

Information Physics: Towards A New Conception of ‘Musical Reality’

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Abstract: For modern science information is not simply considered as just what we do not know. From entanglement and quantum mechanics to black holes it plays a fundamental role. It is a physical quantity which uses matter for its embodiment and energy for its communication. The concept of information can be used to ‘decode the reality’, to explain the formation and action of entities, from molecules to galaxies. Entities exist as long as they have boundaries. Which are the informational, energetic and material boundaries of music entities? How modern science can describe the unfolding of musical events? Is it valid to talk about fields in music and which are the attractive and repulsive forces? Is the distinction of musical past, present and future a convincing ‘illusion’, as it is for physicists? And mainly, which is the role of information while creating music structures?

Keywords: Entropy, Information, Music Analysis, Music Entity, Music Structure.

I. INTRODUCTION

The concept of information has been strongly related to the study of music. Information is a useful key to examine all the steps of a music procedure, from its creation and its transmission to its perception. The significant development in the field has been made by Claude Shannon, who came up with the idea of measuring the quantity of information by considering the message's predictability, its surprise value [1]. Apart from the obvious engineering applications that revolutionised the modern music industry (music data compression methods, such as .mp3 or .wav, sharing of music files through networks, error-correcting coding through transmission, etc.), Shannon's work inspired a wave of interest in applying information theory in music studies. This connection has been primarily made by Meyer who related entropy with meaning in music. He postulated that high entropy (uncertainty) engenders greater subjective tension, which is correlated with more meaningful musical events. [2]. Researchers since then used information-theoretic concepts and methods not only to analyse music but to generate new compositions as well [3] [4].

Another promising field which connects music with the concept of information is that of ‘Music Information Retrieval’ (MIR). In the case of MIR, information is considered to be what a computer doesn't know. Simply put, MIR algorithms allow a computer to recognize features of sound and music, such as tempo, key, chord progressions, genre, or song structure. The computer learns how to ‘listen’ and ‘understand’ audio data, in an effort to reduce the semantic gap between high-level musical information and low-level audio data.

Every consideration of information that has been described departs from the notion of ignorance, being the answer on what we don't know. And we don't know what we cannot predict. Probability is then the basic concept in order to define information. All it is needed is a certain randomness, some uncertainty as to the outcome of what is described.

Although the same term is used and there is a profound conceptual relevance, modern science has expanded its consideration of information. Many scientists, regard information as a physical quantity which is the foundation stone of

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physical systems. Rolf Landauer, a German-American physicist, stated the ‘Information is physical’, [5] a statement that has been successfully experimented [6]. Lloyd, a professor of mechanical engineering at the M.I.T., supports that ‘merely by existing all physical systems register information’ [7], a similar statement with the Wheeler’s famous doctrine ‘it from bit’ which ‘symbolizes the idea that every item of the physical world has at bottom — a very deep bottom, in most instances — an immaterial source and explanation’, suggesting that information is fundamental to the physics of the universe. [8]

In this paper we aim to examine what insights the new notion of information as a physical quantity provides in order to enhance our understanding of ‘entities’, utilizing the case of music.

II. INFORMATION IS PHYSICAL

Our understanding of our material world is mainly explained through the Newton’s mechanical conception. According to that, everything that exists is matter, which moves on the fixed stage of space according to deterministic and reversible laws, in step with universal time. That means that if an agent knows the state of reality of a system, having a ‘God’s Eye’ view, can have, due to determinism and time reversibility, perfect knowledge of the past and of the future of the system as well. In that case the concept of information is redundant at a fundamental level. Does this perfect predictive power mean that the future of ourselves, our world and the universe is already planned and specified? Obviously not. That is why, since 1850, due to the rapid advancement in fluid mechanics and the proponent of chaos theory, the Laplacian determinism has been challenged. [9] The connection of mass, energy and space-time in the theory of relativity of Albert Einstein, made the perception of compact mass to be gradually abandoned, whereas the term ‘matter’ started to give its place to measurable manifestations of mass (inertial, gravitational etc.). The probabilistic foundations of quantum physics were linked to uncertainty, whereas the thermodynamics consideration of entropy (the negative information) drove to new scientific orientation towards the fundamental question of what is real. From that conceptual procedure information has been established as a crucial physical quantity in line with mass and energy.

In recent physics the concept of information is fundamentally important in our understanding of the physical world, being at least as important as the concepts of space, time, mass and energy or maybe even more. Information physics are thought as an umbrella that can capture the essential idea of the unification of quantum physics with general relativity. [10] The intriguing research fields of quantum entanglement and black hole’s information paradox are examples of that perspective.

III. ITFORMATION AND INFORMATION

A. *ITformation vs Information:*

Where the laws of nature came from? Why molecules have certain structure? Why symmetries are observed in the whole universe? How much does the genetic material determine, according the macroscopic features of beings? These questions have a profound philosophical aspect. However, there is a conceptual equality with the question on whether information is a product of physics, or information comes before physics. Modern trends at science tend to vote on the second. Vedral claims that if information indeed underlies both quantum physics and relativity, then we should put information before physics (‘it from bit’ as Wheeler suggested). [10] Davies proposes a new conceptual tool which instead of having mathematics as starting point, then the laws of physics and at last information, it appears reversed with the following hierarchy: information -> law of physics -> matter. [11]

That approach implies that information is built into the future, generating the algorithms that give form to entities, offering the formative and instructive functions. In order to discern it from the engineering aspect of information (C. Shannon theory), Cambourakis proposes the term ‘ITformation’, as the notion used by Wheeler, Davies, Landauer, Vedral et al. This term is closer to the original Latin word ‘informare’ which means ‘give form to’. ‘*The etymology thus connotes an imposition of structure upon some indeterminate mass.*’ [12] ITformation is that which supplies with the instructions which give form to the ‘It’. On the other hand, Shannon’s definition of information deals with the propagation of a message - produced by the transmitter and received by the receiver – through a channel. Information could be thought in a simplistic way, as the ‘current’ produced by moving ITformation. For example, ITformation defines

the way a music entity is structured, why there is a certain sequence of notes as it is notated in a score, whereas Shannon's information studies the transfer of the musical signal through a channel (commonly air or cables).

B. ITformation creates fields:

ITformation creates fields. A field is the space where forces act and therefore events may potentially happen. In a field energy and matter can be produced. Experiment and theory imply that particles are epiphenomena arising from fields. [13] ITformation is consequently connected with the potentiality of events to occur, usually well-orchestrated. For example Wheeler studies electric fields without electrical charges (wormholes). In our modern world 'there is nothing counterintuitive about the ontological idea that nature is built – not out of ponderous classically conceived matter but – out of events, and out of informational waves and signals that create tendencies for these events to occur.' [9]

In the micro – level of music composition, we should consider each note as a creator of a field. Each field is the place where potential events could happen. Then which notes can follow after another note? Through the potentiality being created in the above mentioned field which repulsive and which attraction forces can be created between notes? Every culture and style has its own answers to that question. For example, for western classical music the musical interval of the fifth is by far more likely to appear, than that of the tritone (augmented fourth) which was characterized as 'The Devil in Music' (diabolus in musica). [14] Moreover, the leading tone is almost certain that will be followed by the tonic. We could say that the field which is created by the informational content of the western classical music entities creates attraction forces between the tonic and the fifth (C-G), or the leading tone and the tonic (B-C), but repulsive forces between the tonic and the note a tritone above (C-F#).

In order to clarify better the concept of the field we will present a chord progression assistant which is depicted in the following picture.

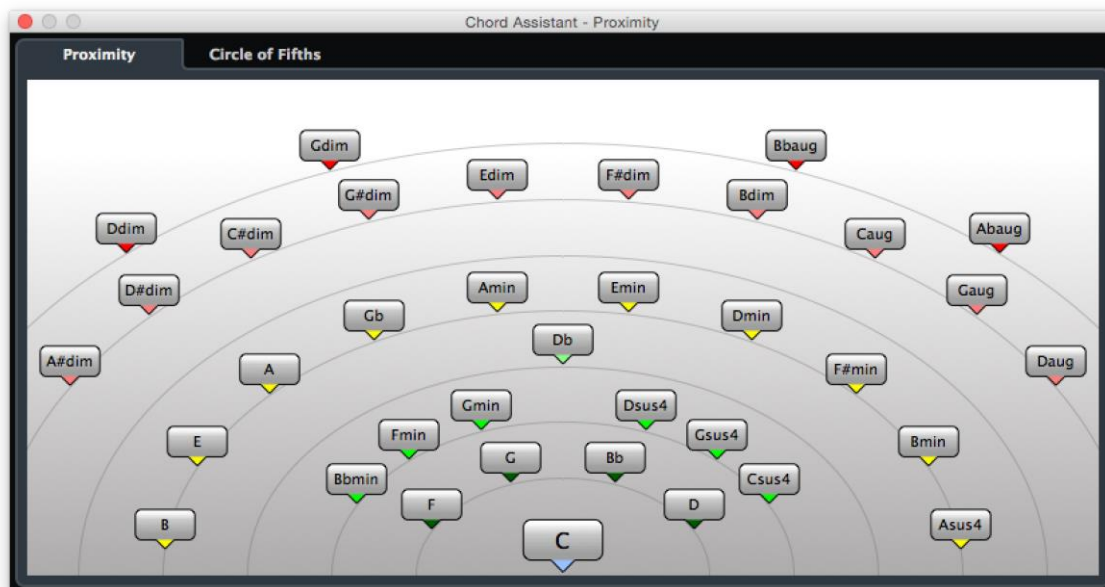


Fig. 1 Steinberg's Cubase 8 Chord Assistant. An example of 'field'

It shows how close chords are in relation with a reference chord. The origin chord acts as a starting point for a sequence of chords. Chord assistant suggest chords that possibly follow the origin chord, considering a set of harmonic rules. Basic relations like tonic, dominant and subdominant are close to the reference chord. More complex variations are shown further out. Proximity chords are of less complexity than those suggested chords further away. As these chords suggestions radiate out the complexity gets more intense. [15] We notice that if a complex chord, unrelated with that of the origin, tries to approach that origin chord the repulsive forces will 'send' it further away from it. On the other hand, attractive forces will keep the chords that are near to the origin in proximity with that. These are consequences of the ITformational field that is caused by the chord of reference.

structure. The guidelines, the manual, the algorithm for the formation of that structures are given by the 'ITformation'. A score is a way to notate the guidelines of the ITformation of a music entity, to store it in memory. ITformation is a timeless quantity. It provides indexes of certain events. It creates the field, the potential, but not the 'current itself'. The stored ITformation in a music score provide the guidelines of the musical events but not the music itself. As soon as the musicians start to perform what is written on the score, then we can talk about music. The guidelines of the score are the 'ITformation', whereas the propagating musical signal through a medium/channel, is the Claude Shannon's information.

IV. ITFORMATION AND ENTITIES

A. Defining the Entity / Boundaries:

The underlying idea that has been described in this paper is how information is related to the formation of the entities. Which are the main conditions in order to define what 'exists' and is formed as an entity?

Existence for most of the sciences is a de facto assumption. Cells, organisms, planets, buildings are presupposed to exist as entities. It is not easy to decide if fields and waves do exist as entities. We do not have a criterion for categorizing and separate entities from concepts (noumena in Kantian terminology). This in many cases creates paradoxes (e.g. Aharanov-Bohm effect/paradox) [17].

In general, as an entity we can define anything that is capable of existence. The characterization of a thing as an entity implies its distinction and individuality. Whatever exists has a start, an endurance and an end. In other words, 'it has confines (boundaries), so it exists'. Departing from the famous 'Cogito ergo sum', Cambourakis phrases 'Habet confines ergo est'. Therefore, the basic criterion to regard something as an entity is to have confines (boundaries). [18]

Information (more accurately, ITformation) is neither matter nor energy, but it uses matter for its embodiment and energy for its communication. Therefore, it is valid to state that entities can be comprised of a) matter, energy, ITformation, (e.g. all entities in the material world) or b) energy, ITformation, (e.g. waves) or c) only ITformation (e.g. laws of any kind, words, music pieces etc.). Since every entity has confines (boundaries) it has to be embedded in some topological manifold or in other words in space. It can be proved that an entity has a different boundary for each flavour of its substance (i.e. an ITformational boundary, possibly an energy boundary and sometimes a material one). We cannot have a functional insight in an entity without an adequate estimation of its boundaries.

Szilard and Landauer have given a correspondence relation between energy and information [18] while Einstein has established the energy mass equivalence. ITformation creates fields and in fields matter can be created. [13] Each boundary can be placed in the light cone as it follows:

- Material boundary is subjected to time-like procedures ($v < c$)
- Energetic boundary works up to near light-like ($v = c$)
- IT-informational boundary can be in the space-like domain ($v > c$)

In the third case the only component that can perform space-like actions is ITformation as information is usually encapsulated in messages carried by energetic or material agents. So an entity can perform actions (interactions) in different domains of space-time simultaneously, although simultaneity is something that needs special attention in this case. If two events are time-like separated they are well-ordered (one always comes before the other, just like the sequence of a sonata form in figure 2), but if they are space-like separated, there exist reference frames, just like the indexes of events that have been described above .

The boundaries of an entity can be, as already stated, material, energetic and/or ITformational. Although it might be difficult to trace them with accuracy, such that of a cloud or the informational boundary of the discography of Beatles, they do exist. Otherwise, their distinctiveness would be at risk. Distinctiveness is by definition prerequisite for the consideration of entities. Especially, as far as entities with informational content are concerned, the difference between the terms 'entity' and 'concept' or 'essence' should be made clear. Music, literature or democracy are concepts, since they do not have boundaries. On the contrary, English legislation, French democracy, or Shakespeare's plays, have boundaries, therefore are considered as entities.

According to the new paradigm the boundaries of a cell for example, are not identical. We can discern the material boundary, the energetic one and the ITformational (informational) which is more difficult to define. The material boundary is easy to recognize as there is a membrane which separates the inside from the outside of the cell. The energetic boundary can be defined if we can measure different fields produced from a cell (or group of cells) internal activities (e.g. electrocardiogram). The informational boundary which usually extends further than the others can be defined as the space that a cell can affect other entities by exchanging information and/or ITformation. [19]

The example of the 5th Symphony of Beethoven can be used in order to clarify the concept. First of all, it exists. Its existence is proven because it can 'do things', it can interact, communicate, affect, cause emotions etc. It is still a very popular choice for all the classical orchestras, it is taught in all the music schools, even its 'brand' name is of great importance. Moreover, it is considered as an entity because it is within boundaries. Its basic substance is ITformation. That specific music piece can cause actions even when it is not performed. Its ITformational boundary is tracked wherever these actions take place. Although the field in which its potential actions occur should obviously be a huge space, it is not infinite. The number of the people who have heard of it (not necessarily have listened it), the number of musicians and music pieces that it has influenced, the references of it, although they are extravagantly a lot, they are finite. Moreover, its performance is not prerequisite for its consideration as an entity. However, during its performance, we could state that its energetic boundary is the boundary of the acoustics waves that are produced and the energy that musicians use in order to perform, whereas its material boundary is the concert hall, the bodies of the musicians, the instruments, the audience, etc.

The idea of the informational boundary has been already examined in science. The black hole physics state that the information which falls into a black hole is stored in the surface of the black hole, in the horizon. The area of the surface of the black hole is proportional to that information. This led to the idea of the holographic principle which was first proposed by Gerard 't Hooft and it was given a precise string-theory interpretation by Leonard Susskind. [20] In larger sense, this ideas can be expanded to the universe and its subspaces. The fact is that the maximum amount of information that is stored in a volume of space is somehow proportional to the area of the boundaries of the region. And that suggests in a way, perhaps metaphorically, the universe, or regions of space, are described as holograms. The holograph sets the limits of observation, the practical limits, and the fundamentals. It is closely related to the ITformational boundary, which is observed in the places where an entity causes actions.

B. ITformation, Information, Energy, Matter and Entities:

But what is the connection of ITformation and/or matter and/or energy? We have mentioned that modern perspectives of science put information (→ITformation) before physics. That means that the physical world is formed through the instructions that are defined by the ITformation and is the product of the algorithms which are created by ITformation. It is common knowledge that the structure of the genome, the sequence structure of DNA is causally related, in a systematic way to biological features, the phenotype. Evolutionary biology states that certain features had some 'inferiority' against others and therefore manage to survive through the evolutionary procedure. Because these features have been 'naturally selected', the DNA sequence from which they occur has survived as well. [21] Basically, it is the features (ITformation) that form the biological structure (energy and matter), with a top down causality, although, in order to connect the genotype with the phenotype we study that structure following a bottom up causality. Universal Darwinism supports that idea, extending the theory of biological evolution in a wide variety of other domains, including psychology, economics, culture, medicine, computer science and physics. The subset that is insufficient gets eliminated and then, whatever somehow survives, keeps coming up with new information. The underlying dynamics, the mathematical description of the whole idea, are surprisingly the same. In the October of 1994 the journal 'Scientific American' dedicated a special issue to 'Life in the Universe', examining the evolution in the Universe. It has been shown that every field (biology, sociology, cosmology, geology etc.) confirms in general the same principles of evolution. Although many studies make connections with the information theory and the evolution ([22] [23] [24]) the aim of this section of the paper is to clarify that ITformation defines its lower levels, that of energy and / or matter. A recent example of that concept is the 'Integrated Information Theory' (ITT) which attempts to explain what consciousness is and each connection with physical systems. IIT 'starts with consciousness' and describes the properties that a postulated physical substrate would have to have in order to account for it.

In music also, the music 'particles', the notes, are not themselves the absolute factor that forms the music piece. Basically, it is the pattern they arrange. An easily understood example is that of transpositions. Most singers transpose the songs in the frequency range their voice performs better. For example, the famous 'Happy Birthday' song, is of minor importance if it is played in Cmajor or in Fmajor (figure 3). Far more significant is the melodic line, the music intervals, in other words the pattern. Although, in the 'Happy Birthday' example, the notes in these two version are different, the aesthetic, cultural, social and emotional impact is (almost) the same. Therefore, as the fields of memetics and semiotics explain, it is not the notes themselves that form a musical essence, but it is the essence which describes the properties that a postulated musical structure would have in order to account for it. Another simplistic example is that of gastronomy. It is the taste you want to achieve that leads you to choose your ingredients. The ingredients serve the implementation of the idea. It is a top down procedure, although there is a profound bottom up interaction. Of course the use of sugar leads to a sweet taste (bottom up), but primarily there is the need for a sweet taste that leads to choose sugar (top down). Just like, the 'taste' of sadness leads to choose minor chords, rather than major.

Happy Birthday

Hap py birth day to you

Happy Birthday

Hap py birth day to you

Fig. 3 Two versions of 'Happy Birthday'. In Cmajor and Fmajor

C. Entities Interact through their boundaries / ITformation is a control signal:

We have demonstrated how the three substances of an entity (ITformational, energetic, material) affect one another. According to the interaction between different entities, it is obvious that each boundary interacts with all the boundaries of another entity. Some of these interactions are studied by some theories but there are still a lot to be said. For example, an electron has three boundaries with which interacts (communicates) with other particles while a photon has only two (no material boundary). So an electron and a photon have six ways of interaction, some of them trivial.

We have stated that music entities have basically only ITformational boundary. The reason is that they do exist even if they are not performed. An experienced musician can interpret musically a notation in a score without playing it, like a 'silent internal performance'. Even the mental recollection of your mother's lullaby can cause nostalgia and melancholy. Music entities do exist through their ITformational boundary, although they use energy in order to communicate. That is the energy of the acoustic waves that are produced by a (material) source (orchestra, loudspeakers etc.). Therefore, the basic boundary for the interaction of music entities with others is the ITformational.

A fundamental component of music is rhythm. The procedures maximize their additional effect when they are synchronized. From the first days of mankind, music has been developed as an indirect way to synchronize manual works, such as puddling or moving heavy objects. Through that obvious interaction of all kind of boundaries (ITformational → rhythm/music, energetic → the work of moving the object and the canoe, material → the bodies and the objects themselves), we notice that information acts as a control signal. It synchronizes procedures.

The interaction of entities requires an exchange of information (ITformation). 'It means neither more nor less than the reciprocal harmonization and coordination of processes'. [25] Information behaves therefore like a control signal. The exchange of information creates resonances, organizes structures and procedures. Of course, that exchange of information (communication) requires energy and / or matter, but these act as the carriers of ITformation.

Imagine a bunch of people who are set randomly through the place. When a music takes place there is a profound rearrangement of them. If there is a stage, people turn to the stage. If it is the occasion of a party, for example, depending

on the type of the dancing music, different patterns will occur (people dancing in couples, frequently duets of different sexes, like waltz, or circular arrangement, like Kalamatianos, the popular Greek folkdance, or solitary dance, like disco). Music arranges the vectors of the audience. This rearrangement of people -objects / matter-, due to the music – ITformation which is communicated through energy (Shannon’s information)-, is an example of boundary interaction which demonstrates the function of ITformation as a control signal. For example, if music stops, then the dance will stop. All of the boundaries are influenced. The material, because the bodies will stop to move and will follow another arrangement in the place, the energetic, because there won’t be any transmission of sound waves, and the energetic biological influence of the bodies (higher heart rate, transpiration, body temperature, hormone secretion) will start to fade out, and all of these due to the control of the ITformational boundary of music.

The ITformational boundary of the music entities does not have as effect only a kinetic synchronization. It coordinates emotional patterns, within the neurological network of neurons. [26] The composer forms an emotional, aesthetic, social, kinetic situation. The first act of control is noticed in the performer. Through the performer (s)he communicates with the audience.

V. CONCLUSION

In this paper we have described the modern approach of science about information, which is considered as physical. The term ‘ITformation’ has been proposed, in order to discriminate it from Shannon’s Information. We have stated that the basic criterion for the existence of an entity is to have confines (boundaries). ITformation is what a music notation describes. It gives the functions, the algorithms of existence. Basically, ITformation creates the field of action of an entity, through its boundaries interaction. As soon as a music entity is stored in memory (scores, cd’s etc.) is able to potentially make actions. The ITformational boundary of a music entity is exactly where this actions can be tracked. Moreover, ITformation is timeless, it offers the indexes of events. As soon as these events take place, then time is created. A music entity exists even without being performed. An experienced musician can mentally translate a music notation without playing the piece and everyone can think of a piece (s)he is familiar with, without listening to it. That is why the basic boundary of a music entity is the ITformational. However, the energetic boundary is used for communication of the entity (acoustic waves through a performance, electric waves through the cables etc.), and the material one is used in order to create that energy (musicians, instruments, loudspeakers, cables etc.). Entities interact through their boundaries. ITformation acts through information as a control signal. It causes synchronization, coordination, resonances and organizes structures and procedures. Music entities, as ITformational ones, cause kinetic (like dance patterns) and emotional synchronizations. That synchronization manifests all of the boundaries interaction (ITformational, energetic, material) between the music entity and the audience.

Of course, that presentation is only a first attempt to connect the new approaches of Information with the study of cultural phenomena. However, we believe that it has been made clear that the insights of modern science can indeed be used in domains beyond science itself. The systematic approach of cosmological entities offers a remarkable tool for the study of cultural and social entities as well. Information seems to be a promising key to extend our understanding of both our outer and inner space.

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