# Can Neural Networks reprogram themselves holistically by detecting the emergence of invariant comportments in learning algorithms by means of their own observation

**Jean-Jacques MARIAGE**
CSAR research group, AI Laboratory, Paris 8 University,
2, rue de la Liberté, St Denis, France, Cdx 93526,
jam@ai.univ-paris8.fr

***Abstract:*** *Neural networks (NNs) are inspired – at least metaphorically –from biological solutions nature selected by evolution. On one hand, learning algorithms' efficacy has been widely demonstrated experimentally, even if the mathematical proof of their convergence is not always so easy to establish (SOM). On the other hand, biological mechanisms like brain wiring or embryology remain partly understood and how life or the bases of consciousness are related to the underlying biological substrate remains a total mystery. The same goes for memory. We don't really know how information is stored in and recovered from biological neural structures. We therein paradoxically use complex systems, the hard core of which we still don't always fully understand, both regarding the models we build, as well as their former roots in the leaving world. In this theoretical paper, we resort to a few biological encoding schemata that bring insights into neural structures' growth, plasticity and reorganization, and suggest reconsidering the metaphor in an adaptive constructivist view.*

***Keywords*:** Learning, memory, plasticity and adaptation, Self-Organizing Maps, stem cells, meiosis growth, entelechy, Darwinian evolution.

## 1. TOWARDS A WHOLE DYNAMIC SYSTEM

Our main research concern is to model and simulate the dynamic character of the learning structures and processes, and their evolution in time.

Among a rather wide number of unsupervised NN models, some (ART, SOM, NeoCognitron, etc.) have now given rise to many variations around their former algorithms. We consider the diversity of the applicative and experimental contexts as similar to an environmental selective pressure that generates an adaptation dynamic of the former NNs algorithms.

Resorting to the evolution of biological systems, we set out to elaborate automatic and incremental knowledge acquisition strategies, we try to apply in turn to the NNs. We considerer primitive extractors themselves as artificial dynamically adaptive self-organizing structures submitted to the power of evolution. We thereby study the possibility to confront NN models to their own observation as a mean to lead them to learn their own configuration parameters and this way to extract and self-learn characteristics of their own evolution in response to environmental variations [12].

The learning algorithm's skeleton has been described in previous reports and papers, see [13]. It is related to the SOM model and to more general map models that are able to develop their structure in time. It is currently undergoing implementation and tests. Results will appear in later reports. Besides this work, we have devised a process flow around an incremental linguistic data extraction system, which leads to a conventional SOM topology. A detailed description of the system, its theoretical foundations and results for French language have been presented in [3] [4] [14] [15]. Further developments will gather both systems to realize a whole dynamic system from data acquisition to permanent learning and investigate its portability to other languages.

This paper concentrates on theoretical foundations of the learning process. Only theoretical aspects of learning, evolution and natural self-organization we have considered to design the mechanisms of our constructivist learning model are discussed here. We first resort to

## 2. LEARNING IS AN ADAPTIVE PROCESS

Complex adaptive behaviors are frequently observed in nature. Systems that exhibit such behavior are immune systems, organs, organisms, the central nervous system (CNS), societies, etc.

Adaptability emerges from nonlinear spatio-temporal interactions among a large number of components or subsystems. To be able to acquire complex behaviors, systems must be open systems. That is components must have temporal interactions with their environment and internalize a more or less elaborated trace of these interactions. As a consequence, the internalization process actively redraws — spatially — the structure of the system in such a way that the new system becomes the system itself. It thereby performs an environmentally driven self-reorganization. To achieve this, the efficient solution nature has elaborated is evolution.

Investigating NNs variations in the light of Darwinian evolution leads to consider learning algorithms like open relational entities more than independent entities, and this at every level, from models to elementary constituents, including learning rules and heuristic choices made in implementations.

Learning thereby behaves as an active transmitter between open systems, agents, or individuals, whatever the point of view we intend to exert. The process is active in the sense that it not only stores information inside a predefined *innate* structure, but it also permanently reorganizes the structure under relational constraints. Constraints are of two kinds. The first type is internal to the system and refers to the spatial arrangement of its structure. That is how each unit relates to the others. The second sort concerns temporal organization of the system. It is the way by which it keeps the history of its confrontation with the universe it *perceives*. The result is somewhat different from a sequence of chronologically ordered events. It is rather a kind of chronology where, as in music, the last event creates, triggers a sense, which brings in light the whole sequence of related anterior events.

According to H. Bergson [2], what really appears new is another kind of order relying on an essential dimension of mind, which is its ability to *see* things in a new light. Mind positively creates sense from temporally and actively gathered content. Disorder, or chaos, doesn't come before (precede) reality. It is the way we figure out what we don't know or understand. It is also what change emanates from, a movement towards novelty and creation. Newness, as opposed to the static difference between order and disorder, is a dynamic differential process between two orders, or between two opposite tendencies towards two orders.

What applies to mind and living beings extends to things. Novelty always reveals a global increase of the *thing* where it happens, not only to push back the frontiers of our understanding, following a preconceived plan, but unpredictably, bringing the proof of an immanent creation, that overwhelms any outside specification. It is a dual process between disorder and novelty regarding mind, and in the living world, two opposite processes that either build up a form by adapting the organic matter and thereby follow a creative impetus by mean of those spatial transformations themselves [22].

## 3. LEARNING EVOLUTION

Besides environmental pressure, there is obviously a social dimension in knowledge transmission. A world involving a single entity seems highly unlikely to occur. Social phenomena are not simply reducible to the sum of – or the difference between – individual comportments. They involve something more that can't be reached by mean of some reverse engineering techniques. Something that arises more than results, a temporary consequence that matches a sense with the global state

+ a means for what is learnt to be passed on

+ dans les deux sens ⇒ interaction .

Between wild animals, the transmission of innovative behaviors that bring selective advantage for reproduction or feeding has frequently been observed. Such a case is ***learning by imitation*** (male whales songs in Australia, great (? or blue) tit in England). It is also well known that some kinds of more *cultura*l or convenient habits, which don't seem at first sight related to selective pressure, can as well quickly ***spread*** over a population (monkeys washing their food in Japan, ??? taking bath). In this case, imitation seems to play the leading role in the process. The learner is not taught or trained at all. It actively enters in the process to take possession of what appears to be new or different.

What remains unclear is if novelty has been selected by evolution or not. the imitation process

What is true with sophisticated individuals in more or less elaborated species is also true at the cell level. In vitro culture of chicken embryonic heart cells have been shown [Ref] to tune their beating frequency when submitted to electric shocks. They progressively all adopt a new intermediate frequency in between their initial one and the frequency of the applied electric shocks.

+ having existed before, but only recently reappearing

+ learning is incremental in essence.

## 4. NEURAL PLASTICITY IS TRAINING-INDUCED

We will hereafter report three kinds of encoding schemes met in neurobiology to put in light various aspects of neural plasticity we grounded on to devise our model of growth dynamics and deal with the stability / plasticity dilemma.

Human brain is developmentally plastic. the result of a gradual process of progressive specialization

brain structures that emerge during the course of brain development. Those products are highly plastic responses to environmental inputs. As Deacon (1997) argues, the human cognitive adaptation is, instead, the process that generates those special-purpose brain structures. That is, with the possible exception of our sensory transducers, it is not the contingently stable brain structures in an adult's brain that are adaptations; rather, the brain's very developmental plasticity is the adaptation, and the relatively stable structures are byproducts of that adaptation's functioning in a particular environment. (This is the sense in which Gould is closer to the truth than Evolutionary Psychologists.)

the product of a selective pressure that conferred fitness advantages to individuals endowed with these abilities.

Functionalities don't rely on a unique module but on various ones, constituted by sub-modules that may intricate. Furthermore, these modules — clearly present in other species — don't seem to recruit other modules in every species [cats auditory/visual cortex]. Comparative studies may lead to a more precise understanding of the evolution of these abilities

Both the number of units as well as their branching connections is not regular and thus cannot be specified in advance. Clustering is a dynamic process by mean of which the structure permanently reorganizes in such a way that the new system becomes the system itself.

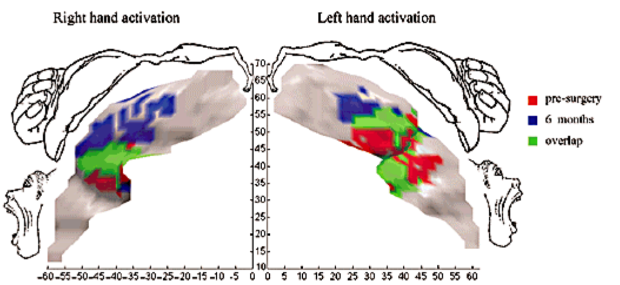
Firstly, at the synaptic level, long-term potentiation (LTP) and its converse mechanism, long-term depression (LTD), provide strong evidences of the Hebb rule and retroaction loops. Those mechanisms can stimulate dynamic growth — or shrinking — of cortical maps, growth of new synapses and even create new neurons [9] + ??.

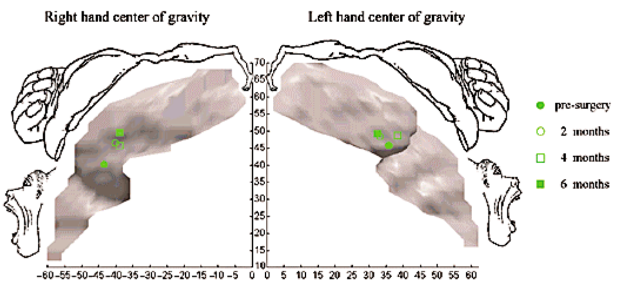
Secondly, considering the phylogenic evolution of the central nervous system (CNS) in an inter-species paradigm reveals that structure modification follows architectural constraints. When new structures appear (neocortex), they are not simply added to the previous ones. Specialization leads to a volume increase of the concerned regions. The whole size of the brain does not change according to the size of the new part. Pre-existing parts, which were devoted to other functions, are also utilized and fed into the new structure. An increase in a zone is correlated to the diminution of other parts of the brain.

A study of brain structures' evolution [Ref] states that the neocortex increase in volume is proportional to the decrease in size of other brain structures (medulla, mesencephalon, diencephalon). The cerebellum, where orientation and balance centers are located in, has a relative volume that accounts for 13 % of the total volume of the brain among the majority of the mammals. It increases in bats and Cetacea. Conversely, the neocortex, that plays a major role in complex cognitive functions, only accounts for 28 % of insectivores' brain against 81 % in primates.

The third characteristic is that once developed and clearly established, should the representational structure become unused, it progressively diminishes in time but not totally. There remains a part from which the representation can be restored.

Experiments carried out on monkeys have shown cortical maps reorganization for fingers
The first transplant of the two forearms in human, allowed a real time access to cortical projection maps reorganization by NMR functional investigation.




## 5. SPONTANEUS EMERGENCE

Be it a convenient working hypothesis, only designed to draw the line from where we leave aside our lack of knowledge when faced to complexity, the concept of emergence allows to account for structures arising, transformation, and vanishing, in a wide range of domains in nature. Emergence

Our purpose here is adaptive constructivist methods. So we will not enter into the usual debate and just discard the reductionist view. To specify our position, we will refer to Illya Prigogine [Ref] who doesn't reject reductionism as such, but points out its limitations. In essence, for him, "*reductionism can be efficient in relatively simple situations, but quickly becomes ineffective as soon as the number of factors to consider is important*". If we consider a few organization steps ranking from molecules, neurons, neural networks, brain to mental states, nobody could explain the latest based on an analysis of the interactions in the former.

The fact remains between two more closely related organization levels like neurons and neural networks, even thought the increasing power of techniques like medical imagery (MI) now permits deeper investigation. To set matters straight, what we have found so far is complexity at all, and we still must resort to modelization and computing simulation, be it in a full spoon approximation only.

Moreover, the top down approach in traditional cognitivist artificial intelligence is directly related to the obvious requirement to fit logic formalism needs and its claims to universality, namely symbols' sense and form sharing and the innate assumption [18].

So we will leave complexity apart for the moment, to focus on the adaptive aspect of the problem and assume that there exists an ascending encoding scheme

We will here get closer to Piagetian constructivism, F. Varela's concept of *enaction* [18] [17] as productive action, R. Brooks embodiment and to G. Edelman neural group theory.

According to F. Varela, the structural coupling history enacts (makes emerge) a world by mean of network of interconnected elements, capable of structural changes in the course of a non-interrupted history. When it adjoins a preexistent world of signification in continual development, (as it is the case for young of all species), or creates a new one (as it happens in evolution history). Approach en emergence, auto-organization, association, and dynamic networks.

Symbols, in the conventional sense of the word, are excluded. Significant elements are not the symbols but complex patterns of activity between the multiple elements of the network.

Discard the cognitivist axiom according to which cognitive phenomena explication requires a distinct symbolic level.

Sense is not enclosed inside symbols. It is a function of the global state of the system and remains closely related to the general activity inside a given domain, such as recognition or learning. emergence is a contradiction for traditional logic.

We will make the assumption that there exists an ascending encoding schema and further concentrate on the review of a couple of questions inherent to this view. Resultant phenomena are accessible analytically. Conversely, emergent ones are not merely understandable from the study of their elementary constituents. Morgan [16] considers evolution, from inorganic matter to man, as a reorganization of the relations between entities into more and more complex structures. Progressively, structures intricate into higher organization levels (electrons, atoms, molecules, cells, organs, organisms). Each step being characterized by new properties which in turn constrain events in inferior levels.

take into account the complexity of the different organization levels in nature and the way they are interlinked.

A perception-action loop for only logic as fundamental mechanism of the neural system.

+ dissipative structures theory from Illya Prigogine ..\..\..\..\Notes\Emergence\La révolution morphologique.DOC

Entelechy:

Everything in the universe is finite. If we want to realize an artificial system that exhibits properties similar to those of the living beings, it seems essential that to intrinsically include its own end in itself. In order to endow NNs with an artificial *vital impetus*, nodes have a restricted life span.

Learning bypasses, overcomes interspecies barrier

Not a linear time but a more atomic one gathering parts of a history

Darwinian selection doesn't favor perfection, but efficacy.

…drained of less strength. This reinforces the *survival-of-the-fittest* underlying methodology…a link survival threshold …good relations to be remembered (or strengthened) while forgetting (or weakening) bad ones. It also has a hand in conserving

activity in the layer by preventing overly common words (such as prepositions) from amassing large numbers

of potentially irrelevant and highly weighted links

Fitness functions in Wicker.pdf: (p. 180-181) more or less in the spirit of biases definition and the automatic scaling of values adapt_preprocess from Ruda, H., and Snorrason, M. (1995).Three major approaches to synthesizing neural networks can be found in the

literature.The rst,reductive,is to start with an over abundance of nodes and

connections and then reduce the network.The second,constructive,is to start with

a small network and add nodes in a carefully prescribed fashion.The third uses

evolutionary learning to evolve populations of networks.

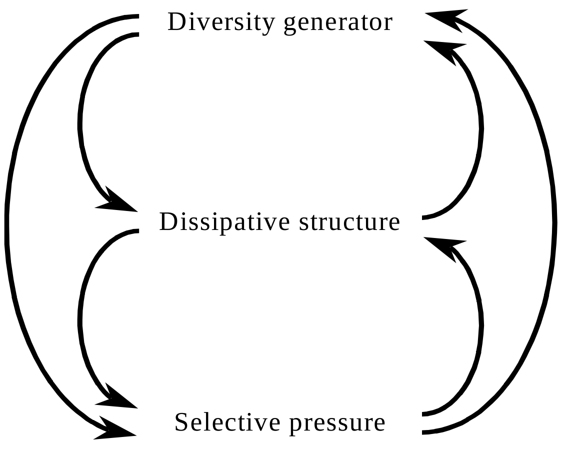



**Fig.1 – Different kinds of interactions.**

Deuneubourg : (From Article deneu sel nat.htm) "*Natural selection takes place in any group of elements holding (possédant) the three following elementary proprieties: reproduction, variation and heredity*".

Elle peut s'appliquer à tout système qui possède des propriétés élémentaires : La capacité de se reproduire et celle de varier légèrement et aléatoirement d'une génération à l'autre. (evolution)

les deux composantes minimales d'un système évolutif sont donc :

un générateur aléatoire de diversité

un tri (la sélection) qui se décompose en deux propriétés : reproduction et entéléchie

Deuneubourg : (From Article deneu sel nat.htm) La sélection naturelle intervient dans n'importe quel groupe d'éléments possédant les trois propriétés suivantes : reproduction, variation et hérédité. Pour rendre l'évolution possible, ce mécanisme est nécessaire et suffisant.

reproduisent, le nombre d'éléments augmente, jusqu'au moment où la compétition pour les ressources nécessaires empêchera certains éléments de se reproduire. Comme ils varient entre eux, d'autres auront des caractéristiques leur conférant une plus grande probabilité de remporter cette compétition pour les ressources. Ces éléments-là sont ceux qui laisseront le plus de descendants. Et si ces descendants héritent des caractéristiques de leurs parents, la proportion d'éléments possédant ces caractéristiques va s'accroître. Après un certain nombre de générations, ce dernier groupe d'éléments va graduellement dominer. Sans reproduction, pas de compétition. Sans variation, pas de différences entre les individus quant à leur chance de se reproduire. Et sans hérédité, la reproduction différentielle des individus en fonction de leurs caractéristiques ne serait pas préservée sous forme de changement dans la fréquence relative de ces différentes caractéristiques dans la population

**More extensive discussions on a broad array of topics pertinent to** ..\..\..\HIS02.SOH.Notes.DOC Elmann, 99 & Channon 99.pdf

## 6. A CONSTRUCTIVIST VIEW

The three main approaches used to optimize NNs can be summarized as reductive (pruning), constructive (incremental), and evolutionary (mostly genetic algorithms (GA) and their combination with combination NNs) [20].

In accordance with the approach developed here above, we have chosen an alternation process between creation and suppression.

Fitness functions in Wicker.pdf: (p. 180-181) more or less in the spirit of biases definition and the automatic scaling of values adapt_preprocess from Ruda, H., and Snorrason, M. (1995).

Meiosis growth

Meiosis vs. mitosis processes compared to SOM uncommitted nodes?? .

**Meiosis** generates diversity. Duplication recombines the genetic material by crossover. The process thereby differentiates resulting daughter cells from the initial ones. Mitosis is only a multiplication process. New cells are identically alike the original.

In growing models related to the SOM algorithm, the duplication dynamic is generally mitosis inspired [refs]. To realize meiosis growth, when we initialize new cell's weights, we insert a trace of the triggering data prototype together with a trace of the features gathered in the relational neighborhood of the cell it splits from. Immediately after what the daughter cell enters in the process of migrating towards the most related cells inside the whole system. This is achieved by re-computing the widest neighborhood tree possible.

Stem cells

## 7. INNATE STRUCTURE IMPORTANCE

The importance of the initial structure is far from being of no consequence.

A rare genetic disease, called William's syndrome (WS), generates peculiar effects on astonishingly spontaneous musical abilities of the affected people. Their brain organization seems to indicate that there exists an encoding schema not only relaying on the number of units devoted to one functionality, but also on the ratio between the respective proportions of the various neural clusters which participate in functions encoding and the whole size of the rest of the brain.

WS appears in every populations with a prevalence of about 1/20 000. Affected people show serious neurological and neurophysiological developmental troubles associated with a special brain organization [10].

They hardly carry out very simple visuo-spatial coordination tasks (walk, lace up shoes, use knives and forks, …). Their results in spatial organization tests show a selective attention to details, regardless of the whole. Despite a general deficit of spatial and cognitive functions, their linguistic capacities remain relatively preserved [1]. They talk easily but their speech, albeit rich semantically, sometimes proves to be absurd.

Surprisingly, they spontaneously exhibit an auditory hypersensitivity and uncommon musical skills, very unusual in confirmed musicians (absolute pitch, complex rhythms reproduction or rhythmic dialogues production).

People with absolute pitch memorize sound height while those with relative pitch memorize intervals. Absolute pitch offers the advantage of no reference point needs (diapason). Actually[1], the European reference is an A at 440 hertz. People with relative pitch identify sounds' height based on this reference. A memory organized by intervals is more suited for height variations of the diapason. Any reference change shifts all the notes the same way. In addition, the ageing process modifies hearing. The reference is perceived less and less accurately. Height-organized music sound perception prevents chords synthetic appreciations or intervals. Both must be computed.

WS subjects' limbic, frontal and temporal structures remain relatively preserved compared to the mean size observed in non-effected people. The interesting fact is that musicians generally present an oversized region in the temporal lobe. WS affected people's brain is globally undersized by an amount of about 30 %, but the size of the same zone in the temporal lobe is *normal*. The proportion between this zone and the rest of the brain seems to encode their unusual musical skills. **+ bosse des maths**

Degenerative changes in auditory structures neural organization of congenitally deaf adults [23] highlights neural structure reorganization. Animal studies have shown that congenital deafness produces degenerative changes in the central auditory pathway (1, 2). Degeneration in the central auditory system subsequent to profound hearing loss has also been reported in humans. For example, Moore and colleagues (3) observed cell size reductions in the **cochlear nucleus** of profoundly deaf adults. However, it is unclear whether auditory deprivation from birth results in degeneration of primary auditory cortex in either animals or humans. The pattern of subcortical projections to primary auditory cortex in congenitally deaf cats is similar to that of normally hearing cats (4, 5), suggesting that cortical auditory regions may continue to receive input from subcortical regions and might not exhibit degeneration. However, functional deficits are observed in synaptic activity and organization within auditory cortex (6), suggesting the possibility of variation in the structure of auditory cortex as a consequence of congenital deafness.

…. Neurons within HG and auditory association cortex may not atrophy because these neurons may come to respond to nonauditory input. Responses to both tactile (38) and visual (16) input have been reported in auditory cortex of congenitally deaf individuals.

In sum, this is the first study that we know of to report WM changes in human primary sensory cortical regions due to sensory deprivation from birth. The reduction in WM volume was not accompanied by a similar reduction in GM volume. This finding can be seen as consistent with reports of neural activity in auditory cortices for deaf individuals in response to nonau-ditory stimuli (13–16, 38). Finally, congenital deafness accom-panied by life-long use of sign language does not seem to alter the leftward asymmetries found for HG (primary auditory cortex) or the PT.

## 8. RETROACTION LOOPS

Data driven programming and error measures to let the system self supervise. + selfishness, Cf. F. Varela.

+ open system.

Dans les implémentations de systèmes fonctionnant en temps réel, la nécessité de repérer des séquences temporelles a conduit à mémoriser leur contexte pour les différencier. Les réseaux récurrents offrent une solution où des boucles de rétroaction internes au système réinjectent le contexte associé aux entrées. Les boucles introduisent un délai qui prolonge l'activité du neurone pendant un laps de temps suffisant pour que la trace des états antérieurs soit conservée. D'autres auteurs ont imaginé des solutions autour de l'idée d'une cellule de base composée de plusieurs neurones.

Les architectures neuronales les plus simples pour traiter les séquences temporelles sont les TDNN (Waibel, Hanazawa, Hinton, Shikano et Lang (1987, 1989)). La séquence temporelle est convertie en un vecteur concaténé “via a tapped delay line”, et le vecteur est passé en entrée au réseau. L'inconvénient majeur de cette méthode est la difficulté à déterminer la taille du délai temporel à introduire entre deux fenêtres de données à prendre en considération.

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1 Historically, until the 19th century, each important town in Europe had its own diapason.

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Genicot et Naranjo (1991) utilisent des cellules duales. Ils font apprendre, reconnaître et reproduire des séquences de séries temporelles par un réseau constitué de cellules totalement connectées deux à deux. La cellule de base est duale et fonctionne de façon récurrente selon le shéma reproduit ci-dessous.

Fukushima, Okada et Hiroshige (1994) ont recours à une solution comparable. Ils dotent le Néo-Cognitron d'une couche duale qui améliore la tolérence du modèle au bruit. Dans la première couche, la sous-couche de cellules complexes est dupliquée Cf.???. Les cellules de coordonnées identiques dans ces deux sous-couches de cellules complexes ont les mêmes champs récepteurs dans la couche de cellules simples précédente. Elles diffusent vers les mêmes cellule dans la couche suivante. Ils obtiennent ainsi deux hypercolonnes.

Les systèmes à apprentissage non supervisé sont guidés par les évènements qui génèrent un changement dans l'évolution de leur adaptation à la distribution des données. Une fonction d'erreur — or cost — ramène cette information en retour. L'erreur globale rend compte de la qualité de convergence de l'algorithme. Pour certains algorithmes, une erreur globale suffit (méthodes statistiques, MLP, …). Pour d'autres (SOM), le rôle déterminant des liaisons de voisinage dans le processus d'encodage impose une mesure plus sophistiquée qui tienne compte de l'erreur locale. L'erreur locale permet d'apprécier le degré d'organisation de la topologie et de détecter les conflits. Les conflits sont interprétés comme une pression de l'environnement qui génère une accumulation d'activité sur une zone de représentation dont la résolution est insuffisante.

## 9. AN EXAMPLE IN SOM NEURAL NETWORK

We have chosen the SOM model because it gathers many of the elementary characteristics we tried to review here above. The underlying biological metaphor is cortical projection maps.

Hereafter, we will just briefly focus on the properties of the SOM model related to data analysis, and refer to [7] and [8] for an entire description.

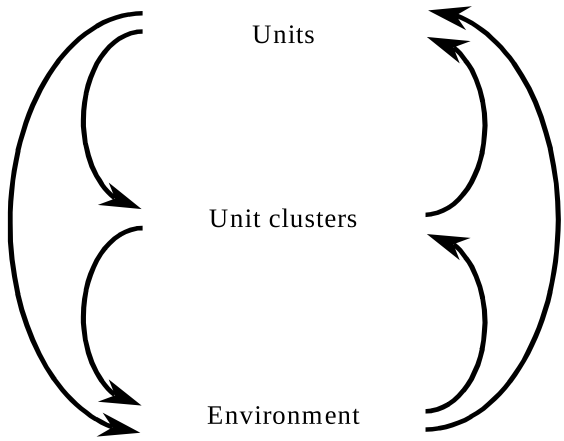


**Fig.2 – Interactions between units, clusters and environment.**

The usual unsupervised SOM learning algorithm is a classifier. It maps the input data classes, from their own multi-dimensional space, into an internal bi-dimensional memory space. The algorithm builds a topological ordering of the implicit relations it discovers between the data classes. The dimensional reduction of the internal representation allows to analyze, or even to discover, relationships between data classes.

The bi-dimensional space provides a convenient visualization interface. It depicts similarity between data classes by encoding them in the proximity between clusters of units distributed over the map: related forms in the data space are near one another in the map space.

## 10. CONCLUDING REMARKS

Regarding the aim of our community that is brain functioning simulation and more generally biological systems by mean of artificial intelligence connectionist techniques, we would like to make a few remarks.

We should also reconsider our modeling in an interdisciplinary paradigm including not only biology, mathematics and computer science, with which the relation is obvious, but also philosophy, the purpose of which is to study the development of ideas, psychology, to compare the efficacy of our models to living beings performances and social organization and join our mutual contribution, to respectively adjust the power of simulation tools we develop in accordance with the theoretical models we build by mean of experimental observations, in a cross validation perspective.

+ the stimulating reward for successfully realizing an autistic systems.

Far from autistic

Elles permettent d'incorporer aux modèles de réseaux neuronaux non supervisés une dynamique de contrôle de leur évolution. Il devient dès lors possible de fabriquer des outils véritablement autonomes qui s'initialisent automatiquement, apprennent en permanence et oublient si nécessaire, tout en adaptant leur structure en conséquence.

Pour construire des machines intelligentes, l'intelligence artificielle (IA), discipline fédérative par essence, s'appuie sur les sciences connexes pour bâtir des modèles.

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