Relations in Contexts

A Cognitive, Object-Oriented Modal Logic for the Semantic Web

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ABSTRACT

I explore how theories from the domains of cognitive grammar, modal logic, and object-oriented lambda calculus can be practically applied to Semantic Web technology. Specifically, I explain some motivations behind a C++ library called CLOSXML, which is an Embedded Common Lisp adaptation of SXML or "S-Expression XML". Originally conceived around Scheme tools, SXML uses simple syntactic policies to express XML documents as S-Expressions. CLOSXML markup uses an expanded Lisp syntax better suited to Object Oriented data, and conceives "Markup" itself in fundamentally Object Oriented terms, drawing particular inspiration from the C++11 and Common Lisp Object Systems. Philosophically, I suggest that modeling objects' variable internal state provides an alternative to "possible world" semantics, one consistent with certain cognitive-linguistic models but also describable using formal systems such as object-lambda calculus, adapted for a graph-oriented algebra with modal operators.

Cognitive Modal Logic (CML)[1] considers possibility and necessity as aspects of how real-world objects and facts are conceived. As such, CML permits ontological elimination of "Possible Worlds", at least if these are conceived as "other universes" with all the cosmological trappings. Many philosophers hedge that their "worlds" are not *those* worlds, and say that Worlds are really "states of affairs", or "ways", or "realms" (the World (realm) of Politics, etc.). But many issues in (philosophical) modal logic seem to draw their force from the "worlds as *Worlds*" paradigm. The broad strokes of Alternative Worlds can obscure, or thematically overwhelm, the parameters of contingency itself: the (conceptual, data, measurement...) structures providing sites for counterfactuals. These are not just philosophers' puzzles: Modal Logic is entrenched in a key trio of formulations central to how most researchers understand *language* in terms of *logic*, thereby setting paradigms for domains like Artificial Intelligence, Knowledge Modeling, and, I contend, the Semantic Web.

A case in point is the problem of *counterparts*. (This includes more technical problems, like the "Kaplan Paradox" [16], which involves cardinalities of sets of possible worlds as against possible individuals). If worlds are "realms", then certainly we travel in multiple circles. Slavoj Žižek is a figure in (Continental) philosophy and (Slovene) politics. But they're the same guy; we don't call Žižek-the-politician a "counterpart" to Žižek-the-philosopher in the World of Politics. Maybe Canada's counterpart to Žižek (another philosopher and essayist with a brief career in politics) is Michael Ignatieff. But this explicitly mentions *two* people: ordinarily, counterparts are different things sharing some property or role. François Hollande is Barack Obama's counterpart in the French state. Obama could have lost the 2012 election, so philosophers can mention possible worlds where Obama is not now in office. The non-president Obama is then called Obama's "counterpart" in such worlds. Yet unlike (say) Hollande, that person is not Obama's counterpart; he's Obama.

Not all scholars accept the Phenomenologists' notion of *intentional relations* [20]: that cognitions create connections between consciousness and the object (or *noema*) "grasped" in thought. If we do accept this notion, then thinking about Obama losing the election means that I begin with Obama in general — that is, I begin from an intending or mental grasp of (real-world) Obama, and then select related points of knowledge to imagine varied. My intending does not lift away from Obama and re-attached to some Doppelgänger copy; instead, I engage a cognitive episode which is in large measure the same as ones involving no counterfactuals at all, and then vary select details. Moreover, we cannot rightly cognize Obama without pausing, however briefly, to conceptually scan the junctures where things could have gone differently. It is an intrinsic part of Obama's life and historical place that he could have lost the elections. Contingencies are *part of* the historical narrative, and in that sense it is more appropriate to say that the "counterfactual" Obamas (like one who lost the election) are *parts of* Obama. Representatives in "other possible worlds" are *parts*, not *counterparts*.

The question of how mental, linguistic, or symbolic representations refer to things in the world, is especially important in Modal Logic, which tends to quantify over messy real-world objects. By allowing propositions to be contin-

[1] My (nonstandard) name for work overlapping modal logic and cognitive linguistics, using logics that deviate from (maximal) Possible Worlds and/or model intensions and belief states: Situation Semantics [9], Bisimulation, Two Dimensionalism, Partiality [19], "countermereology" [7], etc. In these and subsequent citations, I mention only select examples of a topic that are unusually apropos to my concerns.

gently true, Modal Logic seems compelled to engage with the kind of real-world, non-mathematical things which *have* contingent truths. Like any logic, then, Modal Logic must *ground* its symbolic representation of non-abstract entities. We cannot just talk about (im)possibilia in the abstract. It is impossible for the White Queen and the Black King to be in B4 together. Certainly the two pieces can be physically placed in the same square; what this means is that no exemplification of a chess match (on a board, on paper, in someone's mind, whatever) will have such a formation. The names in this case (Queen, King, B4) refer to slots in a formal structure (one fixed by the rules of chess). These slots can be embodied by physical objects, but any discussion of what is possible (relative to the chess-structure) refers to such objects only *insofar as* they embody those slots.

In general, as we apply logical models to empirical reality, we refer to objects in their guise of taking on structural roles [6]△. The world does not come prestapled with lowercase Greek letters: abstract symbols build abstract structures, and logical reasoning applies to real objects because we can treat sets of objects as systems exhibiting these structures. Explicitly or implicitly, this commits us to account for *why* these objects collectively realize these structures. In the Philosophy of Science, this account is often discussed in terms of "emergence theories". Thermodynamic equations apply to molecular systems, for example, because they exhibit emergent, large-scale behaviors which can be approximated by relatively simple quantitative models. In general, some such emergent or scientific theory is needed to connect logico-mathematical theories with empirical realities.

The problem for Modal Logic is that many of the parameters, which are subsumed into logical idealizations, are themselves potentially subject to modal operators. If I endeavor to represent propositions or objects with symbolic labels, I need to account for how the real-world objects involved are to be isolated as symbolic referents. I need to assign them, despite their inevitable evolution and variability (losing some parts, changing some properties, etc.), some stable inner core of identity and individuality. In general, mental and linguistic reference allows for referents' continuation across and change in time and space. However, such changes are themselves candidate modalities: contingencies and idealizations in the symbolic labeling of objects can potentially be absorbed by modal formalisms, where we index not just objects but their counterfactual (temporal, intensional...) counterparts. Ironically, then, despite — or really because of — Modal Logic providing formal models of real-world contingency, these logics actually face an especially acute version of the "grounding problem" which is familiar to Artifical Intelligence. We accept some idealization in mapping logical symbols to worldly things. The problem is that Modal Logic gives us the potential to quantify over minutiae (time-indexed states, state contingencies) which ordinarily would be hidden behind the idealization itself.

With respect to science, we presume an idealizing abstraction involved in relating symbols in scientific theories to real objects. However, a similar idealization is not always recognized when it comes to the relationship between logic and language. The key culprit here is "truth conditional" semantics, according to which the meaning of a sentence is the conditions (proof, observations...) which render it true (justifiably believed, provisionally accepted...). We can similarly consider the conditions which make a *scientific theory* true (believed, accepted); but in this case we know that true means true *up to* some abstracting and idealization. When considering truth conditions for language artifacts, however, we seem to reason as if the relation of words (in language and in people's minds) to things, is analogous to the relation of logical symbols to things. The leading, "model-theoretic" paradigm in formal semantics aims for a fairly direct correlation between atomic language entities and worldly things, while modeling larger-scale language features, like sentences, in terms of truth-conditions. So logical symbols (and language lexemes) are basically just labels affixed to objects. The obvious cases where words refer to counterfactual, imaginary, or past objects (Sherlock Holmes, or the Obama who lost in 2012, or Obama as a child) are then subsumed by modalities — Sherlock Holmes is a label for an object in some possible worlds; Obama-as-a-child labels Obama in a past temporal world, etc. Modal Logic is therefore an intrinsic part of Model-Theoretic theories being pre-eminent for language and meaning — including theories that have lent algorithms and representational machinery (like Description Logic and Domain Ontologies) to the Semantic Web. This explains the demand for globally unique indexed resources: a consistent, universal domain of discourse where distinct worldly entities are distinctly labeled, and globally accessible ontologies defining truth-conditions that can be canonically applied to an ever-expanding, universal data space. In combination, they allow the Semantic Web to enact a large-scale, open-access model of a Knowledge Reasoning system.

Modal Logic, Possible Worlds (as its "semantics"), and Model Theory (for natural language), provide a triple infrastructure for a philosophical semantics (and a Semantic Web) that conceives language as a kind of logic. The computational corollary is that implementations of logical processes (like Logic Programming) can also simulate human signification. Computer languages and software provide a "sandbox" where intuitions about language are forged, so perhaps this connects the lacks (I claim) of both a well-developed Object Orientation for (on the one hand) Semantic Data, and (on the other) for research connecting formal and natural languages. "There is much more to semantics than syllogisms", as Peter Gärdenfors puts it; "the Semantic Web is not very semantic ... It is an unfortunate dogma of computer science in general, and the Semantic Web in particular, that all semantic contents are reducible to first order logic or to set theory" [10, pages 1-2]. In response, [18]△ developed `CSML` (Conceptual Spaces Markup Language), which conveys the geometry and topology [11]△ of conceptual relations, contexts, and similitude. I think the cognitive roots of `CSML` can be strengthened even further, by first the simple syntactic translation of `CSML` into Lisp (`SXML` [14]) code, then integrating `O·O` structures. If the Semantic Web emerged in a paradigm space preconceived in logical/functional terms, then I believe that Object Orientation provides a counter-paradigm better suited to a more cognitive semantics.

Modal Theoretic semantics is not hegemonic: there is a vocal minority or "Second Generation" cognitive science, especially cognitive linguistics [21], which embraces a more enactive, even phenomenological perspective [22] — highlighting the cognitive, experiential, interpersonal, "embodied" foundations of language and reasoning. Cognitive does necessarily mean "psychological"; the point is not that structures of meaning should be relativized to individuals' idiosyncratic mental states. Instead, semantic associations need to be contextualized to cognitive frames, which are not generally local to a single person, but are shared in a process of collective world-representing itself is facilitated by language. Within these frames, we can treat objects as vehicles for symbolic designation; however, this symbolization is only possible against the backdrop of frames' assumptions and emphases. Cognitive frames provide contextual selectivity analogous to objects conceived in the guise of structured systems (like chess) or exhibiting scientific theories. Symbolization may encapsulate some of the variability and complexity of objects, but objects themselves are considered to intrinsically bear an inner detailing which is only partially captured by different framings. This "encapsulation" hopefully carries an echo of Object Orientation (`O·O`) in computer languages. Here, I will argue that `O·O` languages can provide the same kind of formal sandbox for Cognitive Linguistics (`CL`) which Logical or Functional Programming (so I claimed) provide for Model-Theoretic Semantics.

1. Objects and Cognitive Grammar

Within `CL`, Cognitive Grammar (`CG`), in particular, studies how cognitive frames mediate between language and reality. Instead of direct association between language- and world-entities, linguistic structures guide the construction of cognitive spaces which, in turn, filter and organize appraisals of worldly referents. Ronald Langacker [13] — probably the leading `CG` proponent — undermines the distinction between syntax and semantics: both semantic meaning and syntactic structure contribute to space-building effects.

Consider these sentences:

- (1) Paul's report is on your desk.
- (2) Mary edited Paul's report.
- (3) I threw Paul's report in the trash.

Each creates a mental space with "attention" allocated for several entities (Mary, Paul, his report, your desk). If evaluated with trivial "word-to-world" mapping, then in each of (1-3) the phrase "Paul's report" probably refers to some physical entity (some stacked sheets of papers). However, according to the implied cognitive-grammatic framing, the conceptual status of "Paul's report" is more general. For instance, Mary may have made some marks on one copy of the report, but we assume that the purpose and result of this action was to change the *contents* of the report, including other, future copies. The same space building explains why we read (3) as a critical evaluation of the report, not just a literal statement of a physical action. In (1-3) a particular, physical instance of the report is treated as conceptual proxy for some trans-physical entity, one which sustains as a single concept-instance across multiple physical tokens.

This "trans-physical" status comes from the intersection of linguistic structure and conversants' prior familiarity with relevant empirical scenarios. Varying either the discourse or the prior knowledge can imply different cognitive framings:

- (4) Mary edited Paul's report, and Peter read it.
- (5) Mary edited Paul's report, but he rejected the changes.
- (6) Mary edited Paul's report, but I prefer the original.

Sentence (4) remains consistent with the simpler framing where "Paul's report" names a single concept-token in the current context; but (5-6) force a reframing. These sentences may be spoken, but can also describe someone's prior familiarity with the situations at hand: for example, someone hearing (2) may already know (5) — so while the speaker of (2) assumes that a simple "singular" framing for "Paul's report" suffices for the current discourse, the hearer's prior knowledge demands a more complex framing, separating the original from the edited report. (5) also presupposes a convention where authors ultimately determine the contents of their writing: in other words, we assume that the original report remains its canonical version, so (5) asserts only a temporary reframing, where we need two different "Paul's report" concept-tokens for only one specific, brief context. This is a semantic matter but also pragmatic/institutional, depending on non-linguistic, potentially varying social contexts. In some settings Mary could have the authority to overrule Paul's objections, and the framing for (5) must then allow for the definitive status of Pauls' report, at the moment of enunciation, to be undecided. Further variants:

- (7) Peter read Paul's report and Mary edited it.
- (8) Peter read Paul's report, then Mary edited it.
- (9) I accidentally threw out Paul's report; can I borrow yours?

Sentence (7) reads interestingly ambiguously. We generally form the most economical cognitive frame possible, so that, here, we are disposed to identify only one concept for "Paul's report": an instinct strengthened by the pronoun "it", which implies that the report edited by Mary is "the same" as that read by Peter. But *and* usually matches temporality to the order of exposition, which first mentions Paul's reading; and, since "editing" implies state-change, this points to conceptualizing two different states: a version read by Paul and another resulting from Mary's edits. Given this tension, I do not immediately hear (7) (contrary to the norms of this syntax) as implying a left-to-right temporal ordering. In (8-9), however, this order is explicit, which forces a double-framing: we need to track two concepts of the report's content (8) or distinguish the content from a physical copy (9).

The maxim illustrated by these examples is that *object-identity* is relative to particular cognitive frames, and that, as mental constructions, these frames will evolve as new worldly and linguistic data comes to bear. A copy of Paul's report (call this $\mathcal{C}$) is not a wholly separate real-world entity, which merely has some relational connection to the report's contents ($\mathcal{R}$) — the kind which might be modeled as an `RDF`-style triple like $\mathcal{C}$ PHYSICALLY-REALIZES $\mathcal{R}$). Nor is $\mathcal{C}$ a mere conceptual proxy for $\mathcal{R}$, even if it behaves as such in some cognitive/linguistic contexts. When Mary edits $\mathcal{C}$ she may (or may not) be considered to be simultaneously editing $\mathcal{R}$. We can say that $\mathcal{C}$ "semi-proxies" $\mathcal{R}$, meaning that it is a proxy in some contexts but not others. This notion of a "semi-proxy" is useful for discussing several themes in cognitive linguistics, such as space-building and cross-space references — for example, using actors' names as proxies for characters they play. Here is a more complex kind of example, discussed by Gilles Fauconnier [8, p. 12]:

- (10) In the painting, the girl with blue eyes has brown eyes.

Fauconnier points out that there are two possible readings of (10): the more natural reading is that "in the painting" serves as "space-builder", which provides a mental container for a referent "the girl with blue eyes", which is therefore a referring, rather than assertorial, expression; the assertion is then "has brown eyes". On this reading, the girl has brown eyes in the real world. The alternative reading requires extra structure in the discursive context; but if it so happens that there are several real-world girls depicted in the painting, "the girl with blue eyes" can be a referential selector from that set, so "blue eyes" has referential "scope" whereas "brown eyes" has assertive scope. In this contrary reading, the girl has blue eyes in the real world and brown eyes in the painting. Which reading the hearer infers depends on context: unless the discourse situation permits the second framing, the first reading should be inferred by default.

Such issues of reference and proxying have practical consequences outside of theoretical linguistics. For example, Paul's report might be a digital resource in a collaborative document-sharing platform. The software implementation needs to make some choices about how different versions of documents are to be managed. Perhaps each view of a document, delivered to an end user, is a separate programming object which holds local edits; these edits can then be "folded in" to the original object under certain circumstances. The implementation may want to track version history, time-stamping changes or preserving prior document state; to allow branching alternative document versions; to define different levels of access to documents (authority to read; to make local edits on a copy; to make global edits on the primary document; etc.). Aside from these low-level details, which will influence how the data backend for the software is structured, we can also consider high-level reasoning about the system, for example for querying the document database. If we envision these queries as supporting a logic-programming reasoning engine, then assertions like (2) and (4-8) may be facts in the database, and the engine would need to make subtle judgments with respect to the identity and variation of objects, such as Paul's report before and after Mary's edits. If system knowledge is modeled via Conceptual Graphs, then any nodes connected to $\mathcal{R}$ may need to be time-stamped to consider whether they concern the original or modified report; or we may assign separate nodes for the two versions, but then we need to identify that the distinction implied by this separation is not recognized in some query contexts. In general, semi-proxy relations introduce profound complications into knowledge modeling. Object Orientation is one way to manage semi-proxying and the consequent overlapping or "interlocking" of object state.

1.1. Modality and Cognitive Frames

Consider some further examples I say involve semi-proxies:

- (11) India borders China.
- (12) Manhattan is south of Syracuse.
- (13) Brooklyn could have included Ridgewood.
- (14) This (clay) sculpture could have been executed in wood.
- (15) Sherlock Holmes could have been French.
- (16) The first woman president will be a Democrat.

The India/China border is disputed in certain remote Himalayan regions; so when (11) is asserted by a Chinese (or conversely Indian) diplomat, they have different versions of what "India" and "China" mean, or at least which geospatial regions they label. The Indian official means "India$^+$ borders China$^-$" (using + and - to mean the nations with or without the contested territory); whereas, for Beijing, the fact is rather "India$^-$ borders China$^+$" (at least officially). Linguistically (and in terms of logical models of language semantics), the question is: which of these is *the* meaning of (11) — or is it both of them; or neither?

The example (12), which was discussed by the philosopher Mark Heller (who coincidentally has had a long career teaching in Syracuse), turns out to be similar. Heller's own point is that the referent "Manhattan" is imprecise, because if we suppose that it names a geospatial region we cannot say precisely which region is being named, considering for example that different points on the island of Manhattan are above-water (and therefore part of "Manhattan") at different times. For this reason Heller suggests that "Manhattan" actually names, not a specific geo-spatial region, but a "conventional object" which significantly overlaps with a geo-spatial region. Indeed, few if any people competent to use the name have actually walked around the island's perimeter and formed a detailed account of its geospatial extent. Knowing what or where Manhattan is does not imply this precise extensional acquaintance; it is rather familiarity with Manhattan as a social reality, with a distinct political, cultural, and historical profile. However, there is a further complication which Heller does not consider, but nicely illustrates the point: "Manhattan" can actually refer either to the island or to the Borough of Manhattan, which includes several other islands as well as a small part of the mainland (the Kingsbridge neighborhood, connected to the Bronx). So does (12) mean that M_I (Manhattan the island) is SOUTH-OF Syracuse, or M_B (the borough), or both? Even granting Heller's "conventional objects", which is the conventional Manhattan (M_I, M_B, both)? [2]

In lieu of Heller's analysis, we can approach this question from the direction of cognitive framing. I find that the linguistic structure of (12) suggests a singular framing for "Manhattan"; so there is just one Manhattan here, we do not have both M_I *and* M_B. (Other frames, for example for sentences about political representation in Kingsbridge, may need to model this distinction.) The point is that, *within this frame*, Manhattan does not label *either* M_I or M_B; but rather the $\mathrm{M}_I/\mathrm{M}_B$ distinction is not relevant to or recognized by the frame. The name "Manhattan" does not label some precise geospatial region, but rather connects to an attentional focus in a cognitive frame, which mediates any perceived mapping of the word to a geospatial extent. Michael Jubien, who developed a property-theoretic semantics to address the kind of modal ambiguities which Heller broached through his theory of "conventional objects", argues that a name like "Manhattan" should be read as invoking a property of *being Manhattan*; and we can argue that both the island and the borough are reasonable instantiators for this property in contexts such as (12). In effect, instead of conventional objects we have conventional properties; in the domain of cognitive grammar, we can say that properties are conceptual roles assigned to elements of cognitive frames. Both M_I and M_B can play the Manhattan "role" in someone's conceptualization of (12). So M_I, India$^+$, etc., are semi-proxies for coarser-grained conceptualizations derived from cognitive geospatial frames, not just lifted from

[2] For this, and next paragraph's counter-analysis, see [12].

a realm of geospatial regions onto a set of linguistic labels. By analogy, in Langacker-style analyses of nominals like

(17) Three times, *a student* asked interesting questions.

here the phrase "a student" actually appears to identify three different students. Langacker argues that both "student" and "question" can be either grammatically singular or plural in (17) with no important change in the semantics (consider: "Three times, students asked an interesting question").[3]

Our framing for (17) includes a "virtual plane" with numerous students, and "a student" selects one generic instance from that plane, a temporary site of cognitive focus "conjured", in Langacker's words, to provide a non-committal referent for "a student". The word can be either singular or plural because the conjured entity is singular, but the cognitive framing guided by (17) has that conjuring process repeated three times. The analogy to Jubien-style, property-theoretic semantics is that properties specify roles which components of cognitive frames are to play. Property instantiators are framed by their cognitive roles. This also applies to counterfactual, speculative, or imaginary scenarios where we do not have concrete property-instances on hand. So, in (15), we have to conjure a cognitive site to play the role of something instantiating the property *being Sherlock Holmes*. In fictive semantics, frame-construction is guided by language structures but also by narrative conventions. As a cognitive "site", the concept Sherlock Holmes belongs within a conceptual network, which we can model as a Conceptual Graph if desired, and which conveys such information as Homes LIVING-IN London. The authority to assert facts within these graph-triples rests with the convention that authors narrate fictive worlds. It is *true* that Holmes was English; but (15) is *possible* because Conan Doyle *could have* written a story revealing that Holmes was really a French spy.[4]

Any counterfactural, speculative, or fictive use of language involves a "space-building" where entities are represented in a cognitive frame which is explicitly assumed to differ from what is known or assertable. In (16) — unless we have some concrete person (like Hillary Clinton) in mind — "the first woman president" does not profile a specific person, but a cognitive slot defined as a ground for further predication. In (13), New York's Ridgewood neighborhood, on the Brookyln/Queens border, was once part of Brooklyn; apparently its residents chose to become part of Queens instead, to emphasize their separation from the neighboring, once bleak neighborhood of Bushwick (which, ironically, has become rather North-Brooklyn trendy). Certainly they could have foreseen this reversal and chose to remain in Brooklyn. As a set of geospatial points, obviously "Brooklyn" either contains or does not contain smaller parts, like Ridgewood; however, as cognitively framed, "Brooklyn" profiles not only a specific spatial extent, but situates this geo-spatial designator in a larger temporal and modal domain. So the geospatial union of Brooklyn and Ridgewood could indeed have instantiated the property *being Brooklyn*, and our concept of Brooklyn plays a cognitive role which can recognize this possibility. Similarly, Jubien analyzes (14) as asserting that some block of wood (rather than clay) could have instantiated the property *being this statue*; and we frame a concept of *this statue* not just as a material object, but a work of art: that is, we frame it in terms of *being this statue*. Cognitive frames acknowledge histories, possibilities, contingencies, and diverse scales of observation, for things, places, people, and events. To know that Obama won is to know that he could have lost, which builds a modal space, semantically and pragmatically invoked by words like "election", that is among those intrinsic to Obama's worldly facticity.

1.2. Counterparts and Semi-Proxies

This cognitive-linguistic approach to modality contrasts with Possible World Semantics and "Counterpart theory". If each word is a symbol which points to some worldly entity, then we need to account for words used in ways specifically to refer to imaginary and counterfactual things: what does the symbol "Holmes" refer to; or "Brooklyn" when considering the possibility of it still containing Ridgewood; or the "Obama" we visualize having lost re-election; or "This Sculpture" when we imagine it made of wood? The paradigm calls these symbols for counterparts in "other Possible Worlds".

In light of *temporal* modal logic, we can compare Possible Worlds semantics to "Endurantist" theories of object temporality. In these theories, objects at different times are each others' temporal counterparts: so Obama the Senator is a different object than Obama the President, but the one is the other's futural (respectively past) counterpart. By analogy, contingency means that there is a "modal counterpart" of Obama who lost the election. Metaphysics contrasts Endurantism with Perdurantism [5], which holds that objects persist through time, and have different temporal parts: so the Senator and the President are both temporal parts of one single object. This can also be demonstrated with a software example: a content-management system, for example, can model documents as single perdurant entities, tracking version and history by adding data to each object marking the changes they undergo. Alternatively, each timestamped version of a document can be assigned its own object, and the document itself modeled as a collection of these distinct objects. The Endurance/Perdurance distinction becomes more substantial [3] if we extend the analogy to modal or granular variations, as well as temporal. Any cognitive framing recognizes objects in a space of possible variation, including variation through time, through degrees of descriptive detail, and variation in possible state. The different states captured by this variation are not "counterparts" of one another; they are packaged and unified into the cognitive framing of *one single* object. On this account, Possible World semantics, analogous to "Endurantism" across possible worlds, is an artifact of a word-to-world mapping which neglects the mediating role of cognitive framing in any association of semantic labels to worldly entities. This suggests the possibility of using cognitive frames as a philosophical basis for alternative modal-logic models (for example a logic of "modal parts", occasionally called "modal perdurants"): considering spaces of possibility as "contained inside" cognitive frames of individual objects, analogous to how Perdurantism treats temporal parts as contained inside a perduring whole.

[3] For related examples see e.g. [13, p. 119; 128]; also page 72 here for a CL approach to Possible Worlds and quantification over worlds and over "fiat", semantically conjured entities.

[4] But *only* Conan Doyle has (had) the right to change "facts" about Holmes; a modern writer could produce a thriller where Holmes was a French double-agent, but we would not considered this character the "real" Sherlock Holmes.

The theory I just sketched identifies modal, temporal, and granular parameters of variation as contained within a spectrum of states, or "state space", of individual objects, which are (partially) modeled by cognitive frames. Neither M_I or M_B are "right" or "wrong" referents of a geospatial name (or India$^+$, etc.); these are "granular parts" of larger objects which, in turn, have different extensions in different contexts and resolution scales. A "Manhattan" reference is noncommittal between the borough and the island in the same way as it designates a present-moment Manhattan but presumably applies as well to the indefinite near future: the referring act allows for a range of future possibilities, points forward in time from the moment of enunciation; and, analogously, for a range of finer-grained elaborations, points on a scale of resolution more precise than the one deemed relevant for the current discourse. Discursive reference to "Manhattan" builds a frame where present-moment Manhattan, conceptualized rather imprecisely, semi-proxies Manhattan at points forward in time and more detailed in granularity. In lieu of Possible Worlds, we can consider a "Cognitive Object" semantics of cognitively framed objects with multi-faceted internal state-spaces. Here Object Oriented programming can both refine intuitions and also engender concrete tools for which Cognitive Object Semantics provides inspiration.

In the evolving of cognitive frames, objects can be sometimes unified and sometimes distinct from other objects: a physical copy of Paul's report is sometimes framed as proxy for the report's contents, and sometimes not. A proxy for an object is a representation which captures some (but assume not all) of its state; such a proxy however may then evolve to become a separate "semi-proxy" object, which nevertheless shares much of its state with the original. Given object $\mathcal{O}$ and semi-proxy $\mathcal{S}$, we can say that $\mathcal{O}$ and $\mathcal{S}$ have "interlocking state" if there is an overlap in their respective state-space. A semi-proxy provides a view onto an object's state and adds further state and logic of its own. For example, suppose an "`Assignment`" object in a classroom application refers to a `Document` object, and adds fields to represent a date, and the pages in the document which are assigned for reading. In principle, the `Assignment` objects should be dynamically updated if the document itself changes, for example to account for repagination. Objects' state can interlock in different ways: in the prior example the `Assignment` objects are sensitive to changes in the `Document`, but cannot initiate these changes. In other cases, a pair of objects can each modify each other's state. Different `O·O` mechanisms — constant pointers and references, accessor methods, different access levels (public, protected, and private methods, fields, and inheritance), copy constructors, and assignment operators — allow programmers to manage interlocking state, including specifying which parts of state-space are visible and/or modifiable across semi-proxy boundaries.

So far I have considered a "multi-faceted" state space with different parameters, including modal, granular, and temporal dimensions. Different parts of object state can be associated with different granularities, or different levels of detail in exposing information about the object. This generalizes both access levels and code re-use. In the Assignment/Document example, each `Assignment` object models some details of `Document` objects (such as author, title, and publication year), but there are finer-grained details which `Assignments` cannot or need not access. In general, when objects are exposed in a data-sharing network, each endpoint which re-uses object data does not want to reconstruct the entire state space, but selects only certain information; what results is a distinct representation of the object reflecting the local needs and paradigms where the translated object is being used. We can call these simplified representations as "projections" of the original object into a different "Local Object System". Aside from conceptual concerns, these systems may use different programming languages, libraries, design patterns, etc., so that the information and behaviors assumed for one local system need to be projected onto other systems. Developing concrete tools for object-sharing, in my opinion, importantly includes reasoning about these translations between distinct Object Oriented atmospheres.

While objects are shared relative to different levels of granularity, it may also be useful to share information about all *possible* object-states. Consider books for sale, with several defined attributes: price, length in pages, and, say, a "reading level" measure from perhaps $0 - 20$, starting at young children's books, then US grades $1 - 12$, 13+ for collegiate and adult books, and numbers near 20 for technical and professional books. Each book therefore has an associated vector of three numbers, $\langle level, price, length\rangle$. Now suppose books have bounds on length and price, say $5-1000$ pages and $\$1 - 200$, so all book vectors are contained in a box $\mathcal{B}$ spanned by the vectors $\langle 0, 1, 5\rangle$ and $\langle 20, 200, 1000\rangle$. This $\mathcal{B}$ represents the set of possible states for books, which client software may use to calculate similarity between them, match queries, look for anomalies like good values, and so on (we expect, for example, longer and more technical books to be more expensive). Objects may communicate, not only their current state, but a presentation of all possible states (even if coarse-grained: here the vectors only describe possible state in the $\langle level, price, length\rangle$ dimensions).

If we combine modal, granular, and temporal parameters as all potentially relevant to selecting some portion of state-space to expose in object-sharing (and parameters of potential interlocking state), we therefore combine several different "Perdurance" and/or modal models, including conventional temporal perdurance (and temporal modal logic); modal perdurance (in lieu of possible worlds), and "granular perdurance" (and potentially a granular modal logic such as that of Barry Smith). Here "perdurance" means that the spectrum of (modal, temporal, and/or granular) state is considered to be contained within a single object, which encompasses an internal state-space, rather than assuming that each point in this state-space is a unique object (or value, datapoint, etc.). The motivation for this object-oriented perspective, as I have argued, may come from cognitive and linguistic considerations; however, by framing spaces of state-variation in terms of Object-Oriented data management, we open the possibility of using theoretical work on `O·O` programming languages to help formalize these modal intuitions concerning granularity, temporality, and possible state, into formal systems for logic and programming.

2. An applied object-oriented modal logic

The remainder of this paper will describe a concrete software library which presents one specific generalization of modal logic and the lambda calculus. Philosophically, I have emphasized the representation of objects in cognitive frames; formally, this implies that objects should be described via knowledge or conceptual representation formats, with their roots in cognitive linguistics. The simpler `RDF` model is useful for programming, but the more expressive Conceptual Graph Semantics (`CGS`) model [2] provides a better description of language and phenomenological structure (for example, `CGS` networks can trace the sequence of attentional foci as people perceive and interact with their environment, an experiential unfolding which natural language simulates via space-building). Here I will adopt a compromise "`BCF`" (for "Binary Conceptual Graphs with Frames") Representation which uses underlying `RDF`-style graphs, but can reconstruct `CGS` complexes by "framing" (sub)graphs, perhaps with additional structure. `BCF` graphs are bipartite with vertex-sets $\Gamma_{\mathbf{C}} \cup \Gamma_{\mathbf{R}}$ of concepts and relations. Unlike `RDF`, relations are nodes, not just labels, with a poset (partially ordered) type hierarchy analogous to the concept-types. `CGS` allows arbitrary relation arities and signatures, which can be simulated by "framing" a collection of relation nodes so as to unify them.[5] Aside from representing `CGS` relation signatures, frames can also capture `CGS` contexts and nested subgraphs, and can provide interpretations and specifications of `BCF` graphs which facilitate their analysis and traversal.

Here my semantic models involve knowledge representation, but my programming paradigm is object-orientation. Objects in this sense are not just *resources*, or collections of data; we also want to represent object behavior and functional interactions. Being particularly interested in interlocking state, I am especially concerned with the local or remote alteration of state across semi-proxy boundaries, and in particular the methods and functions which implement this state dynamics. In effect, representing objects must include representation of their methods. Such representation can be accommodated in a knowledge-representation context by assuming functions-as-data, or "homoiconicity". Prototype-based languages (like JavaScript) define functions on objects by assigning functions as data fields on object prototypes. Similarly, we can assume that objects belong to classes, which provide default values for all data — including functions — that objects can access. This supports modeling object systems where objects can override methods with their own idiosyncratic definitions, a capacity provided for example by Ruby (though technically here Ruby uses derived singleton classes rather than functions-as-member-data). Functions-as-data can also provide for Aspect Oriented techniques, or method "refinement" (where a derived-class method can override some parts, and inherit other parts, of its base-class equivalent). In these scenarios we want to destructure function definitions and then dynamically alter and re-combine them.

Having settled on representing functions as data, the next concern is mapping function definitions to `RDF` (or `BCF`) style representations. Note, first, that Conceptual Graphs are natural vehicles for representing program functions (and source code in general), and can help clarify the conceptual structures which programmers identify and intend when writing code. There are numerous relations which can exist between program elements: an identifier can be bound to a type, assigned a value, passed into a function, sent a message, etc. In the other direction, arbitrary (sub)graphs can be interpreted as defining functions under certain circumstances. Treating a subgraph as a function amounts to a special kind of traversal. Such traversal can be performed within a frame $\mathcal{F}$ if relation-nodes in $\mathcal{F}$ can be ordered according to which relation, from a given concept-node, should be "visited" first. Define a *priority frame* as a frame which assigns to each relation-node a *priority*, and imposes certain criteria: each concept-node has at most one outgoing relation node for each nonzero priority, at most one incoming relation node with nonzero priority, and one concept-node is fixed as an "entry point". Zero-priority relations do not factor in to traversal directly, but they can provide semantic and type information. In practice, priority-one relations represent function calls, priority-two relations comprise statement sequences, and priority-three relations reflect code blocks and branching. For node η, define the "prioritized out (or in) degree" $\Delta\overrightarrow{_{n}}$ $(\Delta\overleftarrow{_{n}})$ as a count of outgoing (incoming) nodes with priority p. Given pseudo-code:

(18) `if (null? x){ log "null pointer"; return; }`

the relations if–null? and log–return are priority-2; null?–x and log–`"null pointer"` priority-1; and null?–log priority-3. From an implementation point of view, defining functions in terms of graph structures provides an easy framework for code compilation: source code is tested against regular expressions; the regex captures are used to create graph-nodes; and regexes are associated with callback functions which take those nodes and add them to a program graph, with their choice of relation-nodes to use as connectors.

A priority frame which meets the above criteria can be called a *program frame*, as it defines an executable program-fragment — or, more precisely, a *syntactic* program frame. A *semantic* program frame is then a syntactic program frame with a mapping between certain nodes and function symbols (specifically, those η with $\Delta\overrightarrow{_{1}}(\eta) = 1$ and $\Delta\overleftarrow{_{1}}(\eta) = 0$). A semantic program frame can then be converted into a function definition by a kind of lambda-abstraction: namely, choosing certain concept-nodes to represent variables bound to function parameters. Since we're interested in `O·O` models, we can actually explore graph versions of object-oriented lambda calculi, like the "sigma" calculus, which introduces a separate ς operator to capture abstracting a "self" value, or message-receiver, within a program fragment [17].

So I will sketch a proposed calculus I will call "digamma": the numeric Digamma symbol looks like the "numeric sigma" used for ς-calculus, and we also have that statements in Digamma-calculus model communications between two (sub) graphs, with the symbol Γ (capital Gamma) often used for graphs. Digamma-calculus allows for more than one "self" object on a method, which has some real-world examples.[6]

[5]Suppose "Peter introduced Mary to Paul, and Patrick introduced Mary to Paul". This suggests two graph arcs Mary INTRODUCED-TO Paul: these are not redundant, because they do not express an isolated being-introduced-to relation, but are contextualized by who does the introducing. In a setting where we do not have hypernodes, this can be indicated by including two different INTRODUCED-TO relation-nodes, both incident to Mary and Paul, but in different frames.

[6]In particular, it allows for multiple-dispatch semantics

Given a program frame, we specify nodes — call this a λ *channel* — to be bound to ordinary function parameters; and zero, one, or more nodes — the "sigma" channel — as message receivers, which may be populated implicitly from the calling context (for example, the `this` keyword is often optional). With this idea of channels in place, we can then extend it to accommodate things like closures (a "capture" channel which stores lexically local variables where a function is defined), return values (the "return" channel, which passes values back to the calling context), exceptions (an "error" channel which also passes values back, but signals that they describe some erroneous condition) — and potentially more complex communications as well, as I will discuss.

With this setup, the contrast between data fields and functions-as-data can be defined in terms of which channels they "activate". Data fields do not have a λ; they cannot take function parameters. The raw data in a data field is called a "data channel", and data fields can have other channels as well, like an "advice" channel, which names functions to be called upon certain types of manipulations of the data. Functions can also have data channels — for example, accessor functions associated with the data field they encapsulate; and an advice channel, supporting Aspect-Oriented designs.

Here, then, is a system for encoding functions as well as data within `BCF` graphs. Each object is represented by a graph node, and arbitrary relations between objects (or between objects and values) are modeled through relation nodes. The distinction between objects and values is that there is no presumption of uniqueness among values: if Mary knows Paul and Peter is Paul's boss, then we can assert some connection between Mary and Peter; but if Paul's report is 50 pages, and Peter is 50 years old, this suggests no relation at all between Peter and Paul. Values can be grounds for inter-concept relations, but only when bound to the proper contexts and dimensions. An object's outgoing relation-nodes are called *attributes*, and some attributes are identified as canonical for the object's class; that is, all objects in the class have their version of these relations (allowing for some to defer to prototype defaults). Call these canonical attributes *fields*, and we can define both *data fields* and *function fields*. Objects communicate with each other via *queries*, which can request the value (or propose to change the value) of a data attribute, or request that a function be called. A valid query must be able to populate the active channels for the relevant field or fields, according to the fields' specifications. If a receiving object chooses to honor the query, then the graph neighborhood of the object-node is temporarily fixed according to the active channels' contents, any functions traversed as needed, and the resulting values transferred back to the querying object through "co-channels", like the return and error channels I mentioned.

2.1. Implementation

The preceding ideas have been concretely implemented in a `C++11` library `C`ξ`MENT` (`CLOSXML` Digamma/ξ Modal Embedded Ontologies), `C`$^{\Diamond}_{\xi}$ (C-Dxi) for short. `C`$^{\Diamond}_{\xi}$ objects are `C++` or Lisp structures which can respond to queries called as `C++` methods, or presented as `C`$^{\Diamond}_{\xi}$ code, which is parsed into a graph structure. These objects can host dynamically declared types and/or values; and/or they can expose native-compiled data and methods to dynamic queries. Taking this as briefly summarizing a practical "Digamma calculus", I will focus here on how `C`ξ`MENT` incorporates modal notions. Object state-spaces have multiple facets of variation, including temporal, granular, and modal parameters. Let me first consider contingency variation — in other words, representing not only object state, but a range of *possible* states.

Consider again the example where books have data fields for reading level, page length, and price. These fields have data types (let's say each are integers), but they also have relation types (length in pages, e.g., is a different dimension than cost in dollars). Moreover, the values are bounded — before, they were in $\mathcal{B}$; this further information can be modeled as an additional channel active on the data fields. In particular, the specifications provide an "axiation" of the fields, one which associates them with a semantic dimension and a numeric range. Call this information a *xi* (ξ) *channel* active on the fields. Function fields can have ξ channels also, characterizing their possible return values. For each object $\mathfrak{o}$, the collection of its fields with active ξ channels provides an axiation of its state-space: $\mathfrak{o}$'s current data is positioned against a range of possible values. Usually, these ξ channels are not defined by a single object, but prototyped at the class level. A ξ-channel query $\mathcal{Q}_\xi$ asks for information about the entire possible state-space in lieu of, or addition to, querying a particular object. Alternatively, $\mathcal{Q}_\xi$ can construct a ξ-channel subspace and request a list of objects scoped therein.

I will not describe the technical syntax for these queries; my point here is that ξ-queries represent spaces of possibility where objects are situated. Each ξ channel (and combinations thereof) yield modal operators $\Diamond_\xi$ which act on special "ξ-range" structures. These ranges have several components, including dimension types, *saturations* (to contrast nominal, ordinal, interval, integer, and real-valued data, for example), and numeric or nominal range specifications.

It's worth noting that the interpretation of object identities themselves, as well as object properties, are potentially subject to "ξ-modal" variation. Some data objects profile real-world entities such that their extent or foundation is variable or imprecise. Linguistic examples include cases like (13) (Brooklyn/Ridgewood), but programming case-studies can include, say, image labeling, where objects profile image-segments subject to varying representations. One type of analysis applies different "morphological" operators, such as "erosions" or "dilations" by several "structuring elements". Each segment therefore has different extents, depending on which structuring element is used for representation. Morphological operators are particularly interesting because they give rise to nontrivial discrete topologies. This has potential applications to general ξ-channel spaces, which often involve discrete (e.g. integer or nominal) dimensions, but abstractly treating them as topological spaces invites possible applications from topological modal model theory [1, for example].

Modal considerations of object extent are also interesting in the realm of "Cognitive Phenomenology", which provides a cognitive view of experiential perception and attention analogous to cognitive linguistic treatments of language.

within a single-dispatch syntax. Technically, "flip" sigma-parameters can turn $foo \to bar(x)$ into $x \to bar(foo)$.

Conceptual Graph structures help capture the mental models which we make of surrounding environments and situations, but often the specific nodes in these graphs are perceptual impressions of sensible, environing entities. In general we do not attempt to create highly detailed perceptual pictures, but rather allow our image of external objects to remain imprecise and evolving, as our attention migrates from site to site, and objects enter and leave cognitive focus. Combining `CGS`-style knowledge-representation and its graph foundations, with modal and/or topological models of spatial variation and object extent, helps us to thematize the integration between fine-grained perceptual awareness and larger-scale situational reasoning, as we explore the experiential foundation of real-world human cognition.

These ideas have semantic implications: consider the word "chinatown" — for a concrete example, consider Sunset Park Chinatown, a Brooklyn neighborhood with many Asian shops and restaurants, but no official designation (apart from the larger Sunset Park area itself). The semantics of the "Sunset Park Chinatown" name therefore is not fixed (by an electoral district, postal code, etc.), but rather depends on locals' conventional usage and thoughts — the mental frames involved as people realize when they are in Sunset Park Chinatown, or, say, plan to go there. If we are interested in modeling how a phrase like "Sunset Park Chinatown" refers, we therefore need to consider what extent best captures the typical local's sense of where this neighborhood lies, relative to adjacent ones (like the rest of Sunset Park). This involves spatially mapping those phenomena (like Chinese markets) which are conceptual indicators of the area's uniqueness, but also noting that our conceptions of extended places, like neighborhoods, tend to have rather simple geometric shapes. We will not skew the mental borders of Sunset Park Chinatown just to fit every Asian restaurant within a few blocks of the 8th avenue Ⓝ stop. Of course, people's appraisals of the geometry will also be influenced by how others use the word. Staying in New York City, similar points could be made about (informal) names like Noho or Nolita (North of Little Italy): geographic terms provide rough markers, but locals' sense of the designated blocks depends on identifying unique features — some (geo)spatially "tagged" semantic markers, unified into a coherent spatial image — prevalent within, but less so outside, those mental boundaries (narrow alleyways, small boutique shops, architectural styles, etc.). My point is that linguistic meaning, in this kind of case, can only be understood through the interaction of (social) cognition and spatial morphology.

How objects are situated in a spectrum of possible extents or spatial forms can be formally modeled by "spatial" modal logics, which for instance assign modal operators to possible transformations of spatial entities that preserve certain properties [15]△. A general (if restrictive) example is topological homotopy, with a modal operator represeing possible homoty-preserving maps. A richer view on modality comes from discrete or "morphological" topologies which preserve some geometric or mereogeometric information, like convexivity. Specifying topological, geometric, and/or mereological conditions can provide practical tools for reasoning about spatial or (geo)spatially-indexed information, demonstrated for example by Statistical Topology [23]△. Social-geographic analysis, for example, can consider how markers of sociological attributes (social mobility, ethnicity, access to various goods and resources) map onto (geo)spatial points, and then, to identify meaningful areas, expand these points into topologically coherent regions. Along these lines, $\texttt{C}^{\Diamond}_{\xi}$ uses "profile" objects to mark regions in ξ-channel spaces based on distributions of objects' ξ-vectors — e.g., in the book example, $\mathbb{Z}^3$ tuples in the aforementioned box $\mathcal{B}$, with profiles selected as encircling books mapped to some $\mathcal{B}$ subset.

Homoiconicity gives us an algorithmic picture of modal semantics: let Γ be a `BCF` graph including representation of an object $\mathfrak{o}$; given predicate $\mathfrak{p}$ about $\mathfrak{o}$, $\Diamond\mathfrak{p}$ can mean that no node-structure connected to $\mathfrak{o}$ asserts information which is contrary to $\mathfrak{p}$. If $\mathfrak{p}$ proposes a \$300 book, given a path $\mathcal{P}$ of nodes $\{\eta_i\}$ leading from $\mathfrak{o}$ to the prototype ξ-specification placing book prices in $\mathcal{B}$'s $\$5 - 200$ range, then $\mathcal{P}$ disconfirms $\Diamond\mathfrak{p}$ (and suggests $\Box\neg\mathfrak{p}$). Given the bipartite structure of `BCF`, any Γ-path interleaves concept and relation nodes; whether $\mathcal{P}$ provides modal information about $\mathfrak{p}$ depends on the semantic interpretation (i.e., the concept and relation types) of nodes in $\{\eta_i\}$ and around $\mathfrak{p}$. With homoiconicity, $\mathfrak{p}$ can be expressed as a graph structure itself, another neighborhood in Γ (expanded if needed). The semantic structure around $\mathfrak{p}$ guides the choice of η_i (selecting which nodes around each η to "visit"). If $\mathfrak{p}$ uses λ- or ς-abstraction (i.e., defines a function with non-zero arity and/or an instance method), then there are nodes around $\mathfrak{p}$ with semantically (typed but) nonfixed values that can be linked with values around $\mathfrak{o}$. The semantics of relation-nodes in the program frame $\mathcal{F}$ around $\mathfrak{p}$ guides the choice of η_i, and these nodes (or those selected from "tributary" paths as needed) provide values to pass in to $\mathcal{F}$; this interaction between the $\mathcal{F}$ and $\mathfrak{o}$ neighborhoods can continue until the algorithm finds those nodes with which to evaluate $\Diamond p$. Of course, this all depends on "domain-specific" notions of possibility which must be modeled within the semantic types annotating Γ. For integer-valued ξ-channels, the implicit modal semantics is defined, as expected, in terms of numeric intervals. For more exotic datatypes, modalities may need to be explicitly coded as functions in the relevant implementation classes.

So far I have sketched modal interpretations of ξ-channels, or possible object-state, as well as "spatial modalities" which are meaningful for some kinds of objects (including objects profiling ξ-channel spaces). I have also mentioned temporal variation: indeed, `CξMENT` supports temporalized queries using a "chronos" or χ-channel with several possible configurations; the simplest annotates fields, having active χ channels, with a timestamp of their latest state-altering access. Queries can then be time-indexed and request only updated data. Collectively these possibilities span a "five-dimensional perdurant" modality where spatial, temporal, and object state variation all provide parameters for potential modal treatment. The modalities involved here are not "large" modalities, like maximal Possible Worlds, but narrower "situational" or "partial" modalities which focus on particular forms of variation and states of possible transitions within specific domains (such as temporal, topological, spatial-morphological, and object-state). This "domain specificity" provides narrower alternatives to Kripke frames' standard Worlds and inter-world Accessibilities: perdurant, multi-granular data structures replace Worlds, and compatible axiations provide an Accesibility relation.

I have also argued that linguistic considerations imply a "granular" modality as well (as a kind of "sixth dimension" for "Digamma/Modal" calculus). We can consider CLOSXML as modeling "multi-granular" object systems, where objects are shared in Semantic networks (though without presuming globally unique identifiers). These networks must do more than transfer semantic data to, say, hypothetical Semantic Web browsers. Suppose an art catalog gathers information about artists, works, and events from different galleries and sources, each of which have similar, but not fully isomorphic, data principles. Human intervention, aided by object-oriented design, can be the best solution to these data-merging problems. Local Object Systems play the role of domain models, data merging yields new data types with their own presentations and functionality (e.g., a catalog of art-world objects needs methods for graphical manipulation, PDF generation, etc.), and data integration and representation is achieved by calling functions on data or presentation objects. The goal for CLOSXML is to consolidate the presentation of data and Local Object Systems into a single framework, allowing multiple object types to profile similar or identical real-world concepts and things, offering more or less fine-grained representations, adapted to local situations and to the framing effects of language and cognition.

3. Conclusion

The Semantic Web is associated with several knowledge management (sub) disciplines, like Bioinformatics. One application domain for the O·O systematization I have proposed is "Community Informatics", for several reasons. On the one hand, as my earlier comments about sociology and about Sunset Park Chinatown anticipated, specific analytic techniques — often stressing spatial structures and topology — can help model social phenomena and cognition, and local language and usage dialects. On the other hand, the Internet is a platform for forming virtual communities — and, for that matter, for enhancing our sense of local neighborhoods, by augmenting local communication channels. Promoting exchange of ideas and plans, within both geographic and virtual communities, is an important practical goal for future web technology. Finally, new technologies can promote community-oriented, sustainable development and industry. Lightweight resources (like source code) can be shared globally, but heavier goods should where possible be manufactured locally: perhaps using computer designs — targeted at 3D printers, complex data simulations, etc. — for microindustry, microagriculture, or sustainable architecture.

One hurdle confronting the Semantic Web is that web content creators need a clearer picture of what Semantic technology actually means for them. My object-oriented approach suggests the following answer: assume that your semantic data will serialize objects; that you need to publish a description of your Local Object System and of its implementation; and that consumers of your objects have implemented a distinct system onto which yours is projected. This may be less general than just outputting a stream of RDF triples, but I suggest that it better captures the real nature of networked collaboration. In theory, the Web is a global data space; but in practice, serious work helped by web affordances yields more intimate user communities, unified by shared interests and shared geographical or thematic proximity. The web should be a tool to promote inter-personal collaboration within socio-cognitive territories forged by human projects — streamlining data exchange within these cognitive terrains, but not trying to replace them with some sort of impersonal Reasoning Engine. Programming ecosystems should capture the communicative role, even more than the logical form, of natural language and signification.

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