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TOPICAL REVIEW

The Role of Technology in Improving the Customer Experience in the Banking Sector: A Systematic Mapping Study

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ABSTRACT Information Technology (IT) has revolutionized the way we manage our money. The adoption of innovative technologies in banking scenarios allows to access old and new financial services but in a faster and more secure, comfortable, rewarding and engaging way. The number, the performances and the seamless integration of these innovations is a driver for banks to retain their customers and avoid costly change of hearts. The literature is rich in works reporting on the use of technology with direct or indirect impact on the experience of banking customers. Some mapping studies about the adoption of technologies in the field exist, but they are specific to particular technologies (e.g. only Artificial Intelligence), or vice versa too generic (e.g. reviewing the adoption of technologies to support any kind of banking process). So a specific research effort on the crossed domain of technology and Customer Experience (CX) is missing. This paper aims to overcome the following gaps: the lack of a comprehensive map of the research made in the field in the past decade; a discussion on the current research trends of top publications and journals is missing; the next research challenges are yet to be identified. To face these limitations, we designed and submitted 7 different queries to pull papers out of 4 popular scientific databases. From an initial set of 6,756 results, we identified a set of 89 primary studies that we thoroughly analyzed. A selection of the top 20% works allowed us to seek the most performant technologies as well as other promising ones that have not been experimented yet in the field. Main results prove that the combined study of technology and CX in the banking sector is not approached systematically and thus the development of a new specific research line is needed.

INDEX TERMS Banking, financial services, user experience, information and communication technology, disruptive innovation, internet of things, artificial intelligence, blockchains, product customization, computer security.

I. INTRODUCTION

Customer Experience (CX) is a major tool for achieving competitive advantage in all industries [1]. It is a holistic interactive process, facilitated through cognitive and emotional clues, moderated by customer and contextual characteristics, resulting into unique and pleasurable/un-pleasurable memories [2]. Part of the challenge in building memorable CX is that experience is an intangible quality that is so different from one person to the next [3].

The global interest in CX is continuously increasing. Trivially, using Google Trends we can notice a huge numbers of references to the term (and counting), proving that the interest has never be so high [4]. This lends weight to the fact that this is a truly global challenge [5].

Particularly, the wide spread of both innovative devices and engaging apps has set higher standards for customer expectations in the banking field. Chatbots, wearables, biometry, smart speakers, VR/AR, and machine learning are just some of the information technologies that have profoundly changed the way we live, so we expect they can be used to manage our money as well.

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The ferment brought by Fintech and Techfin companies has shaken even the more reluctant banks, which are now obliged to innovate to retain their customers. Just like opening a bank account today is as easy as taking a selfie, changes of heart are in fact behind the corner. Developing new seamlessly integrated intelligent services is mandatory to control the so-called churn rate, and the perspective for the future is that the deregulation of the market will further amplify the need for technologies in the banking field. Banks have hunger for innovation in the CX field.

This systematic mapping study aims at bridging an existing gap in the state on the art. In fact, despite the numerous contributions of the research community in the banking field, a specific research effort on the crossed domain of technology and Customer Experience (CX) is missing. In particular, a comprehensive map of the research made in the field in the past decade is missing, as other mapping studies exist but they are specific to particular technologies (e.g. only Artificial Intelligence), or vice versa too generic (e.g. reviewing the adoption of technologies to support any kind of banking processes). Consequently, a discussion on the current research trends of top publications and journals is also missing. It could be very useful for researchers for following interesting and promising research lines, as well as developing totally new research lines that are yet to investigated. Finally, the research challenges for the considered domain are unknown, as no other work has tried to match the needs of both the banking industry and the related customers with the nowadays technologies limitations. This work aims at filling the described gaps by providing an extensive, complete and detailed analysis of what the research has proposed in the use of technologies in the banking field from 2011 to the first half of 2022.

This wants to be a reference both for researchers and practitioner. The formers can use the results provided in this study to follow the most promising research trends and to detect possible innovation holes, in order to overcome them by activating new research lines. The latter – which could be bank's Chief Innovation Officers (CIO) or founders of Fintech startups – can use this paper as a catalogue of innovations and figure out which technologies would reach the market in the next 10 years and anticipate needs and changes.

It is important to notice that we are mostly interested in technologies that will shape the CX in the banking sector by the next 10 years. The research already knows the impact of technologies, practices and channels that are well established on the market, such as online and mobile banking, or even more innovative but already consolidated or known by the customers. We want rather to understand how the bank branch of the future will look like, aside of technologies that already find application, and how the customer will access new or renewed services and bank channels, both physical and virtual. Finally – for the same reason as above and also because this mapping study is purely technical – we do not consider surveys or other similar works involving cohorts of customers that are measured while using consolidated technology.

A summary of the main finding of this works is the following. The 40% of the research in the field is made in India, particularly in research institutions based in Chennai. Nevertheless, top papers are originated from USA, Switzerland and Australia. The main journal publishing works in the field is IEEE Access. But the main finding is that there are no prolific authors or institutions: practically every author of the listed 282 has only 1 paper in the field, like such works were by-products of other research lines. This proves that the combined study of technology and CX in the banking sector is not approached systematically and thus a specific research effort is needed given the importance that technology has in the banking sector.

The remainder of the paper is organized as follows. Section II reports on the related works, framing this works in the broader contexts of CX and mapping studies. Section III describes all the steps of our research method. Section IV extract the results and main findings of this work. Section V presents the concluding remarks and sketches the future research that has to be done to advance the field.

II. RELATED WORKS

Being a discipline falling in the broader area of business management, a high quantity of works have already been discussing models, experimentations and implications of CX within companies. For example, on the Scopus database there are 2,045 papers having the customer experience keyword. It is noticeable that if we set the additional ''Computer science'' filter, the number halves (1,007). This rate 1:2 lower to 1:4 when considering only publications on journals: only 253 out of 953 papers discuss the CX from a computer science point of view. Evaluating the customer response to digital innovation require orthogonal skills. In this field, the recent works of Lemon and McColl-Kennedy among the others are relevant [6], [7], [8]. Subsetting to the papers related to the banking sector is a harder work which this mapping study is aimed at handling.

Systematic mapping study – or systematic review – is one secondary study method useful to go through existing primary reports, review them in-depth and describe their methodology and results. Systematic reviews have several benefits: reduce bias, allow more general conclusions, and can detect more than individual studies in isolation by the use of statistical meta-analysis. Guidelines of systematic mapping studies in software engineering are provided by Peterson et al. [9]. In this case, mapping studies are used to take snapshots of the research in a specific domain of the software engineering field (e.g. [10] and [11]).

A couple of mapping studies in the broad domain of CX exist. In [12] authors aims to examine the trends and themes in the field of CX using a bibliometric analysis between 1957 and 2017. The paper analyses 1,767 papers selected from Web of Science (WoS) database using VOSviewer software tool to create bibliometric networks. The findings establish the argument that most of the ideas that follow today in the development of the field are mostly sourced

from the works published in highly reputed journals. Authors and institutes from the American and European countries dominate the contribution to the development of the field. In [13] authors conduct a bibliometric analysis and a mapping study on 337 publications on customer loyalty and brand management from 2000 to 2018. The results present the most cited works on the topic, an evaluation map showing the most frequent and cited words and six clusters of words based on their co-occurrence. Interesting findings include the identification of the most prolific authors. In this case, the higher number of papers per author is 4. Moreover, the USA is by far the lead country in terms of scientific production for the topic, with more than 80 works (follows Australia with around 30 papers).

The conclusions draft by authors of [14] are interesting as well. While conducting a mapping study about CX in e-learning applications, they found that the concept of CX has different definitions, being in fact a little diluted. Moreover, results show there are few publications concerning the subject, particularly in the domain of their interest (e-learning). Such lack of vertical CX-related research works confirms what stated above about the requirement of orthogonal skills.

Very few technological reviews in the banking sector exist. [15] and [16] are two mapping studies collecting the use of data mining and machine learning techniques for two different purposes. The first looks at the implementations of such technologies for bank customers segmentation. The usage of novel technologies to perform Know Your Customer (KYC) procedures is also what we expect to find in our mapping study (but it is not limited to, by the way), because knowing the characteristics of customers allow to offer more personalized products and services that can gratify the client. Authors performed a systematic literature mapping of 87 primary studies published between 2005 and 2019. They found that several data mining and machine learning techniques have been applied to the problem of customer segmentation, with clear tendencies regarding the techniques, tools, metrics and datasets. Particularly, decision trees and linear predictors were the most used data mining and machine learning paradigms in bank customer segmentation. The second ([16]) looks at the implementations of machine learning techniques for fraud detection in financial statements. It is distant from our study because in this case the technology serves at the back-office of the bank, hence not giving any direct nor indirect benefit to the customer perception. Anyway, authors carried out a systematic mapping study of 67 studies. Results shows that since 2015 there was an upturn in the amount of studies that use these techniques for fraud detection in financial statements, where vector support machines are the most used technique (19 papers) followed by artificial neural networks (15 papers) and decision trees (11 papers). Performances of such algorithms span in the interval 70% - 99.9%.

In [17] authors propose a bibliometric and visual study to provide an insight in the FinTech field from 1900 to 2020. The study is very complete as it includes every kind of publications (articles, proceedings papers, book chapters, reviews, etc.) in the broad topic of FinTech (with no limitations to the application of technology in frontend or backend processes and services). The Web of Science scientific database was used to retrieve all the works including the ''Fintech'' or ''financial technology'' words in the title. So, the work is huge: 848 papers were obtained and classified. Authors used the CiteSpace and VOSviewer science mapping analysis tools [18], [19], [20], which generate very readable and intuitive maps.

Finally, the last mapping study found in the banking sector is [21], in which authors aims to classify and provide a thematic analysis of studies on the use of blockchain in the context of financial area, thus allowing to create a clear systematic map of the current literature, and identify challenges and research opportunities. Authors reviewed 1884 studies from 6 data sources, and then selected 23 most interesting studies after a careful filtering process. The main findings of their work includes the fact that over 60% used blockchain technology to increase security, and that Fintech and loan were the most explored application areas.

What is evident from the state of the art is that a mapping study in the banking sector on the use of technology with direct impact on the CX is not currently available, and therefore is clear the need to cope with this hole in the scientific literature.

III. RESEARCH METHOD

The papers were selected first basing on title, abstract and a light full text screening, which became a deep screening in case of doubts. The full paper selection process is shown in Fig. 1. We designed and submitted 7 different queries to pull papers out of 4 popular scientific databases. From an initial set of 6,756 results, we identified a final set of 89 papers that we thoroughly analyzed in order to get their demographics and sketch current research trends. A selection of the top 20% works allowed us to seek the most promising technologies and understand the implications of their use in the sector. This process will be fully described in the next subsections.

A. RESEARCH QUESTIONS

According to the guidelines of systematic mapping studies in software engineering, the first step consists in defining the research scope by means of a number of research questions which should be addresses. The questions are the following:

RQ1: What are the demographics of the primary studies? Knowing when and where important publications in the field are published is important in order to seek prolific research line as well as reference institutions, journals and authors all over the world. Following who in the past has been prolific or precursor of innovation is a good strategy to foresee future trends.

RQ2: Which technologies are primarily used to improve the CX in the banking sector and for which purpose? There is a number of IT technologies that are very good for engaging the bank customers: vocal interaction, wearables, DeFi, NFC, etc. Some of them also works on the backend (e.g. AI).

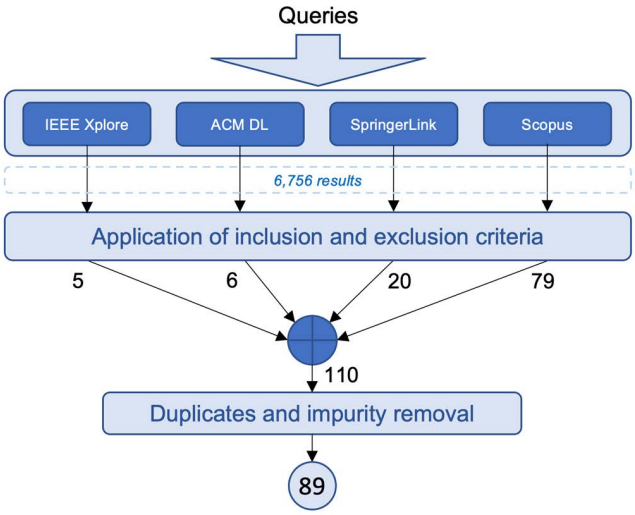

FIGURE 1. Overview of the search and selection process.

We want to map in great detail the research made in the last decade and quantify the research by keywords and by purpose of use.

RQ3: Which are the publication trends in CX for the banking sector? We want to know how the interests of researchers have been moving across the years, for example analyzing the change in the use of keyword. Moreover, we want to know what the research has proposed in the top recent papers.

RQ4: What are the research challenges? It is very important to better focus the possible future works of the research community. Basing on the recent trends in technology, it is expected that they will reach also the banking sector, soon or late, because customers expect it. We will try ty find the top 3 technologies or use cases that have been not reported in the primary studies, trying to underline the practical challenges behind their implementation.

B. DATA SOURCES

We used 4 popular scientific databases that are relevant for the IT sector: IEEE Xplore, ACM Digital Library, SpingerLink and Scopus.

C. INCLUSION AND EXCLUSION CRITERIA

Before designing the search query, we listed a series of inclusion (IC) and exclusion (EC) criteria that the primary studies shall satisfy. They are the following:

- Inclusion criteria:
  1. Articles published on journals;
  2. Articles published from 2011 to the first half of 2022;
  3. Articles specifically focusing on the application of innovative technology having a direct or indirect impact on the CX in the banking sector;
- Exclusion criteria:
  1. Articles published in conference proceedings, book chapters, books and other minor research contributions;
  2. Articles written in languages other than English;
  3. Other reviews or mapping studies;
  4. Papers without technical contribution;
  5. Surveys;
  6. Articles ranked below the 200th position in query result.

Broadly speaking, we are not interested in analyzing the effects of well established technologies, practices and channels, such as online and mobile banking, or even more innovative but already in the market stage. We also exclude expectations gathering in papers not having a technological value. Moreover we exclude all of those papers involving the bank's back-office and operability (e.g. business processes studies and optimization) without a direct effect on the customer perception or activities.

TABLE 1. The considered queries submitted to the scientific databases.

Query ID	Query	Motivation
1	retail banking	To search works that innovates the branch as a physical central point of contact between the bank and the customer. The query aims to find the selected keywords in all the fields (title, abstract, keywords, article text)
2	"customer experience" AND banking	To get works falling in the broad field of this study. The use of exact phrase search in conjunction with the AND logical operator allow is to restrict the search result to the very interesting works.
3	ABS ((robots OR robot OR robo) AND (banking OR bank OR financial))	This very structured query aims at retrieving personal and customized assistants in the financial fields, in all the variants, specifically looking in the abstract of the works, hence ensuring that the thematic is in the main scope and not randomly cited in the article.
4	metaverse banking	To find all the works in the Virtual Reality fields. The use of the "metaverse" word is for giving further precedence to more recent works (anyway the word exists from 1992)
5	ABS (voice AND (banking OR financial))	To find works specifically treating the voice interaction in the banking and financial contexts.
6	((TITLE-ABS-KEY (banking) AND ALL (iot)))	To find works in the banking fields citing the Internet of Things in any part of the article
7	((TITLE (ATM) AND ALL (teller)))	To find innovations for the Automated Teller Machines (ATM). The acronym is used also in other domains, hence we forced the presence of the word "teller".

D. SEARCH QUERIES

We submitted several queries in order to pull the interesting papers out of the 4 scientific databases. Nevertheless, only 7 gave significant results, hence here we report only on these 7. Such queries have been slightly adapted in order to

TABLE 2. Results per query.

Query ID	Number of results				Considered results			
	IEEE Xplore	ACM DL	SpringerLink	Scopus	IEEE Xplore	ACM DL	SpringerLink	Scopus
1	6	225	47	2,328	0	3	4	9
2	1	10	623	130	1	3	6	10
3	13	4	1,977	283	2	0	3	9
4	1	20	15	0	0	0	0	0
5	7	1	332	116	1	0	1	14
6	31	3	151	279	1	0	4	11
7	0	0	14	139	0	0	2	26
TOTAL	59	263	3,159	3,275	5	6	20	79
GRAND TOTAL	6,756				110			

match the specific syntaxes of the engines. There are both simple and more complex queries, which we built basing on the quality of the automatic research delivered by the scientific databases. Despite the number of filters in the query, in some cases the number of results is high and untreatable, particularly for SpringerLink and Scopus databases. For those cases, we set a limit of 200 results per query, being confident in the ability of search engines to rank high in the result lists the most significant works. Basing on the analysis of the results, the number 200 seemed a good trade-off between coverage of the works and feasibility of the study. In Table 1 we show the used queries with a brief motivation and the number of results per database.

Please notice that SpringerLink database does not allow to set specific filters for the abstract (only for the title). Hence the ABS filter became a filter for the title while searching the SpringerLink database.

Table 2 reports on the number of results per query, as well as the number of papers that were selected. A couple of thought are already noticeable. The first is that the Scopus database is the more accountable for the considered research field, in terms of number of primary studies found. This is mainly due to the multi-source nature of this scientific database. The second is that query #4 gave no considerable results at all on every database, hence being a strong hint for shaping the future research activity.

It is mandatory to evidence that the 110 selected papers had duplicates. That is, a paper found on multiple databases or in different queries is always counted. A further refinement process hence removed duplicates as well as impurities that exceptionally bypassed the ECs. The final number of primary studies is 89. See Fig. 1 for an overall overview of the selection process.

E. CATEGORIES

We have used a custom taxonomy to classify the 89 primary studies. The classes are the following:

1) RETAIL BANKING

Studies analyzing user perception and usage of bank's physical presence, as well as proposing new models of fruition for bank branches.

2) IMMERVISE AND UBIQUITOUS BANKING

Focus on solutions allowing a seamless integration between physical and digital world in the banking field.

3) SECURITY

Security solutions in the banking field somehow affecting the user perception or impacting user's operability.

4) UX/CX/UCD

Studies promoting new models of User Experience, Customer Experience and User Experience Design.

5) UI

Studies analyzing the use of innovative UI to access financial services.

6) SERVICE PERSONALIZATION AND NEW SERVICES

Solutions and frameworks tailoring existing financial (technological) services over the specific user needs and features, or creating new banking services.

7) PAYMENTS & MONEY SERVICES

Models and solutions for innovative and user-engadging payment services.

8) CUSTOMER JOURNEY

Studies about the journey of customer moving abroad the different financial services using different channels.

IV. RESULTS

In this section we answer all the RQs by analyzing the results extracted from the collection of primary studies.

A. DEMOGRAPHICS (RQ1)

The total number of authors for the 89 primary studies is 282, affiliated to institutions from 32 countries. In Fig. 2 and 3 the count of papers and authors per affiliation's country is reported. India's contribution to the field is very important: 106 authors (35,37%) contributing on 32 papers (32,37%). China and UK follow, in reverse order in the two charts, evidencing the fact that Chinese researchers tend to be averagely more numerous per paper. It must be noticed that a

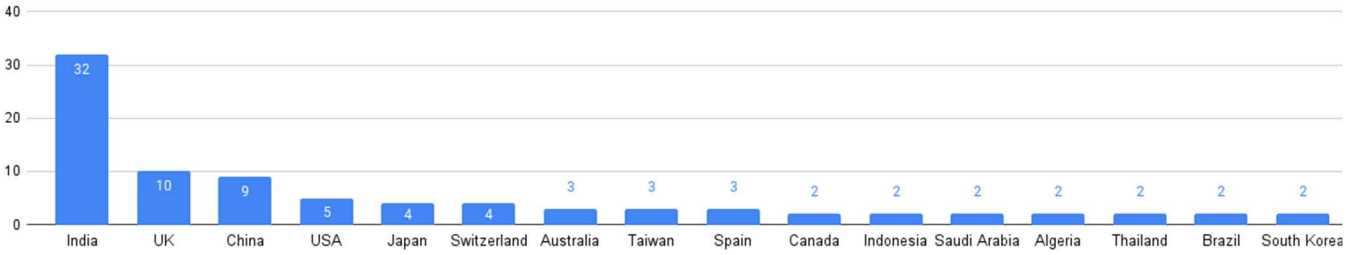

FIGURE 2. Numbers of papers per affiliation's country. Countries with just 1 paper are removed for readability of the graph. They are: Bangladesh, Azerbaijan, Cyprus, Denmark, Finland, Germany, Italy, Malaysia, Netherlands, Pakistan, Poland, South Korea, Rwanda, Turkey, UAE and Ukraine.

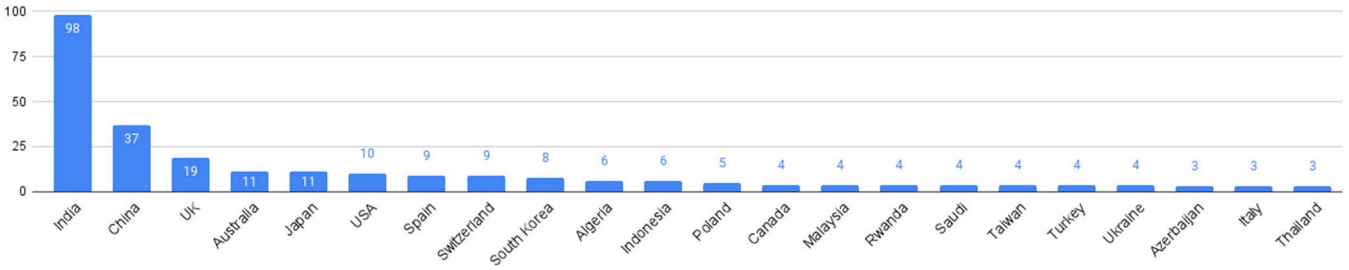

FIGURE 3. Number of authors per affiliation's country. Countries with less that 3 authors are removed for readability of the graph. They are: Bangladesh, Brazil, Cyprus, Finland, Netherlands, Pakistan, UAE, Denmark and Germany.

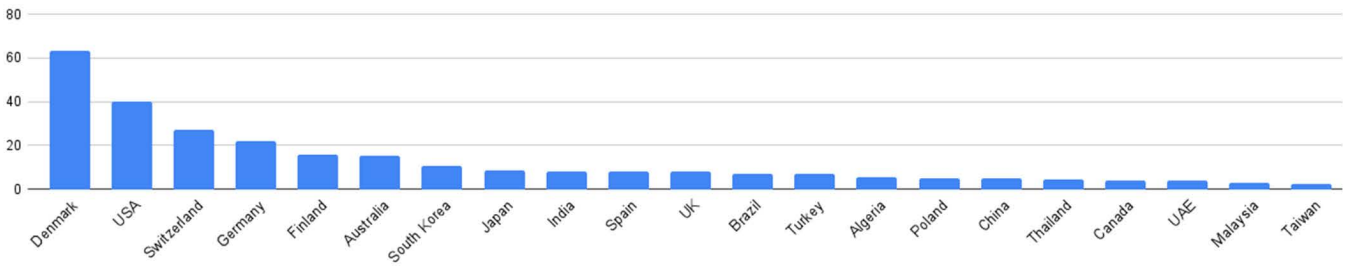

FIGURE 4. Average citations count per country. Countries with a value equal or less than 1 are removed for graph readability. They are: Azerbaijan, Bangladesh, Indonesia, Pakistan, Rwanda, Saudi Arabia, Cyprus, Italy, Netherlands and Ukraine.

paper is counted for a country if at least 1 author belongs to that country. As a direct consequence, the same paper can be counted for multiple countries.

The case of India raised our attention, so we decided to furtherly investigate. The 98 Indian authors considered in this work belongs to 43 institutions, 46,94% of which are in the State of Tamil Nadu. The 43,48% of researchers from Tamil Nadu (20) are affiliated to 8 institutions located in the city of Chennai. Understanding the reason of such concentration of research works in Chennai is out of the scope of this work. Reading from Wikipedia, Chennai has an economic base anchored by the automobile, software services, medical tourism, hardware manufacturing and financial services. Chennai is home to the first European-style banking system in India with the establishment of the 'Madras Bank' on 21 June 1683, almost a century before the establishment of the first commercial banks. Maybe such historical background contributes to the consistent research in the financial sector.

An important finding is that there are no prolific authors in the field, that is the majority of authors wrote just 1 paper. Some small exceptions arise: the following pairs of PS share some co-authors:

- PS23 & PS58 (Hayashi and Ruggiero from University of São Paulo, Brazil)
- PS33 & PS59 (Mervyn, from University of Edinburgh, Ireland)
- PS36 & PS39 (Kumaresan, Senthilkumar and Karthick from Sathyabama University, India)
- PS77 & PS78 (Hernández-Nieves, Hernández, Gil-González, Rodríguez-González and Corchado, from University of Salamanca, Spain)

What about the contribution importance per country? Considering the citations metric, we computed an average citation count per country. In Fig. 4 it is reported the related chart. Beware that the histogram should be consulted with Fig. 2 in mind, e.g. Denmark is the leader in this chart, but with only 1 (very cited) paper. Interesting nations are placed on the left in both figures: USA, Switzerland and Australia are for sure the top 3 countries for this metric. Despite the great number of papers, India ranks quite low in this chart, reaching the same

TABLE 3. Top 10 journals.

Title	H-index	Impact factor	Number of PS
IEEE Access	158	3,952	5
Biometric Technology Today	11	0,783	3
MDPI Sensors	196	3,964	2
MDPI Applied Sciences	75	2,911	2
Journal of Ambient Intelligence and Humanized Computing	52	4,947	2
Proceedings of the ACM on Human-Computer Interaction	38	4,568	2
International Journal of Applied Engineering Research	44	0,649	2
International Journal of Engineering and Technology(UAE)	30	0,673	2
International Journal of Scientific and Technology Research	22	0,412	2
International Journal of Advanced Science and Technology	17	0,468	2

Values of H-index and Impact factor are taken at the time of writing (June 2022). Both metrics are sourced from the website https://www.scimagojr.com/ . The value of impact factor is the most recent two years line in the Citation per document box.

average citations of other countries like the UK which has one third of India's papers and authors.

With regards to the venue of publication, the most relevant journal in the field is IEEE Access, with 5 works published from 2018 to date (PS18, PS19, PS25, PS68, PS69). The second is Elsevier's Biometric Technology Today, with 3 works published in 2016, 2017 and 2020 (PS21, PS55, PS56). Differently from IEEE Access, the Elsevier's journal publishes works very focused on a specific topic. The interest in biometry says a lot about the research trends (we will discuss this in the next sections). Then there are 9 journals with 2 papers and a long tail of 63 journals with just 1 single publication on the topic. Table 3 shows the list of top 10 active journals. Fig. 5 shows the temporal trend of publications in the fields. It is evident the increasing interest of the research community toward the adoption of technology in the banking sector near to the customer. With regards to the classification introduced in section III.E, for each primary study we identified a main category and a second category. This is because every work has a main scope, but also a positive repercussion on other scopes, so we wanted also to capture this side-benefit. In Fig. 6 it is reported the histogram of the classification of the PS, considering both the main and the second category. In Table 4 we report the complete list of primary studies per category.

B. PRINCIPAL TECHNOLOGIES (RQ2)

We obtained the findings we discuss in the next sections by using the software VOSviewer 1.6.18 (0). We feed the VOSviewer wizard by providing a set of CSV files exported from Scopus. Instead of manually searching every publication on Scopus to export the related CSV files, we queried the Scopus' APIs so that all the papers' data were returned automatically. We used the DOIs collected during the search process as IDs to retrieve publications on the Scopus database. Nevertheless, not all the 89 PS have a DOI: 20 out of 89 PS do not have a DOI assigned. For these ones, a manual search by title on the Scopus website was needed to export the CSV files. Moreover, 6 PS were not available on Scopus. For these, we retrieved the needed data on other databases, and manually created a Scopus-compliant CSV file with such data.

Once we had the 89 CSV files, we created a new map on VOSviewer basing on bibliographic data. The type of analysis we demanded to VOSviewer was a fractional-counting co-occurrence, specifying the Author keywords as unit of analysis. We chose fractional counting instead of full counting in order to reduce the influence of PS with many keywords. We chose to use author keywords instead of index keywords for 2 reasons. The first is that, being crowd-sourced and selected by authors, in our opinion author keywords are generally more precise than predefined static taxonomies. The second reason is more practiacal: Scopus APIs do not return index keywords. A drawback of using author keywords is the presence of synonims and duplicates. So a prior normalization was due in the CSV files in order to remove cases like "IoT" and "Internet of Things", or "biometric" and "biometrics", and so on. At the end of this phase, we reached a total number of 349 keywords used by the 89 PS.

Another problem was due to 6 PS missing author keywords. For those PS, we used index keywords instead.

We chose different threshold values for the number of occurrences per keyword, naming it n, particularly 2 to 7 occurrences. The number of keywords meeting the thresholds were rispectively 46, 19, 10, 7, 5 and 3. No author keyword was used more than 7 times in the PS. The top 3 keywords are ATM (18 occurrences), biometrics and IoT (8 occurrences each). In Fig. 7 we show the map for $n = 5$, with the aim to begin having a sea-level map of the research in the field. The size of the frames is proportional to the number of occurrence of the specific keywords. The weight of the link is proportional to the co-occurrence of the connected keywords. The distance between keywords approximaly indicates the relatedness of the PS in terms of co-citation links. Colors indicates the appartenence to clusters of keywords. At a very high level, we can see the predominace of PS involving the ATM, in an interesting cluster involving aspects of biometrics and authentication. Also the Internet of Things (IoT) seems to be crucial for the banking of the future, forming a cluster with AI and the blockchain. In the middle,

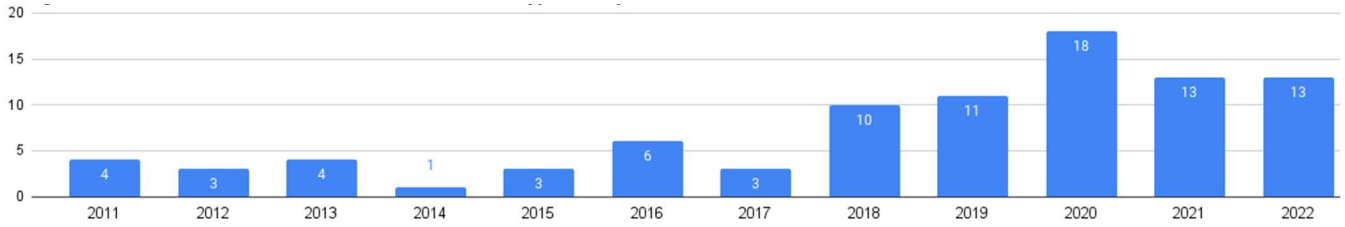

FIGURE 5. Number of papers per year.

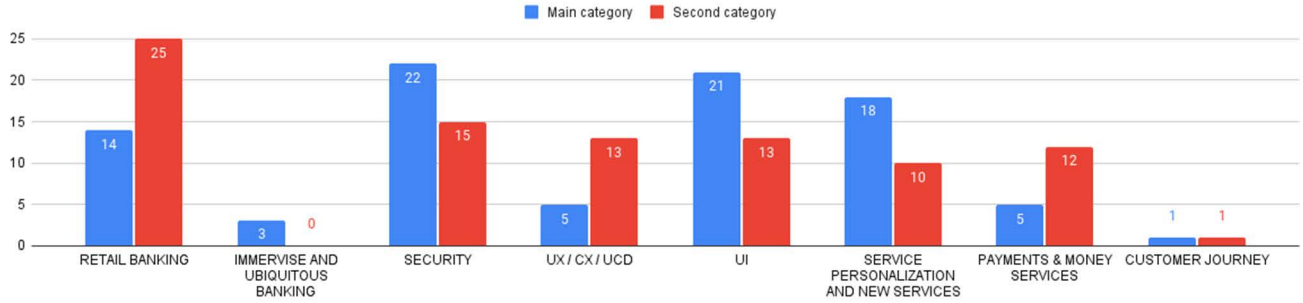

FIGURE 6. Numbers of papers per category. In blue, the count of papers falling in the specific category as main classification. In red, the same count but as second category.

TABLE 4. List of primary studies per category.

Category	Primary studies by main category	Primary studies by second category
1	PS1, PS2, PS3, PS4, PS5, PS6, PS7, PS8, PS9, PS10, PS11, PS12, PS13, PS17	PS15, PS22, PS24, PS27, PS28, PS29, PS30, PS31, PS32, PS33, PS34, PS35, PS36, PS37, PS38, PS39, PS42, PS43, PS44, PS60, PS61, PS62, PS63, PS64, PS65
2	PS14, PS15, PS16	-
3	PS18, PS19, PS20, PS21, PS22, PS23, PS24, PS25, PS26, PS27, PS28, PS29, PS30, PS31, PS32, PS33, PS34, PS35, PS36, PS37, PS38, PS39	PS3, PS4, PS5, PS6, PS9, PS11, PS12, PS49, PS55, PS56, PS58, PS83, PS84, PS85, PS88
4	PS40, PS41, PS42, PS43, PS44	PS1, PS2, PS8, PS14, PS46, PS47, PS53, PS59, PS73, PS74, PS77, PS78, PS89
5	PS45, PS46, PS47, PS48, PS49, PS50, PS51, PS52, PS53, PS54, PS55, PS56, PS57, PS58, PS59, PS60, PS61, PS62, PS63, PS64, PS65	PS10, PS16, PS17, PS19, PS20, PS21, PS23, PS25, PS41, PS70, PS76, PS80, PS87
6	PS66, PS67, PS68, PS69, PS70, PS71, PS72, PS73, PS74, PS75, PS76, PS77, PS78, PS79, PS80, PS81, PS82, PS83	PS13, PS40, PS45, PS48, PS50, PS51, PS52, PS54, PS57, PS86
7	PS84, PS85, PS86, PS87, PS88	PS18, PS26, PS66, PS67, PS68, PS69, PS71, PS72, PS75, PS79, PS81, PS82
8	PS89	PS7

a small cluster only including aspects of security connects the 2 domains. In Fig. 8 it is reported the density visualization map for n = 2, thus only keywords that are used at least twice in the PS are reported.

C. PUBLICATION TRENDS (RQ3)

In this section we map the research trends in 2 steps. First we continue analyzing the keywords adoption in the PS using the VOSviewer software and other metrics. Then, we select the top 20% PSs, providing for them a deeper overview.

With regards to the first point, Fig. 9 and 10 use a chromatic indication of the temporal trend for each keyword. The most recent advancements in the field include IoT, AI and blockchain technologies. This is a confirmation of what we are already witnessing in the banking industry. Other interesting minor keywords are: risk assessment, robots, mobile payments and the smart home. We could summarize saying that the banking customers of the future will access their services autonomously by using multi-channel robots, using both smart home devices

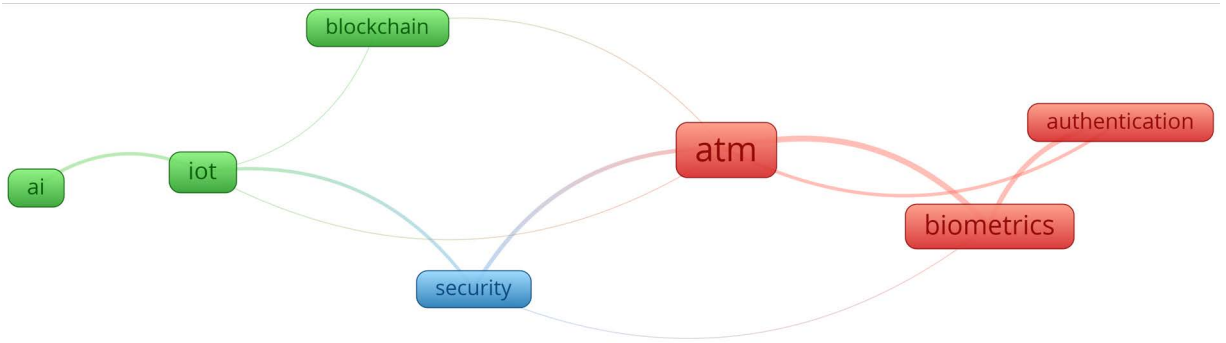

FIGURE 7. Map of the most used keywords in the PS. The size of the labels is proportional to the number of occurrences.

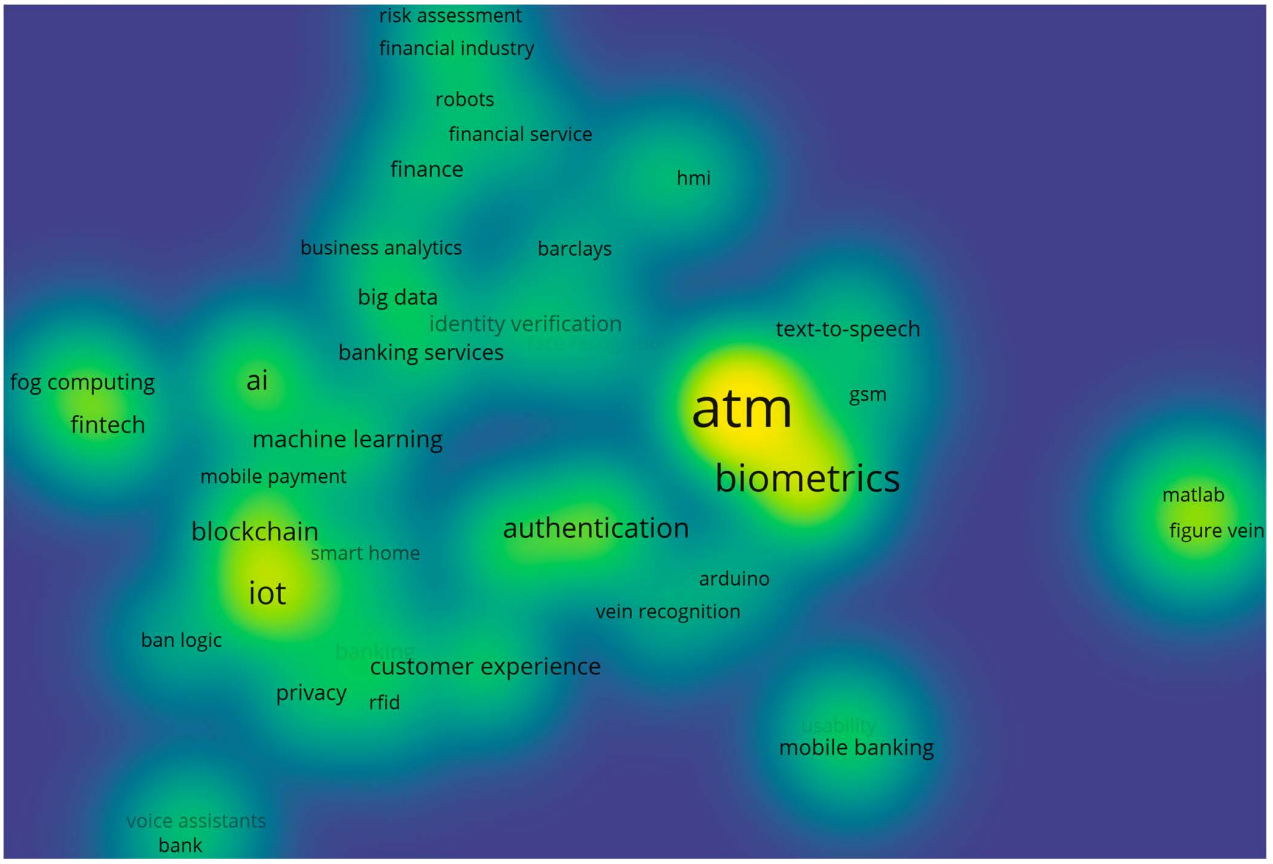

FIGURE 8. Map of the 45 (out of 349) keywords.

TABLE 5. Top keywords occurrence in PS.

Keyword	Occurrences
ATM	20
Biometrics	11
IoT	8
Authentication	6
AI	6
Security	5
Blockchain	5

or in mobility, protected by a customized risk assessment layer.

With regards to the classification we exposed in section III.E, we now count the number of papers by category and year, in order to understand the current research trends by means of the custom taxonomy. Tables 6, 7 and 8 reports such counts using the format of heat maps: the darker is the cell, the greater is its value.

Table 6 accounts for the main classification, Table 7 accounts for the second classification, finally Table 8 reports an overall score considering both the classifications. For each cell we computed a weighted average, in which the weights for the main and second classifications are respectively 2/3 and 1/3. The score is then divided by the total number of PS in order to have a percentage. The provided tables are useful tools to understand the last current trends – which seems mainly falling in the categories 1, 3 and 6 – and to sketch possible next research efforts (see next section).

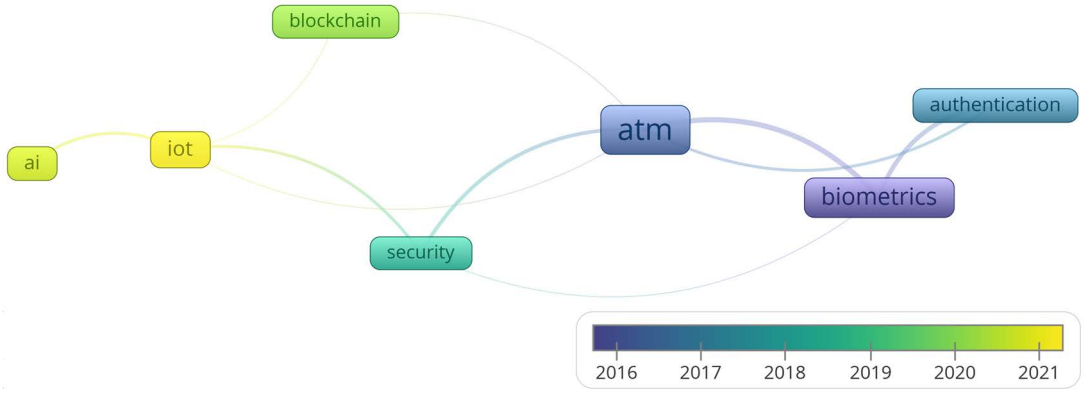

FIGURE 9. Publication temporal trend of the main keywords.

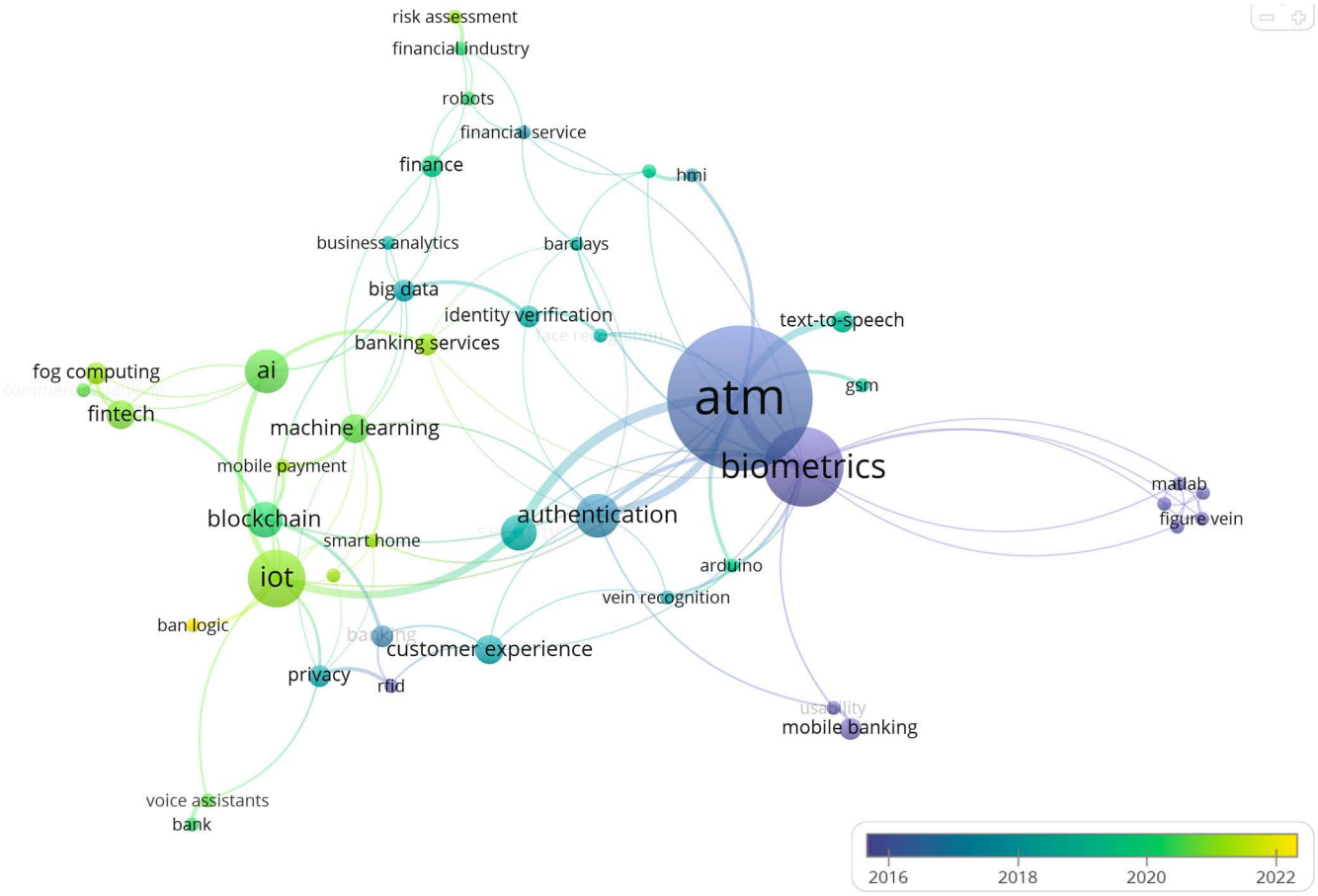

FIGURE 10. Publication temporal trend of the top 45 keywords.

Here we now select and discuss the top 20% papers of this study. We selected the top 2 papers for each category, with a +1 bonus for the top 3 categories cited above, and a −1 penalty for the less performing category (the 8th). Hence, the total number of top papers is 18. The criteria we used to select the most relevant works was quantitative, meaning we have considered for each paper its numerical performances in this order of attention:

1) Number of citations. The more the paper is cited, the more it is relevant;
2) Year of publishing. More recent works have the priority.
3) Journal Impact Factor and H-index. Publications on top journals are preferable.

Despite the precise order, the decision to select or not a paper comes out from an overall evaluation of the 3 criteria. For example, a paper with 8 citations but published in 2022 is

TABLE 6. Heat map of primary studies per main category and year.

Category	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	Total
RETAIL BANKING	5	2	2	3	0	1	1	0	0	0	0	0	14
IMMERSIVE AND UBIQUITOUS BANKING	0	0	1	1	0	0	0	1	0	0	0	0	3
SECURITY	1	2	7	2	1	0	3	1	1	3	1	0	22
UX / CX / UCD	0	0	2	1	0	0	0	0	0	0	0	2	5
UI	4	2	0	2	5	1	2	1	0	1	1	2	21
SERVICE PERSONALIZATION AND NEW SERVICES	2	4	6	2	3	1	0	0	0	0	0	0	18
PAYMENTS & MONEY SERVICES	1	3	0	0	0	0	0	0	0	0	1	0	5
CUSTOMER JOURNEY	0	0	0	0	1	0	0	0	0	0	0	0	1
Total	**13**	**13**	**18**	**11**	**10**	**3**	**6**	**3**	**1**	**4**	**3**	**4**	**89**

TABLE 7. Heat map of primary studies per second category and year.

Category	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	Total
RETAIL BANKING	0	0	4	3	4	0	4	2	1	4	1	2	25
IMMERSIVE AND UBIQUITOUS BANKING	0	0	0	0	0	0	0	0	0	0	0	0	0
SECURITY	5	2	3	1	0	1	2	0	0	0	1	0	15
UX / CX / UCD	3	2	1	3	1	1	0	0	0	0	0	2	13
UI	1	6	4	0	0	1	0	1	0	0	0	0	13
SERVICE PERSONALIZATION AND NEW SERVICES	2	3	1	1	2	0	0	0	0	0	1	0	10
PAYMENTS & MONEY SERVICES	2	0	5	2	3	0	0	0	0	0	0	0	12
CUSTOMER JOURNEY	0	0	0	1	0	0	0	0	0	0	0	0	1
Total	**13**	**13**	**18**	**11**	**10**	**3**	**6**	**3**	**1**	**4**	**3**	**4**	**89**

TABLE 8. Heat map of primary studies, in percentual, by weighted average of main and second category, and year.

Category	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	Total
RETAIL BANKING	3.7%	1.5%	3.0%	3.4%	1.5%	0.7%	2.2%	0.7%	0.4%	1.5%	0.4%	0.7%	19.9%
IMMERSIVE AND UBIQUITOUS BANKING	0.0%	0.0%	0.7%	0.7%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	2.2%
SECURITY	2.6%	2.2%	6.4%	1.9%	0.7%	0.4%	3.0%	0.7%	0.7%	2.2%	1.1%	0.0%	22.1%
UX / CX / UCD	1.1%	0.7%	1.9%	1.9%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	8.6%
UI	3.4%	3.7%	1.5%	1.5%	3.7%	1.1%	1.5%	1.1%	0.0%	0.7%	0.7%	1.5%	20.6%
SERVICE PERSONALIZATION AND NEW SERVICES	2.2%	4.1%	4.9%	1.9%	3.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	17.2%
PAYMENTS & MONEY SERVICES	1.5%	2.2%	1.9%	0.7%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	8.2%
CUSTOMER JOURNEY	0.0%	0.0%	0.0%	0.4%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%
Total	**14.6%**	**14.6%**	**20.2%**	**12.4%**	**11.2%**	**3.4%**	**6.7%**	**3.4%**	**1.1%**	**4.5%**	**3.4%**	**4.5%**	**100%**

probably outstanding with respect to papers with 16 citations but issued 5 years ago. We have noticed a predictable correlation between criteria #1 and #3, even if there are very cited papers published on less quality journals.

Table 9 reports the references of the top 18 PS.

Here we provide a brief summary for each paper in the top 20% PS in order to understand their value.

PS17 provides an eye-based continuous authentication system for VR headsets that can be used to seamless authorize digital payments. By using implicit visual stimuli, i.e. leveraging the content of existing apps, the system does not distract the users from their normal activities, hence providing a non-intrusive payment experience. The paper is Australian and the journal is Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies.

PS7 focuses on detecting matches between bank operation records by means of applied intelligence techniques in a big data environment and business intelligence analytics. This improves the customer experience because it allows to trace the journey of the customer among different services, hence increasing the ability for the bank to provide more customized services. The paper is Spanish and the journal is Elsevier's Information Sciences.

PS10 falls in the Human-Machine Interaction field and provides a study on how Frontline Service Robots (FSR) could be employed in the bank branch. The paper provides actionable suggestions to design and improve the delivery of services that involve FSRs. The paper is Australian and is published on the Journal of Service Management.

PS16 provides a framework for Hybrid Customer Interaction in the banking sector. The physical proximity previously achieved through physical branches is complemented by an emotional proximity via digitization. By offering hybrid products, the limitations of siloed interaction points are overcome, and the customer perceives the interaction of the online and offline world as a ''no-line system''. The paper is Swiss and German, and the journal is Business & Information Systems Engineering.

PS15 proposes an AR game that can be used for effective training of students with intellectual disabilities using an ATM independently. Data are very encouraging, despite it is the only PS using XR in the banking sector. It foster in us a new research question: will the XR allow us to access the (virtual) bank branch of the future? The paper is Taiwanese and is published on the Journal of Applied Research in Intellectual Disabilities.

TABLE 9. References of the top 20% primary studies.

PS ID	Title	Category	Citations	Year	Journal IF	Journal H-index
PS17	*Continuous Authentication Using Eye Movement Response of Implicit Visual Stimuli*	1	26	2017	4.163	13
PS7	*Automatic detection of relationships between banking operations using machine learning*	1	15	2019	8.506	194
PS10	*Customer acceptance of frontline service robots in retail banking: A qualitative approach*	1	5	2022	11.768	69
PS16	*Hybrid Customer Interaction*	2	22	2015	5.192	51
PS15	*Using an augmented reality game to teach three junior high school students with intellectual disabilities to improve ATM use*	2	7	2020	2.336	67
PS33	*Usability Study of Fingerprint and Palmvein Biometric Technologies at the AT*	3	12	2013	1.226	20
PS23	*Non-Invasive Challenge Response Authentication for Voice Transactions with Smart Home Behavior*	3	7	2020	4.352	196
PS25	*Can a Smartband be Used for Continuous Implicit Authentication in Real Life*	3	7	2020	4.342	158
PS41	*Conversational robo advisors as surrogates of trust: onboarding experience, firm perception, and consumer financial decision making*	4	17	2020	13.874	183
PS40	*Personal Information Disclosure via Voice Assistants: The Personalization–Privacy Paradox*	4	8	2020	NA	6
PS46	*Designing mobile interfaces for novice and low-literacy users*	5	178	2011	6.368	95
PS47	*Pen-and-paper Rituals in Service Interaction: Combining High-touch and High-tech in Financial Advisory Encounters*	5	6	2019	4.568	38
PS73	*KYC Optimization Using Distributed Ledger Technology*	6	63	2017	5.192	51
PS78	*Fog computing architecture for personalized recommendation of banking products*	6	22	2020	9.602	225
PS69	*A Big Data Mining Approach of PSO-Based BP Neural Network for Financial Risk Management With IoT*	6	19	2018	3.367	158
PS84	*Resuscitating privacy-preserving mobile payment with customer in complete control*	7	21	2012	3.06	91
PS88	*Blockchain-based e-cheque clearing framework with trust based consensus mechanism*	7	6	2021	2.784	54
PS89	*Customer experience in omni-channel banking services*	8	16	2018	4.471	21

PS33 assesses the usability of four biometric ATM designs in comparison to an existing ATM. Despite usability scores for the ATMs with biometric sensors were comparable to scores for the existing ATM, nearly 20% of the participants said they would not register to use biometric technologies. In our opinion, further research to be done in the field should understand why. The paper is from UK and is published on the International Journal of Technology and Human Interaction.

PS23 improve the CX for digital payments at home by leveraging presence and light sensors' data in order to replace invasive procedure through smartphone notification. Random Forest machine learning models were used for smart home behavior information retrieval. The paper is Brazilian and the journal is MDPI Sensors.

PS25 uses Ubiquitous wrist-worn wearable devices equipped with photoplethysmogram sensors to extract heart rate variability (HRV) and provide continuous physiological authentication for mobile banking. Performance evaluation shows that HRV is a strong candidate for continuous unobtrusive implicit authentication, hence improving the CX. The paper is Turkish and the journal is IEEE Access.

PS41 demonstrates how conversational robo advisors as opposed to static, non-conversational robo advisors, cause greater levels of affective trust compared to non-conversational robo advisors and evoke a more benevolent evaluation of a financial services firm. The paper is Swiss and is published on the Journal of the Academy of Marketing Science.

PS40 explores the personalization-privacy paradox by examining the factors affecting the willingness to disclose personal information based upon the privacy calculus framework and its relation to the continued usage of the Voice Assistant (VA) devices. The analysis shows that personalized services, perceived enjoyment and perceived complementarity influence the perceived benefits, which in turn positively affects the personal information disclosure. The paper is from Thailand and UK, and the journal is SN Computer Science.

PS46 synthesizes a set of design recommendations to grant usability of mobile apps also for the banking, particularly focused for novice and low-literacy populations. This is a very important theme to provide financial inclusivity by design. Results confirm that textual interfaces are unusable by first-time low-literacy users, and error prone for literate but novice users. The paper is from India and USA, and is published on the ACM Transactions on Computer-Human Interaction.

PS47 identifies empathetic, high-touch relationship between those two parties as the key aspect of a successful advisory encounter. Nevertheless, banking advisors were caught between the high-touch and high-tech aspects of an advisory service. To facilitate the high-touch interaction, this article augments pen-and-paper practices with digital content unveiling the potential of mixed reality approaches. The paper is Swiss and the journal is Proceedings of the ACM on Human-Computer Interaction.

PS73 propose a new system, based on distributed ledger technology (DLT), that reduces the costs of the core KYC verification process for financial institutions while improving the CX. The core KYC verification process is only conducted once for each customer, so it can be securely shared by customers with all the financial institutions that they intend to work with. The paper is from Switzerland and Denmark, and the journal is Business and Information Systems Engineering.

PS78 provides a novel Fog Computing solution integrating predictive systems in the process of delivery of personalized customer services for the recommendation of banking products. The architecture includes fog nodes where data are processed by light intelligent agents allowing for the implementation of contextual recommendation. It also supports the evolution toward a one-stop shop approach, hence improving aspects of customer support services. The paper is Spanish, and the journal is Expert Systems with Applications.

PS69 provides a powerful risk prediction model with AI based on big data analytics to predict default behaviors with better accuracy and capacity. The peculiar feature of this approach is the use of IoT sensors to gain real-time data on clients' assets, which would lead to more effective evaluation algorithm of financial risk management. Validation and testing were performed on the dataset obtained from a large commercial bank with IoT-based services in China. The paper is Chinese and the journal is IEEE Access.

PS84 is very interesting, as it underlines the human right to not be traced, particularly when spending our money. We are always connected to the Internet and we leave digital traces everywhere. The paper proposes a peer-to-peer payment system based on NFC and partially blind signature scheme to hide the customers' identity from the bank. Unfortunately, the paper does not solve the double spending problem, as the banks keep on storing some (anonymized) information. Further research should be done in the field, as the paper is from a decade ago and the topic is extremely actual: even the Central European Bank foresees a cash-like payment feature for the Digital Euro project. The paper is from South Korea and the journal is Personal and Ubiquitous Computing.

PS88 proposes a framework to automate the cheque settlement process. It performs cheque generation, processing and settlement through both online and physical modes. The framework is based on blockchain technology, where the blockchain network brings all different banks on a common platform. It also comprises a novel trust-based consensus mechanism for block mining that outperforms the existing proof-of-work based approach by reducing consensus time by 25%. The paper is Indian and the journal is Cluster Computing.

PS89 creates in-depth understanding of how do customers experience omni-banking services and what are the key factors related to their experiences. Customers are demanding more real-time, personalized and seamless banking experience. Results imply that focusing only on the present experiences is not enough, but it is important to pay attention to also past and imagined future experiences as well. The paper is Finnish and is published on the Journal of Financial Services Marketing.

D. RESEARCH CHALLENGES (RQ4)

As a follow up of the previous section, we can make some considerations about what we expected to find during this mapping study, but we didn't, laying the foundation for new research efforts. Among the many others, basing on what the banking industry is currently asking, we can identify 3 main research challenges that should be addressed:

1. Models and techniques for a fully operating and highly humanized self-service branch, that will allow to design a hi-tech unattended branch capable of running autonomously while delivering a high level of CX.
2. Immersive branch, to access all the banking services via the branch's digital twin using the metaverse and the web3 during uncertain times.
3. Privacy-first payments, that is the capability for a customer to withdraw digital currency from a Central Bank Digital Currency (CBDC) and spend it offline as it was cash.

Motivations behind point 1 arise from a very big threat for the CX we are witnessing nowadays. Driven by the increasing costs in running branches (e.g. salaries, rent, utilities, security) banks have been closing most of the non-redditive branches [22], [23], [24]. For example in Italy in the last decade 10.000 branches (out of 33.600) definitely closed [25]. The closing of a branch causes frustration to the customers who have to change their habits [26], [27], by choosing a different, more distant, branch (or even a different bank). It follows a damage for the identity of the bank, which seems betraying and abandoning their customers, giving the feel of a bank not present on the territory. Models of self-service branches are becoming popular as a compromise between costs and services delivered [28]. In these branches, the customer can do everything s/he did with an employee in front, but using advanced ATMs provided with tablets, scanner, printer and so on. When needed, the customer can start a call with a remote consultant. Anyway, level of humanization is low, because in the end persons are definitely missing. The kind of emotional, *de visu*, one to one, relationship between consultant and customer disappears in this approach. A challenge for the research community is to provide solutions to this problem, suggesting models and techniques to design highly emotional and humanized self-service branches. Probably a combination of IoT, AI and voiced-based UI could support such kind of requirements: IoT as a link between the physical and the digital world, providing sensitivity to the presence and security; AI as a KYC tool, and to provide security as well; the voice, as a natural human way to conduct dialogs, also with machines. PS16 could be a nice starting point for the research.

Point 2 is like a consequence of the first. During our times we are seeing tragic events like pandemics, wars, climate changes seriously impacting and upsetting our life. Guaranteeing financial inclusivity and continuity of service

also during insecure times is crucial [29], [30]. Maybe the biggest absent in this mapping study is web3, particularly the metaverse vertical. The lack of results for query #3 (see Table 2) is the confirmation. A research challenge is to provide an ubiquitous immersive 24/7 access to the virtual humanized branch, so that the banking customers of the future will use their visors to manage their banking services while experiencing a high level of humanization. Humanization is needed because consumer viewed brand as a relationship partner. There is different way to achieve this understanding of consumers about brand, one way is to brand are animated, humanized or personalized [31]. Home banking and mobile banking struggle to do this [32]. Hence, consistent research efforts should be spent in the field. PS15 is kind of a forerunner for such research.

Point 3 is about privacy in digital payments. A fundamental human right in the digital age is privacy [33], [34]. We are always connected to the Internet and we leave digital traces everywhere [35]. This is also true for digital payments [36], especially in the perspective of the progressive disappearing of cash [37]. Even if we use decentralized systems like the blockchain, information on our payments is publicly available and our hidden identity could be reverse engineered [38], [39]. People do need a form of cash-like payments that could ensure the same level of privacy as for the cash counterpart [40]. Unfortunately, the double spending problem – that is, the possibility to clone and spend multiple times the same digital currency – blocks the development of secure off-line cash-like P2P digital payments [41]. This problem is currently solved by involving a trusted third party, like a bank or a DLT (hence loosing the privacy of the payment) or using on-line consensus algorithms, which leaves public traces and highly impact on the environmental sustainability of the payment system [42], [43]. A cash-like feature for digital payments will particularly meet a specific and currently uncovered requirement for the Digital Euro project [44]. PS84, reported in this mapping study, approaches but does not resolve the problem, which is extremely challenging and deserve a full research line to cope with.

So, finally, PS15, PS16 and PS84 are the 3 most inspiring primary studies in terms of challenges they open in the use of technology improving the CX in the banking sector.

V. DISCUSSION AND CONCLUSION

The wide spread of both innovative devices and engaging apps has set higher standards for customer expectations in the banking field. Developing new seamlessly integrated intelligent services is mandatory for the banks to cuddle their customers and control the churn rate.

For this reason, in this paper we have discussed the planning and execution of a systematic mapping study about the role of technology in improving the CX in the banking sector. We have taken a snapshot of what the research community has proposed in the field in the last 10 years, by submitting 7 queries to 4 authoritative scientific databases. Starting from the 6,756 results, we have applied a set of inclusion and exclusion criteria, mainly consisting in selecting empirical papers written in English and published on journals. From the 110 results satisfying the criteria, we identified the 89 primary studies after the removal of duplicates and impurities. So we tried to answer 4 research questions involving the demographics, the principal technologies, the publication trends of the PS, and finally the derived research challenges. To help answer such questions, we defined a custom classification taxonomy which considered 8 main kinds of application of the technology impacting the bank-customer relation. Moreover, we used various kinds of classifications as well as the VOSviewer software. At the end we selected and presented the top 20% papers (in terms of citations, recentness and journals' scores), until we identified the final 3 most inspiring papers.

A. CONTRIBUTION TO THE STATE OF THE ART

To summarize the main results of this mapping study, we state that:

- We registered a significative boost in the quantity of works in the field starting from 2018. Top country in terms of number of papers is India, with a focal point in Chennai city. Top countries in terms of quality are USA, Switzerland and Australia. IEEE Access is the top journal.
- There's no prolific author in the field, as most of the authors wrote just 1 paper in this topic, 2 in some very rare cases. This is a sign that the research community publishes papers in this topic like they were some byproducts of other research efforts. Nevertheless, the banking industry is facing vital challenges that deserve a systematic help from the research.
- Top technologies both in terms of number of applications and recentness of works are IoT, AI and blockchain. Top applications are related to the ATM, particularly the use of biometric technologies. Authentication and authorization appear as top use cases.

Comparing with existing mapping studies in the banking fields, the exposed results are new and relevant. As said in the state of the art section, only 3 technological reviews in the banking sector exist. [15] and [16] are two mapping studies collecting the use of data mining and machine learning techniques for two different purposes. The first looks at the implementations of such technologies for bank customers segmentation. The second looks at the implementations of machine learning techniques for fraud detection in financial statements. [17] is a bibliometric and visual study providing an insight in the FinTech field from 1900 to 2020. Our work differs from [15] and [16] because they are strictly focused on very specific technologies. [17] is very general as it includes every kind of publications (articles, proceedings papers, book chapters, reviews, etc.) in the broad topic of FinTech, with no limitations to the application of technology in frontend or backend processes and services.

With regards to the top 3 most inspiring papers (PS15, PS16, PS84), we selected them basing on the needs incoming

from the banking industries, framing them in the literature to show that these are real challenges that should be faced. Such papers are the only ones in this study treating their respective arguments, hence tracing 3 research lines that deserve particular attention for the future. The first is the defining of models and techniques that will allow self-service unattended branches to run autonomously while delivering highly humanized experiences. The second is about the use of web3 and metaverse technologies to deliver immersive and highly humanized experiences in uncertain times. The third is the creation of a cash-like p2p payment system that will ensure privacy and anonymity in digital payments.

Beside the research area, other actors can take benefits from this work, particularly Fintech startups, financial institutions and Government related bodies like regulatory institutions or national banks, and customers themselves:

- Fintech startups can use this paper as a catalogue of innovations and figure out which technologies could reach the market in the next 10 years and anticipate market needs and changes. Digitally enabled financial innovation exploits emerging technologies that have the potential to disrupt the financial services industry [45]. Fintech startups (e.g., payment, wealth management, lending, crowdfunding, capital market, and insurance fintech companies) are based on new technologies, and it is challenging to integrate the fintech applications with existing legacy systems [46]. A map of models and experiences like this work can be helpful for them to face this challenge.
- Financial institutions now have a tool to assess the value proposition of Fintech startups. Since Fintech is a recent development, there is still a scarcity of studies on the social, regulatory, technological, and managerial aspects of Fintech. This makes it very challenging for financial institutions like banks to make informed decisions regarding the investment in Fintech projects [47]. This study can serve as a tool to frame the value proposition of Fintech companies within the current innovation landscape and future trends.
- Government related bodies have a useful map of the technical evolution of banking technologies, so they can better understand their reliability and riskiness before legislating. The arise of innovation facilitators like regulatory sandboxes [48] is also related to this need, because they provide a dynamic, evidence-based regulatory environment to learn from, and evolve with emerging technologies [49]. Another innovation facilitator is represented by innovation hubs, like Bank of Italy's MilanoHub [50]. They allow regulators to better understand the Fintech market and build capacity to support subsequent regulatory reform. Like these initiatives, our study allows the policymaker to understand and identify trends before embarking on a more resource intensive approach towards Fintech.
- Finally, bank customers can take advantage of the higher technical awareness gained by their banks. Indeed, if banks are aware that UX is a key purchasing criterion for end users, then they are motivated to push innovations on the market and hence to provide state of the art, more compelling and customized services. Accessing digital services in banking can be cumbersome for some users, because of the compliance with strict security and privacy guidelines. Technology can help mitigating the negative impact of such regulations on UX. For example, customers could appreciate a simplified journey in online purchases if the Strong Customers Authentication (SCA) would be exempted by means of a customized Transaction Risk Analysis tool [51], [52]. Also, a habit-based behavioral continuous authentication layer in the smart city could allow to access physical banking services without the friction of the authentication process [53]. More generally, a more consistent multi-channel UX could make customers more satisfied and hence generate a positive impact on customer loyalty [54], [55].

B. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Being made from humans, this research effort is not exempt from limitations. We can identify the following threats to validity in this work:

- Considering only the top 200 papers in queries with hundreds or thousands of results. In fact, 7 out of 28 query executions gave more than 200 results. This limit was imposed in order to grant the feasibility of the study. Nevertheless, while scanning the results list from the top to the 200th position, we noticed a graceful degradation in the coherence of the results with respect to the submitted query. This is due to the intelligence behind the search engines in the scientific databases. We do not think that this limit significantly impacts the validity of this work.
- We did not perform snowballing, that is we did not consider the references of the selected PS as candidates to enter the PS list. This was not done for the same reason explained in the previous point. In this case, we think that snowballing could have brought more interesting results. While this mapping study remain as it is, we will perform a careful scan of the citations in the top PS in order to better direct future research efforts.
- While this work started in January 2022, hence initially considering papers in the decade 2011-2021, the time passed fast due to the huge amount of work, and new research works popped up in scientific databases. Anyway, we didn't want to miss the most recent and interesting articles, so we took them in consideration as well. So the 2022 year is not statistically complete as this article has been written in June 2022.

Finally, other potential researchers can use this mapping study as a starting point to advance the field, allowing it to be more effective and fitting in the frame of the state of the art. For example, researchers can work on modeling highly humanized self-service branches by using a combination of

AI, IoT and Natural Language Processing (NLP) techniques to deliver high quality physical banking experiences. It could also be interesting to create a catalogue of use cases that can be delivered in multi-channel (e.g. physically in the branch but also via the metaverse) though a set of APIs that could be called ''open branching''. Finally, the definition of a new payment scheme are needed to exchange digital money completely offline (so, ensuring privacy and anonymity), overcoming the double spending problem in a sustainable and energy efficient way.

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