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Organic Perspectives of Knowledge Management: Knowledge Evolution through a Cycle of Knowledge Liquidization and Crystallization[1]

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Abstract: Our research on knowledge management is rooted in the community perspective. We believe that knowledge systems should serve primarily to help people create and share new knowledge. But we also acknowledge the role of stable, structured and reliable information, both as a component of our systems and as a component of the organizations within which we work. The contribution of the paper is a framework for integrating organizational and community perspectives on knowledge management and its computational support. Our basic idea is that knowledge is not a static chunk of information, but rather, knowledge evolves in a cycle of knowledge liquidization and crystallization. The evolving process takes place through the interactions among conceptual worlds, representational worlds, and the real world. This paper first describes the knowledge liquidization and crystallization framework. We then illustrate the approach with three systems, Knowledge Nebula Crystallizer, livingOM, and ART-SHTA.

Keywords: knowledge liquidization and crystallization, knowledge management, community of practice, Knowledge Nebula Crystallizer, livingOM, ART-SHTA, organic perspective
Categories: K.6, H.3, H.5.3, H.5.4, I.2.4, I.2.6

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1 Introduction

This paper presents our approach for the design and development of computational support for knowledge work in organizations. Our conceptual framework has evolved around organic perspectives of knowledge management.

We view knowledge not as a static chunk of information. But rather, knowledge evolves in a cycle of knowledge *liquidization* and cry*stallization*. Knowledge does not exist as a static entity, but emerges only within a certain context through interactions among conceptual worlds, representational worlds, and the real world [Hori 1994]. Knowledge can only be partially represented as a snapshot of such interactions. Represented knowledge then serves as a seed for the production of new knowledge [Ostwald 1996][Nakakoji et al. 1998].

We have developed the knowledge liquidization and crystallization framework based on the above viewpoint. The next section describes the framework.

2 The Knowledge Liquidization and Crystallization Framework

The *knowledge liquidization and crystallization framework* integrates organizational and community perspectives on knowledge management and its computational support.

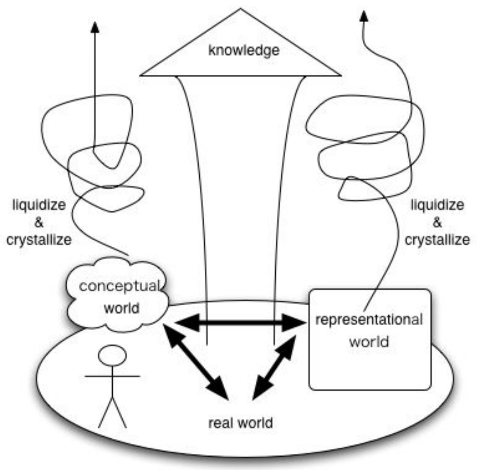

Figure 1: Knowledge evolves in the field of interaction among conceptual world, representational world and real world.

Knowledge evolves in a cycle of knowledge liquidization and crystallization. The evolving process takes place through the interactions among conceptual worlds, representational worlds, and the real world (Figure 1). In the real world, real objects (including humans) exist and certain relations hold among them. In a representational world, there exist words and texts in natural languages and other forms of representations including diagrams, graphs and pictures. A conceptual world exists in the human mind and concepts are formulated there.

Let us now describe the process by using what we have found in analyzing the protocol data of conversations between sales clerks and customers in clothing stores [Shoji, Hori 2003].

In a clothing store, a good sales clerk often develops stories for his/her customer about the customer's wearing the clothes to be purchased; for instance, how the customer would look and be recognized in a wedding party. Thus, a good sales clerk does not only sell a clothing product to the customer but also tell the value or the meaning associated with the product by using stories.

Such stories emerge while the sales clerk communicating with the customer. The sales clerk constructs a story not by merely using his/her knowledge about the product, but also by taking into account the customer's context. Once developed, such a story becomes a part of the knowledge about the product. By listening to the story, the customer's context also changes.

A story of attending a wedding party wearing the jacket to be purchased was constructed in the representational world as a story. The story evoked other concepts in the conceptual world, which were represented in some utterances. They then evoked the search for the corresponding objects or relations in the real world. The knowledge around the jacket (i.e., the value or the meaning of the jacket) emerged in this evolution of the relations among the conceptual world, the representational world, and the real world.

In order for knowledge to evolve in this manner, we argue that both conceptual worlds and representational worlds need to go through an iterative cycle of *liquidization* and *crystallization*.

Traditional approaches in knowledge management are to accumulated as many coherent knowledge units as possible, and generalize them into a cohesive structure. Then, the generalized knowledge can be instantiated when encountering new situations. We argue that these approaches cannot afford dealing with emerging contexts. Knowledge units can be accumulated in a coherent manner only within a certain context. Generalized knowledge therefore is operational only within this context.

Our knowledge liquidization and crystallization framework addresses this issue. The idea is very simple. Knowledge liquidization decomposes a knowledge representation into atomic units. Knowledge crystallization identifies new relationships among some of the units capturing an emerging context. That is, in contrast with knowledge generalization and instantiation, knowledge liquidization divides a cohesive structure into coherent units while knowledge crystallization discovers a new cohesive structure among coherent units. In order to drive this discovery process, the framework demands the involvement of human interaction in the process [Hori 1994][Nakakoji et al. 1998].

The next section presents our approach of the use of computational support for the framework.

3 Systems for Knowledge Liquidization and Crystallization

Our approach is to design and develop computer systems that serve as fields for the knowledge evolution based on the framework described above.

Such a computer system provides the user with the world of representation, where the system makes certain calculation on the relations among the representations and the user looks at and operates on the representations. The user can develop his/her own conceptual world by finding new relations in the real world or in the conceptual world through the operation of the representations. The result of the concept formation is reflected again as new representation.

3.1 Requirements for the Systems

There are three requirements for the systems that are based on the knowledge liquidization and crystallization framework.

- The representation should be divided into small elements to enable new structuring.
- Each representation element should have rich possible connections with other representation elements.
- The structured representation should leave enough room for the user to imagine new concepts.

If the knowledge is represented in a fixed large chunk, it will be difficult to consider other possibilities of new knowledge. Therefore, our system first divides the knowledge into small elements in terms of a certain context. This process is *knowledge liquidization*. Knowledge liquidization can be achieved by both (1) decomposing a knowledge representation into atomic units, and (2) adding links among atomic units of a knowledge representation. A liquidized knowledge representation has a more flexible, "softer," malleable structure.

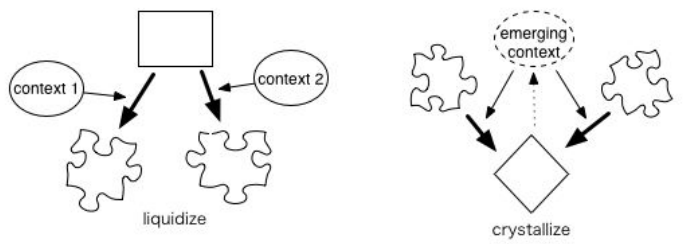

Figure 2: Components and Operations of the KNC

When liquidized, each element should have rich possible connections with other elements. These two properties of fine granularity and rich possible connections become the source of the evolution of new knowledge. The system can calculate possible new structures using the possible connections. This process is *knowledge* *crystallization*. The result of the crystallization should not necessarily be some correct answers but should evoke new concepts in the user's mind effectively. The result of the crystallization should leave enough room for the user to imagine new concepts. These operations are depicted in Figure 2.

A context in Figure 2 serves as a solvent for liquidization (helping to divide artifacts into elements) and an emerging context serves as a catalyst for crystallization (helping to retrieve and structure elements into artifacts). A context determines the relation between elements and artifacts, and can be viewed as domain knowledge.

We have been building computational prototype systems based on the above framework to demonstrate several fundamental knowledge management processes including knowledge reuse, creation, and evolution. In what follows, we present some of our systems to illustrate the framework.

We first describe Knowledge Nebular Crystallizer, which is depicted with a user scenario. We then describe livingOM and ART-SHTA to further illustrate specific aspects of the approach.

3.2 Knowledge Nebula Crystallizer

The first prototype is called the Knowledge Nebula Crystallizer (KNC). The KNC is a demonstration of concept developed at the University of Tokyo. It is used in this paper to describe basic knowledge system functionalities and components. In the scenario below we describe how an idealized version of the prototype might work.

Jane is a graduate student who is developing her initial ideas for her master’s thesis. Her first step is to look, from her own viewpoint, into the work her research group has done in the past. She logs into the Knowledge Nebula Crystallizer (KNC), and tells the system of her interests. She also uploads a 2-page description of her thesis topic to further describe what information she is after.

The screen goes blank except for a small logo signifying that the KNC is working to collect and crystallize (compile in various possible contexts) information relevant to Jane’s research interests. After about 10 seconds the screen is filled with several different editions of reports summarizing the relevant work selected from among the entire body of work done by the research group; each edition shows her a different possible context or a viewpoint discussing the same topic. The reports are organized from the divided parts of the papers her group has produced that are relevant to her interests. The KNC also provided a list of outside references that were most often cited by her group as well as a list of the most prominent researchers in her field, according to the possible different contexts.

The KNC has not written Jane’s thesis, but it has certainly given her a good start on the related work section, and stimulated her to consider possible different contexts to discuss the same topic. It not only saved her substantial time in collecting the material she needs for her own research, but also triggered creating new knowledge.

We now jump ahead 6 months. Jane has finished her thesis. She once again logs into the KNC only this time she is contributing knowledge rather than consuming it. The KNC provides a simple form into which Jane uploads her thesis as a TeX document. The screen KNC again goes blank except for the liquidizing logo. After about 30 seconds a message appears on the screen thanking Jane for her contribution. The KNC has successfully liquidized and integrated Jane’s thesis into its knowledge base, and is now better able to help future users who request information related to

Jane's topic. The KNC may now give the new user the parts of information Jane gave combined with other information under possibly new contexts that are different from the context of Jane's master thesis.

In the scenario, the knowledge nebula evolved as Jane input her thesis into the system. In this sense, the KNC is able to grow and improve over time as the result of the work of users.

The above scenario was a fictionalized account of how the Knowledge Nebula Crystallizer might contribute to knowledge sharing and knowledge construction in a particular organization or community. The scenario depicted two interactions with the user. In the first it output reports based on Jane's query and in the second it accepted Jane's finished thesis. These interactions involve the two essential operations of the KNC, Crystallization and Liquidization, and the repository of the KNC, called the Knowledge Nebula.

3.3 LivingOM

The second prototype is the livingOM (living Organizational Memory), a web-based knowledge system developed at the University of Colorado at Boulder. The livingOM shares the basic functionalities of the KNC, but differs in its implementation and application. The role of the livingOM in this paper is to illustrate how aspects of both community of practice as well as organization perspectives can live together within a knowledge system.

The livingOM supports work within a community of knowledge workers who create, collect, and reuse information resources. It is living in the sense that it grows and improves as it is used to do work and solve problems. The livingOM is a follow-on to the DynaSites system [Fischer, Ostwald 2001; Fischer, Ostwald 2002a; Fischer, Ostwald 2002b], and has been conceptualized and developed as an organizational memory serving a mid-sized research group. It is designed to both support work practices and accumulate the products of work, such as research papers, glossaries of terms, and information about group members and research prototypes. The livingOM is web-based and is currently serving as the web site for the enTWIne research group at the University of Colorado [enTWIne 2004].

Like the KNC, the livingOM manipulates information at both the artifact and the element levels of granularity. Artifacts in the livingOM are hypertext documents, whose elements (such as chapters, sections and paragraphs) are structured hierarchically. A typical way to create a document in the livingOM is to import a document written in MS-Word. The Word document is automatically liquidized into elements and stored in the livingOM. Unlike the KNC the elements are not through of as a nebula, although cross-document searches are supported which return lists of elements.

The livingOM's domain knowledge plays a similar role to the domain knowledge in KNC. Namely, it allows the system to collect and structure information in response to a specific situation, or query. The representation of domain knowledge, however, is different. Where the KNC represented domain knowledge by high-dimensional vectors, the livingOM represents domain knowledge as typed objects connected by relations.

Relations can be either explicitly created by users or automatically created by the system. For example, a livingOM document contains relations to resources such as glossary terms, citations, prototypes, and people that are displayed as hypertext links embedded in the text. When users traverse one of these links they access detailed information about the particular resource (such as the definition of a glossary term) as well as links to other related resources throughout the livingOM information space.

Table 1 compares the two approaches of KNC and livingOM in support of the knowledge liquidization and crystallization.

	KNC	**livingOM**
Artifacts (crystallized Elements)	Documents stored by users and ones dynamically created	Document stored by users and views that link related parts of documents and domain knowledge
Elements (liquidized Artifacts)	Nebula – information elements created from documents and interview transcripts (but they could be created in anyway)	Word documents are automatically decomposed to the paragraph level (but they could also be created piece by piece)
Domain Knowledge	Thesaurus – Hand crafted set of keywords with automatically calculated weight values against different contexts. There is also knowledge of people	Several types of information, including Glossary, references, people, research prototypes

Table 1: Comparing KNC and livingOM

3.4 ART-SHTA

As noted in Section 2, the framework assumes the involvement of human interactions with the system. By interacting with liquidized knowledge representations, humans are to take some parts in identifying structures among elements in the crystallization process. The system's *interaction design* plays a key role in the process.

This subsection gives a brief overview of the ART-SHTA (Sculptural HyperText Authoring) system to illustrate requirements for the visual interaction design for the systems based on the knowledge liquidization and crystallization framework.

ART-SHTA (Figure 3) supports information- and concept-structuring for analytical and scholarly compositional tasks. ART-SHTA employs three hypertext techniques: sculptural hypertext [Bernstein et al. 2001], spatial hypertext [Marshall, Shipman 1995], and hierarchy browsing. The system has been used for such tasks as to understand and specify system requirements, and to clarify research concepts to design a structure for authoring an academic paper.

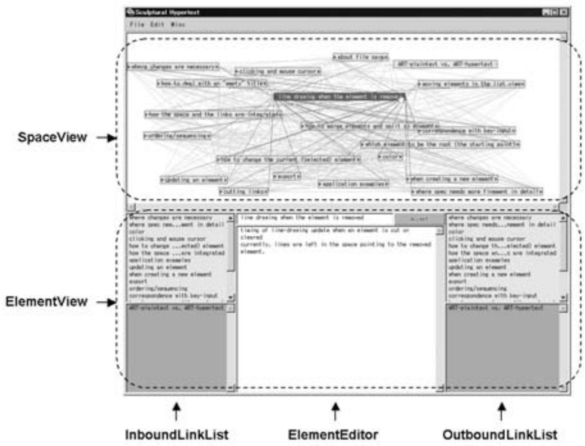

Figure 3: ART-SHTA

Sculptural hypertext refers to a type of hypertext where one “creates a structure by removing unwanted connections, much as a sculptor may create objects by removing unwanted material” [Bernstein et al. 2001]. While the notion of sculptural hypertext was originally explained to provide “exotic tools for hypertext narratives” [Bernstein et al. 2001], we argue that the approach also demonstrates a powerful method for supporting analytical and scholarly authoring tasks, which we call sculptural hypertext authoring.

Spatial hypertext representations help users gradually define and fix relationships among objects using emerging structures [Marshall, Shipman 1995]. Additionally, with the interaction design technique used in the four ART systems we have developed [Yamamoto et al. 2002], a space provides a way to view the entirety, giving a global view of the space of information chunks being constructed.

The 3-column view for hierarchy browsing has been used to display a focused element in the central column, and linked elements in the columns on the both sides. This allows a user to easily move within the hierarchy without losing the context.

The ART-SHTA system has a name starting with “ART” because throughout the interaction design of this system and other systems (such as ART#001, #002, #003 and #004 presented in [Yamamoto et al. 2002]), the design principle called ART (Amplifying Representational Talkback) has been applied. ART emphasizes that computational media should (1) allow a user to easily represent what he/she wants to externalize, (2) allow a user to easily understand what he/she has externalized, and (3) “be quiet,” not offering disturbing services.

4 Discussion

To consider the entire lifecycle of knowledge management systems, Fischer proposes the seeding, evolutionary growth, reseeding (SER) Model [Fischer 1998]. Our knowledge liquidization and crystallization framework can be viewed as a framework for the evolutaionry-growth stage of the SER model.

The SER model provides a conceptual framework to understand how decentralized evolution can be initiated and then sustained over time. The model was developed to understand the balance between centralized and decentralized evolution in sustained development of large systems. Its goal is to apply lessons learned from success cases, such as the open source software, to domains and communities, such as Knowledge Management, that have not traditionally been viewed in from this perspective [Fischer, Ostwald 2001].

The knowledge our systems use to crystallize elements into artifacts is implicit in the artifacts, rather than represented explicitly. There is no notion of complete or correct in our systems, only more or less relevant according to the crystallization method. The reliability of the artifacts is assumed to be high since it is under control of the community, but in any case the validity of the information is determined by the user, not the system. These attributes mark our approach as belonging to the Community of Practice perspective of knowledge management.

As Table 2 illustrates, organizations and community of practice seem to have different perspectives on knowledge.

Organization	Community of Practice
Static (Centralized)	Dynamic (Decentralized)
Information-oriented	Process-oriented
Explicit (about the work)	Implicit (the work itself)

Table 2: What is knowledge? Two perspectives

By looking at the perspective of knowledge liquidization and crystallization, however, we have come to a conclusion that organizations and communities are not always so far apart. Modern organizations need to see themselves not only as keepers of knowledge, but also as creators of knowledge. And communities of practice, likewise, have a real interest in sustaining their practice and providing centralized resources to their users. We believe both organizations and communities would benefit from an understanding of their counterpart’s perspective, and hopefully this paper has provided a framework for doing so.

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