

# Contribution Title

Miklós F. Hatwagner

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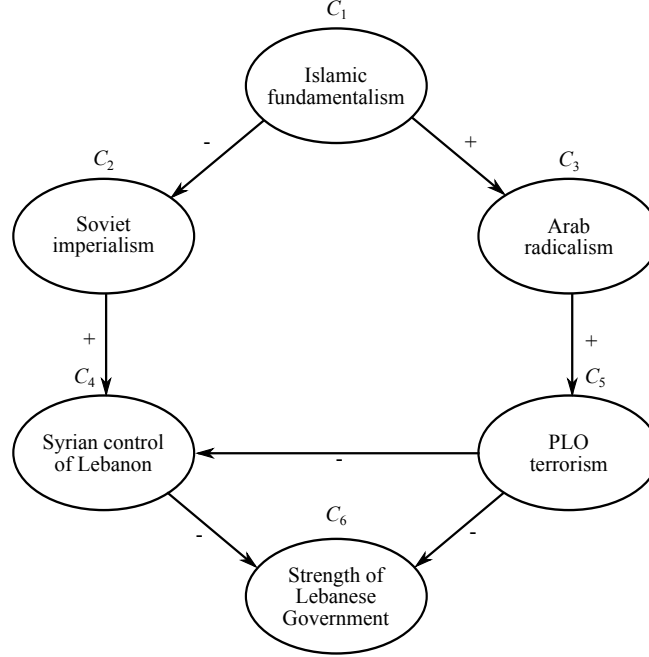
## 1 The birth of Fuzzy Cognitive Maps

Cognitive Maps (CM) are used in political analysis and decision making in international relations, foreign policy for a long time. The method was suggested by Robert Axelrod in his book [1] in the late '70s. According to Bart Kosko's description in [3], these maps are signed digraphs. Graphs, as algebraic structures have two components: nodes and edges. In CM, nodes represent variable *concepts* (eg. social instability) and the causal connections among these concepts are characterized by edges. The edges have a direction and a sign. If concept  $A$  causally increases concept  $B$ , it is represented by an edge from  $A$  to  $B$  with positive sign. On the other hand, if  $A$  reduces the value of  $B$ , the edge has a negative sign. Kosko illustrated CM with an example based on Henry Kissinger's essay "Starting Out in the Direction of Middle East Peace" published in *Los Angeles Times* in 1982 (see Fig. 1). Besides the graph, he also composed the adjacency matrix (Fig. 2) of the model. Only three different values can be found in this matrix, representing the causal relationship among concepts. If  $w_{ij} = w(C_i, C_j)$  is 1, concept  $C_1$  causally increases the value of  $C_2$  (positive edges). On the contrary, if  $C_1$  causally decreases the value

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of  $C_2$ , it is represented by  $-1$  (negative edges), and the value 0 indicates the lack of causal connection.



**Fig. 1** The Cognitive Map drawn by Kosko based on Kissinger's essay.

**Fig. 2** The adjacency matrix of the CM based on Kissinger's essay.

$$\begin{matrix}
 & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \\
 \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \end{matrix} & \begin{pmatrix} 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 0 & 0 & -1 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}
 \end{matrix}$$

It became quickly evident that the structure of a Cognitive Map imply too much limitations. The degree of causality, the levels of the causal effects (sometimes—often, little—much, etc.) cannot be expressed with the existing tool, and needs further development. Kosko introduced the Fuzzy Cognitive Map (FCM) [3], where the edges may have several causality values and he also developed a fuzzy causal algebra for propagating causality in it.

## 2 Simulations

The visual representation and formal description of models may help experts to review the structure of the studied system, but the real benefit of FCMs is the possibility of running simulations. Using a simple inference technique (see Eq. 1), the next state of concepts (also called the *activation values* of concepts, based on the similarity of FCMs and artificial neural networks) can be calculated using their current state and the weight of connections among them [2, 4].

$$A_i^{t+1} = f\left(\sum_{j=1}^n w_{ji} A_j^t\right) \quad (1)$$

Here,  $A_i$  is the activation value of concept  $i$  at time step  $t + 1$ ,  $n$  is the number of concepts and  $f(\cdot)$  is the *threshold function*. Without this function, the activation values of concepts may exceed or fall below their allowed extreme values, which is in general  $A_i^t \in [0, 1]$ . Several threshold functions were published during the years, but the most widely applied one is the *sigmoid* or *logistics* function:

$$f(x) = \frac{1}{1 + e^{-\lambda x}} \quad (2)$$

where the  $\lambda > 0$  specifies the steepness of the function. It's typical value is 5, but with greater values it approximates a binary function, the *sign* function (Eq. 3) better, which is also a popular choice.

$$f(x) = \begin{cases} 1, & x > 0, \\ 0, & x \leq 0 \end{cases} \quad (3)$$

however, for multiline equations we recommend to use the `eqnarray` environment<sup>1</sup>.

$$\left| \nabla U_\alpha^\mu(y) \right| \leq \frac{1}{d-\alpha} \int \left| \nabla \frac{1}{|\xi-y|^{d-\alpha}} \right| d\mu(\xi) = \int \frac{1}{|\xi-y|^{d-\alpha+1}} d\mu(\xi) \quad (4)$$

$$= (d-\alpha+1) \int_{d(y)}^{\infty} \frac{\mu(B(y,r))}{r^{d-\alpha+2}} dr \leq (d-\alpha+1) \int_{d(y)}^{\infty} \frac{r^{d-\alpha}}{r^{d-\alpha+2}} dr \quad (5)$$

### 2.1 Subsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Further on please use the

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<sup>1</sup> In physics texts please activate the class option `vecphys` to depict your vectors in ***boldface-italic*** type - as is customary for a wide range of physical subjects

L<sup>A</sup>T<sub>E</sub>X automatism for all your cross-references and citations as has already been described in Sect. 2.

Please do not use quotation marks when quoting texts! Simply use the `quotation` environment – it will automatically be rendered in line with the preferred layout.

### 2.1.1 Subsubsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Further on please use the L<sup>A</sup>T<sub>E</sub>X automatism for all your cross-references and citations as has already been described in Sect. 2.1, see also Fig. 3<sup>2</sup>

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

#### Paragraph Heading

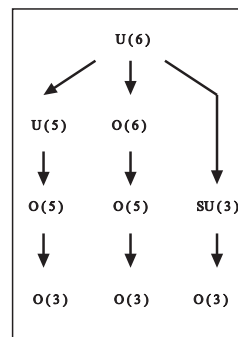
Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Further on please use the L<sup>A</sup>T<sub>E</sub>X automatism for all your cross-references and citations as has already been described in Sect. 2.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

For typesetting numbered lists we recommend to use the `enumerate` environment – it will automatically rendered in line with the preferred layout.

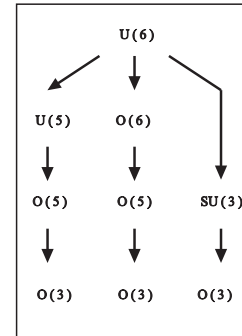
1. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeconomic development.

**Fig. 3** If the width of the figure is less than 7.8 cm use the `sidecaption` command to flush the caption on the left side of the page. If the figure is positioned at the top of the page, align the sidecaption with the top of the figure – to achieve this you simply need to use the optional argument `[t]` with the `sidecaption` command



<sup>2</sup> If you copy text passages, figures, or tables from other works, you must obtain *permission* from the copyright holder (usually the original publisher). Please enclose the signed permission with the manuscript. The sources must be acknowledged either in the captions, as footnotes or in a separate section of the book.

**Fig. 4** If the width of the figure is less than 7.8 cm use the `sidecaption` command to flush the caption on the left side of the page. If the figure is positioned at the top of the page, align the sidecaption with the top of the figure – to achieve this you simply need to use the optional argument `[t]` with the `sidecaption` command



- a. Livelihood and survival mobility are oftentimes coutcomes of uneven socioe-  
conomic development.
  - b. Livelihood and survival mobility are oftentimes coutcomes of uneven socioe-  
conomic development.
2. Livelihood and survival mobility are oftentimes coutcomes of uneven socioeco-  
nomic development.

#### *Subparagraph Heading*

In order to avoid simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Use the  $\LaTeX$  automatism for all your cross-references and citations as has already been described in Sect. 2, see also Fig. 4.

For unnumbered list we recommend to use the `itemize` environment – it will automatically be rendered in line with the preferred layout.

- Livelihood and survival mobility are oftentimes coutcomes of uneven socioeco-  
nomic development, cf. Table 1.
  - Livelihood and survival mobility are oftentimes coutcomes of uneven socioe-  
conomic development.
  - Livelihood and survival mobility are oftentimes coutcomes of uneven socioe-  
conomic development.
- Livelihood and survival mobility are oftentimes coutcomes of uneven socioeco-  
nomic development.

**Run-in Heading Boldface Version** Use the  $\LaTeX$  automatism for all your cross-references and citations as has already been described in Sect. 2.

***Run-in Heading Boldface and Italic Version*** Use the  $\LaTeX$  automatism for all your cross-references and citations as has already been described in Sect. 2.

**Table 1** Please write your table caption here

Classes	Subclass	Length	Action Mechanism
Translation	mRNA <sup>a</sup>	22 (19–25)	Translation repression, mRNA cleavage
Translation	mRNA cleavage	21	mRNA cleavage
Translation	mRNA	21–22	mRNA cleavage
Translation	mRNA	24–26	Histone and DNA Modification

<sup>a</sup> Table foot note (with superscript)

### Run-in Heading Displayed Version

Use the  $\LaTeX$  automatism for all your cross-references and citations as has already been described in Sect. 2.

## 3 Section Heading

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Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

If you want to list definitions or the like we recommend to use the enhanced description environment – it will automatically rendered in line with the preferred layout.

- Type 1    That addresses central themes pertaining to migration, health, and disease. In Sect. 1, Wilson discusses the role of human migration in infectious disease distributions and patterns.
- Type 2    That addresses central themes pertaining to migration, health, and disease. In Sect. 2.1, Wilson discusses the role of human migration in infectious disease distributions and patterns.

### 3.1 Subsection Heading

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Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

If you want to emphasize complete paragraphs of texts we recommend to use the newly defined class option `graybox` and the newly defined environment `svgraybox`. This will produce a 15 percent screened box 'behind' your text.

If you want to emphasize complete paragraphs of texts we recommend to use the newly defined class option and environment `svgraybox`. This will produce a 15 percent screened box 'behind' your text.

### 3.1.1 Subsubsection Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Further on please use the  $\LaTeX$  automatism for all your cross-references and citations as has already been described in Sect. 2.

Please note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

**Theorem 1** *Theorem text goes here.*

**Definition 1** Definition text goes here.

**Proof** Proof text goes here. □

#### Paragraph Heading

Instead of simply listing headings of different levels we recommend to let every heading be followed by at least a short passage of text. Further on please use the  $\LaTeX$  automatism for all your cross-references and citations as has already been described in Sect. 2.

Note that the first line of text that follows a heading is not indented, whereas the first lines of all subsequent paragraphs are.

**Theorem 2** *Theorem text goes here.*

**Definition 2** Definition text goes here.

**Proof** Proof text goes here. □

#### Trailer Head

If you want to emphasize complete paragraphs of texts in an Trailer Head we recommend to use

```
\begin{trailer}{Trailer Head}  
...  
\end{trailer}
```

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### **? Questions**

If you want to emphasize complete paragraphs of texts in an `Questions` we recommend to use

```
\begin{question}{Questions}  
...  
\end{question}
```

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**> Important**

If you want to emphasize complete paragraphs of texts in an **Important** we recommend to use

```
\begin{important}{Important}
...
\end{important}
```

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**! Attention**

If you want to emphasize complete paragraphs of texts in an **Attention** we recommend to use

```
\begin{warning}{Attention}
...
\end{warning}
```

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**Program Code**

If you want to emphasize complete paragraphs of texts in an **Program Code** we recommend to use

```
\begin{programcode}{Program Code}
\begin{verbatim}...\end{verbatim}
\end{programcode}
```

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**Tips**

If you want to emphasize complete paragraphs of texts in an **Tips** we recommend to use

```
\begin{tips}{Tips}
...
\end{tips}
```

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### Overview

If you want to emphasize complete paragraphs of texts in an `Overview` we recommend to use

```
\begin{overview}{Overview}
...
\end{overview}
```

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### Background Information

If you want to emphasize complete paragraphs of texts in an `Background Information` we recommend to use

```
\begin{backgroundinformation}{Background Information}
...
\end{backgroundinformation}
```

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### Legal Text

If you want to emphasize complete paragraphs of texts in an `Legal Text` we recommend to use

```
\begin{legaltext}{Legal Text}
...
\end{legaltext}
```

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**Acknowledgements** If you want to include acknowledgments of assistance and the like at the end of an individual chapter please use the `acknowledgement` environment – it will automatically be rendered in line with the preferred layout.

## Appendix

When placed at the end of a chapter or contribution (as opposed to at the end of the book), the numbering of tables, figures, and equations in the appendix section continues on from that in the main text. Hence please *do not* use the `appendix` command when writing an appendix at the end of your chapter or contribution. If there is only one the appendix is designated “Appendix”, or “Appendix 1”, or “Appendix 2”, etc. if there is more than one.

$$a \times b = c \tag{6}$$

## References

1. Robert Axelrod. *Structure of decision: The cognitive maps of political elites*. Princeton university press, Princeton, NJ, 1976.
2. Julie A Dickerson and Bart Kosko. Virtual worlds as fuzzy cognitive maps. *Presence: Teleoperators & Virtual Environments*, 3(2):173–189, 1994.
3. B. Kosko. Fuzzy cognitive maps. *Int. J. Man-Machine Studies*, 24:65–75, 1986.
4. Athanasios K Tsadiras. Comparing the inference capabilities of binary, trivalent and sigmoid fuzzy cognitive maps. *Information Sciences*, 178(20):3880–3894, 2008.