A belief system's organization based on a computational model of the dynamic context: first approximation

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 Abstract
In this paper we present a model of organization of a belief system based on a set of binary recursive functions that characterize the dynamic context that modifies the beliefs. The initial beliefs are modeled by a set of two bit words that grow, update and generate other beliefs as the different experiences of the dynamic context appear. Reason is presented as an emergent effect of the experience on the beliefs. The system presents a layered structure that allows a functional organization of the belief system. Our approach seems suitable to model different ways of thinking and to apply to different realistic scenarios such as ideologies.

Key-words. Recursive functions, behavioral patterns, belief system, ideology

1- Introduction

It is understood that our behavior is the result of both our beliefs and our capability to implement them by means of actions on the world around us. Belief systems are sets of norms that provide a coherent interpretation of the world and allow a viable interaction between humans and society [1, 2]. Everybody may have a belief system which is shared totally, partially or not shared with others [3, 4] but belief systems don't deal only with individuals, they also develop social structured organizations that promote attitudes and values in order to provide stability and transmission [5]. The interaction between individuals and organizations and the changes in the world may trigger belief revision [6-9]. Ideology is our most closely held belief system, made of values, feelings and opinions which act as the filter through which we see everything and everybody. Ideologies have played a key role in history by shaping governments and political movements. Political philosophers expound on a variety of political ideologies, or ways of government in order to improve the organization of the societies [10-16]. The study of ideologies is also of great interest for sociologists [17-21], psychologists [22-24], biologists [25, 26] and even computer scientists [27-30].

A definition of belief system is provided by [31]. The authors claim a belief system is a set of related ideas, learned and shared which has some permanence in time and space. They also affirm any belief system is formed by two essential levels denoted the abstract level and the material level, and operates as a cybernetic feedback process. The abstract level is formed by a set of substantive beliefs that are the axioms of the system and by a set of derived beliefs that constitute their theorems. Our proposed belief system considers that experience coming from the dynamic context applies to a few initial embryonic beliefs (substantive beliefs) that grow and increase in number (derived beliefs). The experience modifies the beliefs and next, the emergence of reason completes the updating. We claim reason needs previous beliefs and incoming experience to arise, but in our model, the relationship between cognition and experience

is not bi-directional as in [1, 31] so, experience doesn't depend on reason and beliefs have no effect upon experience. The beliefs are modeled by binary sequences (binary numbers) and experiences are modeled by a set of recursive functions that transform the sequences. The dynamic context is always enabled so the experiences (functions) can perpetually apply to the beliefs (binary sequences) and transform them again. As a new experience takes place, it applies to both ancient beliefs that are updated (by reason) and new generated beliefs. Ancient beliefs are the sequences with the lower value and the new beliefs are the sequences of the highest value of the rank. The model presents a layered structure that allows a functional organization of the belief system. The paper is organized as follows: after the introduction, Section 2 develops the computational model based on binary local rules that define logic functions by recursive application. These functions exhibit behavioral patterns that combine and build a layered structure that leads to a functional organization of the belief system. Section 3 discusses the details of the organization of the system. Section 4 explains why the model is suitable to approach realistic scenarios and proposes some applications related to ideologies. Section 5 summarizes and presents some concluding remarks.

2- The computational model

The computational model proposed is based on our own previous research on applications of recursive logic functions [32, 33] and stored logic computation [34, 35].

2.1 Definition of binary local rules

Equation (1) defines binary local rules $\otimes$ as follows:

$$\otimes : (0,1) \rightarrow (0,1)$$
$$(a,b) \rightarrow c = \otimes(a,b) = a \otimes b \tag{1}$$

The rule is particularized by a two input table so, $16 = 2^4$ different rules (tables) can be defined, see Fig.1: m stands for the index of the table which represents the four bit value stored in the cells, $m = a_3\, a_2\, a_1\, a_0$, $i \in [0, 3]$ and $a_i \in (0, 1)$; $m \in [0, 2^4-1]$,

$\otimes$	0	1
0	a_3	a_1
1	a_2	a_0

Fig. 1. Generic local rule represented by a table.

Without loss of generality we set the row operand as the left one and the column operand is the right one in a one dimensional space. For example: $\otimes (0, 1) = 0 \otimes 1 = a_1$ (0 "acts" on 1).

As an example we can consider the rule for $m = a_3\ a_2\ a_1\ a_0 = 1010$.

So, $0 \otimes 0 = 1$; $0 \otimes 1 = 1 \otimes 1 = 0$; $1 \otimes 0 = 0$

2.2 Definition of logic functions

The recursive application of the local rule $\otimes$ defines the functions f_m as shown in Equation (2) where p stands for the sequence length (in bits).

$$
\otimes (0,1)^p \to (0,1)^p
$$
$$
(x_{p-1}......x_1 x_0) \to f_m(x_{p-1}......x_1 x_0) = \tag{2}
$$
$$
[((...(x_0 \otimes x_1) \otimes x_2) \otimes ...) \otimes x_{p-1}]....[((x_0 \otimes x_1) \otimes x_2)x_3][(x_0 \otimes x_1) \otimes x_2](x_0 \otimes x_1)x_0)
$$

As an example: $m = 7 = 0111$; f_7 is defined by a table where: $a_3 = 0$, $a_2 = 1$, $a_1 = 1$, $a_0 = 1$,

for p = 3, if $(x_2\ x_1\ x_0) = (101)$, we have $f_7 (x_2\ x_1\ x_0) = f_7 (101) = 111$,

for p = 4, if $(x_3\ x_2\ x_1\ x_0) = (1101)$, we have $f_7 (x_3\ x_2\ x_1\ x_0) = f_7 (1101) = 1111$,

etc…

We now analyse the functions f_m when p varies by mapping a set of input sequences with different values of p. The left lattice represents the input sequences (rows). See Fig.2. for $f0$ and Fig.3. for $f14$. For p=2, we have four possible input sequences of two elements: 00, 01, 10 and 11 (four initial rows). For p=3, we have eight possible input sequences of three elements: 000, 001, 010, 011, 100, 101, 110 and 111 (eight initial rows) and so on. When p increases one unit, the new input sequences are the previous ones that have been updated by adding a "0" as the most significant bit, and the current sequences that have a "1" as the most significant value (named MSB, on the left of the number array). Without loss of generality it becomes quite easier to organize all the possible input sequences as if they were decimal values 0, 1, 2, 3 etc…. The right lattice represents the output sequences after applying recursively the rule $\otimes$ on the input sequences. The corresponding input/output pair is on the same row. It can be observed that the sequence length is preserved and the less significant bit (named LSB, on the right of the number array) is also always preserved. In the output sequences the cursive characters represent the changes that occur on the updated sequences and the bold underlined characters represent the changes that occur on the current input sequences.

Input sequence

Output sequence

f0

				col1	col2	col3	col4
				0	0	0	**0**
				0	0	0	**1**
				0	0	1	**0**
				0	**0**	1	**1**
				0	1	0	**0**
				0	1	0	**1**
				0	1	1	**0**
				0	1	1	**1**
				1	0	0	**0**
				1	0	0	**1**
				1	0	1	**0**
				1	0	1	**1**
				1	1	0	**0**
				1	1	0	**1**
				1	1	1	**0**
				1	1	1	**1**

				col1	col2	col3	col4	p=2	p=3	p=4
				0	*0*	0	0			
				0	*0*	0	1			
				0	*0*	**0**	0			
				0	*0*	**0**	1			
				0	**0**	0	0			
				0	**0**	0	1			
				0	**0**	**0**	0			
				0	**0**	**0**	1			
				0	0	0	0			
				0	0	0	1			
				0	0	0	0			
				0	0	0	1			
				0	**0**	0	0			
				0	**0**	0	1			
				0	**0**	**0**	0			
				0	**0**	**0**	1			

Fig. 2. The function *f0* for p=2, 3 and 4.

Input sequence

Output sequence

f14

				col1	col2	col3	col4
				0	0	0	**0**
				0	0	0	**1**
				0	0	1	**0**
				0	**0**	1	**1**
				0	1	0	**0**
				0	1	0	**1**
				0	1	1	**0**
				0	1	1	**1**
				1	0	0	**0**
				1	0	0	**1**
				1	0	1	**0**
				1	0	1	**1**
				1	1	0	**0**
				1	1	0	**1**
				1	1	1	**0**
				1	1	1	**1**

				col1	col2	col3	col4	p=2	p=3	p=4
				1	*1*	**1**	0			
				1	*1*	**1**	1			
				1	*1*	1	0			
				1	*1*	**0**	1			
				1	**0**	**1**	0			
				1	**0**	**1**	1			
				1	**0**	1	0			
				1	1	**0**	1			
				0	**1**	**1**	0			
				0	**1**	**1**	1			
				0	**1**	1	0			
				0	**1**	**0**	1			
				1	**0**	**1**	0			
				1	**0**	**1**	1			
				1	**0**	1	0			

			0	1	**0**	1			

Fig. 3. The function *f14* for p=2, 3 and 4.

2.3 Emergence of behavioral patterns

The defined functions exhibit behavioral patterns on the output sequences. Two main patterns can be observed:

1. *The updating process: propagation of a value*

The value can be "1", "0", MSB or MSB' (complement of MSB). The propagation can be

*General: when it is performed on both the current input sequence and the updated sequence irrespective of the input values (no effect on the LSB),

*Forward: when it is only performed on the updated input sequence, irrespective of the input values

*Conditional: when general or forward propagation are performed depending on the input value.

2. *The modification of a value in the sequence*

"**1**1" changes to "**0**1"

"**0**1" changes to "**1**1"

"**0**0" changes to "**1**0"

"**1**0" changes to "**0**0"

The functions f_m are characterized by combinations of these two mains patterns and are structured as follows:

- Layer 0: only propagation

f0: general propagation of "0"

f15: general propagation of "1"

f5: general propagation of the LSB.

f1: if the input sequence is composed of "1" then forward propagation of "0" (like *f3*) else general propagation of "0" (like *f0*).

- Layer 1: no change + propagation

f3: forward propagation of "0".

- Layer 2: one change + propagation

f2: change in the input sequence "11" to "01"; and then forward propagation of "0"

f7: change in the input sequence "01" to "11" and then forward propagation of "1"

f11: change in the input sequence "00" to "10" and then forward propagation of the MSB'

- Layer 3: two changes + propagation

f6: changes in the input sequence "01" to "11" and "11" to "01" and then forward propagation of the MSB.

f9: changes in the input sequence "00" to "10" and "10" to "00" and then forward propagation of the MSB'

f10: changes in the input sequence "11" to "01" and "00" to "10" and then forward propagation of the MSB'

- Layer 4: three changes + propagation

f4: changes in the input sequence: "10" to "00"; "11" to "01"and "01" to "11" and then forward propagation of the MSB.

f8: changes in the input sequence "00" to "10"; "10" to "00" and "11" to "01"and then forward propagation of the MSB'

f13: changes in the input sequence "00" to "10"; "10" to "00"; "01" to "11" and then forward propagation of "1"

f14: changes in the input sequence "00" to "10"; "01" to "11" and "11" to "01" and then forward propagation of "1"

- Layer 5: four changes + propagation

f12: changes in the input sequence "00" to "10"; "10" to "00"; "11" to "01"and "01" to "11" and then forward propagation of "1".

The functions highlight some trends that are divided into two main categories:
1) *Hard functions*: the output is independent of the input (*f0* and *f15*) or depends only on the LSB (*f5*) (Layer 0)
2) *Soft functions*: the output depends on the input.
   * no change is performed on the current input sequence (*f3*), (Layer 1)
   * some changes are performed on the current input sequence that are:
      ** very weak (Layer 2)
      ** weak (Layer 3)
      ** strong (Layer 4)
      ** very strong (Layer 5)

It must be observed that function (*f1*) can be hard (like *f0*) or soft (like *f3*) because its output depends conditionally on the input.

It must be also observed that some soft functions can follow a hard pattern of evolution of the updated sequence because the propagated value is fixed to 0 or 1 and is therefore independent of the current sequence (*f3, f2, f7, f13, f14, f12*)

The following table summarizes the characterization of the functions by their patterns (Fig. 4.)

	Modification of the current sequence				Updating process										
					General Propagation					Propagation of the updated sequence					
										Forward					Conditional
	"00" to "10"	"10" to "00"	"11" to "01"	"01" to "11"	"1"	"0"	MSB	(MSB)'	LSB	"1"	"0"	MSB	(MSB)'	LSB	
Hard functions LAYER 0															
f0						X									
f15					X										
f5									X						
f1											X				*When input sequence is "111……1"*
						X									*For any other input sequence*
Soft functions															
LAYER 1															
f3											X				
LAYER 2															
f2			X								X				
f7				X						X					
f11	X												X		
LAYER 3															
f6			X	X							X				
f9	X	X											X		
f10	X		X										X		
LAYER 4															
f4		X	X	X							X				
f8	X	X	X										X		
f13	X	X		X						X					
f14	X		X	X						X					
LAYER 5															
f12	X	X	X	X						X					

Fig. 4. Characterization of the functions by their behavioral patterns

3- The belief system model

Our proposal aims to model the functional organization of a belief system. As claimed by Usó–Nescolarde [1, 31], beliefs, reason and experience are related to each other and the dynamic context provides new experiences that trigger changes in both beliefs and

ways of reasoning. Our model follows partially this thesis in the sense that the binary growing sequences stand for the beliefs which are transformed by reason and experience. The functions are the powerful tool of the dynamic context which promotes the transformations of the sequences. The modification of the current sequence and the different types of propagation of the updating process shown in Fig.4. represent the transformations of the beliefs triggered by experience and reason respectively. But our approach is more restrictive than [1] because this model doesn't allow for experience to be shaped by beliefs nor reason. We agree with [1, 31] in considering that beliefs need experience to be transformed, and reason is the transformation involved in the updating process so, reason is a consequence of the experience which configures a portion of the belief. Reason also needs previous beliefs and incoming experience to arise. The relationships between beliefs, reason and experience are shown in Fig.5.
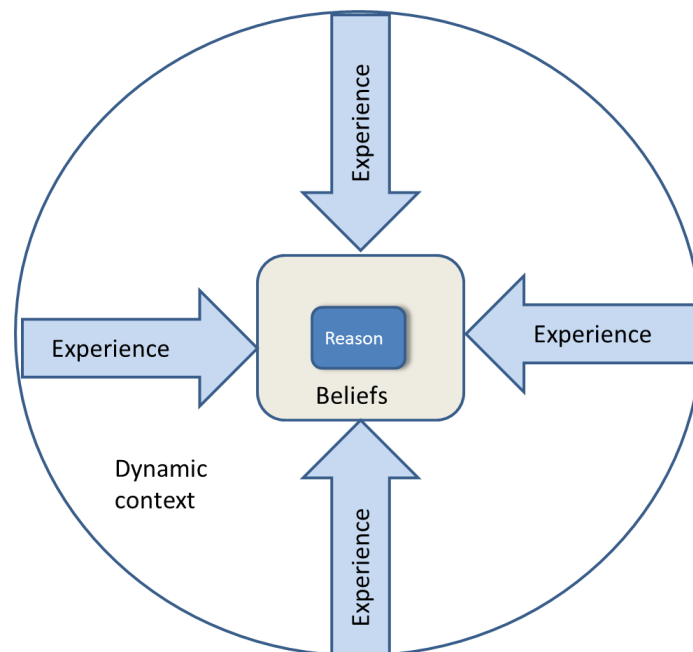
Fig. 5. Relationships between beliefs, reason and experience in our belief system

As defined upper by table Fig.4. our belief system organization is as follows:
- Embryonic beliefs: {00, 01, 10, 11}
- Experiences $\{fm\}$, $m \in [0, 2^4\text{-}1]$,

$\{fm\}$ can apply on the sequences many times. As p increases one unit, a new experience takes place and causes the number of beliefs to double. Generally the previous beliefs are updated (reasoning process) and the new beliefs are modified by experience, but there are exceptions.

The functions belonging to Layer 0 model the rejection or acceptance of a belief without any reasoning process (because they all provide general propagation or forward propagation of a previously fixed value 0 or 1). These are: $f0$ (full rejection), $f15$ (full acceptance), $f5$ (weak rejection/acceptance triggered (only) by the seed value of the previous belief), $f1$ (conditional full rejection or acceptance of the previous belief "111…1").

The function belonging to Layer 1, *f3*, models the acceptance of the previous belief without any reasoning process.

The functions belonging to Layers 2, 3, 4 and 5 model the more or less intense modifications of the previous beliefs and the associated reasoning process (*f11, f6, f9, f10, f4, f8*) or the modifications without any reasoning process (*f2, f7, f13, f14, f12*).

As different experiences always enable, the beliefs are modified many times so, eliminated beliefs can be later reinserted again in the system and accepted beliefs can be later eliminated by means of a new experience. Fig.6. summarizes our belief system's organization.
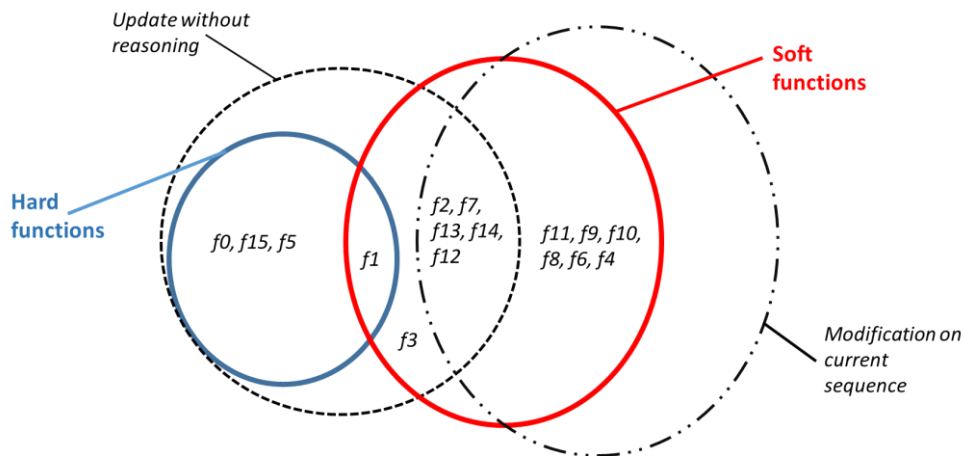
Fig. 6. Model of our belief system's organization

4- Applications

The applications to realistic scenarios are based on the interpretation we make of the behavioral power of the functions. We first denote as "hard functions" the functions whose input is always mapped into a fixed value with no link with the input (or a very weak link). This mimics the situations that trigger a full drastic rejection or acceptance of a belief, without any reasoning process. "Soft functions" are the functions that consider the previous belief before performing a transformation on it. This represents a larger set of functions that mimics the inheritance of the belief with or without changes. When the inheritance occurs with major or minor changes two different situations appear: the changes can be performed after a reasoning process or without it. The application of the belief system to realistic scenarios is summarized as follows, in Fig.7. Obviously, it is quite premature to claim that this application can exactly mimic the case of ideologies. Ideologies have been extensively studied [36-41] and our approach only aims to connect the functions with different ways of thinking rather than pursuing the study of any ideology. Our proposal analyzes the effects of the characterized functions and places them in a proper ideological context.

It may be interesting to compare our realistic scenarios modeled by functions with the classification presented by Walford [42-44]. This author divides the major ideologies in

three main groups that are depicted qualitatively (ediostatic centered on concern about the individual, ediodynamic centered on social concern and metadynamic centered on the defeat of ideologies as factors limiting the individual freedom). In the ediostatic group three different ideologies take place, the protostatic ideology, the epistatic ideology and the parastatic ideology. The path between them is obtained by the progressive weakening of the rigid frontier between the individual and his environment. In more concrete terms protostatic ideology may explain fascism or its equivalents. Epistatic ideology can account for conservatism because it allows some changes in order to strengthen the existing situation. In the parastatic ideology the physical sciences have a great influence because they serve in the struggle for survival. The political embodiment of parastatic ideology is liberalism. In the ediodynamic group society is the target against which or within which it is necessary to act in order to improve man's lot. In this group three different ideologies take place, the protodynamic ideology, the epidynamic ideology and the paradynamic ideology. In the protodynamic ideology society is considered as a complex whole that consists of interconnected classes. The improvement comes from structural changes, not from superficial changes. Social democracy is the political manifestation of this ideology. For the epidynamic ideology, antagonism between classes in the society triggers revolution which is an act of liberation. Communism is the associated political manifestation. For the paradynamic ideology the principle of authority that the state uses to control individuals must be removed. This is the ideology of anarchism. With respect to the metadynamic group, ideologies are not a suitable framework to approach problems. This group seeks to defeat ideologies as factors that limit their freedom. In our model, the main consideration is the strength between the output mapping and the input. This strength determines realistic ways of thinking. Soft functions model conservatism, continuity, reformism and revolutionary thinking depending on both the changes between the input and the output and the presence or absence of reasoning process. Hard functions model essentially unsophisticated thinking, such as totalitarianisms and dogmatic thinking or volatile thinking. It can be highlighted that a scenario can be modeled by more than one function. Our approach is more generic in the sense it doesn't not allow modeling concrete ideologies but trends. As an example, rigid thinking could mean communism and/or fascism. More, evolutionary thinking appears as the more complex scenario that can be modeled by six different functions with different degrees of changes and it is the only that includes the reasoning process. This provides flexibility to define several trends in the same way of thinking (reformism, socialism, social democracy, …).

Function type	Characterization		Effect			Modeling realistic scenarios
Hard	Maps the input into a fixed output value with **no link with the input.**		Full drastic rejection of a belief		*f0*	Dogmatic thinking (religion...)
			Full drastic acceptance of a belief		*f15*	
	Maps the input into an output value with a very **weak link with the input.**		Weak rejection or acceptance of a belief		*f5*	Volatile thinking (immature thinking,..)
Hard/Soft	Always maps the input into a fixed output value with **no link with the input, except** when the input is "11…1".		Conditional rejection of any belief except belief "11…1" which is accepted without reasoning process		*f1*	Rigid thinking (totalitarianism,..)
Soft	Maps the input into an output value which **depends on the input**	No changes	**Without reasoning process**	Inheritance of a belief **without any modification**	*f3*	Traditional thinking transmission (conservatism…)
		1 change		Inheritance of a belief and **weak modification**	*f2* *f7*	Traditional thinking transmission with minor aesthetic changes (continuity)
			With reasoning process	Inheritance of a belief and **progressive modification**	*f11*	Evolutionary thinking (reformism, …)
		2 changes			*f6* *f9* *f10*	
		3 changes			*f4* *f8*	
			Without reasoning process	Inheritance of a belief and **full modification**	*f13* *f14*	Remove the inherited thinking and replace it with another (revolutionary thinking, …)
		4 changes			*f12*	

Fig. 7. Application of the belief model to realistic scenarios

5- Conclusion

In this paper we have presented a belief system organization based on a computational model of the dynamic context. The model focuses on a set of functions that apply recursively on beliefs to model the incoming experience coming from the dynamic context. The initial beliefs are modeled by two bit words that grow, update and generate other beliefs as the different experiences of the dynamic context appear. Reason is presented as an emergent effect triggered by experience. This approach provides a layered structure which highlights how the changes are performed on the beliefs, and is suitable to depict realistic scenarios relative to different ways of thinking such as dogmatic thinking, traditional thinking, or evolutionary thinking.

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