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Pragmatic phenomenological types

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ABSTRACT

We approach a well-known problem: how to relate component physical processes in biological systems to governing imperatives in multiple system levels. The intent is to further practical tools that can be used in the clinical context. An example proposes a formal type system that would support this kind of reasoning, including in machines. Our example is based on a model of the connection between a quality of mind associated with creativity and neuropsychiatric dynamics: constructing narrative as a form of conscious introspection, which allows the manipulation of one's own driving imperatives.

In this context, general creativity is indicated by an ability to manage multiple heterogeneous worldviews simultaneously in a developing narrative. 'Narrative' in this context is framed as the organizing concept behind rational linearization that can be applied to metaphysics as well as modeling perceptive dynamics. Introspection is framed as the phenomenological 'tip' that allows a perceiver to be within experience or outside it, reflecting on and modifying it.

What distinguishes the approach is the rooting in well founded but disparate disciplines: phenomenology, ontic virtuality, two-sorted geometric logics, functional reactive programming, multi-level ontologies and narrative cognition.

This paper advances the work by proposing a type strategy within a two-sorted reasoning system that supports cross-ontology structure. The paper describes influences on this approach, and presents an example that involves phenotype classes and monitored creativity enhanced by both soft methods and transcranial direct-current stimulation.

The proposed solution integrates pragmatic phenomenology, situation theory, narratology and functional programming in one framework.

1. Introduction

1.1. Background

Our intent in this paper is to explore the metatools required for a formal, coherent approach to the multilevel problem in biology, described below. In particular, the focus is on a *type system* that serves our needs. A companion paper (Goranson and Cardier, 2013) describes the theoretical foundations and accompanying methods of a system that models and reasons over the open world and across ontologically discrete system levels. This paper focuses on the metaphysics of the system and implications for the types therein.

A key notion is *narrative*. We use it in its simplest embodiment: the way humans organize what we perceive in order to comprehend and remember. This notion is extended in two directions. We use it to advise a metaphysics based on the assumption that the most *elegant* elegance comes from how we automatically structure the world. We also use the observed dynamics of complex narrative to tease out the hidden agents that co-construct situations within the phenomena of interest.

A key technique is use of a two-sorted reasoning system. One sort is able to maintain current methods in all disciplines and system levels, as inherited from existing research and projects. We add a second sort of reasoning system that is not logic-based, does not have Newtonian legacy and is tailor-made for the phenomena of interest. It operates on the first and reasons at multiple levels about cross-situational dynamics. This second sort is informed by solid theoretical influences, many of which are noted here.

Our research group specializes in using these two approaches to build workable systems capable of doings things previously undoable.

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This paper is aimed at a multidisciplinary audience and care has been taken to avoid the use of jargon and domain-specific notation; more references have been included than otherwise would be the case. Also, in some cases, simple reductions of complex issues have been made to allow the presentation to be more concise as a synthesis of several ideas. We apologize in advance to specialists who feel their domain should have been more fully described.

1.2. The problem

Complex systems operate at numerous levels, and are understood using diverse disciplines – for example, the mind is modeled using chemistry, neurology, biology and psychology. Each level has its own driving imperatives which are recorded in an array of different modes and notations. Modeling the interaction among these systems is a long-standing problem, both for humans and machines.

We follow others in describing coherent aspects of the world as *situations* in which elements are structured so they can be viewed as a whole (Cardier, 2013). In the above example of the mind, each level can be characterized as a situation, and the components within it also be modeled as situations. We frame the driving imperative that is both within, and responsible for, the assembly of these situations as *causal agency. Causal agency* is any imperative that can alter a situation.

The problem is anchored in cross-situational modeling in formal systems. Perception and representation are limited and subjective, and as a result, the ontological reification of any system omits critical aspects of the process. This is especially true of causal agents, which in the open world, facilitate the transformation among heterogeneous states. Formal systems thus struggle to account for causal transformation using logic.

The problem of perceptual limit is a manifest concrete problem for ontology design in knowledge systems. It should be noted that we use the term *ontology* exclusively as computer scientists use it, and not as philosophers (including phenomenologists) would. As noted below, an ontology is a formal characterization of a domain of interest (Gruber, 1993) used in computable reasoning systems.

In computer science, if an ontological conceptualization is closely modeled on a domain, it will likely be conceptually *heterogeneous*: a tight perspective that makes it less compatible with other systems (Acampora et al., 2012; Wigner, 1960; Berners-Lee, 2008). A number of approaches have been developed to address this incompatibility between systems, most of which standardize knowledge so there are no inconsistencies.

The inability of heterogeneous ontologies to communicate with each other is crystallized in our target biological phenomenon. When modeling the multiple-level emergence and transformation of living systems, the usual solution of standardizing or generalizing away inconsistent, conflicting or diverse information is too costly, as it can omit critical aspects of causal agency. As evidenced by narrative processes, such tensions and diversity are needed to propel emergence and transformative imperatives in the first place (Cardier, 2013). (The relationship between narrative and multilevel impetus is described in a moment.)

The difficultly in modeling multi-level dynamics can be found in numerous fields, as one would expect. One statement of the problem relates to formal studies of information flow. *Situations* are similar to a *context*, in that a shift between *situations* alters the effect of facts (Devlin, 1995). Many situations cannot be reduced to facts or reached by logic (Devlin, 1996). Dynamics at the system level have imperatives not evidenced in individual components.

Another statement of the problem is motivated by quantum physics; though it is one of the most successful theories devised, there is no satisfactory proposal for a metaphysics. Some category theorists (Bohm and Hiley, 1993) have an attractive proposal, and (Siek and Phillip) presents a model from first principles. But these are not amenable to engineering of models. The general principle of extractable concepts is addressed in the section addressing Rosen (Santilli).

A third expression of the problem concerns how to reason over multiple system dynamics in living systems; the problem is well stated in previous volumes of this Journal (Bard et al., 2013). Roughly speaking, we have extraordinary tools to model biology at the level of physics, physics as expressed in chemistry and chemistry (and associated physical metrics) as a basis for biology at the molecular level. But we lack models and methods with semantic weight that can subsume these at higher levels and systems and yet give us useful mechanics and associated imperatives of living systems. It is this latter definition of the problem that we use here, though we leverage tools from those working the parallel challenges in quantum physics and ontology design.

The paper outlines the metaformalisms as *types* behind our approach. In computable systems design, types specify the fundamental units of meaning, and underlie the functions of computational comprehension. Due to our focus on multi-level systems, our types must be fundamental both in the context of their sources, as well as in the context of our developing system. In accordance with the notion that *information* is a common organizing parameter across all levels of natural phenomena, the types are chosen to underpin notions of assembling information – those discernable in any framework governed by ordered perception.

We draw upon several bodies of research to devise these types, and the paper is organized to outline these areas in general terms. It forms a survey of the philosophical foundations: phenomenology, symmetry and situation theory in the first sections.

In the body of this paper, we turn to the implementation frameworks leveraged: quantum interaction, calculus and computable two-sorts. Finally, we indicate an experiment and future directions.

2. Phenomenology

2.1. About types

This work requires us to act as both radical scientists and reliable engineers.

On one hand, we have to invent new theoretical tools. By definition, we are approaching problems that are unsolvable by current methods; some of these are extremely high payoff areas. A reliable engineer would work within existing theoretical frameworks, but we need some radical advances. So we work at two levels, in both theory and tool development.

As engineers, we are constructing useful tools, borrowing fabric and methods from others. As this paper outlines, our sources are unusual and are put together in ways that many of the source researchers did not anticipate. On the track from research to utility, only the most trusted and salient components are used. Engineering a type system from scratch is daunting, but necessary given the unique modeling of the problem.

As scientists, we realize invention is required. We don't need to *rethink* science per se, but we agree with the many others cited in this volume that new fundamentals need to be applied. We seek deeper abstractions and abstraction frameworks: abstractions that satisfy at the philosophical level, and related abstractions that have computational affordances to support modeling and practical analysis. We need to understand processes beyond the cellular level, beyond the structural model and across systems to individual and group cognition. The work requires new primitives.

Similarly, the abstraction problem needs both a radical advance and reliable methods. When modeling information processes, we require *typed abstractions* to apply at the working level, where existing approaches have robust frameworks. We also need other types that support a world framework of systems and imperatives.

In order to span these requirements, our abstractions and coherent type systems have at least two dimensions: *higher* levels of abstraction and more *primitive* levels of abstraction. The former will support our notions of situated system behavior, while the latter enables models that are intuitive and computable. This is discussed below.

At the theoretical level, our model is generally informed by principles of *phenomenology* and *symmetry* (in the sense physicists use the term).

Our position on models: there is not a *true* framework or metaphysics for us to discover or invent. Many philosophies are appealing because they explain things elegantly and coherently; some of these are *true* in the sense that reasoning in them doesn't take you far enough from observed life to require cumbersome complexity. A subset of those are *useful* in that if you build models in the scientific tradition that are directly influenced by the abstractions and dynamics of the philosophy, they will suitably explain and predict.

Said another way: being *true* is not enough. We want something true, pragmatic and able to press into new ground, in order to capture useful aspects of phenomena that are elusive yet important in several fields.

2.2. From facts to transformations

This work also represents a shift in focus from *things* to *transformations*. Furthermore, these transitions are not between facts, but among apparently dissimilar *situations*.

In many fields, the focus is *things*. Physics, and by inheritance, chemistry evolved so this is the basic working abstraction — the object as actor — because *things* are conducive to measurement. A focus on things makes causal imperative and transformation difficult to formally model, however. The ontological instability implicit in the (human) comprehension of causal transformation prohibits formal reasoning of the ordinary kind. Entities cannot be named and accounted for, because the entities beneath the names are always changing.

In this respect, the science of chemistry/biology emerged the wrong way around, with the applicable mathematics and metaphysics developed after measurement-centric abstractions were established. Thus we have entities: molecules, particles and forces (which, as they are ordered in fields, are themselves virtual entities). When such things (molecules) change into part of something else coherent (a mind), the approach falters.

Descartes (and others) crafted philosophical frameworks that were influenced by these practical abstractions, even though they are in some sense accidental. In this view, *systems* are things as *collections-of-things*, and subject to similar assumptions about their mechanisms. *Thingness* retained its first class status in physics and the development of formal logic co-evolved to suit.

The mathematicians fixing these ideas did a great job; mathematical foundations for manipulating *things* and *qualities of things* have no unsupported holes for working physicists. Naming and reasoning over *things* and *things-as-facts* is a coherent system. However, observed living systems are motivated to change at numerous levels and these clearly affect each other.

The abstractions that best handle *things* are *sets*. Set theory is the foundation of logic, and therefore science. There is currently no satisfactory set theoretic framework to account for the way systems can change such that their atomic dynamics are subsumed in something that ontologically speaking is entirely different. Even physics itself, as it turns out, needs a similar rethinking of foundational types; phenomena as ordinary as gravity and exotic as the effects of dark matter are not amenable to elegant extensions at the boundaries of current models.

In addressing this problem in both living systems and quantum physics, we have not found *any* pragmatic philosophical position wholly satisfying. If part of our problem is that our current tools were developed the wrong way around, from bottom up (observational convenience to metaphysics), a top to bottom coherence in the specification of types is needed, from metaphysics to working science to computational tools.

Instead of *things*, we instead focus on the nuanced *interactions* among differing systems, which we model as *situations*. For this purpose, we define a situation as “a limited part of reality,” which includes the relations among its elements (Devlin 2009). We particularly consider the way situations capture elusive dynamics in which one situation can be rendered in another, each as a sort of observer. This paper is a snapshot of ongoing work, presenting background concepts with the goal of developing a set of abstractions that can rest easily in any of the below cited frameworks, and yet reach beyond them to address the problem described here.

Simply put, this is where phenomenology gives us leverage. The reader should be aware that the goal is to solve the multilevel modeling problem in biology, not to apply phenomenology in a practical application. We get our tools where we can; when philosophical guidance is needed, we take what is required from the philosophy and nothing more. If the entire agenda we describe seems to comport with the basic tenets of phenomenology, this speaks more to the apparent acuity of the sources.

2.3. Biological systems topology

In the tour of foundations for our approach, our starting point is Rosen (Santilli).

Of the phenomenologists we might select, he has the most concise foundations for our needs: form-as-topology that captures ineluctable but invisible agency. Though he draws from the later work of Merleau-Ponty and Heidegger, the essential insight for our purposes comes from Husserl and is indirectly inspired by geometer Weyl. The concept is simple enough, accepting the role of cognition in order and appreciating the ‘geometry of imagination’ (Hilbert, Cohn-Vossen, 1952; Wille, 2005) to illuminate cause and effect.

This particular deviation (to geometry) from the mathematical default (of ordered, closed sets) makes phenomenology attractive in general. Though he is not likely to characterize his work as such, Rosen *starts* with topology as a fundamental; this is not the usual approach. This commitment allows us to promiscuously expand how topology and form rest in systems phenomena.

Our type system needs at least two hierarchies: generational (from primitives) and abstractional. The former is plastic and a talented mathematician can start anywhere and get anywhere, creating as many loops as she has energy. It is the latter, the two or many layers of *abstraction* that are the most challenging. To start with topology — specifically higher dimensional topology — is to allow the possibility of symmetric structure as a primitive, while inheriting all the intuitive, perceptual structure we associate with geometric form.

It is worth taking a moment to clarify our definition of *symmetry*, which can vary. Across our entire system, a range of manifestations of symmetry are accommodated, held together by a notion that is most abstract. We define this abstract notion as our interdisciplinary symmetry society does, so that *symmetry* exists in a system if it has any sort of recognizable pattern that can be algorithmically generated. *Asymmetry* is neither the opposite or dual of symmetry, but a quality where the symmetry exists but is onticly imperfect. *Dissymmetry* is the absence of symmetry (though the term is often used to mean nearly the opposite). Note that this definition sets symmetry as something that *results* from perception but that assumes a generative history in that perception (Leyton, 2001).

One aspect of our reasoning system directly concerns the world and descriptions pertaining to it. In this part, symmetry is linked to form. This is where our use converges with the definition of symmetry common to conventional science, as well as within discussions of phenomenology. In other areas of the system we use a different notion, one common in type theory, computer science and some areas of mathematics – how this is handled will be described later. For now, it is enough to note that when we describe the influence of Rosen's work, it pertains to the parts of the system that follow description logic, but not the aspects that adhere to our more abstract manifestations of symmetry.

Rosen makes a good case for using formal form; biology reduced to interactions based on form. Any system-level view, if it is to subsume existing models, should be able to integrate these into topological structures. This is similar to two other philosophical frameworks that have been influential on our work. Matsuno (Mill, 1843) (see also his paper in this volume) employs a notion of 'tense' applied to the perception of intent (by the object itself as impressed). Chandler (Chandler) proposes to apply a more apt concatenative arithmetic than usual to successive molecular activity in order to capture generative history.

For our agenda, we take the general approach of phenomenology and the inspiration from Rosen to exploit topology, along with the implied commitment to a geometric physics. In particular, we include well-developed notions of self-perceived process fabrics in systems and their modeling, in something like Rosen's *topo-phenomenological* theory. Also included is the elegant resolution of subject-object priority and the supposition that a geometric logic, as we refer to it, applies to type systems.

The adoption of some ideas taken from a whole vision may not seem appropriate, but in our view, Rosen has reasoned methodically and stepwise, creating the opportunity for others to follow him closely up to a point, and then work in parallel, following in spirit.

This is in contrast to many others with mature phenomenological approaches that leverage topology. For example, Rapoport (Rowlands, 2007) has an approach that is very well developed in terms of examples, and thus might appear more attractive. But the coherence of the approach has circular assumptions that are hard to untangle. Such is inevitable in phenomenological approaches where principles are extracted from phenomenon, but Rosen has taken more care in this regard.

For the underpinning abstractions of our entire system, however, Rosen's approach is too quick to resort to a calculus, adopting the math before the metaphysics. His mission is to apply his constructions, including the calculus (which in his case is an algebra) to build a metaphysics. Our mission is to build something more fundamental that includes both a tractable metaphysics and an ontologically complete calculus. So we work on types first, and build the calculus and resulting reasoning system around them. In practice, that means that while we preserve Rosen's integration of sub-object, we need to move more into the subject side for metaphysical types.

As we move to abstraction, we are able to preserve abstract notions of symmetry and leverage them accordingly.

2.4. Ontic structural realism

At the most abstract end of the model, we are influenced by ontic structural realism (OSR), of the kind described by Ladyman, Ross and Collier (Lehmann, 2008).

The OSR/Ladyman perspective informs this work with the following notions: order is in our experience, not all the agents need to be directly perceivable things and those that are not directly perceivable are still rooted in experience.

This last point has a rather profound consequence for us, because we implement a solution that has virtual agency in our second reasoning system. We thus need to exhaustively identify and understand the types of these virtual entities – and only the types (without *thingness* or even semantics). If the invisible parts behave onticly like the visible ones, it makes the order of the second reasoning system tenable.

Ladyman's recent work on categorical types as *homotopic* is particularly relevant (Ladyman and Presnell, 2014; Ladyman et al., 2009). His overall approach roughly matches Hilbert's notion that when you find a coherent mathematical system, it can inform the dynamics of the system it models. Weyl (and as we will note below, Wigner) had similar views on the nature of the observer's mathematically informed type system being impressed as the reality of the perceived system.

Typically, OSR does not make such an intimate mapping between coherent signification systems and phenomenal behavior. However, we want to focus on the way that virtual (meaning at least not-immediately perceivable) entities can drive the system when their existence makes metaphysical sense. Even though elements of ontic structure need not be individually named (or even identified), their structure is still ontologically governed. We take the notion of using topology-inspired mathematics as our abstract system (as described above in conjunction with Rosen), and combine it with abstract types of that mathematics that though abstract have worldly characteristics.

Another virtue of OSR is its subtle notion of causality, which invokes virtual agents, non-determinism (in the ordinary sense) and what we will call structured *governance* (which will be examined more fully below). Our current domain of application is biomolecular, but the agent vocabulary should be discernable in any framework governed by ordered perception; the ontic influence suggested by OSR is not domain-limited so types discovered by these means will be universal.

To populate our abstraction of ordered perception, we are supporting a crowd sourced project to discover the generic types of our partly invisible second reasoning system and their projections on reality and perception. This companion project uses long form feature films as a distillation of human experience and studies perceptual cues, and is referred to as *redframer* (Goranson, 2015a; Goransonb).

Overall, we apply topological order in an observer-informed, mathematically guided, onticly structured framework to give us a computer-hostable calculus. The virtual aspects are entailed in this whole. The topology at the equivalent of the metaphysical level is coherent under serial symmetry operations, enabling computerized methods.

It is worth making a note on terminology here: in the OSR context, we use the term 'ontic' to mean a concept, agent, cause or effect that is consistent with experience in the world, regardless of whether it is directly experienced. We apply it more generally to inform all of the types in the system, regardless of how abstract. Because we are characterizing elements of the world that don't exist in the normal sense, we conflate two terms, using 'ontic' when the context is philosophical and 'ontological' when the context is a fielded computerized system.

3. Symmetry as fundamental

3.1. The geometric tradition in physics

This project has origins in blue sky government research that was originally advised by Wigner. During this period we became aware of a relatively unspoken metaphysical controversy among senior theoretical physicists. This can be crudely characterized by the institutions they supported and the difference in type systems they imply.

One articulate group was politically influential on science investments in the US at the time, the 1980s. It backed the establishment of the Santa Fe Institute and the concept of complexity theory as useful, fundamental and universal.

A second group had just come from major triumphs in the validation of the Standard Model and its use of symmetry. At the time, their investment strategy was focused on work to be performed at the soon-to-be-canceled Superconducting Super Collider in Texas.

(A third group, not part of the discussion at this point, were those few that believed in foundational logic as the primitive domain.)

These three communities had different notions about the primitives we might employ: from probability, geometry and logic. All three groups successfully employ quantum mechanics and often collaborate without noticing any difference, but hold different religions when describing how the universe is made.

A number of notable minds were in league with Wigner on this, positing that the metaphysical primitives of the universe were inherently geometric (or topological) and that if a type system were being fabulated, *symmetry* or an abstract cousin must be at the most primitive level. Some of the minds in this tradition were Hilbert, Weyl, von Neumann, Oppenheimer, Gödel, Einstein, Feynman, Wigner, Ne'eman, and Husimi. The last three were instrumental in the establishment of an international symmetry society that still influences our project (Goransona) (Wille, 2009).

Nothing in the OSR or Rosen agenda *requires* symmetry as an anchor primitive, but both can be better implemented if we have two chains of types (the abstract and primitive) in our two dimensions that are amenable to symmetry operations. What we take from these considerations is a preference for symmetric types and deep symmetries in type relations.

Some clarification of the notions of symmetry will be made shortly, but for now it will suffice to note that in informing types, the concepts include notions more abstract than employed in the standard model.

3.2. *Processes, transforms and intuition*

Symmetry seems to be a collection of concepts like no other — the representation and the subject seem connected at a deep level. It seems intuitively accessible even in the most abstract of domains. Many classical and quantum mechanisms employ dynamics that can be characterizable using symmetry, and a great many mathematical relations are related. We consider it to be primitive because it seems so, because it registers as *ontic*.

Even if there were not the strong precedent for symmetry as a primitive, it would still be a preferred high-level abstraction, for the way it can infer and generate functions for both causality and transformation. For example, Leyton builds a vocabulary of successive, generative operations to describe every object (Leyton, 2002), using constellations of group theoretic wreath products. The method is intrinsically symmetry-based, a process of 'unwinding' the observed qualities of entities to generative histories.

In theory, we could enable his complex of wreath products for use in the predictive modeling of the kind we need. But the combination of many abstraction layers across many systems that his approach would require does not scale well, even without explicitly subsuming something like the machinery of structural biology. We are thus solely influenced by Leyton's notion of a transformational calculus, one that can support a fabric of interwoven causal threads to model the current and future conditions and interdependencies within levels of systems. Our work (Goranson and Cardier, 2013) uses categories rather than groups, implicit as well as explicit forms, a finer granularity and a phenomenological inclusion of subject and reactive linkages. But the basic idea in the calculus is the same: well ordered, progressive, functional transforms.

Of interest are a class of approaches that are mathematically complete, and entirely computable but that do not provide the semantic anchors a metaphysics requires. Illustrative is the work of Illert (Illert, 1992) which follows a general pattern most clearly seen in Santilli (Smith, 2005). Wolfram and Musès (Palmer and Scott, 2003) are interesting as well. All of these would claim some measure of success.

They all create something like a parallel, higher order computational metasystem, but in every case the higher or parallel abstractions are set theoretic. This allows flexibility in devising computational options to mirror observations. But no new semantics are created.

Self-organizing systems based on higher order cellular automata have the same limits. The most interesting example is (Buckley), and some effort to integrate this work may prove fruitful.

Compared to those works, our approach is similar in having model types onticly related to observed reality, but differ in seeking a calculus that is not similar to the one we seem to naturally live in.

4. Situation theory

4.1. *The philosophical foundation*

Living systems operate at multiple levels and representations; let us now turn to a parallel issue in the domains of natural language and logic.

Our work originally emerged to address a problem for the intelligence community: how can we track driving imperatives across multiple levels and representations?

This problem stems from the way facts do not carry absolute semantics and interpretation (Devlin, 1995). Interpretation is influenced by context, where information is "embedded in a specific domain or situation" (Trabasso and Sperry, 1985). *Situations* require different considerations from *facts*, as we will explain in a moment. The inability to accurately handle situations, and the way unexpected consequences emerge from them, has caused great difficulty for the intelligence domain in the past (Devlin).

The initial work on situation theory is by Barwise and Perry (Barwise and Perry, 1983) and elaborated by many others. An important contribution is by one of us, Devlin (Devlin, 1995; Devlin and Rosenberg, 1996), who devised types and a workable system for identifying and examining (facts about) salient situations.

Our work is founded on a basic assumption of modern situation theory: situations can radically change or inform the operational meaning of a fact, process or effect. This dynamic is an essential problem in any reasoning system, automated or not, as well as a concern in any natural language processing environment — and that is before tackling the larger scope of modeling living systems. Whether in Intelligence or living systems, a fundamental aspect of the problem remains the same: facts alone enable accurate interpretation to a point, but once situational dynamics come into play, another reasoning method must also be used.

There are many ways to frame the distinction between facts and salient situations: for this work, a useful distinction is between static truth (facts) and a transitional, dependent truth (situations). Unfortunately, this flies in the face of current thinking in expert systems which are reliant on ontologies, including those of biomedical systems. A definitional chain of type, class and individual is common in these expert systems; the static binding is essential. For example, it is widely believed the Gene Ontology project (Various.d) once completed, is done forever. But what to make of environments where the 'meaning' of a gene (how it affects its environment) depends on a situational character apparently not ontologically capturable?

Situation theory provides a coherent system, philosophically formal and with coherent mathematical foundations so far as the effect of situations on facts. Here, situations change the interpretation of facts, effectively altering the fact itself when examined. In the experienced world, multiple heterogeneous situations can bear on a fact, each time with a different emphasis. The ability for interpretation to entail simultaneous heterogeneous situations means that current formal models of context do not suffice (Cardier, 2013). To manage this, we have developed a second sort which operates according to principles of governance (governance will be explained in a moment).

In order to satisfy these considerations, we approach the entire model as a *two-sorted* reasoning system. One sort performs ordinary reasoning using reality-informed, ontologically-based logic (however enhanced, perhaps probabilistically). A second sort performs something like reasoning over situations.

There are a few ways to implement our situational second sort: we start with the premise that situations modify the *local ontology graphs* for facts and associated logical statements. In biological terms, a biomolecular imperative (say implicating a gene) will not just have a different outcome, but be fundamentally different as the governance shifts among affecting systems.

A useful feature of this approach is that a very high number of situations can bear on any interesting set of facts and reasoning processes. Whatever the entity being reasoned about, some situations are persistently tacit, while others are salient only after sleeping in the background for some time. There are complex interactions among these: some situations modify others, and the entire presentation to the ontology(s) has governing dynamics, which affect the imperatives driving change across different levels.

Supporting this complexity requires two related reasoning systems, each with their own requirement for types. The two systems are bridged, which means their type systems must be related. Most situations are not exhaustively characterizable as facts for various reasons, which leads to the question of how to characterize them. Because they cannot be expressed entirely as facts, our types for reasoning about situations must support reasoning over the open set. In this context, each sort requires a typed calculus. (We use the term to differentiate subtly from an algebra, and to assert that the reasoning system be tenably computable.)

We may need intercalculi between the two. One transforms logical topology from the deductive system, and the other reports back situated influence.

4.2. *The relation to ontic realism*

Collier observes that situations are rooted in the world, registering pragmatics in situation theory and leveraging Pierce's *abduction* (Collier, 2014). His perspective does not discuss OSR, or application to novel science, but it does provide a philosophical understanding of the spectrum of formal representation: with logic at one end, the fluidity we attempt to capture in the middle, and the flux of creative real life at the other end.

Collier posits that novel usage of a conceptual tool can spawn new conventions. These can become fixed and lead to new general terms. The *novelty* (creativity) is constrained by the context, which further ensures that the novelty is functional (has value). The novelty is a new class under which instances (tokens) can be classified. This is exactly Peirce's abduction (method of hypothesis).

Collier's observation affects us. In addition to rooting our virtual agents of the second sort in ontic reality, we have to type our situations this way too, even though they are abstract. Some situations will be explicitly real, like a brain's chemical state, some of those (like neural action in the brain) will be reality based but partially unknown, some will be imaginary and others will come and go as part of an internal process. All of these must have ontic roots, Collier advises, and we concur.

Our crowd sourced ontic capture project, *redframer* explicitly accommodates this notion. (The *redframer* project is described below.)

4.3. *A two-sorted reasoning system: summary of requirements*

We have two primary reasoning systems.

Using these sources and insights where salient, we can summarize some high level requirements. One reasoning system will be referred to as *System A.* This is the system by which we perform the kind of reasoning normally modeled by natural language, logical statements and formal models. All of what we commonly use in biology fits in this system, in fact all of ordinary scientific theory, reasoning and engineering. An apparently remarkable variety of techniques exist here: arithmetic, probabilistic, relational and logical.

In this domain, there are many current and expected innovations that can expand the power of existing models and frameworks, and we embrace these. Everything that can possibly be done in System A, should be. We do not advocate changing any essential element of this way of doing things. Indeed, when we add the second sort, every *thing* must go, but all representations (and extensions of representations) of things must stay.

Everything in System A can be reduced or factored into logical statements, and for simplicity here we will consider the case of something like first order logic as its natural user-facing calculus. We also assume System A to be well formed in terms of at least one reachable ontology and metaphysics.

Whatever goes on anywhere in our manifold reasoning assembly, the working scientist will receive and manipulate the insights in System A, using terms native to it, even if it involves entities and relations unique to the other reasoning systems and even if it involves a container of unknowns.

System B, then, is the system in which situations exist in their native form and is where the dynamics of situations operate. It is categoric in nature and implemented via functional programming.

Systems A and B will each have their own discrete calculus, the former set theoretic and the latter category theoretic. We also need an additional calculus for the systems that link these together. These are referred to as System A->B, and System B->A.

So that is two discrete frameworks in a two-sorted system, with four type systems and associated operations.

Fig. 1 illustrates the relationships of types within the two-sorted system. System A is on the right hand side of the figure to preserve the spatial arrangement of the two-sorted expressions. The abstraction dimension is right to left (more abstract). The primitive dimension is bottom to top (more primitive).

We can say a few things about these four systems. Using the Barwise notion of *information flow* (Barwise and Seligman, 2008), information flows in abstraction loops in both A and B, and also (A) -> (A->B) -> (B) -> (B->A) -> (A). Therefore, types in that chain abstract from the precedent. Note that this imposes some challenges; *types* abstract from Systems A to B but *information* must abstract going either way.

In System A, types that are close to the user follow existing conventions for biological processes, natural language and ontology definition. These ontological conventions are universally noun-

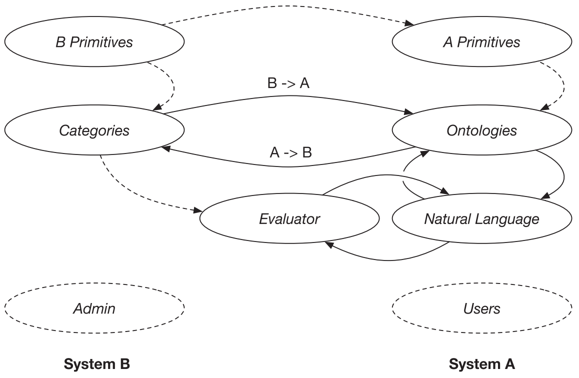


Fig. 1. The relationships of types.

centric, but at more primitive levels, we must be 'verb-centric'.

Connectives in System A are of the *and-then* and *while* types. This is required to make the logic behave as a linear logic and thus make it available for topological abstraction using well known techniques. Fortunately, this comports well with the strategy of understanding structure as (our expanded notion of) narrative. Note that these linear connectives are just what structure is revealed to System B. System A still allows any assertions, deductions or similar operations internally, using whatever connectives are desired.

In effect, that means deductions/abductions in System A are handled in a process related to System (A->B). Thus, operative types in System B reflect the abstracted topology of the linearized statements in System A. These primitive types in System B must also allow reflection over the entire two-sort, a condition required both for reasoning of the kind we encounter, and it also follows from the phenomenalistic approach; each system has to 'see' itself in the other system.

In a system where facts are dependent on context, the *identity* of situations is also conditional. These are characterized through continual instances of temporary framing, from an outside vantage.

As a consequence of the purely categoric approach, native types in System B are symmetric arrows, because of the *if-then* topology of System A connectives. (This notion of arrows is expanded later. Arrows in category theory provide a means of reasoning over *monads*, monads in this context being the structure related to a state of the world.)

Types in System (A->B) have no primitive depth, being purely transitive. That is, the elements passed in A->B inherit type governance from System A. On the other hand, close-to-the-user types in System (B->A) have *ontological presence* integrated into the ontology of System A. The reason is that in both of the transitive systems, the view is from System A.

In System A, the user interacts with representations native to their application. The figure indicates 'natural language; ' this often is English-like (in the aforementioned *redframer* project (Goransonb), for instance), but the bubble represents the 'natural language' of the discipline. In the present case, it is the conventional, dominantly structural microbiological vocabulary.

Normal statements in user-facing System A are small chunks representing facts, assembled as strings using connectives that indicate sequence and apparent cause (and-then) or apparent parallel sequence and no cause (while).

Chunks can indicate static or dynamic information. A static chunk in System A is a fact. A dynamic chunk is a deduction, abduction or process computation, reported back as a fact. All salient operations occur in B, excepting evaluations of dynamic chunks. These are handled in an evaluator whose types are influenced by B primitives because evaluations can change situation governance.

System (A->B) for our purposes is simple topological abstraction. System (B->A) performs graph manipulations and therefore has a categoric reduction in type from arrow assemblies to graph assemblies.

These observations follow directly and unavoidably from the foundations of those cited. They are an inevitable consequence of the philosophical commitments.

4.4. Symmetries across the system

Given Fig. 1, we can now provide some promised detail on the notions of symmetry that apply.

In the same way the rest of the system is generatively specified by both abstract and primitive types, there are abstract and primitive definitions of symmetry within the system as well. These notions of symmetry affect the respective type systems. In all the four cases where definitions differ, they all share the earlier presented core definition: symmetry is an algorithmically generated set of designators that describe patterns in the observed world, and laws that govern them. The difference among the four cases is simply that the world of interest is different, the notion of algorithm changes and so the symmetries of types differ.

System A has an ontology, diagrammatically shown in the lower right of Fig. 1. This area of the system is where the world is represented, together with experiences of the world. Symmetry in this case means what it normally does in the sciences. This notion of symmetry is as commonly understood – it is the observed basis of all of crystallography, notions of time used in quantum physics and of course as the basis of the standard model. This is the definition Rosen uses.

Symmetries of this kind are also a taxonomic tool in data classification tasks that extend to the phonemic agenda described below, which addresses observed behaviors. Sticking strictly to this real-world notion of symmetry, the mathematics that applies is graph theory. Previously noted is the congruence between ontic properties and ontological description, so the ontic properties of System A wherever they have influence also have symmetry-specifiable order.

A second kind of symmetry is found in the upper right of Fig. 1. This is sometimes considered the metaphysics of the 'world' below. Symmetry has a quite different meaning at that higher level, bound to and specifying the operators of the description logic. Any relevant logic can be completely defined by a set of axioms using the properties of sets; description logics, though a bit peculiar are no different. The symmetry relations we use here are these axioms, by definition primitive compared to the symmetries of the perceived world.

An example of a symmetry here is our notion of a non-commutative linear connective in logic. In first order logic, it doesn't matter if you first know that 'all men are liars' and then discover that 'Kurt is a man.' In linear logics and ours in particular it does matter; you would get a different result if the order is reversed. We would say this is an *asymmetric* logic.

Yet more abstract notions of symmetry are used in System B. These notions are also commonly understood, but in this case by type system designers and mathematicians. Examples of these more abstract symmetries are apparent in the specification of the arrow calculus (Matsuno, 2002) which we adapt. Types are generative of course, so there is always that symmetry between the type and term.

The arrow calculus goes further, imposing the notion of a symmetric type/term transform on the basis of the lambda calculus. Arrows as abstract primitive symmetries are quite different in nature than chirality in the experienced world, but we use the ontic principle to relate these between Systems A and B.

Our challenge in designing a type system can be restated as a challenge in integrating these notions of symmetry using the influences noted above, particularly the ontic influence.

We now shift gears to discuss other influences we have chosen, because we do have some flexibility in the remaining details of the type system, based on the design of operations within the system. Some of this is a matter of art, as well as experience with past implementations.

4.5. Implicate order and quantum interaction

Working from the types to the required operational infrastructure makes design decisions much easier, and also satisfies the computational demands. For example, usually expert systems must manage both the semantics *and* the reasoning. We are able to separate these: simple logic is handled by a simple evaluator (in the center of Fig. 1) and semantic interpretation is the responsibility of System B's ontology manipulator. In practice, if the right decisions are made, analyses practically impossible in traditional systems become tenable by this shift.

The preferred calculus of System A is graph manipulation. External ontologies are registered by translation into a combined graph/document database (Various.f). The 'document' component of that database preserves whatever model information the user currently needs.

In the present case, these ontologies capture genetic, cellular, signal and protein elements with associated processes and qualities that we understand. (Examples are in the next section.)

What System A sees from System B is informed by several examples. The first three were encountered by us in the Quantum Interaction series of meetings (Weyl, 1934). These workshops can be characterized as working on von Neumann inspired 'quantum logic' but applied outside of physics. An interesting notion in these workshops is that tools now exist that allow a unified model that is expressed and can be meaningfully managed by geometric, logical and probabilistic means.

From this group, Hiley (Hiley) has developed an algebraic approach that implements the ideas of his collaborator Bohm (Bohm and Hiley, 1993). Bohm's ideas comport well with the agenda outlined above if one only considers the elements we have adopted. Hiley's strategy follows the path devised by Hilbert (Hilbert and Cohn-Vossen, 1952) and employed by von Neumann in the original challenge (Birkhoff and Neumann, 1936), that of mapping the world of interest into Hilbert Space and then devising a categoric algebra.

In other words, Hilbert Space is a set of abstractions (with implicit types). If a world can be abstracted into this space, a vast collection of algebraic techniques are available. The standard approach is to find a means to abstract the reality of interest into this space, something easy to do if ordinary logic governs that world. But much, perhaps most of the world is not so governed, and surely not quantum physics.

To make this work, Hiley and Bohm suppose a universe of virtual agents, an 'implicate order' not unfriendly to the OSR conventions we cite. Louis Kauffman uses a similar approach in his contribution to this volume. We have something like this order in System B but with a key difference.

Abramsky and collaborators (Abramsky and Coecke, 2008) take a different approach than von Neumann (and Hiley, Kauffman). Instead of moving the world into algebra-friendly Hilbert Space and *then* abstracting for a calculus, they do the reverse, moving the world directly into categoric abstractions and then investigate useful modeling spaces. The results are stunning when applied to quantum physics.

The analog in our work is abstracting via System (A->B) into category space directly and applying a relatively small collection of operations in System B. We separate the models used for calculation (in System B) from those used for utility (in System A). Coecke does something similar with his development of string diagrams to support this approach (Coecke, 2010), but not with the distinct separation described here.

Lehmann provides formal foundations (Lehmann, 2010) for *and-then* connectives in System A that specifically enable the Abramsky notion we employ in System (A->B).

Wadler comes from a different perspective — mathematical foundations for programming languages. From that world comes a collection of programming techniques that are category-friendly and that enable our required categoric operations in System B. In particular we have his Arrow Calculus (Matsuno, 2002), a subset of which we can employ both in operation and to further constrain the abstraction space.

Our current design has lattices on the right hand side that characterize action paths indicating paths of ontology graph fragments with our connectives. An example is shown below in Fig. 3. The System (A->B) horizontal abstraction uses the half-dual of this lattice as skeletal categories on the left hand side. All this is enabled by the Lehmann foundation.

4.6. Visual syntax

Our intent is that this framework be widely used, with the dominant use case having experts in a domain, and using the system fluidly without having to deal with unfamiliar methods or representations. Therefore, we aspire to have an intuitive graphical syntax for new notions or operations wherever feasible. Drawings are intuitively accessible to most new users and they allow for intuitive affordances for manipulation. A simple example is given below in Fig. 6.

Working with this assumption further constrains the calculus. Fewer options that would be available otherwise are friendly to a visual syntax, so this has deeply affected architectural decisions (Goranson, 2015b).

When a user works with a new fact, entering it or examining it in context, she will be dealing with both instances and classes, presented ontologically, but using simple directed graphs. System B parses out the relevant entries so that just a fragment is displayed to the System A user, being the most relevant concepts for her use. A user registers the precise, intended meaning of the fact by adjusting relative distance, links and (in some cases) adjusting definitions. The edges of these lattices conform to our 'and-then' and 'while' vocabulary.

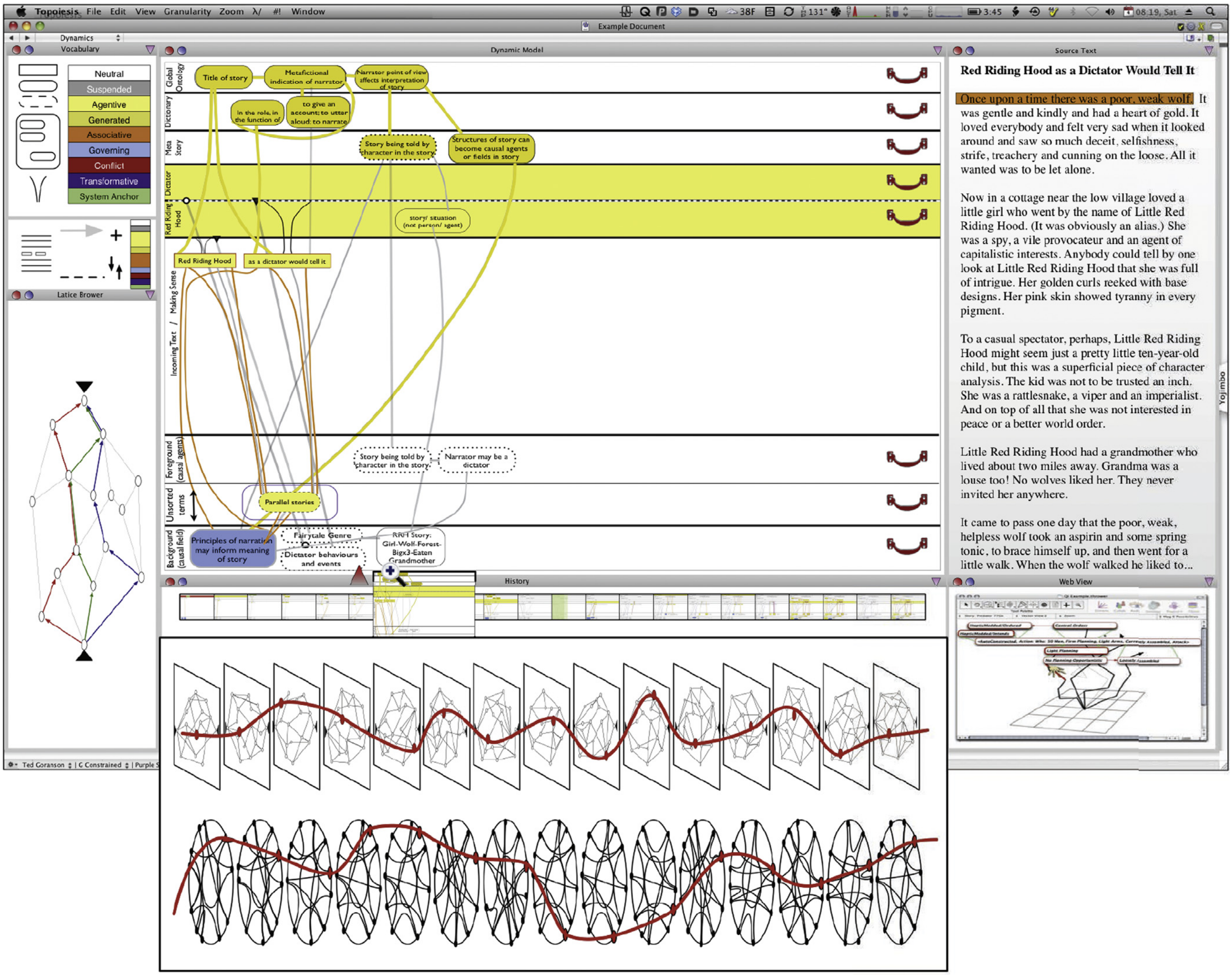
A user can visualize the system 'narrative' by looking at a lattice. These are lattices conforming to mature formal concept analysis conventions (Wolfram, 2002) but with the ability to manipulate and piecemeal examine nodes.

An ordinary user will not have cause to work with elements or behavior in System B, but a curator of the system dynamics will. He/she will be presented with two visual grammars, roughly equivalent to the ontology graphs and narrative lattices of System A.

The operators can be presented as string diagrams (Pittet et al.,), and the type system as arrows (Atkey, 2011). These are less directly manipulatable and represent abstract notions. We are still working out some issues in this area.

4.7. Two reasoning systems

We have described a system with two calculation methods. One uses logic and supports a large class of existing scientific



Red Riding Hood as a Dictator Would Tell It

Once upon a time there was a poor, weak wolf. It was gentle and kindly and had a heart of gold. It loved everybody and felt very sad when it looked around and saw so much deceit, selfishness, strife, treachery and cunning on the loose. All it wanted was to be let alone.

Now in a cottage near the low village loved a little girl who went by the name of Little Red Riding Hood. (It was obviously an alias.) She was a spy, a vile provocateur and an agent of capitalistic interests. Anybody could tell by one look at Little Red Riding Hood that she was full of intrigue. Her golden curls reeked with base designs. Her pink skin showed tyranny in every pigment.

To a casual spectator, perhaps, Little Red Riding Hood might seem just a pretty little ten-year-old child, but this was a superficial piece of character analysis. The kid was not to be trusted an inch. She was a rattlesnake, a viper and an imperialist. And on top of all that she was not interested in peace or a better world order.

Little Red Riding Hood had a grandmother who lived about two miles away. Grandma was a louse too! No wolves liked her. They never invited her anywhere.

It came to pass one day that the poor, weak, helpless wolf took an aspirin and some spring tonic, to brace himself up, and then went for a little walk. When the wolf walked he liked to...

Fig. 2. An example modeling interface view.

approaches. The second does not use logic, and is not based on set theory. It supports a collection of processes that are reflected in the first system. We loosely refer to these as two *reasoning* systems. Because others have proposed approaches (to other problems) that have two reasoning systems, it is useful to note the ways in which our work differs.

The most common of those dual systems is based on the supposed different types of reasoning that occur in the hemispheres of the brain (Various.a). In these models, the two hemispheres support collaborative reasoning systems. However, although

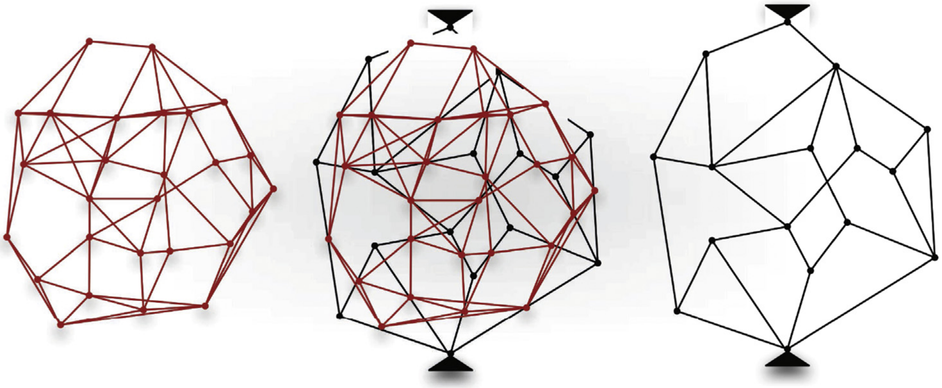
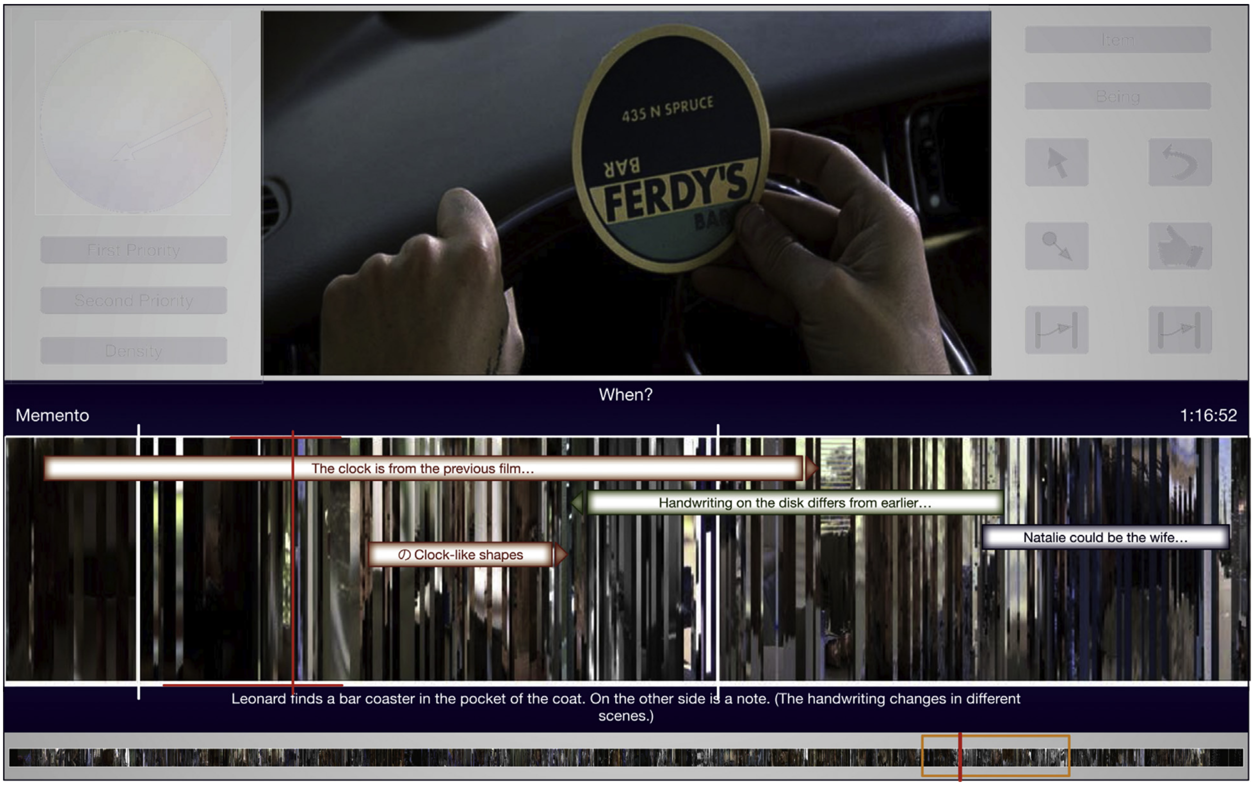


Fig. 3. A narrative lattice on the right and its half dual on the left.



The clock is from the previous film…

Handwriting on the disk differs from earlier…

Natalie could be the wife…

の Clock-like shapes

Leonard finds a bar coaster in the pocket of the coat. On the other side is a note. (The handwriting changes in different scenes.)

Fig. 4. An example film-based ontic capture interface view.

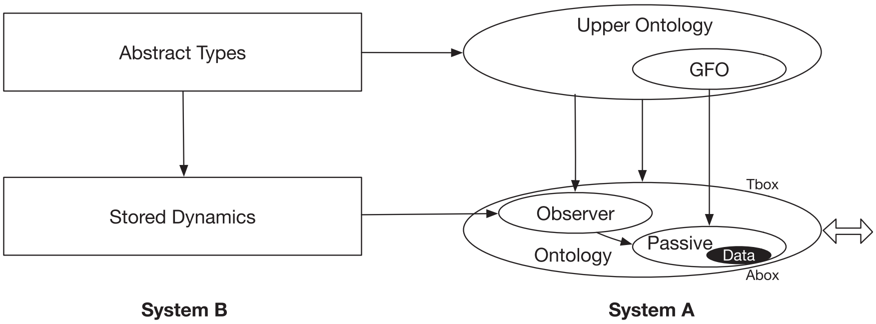


Fig. 5. Ontology relationships.

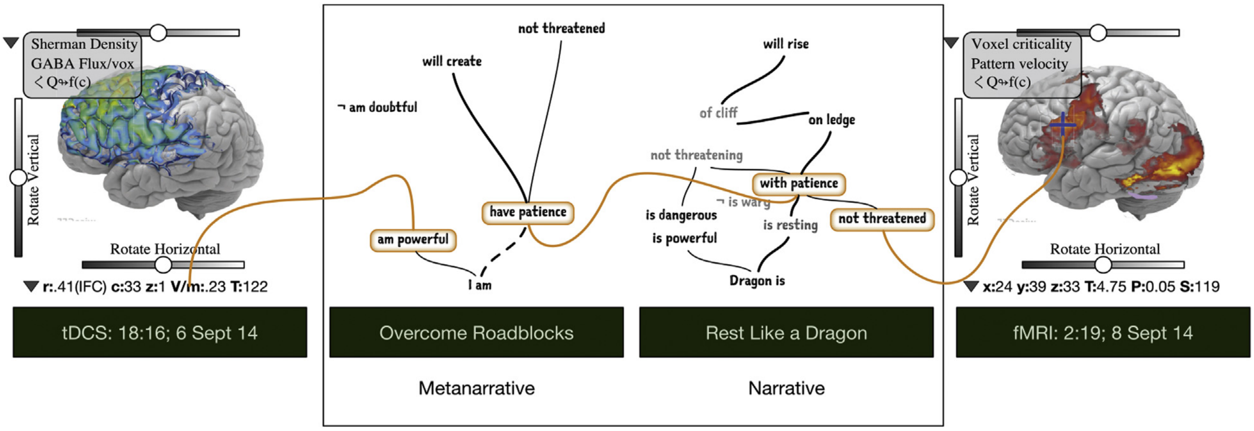


Fig. 6. An example combined neural zone and semantic graph interface view.

neurological research suggests that some cognitive processes clearly prefer one hemisphere, and others depend on collaborative interaction between hemispheres, most cognitive theories (Jaynes 1976) based on lateralization or bicameral dynamics are controversial.

Those models are wholly independent from the work described here. Hemispheric models deal with reasoning directly in the brain in terms of neural processes. Instead, we model cognition in the comparatively external context of information flow. The former can be seen as an instance of biological reductionism, modeling neural activity. The focus of our work is more strictly phenomenological, concerned with the congruence of both what happens in the world and how we model it. The mechanisms involved are drawn from narrative structure, and while they are not solely logical, highly developed operations are still involved.

While we do (elsewhere) propose a project to correlate narrative dynamics to brain activity, our primary goal is to enhance scientific methods in reasoning about complex living phenomenon.

Another system with superficial similarities to our proposal is that of that of Daniel Kahneman (Ladyman et al., 2013) who has demonstrated that many human decisions are not locally rational (as opposed to previous supposition that all human decisions are basically rational, meaning implicitly the result of logical analysis). Kahneman presents a ‘System 1’ which is rational (based on logical processes that maximize utility) and a ‘System 2’ which is less rational in this sense.

As a matter of practice, the science of economics reduces observations quantitatively so Kahneman's System 2 has two characteristics that take it far from our focus. First, he has to fit in a body of existing theory whose types are *utility* types. Rather than examining the nature of types as we do here, he simply adds some more utilities as prospects. Second, rather than fundamentally rethinking how information flows, he complements his first system with another that imposes probability on logic.

Kahneman's *prospect theory* is itself controversial, but that is beside the point. His ‘System 2’ is still set theoretic, does not rethink types and is employed to model a very narrow phenomenon. It is wholly unrelated to our work as described here, except that he uses similar labels.

A more useful comparison to our proposal would be another mechanism in common use that appears to be two independent but connected systems. The most obvious of these are theorem-proving systems, which we suggest are the most relevant of the second order logical systems. Here, the general design is a focus system: axiomatic and constrained by the ‘logic’ of the system, and then a second system which is larger, closer to full first order logic. It covers the consensus world of math, so truth in this second system is accepted truth.

Both of these systems are semantically mechanical in the sense that we describe our System A. One reasons about the other. A similar conceptual relationship exists with term rewriting systems where one system can coherently modify another, assuming the logical foundations of both being congruent.

Our System B below has a similar relationship to System A in that it rewrites its ontology graphs, but not (in the embodiment we describe) the core logic of any element of System A. Unlike rewriting systems, the internal mechanics of System B (our second system) are wholly different from System A in a deliberate attempt to supplementarily fill the shortcomings of reductionist and probabilistic methods.

These are, then, two independent systems, each internally coherent. One (B) can modify the other (A) in important respects that appear non-deterministic but that adequately model what we observe in a way that usefully extends science. Everything currently employed fits in our System A.

We characterize this as a two-sorted logic where the second sort is not logical, but ordered, categoric functors. The original notion of a two-sorted system (Caleiro, Gonçalves) envisioned flexibility in the logic of the sorts as broad as we have, but a more pervasive common algebra in both systems. Strictly speaking, we do not conform to this model as we follow the Grothendieck agenda (Gabbay, 2012) of abstracting between the two systems to allow type flexibility.

This reduces the problem at hand to one of type design, and what we focus on in this paper. In the discussion we use the term: ‘two sorted logic,’ because it helps illuminate what we have, but the reader should know that the type abstraction we employ is at the edge of the art and outside the normal notion of a two-sort.

4.8. An example application

The approach we are taking is not ideal for many problems. If the work concerns problems in which a situational awareness is not critical, for example exclusively cell and protein level processes without reference to system imperatives, then existing tools can be employed without the extra baggage.

This approach is designed for work that involves dynamics of or between whole systems, such as living processes where observations and analyses occur at more than two levels. For example, living systems can be studied as a collection of biomolecular processes, as a collection of behaviors of the being and as the operation of a number of systems within the body, for instance neural regeneration in the olfactory system (Goranson and Cardier, 2013). One example of leveled divisions is depicted in Fig. 7.

An ideal domain would be one where the formal models used can be fully and practically supported in ordinarily available computers and causal models are sought (rather than correlative associations). Also, our causal dynamics synthesize behavior across levels. That is, one should be able use ordinary scientific reasoning in understanding how behavior at one level (for example indicated by voxel patterns in fMRI studies) is related to behavior (for example creativity), and the other way as well (for example the effect of talk therapy on brain chemistry).

Candidate projects are disturbingly numerous, indicating how critical the problem is. They include clinical systems, modeling in manufacturing enterprises (Goranson, 1999), entertainment and intelligence analysis.

The remainder of this paper illustrates the decisions outlined above in the context of one example from this pool. The example involves creative processes, self-monitoring talk therapy and direct

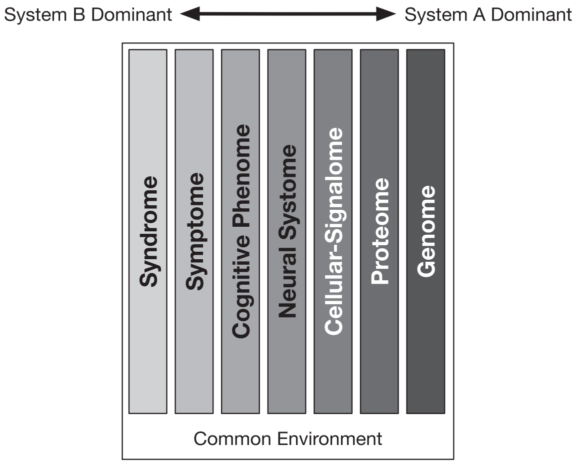


Fig. 7. A suggested genome/phenome hierarchy.

brain stimulation. It is chosen in part because we know there are causal connections among these and because the phenomes implicated cannot be expressed in one ontology, or even a few. It reflects the phenomena of interest, where a system changes itself through representation and introspection. It also gives an opportunity to include the softest phenomena in human urges and what motivates them.

Finally, it provides a way of showing how two-sorted modeling of narrative relates to two-sorted modeling of biophysics and we turn to that first.

4.9. Narrative types

Earlier, we noted that our framework was designed to reflect principles of ordered perception. These principles are based on a specific approach to *narrative*.

Included in our use of the term is the manufactured presentation, a product that can be read or viewed. But we generally mean something more universal, relying on the notion that cognition is a matter of organizing phenomenon and we organize by something like stories. This use of *story* is closest in meaning to that of cognitive narratologist David Herman, who states that it is the abstract, conceptual space delineated by a tale – "a cognitive construct that concerns certain types of entities and relations between these entities" (Herman, 2008).

An advantage of this expanded use comes from our commitment to the philosophical framework outlined above. Simply put, if something like *science* is influenced by the structure of our cognitive processes, then it makes sense to work on a reasoning system that leverages these processes.

One of us, Cardier, is working to understand these dynamics, both in the context of complex cognitive assembly and in models in the two sorted environment we have described. Her dynamics depart to include what we call here phenotypes (behaviors of conceptual structure which are described more fully below) which are a more basic abstraction that can entail the usual narrative criteria based on *things*: character, event and plot (Various.b; Herman, 2002).

Conventional narrative dynamics are subsumed in our System A. Her addition is the System B-hosted dynamics (Cardier, 2013), where narrative is a limited and subjective perspective on an evolving situation. This limited perspective avoids the problems concerned with objectively modeling causal phenomena, which were identified by John Stuart Mill (Musès, 1985). In narrative, information does not stem from an objective truth, but is instead derived from a subjective stance – a stance that is changing.

In stories, this evolution of perspective occurs when interaction occurs between conceptually structured situations with disjunctive elements; their integration produces a new, coherent network. Causal agents – including implicit agents – act within and emerge from this activity. Agents are responsible for manipulations of situational structure and are exposed by the unexpected structure they generate. Thus, narrative and its influence expands to fill the ontic space. Modeling of narrative in this form identifies causal imperatives that transform situations, rather than seeking particular entities or conflicts in sequential occurrence.

This congruence among narrative as stories, as cognitive organization, as ontic structure and as System B dynamics affords a great opportunity. We believe these dynamics to be subtle and elusive, so we have devised a significant project to capture them. It will surround structured perception by stimulating engagement in the user, whilst also recording the engaged behavior. It will thus capture (what we expect to be) tens of millions of human encounters with and within narrative, initially in the context of commenting on filmed and written narratives. This use of fictional worlds is via our previously mentioned redframer project (Goranson, 2015a).

An example of these dynamics and the associated types can be seen in a variant of 'Red Riding Hood' that has been examined in some detail in this context by Cardier (Cardier, 2013). Her example is 'Red Riding Hood as a Dictator Would Tell It,' written in 1940 when contemporary readers would equate Stalin and Hitler to dictator roles.

The example depends on a number of external narratives for most of the meaning of the story. Readers come with different versions of these external resources and apply them differently. The story is designed to present resonant meaning, directly as metaphor of course, but it also uses complex devices such as double irony and shifts in the metaphoric layers.

The reader goes through multiple critical points in the story where retroactive interpretation occurs. Roles and agency presented in the past are reregistered and settled meaning becomes unsettled. The processes that drive this apparently simple story include governance by virtual agents that are invisible to the reader and have ontic properties.

Drawing from our definition of narrative, System A has elements and effects (or structure) among elements. These elements are registered in an ontological context, using whatever domain ontologies exist. For the domain of narrative text, the ontologies are natural language and common knowledge mappings from external sources, supplemented by our evolving additional general knowledge store. If the domain were biomolecular, the ontologies (as described below) would be from those maintained by that community; much of those ontologies defines structural elements and behavior but some attempt to define concepts.

A user registers incoming elements as phenomena in the ontology/knowledge base. This is accomplished by presenting a relevant fragment of the larger ontology as an 'ontology graph.' Filtering of the larger ontology to determine what is displayed is managed first by lexical pattern match and then by iterative application of assumed situations by System B. Using novel user interface conventions (Goranson and Schachman, 2014), the user adapts the registration to account for subtle and resonant meaning. In conducting this registration process, a user may introduce ambiguities not desirable in deductive frameworks. An example of such a graph is illustrated in the next section, as Fig. 6.

For the examples described below, assume that a user is a modeler who wants to work with the system to gain a more detailed or broader understanding of the causal imperatives in her system, perhaps to make predictions. One goal is to create a model that informs the user and also informs the machine's understanding, whether of cognition or dynamics within a living system.

We use an animated graphical modeling tool to show causal dependencies, dynamic reinterpretation, and virtual agency. Situations are represented both as entities being reasoned about and containers that affect interpretive dynamics. Both virtual agents and situations appear.

Fig. 2 illustrates one instance in the animated graphical narrative model, with the scrubber panel choices expanded at the bottom to show lattice and half-dual evolution. (Scrubbers navigate among states in the phenomenon chain. The expanded panel at the bottom allows selection of states in the lattice, viewed two different ways.) Details of this model and display grammar are described in Cardier (2013).

Declarative ontologies are denoted by the bands at the top, which include the yellow bands. These denote what are normally considered knowledge reasoned about in typical Systems A. A novel feature is the layering. Some of this can be specified, for example general ontologies versus domain ontologies, but most of the layering is constructed by System B in creating discrete situations as influence. The order of layering denotes *governance*, being relative ontological influence.

The center zone by convention has the explicit artifacts being interpreted. In this case, it is the first few provocative words of the example story, chunked by concept. There is no restriction on having only one narrative thread.

The bottom zones (where the blue virtual agent is visible) are created and managed by System B, showing entities and relationships created by System B in its role of situated reasoner. They are shown as if they exist in the same ontic world as the elements in the top and are internally called the story or situation ontology.

Situations appear as bands and as enclosing boxes; there are many of these that often have short lives. A special type of transformative situation, drawn as a funnel-shape, transforms ontological projection.

Each of the entities (as boxes) in a band has an associated ontology graph. The ‘handles’ on each band allow one to pull out a ‘drawer’ and edit them directly as indicated below in Fig. 6.

The display as shown in Fig. 2 is handy for the modeler/analyst. Internally, it is represented as a concept lattice in the style used in *formal concept analysis*.

The right hand side of Fig. 3 shows a simple illustration of such a lattice. The originating artifact, in this case a phrase, is at the bottom of the lattice. Directed influence moves to the top where the current understanding of the observed phenomenon so far is indicated. We prefer to draw the virtual entities (from System B) on the left of the lattice diagram, so many of those nodes do not have direct ontological generation. Every node on the right hand side of this lattice (and the elements of Fig. 2) has an associated ontology graph that can be displayed in the z-axis, with the connections among elements of those combined graphs being the actual influences reduced to the edges of the lattice.

Fig. 3 also shows in red on the left hand side the *half-dual* of the example lattice as the simplest example of a category exported to System B. A half-dual of a narrative lattice captures the structure of the causal transforms, stripping out the semantics. The diagram in the center shows how one is generated from the other.

The general case with this method is exporting from the lattice of System A to symmetric and braided monoidal categories in System B, rather than skeletal category in the diagram resulting from the half-dual. In practice, we select the simplest categories we can, given the purpose of the system and often that is the half-dual. System B entity types (our ontic relations) remain constant regardless of the nature of the category space.

Fig. 4 shows one state of the much simpler web interface for capturing ontic dynamics from film. The horizontal bars capture annotations on cinematic moments that have ontological registration. Some of these concern dynamics of interest, registered in the same way as the text of Fig. 2. The bars are laid on a novel display that exploits short term eidetic memory, allowing a simultaneous view of many moments in the film.

Some views of the general modeling tool of Fig. 2 will have Fig. 4 at the center. Individual examples of the equivalent artifact annotation interface for biophysical phenomenon will be adapted from existing tools.

4.10. The additional value of narrated introspection

So far, we have used narrative structure as a strategy to build types and dynamics as ontic structure for an enhanced science of living systems. The structures transport from experience to ontic structure. But what happens when one of the systems being modeled is a narrative system?

Intuitively, it makes sense that any sufficiently complete system should be able to model itself at full comprehension. This is at least a fact resulting from the ability to practically encode it for machines using current and emerging techniques. We've chosen an example that illustrates this reflexive ability by including as one of our levels a conventional narrative, a story. Nesting narrative appreciation in within a narrative-based system reflects one attraction of phenomenology: when one attempts to step outside experience, some essential aspects are lost, yet at the same time a narrative handle on it can be created.

In the example, some of our levels will involve physical systems in the body, but we have chosen an example level that is natively narrative and deliberately self-manipulative. In this category are talk-therapy and self-help books. Talk-therapy allows a person's thoughts and actions to be changed through their own articulation of them in the presence of a skilled observer. Displacing problems into narrative, and then modifying that story, has been proved to have a positive effect on a person's ability to deal with those problems. As Palmer and Scott explain, “having people talk to themselves differently is to have them behave differently” (Pavlovic, 2012).

Self-help manuals offer a similar projection of self into an externalized narrative, but with the added advantage of an artifact to facilitate the process: the book or self-help manual. An effective self-help protocol is basically a self-administered and self-monitored talk therapy. As it happens, the one we have selected as a brief example of self-help therapy has been effective.

We have selected a program designed to enhance creativity as presented in Bryan et al. (1999), Cameron (1992), each being annotated exercises, described and practiced using metaphors. Because the metaphoric language is connected to well known external narratives, we call them *parables*.

Cognitively, parables are important because they are microcosms that extract the essence of the relevant situational structure. They allow an introspective shift outside complex systems, so the most essential dynamics come to the fore. In a narrative-based system, this kind of structure will allow large amounts of information to be organized using a manageable, abstract form. In her model of narrative dynamism, Cardier proposes that parable-like structures (which she describes as being composed of situational derivations, referred to as *ambassadors*) enable tokens drawn from System A reference frameworks to be combined and manipulated, as though in microcosm, changing its arrangements in response to the unfolding story text.

The books present exercises based on parables and has a simple goal: to help individuals map narratives into new contexts in order to be creative. The approach is in the spirit of implicate order and Bohm is explicitly referenced in the text. Many of the exercises are designed to improve and integrate *self-awareness* (and the forgetting of it) into creative work. When it works, it appears to work because in adopting the narrative of the parable, that narrative also conveys to self in an effective manner.

An example of a parable fragment in Bryan et al. (1999) has a *dragon* as the creative spirit, evoking (albeit a westernized view of) Taoism. A set of nine 13th century paintings of dragons is used as an overarching device. Exercises step the reader/participant in the exercise so they are taught to examine barriers to creativity. Within the larger dragon parable are smaller mini-parables embedded, drawn from different external references.

This is a microcosm of a principle of interest, where the participant steps outside the creative process to reflect on it. The common factor is narrative: a system of ordered perception that organizes information using introspective principles, allowing a movement out and in again, to manipulate the causal imperatives of the system.

In the layered biophysical domain, we can use the same ontological strategy as the fiction and films projects, adding some challenging notions of self-examination, awareness and evaluation.

4.11. Building the ontology

In terms of the problem of connecting diverse situations, our formal system can be characterized as an introspective machine, where each side (Systems A and B) uses the other to 'see' itself from a complimentary vantage: the blur of experience (situations in System B) versus its logical rendering (facts in System A).

Though most of the novelty of the approach stems from the value added by the phenomenological System B, the ontological strategy of System A is also important. Some critical features of this have been discovered in our work.

The ontology must deal with real and fictional worlds as encountered through natural and cinematic grammars. It also must deal with the bewildering variety of biology, behavior and phenotype ontologies noted in the next section.

We have to present ontologies that are subsumed and handled internally as if they were untranslated, so that expert practitioners can interact with them as they normally would. At the same time, it must *federate* with external ontologies, those not subsumed for modification by System B dynamics.

By virtue of the 'talk therapy' example of the previous section, observers of several types must be represented and a number of elusive observer, third party causal effects. Finally and perhaps the biggest challenge: the ontology must present System B dynamics and their effects as if they were 'of the world' of System A. This last requirement could provocatively be stated as: whatever happens in System B, viewers from System A should see them as something like abstract parables.

Our strategy to handle all of these enumerated ontology challenges is illustrated in Fig. 5. Typically, an ontology has an 'upper ontology' that specifies basic primitives of the world, more pure. What goes in an upper ontology is a matter of art, and we choose to use only primitives.

For example, how to define what an entity is and how that an entity appears as the result of a phenomenon? In our scheme, this is an upper ontology notion, as is the notion of apparent self-awareness. Concepts such as 'person,' 'woman,' 'sister' and 'mother' are represented in the ontology proper, that lower right oval.

As a matter of art and not of much interest here, inside the ontology a further division is made between basic entities (like 'woman') and knowledge from assertions about them, like 'all mothers are women and all women are persons.' These are Tbox and Abox distinctions, respectively in current ontology work (Gruber, 1993). Abox reasoning happens in that center oval, using ordinary logic.

Now turning to the upper ontology, the oval in the upper right, we have to support a rather complicated arrangement. Some of this is simply because we have to integrate several ontologies of the ordinary kind.

But the major complication is because of the relationships we maintain with System B; primitives in the upper ontology map directly from the abstract primitives from the left side of Fig. 5. For the larger domain (represented as the larger oval), we use the concepts from the basic formal ontology (BFO), modified for the phenomenological context. Within that, we also have a sub-upper ontology that uses the general formal ontology (GFO), shown by a smaller internal oval.

(BFO and GFO are prefabricated collections of basic concepts, offered as standards for those building specialized ontologies. Most ontology efforts in the biomedical domain use one or the other. It is much easier to deal among ontologies who share the same basic concepts of the world, things like time, sequence and being.)

It is a nuisance to keep track of the primitive-generated phenomenological upper ontology, its expression in BFO and the mapping to GFO. But we only have to do it once (per the design of the system), and the projection to the working ontologies allows us to use existing, settled ontological structures and tools.

In other words, we do a lot of extraordinary things in that lower right oval, so we move all of the abstraction that we can into other, more static areas, up and top left in Fig. 5. For example, we can inherit existing working ontologies about common sense (like ConceptNet (Various. et al., Ontologies)) and those from the biomedical world that conform to the open biological and biomedical ontologies (OBO) foundry principles (Various.e). The former is moved into a dynamic space (System B) and manipulated. The latter we keep in a static space (System A), ready to inherit new knowledge from the source projects. Some of the imported information is not ontologically structured, but simple structured data, shown by the small black oval.

The two larger ovals on the right are coded using the semantic web standard description logic (OWL DL) (Horrocks, 2008). It in turn uses logical conventions specified in $\mathcal{SHOIN}^{(\mathcal{D})}$. The description logic is used in the oval of the upper right in Fig. 1; what the ontology community calls 'assertions' are shown in the lower center of Fig. 1 as 'evaluations.'

A description logic is a logic with special rules used to build ontologies. The science is still in an early state, but the semantic web consortium has settled on a description logic for the purpose, one that is friendly to ontologies based on things, and computationally efficient reasoning about things. Our application of the description logic in the upper ontology follows the phenomenological agenda outlined by Smith (Toga and Thompson, 2003), but extends beyond his application of those principles in GFO to accommodate our four abstract primitives of System B.

In summary, we have a System A with which users interact and reason. It is governed by an upper ontology based on phenomenological types, but structured such that existing, noun-based, Newtonian concepts can be used. Some of these are handled statically, without directly affecting their semantics. Other ontological entries having to do with systems, worlds and perception are malleable, controlled by System B.

The description logic used is the most common and best understood. It allows both a categorical view using principles similar to (Poldrack et al., 2011) on the ontology side, (Son and Goldstone, 2009) on the code side and integration with vast and growing pools of knowledge managed by the semantic web, mainstream biomedical community and (as we will note), more ambitious phenotype ontologies.

4.12. Ontological registration of concepts like parables

The described design makes it possible to transfer information across different contexts and modes of representation. A critical feature of this process is the *parable* structure, mentioned earlier. Not only is this feature central to the systems' ability to interface with itself, it is also a key interface for the user.

For example, the modeler of Fig. 2, working with narratives and facts, can work solely in the world of a constructed narrative. Within this, the parable example allows three possible areas of focus. Consider how it operates in the example of the self-help book, *Riding the Dragon.*

First is the world of the story that constitutes the parable. Here, it is important to know what a dragon is and how she sits in the world as described.

Second is the world of the subject who is practicing the discipline that uses the parable. This is a different world, one that a knowledge worker would associate with the *real world*. But there are peculiarities in describing creative blockage in that world that elude useful characterization and are best addressed by the parable.

Finally, there is the neurological system (of the subject) in at least four states: creatively blocked, performing the exercise, changing some cognitive apparatus, being creative. (This latter depends on the neuropsychiatric ontologies and types noted below.)

These three different modes of understanding — self-help, professional writing, neurology — can be integrated in the following way.

When interacting with an artifact (whether a creative exercise, or a story like *Red Riding Hood*, or a film), the user will be presented with a fractional ontology graph, which depicts an estimation of how the situated artifact fits into the relevant worlds (here, that artifact is a part of the exercise description). This estimation is a matter of (usually lexical) pattern matching, modified by System B.

Fig. 6 illustrates what a user could encounter in such a case. The items on the far left and far right are interface studies for the phenome-based example, which will be described in a moment.

(The center area of Fig. 6 can be changed to or integrated with Figs. 2 and 4, depending on the type of work being performed.)

In Fig. 6, the column labeled ‘narrative’ (in the center box) is what a user would see if modeling the dragon exercise directly — perhaps taking notes for herself. In this case, two levels of the process are important: the dragon parable (on the right) and an implicit narrative about a person overcoming creative blocks (on the left). The user is able to model across levels in a single view. (On each end of the figure, metric visualizations are linked to this activity. More on that in a moment.)

Incidentally, this dual situation, where a user is able to model both an artifact and a meta-understanding of it, is typical of what an intelligence analyst encounters.

It is an example of two *levels*, the narrative and metanarrative, but only one *system*. However, one might say they are at two *phenomenological systems*, one nested in the other and this nesting presents some challenges. The next section and accompanying Fig. 7 introduces more complex multiple system level: physical ones ‘below’ and behavioral above.

In implementation of the example seen in Fig. 6, the *ontology graphs* are presented as actual graphs, not as ontology fragments. The difference is not important to the presentation here. A graphical depiction of an ontology uses edges to represent logical connections, like ‘is-a.’ Our ontology graphs are more like topic maps (Garshol) which simply encode association.

Concerning the ontological content: nodes in these graphs are concepts structured using a resource description framework (RDF) like system, but with our phenomenon based emphasis (Goranson and Cardier, 2013). A user can examine in logical form and edit these structures as conventional ontologies.

In the logical expression, the elements are serialized using *and-then* related associations (the bold lines) and those associated with *while*. The logic is stripped off and the presentation is ‘in between’ the logic and a story. Some concepts are shown to ask “did you mean to include this?” but are not connected. Distance is significant, representing strength of association.

The graphs are Husimi trees (Husimi, 1950) abstracted from the combination of stored knowledge and ontology, the ovals on the right of Fig. 5. The purpose of this interface is to have the user register each atomic chunk in the knowledge base, using interaction with the best of System A and B techniques in conversation with the user.

The presentation to the user can be manipulated intuitively. Some nodes are connected to show interpretive influence. Other nodes are shown either to suggest likely alternatives, or to show interpretations that are possible but explicitly not chosen, or to indicate concepts not currently salient but would be in the past or present. Selecting a node anywhere, regardless of whether it is linked opens a popup that reveals its ontology graph in the current situation. The effect is of temporarily moving that node to the origin of a definitional ‘story.’

In the user interface, this ontology graph space also has an internal physics, a way of mapping phenomenological associations as if they were fields. Nodes (and lines) are attracted or repelled. Spatial proximity indicates influence. A three dimensional view can be toggled on to optionally assist the user. Mass and force are indicated by cursor lagginess and tendencies for nodes to snap (Goranson, 2014; Goranson and Cardier, 2014; Goranson and Schachman, 2014).

As a new piece of information enters the system, and/or the user changes the ontology graph, the topology of the situated knowledge at that state is conveyed to System B, which applies known structural dynamics that can change many of the connections in the knowledge base and ontology. In some cases, prior and expected structures may change significantly.

The nature of the observed changes has been noted to be a superset of quantum behavior (Bruza et al., 2009), as one would expect. That behavior is not illustrated here.

4.13. Neuropsychiatric ontologies

Finally, we turn to a more complex and urgent application for this framework. The larger medical research community is building reference ontologies toward a goal of making their results more shareable, both with other researchers in their domain and those in other fields. The previously mentioned OBO foundry principles help with that effort, as long as Newtonian elements and their behavior are captured. As we have noted, this hardly helps with the systems modeling, contributory cause and soft ontologies, like concept ontologies.

In order to address these problems, a group of researchers support an effort to elevate the notion of applicable evidence in the cognitive domain from genomic to include phenomic (Bilder et al., 2009). Without explicitly stating the intent, the associated projects are attempting to build pragmatic *phenomenological* phenotype ontologies.

One domain of interest is *neuropsychiatric phenomics*. A focus is on the *cognitive phenome*, in part because measurements can be made and managed, existing formal models are poor and the ability to move up and down in the levels of Fig. 7, with an ability to identify causal dynamics across those areas, would be highly desirable.

Two projects in this domain are of interest. Phenowiki (Visser et al.,) is “a collaborative online annotative database for phenotype selection.” The idea is basically a wiki imposed on an ordered data dictionary of topics. (A wiki is an editable web page that in theory will collect a growing body of knowledge from experts. That knowledge annotates the entries of the ontology or database but is not formally ordered. In other words, a machine can understand an ontology, but it would take a human to read and understand the wiki pages.)

The cognitive atlas (Various.c) is a more ambitious project that has more ordered, but similar, ‘soft’ annotative wiki features; it allows for ontological registration and focuses on cognition.

The formal framework of the latter (Rapoport and Lucio, 2014) is entirely consistent with the methods described above. In effect, the cognitive atlas is informally two-sorted; it uses whatever System A-like ontological framework that can be brought to the situation, and supplements that with natural language System-B like annotation moderated by human experts and editors. One could build a phase 2 cognitive atlas that better serves the purpose of these ontologies using the more formal techniques described here. We expect that as part of a demonstration project.

The promise is obvious in the simple case: these projects aim to achieve the same benefit claimed by the gene ontology project, in their own discipline. That project exhaustively covers its domain; it uses easily accessible standards and artifacts from it can be losslessly computable.

Because these higher level fields extend the notion to phenomes and address ‘soft’ information, their methods must also be extended with suitable types and practical ‘soft’ methods. A reasonable project would build a second generation cognitive phoneme ontology, using something like the methods described here.

The spectrum of knowledge that can be encompassed is depicted in Fig. 7: ailments can be modeled across numerous levels, from the genome to presentations of the syndrome. Causal triggers can be tracked or discovered within and across levels. The real payoff comes from exploiting the advantages of working in the phenome/phenomenology world, inheriting all the advantages of a suitably repositioned theory.

A possible long-term advantage is to build a new working theory of cross-level phonemes, capturing a fresh set of phenomenological system imperatives. But in the shorter term, huge benefits might occur with fractional bits of such a theory that deal with limited relationships among levels. One need not have a refined, comprehensive theory and metaphysics to usefully address some real world problems today.

We know psychiatric therapy works, as do similar methods that use reflection and explicit self-monitoring. We suspect that there could be effects from transcranial direct current stimulation that influence creative processes. We have rather well defined fMRI methods that can report areas of brain activity, with some correlation to proteome and cellular-signalome phenomenon.

Among any two of these domains, it is difficult to work with them in a unified way, using one metatheoretical envelope to understand cross-level cause. This work puts all these viewpoints together, to support an advance in the science of whole systems.

The next stage of this work will be advanced by a well-designed experiment. This will vary categorized reflective narrative parables for measurable creative effect; vary parameters in tDCS sessions for measurable creative effect using the same tests; and, use the result to seed a second phase, phenome-centric cognitive ontology project.

5. Conclusion

In clinical diagnosis, a majority of our abstractions and tools are limited to one paradigm. A second, integrated phenomenological paradigm will provide many benefits. Using the best of known formalisms, we have devised a two-sorted reasoning system that allows both to be used in concert. Elements of the system have been tested piecemeal and are currently being assembled. Simultaneously, a web-based project is underway to observe and collect phenome dynamics to accrete our ontic virtual agents by learning from human interaction with fictional worlds.

The system follows principles of phenomenology (Santilli) and pragmatic ontic realism (Collier, 2014) in determining basic types and type dynamics. These are implemented in a computational framework formally supported by situation theory (Devlin 2009) and in a two-sorted system (Bohm and Hiley, 1993) using categoric logic (Abramsky and Coecke, 1319).

An enabling principle has structured elements through an expanded notion of narrative (Cardier, 2013) as connected by quantum-friendly linear logic (Leyton, 1999) and applied as parallel serial transforms (Lindley et al., 2010).

A challenge is managing ontologies. As an engineering decision, we strike a balance between subsuming existing methods (Various.e; Various. et al., Ontologies; Various.g; Various. et al., Ontologies) and managing federation internally. Others will likely choose a different balance of consumption versus federation. Also, we choose to be more formal than some uses will require.

To provide increased intuitive access, an integrated set of graphical grammars are being developed, extended from mature techniques (Xiao et al.,). Emerging foundations in functional programming science are employed (Amsden, 2011).

A future report will describe the details of an implementable type system that meets the requirements surveyed here.

An experiment is required to test the concepts described herein, validating the specific approach and the general use of phenomenological concepts. A proposal for such an experiment is being assembled.

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