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Is the structure of our digital world suited for a fair intercultural life?

Intercultural life requires, first of all, a dense net of connections among people belonging to the same culture and with the components of the context in which this culture exists; secondly, a weaker but nevertheless effective network where interactions among different cultures take place. The former is a necessary condition for the very existence of cultural life and its capacity to evolve; the latter is necessary for communication and cooperation between different cultures, therefore, it creates the intercultural space where intercultural life properly exists.

The current digital networks, backed up by big-data technologies, connect people, processes, data, and things, turning information into actions, creating new capabilities and extraordinary opportunities. These digital networks allegedly enable a perfect symbiosis in the interaction between people and machines anywhere, at any time, using any device. In principle, as it is commonly stated, they seem to provide linkage between virtually everybody and everything, thus far exceeding the aforementioned basic requirements for intercultural life. Yet, what is the actual control we really have regarding this connectedness for individuals and cultures? How pervasive is this connectedness really? Is it accessible for everybody and every culture in the same way? What are the filtering mechanisms that make the signalling effective at different levels, and particularly among cultural and intercultural levels?

When we analyse the real structure of the Internet powered by big-data technologies using network theory and the available data regarding connectivity, we observe quite a different reality. In the first place, there is a substantial part of the global population completely outside the digital sphere, particularly if a minimal quality requirement concerning effective interaction is considered. In addition, we can also notice an extreme concentration of connectedness in a few nodes located in Europe and North America and a practical disconnectedness between African nodes or between South American ones. Concerning intercultural relations, it is interlanguage facilities that are considered to be among the most promising technologies to approach cultures. However, when we take a close look, we observe that most languages have practically no chance to be expressed in the digital world, while the global North has an overwhelming capacity to express itself. In these circumstances, how can other cultures and particularly the global South express their points of view in the digital word?

Still, based on the same structural properties of the digital networks, we can see that another way to manage information is possible (Díaz-Nafría 2017a, 2017b). We just need to pay attention to the natural application of the subsidiary principle in living organisms: the amount of information continuously managed through all the biological processes carried out by a single animal in its regular life is certainly impressive (quantitatively larger than the information flow in the Internet) and nevertheless we can peacefully contemplate a sunset. This is definitely not the case of the digital citizen overloaded by digital junk. We will see the application of this alternative organisation in a specific context located in the global South. The scalability of the organisational model shows that it does not need to be confined to a few small-scale cases.

1. What is the real structure of the Internet?

The pervasiveness of the digital technologies in everyday life makes it difficult to conceive the complexity of the inter-connectedness and its varied reality around the world. That everyone is connected is often taken for granted and we seldom think about the existing structural asymmetries regarding the connectivity with one another. In the face of this complexity the network perspective offers a privileged tool to unveil the structural properties of digital networks.

1.1 The Network Perspective

Abstract Networks. A *network* at its most basic level is nothing more than a set of *nodes* with *links* between them. It mathematically corresponds to a *graph*, namely an ordered pair $G = \{V, E\}$ which comprises a set V of *vertices* or nodes together with a set E of *edges* or arcs. An edge is, in turn, a two-element subset of V (i.e. it is related to two vertices, being such relation represented as a pair which is usually ordered). In addition, both nodes and links have some arbitrary attributes (usually codified by labels or colours in the representation). The most relevant feature for the node is its *degree*, k, namely the number of links that connect it with the rest of the network. For the link it is its *directivity*, typically represented by an arrow (though links may also be bidirectional and then not represented explicitly). The most relevant attribute of the network as a whole is the *degree distribution density*, $P(k)$. These few elements of networks offer sufficient flexibility to build a broad variety of models to map many complex real phenomena.[1]

Mapping reality. When our network is mapping something in reality, the nodes (or the vertices in its representation) stand for some sort of *agency*. This can be either *active*, if the agent acts by itself, or *passive*, if it is used by some active agent to perform the action. On the other hand, the links (or the edges) correspond to the *interactions* among agents. This correspondence is quite natural because whenever two real entities are somehow connected they are actually interacting with each other. In order to have a broader spectrum of applicability, agents can be understood as whatever is capable of performing some action (either by itself or through another active agent) of any type (no matter whether it is of physical, chemical, biological or social nature) (cf. Zimmermann 2012; Zimmermann and Díaz 2012; Díaz and Zimmermann 2013a, 2013b). Therefore, what we represent through the network is a set of agents who interact with each other and operate onto other agents by means of their respective interaction.

Figure 1.a illustrates a piece of network where the bidirectional interaction between two nodes, N_i and N_j is highlighted. It is represented by the information exchange between the nodes, understood through a general and processual concept of information: N_i informs N_j, which comprises first a difference in the steady state of the connection, caused by N_i, and consecutively a difference produced in the state of N_j (it is straightforward to notice the alignment with Bateson's information concept, cf. Díaz 2010). Thus we can speak of the information of N_i on N_j, i.e. $I_{i,j}$, and the information of N_j on N_i, i.e. $I_{j,i}$. The network as a whole represents synchronously all the interactions stablished among connected nodes. Figure 1.b highlights the fact that interaction happens ultimately among agents. If we distinguish between active and passive agents,

[1] There are many introductory texts to network theory, Barabasi (2002) has become a successful popular option, while Steen (2010) or Newman (2010), among others, offer more technical details.

both graphs are actually not redundant: though active agents (we can take it as such Fig. 1.b) may use passive ones (Fig. 1.a), there is not a bijective relation between the corresponding components of both networks. Passive nodes can be used by several active ones, and, at the same time, several passive nodes may be required to provide the interaction between two active agents (telecommunication networks vs communicators' networks is a good example of this; but also, more abstractly, the network of a language's words used to compose people's statements vs the network of speakers of that language).

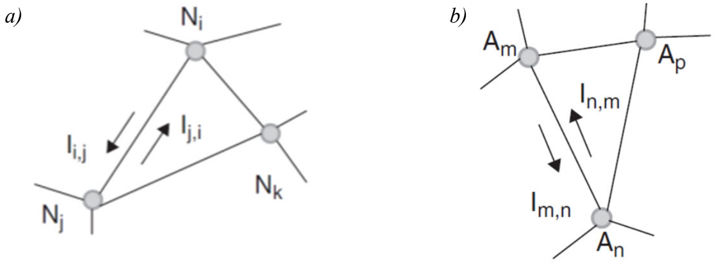

Figure 1. Network as: a) set of nodes and links; b) set of interacting agents

Passive and Active Networks: The Dynamics of Agency. The interaction represented by links can be regarded as *internal* for active agents and *external* for passive ones, since it requires the external intervention of some active agency. This is indeed a relevant difference that can be used to distinguish between the potential interaction of active agents, provided by the connectedness of the passive agents, and their actual interaction, provided by the 'elections' of the active agents (we quote election to be aware that our agents can be of different nature, thus it should not be interpreted anthropologically). Consequently, whenever we just focus on a network of passive agents (a passive network), we are in fact dealing with the potentiality or space of possibilities in which the active agents perform their actions; whereas when we attend to the real interaction of active agents, it is the actuality within the former space of possibilities that is being represented. In other words, when we map the network of active agency on the network of passive agency, we are observing the actualization of the potentialities represented by the passive network. The latter can then be seen as the space where the internal network (of active agents) is moving. This space can be understood as analogous to the phase space for the active network. Nevertheless, in the phase space (or space of possibilities of a system), each possible state corresponds to just one point, while the active network is the result of all the external agents who are actually (not just potentially) active and occupy a subgraph of the passive network.

All in all, the static graph of the network – through this relation between potentiality and actuality of interaction – has the interesting property of representing motion. Indeed, we can regard the physical space as a passive network of locations where the motion of physical entities takes place (by the way, different patterns of adjacency correspond in quantum gravity to different spatial geometries and consequently to different physical relations). A city composed by intersections and streets corresponds to the space where people move around. But the passive network, with which we concern ourselves here, could also be the one composed by telecommunication lines and nodes, which is the space where telecommunication among humans and machines takes place. These are the agents (nodes) of the active network we focus on.

Figure 2 shows a network of (passive) nodes that provide telecommunication connectivity to a set of users. Some nodes (circles) provide direct access to users, while others (squares) interact with other nodes to provide connectivity between users. At the same time, the activity of active agents is represented through the dark shadowing. If the activity changes (for instance, another user get connected) the active network will be modified. If we just focused on the users' network, the only components to consider are the users (who are active agents) and the established channels between user pairs (for the example given, the corresponding representation is a square and its diagonals). As we will see below, the links can either map potential connections or actual ones.

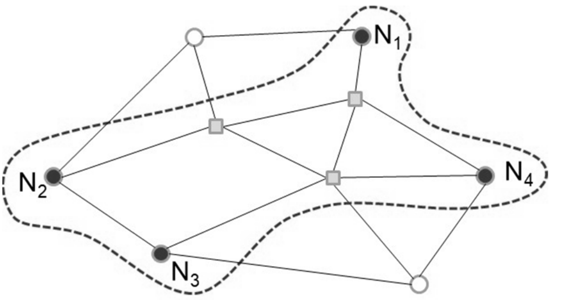

Figure 2. Circle nodes provide direct access to active agents (users). They are dark shadowed in case they are activated by active agents. Square grey nodes (passive) interact to provide connectivity between users. The area bounded by the dotted line corresponds to the passive network that is being activated by the interaction between active nodes (users).

Topological properties. The effects of the global interaction depend significantly on the statistical and topological properties of the network, which are actually entangled. This is something we can come to understand by observing the two most important network types (Barabasi 2002): *random scaled* networks are highly homogeneous and distributed, while *scale-free* networks are heterogeneous having relatively common vertices with a degree that greatly exceeds the average. In the former type, the number of randomly distributed edges to be found is $p \cdot N \cdot (N\text{-}1)/2$, where p is the probability of one node to be bounded with another and N the total number of nodes. The grade distribution density, $P(k)$, for this type follows a Poisson law with a peak in the mean value, in which vicinity most cases arrange. However, in the scale-free networks the grade distribution follows a power law, $P(k) \sim k^{-\gamma}$ (where γ is typically in the range of $2 < \gamma < 3$). Here general network connectivity is guaranteed by the hubs that concentrate a large number of links (interestingly major hubs are followed by smaller ones, which, in turn, are followed by others with an even smaller degree, and so on). Good examples for the first type are the vascular networks in animals and plants or the road networks of a country; while examples of the second kind are metabolic or semantic networks as well as air transportation networks. The second ones are considered scale-free because statistical and topographical features are reproduced when observed at different scales, i.e., they are *fractal*. They additionally provide an interesting topological feature through which networks of this kind constitute *small-worlds*, namely, that most nodes can be reached from every other node by a small number of steps and, at the same time, that they have a large *clustering coefficient* (C: number of closed triplets / number of connected triplets of vertices; that is, nodes tend to create tightly knit groups) (Barabasi 2002; Watts & Strogatz 1998). Hence, most interaction in scale-free networks happens at the level of clusters while global connectivity is ensured with other clusters.

Emergence of Systems. As regards interaction, an open system is characterised by a higher interaction rate among the constitutive parts of the system than between these parts and the surrounding environment. In other terms, we can clearly identify a boundary between the system and its outside. This is certainly fulfilled by clusters within larger networks, but it is not enough to characterise a system. However, this common property of clusters and systems offers a clue to the emergence of systems from the spontaneous interaction of active and passive agents. To speak of a system, the cluster of integrating parts needs to endure within the whole network dynamic. To that purpose the cluster needs to exhibit structural meta-stability (i.e. the coexistence of stable and adapting features) and the capacity to manage its internal system's issues, expressed in terms of the convergent information flows (which, as stated above, stand for interaction) within the cluster and with the environment.[2]

Assuming structural (meta-)stability (at least for a given observation window), we can state that whenever a cluster endures, it is because the interaction within the cluster corresponds to a proper issue management among the cluster's agents; otherwise, the cluster would fall apart – in search of other effective interaction. In terms of information flow, the stability entails that the combined information in all directed loops within the cluster is convergent under issue management (if not, the accumulation of issues would overwhelm cluster cooperation). In other terms, the complexity of the solutions to cope with issues must be able to absorb the corresponding issues' complexity. In addition, information flow outside the cluster may correspond to the complexity excess not handled within the cluster but transported outside. Its amount is expected to be of a lower degree than the information flow within the cluster as a result of cluster's capacity to manage internal issues.

Thus, clusters in (meta-)stable scale-free networks represent some effective cooperation. Subsequently, scale-free networks fulfilling the durability and adaptability requirements seem to be well suited to instantiate the *subsidiarity principle*, namely, that issues are dealt with at the most immediate level that is consistent with their resolution. The additional requirement for the network structure needed to fulfil the subsidiarity principle is that only the interaction corresponding to issues that are better managed at the upper level percolate in that direction, where levels can be regarded in terms of clustering levels (clusters, clusters of clusters, etc.). In cybernetics jargon, this feature can be put in terms of Ashby's law of *requisite variety*, while Stafford Beer's *Viable System Model* (1985) offers the sufficient and necessary structural and functional requirements to enact subsidiarity and sustainability at the same time, as one of the authors has argued elsewhere (Díaz-Nafría 2017a, 2017b,

[2] This feature is equivalent to Stuart Kauffman's *criteria for autonomous agents*, namely, the ability to perform full thermodynamic work cycles for the provision of its own needs (Kauffman & Clayton, 2006). Aligned to this characterisation of systems, Zimmermann (2015) has recently proposed the following definition: "We call system a network of interacting agents producing a space with a well-defined boundary that is open in the sense of thermodynamics." (p.2).

2014). The aforementioned scale-free self-similarity has the counterpart in the recursive levelism which is characteristic of the Viable System Model.

1.2 The real structure of the Internet

Interestingly, when the very idea of the Internet was devised by Paul Baran (1964), it was the *distributed* topology (Fig.3a) that was deemed as most appropriate to provide high resilience under eventual attacks to critical nodes.[3] That is, in fact, the quite obvious benefit for organism resilience provided by the distributed architecture of vascular networks. However, the self-organised evolution of the Internet has actually developed a decentralised topology which is instead scale-free (Fig.3b). Indeed, its small-world property is illustrated by the fact that webpages, despite of being about 5 billion, are at an average shortest distance of only 20 clicks from any other one (assuming that such a path exists), according to the estimative model provided by Barabasi (2001). At the same time, the Internet infrastructure itself – constituted by a network of routers that navigate data packages for one terminal to another – is at an average minimal distance of some 10 steps (*ibid*).

a) Distributed topology (originally intended) *b) Scale-free network structure (similar as observed)* *c) Topology assumed (fully connected)*

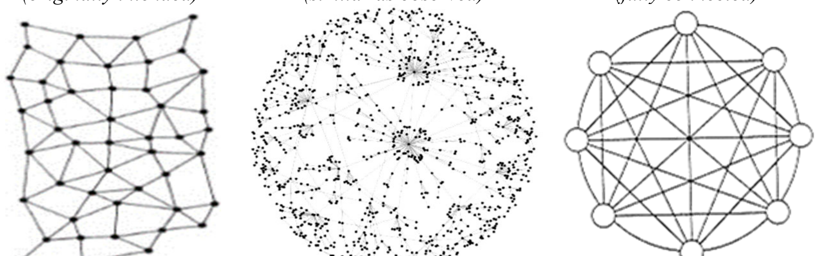

Figure 3. Internet topologies: a) as intended during the development of ARPANET (adapted from Baran 1964), b) similar as it really is, c) as broadly assumed from the user perspective.

Both the Web and the Internet infrastructure are far away from the distributed topology, but still they provide significant robustness under random node failure (though critical nodes might severely affect global performance if they fail). At the same time, the shortening of the network's average distances (with respect to the distributed topology preferred by Baran) improves global performance significantly. In any case, from the users' perspective the Internet seems

[3] The other two models, considered by Baran, were the centralised and decentralised networks.

to offer a full-connectivity among all network participants, whose topology is shown in Fig. 3c. As we will see next, the Internet as-it-really-is certainly differs from this ideal horizontality. Some of the divergences stem from its actual topology represented in Fig. 3b and Fig. 4. This latter figure represents an actual fraction of the Internet's backbone composed by links between IP addresses whose topology is, according to the self-similarity property of its proven scale-free structure, very alike to the Internet as a whole. Due to the alleged similarity between this representation (or others of the same kind) and the brain's neuronal network, it became iconic in connection to the global brain metaphor. This metaphor claims that the Internet increasingly ties its users together into a single information processing system that functions as part of the collective nervous system of the planet (Wikipedia 2018).

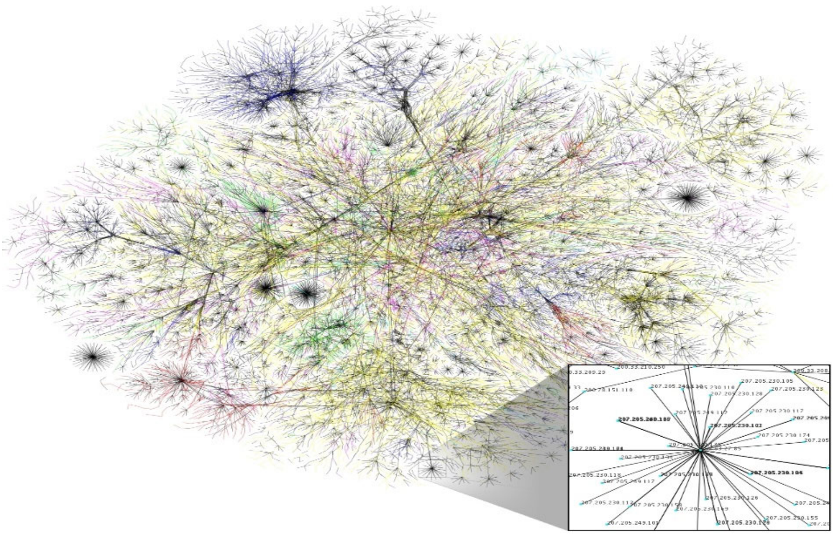

Figure 4. Small look at the backbone of the Internet, actually less than 30% of the Class C networks reachable by the data collection program in early 2005. Each line is drawn between two nodes, representing two IP addresses. The length of the lines is indicative of the delay between those two nodes. Lines are color-coded according to their corresponding RFC 1918 allocation as follows: *yellow*: net, ca, us; *magenta*: com, org; *light blue*: mil, gov, edu; *blue*: jp, cn, tw, au, de; *green*: uk, it, pl, fr; *dark blue*: br, kr, nl; *black*: unknown (Source: Wikipedia 2018, CC BY 2.5).

As we have seen, the topology represented in Fig. 3b and Fig. 4 offers at the same time the potentiality to link any Internet node to any other in a short time and the robustness of keeping overall performance in the face of failures. Being at the periphery can be easily understood as a relative drawback when trying to access any other node of the whole network. However, is this routing network all we actually need in order to provide connectivity among two (active) Internet agents? If they know each other, they can exchange their addresses, and the Internet infrastructure provides the alleged potential for that purpose, but this is not the general case for Internet agent interaction. Actual agents are often looking for contents or other agents to do things. Here big data technologies enter the scene as an essential part of the Internet infrastructure to be discussed in section 2.

1.3 The geographical concentration of the Internet.

Concerning intercultural issues, there is an essential aspect we have not dealt with in the previous analysis of Internet topology: the geographical distribution of the network structure. Figure 5 shows the main overseas cables (actually a fraction of all telecommunication pipes) operating in 2012. As we can see, this basic infrastructure, which significantly supports the passive network on which the actual digital interaction happens, is greatly concentrated in high-income countries (particularly in Europe and North America). As regards distribution, both the passive and the active networks are very alike since communication lines are set up to cope with traffic demand.

Figure 6 shows the actual digital flow within two focus areas: Latin America vs North America, and Europe vs Africa. As it can be observed, digital flow is highly concentrated in the connections to the world busiest nodes (Frankfurt, London, Amsterdam, Paris, Miami, arranged according to 2016 global traffic data as provided by Krisetya et al. 2017). In addition, we can perceive a massive concentration of global digital communication flow in Europe and North America (the five busiest nodes on the planed are represented in these two fragments), while Africa and Latin America concentrate all their exchanges with North America and Europe respectively. This represents indeed an important breach in the subsidiarity principle we discussed above (section 1.1) as a property that could eventually be at hand of the scale-free structure exhibited by the Internet architecture as we saw above disregarding the geographical distribution of nodes (section 1.2), particularly for the focused regions (Latin America and Africa).

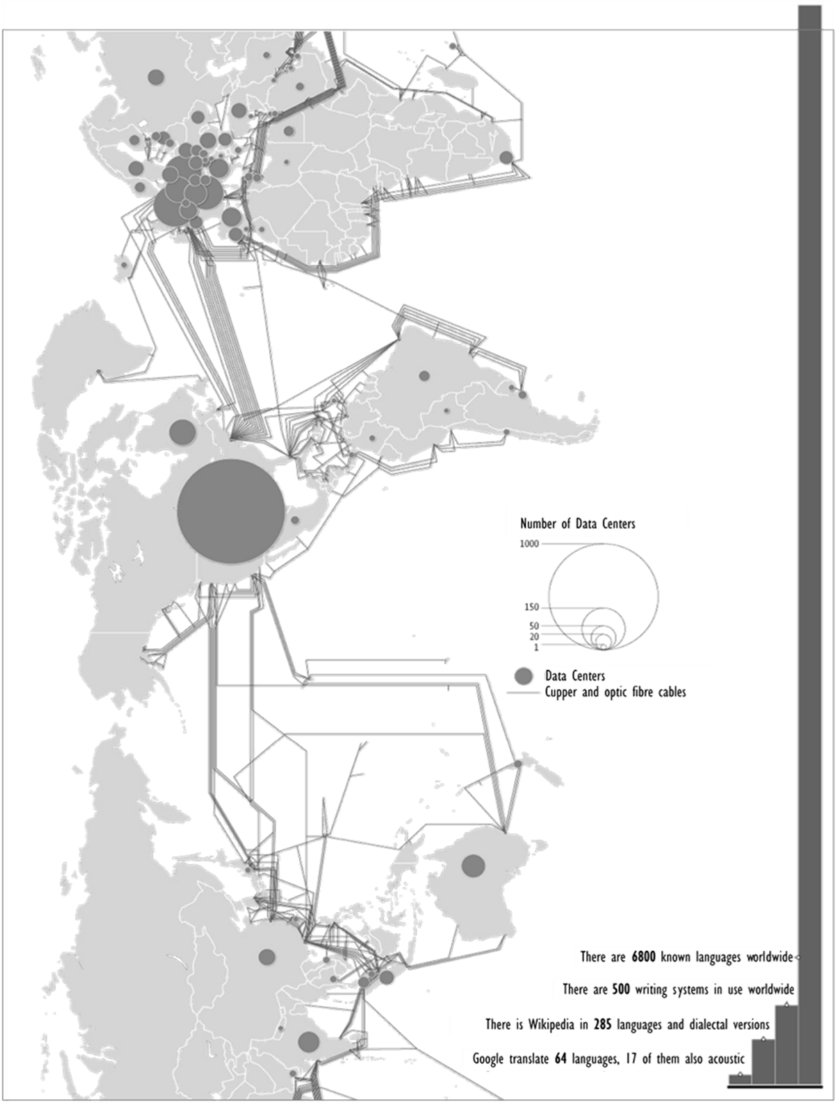

Figure 5. Information Pipes and Data Centers in 2012. How much these information services are represented in the language space is illustrated in the right bars, showing that the Internet sphere is dramatically exclusive (Source: Le Monde Diplomatique (2012), CC BY-NC 3.0).

a)Europe and Africa *b) Latin-America vs North America*

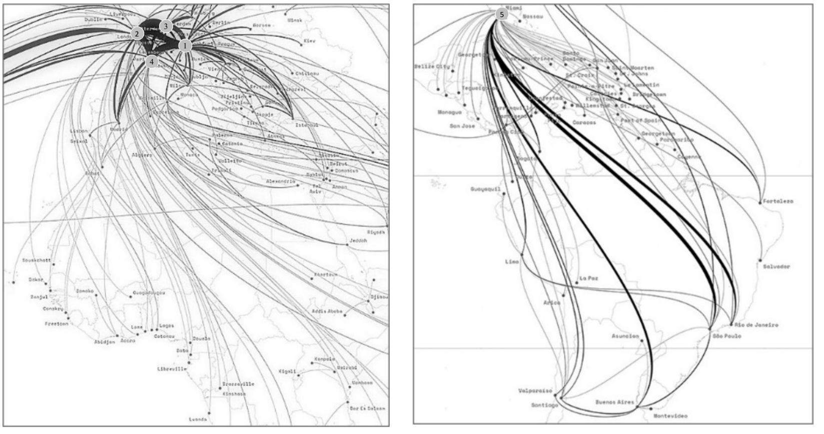

Figure 6. Digital communication flow in 2016 for two focus areas: a) Africa, whose digital communications are articulated through the European hubs (actually the world busiest nodes: Frankfurt, London, Amsterdam and Paris); b) Latin America, whose digital communications are practically spinning around a unique hub (Miami, the fifth busiest node). The 5 world busiest notes are ranked within a grey circle (Illustration elaborated from Krisetya et al. 2017).

From the perspective of the communality of problems and world-visions in both southern regions of Fig. 6, dense clusters, closed within their regional boundaries, would be expected to be found as a result of dealing with internal issues. But instead the network exhibits a star-like topology with centers overseas.[4] Moreover, just considering the perspective of the number of users and the connection distances to the huge hubs located in the northern hemisphere one could expect that regional clustering would bring about a rationality of resources.

Accounting disconnection and connection quality. As we have seen, the global North and South enjoy a significantly different density in digital

4 Comparing Fig.6.b with data from 2012 (Browning, 2012), an incipient emergence of a regional cluster can be noted: the nodes located at São Paolo, Buenos Aires and Rio have increased its relative weight and its links with other subcontinental nodes. This implies an increase in closed triplets (triangles) and the corresponding growth of the clustering coefficient for the subcontinental network. Interestingly, this change has taken place in the context of Latin American governments striving to develop an autonomous regional cooperation framework with enhanced capacities of dealing with regional issues. However, in the last two years this regional movement is significantly weakened through more neoliberal-oriented governments which are more interested in strengthening ties with the North.

connectivity capacity, but we have not yet dealt with the question of whether the network is at least in everyone's reach. The very idea of the Global Information Society assumes that everybody has the possibility to interact globally through the information infrastructure. But as Fig.7 illustrates, this is not at all the case.

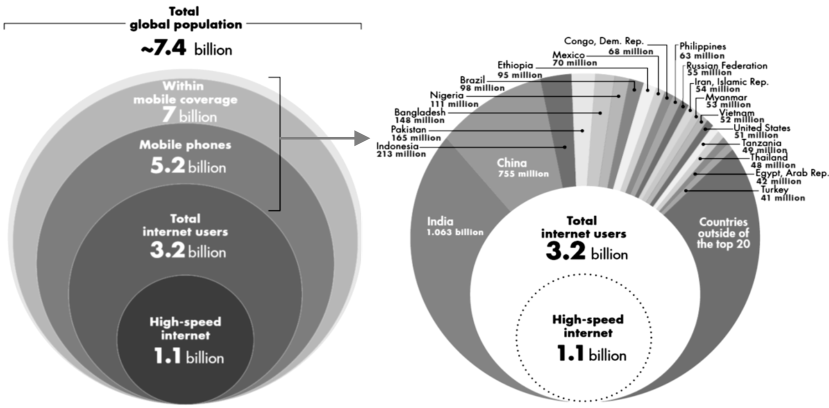

Figure 7. ICT access by population. High-speed access is restricted to just the 15% of the population, while Internet remains unavailable, inaccessible and unaffordable to a majority of the world's population (Source: World Bank 2016, License: Creative Commons Attribution CC BY 3.0 IGO).

The majority of world's population is actually still offline (non-Internet users) and only a few (about 15% in 2016) have access to high-speed services, as shown in Fig. 7 Looking at the expanded information provided at the right of Fig. 7, we can notice that the geographic distribution of the –so to speak– offline continent is mostly located in the so-called developing countries. The social and cultural role of the Internet depends ultimately on what can be done online, and this depends, in turn, on who can actually operate digitally. If many people are left out, online social life will not be as important. Indeed, a critical mass is needed to make online life relevant in the context of a given culture, since it can effectively deal with social issues.

If we consider this remarkable disconnection of social and cultural agents from the network of digital communication, these nodes, which are –so to say– waiting to be connected, are worth to be represented in the structural topology of the Internet. Figure 8 illustrates this situation locating the still disconnected nodes at the periphery. If we map this network periphery geographically we would see –as a consequence of what we saw above– that it is mostly distributed in low-income regions, for instance, large areas of Africa, or more local contexts in low-income suburbs (Maciag 2017). In case we could map the distribution of the network periphery according to cultures, we would also observe, among cultures, a very different connectivity of each culture with the rest.

Figure 8. Representation of an Internet-like network structure (derived from Fig. 3b) in which a number of nodes are not connected as they should if the Internet were developed to be inclusive.

Mere connectivity, i.e. the property of just being connected, sets a minimal requirement to be part of the network, is not enough to qualify the interaction capacity of users. In order to qualify network performance concerning the interaction among humans and digital assets, connectivity needs to be further qualified. *Bandwidth* and *connection stability* (as two prominent parameters among others that qualify digital connection) determine the amplitude and reliability of the interaction that can be carried out, and certainly these are not distributed evenly throughout the globe, as we can expect from the observation of Fig. 6 and 7.[5]

[5] The topic of global inequality in the digital world has been discussed by the authors elsewhere in more detail (Díaz-Nafría 2017b; Díaz-Nafría & Guarda 2017).

Thus far we have focused our attention to the routing network, but as we posed at the end of section 1.2 this is not all we need in order to access cherished resources and peers.

2. Is the big-data approach a proper way to leverage intercultural life?

Finding the right resources or peers is certainly one of the highest concerns in ICT development during the last decades before the unprecedented increase of human capacity to store and to communicate information. Even though each user can be a powerful information producer, the required processing and data curation has been put in hands of *data centers,* which are highly concentrated in a few countries as illustrated in Fig. 5. Here we see how most information services, as well as data and computing units available on the Internet, are not within users' devices, but allocated in *data centers*. These data centers are high-security infrastructures connected at high-speed rates with other network nodes and powered by big-data technologies. Their role in global economy, administration and resolution of complex social and scientific issues has often been highlighted.

From the structural point of view, the Internet driven by big-data technologies changes to a substantial extent the effective structure of the Internet that we have discussed above and which was illustrated in Fig. 3 and 4. In fact, whenever the interacting (active) agent requires big-data mediation, the corresponding network structure turns out to be highly centralized. On the other hand, the activity of big-data agents is significantly alien to the subsidiarity principle discussed above: the bottom level (of data acquisition) is directly connected to the highest level (of storage, curation, analysis and predictive processing) providing meaning affordances and constraints that are used in making sense of the data which is ultimately top-down oriented and used for the benefit of some decision-making process (as far as we know, we cannot devise theoretically unbiased algorithms after all) (Cavanillas et al 2016). There is no mediating upward-downward causation loop in between – closer to where the issues arise – which could contribute to the meaning extraction process. The data is collected massively, but the means to make sense of them are oriented by the need of extracting value from data, which necessarily adopts a top-down perspective. Nonetheless, according to the subsidiarity principle, this approach seems to be appropriate when dealing with global issues which by virtue of their complexity cannot be properly handled at a lower level.

Indeed, it offers a path to face many sustainability issues of the global information society, as global inequality, environmental issues, and the like, and therefore it may become a pillar for devising a sustainable information society (cf. Schwaninger 2015).

The problem arises when instead of dealing with global issues the big-data approach is used to gain a competitive advantage when no minimal equality is guaranteed. Since its ultimate usage concerns the enhancement of decision-making, it is clear that asymmetrical access to these technologies (as a consequence of the high investments required for its implementation) leads to a widening gap among competitors, countries, cultures and communities. On the other hand, neglecting intermediate subjects, who are closer to the objects under study, represents a significant loss in the understanding of problems and their concerned reality, and consequently a diminished problem-solving capacity from the local to the global scale. In this regard, the effect of digitalisation in cultural and intercultural life come to the forefront. Indeed, adopting an *evolutionary perspective* in which cultures are understood as adaptive systems providing effective adaptations within their contexts of development, this detachment from reality represents a relevant threat; and not only with respect to the survival of cultures themselves, but to the very survival of the peoples whose adaptation is mediated by their own cultures. It is the constant interaction of individuals with the environment and with other individuals that keeps cultures permanently alive and evolving. At the same time, the relative difference among cultures in the implementation of big-data technologies for their own benefit gives rise to different capacities in their adaptation to the digital context, and consequently intercultural digital unfairness.

Adopting a *cognitive perspective,* from which cultures are understood as cognitive or symbolic systems, big-data technologies breach the cultural process of *meaning formation*, namely: the creation, preservation and modification of meaning directly resides in the community and its members, assisted by all their cultural assets. Big-data technologies provide automatized mechanisms to confer meaning to data collected pervasively, and these automatized mechanisms ultimately materialise the interest of the institutions and private entities that have implemented these technologies. But, as we saw before (cf. Fig. 5), these mechanisms are extremely concentrated –even more than telecommunication lines– in the Northern countries.

Language as a mirror of an intercultural digital abyss. One of the most relevant aspects of cultural systems is undoubtedly language. Indeed, it constitutes the basic means through which the birth, elaboration, development, transmission, and accumulation of culture take place. It is also a central target of big-data technologies.[6] The bars at the right side of Fig. 6 show how big-data information services are represented in the language space through two prominent cases Wikipedia and automatic translation. As we can observe, today's Internet sphere is dramatically exclusive: only 0.25% of the languages existing worldwide are acoustically available in the well-known translator resource offered by Google, which could naively be seen as a tool for bridging cultural gaps.

Figures 9 and 10 offer an interesting comparison between offline and online linguistic channels: book translations vs Wikipedia editions using a network perspective carried out by Ronen et al (2014). In both cases the languages are represented as nodes whose size is proportional to the number of native and non-native speakers. That makes Chinese (ZHO) with 1.57 K million speakers and English (ENG) the largest nodes, followed by Hindu (HIN), Arab (ARA), Spanish (SPA) and Portuguese (POR). The link strength corresponds, in the book galaxy (Fig. 9), with the frequency of book translations (number of books translated from one language into the other, which has two asymmetric values); in the Wikipedia galaxy (Fig. 10) it refers to the likelihood to be edited in both languages. At first glance, a major difference encountered between the book and the Wikipedia galaxies concerns the presence of more languages in the former, which makes the books more inclusive than Wikipedia as regards variety of linguistic expression. Secondly, though both galaxies are significantly centred in English, books seem to be more decentralised, with several languages (especially Russian (RUS) and French (FRE), but to a lesser degree also Dutch (NLD) and Chinese (ZHO)) being at the center of a constellation of other languages whose primary connection to the network are these secondary central languages.

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6 According to the "Cracking the Language Barrier" federation, "language makes up a very large part of the continuously growing Big Data treasure" (SRIA 2017: 7). This federation, which assembles many European research and innovation projects as well as all related community organisations working on or with cross-lingual and multilingual technologies, estimates that the opportunities of the European Digital Single Market to dominate global markets –significantly beyond current figures– will largely depend on the mastering of these technologies.

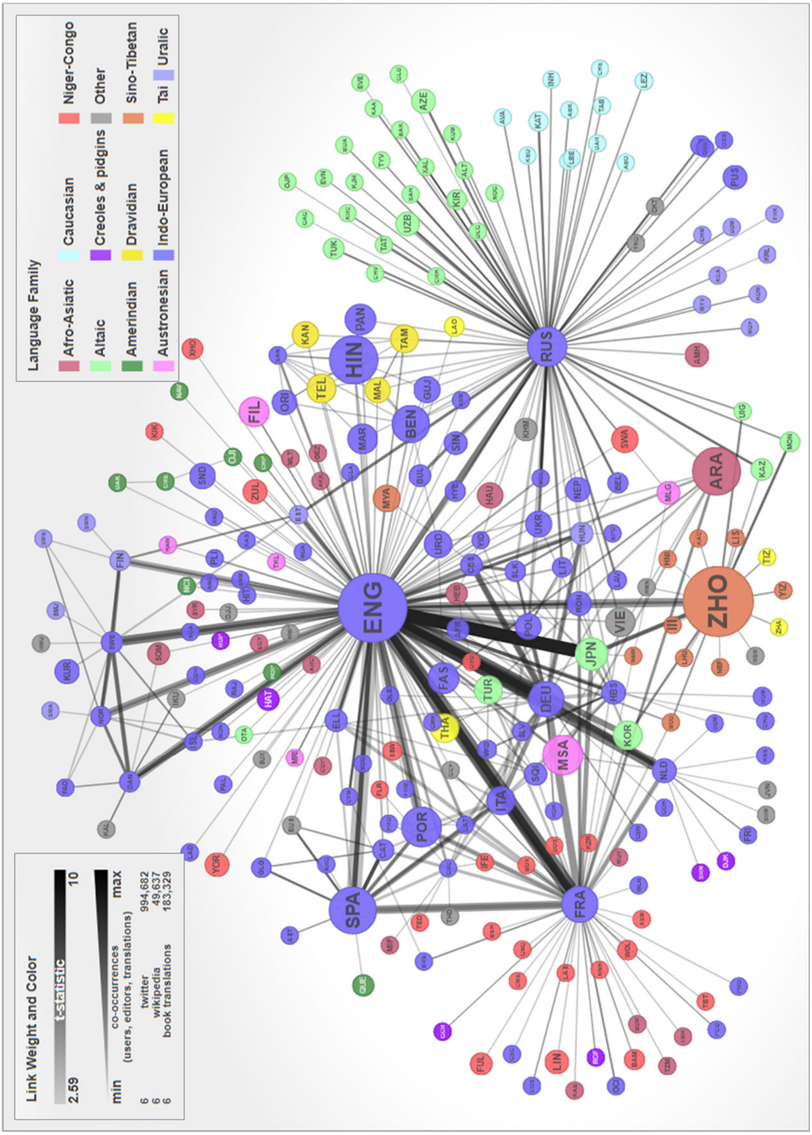

Figure 9. Visualization of the global language network corresponding to book translations. Each node represents a language, weighted by the number of native and non-native speakers, while links are weighted according to the frequency of book translations from one language to another. Book translations. ENG: English, ZHO: Chinese, SPA: Spanish, HIN: Hindu (Source: Ronen et al 2014).

Besides this multicentre network structure, the book galaxy exhibits two very dense areas: one which includes several European Languages but especially French and German (DEU), the two languages with strongest outward expression towards English; the other constituted by the cluster of Scandinavian languages (at the top: SWE, DAN, NOR, FIN). Most triangles of the whole network are located in these two areas.[7]

In the Wikipedia galaxy we also observe a significantly dense area on the right-hand side of the graph mostly constituted by European languages, but also including Japanese (JPN, strongly connected to the European languages, but also to Asiatic ones) and Chinese. By comparing the centrality measures of both graphs and despite the strong centrality of English, we find that it is in this galaxy that we can actually find strongest centers besides English (like German, French, Spanish, Italian). Actually, the eigenvector centrality of English here is 0.66, while it is 0.9 in the book galaxy.

This expressive capacity of European languages, which is obviously positive for their peoples, has nevertheless an important impact as regards the representation of reality (which is a major intention of Wikipedia itself): the geolocated content related to Western Europe is much larger than for the rest of the world whereas large parts of the world have no associated content at all (Sutcliffe 2016; Graham et al. 2011; Graham & Dutton 2014). Consequently, as we showed above with respect to the peripheral status of the global South in the digital routing networks, the digital expression of the global South revolves around the global North; or as M. Graham states "rich countries largely get to define themselves and poor countries largely get defined by others" (Young, 2015; Graham, Dutton 2014). Moreover, the co-edition intensity of European languages combined with the network centrality of English makes the overall expressive capacity of the global North globally dominant whereas the global South has an irrelevant capacity to express itself. All this makes agents from the global North (representing either individuals, communities or cultures) active parts of the global digital networks while agents from the global South remain either passive or silent.

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7 Considering the inward centrality of English with respect to European languages (the majority of book translations into English comes from these languages) makes that they have an expressing route into practically all world languages, whereas the inward centrality of English from peripheral languages of the Global South is remarkable weaker and therefore their capacity to express globally.

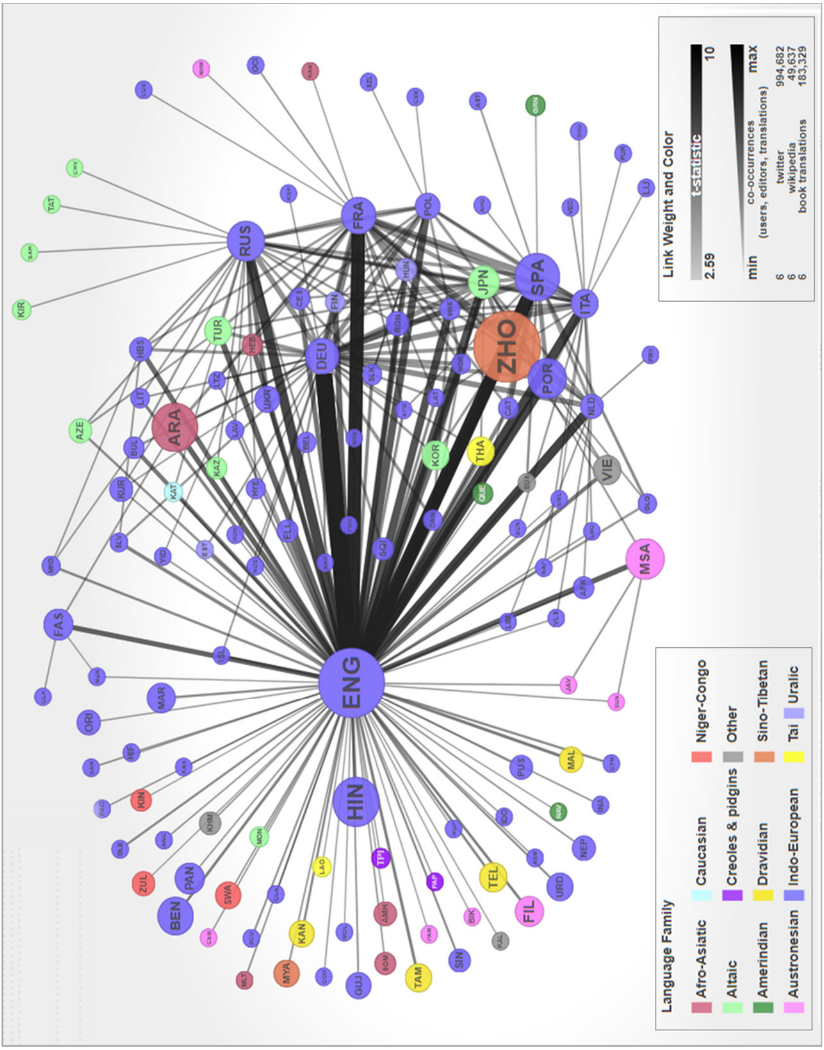


Figure 10. Visualization of the global language network corresponding to Wikipedia articles. Two languages are connected when users that edit an article in one Wikipedia language edition are significantly more likely to also edit an article in another language edition. Node size is weighted by the number of native and non-native speakers of a language, while links are weighted by the frequency of editors editing an article in both (Source: Ronen et al 2014).

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

3.1 Cyber-subsidiarity Model

The common citizen has a very restricted capacity to move autonomously through the digital network –analysed above– which is becoming the ever expanding milieu where our lives take place. At the same time, the capacity to manage relevant information from ourselves and the environment we are living in offers new avenues to deal with healthcare, sustainability or other issues of significant social concern which were previously insufficiently attended (Helbing 2017). Nevertheless, if we compare the information management model attributed to living organisms to the model that corresponds to the internet powered by big-data technologies as discussed in Section 2, we observe significant differences (Díaz-Nafría 2017a, 2017b). Comparing their respective sizes, the information volume in living beings is interestingly much larger for the time being. However, while the internet is notably characterized by the overload of information agents (among which we can mostly find information dwarves and a few information giants), the former is based on the minimization of information management requirements at the higher levels and the recursive coordination of autonomous agency (*ibid*). This is a result of the application of the subsidiarity principle to the organisation of living beings, and a natural pathway to the emergence of sustainable systems, as we showed at the end of section 1.1. Subsidiarity is also, according to international institutions, a basic principle for the social and political organisation of large and diverse groups (*ibid*).

We also showed that the scale-free network structure exhibited by the Internet routing network offers a sound footing for the instantiation of the subsidiarity principle. However, as we observed, the real structure of the Internet, particularly when it is powered by big-data technologies in the current situation of strong inequality, represents an important breach in the subsidiarity principle. Moreover, big-data technologies seem to intensify the already intolerable inequality, pushing the periphery outwards and consequently increasing cultural and social exclusion.[8] To overcome this issue, we propose a *cyber-subsidiarity model* for the organisation of human cooperation backed by subsidiary information management following the Viable System Model, referred to

[8] See footnote 5.

at the end of Section 1.1. This model, based on the decentralised multi-layered organisation of autonomous operational units, offers a means to simultaneously preserve autonomy, identity, environmental and social sustainability at different levels.[9]

3.2 Cyber-Subsidiarity model applied to cooperative organisation: leveraging artisan fisheries in Ecuador

The fishing resources and capacity of Ecuador are among the best worldwide, particularly relative to its costal extension and population. They represent about 14% of the Ecuadorian gross value added, and 15% of total exports (MCPE 2014). However, artisan fisheries, though they provide over 90% of overall employment in the Ecuadorian fishing sector (FAO 2013), "exhibit high iniquity levels; among which the artisan fishers who have no boat, are part of a crew and use no other resources than their own skills are , the most vulnerable" (Benavides & García 2014). The levels of poverty in the artisan fisher communities are certainly alarming (*ibid*). Nevertheless, the Food and Agriculture Organization FAO (2013) highlights the advantageous opportunities for the artisan sector to become an "organized, productive, highly competitive, dynamic and integrating sub-sector of social, economic and cultural development, with integrated and sustainable management of fishery resources".

With the purpose of materializing these opportunities, the same international organization emphasizes the capacities of the cooperative way of organization integrated in *Community Fishery Centers* which, in turn, support *Fisheries Development Units* (Ben-Yami, Anderson 1987). However, according to information directly requested from governmental bodies with respect to the cooperative fishing sector in Santa Elena Province (which allocates one of the most intense fisheries in Ecuador), among the 35 fishery groups registered in the province, only 37% were cooperatives in 2016. Only a few of them would pass the assessment of compliance with cooperative principles and values (Hough 2015).

[9] The authors have presented and discussed the cyber-subsidiarity model in several publications (Díaz-Nafría 2017a, 2017b; Díaz-Nafría & Guarda 2018). In the following sub-section, the model is applied without further discussion of the model's principles and structure. For a deeper understanding, the interested reader should draw on these publications as well as literature on the Viable System Model, for instance: Beer 1985; Walker 1998.

CoopSE project. Taking this baseline into account, a network of fishing cooperatives and associations, as well as academic, governmental and cooperative organisations undertook the objective of setting up a sustainable aggrupation of fishing cooperatives and a Fishery Development Unit for the Province of Santa Elena in 2016 following the principles of sustainable organisation referred to in the previous section (s. Fig. 12).[10] The information infrastructure, developed for the sustainable and autonomous management of the cooperative activity, also serves the purpose of the integrated management of marine resources through the modelling and simulation of the marine ecosystem based on harvesting records.[11] In the long term, by virtue of its structural scalability, this form of organisation is intended to provide a supporting structure for the further integration of cooperative activity in the fishing sector or other socio-economic activities (in particular those that offer additional values to the efficiency of the integrated activities).

In order to provide initial guidance for the application of the cyber-subsidiarity model to the artisan fisheries of Santa Elena, an analysis of Strengths, Weaknesses, Opportunities and Threats was carried out concerning two main aspects, cooperativism and fisheries. This study came to the following major results:

- Regarding *cooperativism*, the Ecuadorian cooperative sector as a whole is socially and economically strong. It has high potential to achieve the goals set by the Ecuadorian constitution regarding popular and solidary economy, which, in turns, offers a suitable normative framework for cooperative organisations. At the same time, it has severe limitations concerning its ability to structure socio-economic activity on an appropriate scale to cope with important economic, social and environmental challenges. On the other hand, the constitution of cooperative organisations currently involves some complex administrative processes that eventually cause deviation from the process into other forms of organisation.

10 This network, coordinated by the University of Santa Elena Peninsula under leadership of the authors, incorporates fishing cooperatives and associations from Santa Elena Province, the Ecuadorian Federation of Fishery Cooperatives (FENACOPEC), local and national administrative bodies, Mondragon Cooperative Corporation (Spain) and other academic institutions from Ecuador and Europe (Guarda et al 2018).

11 Aligned to this goal, FAO states that an adequate and integrated management of fishery resources could make artisanal fisheries an "organized, productive, highly competitive, dynamic and integrating subsector of social, economic and cultural development" (FAO 2009). In addition, it offers a strong support to attain locally several Millennium Development Goals (Pomeroy, Andrew 2011).

- Regarding *fisheries*, the artisanal sector in the province of Santa Elena has a remarkable fishing capacity supported by large fishing resources and traditional fishing techniques, as well as archaeologically-proven millenary tradition (including cherished fish-based gastronomy), an advantageous normative and administrative framework for the protection of fishermen's rights and marine environment, and availability of academic local institutions devoted to marine research. At the same time, it presents significant limitations such as: the lack of rational management of fishery resources; the scarce implementation of sustainable development projects in the sector; the insufficient infrastructure for fishing, conservation, processing and distribution; low level of education, digital literacy and training among the fishing population; and limited capacity for applied research (FENACOPEC 2009, Darricau, Marugán 2012).

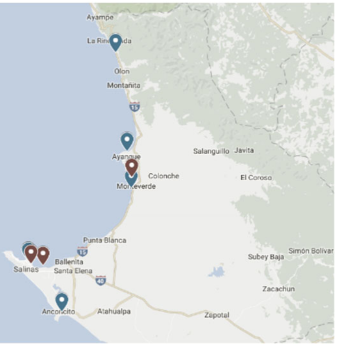
Integration of fishery activity. Figure 11 shows the operational context of the project through the headquarters of the 9 fishing groups (3 cooperatives and 6 associations) that are taking part in the project with the aim of setting up a cooperative aggrupation with integrated activity within the project's lifetime. The geographical distribution of these groups offers a foundation for a simple integration of further activity in the province as intended.

In compliance with the recursive principle of the subsidiarity model, briefly referred to in section 3.1 and described in detail in the references given in footnote 9, the Viable System Model (VSM) structure allows at the same time the articulation of base cooperatives, the aggrupation of fishery cooperatives, and the Fisheries Development Unit (FDU).[12] In order to limit organisational complexity at the level of operative units (the lowest organisational level contemplated in the VSM recursive structure), the number of its members is limited to 10 or slightly more, so that all Viable System functions can be performed by the members of the unit. Since this regulative constraint holds true for the number of operative units at any given level, a base organisation complying with the Viable System Model of a single organisational level can accommodate up to 100 people. If the number of members to be organised in a VSM is larger, more levels will be required.

[12] This structural self-similarity throughout organisational levels is also a trait of the Mondragon Cooperative Corporation (Spain), considered among the largest cooperative groups worldwide, whose organisation has often been highlighted internationally as a paradigm of social responsibility (Narvarte 2006). Interestingly J. Walker (1998) showed its perfect compliance with the Viable System Model.

a)

b)



c)

Figure 11. a) Santa Elena Province; b) Geographical distribution of integrated fishermen's groups of Santa Elena in coopSE project: associations (blue) and cooperatives (red); c) Anconcito, the largest fishing harbour of Santa Elena Province (Source: García & Leante 2010).

Figure 12 shows the nesting of isomorphic organisational structures integrating the Fisheries Development Unit (FDU). The lowest level consists of base co-operatives, the highest level is occupied by the FDU. At the cooperative level, the operative units are composed of several teams devoted to fishing and two other teams dedicated to infrastructure procurement, and commercialisation. The second level corresponds to the fishing cooperatives joined into a group. Taking the size constraint mentioned above into account, this means that the cooperative group could structurally encompass the activity of up to 1.000 people, which is actually close to the size of the fishery community involved in the project. If an additional organisational level were provided for the cooperative group, as conceived for a phase beyond project lifetime, it might incorporate the activity of up to 10.000 people which is close to the size of the whole fishery community of Santa Elena province.

The FDU is composed of five (sub-)units: the *cooperative aggrupation*, a *training and research unit* (especially supported by academic and scientific partners), an *information systems unit* devoted to the development of inclusive information systems to back up the overall viable system (mainly supported by information systems departments of academic partners), a *socio-economic observatory unit* dedicated to increase the knowledge of Santa Elena fisheries (supported by management science departments of academic partners) and the *cooperative integration unit* devoted to set up and expand the cooperative aggrupation (supported by the cooperatives, administrative partners and management science departments of academic partners).

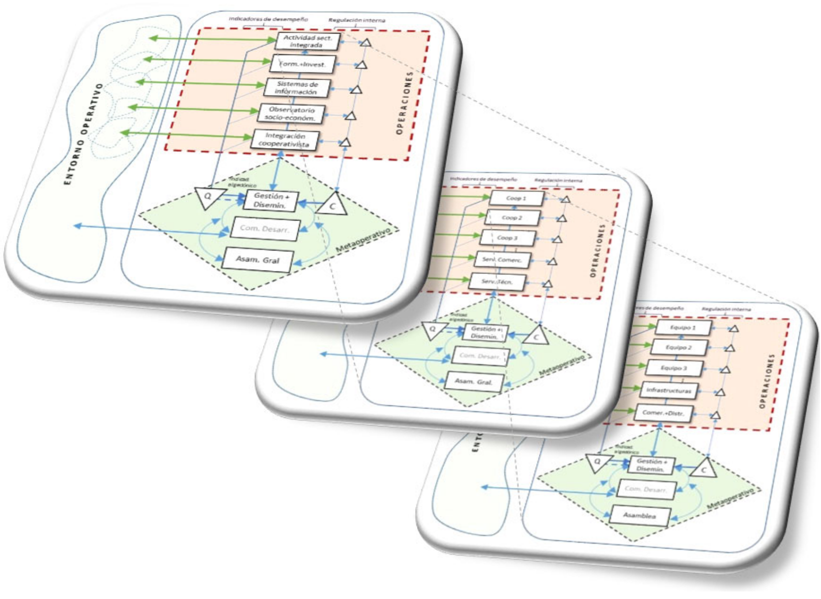


Figure 12. Nesting of organizational structures from FDU to grassroots cooperatives.

Management bodies at any level (from the cooperatives all the way up to the FDU) are composed of the following units: Coordination (S2), Management Team (S3), Quality Assessment (S3*), Development Commission (S4), General Assembly (S5).[13]

[13] S1, S2…, S5 stand for System 1, 2…, 5, which are the subsystems in which the VSM breaks down according to the original description proposed by Beer (1985).

Information management for sustainability and autonomy. According to the organisational principles of the cyber-subsidiarity model (briefly referred to in Section 3.1 and further described in the references given in footnote 9), the articulation of the sustainable management structure requires an information and communication system supporting the whole structure and complying with the principles and regulative requirements of such a model. In addition, the design and training envisaged within project horizon takes the real levels of digital literacy into account. Figure 13.a shows the coordination and management panel of the e-working environment intended to support the adaptive management and the organisation of distributed and interdisciplinary work. In order to guarantee inclusive participation, the applications need to be optimised for smartphone usability. Figure 13.b shows the appearance of the application devised to report catches and bycatches which are essential for the further simulation of fishing resources.

As shown in the Fig. 13.a, the tool concentrates the most relevant information and communication tools to facilitate the organisation of work (the example corresponds to the management panel of a single cooperative which should be accessible to any cooperative member). In the first place, the user has access to the information describing the state of cooperative performance and important announcements regarding coordination tasks. Coloured alerts highlight issues to address or the need for increases in performance. 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) serves as a basis to determine figures and alerts on 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 levels regarding overall performance. The determination of the 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 (Kalman 1960).[14]

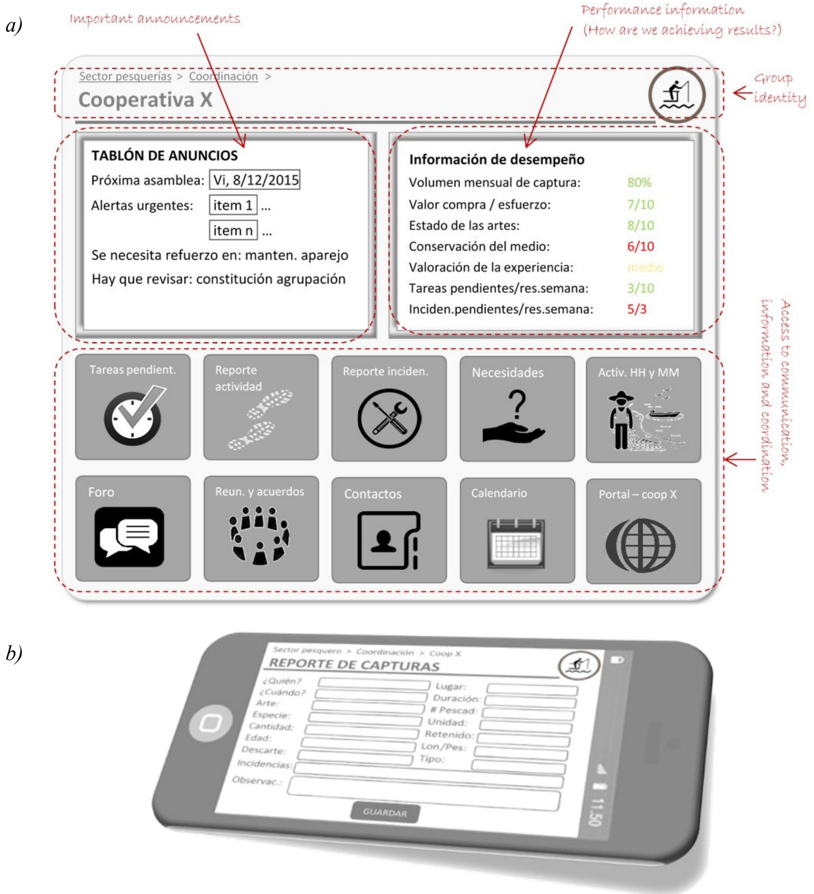


Figure 13. a) Coordination and management panel, b) Mobile application for harvesting reports

4. Concluding remarks

As we have seen adopting a network perspective, the global digital information network, despite its small-world structure, is certainly not inclusive with respect to all people, communities, and cultures (section 1). The global North concentrates the largest part of the overall network capacities and provides the

14 Further information about this solution can be found in (Díaz-Nafría & Guarda, 2018).

global South with an effective network whose information flow circulates through the North. In the process data is often loaded with meaning that encapsulates northern interests by means of big-data technologies (section 2). Regarding expressive capacities, the digital technologies do not bring any change to the dominance of the global North, in particular by the Anglo-Saxon and other European cultures. Moreover, most languages and related cultures will have severe difficulties to survive in the digital world.

However, we have seen that another way to manage information is possible, based upon the scale-free properties actually exhibited by the Internet routing network. Similar to the natural application of the subsidiarity principle in living organisms, the circulation of information in digital networks (ultimately related to social interaction, as shown in section 1.1) can close the loop around immediate stakeholders, increasing their capacities and their autonomy, and offering mechanisms to communicate with the rest of the network according to distributed interests (section 3.1). We have seen how this model can be applied to the organisation of artisan fisheries in Ecuador, deploying mechanisms to filter relevant information according to local interests for the benefit of social and environmental sustainability (section 3.2). Taking the scalability of the model into account, its generalisation offers an alternative way of organising an intercultural digital world from the local to the global contexts, enabling at the same time the autonomy of the multi-layered agency and the capacity to face big challenges (Walker 1998). However, the dominance of a small group that has concentrated too much economic, political and cultural power will be difficult to overcome. Sustainability and even survival are at stake.

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