Death of a Software Ecosystem: a Developer Relations (DevRel) perspective

Daniel Massanori
FACOM/UFMS
Campo Grande, MS, Brazil
daniel.teruya@ufms.br

Bruno B. P. Cafeo
FACOM/UFMS
Campo Grande, MS, Brazil
cafeo@facom.ufms.br

Igor Wiese
UTFPR
Campo Mourão, PR, Brazil
igor@utfpr.edu.br

Awdren Fontão
FACOM/UFMS
Campo Grande, MS, Brazil
awdren@facom.ufms.br

ABSTRACT

The Developer Relations (DevRel) is a strategy to attract, engage and mature developers in contributing to a platform. It supports the establishment of a Software Ecosystem (SECO). However, even with investments in the DevRel, some organizations face the death of their ecosystems, for example: Symbian (2012), Firefox OS (2016), Windows Phone (2017). It can also be compared based on Ecology to a disruption of the "food chain" that can turn a dynamic ecosystem in a static or dead ecosystem. For example, Microsoft announced in 2017 that Windows Phone would no longer push any updates and became only focusing on maintenance. We want to contribute in understanding how, why and when a SECO is turning on static (i.e., dying) and the "post mortem" status of a SECO. We initially study the Windows Phone from 46,030 questions in Stack Overflow to understand what happens to a SECO when the core platform is discontinued. From our result analysis we perceived that it can be useful to understanding the "vital signals" of ecosystem collapse, migratory/survival patterns, technical resource recycling and the energy transfer among individuals, populations, communities and SECOs. We also contributes with 14 insights.

CCS CONCEPTS

• **Software and its engineering** • Software creation and management • **Collaboration in software development**

KEYWORDS

Developer Relations, Software Repositories, Software Ecosystem

1 Introduction

For the industry the process of expanding a platform through a Software Ecosystem (SECO) approach requires the creation of new strategies that promote collaboration of the central organization that maintains the ecosystem with third-party developers [1]. A Software Ecosystem (SECO) can be defined as the interactions between developers around a common platform to meet the demands of users [2]. Only in the mobile SECO (MSECO), Android has about 5.9 million developers involved in creating technical resource or events (e.g., conferences, hackathons). The SECO platform depends on developers because the platform's attractiveness is determined by a frequent evolution of its software offerings [1].

In this context, the Developer Relations (DevRel) team emerges as a key organizational area. Based on [3] the DevRel's mission can be understood as an organizational area responsible for creating a vibrant ecosystem of third-party developers, by being the interface between those developers and the platform's product, engineering, and design teams. The DevRel practitioners need to have a "realistic view" of the SECO aiming to meet the needs of developers and organizational goals [4][5].

If the central organization does not have sustainable strategies, it risks failing to meet the demands of users and developers (e.g., quality and variety of contributions). An unsustainable DevRel strategy over time can result in the "death" of the ecosystem [1][6]; for example, MSECO Windows Phone was officially declared "dead" in 2017 also because the developers did not support the platform. There is studies that addresses the health aspect of SECO [7][8]. Health is related to a dynamic equilibrium state that maintains the structural and functional characteristics within the normal operating standards of the SECO [8]. Our perspective is not on health, but on death that can be interpreted as the definitive interruption of the ecosystem [9].

One of the signs of the SECO death can be observed when the ecosystem becomes static [10][11]. It is an irreversible process of interruption of the activities necessary to characterize and maintain the life of an SECO. It may be necessary to establish a set of criteria involving the conditions that determine whether an individual, population, community or ecosystem is dead.

In Ecology the certification of death requires the demonstration of cessation of essential functions [9]. Thus, the purpose of this study is to advance on investigating what happens with a SECO when the core platform is officially discontinued. Our focus, at this time, is to begin the analysis involving the Windows Phone platform that has been discontinued and the impact on developers within the ecosystem. It can be done by analyzing the behavior of developers. To the best of our knowledge, there is no study analyzing the death of SECO from DevRel perspective [2].

As the developer contributions are usually stored in repositories such as Stack Overflow and GitHub, it can provide effective measurements to analyze developer performance [12]. Thus, we analyzed 46,030 documents (questions, answers and comments) about Windows Phone in Stack Overflow. We came

SBES '20, October 21–23, 2020, Natal, Brazil

ACM ISBN 978-1-4503-8753-8/20/09…$15.00
https://doi.org/10.1145/3422392.3422445

to some conclusions, as follows: (1) the death of a SECO can generate disbelief in other ecosystems of the same organization; (2) there is energy investment for resource recycling and for migration between ecosystems of the same organization and competitors; (3) the quantity of Answer, Favorite and Score may be used a year earlier as possible indicators of "vital signs" of the SECO. We also provide a set of 14 insights for future research.

This research can serve as a basis to mitigate risks around SECO, resource reuse (recycling) analysis, adaptation of DevRel strategies, impact analysis and support monitoring and forecasting mechanisms. And, of course, to establish strategies to recover "something valuable" from the SECO value creation network that died. It is important to provide more knowledge for organizations that maintain SECO and the DevRel area about the reasons for the death of an ecosystem and how to reduce the economic impact.

2 DevRel and Mining Software Repositories

To support the third-party developers within SECO, organizations have a team of professionals working within an area called Developer Relations (DevRel). DevRel involves a group of software engineers who are outgoing and great at public speaking. It considers developer evangelism and advocacy and serves as an interface between developers and organization's platform product and technical teams [13]. A mechanism that can be useful to monitor the actions of the organization that maintains the SECO and the DevRel area is mining software repositories [14]. These repositories keep records of contributions as well as interactions between developers. In this work we used Stack Overflow (SO), a repository of Questions and Answers (Q&A), for our analysis. Q&A repositories, such as SO, are web, collaborative and social allowing crowdsourcing knowledge by allowing user to post and answer questions [12].

In this study, we used NMF (Non-negative Matrix Factorization) based on the paper by Chen *et al.* [21] that NMF demonstrates is more inclined to produce higher-quality topics than LDA (Latent Dirichlet Allocation). NMF is an unsupervised technique that decomposes high-dimensional vectors into a lower-dimensional representation. These lower-dimensional vectors are non-negative which also means their coefficients are non-negative. Using the original matrix (A), NMF will give you two matrices (W and H). W is the topics it found and H is the coefficients (weights) for those topics. NMF will modify the initial values of W and H so that the product approaches A until either the approximation error converges or the max iterations are reached.

After the analysis of systematic reviews and mappings on SECO [2][16][17][18][19][20], no studies were found with focus on death of SECO, the found studies focus on health as a mechanism to keep the ecosystem vibrant.

3 Research Questions and Study's Goal

The goal of this study is to advance investigating what happens with a SECO when the core platform is officially discontinued. Our focus, at this time, is to begin the analysis involving the Windows Phone platform that has been discontinued. As a way to achieve our goal, we defined a set of research questions that are pointed out as follows:

RQ1. What is the activity around the SECO before, during and after its death?

Metrics: view count, answer count, comment count, favorite count and score. It can help us investigate what happens in the year of the announcement of the discontinuity of the platform.

RQ2. To what topics are the last actions (during and after death) in the SECO related?

Metrics: number of topics, topic and words associated with the topic. It can help us to analyze what the developer population does after the "death" announcement of the ecosystem. The research question is related to the latest actions and the analysis of developers' behavior from a technical perspective (i.e. what technical resources they invest efforts in).

In this study we focused our analysis on Windows Phone (WP). WP as a mobile SECO (or MSECO) consisted of DevRel (e.g., developer evangelists/advocates) Global and Local teams. Even with all this environment favoring the SECO, in 2017 it was officially declared "dead". Compared to Firefox OS (dead in 2016) and Symbian (2012), WP was more important because had been experiencing rapid growth in apps (2015: 640,000 apps), it received investments in DevRel and considering Stack Overflow it had more engagement regarding questions (WP ~ 46K, Firefox ~ 588 and Symbian ~ 913). In this sense, WP becomes an interesting scenario for this research.

4 Study Execution

We are based on steps indicated by [22]: (1) Data Acquisition/Preparation: we used StackOverflow's StackExchange tool to assemble the datasets and pre-processed the Body of the posts. We used the NLTK to eliminate non-representative terms and the bag-of-words approach with TF-IDF. In this step, we used Scikit Learn API[1]. The time to execute the NMF and collect the metrics reach 1.05 seconds. (2) Synthesis: we performed the extraction of topics with the NMF algorithm. (3) Analysis: we interpreted the results by: conducting a conciliation meeting (involving the authors) to establish categories regarding the topics; applying linear regression to advance on understanding the engagement of developers to answer questions; analyzing the metrics discussed in Section3. (4) Sharing and Replication: we stored the data and the code[2] to allow for external validation and replication studies. It will be included in a Study Execution section.

5 Results' Analysis and Discussion

A total of 46,030 questions were extracted to compose the dataset from January 2008 to December 2019, containing data related to Windows Phone. In our analyses we established the following time frame: 2016 (year before the platform is discontinued. In Ecology this period is important because it can provide an example of survival tentative and use of resources

[1] https://scikit-learn.org/stable/
[2] https://zenodo.org/record/3978763

[23]), 2017 (year of discontinuation), 2018 and 2019 (years following the discontinuation).

5.1 What is the activity around the SECO before, during and after its death?

Fig.1 shows the violin plot for four years mentioned above. For each year we calculate the number of views for each question, as each year had different axes we applied the normalization between [0 and 1]. It helped us to apply a common scale for comparison between the years. To normalize we divided the value of the visualization of a question by the maximum visualization value of the year.

It can be observed that 2016 presents an approximate behavior of the year 2017. By analyzing the behavior of the violin graph in 2017 there is a higher probability of lower visualizations of questions (the body of the violin horizontally is wider and closer to 0). In all years it is possible to notice a significant presence of outliers indicating that there is no variety of questions with approximate views. We did not remove the outliers so that it was possible to verify whether there would be any behavior that caused it [24]. It can be important to understand the impact of outliers in a dying/dead SECO. For 2018 and 2019 there is an approximate behavior of the presence of outliers, that is, questions that have no proximity considering the view count.

It can be inferred that only more specific questions were viewed. At this point it may be that the developers who posted or visualized are interested in very specific topics and these topics do not involve discussion by other developers. In this regard, the question may be of interest of a reduced set of individuals. This aspect is investigated in RQ2.

Fig. 2 presents the time series mapping the ratio of the number of questions answered to unanswered questions, by month, between the years 2017 (year of death) and 2018 (first year right after death). For this analysis, we also collected data from Android and iOS ecosystems in SO. We use the metrics described above to investigate the behavior of developers: whether there is engagement to answer questions that arise.

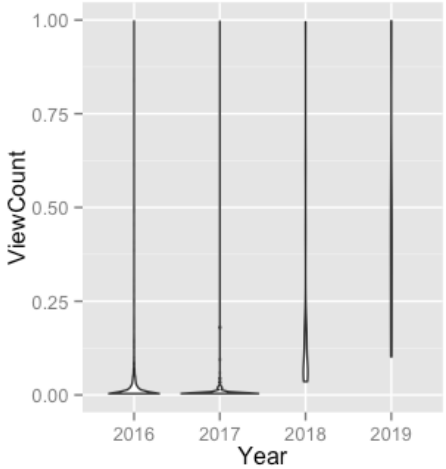

Figure 1. Questions' View (2016-2019)

To support our series analysis we apply linear regression to extract the equation that helps us to predict the metric behavior explained above. It can be observed that the Android ($y = 0{,}0019x + 0{,}7667$ (R^2=0.7)) and iOS ($y = 0{,}0013x + 0{,}7753$(R^2=0.5)) ecosystems have a similar behavior throughout the 24 months analyzed: there are more unanswered questions than answered per month (since the calculated ratio does not reach 1). It can be an indication that the developers are active within the ecosystem, so the time to answer the questions or moderate them does not allow this to be done in the time window and, even if it were, new questions would already be appearing.

For Windows Phone ($y = 0{,}0036x + 0{,}6221$ (R^2=0.008)), the value of R^2 is very close to zero, which may indicate that the model explains almost nothing of the variability of the response data around the mean. This behavior of the percentage of the variation of the response variable indicates to us that the behavior around the metric we are analyzing for the Windows Phone is difficult to predict. There is a behavior that involves the presence of seasonal points for both peak and fall. There are cases for Windows Phone where there are no questions answered (Y axis equals zero), that is, without engagement of the developers.

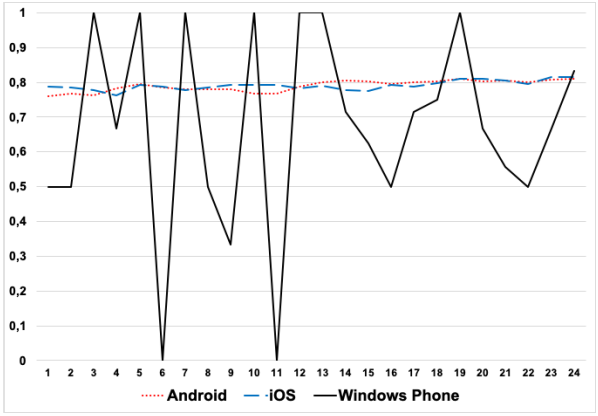

Figure 2. X-axis: Months. Y-axis: Ratio between questions (Answered/Unanswered)

Where the reason is 0.5, there are more unanswered questions. At the peak, where the ratio is 1, there are the same number of answered and unanswered questions. This point needs to be investigated, but we can raise some considerations about the ecosystem that is dead: (1) there is no diversity in the developers' questions and therefore the community does not invest time in answering replicated questions; (2) those who are engaged in technical resources answer specific questions and the others who could answer the other questions are no longer engaged; (3) some questions may be answered in the coming months, so time is not a priority and the Q&A repository is no longer an environment to accelerate progress in the use of resources by a community of developers.

Table 1. View, Answer, Comment and Score Behavior

Posts by Year		View			Answer			Comment			Favorite			Score		
		Qtty	Mean	SD	Qtty	Mean	SD	Qtty	Mean	SD	Qtty	Mean	SD	Qtty	Mean	SD
2015	1038	388316	374	1244.75	1100	1	0.92	1273	1	1.98	176	1	1.36	651	0	1.92
2016	323	77897 (↓ 39%)	241	628.95	320 (↓ 71%)	0	0.65	397 (↓ 69%)	1	1.82	39 (↓ 78%)	0	0.63	166 (↓ 75%)	0	1.22
2017	33	15751 (↓ 39%)	477	1411.71	29 (↓ 91%)	0	0.78	88 (↓ 78%)	2	3.05	2 (↓ 95%)	0	0.55	21 (↓ 87%)	0	2.15
2018	5	319 (↓ 4837%)	63	23.76	3 (↓ 90%)	0	0.55	9 (↓ 90%)	1	2.49	1 (↓ 50%)	1	/	1 (↓ 95%)	0	0.45
2019	1	28 (↓ 1039%)	28	/	0 (↓ 100%)	0	/	2 (↓ 78%)	2	/	/	/	/	0 (↓ 100%)	0	/

An interesting analysis to be done with the metrics used in Table 1 is to involve the same data for iOS and Android. It could be an indication to analyze if the death of Windows Phone has impacted the popularity of iOS and Android, as well as the engagement of developers. The perspective is not a cause-effect relationship, as the popularity and engagement may not have been impacted by the death of the other ecosystem. However, the analysis could give some pointers to further investigate this question: Did Windows phone die because iOS and Android became more popular? Or after the death of Windows Phone, did iOS and Android become more popular?

5.2 To what topics are the last actions (during and after death) in the SECO related?

To answer this question we applied the NMF algorithm for topic extraction. After the extracted topics we held a conciliation meeting to close the category that could describe the set of topics. Table 2 presents the categories and their respective topics for the years: 2017 (2065 questions), 2018 (334 questions) and 2019 (45 questions).

In 2017, the Cordova and PhoneGap categories of creating apps for multiple platforms. However, developers report problems with: (1) WP properties that are not loaded when mounting app with Cordova even if it works on other platforms; (2) WP8 and WP10 conversion packages with Cordova configuration failures; (3) WP specifications not available, which does not allow Cordova to find the platform; (4) javascript events that are no longer recognized in the WP.

This category may motivate us to investigate strategies that developers already use thinking about survival, in this case, in a larger ecosystem: the mobile application ecosystem. Another avenue to investigate is the influence of the death of one SECO on others, as it was possible to realize that Cordova/PhoneGap no longer supports some features for the WP, which increased the effort for the survival of developers and their apps.

The "Windows Phone to Android" category covers the process of converting an application initially developed in UWP (Universal Windows Platform) to Android and the search for equivalent commands between Windows Phone and Android. This point may indicate a movement of disbelief in the most current platform of the ecosystem that died, attempts by developers to migrate their apps to another ecosystem. Point that should be investigated.

Table 2. Extracted Topics

2017	Windows Phone to Android	windows, code, using, know, android, like
	Cordova/PhoneGap	installed, app, stack, studio, 10, npm
2018	Code Migration	project, store, code, package, native, uwp
	Methods, classes, DLLs and services	code, await, response, content, string, current
2019	Developer Tools	code, using, uwp, noreferrer, nofollow, time

Another aspect discussed is the use of tools during this transformation from Windows Phone apps to Android: the Windows Phone simulator to Xamarin.Forms; the Ionic framework plugin that works on Android but no longer works on WP; the PushSharp library no longer works to send notifications to WP but works for Android. With these excerpts we realize that at some times developers look for tools to reuse the C# code (Xamarin.Forms), that is, the developer does not need to transform code into another language, can indicate the attempt to reuse invested energy and resources. Regarding Ionic (development of user interface with html, css and javascript) and PushSharp (open-source server-side library for sending notification) we analyzed that there was a discontinuity of support for WP, which harmed developers who still had apps available in Windows Store.

For 2018, the first year after the platform's death, the first category is "Code Migration". Here developers discuss about: (1) the lack of code samples when trying to migrate code from WP8.1 to a UWP; (2) the export of WP code to React Native or Xamarin; (3) changing the behavior of UI elements in the UWP platform. In this category, our insight for future research is strategies to support migration between future or evolved platforms of the same organization that has experienced the death of one of its ecosystems. The investment in code samples that detail the necessary modifications for the evolutionary

maintenance of the app. We could raise the question of why developers are migrating from WP to UWP. This point is technically linked to the fact that UWP apps run on tablets and Windows computers. This can be a more natural migration process, since the apps make up on a higher hierarchical level the Windows SECO.

Also in 2018, in the category "Methods, classes, DLLs and services" it deals with the incompatibility or unavailability of libraries (DLLs), services like BingMaps and WCF (Windows Communication Foundation), classes or methods (e.g., HttpClient class, Post Async method). This category still deals with the evolution from old WP apps to the most current version (UWP). However, it makes sense for the category to be separate, as it specifically deals with internal SECO resources (libraries, services, classes and methods) that due to failures make the app evolution difficult and, apparently, there is no agile support for the community.

In this aspect, our analysis directs us to the need for investments in monitoring and predicting the death of an ecosystem for associated ecosystems within the same organization. It may be interesting to investigate the boundaries of SECO and the resources, individuals, populations and communities that are positioned at the boundaries. One scenario, which may be interesting, is to analyze the platform as the environment and this association environment and border. The analysis would go to a question of territory, something that can be inspired by Geoecology or "Landscape Ecology".

In 2019 we have only one grouping around the "Developer Tools" category. This category covers questions that deal with device emulators that no longer work in Visual Studio, the integrated development environment (IDE) that has a problem deploying apps to physical devices and the change in the IDE's interface that prevents opening older versions of apps projects. At this point it may not be a good strategy to invest effort to meet this requirement, since maintaining functionality in an IDE also impacts the organization's monitoring and maintenance. In 2019 there are only 45 questions. One point to study from a monitoring point of view is to study how far (in time) it is necessary to support the developer community of a dead platform.

6 Threats to Validity

Regarding the *constructo validity* the theoretical basis of this study considered the weaknesses pointed out in recent literature reviews published in the SECO field, i.e. Death of Software Ecosystem. The choice for Stack Overflow as a Q&A repository is due to the presence of developers who also post questions and answers related to the mobile platform domain. To support the *internal validity* the datasets were not selected randomly, but they were related to the studied ecosystem. To reduce the effect of the experimenters' expectation, the study's analyses followed the procedures indicated by algorithms. the environment is not different from the real one since Stack Overflow is a repository with questions from developers who are somehow participating in a SECO. It supports the *external validity*.

Generalization - the risk of choosing WP, our study is focused on WP, for the reasons described in Section 3, the study needs to be replicated in other SECO. *Effect of the experimenter's expectation* - so that the researchers' beliefs do not influence the analysis of categories for the topics, we are based on the results of the NMF and in conciliation meetings that involved the analysis of topics/questions. *Design of the Experiment* - a problem could be the choice of the algorithm for the topics' extraction, the algorithm used has scientifically proven performance to treat the dataset we use (Section 4).

7 Conclusion and Future Work

In this study, we advanced on investigating what happens with a SECO when the core platform is officially discontinued. Our focus, at this time, was to begin the analysis involving the Windows Phone platform that has been discontinued and the impact on developers within the ecosystem. It was performed by analyzing the behavior of developers within SECO from 46,030 questions of Stack Overflow related to Windows Phone.

Below we describe a summary of the insights from answering RQ1 (What is the activity around the SECO before, during and after its death?):

#1. Developers search for solutions to specific questions;
#2. The set of questions is not extensive within each niche;
#3. Expert developers in a certain niche of questions are no longer engaged to answer other related questions. Is this type of developer the first to leave the ecosystem environment?
#4. The Q&A repository becomes a low priority environment due to the delay in obtaining solutions;
#5. The metrics quantity of Answer, Favorite and Score (over 85% drop) may be used a year earlier as possible indicators of "vital signs" of the SECO;
#6. The quantity of View metrics dropped by over 400% one year after the announcement of the ecosystem death. Views were already falling, but were accentuated with the announcement of the core platform discontinuation.

Below we discuss a summary of the insights from answering RQ2 (To what topics are the last actions - during and after death - in the SECO related?):

#1. Investigate the survival strategies that developers use;
#2. It was realized that developers try to reuse and migrate their resources to a high hierarchical level ecosystem: Windows Phone for Windows;
#3. It may be important to analyze the impact of death of ecosystem that have intersection in resource use;
#4. The death of one SECO can influence disbelief on other platforms in the same ecosystem organization. This can lead to migration to another competing SECO;
#5. The above points indicate the possibility of investigating the energy flow among the SECO developers whose platform has been discontinued;
#6. Study and plan possible migration flows from the dead SECO developers to other ecosystems in the same

organization. It perhaps is the natural migratory process;

#7. Apply concepts of "Landscape Ecology" or "Geoecology" to investigate boundaries and territories of the SECO as a way to mitigate the effects of death on other elements of the ecosystem;

#8. An open question is: what is the ideal time frame for the DevRel area to maintain support for the developer community in order not to damage the reputation of the organization.

Considering the insights presented previously and the inspiration in Ecology we can see as some implications: (1) the analysis of strategies to create opportunities for ecosystem elements to regenerate resources and actors; (2) studying natural selection as a way to maintain survival in other ecosystems of the organization; (3) establishing a understanding of alternate host "ecology" applied to software and potential resistance; (4) investigate the ecosystem element "pathogen" potential for adapting to changing environments or developing new ecosystems (e.g., empower SECO from competitors).

We also realized the need to use the levels of organization in Ecology for the SECO: individual, population, community, ecosystem and "biosphere". Specifically at the individual level, the inspiration in Ecophysiology, it can be useful to study the functional adaptations of individuals in the face of drastic changes or death. Considering an ecological hierarchy our analysis was at the SECO level. The developer profile can be compared to "species" of dev.

The Engagement/Attractiveness/Maturity can be compared to the actions/roles of devs within the SECO (e.g., attractiveness could involve, from a "food chain" perspective, which resources are still attractive to dev). In the case of "post-mortem", for example, we can try to do something inspired by procedures of "autopsy" and indicators of "brain death". For example, it is interesting to explore the result that there is a demand for export/code migration. It would be as if brain death had occurred, but the ecosystem still has some activities or reflexes that come from the elements that compose it. we will consider in future work to use Grounded Theory or Thematic Analysis procedures to analyze answered/unanswered questions. We will review Section 3 to include all metrics used. Our goal in RQ1 was to obtain a quantitative view and in RQ2 a qualitative view based on topic extraction and questions' analysis.

ACKNOWLEDGMENTS

This work was supported by FACOM/UFMS, UTFPR, CAPES - Financing Code 001 and CNPq (process 438017/2018-8).

REFERENCES

[1] T. Kude, "Successfully governing software ecosystems: Competence profiles of partnership managers", *IEEE Softw.*, vol. PP, nº c, p. 1, 2018.

[2] K. Manikas, "Revisiting software ecosystems Research: A longitudinal literature study", *J. Syst. Softw.*, vol. 117, p. 84–103, 2016.

[3] R. Meier, "Why Do We Pay These People Anyway? Relating to Developer Relations and developers", *Medium*, 2015.

[4] A. Fontão, S. Cleger-Tamayo, I. Wiese, R. P. Santos, A. Dias-Neto. On Value Creation in Developer Relations (DevRel): a practitioners' perspective. In: Proceedings of the 15th ACM/IEEE International Conference on Global Software Engineering (ICGSE '20), 2020.

[5] W. Vorraber, M. Muller, S. Voessner, e W. Slany, "Analyzing and Managing Complex Software Ecosystems - A Framework for Creating a Common Understanding and Aligning Shared Goals for Developers and Business Managers, Applied to a Free Open Source Software Project", *IEEE Softw.*, 2018.

[6] J. Wareham, P. B. Fox, e J. L. Cano Giner, "Technology Ecosystem Governance", *Organ. Sci.*, vol. 25, nº 4, p. 1195–1215, 2014.

[7] S. Jansen, "Measuring the Health of Open Source Software Ecosystems: Moving Beyond the Scope of Project Health".

[8] K. Manikas e K. M. Hansen, "Reviewing the Health of Software Ecosystems – A Conceptual Framework Proposal", in *Proceedings of the 5th International Workshop on Software Ecosystems*, 2013.

[9] M. Begon, C. R. Townsend, e J. L. Harper, *Ecologia - De Indivíduos a Ecossistemas*, 4º ed. Porto Alegre: Artmed, 2007.

[10] D. J. Schaeffer, E. E. Herricks, e H. W. Kerster, "Ecosystem health: I. Measuring ecosystem health", *Environmental Management*, vol. 12. p. 445–455, 1988.

[11] D. Dhungana, I. Groher, E. Schludermann, e S. Biffl, "Software Ecosystems vs . Natural Ecosystems: Learning from the Ingenious Mind of Nature", *Proc. 4th Eur. Conf. Softw. Archit. Companion Vol. (ECSA '10)*, p. 96–102, 2010.

[12] S. Meldrum, S. A. Licorish, e B. T. R. Savarimuthu, "Crowdsourced knowledge on stack overflow: A systematic mapping study", in *ACM International Conference Proceeding Series*, p. 180–185, 2017.

[13] A. Fontão, P. Paes, O. Ekwoge, R. P. D. Santos and A. C. Dias-Neto, "Evaluating Processes to Certify Mobile Applications During Developer Relations Activities," in IEEE Access, vol. 8, 2020.

[14] V. Farias, I. Wiese, R.P Dos Santos. What characterizes an influencer in software ecosystems?. IEEE Software. Volume 36 (1), p. 42-47. 2019.

[15] L. Li, J. Yang, Y. Xu, Z. Qin, e H. Zhang, "Documents clustering based on max-correntropy nonnegative matrix factorization", in *Proceedings of the International Conference on Machine Learning and Cybernetics*, vol. 2, p. 850–855, 2014.

[16] O. Barbosa, R. Dos Santos, C. Alves, C. Werner, e S. Jansen, "A Systematic Mapping Study on Software Ecosystems", in *Software Ecosystems. Analyzing and managing business networks in the software industry*, S. Jansen, S. Brinkkemper, e M. A. Cusumano, Orgs. Edward Elgar Publishing Limited, p. 59–78, 2013.

[17] O. Franco-Bedoya, D. Ameller, D. Costal, e X. Franch, "Open source software ecosystems: A Systematic mapping", *Inf. Softw. Technol.*, vol. 91, p. 160–185, 2017.

[18] A. Fontão, R. P. Santos, e A. C. Dias-neto, "Mobile Software Ecosystem (MSECO): A Systematic Mapping Study". Proceedings of *39th Annual International Computers, Software & Applications Conference*, 2015.

[19] C. Steglich *et al.*, "Revisiting the Mobile Software Ecosystems Literature", in *Proceedings IEEE/ACM 7th International Workshop on Software Engineering for Systems-of-Systems and 13th Workshop on Distributed Software Development, Software Ecosystems and Systems-of-Systems, SESoS-WDES,*, p. 50–57, 2019.

[20] C. Alves, J. Oliveira, e S. Jansen, "Software Ecosystems Governance - A Systematic Literature Review and Research Agenda", *Proc. 19th Int. Conf. Enterp. Inf. Syst.*, nº January, p. 215–226, 2017.

[21] Chen, Y., Zhang, H., Liu, R., Ye, Z. and Lin, J., 2019. Experimental explorations on short text topic mining between LDA and NMF based Schemes. Knowledge-Based Systems, 163, pp.1-13.

[22] H. Hemmati et al., "The MSR Cookbook: Mining a decade of research," 2013 10th Working Conference on Mining Software Repositories (MSR), , pp. 343-352, 2013.

[23] J. R. Ginsberg, K.A. Alexander, S. Creel, P.W. Kat, J. W. McNutt, and Mills, M.G.L Millz.1995. Handling and survivorship of African wild dog (Lycaon pictus) in five ecosystems. Conservation Biology, 9(3), pp.665-674.

[24] Larsson, H., Lindqvist, E. and Torkar, R., 2014, December. Outliers and replication in software engineering. In 2014 21st Asia-Pacific Software Engineering Conference (Vol. 1, pp. 207-214).