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Enabling Sustainable Management through Kalman Filtering in glossaLAB: a case study on Cyber-Subsidiarity

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Abstract. The article describes the approach of applying the cybersubsidiarity model, based on Stafford Beer's Viable System Model, to the management of a project oriented to the setting up of a sustainable platform for interdisciplinary knowledge co-creation. The application to this project is shown as a case study for the institution of sustainable organizations based on a subsidiary information management architecture which intends to serve as an innovative alternative to the information management driven by big-data technologies. According to this architecture, the information flow is significantly alleviated and substituted by synthetic in-formation which percolates 'meaningfully' across organizational levels.

Keywords: sustainable management, information management, Kalman filter, cyber-subsidiarity, subsidiarity, viable system model.

1 Introduction: lights and shadows of information prosperity

> "*Without any question, our current age is appropriately described as the "information age". Every aspect of human life is rapidly being invaded and restructured by information technology*" (Terrence Deacon [1])

Indeed, the pillar of the current web of information technologies is the pervasive presence of a variety of things connected to and interacting with the Internet and with each other, sensing and collecting data, supported by a technological (re)evolution in many fields from nanotechnology to organizational techniques. This dense web virtually turns information into actions, creating new capabilities and extraordinary opportunities [2]. Thus, the key issue of our time is how to master information as to cause proper actions and knowledge in the benefit of individuals and social life.

However, what is the real control we have about this ubiquitous connectedness? How much pervasive it is? Is it accessible for everybody in the same way? What are the percolation mechanisms that make the information effective across different levels? These and other open questions are a matter of high concern for our societies[1]. They are linked to the eventual (dis-)empowerment of the people and to the opportunity to develop sustainability with respect to our natural and social environments.

The mastering of information is actually twofold: on the one hand, we must better understand information in its multifarious aspects and context of application –as much as in the 19th century energy was understood-; on the other, coping with the enormous flow of information, overcoming the information overloads in the benefit of solving problems at different levels, from individuals to organizations.

To both sides of the problem, the authors have devoted extensive work, on one side, developing an interdisciplinary approach aimed at building up a transdisciplinary understanding of information across systems of different nature [4–8], on the other, underpinning a model of information management for sustainability [9–14]. The current work is dedicated to applying the second model to the sustainability of the first endeavor.

As regards the mastering of *information management for sustainability* and adopting a systemic perspective, information constitutes in itself propagation and steering of order, and the increase in the order of the system (be it biotic, anthropic or technical)[2], which at the same time is associated to the capacity and resilience of the system. Therefore, the mastering of information is directly linked to the sustainability of systems. However, as we argued above, the alleged proliferation of information in our age is not always linked to the empowerment of the people and organizations, which often feel overwhelmed (see note 1). Indeed, the endeavors on big-data technology respond to the need of coping with the massive availability of data. They create meaning (thus order) from the bulk of data for specific purposes and organizations, which are often private[3]. But the required investments prevent from generalizing its benefits. Being consistent with the systemic approach, the bulk of available data is only informative for whomever have access to adequate big-data technologies and information means, and certainly these are only affordable for a few people and organizations. If the information society is to be sustainable and democratic, it needs a different deal.

This situation contrasts with the management of information in biotic systems, where the information amount is rather impressive (even compared with the volumes of the Internet)[9]. If the organism is healthy there is no information overload whatsoever. Here the information management is structured in such a way that it instantiates the *subsidiarity principle*, namely, that issues are dealt with at the most immediate level that is consistent with their resolution [9,10,14]. Following this principle, a subsidiary

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[1] According to the European Data Protection Supervisor: "Policy makers, technology developers, business developers and all of us must seriously consider if and how we want to influence the development of technology and its application [… and how we should protect] human dignity" [3].

[2] Here "meaning" is understood in a *generalised agent-based approach* for which meaning represents, in the first place, effective courses of actions for the autonomous agents in their interacting environments, and includes pre-reflexive and reflexive meaning [1,15–18].

[3] This trending approach adjusts to DIKAR model and the IMBOK framework [19].

information management architecture has been devised and applied to the project directly aimed to the aforementioned first side of the problem, the glossaLAB project [8]. According to this architecture (namely the *sybersubsidiarity model*) the information flow is significantly alleviated and substituted by synthetic information which percolates 'meaningfully' across organizational levels. Such an architecture represents an innovative alternative to the information management driven by big-data technologies, aligned with the concerns referred above (s. note2) and based on well stablished cybernetic principles and experiences [20,9–14].

2 An alternative architecture for the digital world based on network structural properties

As the authors have shown elsewhere, the free-scale network structure exhibited by the Internet routing network offers indeed a sound footing for the instantiation of the subsidiarity principle [10,11]. However, when analyzed globally, the real structure of the internet, particularly when it is geared by big-data technologies in the current situation of strong inequality, represents an important breach in the subsidiarity principle (*ibid*). Moreover, big-data technologies seem to intensify the already intolerable inequality, pushing the periphery outwards and consequently increasing cultural and social exclusion depriving human agency to address their own issues. To overcome this problem, the authors have proposed the application of the *cyber-subsidiarity model* for the organisation of human cooperation backed up by subsidiary information management following the aforementioned Viable System Model from the individuals all the way up until the global level [14]. This model, based on the decentralised multi-layered organisation of autonomous operational units, offer at a time a means to preserve autonomy, identity, environmental and social sustainability at different levels.

From the network perspective, human agency is constantly interacting with peers and other natural and artificial agents to carry out its individual and collective lives. When a group is capable to succeed in the achievement of a given communal interest in a sustainable manner, the network of human agency becomes properly a system, in which the inside and outside can be distinguished and the identity is preserved in continuous adaptation to environmental changes. At the same time, it can be regarded as an autonomous agent in itself (s.note 2), capable to interact with others and eventually becoming part of a system of higher order.

The process of instituting one of these systems can be regarded as a process of *system emergence* from the network of agents. As discussed in [1011] the structural properties of the network constitute a fundamental condition for the network to emerge as a system, but they do not suffice. The necessary and sufficient conditions to be fulfilled by the interacting agents in order to become a sustainable system will be discussed below. We will first review the general model and subsequently apply to the project we mentioned above aimed at the constitution of a system for the sustainable co-creation of interdisciplinary knowledge. Despite its particular application, the solution is presented as a general case of management for projects aimed at the creation of a sustainable system.

2.1 The Viable System Model as a paradigm of sustainability

Studding the necessary and sufficient conditions for viability of living organisms, Stafford Beer devised his well-known Viable System Model, as a paradigm of sustainability and autonomy for organizations of any kind. This model is grounded in three basic principles [21,20]:

(1) The *principle of recursion*, under which any Viable System (VS) is comprised of nested VS (at the lowest level of human organisations this viability, as shown in fig.1.a, is satisfied by the fact that the human is a VS), symbolically: $\text{VS} \stackrel{\text{def}}{=} \{\{\text{S1}\}, M \mid \text{S1} \stackrel{\text{def}}{=} \text{VS}; \text{M} \stackrel{\text{def}}{=} \{\text{S2, S3, S3*, S4, S5}\}\}$;
(2) Ashby's *principle of requisite variety*, stating that if a system is to be stable in a given environment, the number of states (variety) of its control means must be greater than or equal to the number of states of the system in such environment;
(3) The *principle of subsidiarity*, under which the variety is solved at the lowest possible (recursive) level; as a consequence, only the "residual variety" percolates to the upper organisational level (first to the system's management bodies; then, to the higher recursive level).

As discussed in [14]: "The viability of each nested system means that it is able to autonomously manage the variety of its operational context (namely, solving the problems related to its own activity and subsistence) by means of a proper information management to coordinate cooperation, facilitate meaningful communication, and enable the development of meta-reflexivity. To ensure the necessary and sufficient conditions of system's sustainability, VS must be composed of five subsystems that interact with each other, represented in Fig. 1.b:

(S1) Every VS embraces several primary activities of which different *operative units* take care. Upon the principle of recursion, each operative unit is an VS itself, and performs at least one of the fundamental functions of the organization since they are brought together to satisfy the objectives of the system in the first place.
(S2) represents the information channels and functions that allow the primary activities in S1 to communicate and cooperate with one another while facilitating S3 to supervise and coordinate activities in S1, reducing the variety that S3 needs to confront. It is responsible for the immediate programming and sharing of resources to be used by the operative units, conflict resolution and stability.
(S3) encompasses the structures and controls arranged to establish S1 rules, resources, rights and responsibilities. It guarantees internal regulation, optimize capacities and resources and looks after synergy at the operational level. It has a panoramic view of the processes developed in S1 used to carried out strategic planning, while it offers an interface for S4 / S5 to comply with and facilitate forward planning and preserve system's identity. Within S3, an audit subsystem, System 3* (S3*) is devoted to assess sporadically overall performance.
(S4) has the function of giving account of environmental changes in order to forecast forthcoming scenarios. At the same time, it takes care of how the organization has to adapt to preserve its viability in the long-term, developing forward planning.

(S5) is responsible for political decisions in the organization as a whole, balancing the demands of different parties and guiding the organization as a whole. It preserves and keeps up-to-date system's identity."

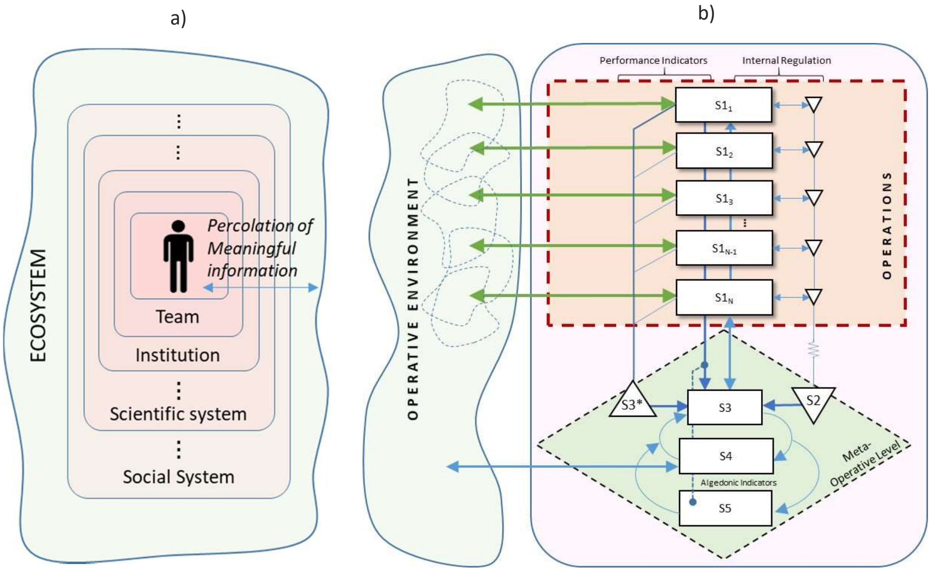

Fig. 1. Cyber-subsidiarity model: a) Vertical nesting, b) Horizontal organization.

These subsystems respond to a triple purpose in system's adaptation: "systems 1-3 deal with the "Inside and Now" of the operations of the organization; system 4 deals with "Outside and Then" as a strategic response to external, environmental and future demands; and system 5 deals with balancing the " Inside and Now " and the "Outside and Then" with political and axiological directives that maintain the identity of the organization as a sustainable entity" (*ibid*).

Along with the fundamental principles referred to above, other regulative principles, aimed at "the distribution of variety, action and information, provide sufficient directives for the design of sustainable organisations and sustainability assessment of already stablished organisations. As regards *information management*, most of the information is handled at the operational level. Here, the information input is filtered in order to focus on the activities and issues the unit is devoted to (to this end, group's ontology play an important role). Since this approach holds at any organisational level, only the information that is needed in order to handle the issues not solved at a given level will percolate to the upper level" (*ibid*).

An interesting mechanism, namely the *algedonic alerting* (derived from the Greek words *αλγος* / pain and *ηδος* / pleasure), illustrates this approach in the extreme cases of dangerous or excellent performance, i.e. the situations in which identity is more concerned. In these cases, specific signals percolate through the metasystem until S5 or through organisational levels (depending on the reach of the threat or reward) [21].

3 Cybersubsidiarity model applied to interdisciplinary knowledge co-creation: Leveraging transdisciplinarity

To see the application of the cybersubsidiarity model reviewed above, glossaLAB project has the purpose of contributing to the urgent need of setting up knowledge integration frameworks, which –as warned by a number of international and national institutions– is required to face global challenges that overwhelm disciplinary knowledge capacity [8, 22–25]. "Under this scope, glossaLAB is devised to make contributions in three main aspects of such endeavor: (i) development of a sound theoretical framework for the unification of knowledge, (ii) establishment of broadly accepted methodologies and tools to facilitate the integration of knowledge, (iii) development of assessment criteria for the qualification of interdisciplinarity undertakings" [8]. To achieve the intended objectives, glossaLAB project acts "at three different levels: at the *technical level*, glossaLAB aims at developing a platform for knowledge integration based on the elucidation of concepts, metaphors, theories and problems, including a semantically-operative recompilation of valuable scattered encyclopedic contents devoted to two entangled transdisciplinary fields: the sciences of systems and information. At the *theoretical level*, the goal is reducing the redundancy of the conceptual system (defined in terms of "intensional performance" of the contents recompiled), and the elucidation of new concepts. Finally, at the *meta-theoretical level*, the project aims at assessing the knowledge integration achieved through the co-creation process based on (a) the diversity of the disciplines involved and (b) the integration properties of the conceptual network stablished through the elucidation process" (*ibid*)[4].

3.1 glossaLAB project

As in other projects aimed at instituting sustainable systems, glossaLAB project stems from previous experiences that were capable to achieve results in a common interest, in this case, the setting up of transdisciplinary scientific frameworks; more concretely, the conceptual integration of knowledge in the *general study of systems and information*. Under this goal, glossaLAB has the objective of developing the *Encyclopaedia of Systems Science & Cybernetics Online* (ESSCO), building upon the corpus carried out under three previous projects the *International Encyclopedia of Systems and Cybernetics* [26], the *Principia Cybernetica* [27] and *glossariumBITri* [5-7]. One of the methodological grounding worth mentioning is the so called "*interdisciplinary-glossaries* developed under BITrum project as elucidation tools devoted to the clarification of concepts, methods, theories and problems in interdisciplinary settings" [8]. These interdisciplinary-glossaries are used within the project as proxies for the assessment of the related knowledge integration [7].

Applying a subsidiary integration of interdisciplinary-glossaries*,* glossaLAB is devised to host, underneath ESSCO, other focused ID-glossaries dedicated to specific re-

[4] The interested reader can find more detailed information in this publication [8].

search and innovation frameworks. The subsidiary integration "implies that those articles sufficient general as to become of general interest for the study of information and system can escalate to the level of ESSCO" [8].

With the "purpose of strengthening the capacity of systems science for the integration of knowledge", the project not only analyzes and fortifies the network of concepts, but also the network of agents through "the development of communication and impact mechanisms linked to the glossaLAB platform for knowledge co-creation" (*ibid*).

Fig. 2 provides a bird's-eye view of the project, "highlighting the flow of content from the corpus to the glossaLAB platform and from here to other dissemination pathways" (*ibid*).

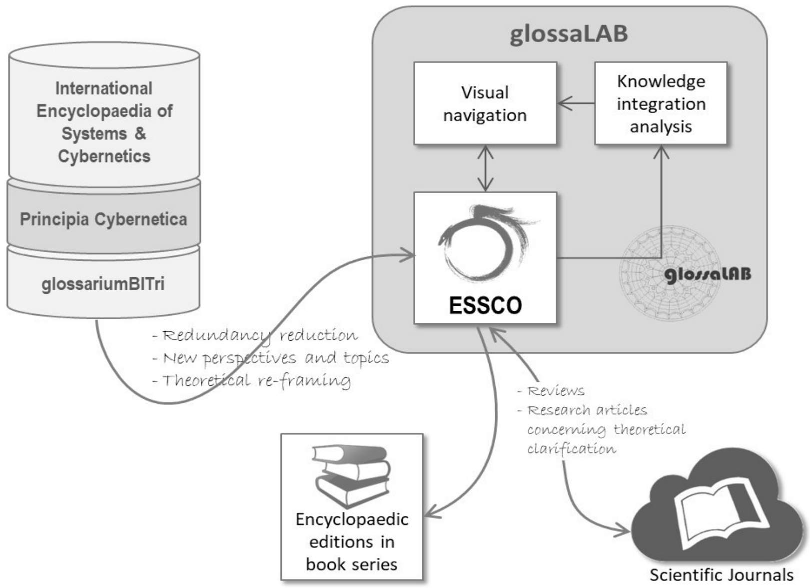

Fig. 2. Overview of glossaLAB project as regards ESSCO's development and content flow.

In order to achieve project objectives through the application of the cybersubsidiarity model reviewed above, the managerial structure of the project was articulated as shown in fig.3. As we can observe, the operative units are devoted to 4 sufficiently distinct endeavors as to operate autonomously: (i) the development of the edition and publication platform (technical development); (ii) the re-compilation and curation of contents (theoretical and editorial work); (iii) the assessment of knowledge integration (metatheoretical work), and (iv) the exploitation of results (aimed at increasing impacts as well as strengthening and widening the network of scientists).

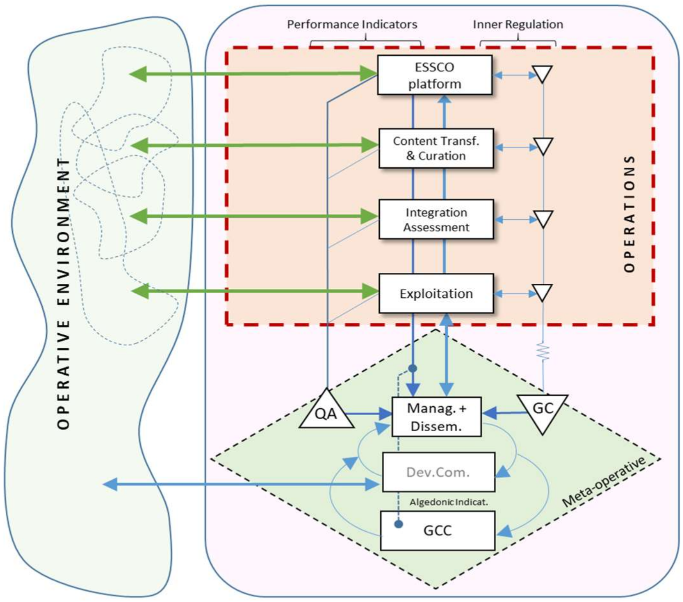

Fig. 3. Organizational structure for glossaLAB project.

3.2 Information management for sustainability and autonomy

According to the organisational principles described in section 2.1, the articulation of the VSM requires an information and communication system backing up the whole structure and fulfilling VSM's principles and regulative requirements. Figure 4 shows the coordination and management panel of the e-working environment intended to back up the adaptive management and organization of distributed and interdisciplinary work. As it can be observed in the illustration the coordination platform concentrates the most relevant information and communication tools to facilitate the organisation of work. The example corresponds to the management panel of the project as a whole, but the structure, appearance and distribution of contents is the same for the coordination of any of the operative unit mentioned above, though adding the appropriate level of details for the dealing of the issues at stake, Consistent with the principle of requisite variety.

According to the distribution of contents in the panel, the user has access, in the first place, to the information describing the state of unit/project performance and important announcements regarding coordination tasks. Coloured alerts regarding issues to address, or performance to be increased. Below these information panels, the user has access to communication, information and coordination tools (pending tasks, activity or incidence reports, resources request, meetings, forum, agenda, etc). The continuously gathered information (particularly from activity reports) supports the determination of figures and alerts of the information boards.

At each level, the information shown in the management panels corresponds to the activity framework the teams are devoted to, which is related (according to the principle of requisite variety) to the variety not solved at the lower level. The performance indicators and alerts will be based on aggregate information from the lower level regarding overall performance. Figure 5 shows the functional structure of this environment with respect to the information recorded. The determination of system's state, in terms of performance information, is not in direct relation to the last updated performance indicators, based on recorded observations, but rather on a Kalman filtering grounded on the sequence of previous values and a model of the operational system as we will see below.

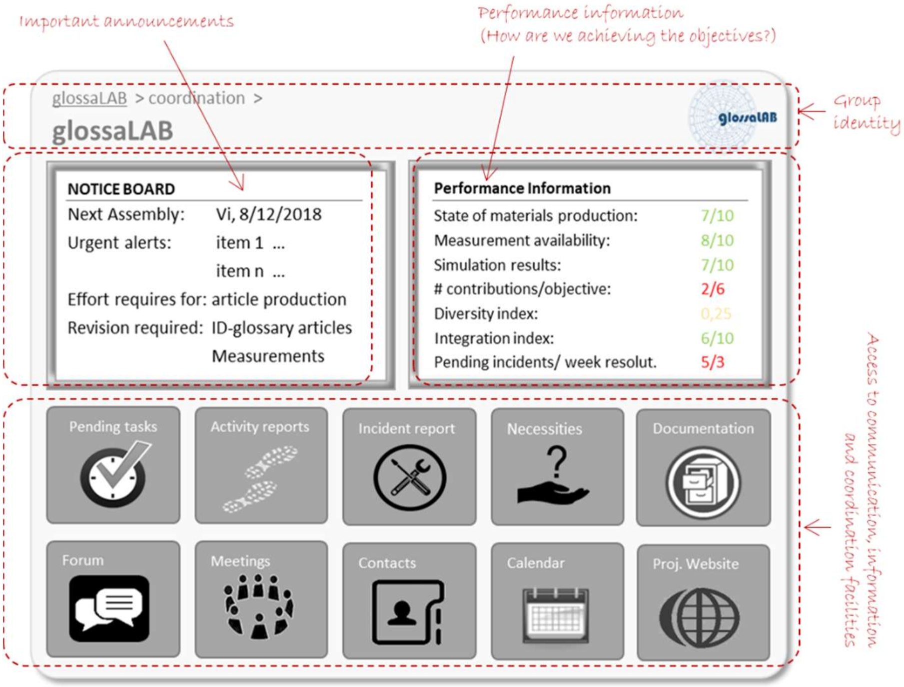

Fig. 4. Coordination and management panel as a hub of communication and information facilities for the integration of distributed cooperation.

3.3 Information filtering across organization levels

At the lowest organizational level, performance indicators –to a substantial extent– will be straightforward derived from the information provided by the people involved. Keeping this information up-to-date is therefore a fundamental commitment from participants to make the whole organization viable. A critical aspect for the regulation of the integrated activity, regarding the distribution of variety among levels, concerns the aim of filtering the residual variety upwards. Since each level has to manage the (horizontal) sum of all residual variety of the lower levels (corresponding to the set of operative units managed), the performance indicators at the higher level must be composed by the aggregate of the lower levels so that they are maximally relevant for the decision-making [21].

Hence, at a given level n, the performance indicators, z, will be the aggregated result of indicators from the lower level (n-1) automatically filtered, F{.}, applying the relevance rules fixed at managerial level, and additional indicators from own level activities:

$$\boldsymbol{z}_n = \{F\{\boldsymbol{z}_{n-1}\};\ \boldsymbol{z}_n\} \tag{1}$$

Unveiling system's performance beyond observation. Mid- and long-term management requires not only monitoring current outputs, which also depends on spurious outer variables, but particularly system's state, $\boldsymbol{x}$ (for instance, crew performance can be very reliable, though harvesting can be temporary diminished due to short terms meteorological variations that can modify the daily harvest but not crew performance or the harvesting in longer terms). Another relevant aspect to ground decision-making is uncertainty. It is not only worth knowing how system is performing and in what situation it really is, but also how uncertain this knowledge is. To this end, performance indicators and other measurements constitute the phenomenological layer of the system itself, which is non-observable as a whole. We map the system through models (for state transition, for control-input, for the relation to observables) that can be linear or non-linear, depending on the complexity and dynamics involved, and our knowledge about the system. With these models and previous observations, system's state, forthcoming dynamics and associated performance can be previewed and contrasted with the observations. According to the overall model, the current state is determined by the transition from previous state, the effect of control inputs and processual noise:

$$\boldsymbol{x}_k = \mathbf{F}_k \boldsymbol{x}_{k-1} + \mathbf{B}_k \boldsymbol{u}_k + \boldsymbol{w}_k \tag{2}$$

Where $\boldsymbol{x}_k$ represents the system's state in current iteration (k-1 is the previous one), **F** the transition model, **B** the control-input model, $\boldsymbol{u}$ the control-vector, $\boldsymbol{w}$ the process noise (assumed to be Gaussian).

At the phenomenological level the observable is determined by the state of the system and the observation noise:

$$\boldsymbol{z}_k = \mathbf{H}_k \boldsymbol{x}_k + \boldsymbol{v}_k \tag{3}$$

Where z_k represents the observable in current iteration, $\boldsymbol{H}$ the observation model, $\boldsymbol{v}$ the observation noise (which is assumed to be Gaussian).

The correction carried out to improve estimates through generalised *Kalman filtering* enables tracking more precisely system's performance and uncertainty, upon which decision-making can be more solidly grounded [28, 29].

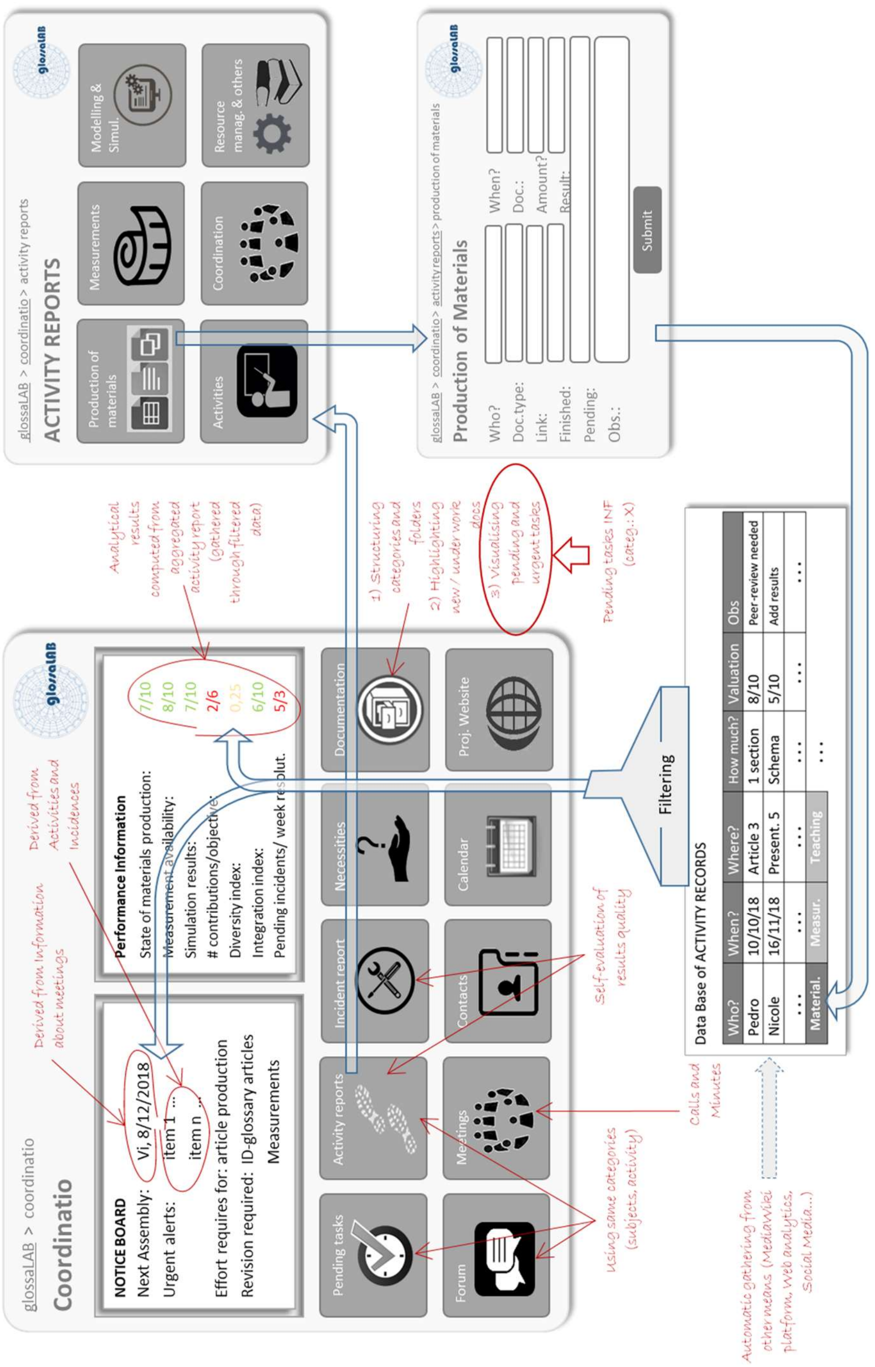

Fig. 5. e-Working environment for the adaptive coordination, monitoring and management of glossaLAB project and its operative units.

Reducing global network information flow. Turning back to the network perspective, glossaLAB informational structure, in comparison to the effective networking under big-data operation, reduces significantly the information loop and the information flow itself, critizised in section 1 and [10,11]. However, this is not because the size of the information cannot be accounted as big-data, but because the information management is completely different. Similar as what the living organism do through a natural application of the subsidiary principle, we have closed the loop of information meaning extraction and use, reducing the information flow in the overall network. Indeed, in a situation of full deployment of the organisational structure devised as to embrace the whole editorial activity of the glossaLAB platform, the information harvested may acquire a considerable size. The authors have also applied the approach to the sustainable management in the Ecuadorian cooperative artisan-fisheries, involving the potential articulation of a population of about 70.000 fishers and the acquisition of maritime sensorial data for the simulation of the fishery's ecosystems which certainly have a size similar to other big-data projects [11].

Most of the information flow actually takes places at the level of the operative units. Above this level, the data is transformed into most meaningful information for the decision-making regarding the problems tackled through the filtering and data aggregation explained above. This turns the game we saw in section 2 upside down, instead of making the information circulate through a node and data center controlling all the information management (encapsulating alien interests), the information is pushed from bellow and ends where the issues are solved or where the upward impulse decides to.

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