Call of Survival: Stigmergy for Matters of Concern

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Abstract: Harsh consequences of social inequality and unsustainable practices are responsible for altered local landscapes, and an unbalanced global system challenging designers to resolve inter-linked problems of mammoth complexity, that are more than just wicked. These problems are extremely volatile and unique - a nexus of interconnected vicious loop of complex local actions exerting changes in global patterns of vast magnitude in scale as well as impact, that insist upon urgent action to ensure ‘collective survival’. To sustain and save the social and environmental fabric, we need adaptable and self-sustainable systems with equitable prospects of contestation for harnessing collective actions. We recommend stigmergy – a naturally evolved phenomenon for collective survival, as a possible approach for harnessing collective intelligence and action to achieve a common global goal, and argue for the characteristics that make it appropriate for resolving complex concerns of high magnitude.

Keywords: Collective actions, Stigmergy, Complex problem, Global issues, Design ecology

1. From Pixels to Images: Understanding the Global nexus of collective survival

We do not live in isolated compartmentalized bubbles, but rather cohabit a world where all actions are directly or indirectly interconnected with us, and also with those of others, in ways that are not often certain or predictable. Actions of human agents, the artifacts they produce, and the environments in which they use them are not bordered/fenced unlike contested boundaries of nations. Hence, our interdependency makes our cultural, social, economic or environmental system porous, irrespective of rigid territorial division of nations. (Carpa & Luisi, 2014; Escobar & Jacoby, 2009; Forsyth, 2003; Irwin, 2004; King & McCarthy, 2009; Latour, 2008; Manzini, 2016)
In such a dynamic interdependent network, the whole consists of a network of relationships in which no part is more fundamental than another; whatever we call a part is merely a stable pattern (Carpa & Luisi, 2014; Haug, 2015; Irwin, 2004; Resnick, 1994, 2009). The global whole, then, emerges as the amalgamation of porous boundaries of the local parts similar to the emergence of a global image from the integration of pixels. Each pixel in itself is merely a small dot, but a group of pixels builds diverse patterns at interim scales, eventually displaying a complete pattern at the global level. The Human global system is similar to the dynamic interaction between pixels and images, where pixels shape and are shaped by global changes creating a complex vicious loop of becoming the cause and consequence of each other, often inconspicuous to the centralized mind (Resnick, 1994, 2009).

Global changes emerge out nonlinearly from interconnected local actions. From the past decades, harsh consequences of unsustainable practices have not just altered the local conditions of the pixels but have also developed an irreparable damage and imbalance at the global systemic level bringing forth various global issues (Cumming, Cumming, & Redman, 2006; Wilbanks & Kates, 1999).

Global issues are systemic views of common trans-national problems that have or hold the potential to impact large number of people and “the planet”, and go beyond the nation’s capability for resolution (King & McCarthy, 2009; Levin, Cashore, Bernstein, & Auld, 2012; Smil, 1993; Turner, n.d.; Wisner, Blaikie, Cannon, & Davis, 2003).

Tracing the causal connection between global events and local actions is complex (Cumming et al., 2006; Wilbanks & Kates, 1999), as global level changes are of high magnitude, invoking multiple layers of engagement and are intractable from direct observation at pixel level. Willbanks contemplates that an integrated assessment of population, socio-cultural aspects, economy, technology and environmental change will yield a deeper perspective of the interwoven complexity associated with the linkage between local and global phenomenon (Cumming et al., 2006; Ostrom, Burger, Field, Norgaard, & Policansky, 1999; Wilbanks & Kates, 1999). Further, he gives several arguments to explain the linkages between local patterns through which global problems emerge. In the Domain argument, the emergence of environmental systems from different domains of nature and society is discussed. Local and regional domains relate to global ones either systemically or cumulatively (B.L. Turner et al., 1990). Systemic changes involve fundamental changes in the functioning of a global system, which may be triggered by local actions (and certainly may affect them) but that transcend simple additive relationships at a global scale. Cumulative changes result from an accumulation of localized changes, the resulting systemic changes are not global. The Agency domain is established in the context of agency (human action) and structure (organization or institution) whose scale is regional, national, or global. The scale of agency and its actions are often intrinsically localized where its structure directly - indirectly governs and shapes the actions.

Willbanks further affirms that the driving forces behind environmental change involve interaction processes at different locations, areal extents and time scales, the effects of which vary related to geographic and temporal proximity and structure. Additional arguments elucidate how we learn about the world. Complex relations between environmental, economic, and social processes can only be tackled carefully at the local level. Variance in observations in terms of diverse range of processes and relationships at local scale as well as change in perspective- top down and bottom up can provide an informed view of such complexities.

It is evident from Willbanks study that complexities of global issues are resolvable only at local level. But even after decades since we were forewarned about the complex global issues and its impacts, we are still dealing with matters of concerns (Latour, 2008) only partly with short term view of problem within a pixel boundary unconcerned with its systemic associations (Banathy, 1996;
Dubberly & Pangaro, 2004; Irwin, 2004; Jones, 2013). Episodes of local action and intervention confined to limited pixel boundaries fail to transform to a higher level, consequently affecting the global picture (Cumming et al., 2006; King & McCarthy, 2009; Wilbanks & Kates, 1999). These problems are extremely complex and unique with interconnected vicious loops of local and global level concerns that demand urgent design action to build an environmentally friendly and socially equitable future for all. This nexus of extremely complex wicked global concerns require design to evolve ‘big strategies from little ideas in strange places at unexpected times’ (Mintzberg, 1994). As Fallan has clearly expressed “making society through science and technology” sustainable or unsustainable is “a matter of design”(Fallan, 2014). Complex problems of survival are a nexus of interconnected wicked problems that are accelerating in both, complexity as well as magnitude overtime. These emergent problems have porous boundaries requiring a shift in our resolutions from designing artefacts to designing ecologies. However, in order to understand this lacunae, let us first try to comprehend the nature of the beast. What makes complex problems of collective survival so different from the current design problems?

2. Nature of the Complex problems of Survival

No era in human history has been beleaguered by such a range of mutually exacerbating problems that have challenged the sustainability of human and non-human life support systems. (Escobar & Jacoby, 2009) This range of mutually exacerbating problems are even more resistant to resolution than the wicked class of ill formulated social system problems elucidated by Rittel. (1960) Levin et. al (2012) elucidated the nature of global concerns as ‘super wicked problems’- a new class of global environmental problems which depart from wicked problem on four grounds, (a) time is running out, (b) those who cause the problem also seek to provide a solution, (c) central authority needed to address them is weak or non-existent, (d) and occurrence of irrational discounting pushes responses into the future. Some other aspects of the problems of survival are elaborated below.

- Lack of central control: Global concerns are common transnational systemic issues that lack a central body with specialized power and authority restricted for engagement with them alone. Global governance requires an extremely complex and strong structure of multi-level national, regional and local administrative support for effective alliance of knowledge, resource and decision-making. In the absence of any central authority, it becomes a general problem of cooperation, and eventually the "tragedy of common"(Hardin, Hardin, & Ph, 2001).
- Agents causing the problem, are often assigned to resolve it too: Unlike other environmental problems with discrete antagonists and protagonists, human-induced global concerns result from individual as well as collective activities. (Levin, ---) Every concerned person trying to reduce climate change, in some way or the other has also contributed to it.
- Emergent nature of the problem: According to Cherns most existing complex problems are not born, but just grow non-linearly. Emergent nature of complex problem of survival makes it difficult to predict and control at the global level. Local concerns persistently influence each other in an uncertain way, eventually emerging into an unpredictable global pattern (Cherns, 1976).
• Inclusivity of Experts and non-Experts: Till date, bulk of the research relating local actions to global changes has been top-down, from the global toward the local, concentrating on methods derived from global models that may have little regional or local specificity. (Wilbanks et al, 1999:601) Problem resolution of complex problems is not limited to exclusive experts who understand the constrains of global issues and the dynamics of variance scales(Wilbanks & Kates, 1999) in context of the local inquiry. Of equal significance, are the local stakeholders who lack the expertise of the former, but play an equal role in the appropriate comprehension of the problem and implementation of its resolution. Inclusivity of the non-experts or the local agents is also essential to minimize contestations and evolve a process of collective action among heterogeneous agents.

• Shift from design artifact to design ecology: Complex problems of survival demands a shift in design approach from designing an immediate general fit size solution based on homogenized assumptions of user and the context, to design ecology for customizable interventions for heterogeneous problems and context integrated within the living system (Forsyth, 2003). Sim Van der Ryn and Stuart Cowan define ecological design as “any form of design that minimizes environmentally destructive impacts by integrating itself with living processes.” Designing living systems is an interconnected interaction of continuously evolving and self-organizing interventions for long-term vision of sustainable future.(Irwin, 2004; Salazar & Baxter, 2015)

• Porous boundaries of problem: Complex problems of survival are not isolated, but rather resonate with other such complex problems exerting pressure on each other. Changes in one affect another, therefore, entangling an interconnected to seek independsnt resolutions is difficult. Porous boundaries increased the difficulty in comprehending and approaching a design concern, as blurred boundary of one concern dynamically increase agency, interaction, variance and perspective (Wilbanks & Kates, 1999)in of another.

• Extremely high magnitude: The magnitude of these concerns is unimaginable, posing a great overarching intellectual challenge of our age(Diamond, 2005; King & McCarthy, 2009; Levin et al., 2012; Wisner et al., 2003)s. Magnitude of the problem transcends disciplinary boundaries, both spatially and temporally of the cause and its effect.[10] Spatial dimension is the global area affected by and causing the problem. Temporal dimension is the duration of impact either temporary fluctuations or permanent impact caused sometimes by the limited time for resolving the problem. The conceptions of nexus of complex wicked problems that are truly global in magnitude are further novel to us (Levin et al., 2012; Ostrom et al., 1999; Strogatz, 2003; Wisner et al., 2003)

None of the human generations has faced wickedness of this magnitude; neither are they prepared to face the consequences of the same. Together these characteristics of complex survival problems challenge the existing framework and demand a change in the design approach. Design approaches are developed to tackle ‘wicked problems’ (Rittel & Webber, 1973; Simon, 1996) but these complex concerns pose a unique challenge in understanding linkages between macro-scale and micro-scale phenomena. Introspection has revealed that unintended consequences of designed artifacts have induced inequitable contestations, and unsustainable practices in our social and environmental ecology. (Baek, Meroni, & Manzini, 2015; Fallon, 2014; Margolin, 1996; Papanek, 1972; Salazar & Baxter, 2015) But, we are also aware of the potential and central role played by responsibly designed artifacts to achieve a sustainable (Escobar & Jacoby, 2009; Fallon, 2014; Fuad-uke, 2007;
3. Reigning the growing beast: Design approach for collective survival

In the previous section, we discussed the limitations of design approach in resolving complex global concerns. Their complexity has gone beyond the capability of any centralized control intractable at the local level (Levin et al., 2012), demanding urgent attention and action. The negligible effect of centralised episodic intervention at the global level, and the yet less explored possibility of resolution at the pixel level, urgently implores us to probe a self-sustainable, systemic approach of interconnected local actions to reign the beast for our own collective survival.

‘Collective survival’ is an evolutionary impulse present in many species of insects and animals like ants and termites, where individual power is inefficacious against external forces, but collective strength assists individuals to adapt and prosper against odds that are many times stronger than their own abilities. Stigmergy is a similar evolutionary phenomenon inferred from the coordinated behaviour of social animals for survival from prey or any other external agency. Seemingly, incoherent individual signs and corresponding actions at the local level emerge into a global complex pattern resolving the problem. This phenomenon leverages the innate survival instinct of each individual in the absence or lack of direct communication and central planning. (Susi & Ziemke, 2001; Theraulaz & Bonabeau, 1999) Individual action in the environment produces temporary or permanent changes (sign). These changes in the absence of direct communication triggers further action and sign-based-feedback to other agents in the shared environment. Collectively, local actions emerge as a self-organized, coordinated, and optimized pattern to achieve a common goal such as survival, foraging, nest building etc.

Stigmergy is a broad class of multi-agent coordination and self-organization mechanisms that rely on information exchange through a shared environment. In the absence of direct communication, signs mediate communication and provide feedback in the shared environment. It produces complex, seemingly intelligent structures, without need for any planning, control, or even direct communication between the agents. It supports efficient collaboration between extremely simple agents, who lack any memory, intelligence, and at times even individual awareness of each other.

The following sections discuss the adaptation of the stigmergic framework for complex design problems for collective survival. The framework attempts to contextualise an emergent decentralised systemic approach for designing an empowering, equitable, and sustainable future. We do not claim a best fit, but a better fit through the use of a stigmergic approach. As Cherns reminds us, taking a piecemeal approach to such issues will invariably lead to problems around those incomplete elements that arise from reductionist approaches. (Cherns, 1976)

4. Stigmergic Design framework

In 1959, French entomologist Grassé closely observed termite hill construction. He was intrigued by the collective ability of low cognitive species like termites to construct a complex and coherent pattern of a termite hill without any direct interaction between each other and any shared blueprint of the design as shown in figure 2. He explained this long existing coordination paradox with a new
term ‘stigmergy’. According to Grassé, an agent’s actions leaves ‘signs’ in the environment; signs that other agents sense and subsequently shape their own actions upon.

Stigmergic phenomena has intrigued the mind of researchers as it provided an explanation of the emergence of a complex structure at global level from simple distributed actions at local level without direct communication between agents of low cognition. (Marsh & Onof, 2008; H. V. D. Parunak, 2005; Susi & Ziemke, 2001; Theraulaz & Bonabeau, 1999) It explains social cohesion at two levels, firstly, ‘inter-attraction’ between society and individuals and ‘interaction’ between neighboring agents at the local level that facilitates interconnected response of agents to stimuli/action in a shared environment (Dipple, Raymond, & Docherty, 2014; Heylighen, 2015; Marsh & Onof, 2008; Ricci, Omicini, Virol, Gardelli, & Oliva, 2007; Susi & Ziemke, 2001). Individual insects cannot survive alone, but collective inter-attraction and interaction assists in their optimal adaptation and survival from external conditions.

According to Parunak, in a stigmergic process local agents with limited knowledge and resources are not overwhelmed with global complexity, as they are exposed to optimal information load and problem solving which requires only simple actions. Self-organization of local interactions can yield a coherent systemic outcome that provides required control in the hands of local agents, who are unaware of the global problem as well as the impact of their own actions on it, and at times, even of the actions of their local peers. (H. V. D. Parunak, 2005; H. V Parunak et al., 2009)

In the past, stigmergic framework found limited application in the field of economics, artificial intelligence, cognitive sciences, biology, and multiple agent system design, where several agents of limited cognition interact with a programme, device etc. After 2001, researchers have argued for its broader relevance in “artefacts” mediating stigmergic interaction in human system for cohesive collective actions, similar to Wikipedia, Web 2.0, open software development, Google review, traffic navigation, smart highways and many others. (Dipple, Raymond, & Docherty, n.d.; Dipple et al., 2014; Elliott, 2007; Heylighen, 2015; Marsden, 2013; H. V. D. Parunak, 2005; Ren, Huang, & Jin, 2010; Ricci et al., 2007; Susi & Ziemke, 2001)

With advancing technology and internet networks, stigmergic interactions based on human mediated artifacts have proven successful in the emergence of self-organized structure of collective actions, irrespective of the agent’s global location. Every agent is interconnected with many other networked agents, in both physical and virtual world that provides an appropriate condition for exploring stigmergic interaction. Fold-it exemplifies the same. It leverages the collective intelligence of masses to fold complex structures of proteins to determine the possibility of a native structural configuration that can be applied to eradicate diseases in real world. (Collin2016) Fold-it has unravelled many complex and unsolved structures of protein, including a 15 year old problem of a protein structure relevant to HIV in merely 10 days. Seth Cooper and biochemistry professor David Baker developed this game in 2008 to discover novel methods of protein folding using the unique human capability of pattern matching and spatial reasoning. Interestingly, the participants (even kids) of Fold-it are often novices and not scientists. Technology and artefacts like Fold-it are exploiting stigmergic interactions to harness the higher cognition of distributed human agents to solve complex global problems by directing shared collective knowledge and actions operating at local levels towards a common goal.
4.1 Significance of Stigmergy in Complex problems of survival

To sustain and save the fabric of our future society, we urgently need adaptable and self-sustainable systems with equitable negotiation opportunity and collective actions. Design thinking today demands a decentralized framework for “collective survival” to tackle global complexities through connected local actions. Stigmergy has potential to emerge as a backbone strategy to tackle complex problem of survival “holistically”, considering its significance in negotiating collective actions into meaningful order directed towards a common goal that can sustain and self-adapt in relation to proximal local actions. Its evolutionarily fit nature makes it pertinent for small, highly contextual and personalized design environment, which facilitates maximum customization.

In 2007, Elliot argued that mass collaboration is fundamentally dependent upon stigmergy. Advancing technology has unlocked the immense opportunity of harnessing the ability of masses to co-design resolutions for commonly shared problems on participatory platforms. (Heylighen, 2007; Kittur & Kraut, 2008; Marsden, 2013; Tapscott & Williams, 2008). Emergent property of stigmergic design holds potential to resolve multi-layered complex problems simultaneously, through interconnected goal directed actions and conflict resolution in multiple local directions and dimensions.

Agent, artefact and environment are three core components of stigmergy, where artifact mediates communication, and sometimes even actions amongst agents in a shared environment. This provides a holistic approach for designing dynamic interconnected interactions between all core components. In addition, reflexivity towards a priori impact prediction on interconnected system minimises the unintended negative consequence on society or environment. Any external disturbance or contextual discontinuity is self-adjusted and adapted within the systems cybernetic feedback loops, which triggers further closure by action aligned to common goals, synergizing independent coordinated actions into a harmonious whole. (De Wolf & Holvoet, 2007; Heylighen, 2001, 2015; Marsden, 2013)

Each action in the environment constructs either positive or negative feedback for controlling errors in the system. Negative feedback are deviations from the goal and positive feedback is the amplification of action towards the goal. For instance, strong pheromones amplify the chances of food source, while weak pheromones explain the absence or depletion of the food source. Local actions are designed with constant feedback system that aid, control, maintain, and shape local decisions of each agent directed towards a common global goal. Feedback on local action aligns agents with the global goal. Therefore, the stigmergic framework adapted with advancement of technological tools is appropriate for “thinking global and acting local”.

One of the most significant feature of stigmergy is the process of self-organization of actions without any direct communication amongst agents. Agents act collectively without being aware of other agents; their actions become a mode of communication which eradicates social and personal biases from the system. Indirect communication mediated through artifacts or environment provides an efficient way of channelizing collective action free from biases, while providing opportunity for equitable negotiation to build a cohesive community of commons. Social negotiation in stigmergy is either implicit or unknown to agents in a shared environment that aids seamless integration of contributions from agents for the common goal. According to Elliot (2007) stigmergic communication
sidesteps social negotiations effectively, fast-tracks the creative gestation period, and removes social boundaries, as a consequence of which ‘costs’ of contribution is lowered. In addition, stigmergy provides a framework to build intuitive collaborative systems in textual or non-textual artifacts providing an incentive to the less privileged to seek information and opportunities.

In stigmergy, every agent is a designer, channelizing his problem solving ability to the local problem at hand. Each individual is considered an active agent for change, who in isolation has limited resources, knowledge and opportunity, but collectively can emerge as a ‘global brain’ (Heylighen, 2007) capable of breaking down complexity in multilayer fragments for appropriate resolution (Heylighen, 2002; Murty, Paulini, & Maher, 2012). It creates a transparent system for collective actions where each agent shares equal knowledge, ownership and accountability.

Theoretical analysis of stigmergic frameworks illustrates fundamental mechanism of mass coordination through simple, self-organised and adaptable local interaction to achieve complex systemic goals. Stigmergy provides a robust framework for resolving global scale complex problem of survival with interconnected local actions. (Heylighen, 2002; Murty et al., 2012) It provides an appropriate way of channelizing local social innovation (Björgvinsson, Ehn, & Hillgren, 2012; Morelli, 2007; Paulini, Murty, & Maher, 2012) to emerge as a global community of practice (Wenger & Trayner-Wenger, 2015) for resolving issues at local level for sustainable future. The current trends of practice, research and advancement of technology for collective interaction provides immense opportunity for exploring and designing stigmergic interaction.

Stigmergy in human system design is still underdeveloped demanding further exploration from the design community to build a self-organised living system to resolve complex problems collectively, and build an equitable global community for sustainable future. This requires sophisticated simulation and prototyping tools for stigmergic experimentation. Only then, will the full potential for harnessing human collective intelligence and actions be fully discovered.
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