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Mapping the structure of the global Maker laboratories community through Twitter connections

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Abstract

The Maker Movement is currently considered an interesting and promising phenomenon with social and economic implications, especially through a series of locally implemented but globally connected laboratories for making. The social structure of such global community as a whole has not been examined yet. This research proposes therefore to analyze the connections of following and being followed among the Twitter accounts of such Maker laboratories, as a proxy of their pattern of trust and influence. The Twitter accounts were manually gathered in Twitter lists with the help of the search functionalities of Twitter, and the data was later accessed and reconstructed with a script based on the NetworkX library. The network was reconstructed from the ego-networks of each account on the examined lists, and accounts who were not part of the lists were removed. The resulting network shows a relevant polarity between roughly Fab Labs on one side and Hackerspaces, Makerspaces and TechShops on the others. Further analysis of the data revealed that the Fab Lab sub-community is much more diversified and less homogeneous than the other part, with further insights on the impact of the organization of such laboratories and their networks. Furthermore, the analysis of some centrality measures showed how few nodes bridge these polarities, while most of the nodes are very close to each other and the Fab Lab network has a more relevant and distributed influence. A possible direction for improving this research along multiple dimensions is proposed as a conclusion.

Keywords

Fab Lab, Makerspace, Hackerspace, TechShop, Makers, Social Network Analysis, Twitter, Community

1. Introduction

The Maker Movement is currently considered an interesting and promising phenomenon with social and economic implications (Anderson, 2012; Hatch, 2014). The "Maker" term is quite broad, and there are currently many discussions regarding how to clearly identify Makers. Generally, however, Makers are usually defined as a people who are interested in designing, making, repairing physical objects with digital tools, and that have the required skills for such activities and share their projects, experiences or time in local laboratories. The emergence of Makers has been facilitated by three factors: (1) the growing accessibility of tools for manufacturing physical objects; (2) the evolution of web platforms from just discussion to even design, prototyping and manufacturing; (3) the growing number of local laboratories for individual and collaborative design and making. On one side, the development of

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manufacturing technologies and especially technologies based on digital fabrication (Gershenfeld, 2005, 2012) has been increasing the quality of manufacturing processes, it has been lowering the cost of such technologies and processes which consequently started to be more widespread available. Many open source software and hardware projects like the RepRap 3D Printer (Sells, Bailard, Smith, Bowyer, & Olliver, 2009) or the Arduino development board (Banzi, 2009) lowered the barriers to creating physical objects regarding the low price, the local availability, the easiness of building and repairing and the easiness of studying and developing projects on top of them. On another side, the emergence of the Web 2.0 or Social Web phenomenon (O'Reilly, 2005) generated multiple experiments of online platform for the emergence of collaborative communities, both non-profit and for-profit, that represented a further development of the first online communities, bringing them to online discussion to online software, hardware and design development, prototyping and manufacturing with platforms like GitHub[1], Thingiverse[2], UpVerter[3], Shapeways[4] and Ponoko[5] (Anderson, 2012; Benkler, 2002; Howe, 2006; Tapscott & Williams, 2006). On a third side, the emergence of many different formats of Maker facilities like Hackerspaces, Makerspaces, TechShops and Fab Labs made these technologies and processes locally available in a growing number of localities (Anderson, 2012; Cavalcanti, 2013; Gershenfeld, 2005; Hatch, 2014; Maxigas, 2012; Tweney, 2009). The interactions among these three phenomena are creating the conditions for the emergence of the Open and Distributed Manufacturing scenario, where design and production are re-localized, supply chains redesigned and new business generated, all based on local communities which are connected globally (Bauwens, 2009).

Therefore, it is especially through a series of such local laboratories but globally distributed, that this phenomenon of the Maker Movement (i.e. the people) and of Open and Distributed Manufacturing (i.e. the technologies and the business) is taking place and growing with new members, technologies and businesses. Such laboratories have different names and formats like Hackerspaces, Makerspaces, Fab Labs, TechShops and so on. Each format has a different story, culture, typical business plan and tools for networking among them. Boundaries among these formats are not always well defined, as there are both places that may fit into different formats and Makers who participates in different formats. As a whole, these laboratories constitute the local dimension of the whole Make Movement. Currently, it is widely considered that such laboratories (and the whole Maker Movement) constitute a global community thanks to the use of ICT technologies for communication and coordination. The social dimension of the local community of some specific laboratory has been investigated, but the global community as whole has not been examined yet. For example, some researchers analyzed the local community that gathers around Fab Lab Amsterdam (Ghalim, 2013; Maldini, 2014); others focused on the national community of Fab Labs, Hackerspaces and Makerspaces in Italy (Menichinelli & Ranellucci, 2015) or the national community of Makers in Italy (Bianchini, Menichinelli, Maffei, Bombardi, & Carosi, 2015). Thus there is no evidence yet that such a movement really constitutes a global community or just single laboratories or patterns of single laboratories and of more coordinated and connected laboratories.

The aim of this research is to shed a first light on the social dimension of the global phenomenon of Maker laboratories. The task of examining such a wide phenomenon can be extremely difficult because of its global and distributed nature, and because each format uses different tools and governance strategies for networking. This research therefore propose to analyze the Twitter accounts of such Maker laboratories, as a proxy of the global phenomenon. Twitter was not designed as a place for community building, but some investigations proved that it could actually give place to communities (Gruzd, Wellman, & Takhteyev, 2011). The goal of this research is of analyzing the patterns of connections among such Twitter accounts, in order to find which kind of social structures they have and which kind of community or sub-communities they form. In order to discover such structures, this research analyzes the connection among the Twitter accounts of such Maker laboratories and their connections of

1 https://github.com/
2 http://www.thingiverse.com/
3 https://upverter.com/
4 http://www.shapeways.com/
5 https://www.ponoko.com/

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following / being followed, as a proxy of the disposition to communicate with other laboratories and of therefore the influence of laboratories in being listened to. Since such laboratories represents experiments in forms of networked and distributed organizations, such analysis could shed a first light on the role and distribution of influence and organization in such distributed systems.

2. Method

This research focused on analyzing the connections of following or being followed among the Twitter accounts of such Maker laboratories as a first step in analyzing such global community. The Twitter accounts were manually gathered with the help of the search functionalities of Twitter, in order for the researcher to be able to select those account that were really related to the context of the research: several Twitter accounts have a name that could suggest their belonging to the global community, but upon a closer examination they showed to just use the same keywords. The accounts that were considered were of laboratories, events or organizations related to the global Maker community, since these entities are strongly linked. The accounts were initially separated in three Twitter lists, but these lists were joined later during the analysis of the data, therefore constituting one single list.

The social network of following or being followed connections among the accounts was built with an ego-network of each account: for each account analyzed, Twitter accounts that followed or were followed by it were gathered. Before analyzing the data, all the Twitter accounts that did not belong to the lists were removed. In this way, only the Twitter accounts of the global Maker laboratories were finally analyzed. The data was downloaded and reconstructed into a graph with a custom Python script, based on the NetworkX library (Hagberg, Schult, & Swart, 2008) that accesses the lists trough the Twitter API (Menichinelli, 2015). The script has been released with a Free Software / Open Source license and its code and development can be accessed, commented and contributed to online on GitHub[6]. The obtained data was later analyzed and visualized with Gephi (Bastian, Heymann, & Jacomy, 2009) with the a Force-Directed layout (Force Atlas) and NetworkX with the Matplotlib and Seaborn Python libraries (Hunter, 2007; Michael Waskom et al., 2014). The resulting network was first analyzed in terms of the different sub-communities, in order to understand its structure, and then in terms of several centrality measures, in order to understand the distribution of influence among the nodes. Before exporting the final data, the Twitter accounts were anonymized; however the awareness of the identity of the Twitter accounts proved to be useful during the analysis, in order to understand the sub-communities present in the global network. The research can be replicated with the same software developed for it (Menichinelli, 2015) and one or more Twitter lists.

3. Results

3.1 General information

The development of the script and the analysis of the data took place along several months during 2014 and 2015; one intermediary analysis was done on the 08th of January 2015 and the final analysis was done on the 26th of May 2015. The act of following or being followed on Twitter is asymmetric, therefore the collected graph was reconstructed as a directed graph. The full network of accounts who were followed or followed the Twitter accounts of the Maker laboratories consisted of 499,681 nodes and 1,098,373 edges: there were errors with accessing the information of only 10 Twitter accounts, who where most likely unaccessible as a consequence of a privacy setting. The final network consisting only of Twitter accounts of Maker laboratories consists of 946 nodes and 29,821 edges. The density of the network is quite low at 0.033: a common value for large networks. The average path length is 2.755, indicating that

6 The GitHub repository of the software can be accessed here: https://github.com/openp2pdesign/Twitter-Lists-SNA-EgoNetworks

nodes are highly connected and information can flow quickly among them. The diameter is 10, indicating that there are 10 connections between the farthest nodes in the network: this is a small path, if we consider that the network has 946 nodes. These values could be considered a first measurement of the size of the global Maker laboratories: it is a difficult task to calculate the number of laboratories since there are several online platforms for mapping them. Furthermore, since most of these laboratories start as bottom-up initiatives, it is difficult for such platforms to keep track of the development of the global Maker laboratories community.

3.3 Modularity measure: the structure of the sub-communities

The most relevant feature of the network is how it is subdivided into two main polarities, which are only loosely connected by few nodes. These two polarities consists roughly of Fab Labs on one side and mainly of Hackerspaces, Makerspaces and TechShops on the other side. In order to understand the different sub-communities that constitute such global phenomenon, the network was analyzed with a modularity detection. The measurement was done in in Gephi (Bastian et al., 2009), which uses as specific algorithm for modularity detection (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008) with a resolution parameter for identifying more or less communities (Lambiotte, Delvenne, & Barahona, 2008). At first, the network was analyzed with a resolution of 1.0, and then with a resolution of 0.5, going then deeper into its sub-communities.

Size of the sub-community related to the global network	Sub-community identified
53.28 %	Makerspaces and hackerspaces
37.1 %	Fab Labs
4.97 %	A subset of French Fab Labs
< 1.0 %	Several smaller sub-communities

Table 1: Main sub-communities identified with modularity detection with a resolution of 1.0

In the first case (Table 1), with a resolution of 1.0, 41 communities were found but only three big communities are relevant for their size: Hackerspaces, Makerspaces and TechShops together on the right, and Fab Labs on the left and a separated subset of French Fab Labs on the lower part of the left, pointing out a first subdivision of the Fab Lab community and instead a more homogeneous structure of Hackerspaces, Makerspaces and TechShops (Fig. 1). As a whole, Makerspaces and Hackerspaces constitute 53.28% of the network, while Fab Labs are 42.07% of the network.

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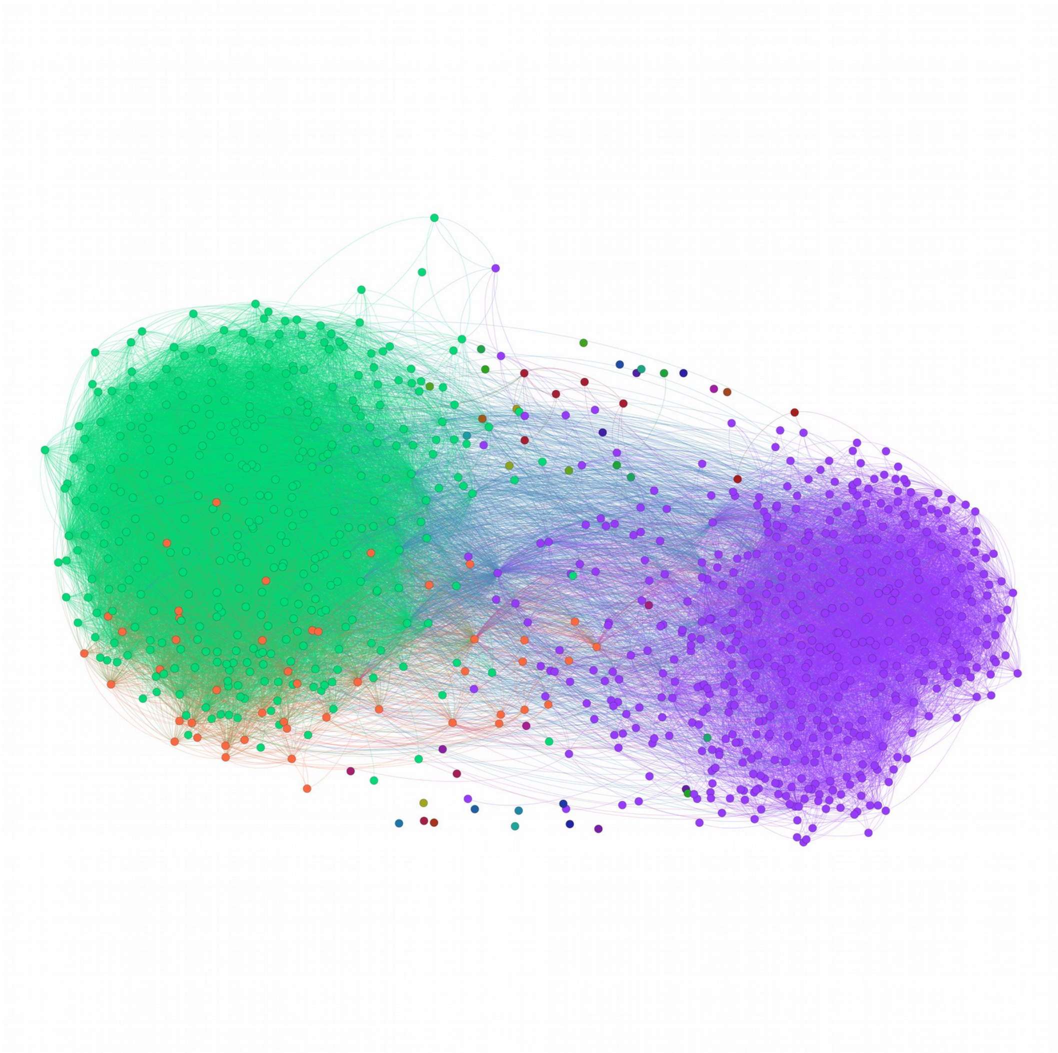

Fig. 1: The main sub-communities found with a resolution of 1.0 (highlighted with a different color).

In the second case (Table 2), with a resolution of 0.5, the number of sub-communities rises to 54: on the right, we can clearly distinguish Hackerspaces (in green), Makerspaces (in yellow) and TechShops (in dark red) (Fig. 2). Counting with a longer history, Hackerspaces constitute 32.66 % of the network, while Makerspaces constitute 16.7 % of the network. TechShops, which is the format that mostly related to a franchising of Maker laboratories, constitutes only 1.48 % of the network. This is consistent with the common idea that these are connected but somehow different format of laboratories: at this resolution therefore we can identify some common formats. On the other side of the network on the left, at the same resolution, we find many more sub-communities, pointing out how the Fab Lab network is a much more diversified and articulated network of laboratories: a union of sub-communities more than a homogeneous community. While at this resolution we find the main Hackerspaces, Makerspaces and TechShops sub-communities, on the Fab Lab side there is a much more diversified structure. Few sub-communities on the Fab Lab side are related to a country (French, Italy, Spain), others are more mixed, but with a more prominent country (Netherlands, Japan). Finally, more sub-communities are constituted by laboratories from mixed countries.

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Size of the sub-community related to the global network	Sub-community identified
32.66 %	Hackerspaces
16.7 %	Makerspaces
6.66 %	A subset of French Fab Labs, Hackerspaces, Makerspaces
6.13 %	Most of Italian Fab Labs
5.71 %	Mixed Fab Labs from all over the world
5.6 %	Mixed Fab Labs from all over the world
3.7 %	Most of Spanish Fab Labs
3.7 %	Mixed Fab Labs from all over the world
3.38%	Mixed Fab Labs from all over the world
2.11 %	Mixed Fab Labs from all over the world
2.11 %	Mixed Fab Labs from all over the world, with especially Dutch laboratories
1,59 %	Mixed Fab Labs from all over the world, with especially Japanese laboratories
1.59 %	Mixed Fab Labs from all over the world
1.48 %	TechShops
1.37 %	Mixed Fab Labs from all over the world
< 1.0 %	Several smaller sub-communities

Table 2: Main sub-communities identified with modularity detection with a resolution of 0.5

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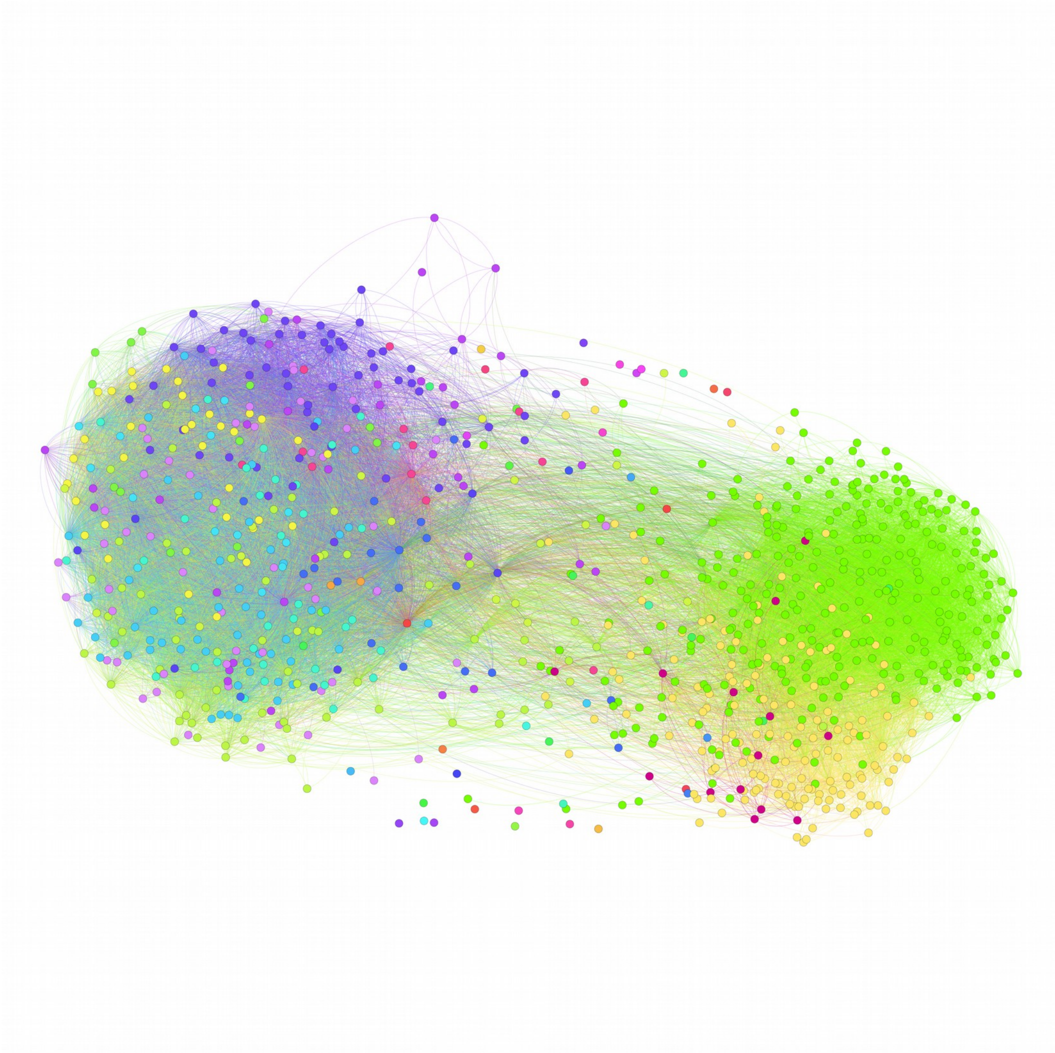

Fig. 2: The sub-communities found with a resolution of 0.5 (highlighted with a different color).

3.2 Centrality measures: importance and influence in the network

After having identified the structure of the sub-communities in the whole network, several centrality measurements were calculated in order to understand the health and the distribution of influence in all the network and the differences in the sub-communities. Degree centrality was calculated first: the number of incoming and outgoing connections for each nodes is a first measurement of the importance of each node. Since the analyzed network is a directed graph, in-degree and out-degree were calculated: however the results are quite similar, with only few nodes more prominent on out-degree than in-degree. The average degree is 31.523, with only few nodes have an outstanding degree: the network is quite homogeneous beside these exceptions, and the distribution of degree follows a common power-law distribution (Fig. 3). However, such an average degree is quite high, meaning that on average each laboratory is connected to 31 other laboratories. A higher number of nodes with higher degree values can be found in the Fab Lab sub-community compared to the Hackerspaces, Makerspaces and TechShops sub-community (Fig. 4). The nodes with a higher degree can be found in the Fab Lab sub-community but at the interface with the sub-community of Hackerspaces, Makerspaces and TechShops.

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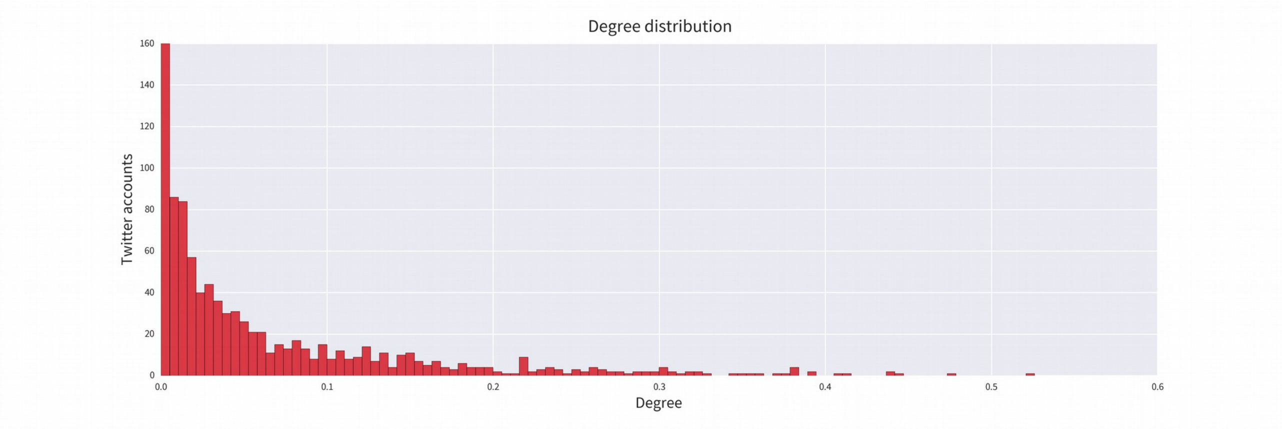

Fig. 3: Distribution of Degree centrality among the Twitter accounts gathered

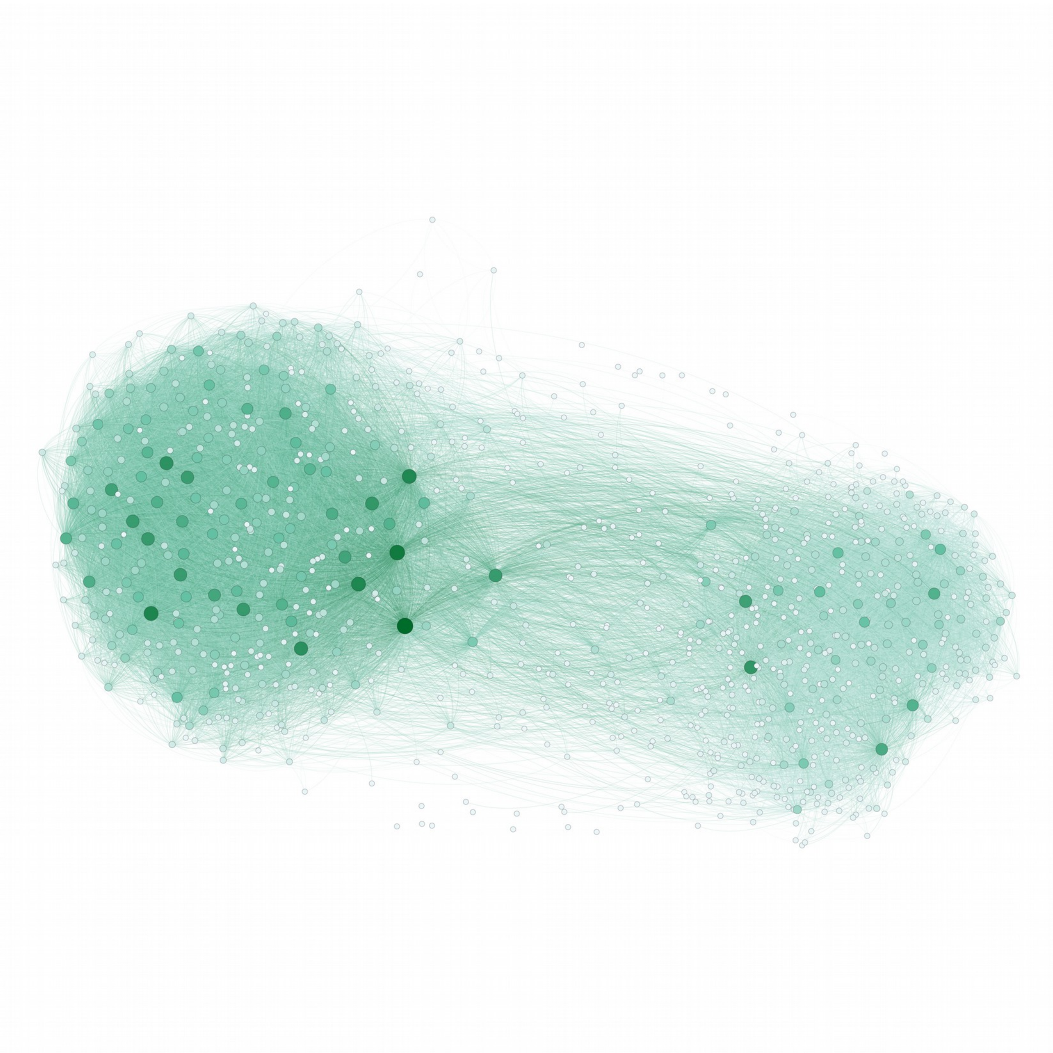

Fig. 4: Distribution of Degree centrality among the Twitter accounts gathered

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Betweenness centrality was then measured (Brandes, 2001) in order to understand the nodes who acts as a bridge among the many sub-communities found. Another common power-law distribution was found (Fig. 5), but this time with a much higher number of nodes with a very low or close to zero value. Betweenness centrality is less uniformly distributed than degree centrality, with only few nodes in the Fab Lab sub-community (the same nodes noted before at the interface with the other sub-community) and then, with a lower value, few nodes in the Hackerspaces, Makerspaces and TechShops sub-community (Fig. 6). Very few nodes act as a bridge among the two main sub-communities: 3-4 nodes on each sub-community interface with the other sub-community. Both main polarities are then connected by very few nodes.

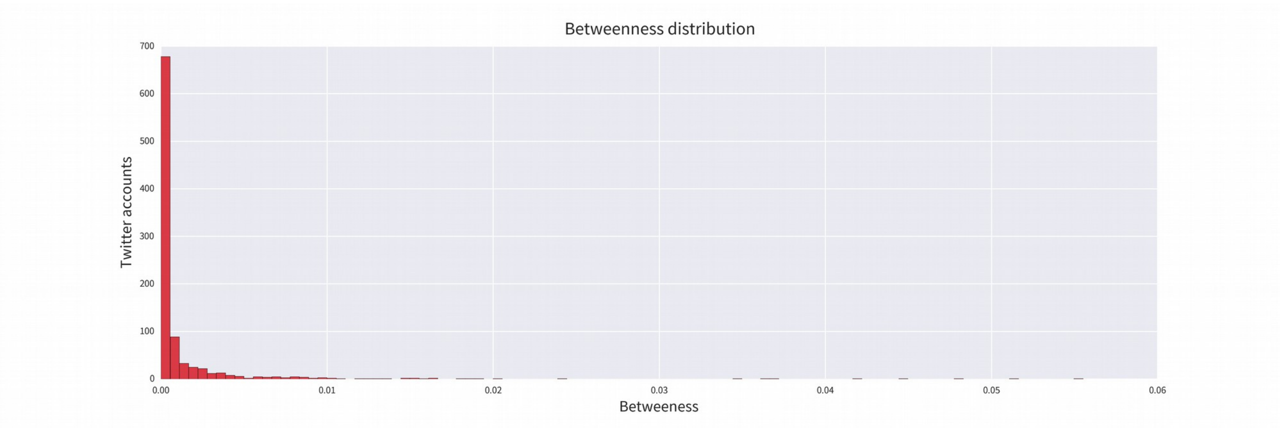

Fig. 5: Distribution of Betweenness centrality among the Twitter accounts gathered

In order to understand how close the nodes are compared to all the other nodes in the network, closeness centrality was calculated (Freeman, 1978). Here instead we have a different distribution: there is a peak at zero, and then the distribution is a normal one (Fig. 7). Therefore, except for several nodes (21.67% of the whole network) that are far from the other nodes in the network (as they are disconnected regarding in-degree or out-degree), most of the network (78.32% of the whole network) has a more uniform distribution of closeness, showcasing short distances among nodes and therefore a common ability to spread information quickly (Fig. 8). Both main polarities are strongly connected, where all nodes can easily communicate with each other and information can spread quickly: most of the laboratories are uniformly closed to each other, as in a real global community.

In order to measure the importance of each node related to its neighbors, Eigenvector centrality and PageRank centrality (Brin & Page, 1998; Page, Brin, Motwani, & Winograd, 1999) (with a probability of 0.85) were calculated. These values measure the influence of each node on its neighbors and the network. Both measurements presents a common power-law distribution (Fig. 9-Fig. 11). There are differences, however, in the distribution of the measured values in the main sub-communities. Regarding Eigenvector centrality, nodes get more importance according to the importance of the neighbors: in this case the Fab Lab sub-community has clearly almost all the higher values, compared to the other part of the network (Fig. 10). Nodes in the Fab Lab sub-community are clearly more influential in the whole Maker laboratories global community than the other laboratories, and this influence takes place with a power-law distribution where nodes with a higher influence are concentrated in the Fab Lab part of the network. Regarding PageRank centrality, it represents the likelihood that a Twitter account will reach a particular Twitter account in the network following the connections among all of the accounts. In this case, the value measured shows a power-law distribution as well but is concentrated only in very few nodes instead, especially in the Hackerspaces, Makerspaces and TechShops sub-community, with few nodes with a lower value but clearly identifiable in the Fab

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Lab sub-community (Fig. 12).

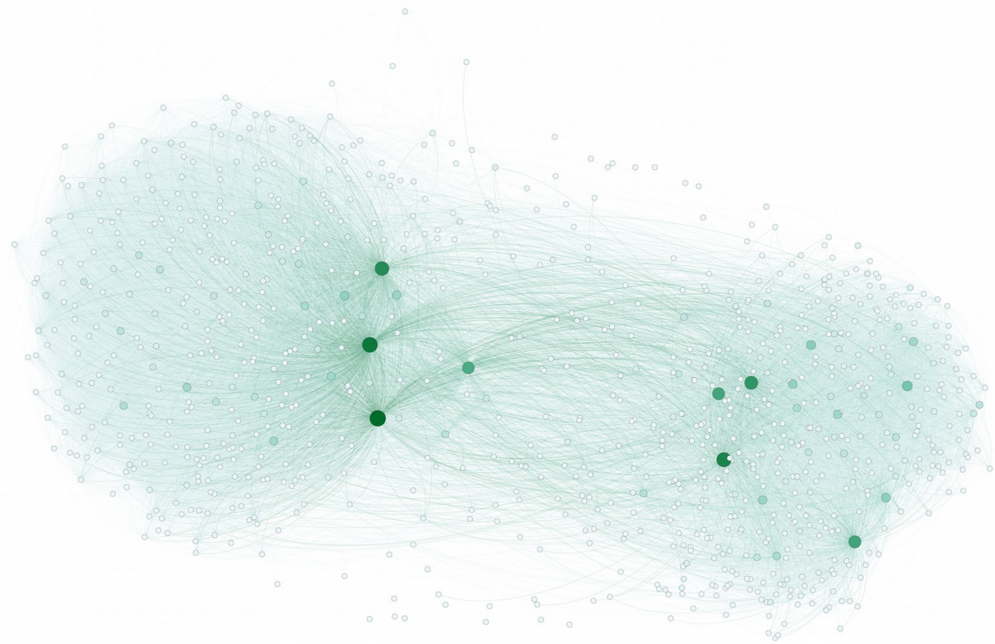

Fig. 6: Distribution of Betweenness centrality in the network (highlighted with a color and size related to the value)

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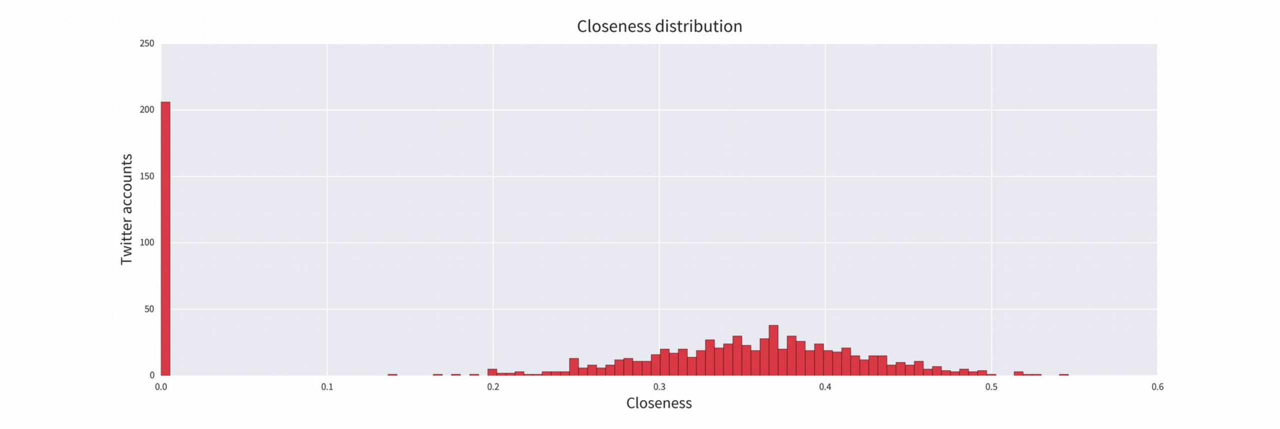

Fig. 7: Distribution of Closeness centrality among the Twitter accounts gathered

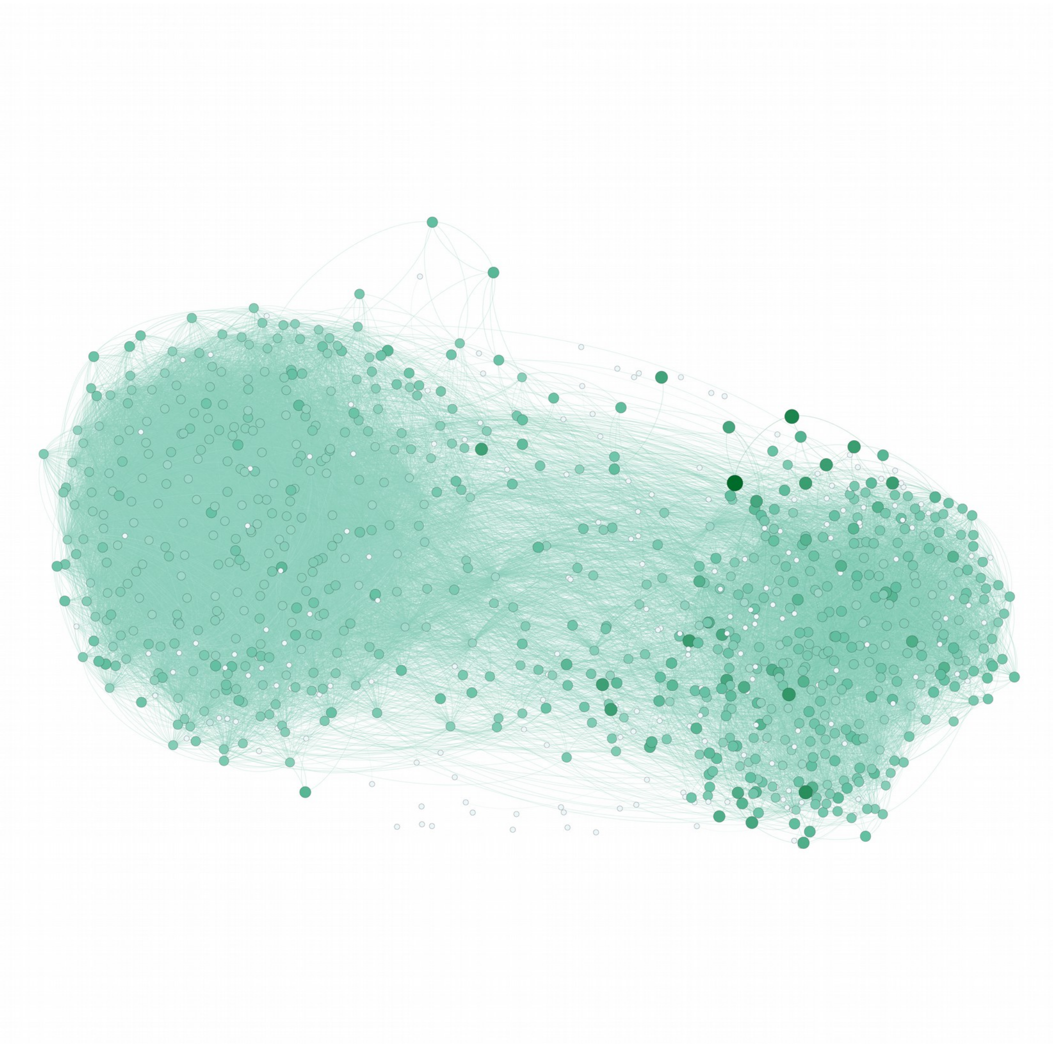

Fig. 8: Distribution of Closeness centrality in the network (highlighted with a color and size related to the value)

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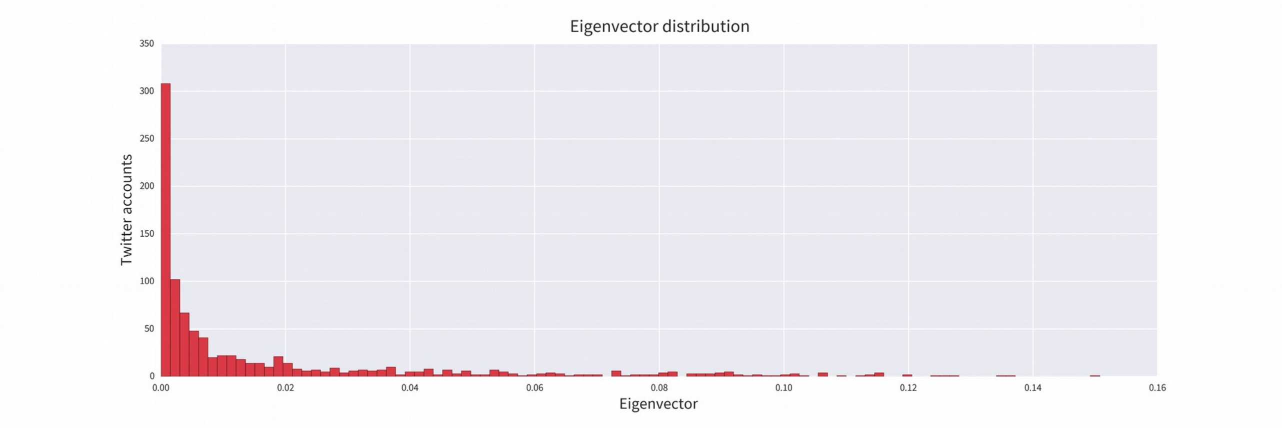

Fig. 9: Distribution of Eigenvector centrality among the Twitter accounts gathered

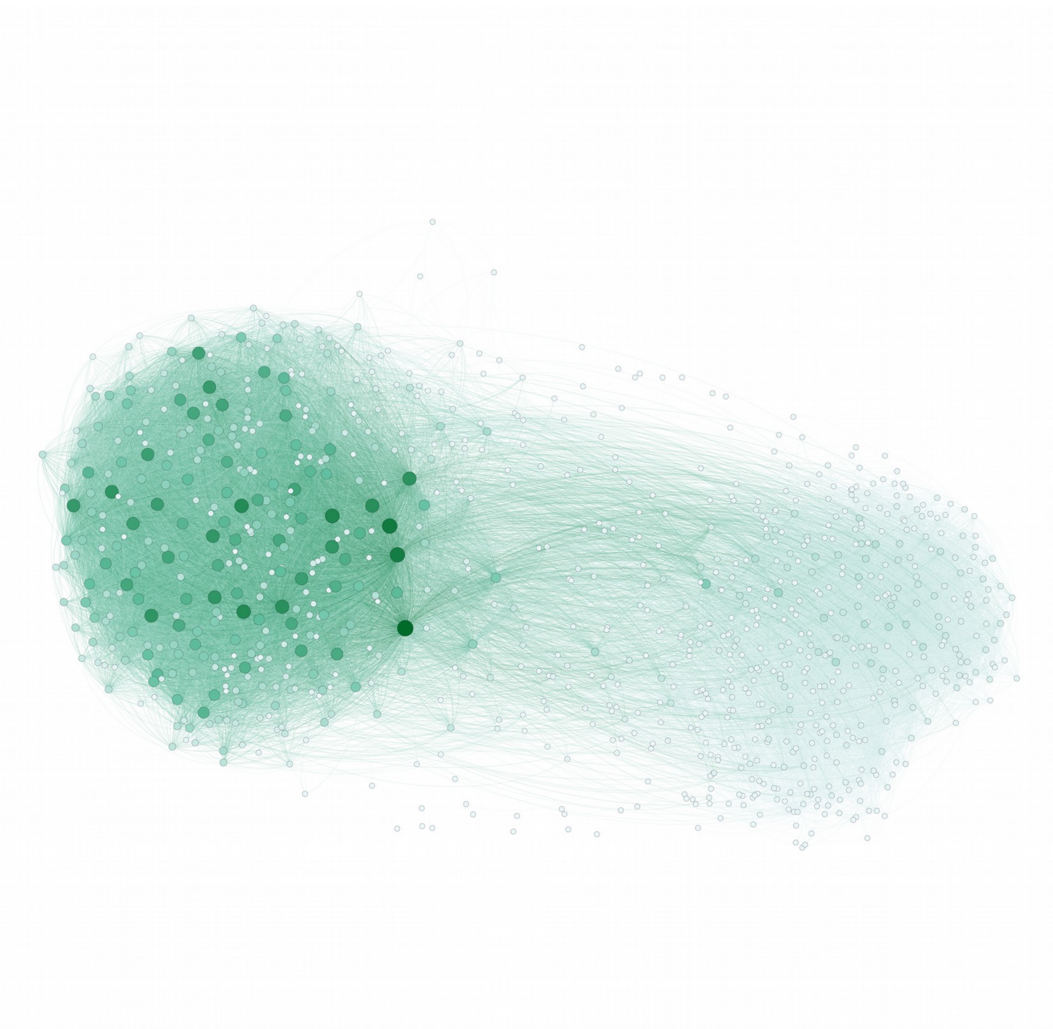

Fig. 10: Distribution of Eigenvector centrality in the network (highlighted with a color and size related to the value)

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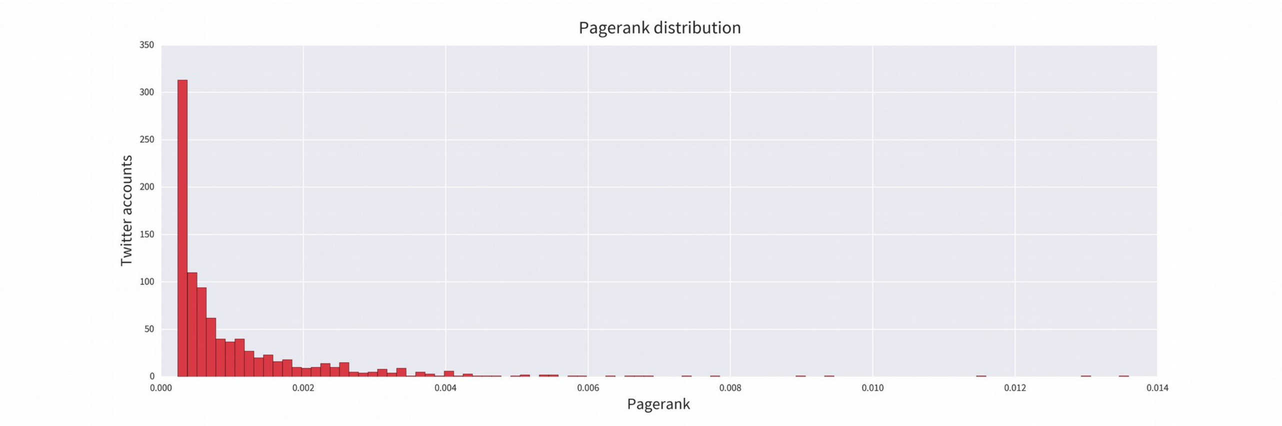

Fig. 11: Distribution of PageRank centrality among the Twitter accounts gathered

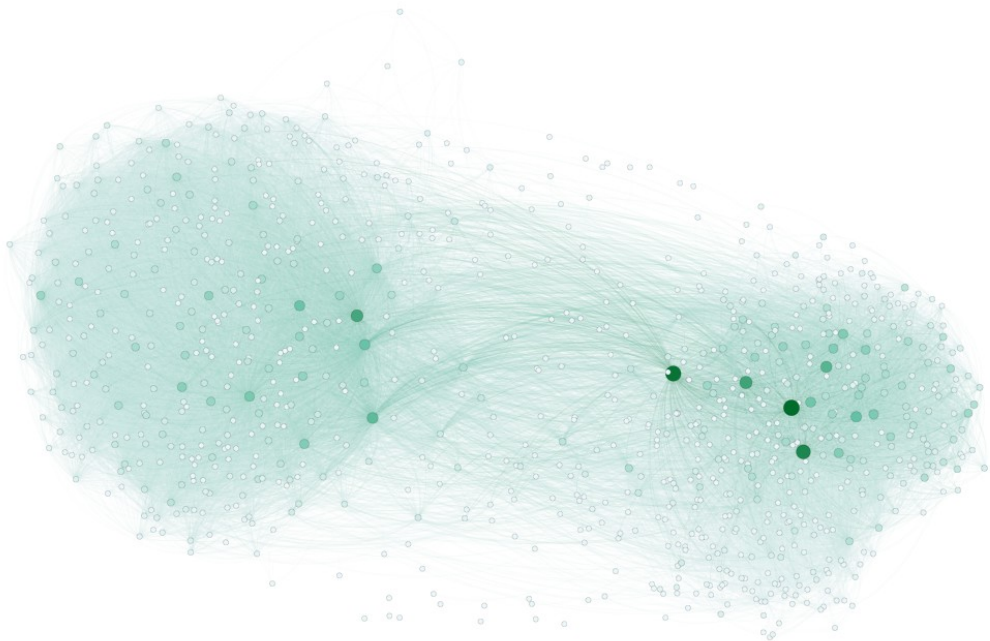

Fig. 12: Distribution of PageRank centrality in the network (highlighted with a color and size related to the value)

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4. Conclusions

The data obtained with this research give first insights about the structure and the distribution of influence and trust in the global Maker laboratories community on Twitter. The sub-communities obtained give insights about the social structure of the global Maker laboratories community, showing how Hackerspaces, Makerspaces, and TechShops are more homogeneous groups compared to Fab Labs, and how these two polarities are well separated, even if with few connecting nodes. Some sub-communities are geographically located, but more are a mix of laboratories from different places, showing the global nature of the community. The presence of more sub-communities in the Fab Lab part could represent the presence of more groups inside the global community that could grow apart in the future, or it could represent how the global format and community of Fab Labs is growing to a more local level or how it could bridge distant localities together. Except few nodes with high degree and betweenness with a common power-law distribution, closeness is more uniformly distributed for connected nodes. Power-law distributions take place also regarding influence and trust: while 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. Therefore, trust and influence take a different meaning in Fab Labs and in Makerspaces and Hackerspaces, according to how they are measured. The whole network is therefore constituted by several identifiable sub-communities that are organized in two polarities, with few nodes bridging them with a stronger role and trust; however most of the nodes are very close to each other in a strong community. Since each of the format of Maker laboratories follows different design processes, organizational structures and policies, these data could be used in order to further study the impact of such elements on the social structure of a global community, in order foster cohesion, communication and coordination.

This research represent a first analysis of the global Maker laboratories community on Twitter, as a proxy of the global connections among the laboratories. It focused only on the connections of following or being followed by Maker laboratories Twitter accounts. Therefore, no real interactions were analyzed in this research: future research should investigate this global phenomenon along more multiple directions (Gruzd et al., 2011) in order to understand if such patterns of connections constitutes a real community and not just a consequence of activity or interest in Twitter. For example, further research could focus on the online discussion among Maker laboratories accounts, and also among them and users, and only among users, in order to understand the difference structure of the community as experienced by laboratories and as experienced by users.

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