Managing the global knowledge metabolism of an evolving community

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Abstract: The experience as systems engineer- led me to a holistic vision about knowledge management. Knowledge is "incarnated" in people- evolving in the context of their cognitive system, explained in resources, implied in activities producing competence changes. Between the management of knowledge reference systems- used for indexing persons, documents and actions- and the management of the processes in which this knowledge is used and modified- a profound and cybernetic interaction operates. I carefully considered it in conceiving the architecture of TELOS. By means of the "metafunction" mechanism, prototyped in the GEFO system we can model the global metabolism of the community's evolving knowledge. Using system meta-ontologies and the facilities to observe and support the "semantic equilibrium" offered by (meta)functions- we obtain a powerful tool for the global management of knowledge based systems' physiology.

Keywords: TELOS, GEFO, Knowledge management, Competence management, Document indexation management, Activities indexation and management, Instructional systems, Global knowledge metabolism, Holistic and transdisciplinary approaches
Categories: H.1.1, H.5.3, J.4, J.7, K.3.0, K.4, K6.4

1 The evolution of a knowledge-based system

The interest for the general theory of systems (processes) and my experience as telecommunication, information and instruction engineer [PAQ 03, PAQ 01] have led me to a holistic vision on the knowledge based systems' metabolism [ROS 00]- exposed in my doctoral thesis [ROS 99]. In the TELOS architecture [ROS 06-2] I have proposed the blending, in a coherent whole, of the reference systems' management, persons' expertise management, documents' bibliographical management and the management of activities in which knowledge is modified [PAQ 04].

My vision utilizes biological metaphors and relies on principles as:

Person in society: cognitive duality. In the same way a cell's metabolism coexists with the metabolism of the organism it belongs (influencing themselves reciprocally), the individual cognitive metabolism interferes with that of the community- in which it is "situated". The communication between two persons can be seen as a relation between two distinct cognitive systems, but also as a manifestation of the cognitive physiology of the species' system, ensuring spiritual evolution, through knowledge propagation.

Knowledge as a communicational system. Phenomenology reveals the unity of the pair (observed object – observing subject). We can extend this vision to take into account the shared character of knowledge, including, in a single whole, the represented subject, the representing symbol and the human pair communicating on the subject- using the representation. We obtain a systemic meaning of "knowledge", that can orientate the research on knowledge engineering.

The wide specter of "assistance" and its metamorphosis. The concept of "assistance" - covers a large range of significations. It can mean simple "information" – the delivery of an appropriate and intelligible message. When the understanding of concepts meets difficulties – "clarifications" are required. If necessary, the beneficiary is helped to "learn" the information – in order to be able to reuse it anytime. Instead of explicative messages (what is to be done, how, with what instruments), new tools can be provided ("equipment") or the work with the existent ones can be "facilitated". The advanced "support" systems allow the combination of these possibilities, the choice being adapted to users' needs. I call "metamorphosis" the transition of a system from an assistance posture to another, without leaving the ongoing operations' chain.

Distributed intelligence. The intrinsic qualities of a human assistant (appropriate, available and well-disposed) are difficult to mechanize. The posture of information "emitter" is multipliable (through the diffusion of the conceiver's "message"), but that of a learner "listener" or interactive partner- much harder. The assistants' "artificialisation" is problematic practically and ethically. The "reproductive" realizations, accomplished in the name of "efficiency", can lower the quality of education and must be used circumspectly and with good reasons (cost-cutting measures, inaccessible experts, etc). Instead of degrading the explicative dipole, the synaptic "matching" infrastructure, based on the computer network, can provide contact, contract and management services.

Complexity, perplexity, pragmatism. The engineering of instructional "lifecycles" chains (of a fabrication platform A, of the authoring instruments B – produced with A, of the explanations/lessons C – prepared with B, of the knowledge D obtained with C by the learners E – usable or valuable in the context F) supposes a "phylogenetical" approach: to prepare "grand-grand-mother" systems that can produce "grand-mother" systems with which "mother" systems can be conceived, witch can generate the desired "knowledge – children" systems. The ambition of the systemic approach is therefore paid by confronting the complexity. A rigorous resolution is problematic. Even when it is possible, the energy expenses can surpass what is gained from it. The impressive number of: elements and phases, aspects and dimensions, criteria and methods, contexts and versions – require the simplification of the models, strategies and instruments, according to a "pragmatic" orientation: get the most useful services through the most accessible means; seeking the optimization of the effort/result ratio – when the resources are limited.

Transdisciplinary epistemology. The difficulties of knowledge engineering are correlated with the modeling limits of its global transformation process. We are obliged to see a unitary phenomenon through the multitude of prisms of a wide range of domains, each having its own primitives, epistemology, language, paradigms, experience, rituals, models and priorities. This situation produces a dispersion of the observations and formulas, the secondary space of reflection becoming more complicated then the first-of the observed phenomenon. A integrative approach would be necessary, one that would remake the unity of the observation's target, coagulating a model image. But the program of the trandisciplinary movement [NIC 96] is not yet backed by an adequate epistemology.

2 Global knowledge physiology and its management

2.1 Management of knowledge representations (also see [ROS 06])

Knowledge and its representation. Aware of the principle difficulty of defining "knowledge", I use the following meaning: *cognitive living, reflecting a certain reality (exterior or psychical), perceived in a certain context, expressed by a fragment of language (cultural reference system constructed by coexistence and instruction), understood (shared) by the members of a community – that integrate it in certain "knowledge domains" and decompose it in sub-components.* Through the "word" that represents it, a live knowledge is reflected in the mirror of its reification. The communication process allows the use of representations, the meaning being recuperated at the time of interpretation.

Domains used as referencing systems. Based on the language's natural reference system, knowledge domains (spaces) can be built, according to various organization norms. These systems, establishing relationships between the representations, model (declare) relationships between the represented knowledge (and between the realities that they reflect). Therefore they can enrich (explicit) the "meaning" of knowledge and can be used as reference systems. The utility of such a "reference" depends on the expressiveness of the notion's localization in a domain and on the usage context.

Reference system's organization. The various forms (norms) of "knowledge reference system" organization (and, consequently, of the indexing and retrieval processes) have all their qualities. A "classification" (taxonomy, catalog, tree) facilitates the orientation and the "inheritance" of the attributes eventually connected to nodes (competences, etc.) The relational structures (databases, XML) – refine the management. "Dictionary" type organization accelerates the searching of terms. Even pointing towards a thesaurus or a text collection – can be useful. The hypertextual structures advantage navigation. The declarative languages valorize their recursive possibilities in sustaining inferences. The graph modeling techniques as MOT [PAQ 03] introduce typed links (composition, precedence, etc)- suggestive for humans and useful for mechanical deductions. The best potential of automatic inference (assistance) is obtained when the reference system is organized according to a "computer-comprehensible" logic – hence the interest for "ontologies".

Decomposition and aggregation. Knowledge can be detailed by decomposition, in notional sub-spaces, organized conforming a norm and usable as a reference system for its sub-knowledge. This decomposition process can continue in cascade. In the opposite way, aggregation can take place, linking (merging, fusing) notional spaces.

Management and engineering of norms and reference systems. Placed at the foundation of knowledge management systems (and sometimes being its goal – see the intellectual capital problem) the organization of reference systems confronts difficult problems such as: the optimization of the referencing process implied in the functioning of a certain system, the evolution of reference domains (refining, correcting, versioning) and the recalculation of already operated references [ROG 04], the translations imposed by the collaboration between persons, institutions and communities using reference systems with different organization norms, the organization of a meta-reference-system for the "knowledge management" domain, the coordination of activities- in cooperative knowledge management etc.

2.2 Indexation of persons and documents

Participants' management. Lucrative or instructive processes (emergent or planned) can involve- as actors operating in various postures- participants of several types, selected from those registered in the corresponding repertories: persons, groups of persons (enumerative collections), categories of persons (defined by common characteristics), teams (aggregation implying roles and protocols) and agents (human or artificial, acting for others). Their pertinent choice (intervention) requires the prior declaration, in the record's fields, apart the general data regarding each potential participant, of information witch can influence the decision (negotiation) of its implication (competences, interests, availabilities and requirements, communicational, linguistic and technical particularities/preferences, etc).

Documents' management. The material resources implied (as work instruments or products) can be placed in collective repositories or personal portfolios. They can be shared, respecting the administrative protocols (negotiation of retrieval, access or use) and the technical ones (inter-operability, adaptability to the usage conditions). In order to facilitate the retrieval, each documentary resource's record has, apart the general fields (identifier, author, address, size, version, publication date etc), some fields dedicated to technical and administrative aspects and others for specifying the content (semantic references).

Indexation of persons and documents; knowledge and competences. The "knowledge references" that we meet in document indexation or in expertise declaration are, sometimes, equivocal (they signal that a person detains them or aims at obtaining them?; that a document or support person presumes them from the assisted one or can explain them to him?) or hide a binary approach (knows / does not know). This reductionism eludes the gradual character of "learning". In a support (instruction) system, it is exactly the evolution of the subjects' understanding and the contributions to this evolution witch must be followed. We therefore need qualitative and quantitative descriptions of someone's relationship relative to some knowledge: a "*competence*" - managed conforming to a norm C.

Mastering level, abilities and postures. Similarly with the evaluation of material operations execution's success (of person-object relationships as "utilize", "produce", "modify"), the cognitive operations (relationships in the person/knowledge pair space) can be evaluated by a "mastering level", measured on a scale M. Another organization [BLO 56] proposes "*abilities*" (knowledge/ comprehension/ application / analysis/ synthesis / evaluation), witch can be treated as separate person-knowledge relationships (sustaining fine-grained qualitative inferences) but also as a universal competence scale for the "to know" relationship. In order to observe the competence equilibrium around pedagogical operations, I have introduced [ROS 06] the characterization of the participant P's competences (or of the support document D witch he has produced and substitutes it) by "*postures*": (knowK, aimK, explainK(x,y), describeK(x,y), evaluateK(x,y), recommendK(x,y))- where the parenthesis show a predicate depending on the detained (x) or aimed (y) "mastering level" of a person (learner etc) to which P could explain directly (describe in a document, evaluate, recommend) the knowledge k.

Deductible competences. Once the mastering scales chosen, we can express, based on them, the " mastership" for each ability or posture, obtaining vector type characterizations of the competence P, referring to k. But how can we calculate the global competence- starting from this decomposition? Or starting from the competences on the sub-knowledge decomposing K? The organization of the competence reference systems poses additional problems. How could their declaration be organized economically, using the inference possibilities of the taxonomies, declarative structures, conceptual graphs or ontologies- to make reasonable presumptions about the competences attached to two knowledge- pieces connected by some relation? How can we evaluate the relationship between doing and knowing to do? How can we measure, in practice, the mastership for various abilities and postures? These complications led to simplifications such as the (discussible) use of uniform evaluation scales M like: 0-1, 0-10, 0-100, A-F etc)- instead of a fine-grained competence management.

Competences' management. Is confronted to supplementary complications, such as the negotiation of concurrent evaluations – according to an authority protocol. (What does the estimation of someone's competence represent? His opinion on what he knows? The result of a concrete (official) evaluation? The point of view of an institution? Someone else's opinion? Emitted in what conditions, with what mandate and what credibility?). The pragmatic compromises are inevitable, but their orientation calls for a more coherent theoretical frame.

2.3 Emergent chaining of activities involving knowledge

[I insist here on the knowledge processing.]

Publishing a knowledge (re)source. The participants having this right (mandate) add new documentary resources to the appropriate repositories. These potential knowledge sources are accompanied by descriptive records, comprising references (implied knowledge and competences) to the K-C reference systems (see part 1 and 2). Some resources can result from the aggregation of already registered ones [ROS 02]. The participants' directories are enriched with analogue records.

Finding and using the resource. The participants connected as resource users exploit the retrieval instruments based on the link between the language of the requests and the knowledge reference spaces employed for the semantic, technical and administrative indexation. Some facilities for adapting the selection according to the users' competences may occur.

Chaining emergently. Operational cascades are established freely, according to the users' necessities (initiatives). The concurrence situations are solved by negotiation mechanisms. Sometimes, the same user will tie, as executor of a unitary activity, the chain of pertinent operations. The utilization by a user A of an object produced by a user B in a precedent operation signals an emergent chaining.

Reacting and updating. The activities implying knowledge partners (humans or documents) can lead to competences' changes. Additionally, following the use of some resources, data (traces or annotations) can appear. This information constitutes suggestion for modifying some references or a reference system- in subsequent phases. Thus, the management of instructive activities is indissolubly (cybernetically) blended with the evolution of its knowledge layer base.

Watching and modeling. Through a participative or an exterior observation of the actions (using eventually sensor-surveillance facilities) or through post-factum data analysis, emergent process' occurrence can be understood and eventually modeled. This can be the inspiring source for conceiving "operations" and "functions" – preparing the orchestration of analogue chains.

2.4 Orchestrated and adaptable operations (functions) and their indexation

I resume here the knowledge processing.

Procedure, operation, function, metafunction. Procedural models represent the elements (persons and resources) and the rules implied in the realization of an activity, seen globally ("operations") or decomposed in steps or interlaced threads ("functions"). After the composition of a generic model and the particularization of "derivate models" by the concretization of some appropriate elements, these models can be indexed and published in a repository, becoming retrievable – as any resource. At use time, these "procedural aggregates" take advantage of the assistance facilities incorporated in them (guiding, supervising, manipulating, coordinating, matching etc). Throughout the functions' lifecycle, occurs -according to the "life mode"- the components' concretization process, piloted by the observation of the "competence conditions". These transformation cascades, operating between the model and the procedural reality that it mirrors and (re)produces can be managed through metafunctions (based on system ontologies).

Actor and instrument indexation, concretization and selection. The actors A (and generic instruments D) that appear in the operations' models have c(a/i,k) competence characterizations, analogue to those of the participants P (or documentary resources R), that will concretize them, allowing the work of selection criteria as c(p,k)>=c(a,k) (the sense of the order relationship depending on the chosen competence structure).

Orchestrated executions and global procedure indexing. If all operation's elements have been specified (connected) – with the exception of its "user" – we are dealing with an assistance "contract", placed in the "prepared activities" directory, waiting for its client. The global indexation of such an aggregate is similar to those used for other support resources: the competence levels required (C1) and obtained (C2) for/through the execution of that particular activity are signaled. But the concrete users having the level c1 (instead of C1), and the intentions c2, the effective execution acts like an operator changing the c1 level in L(c1), witch can differ from C2 and c2 (the presumptions about the lesson's effect having only a statistical value).

Internal indexation of operations and progressive concretization. We can optimize (assist) the selections (persons and connected documents) operated in any phase of the concretization chain if we provide mechanisms for watching each operation's internal competence equilibrium. These facilities are created by the use of the same reference systems for the indexation of actors (persons), operations (activities) and instruments (documents) and by the definition of competences by postures (see 2.2). The rules (equations) that intervene depend on: the procedure's "topology" (Toead – operation, executer, assistant, support document, Toea, Toed, Toe, etc.), the concretization order (for instance: first d(o), then a(o,d) and finally e(o,a,d)) and the assistance strategy. For example [ROS 05], for an operation requiring a competence level O, approached by a learner having a competence C, supported by a an assistant capable to sustain (C1, C2) leaps and by a document

capable to sustain (C3, C4) evolutions, we can observe situations as: *(C1<=C<O<=C2* or *C3<=C<O<=C4*)- any support component is sufficient or (*C1<C<C3<C2<O<=C4)* – the assistant can lead the executor in the document's efficiency range.

Semantic services for an adaptable model. The mechanisms suggested above are useful in the model preparation phase. They can also intervene in the execution phase, if concretization liberties have been allowed. "Semantic services" are realized by optimization agents supporting at run-time the selection of connectable resources and persons, launching useful alerts, matching automatically etc.

3 The global physiology of a knowledge based system

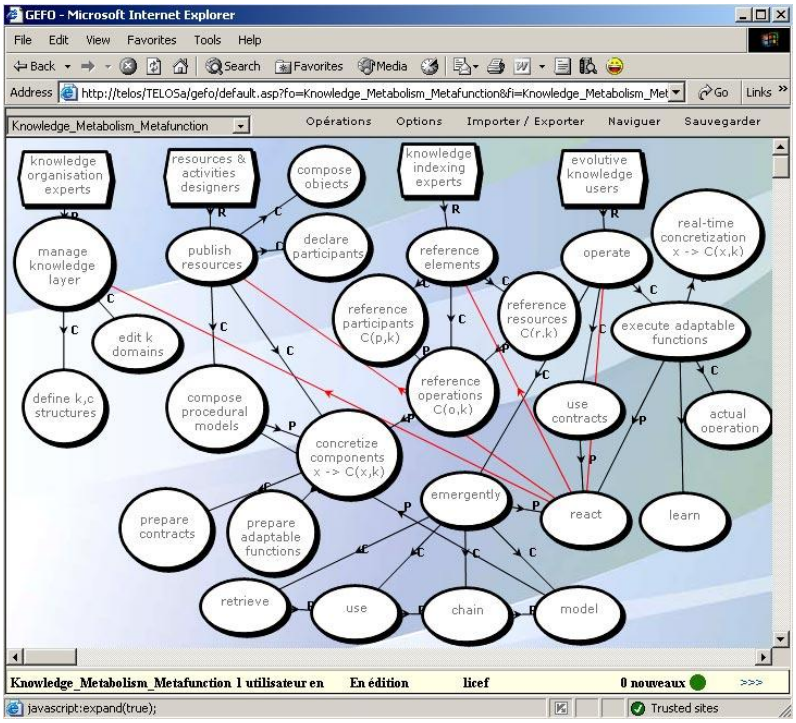

Figure 1: Metafunction representing (managing) a global knowledge physiology

The processes described in paragraph 2 form a complex but unitary metabolism for knowledge… represented in reference structures… incarnated in participants… whose competences evolve… as a consequence of executing procedures with instructive effects…which exploits the competence leap potential of the explanations …incorporated in documents and provided by assistants.

Here is the interest for using metafunctions in the global management of knowledge (modeling, explaining, orchestrating, adapting and reproducing the

system's desired physiology). I have already used [ROS 04] the GEFO prototype for demonstrating this chain (figure 1): After the definition of a knowledge process meta-ontology and the preparation of functional facilities (chaining, manipulation of system resources, orchestration, matching etc) such metafunctions can become tools for the unified meta-management of the systems supporting the management of knowledge and of the resources, expertise and activities- related to it.

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Note: These texts detail the considerations presented above

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