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MAIN SECTION

First Exploratory Geographical and Social Maps of the Maker Movement

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ABSTRACT

The Maker Movement emerged in the last decades through a mix of both bottom-up and top-down initiatives, promotions, communities and companies, informal experimentations and rigorous research projects. The result is a global system of design and making actors localized in community places of Maker Laboratories such as Fab Labs, Makerspaces, Hackerspaces, DIYBio Labs, Repair Cafes and so on. This contribution explores the first maps of the Maker Movement in terms of geographical distribution and of architecture of social networks of its Maker Laboratories and proposes a specific data analysis for each of these two directions. This article draws an overview of the social, local and global nature of the Maker Movement and of its laboratories, with the overall aim to provide spaces for democracy, participation and citizenship.

KEYWORDS

Maker Movement; Geographical Distribution; Social Network Analysis; Mapping; Community.

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1 Introduction

The development and application of digital technologies have already been in expansion for several decades, with relevant social and economic impacts. The Dotcom bubble was a clear example of the extreme enthusiasm towards such technologies, a phenomenon that has probably never completely disappeared[1] since the rate of digitalization, datafication and financial investments and economic impact has not decreased. However, the explosion of the bubble also triggered a backlash against an innovation focusing only on the digital dimension, showing the dangers of forgetting the physical, local and making dimensions of innovation.

An example of such newly-found interest can be found in the Maker Movement, which emerged in the years immediately after the Dotcom bubble. The start of the Maker Movement is usually associated with the launch of the MAKE Magazine by Dale Dougherty in 2005, conceived with the goal of promoting technology, creativity and fun.[2] Since the beginning, the term was chosen to be as broad and appealing as possible, shaping a global community, a movement, and a market at the same time. The Maker Movement emerged then through a mix of bottom-up initiatives and top-down promotions, communities and companies, informal experimentations and rigorous research projects, resulting in a global system of design and making actors. The social and local dimensions have always been a key trait of the movement, for example in collaborative efforts such as local events (Maker Faires, for example) and in laboratories that provide access to digital fabrication technologies: Fab Labs, Makerspaces, Hackerspaces, DIYBio Labs, Repair Cafes, Sewing Cafes and so on.

If the Maker Movement is particularly relevant for mixing digital and analog, global and local, competitive and collaborative issues through a social movement, how could we understand them? How can we move away from talking about the social and local dimensions of the Maker Movement as one-dimensional points on a vague map, and move towards a more nuanced, layered and complex understanding of its architecture? This article explores these questions. It reviews the first maps of the Maker Movement, its geographical distribution and the architecture of social networks, drawing an overview of the social, local and global nature of the Movement and its laboratories. The overall aim is to understand where and with which social structure the Maker Movement is distributing spaces for democracy, participation and citizenship. This contribution explores the general research question (RQ0): how can we design maps of the Maker Movement? This broad research question is operatively organized into two sub-questions:

1. Ben Geier, "What Did We Learn From the Dotcom Stock Bubble of 2000?," *Time*, March 12, 2015. Accessed January 21, 2020, http://time.com/3741681/2000-dotcom-stock-bust/.

2. The Blueprint, "An Interview with Dale Dougherty," The Blueprint, May 13, 2014. Accessed June 14, 2016, https://theblueprint.com/stories/dale-dougherty/.

1. (RQ1) How can we map the geographical distribution of the Maker Laboratories?
2. (RQ2) How can we map the social structure of the Maker Laboratories?

Ultimately, addressing these research questions could improve our understanding of where makers are and how they are connected, in turn contributing to more refined definitions of the Maker Movement. Maker Laboratories are the main focus of this research, considered as a proxy of both the Maker Movement, being largely constituted of laboratories and because makers often meet in such laboratories. This article adopts a mixed methodology for each question, consisting of a literature review of previous analyses, and a data analysis of existing datasets from online platforms.

After this introduction (1), the next section (2) details models that can be used as conceptual maps for navigating the complexity of the Maker Movement and for understanding how to best map its distribution and structure. The geographical distribution of Maker Laboratories is analyzed in the following section (3) replying thus to RQ1, through a literature review of existing contributions and through a custom analysis of a dataset containing data of the distribution of Fab Labs, DIYBio Labs and Hackerspaces from three different platforms. The social structure of the Maker Laboratories is analyzed in order to reply to RQ2 (4), with a literature review first and then with the replication of an early analysis of Maker Laboratories on Twitter in order to investigate the evolution of the community after several years. The results are then contextualized within the limitations of this research and with potential future endeavors (5).

2 Conceptual models of the Maker Movement as exploratory maps

2.1 Models of maker roles and identities

The literature review of this section revolves around conceptual models of the Maker Movement presenting conceptual maps as another type of exploratory maps. These are models of who and where makers and their laboratories are and how they could be found, analyzed and understood, in a sense-making effort for orienting their exploration. The first model depicts the roles and identities of makers as the starting point for understanding the nature, distribution and social dimension of the Maker Movement.

The definition of maker proposed by Dougherty and MAKE Magazine is broad and fuzzy enough to promote the growth of a global phenomenon,

but less clear for analyzing and organizing it.[3] Chris Anderson improved the definition with specific practices and principles based on: a) digital design and prototyping; 2) a shared practice of collaboration and sharing of projects; 3) digital fabrication technologies and spaces.[4] Makers can be considered (and often are) designers or a new kind of designers, be them formally trained and employed or informally active and self-taught. Often working with open, peer-to-peer, distributed and Do It Yourself (DIY) approaches in a collaborative way,[5] makers adopt digital fabrication technologies[6] and work often for cultural change,[7] educational[8] and social[9] purposes, beside entrepreneurial ones.[10]

If anybody can be a maker,[11] then the identity of a maker is likely to result from the integration of different profiles, roles, knowledge, practices and identities. Therefore, an exploratory approach to start addressing the complexity of makers' profiles can be developed through a simple model[12] that enables to view the roles and identities of makers in a more nuanced and layered way. Within this model, the makers' identity is the result of the integration of different roles and practices that concur for the same common purpose of their initiatives [Fig. 1]. Depending on the nature of the common purpose, several versions of this model of makers' identity could be elaborated: for example one for makers working with social innovation;

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3. Dale Dougherty, We Are Makers (TED@MotorCity, 2011), accessed January 21, 2020, http://www.ted.com/talks/dale_dougherty_we_are_makers; The Blueprint, "An Interview with Dale Dougherty."

4. Chris Anderson, *Makers: The New Industrial Revolution* (New York: Crown Business, 2012).

5. Yekta Bakırlıoğlu and Cindy Kohtala, "Framing Open Design through Theoretical Concepts and Practical Applications: A Systematic Literature Review," *Human–Computer Interaction* 0, no. 0 (February 22, 2019): 1–45; Massimo Menichinelli, "A Framework for Understanding the Possible Intersections of Design with Open, P2P, Diffuse, Distributed and Decentralized Systems," *Disegno—The Journal of Design Culture* III, no. 01–02 (2016): 44–71.

6. Neil Gershenfeld, "How to Make Almost Anything: The Digital Fabrication Revolution," *Foreign Affairs*, 2012; Neil Gershenfeld, *FAB: The Coming Revolution on Your Desktop--From Personal Computers to Personal Fabrication* (New York: Basic Books, 2005).

7. Elizabeth Garber, Lisa Hochtritt, and Manisha Sharma, eds., *Makers, Crafters, Educators: Working for Cultural Change*, 1 edition (New York, NY: Routledge, 2018).

8. Lee Martin, "The Promise of the Maker Movement for Education," *Journal of Pre-College Engineering Education Research (J-PEER)* 5, no. 1 (2015): 4; Sylvia Libow Martinez and Gary S. Stager, *Invent To Learn: Making, Tinkering, and Engineering in the Classroom* (Torrance, Calif.: Constructing Modern Knowledge Press, 2013).

9. Elisabeth Unterfrauner and Christian Voigt, "Makers' Ambitions to Do Socially Valuable Things," *The Design Journal* 20, no. sup1 (September 6, 2017): S3317–25.

10. Markko Hamalainen and Jesse Karjalainen, "Social Manufacturing: When the Maker Movement Meets Interfirm Production Networks," *Business Horizons*, THE GENERATIVE POTENTIAL OF EMERGING TECHNOLOGY, 60, no. 6 (November 1, 2017): 795–805; Eric Joseph Van Holm, "Makerspaces and Contributions to Entrepreneurship," *Procedia - Social and Behavioral Sciences*, World Conference on Technology, Innovation and Entrepreneurship, 195 (July 3, 2015): 24–31; Russell E. Browder, Howard E. Aldrich, and Steven W. Bradley, "The Emergence of the Maker Movement: Implications for Entrepreneurship Research," *Journal of Business Venturing* 34, no. 3 (May 1, 2019): 459–76.

11. Dougherty, *We Are Makers*.

12. Massimo Menichinelli, Alessandra Gerson Saltiel Schmidt, and Priscilla Ferronato, "Mapping Strategies for Distributed, Social and Collaborative Design Systems of Makers, Designers and Social Entrepreneurs," *Conference Proceedings of the Academy for Design Innovation Management* 2, no. 1 (November 30, 2019).

another one for makers working with commercial purposes or for cultural purposes, and so on.

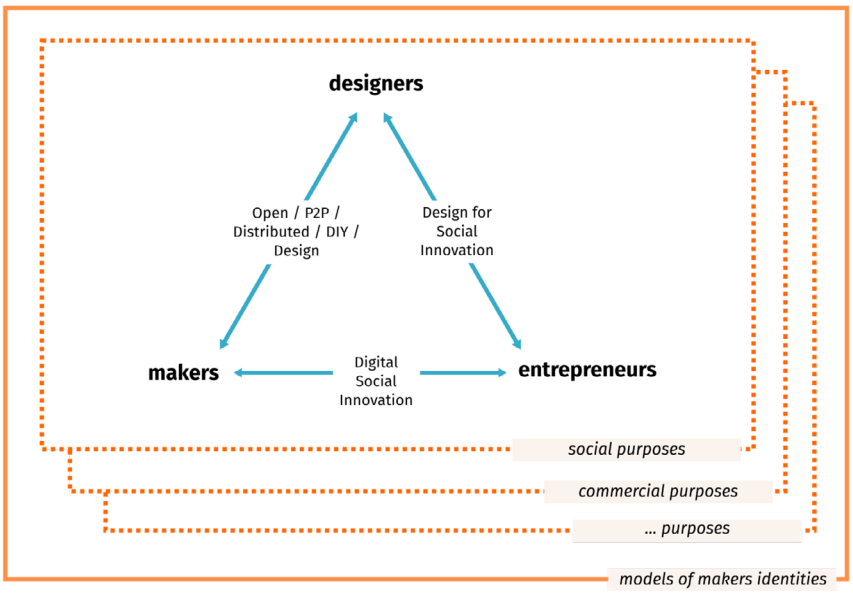

FIG. 1 A model for defining different identities of makers according to their purposes*

2.2 Places, communities and scales of the Maker Movement

A second map for navigating the Maker Movement can be drawn for representing a model of the different communities that can be found in the movement, and how they interact among each other and at which scale they operate. Such communities can be found on three levels and with a cross-cutting socio-technical dimension of digital platforms [Fig. 2]:

1. Local: communities that form in and around local laboratories and events.
2. Global: a global community emerging all the local events and laboratories. This will be explored in depth in section 4, especially with an updated analysis (4.2).
3. Projects: the communities that form around the development of projects which are typically prototyped and manufactured locally in the laboratories; projects could also be completely global, especially when developed digitally in a common repository.
4. Digital platforms: a cross-cutting dimension that connect the previous three scales, for example for sharing projects openly as Open Design, which then become community-based initiatives. This will be explored in section 4, in the literature review (4.1).

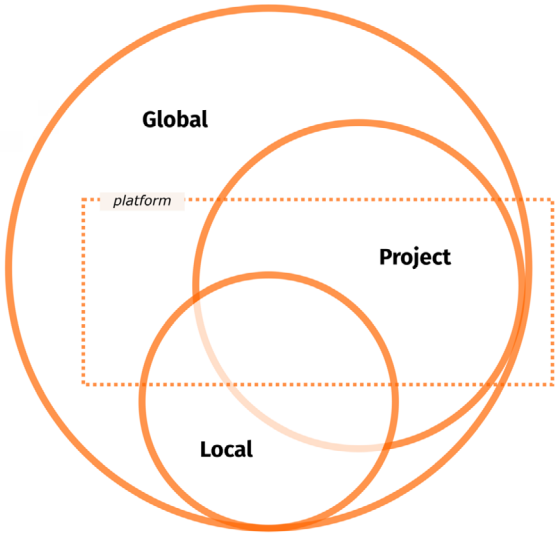

FIG.2 Model of the types of communities in the Maker Movement at different scales, and the dimension of digital platforms

2.3 Models of Maker Laboratories

Different practices and roles constitute who makers are and how their communities work at different scales and dimensions: as a result, we find different places with specific traditions, practices, technologies, business models and values [Fig. 3].

Roots of Maker Laboratories can be tracked back to the Hacklabs movement, which started around 1995 and peaked around 2005: voluntary-run spaces that provided access to machines with GNU/Linux and Free Software, programming and electronics as a physical and local platform for developing and promoting the hacker culture, autonomous movement and media activism, post-capitalism and alter-globalization politics. Hacklabs typically have a strong political agenda, and they share overlapping but different trajectories with Hackerspaces, less politically inclined and more widespread.[13] Hackerspaces started as well in the 1990s, and went through three waves, and only recently they flourished with a stronger effort on the organizational dimension and focus on the physical dimension of hacking, from microelectronics to 3D printers.

Fab Labs emerged, almost by accident, as the outreach and democratization of the work of Neil Gershenfeld at MIT on digital fabrication as the key translator between bits and atoms, of information and matter.[14] This is the main focus of Fab Labs, at least at the technological level: it is not by accident that the concept has been developed at MIT at the Center for Bits

13. Maxigas, "Hacklabs and Hackerspaces. Tracing Two Genealogies," *Journal of Peer Production*, no. 2 (July 2012).

14. Gershenfeld, *FAB*; Gershenfeld, "How to Make Almost Anything: The Digital Fabrication Revolution."

and Atoms,[15] not at the High-Low Tech[16] research group. Fab Labs offer a partially defined and shared set of tools, processes and knowledge for developing physical representations of digital data, for extracting digital data from physical contexts and for experimenting how digital technologies can influence the development of physical objects. Furthermore, the Fab Lab community focuses on sharing same protocols, practices, communication channels and initiatives in order to enable any project to be replicated everywhere.

Makerspaces are similar places, but with less focus on the digital dimension of making and more on the analog one; they are sometimes considered as the main term for representing the whole formats of Maker Laboratories. However, sometimes they can be clearly defined as a separate community from Fab Labs and other labs, and are often promoted by MAKE Magazine.[17] Several different approaches at organizing Makerspaces can be found: one example is the now-defunct network of TechShops, who were typically ten times larger than a Fab Lab and with a more entrepreneurial approach than a community-driven one.[18] Sewing Cafes[19] are similar places but with the goal of enabling their members to work with textiles and fashion. Repair Cafes, emerged in Amsterdam in 2009, are also related, but with a specific focus not on making but on fixing existing commercial products for local neighbors.[20]

The same hacker ethic of sharing knowledge, free access and collaboration[21] has been adopted and promoted by the DIYBio Movement and its members:[22] DIYbiologists have expertises and experiences different from the makers' ones, but share with them some common principles, representing thus a similar culture and community. The DIYBio Movement aims at democratizing access to research in biotechnology, and this approach is increasingly adopted within the Maker Movement, for example for the design of 3D printers that employ orange juice and

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15. http://cba.mit.edu/, accessed January 16, 2020.

16. http://highlowtech.org/, accessed January 16, 2020.

17. Adam Kemp, *The Makerspace Workbench: Tools, Technologies, and Techniques for Making* (Sebastopol: Make Books, 2013).

18. Mark Hatch, *The Maker Movement Manifesto. Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers* (New York: McGraw-Hill Education, 2014).

19. Anja-Lisa Hirscher and Ramia Mazé, "Stuff Matters In Participation: Infrastructuring A Co-Sewing Café," *Journal of Peer Production*, no. 13 (April 2019), accessed January 21, 2020, http://peerproduction.net/issues/issue-13-open/peer-reviewed-papers/stuff-matters-in-participation/.

20. Sven Eberlein, "How to Start a Repair Café," *Shareable* (blog), March 29, 2013. Accessed January 21, 2020, https://www.shareable.net/how-to-start-a-repair-cafe/; Darren Sharp, "The Repair Café Foundation Builds Community by Fixing Things," *Shareable* (blog), March 6, 2018. Accessed January 21, 2020, https://www.shareable.net/the-repair-cafe-foundation-builds-community-by-fixing-things/.

21. Pekka Himanen, *The Hacker Ethic and the Spirit of the Information Age* (New York, NY, USA: Random House Inc., 2001).

22. Alessandro Delfanti, *Biohackers: The Politics of Open Science* (London: Pluto Press, 2013), accessed January 21, 2020, http://escholarship.org/uc/item/5fq395w7.

modified bacteria instead of plastic filament.[23] This connection between the Maker Movement and the DIYBio movement has also been fostered by MAKE Magazine and Maker Faires with the perspective that biology could be considered as a 'personal technology' just like making and digital fabrication.[24]

A third conceptual map can be drawn to communicate the dimension and connections among such type of laboratories. This is a preliminary, hypothetical map based on the experience of the authors, who have not only been just researchers and professionals of the Maker Movement, but also participants of several of its communities for years **[Fig. 3]**. Fab Labs, Hackerspaces and Makerspaces are shown with a larger size since they are the main formats in terms of status of development, distribution, number of places and popularity. Because of this, they often tend to include other spaces (Repair Cafes, Sewing Cafes, DIYBio Labs) or at least part of their technologies, practices and communities. The overlaps between these formats are related to the making and entrepreneurship activities that connect them, building opportunities for recognition, the

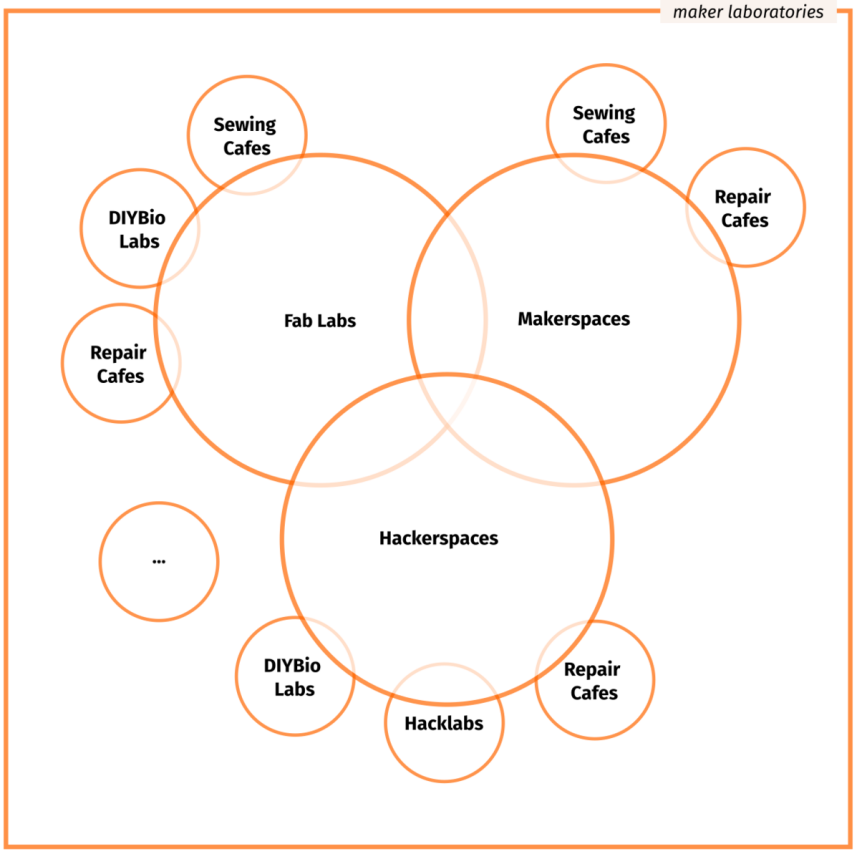

FIG. 3 A conceptual model of the types of communities in the Maker Movement based on the experience of the authors

23. Allan Alasdair, "3D Printing Using Genetically Modified Bacteria and Orange Juice," Make: DIY Projects, How-Tos, Electronics, Crafts and Ideas for Makers, November 15, 2014. Accessed January 21, 2020, http://makezine.com/2014/11/15/3d-printing-using-genetically-modified-bacteria-and-orange-juice/.

24 Sara Tocchetti, "DIYbiologists as 'Makers' of Personal Biologies: How MAKE Magazine and Maker Faires Contribute in Constituting Biology as a Personal Technology," *Journal of Peer Production*, no. 2 (July 2012). Accessed January 21, 2020, http://peerproduction.net/issues/issue-2/.

construction of communities, the exploitation of value created, as well as possibilities for replication of social innovation initiatives. As a consequence, the emerging landscape is a holistic ecosystem of value creation for societal change. Section 4.2 provides a data analysis for the validation of such simple and conceptual map.

3 First maps of the geographical distribution of the Maker Movement

3.1 Literature review

Maker Laboratories often act as (or are part of) schools, community hubs and professional centers where the Maker Movement has been emerging and building social and collaborative initiatives. Because of the often bottom-up nature of the movement, the number of these laboratories is always changing, making it difficult to be completely tracked over time. Their amount is of strategic importance as it could be considered as a proxy of the overall number of makers by considering each local community, through the estimation of average quantities or by directly contacting laboratories to receive a more accurate estimate.

The "Makers' Inquiry" initiative[25] aimed to explore the emergence of the phenomenon in Italy, in its first years. It proposed that the geographical distribution of the Maker Movement could be assessed from different places where makers "make" their making activity (home, office, co-working, workshop, artisan workshop, school or university, factory, Maker Laboratories and so on). The most interesting fact is that these activities are carried out in a range of different places and that these places could be complementary to each other: not only Fab Labs, but also schools, studios and at home. Most of those laboratories were found to be located in North and Central Italy, and therefore may be directly linked to the local industrial traditions, and they are hosted in places more related to crafts, business and production rather than research and education. A similar distribution was found in another research about Maker Laboratories in Italy.[26]

Another initiative analyzed laboratories in France,[27] exploring it with a "tour of the labs" experience. It is not only as a way to identify the distribution of Maker Laboratories, but also to get in touch with makers' peers, learn new practices, while helping to animate the network.

The Joint Research Centre (JRC), the European Commission's science

25. Massimo Bianchini et al., *Makers' Inquiry. Un'indagine Socioeconomica Sui Makers Italiani e Su Make in Italy* (Milano: Libraccio Editore, 2015), accessed January 21, 2020, http://makersinquiry.org/.

26. Massimo Menichinelli and Alessandro Ranellucci, "Censimento Dei Laboratori Di Fabbricazione Digitale in Italia 2014" (Roma: Fondazione Make in Italy CDB, February 26, 2015), accessed January 24, 2020, http://makersinquiry.org/edition02.html.

27. Camille Bosqué, Constance Garnier, and Matei Gheorghiu, "Livre Blanc· Panorama Des Fablabs En France, 2017-18" (Conseil Scientifique du Réseau Français des Fablabs (CS-RFFLabs), May 2019), accessed January 21, 2020, http://www.fablab.fr/le-conseil-scientifique-du-rfflabs-a-le-plaisir-de-publier-son-livre-blanc-panorama-des-fablabs-en-france/.

and knowledge service, recently elaborated a report that proposes an overview of Maker Laboratories at European level using several sources of data. According to this analysis, Fab Labs account for nearly half of the laboratories in the European Union (48%; 397 laboratories), Hackerspaces are 40% (327 laboratories) and then there are other types of laboratories for 12% (102 laboratories). The average number of laboratories per country is 29.5. France, Germany and Italy represent 53% of the laboratories within the European Union.[28]

An analysis of the hackerspaces.org platform found that Hackerspaces are a global phenomenon in 71 countries but with a greater presence in Europe and the USA.[29] The majority of labs are in the USA with 238 labs, with Germany at the second place with 131 labs, then the United Kingdom (51), France (42) and the Netherlands (28). Brazil has the largest number of Hackerspaces in South America with 28 labs, and China the largest in Asia with 26. South Africa is the largest in the African continent with 4 labs.

3.2 Data analysis: the geographical distribution of Maker Laboratories on fablabs.io, hackerspaces.org, diybio.org

In order to advance the mapping of the geographical distribution of Maker Laboratories, in this section we present the analysis of an already formatted and openly accessible dataset that collected data from the fablabs.io,[30] hackerspaces.org,[31] diybio.org,[32] platforms on January 25, 2018. Such dataset was created with a custom software module that accesses and standardizes data from many Maker platforms in order to produce a common set of APIs.[33]

In this section we plot the geographical distribution of these labs at global, continent, country and major city level **[Fig. 4-7]**. At global level **[Fig. 4]**, the majority of the laboratories are Hackerspaces (2,237 labs), almost the double of Fab Labs (1,216); DIYBio Labs (104) are a minority. This could be both a measurement of their popularity, but also of the efficiency of the platforms in mapping them, or the quality of the gathered data (hackerspaces.org is a wiki and can be edited by anybody, the other two platforms have an editorial team).

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28. Paulo Rosa et al., *Overview of the Maker Movement in the European Union*, EUR 28686 EN (Luxembourg: Publications Office of the European Union, 2017).

29. Sandra Álvaro Sánchez, "A Topological Space for Design, Participation and Production. Tracking Spaces of Transformation," *Journal of Peer Production*, no. 13 (March 2019), accessed January 21, 2020 http://peerproduction.net/issues/issue-13-open/peer-reviewed-papers/a-topological-space-for-design-participation-and-production/.

30. https://www.fablabs.io/, accessed January 21, 2020.

31. https://wiki.hackerspaces.org/, accessed January 21, 2020.

32. https://diybio.org/, accessed January 21, 2020.

33. Massimo Menichinelli, *Openp2pdesign/Makerlabs: V0.21.2* (Zenodo, 2018), https://doi.org/10.5281/zenodo.1182676; Massimo Menichinelli, "WP7 MakerSpacesRadar" (Zenodo, February 15, 2018), https://doi.org/10.5281/zenodo.1182468.

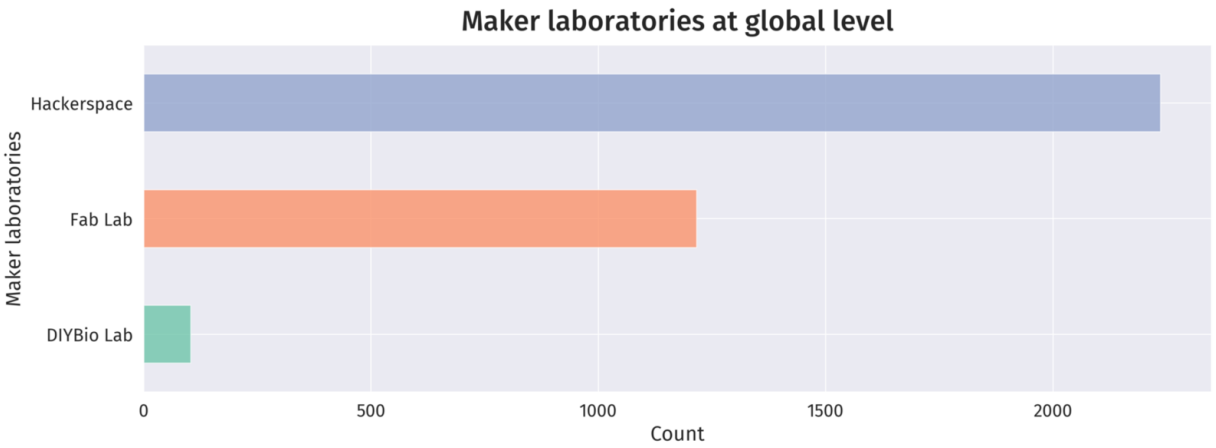

FIG. 4 Geographical distribution of Maker laboratories at global level, by type (Source: diybio.org, hackerspaces.org, fablabs.io, January 25 2018).

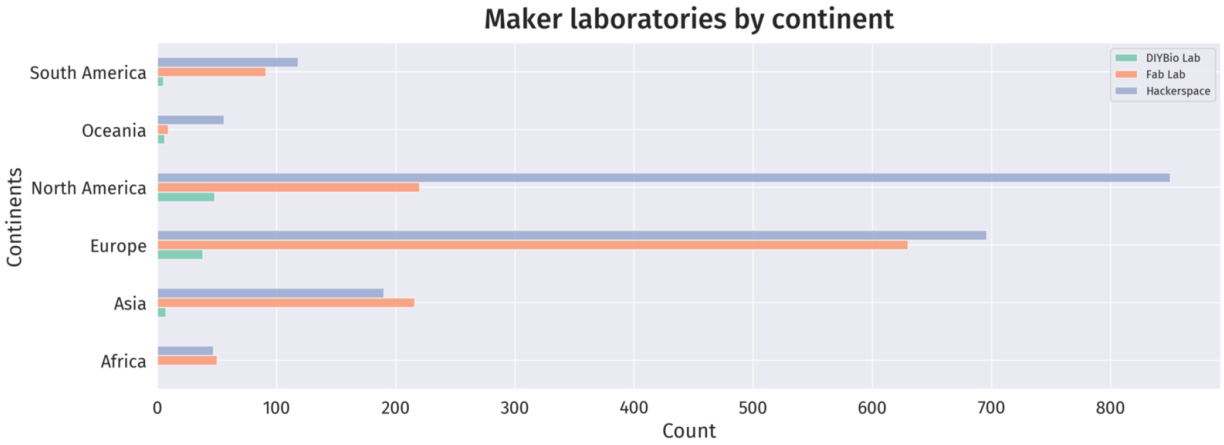

FIG. 5 Geographical distribution of Maker Laboratories by continent and type (Source: diybio.org, hackerspaces.org, fablabs.io, January 25 2018).

At continent level **[Fig. 5]**, North America and Europe are the main places where labs can be found, but while in North America Fab Labs are one fifth of Hackerspaces (220 labs and 850 labs, respectively), in Europe they reach similar numbers (630 and 696 labs). In Asia Fab Labs are the majority (216 and 90 labs) as in Africa (50 and 47), and in South America again Hackerspaces are the majority (118) but Fab Labs are very close (91). The highest concentration of DIYBio Labs is in North America (48) and Europe (38).

At country level **[Fig. 6]**, USA has the main concentration of laboratories (352 Hackerspaces, 170 Fab Labs, 38 DIYBio Labs); China has the second place for Hackerspaces (212) but has no Fab Labs and there is only one DIYBio Lab. Germany comes third for Hackerspaces (185), but has only 47 Fab Labs and 5 DIYBio Labs. It is interesting to note how we can find a majority of Fab Labs instead of Hackerspaces in France (155 and 76 labs) and Italy (134 and 33 labs).

At city level **[Fig. 7]**, the majority of cities have more than three laboratories; Europe also concentrates a huge amount of laboratories, but there are interesting exceptions, like Tbilisi with 11 Fab Labs at the first place. Main cities can be considered Paris (9 Hackerspaces and 8 Fab Labs) and

Shenzhen (7 Hackerspaces and 5 Fab Labs). New York and Los Angeles have the same number of Hackerspaces (9), but no other labs. In terms of Fab Labs, we should note Boston (8), then Lima and Milan (6), then Sao Paulo, Shenzhen, Quito, Porto Alegre, Madrid, Dubai (5).

Generally, the Global North concentrates more laboratories than the Global South. The areas with the highest concentrations of laboratories are Europe, the East Coast and Midwest in the USA, South of India and Brazil, whereas China has Hackerspaces distributed all over the country.

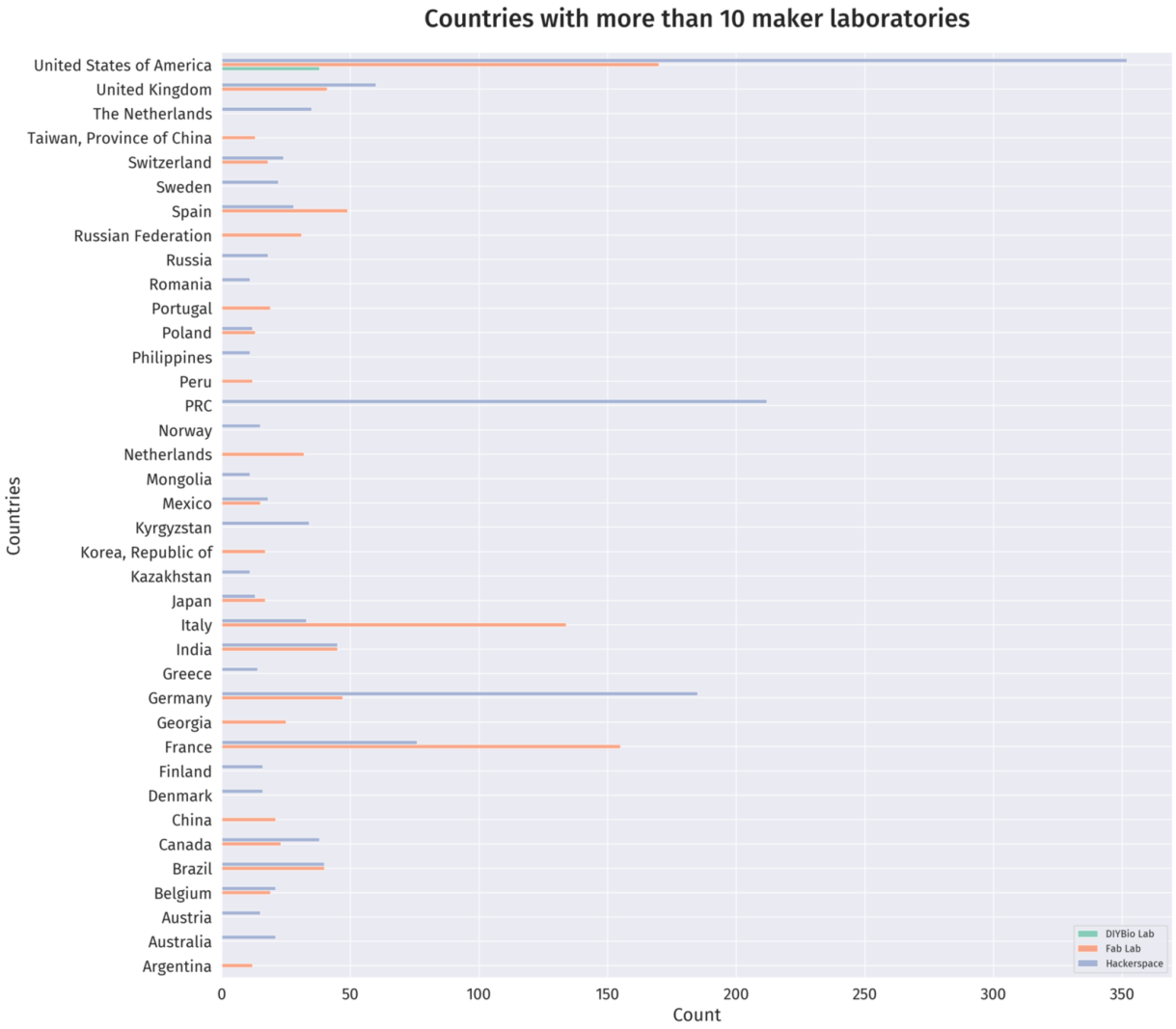

FIG. 6 Geographical distribution of Maker laboratories by country and type. Only countries with more than 10 maker laboratories are considered (Source: diybio.org, hackerspaces.org, fablabs.io, January 25 2018).

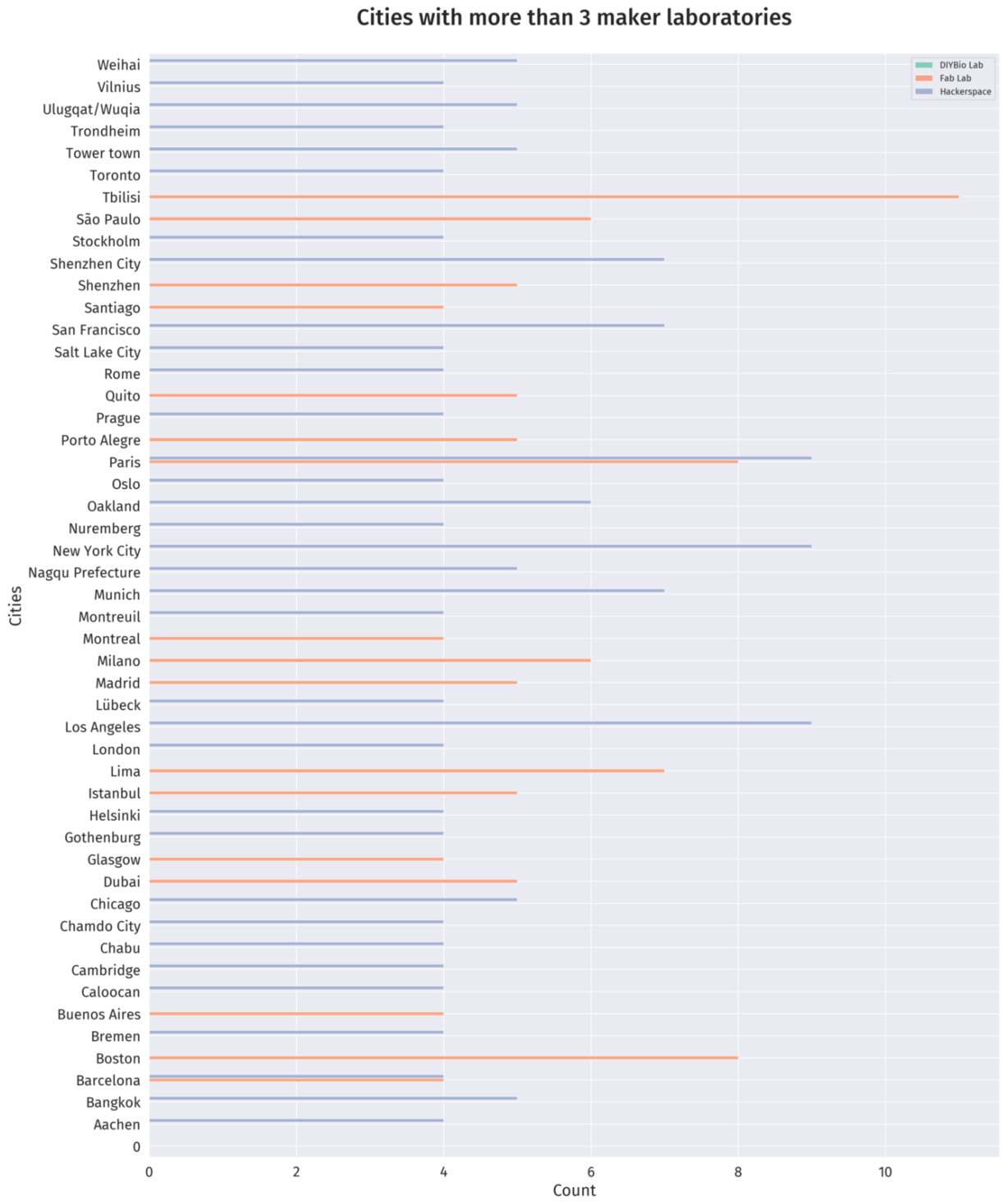

FIG. 7 Geographical distribution of Maker laboratories at city level, by type. Only cities with more than 3 maker laboratories are considered (Source: diybio.org, hackerspaces.org, fablabs.io, January 25 2018).a

4 First maps of the social structure of the Maker Movement

4.1 Literature review

Digital platforms, analyzed with a social network analysis, are the main source for all the overviews of the social structure of the global community of Maker Laboratories and in-depth analysis of specific maker projects elaborated so far. The ubiquity, scale, ease of use, quantity and

quality of available data render platforms not just important for users, but also for researchers.

For example, an analysis of the global community of Hackerspaces considered hackerspaces.org as the main source for the data, but did not explore the geographical distribution of labs but their social structure.[34] The list of labs presented on the platform (a wiki) was analyzed in their connections by in-degree, first at depth 1 (considering only links between labs listed on the platform) and then by connecting the labs found at depth 1 with the ones originally listed in the platform but not directly included or connected to it. In the first case, 941 labs were found, structured with a densely connected centre surrounded by a concentric distribution of less connected labs: two main labs can be found at the core, ccc.de (Chaos Computer Club), located in Germany and the noisebridge.net (the Noise Bridge) located in San Francisco in the USA, with Metalab (Austria) between the two. These labs are surrounded by the ones from their same country first and then by the labs from other countries, belonging to Europe, The United States and Canada, South America, Australia, Asia and Africa. In the second case, 1,034 labs were found, with a more clustered network with more links at the country level, and a strong sub-community from Germany made of Fab Labs and not Hackerspaces. Both analyses found also the presence of several Makerspaces, showing thus how the boundaries between these formats of labs are not so clear, even on platforms with a clear identity such as hackerspaces.org.

Another analysis focused on the whole global community of Maker Laboratories (Fab Labs, Makerspaces, Hackerspaces) by using instead Twitter as the main source of data, mined with a custom software released as open source that analyzes who follows whom in a manually-curated list of Twitter accounts of Maker Laboratories.[35] Here Twitter is considered as a proxy of the global connections among the laboratories, and the obtained network consists of 946 nodes and 29,821 edges among them, representing thus a first data-driven measurement of the size of the global community. The community is split into two main polarities, and an exploration of its sub-communities at a high level of resolution[36] shows that Hackerspaces, Makerspaces and TechShops are grouped together on one side (53.28% of the nodes), and Fab Labs on another side (42.07% of the nodes), with a subset of French Fab Labs as a separate sub-community, showing a first subdivision of the Fab Lab community. At

34. Álvaro Sánchez, "A Topological Space for Design, Participation and Production. Tracking Spaces of Transformation."

35. Massimo Menichinelli, "Mapping the Structure of the Global Maker Laboratories Community through Twitter Connections," in *Twitter for Research Handbook 2015–2016*, ed. Clement Levallois et al. (Lyon: EMLYON Press, 2016), 47–62.

36. Vincent D. Blondel et al., "Fast Unfolding of Commun https://publications.europa.eu/en/publication-detail/-/publication/5d8dfbab-ca80-11e7-8e69-01aa75ed71a1/language-enities in Large Networks," *Journal of Statistical Mechanics: Theory and Experiment* 2008, no. 10 (October 9, 2008): P10008; R. Lambiotte, J.-C. Delvenne, and M. Barahona, "Laplacian Dynamics and Multiscale Modular Structure in Networks," ArXiv:0812.1770 [*Physics*], December 9, 2008.

a finer resolution, the number of sub-communities rises, clearly showing the distinctions between Hackerspaces (32.66 %), Makerspaces (16.7 %) and TechShops (1.48 %). Within Fab Labs, however, many more sub-communities can be found, suggesting that form a much more diversified and articulated network of laboratories. Generally, few nodes have high degree and betweenness with a common power-law distribution, and this can be found also regarding influence and trust, which have a different meaning in each polarity: Eigenvector centrality is much more concentrated in several nodes in the Fab Lab community, and PageRank centrality is concentrated in very few nodes among Makerspaces and Hackerspaces. A static perspective on trust finds it to be distributed among many labs in Fab Labs; a dynamic perspective finds it concentrated in very few nodes on the Makerspaces and Hackerspaces side.

Within the Maker Movement, projects can be at both local scale and global scale: leveraging the principles and the attitude of Open Source Software, projects can potentially scale up to many participants, but typically they are small projects that start from the local context, since the hardware dimension renders upscaling much more costly and cumbersome. As in many research initiatives about Open Source Software, projects are analyzed through their hosting on version control systems like Git and their platforms like GitHub. A large scale social network analysis of Open Source Hardware projects (105 projects) was developed in order to understand to which extent the transparent and participatory processes of software development reached hardware product development: the result is that these initiatives are generally small-scale and heterogeneous.[37] Social network analysis has also been adopted by makers/researchers in order to understand their participation in open and maker projects, and their position in the networks of interactions emerging from the collaboration in GitHub in defining Open Design, teaching it and developing a maker platform for Open Design projects. These are all meta-design activities that build a socio-technical infrastructure of Open Design projects, rather than directly designing Open Design projects.[38]

4.2 Data analysis: An update of the global structure of the Maker Movement on Twitter

The software developed for the analysis of the whole global community of Maker Laboratories on Twitter mentioned in the section above[39] is openly accessible, and therefore we adopted and updated it in order to replicate

37. Jérémy Bonvoisin et al., "How Participative Is Open Source Hardware? Insights from Online Repository Mining," *Design Science* 4, no. 19 (November 21, 2018).

38. Massimo Menichinelli, "A Data-Driven Approach for Understanding Open Design. Mapping Social Interactions in Collaborative Processes on GitHub," *The Design Journal* 20, no. sup1 (September 6, 2017): S3643–58.

39. Menichinelli, "Mapping the Structure of the Global Maker Laboratories Community through Twitter Connections."

the same analysis five years later and compare how the community has evolved so far. Here again the accounts were manually added in another updated list and analyzed in terms of who follows whom, as a proxy for collaboration and trust among the Maker Laboratories, resulting in a larger network of 1,278 nodes and 52,533 edges.

Sub-communities can be observed with the same algorithm[40] adopted by the previous research, providing different resolutions that enable the uncovering of network structures at different scales. With a resolution of 1.0, we can see that the larger part is made of Hackerspaces and Makerspaces (45.07%, blue nodes on the right), followed by Fab Labs (31.61%, red nodes on the left), then by French Fab Labs (10.02%, orange nodes on the left), then by Maker Faires (7.36%, light blue nodes on the right) which are closer to Makerspaces and Hackerspaces than to Fab Labs (this might be a stronger connection of MAKE Magazine to Makerspaces than to Fab Labs). It should be noted how Repair Cafes, at 1.49%, are a separate branch on the top left, and that there is handful of completely disconnected labs, mainly Makerspaces and Hackerspaces [Fig. 8].

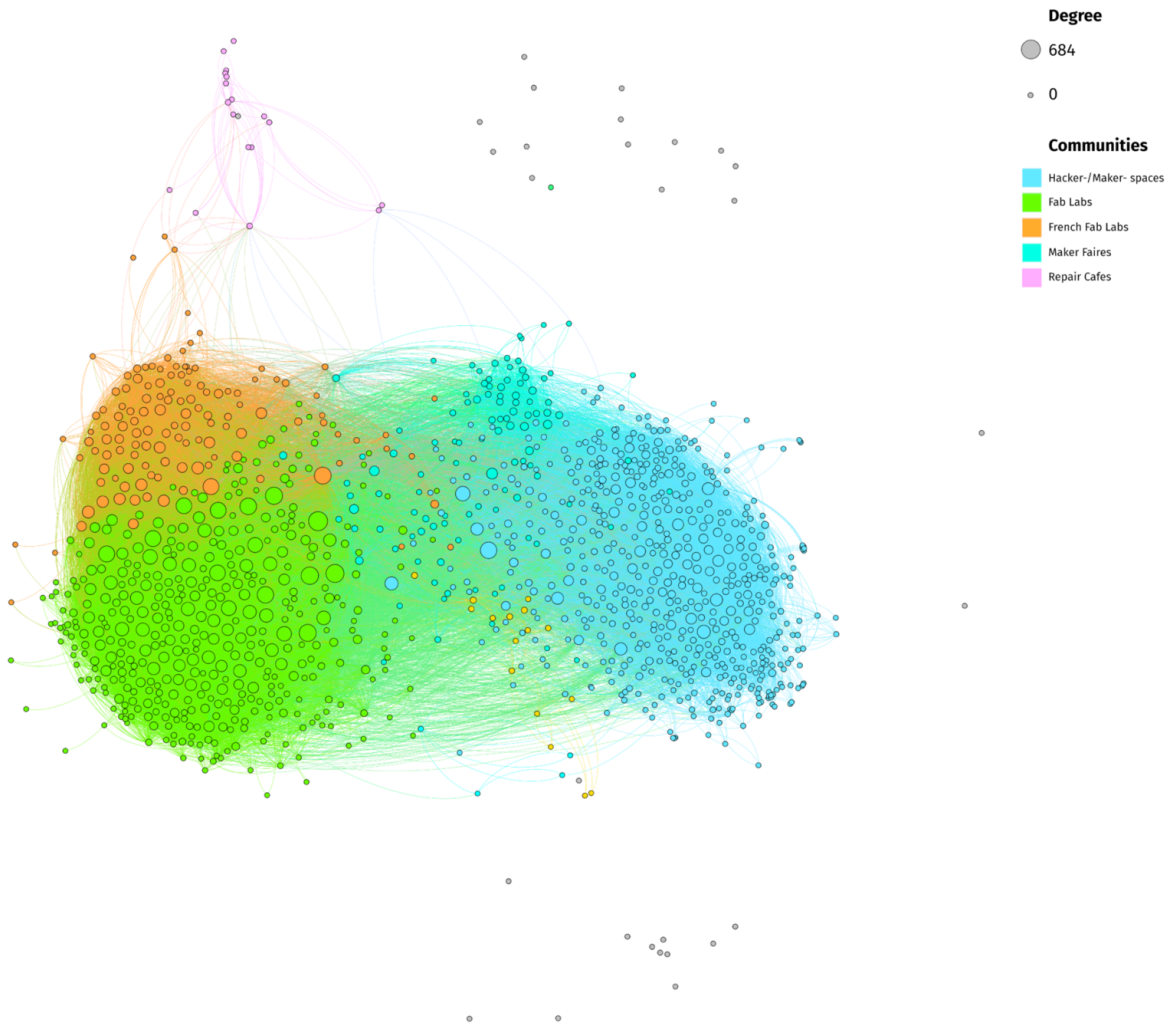

FIG. 8 The main sub-communities found with a resolution of 1.0 (Source: Twitter, June 25 2019).

40. Blondel et al., "Fast Unfolding of Communities in Large Networks"; Lambiotte, Delvenne, and Barahona, "Laplacian Dynamics and Multiscale Modular Structure in Networks."

At a smaller scale and finer network architecture, with a resolution of 0.5, more sub-communities can be found: Hackerspaces (24.41%, orange nodes on the right) and Makerspaces (15.26%, yellow nodes on the right) are again separated at this level, but now they are not so defined, as labs can be found in either part. We can then observe French Fab Labs (9.7%, pink nodes on the middle left), Italian ones (6.96%, light blue nodes on the left), followed by Maker Faires (5.87%, yellow nodes on the right) and only later by Fab Labs from mixed countries (5.71%, dark blue nodes on the bottom left) [Fig.9]. TechShops are here now part of the Makerspace community, and while the French Fab Lab community was almost separate already five years ago, the Italian community has now emerged as a more identifiable entity now.

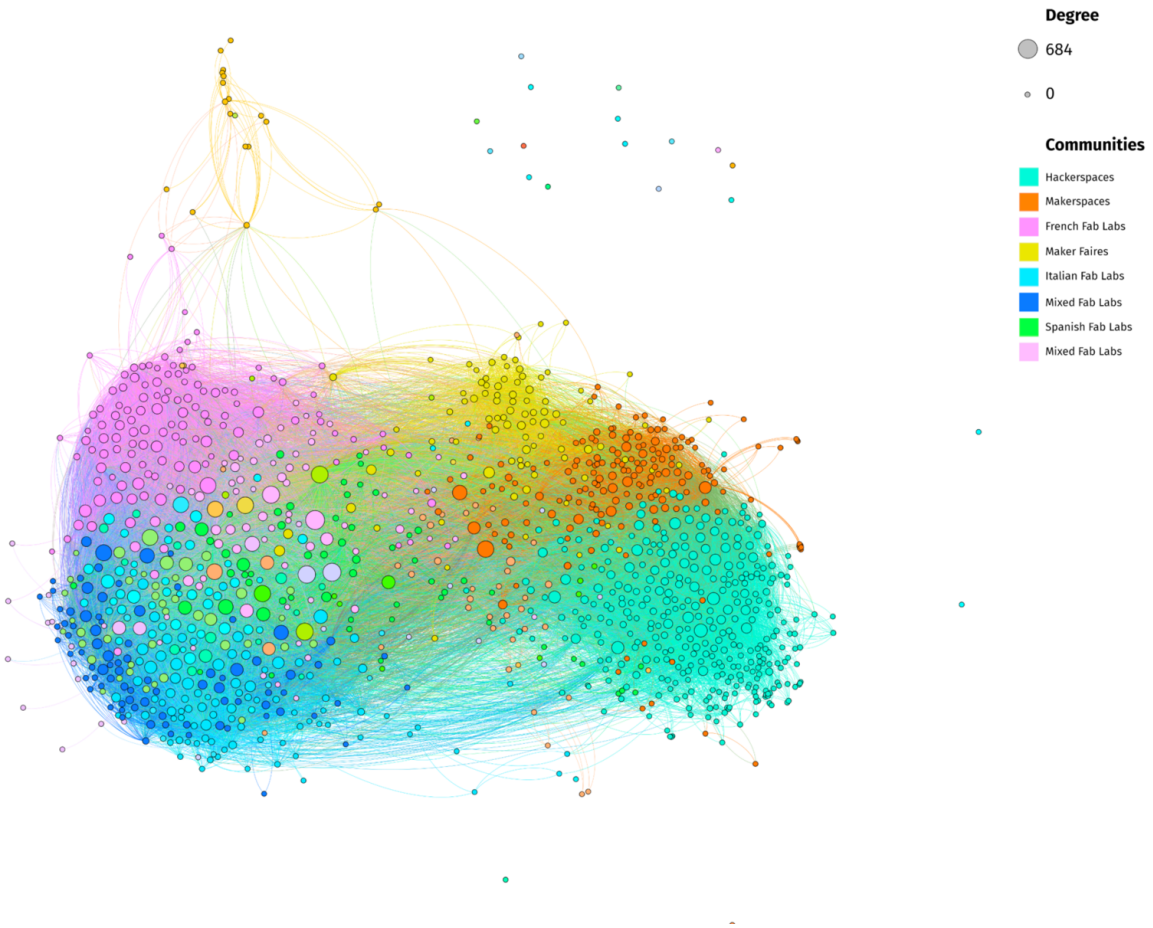

FIG. 9 The sub-communities found with a resolution of 0.5 (Source: Twitter, June 25 2019).

The distribution of Degree centrality (i.e. the number of edges of a node—the more the edges, the higher the centrality in the network) shows a larger concentration of high degree centrality in the Fab Lab community [Fig. 10].

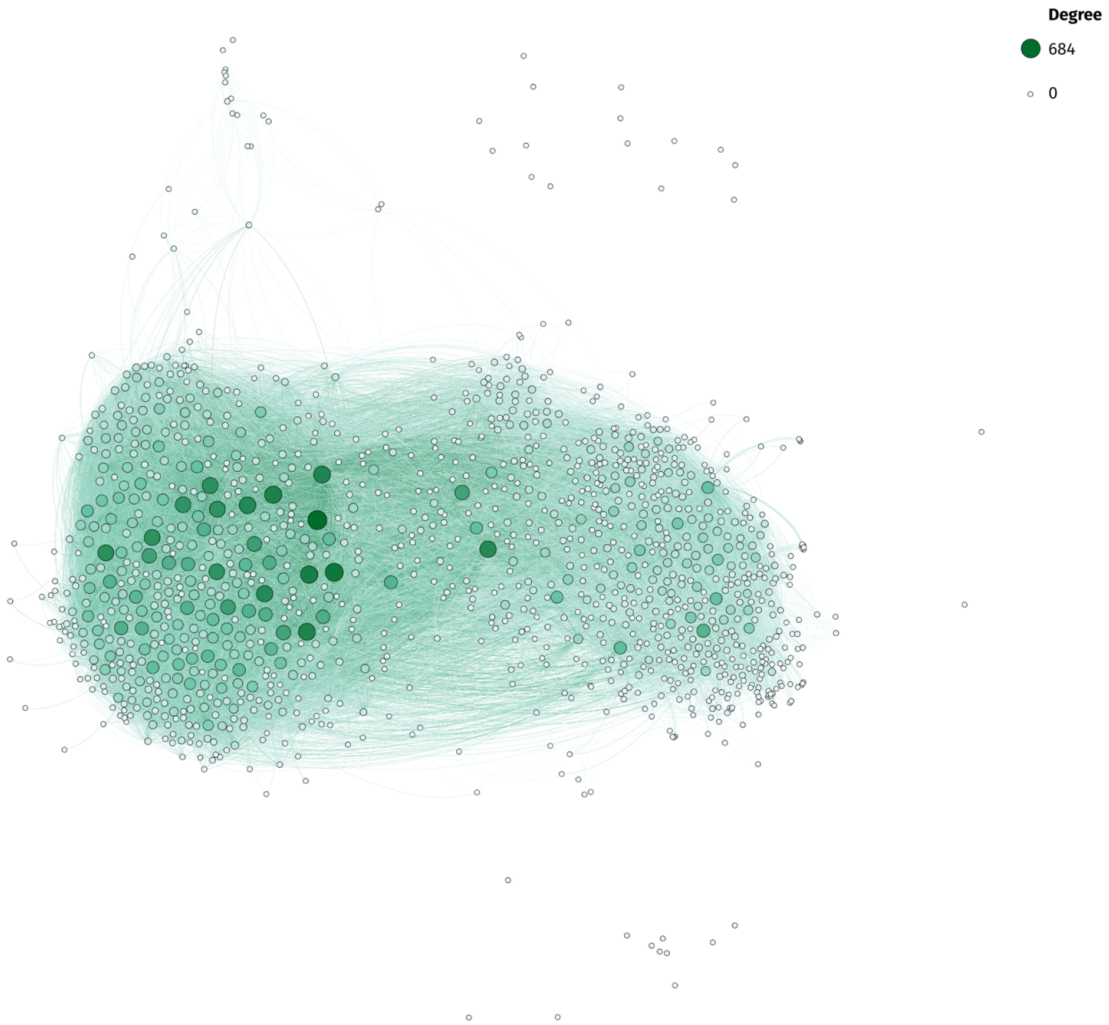

FIG. 10 Distribution of Degree centrality in the network (color and size related to the value) (Source: Twitter, June 25 2019).

The distribution of Betweenness centrality shows very similar results compared to the previous study, pointing out how still very few nodes bridge the two polarities **[Fig. 11]**. Betweenness centrality measures how many times a node acts as a bridge along the shortest path between two other nodes, i.e. how many nodes it can bridge.

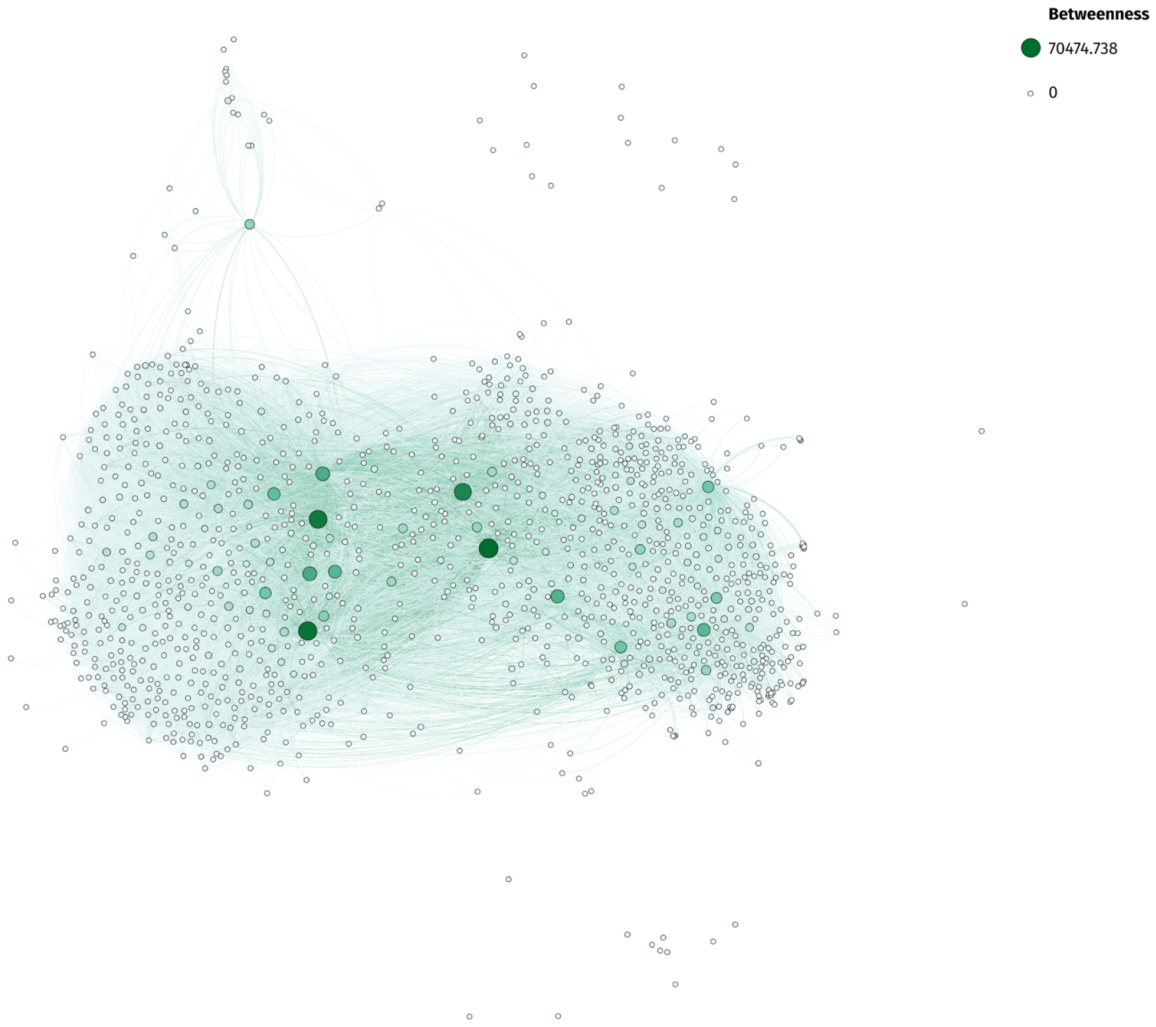

FIG. 11 Distribution of Betweenness centrality in the network (color and size related to the value) (Source: Twitter, June 25 2019).

The distribution of Closeness centrality is rather homogeneous in the network, with rather high values shared and very few nodes with a very high value. Closeness centrality measures the distance (shortest paths) between a node and all other nodes in the network, i.e. the closer a node is to all other nodes, the more central it is. Almost all nodes are therefore very close to each other and able to spread information efficiently [Fig. 12].

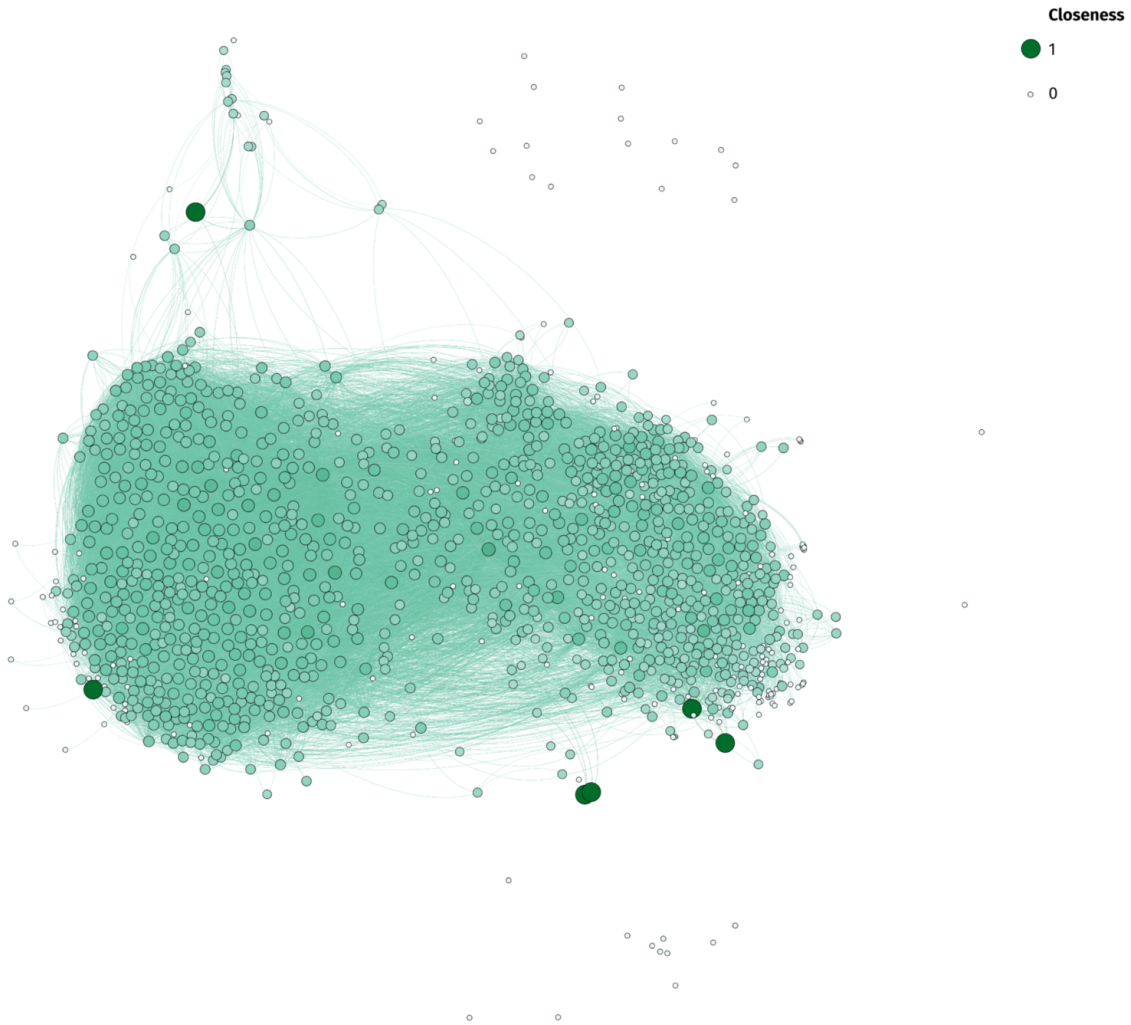

FIG. 12 Distribution of Closeness centrality in the network (color and size related to the value) (Source: Twitter, June 25 2019).

The distribution of Eigenvector centrality shows how trust and influence is more concentrated in the Fab Lab community, as it was previously found, but also rather fairly distributed among most of the labs **[Fig. 13]**. In Eigenvector centrality a node is important (central) if it is connected to other important nodes.

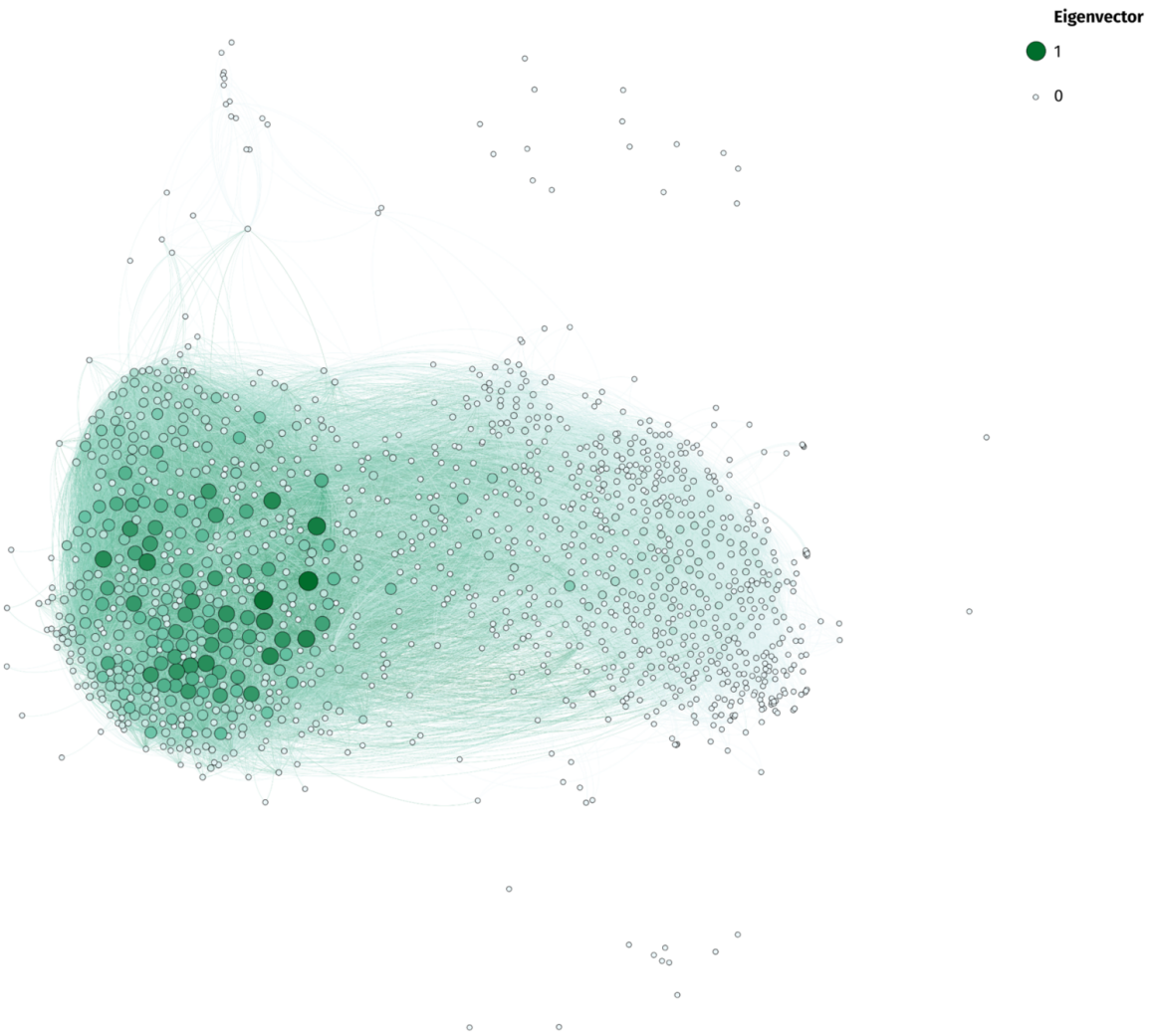

FIG. 13 Distribution of Eigenvector centrality in the network (color and size related to the value) (Source: Twitter, June 25 2019).

As for Betweenness and Eigenvector, the distribution of PageRank centrality shows very similar results to the previous study: trust in the network has stayed almost the same **[Fig. 14]**. PageRank centrality is a variant of Eigenvector centrality: here influence is determined with an iterative approach where nodes vote for the importance for other nodes (influence is calculated with iterations of voting over connections instead of connections only).

Overall, the network has become slightly larger, with Maker Faires and Repair Cafes emerging, and TechShops disappearing, and the Fab Lab community split between French, Italian and other countries (and the last two groups are more integrated into each other than the French part). The distributions of the centrality measurements have remained similar to the previous analysis.

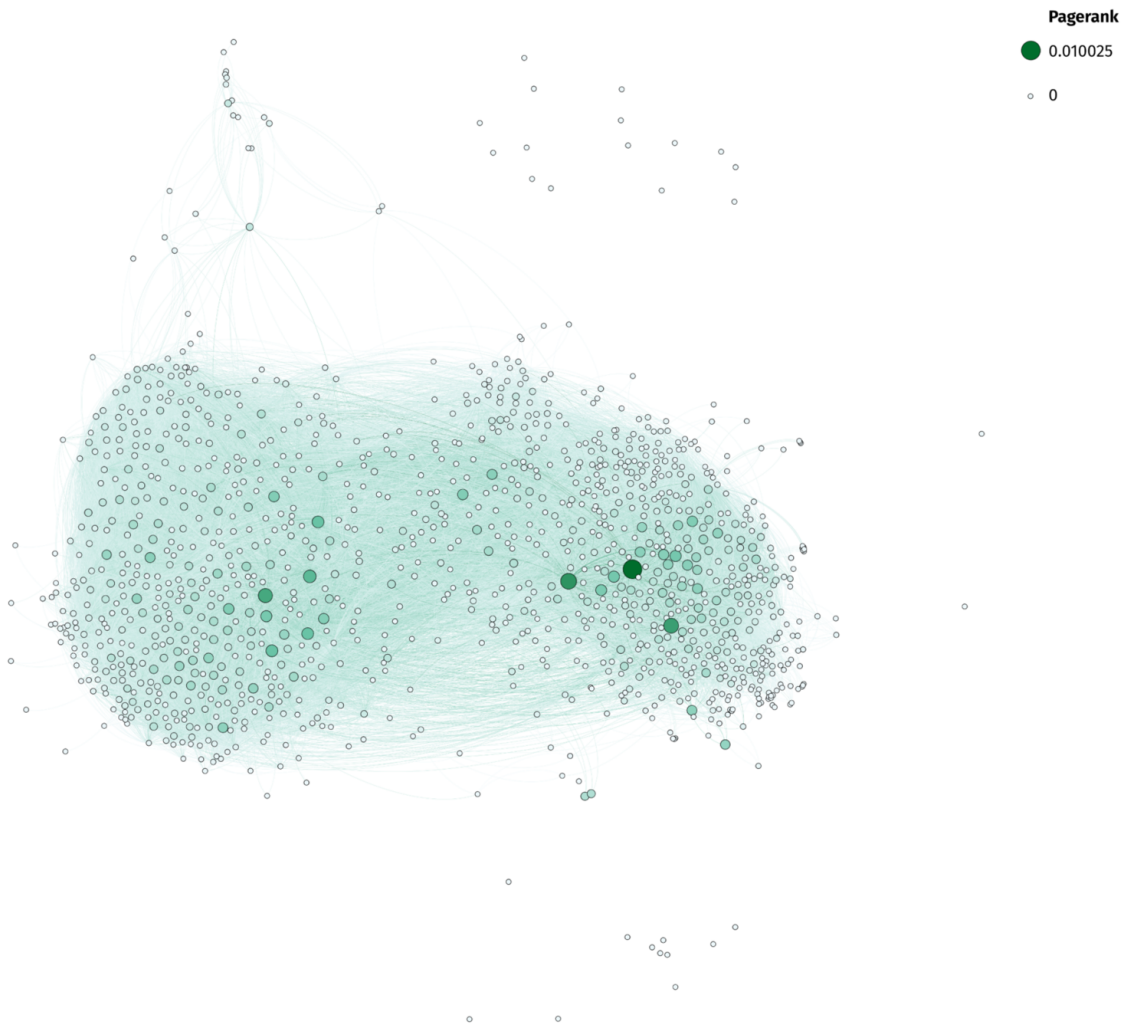

FIG. 14 Distribution of PageRank centrality in the network (color and size related to the value) (Source: Twitter, June 25 2019).

5 Conclusions

The Maker Movement, a social movement of democratization of digital technologies, has emerged through a mix of diverse both bottom-up and top-down initiatives almost everywhere. Because of this recent and mixed nature, tracking its evolution, expansion and interactions has not been a trivial task, and with this article we propose a way forward: from conceptual models and broad literature reviews for orienting how to explore it, to more specific literature reviews and data analyses about geographical distribution and social connections for exploring it. Data was gathered from digital platforms, and these analyses are also an example of the possibilities given by this global digital infrastructure.

The geographical distribution of Maker Laboratories shows inequalities and cultural differences, richness of resources and possibilities but also limitations for collaboration and initiatives. This complexity also constraints the elaboration of contributions towards policymakers and practitioners for at least two reasons. On one side, this research is still about the very first exploratory maps of the phenomenon, and more in-depth analyses are necessary in order to elaborate suggestions for policies and practice. On another side, local contexts and differences played a role in the emergence of the phenomenon, but the granularity of this analysis does not enable the highlighting of the differences made by each local context. The main contributions of this article are towards methodologies for understanding the unfolding of the Maker Movement geographically and socially but at global level. We suggest that further research should then focus on adopting and extending such methodologies with more in-depth analyses at local level in order to bring light to the contexts that influence and are influenced by the movement.

The social network analysis clearly identifies communities and sub-communities and their collaborations, and in some cases (France and Italy) it shows the importance of the geographical distribution on the social structure of the movement. This approach is also interesting for validating hypothetical and conceptual perspectives on the Maker Movement [Fig. 3] by adding more nuances in order to show the fuzziness and richness of structures and their boundaries.

Overall, for makers and designers, knowing their place on the geographical and social maps might unlock new projects, collaborations and distribution of such projects. An awareness of one's own position in these dimensions might enable the ability to consider strategies for creating value chains and supply chains while at the same time being able to understand their social impact. Initiatives for improving this understanding might further contribute to enabling makers to take the social entrepreneurs' role of creating a significant impact to their networks and communities by using business models that provide solutions for difficult and com-

plex social problems.[41] Platforms here are a key infrastructure for extending the reach of this activities to global level, either by scaling or sharing their assets and efforts, and also by understanding how local initiatives might generate impact.[42]

This exploratory approach has, however, some limitations. For example, the number and position of labs depends on how the data is gathered and filtered on the platforms, which has been shown to have redundancies, overlaps and might need more editing. The usage of Twitter is a simple way to get a proxy for social interactions, but real interactions should be then also assessed in order to validate the results obtained. Furthermore, sound research strategies for identifying missing accounts should be established, as not all laboratories might have created accounts. Traditional approaches such interviews might be used in order to fill these gaps.

At least three topics for further research emerge here. Firstly, the diversity of such networks of laboratories should be clarified, distinguishing the self-organized part and the institutional ones, in terms of fundings, accessibility, organizations and local ecosystems. Exploring the geographical distribution of laboratories should also contribute towards understanding what might have caused such distributions and how to connect laboratories taking their diversity in consideration, especially between the Global North and Global South. Secondly, the nature of the communities and sub-communities identified should be understood more: are these similar to online communities, ethnic groups or something else? How do cultural differences emerge and are self-perpetuated in such distributed systems? How do they relate to existing local contexts and how they could support or hinder future trajectories? Thirdly, given the centrality of platforms not just for these networks but also for the research upon them, future research should investigate their openness, impact and how they relate with social diversity.

We therefore suggest that future research should address these issues by both improving existing digital platforms or creating new ones that are more apt for the Maker Movement, and by integrating them with data from other sources and approaches. Furthermore, we suggest that the tools and results developed should be designed and tested with all the members and stakeholders of the Maker Movement.

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41 Shaker A. Zahra et al., "A Typology of Social Entrepreneurs: Motives, Search Processes and Ethical Challenges," Journal of Business Venturing, Special Issue Ethics and Entrepreneurship, 24, no. 5 (September 1, 2009): 519–32.

42 Massimo Menichinelli and Alessandra Gerson Saltiel Schmidt, "Measuring the Social Impact of Maker Initiatives. Frameworks and Guidelines for Scaling the Assessment on Digital Platforms," in Sharing Society. The Impact of Collaborative Collective Actions in the Transformation of Contemporary Societies., ed. Benjamín Tejerina, Cristina Miranda de Almeida, and Ignacia Perugorría (International Conference Sharing Society (Bilbao, May 23-24, 2019), Leioa: Universidad del País Vasco/ Euskal Herriko Unibertsitatea, 2019), 526–37, accessed January 21, 2020, https://sharingsocietyproject.org/2019/05/08/conference-proceedings/.

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