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High Analytics Information Technological Routes: a patent network analysis

Rotas Tecnológicas de High Analytics Information: uma análise da rede de patentes

Rutas tecnológicas de High Analytics Information: un análisis de red de patentes

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Abstract
Knowledge-intensive significantly contribute to technological development. This paper aims to explore technological routes (TR) on high analytics information (HAI) technologies for sake of technological forecasting through social network analysis (SNA) in a patent database from 2001 to 2020. Applying search path link count (SPLC) algorithm, this study provides five different TR in various business sectors. This study support decision makers to find additional core of technologies for their innovation strategies and help researchers in identifying HAI technologies that may still emerge in different industries support strategic R&D decisions about prioritizing investments, identifying partnerships to innovate, and collaborating in public policies based on promoting new HAI technologies development.
Keywords: Information technologies; Technological routes; Social network analysis; Patents analysis; High analytics information.

Resumo
O conhecimento intensivo contribui significativamente para o desenvolvimento tecnológico. Este artigo tem como objetivo explorar rotas tecnológicas (TR) em tecnologias de informação de alta análise (HAI) para fins de previsão tecnológica por meio de análise de redes sociais (SNA) em um banco de dados de patentes de 2001 a 2020. Aplicando o algoritmo de contagem de links de caminho de busca (SPLC), este estudo fornece cinco TR diferentes em vários setores de negócios. Este estudo auxilia os tomadores de decisão a encontrar núcleos adicionais de tecnologias para suas estratégias de inovação e auxilia os pesquisadores na identificação de tecnologias de HAI que ainda possam surgir em diferentes indústrias, apoiando decisões estratégicas de P&D sobre como priorizar investimentos, identificar parcerias para inovar e colaborar em políticas públicas baseadas na promoção desenvolvimento de novas tecnologias HAI.
Palavras-chave: Tecnologias de informação; Rotas tecnológicas; Análise de redes sociais; Análise de patentes, High analytics information.

Resumen
El conocimiento intensivo contribuye significativamente al desarrollo tecnológico. Este artículo tiene como objetivo explorar las vías tecnológicas (TR) en tecnologías de high analytics information (HAI) con fines de pronóstico tecnológico a través del análisis de redes sociales (SNA) en una base de datos de patentes de 2001 a 2020. Aplicando el recuento de enlaces de ruta de algoritmo (SPLC), este estudio proporciona cinco TR diferentes en diferentes sectores comerciales. Este estudio ayuda a los tomadores de decisiones a encontrar núcleos tecnológicos adicionales para sus estrategias de innovación y ayuda a los investigadores a identificar tecnologías HAI que aún pueden surgir en diferentes industrias, apoyando decisiones estratégicas de I+D sobre cómo priorizar inversiones, identificar

asociaciones para innovar y colaborar en políticas públicas basadas en promover el desarrollo de nuevas tecnologías HAI.
Palabras clave: Tecnologías de la información; Rutas tecnológicas; Análisis de redes sociales; Análisis de patentes, High analytics information.

1. Introduction

Technologies are an outstanding advance of the latest decades (García-Fernández et al., 2020). Business sectors are diligent about its importance and their needs to improve efficiencies and resources to take competitive advantage (García-Sánchez et al., 2018; Mao et al., 2016). Innovations represent itself technology-intensive developments and efforts that have demanded global networks of partners and new capabilities to improve these technological reaches (Luqueze, 2018). In fact, technologies create volatile environments for changing on a fast-track routes of newest findings and high analytics information technologies (HAI) are part of it.

HAI associate different technological products related to business and productivity software and licensing services, database management software, development tools and programming languages software, business process management services, various supporting services for networks and systems management, website hosting services, installation services of mainframe computers, and so on (Inaba & Squicciarini, 2017). Understanding HAI relevance in various business sectors become something logical for those are keen on innovating or creating technological planning. One way is pursing and comprehending technological routes (TR) evolution of HAI to deal with prospecting, path of knowledge, and potentially promising technologies for better chances of innovation.

As HAI technologies are key underlying technologies or complementary technologies depending on business sector, and never analyzed before under, this perspective of TR analysis method is the best approach and social network patents analysis (SNPA) seeks to understand these implications of relationship patterns for technologies developments and innovations with common interests among different assignees, constituting, therefore, structures of affinities and perspectives. Hence, having quantitative advantages over qualitative approaches in perceiving useful information about technologies analysis per considering knowledge links and spillovers (Breschi et al., 2003; C. Kim, 2017; Linares et al., 2019), this study intends to validate innovative trends associated with HAI technologies.

Regarding to relevance of TR analysis to understand innovation initiatives, trends, and how technologies are formed enhancing technological planning accuracy for organizations, a research question rises about what are recent technological trends developed in High Analytics Information technologies (HAI) into business innovation? Furthermore, TR method has already proven to be robust by other authors (Linares et al., 2019; Pereira et al., 2018; Porto et al., 2012), therefore, the trends associated with TR method validation are used in this study also due to importance of HAI into many business sectors to support better decision-making about higher innovative developments.

The literature does not also fully explore skills and capabilities' impact in TR. Technological capabilities (TC) become a remarkable asset in business innovation, in competitive advantage and in technological developments as dynamic capabilities in supporting innovative growth, change adaptation, acquisition, deployment, combination and reconfiguration of technological resources, skills and knowledge in improvement of technological output of organizations (García-Fernández et al., 2020; Wilden & Gudergan, 2015). Thus, this study also brings a perspective about it, as well.

2. Technological Routes and HAI Emerging Technologies

Prospecting promising technologies through patents investigation into a domain may support organizations in numerous aspects, such as trends analysis, novelty definition in patent, technological fields not yet granted through patents, hotspots (i.e., fields intensively filled by patents) and supporting strategic technologies planning, as well (Pessôa et al., 2021).

Due to the lack of standardization in patents database different techniques are proposed and applied in recent literature to prospect patented technologies: text mining (Chartoumpekis et al., 2020; Pessôa et al., 2021; Zarrabeitia et al., 2019), visualization approach (Abbas et al., 2014), patent citation network (Jeon & Suh, 2019; Kumar et al., 2021; Linares et al., 2019) or patent co-citation network (Janavi & Emami, 2020; Smojver et al., 2021). Text mining involves finding out rules and patterns using lists, maps, and trends through unstructured information; on the other hand, visualization approach expresses visual structured data, where maps or clustering methods are employed to extract useful information; citation network to discover core fields and technology (Janavi & Emami, 2020; Kumar et al., 2021; Pessôa et al., 2021).

Technologies routes (TR) are not linear; however, a particular division of each route may constitute entirely different paths, focus or competencies (Kumar et al., 2021). They are innovation threads that together are intertwined event of evolution (L. Kim & Ju, 2019). Many authors explore TR through patents, (Kumar et al., 2018) investigate TR in energy domain, (D. Kim et al., 2017) highlight TR factors in technology convergence phenomenon, (Linares et al., 2019) in food biotechnology and (You & Park, 2018) identify developmental TR in electrical steel domain, among others.

Therefore, TR might be considered as a knowledge inheritance across innovations paths and as a technological innovation ecosystem of development (Chang et al., 2012; Kuan et al., 2013; Kumar et al., 2021). They also provide data about emergent technologies (ET) introducing a relevant impact in the way societies may perform daily activities, as well as introduce additional dimensions to be aware about socio-economic structure (Hesse-Biber, 2011; Rotolo et al., 2015; Zhou et al., 2019).

There are several aspects of sources of ET (Zhou et al., 2019), however, they are formed from previous technologies in some precise way through evolution and developed through a comprehensible adaptive process (Arthur, 2007; Zhou et al., 2010, 2019). In the research, (Rotolo et al., 2015) indicate that ET have the following core characteristics – coherence, radical novelty, relatively fast growth, prominent impact, ambiguity, and uncertainty. Several objective data are utilized in the research to identify ET from a perspective of technology evolution trajectory and technology forecasting, i.e., from a perspective of TR (de Paulo & Porto, 2018; L. Kim & Ju, 2019; Kumar et al., 2021; Linares et al., 2019; B. Wang et al., 2018; Xu et al., 2018; Xue et al., 2016; You & Park, 2018)(Li et al., 2016; Wang et al., 2018; Xu et al., 2018), therefore, this study also follow this perspective of findings ET through TR.

Additionally, technological evolution landscape also highlights technological capabilities (TC), technological learning, and innovation performance (Carvalho et al., 2019; García-Fernández et al., 2020) as crucial factors. They are essential to analyzed significant patents in the main TR over different periods of time and understand from a technological perspective various element of development in different directions of application. In other words, TC applied in TR analysis includes not only systems itself analysis but also interaction among tech element and common development process (Kumar et al., 2021).

Regarding to HAI technologies popping up in the literature, big-data analytics emerges as a phenomenon in reporting potentialities to transform how firms enhance high value businesses performance (Popovič et al., 2018), in high-frequency trading in financial markets (Seddon & Currie, 2017), or even in hospitals for routine work (Bhatt et al., 2019). Web hosting service appears to platform that ensures confidentiality, integrity, and availability (Huynh et al., 2019). All means that HAI have a thousand of ways to be applied in many business sectors demonstrating relevance, impact, innovativeness, and applicability.

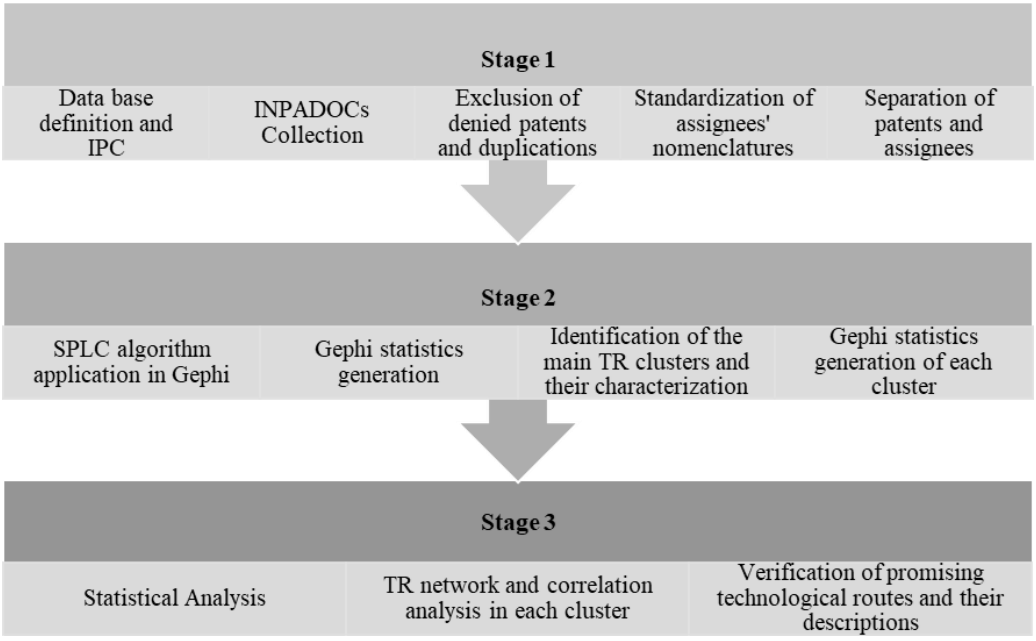
HAI are also related to network management services offering by 5G to user equipment's' in indoor environments (e.g., home, living room or kitchen), which enables to use smart phones or selecting media content servers to cast on TV set (Jawad et al., 2019), or in neural networks architecture having a potential to be an accurate and effective computational intelligent forensics tool for network analysis, encrypted traffic identification in real time and demystification of malware

traffic (Demertzis et al., 2021). HAI diversification impact make sure that this is an important domain of technologies to be analyzed.

3. Data and Method

This research begins discussing with specialists about relevant IPCs related do HAI technologies and analyzing Information and Communication Technologies (ICT) classification (Inaba & Squicciarini, 2017) to collect appropriate patents data from Derwent Innovation by Clarivate. The IPC elected is G06F 17/00 (Equipment or methods of digital computing or data processing, specially adapted for specific functions) from 2001 to 2020 for this search. Only the earliest patent of each INPADOC (patent families) was recovered to avoid redundant data about countries where there were applications for same invention (Linares et al., 2019). The following patent data extracted are publication number, title, application date, IPC code, standardized assignee, cited references (backward citations), number of cited references (patents), and number of assignees. Figure 1 depicted our methodological overview.

Figure 1. Methodological Stages.



Source. Elaborated by authors.

In stage one, the verification of the legal status of all collected INPADOCs is also carried out, excluding duplicates and those in a restricted legal situation. The refinement of the names of the first patent assignees is carried out to obtain better standardization, since there are syntax variations of the same names, different formatting, and characters in the base. OpenRefine, an open-source software developed by Google, supports to clean up and transform confusing data, to group and standardize common names (Verborgh & De Wilde, 2013), in addition, manual verification of each INPADOCs to correct errors not captured by the software.

The presence of more than one assignee in each INPADOC indicates partnership or a cooperation relationship. Assignees classification as Companies, Government or STIs (Science and Technology Institutions) is to represent them differently into SNPA providing more visibility among different actors and their corporate names are used for this classification.

In stage two, after the composition of the patent database, the analysis to evaluate TR begin using search path link

count (SPLC) algorithm trough SNPA (Hanneman & Riddle, 2005; Newman, 2010). The software Gephi (Bastian, Heymann & Jacomy, 2009) support the visualization and statistical analysis of social networks. To make the analysis more structured, in addition to the general network, separate networks are built in clusters (community).

Based on TR methodology proposed by (Hummon & Dereian, 1989) and applied by (de Paulo & Porto, 2018; Fontana et al., 2009; Linares et al., 2019; Verspagen, 2007), the relevant connections analysis by SPLC algorithm measures the frequency of patents located in different paths. In turn, a path is a sequence of citations that extends from most recent patent to the oldest one through intermediary's patents, therefore, this path represents technological knowledge flow.

Furthermore, SPLC algorithm used in this study is based on the construction of a directed patent's network that, when placed in an orderly sequence, it points to the different TR being possible identify technological trends. Although the SPLC focuses on link counting, and its choice is an arbitrary decision of the researchers (de Paulo & Porto, 2018; Verspagen, 2007). TR concepts propose a process of technological mapping to identify temporal technological evolutions and developers' contributions allowing that the latest technologies may be called emerging technologies (de Paulo & Porto, 2018).

There is a dependance of elements captured on technological routes that can be updated or complemented through integrating other databases (Linares et al., 2019; Porto et al., 2012). One advantage to use TR is it is no longer necessary to have a previous list of possible development candidates what diminishes researcher bias. A recommendation is raised to map TR, the data must be processed to prevent the citations of previous patents citing later ones. This method uses functionalities to identify central positions and more relevant links in SNPA. Figure 1 depicted our methodological overview.

In stage three, after identifying clusters, betweenness centrality statistics support networks identification (Blondel et al., 2008) to take the main TR, being possible to analyze ET. Betweenness centrality metric is a useful metric and well-established method to identify influential actors in SNPA (Barthélemy, 2004; Suppa & Zimeo, 2015). Afterwards, five TR are presented describing the main ETs.

4. Results

Clarivate's Derwent Innovation patent database for the defined IPC (G06F-17/00) between 2001 and 2020 allowed the identification of 48,882 patent families (INPADOCs) in which there are existence of technological cooperation between assignees in 26,810 INPADOCs and 38,230 INPADOCS in cited-refs building technological routes. In the 20 years analyzed, there is an increase in the number of HAI patent applications, especially from 2003 onwards. Until 2014, the number of new patents reached an average of 93% growth per year, however, from 2015 it is possible to notice a decrease in the number's absolutes in patents applications. Patents in cooperation show a similar behavior where its average is 61.4% between 2003 and 2013 decreasing to 42.70% from 2014.

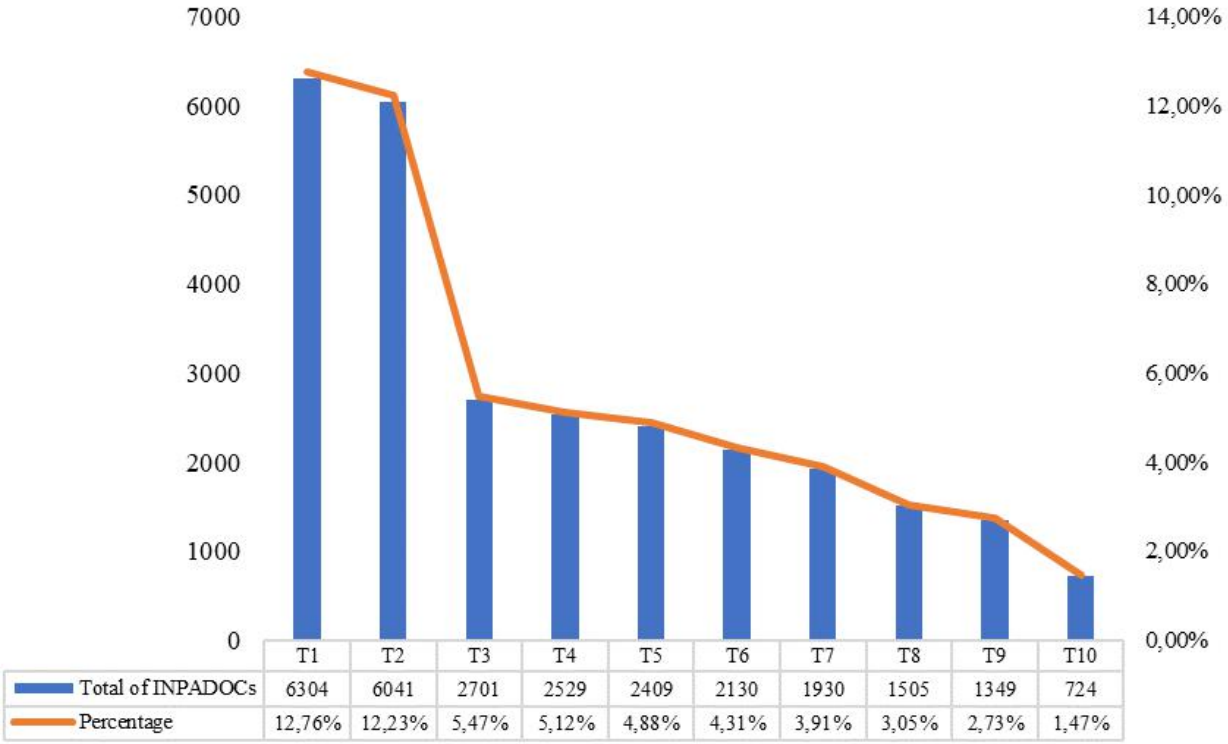
This downward trend of HAI innovations goes hand in hand with the high offer of technologies to meet various demands from different business sectors, as well as it may be aligned with the evolution perspectives of organizations that use this type of technological source. Anyway, these results already offer evidence of a balance of organizations in developing their technologies in a proprietary and cooperative way (54.85%) and using existing patent sources (78.21%), which demonstrates a clear evolution for HAI technologies.

By detailing more HAI technologies that make up this class of IPC, by technological subgroup (Figure 2) using the new ICT classification called "J tag" classification (Inaba & Squicciarini, 2017), there is a distribution with a predominance of computer architecture technologies (12.76%), Image and sound technology (12.23%) and Storage unit technologies (5.47%), which can and should be associated with the increase of digital information in organizational routines that need be analyzed and disseminated for better decision-making into business. Other technologies can be identified as relevant in this context and are also highlighted as Data Processing (5.12%), Data and Numerical Analysis (4.88%), Telephone and Mobile

Communications (4.31%), Electronic Measurement (3 .91%), Security (3.05%), Digital Transmission (2.73%) and Intelligent Sensors (1.47%). Figure 2 show top 10 HAI technologies distribution.

Historical evolution of HAI patent applications, it is noted that between 2001 and 2020 applications on computer architecture (T1) and image and sound technology (T2) are focus of innovations in HAI patents in absolute numbers, with greater emphasis on the years 2007/2008 and 2012/2013 (Figure 3-a). As of 2015, these two subgroups lost representation, but still maintained their predominance. With the aid of a logarithmic scale (Figure 3-b) it is noted that all technologies showed a large growth variation over the period analyzed with a slight downward trend in the last year.

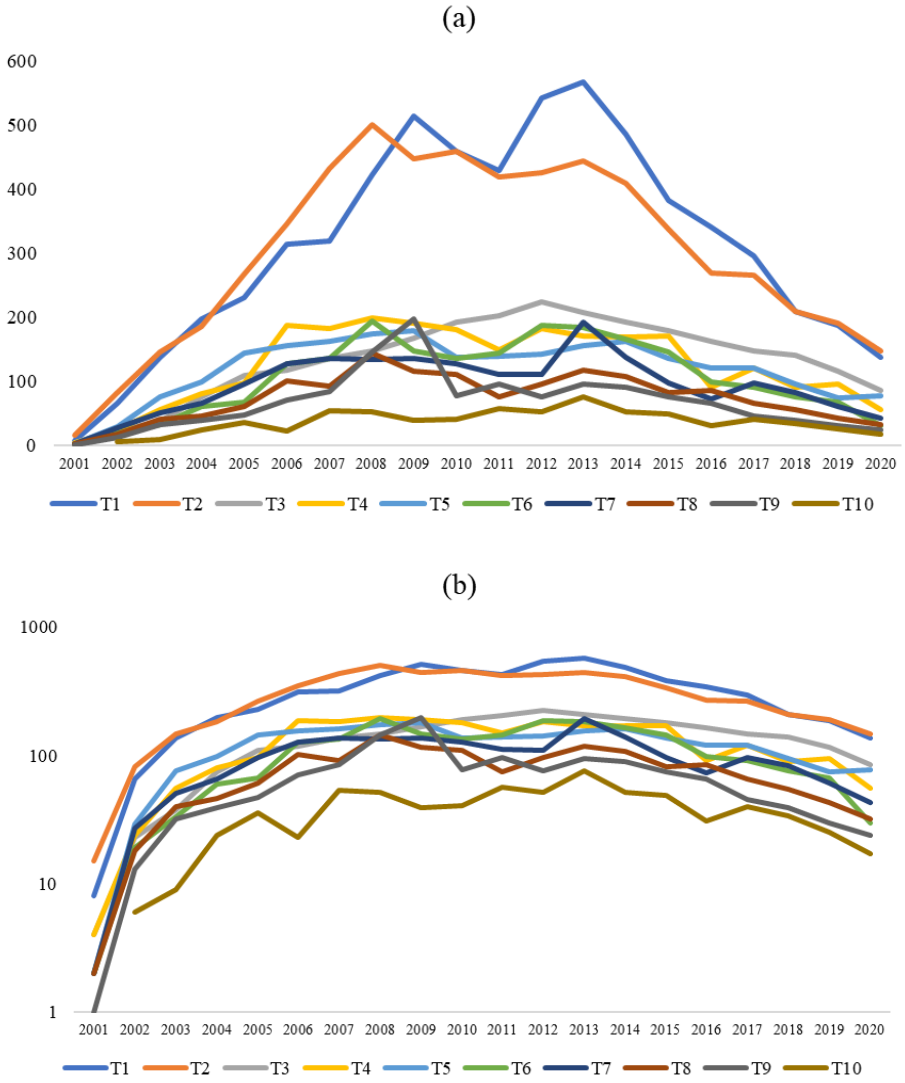
Figure 2. Distribution of the 10 main technologies deposited.



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Total of INPADOCs	6304	6041	2701	2529	2409	2130	1930	1505	1349	724
Percentage	12,76%	12,23%	5,47%	5,12%	4,88%	4,31%	3,91%	3,05%	2,73%	1,47%

Note. Legend: 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 Source. Elaborated by authors.

Figure 3. Evolution of patents by technological subgroup: (a) absolute values; (b) logarithmic scale.



Note. Legend: 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. Source. Elaborated by authors.

The distribution of HAI patents by the most representative applications countries indicates that 58.57% were first protected in the United States, followed by Japan (10.99%), South Korea (7.22%) and Other Countries (23.22%). The dispersion of deposit countries in this group of technologies demonstrates a global need of countries for HAI technologies for the execution of their businesses, such as data storage and technologies for measuring market and/or business information, for instance.

The assignees of HAI patents were classified according to their nature into three groups: “Universities, Technological Research Centers and Institutions”, “Governments” and “Companies”. This categorization aims to identify how organizations with different natures present behaviors in relation to collaboration and different interests in the development of HAI technologies. Although researchers (de Faria et al., 2010; Etzkowitz & Leydesdorff, 2000; Ritter & Gemünden, 2003) point out the competitive advantages of companies when exploring technological developments in conjunction with universities, research centers, research laboratories, among others, increasing in recent years, the participation of this type of actors in HAI technological field is still not significant. This leads us to consider that mostly developed by private companies and, possibly, for reasons of competitive strategy, they end up choosing to develop patents in their internal R&D areas or, at most, in

partnership with other companies with the same business expertise.

Table 1 shows the top twenty HAI patent assignees from 2001 to 2020. It is noted that most patent assignees have been reducing patent applications every five years, except for Amazon and Alibaba, which show an interesting growth, largely due to the evolution of their e-commerce platforms that demand the management of large volumes of data and requires the analysis of consumer profile and confidential data security of your customers and financial transactions of payment products. There is a slow movement of reduction in patent applications by the main assignees Microsoft, IBM, Google, and Samsung that has slowed down their developments. Its biggest increments occur between 2006 to 2010. Toyota, Apple, Hewlett Packard companies improved their participation in the development of these technologies between 2006 and 2015, and after 2016 they reduced their technological efforts, as well.

In general, there is an absolute dominance of patents of North American companies (Microsoft, IBM, Google, SAP, Oracle, General Motors, General Electric, Ford Global Tech, Amazon, Hewlett Parckard, IGT, EMC Corp, Apple), the others being of South Korean origin (LG Electronics, and Samsung), Chinese (Alibaba) and Japanese (Hitachi, Toyota, Sony, and Canon) for the HAI patents.

Table 1. Production of patents for the 20 largest assignees.

	2001-2005	2006-2010	2011-2015	2016-2020	Total of INPADOCs
Total	**1.428→**	**5.063 ↑**	**4.328 ↓**	**2.462 ↓**	**13.281**
Microsoft	286 →	1.405 ↑	773 ↓	401 ↓	**2.865**
IBM	246 →	654 ↑	520 ↓	438 ↓	**1.858**
Google Inc	23 →	214 ↑	446 ↓	197 ↓	**880**
Samsung	51 →	358 ↑	295 ↓	140 ↓	**844**
SAP	143 →	299 ↑	155 ↓	68 ↓	**665**
Oracle	98 →	309 ↑	152 ↓	60 ↓	**619**
Sony	103 →	255 ↑	165 ↓	72 ↓	**595**
General Motors	35 →	255 ↑	229 ↓	41 ↓	**560**
Toyota	23 →	140 ↑	270 ↑	63 ↓	**496**
Apple Inc	10 →	189 ↑	205 ↑	72 ↓	**476**
Hewlett Packard	56 →	125 ↑	139 ↑	107 ↓	**427**
Amazon	2 →	38 ↑	142 ↑	220 ↑	**402**
IGT	121 →	141 ↑	124 ↓	22 ↓	**408**
EMC Corp	14 →	72 ↑	146 ↑	133 ↓	**365**
General Eletric	63 →	137 ↑	99 ↓	58 ↓	**357**
Canon	40 →	137 ↑	100 ↓	32 ↓	**309**
Hitachi	47 →	108 ↑	100 ↓	44 ↓	**299**
Ford Global Tech	35 →	84 ↑	120 ↑	58 ↓	**297**
LG Electronics	32 →	131 ↑	94 ↓	26 ↓	**283**
Alibaba		12 →	54 ↓	210 ↑	**276**

Source: Elaborated by authors.

When analyzing markets of interesting (Table 2), the main assignees are in descending order in number of patents applications, while markets are ordered according to their representation in the total applications made. Values are in percentage representing the impact of each market in the total of patents application for each assignee. The assignees follow the same strategy in choosing their home country as the market of preference for patents applications, with Sony and LG Electronics being assignees that have more balance related to their home country as main market. International Cooperation Agreement (WO) arises its representation in protection interests for most part of assignees. The markets of Japan, South Korea and China are also highly targeted. Thus, companies can be seen focusing on a less fierce level of global competition for this type of technology.

Table 2. Main markets of protection of the twenty largest assignees

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Assignees	Home Country	Total of patents	Market participation (in percentage)							
			US	JP	KR	CN	WO	EP	IN	MX
Microsoft	US	2874	88.31		0.03	0.07	0.73	0.10	0.49	6.37
IBM	US	1873	84.14	3.04		2.67	0.16	4.06	0.16	0.11
Google Inc	US	885	94.01	0.11	0.11		1.92	0.11	1.02	0.11
Samsung	KR	854	8.67		76.35	0.94			9.13	2.93
SAP	US	668	88.17			1.35	0.45	8.83	0.90	
Oracle	US	620	95.16				0.16	0.16	4.35	
Sony	JP	595	24.87	68.57		0.17		2.52	0.17	0.84
General Motors	US	561	96.08				0.18		1.07	
Toyota	JP	500	7.60	70.40			19.40		1.20	
Apple Inc	US	477	96.86				0.21		0.21	0.42
Hewlett Packard	US	430	53.95			0.23	33.72	0.23	8.37	0.47
Amazon	US	419	100.00							
IGT	US	410	92.44				1.22	0.73		0.73
EMC Corp.	US	370	95.68			1.35	0.54	0.27	0.27	
General Eletric	US	357	82.35	0.84		0.56	0.56	0.28	1.12	7.28
Canon	JP	311	2.57	86.82	0.64	0.32	0.32	0.32	0.64	
Hitachi	JP	300	4.67	81.67			12.00	0.33	1.33	
Ford G Tech	US	299	89.97	0.33			3.01	1.34		
Alibaba	CN	293	1.02			64.16	2.39			
LG Eletronics	KR	283	21.55		68.55	0.35	1.06	0.35	1.41	6.71

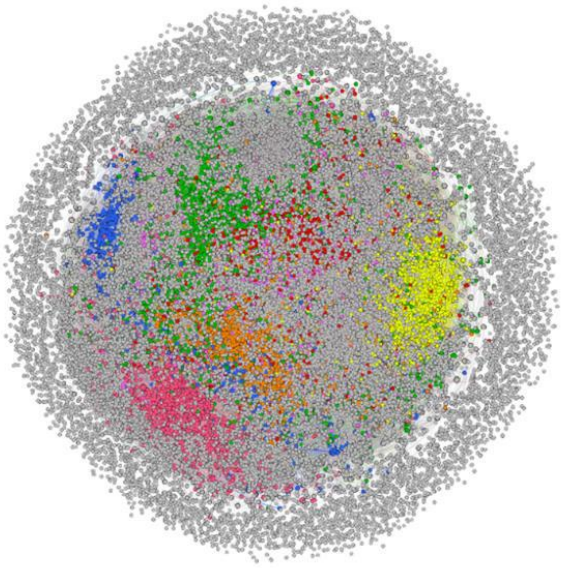
Note. Total of Patents are um absolute number and markets of interesting in percentage. Legend: CN = China; EP = European Patent Office; IN = India; JP = Japan; KR = South Korea; MX = Mexico; US = United States; WO =International Cooperation Treaty. Source: Elaborated by authors.

5. HAI Clusters

The HAI technology network (Figure 4) is composed of 6,953 clusters and shows an intense density, thus making the exchange of information between technologies more efficient since this feature has a great impact on the flow of information within networks. The average path length is an important characteristic in the diffusion and efficiency of information and mass transport of data over the network. The general network has an average length of 3.67, i.e., there are about 4 patents along the paths for all possible citations in the network.

By applying the modularity function of Gephi 9.2, the 5 main groups are identified to analyze in depth the TRs and promising technologies on HAI. The citation network of these 5 clusters is composed of 105,723 patents (nodes) and 172,448 citations (edges). These groupings were chosen because they concentrate 18.79% of the nodes and 16.74% of the edges of the general network of HAI patent citations, as well as containing the patents with the best statistics in the network (Table 3), in addition to enabling a further analysis of the data. Table 3 brings statistical indicators in terms of nodes and edges comparing the clusters' size into the networks to facilitate for a better choice among many clusters.

Figure 4. General HAI patent citation network and selected clusters.



Source: Gephi software.

Table 3. Statistics from the top 5 clusters of HAI patent citation network.

CLUSTERS									ROUTES	
Cluster Number	Color	Nodes		Edges		Average Degree	D	Average Length path	Nodes	Edges
		N	P	**N**	**P**					
19	Green	30.515	5.42	42.854	4.11	1.40	7	2.22	40	41
41	Yellow	27.148	4.83	58.951	5.66	2.17	8	2.67	40	39
8	Orange	26.875	4.78	43.802	4.20	1.63	6	1.71	39	38
27	Red	11.944	2.12	15.145	1.45	1.27	6	1.94	36	35
23	Purple	9.241	1.64	11.696	1.12	1.27	7	2.51	41	45
Total dos Clusters		105.723	18.79	172.448	16,54					

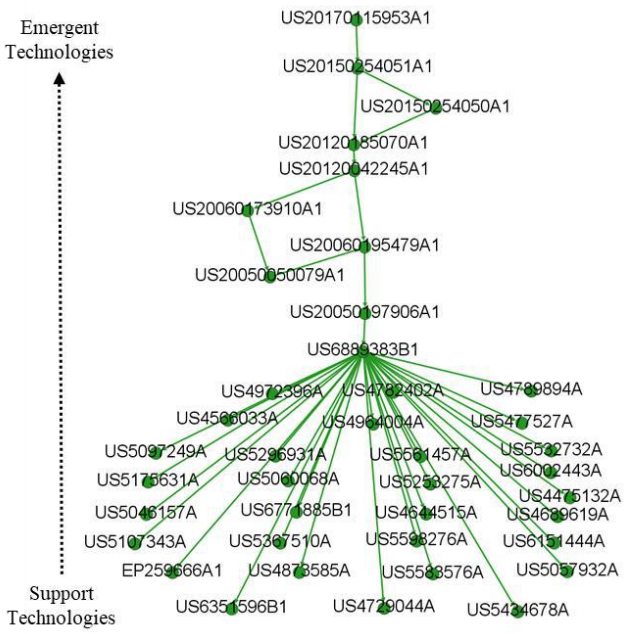
Note. Legenda: N = total of Patents; P = percentage; D = Diameter. Source: Elaborated by authors.

TR concept is based on the evolution that a technology has presented over the years identified through citation analysis based on "backward citations" and the SPLC algorithm and is supported by researchers at initial publications (Hummon & Dereian, 1989; Verspagen, 2007), as well as in more recent studies (Linares et al., 2019; Pereira et al., 2018; Porto et al., 2012). TR mapping, in addition, points out the path of 190 HAI patent developments over the years, also identifying emerging technologies (ET), its characteristics in relation to the main topics covered, patents of greater influence on the route, level of cooperation as results of partnerships or internal efforts of the R&D areas organizations holding these patents.

6. Technological Routes Description

The first cluster, called green, consists of a network formed by 30.515 nodes (patents), 42.854 edges (cited refs) and the TR green formed by 40 nodes and 41 edges, which had originated in 1983 and runs until 2017 (Figure 5). It is observed that patents US20060195479A1 (Method for sharing and searching audio playlists) which is assigned by Huawei Technologies and patent US20150254050A1 (Generating a Playlist Based on a Data Generation Attribute) which is assigned by Gracenote Digital Ventures had great influence on the ET due to their high betweenness centrality in this community.

Figure 5. Green technological route.



Source: Gephi software

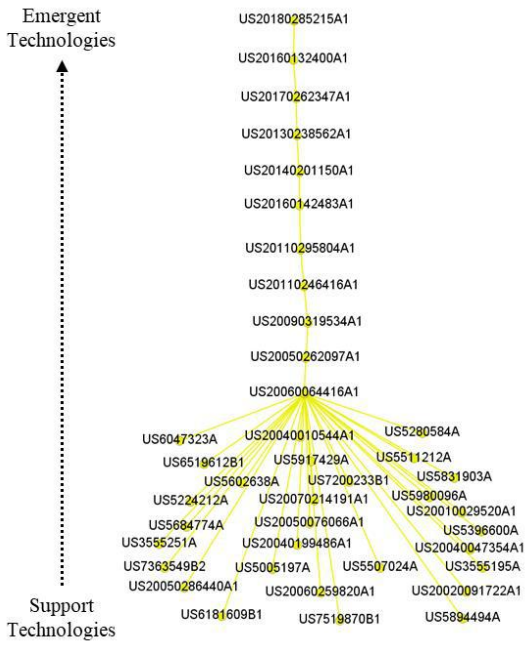
The patent US20170115953A1 (Controlling audio playback based on activity) is the ET of this route and contemplates a technology that can perform operations to: receive information about user's scheduled activities; determine a time associated with an activity based on the information received; determine that audio content is playing on the audio at the time of the activity; and control content on device is based on time to alert the user to this activity. This patent was applications in 2017, only in the United States. The holder is Bose Corp, an American company, which predominantly sells audio equipment.

Regarding the development of technologies in cooperation, only 12.5% of the patents on this route are a result of technological cooperation. Most partnerships are made among companies, and a less collaborative profile of the applicants is evident, which leads us to understand a profile of more proprietary technology using internal R&D.

When evaluating the technological evolution of the green route, it appears that the first patents are based on innovations on interactive video disc, including audio and video distribution technologies and technologies aimed at controlling audio and video devices to allow a parent, for example, control of a device usage for a child, as well as technologies that from creating a list of media items to technology to receive information about an activity scheduled for a user as of an audio playback device that here is identified as a ET has already described previously.

The second cluster is formed by 27.148 patents and 58.951 cited refs, obtaining the TR yellow on virtual data restoration, consisting of 40 patents (Figure 6), which were applications mostly in the United States. When analyzing the most influential patents in this grouping due to the degree of intermediation, the patent US20060064416A1 (Method and system for data reduction), US20110295804A1 (Systems and methods for performing data replication), US20140201150A1 (Single snapshot for multiple agents) and US20160132400A1 (Cross-platform virtual machine backup and replication) were developed by Quest Software Inc.

Figure 6. Yellow technological route.



Source: Gephi software.

The ET identified in this grouping is the patent US20180285215A1 (Granular restoration of virtual machine application data). This patent presents applications like SharePoint, SQL, Exchange, and similarities. This patent application was in 2017 and protected only in the United States and is assigned by Commvault Systems Inc.

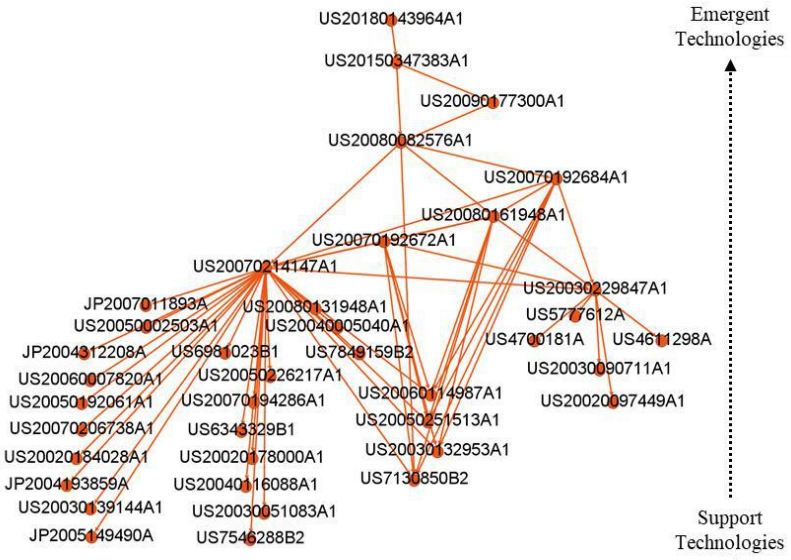
Until reaching the ET, the evolution of this route has technologies focused on: i) digital data communicated between a portable data collection unit and a data reception unit without direct electrical connection, transmitting them through a contactless connection system and bidirectional flow; ii) a parallel virtual directory system to extend the file system by providing a superior method for organizing the physical storage devices or locations of a computer system; iii) "direct" data management technique to achieve delta file management efficiency and eliminate read latency when accessing historical data, and iv) data to include one or more virtual clients instantiated on a host proxy computing device, where those virtual clients can only have indirect access to a storage device through the proxy computing device.

Analyzing the technologies developed in cooperation in this TR, only the patent US20050286440A1 presents a partnership between Motorola and Mesh Networks, with the rest being the result of internal efforts of R&D areas of assignees.
The third cluster has 26.875 patents and 43.802 cited refs maintaining characteristics of predominantly North American patents with some participation of Japanese technologies. TR orange is related to on digital data entry and has 39 patents (Figure 7). The intermediation importance of ET US20180143964A1 (Data input system using trained keypress encoder) by Microsoft in 2016 and patent US20150347383A1 (Text prediction using combined word n-gram and unigram language models) by Apple in 2014, demonstrate the subtlety of technological details associated with a simple typing of words on a spreadsheet or blank page.

The data entry system of these patents is described in virtual keyboard perspective and allows the user to type a text string into a computing device. The data entry system has an input likelihood generator that is configured to calculate keystroke evidence that understands probabilities that user input events on a virtual keyboard matching with keyboard characters or functions. The data entry system has a keystroke encoder trained using the evidence of those keystrokes and matching words. The keystroke encoder records evidence in a numeric encoding and has a completion/correction predictor that

is configured to take as input the numeric encoding of one or more text items into string already entered in the computing device, to predict a character in a text string.

Figure 7. Orange technological route.



Source: Gephi software.

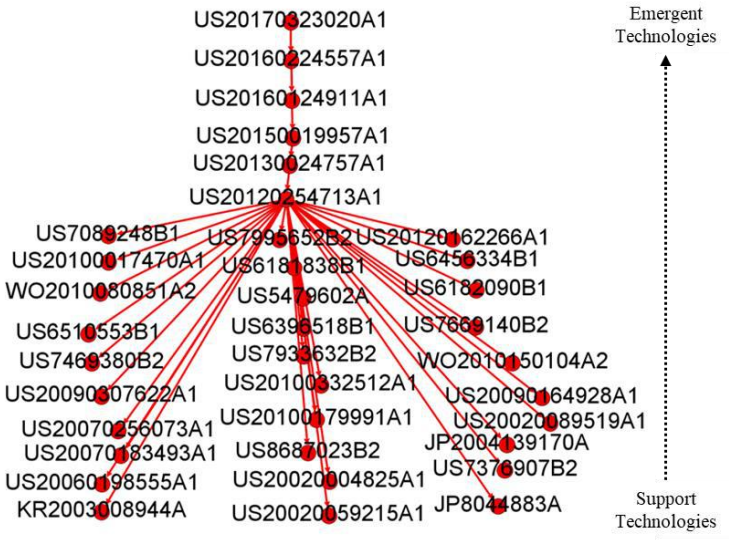
In other words, RT orange presents a completion and correction predictors configured to take as input the numeric encoding and an encoding of one or more text items in sequence inserted into a computing device. It is observed that it is a RT with domain of technologies from several important market assignees such as Microsoft from Fuji Electric (3 patents), Apple (2 patents), IBM (4 patents) among other large organizations such as Cisco, Intel, and Siemens, which mostly has North American as home country.

Exploring digital data entry universe, explained flow clarifies the disclosed system and its process to predict data entry in a virtual environment, such as text entry, where candidate words and the probabilities associated with them can be determined by combining an n-gram language model of words and a unigram language model. Thus, candidate words starting with characters identified along with a likelihood for each candidate word.

Finally, it is worth highlighting the participation of University of California in this route with the patent US20070194286A1 (Fabrication of polyaniline nanofiber dispersions and films) applications in 2006. It was also observed no patents are in cooperation, and only 4 have different individual inventors, demonstrating that this route brings together types of technologies whose assignees chose to develop know-how exclusively in their R&D centers.

The fourth cluster, has 11.944 patents and 15.145 cited refs. The TR red (Figure 8) is about on digital content browsing and is composed of 41 patents applications primarily in the United States, but also protected in Japan, Brazil, China, EPO and Taiwan, among other countries. It presents the patent US20120254713A1 (Techniques for electronic aggregation of information) as an influential patent according to the centrality of intermediation, as if it were a technological divider to reach out the ET. This technology combines techniques of an electronic assembly system, that is, an apparatus that can comprise a logical device arranged to execute an assembly application that comprises an operative authoring component to provide a presentation surface with several presentation blocks, receive directives from control to associate content files with presentation blocks, generating block objects for the content files based on content types for the files, and store the presentation surface and block objects as an assembly.

Figure 8. Red technological route.



Source: Gephi software.

The patent US20170323020A1 (Accessing content from suppressed URL index) is the ET, which presents a system, method, and device to generate and suppress indexes that are used to browse content. For example, after a search query is processed, results are received including a list of URLs, or other list of web pages, identified in the search results. So, before and without rendering the specific URL / web page listing, this same specific URL / web page is identified from the search results. That URL / web page is then accessed and displayed automatically while offering an incoming link displaying the URL / web page listing. This ET was deposited in the United States in 2017 by Cake Technologies and Lips Labs Inc in a cooperative partnership.

In sum, TR red starts with patents aimed at recording mechanisms and structures, means method to generate and display a content-based representation of a standard icon on a computer screen, also passing through link technologies avoiding the overlapping of areas of partial views and deterioration of data appearance providing dynamic layout change and avoiding complicated processing, until arriving at techniques for dynamic layout of presentation blocks in a single grid or presentation screen. These patents represent the technological basis for the selection of data and content accessed digitally.

Finally, TR purple which is about on digital content selection comprising 41 patents mostly protected in the United States and recent patents protected in offices in Europe, Japan, Canada, and the United Kingdom. TR purple comes from a cluster that has 9.241 patents and 11.696 cited refs, with the most recent patents coming from assignees like Renaissance Learning, a company that makes preschool and fundamental, cloud-based educational software and Chegg Inc., a North American educational technology company. They provide digital and physical book rentals, textbook solutions, online tutoring, and other student services.

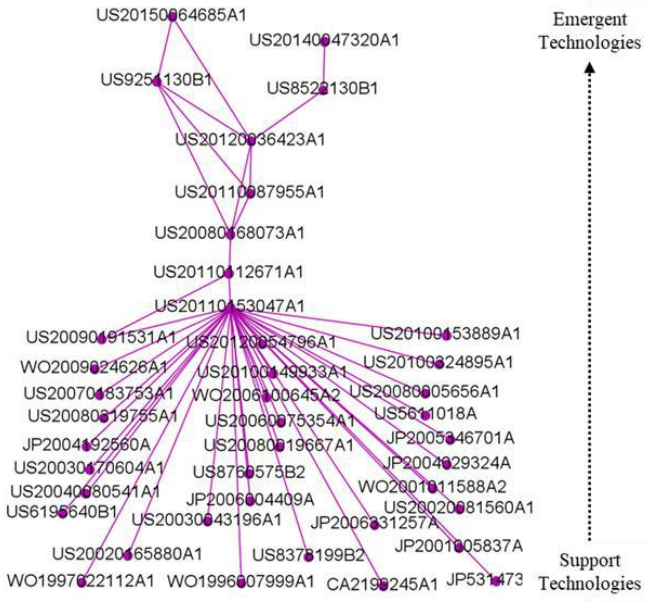
The patents US20110153047A1 (Method and System for Making and Playing Soundtracks) applications in 2008 and US20120036423A1 (System for and Method of Collaborative Annotation of Digital Content) applications in 2010 have great influence on this route due to their high degrees and were developed respectively by Booktrack Holdings a company recognized worldwide as a leader in audiobook technology and services and an innovative editorial with soundtracks for e-books and educational literacy products, and by Copia Interactive a social media and delivery platform content that allows users to collaborate, socialize, and buy content (Figure 9).

The ET is US20150064685A1 (System and Method for Automatically Attaching a Tag and Highlight in a Single Action) a system and method to allow users to attach a tag and highlight in a single activity a selected part or part of text in

digital content (for example, in a digital book or other content provided for viewing on an electronic device). For example, a teacher can associate a "tag" to specific text in the assignment, send it embedded in the "tag" to students, and the tag automatically becomes visible to them through the highlight menu when they open the task for completion. With this single activity, users can easily select and share tasks, comments etc., easily creating and executing tasks efficiently. This patent was applications in 2013 by Renaissance Learning.

Regarding the development of technologies in cooperation, only the patent US20020165880A1 (Digital book educational amusement device) was applications by Trend Masters Inc. and All-Season Toys Inc., thus maintaining the TR profile found in other routes in developing technology proprietary through R&D as predominant. It is noteworthy that the ET developed by Renaissance Learning was not a result of partnerships with other companies. In TR purple, it is noted that the first patents were based on technologies to provide portable display device to be used as a replacement for a book, transporting it in mobile installations.

Figure 9. Purple technological route.



Source: Gephi software.

7. General Insights

Based on findings, those patents found on the TR are predominantly applied in United States providing some technological bases on HAI over the past few years. Yet, cooperation rate of these TRs is relatively low and only TR green has a greater number of patents in cooperation, noting a predominance of proprietary technologies on respective assignees of these patents. Table 4 presents a summary of the main features of HAI patent TR and ET identified in each TR. Hundred percent of the assignees have North America as home country. Outstanding as ET assignees are Bose Corp, Commvault Systems Inc., Microsoft, Cake Technologies, Lips Labs Inc and Renaissance Learning. However, only Microsoft is identified as a relevant agent of cooperation. Another aspect is about few cooperative relationships that appear are done among private companies, not corroborating with the Triple Helix concept (Etzkowitz & Leydesdorff, 2000).

No intensively cooperation among assignees leads us to presume that HAI technologies development is a result of exclusive efforts in R&D. Thus, findings here corroborate with the results obtained by (Lei et al., 2013) who pointed out a low occurrence of collaboration and, when this occurs mostly, they are collaborations between inventors, not analyzed in this study. It can be concluded that HAI development industry is predominantly closed, especially to potentially disruptive technologies such as those defined here as ET.

Table 4. Summary of the main features of Technological Routes.

Technologial Route	Patents with greatest influence in the TR	Main Markets	Basic Technologies Description	ET	CL
Audio and video playback (TR Green)	US20060195479A1 (*Method for sharing and searching playlists*) US20150254050A1 (*Generating a Playlist Based on a Data Generation Attribute*)	AU, BR, CA, CN, DE, EP, JP, US, WO	Interactive video disc technology, through audio and video distribution technologies and technologies aimed at controlling audio and video devices, and technologies for creating a list of media items	US20170115953A1 (*Controlling audio playback based on activity*)	12,5%
Restoring virtual data (TR Yellow)	US20060064416A1 (*Method and system for data reduction*) US20110295804A1 (*Systems and methods for performing data replication*) US20140201150A1 (*Single snapshot for multiple agents*) US20160132400A1 (*Cross-platform virtual machine backup and replication*)	CA, CN, DE, DK, EP, GB, JP, KR, US, WO	Digital data communicated between a portable data collection unit and a data receiving unit without direct electrical connection, virtual directory, data management technique, data storage environment to include one or more virtual clients	US20180285215A1 (*Granular restoration of virtual machine application data*)	2,5%
Digital data entry and formation (TR orange)	US20180143964A1 (*Data input system using trained keypress encoder*) US20150347383A1 (*Text prediction using combined word n-gram and unigram language models*)	CA, DE, EP, GB, JP, US, TW, WO	Data storage, retrieval, and manipulation system to produce a display and electronic storage and retrieval of data files linked together to form a hierarchical information tree and classification at various levels	US20180143964A1 (*Data input system using trained keypress encoder*)	0%
Browsing digital content (TR Red)	US20120254713A1 (*Techniques for electronic aggregation of information*)	CA, EP, GB, JP, KR, US, WO	Recording mechanisms and structures through link technologies preventing overlapping of partial display areas and deterioration of data appearance providing dynamic layout change and techniques for dynamic layout of presentation blocks in a single grid or presentation screen.	US20170323020A1 (*Accessing content from suppressed URL index*)	2,9%
Selection of digital content (TR Purple)	US20110153047A1 (*Method and System for Making and Playing Soundtracks*) US20120036423A1 (*System for and Method of Collaborative Annotation of Digital Content*)	AU, AT, CA, EP, GB, JP, US, WO	Technologies to provide portable display device to be used as a replacement for a book, carrying it in mobile facilities etc.	US20150064685A1 (*System and Method for Automatically Attaching a Tag and Highlight in a Single Action*)	2,4%

Note. ET = Emerging Technologies; CL = Cooperation Level; AT=Austria; AU=Australia; BR=Brazil; CA=Canada; CN=China; DE=Germany; EP=European Patent Office; ES=Spain; GB=Great Britain; IL=Israel; IN=India; JP=Japan; KR=South Korea; SG=Singapore; TW=Taiwan; US=United States. Source: Elaborated by authors.

Still regarding the main ET identified and presented in Table 5, it is possible to see a description of each ET, its assignee and year of publication. ET are concentrated where technological efforts seek systems and methods to enable the visualization, search, introduction and classification of data and digital content that allow greater efficiency in the daily activities of users, as well as navigation in digital environment to massify HAI technologies utilization. Most of ET patent's headquarters are based in the United States influenced by its market for HAI technologies, not only for their capacity for technological innovation, but for their high consumption demand, speed in actions and decisions, and especially for its ability to generate scale and technology investments to compete with Asian markets whose are major competitors in terms of commercialization, but they are, so far, limited to regional demands.

Furthermore, even most TR being a result of proprietary technology, assignees' reference other global technologies not protected in the applications country. There may be cultural or language issues that prevent or hinder a greater integration of assignees, which is still another point of attention in this context. This study corroborates with other authors (de Paulo & Porto, 2017, 2018; Huo & Zhang, 2012; Paulo, 2019) who point out critical problems such as market's incentive scheme, public R&D model, or technical and resource integration standards that impede a sustainable development of technologies in cooperation to increase a generation of digital disruptive innovations.

In terms of developing ET, a focus on different countries' capabilities may be associated with individual TC (Carvalho et al., 2019), however as several interpretations about this reality emerges, (García-Fernández et al., 2020) point out that TC have no value itself, but it comes from business decision-making and must be transmitted to partners, suppliers, and employees. In other words, TC as a dynamic capability (García-Fernández et al., 2020; García-Sánchez et al., 2018; Y. Wang et al., 2019) might be seen as value resource for developing ET, however only its multidimensionality and complementarity combined with means and other organizational dynamic capabilities can generate value. And these combinations depend on investments to form a unique TC over time to generate ET.

Finally, even Asian countries seen today as a technological hub, their companies are not the main actors of HAI development, however, in the next few years, if changes in the technological bases regarding basic technologies occur, new HAI assignees in these regions are due to the strong investment in innovation processes (Zhang, 2010), which are highly supported by public policies and government subsidies to foster the development of technologies (Huo & Zhang, 2012; Paulo, 2019; Zhao et al., 2016), the influence of disruptive innovations multilevel factors [(individual, company, industry, country/economy); (Si & Chen, 2020)] should be considered in countries like China, South Korea and Japan, actors to be constantly monitored.

Table 5. Emerging and promising technologies summary.

Technological Route	ET (Emerging Technology)	Apllication Year	Technology Description	Assignees	Markets Protection
Audio and video playback (TR Green)	US20170115953A1 (*Controlling audio playback based on activity*)	2017	Receive information about an activity scheduled for a user from an audio playback device; determine a time associated with the activity based on the information; determine that audio content is playing on the audio playback device at the time of the activity; and control the playback of audio content based on time to alert the user to that activity.	Bose Corp	US
Restoring virtual data (TR Yellow)	US20180285215A1 (*Granular restoration of virtual machine application data*)	2017	System and method of restoring application data stored by a virtual machine database to an application (e.g., Exchange, SQL, SharePoint, and so on) running on the virtual machine by creating an embedded "snapshot" of the stored application data in the virtual machine database through a virtual server agent.	Commvault Systems Inc	US
Digital data entry and formation (TR orange)	US20180143964A1 (*Data input system using trained keypress encoder*)	2016	A virtual keyboard-type data entry system that allows a user to type a string of text into a computing device. The data entry system has an input probability generator that is configured to calculate keystroke evidence. Keystroke evidence comprises probabilities that user input events on the virtual keyboard match keyboard characters or functions.	Microsoft	US
Browsing digital content (TR Red)	US20170323020A1 (*Accessing content from suppressed URL index*)	2017	System, method, and device for suppressing and generating indexes that are used to browse content. For example, after a search query is processed, search results are received including a list of URLs, or other list of web pages, identified in the search results.	Cake Technologies | Lips Labs Inc	WO, US
Selection of digital content (TR Purple)	US20150064685A1 (*System and Method for Automatically Attaching a Tag and Highlight in a Single Action*)	2013	System and method for allowing users to attach a tag and highlight in a single activity selecting part of text in digital content (e.g., in a digital book visualization through an electronic device)	Renaissance Learning	GB, US, WO

Source. Elaborated by authors.

8. Conclusion

The present work, by approaching a 20-year horizon, allow HAI analysis in terms of their relevant impact in various business sector in recent innovations. HAI have a vast influence on generating data and information for business decision-making. The broad reflection on TR of HAI carried out allows practitioners planning on the future investigations and / or developments of HAI from one co-ownership of patents or investments in R&D in distinction areas to be prioritized based on potential technological evolution paths.

When assessing whether technology needs can be met, it is important to examine how innovation can sustain business growth. Hence, the technology for the next generation of products and / or services not available today, certainly may come from a deep analysis about TR from developers and this study may support them. Additionally, goals of companies are always creating a competitive advantage to prevent competitors from easily following them and, in this sense, the premise that companies with a significant technological capability degree to exploring a and more diffuse information will be in advanced position.

HAI efforts show a up and down among assignees in terms of patents applications mainly in the United States and South Korea, however, it seems that this will be a long way to go until we can find technologies developed with HAI focus on other markets. Perhaps, assignees do not perceive real demands of these technologies in different market or because they evaluate that the export would not be threatened by potential copies due to the lack of technological capacity of the local actors to use the technology.

From theorical aspects, this study contributes to enhance patents analysis in a new technological domain – high analytics information technologies – reinforce the relevance of having patents analyzed to capture potential emergent technologies. From practical aspects, it adds more visibility about HAI for developers to support their future technological planning. And, even though TRs here analyzed imply in a less collaborative development profile and possibly assignees prefer to create technologies by themselves or acquire them from individual researchers, this a good thermometer to think about having more partnerships or cooperation that potentially would rise innovative HAI in a near future. ET identified in this research can also support several R&D and market decisions as well. Further, future research could employ additional data sources to cover full scope of HAI or include patents under process of litigation or approval to analyze potential different trends.

Finally, as in any patent analysis, there are some limitations, which are identified throughout the process, although they have not harmed the results obtained. Some of them is related to manual development of the database, lack of standardization of assignees' names, limitation in the ability to manipulate large databases analyzed in Gephi, and lag inherent in patent process in non-capture of applications close to the period of data collection. Furthermore, limitations regard to not all inventions are patented because of some technical fields and patent strategy, patent data are complex, generating complex economic and legal processes and therefore not all HAI technologies might be captured.

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