INFORMATION –SYMMETRY AND FEYNMAN-DIAGRAMS APPLIED TO COMPUTING MODELS

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ABSTRACT

The evolving complexity of modern technologies brings new concepts, solutions, tools, but also new needs and problems. We review a computing and communication model inspired in physics, to examine complex systems under a perspective of physics-inspired principles like symmetry and conservation-laws. Aiming to help design, build, and control systems, we apply concepts like Information-Symmetry, propagation of information, or inertia to model communications. Modelling computing under physics reactions and conservation laws gives tools to automatically audit each process and create side effects on deviations, bringing advantages in verification, security, and to gain reliability. We review the Feynman-diagrams in computing, rotating diagrams to obtain reversible operations from one formula, and using the diagrams to verify consistency against a unique computing expression. Applications include dealing with data uncertainty, we show advantages to control fuzzy systems and reduce dataset needing further screening. Model and diagrams are proposed as tools to help automate and refine designs, and to gain in reliability.

KEYWORDS

Unconventional Computing Model, Inertia, Data Communications, Symmetry, Reliability, Cloud, Fuzzy.

1. INTRODUCTION, RESEARCH PROBLEM

The evolving complexity of modern technologies brings new concepts, solutions, new tools, but also new needs and problems. Analysing or implementing complex systems, cloud, security… often needs complex techniques followed by new failures or delays in adoption.

Reliability and security in the computing and communications revolution had choking errors in the memory of all: Spacecraft crashing on Mars due to data-unit mismatch 1989; a Bank trader losing billions dollars in 2008 without triggering proper security alerts.

We can learn how the industrial revolution had disasters but gradually put safeguards in place: Mines use chemicals to trigger alerts; Dams have water escapes to prevent collapsing. Could we apply these lessons to speed up solutions on new computing and communications paradigms?

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2. OUTLINE OF OBJECTIVES

Let us consider reusing concepts from chemistry, physics, and mathematical tools proven for centuries to study Nature. For instance, let us apply "conservation principles" to information.

A goal is to have intuitive tools to deal with problems. As humanity developed principles, laws, models, concepts to study nature, as children grasp quickly the intuition of inertia (conservation of physical momentum). Could inertia be useful to model information-propagation as well?

Another natural or intuitive concept from daily life experiences is that a change or action does not occur isolated but always bring some side effect. Could this help us to gain reliability?

Long-term goals of the research were: i) to study the Nature of Information; ii) to build a Multi- disciplinary Model; and iii) present concepts in practice to help develop and verify applications.

We review an Information-Symmetry model where any change generates and sends side effects. Side effects can build reliability as done in chemistry or mechanical engineering: any deviation in the sum of computing-side-effects will get automatic alerts or even stop a system for safety.

3. STATE OF THE ART, EVOLUTION OF QUANTUM REVERSIBILITY

The observation of nature inspired this research, while searching new perspectives found among historic papers of Fredkin and Feynman strikingly powerful concepts worthy to revive here.

Reversibility appears early in Feynman Diagrams [1] of physical processes: where one formula describes several different processes depending on the time relations of the variables (Section5).

The Conservative logic [2] modelled reversible logic gates using Billiard Balls. That computing model conserved kinetic momentum: a billiard table where the balls are carry data and their interactions do the logical operations. This was reversible: could obtain inputs from the outputs.

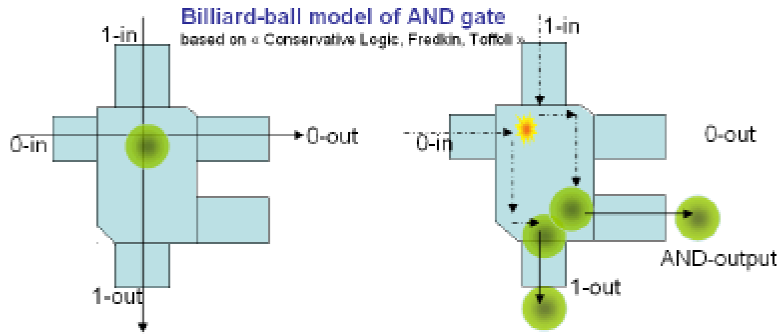

Fig.1, Billiard-Ball model, Fredkin-Toffoli gate modelled after physical balls' collisions

The Information Mechanics unconventional research on complex systems included chemical-reactor of computing and the amorphous-computing [3], and borrowed ideas from physics to use S-Matrix, Temperature, Entropy, Conservation and Symmetry.

A nature-inspired model [4] formalized the mathematic equivalence between computing meta- model frameworks (State Machines, Turing,) and the use of modelling-Particles and reactions. The "particles" model signals and states, and each "change" or "interaction" models a process.

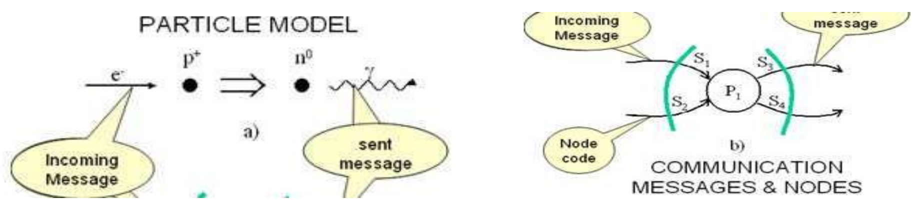

Fig.2. Mapping between Particles & Reactions and computing Data & Processing

In such model, a designer can create specific reactions to govern her system, not just kinematics, electrical, or nuclear reactions. Communication networks [5] are also seen as functioning by chaining actions or changes in sequence, in more or less planned manner: combining modelling- particles, their interactions (reactions), and governing laws (like physics & symmetry laws).

Other nature examples from Brownian motion to fuzzy bee-swarm [6] helped solved problems. As recent works bring results from security [7] to fault-tolerant [8], this paper applies the geometry, symmetry and conservation laws for their use in reliability.

Feynman diagrams was applied in rotation of computing functions [9] and collective analysis of cooperative phenomena with a similar methodology to the used in the many-body problem [10].

Inspired in works on Quality [11] network applications [12][13] and conceptual maps [14] we highlight uses of location, dimensions, and concepts like inertia in communications [5][15].

4. Methodology and Model Review

The research methodology covered the stages: i) state of the art; ii) investigate and propose generic models; and iii) apply or put in practice models for current problems in computing.
Let us start reviewing the reference models [4][5] and explain how to treats computing systems under the prism of 1) Change as Reactions, 2) Values as Dimensions, and 3) Conservation & Symmetry, in a 4) Cyclic equilibrium or feedback.

We start in sequence since any goal - whether a Cloud Deployment or cooking an apple-pie – needs a sequence of actions to carry out. Each of those actions modelled by a "reaction".

4.1. Step 1: Model each change with a nuclear-like reaction.

We model each change with a *reaction:* with *modelling particles*, *interaction zones*, and *rules*.

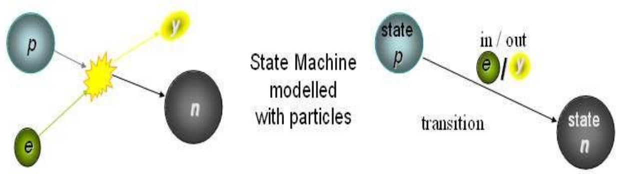

Fig.3. The reaction p e → n y (left) models the change in a State machine (right).

It was shown formally [4] how *interaction zones* model process executions; the *rules* model the program or algorithm; and the *particles* model inputs, outputs, code, signals, states, …
For instance, the reaction bellow models the operation of calculating an angle´s cosine. The formula shows original states (left), a change (→), and final by-products (right side).

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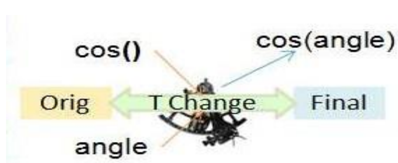

Fig.3. Reaction: angle cos() → cos(angle) .
Value Function Change Value

Here, a particle models the origin or input (angle), another the function (cos), a third particle models the final output value. The interaction or collision ( ) models the change, or execution.

4.2. Step 2: Model data-structure using dimensions and geometry.

In the model, each observed particle e has tag and values: e ∈ T x V = X_1 x X_2 …X_N. Tags model precedence relationships (time…). Values model any possible parameters including: data-type, cloud-zone, membership, version, code, laser-path, node-type,…

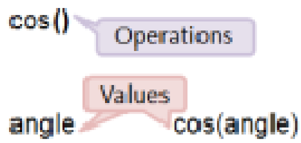

Fig.4. Dimensions Angle.type=”value” Cos.type=“operation” .

Each data parameter has an axis (Xi) so modelling-particles move in a multi-dimensional space.

4.3. Step 3: Control by conservation and symmetry laws. Use Side effects.

In nature, the reactions conserve certain sums of charge, energy, momentum… The total sum of values (charges, energies…) remains constant adding inputs and in outputs. Chemists utilize such conservation laws in order to plan and control the products they want to obtain.

In our model, a designer controls system behaviour and outputs using similar conservation laws. A programmer focus on certain magnitudes (e.g. monetary value), aggregate them regularly, and enforce its sum unchanged (conserved) in the outputs otherwise generate a side effect (alert).

For instance, a designer aiming to build a reversible system could set a law to conserve the total amount of information. In the example, that law will force emitting a side-effect particle: sin(a):

angle ReversibleTrigonom() → cos(angle) sin(angle) # added sin

This permanence or conservation of magnitudes on interactions models the system-control. The modelling-conservation-law lead to the new particle and to achieving the goal of reversibility:

cos(angle) sin(angle) → angle ReversibleTrigonom() # reversed

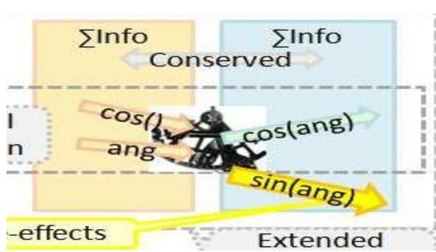

Fig.6 Conservation of information to compute cos(a) computes also sin(a) as a side-effect. The computation of cos(a) is reversible when from the outputs (sin, cos) can infer the input angle.

Conserved magnitudes relate to reversibility and “symmetry” as in physics Noether’s theorem [15], understanding symmetry as the invariance of a function respect to certain parameters.

In this model, if the computing system had a certain sum of X values, and sum of Y values, a designer combines and create the modelling conservation-laws that enforce business goals.

4.4. Step 4: Cyclic Interrelation. Propagating side effects and feedback.

Cycles occur in nature, often because conservations of overall magnitudes coexist with local changes, as resonances respect to local values. Water waves are cycles of local water level while the overall level in a lake remains permanent (conserved). This allows modelling radiation and propagation as change simply seen from a space reference framework.

These concepts fit well to networking and data communication as we model transmission, radiation, or communication. In a lake, the sudden change of water level in one coast travels (or propagates) to other coasts in waves. This propagation, seen as the conservation of “local change”, allows designing and implementing two separated parties that communicate.

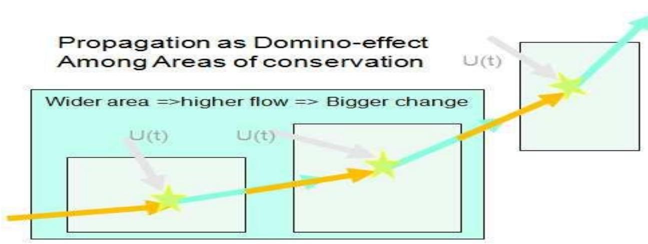

Fig.7 Domino, The cloud nodes (interaction zones) propagate the change if the reactions leading the system are independent of the node index, or equivalently set a law conserving ∑p total momentum. The system defined is then symmetric respect to translation, among nodes i.

5. INFORMATION-DIAGRAMS. FEYNMAN-DIAGRAMS OF INFORMATION

In physics Feynman-diagrams [1][9][16], each diagram rotation represents a different process:

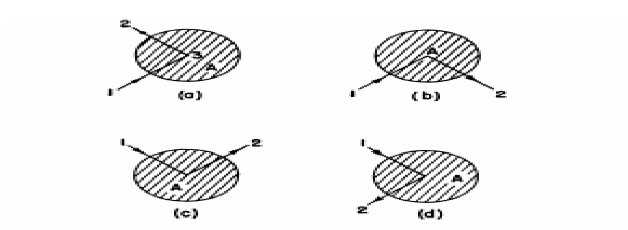

Fig.8. the four processes shown in 1949[1](pg753): (a) An electron at 1 will be scattered at 2 (and no other pairs form in vacuum). (b) Electron at 1 and positron at 2 annihilate leaving nothing. (c) A single pair at 1 and 2 is created from vacuum. (d) A positron at 2 is scattered to 1.

When we model computing with reactions, similar diagrams can apply. Remember observed-particle model computing objects including data, states, codes, signals… and the interactions model the operations, the changes.

Consider a basic number-increase function, as inc(5), also think of a finite state machine where a signal *inc* brings the state 5 into a state 6. Both modelled by one reaction:

Six = inc (Five) # Written as a function in a code

5 Inc> → 6 # As a Reaction. Modelling: FSM, Turing, …

This reaction corresponds to the Information-Symmetry diagram in Fig 9, upper left. Just rotate one diagram and you get new processes including b) a comparison > ; c) a decrease, or d) dissecting 6 into its components (5 & inc). This shown in a symmetry reversible Feynman-like diagram with the fours processes corresponding to one unique reaction:

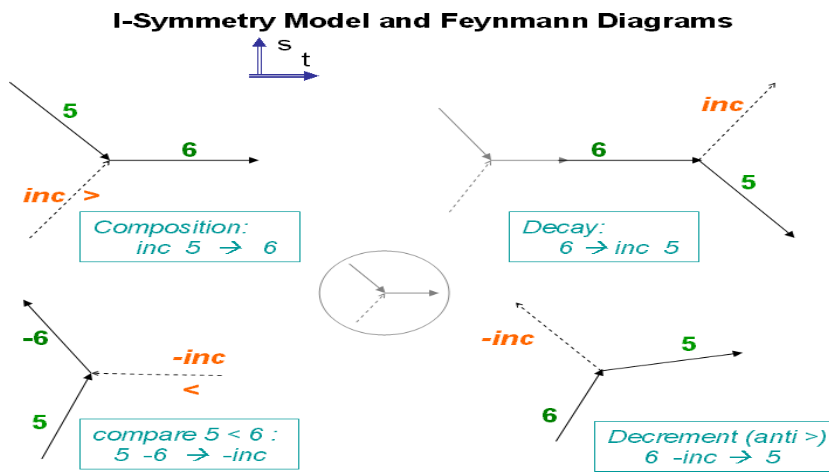

Fig.9. Feynman diagrams employed to modelling information, the diagrams enforce coherence among an operation (inc 5 → 6) and its mirrors (dec 6 → 5) or (6 → 5 +) …

Having different operations represented by a unique formula allows checking for coherence, and automatically verifying consistency. In software development, the Feynman-diagrams rotation let us generate related operations based on one canonical formula. For instance, to declare just the increase operation and automatically have the system able to decrease, and compare values.

In systems, a proposal is to use Feynman-like Information-diagrams to verify consistency and reversibility. E.g. Define a server-commissioning operation, then use diagram rotations to verify or calculate decommissioning and checking operations based on the same unique operation.

6. APPLICATION OF THE REVIEWED MODEL TO DIVERSE AREAS.

A practical application of the model in examples aims to serve multiple paradigms, a proposal to model advanced computing under the perspective of reactions and conservation laws.

6.1. Step 1: Model changes with reactions and output particles.

Inspired by nature and the physics-based model, a first step is to see each process or change as a reaction and account all reaction products as modelling-particles as well.

For example, a cloud node booting could simply leave a logs message as a forgotten entry in a log … instead, the model sees the message as a modelling-particle it is able to interact further. The up message is broadcasted to nearby monitoring nodes, indicating the node is up. NodeX_IsDown Start_Boot → NodeX_IsUp Signal_Up Signal_Up' ..

As other cloud nodes interact with the message, the system can constantly account sums and side effects for feedback and learning. Here is how a watching-node keeps system status as each node sends a heartbeat to neighbouring nodes:

Signal_Up WatchingNode_Sum7 → WatchingNode_Sum8

6.2. Step 2: Model data dimensions and geometry.

Model each parameter with an axis X_1 X_2 … X_n in n-dimensional space. Thus, we can represent a computing node existing in a space with several axis as follow: $x_1 \in X_1$ = *Environment = { TEST, PROD, DEV …}* ; $x_2 \in X_2$ = *Location_Axis = { Chicago, DR, Tokyo…}*; and $x_3 \in X_3$ = *{ Web, Database, Security…} = Application_Axis*

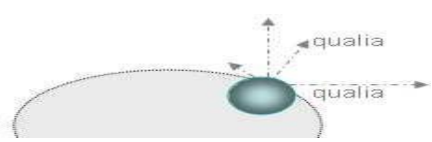

Fig.10. Model nodes as paticles with multiple dimensions.

6.3. Step 3: Aggregate values, Control with conservation-laws (Symmetry).

Consider adding-up the side effects of multiple processes. Design laws or interrelations between the particles. Search or Set conservation-laws where possible.

For instance in 6.1, let us verify cloud status quickly: Instead of checking all nodes in sequence (Fig.11 left), we can now track the total sum of messages received by watching-nodes. The variations detected between watching-nodes points to which cloud sub-zone might have issues.

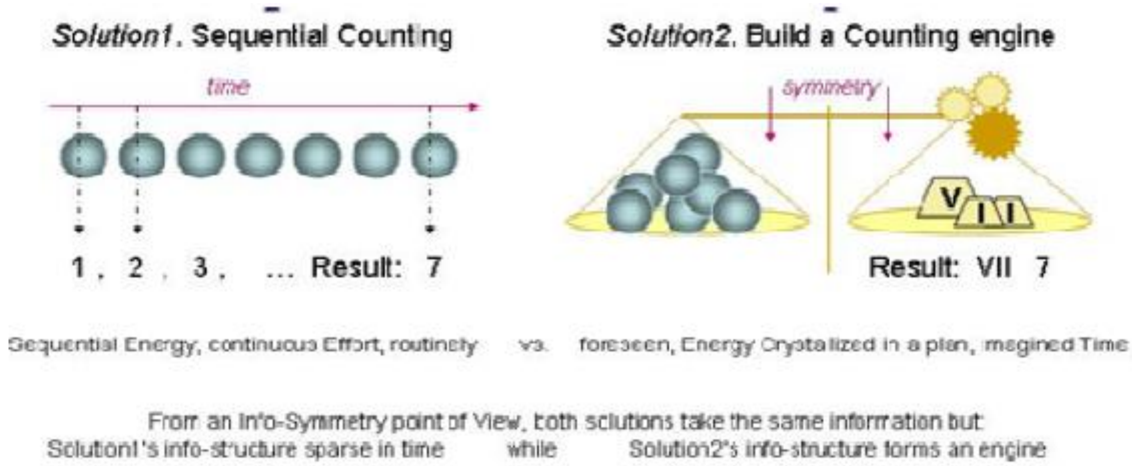

Fig.11. Sequential Counting (left) vs. inferring the count from total weight conservation (right)

For instance in 6.2 we can have: An architect sets a model-conservation-law asking for each production node to have a corresponding or mirror node in the TEST environment.

Conservation Law: Sum of Nodes Type TEST = Sum of nodes Type PROD

$$|\{ x \mid x_{type}=TEST \}| = |\{ y \mid y_{type}=PROD \}|$$

An advantage of this systematic approach – i.e. highlighting goals and constantly aggregating or auditing the system - is a simple and transparent way to control closeness to business objectives.

An example: A node computing a bank transaction can track the monetary value of inputs and outputs, sum value should be equal in input and output (conserved) to avoid leaks in the system.

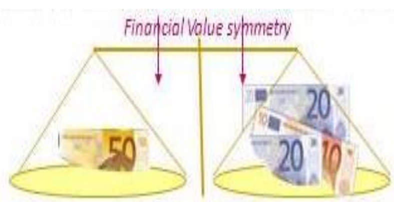

Fig.11. Parts-Whole[s]. Adding the monetary values in an aggregation perspective.

In the example, the total monetary value remains constant. Symmetry, understood as invariance of functions from certain parameters, leads to conservation as showed in physics. This symmetry between changes' causes and consequences, not just between values, serves with the intention not to reverse a process but to infer inputs from all outputs (automatic audit).

6.4. Step 4: Cyclic Interrelation. Propagating side effects and feedback.

A designer can "Code by Goals" by setting conservation laws on the modelling reactions. A law to conserve Momentum, INC=1, leads the system to generate numbers in loop as in the figure. Changes (aka action, impermanence) model time evolution, each step is a "reaction" in a chain.

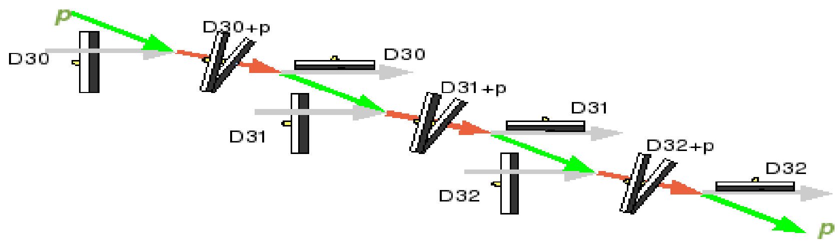

Fig.13. Cyclic Chain of Feynman-diagrams in a Domino Effect. A goal to increase numbers just need a conservation-law like INC=1 and numbers increased by one with each reaction.

In this example, one conservation law like INC=1 remains invariant symmetric in space and produces a move of particles. The conservation law designed here does embed the goal in the system and drive all behaviours from it: A loop to increase a variable automatically.

7. APPLICATION OF CONSERVATION IN RELIABILITY.

One benefit of bringing symmetries to advanced computing is analogous to how physics-laws help in engineering: fast, scalable, and reliable (e.g. build double-checks using weight-balance).

Section 6 and 8 apply side effects to enforce goals over errors. The designers embed goals in conservation laws, stressing the project's success despite commonly encountered errors.

Conservation laws gives a similar advantage to that exploited by physicists or accountants in their fields: gaining in reliability and tracking. The aim is to automate double-checks; have system feedback; gain reliability; reduce delivery time.

Mechanical engineering learned from experience, today no bridge will collapse due to small vibration at the wrong resonance rate. Is computing so robust to errors in small areas?

Consider when a bridge is about to crash, side effects like noises and jerk shakes alert us that something is wrong. This model proposes to account side effects in computing and leverage them to constantly account for Information-Symmetry and alert automatically if fails.

In communications, the side effects can avoid losing important alerts such as "message not send". Such alerts often do not arrive to the concerned sender or operator. We see how software needs constant revision, such as including alerts to prevent users from forgetting an attachment.

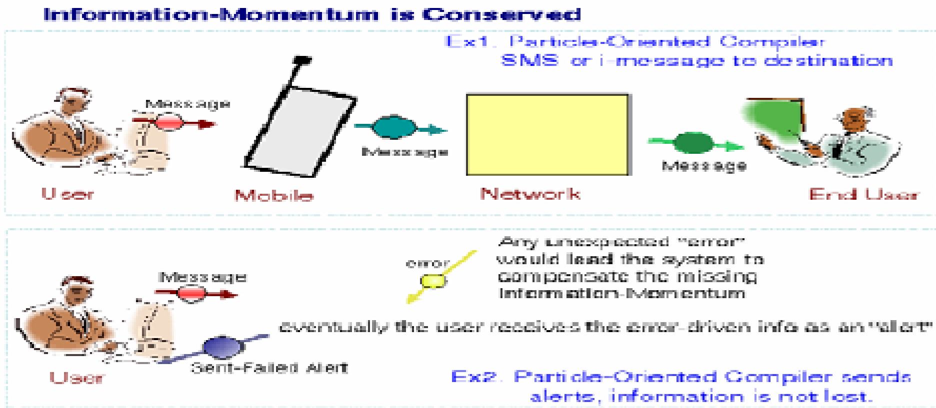

Fig.14. Communications. Conservation of inertia or "momentum of information"

The symmetry model helps when the designer did not foresee the trigger of an issue, as follows:

a) A designer quantifies business-goals in values like “message-sent”; b) The system keeps on accounting for such goal values automatically … and c) as soon as a message-sum conservation fails, the system creates and propagate an alarm automatically. Hence, following those steps and model, a system detects an issue impacting business goal even if the cause was unexpected.

8. Applications of Side Effects When Modeling Uncertainty.

Research of uncertainty [17] include exploration of Fuzzy versus Quantum [18], photonics [5], physics [19], studies on Quantum Probabilities and Logic [20], and fuzzy bee swarms [6]. As Fuzzy sets help dealing in analysis of data, we research how to apply the model to uncertainty.

In a basic example of how Fuzzy sets can use this model starts with the goal to classify a list of academic institutions by location. Let us start by a dataset clustering by city. A complexity comes from having institutions address with typos or other details leading to the wrong location.

Among many good fuzzy tools, this example uses the python library fuzzywuzzy [21], which compares two strings giving a fuzzy matching value of one string being contained in another. It should give almost 100% if we ask if “University of California, Berkeley” is in “Berkeley”.

8.1. Modelling change by reaction.

First, computing the membership of a data series will give not just the fuzzy membership value, instead the model make us ready to have some side effect able to reconstruct the input.

InstitutionX InCityYcluster? → XmemberOfY% side_effects … # reaction R1

XmemberOfY = process.extract (CityY , InstitutionX) # python fuzzy modelled by R1

8.2. Modelling dimensions and geometry.

We use several dimensions X_1 X_2 X_3 … to model data. Thus, an institution might have in X_{23} the fuzzy membership to Kiev, and X_{22} the membership to Kyiv, and so on …

The geometry allows non-orthogonal axis $X_2 \supset X_{21} \cup X_{22} \cup X_{23}$, meaning X_2 Ukraine includes all cities. When the data analyst realizes X_{22} and X_{23} are the same city could merge both axis.

Dimensions therefore include layer, abstraction level, relationship … and such geometry can model architectures, modelling-zones interconnection, or visually organize the data.
In the example, a fuzzy membership to city by simple matching to word (Kyiv Kiev) has the strong membership only for institutions names containing Kiev or Kyiv:

Table. 1. Fuzzy Membership to Cluster Kiev

Full Name Institution	**Membership to Kiev Kyiv**
Taras Shevchenko National University of Kyiv	.86
Kyiv National University of Culture and Arts	.86
National Univ of Life and Environmental Sciences of Ukraine	.48
Wisconsin International University in Ukraine	.48
Open International Univ of Human Development Ukraine	.48

Fuzzy grouping by country X_2 the "Wisconsin International University in Ukraine" has a direct strong membership in X_2 (Ukraine):

Table. 2. Fuzzy Membership to Cluster Ukraine

Full Name Institution	**Membership to Ukraine**
Taras Shevchenko National University of Kyiv	.31
Kyiv National University of Culture and Arts	.51
National Univ of Life and Environmental Sciences of Ukraine	.60
Wisconsin International University in Ukraine	.90
Open International Univ of Human Development Ukraine	.60

The membership to USA should be in another axis X_7. The clustering problem in the example institution is that seems to be in two countries: high memberships in X_2 and X_7.

8.3. Controlling with customized conservation-laws.

The symmetry-model allows a designer to create conservation laws on certain sum of values. A designer combines and create the modelling conservation-laws that enforce business goals. In this example, we want to control each institution is in one country only. The fuzzy designer can customize a relationship of values Xi and Xj to make both incompatible. A way to do this is to constraint that when Xi is high then Xj needs to be low. Such combination in fuzzy methods [23][22] is modelled here under the symmetry perspective as tool to help design systems.

This example verifies if a behaviour aligns well with the business goal. A designer will create a repulsive force that forbids classifying an institution in two countries Xj and Xi (e.g. Ukraine and USA) simultaneously. A designer sets the one-country restriction with a conservation law:

$$\text{Sum} (\ldots X_i + X_j + \ldots + X_n) < 1.5 \quad \text{\# Sum under 1 with some Fuzzy-Margin}$$

The conservation of values relates to humans recognizing the patterns in nature. It appears in the history of science as far as the Archimedes principle of conservation of water volume in a basin. Exploring interactions we observe how certain aggregation of magnitudes remain unchanged.

8.4. Leveraging Side Effects

In this example, what happens to the clustering of this institution *x?* The membership to USA x_7 is high, and so is to Ukraine x_2. As the system computes the sum of values and compares it constantly to our laws, it soon detects a break in the conservation law:

$$x_1 + x_2 + x_3 + \ldots + x_6 + x_7 + \ldots < 1.5 \text{ \# Set conservation law Ad-hoc.}$$

$$0.1 + 0.9 + 0 + \ldots + 0 + 0.9 + \ldots >! \ 1.5 \quad \text{\# It breaks a conservation law!}$$

In physics, and in the symmetry-model reviewed in sections two and three, an unbalance creates a new particle in order to compensate and comply with the designed conservation law. Hence, the example needs a side effect particle and a special axis X_w (w Warnings). The conservation law forces the value to be in a negative range in X_w in order to comply with the designed law:

$$x_1 + x_2 + x_3 + \ldots + x_7 + \ldots + x_w < 1.5 \Rightarrow X_w \sim [-1 , -0.8]$$

In practice, that side effect, that particle with negative Xw, is simply a warning raised to the rest of system to alert something when wrong. We can feed the alert back to the system or use it.

Those “particles” are simply negative values showing in the operator logs, those highlight the few institutions needing manual classification, often needed in fuzzy sets for clinic studies [23].

The advantage of applying this model on top of existing fuzzy systems is that it gives a method to reduce the population to screen to a small set of institutions that “broke conservation laws”.

9. CONCLUSIONS

The research expanded on the physics based modelling, reviewing the changes or reactions, and conservation laws. The modelling geometry can convey not only architectural information but also type of service or abstract concepts we can later aggregate.

Designers can set conservation laws to plan and drive their systems. The model and diagrams proposed here are tools to help automate and refine designs, and gain in reliability. Applications include networks, clinic uncertainty studies, cloud computing, and in general, reliability.

These historic physics concepts could simply reflect how humans see the world. We use this as a way to explore the nature of information, and as an intuitive tool to design, build, and operate.

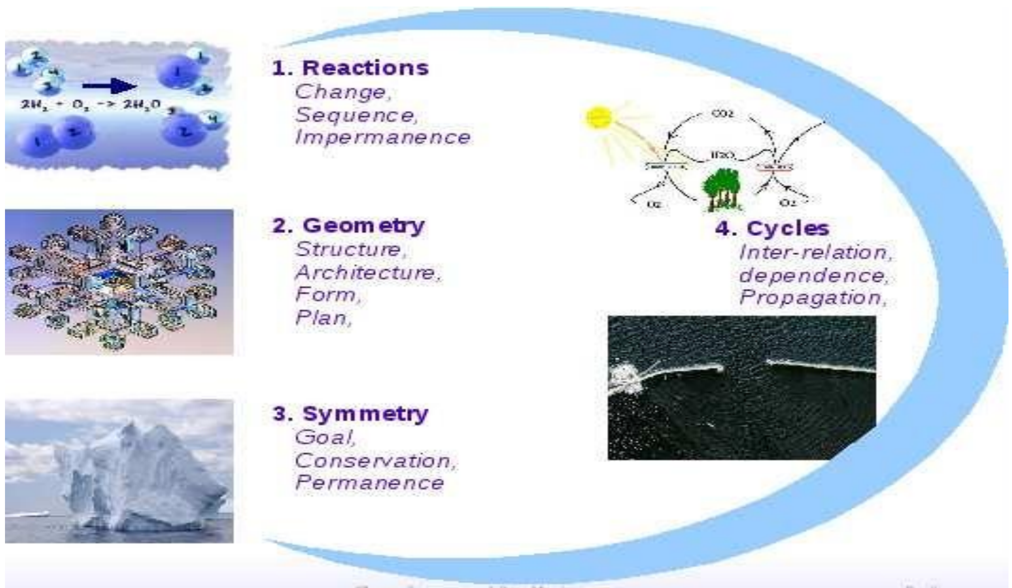

Fig.15. Information-Symmetry Model concepts: Reaction -> Geometry -> Symmetry -> Cycles.

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