SIMULATION OF ATTITUDE TRANSFORMATION BY USING AUTOMATA NETWORKS

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Abstract

We will show how automata network models can conceptualize and simulate human attitudes faced with a new "offer" which can be weight up according to different formal attributes. From a first presentation of the classical representations of the attitude concept using a cognitivist inspiration, we will propose a new connectionist approach based on automata networks. Then, we will show how this kind of models can represent in term of conceptual and formal unification - by integration in the same movement based on the Gestalt and cognitive perspectives, the human attitudes forming and transforming processes. For example, our work could be useful for a R&D manager who already selected different 3D CAD softwares (i.e. the "offers") according to technical specifications and who would like to choose which offer will better match the future user's perceptions. Thanks to our model, the attitude forming and transformation dynamics can be simulated for each engineer according to the values and weights he allocates to each attribute like the software ergonomics, the estimated learning difficulties, the ability of rethinking in three dimensions,… More generally, these connectionist models aim to improve the human perceptions dynamics faced with technological changes

Keywords: Social Sciences, human behaviour representation techniques, discrete automata networks, technological changes, attitudes forming, attitudes transformation.

Presenting Author's biography

Daniel Thiel, Ph D, Eng., is full professor in Industrial Management and Operational Research at ENITIAA. He is the coordinator of a Food Economics and Industrial Management Research Laboratory at ENITIAA composed by six professors, five PhD students and two permanent staff. This lab is associated with the Economics and Management Laboratory of the University of Nantes which is composed by 68 professors and 60 PhD students. Previously, he worked more then ten years in different industrial companies. A short professional biography of the presenting author should be put here, starting with the presenting author's name.

In the present practices of psychology and psychosociology, the attitude modelling is one of the investigation field which clearly develops the cognitivist a priori that thinking is calculation. Fundamentally, the attitudes correspond to predispositions to action [1] whether based on compensatory evaluating goals of the action or on non-compensatory goals - according to the complexity of the process which can be low or not [2] ; [3] ; [4].

The compensatory evaluation process is linear and corresponds to a step-by-step calculation procedure which estimates the different attributes weighted by their subjective importance [5].

The non-compensatory processes are non-linear and the models are usually conjunctive or disjunctive according to the necessity or not that the prominent criteria of a given proposal submitted for evaluation, are all greater than a minimum appreciation threshold, so that the proposal will be finally accepted [6];[7].

Although most of these models are applied to consumer behaviour, we will describe in this paper a dynamic modelling of the attitudes forming and transforming in the field of “social marketing”. This means for example how to decide for a new investment (the object) by taking into account the human perceptions (cf. the attributes positively vs negatively weighted) towards any technological changes.

Firstly, we will choose to work on linear and static compensatory models of attitude forming and secondly, on static attitude transformation models. For each of these models, we will show some corresponding connectionist models based on automata networks.

1 Compensatory attitude models

One of the first compensatory models shows the decision process as a choice among different offers which gives the higher satisfaction (cf. Edwards model [8];[9]). For each offer submitted to an individual I, his cardinal utility function U_d (cardinal in the sense that it assigns numerical values to utilities) can be calculated by:

$$U_I = \Sigma_i (PS_i \cdot U_i) \qquad (1)$$

where PS_i corresponds to the subjective probability that the offer chosen by the individual I is linked to the occurrence of different events i,

and U_i the utility valuation brought by each event i.

Following Edwards [9] and Rosenberg's [10] models, Fishbein [11] also concludes on an additive linear representation of the attitude concept – but he means a global evaluation which is calculated by an aggregation of local evaluations.

The attitude value A_O is calculated by:

$$A_O = \Sigma_j (C_j \cdot V_j) \qquad (2)$$

where C_j corresponds to the probability that the option O can be qualified by the attribute j,

and V_j the corresponding weight given by the individual to this attribute j.

In the Bass and Talarzyk's model [12], the global evaluation of each option is given by a similar linear local compensatory evaluation equation:

$$A_o = \Sigma_k (P_k \cdot A_{ko}) \qquad (3)$$

where P_k corresponds to the weight given by an individual to each assessment criterion k;

while A_o and A_{ko} give respectively the global evaluation of the option O and the local evaluation of each criterion k regarding the option O.

According to this last model and to the Fishbein's extension of his first attitude process representation by integration of social norms (influence of membership and reference groups on the individual perceptions), Beckwith & Lehmann [13] introduces the halo effect concept and proposes to formalize the attitude forming process for each offer p, the following equations :

$$A_p = \Sigma_j \omega_j B_{pj} + \gamma A^*_p + u_0 \qquad (4)$$

and $B_{pj} = \beta_j A_p + \gamma_j B^*_{pj} + u_j$
for $j = 1$ to n (number of attributes)
where A_p corresponds to the individual attitude for an offer p;
A^*_p is the average attitude of the whole population in relation to this offer;
B_{pj} indicates the individual perception of the offer p according to its attribute j ;
B^*_{pj} is the average perception of the offer p according to its attribute j ;
ω_j is the weight given to each attribute j;
γ is the weight of the average attitude,
β_j shows the importance of his own attitude towards the offer p in the individual perception process B_{pj},
γ_j quantifies the average perception B^*_{pj} importance in regard to his own perception B_{pj}.
u_0 and u_j represent random differences.
All these works are very illustrative of the cognitivism movement: there is often no algebraic difference between these additive models. Empirical tests show sometimes an advantage for the Fishbein’s model comparing to the Bass and Talarzyk’s model [14] or sometimes an advantage for the Bass and Talarzyk comparing to the

Fishbein's model [15],… From these observations, new developments in this area can be launched by a new paradigm breakthrough.

2 Connectionism as a new research paradigm of the attitude concept

2.1 Cognitivism *vs* connectionnism

Faced with the cognitivism and its computo-symbolic representations of the cognition, a new movement of ideas comes to light which was firmly in opposition to the previous one : an explosion of works which introduced the relationships between mind-body-spirit [16]; [17]; [18]; [19] and a movement of ideas called *connectionism* [20]; [21] which can be considered in the psychology field as a paradigmatic revolution [22].

Using the computer as a support of theoretical functional representations of the mind, it corresponds, in practice, to the equivalence of the functions between the model and the real world - an analogical equivalence which *a priori* does not requires to take into account the structural characteristic of this real world. In concrete terms, it implies a total indifference to the cortical matter.

One of a rival project of the cognitivism tries to *naturalize the spirit* by refusing the idea of the dissociation of the psychology and the neurobiology and tries to *incarnate the spirit* in the cerebral tissue [23]. This "paleo-connectionism" [24] or neo- connectionism corresponds to a *neurocalculation* and to a "neurological authenticity" [25] of the model according to the idea that it is absolutely necessary to take into account the singular ways that the cognition is instanced. We also will notice here that connectionist modelling will be continuously improved thanks to the explosion of neurosciences and particularly of neuroimaging (IRM).

In the next section, we will describe connectionist models based on automata networks for simulating attitudes forming and transforming.

2.2 Automata Network Principle

An automata network (AN) can be considered as an oriented graph where the nodes are the automata and the arrows, connections from the output of an automaton toward the input of another one. The particularities of a AN are that there can be defined as a set of cells (finite automata) which are locally interconnected and which can move by discrete iteration thanks to the mutual interactions. Formally, a AN can be described by a mapping F which corresponds to an application of E^n into itself, where E is a finite space of the states. The network is composed by n interconnected cells. The connection structure is defined by F: the cell i is connected with j if F_i depends of the jst variable (F_i is the ist component of the mapping F). The state of the network is represented by a vector x in E^n. The network dynamics is then defined by a rule which transforms each vector x in E^n into a vector y of E^n. For example, the parallel iteration is defined by : $y = F(x)$ and can be interpreted as following : at each iteration, each automaton calculates its new state according to the mapping F_i in the present state x. Because the state space F is often finite, it is demonstrated that all trajectories are periodic (limit cycles) or fixed points [26].
According to Weisbuch [27], the choice of the AN simulation as mathematical model in state of differential systems, can be interesting to forecast the dynamic proprieties of a network structure (see also [28]). In fact, the AN can bring in light loops of repetitive states or fixed point attractors with the possibility to define their period, their length and the delays of the transient states [27]. For instance, the Hopfield's model [29] is based on a threshold automaton principle (cf. [23]) with a state change function x_i of the threshold automaton i (or neuron i) defined by :

$$x_i(t) = Y[\Sigma_j T_{ij} x_j(t-1) - \Theta_i] \quad (5)$$

where :
Y is the Heaviside's function (Y=1 for a positive argument and Y=0 for a negative argument or equal to zero).
Θ_i is the threshold of the automaton i (or the neuron i).
T_{ij} is the intensity of the interaction between the automaton j and the automaton i. In a Hopfield's model, the T_{ij} are the synaptic weights referring to the biology. When T_{ij} is positive, it is interpreting as an exciting connection and an inhibiting connection if T_{ij} is negative.

Practically, the simulation of such connectionist model does not proceed by a sequential step-by-step calculation but corresponds to a dynamic trajectory. While cognitivism interprets facts and phenomena of the cognition by the *logic* (of the discontinuous), connectionism concerns the *dynamics* and the *topologic* (of the continuous). In the two next sections, some examples of AN modelling will illustrate this last point of view. The section 3 will propose new attitude *forming* models and the section 4 new attitude *transforming* models based on AN.

3 Automata Network Modelling of the Attitude Forming

Il est aisé de constituer ce réseau à partir des relations de causalités linéaires entre, d'une part A and (B_j, A^*_j) and between B_j and (A, B^*_j) (voir également des travaux similaires dans Thiel, 1995a, b).

From the previous Beckwith and Lehmann's model, we proposed to build an automata network (AN) according to the previous equations (4) and (4'). We transform each variable A, A^*, B_j and B^*_j into an automaton (or neuron) which will take discrete values. The connections between the different automata have the following weights: ω_j, β_j and γ. This network is built according to the linear causality relationships between first: each B_j and A, A^* and A (cf. equation 4) and second : A and each B_j, B^*_j and each B_j (cf. equation 4') (see also similarly works in [30]; [31].). The figure 1 shows the global structure of this AN.

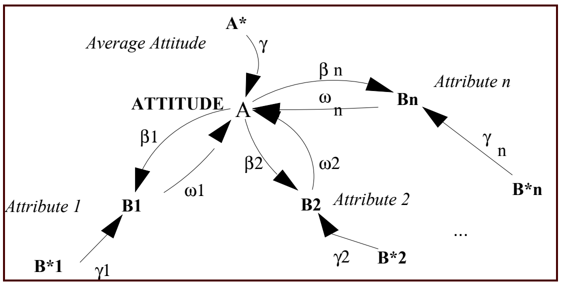

Fig. 1 Beckwith and Lehmann,'s AN model

To demonstrate the didactic and heuristic interests of this model, we present a numerical example.

Let us choose the case of an investment choice of a 3D design software. After choosing some technically well-adapted solutions, one decider would like to forecast how his engineering staff will change their attitude faced with this new software. For each engineer, he has to ask him how he feels this new object according to main given attributes like for instance: the software ergonomics, the estimated learning difficulties, the ability of rethinking in three dimensions. To model this attitude, we propose to transform the different vertex of the graph shown in the figure 1 into automata and the arrows into connections between the automata. The valuations of these arrows correspond to the connection weights included between -3 and +3 (semantic differentiator going from "less important influence" to "very important influence" with intermediary discrete values -2, -1, +1, +2). These values are corresponding to the valuations of the graph arrows (see figure 2).

Then, the attribute values given by the future user are n_1, n_2 and n_3. Four possible values included between 0 and 3 depend on whether the attribute i is very negatively perceived ($n_i = 0$) ; or has an effect neither positive nor negative ($n_i = 1$) ; or moderately attractive ($n_i = 2$) ; or finally very attractive ($n_i = 3$).

The final attitude n_8 will be simulated by the AN and corresponds to the final rejection of the project ($n_8 = 0$) or it expresses a hesitation or an indifference in the final attitude of the future user ($n_8 = 1$) who finally accepts this software which matches the decider social objective ($n_8 = 2$).

The model constants n_4, n_5 and n_6 corresponds to the average attitudes of the R&D community towards each attribute j which can be either unfavourable ($n_j = 0$) or favourable ($n_j = 1$). In this example, we choose the value 1 which considers the new solution attributes as attractive by most of the employees.

The average attitude n_7 towards the new software can take two possible values : 0 for a negative attitude or 1 for a positive attitude. We chose in our example the value 1.

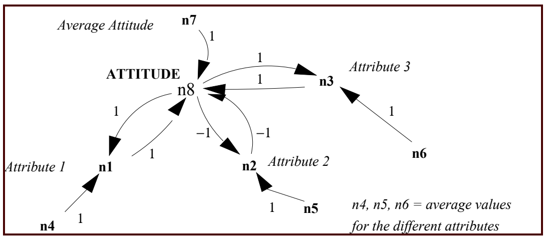

Fig. 2 Example of a AN of attitude forming

The automata activation rules and threshold functions are defined by the following equations:

If $(n_4+n_8-1) > 0$ Then $(n_1=n_4+n_8-1)$ Else $(n_1=0)$

If $(n_5-n_8+1) > 0$ Then $(n_2=n_5-n_8+1)$ Else $(n_2=0)$

If $(n_6+n_8-1) > 0$ Then $(n_3=n_6+n_8-1)$ Else $(n_3=0)$

If $(n_7+n_1-n_2+n_3-1) > 0$ Then $(n_8=n_7+n_1-n_2+n_3-1)$ Else $(n_8= 0)$

$n_4 = n_5 = n_6 = 1$

$n_7 = 1$

This AN model can now be simulated to show the dynamic proprieties of the attitude forming process for each future user - especially stationary (fixed points) and periodic (limit cycles) attractors.

Analysis of the observed attractors

Three fixed point attractors and two 2nd order limit cycle attractors have been observed.

First fixed point attractor

Neurons	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	
	0	2	0	1	1	1	1	0	STATES

In case the attributes 1 and 3 (n_1 and n_3) turn out to be unimportant for the user and the attribute 2 (n_2)

is moderately attractive, the final attitude correspond to a rejection of the software (n_8= 0).

Second fixed point attractor

Neurons *(1) (2) (3) (4) (5) (6) (7) (8)*

2 0 2 1 1 1 1 2 STATES

The attributes 1 and 3 are here be considered as moderately attractive by the user while the attribute 2 is considered as a repulsive level (n_2=0). By compensation and taking into account other decision criteria (the "social norms"), the final attitude corresponds to the software acceptation (n_8=2).

Third fixed point attractor

Neurons *(1) (2) (3) (4) (5) (6) (7) (8)*

1 1 1 1 1 1 1 1 STATES

Here the individual is not particularly attracted by the different software attributes which are taken separately into consideration (neutrality of the states n_1, n_2 and n_3 all equal to 1). Contrarily, the fact that the other users consider the different attributes as attractive does not change his personal appreciation : finally, we observe a hesitation attitude (n_8 =1).

First 2nd order limit cycle attractor

Neurons *(1) (2) (3) (4) (5) (6) (7) (8)*

1 1 1 1 1 1 1 0

0 2 0 1 1 1 1 1 STATES

In this circumstance, we observe a long term stable behaviour which oscillates between the rejecting and the indifference attitudes. After a certain time of the evaluation process, the individual preferences move to a neutral appreciation of the different product attributes (n_1= n_2= n_3 = 1) which is in contradiction with the right and contextual evaluation. While the social norm is positive (n_7=1), the individual intention is firstly negative (n_8=0). The reached state will be then unstable: the individual moves from a neutral appreciation situation to a reconsidering of the local evaluation (n_1=0; n_2=2; n_3=0). This situation is also unstable because the trajectory of the neurocalculating does not ended on a fixed point, but on an oscillating and undecided attitude (cf. limit cycle).

Second 2nd order limit cycle attractor

Neurons *(1) (2) (3) (4) (5) (6) (7) (8)*

2 0 2 1 1 1 1 0

1 1 1 1 1 1 1 2 STATES

In this case, during the product evaluation process, we observed a positive appreciation of two attributes but without a final acceptation (n_8 =1). In other terms, it seems like the application of a disjunctive rule which rejects the new software because of one of the evaluation criterion - here, the number 2 - is negatively considered. This state is not the last one : on the next step, the individual moves to a acceptation attitude (n_8=2) which stems simultaneously from a depreciation of the criteria 1 and 3 (n_1 = n_3= 1) and from a new appreciation of the criterion 2 (n_2 = 1). This operation corresponds to the affective halo effect where the global attitude (n_8) constraints the local evaluations (n_1, n_2 and n_3). The state n_8 (equals to 2) plays here the role of a final cause in the evaluation process. The situation is here unstable and the individual oscillates between a neutral and a positive attitude towards the software. Let us here notice that the interpretation of this dynamics is not exclusive to other analyzing possibilities. We show by this example the didactic and heuristic interests of the AN modelling approach.

Theoretical interest: Whereas the cognitivist models systematically give a stable attitude, the connectionist models furnish the possibility to take into account the periodic solution cases. These cases are not purely idealist or conceptual, but are empirically observed (by observation and by experimentation) and are particularly interpreted in Lewin's topologic inspiration work [32] which deals with psychological conflict situations which depend on the equality of a "goal gradient" in the people ways of life. By integration of these data, the connectionist models give the opportunity of a dialectical surpassing of the cognitivism and the Gestalt psychology.

The *educational interest* of the connectionist model simulations lies in the diversity of the possible interpretations of a same observed trajectory : thus, for the previous example, the existence of a 2nd order limit cycle can be explained as a contradiction between the personal local evaluations and the average population evaluation : these ones act such as standards and consequently bring the individual to a local *and* global estimation change (of the attributes *and* of the object), which explains the loop.

4 Automata Network Modelling of the Attitude Transforming

The most interesting contribution of attitudes connectionist modelling should consist in a conceptual unification of attitudes forming and transforming models. Le Moigne qualifies the present situation as an "epistemological incongruity" [33] - of the rules which control both the attitudes forming and transforming. From the theoretical and metatheoretical points of view, these two models are completely different: the attitudes forming process is usually the result of a calculation based on arithmetical rules while the attitudes transforming process follows homeostatic regulation laws. In other terms, we observe here the coexistence of an analytic logic (of elements or elements setting) and a holistic organization logic (systemic).

The connectionist approach can help to overcome this duality as shown below.

Proposition 1 : AN based on Heider's theory of equilibrium [34]

Let us take the example of two engineers *A* and *B* faced with a new offer *O* (for example a new CAD 3D software). Their respective attitude against *O* is *A/O* and *B/O* and the affective attitude of *A* against *B* is *A/B*. The attitude scale goes from 0 (negative attitude against *O*) to 2 (positive attitude against *O*) - the intermediary level 1 corresponds to the situation of indifference towards *O*. In the AN model, we will consider that the attitudes change according to the variations of the initial attitudes values and to the automata relationships, whether by releasing the affective links between *A* and *B* (relations *A/0* or *B/O* towards *A/B*) or by minimizing the disequilibrium importance, i.e. the values of *A/O* against *B/O*. Each vertex of the graph corresponds to an automaton (see figure 3). The activation rules of these different automata have been formalized according to Heider's theory [34] which is explicitly inspired by the Gestalt theory. The instantiation of this AN can help to show the whole dynamics of this social interactions and the main attractors which correspond to the different steady states.

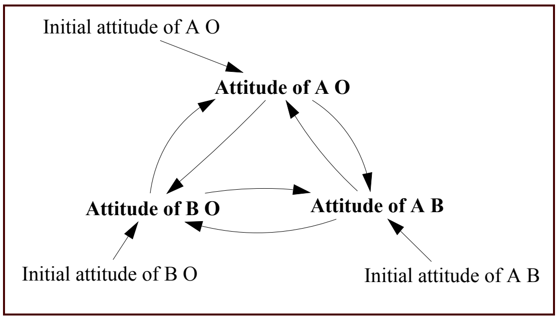

Fig. 3 Heider's AN attitude transformation model

Proposition 2 : AN based on Festinger's cognitive dissonance theory [35]; [36].

This model tackles the individual internal psychological processes and the consonance between two informations. Let us set $X_{reference}$ as the individual perception given to an object *O* and $X_{observed}$ the real value of *O*. We call *dX* the cognitive dissonance between this individual perception and the reality. By changing his behaviour *Y,* he can reduce this dissonance whether by acting on the reference $X_{reference}$ of by reinterpreting the information $X_{observed}$ (see also [37]). The figure 4 represents the AN basic structure which can simulate the cognitive dissonance and shows the dynamic equilibrium according to the characteristics of the relationships between the different automata $X_{reference}$, $X_{observed}$, *dX*, *Y* and given thresholds values.

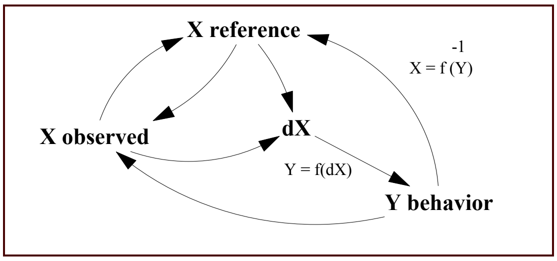

Fig. 4 Festinger's AN attitude transformation model

5 Conclusion

Based on the connectionism paradigm, we proposed to implement automata networks which really brought a new epistemological contribution in research in human attitude forming and transforming. The next step of our research will consist in validating these models by using empirical data.

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ISBN 978-3-901608-32-2