The Multiscale Paradigm

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1 The Reductionism and The Multiscale Paradigm

The present paper is introducing the Multiscale Paradigm. in a wide range of domains and fields.

The reductionist dream (and its extreme form - physicalism) accompanied science from its very birth.

The hope to reduce all reality to simple microscopic fundamental laws had its great moments in the physical sciences (Newton, Maxwell, Planck, Einstein, Gell-Mann) but it suffered bitter discrediting early defeats in explaining life (Descartes), conscience (La Metterie), thought (Russel) and socio-economical phenomena (Marx).

In the last decades, the reductionist ambitions got rekindled by a series of methodological and technological new tools.

Some of the new developments highlighted the role of the Multiscale Paradigm in describing and explaining the macroscopic complex phenomena in terms of a recurrent hierarchy of scales.

In a Multiscale Hierarchy, the properties at each scale level are explained solely in terms of the underlying finer level immediately below it.

The main operations involved are:

- the identification of the relevant objects appropriate for describing the dynamics at each scale.
- expressing iteratively the emergence of the coarser scale objects as the collective features of a finer scale.

In many cases, the identification of the hierarchy of scales involves sofisticated computer simulation, visualization and interactive animation tools bordering artificial reality.

In this interactive research process, the computer programs and methods become often the very expression of the scientific understanding which they helpe to uncover.

In exchange, for this cognitive and language shift, the multilevel approach yielded to the reductionist effort new important results in systems spreading over a wide range of subjects:

quantum gravity, (un-)computability of physical systems, field theories, solid state systems, quarks and gluons, dynamical interfaces, molecular dynamics, spin glasses, protein dynamics, psychophysics, vision, image processing and understanding, inventive thinking, cognition and thought dynamics, economics and social planning.

The Multiscale physicalist Paradigm might eventually develop into a discipline framework for defining, identifying and studying the salient collective macroscopic features of complex systems in a most general context. As such it would constitute a strong conceptual and methodological unifying factor over a very wide range of scientific, technological (and other) domains.

2 Elementary Microscopic Representation of Complex Macroscopic Dynamics

We describe below a general framework for treating formaly complex systems in terms of their basic elements ("microscopic degrees of freedom " = "micros").

In order to emphasize the width of the approach we give in addition to scientific systems (Geometry, Algebra) rather extreme examples from traditionally humanistic fields such as Lingvistics, Cognition, Cabala. The hope is that even within a wide readership, each of the readers may be familiar with at least some of the examples (and can ignore the others).

We call this general structure endowed with dynamics "drama". It is a kind of vulgarization version of the Universal Dynamics introduced in [gerhard].

The main ingredients of a "drama" are:

- Objects.

  Examples from various fields:

  - Euclidean geometry objects: points , lines, planes.
  - Algebraic objects : group elements, numbers, symbols.
  - Lingvistic entities: words, letters, sounds.
  - Thought elements : concepts, conditions, ideas.
  - Cabalistic entities: sefirot, souls, "simple light".
  - Stock Market: investors, shares, prices, individual wealth.

- The state of the objects at a given "time".

  Examples:

  - Point being placed in a particular place,
    Line being vertical or horizontal.
  - Group element being equal to identity element,
    or belonging to a proper subgroup.
  - Concept being not yet conceived,
    or being in the latent state,
    or being in the explicit state.

- Statement being true or false.
- Sefira being potential,
  or already emanated.
  Vessel being broken,
  or still functioning,
  or restored.
- The price of a share, the wealth of an individual.

- The possible relationships between objects.

  E.g.

  - 2 lines being orthogonal.
    A point belonging to a line.
  - 2 group elements being commutative.
  - A concept bringing up another concept
  - A statement implying (or being equivalent to) another statement.
  - A sefira light being contained in a vessel.

- The state of the relationships at a given "time".

  E.g.

  - The relationship existing or not at the time.
  - In 2 dimensions 2 lines relationship is either "intersecting" or "parallel".
    In 3 dimensions the very nature of the possible relationship can change as 2 lines are most of the time in a 3-rd state: "non-parallel and nonintersecting" (i.e. not belonging to the same plane).
  - For real numbers there exists a relationship expressing wether they have the same sign or opposite.
    For complex numbers this relationship changes nature: they can just differ by a phase.
  - In a certain higher worlds (e.g. "assyia"), there is no temporal relationship between objects, while
    In a material world the "before" and "after" relationships is relevant.

  - An investor owning a certain percentage of a stock.

- The elementary rules for deducing from the state of the objects and of their relationships at the present time instance, the state at the next time instance. This rules give the actual dynamics of the "drama".

  Examples:

  - Example from the "drama" of prooving a theorem:
    "time" 1: lines 1 and 2 belong to the same plane and do not intersect.
    "time" 2: line 1 and 2 are parallel.
    (the dynamics here is logical-mathematic implication made explicit and the "drama" is the process of theorem proving).
  - Example from Cabala:
    "time 1" : Lighs pumped illimitedly in the vessel
    "time 2" : vessel breaks
    (the passing from 1 to 2 is based on one of the Ari postulates).
  - Other example:
    "time 1" :number 29 is being uttered
    "time 2" : number 30 is being uttered
    (you guessed: the "drama" here is "counting").
  - Based on the past data, the investors make the bids each of them considers optimal. Their combined bids determine the price of an equity.

The rules can be stochastic in nature and/or can depend on "time" itself.

Note that the dynamics induced by the elementary rules is in addition to the "postulates" which act only as (kinematic) constraints to the various possible dynamics.

E.g. somebody which starts from the Euclid postulates may choose to develop first the plane geometry till its last implications or, alternatively he can choose to address at a very early stage the relationships between the volumes of 3 dimensional objects.

So the actual scenario followed in each particular instance by the drama may not be causally implied by the postulates and the initial conditions. Rather, probabilistic rules for chosing one course or another can be introduced.

E.g. somebody which is constructing a cabala-creation-story can probe the implications of sending the light from sefirot to pass *by* the vessels and go to infinity rather than sending it *into* the vessels.

Proving a particular theorem, describing a particular alternative of the creation process is a "scenario" in a "drama". By definition , a "scenario" is one particular realization out of the various ways in which the system can evolve consistently with the postulates.

We will see that if logics is not introduced explicitely, systems of concepts may reach "absurd" states which however might be usefull in leading to valid and intersting final states.

In the examples above, one can ask:

- What is the most probable "scenario"?
- Starting from a certain set of rules is one bond to converge at a certain stage (with overwhelming probability) to a particular scenario (or to a set of scenarios)?
- One can also simply ask: out of the infinities of theorems (most of them trivial) which the Euclid geometry contains, what singles out the theorems which we consider interesting?
- In the same sense: out of the stories which can be told based on the Cabala premises, what characterizes the interesting ones?
  I.e. what are the interesting scenarios?

One important class of interesting systems display critical dynamics and self-organzation in the sense that stories which end too fast or just escalate uniformly would be unintreresting (corresponding to non-critical systems), while "scenarios" which involve dynamics over many scales (i.e. contain subsystems behaving autonomously as new objects with a new effective dynamics in a nested way over many scales) would be considered valuable.

Examples of critical scenarios:

- When the process of making a cabala story more and more detailed and specific is generating significantly new structures.
- When the process of exploiting the implications of an idea evolves in a "marginal" way: i.e. is neither trivially progressing nor is it blocked by contradictions.

To trivialize: to have a successful "critical" scenario we wish the charming prince to get eventually to the sleeping beauty, but not too soon.

This is speculation. However, there are 2 pieces of science which are very powerfull and well established and which can be used as tools to explicitate and study these speculations:

1. The fact that one can give an algebraic (group theoretical) description to any set of axioms and in fact one can relate the set of theorems which can be achieved from those axioms with topological properties of a group.

   Therefore one can give a precise (and even graphical- by visualizing Alexander moves and their global generalizations) description of any "drama" including the statistical and other properties of its "scenarios".

2. The know-how developed by physicists in the framework of renormalization group theory and criticality in dealing with the emergence of long range collective dynamics in systems with many microscopic degrees of fredom. A "drama" which has only short scenarios is not an important scientific (or cultural) field. Therefore, to get to interesting pices of science, or acts of culture, one should look for systems which present long range correlations.

The techncal "details" of fitting of the tools 1 and 2 to the various field above is the next step.

3 The Strucure of the Multiscale Paradigm

One of the striking features of the new Paradigm is that while many of its applications lay in "soft" fields such as psyhology (ref Esti), image processing, advertisment (yanco), marketing, economics (Shiki) its origins lay in computational mathematics (Brandt) and fundamental theoretical physics (Wilson, Kadanoff) almost 3 decades ago.

The original Renormalization Group works in quantum field theory allowed the systematic study, understanding, prediction and manipulation of the large scale dynamics of certain continous complex systems.

Such systems are difficult to deal both at the technical and computational level and at the conceptual level: "fluid" concepts are difficult to "grasp" and "handle". This leads to legends of ineffable and unformalizable about many "intrinsically humanistic" fields. Our objective is to shatter the bonds of these self imposed limitations and try give physicalist models whenever this is possible.

The following steps are a first sketch of the main ideas:

- Microscopic Representation

  Represent the (continous) system in terms of (many) "microscopic" objects (called usually "elementary degrees of freedom") which interact by simple rules.

- Collective Macros

  Identify sets of (strongly coupled) elementary degrees of freedom which act during the evolution of the system mostly as a single collective object (macro).

- Effective Macro Dynamics

  Deduce the emergence of laws governing effectively the evolution of the system at the Macros scale as a coarse (average) expression of the simple rules acting at the elementary level.

- Emergence of Scale Hierarchies

  Apply iteratively to the Macros systems at various scales the last two steps. This leads to a hierarchy of Macros of Macros (etc.) in which the emerging laws governing one level are the effective (coarse) expression of the laws at the finer level immediately below.

- Universality

  The general macroscopic properties of the coarsest scale depend on the fundamental microscopic scale only through the intermediary of all the levels in between (especially the one just finer than the coarsest). This usually means that relevant macroscopic properties are common to many microscopic systems. Sets of microscopic systems leading to the same macroscopic dynamics are called universality classes.

- Irreducible complex kernels.

  One can show that there exists classes of (sub-)systems for which one cannot reexpress the fundamental microscopic dynamics in terms of effective interactions of appropriate macros. We call them Irreducibly complex (sigtuna). Such (sub-)systems are in general non-universal and their properties are in many respect unique. All one can do is to become familiar with their properties but not to explain (understand) them in terms of the functioning of their parts. If in the process of analysing a system in terms of a macro hierarchy one meets such irreducible kernels, the best thing is to treat them as single objects and construct explanations taking them and their interactions as the starting point.

The main message of the Multiscale approach is that domains, fields and subjects which until now seemed to allow a continous infinity of possible variations of their behaviours, may be treated in terms of a limited number of discrete objects (macros) subjected to a discrete limited number of effective rules.

This greatly limits the options for the effective macroscopic dynamics and the effort to analyse, predict and handle it.

In turn, the Macros and their effective rules can be understood (if one whishes a finer level of knowledge) in terms of a limited set of interacting components.

The criticism of the above scheme can range between "trivial" to "far fetched" but it turned out to give non-trivial valid results in a surprisingly wide range of problems in theoretical physics (allsorin), chemistry (zeiri), computational physics (PTMG), image processing (issum), psychophysics (nava,bulg), spin glasses (nathan,PRE), ultrametric systems (sigtuna), economy (shiki), psychology (esti) and creative thinking (yanco).

The basic paradigm returning in those examples is that upon carefull scrutiny "continous" macroscopic long range, long time scale behaviour can be expressed in terms of (multiscale hierarchies of) discrete objects and rules.

Once the dynamics is expressed in terms of the relevant macros, it becomes easy to understand and manipulate.

This emphasis on the macroscopic independence on details originating in structural similarity of different systems may have deep Cognitive implications in as far as it gives a "hard" formulation to methods characteristic to "soft" fields based on analogies and metaphors.

Indeed, the equivalence relation which it induces between large classes of superficially different dayly life situations constitutes a framework for very powerfull and nontrivial cognitive acts of the "generalization" type.

The general procedures, go as deep as the very core of human creativity as proven in (). In fact they may be the very matter from which the human creativity is made of.

We present accelerated algorithms for stochastic complex systems and display explicitely their relation to the effective dynamics of specific collective degrees of freedom (macros).

We relate the emerging multiscale space and time hierarchies to various forms of (reducible and irreducible) complexity.

4 Stochastic and Multiscale Complex Systems

One of the main characteristics of complex systems is their computational difficulty: the time necessary for their investigation and/or simulation grows very fast with their size [**?**]. The systematic classification of the the difficulty and complexity of computational tasks is a classical problem in computer science [**?**].

The emergence of large time scales is often related to random fluctuations of multiscale spacial structures within the system. Long range and long times scale hierarchies (**Multiscale Slowing Down**) are usually related to collective degrees of freedom (**macros**) characterising the effective dynamics at each scale.

Usually, it is the dynamics of the **macros** during simulations which produces the Multiscale Slowing Down and reciprocaly, the slow modes of the simulation dynamics project out the relevant macros [**?**, **?**].

Therefore, a better theoretical understanding of the multiscale structure of the system, enables one to construct better algorithms by acting directly on the relevant macros. Reciprocally, understanding the success of a certain algorithm yields a deeper knowledge of the relevant degees of freedom of the system. (e.g. hadrons in the theory of quarks and gluons, Cooper pairs in superconductors, phonons in crystals, vortices in superfluids, flux tubes, instantons, solitons and monopoles in gauge theories, etc.).

One can entertain the hope that many complex systems in biophysics, biology, psychophysics and cognition display similar properties and may be some kind of multiscale universality generalizing the universality classes and scaling of the critical systems. Such a situation would have a significant unifying effect on a very wide range of phenomena spreading over most of the contemporary scientific fields.

In the absence of a rigorous theoretical basis for such a hope, its investigation relies for the moment mainly on the use of computers.

The present paper implements this point of view into the study of general random complex systems and gives some examples.

Reducible vs. Irreducible Complexity

Certain complex systems with high level of frustration and connectivity present a certain hierarchy in their energy landscape which is responsible for the hierarchy of time scales characterizing their multiscale slowing down. This "rugged energy landscape" is also the origin of ultrametric (UM) properties of their ground states space.

One could hope to make some relation between the ultrametric hierarchy and the existence of an effective representations of the dynamics in terms of a spacial multiscale hierarchy of macros. This in turn would become the basis of an efficient MCA.

It turns out and it was rigorously proven in [?] that the case is exactly the opposite: the ultrametric hierarchy **insures** the **in**existence of a representation of the effective macroscopic dynamics of the complex system in terms of their macroscopic disjoint sub-sets. [1].

In conclusion, in ultrametric systems it is ruled out that various regions of the system can be treated as independent collective degrees of freedom (**macros**). This picture can be extended to finite but small temperatures with the help of the "pure state" concept [?].

This failure of separability of the whole into (almost) independent parts has conceptual implications in the sense that one cannot "understand" the complex system by "analyzing " it into its parts. In this sense an ultrametric system is conceptually irreducible to simpler entities. We will see that optimal global algorithms reduce in fact a system to its "irreducible" core.

One is tempted to conclude that the entire discussion of reductionism can be reformulated in terms of "irreducible complex systems". I.e. in place of **assuming** ultrametricity and deducing the inexistence of independent dynamical sub-objects, one can propose this **dynamical inseparability** as the fundamental property underlying irreducible complexity.

The situation can be compared with having to find one's way in a labyrinth in the phase space: each small local change in the position of the potential energy labyrinth walls determines large unpredictable changes of the solution route depending on details scattered across the entire phase space.

Consequently, we are discerning 3 main complexity cases:

- In very simple cases the pattern of complexity is reducible (may be by an iterative multiscale procedure) and the MCA's capturing this reducible complexity are an efficient computational and conceptual tool.

[1] I.e. a complex ultrametric system is irreducible to a set of interacting sub-systems This might have something to do with phenomena like catastrophic forgetting in neural networks.

- In the general case one has to put an exponential computational effort to fully "understand" the structure of the system.
- In some cases the system contains certain macros which are "irreducibly complex". Yet the interactions between these macros are tractable by MCA or other algorithms. In these cases, MCA can help reduce the "less complex" part of the dynamics leaving the "irreducible core" for a separate treatment.

Recognizing the "irreducibly complex" parts of a complex system (rather than trying vainly to solve them by multiscale means) might be a very important aspect both conceptually and computationally.

Conclusions

The macros appearing in complex systems can be multiscale reducible i.e. can be iteratively broken into smaller tighter macros. However, in many cases there might exist complex irreducible cores. While such irreducible macros might have fortuitous characteristics, lack generality and present non-generic properties, they might be very important if the same set of cores appears recurrently in biological, neurological or cognitive systems in nature.

In such situations, rather than trying to understand the macros structure, dynamics and properties on general (multiscale, analytic) grounds as collections of their parts, one may have to recognize the unity and uniqueness of these macros and resign oneself in just making an as intimate as possible acquaintance with their features.

One may still try to treat them by the implicit elimination method [**?**, **?**] where the complex objects are presenting, isolating and eliminating themselves by the very fact that they are projected out by the dynamics as the slow-to-converge modes.

E.g. finding the exact configuration of a molecule might involve very complicated quantum mechanical computations. Yet, for deducing the volume-pressure relation of a dilute gas of such mulecules one can treat them as irreducible elementary objects.

This kind of decisions may iterate: in deciding the shape of the molecules, the structure of the nuclei of the atoms may be considered as irreducible elementary objects. Their composing protons and neutrons (in turn composed of quarks and gluons) can be ignored.

Of course this is not the case at nuclear reactions energy and length scales where the nucleons interactions are crucial.

Identifying the relevant degrees of freedom for each phenomenon is therefore both crucial and non-trivial.

The implicit elimination method: identifying the slowly converging modes and their associated macros, is therefore of great practical and conceptual value.

5 Relation to Renormalization Group in Critical Systems

If one throws a stone and wishes to predict its trajectory one needs only to consider it as a single rigid body.

If one wishes to study its light spectrum, one has to consider only its atomic and molecular structure.

If one wishes to study how the stone deforms under pressure, one may treat it as an elastic continuum.

However, if one increases the pressure and one wishes to know how it breaks, one has to consider it as a conglomerate of smaller stones (and stones within stones) with cracks and faults developing over many space and time scales down to the microscopic one.

The present paper concerns complex systems for which the origin of complexity can be traced to the very attempt by our perception to describe a macroscopic number of microscopic objects and events in terms of a limited number of macroscopic features.

We will discuss the techniques through which one can systematically follow the birth of the complex macroscopic phenomenology out of the simple fundamental microscopic laws.

In the field of fundamental physics, such understanding was obtained for a wide range of phenomena using theories based on a **Microscopic Representation** (in short, in the following text **MicRep**) paradigm.

The MicRep paradigm consists in deducing the macroscopic objects (**Macro**s from now on) and their phenomenological complex ad-hoc laws in terms of a multitude of elementary microscopic objects (**Micro**s from now on) interacting by simple fundamental laws. The Macros and their laws emerge then naturally from the collective dynamics of the Micros as its effective global large scale features.

However, the mere microscopic representation of a system cannot lead to a satisfactory and complete understanding of the macroscopic phenomena. Indeed, the mere copying on the computer of a real-life system with all its problems does not by itself constitute a solution to those problems.

It is clear that a satisfactory MicRep procedure of such complex systems has to be Multiscale, i.e.:

- one has to recognize the relevant objects which describe effectively the system at each scale and

- one has to establish the relations between the objects and the laws prevailing at different scales.

Therefore, the MicRep approach is not trying to substitute the study of one scale for the study of another scale; one is trying to unify into a coherent picture the complementary descriptions of a one and the same reality.

In fact one can have a multitude of scales such that the Macros of one scale become the Micros of the next level. As such the "elementary" Micros of one MicRep do not need to be elementary in the fundamental sense: it is enough that the details of their internal structure and dynamics are irrelevant for the effective dynamics of the Macros.

More precise expressions of some of these ideas were encapsulated in the renormalization group (**RG**) [**?**] and in the multigrid (**MG**) method [**?**].

MG was offered for the last 20 years as a computational philosophy to accelerate the computations arising in various scientific fields. The idea was to accelerate algorithms by operating on various scales such that the computations related with a certain length scale are performed directly on the objects relevant at that scale.

In our present view, the multi-scale phenomena and the relevant Macros hierarchies are considered for their own interest even (sometimes) in the absence of a multi-scale algorithm which accelerates the computations.

The multi-scale concept is proposed as a tool to reformulate and reorganize the way of approaching the problematics of various fields. Thus its usefulness transcends by far the mere application of a computational technique and may induce in certain fields a shift in the concepts, the language, the techniques and even in their objectives.

The phenomenon by which a system defined by microscopic laws presents macroscopic phenomena is called "criticality" and ξ is the "critical length".

The macroscopic dynamics of the critical systems, at scales larger than ξ is "universal" i.e. largely independent on the details of the microscopic dynamics used in the microscopic definition of the system [**?**]. In particular, universality allows one to choose a highly simplified version of the microscopic definition of the system and still obtain an accurate description of its macroscopic properties.

Moreover, it was shown that the resulting macroscopic properties of the critical system can be appropriately described in terms of the effective dynamics of a limited number of macroscopic objects (e.g. "relevant operators" [?]).

Understanding the critical behavior of a microscopic system of Micro's reduces then to the identification of the relevant Macro's and the description of their long time-scales evolution. Conversely, finding an appropriate MicRep explanation for a macroscopic complex phenomenon is to find a system of Micro's whose effective macroscopic critical dynamics leads to Macro's modeling well the macroscopic complex phenomenon.

For a system defined by given Micro's, the RCSD algorithms were based on identifying and acting upon the relevant Macro's. As such, these algorithms were at one and the same time

- the result,
- the expression and
- the source

of understanding the critical dynamics of the systems to which they applied.

We suggest a quantitative measure for the "knowledge" or "understanding" contained in an algorithm. It is the amount by which it succeeds to lower the dynamical critical exponent and reduce thereby the Critical Slowing Down.

The emergence of this sort of algorithmic operational way of acquiring and expressing knowledge has a very far reaching methodological potential. This is even more evident when coupled with the modern computers simulation, visualization and animation capabilities [?, ?]. In fact, we performed many such experiments [?] in which certain systems were successfully studied by performing computer experiments which involved the animation of their evolution under the action of various algorithms. The following research routine was common for most of these experiments:

- modeling the system as composite of many Micros.
- computer simulation and visualization of the resulting model.
- identification and computer experimental study of the CSD modes within the microscopic system.
- identification of the Macros.

- predictions based on the Macros behavior of the model.
- comparison with the experimental macroscopic behavior
- confirming or correcting the microscopic model in view of the comparison.
- starting new experiments based on these results.

The use of this dialogue with an artificial system created in the computer in order to understand its critical properties extends to systems away from equilibrium and to complex systems which are not characterized by an energy functional or by an asymptotic probability distribution.

For such general systems, some of the notions usually associated to criticality might become inapplicable. Yet, one needs criticality in order to insure the emergence of the universality properties which make the MicRep method reliable at macroscopic scales.

We propose to use the very emergence of CSD in the dynamics as a criterion for the legitimate use of universality. We turn the tables and transform the CSD from a curse into a blessing in disguise. We use CSD as the label which isolates the relevant Macro's. We use the RCSD algorithms as operational proofs that the relevant Macro's were efficiently identified and expressed algorithmically. We use the Macro's in order to visualize and understand the emergence of the collective dynamics, in order to relate the salient complex phenomenology to the simple underlying microscopic causes [?].

We propose to use this understanding in the task of formulating and studying MicRep models for basic problems in a wide range of fields. We are claiming that CSD is the key to characterize, build, identify and study such models.

6 Is Multiscale Intrinsic to Understanding ?

The Multiscale Paradigm might seem at first sight artificial and limited in its scope.

However there are reasons to believe that it is quite intrinsic to our representation of the real world and it has a determinant role in our capabilities and limitations in comprehending reality.

While the real world is continuum, our mind (mathematics, cognition) can deal directly with discrete (rational) numbers (or other equivalently discrete symbols: letters, bits, words).

This in itself might be related to the serial, time oriented irreversible character of the data imput in our brains: there is no way to order continuum sets of dimension more then 2 (e.g. the points in a plane cannot be ordered in a way in which one orders , say in ai continuum time sequence the points of a line).

Therefore , the standard definition of continuum (real) numbers starts from rational numbers and involves an infinite "multiscale" procedure. More precisely one considers an infinite discrete sequence of rational numbers converging towards "something" which is not rational. That "something" is defined as a "real" number.

In order to insure convergence, the sequence has to consist of an infinity of terms each differing from the previous by an ever-decreasing distance.

One has therefore at each staep another distance scale and as the process advances the mesh becomes finer and finer.

It is therefore not surprising that in order to treat continuum phenomena, one has to adopt a Multiscale formalism and methodology.

The hierarchy of ever-increasing length-scales characteristic to criticality is also built in such a cognitive scheme.

Indeed, suppose one describes a continuum system by considering a sequence of discrete systems with ever finer meshes.

For a feature of the system to be of real interest in nature, its properties have to be insensitive to the discretization process. Consequently, it is necessary that its scale is arbitrary large compared with the (arbitraryly small) distances involved in approaching continuum.

So, the real properties of the system, have to show up at arbitrarily large scales when measured in terms of the discretization length.

Looked from the other end:

having a microscopic discrete representation of a macroscopic continuum system, it is necessary that the fundamental microscopic rules are such as to induce effects which are infinite range in terms of the discrete system lengths scales.

The fundamental laws themselves have however to be of the scale of the discretization length in order to avid non-causal "action-at-a-distance" ("deus-ex-machina") fundamental laws in the continuum.

More precisely, each point should be able to influence directly only its immediate (infinitessimal) neighbourhood.

These contradictory requirements:

- infinitesimal scale of the fundamental laws
- macroscopic scale of the phenomenological effects

lead to the necessity of criticality and to the high probability for universality.

One should remark however that the passage between discrete to continuum is not without perils: in fact it can be proven rigorously that it might drastically limit our comprehension of nature: continuum systems which are perfectly deterministic, become uncomputable (their future behaviour cannot be predicted a priori) upon discretization.

Of course one can take a complementary position:

1. Reality is discrete.
2. Its laws are local.
3. Most of its effects are local (very short scale) and irrelevant to our scale.
4. The effects which are of relevance at our scale are only the ones which can be described by a long (almost infinite) sequence of scales and
5. Therefore they behave (almost) as continuum systems at our scale.
6. They are therefore (almost) critical and (almost) universal.

In this case, the amount of information lost in further "chuncking" in "macros" the discrete microscopic reality is less allarming though it still might introduce puzzling paradoxes.

For instance, systems which are reversible and deterministic at the microscopic fundamental level (microcanonical distribution) become irreversible and stochastic at the coarser levels (canonical and macrocanonical distributions). In short, mechanical systems become thermodynamical systems.

Such an example is in traffic flow [?]: the initial models were inspired from fluid dynamics and considered the flow as a continous process. Recently, one considered "microscopic models" in which the individual cars are represented as such. At very long distances and times of the fluid flow type features are recovered, while in addition one is able to represent in detail the intermediate scale mechanisms which lead to traffic jams of various sizes and the fluctuations in traffic speed and density.

Similarly in the Stock Market, one traditionally describes the share prices evolution as continous macroscopic functions governed by differential equations which express in an averaged way the market drift and the external random (white noise) influences.

In contrast, one may describe (see section 14) the stock market in terms of individual investors performing at each trade cycle buy-sell operations which regulate the share prices according to the bidding procedures of offer and demand.

While when summed over the entire market, some of the effects of the differential equations of the continuum are recovered by the microscopic discrete model, one obtains a much vaster quantity of information about the wealth distribution among the investors and about the nature of the non-white (Levy-distribution) noise which arrises intrinsically in the model.

In particular, at each wealth scale one finds investors with a corresponding influence on the market. Therefore the market behaves as a multiscale system (see section 14).

7 Coarse grained Molecular Dynamics

We start now a series of examples of MicReps and Multiscale systems.

Multiscale systems might develop in the study of non-equilibrium, non homogenous chemical systems.

Using a very simple minded "Coarse Grained Molecular Dynamics" **CGMD** method of simulation [?], we were able to describe and predict the nonequilibrium distributions of reactants in certain Chemical Reactions. The microscopic "elementary" objects did not necessarily represent the molecules dynamics faithfully: the "elementary" Micros moved on straight trajectories except for a certain cross sections for elastic and inelastic collisions as well as a cross section for the chemical reaction to take place if the colliding Micros were in the appropriate excited internal state. In spite of its coarseness, this approach allowed the realistic treatment of reaction rates, and chemical distributions arbitrarily far away from equilibrium.

We may describe this application schematically as:

- **coarse grained molecular dynamics** in far from equilibrium systems [?].
  - Micro - "molecules"
  - INTER - collisions, excitation, activation, bonding and dissociation.
  - Macro - reaction rate, density and energy distribution

The use of this type of CGMD might be absolutely unavoidable in describing systems in which various reaction chains are mutually exclusive and a *de facto* segregation takes place in the system between regions in which various mutually-exclusive reactions take place. We have in mind the situation in which the same set of enzymes are capable in principle to sustain 2 or more different reaction chains but due to certain inhibitory cross-interactions taking place at certain intermediate steps between the chains, the chains cannot take place simultaneously in the same spatial region. There is preliminary evidence also for the opposite effect: reaction chains mutually sustaining one another into active states which would not be viable in the absence of their coexistence and cross interaction.

The implicit assumption of continuity imposed by a continuum hydrodynamic - like model is then invalid for such self-segregating reactive systems while the CGMD remains a valid MicRep of the system.

This situation is also representative for the typical biological systems where the same genes and proteins lead spontaneously to different reaction chains in different spatial regions of the cell/organism.

For instance , one can see how the same immunological system may react differently in space and time to various initial and boundary conditions.

Another example is in linguistics in which the carriers of languages (speakers) are usually spatially segregated and the transitions between various languages are quite sharp rather than through a continuum of interpolating dialects.

Similar effects appear in the ecology of various species populations.

The coarse grained MicRep rather than the continuum approach may also be necessary if one is interesting to go beyond continuous deformations of solids and study the appearance and spreading of cracks and fractures.

We have shown that while systems which preserve microscopic conservation laws present a very robust invariance to variations of the microscopic laws, systems which do not have such properties are very susceptible to present self-organized patterns, breaking of the space and time invariances of the system.

In fact we were able to obtain fractal multiscale structures breaking spontaneously the translation invariance.

The non-trivial ingredient was that the molecule was slowed down as it entered a region with a lower density of molecules of its own kind. While this would constitute naively a mild trick for implementing surface tension, the result turned out to be the (quite unexpected) emergence of self organized patterns. We were able to trace the origin of self-organization to the fact the the "surface tension rule" did not originate in a rigurous "potential" interaction. We are studying now the scaling properties of the 2 -body correlations and their relation to the fractal structures which self-organize in the system. These phenomena are salient in as far as they probe the sensitivity of the macroscopic dynamics to even mild departures from the energy-derived forces of conservative systems.

It is an open question whether the new systems can be characterized by scaling and universality properties similar to the ones governing critical equilibrium statistical mechanics systems.

8 Various Micrep Examples

We are listing below the MicRep scheme of a few other systems. System 1 and 7 were already introduced in section 6.

Systems 4-7 are going to be further described in the following sections.

Each scheme, lists the microscopic degrees of freedon (MICRO), their fundamental interactions (INTER) and the macroscopic emerging features (MACRO):

1. -**Microscopic Drivers and Macroscopic Jams** [?].

   - MICRO - cars
   - INTER - go ahead/give way at intersections.
   - MACRO - traffic flow, jamming.

2. **Microscopic Einsteins and Macroscopic Proofs** [?]?

   - MICRO - links, letters, geometrical elements.
   - INTER - simplexes, words, postulates, Alexander moves.
   - MACRO - global topology, statements, theorems.

3. **Dramas - mathematical categories endowed with dynamics** [?].

   - MICRO - categories
   - INTER - relations, composition laws
   - MACRO - (stories) dramas

4. **Microscopic Concepts and Macroscopic Ideas** [?].

   - MICRO - elementary concepts
   - INTER - archetypical structures and thought procedures
   - MACRO - creative ideas and archetypes

   see sections 10-11.

5. -**Microscopic Seers and Macroscopic Sight** [?].

   - MICRO - line elements, points in 2 Dimensions..

- INTER - time and space data integration.
- MACRO - 3 Dimensional global motion.

see section 12.

6. -**Microscopic Picassos and Macroscopic Drawings** [?].

   - MICRO - line curvature, speed, discrete mental events.
   - INTER - continuity, kinematics, breaks, (mind) changes.
   - MACRO - shapes , representational meaning.

   see section 13.

7. -**Microscopic Wealth and Macroscopic Power Laws** [?].

   - MICRO - investors, shares
   - INTER - sell/buy orders
   - MACRO - market price (cycles, crushes, booms, stabilization by noise)

   see section 14.

9 Macros in Concept Dynamics Models (scene segm in 1d)

One of the main issues in the context of Multiscale Algorithms is the identification of Macros and the imposition of dynamical steps which act directly on the Macros rather than the elementary degrees of freedom.

Therefore it is crucial both algorithmically an conceptually to decompose the configurations of the system under study in terms of macros.

If one whishes to make this identification authomatically, one is lead to a pattern-recognition problem.

Suppose the system is a macroscopic string of bits: [0010100101.....00101] which is evolving according to certain dynamical (possible statistical) rules.

At each time t , one would have another string of bits $S(t)$ which we call "the configuration of the system at time t". In systems with long range (spacial and temporal) features, strings at various times might have large substrings in common.

In fact, certain (types of) substrings might have the tendency to recurr very frequently. The efficient algorithm has to be capable to recognize such substrings and act directly on them.

The various substrings which the system recognizes form a set which we call the memory of the system.

For instance, suppose that at time $t = 3$ the configuration of the system is $S(3) = [0010100101.....00101]$. Note that the substrings $B1 = [00], B2 = [00101], B3 = [101]$ appear each 3 times in $S(3)$ and have a good chance to be relevant macros for the systems which S represents.

In particular, one can express $S(3)$ as $S(3) \equiv [B1B3B1B3...B1B3] \equiv [B2B2B2]$

It is clear that this expression of a macroscopic string as a set of macros is an operation which appears in a much wider context than strictly physical and mathematical problems.

In particular, we are performing such an operation whenever we separate a text in chapiters, statements and words.

We are now considering the general problem of decomposing strings S in strings of macros B (may be with some blanks for "noise bits in between the B's).

We will call the algorithm by which this problem is solved a "solver".

For each particular dynamics or distribution of the S's there is a particular optimal distribution of B's which the "solver" should use..

We define optimization by associating a certain price for the solver to memorize B's, to serach the set of B's , to compare a B to a certain substring of S, etc.

We also consider the optimization of the search by the solver of the set Bs. For instance, the solver might like to try the fitting into S of $B2$ whenever $B1$ or $B2$ fit successfully. This would model a solver with associative memory: it invoques from the memory a Macro whenever a subset of the Macro is observed in S. By iterating this criterion, one might be lead to a multiscale memory structure.

This rudimentary pattern recognition machine, has therefore the capability (or rather the abmbition) to decompose every configuration S of the system in macros B stored in its memory.

One can now study the various ways to organize the memory and fitting procedure as to have an optimal solver. Moreover, one can consider certain adaptive procedures to make the solver fit to the particular distribution of S's which the system has. For instance , if a particular string B appears often in S, one should include it in the memory. If it appears very often, one may increase the probability of trying to fit it into S.

Observe that the model is essentially a 1-dimensional puzzle-solver or a 1 -dimensional black-and-white visual scene decomposition machine.

A very interesting modification of the system s to consider that the strings S are generated by an automaton similar to the solver by using a particular memory set A similar to the set of B's and having certain associative relations between the A's.

By adaptation, the set B, will eventually come to have a structure similar to A.

Morover, if each of the automata A and B acts alternatively as generator and solver of S, one might have a "co-evolving system".

In the case of many such automata, one would watch the emmergence of a semiotic system. In this case the system represents the emerging of a common language rather than the internal reflection of a certain reality.

With further modifications, one should be able to study optimal ways to organize cooperation in problem solving by different agents, as well as the emergence of representation of communication with the external world.

In both cases the internal structure reflect a "view of the world" and in principle rudiments of self-representation as part of the worls might emerge ("conscience").

Another interpretation of this model is to identify the S configurations with antigenes, the recognizable string-bits B with epitopes, and to find the optimal structure of the "solver" as a defence mechanism (e.g. by destroying the "recognized" anti genes). The model can take into account the self-immune effects, by submiting "B"'s as "S"'s [irun]. Again, the recognition of "self-antigenes" might be interpreted as the emergence of rudimentary "concience" in simple computer models.

While the model can be described visually in terms of an 1 dimensional Solid-On-Solid dynamics, we expect it to be relevant to general issues related to computability, regular expressions, game theory, pattern recognition, protein folding, gene-sequence replication, random surfaces, AI for complex systems and other general problem solving using macros and multiscale concepts.

In these projects, one can use a "class dynamics" simulation library [hamburg] for general dynamical systems and to study in particular the systems for which multiscale dynamics emerges naturally. We are also going to try to isolate the "irreducibly complex" cores [**?**] and treat them by the "Principle of Implicit Elimination" [**?**, **?**, **?**, **?**].

10 The Dynamics of Creative Ideas

The interactive multiscale and animation-visualization techniques proved so powerful that one had sometimes the feeling that they tap into a short-cut leading directly to the inner mental representation forms manipulated by the human mind in the process of understanding. A possible explanation for it is that the natural structures inherent to the human thought are intrinsically multi-scale. As such, they might be considered as a legitimate target for further MicRep study.

As commented in a previous section, it is important to find the optimal macros and/or macros/hierarchies for describing a certain phenomenon in terms of their simple interactions (if their interactions turn out not to be simple and neither can they be realistically be approximated by simple interactions the chosen Micrep is not appropriate).

In the thought case , there are quite a few important scales with their relevant objects.

Among them there are 2 levels which fascinated the reseraches for alreay 100 years and for which we propose in the next sections the application of the Multiscale Paradigm:

- the mechanisms by which the conscious perception, or thought or idea is conceived. The difficulty to treat this issue is obvious: our means of expression and communication are taylored for "finished thoughts". Therefore expressing something about the mental entities and events which are not yet at the "finished thought" level is non-trivial. In particular, the very definition and characterization of the relevant macros is not clear a-priori.

  We will concentrate on this class of phenomena in a few contexts: - emergence of meaning in drawings. The objects are certain spontaneous mental events (which act as thought-shells looking for a content), their graphical counterparts (breaks in the line direction) and the external objects. The meaningfull drawing is the result of the association of an external object to the mental event through the intermediary of the graphical element.

  - emergence of 3 dimensional percept out of moving 2 dimensional projections on the retina. The relevant objects here are the point-like signals and their receptors. This statement is not trivial as physiologically most of the emphasis until our work was on countour, line-like signals and receptors. The elementary interactions involve only velocities and positions and no higher order motion derivatives or motion integration. This again is a departure from the usual 3D reconstruction theories which assume the visual system uses all the information encoded in the sequence of immages. These 2 statements on the relevant degrees of freedom and their relevant interaction have dramatic implications on the macroscopic functioning of the visual system. In particular we predicted highly nontrivial illusions and insensitivities of the human subjects in well defined experimental conditions. The actual experiments confirmed dramatically the predictions of our theory.

- emergence of creative ideas. In order to eliminate the effects of previous knowledge, technical skils, awareness of phenomenological facts, etc, we have chosen problems in which creativity is almost the only factor of interest. In particular we addressed the emergence of creative ideas in advertising. The only imput there is the product and the quality to be advertised. We were able to divide the creative process in steps which by themselves are rather straightforward (though they still assume certain common human qualities). We provided experimental checks for the efficency of our method. The steps of our "creative process" involve operations directed towards the construction of particular logically consistent "inventive strctures". Yet , the intermediate steps are "logically inconsistent" and would not be naturally accepted by a logically inclined mind. We assume that such steps are accessed by the unconscious mind but in a random rather than well directed way (as it happens in our method). This might explain the efficiency and speed of our method.

- The mechanisms by which the same concepts, images and structures recurr in a general way to a vast range of individuals belonging to different populations and cultures. We associate these properties to "universality" properties of the "pre-conceptual" level dynamics described above.

  Our results indicate that creativity operates at a coarser level then the details of each object and environment. It acts on archetype level (or

> hierarchy of levels) and not at the common sense, belief and personal (or generic) mental connotations level. This implies that these aspects may be treated as irreducibly complex macros and reffered to general data bases while working on creative issues.
>
> Consequently our procedures concentrate on the level immediately generating the creative one as its collective dynamics while using the lower scale structures as macros to be treated mechanically (e.g. tabulated etc).

As a first example of reducing thought to mechanics, we designed procedures which, produce in a systematic way advertisement ideas which are perceived as creative.

Our method consists in identifying classes (archetypes) of advertisements sharing the same structure and in prescribing well defined constrained procedures which lead to new advertisements (on different subjects) with the same structure.

These procedures start from the basic objects of an advertisment (product and quality) and generate new additional objects and relationships within a well defined general dynamical scheme (archetype).

We performed experiments in which advertisement professionals graded advertisement ideas according to their creativity.

The marks obtained by laymen using our method were significantly better than the marks obtained by advertisement professionals using standard methods.

One can therefore say that we layied the foundation for the development of effective methods to support the automatic production of creative ideas.

The reason that we have chosen to concentrate on creative ideas in the advertisement field is because the special status of creativity in this field.

While in other fields, creativity is only a tool to fulfill other criteria, creativity is the prime matter of advertising. In fact, advertising is one of the few industries to have a specialist "creative department". However, no detailed methodological tools have been defined until now to allow the generation of creative ideas in an industrial fashion (i.e. in industrial quantities, industrial standards and industrial scheduling). One of the reasons for the lack of systematic tools is the widespread belief that the creative process involves some kind of "mystical spark" which cannot be studied or reconstructed by analytical methods.

We challenged this state of matters. We restructured in a novel way material accumulated during decades of advertizing. The new structure allows the mechanical production of creative ideas.

This rather provoking position relies on 2 superficially paradoxical claims:

- creativity can be categorised and captured in a set of rules.
- creativity is increased by limiting one's horizon.

Yet these claims have been already asserted, developed and experimentaly confirmed by prominent researchers (for more details see Altshuler[], Finke[]).

Moreover, the validity of our method is established by the experimental results. In one of the experiments subjects with no previous experience in advertising were instructed to follow our procedure and create a print ad for a specified product and promise. The performance of these subjects was then compared by 5 expert judges with the performance of experienced creative teams who worked on the same problem without knowing our methods. The result was that the inexperienced subjects following our method got significantly higher creativity marks (4.7 ± 0.2 on a scale of 7) than the experienced teams (3.7 ± 0.2).

Our approach to the production of highly creative ideas uses the claims above in its 2 main departing points:

- Large sets of highly creative advertisments sharing the same structure are identified and classified as "**archetypes**".
- For each archetype, we define a standard "mechanical" **procedure** which, given a message, generates an ad belonging to the archetype.

Identifying Archetypes

To avoid misunderstanding, we decline form the begining any claim that we invented the archetypes which we present below.

Our contribution is limited to:

- the identification, analysis, classification and detailed characterization of archetypes within the pool of preexisting advertisments.

- the construction of well defined procedures which (if followed) lead automatically to the construction of new advertisements which belong to the corresponding archetypes.

- The discovery that the resulting advertisements are perceived by professionals and public as very creative.

In order to identify creative archetypes pre-existing in the field, an Israeli advertising company ("Symbol - Peres") searched a large initial pool of advertisements (print-ads and commercials) from around the world. Out of it, they selected more than 450 advertisements judged by their experts to be highly creative. Most of these advertisements had been awarded prizes.

By comparing the 450 examples, it was possible to group many of them in sets which shared common structural features. We defined these sets as archetypes.

It turns out that 95% of archetype members were among the the selected 450. This indicates that the mere belonging of an advertisement to an archetype insures its classification by the experts as creative.

The Trojan - Symbol archetype

The most wide-spread archetype (15 examples) was the Trojan - Symbol.

The procedure we constructed to implement its structure involves the following elements:

- Start from a Product and and the Quality which one whishes to associate with.
- Find a Symbol to the Quality. The symbol has to be a concept which is very strongly associated with the Quality in the collective mind of the target population.
- Find objects which are strongly associated in the target population collective mind with the Product and respectively with the Symbol.
- Find a scene, picture , etc in which an object associated with the Product is identified (in shape, color, texture, context) with an object associated with the Symbol.

The procedure splits the above scketch into elementary mechanical steps which by themselves do not require any creativity. The steps a they are presently formulated require still human decisions, but we are in the process of reducing the procedure to a computer procedure and isolate the eventual (irreducibly complex) steps which are still non mechanizable.

The main point is that certain intermediate steps involve "non-ideas" which would not be considered in a normal search. In this sense, our procedure takes over some tasks which in normal instances are left to the inconsciemind.

Summary of the ad example

We presented a method consisting of the following steps:

1. Creating large collections of remarkably creative ideas.

2. Defining archetypes within these collections.

3. Creating a procedure for each archetype which, given a product and a promise, leads to an idea belonging to the archetype.

The introduction of archetypes allows one to define advertisment production procedures depending only on the archetype but not on the particular objects which appear in the advertisement.

Once one decides which archetype one wishes to use and which objects to advertise, these general procedures are capable of leading automatically towards the appropriate advertisement.

At the practical level reducing the problem to a discrete well-defined set of objects and rules is paving the way to a formalization of the system which would allow its representation on a computer.

In turn this would mean that given the basic rules characterizing the archetype and the particular objects on which it is to be applied, one could generate creative ideas by computer.

The philosophycal discussion of whether this would mean that the machine "thinks" etc. is outside the scope of the present article.

Let us enumerate the practical advantages of the "archetypes approach":

- According to Finke [] and Weisberg [] the constraints inherent to the well defined procedure favorise creativity more than approaches that are based on total freedom.

- The resulting idea belongs to a high-creativity archetype which (according to our statistics) ensures that it will be considered (by experts in advertisement) as a creative idea.

- One can repeat the procedure as many times as desired to obtain a multitude of creative ads. In particular, defining an archetype allows the creation a long and consistent campaign.
- The systematic approach allows one an industrial level of planning and management control of the search for creative ideas.
- The emergence of a systematic procedure, vocabulary and grammar for an activity is a decisive step in transforming it into a research discipline. Therefore we are on our way to transforming the "creative" into a science. For similar successes in cognition Adi[], psychophysics Rubin[] and economics Levy[] and other complex systems Solomon[].

11 New Products Dynamics

Systematic Generation of Ideas for Marketable New Products
An Exercise in Mechanical Manipulation of Thoughts

We introduced a paradigm for new products development. In our method, the starting point is an existing product rather than the market environment. The properties of the existing product are represented as the components of an initial abstract structure. By a sequence of formal operations on the initial structure one is lead to an "inventive" structure corresponding to a new product. The sequence of operations is prescribed by well defined, easy to follow, mechanical procedures.

Our experiments show that a small set of such procedures (which we call "Archetypes") can generate most of the successful new product ideas.

This point of view is a drastic departure from the usual marketing procedures.

The prevailing marketing paradigm views the development of products as driven by external events such as changes in the available technology or in the market factors (consumer needs, physical environment, culture, tastes, state of economy etc.). Accordingly, the primary focuss in new product development (NPD) are the external factors while the changes in the products are treated as mere consequences.

This approach is certainly justified for long time scales (decades) which characterize the dynamics of significant technological, economical and social changes.

Our claim is that at shorter time scales, which are typically more relevant for the profitability of individual companies, *the external changes are less essential.* Rather, on these time scales, NPD dynamics is determined by the intrinsic features of the product and can be described, predicted and controled independently of the external perturbations. (see relation to the stock market intrinsic dynamics).

To partially tame the provoking tone of the above statement let us add the following parantetical clarification: We do not claim a new product can be successfull without fulfilling market needs. We only claim that enough information on the market is carried by the **existing** product in its very structure. Therefore, **new** products can be conceived simply by acting formally on this initial conceptual structure.

The use of mechanistic procedures to manipulate concepts towards inventive creative ideas was first suggested by [Altschuler] in the engineering context. He called them "Archetypes".

"Archetypes" were recently introduced in advertising and have been proven to generate systematically highly creative ideas [yanco]. They are currently being computerised [sol].

The role of closed deterministic dynamical systems (as opposed to systems driven by external uncontrolable forces) was demonstrated also in technological creative thinking [roni], graphical expression [eti] and equity markets [shiki].

In this section we propose to introduce the Archetype Paradigm in NPD.

The Archetype Paradigm views NPD as an internal process enforcing a particular Archetype procedure on a closed system representing the existing product. More precisely, the closed system is an abstract structure whose components represent various parts or properties of the product. Each Archetype procedure modifies in a particular way the components of the abstract structure and their relationships. These changes in the abstract structure amount to changes in the nature of the product. Ultimately, the application of an Archetype on an existing product results into defining a new candidate product.

Once a candidate new product is conceived and precisely defined, marketeers can explore and forecast its benefits **before** engaging in the usual wide and costly market studies.

The subsequent validation by traditional marketing tools is cheaper, more focussed and more reliable when one has already a precise definition and concept of the new product.

Another resources saving characteristics of the Archetype Paradigm is that the new products are not based on (and in fact do not require) new technology.

The investment in the marketing of these new products is also small as they inherit the marketing infrastructure of the existing product.

We submited new products defined through the Archetype Paradigm to the evaluation of senior marketing professionals. The experimental results confirm quantitatively the efficiency of our method with a statistical significance much above the statistical errors. In fact it turns out that a small number of Archetypes account for most of the successfull ideas.

Our method is based on the hope that one can define marketable new products by repeating a procedure which has been proven successfull in the past. This naive hope is qualified and formalized in a systematic and scientific form by the Archetype Paradigm.

The starting claim of the Archetype Paradigm is that it is possible to classify the successfull NP ideas into classes (Archetypes). *NP ideas belonging to the same class have the same conceptual structure.*

The fundamental property which makes the Archetype method usefull [yanco] is that any new idea which is constructed according to an Archetype conceptual structure turns out to be (most of the time) successful too.

This leads to a general method to develop systematically and straightforwardly successful new products: All one has to do is to devise and apply Procedures which generate the products in a way consistent with one of the Archetypes.

Role of the Close System in the Archetype Paradigm

Constraints increase creativity

Our decision to concentrate on the intrinsic properties of products is not trivial.

This limitation is a necessary condition in order to find a manageable number of well defined procedures with predictibly sensible results.

For an open or infinite system this would be impossible: one would encounter the "frame problem" [look for refin Hofst] being either paralized by the continous infinite of factors which one has to consider , or having to arbitraryly choose a small subset which does not necessaryly behaves as a system with its own rules, but rather is at the mercy of external perturbations which have not been considered by the model.

The capability to construct finite discrete subsystems which are in some approximation independent on the "rest" is fundamental in natural sciences. It migh also be an intrinsic feature of understanding [eco].

The surprising fact is that the limitation of the variables of the product-space from a continuous infinity to a discrete finite number, has the effect of increasing rather than decresing creativity as demonstrated in a wide range of subjects ()() and (). [Alschuler][Finke].

It is a crucial feature of the Archetype Paradigm that while generating a small, specialized, set of sensible cases it eliminates virtually all the non-sense ones.

This is important because in the a priori infinite pool of cases the sensible cases zero probability to appear (are "measure zero").

Causality in the Archetype Paradigm

One may wonder if the particular choices of the relevant Components, Functions and Variables for the Initial Structure is not arbitrary an in fact subjective.

The answer is that the value and reproducibility of the Archetypes relies on the preexistence in the consumers mind of a collective strong and highly reproducible concept of what the relevant parts of the product are.

In the context of advertising , we have found and exploited similar perceptions preexising in the collective consumer psyche.

As a consequence, a small set of efficient Archetype Procedures recurr in large classes of particular product examples.

The fact that a small number of structures recurr in such a vast number of cases parametrized by a potential infinity of variables (each with a continous infinite range) might seem a miracle.

However, one can find very simple analogues to this phenomenon in natural sciences.

For instance, a very limited number (14) of crystal structures (cubic, hexagonal, tetragonal, etc.) are possible in nature even though the forces and the a priori positions which each particle can assume are a continous infinity Every single instance of a crystal in the world, (irrespective of which of the thousands of substances is made of) belongs to one of the 14 types.

This suggests a mechanistic explanation to the Jungian archetypes making plausible that simple laws of elementary mental events may explain the recurrence of the same symbols and mental structures across all cultures.

The role of the logically inconsistent intermediate structure

The usefulness of the Archetype Paradigm trancedes the boundaries between fields.

In particular, the Replacement Archetype was developed and successfully applied to technology (altsch), advertising (us), etc.

One of the reasons of its universal aplicability to problems which otherwise require "guesses" , or "inspiration" might be the existence of the logically inconsistent Intermediate Structure in this Archetype.

While this structure is "absurd" by itself, it is a necessary step towards the solution.

Should such an inconsistency arise in a normal research process, any logically rigurous worker would reject the entire idea altogether.

Therefore, in usual solution search is usually left to the unconscious activity to perform such "illegal" transgressions. Only after the inconsistent phase has passed and a consistent sucessfull structure is arrived to by the unconscious, the control is transfered to the conscious (critical) part of the mind.

It is a possibility that the integrative functions which are atributed to the subconscious (Right Hemisphere) are partially discharged by rather analytical (but logically inconsistent !) steps.

This would explain the subjective feeling by the conscious mind that a "creative spark" must have been involved in comming up with the Inventive Structure. Indeed, the conscious mind cannot conceive (and rightly so) that such an idea could be reached by a sequence of **consistent** logical operations. In fact **it cannot**; and the inconsistent intermediate structures are necessary [debono]. (compare with the spontaneous mental events in drawing, which are not really finished thoughts but rather thoughts shells looking for a content)

Summary

We believe the Archetype Paradigm may highly improve the marketing performance in speed and quality.

In addition to NPD in stationary market conditions, it allows to identify new products opportunities, as soon as the market and technological opportunity arises.

Time is money in this respect: -each moment that a marketable product is not there it cannot be sold and the associated profit is lost.

-worse, if the product appears too late it might result in losses (scooped by competition, rended irrelevant by new technology, etc).

The ability to keep the product evolution ahead of the market is a substantial advantage. Firms which forecast in advance the needs for new products before they become apparent in the market trends have a significant advantage over firms that respond only to current market opportunities. Empirical research has shown that significant and long-lasting benefits in market share and profits are often associated with being first to market with novel consumer products (Urban, Carter, and Mucha, 1983).

The NPD Archetype Paradigm offers a few advantages.

- The changes in the product are minor this fact implies for plausible investments in introducing the new product to the market.

- Changes introduce benefits from different segments and consumers needs.

- Analyzing the potential changes in a product provides a map of attributes and benefits long before they emerged in the market.

- The very timing of introducing the new product can be determined by examining the predicted responses of the market to the new product.
- One can optimally devise NPD campaigns in which the very succession of various products is decided according to an appropriate Archetype procedure.

The emergence of a systematic procedure, vocabulary and grammar for an activity is a decisive step in transforming it into a research discipline. Therefore it should be part of the NPD science.

12 Visual Psychophysics of the Kinetic Depth Effect

Macroscopic 3D structure from microscopic 2D moving elements

When Macroscopic objects pass through our visual field, in order to recognize them as such, the visual system faces the computational task of integrating the information from many microscopic receptive fields (each primary visual cortical cells covers a region of less then 1^0) into Macro's.

The kinetic depth effect (KDE) is a particular manifestation of this local-to-global computations the visual system has to perform daily. KDE consists in percieving 3D structure and motion out of the 2D moving image provided by the receptive fields ([ref] Wallach) Wallach and O'Connell (1953).

In order to construct a MicRep for the visual system, one has to identify the approriate Micros.

Therefore, it is important to find out whether indeed "line-like" Micros can serve as primary clues for 3D global motion computation. We have addressed this question by combining mathematical results and perceptual observations. Not only did we obtain the Micros but we also obtained clues about the mechanisms integrating them into the Macro percept.

First we showed that given the 2D-projected instantenous velocity field of the "line-like" Micros, it is mathematically impossible to discriminate rigid rotations from non-rigid transformations and/or to recover the rotation parameters.

The proof relies on the fact that for *any number* of straight contours there is always a rigid 3D interpretation (even if their positions and instantaneous velocities were chosen, say, randomly). In fact, there is an infinite number of such rigid 3D interpretations, since one can derive such an interpretation for (almost) any axis of rotation chosen.

Therefore, even the seemingly simple task of the determination of the axis of rotation (under the assumption of rigid motion), cannot be done on the basis of two-frame motion. This situation is to be contrasted with the case when global 3D structure and motion are computed on the basis of 2D signals, where both the rigid/non-rigid discrimination, and the recovery of much of the structure and motion information itself, can be performed already on the basis of 2-frame measurements.

However, theoretical considerations alone cannot altogether exclude the

1D approach, since in principle, computations performed on 1D measurements gathered from prolonged observations (3 frames or more) can be used to overcome the initial two-frame ambiguity.

Therefore we turned then to psychophysical observations to obtain the definitive evidence for the crucial role of the "point-like" Micros.

In the experimental study, we directly tested the ability of human subjects to perform global motion computation tasks solely on the basis of 1D motion clues. We used images that, in the presence of "point-like" clues, evoke a strong KDE percept. These are the orthographic projections of rigidly-rotating 3D wire-frames. When viewing such images, observers immediately report the percept of a wire-frame moving in depth while maintaining its 3D shape unchanged. The perceived 3D shape has been shown to be a good qualitative match of the actual underlying 3D shape (Wallach and O'Connell 1953). In fact, we found that under normal viewing conditions, the visual system is quite resistive to distortions in the image, and in many cases where the 3D shape undergoes extensive non-rigid transformation, subjects perceive a shape-preserving 3D motion.

In contrast, we found that when the point-like clues are eliminated from the image, the situation changes dramatically: the image seems to be distorting in the plane of the screen, and evokes no perception of depth at all.

We were thus led to the conclusion that not only does the process of correct global motion computation relies heavily on the Micros of the "point-like" type but that these are necessary for the mere occurrence of perception of motion in depth.

Moreover, the inability to use the "line-like" clues suggests a general inability of the visual system to use higher order time derivatives (or, equivalently, more than 2 frames at a time) in order to perform the higher-order temporal calculations needed for completing the missing structure and motion information on the basis of third-frame measurements.

This hypothesized limitation should be contrasted with the models suggested thus far which assume that such high-order temporal calculations are in fact performed by the visual system the ability of human subjects to perform global motion computation tasks solely on the basis of 1D motion clues.

Following this line of thought we were then lead to a system of postulates which encompass all the stages that lead to a 3D percept of structure and motion from a time varying 2D image.

They are far from being a full description of all the processes involved, since they do not refer to the specific nature of the neural computations undertaking these stages but they determine the goals - and limitations - of what these computations must achieve.

As opposed to the classical mathematical models of reconsructing structure from motion, our system of postulates predicts a series of failures and illusions which should systematically in our visual system. We were able to find confirmations of these predictions in real experimental data.

To summarize our work suggests that in computing 3D global structure and motion, the visual system relies heavily on computation performed on local motion signals obtained from two-frame motion sequences. In doing so, the visual system by necessity using 2D local motion signals, since this strategy could not be used with 1D motion information alone. This implies, that local detectors that reliably signal 2D motion in the image must exist in the early stages of visual processing.

13 Thought Dynamics in Drawings

We identify and characterize the first instances in which children (aged two to three) associate representational meaning to their drawings. We show that at this age children systematically associate meaning to a specific type of discrete sharp corners in their **own** drawings which we call **breaks**. Usually, these children do not associate meaning to the drawings of other children. Moreover they associate meaning to **breaks** only within a short time from having the experience of drawing them. We suggest that the **breaks** are associated with spontaneous, discrete mental events which are the origin, and precede, the representational act.

This allowed us to identify and characterise the first instances in which a child attached referential meaning to his/her own drawing. We found that such instances can be traced as early as age 2-3, and in a regular and stable manner *(2)*.

Our findings can be summarized as follows:

1. During the early drawing process one can identify *inertial* periods of a few seconds in which nothing happens with respect to representation. During these periods, the motion is characterized by a simple *kinematic* rule (the "2/3 power law" *(3)* which is esteblished in Experiment 1).

2. These *inertial*, *kinematical* periods are separated by discrete events characterized by a **break** in the continuity of the speed and direction of the pencil motion. Due to the central significance to our work of this specific drawing element, we shall give later a precise characterisation of the term **break** and we shall use in the rest of the article bold faced characters to differentiate between the technical term and the usual english word.

3. The child initially attaches representational meaning only to the **breaks** in his/her drawing while (s)he is treating the smooth, *kinematic*, *inertial* parts as non-significant.

   Experiment 2 establishes that the breaks are correlated with a posteriori representation thus indicating that in its first steps towards pictures the child singles out irregular discrete events as associates to representation.

4. The child attaches meaning to **breaks** only in his/her *own* drawings (experiment 3) and only just after having experienced the act of producing them (experiment 4).

We argue that the **breaks** are related to spontaneous mental activity.

Discussion

We conclude that the mere visual features of the **brakes** are not enough to trigger a representational interpretation.

The results of Experiments 3 and 4 imply that the tendency of a child in the age range examined to attribute representation to **breaks**, is dependent on his/her having just experienced the act of producing the curve.

Taking this into account together with the evidence against a pre-planned action *(9)*, one may speculate that the child's mind generates spontaneously, while drawing, elementary mental events which are not yet thoughts (rather thought-shells looking for a content). These mental events achieve a content and become meaningful thoughts a posteriori by their very (rather arbitrary) representational assignement to an object from the real world.

14 Economic Simulations ; Wealth and Power Laws; Levy Distribution

In the study of economic systems, the simulation of the money market is usually based on the integration of a differential stochastic equation in which the average interest rate and the momentary dispersion (volatility) are parameters. In more involved estimations of futures values, various versions of the resulting stochastic dynamics are considered and an average is performed over the possible histories.

The MicRep formulation allows a more first-principles treatment [**?**] by considering explicitly a set of investors which sell or buy equities according to simple rules of maximizing the expected value of a utility function. The expectation regarding the future is constructed on the basis of their previous history and prejudice.

The market price of the equity is then computed based on the bidding prices from all the participating investors. This in turn influences the wealth of the investors, and their prejudices.

The collective emerging dynamics is by-and-large independent on the details of each individual buy-sell particularities and displays general features.

In particular we found the natural emergence of cycles of booms and crashes and the dependence of their timing and intensity on the dispersion of the individual buy-sell criteria.

By comparing the standard approach with the MicRep one, one sees that the relation is similar to the one between thermodynamics and statistical mechanics: while thermodynamics can provide a general macroscopic framework which **relates** the **possible** values of certain parameters which parameterize the macroscopic dynamics, statistical mechanics can address more detailed questions and eventually **deduce** the macroscopic parameters from the microscopic properties.

The strength of our approach is that it is very robust to the further introduction of any degree of realism one deems necessary.

The non-trivial fact is that already in the absence of the effects of real goods production, prime-matter price fluctuations, public policies interference, taxation, global politics, etc. the system presents realistic behaviour of its nontrivial cycles dynamics.

One of the interesting findings in our economic simulations is the natural emergence of power law distributions.

This supports the view that the stock market has a structured (not pure noise) dynamics by itself, autonomous to a large extent from the details of its environment. This is an important prerequisite for any attempt to predict and characterize stock market future tendencies.

Power laws are found in a wide range of different systems: from sand piles to word occurrence frequencies and to the size distribution of cities. The natural emergence of these power laws in so many different systems, which has been called self organized criticality, seems rather mysterious and awaits a rigorous explanation. We studied the stationary regime of of a stock market model. We find that the wealth distribution among investors spontaneously converges to a power law. We are able to explain this phenomenon by simple general considerations. We suggest that similar considerations may explain self organized criticality in many other systems.

The appearance of power laws in a multitude of diverse systems seems a puzzle. Bak et al [1-4] who coined the term "self organized criticality" and discovered this phenomena in many systems suggest that many complex systems have a natural tendency to converge to a statistically stable state which can not be characterized by a specific scale. Scaling has been recently found in the behavior of economic systems [5]. The mechanisms driving systems into the state of criticality remain rather unclear. There have been recent attempts to explain self organized criticality via the renormalization group approach [6-8]. It is not yet certain how far this approach can be stretched in order to apply for a large class of generic complex systems.

In our work we study the emergence (in the time-stationary regime) of power laws **in the distribution of wealth** among the investors represented in the model.

We offered a general explanation for the emergence of a power law in this context. Our explanation is related to the fact that investors tend to gain or lose wealth in quantities which are proportional to the wealth they have (rather than absolute quantities). We suggested that similar reasoning may offer an explanation for the spontaneous emergence of criticality in many other complex systems.

The Economic Model

Since the point that we are trying to make does not depend on the details of the microscopic model, and for the sake of brevity we describe only the main features of the model which are relevant to our present argument. A detailed description of the model can be found elsewhere [9,10].

The microscopic 'elements' of the model are $N = 10^n$ individual investors. Investors must divide their money between two investment options: a riskless bond and a risky stock. Investors interact via the buying and selling of the stock and bond. Investors employ historical data regarding the performance of the stock in order to estimate the future stock performance. Each investor is characterized by a "memory span", which determines how far back into the past the investor looks. The two main aspects of the model which lead to the convergence of the wealth distribution into a power law are:

- Investors make decisions regarding the *proportions* of their investment in the stock and the bond. They therefore tend to gain or lose wealth in quantities which are proportional to the wealth they have (rather than absolute quantities).

- The investors' wealth does not influence their decisions regarding investment proportions. Thus, the probabilities for gaining or losing a certain proportion of the wealth do not depend on the wealth itself.

When the parameters of the model (interest rate, dividend growth rate, etc.) are chosen realistically the resulting stock price dynamics are very realistic [9].

We find a spontaneous emergence of a power law in the distribution of wealth among investors. Thus, in the long run steady state the wealth is divided very unevenly, and therefore only a relatively small number of investors (the richest ones) are relevant for the long time scale dynamics. This has implications for the size effects of such stock market systems [11] and implies a Levy distribution in the fluctuations.

The self organized criticality in this model is explained by simple considerations of the dynamics. The two essential features of the model which give rise to the emergence of a power law are:

a) The measured variable (wealth) is *multiplied* by a random variable in each time step.

b) The multiplicative random variable is drawn from a distribution which is independent of the value of the measured variable.

We suggest that any system with the above two properties will end up with a power law distribution of the measured variable. For example, if one assumes that a city's population changes by a fraction of the population in each time period (a), and that this fraction is a random variable drawn from some fixed distribution (b), then one obtains the power law distribution of city size as a natural consequence of the dynamics.

Consequently, the population fluctuations of various geographycal regions will obey Levy stable distribution laws.

It is our belief that reasoning of this nature can be extended to provide some insight into the appearance of self organized criticality in a variety of different systems.

The emmergence of power distributions and the ensuing presence of all scales in the dynamics of these models reinforce the hope that a wide range of phenomena are treatable through the Multiscale Paradigm.

15 Conclusions

The last example is well fit to conclude with. In this particular case, the cycle of the Multiscale Paradigm is to a large degree closed:

Starting from a system which is usually expressed as a continous function governed by macroscopic differential equations, we were able to identify the relevant microscopic degrees of freedom and their elementary dynamics.

Moreover, we were able to identify the multiscale distribution of the macros (power law in the wealth) and the dynamics (non-gaussian fluctuations) governing the system.

This in turn showed that much of the salient dynamics is inependent on the microscopic details and on the external influences.

This justifies a posteriori considering a closed system and using simplified laws which ignore finer levels (psychology of investors, way of transmitting sell-buy orders etc.).

On the other hand the very successes of this model highlight its limitations: no dramatic progress was achieved in predicting in detail the next market trend: we only get an averaged , if nontrivial prediction capability.

Yet, one cannot be but encouraged of the very applicability of our methods to such a range a problems usually outside the grasp of the quantitative natural sciences.