy Logic Toolbox of MATLAB, and is evaluated on ten different cases, which are presented in order to show the methodology, the behaviour of the model and the results.

Key words

Home automation, fuzzy logic, electrical engineering code

1. Introduction

In general, automation, energy technical management, and security in housings and buildings system installations are known as domotics (word that derives from Domus –house in Latin– and Robotics), in the case of individual housings such as typical houses, or inmotic in case that the installation refers to buildings (we will refer both as domotics for simplicity).

Last February of 2007 the Spanish Government, by its Ministry of Industry, Tourism and Commerce has published inside the Technical Guide of Application of the Spanish Electrical Engineering Code of Low tension (REBT from its Spanish name "Reglamento electrotécnico de Baja Tensión") the document GUIDE-BT-51: "Installations of automation, energy technical management, and security in housings and buildings " in which the nets that compose the installation of a housing or building are defined. The following nets can be distinguished (Figure 1):

- Net of Information technologies.
- Television Net
- Phone Net
- Domotics control Net (integrated inside the electrical net).

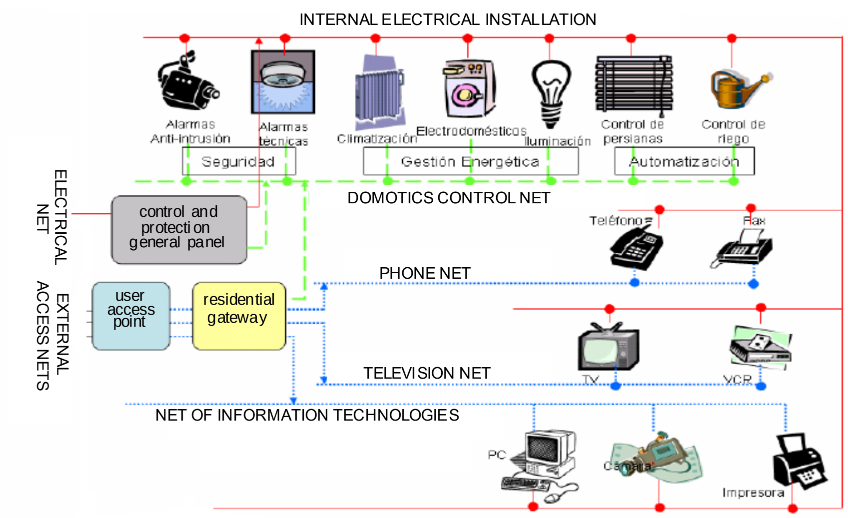

Fig. 1. Nets that compose the installation of a housing or building.

The domotics net is regulated by the REBT in its Instruction Technique-51 (IT-51), dealing with electrical security and electromagnetic compatibility control; it should be integrated within the electrical power net and coordinated with the rest of the nets with which it is related. The mentioned net can be implemented by means of specific wire or through carrier waves coupled to the electric net.

2. Installation possibilities

Systems of automation, energy management and security in housings and buildings receive information coming from the input signals (sensors or controls), process it and emit orders to actuators and outputs in order to improve comfort, energy management, and people, animal, and goods safety. These systems can also have the possibility of communicating with external communication nets such as the Commuted *Telefónica* Net or Internet services.

For the implementation of the installation three types of architectures are admitted (Figure 2):

- Centralized: a central node holds the control functions and the control. All the entrance devices and actuators are physically wired to the node.
- Semi- Decentralized: a central node holds the control functions and control. Intermediate nodes that communicate with the central node for information transfer exist. The entrance devices and actuators are physically wired to the passing nodes.
- Decentralized: all the components share the communication line, holding each one of them some of control functions.

The REBT-IT-51 admits the ring, tree, bus and star topologies, as well as any combination of them.

The physical means admitted are:

- The conductors of the electrical net (carrier currents)
- Specific wires for the installation: twisted pair, parallel, coaxial, and optical fiber.
- Radio signals: infrared, radio frequency, ultrasounds, or systems connected to the telecommunications net.

The installation documents must include:

- User manual
- Installer manual

Two automation levels are defined, basic and normal, with functionalities and specific applications.

3. Fuzzy model and methodology

Diverse solutions exist in market for the development of domotics installations by using any of the tree different architectures presented: centralized, decentralized, and semi-decentralized.

A study and comparative of the different types of existent solutions in market have been developed in order to help to decide which is the most appropriate solution in each case, depending on the characteristics of the domotics installation to design and on the recommendations of the REBT-IT-51.

The methodology used to carry out the comparative of systems is based on fuzzy logic. A fuzzy model has been designed, validated, and employed, using MATLAB and its Fuzzy Logic Toolbox.

The work also includes the study and analysis of the most outstanding factors for the decision of the most suitable installation and its characteristics. As factors for the decision taking the following ones (Table 1) have been considered for buildings and semidetached houses; the input factors considered for houses are very similar (Table 2):

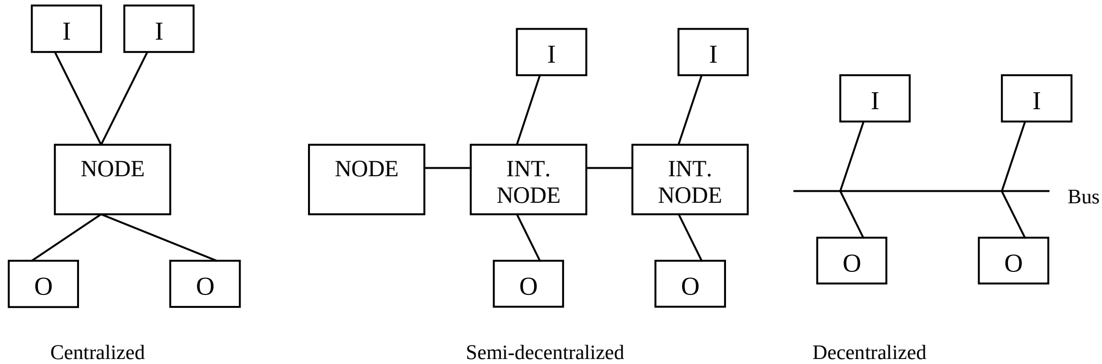

Fig. 2. Different architectures in the implementation of the installation

Table 1. Factors considered for the choice of the most suitable domotics installation in buildings and semidetached houses

number of housings
number of rooms per housing
building age
number of functionalities
number of external measures
estimated cost per housing
design and planning time
implementation and start-up time
extension possibility
maintenance
user age
supervision
external control of the installation

Table 2. Factors considered for the choice of the most suitable domotics installation in houses

number of buildings
number of rooms per building
building age
number of functionalities
number of external measures
estimated cost of the building
design and planning time
implementation and start-up time
extension possibility
maintenance
user age
supervision
external control of the installation

For every input variable a domain is defined, as well as the associate membership function. For instance the variable "number of housings" has associate three gaussian membership function, named lower, half and high respectively, which is defined in the following way in Matlab (Table 3) with the result shown in Figure 3:

Fig. 3. Input variable "number of housings" on Matlab Fuzzy Logic Toolbox

Table 3. Definition of the three gaussian membership functions for the input variable "number of housings"

[Input1]
Name='Numero viviendas'
Range=[1 200]
NumMFs=3
MF1='bajo':'gaussmf',[34 1]
MF2='medio':'gaussmf',[34 70]
MF3='alto':'gaussmf',[34 200]

As output variables the following ones (Table 4) are considered in both cases (buildings and houses):

Table 4. Output variables of the fuzzy application

bus system
carrier current system
centralized system
decentralized system
mixed system
preprogramable system
SMS
telephone
Internet
touchscreen
PC

In the same way the output variables are defined, as for instance the “Bus system” variable shown in table 5 and Figure 4, which has three triangular functions named “non-advised”, “advised”, and “highly advised”.

Table 5. Output variable “Bus system” on Matlab

[Output1]
Name='Sistema bus'
Range=[0 1]
NumMFs=3
MF1=' nonadvised ':'trimf',[-0.4 0 0.4]
MF2=' advised':'trimf',[0.1 0.5 0.9]
MF3=' highlyadvised ':'trimf',[0.6 1 1.4]

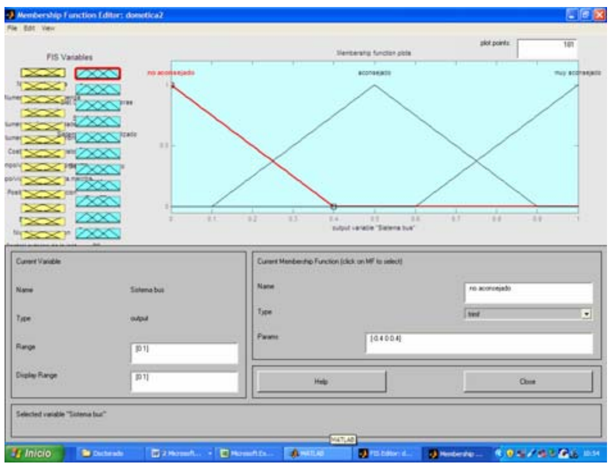

Fig. 4. Output variable “Bus system” on Matlab Fuzzy Logic Toolbox

The relationship between the input and the output variables is implemented by a series of rules whose interpretation uses the "Mandani" method.

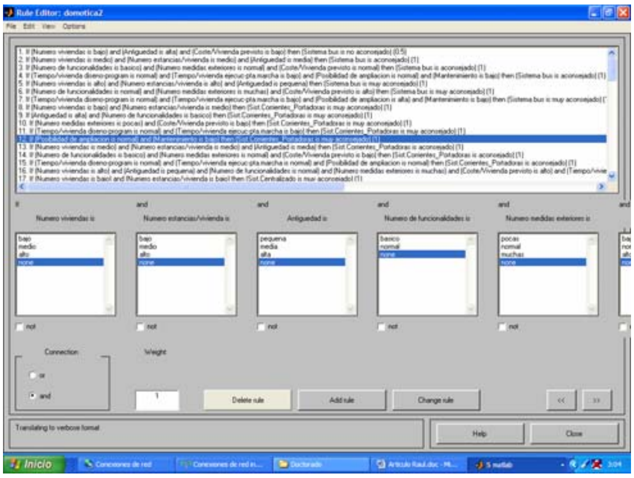

Fig. 5. relationship between the input and the output variables with the "Mandani" method.

The fuzzy model presents 13 input variables, 11 output variables and 79 inference rules. As instance, the rules relating the first output are shown in indexed way; the first 13 columns represent the inputs, the 11 following the outputs, the penultimate one the weight of the rule and the last one indicates the link type between the AND or OR conditions:

Table 6. Rules relating the first output

1 0 3 0 0 1 0 0 0 0 0 0 0, 1 0 0 0 0 0 0 0 0 0 0 (0.5) : 1
2 2 2 0 0 0 0 0 0 0 0 0 0, 2 0 0 0 0 0 0 0 0 0 0 (1) : 1
0 0 0 1 2 2 0 0 0 0 0 0 0, 2 0 0 0 0 0 0 0 0 0 0 (1) : 1
0 0 0 0 0 0 2 1 2 1 0 0 0, 2 0 0 0 0 0 0 0 0 0 0 (1) : 1
3 3 0 0 0 0 0 0 0 0 0 0 0, 3 0 0 0 0 0 0 0 0 0 0 (1) : 1
3 3 1 2 0 0 0 0 0 0 0 0 0, 3 0 0 0 0 0 0 0 0 0 0 (1) : 1
0 0 0 0 3 3 0 0 0 0 0 0 0, 3 0 0 0 0 0 0 0 0 0 0 (1) : 1
0 0 0 0 0 0 2 1 0 0 0 0 0, 3 0 0 0 0 0 0 0 0 0 0 (1) : 1
0 0 0 0 0 0 0 0 3 1 0 0 0, 3 0 0 0 0 0 0 0 0 0 0 (1) : 1

4. Evaluation of the model

The developed fuzzy model has been evaluated by applying it on 10 different significant cases, and checking that the results agree with the results obtained after a detailled analysis without the use of the application. The selected 10 cases are:

a. Semidetached house
b. Small building
c. Medium building
d. Big building
e. Rural house
f. Hotel in a city
g. Office building
h. Museum
i. Shopping centre
j. Temple or church

In next subsections, the input data used, the obtained results, and a brief interpretation of them are shown in every case.

A. *Semidetached house*

Tables 7 and 8 show the input data used in the developed model, and the output variables obtained. From them, the most suitable system is a decentralized system (0.679) using a PC (0.585) and Internet (0.430) for the development of control and supervision tasks.

Table 7. Input data of a semidetached house

number of housings	1
number of rooms per housing	5
building age	3
number of functionalities	5
number of external measures	3
estimated cost per housing	6000
design and planning time	10
implementation and start-up time	20
extension possibility	0.5
maintenance	0.2
user age	30
supervision	0.8
external control of the installation	0.25

Table 8. Output variables of the semidetached house

bus system	0.63472
carrier current system	0.66590
centralized system	0.57150
decentralized system	0.67900
mixed system	0.63760
preprogramable system	0.61900
SMS	0.17380
telephone	0.17380
Internet	0.43000
touchscreen	0.54020
PC	0.58550

B. *Small housing building*

Tables 9 and 10 show the input data used in the developed model, and the output variables obtained. From them, a carrier current system or a decentralized system are equally recommended (0.727), as well as the use of a touchscreen (0.559).

Table 9. Input data of a small housing building

number of housings	6
number of rooms per housing	3
building age	1
number of functionalities	3
number of external measures	1
estimated cost per housing	2000
design and planning time	2
implementation and start-up time	20
extension possibility	0.5
maintenance	0.2
user age	35
supervision	0.2
external control of the installation	0.1

Table 10. Output variables of the small housing building

bus system	0.55508
carrier current system	0.72745
centralized system	0.69894
decentralized system	0.72745
mixed system	0.53171
preprogramable system	0.59198
SMS	0.26505
telephone	0.26505
Internet	0.19688
touchscreen	0.55866
PC	0.22839

C. Medium housing building

Tables 11 and 12 show the input data used in the developed model, and the output variables obtained. From them, a carrier current system or a decentralized system are equally recommended (0.624), as well as the use of a touchscreen (0.559).

Table 11. Input data of a medium housing building

number of housings	35
number of rooms per housing	3
building age	0
number of functionalities	5
number of external measures	1
estimated cost per housing	4000
design and planning time	6
implementation and start-up time	20
extension possibility	0.5
maintenance	0.1
user age	35
supervision	0.1
external control of the installation	0.1

Table 12. Output variables of the medium housing building

bus system	0.60341
carrier current system	0.62408
centralized system	0.60474
decentralized system	0.62408
mixed system	0.59087
preprogramable system	0.61787
SMS	0.52592
telephone	0.52592
Internet	0.19688
touchscreen	0.55866
PC	0.19688

D. Big housing building (development)

Tables 13 and 14 show the input data used in the developed model, and the output variables obtained. From them, the most suitable system is a centralized system (0.853), although a descentralized system is also advisable (0.798). A touchscreen is proposed (0.572) in order to develop the supervisión, and the telephone or SMS systems (0.525) to control the installation from outside.

Table 13. Input data of a big housing building (development)

number of housings	200
number of rooms per housing	2
building age	5
number of functionalities	3
number of external measures	2
estimated cost per housing	3000
design and planning time	6
implementation and start-up time	20
extension possibility	0.5
maintenance	0.1
user age	45
supervision	0.2
external control of the installation	0.2

Table 14. Output variables of the big housing building (development)

bus system	0.60341
carrier current system	0.66382
centralized system	0.85355
decentralized system	0.79812
mixed system	0.50008
preprogramable system	0.61787
SMS	0.52592
telephone	0.52592
Internet	0.19944
touchscreen	0.57246
PC	0.19944

E. Rural house

Tables 15 and 16 show the input data used in the developed model, and the output variables obtained.

Table 15. Input data of a rural house

number of buildings	1
number of rooms per building	10
building age	50
number of functionalities	3
number of external measures	1
estimated cost per housing	2000
design and planning time	10
implementation and start-up time	15
extension possibility	0.2
maintenance	0.1
user age	50
supervision	0.75
external control of the installation	0.05

Table 16. Output variables of the rural house

bus system	0.70747
carrier current system	0.70747
centralized system	0.84690
decentralized system	0.68899
mixed system	0.50070
preprogramable system	0.56457
SMS	0.18100
telephone	0.18100
Internet	0.19502
touchscreen	0.50515
PC	0.54258

From them, the most suitable system is a centralized system (0.847), although bus or carrier current systems are also advisable (0.707). A PC (0.543) and a touchscreen (0.505) are also proposed.

F. Hotel in a city

Tables 17 and 18 show the input data used in the developed model, and the output variables obtained. From them, the most suitable system is a preprogramable system (0.763) using a PC (0.571) for the development of control and supervision tasks.

Table 17. Input data of a hotel

number of housings	100
number of rooms per housing	2
building age	0
number of functionalities	3
number of external measures	3
estimated cost per housing	2000
design and planning time	10
implementation and start-up time	20
extension possibility	0.5
maintenance	0.1
user age	50
supervision	0.9
external control of the installation	0.2

Table 18. Output variables of the hotel

bus system	0.61237
carrier current system	0.62442
centralized system	0.60341
decentralized system	0.62260
mixed system	0.59971
preprogramable system	0.76281
SMS	0.15912
telephone	0.15912
Internet	0.19680
touchscreen	0.50748
PC	0.57122

G. Office building

Tables 19 and 20 show the input data used in the developed model, and the output variables obtained.

Table 19. Input data of a office building

number of offices	40
number of rooms per office	6
building age	0
number of functionalities	4
number of external measures	2
estimated cost per housing	6000
design and planning time	10
implementation and start-up time	10
extension possibility	0.5
maintenance	0.25
user age	35
supervision	0.5
external control of the installation	0.01

Table 20. Output variables of the office building

bus system	0.66534
carrier current system	0.66890
centralized system	0.75431
decentralized system	0.58818
mixed system	0.58182
preprogramable system	0.70927
SMS	0.19501
telephone	0.19501
Internet	0.19510
touchscreen	0.55369
PC	0.55344

From them, the most suitable system is a centralized system (0.754), although a preprogramable system is also advisable (0.709). A touchscreen (0.554) and a PC (0.553) are also proposed.

H. Museum

Tables 21 and 22 show the input data used in the developed model, and the output variables obtained. From them, the most suitable system is a centralized system (0.858), using Internet (0.571) or a PC (0.585) for the development of control and supervision tasks.

Table 21. Input data of a museum

number of buildings	1
number of rooms per building	10
building age	60
number of functionalities	3
number of external measures	2
estimated cost per housing	6000
design and planning time	10
implementation and start-up time	20
extension possibility	0.05
maintenance	0.15
user age	45
supervision	0.95
external control of the installation	0.75

Table 22. Output variables of the museum

bus system	0.83252
carrier current system	0.83252
centralized system	0.85845
decentralized system	0.66198
mixed system	0.53330
preprogramable system	0.52084
SMS	0.38279
telephone	0.38279
Internet	0.57057
touchscreen	0.50342
PC	0.58499

I. Shopping center

Tables 23 and 24 show the input data used in the developed model, and the output variables obtained. From them, the most suitable system is a preprogramable system (0.717) using a PC (0.554) or a touchscreen

(0.516) for the development of control and supervision tasks.

Table 23. Input data of a shopping center

number of establishments	50
number of rooms per establishment	1.5
building age	5
number of functionalities	4
number of external measures	2
estimated cost per housing	3000
design and planning time	10
implementation and start-up time	20
extension possibility	0.75
maintenance	0.01
user age	40
supervision	0.65
external control of the installation	0.05

Table 24. Output variables of the shopping center

bus system	0.61537
carrier current system	0.61537
centralized system	0.55858
decentralized system	0.55858
mixed system	0.65413
preprogramable system	0.71732
SMS	0.19131
telephone	0.19131
Internet	0.19513
touchscreen	0.51558
PC	0.55382

J. Temple or church

Tables 25 and 26 show the input data used in the developed model, and the output variables obtained. From them, the most suitable system is a centralized system (0.867), although bus or carrier current systems are also advisable (0.814), as well as telephone or SMS systems (0.547) in order to control the installation from outside.

Table 25. Input data of a temple or church

number of buildings	1
number of rooms per housing	6
building age	100
number of functionalities	3
number of external measures	2
estimated cost per housing	6000
design and planning time	10
implementation and start-up time	30
extension possibility	0.05
maintenance	0.05
user age	60
supervision	0.01
external control of the installation	0.05

Table 26. Output variables of the temple or church

bus system	0.81449
carrier current system	0.81449
centralized system	0.86689
decentralized system	0.77579
mixed system	0.52203
preprogramable system	0.50556
SMS	0.54707
telephone	0.54707
Internet	0.19401
touchscreen	0.41360
PC	0.19401

5. Conclusions

A fuzzy model has been developed in order to allow deciding and quantifying the best system to use in an domotics or inmotics installation. The model has been developed and validated with the Matlab fuzzy logic toolbox, and has been tested with 10 significant cases based on different types of buildings and housings, obtaining the expected results. We are working in order to improve the factors to considered as input, as well as the inference rules, which constitute the “intelligence” in the calculation of the output variable values, the results.

Acknowledgement

This paper has been partially supported by the project DPI2007-66679 from the Spanish Education and Science Ministry, and by the University of La Rioja.

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