MODEL BASED ENGENIERING OF PRODUCTION CASCADES

A system phylogenetic approach

Keywords: dynamic system approach in software engineering, procedure orchestration with functions and metafunctions, evolving use cases, ontogenetic life cycles, phylogentic production cascades, metamodelling,

Abstract: Experience has led me to a holistic vision on the system-in-processes involving (aggregating) persons, objects, activities and knowledge. That is why I've met with interest and attempted to extend the new orientations in software engineering, when I've elaborated conceptual architectures for systems facilitating the distributed instruction through the Internet. I have grounded the methodology for (re)producing procedures instrumented with computers on the idea of using their models as orchestration instruments- introducing "functions", explored with the GEFO prototype. The "use cases" – have hence become an assistance tool for the utilization of the constructed systems, evolving along with them, both as their model and as one of their parts. The model-reality circular relationship also has show up in the evolution of the TELOS system designed in the LORNET project, justifying a software engineering approach based on metafunctions. Observing the recursive situation, I have investigated the transition from the separate management of "ontogenetical" production chains to the unitary management of "phylogenetical" production cascades.

1 THE PHYSIOLOGY OF SOFTWARE EQUIPPED SYSTEMS,

My career as system engineer began with my involvement in electronics and telecommunication projects, deepened in programming and information management projects and opened to new dimensions on the occasion of the instruction engineering projects. These experiences, along with the appropriate study of the system theory (Zadeh, 1962; Bertalanffy,1975; Le Moigne, 1990; Salamon, 1993) have led me to a holistic vision regarding the functioning, modelling, instrumentation and management of systems involving persons, objects, activities and knowledge, resumed here in a few principles:

P1. The physical and conceptual entities, tied by relationships, create systemic units and determine their behaviour (physiology). Conversely, the physical and cognitive processes sediment structures (entities and relations). A complete systemic vision must reveal the existence-becoming (structure-process) duality, using "structures in process" models.

P2 The individual cognitive metabolism is "situated" in that of the community (Clancey, 1992). We can extend the phenomenological vision on the unity of the (observed object / observing subject) pair to a systemic meaning of "knowledge": including, in a single whole, the represented subject, the representing symbol and the human pair communicating on the subject, through the representation.

P3. The explicative relationship between an "expert" and a "novice" is essentially a bipolar phenomenon (see also Fisher, 1978), based on the collaboration between two decision centres. It exploits the physical interaction through objects and the innate or cultivated human communication capacities (language etc.) Evolved assistance systems combine instruction and support, using novice-computer pairs (the expert is represented by a simulator) or the "triple command" work: the expert intervenes when the computer can't face to the assistance task any longer (Rosca & Morin, 1996).

P4 As co-action and communication partner, the human assistant has intrinsic qualities - difficult to mechanize. The posture of information "emitter" is multipliable but that of the learner "listener" or interactive partner- much harder. The assistants' "artificialisation" is problematic - practically and ethically. We should not be interested by letting combinatorial hazard establish explicative sequences... The "reproductive" realizations, seeking "efficiency" - can lower the quality of education.

P5 Before cooperating or communicating, the partners must equip, find and agree. Afterwards, they must update the model that sustains their coordination. The computer network can provide contact, contract and management services, forming a "synaptic" (matching) infrastructure for the collective brain's physiology.

I tried to convince my colleagues from the SAFARI project and ITS'96 congress that a pragmatic distribution of intelligence in man-machine systems, it's the best approach, but at that time the idea wasn't too popular. Even today, the management of the computer assisted systems evolution is not treated by a global engineering- in which software engineering should be only a component.

But such a systemic approach lead us to a fearsome complexity (see Morin E, 1990) and to the lack of an operational inter(trans)disciplinary epistemology (methodology). I have tried to signal, in my PhD thesis (Rosca, 1999), the difficult problems posed by the modelling of instructional systems. We are obliged to observe unitary phenomena through the multitude of prisms of a wide range of domains, each having its own primitives, epistemology, language, paradigms, experience, rituals, models and priorities. A rigorous resolution is problematic. 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 optimisation of the effort/result ratio.

The principles resumed above and the modelling problems that I have encountered have led me to biological paradigms and metaphors, under the influence of inciting interdisciplinary works (Maturana, 1998; Varella, 1999). I have begun to replace terms as "structure" and "behaviour" with "morphology" and "physiology", observing the cognitive systems. To follow the "lifecycle" of new resources, obtained through the aggregation of existent ones (Rosca & Paquette, 2002). To consider the "adaptation" processes in the context of objects and persons global "evolution". To investigate the link between the "ontogenesis" (formation of a system) and the "phylogenesis" of system (re)production cascades.

That is why I met the new orientations in software engineering with interest and tried to explore and use them in certain large projects, such as LORNET- that seeks the design of an infrastructure for sustaining the technical and semantic inter-operation between educational service sources and resource repositories, accessible through the Internet. To this purpose, I have built the architecture of a "learning operating system" TELOS, attempting an extension of the global - evolutionary approach in the engineering of software-equipped systems (Rosca & others, 2006). I dedicate the four paragraphs of this paper to explain my proposals: 1 The unification of person, object, activity, knowledge and competence management. 2 The modelling of the aimed instructive-productive physiologies and the use of their models as instruments in their reproduction. 3 The blended management of instruments' production and use processes- with the help of metamodels. 4 The binding of ontogenetical chains in phylogenetic cascades- by longitudinal system engineering. The exemplification of these ideas with the exploratory GEFO prototype (Rosca & Rosca, 2006) will be the subject of a workshop dedicated to metamodelling.

I have approached the TELOS project on the basis of the following strategies, inserted in the vision document (Rosca & Paquette, 2003): "1 [] solutions not only in terms of system's tools, but also in terms of processes [] to use them effectively in real contexts. [] the driving force will be the careful definition of use cases [] 2 Reusing and integrating existing and new tools [] 3 Concentrate on essential developments - reduce risks [] 4 Flexible and pragmatic approach. [] 5 [] a view where humans and computer agents are interacting parts of a unique system. [] 6 Build technology-independent models. [] part of the system, maybe its fundamental layer. 7 [] tools to model the complex processes involved in a distributed learning system: before the process (to design), during it (to support users and observe their behaviour) and after it (to understand, evaluate and react). 8 [] The architecture will promote "horizontal" (structural) modularity (between components) and "vertical" (evolutional) segmentation (layers for various stages: specification, architectural model, etc) . [] 9 [] Even at the "kernel" level, the general functions could be covered by one or more alternative modules, accessible on a distributed "services bus" [] 10 [] a coordination and synchronization set of functionalities for the interaction of persons and computerized resources that together constitute a learning or knowledge management system."

The conceptual architecture resulting from the application of these principals (Rosca, 2006) will allow to the TELOS system to facilitate technical and semantic inter-operation between its (distributed) users and modules and those of external systems. At the technical layer, it uses a microkernel design pattern: a "communication bus" coordinated by a "kernel" that deploys and connects the communication interfaces (agents). All the core modules must be "pluggable" to this bus, using a TELOS inter-communication protocol (working above the network layer protocols). The kernel will also contain a general resource controller (delegating the control of any resource to the appropriate handler) and an import-export module- opening TELOS for communication with systems based on other norms.

A micro-service cascade leading to a coherent result for the users forms an "elementary operation"- the first level of granularity considered in the system's physiology. The linking of operations (composition of a generic "class", progressive particularization of derived instances, publishing, retrieval, run-time adaptation and use, annotation and feed-back)- by the resource that evolves throughout the chain- forms a "lifecycle". This second level of procedural granularity can be modelled and managed with "functions". A resource produced by a chain can be used (as raw material, authoring tool or inspiring source) in another, thus creating "phylogenetical" cascades- the third level of granularity. The process of structural or procedural aggregation can continue recursively, leading to more and more complex resources and processes.

The systemic approach focuses the research on the problem of whole-part relationships and of the process of composing-decomposing structures and procedures. The LORNET project pays maximum attention to the aggregation of new resources (starting from the existing ones). The management of "primary" resources (persons, documents, tools) – based on metadata characterization records- is extended by the management of "secondary" resources (obtained from the primary ones by "wrapping" them with intermediation interfaces). This preparation also eases the production of various types of "aggregates": "collections" (set of resources, equipped with element management tools); "fusions" (systems having their global behaviour determined by the components' interconnection), "operations" (aggregating an action, its executor, support actors, support or target resources), "functions" (procedural aggregations, the required resources being connected to the modelled /orchestrated operations (Paquette & Rosca, 2003).

I have segmented the primary TELOS system production cascade in: 1. The construction of an authoring system (LKMS - learning and knowledge management system) with the instrument toolkit available in the TELOS core and its particularization for various beneficiaries 2 Its use in the construction of application scenarios (LKMA - learning and knowledge management application) 3 The instructional use of these LKMA, producing living-knowledge modification (learning), and eventually some user objects (LKMP- learning and knowledge management products) 4 Analyse and feed back operations (changing knowledge reference systems and competence profiles, user model and portfolio management, system reorganization etc).

Therefore, the system blends, in a coherent whole, the management of the knowledge reference system, of the evolving participants, of the involved documents and tools and of the activities that modify objects and knowledge (Paquette & Rosca, 2004). It supports these activities in various modes: from the emergent cases (the users search human and material support resources and chain operations freely) to the orchestrated ones (they act through rigid or adaptable scenarios).

Towards this aim, I have "indexed" all the elements: potential participants P (persons, groups, categories, agents), documentary resources D, generic actors A and instruments I, specified in the activity scenarios- relative to the same "knowledge domains" K, used as reference systems. The evolution of the subjects' understanding is observed and supported using "*competences*" (qualitative and quantitative descriptions of someone's position relative to knowledge) (Rosca, 2005).

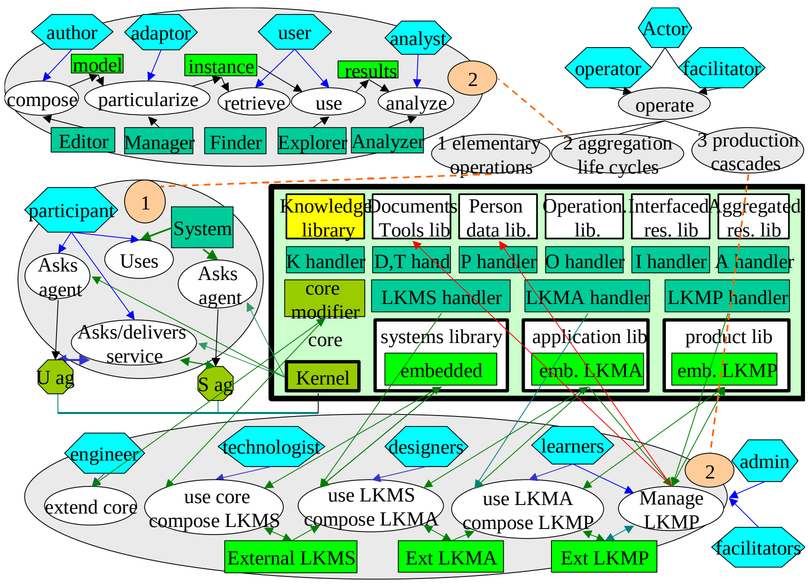

Figure 1:The TELOS system physiology

2 … IS MANAGEABLE USING ITS MODELS,

The interest for using process graphs (workflow, flowchart, petri-nets etc) in the description and orchestration of procedural chains is well known. For instance, Lehmann & others (2002) use them to follow and manage the global application lifecycle, at a level of granularity appropriate for observing and optimising the ratio between the costs implied by the progressive versus anti-regressive efforts- mixed in the project's evolution.

A procedure's model uses representations for the components reflected in its "mirror": actors (represented with hexagons in this paper's figures) - which can designate generic participant categories or specified persons, instruments (here, rectangles) - which can designate concrete or generic resources, operations (ovals) - designating particular or generic processes, realized or to be realized. Some procedures are dedicated to a single actor, their purpose being to order actions and access the necessary resources; others can negotiate the "flow-control" between the elements that intervene concurrently in an operation; others can manage complex scores for "man-machine orchestras"- combining connection, ordering and coordination.

To assist, present or teach a procedure - the simple model of the operation chain can be useful, the assistance not having been planned in the model. The pedagogical management of a procedure is a flexible solution, but it can create organization difficulties (finding support etc). The management of pedagogical procedures- supposes the explicit representation in the procedure model of the support actors and instruments, reducing the freedom of choosing them, but assuring the conformance to the didactical intentions of the model's author. Leaving certain concretisation choices, this one can specify the knowledge required by the operation, the competence profiles supposed for the actors, the "competence leap" covered by support documents.

I have continued the long standing study of procedure modelling by analysing the problem of transforming MOT (an editor conceived for the management of procedural knowledge, pedagogical scenarios and resource diffusion plans (Paquette & Rosca, 2003)- towards a collaborative editor for cooperative procedures' orchestration scenarios. Then, working on the Explora2, SavoirNet, and TELOS architectures I compared our pedagogical workflow modelling formulas (learnflow) with similar developments coming from CSCW (or CSCL)- analysing the inter-operability problem sustained by norms like EML or IMS-LD. In order to deepen the research about the physiology of the ensemble formed by the procedural reality and its orchestrating model, I have piloted the prototypal development of a "function manager" (Rosca & Rosca, 2006).

The representation of the meta-process of reproducing procedures by modelling them and using these models to create more or less similar phenomena (procedure "phylogenesis")- is the key of GEFO prototype's use in the illustration of the TELOS system (Rosca &. Paquette,2004) My approach (represented in figure 2) emphasizes on observing and managing cycles such as: 1. **Modelling**. A primary procedural phenomenon P

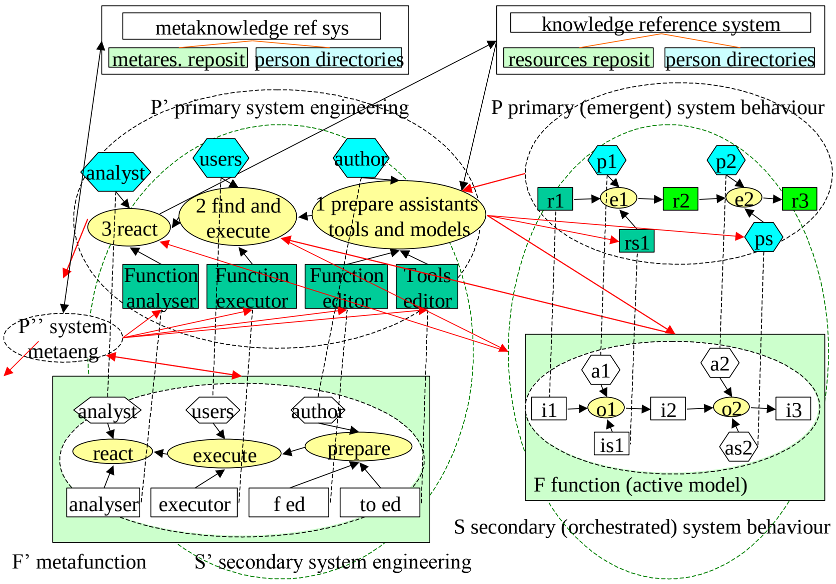

Figure 2 Model based engineering of production cascades

(consisting of a chain of actions e, executed over some resources r, by persons p assisted by support persons and resources ps/rs) is observed (imagined) by designers, who edit its model F (that I have called "function"). They may also prepare some appropriate resources (tool engineering) and assistants (support person training) 2 **Reproduction**. The phenomenon P, supported by the prepared resources and assistants, is reproduced in a number of secondary phenomena S, through "executions" of its functional model F- which can mean: 2a The model is used as an explicative guide, inspiring the actions' sequencing. 2b The participants declare and produce exploration data, which the model memorizes or uses for reactions (verifications, support etc). 2c The model is used as an interface, for launching and controlling some resources, facilitating their manipulation and their procedural aggregation. 2d In the case of cooperative use, the model mediates the participants' communication and coordination (floor-control, signalling, etc) 2e If it is semantically indexed, the model can provide retrieval, selection and alerting services, sustaining the run-time concretisation of the components (matching role) 3 **Meta-modelling**. Observing (imagining) the primary process P' of the model's preparation (or the P-1-2-S chain of procedure reproduction), process engineers can edit meta-models F' in order to explain or support the active modelling process 4 **Meta-reproduction**. Using meta-functions F' (in the a,b,c,d,e sense), the primary process P' of a model edition can be reproduced (with variations) in secondary editing processes S', generating functions F usable in P-P'-S chains. 5 **Meta- engineering**. The layered physiology may be continued further, with P" chains reflecting and orchestrating the lifecycle P' of a function modelling (orchestrating) a process P.

Therefore, when the "orchestrated working mode" is adopted (through "functions"- rigid or adaptable scenarios), the (instructional) phenomenon's "model" is used as a coordination instrument by its participants. The reality and the model form a global system, whose physiology deserves being understood, modelled and optimised.

When users prefer the freedom to freely order the operation sequence (resource conception, adaptation, retrieval, use etc), the TELOS system offers them instruments for finding the appropriate resources (support tools and persons, previously "published" in the resources repositories): semantically pertinent, administratively available, and technically operable.

Also interesting is the a posteriori modelling of the emergently established chains (after a natural or demonstrative execution, observed directly or through captors placed in the secondary resources' wrappers), enabling us to understand processes that merit to be conserved, reproduced or ameliorated.

The models can also be imagined before the procedures realization, for the purpose of orientating the production of resources usable in their execution. In the case of the system TELOS, the attempt to adopt/adapt the RUP method (an engineering steered by "use-cases") has led us to a vicious circle, because the project was about building… procedure-modelling instruments… That pushed me to a "recourse to the method" approach, using the procedure edition and execution tools elaborated by us in the project's n-th phase in the management of the system use-cases for the phase n+1. This "spiral" exercise allowed me to observe that a "use case" type procedural model used in the P' resource engineering phase can become a support tool for their use phase P- once delivered to the beneficiaries. The continuous perfecting of the product X, during the project's evolution, could be blended with the improvement of its use model P(X). The [X, P(X)] pair forms an evolving system, requiring a global engineering. The P(X) use hence attain a dual character: they are instruments for obtaining the "deliverable" of the project, but in the same time… portion of it.

3 …IN AN ENGINEERING PILOTED BY METAMODELS,

When the process P' of equipping a group of aimed projects Px with functions Fx, is, at its turn, modeled with a "meta use case" F' (more or less active in the S' engineering process seconded by it)- we can call these models "metafunctions". But even if, in the P' process of preparing resources that are going to equip a system (tool construction, document writing, assistant preparation), passive or active models of their use (functional aggregates), are not built- we are facing a "engineering lifecycle" P', that can emerge or can be managed with the help of functional models S'. The services of functions (reflection, assistance, tracing, manipulation, coordination, matching etc) can therefore be exploited in software engineering.

In order to take advantage of advanced semantic support mechanisms (like assisting the selection of the elements that maximize the competency equations (Rosca, 2005), the notions relative to the physiology of resources and models production must be organized in software engineering ontologies, used as metareference systems. This way, we could accomplish the connection of the software industry to/through "semantic web" (see Oberl, 2005) not only at the level of application services, but also for allowing the interoperation between project management layers.

The tight link between the equipped and the equipping processes and the need for a continuous modification of the processes and structures of both layers, require the passage from "tools re-engineering" to a "continuous engineering"- interweaved longitudinally with the evolving physiology of the tools' use processes.

The coupled use of functions and metafunctions is interesting for the engineering of the stratified evolving chains P-P' (see figure 2 and 4). The suggestions of Garcia-Cabrera & others (2002) go in the same direction (the observation of the evolution for the conceptual, presentation and navigation sub-systems - in parallel with their metamodels).

Additional steps must though be taken towards spreading a radical systemic vision. On the occasion of a web design course presented (in 1999) at the University of Montreal, I noticed the students' surprise when I showed them the distribution of the system to optimize on three structural-procedural in inter-related layers: that of the application's exploration (the use of a virtual store by persons having certain objectives, mandates and particularities), that of the computer artifact to be built (architecture and behavior) and that of the development process (the competences, interests, instruments and organization of the design team). The problem posed to the "project manager" proved to be complex and difficult to model.

These complications probably explain why some producer/promoters of evolved software management tools- for financial, educative, medical applications- use relatively rudimentary methods and instruments, in the process of their work… The missing of such an auto-calibration opportunity could indicate the inadequacy of the rigid and heavy engineering methods- in very labile situations such those lived by the software products (Andrade, 2002). Even when it reaches the utilization phase, a system keeps its character of in-work prototype. That is why the proposition (Larman, 2002) to segment the modeling processes short phases alternating with the models' application, and the appropriate corrections- must be completed with methods (instruments) for the longitudinal observation of the parallel evolution of the model and of the system built on its basis.

The need for an engineering method coherently distributed in time is acutely felt in research projects (like LORNET)- that require refined (specialized) RUP-type methods. The researchers, architects and developers' interests and languages do not coincide- unfortunately- thus requiring a support for project advancement negotiation. Programmers need well-defined and stable specifications (or at leased with a controllable evolution). But, if a researcher can precisely describe the desired behavior, his mission is finished. He is interested to continuously observe and improve the physiology (and, consequently, the morphology that makes it possible). I am in the position to signal the painful posture of an architect-coordinator-mediator in a project that continuously oscillates between "prototypes" and "products".

In figure 3, for instance, the fact that the system TELOS's evolution cannot be separated from that of its use's evolution- can be observed. Any finding from the technical or behavioral testing phases, or any modification request, will re-launch the production loop in a new spiral, posing delicate problems such as: version management, consistency securing, etc.

The use of metafunctions correlated with the use of the functions of which they model (manage) the lifecycle- can offer support for the definition of a *system evolution typology* (that I have called "life mode". For instance, the function definition process, starting with the base (class) model (that includes abstract actors, operations and instruments) can be continued by concretizing the elements (participants and resources chosen from the accessible

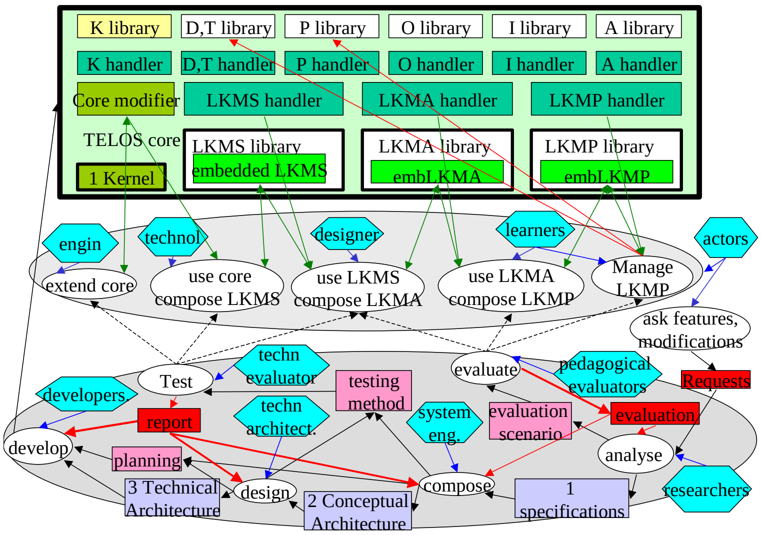

Figure 3 Layered process of TELOS use and TELOS fabrication

repertories)-in many ways. Concretization can mean specifying the final components or just restricting the selection criteria (administrative, technical, and semantic), eventually using competence optimization services (if the elements are indexed on a knowledge reference system) (Rosca, 2005). An arborescence of increasingly particular "derivated" models can be obtained this way, leading eventually to "contracts" (allowing only the liberty of changing the potential users) or to a "scheduling model" (fixing all participants). The "life mode" characterizes the liberty space of this derivation process or its effective growth. We can, for instance, establish (observe, coordinate) modes such as: the editor fixes only the topology of the implied operations, leaving the right to fix resources to the administrator, and to find support partners- to the executor. Or: the editor fixes the support resources; the administrator allocates participants etc.

To sum up, the organization of the TELOS's system fabrication in the project LORNET, posing problems and requiring instruments similar to those we wanted to resolve/construct- has obliged me to explore the relationship between the software engineering and the engineering of software-equipped systems.

4 …AND TRACKING THE PRODUCTION CASCADES.

The left zone of Figure 2 suggests that the (equipping process)-(equipped process) relationships (assistant process- assisted process, process-metaprocess) can continue "upstream", eventually leading to meta-meta processes (models) for the management (equipment) of software engineering processes that allow the construction of the TELOS system core.

In the figures 1,3 we can observe that the generative scale also manifests "downstream" in the processes (eventually supported by functional methods) of LKMS construction (by technicians) using the core, then, of LKMA construction (by the course conceivers) using the LKMS and finally of LKMP construction (by the assisted students) using the LKMAs. The distinction of these phases in function of the involved actors is pragmatically justified. But the situation is obviously recursive. We can obtain chains of any length by coupling repeatedly the (orchestrated) production of systems that prepare the (orchestrated) production of systems that …

That is how we could respond to problems such as that signaled in an older text (Rosca &Morin 1996) dedicated to the foundations of a global engineering for instructional systems: "With what strategies and tools should we equip the technologists A and methodologists B, that wish to provide composition and management methods and instruments to a public of authors C and managers D, that organize instructional systems, in which a group of assistants E can instruct a group of learners F so that they obtain an amelioration G of their competences in the knowledge domain H, necessary to reach the performances I in the contexts J- the entire chain being optimized according to criteria K, verifiable by the methods L".

The engineering of such "lifecycles" chains supposes a "genetic" 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 "children" (material or cognitive) systems. This kind of problem forces us to investigate the passing from the separate management of "ontogenetic" production chains, to the unitary management of "phylogenetic" production cascades. We should be able to coherently manage the way a component "flows" through a genetic cascade, transforming itself. (For instance, a module produced by the system core engineers can be adapted and incorporated in an LKMS, then placed into an LKMA - from where it can finally get into an LKMP).

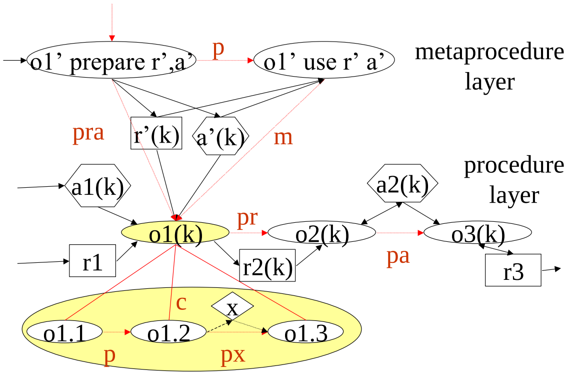

Figure 4 Relating operations to produce cascades

At the base of these chains' modeling stands the organization of the space of possible relationships between two procedures. As we can see in figure 4, the temporal concatenation between o1 and o2 (the precedence relationship) can be simple – *p*, mediated by the transmission of a parameter- *px*, realized through the use in o2 of a resource produced in o1 – *pr*, or through the implication of the some actor in both procedures- *pa*. The chaining can continue indefinitely.

The evolutionary approach makes us observe that a component participating in a procedure (executor/learner, support actor, documentary tool or resource) can at its turn come from another procedure, be modified in the current procedure and be used in others, thus having its own evolution thread. The use of "states" can help us model the existential continuity of such a plastic entity. The physical modifications are accompanied by changes of the competences (in the case of actors) or of the knowledge implemented in the support objects, fact emphasized by the elements dependency of the on K (semantic reference) layer.

We also need c relationships, in order to decompose an operation in sub-phases (carefully distributing throughout them the "roles" of the component entities).

A third organization dimension for the "operational arborescence" involves the relationship m between a procedure o1 (in which an actor a1 must use a resource r1 to produce a resource r2) and the corresponding "meta-operation". This one signal the use of the support resource r' and the support actor a' prepared in the preceding phase- of the metaprocedural chain (linked to o1 by a *pra* relationship).

I intend to apply these ideas, constructing a development environment that will combine work cooperation with the instruction of the trainees involved in the project, facilitating the resuming, at any moment, of a suspended development process.

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