Phishing Through Time: A Ten Year Story based on Abstracts

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Keywords: Phishing Trends, Systematic Literature Review.

Abstract: For a researcher interested in phishing, it would be useful to access an overview of phishing evolution through time, where a set of methods, tools, solutions, user studies, type of attacks, countermeasures and so on, could be acquired from a single story. This story is essential for the security community to improve on existing research as well as build new effective countermeasures to face phishing attacks. However, no systematic review exists in the literature providing a wide overview of all phishing topics. Available reviews usually focus on one or two at a time. In fact, since there is widely available and varied literature on phishing, making a comprehensive review can take a long time and be cumbersome. This paper describes a method to perform a review on abstracts of 605 scientific papers selected from major online research databases, between 2006 and 2016. The study uses a qualitative categorization software to, for the first time, achieve a story of phishing trends in its existing research strands for that period. According to obtained results, no single solution for the phishing threat could yet be found and most research is turning now into more integrated socio-technical and human related solutions.

1 INTRODUCTION

The more we use technology as the main way of communicating, the more phishing is bound to grow as well as become more sophisticated and adaptive, and this can happen independently of the users' technological literacy (Hong, 2012) (Boodaei, 2011). To look more appealing and trustworthy, phishing makes use of a plethora of persuasive elements (Harrison et al., 2015) carefully framed to make the message sound personal and mimicking normal/real daily communications and interactions. Examples of these are phishing emails that contain links: new research suggests that whoever is used to social networks is less cautious and more likely to click on active links (Dutton, 2015).

A recent study confirms that phishing is far more successful and more professionally exploited than commonly thought (Bursztein et al., 2014) so we need better means to understand the phishing process and characteristics so that effective countermeasures are taken to improve employees' ability in the decision making process (Ma, 2013). A deeper understanding of victim's profiles, types of attacks, phishing tools, methods and user studies to identify what makes phishing attacks so successful is essential for the security community to be able to focus resources to build more adequate and effective countermeasures (Hong, 2012).

Such comprehensive scientific knowledge can be obtained with literature reviews which summarize current knowledge into a particular field and interpret that knowledge and the information-organizing spectrum upon which researchers depend in order to stay informed (Schultz, 2011). However, the authors could not find such review in the literature regarding phishing. This can be explained by the fact that there is widely available published research on the topic and its various subjects and such exhaustive research would imply a lot of time and resources and become this way a very cumbersome task. Existing reviews focus on more specific phishing subtopics such as: countermeasures and their effectiveness (Purkait, 2012) or current state of phishing approaches (Zeydan et al., 2014).

With this in mind, this paper describes a method to perform a review on abstracts only, of 605 scientific papers selected based on queries performed to the major online research databases, between 2006 and 2016. The study uses a qualitative categorization software, introduced in the Methods section, to help deriving from the abstracts the categories and subcategories that will structure and aggregate the various themes mentioned in the articles. This review provides, for the first time, a story of phishing trends for the past ten years, in all its existing research strands. The

Ferreira, A. and Vieira-Marques, P.
Phishing Through Time: A Ten Year Story based on Abstracts.
DOI: 10.5220/0006552602250232
In *Proceedings of the 4th International Conference on Information Systems Security and Privacy (ICISSP 2018)*, pages 225-232
ISBN: 978-989-758-282-0

result of this review can provide useful recommendations and support regarding future phishing trends as well as research requirements and directions.

Next section describes the methods used to collect and analyse the articles and respective abstracts included in the review while section 3 presents the results obtained. Section 4 details a discussion on phishing trends research overtime and the last section concludes the paper.

2 METHODS

2.1 Query Search

The terms used in order to search for the articles regarding phishing attacks were: *phishing* and *social engineering* in IEEE, ACM, Thomsom Reuters and Scopus databases; and *phishing review*, in IEEE, Thomsom Reuters and Scopus databases.

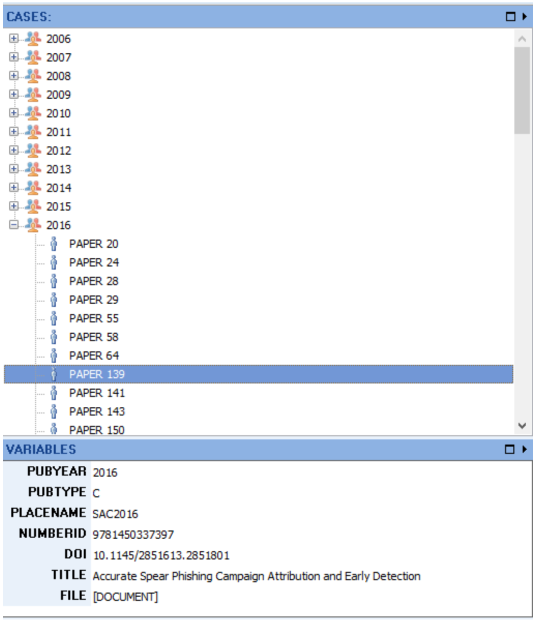
We used more general terms because we aimed to perform a comprehensive review on the theme an get a bigger sample with a wide range of subjects. Papers were selected according to titles and abstracts, written in english, ranging from 2006 to 2016, which mentioned the topic in study.

2.2 Cases and Variables

Selected papers were imported to Mendeley management database so that they could be exported with the same structure to a txt file, which included the following tags: TY - type of publication; T1 - title of publication; A1 - authors; Y1 - year of publication; JF - Name of the place of publication; SN - ISSN or ISBN; DO - DOI reference; and N2 - abstract.

This structured data was then imported to QDA Miner Lite - a free qualitative data analysis software (Provalis, 2017) - and each article was transformed into a CASE with several variables such as: PUBYEAR, PUBTYPE, PLACENAME, NUMBERID, DOI, TITLE and FILE. A FILE contains all the content of the variables and all cases were grouped by year (Figure 1).

During this process, repeated articles, with the same title and abstract or those that did not refer to the topic at hand, were eliminated.



CASES:

2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
PAPER 20
PAPER 24
PAPER 28
PAPER 29
PAPER 55
PAPER 58
PAPER 64
PAPER 139
PAPER 141
PAPER 143
PAPER 150

VARIABLES

PUBYEAR	2016
PUBTYPE	C
PLACENAME	SAC2016
NUMBERID	9781450337397
DOI	10.1145/2851613.2851801
TITLE	Accurate Spear Phishing Campaign Attribution and Early Detection
FILE	[DOCUMENT]

Figure 1: Example of variables of a case.

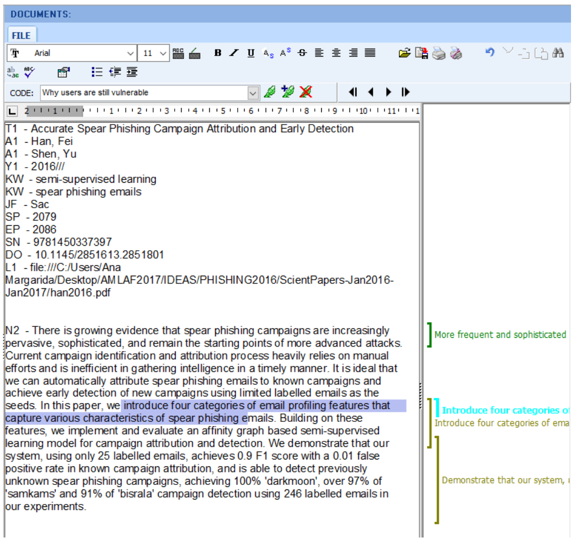
2.3 Coding Abstracts

For each abstract of each case, codes (categories) were created while data were analysed, using the technique of line-by-line coding (Eaves, 2001), adopted from Grounded Theory research. With this technique, we can highlight key term phrases that describe or focus on the subject we are studying. In the case of this review we can highlight the objective of the article, e.g., if it is a study, a review, a discussion or the implementation of a new technology. Other hints such as the knowledge acquired during research that were referred by the authors regarding the main theme were also highlighted. Line-by-line coding helps to identify gaps, define actions and explicate both actions and meanings, which therefore lead to developing categories. In QDA software, selected text is highlighted and a different color can be associated to it. Every code appears on the right hand side in the position where the text appears (Figure 2).

During the review, categories and subcategories were generated and developed into meaningful clusters. At the end of the review, since there was a high volume of codification and categories, a specific focus was made on re-reading and restructuring all the obtained categories, while repeated and/or misplaced ones were eliminated and/or re-categorized.

2.4 Analysis

Data for analysis were exported to excel files that contained categories/subcategories, which papers these related and how many times they appeared. After this, we analysed both frequencies and trends of those categories/subcategories overtime and summarized the results. Figure 3 shows how the number of codes and related cases are stored within QDA.

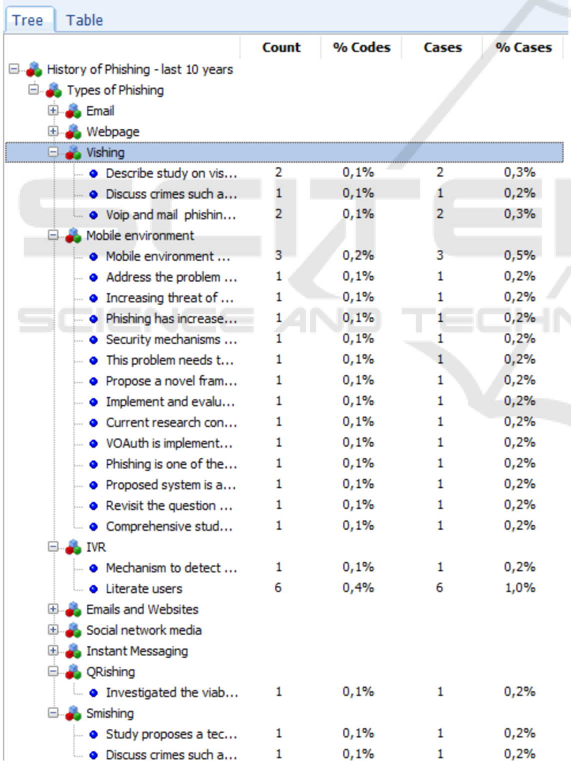


T1 - Accurate Spear Phishing Campaign Attribution and Early Detection
A1 - Han, Fei
A1 - Shen, Yu
Y1 - 2016///
KW - semi-supervised learning
KW - spear phishing emails
JF - Sac
SP - 2079
EP - 2086
SN - 9781450337397
DO - 10.1145/2851613.2851801
L1 - file:///C:/Users/Ana Margarida/Desktop/AMLAF2017/IDEAS/PHISHING2016/ScientPapers-Jan2016-Jan2017/han2016.pdf

N2 - There is growing evidence that spear phishing campaigns are increasingly pervasive, sophisticated, and remain the starting points of more advanced attacks. Current campaign identification and attribution process heavily relies on manual efforts and is inefficient in gathering intelligence in a timely manner. It is ideal that we can automatically attribute spear phishing emails to known campaigns and achieve early detection of new campaigns using limited labelled emails as the seeds. In this paper, we introduce four categories of email profiling features that capture various characteristics of spear phishing emails. Building on these features, we implement and evaluate an affinity graph based semi-supervised learning model for campaign attribution and detection. We demonstrate that our system, using only 25 labelled emails, achieves 0.9 F1 score with a 0.01 false positive rate in known campaign attribution, and is able to detect previously unknown spear phishing campaigns, achieving 100% 'darkmoon', over 97% of 'samkams' and 91% of 'bisrala' campaign detection using 246 labelled emails in our experiments.

More frequent and sophisticated
Introduce four categories of
Introduce four categories of ema
Demonstrate that our system,

Figure 2: Example of line-by-line coding in QDA software.



	Count	% Codes	Cases	% Cases
History of Phishing - last 10 years				
Types of Phishing				
Email				
Webpage				
Vishing				
Describe study on vis...	2	0,1%	2	0,3%
Discuss crimes such a...	1	0,1%	1	0,2%
Voip and mail phishin...	2	0,1%	2	0,3%
Mobile environment				
Mobile environment ...	3	0,2%	3	0,5%
Address the problem ...	1	0,1%	1	0,2%
Increasing threat of ...	1	0,1%	1	0,2%
Phishing has increase...	1	0,1%	1	0,2%
Security mechanisms ...	1	0,1%	1	0,2%
This problem needs t...	1	0,1%	1	0,2%
Propose a novel fram...	1	0,1%	1	0,2%
Implement and evalu...	1	0,1%	1	0,2%
Current research con...	1	0,1%	1	0,2%
VOAuth is implement...	1	0,1%	1	0,2%
Phishing is one of the...	1	0,1%	1	0,2%
Proposed system is a...	1	0,1%	1	0,2%
Revisit the question ...	1	0,1%	1	0,2%
Comprehensive stud...	1	0,1%	1	0,2%
IVR				
Mechanism to detect ...	1	0,1%	1	0,2%
Literate users	6	0,4%	6	1,0%
Emails and Websites				
Social network media				
Instant Messaging				
QRishing				
Investigated the viab...	1	0,1%	1	0,2%
Smishing				
Study proposes a tec...	1	0,1%	1	0,2%
Discuss crimes such a...	1	0,1%	1	0,2%

Figure 3: Illustration of the number of coding lines per category.

3 RESULTS

3.1 Sample Characterization

The analyzed sample included 605 abstracts with a yearly distribution presented in Figure 4. They mostly correspond to conference and journal papers.

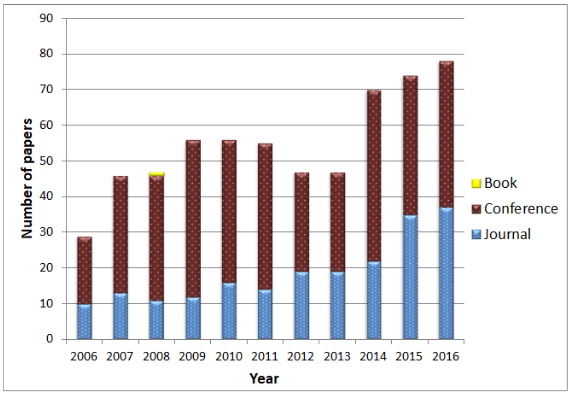


Figure 4: Sample distribution by year and type of publication, e.g., an article on a journal, a conference or a book.

Papers of selected abstracts are published in a wide variety of venues with different themes. The venues with more than five of those papers published are presented in Figure 5.

Publication venue	N
eCrime Researchers Summit	28
Lecture Notes in Computer Science	25
ACM International Conference Proceeding Series	9
Communications of the ACM	7
Computers in Human Behavior	7
Decision Support Systems	7
Advances in Intelligent Systems and Computing	6
Annual Hawaii International Conference on System Sciences	6
IEEE International Conference on Intelligence and Security Informatics	6
Lecture Notes in Electrical Engineering	6
ACM Conference on Computer and Communications Security	5
Expert Systems with Applications	5
IEEE Security and Privacy	5
IFIP Advances in Information and Communication Technology	5

Figure 5: Sample distribution by year and type of publication, e.g., an article on a journal, a conference or a book.

3.2 Frequency Analisys

The 10 main categories (and associated subcategories when these exist) that were generated from the abstract analysis are illustrated in Figure 6. The complete list is the following:

- **Types of phishing**: email; webpage; vishing; mobile environment; IVR - Interactive Voice Response; emails and websites; social network media; instant messaging; QRishing (phishing using QR codes) and smishing (phishing using SMS messages);
- **Sophisticated phishing**
- **Technical solutions:** authentication-based; cryptography-based; Baesyan, data mining, heuristics, machine learning, decision trees, classifiers and clustering; white-black and other lists;

visual characteristics; fuzzy logic; honeypots; IDS - Intrusion Detection Systems; plug-in; feature extraction; mobile context; biorelated and insufficient technical measures;

- **Human-related solutions:** games for training; education-training and awareness and existing solutions not enough;
- **Why phishing works:** appear authentic and familiar; complex and multi-dimensional; lack of awareness and education; lack of effective protection techniques;
- **Trust**
- **Legislation, regulation and ethics**
- **Reviews and discussions:** phishing characteristics; antiphishing measures; users and phishing and trends;
- **Studies and prototypes:** user studies; tech studies to validate tool accuracy; complementary tools and bank environment;
- **Phishing attacks:** new attacks; review and discuss phishing attacks; show unsecure technologies and banks.

There are also other subcategories that are attached to the main ones without a subsequent categorisation. The totals for each category are presented next.

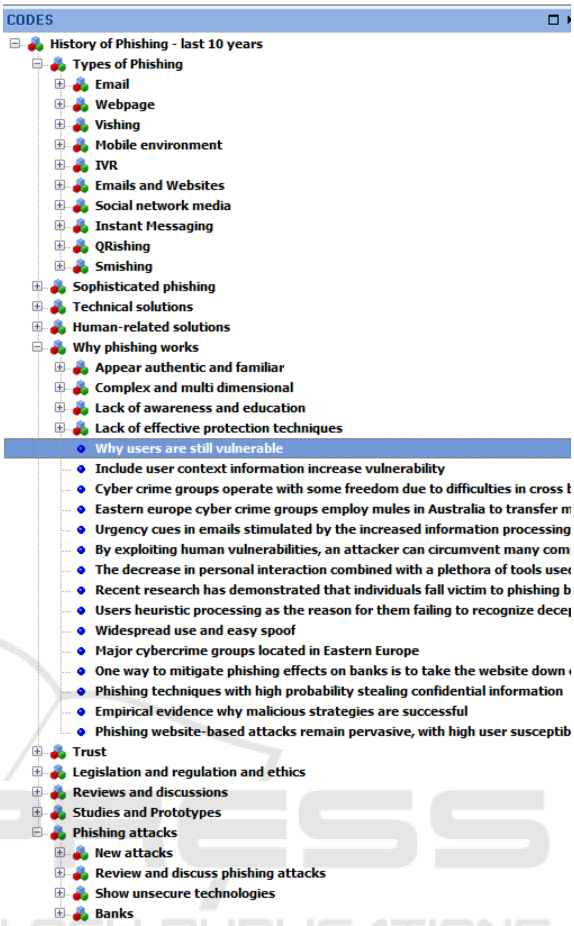
For the category **Types of phishing**, most phishing research focuses on webpages (Figure 7).

For the other nine main categories, Figure 8 shows that most papers present technical solutions and with some sort of study or prototype to evaluate and test those solutions for efficacy and accuracy. There is also a big part of human-related solutions as well as reviews and discussions.

Regarding now the most common subcategories, Figure 9 describes them within their main categories together with their frequencies.

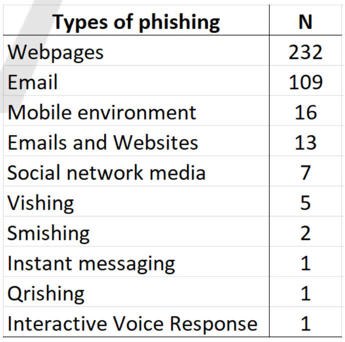
In the following paragraphs, uncategorised categories are those categories that were not aggregated into a specific subcategory but are still part of the main category. An example can be seen in Figure 3 where the highlighted category belongs to the main category **Why phishing works** but is not aggregated into any other cluster.

Figure 9 shows that for the category **Technical solutions** most new developments are made using methods like *Bayesian, data mining, heuristics, machine learning, decision trees, classifiers and clustering*, followed by *authentication-based*, complemented with the reference that *technical measures* are still not enough to solve the problem. There are also



- History of Phishing - last 10 years
  - Types of Phishing
    - Email
    - Webpage
    - Vishing
    - Mobile environment
    - IVR
    - Emails and Websites
    - Social network media
    - Instant Messaging
    - QRishing
    - Smishing
  - Sophisticated phishing
  - Technical solutions
  - Human-related solutions
  - Why phishing works
    - Appear authentic and familiar
    - Complex and multi dimensional
    - Lack of awareness and education
    - Lack of effective protection techniques
    - Why users are still vulnerable
    - Include user context information increase vulnerability
    - Cyber crime groups operate with some freedom due to difficulties in cross
    - Eastern europe cyber crime groups employ mules in Australia to transfer
    - Urgency cues in emails stimulated by the increased information processing
    - By exploiting human vulnerabilities, an attacker can circumvent many com
    - The decrease in personal interaction combined with a plethora of tools use
    - Recent research has demonstrated that individuals fall victim to phishing b
    - Users heuristic processing as the reason for them failing to recognize dece
    - Widespread use and easy spoof
    - Major cybercrime groups located in Eastern Europe
    - One way to mitigate phishing effects on banks is to take the website down
    - Phishing techniques with high probability stealing confidential information
    - Empirical evidence why malicious strategies are successful
    - Phishing website-based attacks remain pervasive, with high user susceptib
  - Trust
  - Legislation and regulation and ethics
  - Reviews and discussions
  - Studies and Prototypes
  - Phishing attacks
    - New attacks
    - Review and discuss phishing attacks
    - Show unsecure technologies
    - Banks

Figure 6: Main categories generated from the review of the abstracts.



Types of phishing	N
Webpages	232
Email	109
Mobile environment	16
Emails and Websites	13
Social network media	7
Vishing	5
Smishing	2
Instant messaging	1
Qrishing	1
Interactive Voice Response	1

Figure 7: Number of abstracts focusing on the various types of phishing, 2006-2016.

129 uncategorised categories within this main category.

In **Human-related solutions** the most common subcategory refers to *Education, training and awareness* and *Gaming training*, while there are also 42 uncategorised categories.

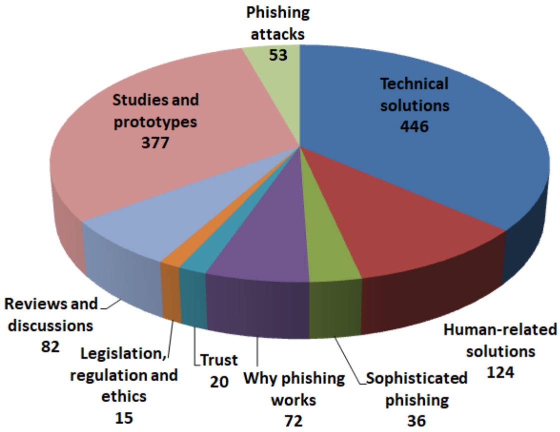


Figure 8: Total number of coded lines within the analysed abstracts for the main categories and most common subcategories.

For **Why phishing works**, the most common subcategories relate to *complex and multidimensional* characteristics of phishing attacks and also the *lack of effective protection techniques*. There are also 25 uncategorised categories.

The main category **Reviews and discussion** has the most common subcategories *antiphishing measures*, *phishing characteristics* and *users and phishing*, while 91 categories remain uncategorised.

For **Studies and prototypes**, *tech studies to validate tool accuracy* and *user studies* are the most common, with 91 uncategorised categories.

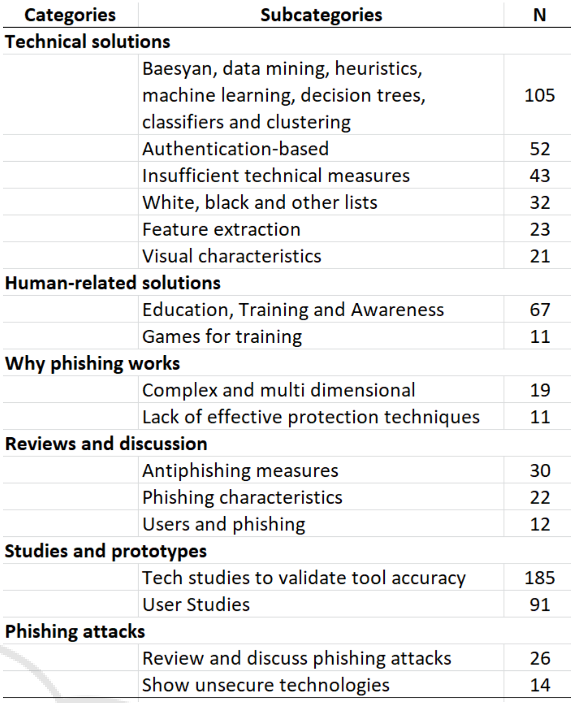
Finally, for **Phishing attacks**, the most common subctegories are *review and discuss phishing attacks* and *show unsecure technologies*.

Now regarding the uncategorised categories, the most common ones are *Increased sophistication*, *Black lists a not good enough*, presented technological solutions are *Better than existing ones* and that *Trust is shattered by phishing*.

3.3 Ten-year Trends

In order to evidence how categorized items evolve through time, papers were grouped by year and category. A bubble graph was produced representing the trends along the ten-year review. The circle size was defined using the number of categorizations per year.

Due to space constraints and visual limitations, Figures 10 to 12 only show trends for the most common categories/subcategories, which were introduced in Figure 9. Succintly, those figures illustrate that research on webpages, mobile technology, social networks (Figure 10), and technological user studies (Figure 11) have been recently increasing while antiphishing reviews/studies (Figure 11) as well as Bayesian, classification and similar methods (Figure 12) have been decreasing.



Categories	Subcategories	N
Technical solutions		
	Baesyan, data mining, heuristics, machine learning, decision trees, classifiers and clustering	105
	Authentication-based	52
	Insufficient technical measures	43
	White, black and other lists	32
	Feature extraction	23
	Visual characteristics	21
Human-related solutions		
	Education, Training and Awareness	67
	Games for training	11
Why phishing works		
	Complex and multi dimensional	19
	Lack of effective protection techniques	11
Reviews and discussion		
	Antiphishing measures	30
	Phishing characteristics	22
	Users and phishing	12
Studies and prototypes		
	Tech studies to validate tool accuracy	185
	User Studies	91
Phishing attacks		
	Review and discuss phishing attacks	26
	Show unsecure technologies	14

Figure 9: Total number of abstracts and coded lines for the main categories.

Furthermore, education, training and awareness as well as the use of games for training research have been going hand in hand with a slight increase in the last year while the reference to insufficient technical measures have been made within the first three years of analysis then was hardly mentioned in the research but reappeared with a high increase in the last year (2016) (Figure 12).

A more detailed discussion and analysis will be presented in the next section.

4 DISCUSSION

This study aims to provide a ten-year story regarding phishing research based on abstract analysis only. We decided to use a qualitative approach based on grounded theory and line-by-line coding so not to limit data and their categorization from the start but to wait for these to come up from the analysed sample itself, without much restrictions but for the order/clustering the researcher gives to the codes.

The used software, QDA, is a free version that allows to insert descriptive data regarding each case, and text or documents associated to that case. For our purpose, this version of software was easy to install

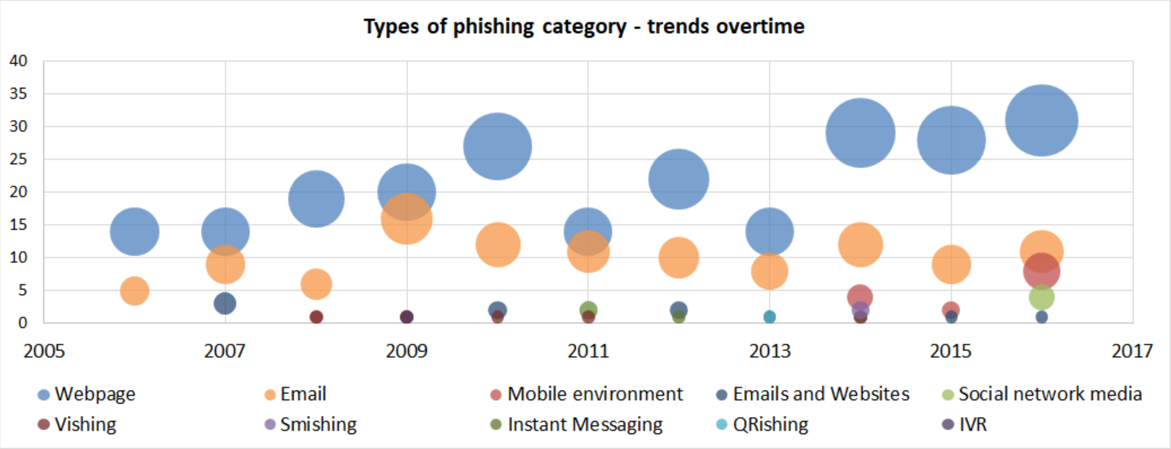


Figure 10: Types of phishing, ten-year trends.

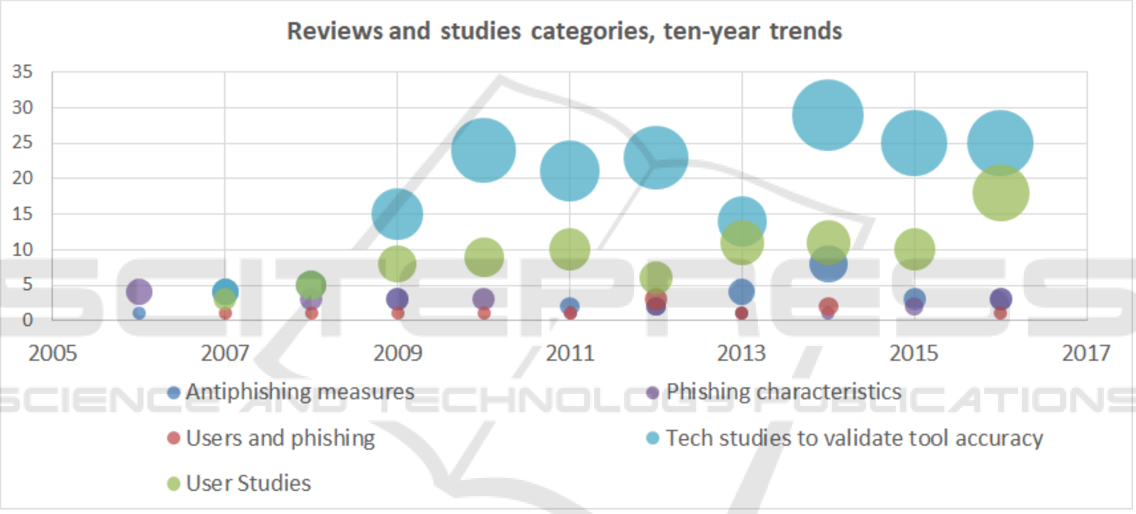


Figure 11: Reviews and studies, ten-year trends.

and use allowing a quick way to code and structure categories that were being generated. It is also easy to summarize frequencies as well as relate cases with coding results.

Regarding the used sample, we could only verify its heterogeneity once the review was completed. It was possible to achieve a variety of categories and subcategories that show how research themes in phishing have been handled. The sample was well distributed regarding both journal and conference publications and is even possible to see that the early tendency of more publications in conferences is getting more balanced in the last few years by half of the papers being published in journals and the other half in conferences. In total, papers on phishing have almost tripled over the past ten years. This can be explained by the fact that this problem is far from being solved and a high number of different positions and approaches have been tried since. Also, in some categories such as technical solutions and technical studies, the difference in the place where this type of articles are published is accentuated as the publications in conferences are double and sometimes almost three times of the ones in journals. Generically, most common venue is the *APWG eCrime Researchers Summit* while for user studies and solutions the most common is the journal *Computers in Human Behaviour* and for technical solutions and studies the most common venues are security related ACM conferences and the *Computers and Security* journal. Moreover there is a high number and variety of themes and publication venues, both journals and conferences, which shows that this subject can interest a very heterogeneous audience.

Focusing now on the main themes that were extracted from the analysis, it is to be noticed that most

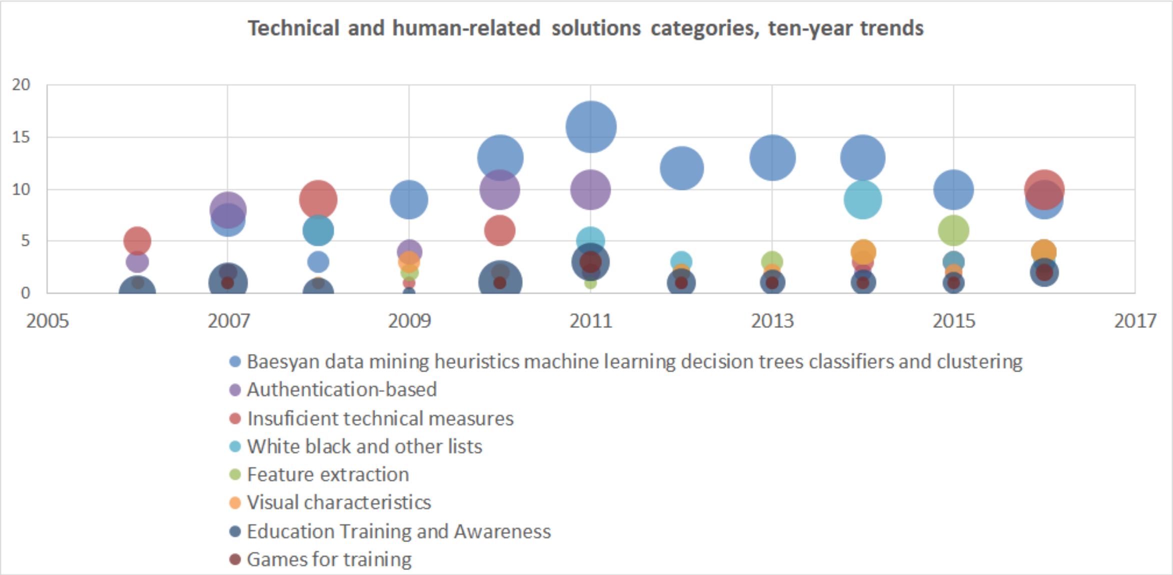


Figure 12: Technical and human-related solutions, ten-year trends.

research is applied to phishing via webpages since this is the most common mean of fraud that target homebanking or email account users. Although there is much fraud via email, most of the times, the way to get credentials and personal data is via the filling of a web form in sites that mimic legitimate pages. It also makes sense that one of the current growing research strands relate to mobile environment and the threats that are associated with it. Its specific characteristics and security flaws can exacerbate in some way the already existing phishing issues in ”older” technologies. The same is true for social network media as seen in Figure 11.

One main category that stands out is the one regarding technical solutions. This category is the most common with almost four times entries than the human-related solutions although with very little entries before 2009. Despite this, the other categories remain in much smaller number apart from the studies and prototypes which is explained by the fact that most technical and human solutions articles present some form of evaluation and testing. Similarly, user studies are around half of the technical studies. However, trends show that user studies have doubled last year (Figure 12). A reason may be that although there exist many attempts to implement the perfect technical solution(s) to solve the problem of phishing, it seems that the research community is trying to turn a page and focus on understanding better this sociotechnical complex security problem. Better understanding users’ interactions with technology and specially with phishing attacks can possibly lead to more effective countermeasures.

To back these data up is the fact that focusing on antiphishing measures discussion, authentication-based solutions as well as technical solutions that focus on Bayesian, data mining, heuristics, machine learning, decision trees, classifiers and clustering (the second most common subcategory in the whole sample) have considerably decreased in recent years (Figures 11 and 12). Furthermore, in Figure 12, there is another category - insufficient technical measures - that stands out. Trends show that there have been some statements related to it in the first half of the analysed period but it has reappeared with high visibility only in 2016.

Although user studies and the awareness that technology based only solutions are not enough to solve phishing attacks, there is a very small increase in 2016 regarding education, training and awareness solutions. There is a tendency for the development of game-based training solutions which may be because, once more, mobile environment is growing fast and the possibility of game-based applications that can tackle social-engineering are at least to be tried and evaluated.

Limitations. For this study, the Lite version of QDA software did not allow for extensive analysis features so we had to use excel to accelerate the process. Also, an import functionality was not available which much delayed the analysis phase since every abstract (CASE) and related data had to be entered manually. Still, the frequency analysis that was needed at this point was achieved with other available tools. Due to space constraints it was not possible to further detail and analyse obtained results.

Another limitation of this work was the fact that only one reviewer was available to perform all the coding. With all the disadvantages this can have, there is also some advantages since this was a qualitative coding analysis, it is most likely that the same person will categorise similar data in the same way. Also to notice that results are biased or limited by the content of the abstracts, which, sometimes, may not clearly state what is really presented within the full article. However, analyse other parts of the paper such as the introduction or the conclusion would make the process even more time consuming and complex.

Finally, although the used method was still cumbersome and time consuming, if there is the possibility of using a complete set of qualitative analysis software, automatic importing data and detailed analysis features, the process will be much faster which then can leave more time for coding as well as category generation and structuring.

5 CONCLUSION

This paper gives an overview of phishing research trends over a ten year period based on the review of abstracts only. According to obtained results and subsequent analysis, the authors believe that it is clear that no single solution can be found for the phishing threat. Future research needs to focus on socio-technical and integrated solutions that can reflect a comprehensive understanding of both human computer interactions and users' unique characteristics as well as the application and proper testing of advanced, resilient and human adaptable security technology solutions.

Future work includes performing more detailed analysis using a more complete qualitative software that can provide more views on the results and possible relations that have escaped on the first analysis.

ACKNOWLEDGEMENTS

This research is supported by NanoSTIMA - Macro-to-Nano Human Sensing: Towards Integrated Multimodal Health Monitoring and Analytics (NORTE-01-0145-FEDER-000016).

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