2nd Energy Tech Forum

Session 3

Increasing the Energy Efficiency of Buildings using Human Cognition; via Fuzzy Cognitive Maps

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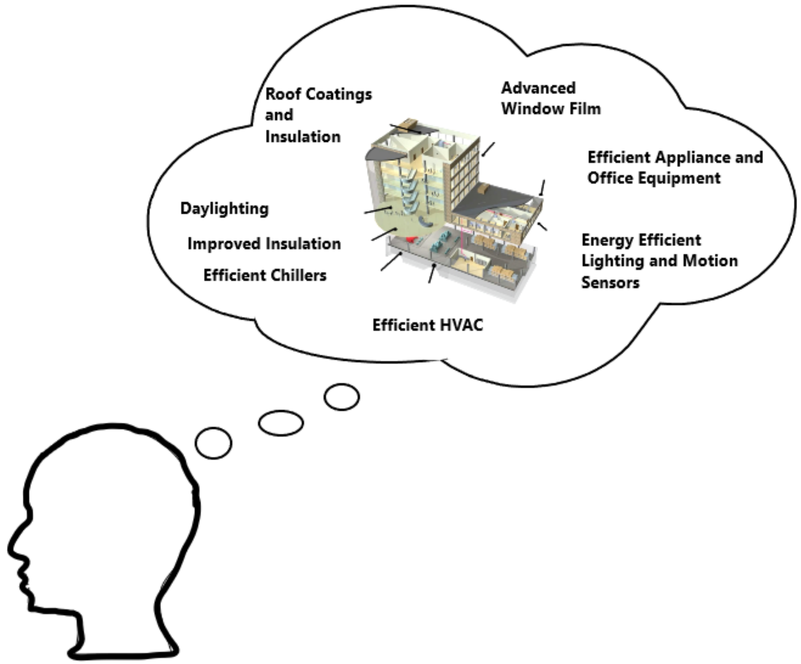
Presentation Outline

- Problem Statement
- Intelligent Buildings
- Introduction to Fuzzy Cognitive Maps
- Fuzzy Cognitive Map Modeling
  - Case study: *Reduce the consumption of a building by shifting excess loads*
- Results
- Conclusions
- Future Research

Problem Statement

How can we use human cognition procedures to achieve high energy efficiency in buildings?



Intelligent Buildings- Definitions

IBs

Services based

Services offered to users:

- communication
- office automation
- building automation

Japanese Intelligent Building Institute (JIBI)

System based

Integrated Technology:

- building automation
- communication automation
- office automation

Chinese IB Design Standard (GB/T50314–2000)

Performance based

Expected Performance:

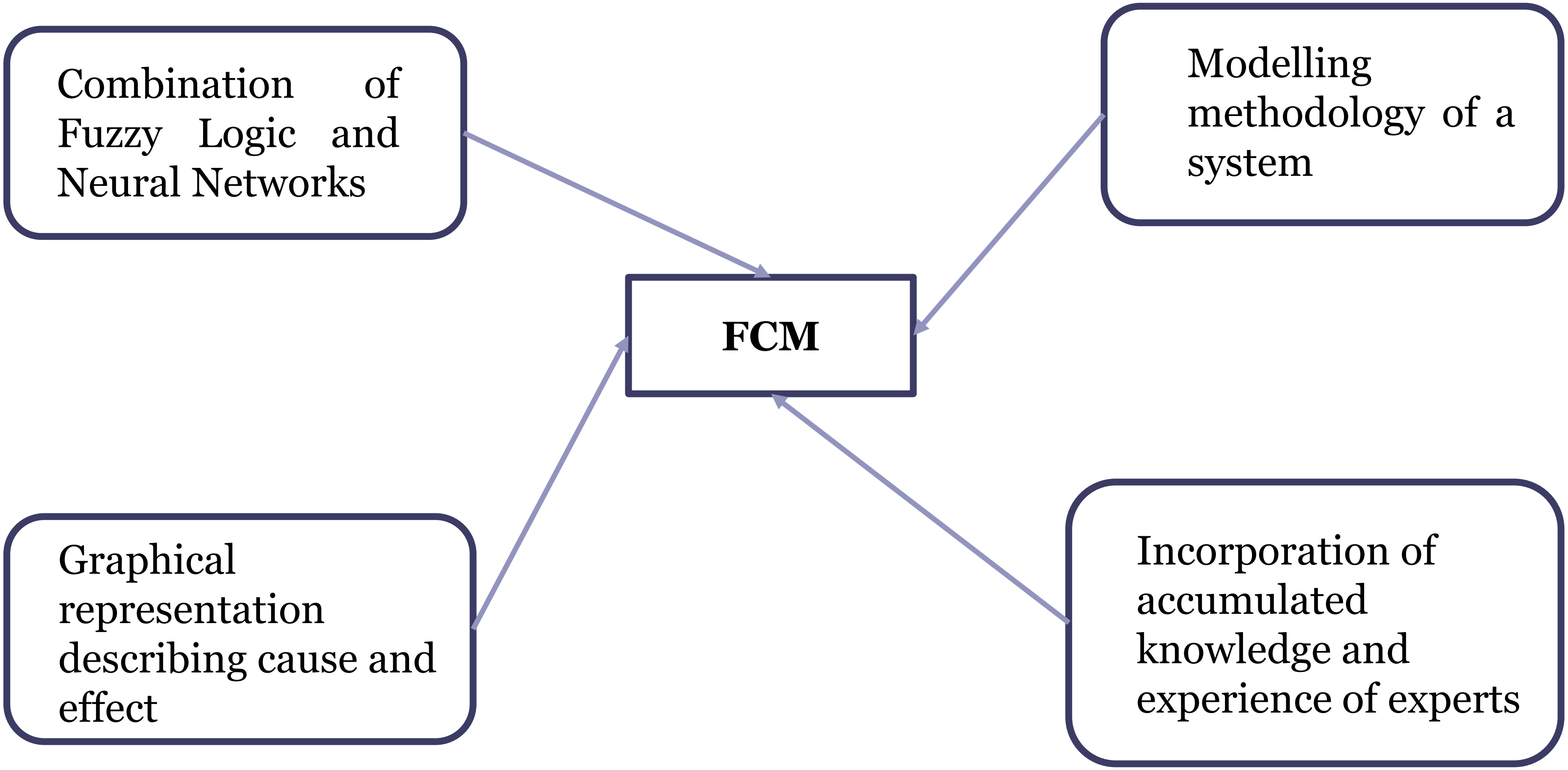
- efficient management of resources
- cost reduction
- Meet the users' needs

European Intelligent Building Group (EIGB) & Intelligent Building Institute (IBI) ,United States

How to create and energy efficient building

- Solar collectors for air and water heating
- Small scale solar cooling units
- Development and demonstration of standardized building components
- Software for building simulation
- Integration of renewable energy supply

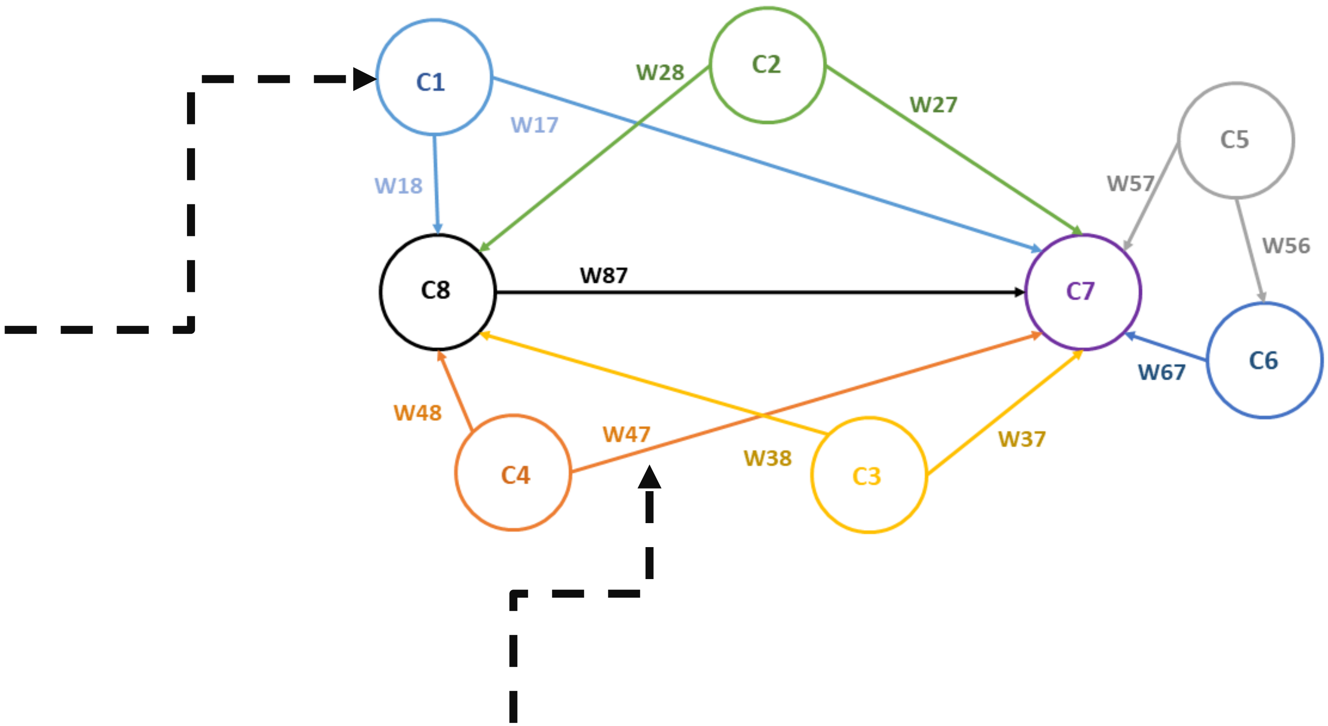
Fuzzy Cognitive Maps – An Introduction (1/2)



Fuzzy Cognitive Maps – An Introduction (2/2)

Concepts:
Key factors of the system (states, inputs, outputs, failures, events e.t.c.)

Values interval: [0,1]

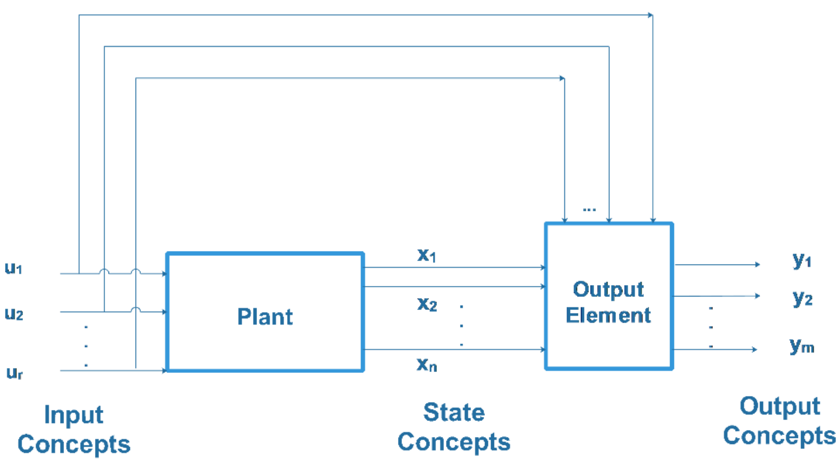


Weighted arcs: causal relationships between nodes
Values interval: [-1, 1]

- Value: strength of influence between Ci and Cj
- Sign: direct or inverse relationship
- Direction of arc: whether Ci influences Cj or vice versa

FCM- A system's approach

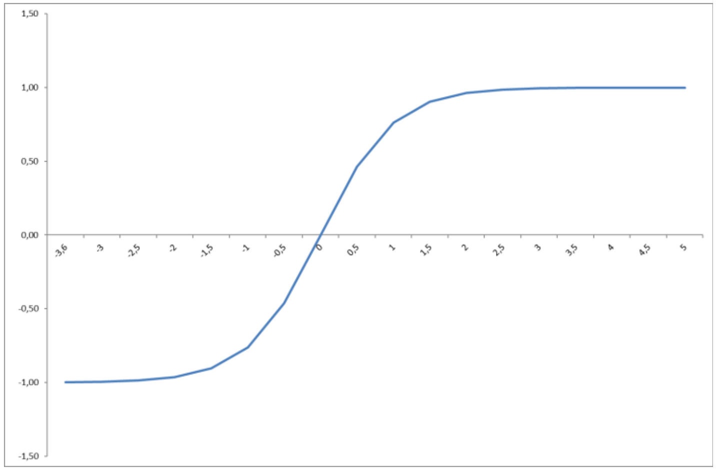
State Space Approach



$$x_{k+1} = Ax_k + Bu_k$$

$$y_k = Cx_k + Du_k$$

Fitting the Inputs



$$f(x) = m + \frac{M - m}{1 + e^{(-r(x - t_0))}}$$

- m= lower limit
- M= upper limit
- r=slope
- to= symmetry to the y axis

FCM- Mathematical Representation

Concepts Calculation at each iteration step

$$x_{k+1} = x_k + \frac{\Delta x_{k+1}}{\sum_{j=1, j\neq i}^{n} |w_{ji}|}$$

$$y_{k+1} = y_k + \frac{\Delta y_k}{\sum_{j=1, j\neq i}^{m} |w_{ji}|}$$

where:

$$\Delta x_{k+1} = A\Delta x_k + B\Delta u_k$$

$$\Delta y_k = C\Delta x_k + D\Delta u_\kappa$$

System's description

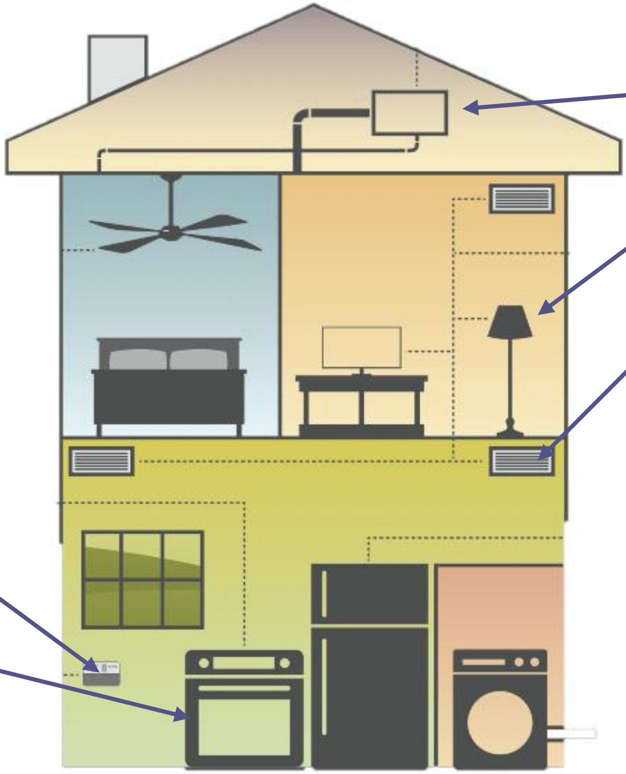
Objective: Reduce the consumption of a building by shifting excess loads

State Parameters:

- Ventilation
- Lighting
- Air-Conditioning

Input Parameters:

- Temperature
- Air quality
- Luminance
- Room thermal quality
- Extra load



Output Parameters:

- Consumption

Fuzzy Cognitive Maps Modeling (1/3)

STATES

- C1: ventilation
- C2: lighting
- C3: air- conditioning

INPUTS

- C4: steptemp
- C5: stepair
- C6: steplum
- C7: roomthq
- C8: extraload

OUTPUTS

- C9: consumption

Fuzzy Cognitive Maps Modeling (2/3)

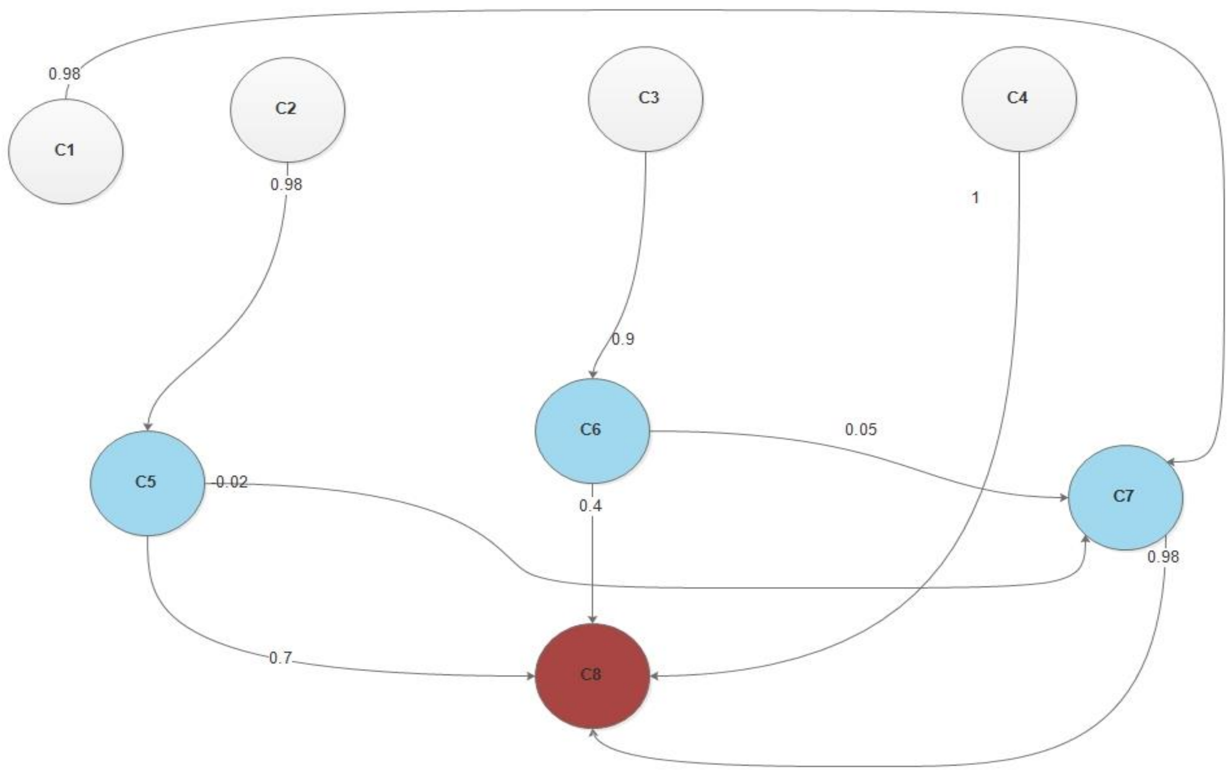
Initial Weight Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0	0	0.12	0	0	0	0	0	1
C2	0	0	0	0	0	0	0	0	1
C3	0	0	0	0	0	0	0	0	1
C4	0	0	0.98	0	0	0	0	0	0
C5	0.98	0	0	0	0	0	0	0	0
C6	0	0.9	0	0	0	0	0	0	0
C7	0	0	-0.5	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	1
C9	0	0	0	0	0	0	0	0	0

Individual Weight Matrices

$$A = \begin{vmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0.12 & 0 & 0 \end{vmatrix} \qquad B = \begin{vmatrix} 0 & 0.98 & 0 & 0 \\ 0 & 0 & 0.9 & 0 \\ 0.98 & 0 & 0 & -0.5 \end{vmatrix} \qquad C = [1 \quad 1 \quad 1] \qquad D = [1]$$

Fuzzy Cognitive Maps Modeling (3/3)



Results (1/3)

Inputs	Case Study 1	Case Study 2
Internal Temperature	35	30
Optimal Temperature	25	27
Internal Air Quality	900	1000
Optimal Air Quality	800	700
Internal Luminance	100	300
External Luminance	500	500
Extra Load	2	4
Room Thermal Quality	Very Good	Poor
Extra load Type	Critical	Schedulable
Hour type	Peak Time	Peak Time

Results (2/3)

Initial Vector:

Case Study 1:[1 0 1 0.5 0 0 0 0]

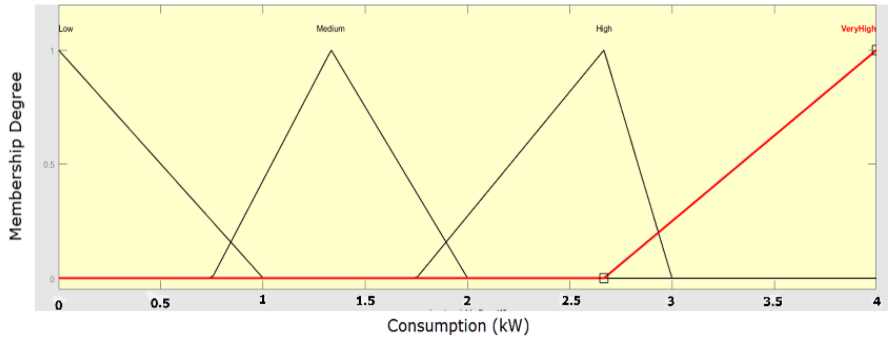
Case Study 2:[1 0.66 0 1 0 0 0 0]

Final Values for states and outputs:

1: x=[0 1 0.17] and y=[0.84]

2: x=[0.66 0.0 1.79] and y=[1.72]

Interpretation criterion:



Results (3/3)

	Case Study 1	Case Study 2
Consumption	Low	Medium
Extra Load Type	Critical	Schedulable
Hour Type	Peak Time	Peak Time
Load Shifting	Run Load	Shift Load

Conclusions

- Very effective and convenient method when facing complex problems, it is fast and accurate without wasting time in the mathematical modeling of the problem.
- Simplifies the study of energy saving.
- Combines the theoretical knowledge on systems' control with the experience and knowledge of experts

Future Research

- Further improvements of the FCMs via the implementation of learning techniques, in order to adjust the FCM to the specificities of each building

- Application of the FCMs in even more complex systems i.e. buildings in order to reduce their energy consumption

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Thank you for your attention
Questions?

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