CONCEPTUALIZATION AND VISUAL KNOWLEDGE ORGANIZATION: A SURVEY OF ONTOLOGY-BASED SOLUTIONS

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Abstract

Conceptualization and Visual Knowledge Organization are overlapping research areas of Intellect Augmentation with hot topics at their intersection which are enhanced by proliferating issues of ontology integration. Knowledge organization is more closely related to the content of concepts and to the actual knowledge items than taxonomic structures and 'ontologies' understood as "explicit specifications of a conceptualization" (Gruber). Yet, the alignment of the structure and relationship of knowledge items of a domain of interest require similar operations. We reconsider ontology-based approaches to collaborative conceptualization from the point of view of user interaction in the context of augmented visual knowledge organization. After considering several formal ontology based approaches, it is argued that co-evolving visualization of concepts are needed both at the object and meta-level to handle the social aspects of learning and knowledge work in the framework of an Exploratory Epistemology. Current systems tend to separate the conceptual level from the content, and the context of logical understanding from the intent and use of concepts. Besides, they usually consider the unification of individual contributions in a ubiquitous global representation. As opposed to this God's eye view we are exploring new alternatives that aim to provide Morphic-like live, tinkerable, in situ approaches to conceptualization and its visualization and to direct manipulation based ontology authoring capabilities. They are uniformly applicable and user-extendable through meta-design both at the content, as well as all emergent conceptual meta-levels, within collaborative frameworks like *Conceptipedia*. In such a framework negotiation games played at the meta-level of knowledge items can support emergent conceptualization until viable alternative taxonomic structures emerge and workable situated ideas win out. Distributing the workload and responsibility through Crowd Authoring, concept alignment and challenges of social, collaborative concept matching and revision can be addressed in a knowledge management kernel which is also capable to supplement education technology.

Keywords: Conceptualization, Visual Knowledge Organization, Exploratory Epistemology, Ontology Engineering, Ontology Integration, Traversal Frequency, Knowledge Graph, Morphic, Augmentation.

1 ONTOLOGIES AND INFORMATION ARCHITECTURES

1.1 The Metaphysical Heritage

Ontological research has a long history, from early reflections by Aristotle in his Metaphysics, Christian Wolff's use of the term in the C18th for the "study of being in general", to its more recent upsurgence in computer science, along with linguistics and conceptualization issues within a variety of other sciences such as physics, cognitive psychology and genetics. Ontology Engineering (OE) has been closely bound up with theories of *formal ontology*, which describe the basic categories of being, the general features of reality and their relations. This focus on reality can be contrasted with recent developments in the field of information organization. The "metaphysical heritage" of OE supplies us with domain-independent systems of "upper ontologies", which is to say high level categorical systems which support the conceptualization of domain-specific knowledge and special purpose "domain ontologies" in various specialized fields. This line of OE can be called 'metaphysical' because ontologies in this tradition, be they scientific, philosophical, or derived from our common sense, assume some kind of adequacy or correspondence between the categorical representations of a given domain, and "the real world itself". [3, 5] They seek entity taxonomies at every level of complexity, and apply "adequatism", or "substantialism" or other ontical doctrines. [10, 11, 12, 7, cf. 5] These approaches readily ally with some form of "Conceptual Atomism" in philosophy and the natural sciences, and they also adopt Representational Theories of Mind from the cognitive sciences. [2, 6] The most basic categories of "being in general" however are far from uniform: the "highest" level of ontologies differ in their universals, both in their abstract and concrete modes of existence, and their endurants and perdurants, with the consequence that there are alternative top level terms and descriptive systems of foundational ontologies (e.g., BFO, DOLCE, GFO, PROTON, SUMO or Sowa's ontology [9]).

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1.1.1 Structural Domain Models

Different epistemological positions are reflected in the definitional differences between ontologies which treat conceptual systems as reflecting the structure of reality *independently* of their (vernacular or formal) linguistic representation, and *language dependent* systems which determine what descriptive categorizations of a domain are admissible. In the former approach modeling methodologies and ontology representation languages are primarily evaluated in terms of their *completeness* and *expressibility* in addressing a state of affairs in a specific domain at different levels of granularity [20]. The latter however are treated in terms of *computability* issues, and *standards of usability comprehensibility,* and *domain appropriateness* for the purpose of conceptualization. [15]

Domain models (which are also called semantic data models and structural conceptual models) are generally taken to be conceptual representations of a state of affairs in the real world or a system of categories which can be used to describe aspects of the structure of a knowledge domain. [8, 14, 32] They consist of general notions about the types of entities in that world and their instances (e.g., classification of objects and their intrinsic properties represented in value spaces); sorts of types (e.g., kinds, roles, phases, mixed contingent collections) and the relations between these entities (e.g., identity and the properties of relations). Since various sorts of categories and their relational properties (rules/axioms defining the properties of relations) determine the admissible relations and their instantiations, conceptualization clusters together sets of terms which articulate the abstract structure of reality, creating a formal model of its state of affairs. These models, or rather the model specifications, are formal representations of the conceptualization. [Cf. Figure 1. below, adapted from 3, p. 50]

1.1.2 Foundational and Domain Modeling Languages

General entity–relationship models [28] and domain specific modeling languages which have faced problems of expressiveness and relevance were early developed to represent model specifications (e.g., LINGO, GLEO and IDEF5 for graphical expression of ontologies) before the prevalence of OWL and the use of UML for ontology modeling. [22, 29, 32] Since a modeling language determines the grammatically correct specifications which can be constructed in that language (limiting the space of possible conceptualizations) the conceptualization formulated in the admissible terminology of the given modeling language fixes the set of all possible models of states of affairs of the world or a given problem domain. [60] The Modeling Language icon depicted in Figure 1. represents the specification of the conceptual model underlying the language, or what following Guizzardi can be called 'metamodel specification'. [3] Formal Ontological theories, just as information systems grammars that served the evaluation and redesign of these languages focus on specific sets of concepts in order to equip them with a reference-, or an adequate real-world semantics. [3, 29] The latter usually employed "… an ontology named BWW (Bunge-Wand-Weber) which is based on the original metaphysics proposed in [7]…that is … committed to capturing the intrinsic nature of the world in a way that is independent of the *conceptualizing agent*, and, consequently, an approach in which cognition and human language play a minor or non-existent role." [3, p. 9, italics added] Information systems grammars, reference models and communication purposes forced us to further integrate language design, for the sake of general and universal descriptions of models and categorical systems. The foundational ontologies that Guizzardi, and Masolo et al. describe [3, 44] give us reference models which prescribe the general categories of a specific conceptualization within a system of the formal relations of linguistic terms which a modeling language admits satisfying general formal requirements for modeling languages. The primary objective of Guizzardi [3] is "to establish a systematic relation between a modeling language and a reference ontology, and to propose a methodological approach to analyze and (re)design modeling languages to reinforce representation adequacy exploiting this relation." (p. 35) This modeling approach is based on the classic 'Bolzano-Ogden-Richards' semantic triangle between a thing in reality, its conceptualization, and a symbolic representation of the conceptualization. Hence, the shared taxonomies of categorical types, roles, attributes, values, relationships, and relational properties usually accord with a metaphysics which underlies the various ontological accounts, since they are all based on the semantic foundations of *knowledge representation*. [cf. 27] Consequently, the ontology modeling language standards which are applied in various fields of computational, scientific, and social domains, share the following principles: (1) the search for a uniform domain independent *or* explicitly domain dependent formalism which can capture ontologies (top down and bottom up, *resp.*); (2) the requirement of a logic and machinery which can support inference, while maintaining some measure of (3) completeness (since an incomplete language is bound to produce incomplete specifications) and (4) consistency (because modifications allow only conservative extensions) (5) domain dependent expressibility. These goals and requirements inevitably lead to an ontological variant of the "closed world assumption": in which that which cannot be expressed in the terms of your ontology is deemed not to exist.

Approaches which address the issue of conceptualization in a space that includes concepts, metadata, domain modeling, the context of conceptualization, *and* the *cognitive subject* raise the issue of whether or not concepts and features of reality exist without the personal knowledge and agency of a knower. [19, 52] This is the case even without considering the historical embeddedness of concept development. [21] These approaches are frequently suppressed by the practical requirements and success of *applied ontologies* which span a wide spectrum of relatively well defined uses and domains. [42] In a metaphysically neutral methodological categorization, taxonomies, meta-data structures, the composition of topics, and the understanding of interpretative and learning contexts, do not exist without an interpreter of the meaning of expressions performing *intentional* epistemic actions. Since epistemic actions not only include public announcements but also doxastic interactions and categorical revisions, mutual understanding requires the conciliation of Human-Agent Information Architectures for personal and social conceptualization with collaborative knowledge organization. [17]

1.2 Metaphysically Neutral Information Architectures

Knowledge Organization (KO) is closely related to, and in several key aspects overlaps with, ontology research in Information Science (IS). In IS ontologies are required for the purpose of information retrieval, and for semantic transparency in the organization or arrangement of stored items. This form of KO concentrates on the gathering, manipulation, classification, storage, and retrieval of recorded semantic information. Given the close relationship between IS and library science, the ontologies which have been developed for various application areas (including taxonomic systems and metadata standards) tend to be more or less static (though extensible). [23,15] Ontological commitments, that is, agreements to consistently use a controlled vocabulary such as the Unified Medical Language System, became as conventional as the Dewey Decimal Classification, in widely accepted forms of KO and interchange, from the general supply of health care to more domain specific areas such as security threats and virus classification. Computational frameworks like the ARPA Knowledge Sharing Effort [35] facilitate the reuse of ontologically grounded knowledge, and supply us with mechanisms for translating between knowledge bases. Comprehensive and versatile intelligent databases such as the massive CYC project accumulate commonsense knowledge for natural language understanding or in applications like the Terrorism Knowledge Base. Standard computer readable representations like the Knowledge Interchange Format (KIF) give us declarative knowledge description languages which have proved to be effective tools for ontology reconciliation and integration. Since the most common solution for handling the alignment of static ontologies is ontology matching via “upper ontologies”, these formats have been actively used in projects developing Standard Upper Ontologies, such as SUMO or OpenCyc.

With respect to IS Fonseca [24] differentiates ontologies *of* information systems from ontologies *for* information systems. The first describes information systems and supports the creation of better modeling tools. The second are computational forms which support the validation of ontology-driven information systems, and ensure that our conceptual modeling schemas are correct. He contrasts Gruber’s (generally accepted, 1992) definition that an ontology is a “specification of a conceptualization” [22] with Guarino’s conception [23] which takes an ontology as a “logical theory” which accounts for the “intended meaning of a formal vocabulary” (including Gruberian specifications). If we interpret the latter conception as suitable for understanding “ontologies *of* information systems” as ontologies applied for building “ontologies *for* information systems”, we can consider ontology languages such as DAML+OIL, OWL, RDF as tools which are used to construct ontologies (in the sense of Gruber’s definition) for information systems. If however we accept that ontologies behave as theories, UML or OML should be considered as proper level modeling languages, equipped with a grammar capable of describing the conceptual schemas of information systems if and only if we have a conceptual modeling method and an associated intended model that together generate a theory which corresponds to Guarino’s conception. Like Smith [5] Fonseca criticizes ‘instrumental ontologies’ and confronts Gruber’s formulation of the ‘closed world assumption’ of artificial intelligence (in which “what ‘exists’ is that which can be represented” [22, p. 907]) with ‘Gruberian’ instrumentalist OE. According to Guarino’s interpretation it is not ontologies we are constructing, but theories of conceptualization which are being developed to construct info-bases on ontological grounds.

1.2.1 The problem of Non Categoricity

Guarino and his colleagues argue [27] that the intended meaning of a particular ontology (which should be described in modal, intensional logical frameworks) is always underdetermined by our theory, which always has unintended models (which can be considered as an ontological generalization of the Duhem-Quine thesis for scientific theories. [46]). Consequently, a theory of conceptualization necessarily provides only a partial “approximate characterization” of its intended meaning. Thus the requirement that our interpretation must be isomorphically determined (i.e. categoricity in the usual model-theoretic sense) turns out to be an unrealistic requirement for ontology building. This does not seem to be a serious problem if we are working in the framework of a single ontology with a relatively homogeneous scope. If however this theory encapsulating an intended model encounters different conceptualizations, non-categoricity becomes a serious problem: merging or integration oriented comparisons unavoidably focus on the differences, and it may turn out that even the intended models are different as it is illustrated by the known problem of *false agreement* (Figure 2.) adapted from [4, cf. 16]. The consolidation of such differences in case of overlapping vocabularies and intents clearly points to the need for better techniques of reflection at the meta-levels. The situation however is not less acute/severe if the intended models themselves overlap (e.g. in a context of discovery), though the purposes of application, the "intents", are different.

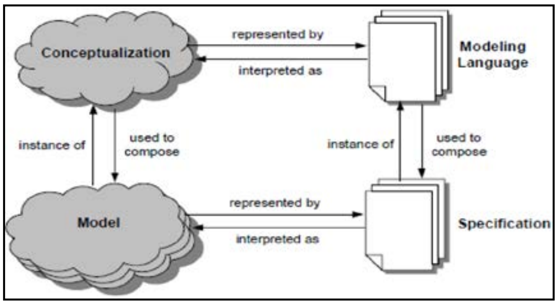

Figure 1. Relations between conceptualization, Model, Modeling Language and Model Specification [3, p. 50]

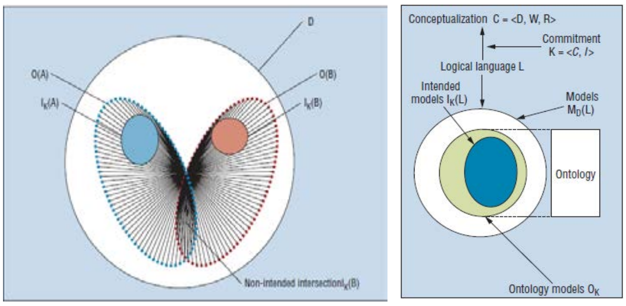

Figure 2-3. The relationship of disjunctive intended and overlapping all models in a domain D (adapted from [4]).

1.3 Change Management based on Upper Ontologies

After the initial period of large scale intelligent data-base development, upper ontology research soon faced the problem of the situated and intent dependent nature of ontology construction. [29] The goal that any "local" ontology be defined in terms of a single shared "upper ontology" so that every term in one ontology and every term in another ontology can be boiled down to categories in an upper ontology turned out to be tenable only for relatively homogeneous domains. Merging ontologies in *heterogeneous* contexts [38] was relatively successful only within similar reality perspectives and areas of application, e.g. in health science, enterprise modeling or genetics. [+59] In order to accommodate change as new results are discovered, and old hypotheses refuted in science oriented ontologies for example, frameworks like the OBO Foundry [30] were designed with the additional goal "on the meta-level […] to establish ontology development itself as being, like statistics, a recognized part of the scientific enterprise" but even in case of the development of successful existing ontologies, like the Ontology for Ontology for Biomedical Investigations, maintaining principles like *orthogonality* for the sake of interoperability had its pros and cons. [31, pp.23-26] Tracking changes in Change History Logs, providing modules for change recovery, and on the fly visualization of change effects, e.g. in Protégé, are relatively new results, [37] though early experiences already showed that versioning is not sufficient for the maintanance of multi-agent ontology revision. Extensions and revisions run into obstacles in heterogenous domains especially in case of distinct scope. [38, 65] The parallel dynamics of re-constructing the upper and the local domain ontologies led to several logical and computability problems, since changes in the top level ontology affect all local ontologies, even if their context did not change. However, intent and context dependence proved to be the main reasons, in addition to the needs of *knowledge discovery* and *collaborative* content creation, why ontologies have to be evolvable and changeable via revision and refactoring. [1, 39, 43] These requirements imply the integration of KO capabilities not just in "design time" but at run time and, in the collaborative case, "on the fly" throughout the whole 'life cycle' of the ontology. [63] This way, *dynamic* ontology building and *maturing* [42] arrived at technologies for permanent *refactoring* with open ended lifeline including the possibility of *bootstrapping* the ontology management framework. [65] Upper ontologies and rules of extension help us to keep the ontology in context, but they ultimately contribute to closed world assumptions. It is not only that the knowledge we wish to capture expands relentlessly, but also our meta knowledge about what we have learned about how best to organize and use that knowledge. When building a system what seemed a good idea at the "design" time is bound to become a limiting factor, unless we can rebuild the ship while still at sea. The primary motivation of upper ontologies can be seen in the desire to find uniformly applicable means for managing ontologies. Uniformity is required for satisfying users expectations to learn only once how to "drive" the system, but this aim should not lead to the homogenization of the content, as it usually the case with upper ontologies. Since the turn of century, when refactoring had come to the fore, the aim has been to develop computational means for managing change keeping the system fully working. It also applies to upper ontology construction that the growth of *alternative* conceptualizations requires the application of uniform *refactoring methodologies* and *technologies* at all levels.

2 PROBLEMS OF CONCEPTUALIZATION IN THE CONTEXT OF KNOWLEDGE ORGANIZATION

Knowledge Organization (KO) is more closely related to the content of concepts and to the actual knowledge items than taxonomic structures and 'ontologies' understood as "explicit specifications of a conceptualization" (Gruber [22]). The further component of Gruber's definition (which has settled debates about earlier discussions on what ontologies are), namely, that they are "shared" specifications, bounds conceptualization to the goal of communication. "Communication between people with different needs and viewpoints arising from their differing contexts" [59] positioned ontologies as 'Inter-Lingua' providing descriptive and normative models of shared understanding originally for multi-agent systems, e.g., Ontolingua, KQML, and FIPA-ACL] This goal which in the heydays of artificial intelligence research tended to refer to the internal and external communication of multi-agent systems [18] has changed into an explicit recognition of the importance and priority of human communication, especially in result of the semantic needs of the web. [42] Although Gruber's definition was criticized in certain aspects [23, 24] the relatively early point of view became widely accepted that "the adequacy of a conceptual modeling notation rests on its contribution to the construction of models of reality that promote a common understanding of that reality among their *human users*." [14, p. 52. Italics added.]. This approach which applies both to automated ontology construction and human centered collaborative and communicative conceptualizations suppressed the personal aspects of knowledge building and the context of discovery gained attention only recently [43, 45] when the exploration of the web for the personal purposes of KO became standard practice nearly in all fields. [52] The requirements of *pragmatic efficiency*, *conceptual clarity* and ability to support means of communication were consequently complemented with *comprehensibility* and *domain appropriateness* [15] and further formal requirements (e.g., soundness, lucidity) discussed by Guizzardi [60]. It is increasingly suggested that these requirements need to be a subject of re-evaluation in the context of discovery [45, 49, 50, 56]. Gricean conversational maxims may turn out to be untenable for dynamic knowledge building in light of Brewter's and Wilks' conception of ontologies for example, which are expected to function as a "Medium of Human Expression". [45]

2.1 Dynamic Knowledge Architectures

2.1.1 Referential meta-models versus meta-circular development

In the context of discovery the main problem is not representational adequacy but *representational flexibility* emphasizing the process of elaboration instead of insisting on "frozen" results of precision. [1] The *exploration* of new knowledge and its organization forced recent efforts by Semantic Web practitioners to address the problem of conceptualization from the point of view of linked information as *emergent* knowledge structures that do not assume a pre-existent reality to which they have to correspond. [42, 51] The semantic information, the content at given nodes of a Knowledge Graph for example, may refer to such reality and the emergent architecture may correspond to abstractions of certain state of affairs, but the conceptualization and the representational structure is not measured in terms of adequacy or correspondence to a domain of the real world, rather it develops together with the user's understanding of the information, her personal knowledge organization process that is dependent upon its *purpose*. For this reason recent efforts in *visual* KO point to a more flexibleapproach to conceptualization. [1, 54, 55, 56] These works are seeking *situated*, *goal directed*, *cooperative*, approaches to knowledge exploration and a *dialogical*, *interactive emergent semantics* that assumes, from the point of view of web based KO, a "self-supporting" [55] bootstrappable ontology authoring environment. [48, 51?] Emergent "bottom up", evolutionary semantics, "refers to a set of principles and techniques analyzing the evolution of decentralized semantic structures in large scale distributed information systems" in which representation of semantics and the discovery of the proper interpretation go hand in hand. [53] In the case of augmented environments of conceptualization such as Codex [56], WikiNizer (regarding its collaborative reference model: *Conceptipedia* [54, 64]), or OntoWiki [48], it is also a goal to built upon universal (in the sense of universal function) and "meta-designable" means of combinations with closure operations to create objects that are within the original domain of investigation, allowing recursive compositions, and "meta-reflective" "means of abstractions" for the generated contexts of application [36, 58]. If we add the goal of *self sufficiency*, in the sense of providing meta-circular self-supporting executable definitions of the systems entire repertoire of capabilities, to the requirement of flexibility, the knowledge and experience gained in organizing knowledge can be articulated *within the system.* Thus, s*elf sufficiency* yields ever more powerful tools of knowledge organization that are bootstrappable in an Engelbartian sense. [57] This allows not only for rebuilding the ship, while at sea, but could be building a better ship. Systems capable of this kind of meta-reflective meta-design can be called in the spirit of his NLS, an Augmentation Engine [58]. The implications of these solutions can be drawn and contrasted with the principles formulated above (1-5 resp.) in section 1.1.2 in the following terms: (1) Elaborate particular domains of interest in a *dynamic* form that is *open*, and *extendable*. (2) Each domain and meta-domain can have their own domain specific inference scheme, and can co-evolve with the growth of knowledge. (3) Scalability to *increasing* levels of completeness, (4) optionally lifting the requirements of consistency for the sake of admitting non conservative operations. (5) Increasing expressibility via bootstrappig without changing the computational metaphor at the meta-levels.

2.1.2 Static versus Dynamic Presentation of Semantic Information

Although there are process ontologies, and ontologies of temporal (social and historical) events, i.e. descriptions of dynamic aspects of the world, these are not designed for the description of the personal or collective development of conceptualizations. [30, 37] The creation of the "great chain of bootsrappable meaning" requires autopoetic expressive power to elaborate dynamic knowledge architectures. Instead of seeking to formulate uniform metaphysical upper ontologies these endeavors seek to develop a uniform meta formalism, "the simplest" self-applicable and extensible thing "that could possibly work". Live systems of this kind are hard to find in the literature, the closest are [55, 56, 58,]. Cunningham developed the Wiki as the "simplest database that could possibly work". OntoWiki aimed at creating a semantic wiki as the "simplest knowledgebase that could possibly work". WikiNizer is aiming to take this line of thinking to its conceptual conclusion by bootstrapping the "simplest possible personal augmentation engine that could possibly work". WikiNizer aims to take us "Beyond Ontologies" in the spirit of Codex. [56] In addition, by taking advantage of emerging technologies like "mobile first" HTML5 as a platform and web scale NoSQL databases, it is now possible to develop computer support for *personal* as well as *collaborative* knowledge work (as described in the reference model of *Conceptipedia* [54, 64]) that could possibly bring about the "cultural shift" [56, p. 672] needed to bring the benefits of open collaborative computer support of knowledge work to the way knowledge is produced and disseminated. The development of a dynamic, visual collaborative technology has to satisfy the evolving needs of bootstrapping in the process of knowledge building. The meta framework supported by augmented technologies can be used to capture, identify and define all possible objects and their relations of interest at the necessary emergent meta-levels. Taken together these methodologies constitute the organization and conceptualization of a knowledge domain together with all the content organizing meta-concepts that will emerge. Discursive elaborations of domain knowledge thus get fully integrated into a workflow that allows the ad-hoc but purpose/intent-ful introduction of meta-level concepts without breaking the original flow of expositions. As in a Wiki, when we get to the edge of our knowledge, be it at the domain or any meta level, we simply create a new "page" (as a node in a meta Knowledge Graph) to be worked on as the needs and the available knowledge dictates. Those existing approaches to ontology change that are not static and "thing"-based, are aware of the importance of traceability [37, 65] and that "history matters" in incremental ontology reasoning [61] but they are not reflective. They do not satisfy the dynamic requirements of reorganization, *intellectual manageability*, and *cognitive flexibility.* Restructuring knowledge and contexts of discovery require more dynamic forms of knowledge representation. *Augmentation engines* [58] and visual KO tools can help us build conceptual meta-structures through design processes. Interactive visualizations of problem spaces in the form of conceptual graphs serve problem framers by playing an active role in defining the problems to be solved, and "Going Meta" in Simonyi's sense, can make cross-interdependence between conceptual domains comprehensible by changing the level of abstraction and exploring the class of problems of which the current one is an instance, in a bottom up way.

2.1.3 Bottom Up Live Micro Ontologies

The structures that emerge in the course of knowledge building that includes discovery and conceptualization typically have all the characteristics we have described in the previous section. To distinguish the emerging Knowledge Architectures from alternative approaches we propose to refer to them as "Bottom Up Live Micro Ontologies". Bottom up', in compliance with the literature, [62], because they are created in the course of elaborating a concrete domain and 'micro', because the meta terms introduced can affect a single node or any that are linked to a node in a piecemeal agile way and in close contact to the context from which they emerge. These micro ontologies are usually smaller in size than the so called "local ontologies" in domain modelling [16] because they are amenable to reuse from any context, way beyond the one that gave rise to them. Using Micro Ontologies it becomes possible to define and manipulate domain knowledge with the aid of meta-level structures introduced on the fly, and these meta-structures can also be treated later as domains of their own right. Elaborating meta level structures as domains of their own right, leads to additional meta-meta level structures, and the same process can be repeated as far as needed. So knowledge architecture constructions are "turtles all the way up". In a bottom up approach domain specific, as well as meta-level concepts and methods can be developed in a form of "instance first". "In instance-first development, one implements functionality for a single instance, and then refactors the instance into a class that supports multiple instances" [13], which is to say we are "going meta". Only through live exploration and elaboration of descriptions of exemplars, specific instances of objects of interests, it is possible to develop suitable situated elaborations and conceptualizations that can capture ontologically what "there is" across many instances. This can be stated as the methodological requirement of the "primacy of bottom up live development": the characteristics of instance descriptions and the relationship with other instances should not be lost as we construct conceptualizations that are applicable to the class of things that are being described. Hence, instead of "conceptual atomism" [2] and correspondences between descriptions and some aspects of reality, KO seeks to establish correspondence between the structure including the relationships between instances and their class models in a more abstract sense of 'images', or using a current term 'visual models of reality', in the spirit of Hertz's Principles of Mechanics[1]. In the process of KO the formation of these 'images' is however, much closer both historically and methodologically, to Whewell's "consilience of inductions" trough the "*colligation of facts*". [41, p.74]. To paraphrase Ward Cunningham's quoted dictum: the emerging live, visual knowledge architectures should be "the simplest thing that could possibly work" that enable us to achieve our knowledge goals and intentions in a given situation. With respect to ontology evolution timelines, it is not only the results of conceptualization that matter but the creation of "knowledge model[s] that preserves audit trails of resource manipulation" as the records of "concept growth can increase the transparency of a research enterprise". [56, p. 672] The vision that takes us "beyond ontologies" had largely been explored with the Augmentation System that Engelbart created in his NLS half a century ago on a 'milli iphone'. With the millionfold increase of computing resource available even to individuals today, we can embark on developing the means to promote the "culture shift" i*Ibid.*] that could lead to collaborative creation of the 'great chain of emergent meanings'. In this quest we need dynamic mechanisms for recognizing and merging alternative conceptualizations.

3 THE DYNAMICS OF LIVE CONCEPTUALIZATION AND ITS VISUALIZATION

The simplest visual knowledge architectures capable to manage the content correlated dynamics of concept development are the graph structures of visual semantic wikis like ThinkBase. [47] They need proper mechanisms to cope with the various aspects of ontology change management [65]: *mapping, matching, alignment, revision, versioning, merging, evolution* and *integration*. Flouris et al. [33] give a classification of terms, methods and operations that can correlate concept development with the enrichment of knowledge domains. AGM theory and its recent extensions in the general framework of Dynamic Epistemic Logic provide formal belief revision operators for model fitting applicable to iterated stepwise update and expansion of a knowledge base. Formerly, truth maintenance systems applied non conservative entrenchment to implement nonmonotonic reasoning for the purposes of knowledge discovery. Until recently, however, ontology engineering worked either by expert-based or automated/semi-automated methods of centralized Knowledge-based Systems for solving problems of conceptualization. Human-Agent Negotiation techniques and protocols required by the Semantic Web came to the fore partially as a result of the poor record of automatic ontology generation and partly as a reaction to the rise of new issues of collective conceptualization in emergent semantics. [26, 42, 51, 52, 53] The requirements of live visualization and collaboration for a wiki-like concept organizer of a global giant graph knowledge base [1], emerging concepts and their intellectual manageability become central issues. As it is described in the reference model of "*Conceptipedia*" [54, 64], conceptualization can be improved by social interaction, cooperative learning and through collaborative sense-making. In collaborative knowledge work and problem solving the discovery of informative connection subgraphs can be based not only on data mining techniques and ranking-based discovery of semantic associations or similarities between linked data, (e.g. in SWETO Schema – Visualization) but also on *patterns* of *user interaction* with her resources and peers. Current technology makes it possible to trace and generate trails from a user's movements trough links between entities in a knowledge graph. The analysis of the traversal frequency of the graph provides meaningful relationships and patterns of

[1] "We form for ourselves images ('Bilder' in Hertz's original German) or symbols of external objects; and the form which we give them is such that the necessary consequents of the images in thought are always the images of the necessary consequents of the things pictured." [40, Introduction, p.1.]

user behavior which can be utilized for modeling the dynamics of the *personal use* of the concept graph. Such an analysis could provide user generated emergent semantics for categorical and aspect dependent conceptualizations at the organizational meta level of our knowledge resources. These conceptualizations usually take place during knowledge discovery and organization determined by the intent of the user. Since our knowledge grows not in isolation but in the form of collective *in situ* efforts to share our explored, re-usable paths of conceptualization, co-evolving direct manipulable visualization of concepts and learning objects are needed both at the object and meta-level to handle the social aspects of learning and knowledge work in the framework of an Exploratory Epistemology. [54, p. 117] Current systems tend to separate the conceptual level from the content, and the context of logical understanding from the intent laden use of concepts. Besides, they usually consider the unification of individual contributions in a ubiquitous global representation. As opposed to this God's eye view current research explores new alternatives that aim to provide live, tinkerable, in situ Morphic visualization of concepts and *direct manipulation* based authoring capabilities. [55, 58] Liveness at the visualization level means that screen objects are interactive and active, they react to user input and can have custom behavior. [55, p. 3] Direct manipulation means that the manipulative affordances of all objects are made clear to the user. ‘Worlds’ in Lively Kernel are the units of persistence. In contrast to Lively Kernel, in WikiNizer the basic units of persistent elements that are modified through *user interactions,* are not Worlds, but individual nodes and edges in the underlying graph. In WikiNizer Worlds (arbitrary collections of nodes, edges or graph fragments) are more like conceptual units like named tags in a Concurrent Versioning System. The implication of this solution is that collaboration can take place at a much finer grained level. For this reason, the authoring capabilities are uniformly applicable and user-extendable through meta-design both at the content, as well as all emergent conceptual meta-levels, within a collaborative frameworks like *Conceptipedia*. Morphic integrates verbal and pictorial models of conceptualization in its graphics system of intentful workflows as flexible, reusable building blocks for collaborative work. Distributing the workload and responsibility through Crowd Authoring, concept alignment and contributions from an online community filters out errors and misconceptions. Negotiation games played at the meta-level of knowledge items supported by a reputation system mechanism can support emergent conceptualization until workable ideas win out and taxonomic structures are settled. This way, challenges of social and collaborative concept matching can be addressed in a augmented knowledge management kernel that is also capable to supplement education technology.

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