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**Relating Systems Thinking and Design  
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## **Hackerspaces as Complex Systems for Emerging Collective Creativity**

**Diego Fagundes da Silva and Erica Azevedo da Costa e Mattos**

This paper contrasts the concept of innovation as it has been assimilated by the liberal capitalist discourse, built on the figure of the individual entrepreneur and currently reflected in the heroic image of the maker, to the process which we call *emergent collective creativity*, that can arise from complex organisation systems such as seen in hackerspaces. This process was observed within a particular Brazilian hackerspace through the techno-political action called “Revolta da Antena” (or The Antenna Uprising), which unfolded in a particular context of popular mobilisations that occupied the streets in 2013. That experience is now revisited in this paper ten years later as a starting point for a reflection on the relevance of the principles inherent in the hacker ethos and as an invitation to think about the future of our relationship with technology and control systems. Both the hackerspace organisation—composed of human and non-human elements—and this action catalysed by it will be presented from a systemic standpoint using concepts and tools provided by the fields of cybernetics and complexity theory, associating both phenomena to what has been defined as the edge of chaos.

**KEYWORDS:** systemic innovation, hackerspaces, cybernetics, complex systems, social systems

**RSD TOPIC(S):** Cases & Practice, Society & Culture, Sociotechnical Systems

## Introduction

The hero archetype—an unconscious image of a person that, against all odds, is single-handedly capable of the greatest achievements—is still one of the most pervasive in our society. Different historical periods gave this general idea specific guises, and Schumpeter's (1939) characterisation of the creative entrepreneur is just one example that has been updated to the changing settings of the global economy. With capitalism's focus on the "next great idea", innovation has been the biggest reward of this liberal hero. In the mid-2000s, a socio-technical discourse emerged, with the maker as the idealistic central figure. The maker movement, which initially appeared to be renewing the non-consumerist DIY spirit originally linked with the Punks of the 1980s, ended up within just a few years being labelled as the seed of a new industrial revolution (Anderson, 2012). Proclaiming an alternative model to personal technological production, the movement's supposed stance against the centralised and hierarchical economy proved itself to be not only a new market niche for hobbyists but also a rebranded ideal for business innovation in a fluid economy. Even if this movement appears to consolidate the vision of a community, in reality, the focus remains on the maker as a grand individual—visionary, inventor and developer—who many times ends up only as CEO of a single-person start-up.

As enablers of this phenomenon, we see a myriad of physical spaces coming into prominence that offer at the same time access to important technological resources and a place to work and socialise. Besides the business-oriented co-working spaces, accelerators and incubators, and the FabLabs, makerspaces and hackerspaces are some of the other genres that make up this not-so-new configuration. The broad definition of *shared machine shops* (Troxler, 2010; maxigas, 2016) can cause us to see these spaces as the same, but the different names come with different backgrounds and values that are realised in their specific instances. On one side, FabLabs and many makerspaces are more prone to liberal cooptation because of their associations with powerful institutions and alignment with the aforementioned discourse of maker innovation. The

term makerspaces is connected with the influence of *Make*:<sup>1</sup> and the FabLab nomenclature, which will always be linked with the standardised model created at MIT. Initiatives such as the Nation of Makers, launched by the Obama administration in 2014, assume that these cultural trends are a new kind of economic production that will change the basis of the social American structure. Such could be pointed out as an inspiration for an initiative in the Brazilian city of São Paulo for the creation of 12 public FabLabs managed by the city hall. On the other side of the spectrum and from a different background, we have hackerspaces—in many ways, related to what we call a hacker ethos—which promote greater resistance to market pressures. As with other kinds of shared machine shops, hackerspaces have spread worldwide over the past decade—but without a central institution figure and somewhat unclear definitions, each instance is more easily adapted to its own context.

### **Proposing a discussion**

Our paper starts with a reflection on innovation to discuss creative and action processes under a lens that considers the complex aspects of the current scenario of information commodification. We will address this phenomenon as the emergence of new patterns in a continuous collective process, whose variables involved make any attempt at control or even prediction a very difficult task. For this, we will refer to the image of hackerspace as a specific location, a contemporary and expanded manifestation of a hacker ethos, which brings with it modes of creation, collaboration and learning that are associated with direct action in the world and the constant critical exercise of looking, rethinking, and reinventing.

The paper draws on discursive and theoretical contributions from the fields of cybernetics and complexity theory associated with our own empirical experience with the hackerspace Tarrafa Hacker Clube, or Tarrafa HC, in the south of Brazil and its specific context in relation to the rest of the country. As an illustration of the process we call *emergent collective creativity*, we present the action known as The Antenna Uprising (A Revolta da Antena), which occurred in 2013. This particular action happened during

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<sup>1</sup>An American magazine, described as “The premier publication of maker projects, skill-building tutorials, in-depth reviews, and inspirational stories, accessible by all ages and skill ranges.” <https://makezine.com/>

the Journeys of June that took place that year in Brazil, demanding a reduction in public transport fares, raising debates on urban mobility and with a direct influence from the high school student movement and working classes. The project was developed to support popular mobilisations by providing a *mesh* network for permanent movement, collecting digital records produced by protesters in front of the repressive actions of the police. Instead of discussing the effectiveness of this specific action, the focus is to point out the confluence of factors that culminated in its simultaneous design and execution process based on the structure of the Tarrafa HC. That experience is now revisited ten years later as a starting point for a reflection on the relevance of the principles inherent in the hacker ethos and as an invitation to think about the future of our relationship with technology and control relationships.

Finally, we understand hackerspaces as complex self-organised systems and identify tendencies that constantly oscillate between order and chaos within them. One of these tendencies is related to the *rules* and *protocols* for communication, use of space, and members' association, while the other is related to clutter and scrap accumulation, unfinished projects, and the variety of interests and backgrounds of its members. Therefore, we can make sense of the dynamics of operation that have been recognised in complex systems studies as *the edge of chaos*. This term, in fact, encapsulates much of what can be associated with this particular type of space, with its volatility and dissemination.

### **The maker movement vs. the hacker ethos**

The renewed focus on technological DIY practices in the last years, coupled with more available but still expensive machinery and the high price of the urban land, has catapulted the proliferation of shared machine shops in all kinds of genres. While some of these spaces are commercial initiatives like the former TechShops, or models developed in research facilities such as MIT's FabLab, others, such as makerspaces and hackerspaces, are more or less independent and self-organised. We should point out that the difference between maker- and hackerspaces is not objective and definitely not consensual, but we can say that they mirror the same kind of difference that the images of the maker and the hacker have.

A few years ago, the word “maker” would have sounded strange in the context that it is now used—as writer and curator Justin McGuirk once pointed out (McGuirk et al., 2014), besides the religious expression “God, Maker of all things,” it was not a frequently used term. With the advent of the maker movement, even people from parts of the world that do not have English as their main language are identifying themselves by this word. Dale Dougherty first proposed the now common meaning of the word in the editorial of the premier edition of the North American DIY magazine *Make*: “More than mere consumers of technology, we are *makers*, adapting technology to our needs and integrating it into our lives.” (Dougherty, 2005, p. 7). The term and the American idea of liberal autonomy were linked from the beginning. Bre Pettis, co-founder of MakerBot Industries (a 3D printer company), summarised this connection in a very direct way: “making today is two clicks away from becoming an entrepreneur” (Pettis, 2015). For the artist Garnet Hertz (2015), the maker could be seen as the outcome of the hacker minus the intrinsic politics and controversy that come with this later image.

The idea of the hacker is, comparatively, an older one. Between *builders* and *breakers*, different meanings and interpretations have evolved and overlapped since the term was first consistently used in the 1960s (Coleman, 2014). First applied to designate a group of computer enthusiasts based at the Massachusetts Institute of Technology (MIT) who “courted contingency, disregarding norms or rules they thought likely to stifle creative invention” (Coleman, 2016, p. 158), by the early 1980’s the hacker had become an archetype, being displayed in popular culture as a powerful digital criminal. More than a simple dichotomy, hacker practices are very heterogeneous—from the hacker underground to Free Software, passing through Anonymous, WikiLeaks, and hardware hacking and hackerspaces (our focus here in this article), we have no shortage of examples (Coleman & Golub, 2008; Coleman, 2011). Even with the multifaceted aspect of these practices, ethics, and values, it is possible to identify a general ethos that is articulated by subgroups in different ways. What we call here the *hacker ethos* is a cultural underlying belief that guides the ways of living in the world—what a person is able to conceive and is willing to do. This ethos is connected with ideals of human freedom, articulating through technology issues of work and leisure, production and idleness, value and futility, learning and expertise, autonomy and collaboration.

On another point, it is interesting to see the parallels between the histories of hacking, the evolution of the computer industry and cybernetic thinking. If the maker movement is linked with the popularisation of personal fabrication tools, the hacker has always been in the midst of social-technological development and transformations.

### **Cybernetic systems and complexity: tools for understanding**

The term cybernetics denotes a field of study for the strategic use of control and communication processes in systems constituted by human and non-human entities—initially referred to by Norbert Wiener as the animal and the machine. This notion still raises strong criticism since its origin can be considered a deployment of the World War II military field operations research, enabling later all sorts of computational and decentralised control systems with which we are confronted today. Beyond its warlike roots and initial preoccupation with the question of control, cybernetics is notable for its systemic and pragmatic view of observable phenomena. Ernst von Glasersfeld (1992, p. 1) proposes his particular definition for the field as "a way of thinking, not a collection of facts." This conception reveals the field's later concern with constructing understandings about the world, changing the focus of objective reality—a modern vision—to the construction of viable models to act in the world. It is thus to identify certain patterns that will be treated as systems using resources and tools that allow us to act on and from them.

Systems are defined by the British cyberneticist Stafford Beer (1967, p. 7) as "any cohesive collection of dynamically related items". Further differentiations associate other qualities with systems, i.e. oriented toward a specific goal or purpose (Meadows, 2009). John Holland (2014), a mathematician who developed the genetic algorithm, proposes that systems be considered complex if they exhibit emergence, that is, an overall behaviour that is not the mere sum of the behaviours of its isolated parts. However, Horst Rittel (1992) presents a conception capable of encompassing and conciliating others by synthesising systems as reflections of one's understanding of something. Thus, considering environments like hackerspaces as complex systems comprises both a particular aspect of our own comprehension of a phenomenon and a practical understanding of the internal dynamics provided by the interaction between its parts. Still, according to Beer (1967), systems of such complexity are characterised by

their adaptability, reflected in their ability to maintain their organisation against external or internal disturbances. For the author, external perturbations denote the intense relationship between complex systems and the environment in which they are inserted, while internal perturbations refer to the number of possibilities available to the system—synthesised by Ross Ashby (1956) in the term “variety.” In other words, adapting means learning through the accumulation of experiences—*inputs*—and the production of responses—*outputs*—appropriate to the transformations of the context while also acting on it—*feedback*. This process ensures the maintenance of the integrity of the system and its continuous adjustment. This process is what cybernetics generally defines by *circularity*, a major focus of interest to the field.

We should consider that the concepts outlined above could help us to understand complex social organisations and have, in fact, been used for this purpose in trying to identify trends and predict risks, i.e., weather predictions and market fluctuations. They are, therefore, models of simplification, which certainly do not invalidate them, but it is always important that we recognise their limitations, especially when we talk about complex and chaotic systems. John Holland (1997) was one of many authors who argued about the nature of models as attempts to reduce the chaos of the world to treatable and computable levels. For him, the ancient sacrifice to the gods and the invention of mechanisms and computers represent our eternal search for progressively more complex explanatory models.

### **The edge of chaos or a place where new ideas emerge**

A conceptual model may be useful to understand the functioning of self-organised systems; it can be identified in the study of complexity theory that deals with systems whose dynamics between entities escape any attempt of external control. Systems such as weather, economic and social systems generally belong to this specific class.

Within this type of system, as suggested by biologist Stuart Kauffman (1993), there are tendencies that alternate between crystallisation and dissolution. The evolutionary space, for the author, is the space that we could consider as the space for creation. The edge of chaos is a constantly shifting zone—between stagnation and anarchy—where a complex system can achieve spontaneity, adaptation and even life. For some biologists like Kauffman, it is a basic principle of evolutionary systems: when a system acquires the

ability to bring order and chaos into a special kind of balance, it is when its components never lock into place and yet never quite dissolve into turbulence, either. Other complexity scientists like Holland (2014) argue that the same principle can be applied to social and economic systems, as well as promote an understanding that surpasses the linearity and predictability of the Newtonian vision of the world. Since then, the complexity approach has been applied in diverse computational simulations, and its adoption here allows us to understand in a very didactic way the phenomenon of the emergence of new patterns, which is analogous to the idea of innovation.

### **Hackerspaces are not about problem-solving or making money**

Here, we will approach hackerspaces as a specific type of socio-techno system and a particular genre of the contemporary trend of shared workshops. We will highlight certain aspects and characteristics already identified by scholars, which can also be understood through the lenses of cybernetics and complexity theory.

Bringing back a term first used by Karl Hess in the late 1970s, shared machine shops is a definition used in the peer production field of study (Troxler, 2010) to draw together new kinds of spaces where a group of people can share resources. Its dissemination during the last decade is due, among other things, to significant technological developments that have made economically more accessible resources and tools that previously would only be found in the largest university laboratories or research centres of companies.

Like other shared spaces, hackerspaces are more or less permanent physical places where various activities can happen simultaneously. However, unlike more market-oriented or institutional spaces, they are usually self-organised, and many of their activities cannot be considered productive in the usual sense of the word. People come together or interact to have casual conversations or simply to meet for no specific purpose. In hackerspaces, we can find variety in the different backgrounds, objectives and interests of its members or in the diversity of resources and artefacts available, just to name a few.

Members and academics seem to agree that hackerspaces can be understood as a *third place* (Moilanen, 2012; Schrock, 2014). This concept, already defined by the sociologist

Ray Oldenburg (1999), refers to informal settings that foster broader and more creative community interactions distinct from one's home or workplace. Informality, flexibility in relationships, and detachment from labour are key characteristics that underpin the functioning of these spaces. In our perspective, such spaces are tied to what we defined in a previous section as a *hacker ethos*. In hackerspaces, we find echoes of these values in their practices and operations, as well as in their exploratory, critical, and creative positioning in relation to technology and its relation to the world. Rather than being seen as a means to meet previously defined clear goals, hackerspaces should be seen as places where goals, motivations, and desires can be explored, discovered, and constructed. This perspective is radically different from the mere problem-solving approach, where many designers seek to explain the creative process—or innovation—to satisfy the market economy. We believe that hackerspaces should not be treated as centres for this kind of innovation—and to consider them in this way will probably result in great frustration—but as complex systems where emergent collective creativity could be found.

### **A design pattern is a dive into contingencies**

It is important to understand that hackerspaces do not constitute a closed formula for ready applications like FabLabs, which have rigid dispositions describing an ideal laboratory layout with complete specifications for tools and software and community actions. In turn, hackerspaces deal with contingencies and the accumulation of shared experiences directly between individuals, usually through forums, email lists, or meetings. They adapt themselves to an ongoing learning process.

In a curious way, we see that among the information shared within the network of hackerspaces, we have at our disposal a framework of *design patterns*—a name usually linked to software programming (Gamma, 1995) but with direct inspiration in the work of the architect Christopher Alexander and his language of patterns (1977). Based on initial documentation presented at the *24th Chaos Communication Congress* in Berlin in 2007, the design patterns continue to be updated collectively and can be found on the collaborative website maintained by a group of people responsible for mapping and dissemination of information about hackerspaces. (*HackerspaceWiki*, n.d.)

In contrast to a fixed set of rules that determine the set of possibilities and leave little space for creativity, design patterns act as *constraints* that help to recognise ever-changing disruptive situations. The difference between determining what should be and what is not may seem too subtle, yet it is what guarantees the flexibility and adaptability of a hackerspace. This discussion has been elaborated for some time now within the framework of cybernetics. (Fischer and Richards, 2017)

Recurring issues diagnoses were compiled from the experiences of other spaces and, with them, possible ways to overcome difficulties, such as the sine curve pattern, related to maintaining recurring activities and engaging regular and visiting members. In the example above, the pattern suggests there is a four-year cycle described by a bell curve. In this case, the solution would be to keep things running do not give up because it is likely that in two years, the hackerspace will overcome the low curve, resuming its dynamism. In addition, one can hope for an exciting new member to appear at the door. This example illustrates how these and other issues are handled in an open and unobtrusive way.

The fact that hackerspaces operate based on the notion of patterns holds great significance in understanding their organisation and resulting outcomes. Once again, contingencies are consistently assimilated by the flexible and adaptive structure, giving rise to ad-hoc solutions as needed and discarding them when they cease to be useful. As a result, the incorporation of patterns can vary for each location and context, enabling hackerspaces to prioritise the values and specific interests of their members. Certain applications may eventually evolve into new patterns and become accessible to the entire community.

### **Tarrafa Hacker Clube—a Brazilian case**

A particular fact about the Brazilian context is a perceived inclination towards the appropriation and transformation of technologies and artefacts. Such is described locally by the term *gambiarra*—something like the creative improvisation from available materials—which, in a way, reflects the condition of a peripheral economy in global capitalism that always seeks to do as much as possible from scarce resources. Thus, during the 1980's, a scene emerged for the cloning and modification of games and consoles, which until then were difficult to access. The scene of the Brazilian *modders*

became internationally known to the point that, at the time, they had attracted the attention of major technology industries. This is just one of many examples that demonstrate that, although the terms hacker and hackerspace were brought from abroad, the values they represent were already present in the cultural life of the country.

The Tarrafa Hacker Clube (HC) was the first active hackerspace in the city of Florianopolis, located in the south of the country, hosting events, workshops and regular meetings at its headquarters. Its structure, based on the design patterns, adapts to the particular context of the southern region, transforming it into a specific case that deserves our attention. Our experience as co-founders of Tarrafa HC in 2012 and our academic background allow us to identify many of the already generalised aspects of this type of space, like focus on collective learning, experimentation involving digital technologies and a varied community covering architects, engineers, programmers, artists and hobbyists in general. The hackerspace incorporates the local culture of the *gambiarra* while continuing the trend initiated by European spaces such as c-base and Metalab—the first contemporary hackerspaces—incorporating strongly the references of American spaces such as Noisebridge and NYC Resistor and still with great influence of Garoa HC, the first Brazilian hackerspace and the most active promoter of the movement in the country.

However, as the subject of this study, it is worth highlighting which elements have made The Antenna Uprising—an example of what we define as emergent collective creativity—to be started at the Tarrafa HC. The Tarrafa HC has as its main specificity its close connection with the local public university, mainly because it was initially composed almost exclusively of computer science and engineering students from the institution. This factor also leads to a high turnover of its members who enter and leave the university every year, which, from time to time, leads to a complete restructuring of its operations. Another striking element that we think deserves special mention is the fact that while contradicting some of the basic guidelines for this type of organisation, the hackerspace came to occupy a room available on a temporary basis within the university's architecture department. Its friendly relationship with the departmental administration has fostered the development of fruitful experiments, such as bridging two disciplines to facilitate architecture students' understanding of technological

hacking and promoting direct action within the space. However, institutional independence has always been maintained despite the fact that Tarrafa HC is still located in the same space as the architecture department.

From the foregoing, we found that at least three entities act in the constitution of hackerspaces: individuals, artefacts and the physical space. Thus, equalised, both human and non-human elements are dynamically interrelated in what is observed as a complex system of adaptive characteristics and emergent behaviour. Behymer and Flach (2016) build on the idea of collaboration, proposing a model comprised of actors or agents, both human and non-human, in many ways similar to Latour's Actor-Network Theory or even the cybernetics approach. In our particular case, we emphasise the physical space itself as a special kind of agent, which has been overlooked in many cases. (Figure 1) It is interesting to realise that in this type of organisation, fluctuations in socio-technological context are quickly incorporated into the system, increasing its variety. Although terms like systems, emergency, adaptation or variety have been assimilated and trivialised by the vocabulary of contemporary business schools, if taken in their original meanings from cybernetics, constitute a possible way to understand how the creative process develops over time, which in these spaces is intrinsic to the way the system itself is structured. In this sense, we can assume that both the hackerspace system and the practices developed within it are fundamentally isomorphic (Baldwin & Clark, 2000).

### **The Antenna Uprising**

Among several projects and practices developed through the Tarrafa HC, we are highlighting the Antenna Uprising as a manifestation of what we are calling emergent collective creativity. This techno-political action took place in Florianopolis in the midst of a series of mobilisations that took the Brazilian streets in the year of 2013. The Journeys of June, as they became known, followed the global momentum of self-organised and decentralised movements like the Arab Spring and the Occupy. Later, this moment of insurgency proved itself to be the starting point of a turbulent political phase in the country, which culminated in the impeachment of the then-president and was followed by the rise of a far-right government in the last presidential elections.

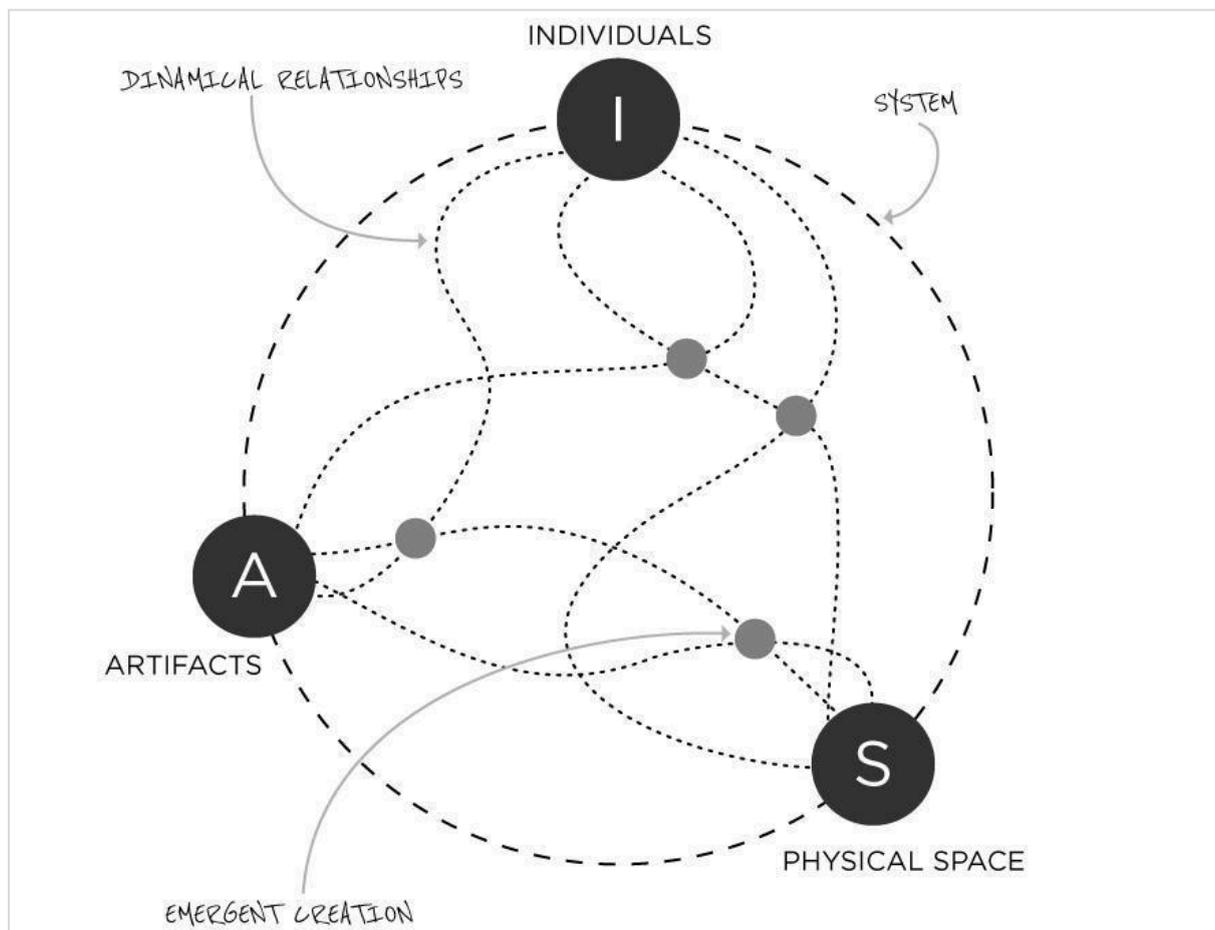


Figure 1. Hackerspaces as complex systems formed by the dynamical relations between human and non-human entities or actors. This kind of relationship usually leads to emerging creations.

With the abrupt end of the Workers' Party administration, we are now entering a time of uncertainty concerning the future of countless social and labour achievements obtained during the previous period. Nevertheless, beyond the broader Brazilian representative politics, *the Antenna Uprising* made a local contribution within the free/independent media context with the development and implementation of a special kind of wireless mesh network infrastructure intended to support personal live broadcasting, especially police misconduct during the mobilisations.



Figure 2. The antenna conveyors at one of the many mobilisations in 2013.

Internet access to the protesters was made possible through the creation of a mobile infrastructure of access points interconnected in a mesh topology—a network in which each node receives and retransmits data, cooperating for its stability and distribution. This infrastructure was a set-up formed by battery-powered routers mounted in construction safety helmets that were to be carried through the streets by volunteers called *anteneiros* (meaning something like the antenna conveyors). At the manifestations, these devices were to be connected to each other and to access points openly available on the route, and in this way, amplify the internet signal to other protesters (Figure 2).

We are not capable of pinpointing the person who came up with the idea for this action and, even less, one responsible for its realisation. Even though one of the members already had a project for an independent urban mesh network, and others had the coding and hardware expertise to do this kind of technical work, it was only at that moment that something else emerged. In that context, within a short period of time, several people from diversified backgrounds became involved, and, with a creative and operational synergy, a series of self-appointed tasks and responsibilities made this experience a reality.

These people contributed with different abilities following their own personal interests. In that we identify similarities with some Free-Libre Open Source Software (FLOSS) organisation principles—the modularity and granularity of tasks—but in an organic, not as formalised, manner. Some of the activities involved the creation of a Facebook page for divulgation, the development of physical and digital posters, the programming of the software used and the assembly of the helmets with the hacked Wi-Fi routers powered by 12V DC batteries (Figure 3). This project had great repercussions in online media and social networks, both local and nationwide, and its example inspired groups in other regions of the country.

### **Some considerations**

This paper demonstrates how a widely accepted interpretation of the concept of innovation emerges from the alignment between a liberal economic model and the notion of the creative and individual entrepreneur. This cultural construct finds resonance, particularly in the technology field, where a distinct type of innovator has emerged: the maker, with their unique set of expertise and values synthesised by the maker movement. In contrast, we present the figure of the hacker, closely linked to the development of computing itself, as well as the disciplinary field of cybernetics, which serves as our analytical lens in this study.



*Figure 3. Some of the equipment created for The Antenna Uprising: construction safety helmets combined with hacked Wi-Fi routers.*

Our aim was to shed light on a contemporary phenomenon that feeds on the creative and questioning spirit of the hacker materialising in the growing number of new shared spaces around the world. The hackerspaces, however, go beyond the simple definition of shared machine shops; they are places with great transformative potential for contemporary production practices, often opposing market assimilation attempts and even traditional notions of labour. Our experience as co-founders of a hackerspace and our immersion in this culture enables us to simultaneously assume the roles of observers and actors within a complex system. This system can be simplified as the fortuitous result of the interaction among three main elements: a community eager to learn together, technological artefacts, and a stimulating and welcoming physical space. The Antenna Uprising was a specific event whose origins and development are not easily identifiable. Our argument proposes that such action should be taken as a result of an emerging collective creative process in complex social organisations such as

hackerspaces. In the particular case of Tarrafa Hacker Clube, we tried to demonstrate that there is a mirroring between its organisation and its internal dynamics that, in addition to the Antenna Uprising, produced and continues to generate new projects, actions, and impacts.

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