A Nested Detector With a Fractal Temporal Interface

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Abstract
Most time series analysis is carried out in retrospect, i.e., after the data has been acquired. Direct observation, and with it, anticipation of the temporal development of a system, is often limited to one level of description. This would not suffice if one wished to detect scaling behaviour in real time. An algorithm is introduced which describes a fractal, nested detector. This nested detector anticipates scaling structures in real time, and registers space time as a function of the Prime Structure Constant. Depending on where the interfacial cut is set, the nested detector could be a brain, a computer program or a mechanical measuring device. Fractal nested detectors are an example of strong anticipation, as the scaling behaviour, which is inherent in the underlying system's dynamics, is adopted by the detector in order to further differentiate its interface.
Keywords: time series analysis, scaling behaviour, fractal time, nested detectors, strong anticipation

1 Introduction

How would the time window of a detector or a brain need to be structured in order to render possible the recognition of scaling behaviour in real time?

A system diplays scaling behaviour if it consists of superimposed temporal patterns or distributions which are nested inside each other. The term *in real time* should be understood as *virtually simultaneously*: If an observer registers an event in real time, there is only a slight time delay between the moment the stimulus hits the detector interface or the measuring chain and the time it is registered. This delay is due to processing performances.

First of all, the time window in which a measurement or observation takes place must be long enough to host a meaningful event and short enough not to be divisible into two or more events. For a brain, this smallest meaningful time window is the observer's Now [1]. An analogy for a detector will be drawn later in this paper. So how would an observer's Now need to be structured if he wished to observe temporal scaling behaviour in real time?

I shall follow a phenomenological approach which focuses on the Now as the interface between the observer and the world, between the observer and a measuring chain or between a detector and the system to be observed. The idea of the Now as an interface between the observer and the world was developed by Otto Rössler [2]. According to Rössler, the interfacial cut is defined by specifying assignment conditions, i.e. stating what part of the system belongs to the observer and what part belongs to the world. The concept of assignment conditions was also developed by Rössler, whose approach is microscopic [3]. In this paper, macroscopic manifestations of assignment conditions are considered.

Whether and to what degree it is the influence of the observer or the world which shapes the structure of the interface is not only a question of epistemological concern. In order to generate an interface with anticipatory faculties, it is essential that the assignment conditions are clearly defined before venturing on a real-time observation of scaling structures. The assignment conditions which define an observer's Now may be extracted by describing what structure needs to be presupposed in order for an observer to be able to perceive a meaningful time series, such as a tune.

2 The Now as a Nested Structure

The notion of the observer's Now as a nested structure was first described by the German philosopher Edmund Husserl [4]. He observed that when we listen to a tune, we do not simply hear a succession of unrelated musical notes – we hear a tune, a meaningful entity which covers an interval of time. According to Husserl, this is possible because the note we have just heard still lingers on (retension) and, assuming that this was not all, we anticipate the next note (protension), both in the consciousness of the present, the Now. He defines notes as time objects (*Zeitobjekte*), which are, in themselves, extended. Exemplified by the perception of a series of notes as a tune, he shows the necessity of assuming concepts such as retension and protension – i.e. recollection and anticipation – in order to understand our skill to recognize not only a series of isolated notes, but a tune:

> "The fact that the section of the tune which has been played is objective to me, I owe - one is inclined to say - to recollection. And the fact that I do not, having reached the appropriate note, presume that that was all, I owe to anticipatory expectation ..." [4]

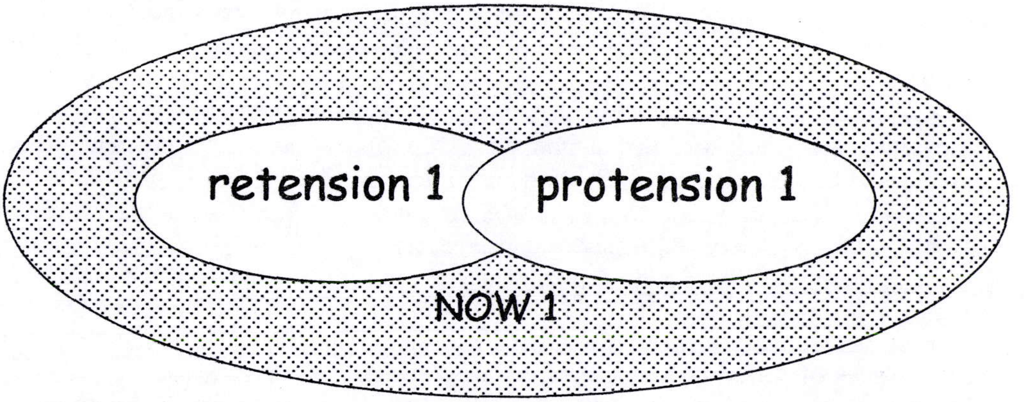

Figure 1: The Now contains memory and anticipation (retension and protension).

By creating this overlapping of retention and protention within the consciousness of the present, we create a nested temporal structure: the Now.

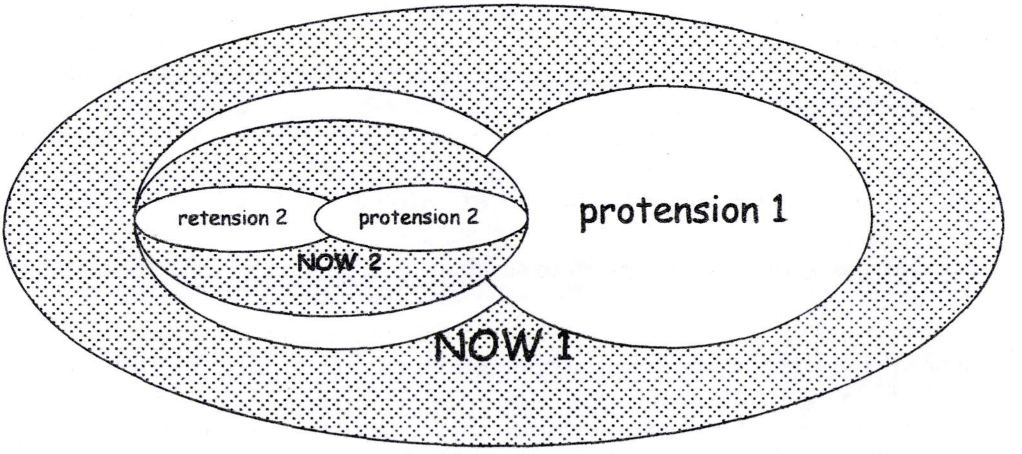

Figure 2: A nesting cascade of memory and anticipation (retensions and protensions).

3 Fractal Time

Existing concepts of time do not to allow for such a nested structure. Physical notions of time in particular, disregard the observer's Now and focus on before and after relations. In my Theory of Fractal Time [1], I have taken account of both the observer's nested Now and the physical parameter time of before-and-after relations by differentiating between

- Δt_{length}, the length of time, which is the number of incompatible temporal extensions in a time series. Δt_{length} measures the succession of events on one level of description (LOD).
- Δt_{depth}, the depth of time, which is the number of compatible temporal extensions in a time series and, therefore, the number of LODs. Δt_{depth} measures simultaneity and provides the framework time which allows us to structure events in Δt_{length}.

N.B.: Without Δt_{depth}, there is no Δt_{length}! Without a reference framework in the form of a next LOD, no succession would be conceiveable.

- $\Delta t_{density}$, the fractal dimension of time, which measures the temporal density of a time series.

These notions may be exemplified by the perception or registration of superimposed sound waves of differing frequencies, as they appear on our interface between the observer and the world or the detector and its embedding environment. If, for example, the individual nested frequencies are arranged so that from one LOD to the next, the frequency doubles, we would have a nesting cascade of sounds separated by octaves. Δt_{length} may then be measured, for each LOD, as the number of peaks per second. In each case, the higher frequency on an embedded LOD would produce a larger value for Δt_{length} than that of the embedding LOD. If separated by an octave, each embedded LOD would measure twice as many peaks – units of Δt_{length} – as the embedding LOD. Δt_{depth} is simply the number of LODs taken into account, the number of nestings. The resulting fractal dimension of the time series may be calculated from the relation of Δt_{depth} and Δt_{length}: $n=s^d$, where n represents the number of units, s stands for the scaling factor and d is the fractal dimension.

4 Primary Experiences of Time

The notions of simultaneity and succession within the Now as defined by the Theory of Fractal Time also lead to a new concept of duration. Duration may be described both in Δt_{depth} and in Δt_{length}, with the resulting notion of varying densities of time ($\Delta t_{density}$). The notions of succession, simultaneity, duration and the Now can also be found in Ernst Pöppel's neuro-scientific approach [5]. Pöppel takes the subjective experience of time as a starting point. In this context, he differentiates between four primary experiences of time: the experience of simultaneity, succession, the Now and duration. These four experiences constitute our primary experience of time, which, he suggests, precedes the physical and semantic concepts of time.

Our senses both render possible and limit our experience of simultaneity. The differing ways of experiencing simultaneity correlate with various sensory perceptions. We perceive everything we hear as simultaneous if it is perceived within an interval of 2/1000th of a second. Sounds which last longer, i.e. which are separated by three or more seconds, are not pereived as simultaneous by most people. Our visual senses show a different sensibility to simultaneity. Here, all impressions we perceive within an interval of 3 to 10 milliseconds, are experienced as simultaneous. Impressions which last longer than approximately 20/1000th of a second are no longer perceived as a unity – they are not experienced as being simultaneous.

Our experience of succession is also limited: There must be at least 30/1000th of a second between successive events in order to make us recognize them as a succession. To explain this phenomenon, a qualitative jump is necessary, which connects the processing of a stimulus by our sensory organs to the processing which goes on in our brains – the point where we knock sense into what we have heard or seen.

The experience of the Now is based on yet another performance carried out by our brains, namely integration. Impressions are experienced as present when our brain assembles them into perception gestalts. Pöppel exemplifies this idea with an example from language which is reminiscent of Husserl's example of hearing a succession of musical notes as a tune.

"... the word *Now* is made up of successive phonetic events. But when I hear the word *Now* now, I perceive the whole word now and not a succession of individual phonetic entities." [5]

The integration performance carried out by our brains turns such successive phonetic events into a meaningful entity, a gestalt in the form of a word. According to Pöppel, it is such perception gestalts which constitute the Now. They are extended – in fact, up to two to four seconds (the upper limit of a time interval in which integration of phonetic events into a word is possible). Think of Mary Poppins' remarkable word creation *supercalifragilisticexpialidocious*.

This notion of something being present results from a clustering of perception-related experiences which are based on meaningfulness, i.e. perceptual gestalts are constructed by our brains. From this, we may conclude that the duration of the individual present depends on the mental capability of the person who experiences the event. The more differentiated and more comprehensive the language, the more complex are the perceptual gestalts this person may construct and, as a result, the more extended this person may define his present. It is common knowledge that if little happens and, therefore, little is processed by our brains, we experience boredom – time seems to stretch. In retrospect, however, this time interval is remembered as being short and empty. The reverse is true for intervals with rich, interesting content: Here, time seems to fly, but in retrospect, this interval seems to be long, full of rich content. This apparent paradox may be solved by applying the concepts Δt_{depth} and Δt_{length}, which I introduced above in my Theory of Fractal Time. According to this theory, new nestings generate simultaneity, i.e. Δt_{depth}. This makes an interval of time appear long and rich during recollection, as many embedding performances create density in the form of simultaneity. Conversely, the inability to create temporal nestings by embedding experiences into new LODs prevents the creation of Δt_{depth} and forces the observer to arrange all events on a single LOD, thus extending Δt_{length} excessively. This leads to boredom, which makes the temporal interval appear long, but, in retrospect, it is remembered as short and empty, lacking weight and density:

"New nestings often occur in clusters, i.e. in situations in which past facts are rearranged by innumerable recollection performances. Class reunions, housewarming parties, slide-shows on Christmas Eve and the like serve as good examples for such recollection clusters. During such events, recollected facts are often nested over and over again, and thereby newly arranged, as old stories are discussed, corrected and retold by individuals.

Through recollecting and newly arranging past facts on new LODs, Δt_{depth} increases perpetually. Δt_{length}, in contrast, seems to contract. During a class reunion, time seems to fly (unless the pitiable families of the former class members were invited too. For them, Δt_{length} increases steadily, since they are not able to join in the recollecting and have to arrange everything they experience on a constant number of LODs - in other words, they are bored stiff)." [1]

From experimental evidence which supports the above-mentioned anecdotal evidence, Pöppel draws the conclusion that the experience of duration depends on the comprehensiveness of the events processed by the brain. In order to render possible the experience of duration, two components are necessary: firstly, the "identification and integration of perceptual gestalts" [5] and, secondly, memory, by means of which time may be skipped and even be conquered through reflection by providing past experiences for our reflective consciousness.

5 Physical Concepts of Time are Anthropocentric

The four elementary experiences of time described constitute our primary experience of time. Our experience of time thus turns out to be something given and becomes the starting point of philosophical questions concerning the conditions which render experience of time possible. These conditions are generated in different ways, depending on the underlying belief system. Pöppel presents both physical and semantic concepts of time as examples of attempts to deliver an explanation, but shows that both physical and semantic approaches are anthropocentric and thus derivatives of our subjective experience of time.

> "As our brain has only one perspective on the world (whose extent we cannot possibly imagine) as a result of its evolutionary history, all physical theories are necessarily a view through only one (namely our) window to the world. As a result, physical theories are necessarily anthropocentric." [5]

Physical concepts of time should thus be regarded as derivatives of our subjective experience of time. They cannot be disentangled from the constraints given by our perceptual apparatus and mental processing abilities. Therefore the concept of time referred to in the phenomenological approach of this paper refers to interface time, which embraces the manifestations of both psychological and physical time.

6 Fractal and Non-fractal Observers

There are two types of observers: fractal and non-fractal ones. A non-fractal observer perceives a time series on one LOD only. He registers successive events in Δt_{length} but cannot make out a succession, as he is lacking a reference frame against which he may create the one-dimensional structure of succession. Neither can he register simultaneous events, as no additional LODs are at his disposal to create Δt_{depth} by means of nesting existing levels into additional ones. A non-fractal observer is not capable of memory formation – he would live in an eternal succession of unrelated Nows [6], [7].

A fractal observer can perceive a time series both in Δt_{length} and Δt_{depth}. He is able to experience both succession and simultaneity. This enables him to successfully navigate through the world.

Most human beings are fractal observers. It is an intrinsic perspective which makes us perceive events on nested levels of description simultaneously. Apart from individuals who cannot generate a nested perspective as the result of an impairment such as a neurodegenerative disease, we are all fractal observers and see both succession and simultaneity. As we know the world only through our acquired perspective, we usually do not question this perspective and are not aware of it in every day life. The fact that both nested and non-nested perspectives exist may only dawn on us when we encounter tangled hierarchies or conceptual curiosities which lead us to reflect on our perspectives.

Here is an example of a fractal observer as opposed to a non-fractal one:
There is a beautiful plant whose name - the *yesterday, today, tomorrow shrub* – presents a curiosity which leads us to reflect on our temporal perspectives. The shrub's blossoms change within days from deep violet-blue to a light blue and finally to white. The development of the plant's blossoms is staggered, therefore the shrub always displays blossoms of all three colours. To come up with the name *yesterday, today, tomorrow shrub*, the person who did so must have looked at it on at least two LODs, i.e., on *both* the plant as a whole, as well as at its individual blossoms. This presupposes a perspective through a fractal interface, a nested Now, which allows both succession and simultaneity to be taken into account at the same time. This is the perspective of a fractal observer.

The perpective of a non-fractal observer would not allow for such a double-perspective which includes both succession and simultaneity. He would have only one LOD at his disposal, which means that he could perceive neither simultaneity nor succession, as both can only be generated if at least one temporal nesting is present. This non-fractal observer would look at the blossoms of the shrub and their individual development through the successive colours. As he lives in an eternal present, he could not come up with a name like *yesterday, today, tomorrow*. Non-fractal observers cannot look at the whole and its parts simultaneously. This ability requires a nested interface which provides for both simultaneity and succession. The resulting temporal fractal perspective, which allows the observer to refer to the past, the present and the future in the Now, is not limited to human observers. As smart detector could also be programmed to observe a system both as a whole and in terms of its parts simultaneously.

The fractal temporal perspective is an intrinsic property of the observer which allows him to perceive events on nested levels of description simultaneously. This perspective is the temporal analogue to Michael Barnsley's *Box Counting Method* [8]. This method is a way of determining the fractal dimension of a structure. It was developed by Barnsley in order to determine the fractal dimension for both self-similar and non self-similar structures. Barnsley's approach allows us even to describe plane-filling structures as fractal. This shifts the property of fractality to the observer. His internal differentiation allows him to register the outside world as fractal, without making any claim as to whether the thing-in-itself, the structure which exists independent of the observer, also displays a fractal pattern. For a phenomenological approach, Barnsley offers the most suitable definition of a fractal, as it allows us to describe an intrinsic filter through which an observer or a detector monitors events.

Fractal observers may therefore be defined as individuals or detectors with an intrinsically generated fractal perspective.

7 Condensation Induced by Means of the Prime Structure Constant

In order to relate nested LODs to each other, a translation is required, as each LOD is defined by different basic intervals, i.e., Δt_{length} of the smallest conceivable unit of time varies between LODs. This translation may be rendered possible by defining a constant, which represents the smallest structure recurring on all LODs in differing Δt_{length}. This structure would cover a much larger interval in Δt_{length} on the outermost LOD than on the innermost one. For the innermost LOD, I have defined the smallest structure in a nesting cascade of overlapping LODs, the prime, as the structure without nesting capacity [1]. It is indivisible in the Bergsonian sense and can therefore not host further, smaller structures: it is an atom of time.

If an observer set the structure of the prime, which recurs on all LODs, albeit in differing $\Delta t_{lengths}$, as a constant, condensation would occur. Condensation is a property of spacetime: It is generated as a result of congruent scale-invariant nestings. As a result of this congruence, spacetime is distorted with respect to the prime structure constant (PSC).

Condensation may be measured in condensation velocity v(c) and condensation acceleration a(c). The quotient of Δt_{length} of LOD_n and Δt_{length} of LOD_{n+1} equals the condensation velocity for LOD_n ↬ LOD_{n+1} (↬ denotes *nested in*). For scale-invariant structures, v(c) is identical to the scaling factor [1].

For strong anticipatory systems as defined by Daniel Dubois [9], an observer who has integrated a PSC into his interface, spacetime would be bent as a function of the PSC. He would have created an endo-perspective (which differs from the exo-perspective), and, in its wake, a distortion of spacetime. This PSC translates between LODs and, possibly, between observers, provided the mutual information of these observers includes the PSC [10].

The prime is a temporal natural constraint (TNC), as it limits the divisibility of temporal intervals. TNCs could also come in the shape of transition rules, such as Feigenbaum's number, which governs period-doubling scenarios. If there are shared TNCs (observed by more than one observer or detector), these may be the result of a selection process. Shared TNCs may reveal objective distortions in Δt_{length}.

8 An Algorithm for a Nested Detector with a Fractal Temporal Interface

An algorithm for a nested detector with a Fractal Temporal Interface [10], which can perceive and anticipate scaling structures in real time, could be set up as follows:

Step 1: Register incoming signals S simultaneously on LOD_n and LOD_{n+1}.
Step 2: Compare the readings $S(LOD_n)$ with those for $S(LOD_{n+1})$ until a scale-invariant nesting is detected.
Step 3: If a scale-invariant nesting is detected, set the structure of S which recurs on both LODs as the PSC.
Step 4: Modify your interface so that the new measuring units mimic the structure of the prime on both LODs.
Step 5: Search for scale-invariant nestings on the next LOD (LOD_{n+2}). Continue to look for the PSC on the next level of the nesting cascade for a pre-defined number of steps.
Step 6: Generate a nested interface which mimics the PSC on all LODs simultaneously.
Step 7: Carry out simultaneous readings with the PSC as the new measuring unit.
Step 8: Display readings.

At least one nesting is required, more are preferable: The deeper the nesting cascade, the larger the distortion of spacetime in its wake.

During the initial phase of the observation, the interface is being formed. Before the PSC is identified and successfully integrated into the observer's interface, there is no real-time observation of scaling behaviour. Once the fractal temporal interface is formed, it registers a scaling temporal structure as a non-scaling one. The interface acts as a condensator which sets $\Delta t_n = \Delta t_{n+1} = \Delta t_{n+2}$ (for a pre-defined number of steps) [11].

The effect may be compared to that of gravitational lensing. In the temporal analogue to the density of a mass, which has a distorting effect on spacetime, it is the amassing of nested LODs which distorts the temporal perspective of the observer.

The resulting measurement is an endo-phenomenon. An endo-phenomenon is a structure as seen from an inside perspective, i.e., the observer or the detector is embedded in the system observed (as opposed to an exo-observer, who is located outside the system he observes). In order to make such a reading communicable to the outside world, two nested detectors – a fractal one and a non-fractal one - may be employed simultaneously, both nested within a third detector. This third detector may compare the readings and display the difference in measurements of the two nested detectors (The nested detectors may communicate their meauring results to their host detector by, for example, switching themselves off if a scaling structure is recognized).

Multifractals, i.e., $a(c) \neq 1$, may be explored by superimposed fractal temporal interfaces, each mimicking the scale-invariant structure and the scaling factor of one self-similar domain.

The fractal temporal interfaces generated by a fractal nested observer or detector are an example of strong anticipation. This is so because the scaling behaviour, which is inherent in the underlying system's dynamics, is mimicked by the observer or detector in order to further differentiate his/its interface.

9 Possible Applications

Possible applications of fractal temporal interfaces include a custom-made translation tool which could be used for encryption. The encoding process would consist of embedding data into a context on another LOD. As a result of this new contextualisation, the original clear text (the data on the first level of description) would be interpreted differently by an observer or the detector who sees this clear text embedded in the next-higher LOD. This contextualisation procedure may be repeated a number of times, in order to make it harder to recover the clear text, by continued nestings.

Also, it may be helpful to understand memory formation not as a one-dimensional process, but a multi-layered one, generated by a nested structure, which may, at the same time, be interpreted as one whole. Based on the observation of ubiquitous 1/f scaling in human cognition and physiology, van Orden et al make the prediction that cognition does not divide into statistically independent processes [12]. They propose that cognitive performance in very short and very long time frames are governed by the same processes, which opens the possiblity of considering a single memory system and a unitary theory of forgetting.

Finally, universally shared TNCs may reveal objective distortions in time which we are probably familiar with but do not recognize as such.

10 Conclusion

Back to my initial question: How would the time window of a detector or a brain need to be structured in order to render possible the recognition of scaling behaviour in real time? I have tried to show that this time window would need to be a nested structure generated by an observer or a detector with a fractal temporal interface.

If this interface mimics the PSC, condensation is induced, which generates a distortion of spacetime for the observer (or the detector). This distortion occurs on the interface between the observer and the rest of the world. As it is only interface reality we are concerned with in this phenomenological approach, any questions on the line of naive realism, such as the possibilty of an access to the thing-in-itself, are not addressed. However, it is presupposed that time is not generated by the subject, as can be shown by Husserl's approach: we have to assume time to exist independent of the observer in order to avoid an infinite regress. The observer does, however, structure time. He may even modify temporal structures as they appear on the observer-world interface, by modifying his temporal fractal perspective. This may be achieved by contextualisation and de-contextualisation, i.e. nesting and de-nesting performances.

On a speculative note which exceeds this phenomenological approach, one may ask whether the invariance of data on nested temporal LODs is the result of the observer's intentionalism or that of impacts which exist independent of the observer. As our only access to the world, however, is interface reality, we are not in a position to make this distinction from an exo-perspective, i.e. from the point of view of a super-observer. Only a super-observer would be in a position to judge whether a fractal observer would perceive a fractal structure which exists independent of our experience as a non-fractal one. This idea was expressed in a nutshell by Rössler: "It could turn out, for example, that a universe that is chaotic itself *ceases* to be chaotic as soon as it is observed by an observer who is chaotic himself." [13] Again, any such speculation would exceed the phenomenological approach this paper is based on. Interface reality is all we are concerned with.

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