



HIGH ANALYTICS INFORMATION TECHNOLOGIES: A PATENT-BASED COOPERATION NETWORK ANALYSIS

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ABSTRACT

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Technologies that involve great part of firms are those based on high analytics information (HAI) technologies as an essential resource for operating different types of businesses. Through HAI patents analysis filed between 2000 and 2020 in the main patent offices in the world, this study aims to understand whether assignees have been developing HAI technologies in cooperation and emerging HAI technologies using social network analysis (SNA). Findings show that HAI patents assignees prioritize half of their developments in R&D internally, and the other half in partnership with other companies, primarily. It is also identified that cooperation relations are between organizations with the same nationality, especially those in South Korean and North American. In addition, United States is the main market of interest even the number of HAI technologies patented have been decreasing over the last five years. Despite this context, the identification of relational capabilities between assignees and the reconfiguration of resources, as a dynamic capability, is evidenced in HAI technologies development. Findings may support to identify HAI that still emerge in different industries, especially in service industry and support strategic Research & Development (R&D) decision-making processes to prioritize investments, identify new partnerships to innovate, or collaborate to develop public policies to foster new HAI technologies development.

Contribution/Originality: This study is original to bring a patent-specific context in HAI technologies opening new avenues about their relevance in business operations. Further, emphasizing relational capabilities as an antecedent of patents development, it uncurtains different ways of seeing capabilities through innovativeness.

1. INTRODUCTION

Information and communication technologies (ICT) are spread out among different types of business and its role in economic growth, or even its taxonomy has been receiving attention from scholars (Inaba & Squicciarini, 2017). Cooperation efforts became a common way of firms to enhance ICT innovations and its technological development with clear determinants about their beneficial effects, and therefore, the literature is well established in this subject (Pereira, Picanco-Castro, Covas, & Porto, 2018).

Social Networks Analysis (SNA) has been applied to understand cooperation among firms in business sectors such as, phytosterols (Preschitschek, Niemann, Leker, & Moehrle, 2013) solar energy technologies (De Paulo & Porto, 2017) biotech sector (Pereira et al., 2018) m-payment (Kumar, Gaur, Zhan, & Luo, 2019), food biotech (Linares, De Paulo, & Porto, 2019) laser additive manufacturing (Zarrabeitia, Bildosola, Río Belver, Alvarez, & Cilleruelo-Carrasco, 2019) autoimmune Diseases (Chartoumpekis, Fu, Ziros, & Sykiotis, 2020) security (Janavi & Emami, 2020) audio-visual (Pantano & Styliadis, 2021) car headlights (Smojver, Štorga, & Zovak, 2020) among others. Therefore, investigating ICT presenting in business daily basis through SNA may bring a broader view about trends in high analytics information (HAI) technologies which potentially represent parts of ICT in organization activities, specifically those focus on data processing equipment, methods, or digital computing. Yet, the level of cooperation, analyzing the main assignees and their different kind of technologies protected by patents tend to uncover another side of efforts to produce HAI technologies that might represent a fundamental stone for other differentiate technologies. Therefore, it is relevant to investigate even those technologies that might not be part of core businesses but are essential for and see the future of HAI technologies.

The literature under patent analysis does not explore ICT as needed, being HAI technologies an important piece of it, because these technologies are essential into business. Hence, this study brings a perspective about what are HAI technologies involved in relevant innovations nowadays. It also has advantages in providing useful information for policy markers promoting added knowledge to foster other technological interests and developments. Considering the needs for emergent information about ICT, actually, this exploratory analysis pursues to identify how HAI technologies development flourish among different business models under cooperation.

Supporting this analysis, a classification taxonomy for ICT called “J” tag (Inaba & Squicciarini, 2017) is used to interconnect patents information identifying cooperation and ICT trends of most promising HAI technologies. This study is looking for partnership establishment between companies and government together with institutes, agencies, research centers, foundations, laboratories, and universities enhancing technological innovation likelihood.

Doing so, this paper pretends to answer through social network analysis (SNA) the research question about what are the level of cooperation and technological opportunities for HAI technologies? In other words, it points out cooperation paths and main technologies in the main assignees’ radar. Furthermore, this method proven to be robust by other authors (Jeon & Suh, 2019). Therefore, the trends associated with HAI technologies through SNA method validation is used as a main subject to investigate technologies supported by Knowledge-Intensive business dependent on ICT (Chichkanov, Miles, & Belousova, 2021). Finally, a great contribution emerges here on giving for HAI technologies a relevant place in the digital world because without their presence various technological developments will not evolve to allow new paths for innovative technologies.

2. REVIEW

Information and communications technology (ICT) have a positive impact in countries performance in different areas such as Grow Domestic Products (GDP) growth, employment, productivity, poverty alleviation, quality of life, education, and healthcare (Broz, Buturac, & Parežanin, 2020; Palvia, Baqir, & Nemati, 2018). On international trade, ICT impact enhance countries integration (Gnangnon & Iyer, 2018) and boost their export (Bai, 2019; Rodríguez-Crespo & Martínez-Zarzoso, 2019). The interaction between Research & Development (R&D) expenditures and the internet proves to be an important factor for explaining the growth of countries’ GDP, as well (Choi & Yi, 2018). However, ICT impact on the economic growth may be limited in some regions becoming dependent on the decision makers (Ghosh, 2017). In sub-Saharan Africa, due to the lack of ICT skills, this impact is almost negligible (Haftu, 2019) which demonstrate that for development of this kind of technologies dynamic capabilities is unreplaceable asset to create tremendous opportunities and challenges to the countries (Broz et al., 2020; Groen, Lenaerts, Bosc, & Paquier, 2017).

According to OECD (2009) manual, patents represent most significant business inventions based on R&D in technologies and information is public and available to countries with patent systems. Therefore, understand ICT evolution through patent analysis assume strategic importance recently because they are an indicator of innovation and its processes complexity, short cycles and countries capabilities to attend volatile market demand (Geum, Kim, & Lee, 2017; Park, Yoon, & Lee, 2005). Kim and Bae (2017) pointed out technology-based service development to attend market changes is riskier because shorter innovation cycles are usual nowadays (Ahn & Skudlark, 2002; Kim & Bae, 2017). In this scenario, among having high performance, being innovative, developing technologies and managing shorter cycles, cooperation among parties may become, in various situations, the only way of competing properly. However, cooperation only succeeds when resources and capabilities are combined and parties define jointly how to enhance and use them accordingly (Snow, 2015).

Cooperation networks operating in different organizational levels are present in different patterns and characteristics of evolution, they require different actors and capabilities in the network composition to become a remarkable asset in developing technologies to be patented afterwards (Gomes, Galina, Vicentin, & Porto, 2017).

2.1. HAI Technologies

Not all technologies used in ICT products are ICT-related technologies (Inaba & Squicciarini, 2017). In ICT case, technologies may differ from products because they rely on a bundle of technologies, therefore the "J" tag taxonomy has an advantage to map ICT regardless the products in which they applied. The ICT taxonomy, called "J tag" proposed by Inaba and Squicciarini (2017) subdivides technologies into 13 different areas defined by the functions and specific technical features. It further subdivides ICT technologies in areas corresponding to specific functions and uses providing details about technologies related to ICT products. Therefore, the HAI technologies analyzed in this study are technologies that offer large-capacity information analysis, such as digital computing or data processing equipment or methods, specially adapted for specific functions. Table 1 illustrates the relationship between ICT products and HAI, especially the way in which products relate to technology areas. This analysis is relevant to understand what fields an invention is associated and therefore, it is a signal that such technology at stake is must and relevant to products and developments enhancing our visibility about HAI technologies impact into businesses.

Table 1. HAI technologies areas for ICT products.

Products Area and Description	
Business and productivity software and licensing services	Type
Database management software, packaged	**
Development tools and programming languages software, packaged	*
Information technology consultancy and services	
Business process management services	**
IT consulting services	**
IT support services	**
IT design and development services for applications	**
IT design and development services for networks and systems	**
Website hosting services	**
Application service provisioning	**
Other hosting and IT infrastructure provisioning services	**
Network management services	**
Computer systems management services	**
Other ICT Services	
Installation services of mainframe computers	*

Note: ** key underlying technology; * complementary technology.

Source: Inaba and Squicciarini (2017).

Navigating into different business sectors, HAI dispose their dominance to shape service, operations, and communications beyond their support in the effective information processing which is significant in helping to

enhance innovations. For example, in financial business important technologies are relate to electronic secure and effective data processing as a key strategy to be succeed in the sector. Other example is ICT industry itself that involve up to 68% of the total number of patents, where data processing is one of the top classes. Other industries also utilize HAI such data processing for signaling, equipment, machinery, and containers in food service industry. HAI technologies can be also found in real estate, where data processing of information about land, and professional services is valuable and imperative (Geum et al., 2017). Finally, HAI technologies is also employed in information systems to make easier operations in service industry activities and are widely applied across all categories (Administrative, Arts, Education, Finance, Food, ICT, Professional, Public, and Real State), thus having a significant impact (Geum, Kim, Lee, & Kim, 2012; Geum et al., 2017).

3. DATA AND METHOD

This study has a qualitative and quantitative nature that analyzing patents database in high analytics information technologies (HAI) granted to companies, governments and Science and Technology Institutions (STIs) represented by institutes, agencies, research centers, foundations, laboratories, and universities. Patent metrics technique, as a technological production indicator, was associated with cooperation networks analysis expecting to present an overview of HAI patents scenario in essential technologies used by various business sectors. Methodological overview of stages followed are presented in Figure 1.

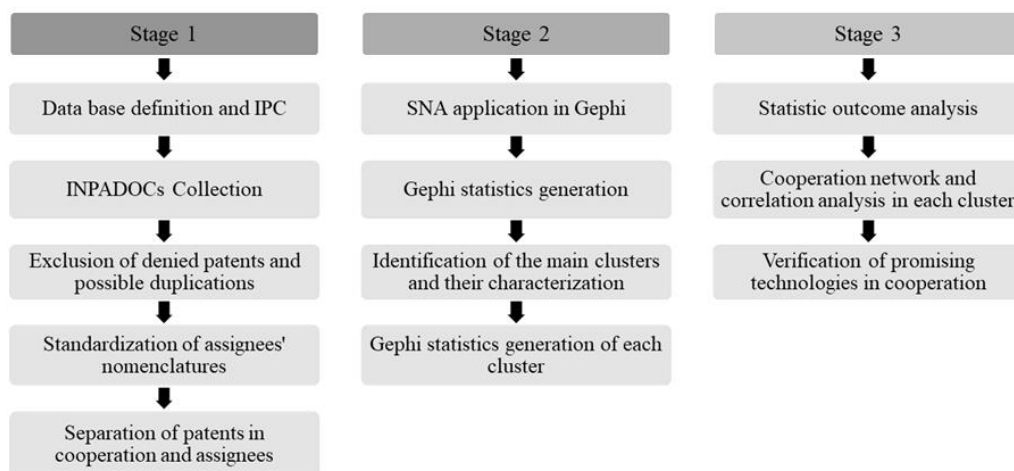


Figure 1. Methodological overview.

In Stage 1, to build and extract those patents with International Patent Classification (IPC) related to HAI technologies counting with specialists involved in the process previously. The IPC elected in this search is G06F-17/00 (Digital computing or data processing equipment or methods, specially adapted for specific functions).

It was collected patents data from Derwent Innovation by Clarivate, that identified 59.481 International Patent Documentation (INPADOCs) or 'patent families' from 2001-2020. The patent data used were Publication Number, IPC Current, Title, Abstract, Assignee, Priority Country, INPADOC Legal Status, Publication Year, INPADOC Family Members, and Claims.

Yet, legal status situation of INPADOCs analysis exclude duplicate ones and those in a restricted legal situation letting 48.882 INPADOCs available after cleaning up. A second cleaning up in patents codes and assignees names provide higher accuracy of data. Additionally, these data are standardized to avoid any further analysis distortions, using *OpenRefine* software (Verborgh & De Wilde, 2013) a freeware tool (openrefine.org). During this process the presence of more than one assignee in each INPADOC indicates a partnership or a cooperation relationship among Companies, Government or STIs. This relationship is known as cooperation network which providing more visibility about collaboration among different actors.

In Stage 2, spreadsheets of general statistics help to organize nodes (patents and assignees) and edges (patents related to their assignees) data loaded into Gephi to create bipartite networks. In General cooperation network, nodes' sizes are adjusted according to degree and assignees' cluster networks are created by using a plug-in called *Multimode Networks Transformation* (<https://github.com/jaroslav-kuchar/Multimode-Networks>), which eliminated patent nodes and turned them into a criterion of link between assignees (Pereira et al., 2018).

Gephi' statistical measures are used in each network identified, such as modularity (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008) average degree, page rank, and betweenness centrality (Hanneman & Riddle, 2005; Newman, 2010). The largest networks from the general cooperation network through the "modularity class" filter, following a node's identification (ID) command create five clusters of cooperation present afterwards. Using to build visible clusters networks a filter of Gephi software in degree partition number 2 provide better visualization and adjust of assignees who have high degree of cooperation.

In Stage 3, using the proposed definition by Inaba and Squicciarini (2017) all HAI verification respect specific technical functions and features that they are supposed to accomplish (e.g., computer architecture), identifying for the main assignees, their cooperation clusters, and top 10 technologies they have invested in cooperation or in internal R&D.

4. FINDINGS AND DISCUSSION

This study addresses technological cooperation analysis resulted in HAI technologies patents (IPC class G06F-17/00). Altogether, 48.882 INPADOCs (patent families) to 111.611 different assignees among companies, government and STIs, since 2000 to 2015 are in growing number of patents publications and since 2016 these numbers have been reducing Figure 2. The STIs group appears with 2,301 occurrences (2.06%) and is composed of institutes, agencies, research centers, foundations, laboratories, and universities. The group of "Companies" with the largest number of assignees appears with 108,943 occurrences (97.6%) and the "Government" with only 367 occurrences (0.33%). The STIs presence is still incipient, showing low participation or interest of this group of entities in HAI technologies development or even a greater partnership with other assignees. However, researchers (De Faria, Lima, & Santos, 2010; Etzkowitz & Leydesdorff, 2000) point out a better competitive advantage of organizations when they explore technological developments in partnership with universities, research centers, research laboratories, among others. Cooperation in HAI development appear mostly in companies by competitive strategy reasons. They choose to develop patents in their internal R&D areas or in partnership with other companies into the same business expertise.

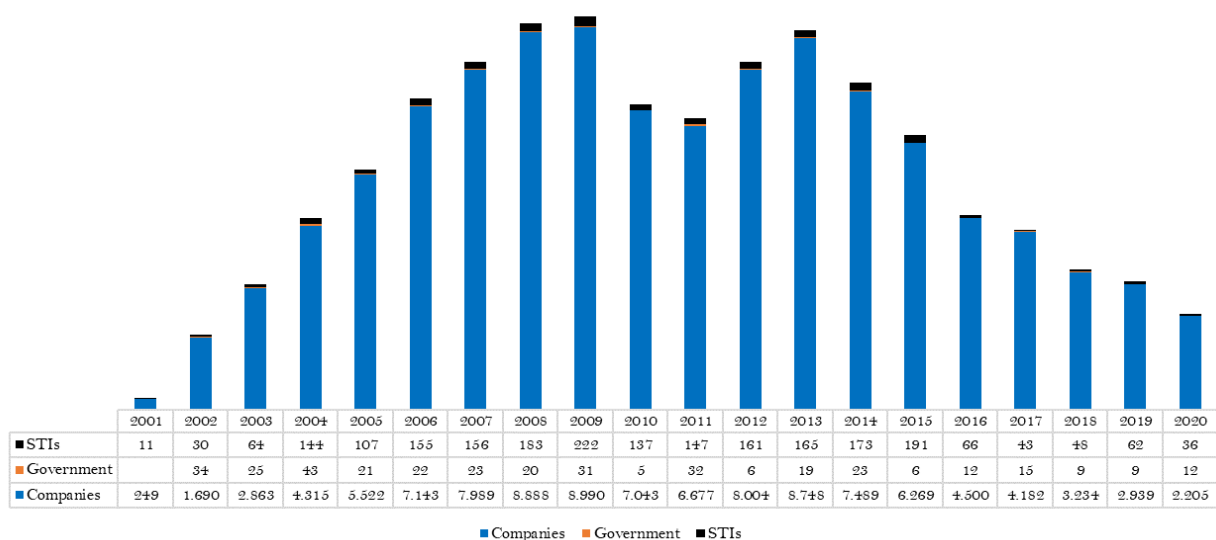


Figure 2. Participation in patent publications over time by type of Assignee.

Examining the patents regarding markets of interesting (countries), findings show that 58.57% of the INPADOCs are in The United States (USA), 10.99% in Japan, 7.22% in South Korea, and 4.62% in China. Requests for protection at other countries represent 18.16% of the inventions, respectively. Patents' publications appear preferably in home countries of the assignees Figure 3.

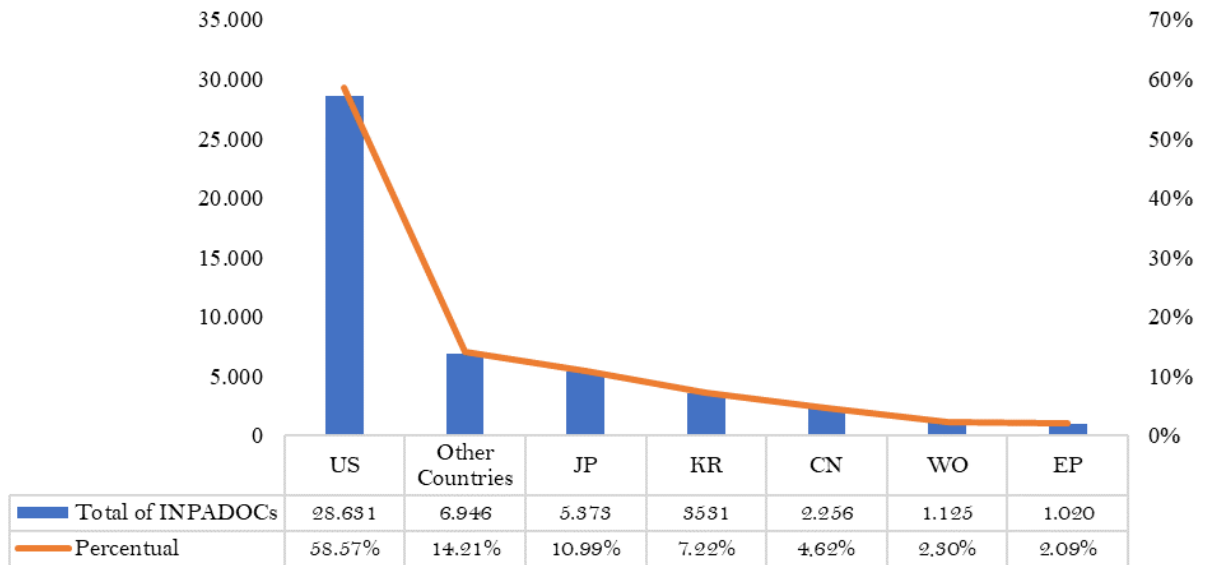


Figure 3. Countries patents publications.

Note: CN = China; EP = European Patent Office; JP = Japan; KR = South Korea; US = United States; WO = International Cooperation Agreement

The top ten HAI technologies Figure 4 are computer architecture (12.9%) and Image and sound technology (12.4%). In sequence, Storage Unit Technologies (5.5%) and data processing (5.2%), followed by Data and Numerical Analysis (4.9%), Telephone and mobile communications (4.4%), Electronic Measurement (3.9%), Safety (3.1%), Digital broadcast (2.8%) and Smart Sensors (1.5%).

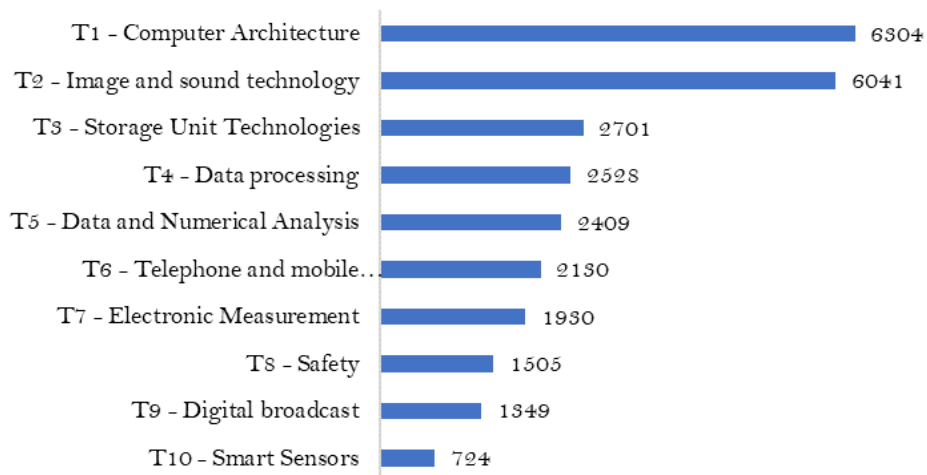


Figure 4. Top 10 HAI technologies most frequently found in patents analyzed.

The top twenty assignees represented only by companies have 13,281 INPADOCs in proprietary technology or technologies in collaboration Figure 5. These results show that 54.6% of HAI developments are in cooperation and 45.05% in proprietary technology, i.e., in internal R&D. Alibaba, General Motors and Hewlett Packard, Toyota, System Analysis Program Development Company (SAP), and Ford Global Tech stand out, whose collaboration average is above 70%. However, three assignees Canon, International Game Technology Company (IGT) and Samsung show an inverse behavior with low cooperation with percentage above 70% for proprietary technology,

which demonstrates their efforts in R&D (Research & Development). The other assignees maintain a balance between cooperation and proprietary technology.

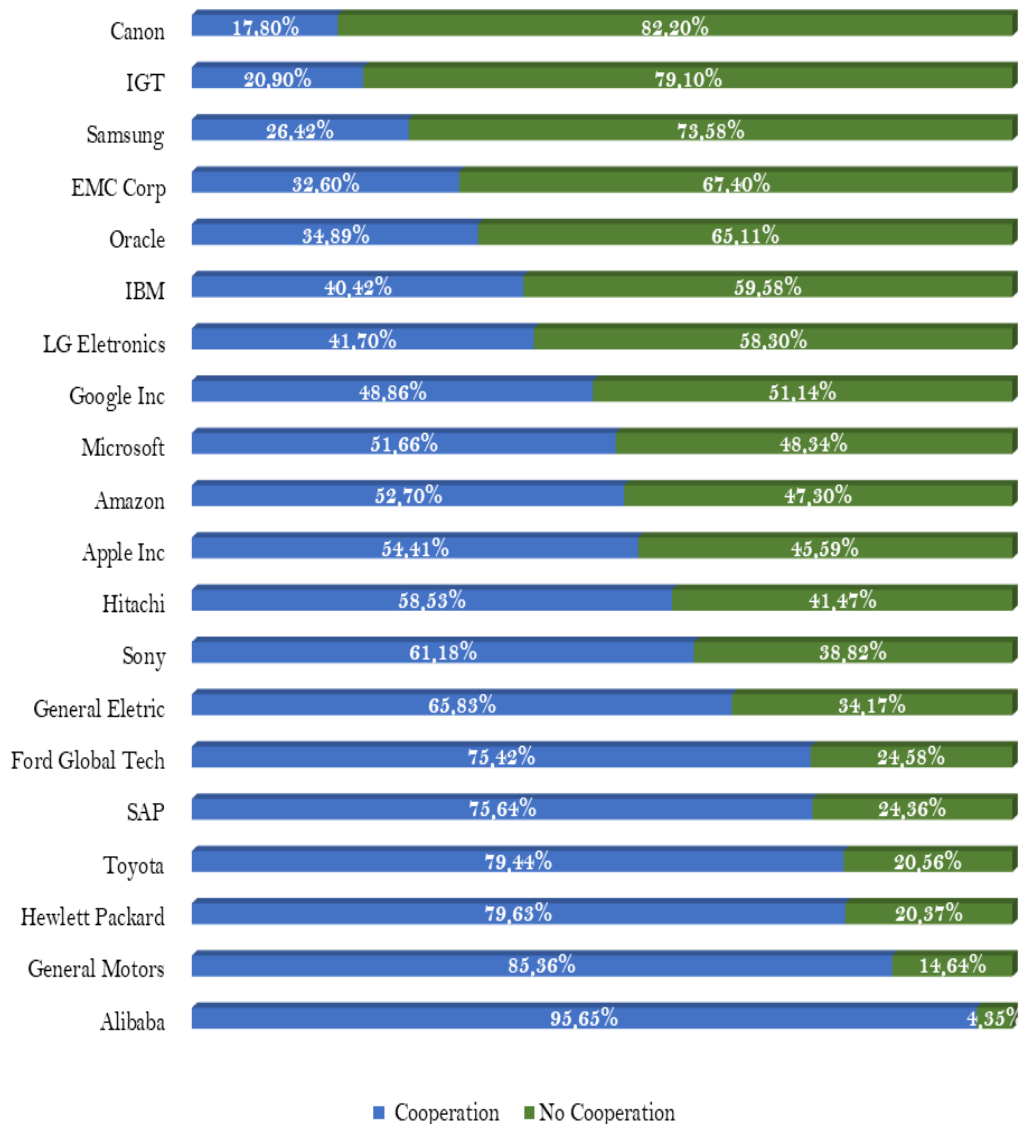


Figure 5. Patent development profile for the top 20 assignees.

4.1. HAI Social Cooperation Networks

In very large networks, such as the “General network of cooperation of assignees” Figure 6a visual identification compromises an interpretation and, therefore, using the giant component Figure 6b helps in a better analysis of the connections between nodes (De Faria et al., 2010; Pereira et al., 2018).

Modularity values are close between networks demonstrating a confident level of data [(Newman, 2010); Table 2]. Modularity supports to identify clusters that stand out among all clusters in the general cooperation network, The "general cooperation network" has 1,384 communities and the "Giant component network", 33. Thus, Giant component network allows for a greater grouping between the like-minded assignees, which allows for a more accurate analysis and characterization of cooperation clusters.

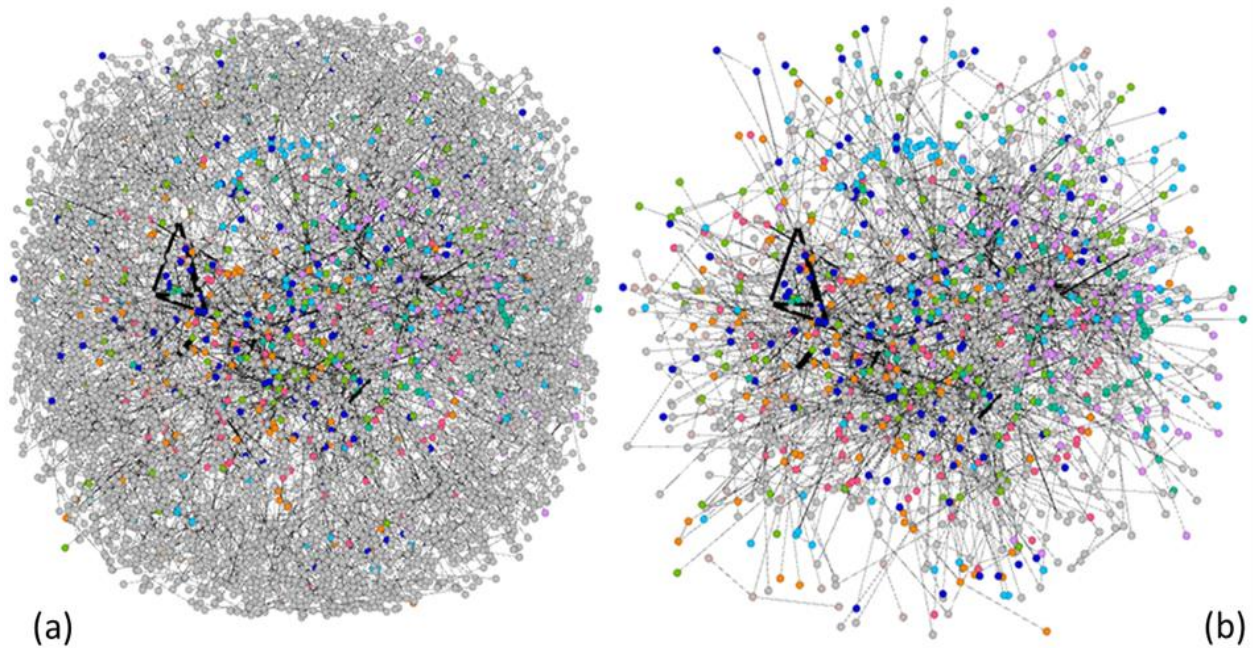


Figure 6. (a) General cooperation network of HAI; (b) Giant component network.

Table 2. Comparison of cooperation network measures.

Metrics	General network of cooperation	Giant Component Network
Average Degree	1.864	2.961
Weighted Average Degree	4.346	8.854
Number of Communities	1.384	33
Connected components	1.360	1
Average clustering coefficient	0.696	0.620
Number of Triangulations	4.020	2.370
Average length of path	6.469	6.489
Modularity	0.961	0.912
Number of nodes	4.711	1.373
Number of Edges	4.390	2.033
Triangulation ratio by the total of nodes	1.172	0.579

The network's average clustering coefficient measures the concentration of a node's neighborhood. Such metric is similar in both networks indicating a common behavior of nodes to connect to each other (0.696 and 0.620). As it is a much larger network, the General cooperation network have more triangulations than the Giant component network (4.020 and 2.370) which is something expected in terms of a higher proportion for first one (50.6% higher). Both networks have an average path length of around 6.4 average steps from one patent to the other, this distance indicates how efficient the flow of information over such network can be (De Paulo & Porto, 2017).

Table 3 shows the twenty most highly ranked incumbents in each network statistic, ordered by betweenness centrality metric, a useful metric and well established method to identify influential actors in social networks (Barthélemy, 2004; Suppa & Zimeo, 2015). The presence of few STIs and Government partnerships demonstrates that cooperation is more associated between company-to-company in the five clusters networks present in a sequence. Samsung, IBM, Microsoft, Google, General Electric, Toyota, Hewlett Packard, IGT and Sony differ from the others, and they are among the top twenty assignees. North American assignees represent the most presence (45%) followed by Japanese (20%), Chinese (10%) and the others distributed in South Korea, Finland, Holland, and Germany.

Table 3. Ranking of assignees with the highest statistics in the general cooperation network.

Assignee	Nature of Assignee	Home Country	Degree Centrality	Betweenness Centrality	Page Rank	Number of Triangulation
IBM*	Companies	US	8	278.357	0.0043	13
Siemens	Companies	DE	9	156.392	0.0018	12
Microsoft	Companies	US	9	141.098	0.0035	8
Sony	Companies	JP	9	139.586	0.0018	8
Philips	Companies	NL	8	120.732	0.0021	8
State Grid China	Companies	CN	11	109.415	0.0045	70
Samsung	Companies	KR	10	108.033	0.0023	25
Fujitsu	Companies	JP	9	106.762	0.0011	19
Google	Companies	US	9	104.613	0.0030	12
Toyota	Companies	JP	9	97.820	0.0015	18
AT & T Global*	Companies	US	9	95.125	0.0011	4
Qualcomm	Companies	US	8	83.451	0.0012	4
General Electric	Companies	US	9	79.548	0.0016	1
Hewlett Packard	Companies	US	9	71.896	0.0015	6
China University	STIs	CN	11	67.763	0.0008	13
Korea Telecom Corp	Companies	KR	9	65.769	0.0008	35
Oracle	Companies	US	10	56.393	0.0024	9
IGT	Companies	US	11	50.098	0.0015	10
Nokia	Companies	FI	10	41.329	0.0013	10
Dentsu Group	Companies	JP	10	40.206	0.0011	17

Note: CN = China; DE=Germany; KR=South Korea; FI = Finland; JP = Japan; NL = Netherlands; US = United States.

* IBM = International Business Machines Corporation and AT & T = American Telephone and Telegraph

Degree centrality = the number of forward links that originate or terminate at this vertex k (Newman, 2010; Zhang, 2010). Betweenness centrality = refers to the number of times a node k connects pairs of others at i and j in such a way that without the intermediation of node k, nodes i and j would not be able to connect and communicate (Jackson & Watts, 2002; Newman, 2010). Page Rank = used to point out the most important vertices in the network both quantitatively [(because it has connections with many other nodes) and qualitatively (by receiving points from several important nodes); (Page, Brin, Motwani, & Winograd, 1999)]. Triangulations allow to get a confirmation of results from different perspectives (Jack & Raturi, 2006; Jackson & Watts, 2002).

4.2. Clusters Analysis

The five clusters Figure 7 represent 27.1% of the Giant component network and these clusters have assignees who meet the following criteria: they have a large representation of connections in the network (degree) and broad partnerships (number of triangulations), they have a high capacity for control and interconnection (betweenness centrality), and they connect to other relevant nodes (page rank). In addition, they also have assignees partners from different countries, which also helps to identify whether the assignees' nationality influences their profile of technological cooperation. Clusters' names are the central actor's name in each community.

Cluster IBM. This cluster assumes an ego network characteristic IBM's cooperation network is a centralized community with visible subgroups and that, directly or indirectly, controlled by IBM, which has the second highest page rank and the best statistics of this community, thus constituting itself one of the most important assignees. In this way, its presence interferes in the entire ecosystem of HAI technology development interconnection. From 49 cooperation relationships made with IBM, only 4 occurred with universities, such as Baylor University, Nebraska, Texas, and Ireland Nat Universities. This indicates a low diversity of interaction with diverse types of assignees (8.2%), signaling a priority option for company-to-company cooperation.

Few assignees have cooperation relationships with other universities, such as the Dhahran University, Illinois, Lancaster, and Iowa Universities, which leads us to reaffirm that the companies' cooperation relationship is stronger. Organizations in cooperation are from North American countries, except to Tokyo Electron, a Japanese semiconductor manufacturer based in Akasaka, Minato-ku, Tokyo, Japan.

The 10 top technologies are part of this network with greater emphasis on computer architecture (T1), image and sound technology (T2), storage unit technologies (T3), data processing (T4), data and numerical analysis (T5) totaling 84.13% of patents aligned with the business model and products available on the market by IBM in recent decades. On the contrary, the patents on telephone and mobile Communications (T6), Security (T8), Digital

Transmission (T9), Intelligent Sensors (T10), which in recent years, especially 2020, had a significant reduction. The electronic measurement patent (T7), despite its small expression, has been present since 2003. Regarding the market of protection interest, the patents in the IBM cooperation network apply the United States (85.25%) as country of preference.

Finally, a business sectors diversity presence is from those specialized in sound and image products (Toshiba), mobility services (Uber), equipment (Honeywell), pharmaceuticals (Validus Biopharma), technology (SAP), among others. It demonstrates organizations' interest in complementing their portfolios with HAI technologies.

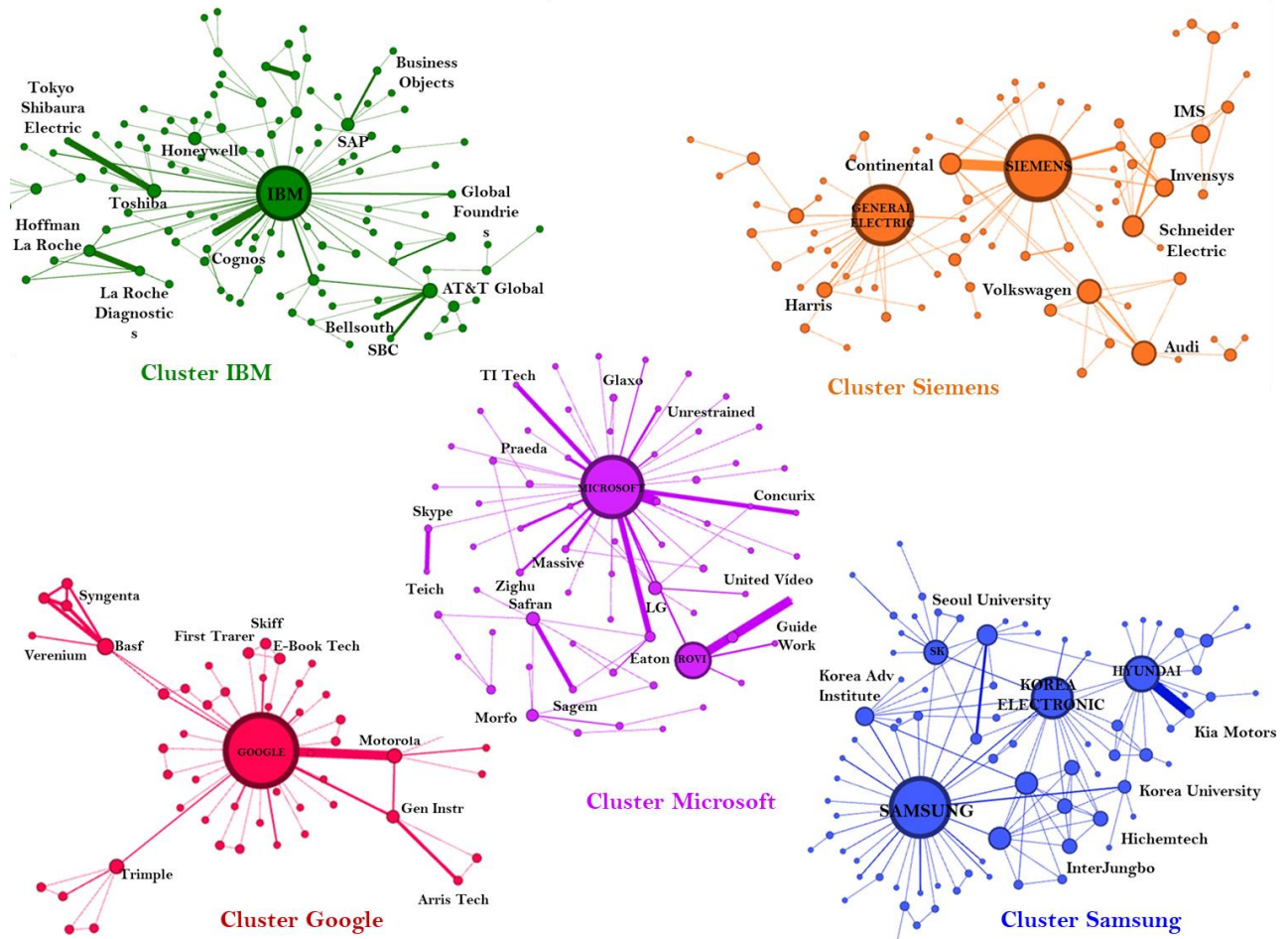


Figure 7. Clusters networks cooperation analysis.

Cluster Samsung: This cluster has as central actors the organizations Korea Electronics and Samsung presenting itself as a decentralized community. Yet, 70.31% of patents are focus on computer architecture technologies [(T1); (10.34%)], image and sound technology [(T2); (40.04%)] and telephone and mobile communications [(T6); (19.92%)]. Although the characteristics of these 3 technology groups are at serving the development of mobile communication products. The interest in this type of technology has been intense since the 2002's, when the projection of mobile phones reached out a large presence scale in the society. The patents on devices in radiation energy conversion into electrical energy had a peak of deposits between 2009 and 2012. The patents for the data and numerical analysis group (T5) began to appear in 2003 and the other technological groups punctually deposited over time but demonstrate isolated patents or complementary technologies.

Regarding the market target, South Korea (78.25%) is the primarily option which also is Samsung's home country. The United States (8.89%) and India (8.29%) also appear as markets of interest from 2005 onwards.

Mexico, on the other hand, presents itself as an attractive market only from 2007 to 2013. Finally, two-thirds of patents are in Asian market, thus reinforcing the finding that assignees prioritize their markets of origin.

This network has a decentralized formation with well-defined sub-groupings, and a strong participation of "STIs." Samsung has a pool of universities as direct development partners and is among the top ten statistics in the overall network [Table 3](#) with a considerable number of repeat partnerships with these universities. It is the most important and influential HAI developer in this cluster, since it has the most expressive betweenness centrality, thus demonstrating its power to intervene and control the information flow of the network. Furthermore, Korea Electronic presents itself as a second grouping connected to other important assignees as Hyundai, Kia Motors, Telecoms Institute, Pantech, Pusan University, among others.

When looking at Samsung more closely, out of its thirty partnerships, nine are with STIs such as Information & Communication University, Korea, Yonsei, Kyungwoon, Kyunghee, Myongji, Korea, Seoul Nat, Sungkwan and Sejong Universities. Hyundai, for example, has also developed partnerships with STIs and indirectly with government agencies.

All the main assignees of this community (Samsung, Korea Electronic, Hyundai, SK Communications) cooperate with each other through STIs and are also organizations of Asian origin, thus confirming that technological cooperation takes place more intensely between organizations of the same origin, possibly due to cultural aspects such as language and other values, even economic aspects related to fostering and encouraging research and technological development in a particular country or region ([Santamaría, Nieto, & Rodríguez, 2021](#)).

All ten top technologies are in Samsung's patents and there is a uniqueness of partnerships for the technological area focused on semiconductors with Korea Electronic, SK communication, Hynix semiconductors, among others. This non-diversity of co-assignees and technological areas, in addition to generating dependency between partners, can make technological development less agile and thus characterize an important monopolization of actors that make up the present network.

Cluster Siemens. The central assignees are General Electric and Siemens; however, Siemens' is the second-best statistic in the general network cooperation. This cluster has 5.39% of representativeness with 93 patents among 78 assignees. It has as main HAI, Computer Architecture (T1), Image and Sound Technology (T2) and Electronic Measurement Technology (T7), totaling 74.45% of patents. The HAI patent publications kept a similar frequency over the period in terms of absolute numbers. Patents for telephone and mobile communications (T6) are no longer part of Siemens' list of patents as of 2007, motivated by the exponential evolution of this type of technology by organizations such as Samsung and Apple that changed the concept of telephony worldwide speaking.

The other technological groups investigated in this study had punctual and sparse deposits over time, which may indicate isolated initiatives in developments of HAI. Among 137 patents of Siemens, they are distributed in Computer Architecture [(T1); (28.47%)]; followed by image and sound technology [(T2); (27.01%)]; Electronic Measurement [(T7) ; (18.98%)]; Data processing [(T4) ; (7.30%)]; Data and Numerical Analysis [(T5); (7.30%)]; Storage Unit Technologies [(T3); (4.38%)]; Telephone and mobile communications [(T6); (2.19%)]; Smart Sensors [(T10); (2.19%)]; Safety [(T8); (1.46%)]; and Digital broad [(T9); (0.73%)].

Regarding the markets of interest, 49.58% of patents filed in the United States, 32.20% in Germany, 11.02% in the European Patent Office, 2.97% in the International Cooperation Treaty, 3.39% in Mexico and less than 1% in India. Patents occurred mostly in the United States, however, the strategy adopted in 2019 and 2020 demonstrates a worldwide strategy distributed in the European Patent Office (EPO) and in the International Cooperation Agreement (WO), in addition of Siemens' country of origin, the USA. From the perspective of technological cooperation and network statistics, Siemens privileges company-to-company interactions with important market "players" such as Audi, Volkswagen, Schneider Electric, EMS, Alstom, and Bank of America.

Even Siemens with the second greatest betweenness centrality which places it in a privileged position of interaction with the other assignees, General Electric has the best stat on the number of deposits made (357 versus

245). Siemens and General Electric do not have direct relationship in the network; however, two assignees are intermediating this relationship, they are Harris and Rapisten Systems.

Finally, assignees in cooperation with Siemens and General Electric are also from German, French and English origin, which reinforces the tendency to form global cooperation clusters. In addition, there is a very specific focus in the year 2020 for the development of storage unit technologies (T3), data and numerical analysis (T5) and electronic measurement (T7) with organizations in various sectors such as automotive (Audi and Volkswagen), electronic components (Schneider Electric), Health Care (EMS Company, Gen Hospital), finance (Bank of America) and a single partnership with STIs made by General Electric with Washington University.

Cluster Microsoft. Microsoft's cooperation network focuses on developing data processing technologies [(T4); (21.26%)], followed to computer architecture [(T1); (20.19%)] and image and sound technology [(T2); (17.17%)]. It has an average of 17 deposits per year between 2006 and 2009, 11 deposits between 2010 and 2013 and in other years an average of 5 deposits made by Microsoft. Patents for storage unit technologies [(T3); (12.07%)] and data and numerical analysis [(T4); (12.27%)] ranked fourth and fifth in terms of representativeness. Telephone and mobile communication technologies (T6), electronic measurement (T7) and security (T8) were 5% and the other technological groups (T9 and T10) with less than 1%, featuring specific developments of technologies related to Microsoft's best-known products, such as the Office package, its flagship of greatest interest.

Regarding markets of interesting, 90.2% of patents are in the United States, 6.52% in Mexico, and 2.53% in Asian countries such as Hong Kong, Philippines and Thailand and 0.75% in European countries, and very irregularly in other offices, such as Mexico between 2008 and 2013 and Thailand from 2016 onwards.

This network has a centralized formation in Microsoft characterized as an ego network (Jackson & Watts, 2002; Newman, 2010; Scott, 1988). The cooperation between companies and STIs is only 1.6% and most cooperative relationships occur with individuals, autonomous researchers or researchers linked to Microsoft itself and other organizations. Despite the suppression of the individual profiles in this study, this kind of relationship stood out, however this study keeps focusing on cooperative relationships between companies, government and STIs.

There is a partnership made between Microsoft and Commissariat Energie Atomique, a French public organization (government), but most partnerships are with North American organizations, with special emphasis on LinkedIn, one of the main platforms for professional social network, which, maintain connections with professionals around the world.

Cluster Google. This is the smallest network represents 3.79% of the General cooperation network. Google has focus on data processing technologies [(T4); (20.40%)], computer architecture [(T1); (31.62%)] and image and sound technology [(T2); (21.88%)]. There was a peak in deposits of Microsoft in 2013 to 2015 for all top 10 technologies analyzed in this study, except for smart sensor technology (T10). As in most clusters already described, excepting Samsung cluster, market of interesting is the United States representing 94.85% of patents and it is Google's home country.

Australia appears especially in 2003 together with other locations but without representation in general. A centralized community strongly dependent on Google, directly or indirectly interconnected with it. Google has the ninth position of the best statistics in the general cooperation network (Hanneman & Riddle, 2005; Newman, 2010).

In this way, Goggle has an enormous indirect influence on HAI development ecosystem creating multiples company-to-company partnerships without any together with STIs or governments. Partnerships with larger organizations such as Motorola, Syngenta, Basf and Carterpillar stand out. In this vein, the importance of having international collaborations or even collaboration with different partners bring an appropriate level of disruptive innovation and keep business in advantage because an idea of an innovation system coordinated at only one level might be outdated (Arranz, Arroyabe, & Schumann, 2020; Hernández-Trasobares & Murillo-Luna, 2020).

4.3. Cooperation Networks' Insights

In general, North American presence in technological development of HAY is strong and appear as primary and secondary strategies of supportive technology to the business. Microsoft's case with its MS Office package is a perfect example of primary strategy and Google case with Google meet as secondary strategy about HAI usage.

In addition, in cooperation networks, STIs and governments' role are not preponderant or found as central nodes or intermediaries of cooperative relationships, except to Samsung's cooperation network where the presence of universities is highly evidenced corroborating with (Fischer, Schaeffer, & Vonortas, 2019) who mention that multinational corporations deeper connections with domestic and foreign agents are needed to accelerate universities' contribution for technology upgrading.

Even IBM, which plays an essential role in its network, has little influence on the collaboration ecosystem with governments and STIs. A strong presence of companies in cooperation, leads us to infer that the relationships, partnerships and alliances are preponderant to the development of HAI technology, reinforcing a relevant presence of organizations' relational capacities, an important dynamic capability, into a technological development of ecosystems in line with (De Silva & Rossi, 2018; Helfat & Raubitschek, 2018) representing one of the relevant factors in digital disruptive innovation also pointed out by Si and Chen (2020).

On the other hand, when analyzing the relevance of assignees based on network statistics, the companies' relationships stand out in the metrics of centrality, placing in a privileged condition about generating and controlling of knowledge-intensive, as well as their influence on HAI development flows. Additionally, the value of resources reconfiguration in partnerships practices demand others dynamic capabilities from assignees to create appropriate conditions to innovate, being this reconfiguration, the main conductor of diffusion and acceleration of technological knowledge-intensive flows also highlighted by Mao, Yu, Zhou, Harms, and Fang (2020) in his study about knowledge growth in university-companies innovation networks.

Cooperation and dynamic capabilities are positively associated (Yang & Gan, 2021) where trust and long-term relationships promote inter-organizational integration and their effects of domestic firms' relational embeddedness on resource reconfiguring capability can mediated by foreign firms' embeddedness in the process of innovation (Du, Lu, & Zhou, 2020; Prajogo & Olhager, 2012). In low and high-innovative environments that can be distinguished in terms of information technology knowledge, infrastructure, and commitment-based (Popa, Soto-Acosta, & Palacios-Marqués, 2021) dynamic capabilities presence may enhance cooperation goals (Yang & Gan, 2021). Additionally, the United States is in a "bubble" of patents publications in its domestic market, opting for hybrid technological development in exclusively R&D units or when in cooperation the priority is in organizations within their own country and well-developed partners in their sectors, indicating that technological development model is in a half in R&D strategy and the other half in cooperation with partners in the same nationality or region, corroborating with Lei et al. (2013) who mention that technological cooperation takes place mainly between organizations from the same country. Samsung focuses on South Korea even HAI patents number have been decreasing over the last five years, for instance.

Analyzing under a knowledge transmission perspective, findings presents coexistence between partners among the decades, symmetry in power relations, sharing of values, similar cognitive basis, and respectful credibility among the assignees which are elements analyzed in the theory of social capital mentioned in De Paulo and Porto (2017); Turchi, De Negri, De Negri, and Figueiredo (2013) and in the theory of dynamic capabilities in aspects of partnerships, trust and credibility of partners pointed out by Helfat and Raubitschek (2018); Snow (2015).

In addition, under technological perspective, all assignees have patents in the ten main technologies analyzed, emphasizing in technologies over others, but in majority the focus is on computer architecture (T1), followed by imaging technology and sound (T2), storage unit technologies (T3), data processing technology (T4) and data and numerical analysis (T5) as most preferable HAI. Table 4 provides an overview of all cooperation networks.

Table 4. Summary of the main characteristics of cooperation networks.

Cluster Name	Relevant Assignees*	Most Relevant Relationships in the Cooperation Network**	Network formation and Profile of Relationships	Main Technologies	Markets of Interesting
Cluster IBM	Lenovo Toshiba Repsol Honeywell	Cognos IBM (22) Tokio Shibaura Electric Toshiba (19) Hoffman La Roche Roche Diagnostics (17) Saudi Arabian Oil Aramco Services (15) AT&T Global SBC Knowledge Ventures (13) A&T Global BellSouth Intellectual Properties (9)	Centralized in the general network; Centralized into cluster; 11.1% of Company-ICT relationships; Preference in cooperation with organizations of the same nationality (US).	T1 (23.5%) T3 (15.5%) T4 (15.8%) T5 (19.1%)	US (85.25%) EP (4.15%) JP (3.11%)
Cluster Samsung	Univ.Korea Quixey S-Printing Medison	Hyunday Kia Motors (56) SNU R&D Found Univ Seoul (13) Samsung Univ Korea (6) Samsung Quixey (6) Samsung S-Printing (4) Samsung Medison (4)	Centralized in the general network; Decentralized into cluster; 29.3% of Company-ICT relationships. Preference in cooperation with organizations of the same nationality (KR).	T1 (10.3%) T2 (40%) T6 (19.9%)	KR (78.25%) US (8.89%) IN (8.29%)
Cluster Siemens	Audi Deut Bank Unify Continental	Siemens Continental Automotive (28) Quantum Siemens (8) Audi Volkswagen (6) Schneider Electric Square (6) Quantum Invensys Systems (4) Schneider Electric Invensys Systems (4)	Centralized in the general network; Decentralized into cluster; 4.3% of Company-ICT relationships; Preference in cooperation with organizations of other nationalities (US; DE).	T1 (28.5%) T2 (27%) T7 (19%)	US (49.5%) DE (32.2%) EP (11.0%)
Cluster Microsoft	LG Electronics Linkedin Unisys Expedia	Microsoft LinkedIn (15) Rovi Tech United Video (14) Microsoft Eaton (9) Microsoft Concurix (7) Guideworks Rovi Tech (7) Safram Electronics Sagem Communication (7)	Decentralized in the general network; Centralized into cluster; 1.37% of Company-ICT relationships; Preference in cooperation with organizations of the same nationality (US).	T1 (20.2%) T2 (17.2%) T4 (21.3%)	US (90.2%) MX (6.5%)
Cluster Google	Motorola BASF Gen Instr Exbiblio BV	Google Motorola (23) BASF Diversa (9) BASF Verenum (9) Diversa Verenum (9) Arris Enterpresis Gen Instr (8) BASF Singenta (6)	Decentralized in the general network; Centralized into cluster; 100% Company-Company relations; Preference in cooperation with organizations of the same nationality (US).	T1 (31.6%) T2 (21.9%) T4 (20.4%)	US (94.9%)

Note: DE = Germany; MX = Mexico; EP = European Patent Office; FR = France; IN = India; JP = Japan; KR = South Korea; US=United States

T1 = Computer Architecture; T2 = Image and sound technology; T3 = Storage unit technologies; T4 = Data processing; T5 = Data and numerical analysis; T6 = Telephone and mobile communications; T7 = Electronic Measurement; T8 = Security; T9 = Digital Transmission; T10 = Smart Sensors.

* Relevant Assignees who partnered with the Central Actor; ** In parentheses are the weights of the relationships in the cooperation network

5. FINAL REMARKS

HAI patents analysis made possible to see deepen aspects about emerged technologies from 2001 to 2020 in cooperation networks proposing to investigate distinctive characteristics of these innovations not yet analyzed in the literature, and which are essential in different industries. Using SNA techniques and Gephi software, the data treated answered the research question showing organizations that are holding HAI patents prioritized in their developments through internal R&D and cooperation, primarily with those highly specialized in this type of technology. General statistics on HAI patents networks confirmed the United States as the main market of interesting noting its representativeness of 58.57% of technological production patented. Japan has also invested in domestic technological production (10.99%), thus taking advantage of its internal demand, and seeking to consolidate alternative sources of supporting rapid information analysis through derivatives technologies.

Regarding the most produced technologies, the patents on computer architecture (T1), image and sound technology (T2) and storage unit technologies (T3) are priorities. An interesting example that uses HAI technologies are the professional data access platforms, LinkedIn, that store career information and professional achievement histories. Another one is virtual communication technologies, like Google meets, Zoom, and Microsoft Teams that made possible to conduct virtual conferences and meetings, especially during the COVID-19 pandemic period. From the twenty largest HAI patent assignees, the percentage of their cooperation (54.95%) is in line with the general average of cooperation among all assignees on the analyzed sample (54.85%) confirming a significant impact of dynamic capabilities to keep these partnerships alive. Organizations with greater intensity of cooperation are mostly large organizations who are not dependent of innovation ecosystems but their hybrid strategies in growth and sustainable businesses emerge in response to innovation. Thus, this study contributes to social networks, dynamic capabilities, and social capital theories in demonstrating a relevant impact of cooperation in HAI development. Additionally, it also contributes to practitioners may see a tendency of technological development in HAI to create a near future technological planning or analysis to any gaps in terms of innovative technologies development in near future. Finally, Patent analysis has some limitations identified throughout the process. Although, they have not affected the quality of the results obtained. The limitations are: manual development of the database due to the limitation of only 60,000 records per query in Derwent platform Innovation, lack of standardization of assignees' names since there are names abbreviations errors or variations in abbreviations, limitation in the ability to manipulate large databases analyzed in Gephi, and lag inherent in patent process, since newly filed patents are kept confidential for up to 18 months, increasing the non-capture of deposits close to the period of data collection, making their analysis impossible. Yet, limitations regarding to not all inventions are publicly available because of technical fields, patent strategy, or they have no value to society, therefore, have no industrial application; additionally, over the years changes in patent laws call for attention; and patent data are complex, generating economic issues and legal processes might not capture all HAI. For future studies, complementary methods of analysis, based on more IPCs related to HAI can predict future combinations of the research topics outlined here.

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