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Systematic Literature Review (SLR) Development of the IoT Industry in the South America Region

Izialber Muniz[1], Douglas Castro da Silva[2], Bryan Alexander Saravia[3]

[1]Master student in Industrial and System Engineering (CEFET-RJ), MBA in Information Security Management (UNICIV-2021) and Bachelor of Electrical Engineering (UNESA-2021), Rio de Janeiro, Rio de Janeiro, Brazil. Curriculum Lattes: http://lattes.cnpq.br/3216603966162180. ORCID: https://orcid.org/0000-0001-5576-943X. Email: izialber@gmail.com
[2]Master student in Systems and Computer Engineering (UFRJ) and Bachelor of Computer Science (UFRRJ-2019), Rio de Janeiro, Rio de Janeiro, Brazil. Curriculum Lattes: http://lattes.cnpq.br/3138960048156431.
Email: douglascastro@cos.ufrj.br
[3]Student Master of Science Electrical Engineering (UFRJ) and Bachelor of Electronic Engineering, Automation and Control (ESPE-2020), Rio de Janeiro, Rio de Janeiro, Brazil. Curriculum Lattes: http://lattes.cnpq.br/3418304829623775. ORCID: https://orcid.org/0000-0003-0950-0602.
Email: bryan.saravia@coppe.ufrj.br

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Abstract *— In the 2022 and later we know that the technology will have a key participation to help us in all kind of tasks mainly using internet connection, due the new normality. Industry 4.0 has been one of the most relevant field. IoT as part of it. This Systematic Literature Review (SLR) we will cover the South America countries and their development status, addressing the development categories and the Hardware that has been cited on papers on the last 5 years.*

I. INTRODUCTION

IoT (Internet Of Things) is been bigger them ever according to the World Economic Forum's State of the Connected World report, there are more connected devices than people in the world and 41.6 billion devices are expected by 2025, with the impact of COVID-19 the demand of IoT market estimates and expectations for its current and future growth [Amon et al.].

The main purpose of this paper is to carry out a systematic literature review in order to assess the current scenario of *IoT* development in South American countries, analyzing which countries are most engaged in the development of new *IoT* solutions, what types of hardware are used by their works and what are the main topics addressed bythese works. For this, we analyzed about 1400 articles that were obtained from sources such as *IEEE (Institute of Electrical and Electronic Engineers)* and *ACM (Association for Computing Machinery)*.

This paper consists of five sections. Section I contains a brief introduction and explains the structure of this paper. Section II explains the methodological stages of a systematic literature review *(SLR)*, namely: Planning to Conducting. Section III includes findings from the review literature. Section IV contains conclusions on the reviews and findings obtained, supported by the Future Works Section, which illustrates the potential for further research that can be done sourced from this research.

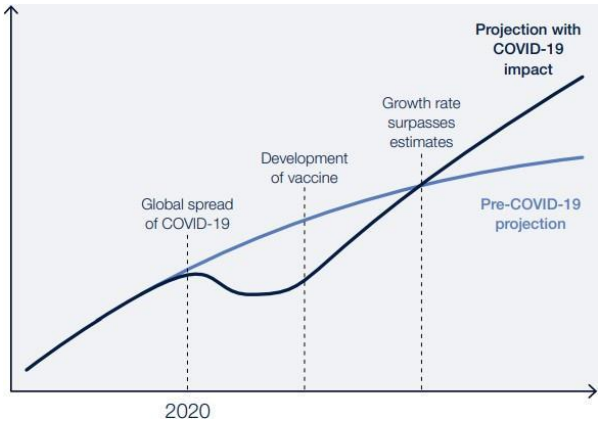

Fig. 1: IoT connections growth rate

II. RESEARCH METHODOLOGY

The systematic literature review (SLR) will be used for this study. Based on search results of papers published on journals.

The countries in the research are Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay and Venezuela all from South America [Yaseen et al.] [Khan et al.]

2.1 Planning

2.1.1 Research question

The main objective in this SLR, is to have an overview in the development of the IoT industry in countries of South America. In order to get that goal we have consider some questions:

a) What is the current state of IoT industry development in the South America Regioncountries?

b) What are the Development Categories on IoT industry for the contries in the SouthAmerica Region?

c) What are the IoT hardware platforms used for development in the South America Region?

2.1.2 Data source

Sources that have all topics related to technology and innovation, and have listed journals that contains information of electronics and computer science: IEEE and ACM Digital Libraries.

2.1.3 Search string

A search string is composed using Boolean connectors AND, OR based in the main words related of our research questions and its population. Such string will give the output in an advanced search from the different sources used.

(”Argentina” OR ”Bolivia” OR ”Brazil” OR ”Chile” OR ”Colombia” OR ”Ecuador” OR ”Guyana” OR ”Paraguay” OR ”Peru” OR ”South America” OR ”Suri name” OR ”Uruguay” OR ”Venezuela”) AND (”Internet of things” OR ”Industrial Inter net of Things” OR ”IIOT” OR ”IOT” OR ”Smart devices” OR ”Web of Things”) AND (”Software” OR ”Hardware”)

2.1.4 Inclusion and exclusion criteria

As inclusion criteria we have stated three items to check using them to accept the article to be pass to next phase that is quality criteria selection.

2.1.4.1 Inclusion

The selected research must be written in English; related to South America; the solution developed must be aimed to solve problems on IoT industry.

2.1.4.2 Exclusion

Articles not published in the English language; before 2016; duplicated; not related to South America; the solution developed is not aimed to solve problems on IoT platform.

2.1.5 Quality criteria for study selection

To evaluate quality of the articles to be selected we have taken the following considerations:

a) What is the main topic related with IoT development;

b) There is a discussion in IoT industry;

c) There is used a hardware or software involved in the IoT industry;

d) Is it a research proposed from an university or another organization.

The selections was based in take topics and subtopics, classify article by one article and list them into columns to have categorical information.

2.2. Conducting

2.2.1. Primary study selection

The sources listed is filtered using Tollgate Approach following the phases.

Phase 1: do a search using the search string. In this phase we found 1390 articles in Phase one with the string on IEEE and ACM as per Table 1;

Phase 2: remove duplicated articles. We could find 570 duplication’s;

Phase 3: Based on the Inclusion and Exclusion Criteria, accept or reject articles by reading titles and abstract;

Phase 4: Based on the Quality Criteria, accept or reject articles by reading the full article.

Table 1. Search results

Database	Search result
IEEE	556 articles
ACM	834 articles
Total	1390 articles

2.2.2 Data extraction and synthesis

Classification of papers due to the country.

Table 2. Country distribution data

Country	Total	Percentage
Argentina [1]	6	3.73%
Bolivia	0	0%
Brazil [2]	126	78.26%
Chile [3]	2	1.24%
Colombia [4]	11	6.83%
Ecuador [5]	9	5.59%
Guyana	0	0%
Paraguay	0	0%
Peru [6]	9	5.59%
Suriname	0	0%
Uruguay	0	0%
Venezuela	0	0%

From a brief analysis of Table 2, we were able to identify that Brazil is much more relevant in IoT considering papers than the other countries in South America, being followed by far from Colombia, Ecuador and Peru.

Table 3. Topics distribution

Topic	Total	Percentage
Agriculture	5	3.03%
Health	12	7.27%
Environment	29	17.57%
Industry	1	0.06%
Framework	15	9.09%
Other	103	62.42%

As we can see on Table 3, there are a widely distribution of the topics and we were able to identify that Environment, Framework and Health are the main topics areas and most the papers are distributed over other that shows the multidisciplinarity use of IoT and not able to find any high development in a specific topic.

Other relevant information that we could extract from the SLR is that 31.5% of the papers were not related to software or hardware implementations. They were studies or literature reviews.

[1] [Tsigkanos et al. 2019] [Bor et al. 2016] [Lobo et al. 2017] [Tsigkanos et al. 2020] [Chesnevar et al. 2020] [noa]

[2] [Antunes et al.] [Azevedo et al.] [Delabrida et al. b] [Farias et al. a] [Fernandes et al. b] [Kon et al.] [Magrani] [Motta a] [Sant'Anna et al.] [Vasconcelos et al.] [Almeida et al.] [Andrade et al. a] [Andrade et al. c] [Andrade et al. b] [Bachiega et al.] [Bao et al.] [Barros et al. b] [Barros et al. a] [Batista et al.] [Bezerra and Souza a] [Bezerra and Souza b] [Bischoff and Farias] [Borba et al.] [Braga et al.] [Branco et al.] [Brandao] [Campos et al.] [Carrero et al.] [Carvalho et al. a] ˜ [Carvalho et al. b] [Chagas et al.] [Chauhan et al.] [Cortes et al.] [Costa et al. b] [Costa] [Costa et al. a] [Costa and Teixeira] [Cunha et al.] [Dantas et al.] [Delabrida et al. a] [Dias et al.] [Domenech et al.] [Duarte and Prestes] [Farias et al. b] [Feio et al.] [Fernandes et al. a] [Ferreira et al.] [Filho et al. a] [Filho et al. b] [Fonseca et al. b] [Fonseca et al. a] [Gama et al.] [Garcia and Lara] [Gonçalves et al.] [Junior and Gama] [Kassab et al.] [Lopes et al.] [Lunardi et al.] [Luz et al.] [Maike et al.] [Makara et al.] [Martini et al.] [Martins et al. a] [Martins et al. c] [Martins et al. b] [Mauro et al.] [Moraes and Martins] [Moratelli et al.] [Moreira et al.] [Motta et al. b] [Motta et al. a] [Motta b] [Motta et al. c] [Moura et al. a] [Moura et al. b] [Muck et al.] [Nepomuceno et al.] [Neto et al. a] [Neto et al. b] [Neu et al.] [Oliveira et al. b] [Oliveira and Lopes] [Oliveira et al. a] [Paldes et al.] [Perdomo et al.] [Ponciano et al.] [Potter and Sztajnberg] [Rangel et al.] [Reis et al. b] [Reis et al. a] ¨ [Rodrigues et al.] [Rodriguez et al.] [Rodriguez and Batista] [Roriz et al.] [Salgado et al.] [Santana et al. c] [Santana et al. b] [Santana et al. a] [Santo et al.] [Santos et al. b] [Santos et al. c] [Santos et al. a] [Savoine et al.] [Sepulveda et al.] [Silva and Braga] [Silva and Baranauskas] [Silva et al. b] [Silva et al. c] [Silva et al. a] [Sousa et al. c] [Sousa et al. a] [Sousa et al. b] [Souza et al. d] [Souza et al. b] [Souza et al. a] [Souza et al. c] [Tsuchiya et al.] [Valle et al.] [Veiga et al.] [11] [Nascimento] [Pico-Valencia et al.] [Frohlich and Resner] [Farahmandpour et al.] [L. et al.] [Courtais et al.]

[3] [Ko et al. 2016] [Villegas et al. 2019]

[4] Gomez et al. 2017] [Cabrero et al. 2017] [Velasquez et al. 2017] [Rodriguez et al. 2017] [Wynn et al. 2017] [Arevalo-Gómez et al. 2018] [Cano et al. 2019] [Rivera et al. 2020] [Osorio et al. 2020] [Sepulveda et al. 2017] [Ahmed et al. 2018]

[5] [Nugra et al. 2016] [Yanez et al. 2016] [Chilcañán et al. 2018] [Avila-Campos et al. 2019] [Placencia et al. 2019] [Chilcanan et al. 2019] [Abril et al. 2019] [Campana and Dominguez 2020] [Flor et al. 2021]

[6] [Guerra and Perez 2016] [Guerra and Perez 2017] [Burd et al. 2017] [Burd et al. 2018a] [Burd et al. 2018b] [Benites et al. 2019] [Perez et al. 2020] [Chavez et al. 2020] [Kon et al. 2020]

2.2.3 Supporting data from government reports

When getting data from government we selected the three biggest economies in south America and looked into their official government website to retrieve data related to IoT and how the country is expecting that to near future. Based on that premise with support data acquired on the world bank we have Brazil, Argentina and Colombia and the biggest economy in South America [dat].

Based on Brazilian Ministry of Science, Technology and Innovations "IoT.BR National Plan seeks to carry out actions to improve the quality of life of citizens, to increase the country's competitiveness and productivity, as well as to strengthen the production chains of the various economic sectors.

In this context, the National IoT Plan - IoT.BR was launched, through the publication of Decree 9854, of June 25, 2019, whose aspiration is to make the Internet of Things an instrument of sustainable development for Brazilian society, capable of increasing competitiveness of the economy, strengthen national production chains and promote better quality of life. Based on this objective, four application environments were prioritized: Smart Cities, Health 4.0, Agro 4.0 and Industry 4.0" [min] Based on Argentina chief of cabinet of Ministers of public innovation "The development of the Internet of Things requires a multidimensional approach, which includes different actors from the public, private, academic and civil society sectors. Under this framework, we seek to accelerate the deployment of IoT and chart a path to boost the economic and social development of Argentina, leveraged on this technology. To do this, we are working on a National Plan for the Internet of Things from the interaction of different areas of Government, with the inclusion of actors from the public, private, academic and civil society sectors.

The articulation of the State with private actors is a key instance for the integration of global supply chains, caring for the environment, the formation of digital cities, the advancement of industry 4.0, the growth of IoT in agricultural production, as well as in sectors related to mining, oil and electricity, home automation, to name a few.". [Arg 2018] In the Colombia official web site we were no able to find any relevant information related to IoT.

III. FINDINGS

3.1 The IoT industry distribution in South America on research studies

The distribution of the Internet of Things industry in South America countries was obtained from the research publications on IEEE and ACM Digital Library as per Table 2. We were able to find the distributions of the countries with top three Brazil (78.26%), Colombia (6.83%) and Ecuador (5.59%) as it has been pointed out on Table 2. We were no able to find any research publications on the six countries namely Bolivia, Guyana, Paraguay, Suriname, Uruguay, Venezuela.

3.2. Classification of research fields

After the study we could identify, based on Table 3, that the South America focus the studies in Environment, Framework and Health but the majority of papers was distributed in several different areas.

3.3. Paper's hardware distribution

This SLR has reveled to us that the most used by researchers in South America is the Arduino and Mobile platforms, as shown in Figure 2.

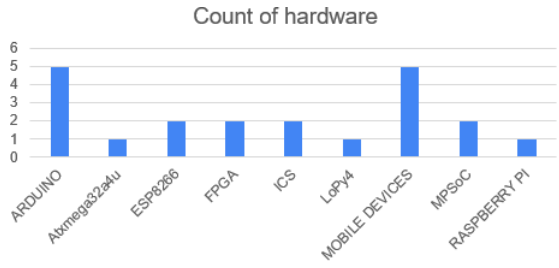

Fig. 2: Hardware for IoT

3.4 Paper's annual distribution

Looking for the papers distribution over the last 5 year we were no able to identify any pattern but we can see the data on the Figure 3.

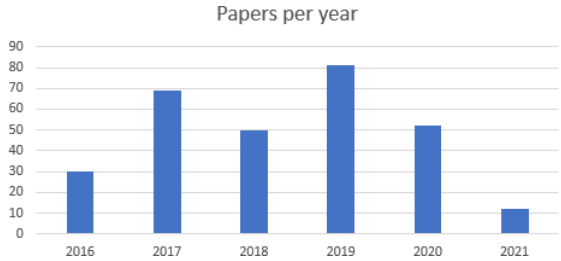

Fig. 3: Papers published per year

IV. CONCLUSION

Using the scientific sources of publications we filtered 1390, to know that Brazil is the main researcher country and there are 6 of 12 countries that are not publishing in areas related to IoT and it represent an opportunity to get involved in such area, given that in South America there are many applications in topics like agriculture that has only 5% of presence in all the studies reviewed.

As shown in the Findings section and the Table 3, we discovered that the main areas addressed by the publications analyzed by this work were Environment, Framework and Health but the most works were distributed over other topics showing us the multidisciplinarity use of IoT.

We identified by the Figure 1 that the hardware most used on the publications were Arduino and Mobile devices, showing how important is a low cost device as Arduino and how IoT could me applied to mobile devises due to his small size and low energy consumption.

We also noticed that in the year 2021 there were fewer publications than in the last five years, as we can see on the Figure 2. We attribute the lack of publications is related to the COVID-19 pandemic that has been restricting the number of research studies.

V. FUTURE WORKS

This topics will cover similar studies that can be done next to this SLR. The same study can be done in the future to understand how that technology is growing over the years in IoT field in South America. Similar study can be done in other regions to understand its maturity and compare with that study to get a brother view of the IoT in the world. Going forward with industry 4.0 similar studies can be done with different technologies ie. (Smart manufacture, Smart factories, Cloud computing, Cognitive computing, Artificial intelligence) that will help to identify witch region or country is growing more in a specific area. With all that studies done together we will have a broad view of the development of industry 4.0 that will support humanity over the next years ahead.

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