Health Evaluation in Software Ecosystems

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Abstract: Context: The quality of a Software Ecosystem (SECO) platform and its available products are important characteristics to ensure its success. However, this concept goes beyond the traditional approaches of quality assurance, including concepts such as SECO´s health. Objectives: The aim of this study is propose an evaluation process to application of health metrics. In addition, this metrics were formalized to make feasible your application and improve the obtained results. Method: A systematic mapping was conducted with the aim of analyzing the SECO quality research area, highlighting the state of the art and identifying its main characteristics. In addition, the main approaches and metrics present in the literature for SECO quality and health evaluation are detailed. This work presents an observational study used to define relevant heath metrics considering an evaluation process. Results: The metrics were formalized and evaluated by specialists. A health evaluation process was developed to applicate this metrics. This process is supported by an architecture named HEAL ME.

1 INTRODUCTION

Software development scenario has rapidly been changing (Jansen 2013). Currently, there is a massive presence of Software as a Service (SAS) approaches, driven mainly by ubiquitous computing. In this context and with the emergence of challenges such as Distributed Software Development (DSD), just maintaining a central architecture is not enough for most enterprise developers. They need to open their architectures for the collaboration of external developers (Bosch 2009). This has given rise to a new concept of development, where several software solutions, companies and developers adhere to a common platform. This scenario is called Software Ecosystem (SECO) (Jansen 2013).

A SECO is considered an open software platform, is basically composed of a keystone, a platform and a set of niche agents (Bosch and Bosch-Sijtsema 2010). The centralizer acts in the development of the platform and in the management of relationships with external parties. However, niche agents are those that influence the development of the ecosystem.

For the companies that maintain the platform, i.e., the keystones, there are several advantages of adopting a SECO approach. Increase their platform scope, reaching a greater number of users with their software solutions, is one of them. Also, the cost reduction with R&D (Research and Development) can be considered, since several new software solutions are developed by external companies (Bosch 2009).

However, the scenario created by SECO brings new challenges. Among them we can highlight the quality assurance of products and platform. The independence of external developers as well as the platform characteristics can influence the quality of the entire ecosystem. In addition, due to the complexity of the scenario, quality assurance in the context of SECO has its peculiarities (Santos et al. 2014). Unlike traditional development, the SECO platform maintainer does not have control over models and development processes used by outside companies. In this way, the keystone cannot directly guarantee the quality of the products developed on the platform (Santos et al. 2014). Some keystones strengthen the distribution of these products, making a deep quality control before providing them. However, certain companies avoid developing on these platforms due to the difficulty of making their products available (Jansen 2013). Therefore, in addition to the quality standards observed in software

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products, considering the product and the process quality evaluation, there are other dimensions to be observed in the context of a SECO. Some of them have a platform-oriented approach, such as the SECO health dimension (Santos et al. 2014).

Common quality concepts do not cover the complexity of the environment created by a SECO, as the large number of employees grouped in development communities, as well as a large relationship network (Fotrousi et al., 2014). Furthermore, independent developers and a larger number of users, each one with his/her own needs, make quality assessment processes a challenge. This situation led to a new evaluation dimension, known as "SECO health" (Amorin et al., 2017), as mentioned before.

According to (Santos et al. 2014), SECO health is the degree to which a Software Ecosystem provides opportunities for collaborators and for those that are platform dependent. Health can also be defined from the point of view of SECO investors. According to (Bosh 2009), one of the advantages of adopting SECO is the reduction of investments in R&D by the keystone, since these investments are carried out by companies that join the SECO. Investments applied in a SECO are high, besides the dependency between the components and the platform. In order to avoid losing these investments and to meet the expectations of those who adopt it, there must be no risk of SECO death or failures (Amorim et al., 2017).

With the goal of identifying researches in SECO quality, mapping the state of the art and detecting possible shortcomings and research gaps, a systematic mapping (Kitchenham 2004) of the literature was carried out. With the results, it was possible to identify specific key points on SECO quality research and, to propose a quality assessment approach focused in health considering SECOs context.

Among the papers selected during the systematic mapping process, some of them propose health assessment metrics for SECO. These metrics were automated by the HEAL ME architecture, described in (Carvalho et al., 2017), as our first effort to define the process. However, the applicability and adherence of these metrics were not evaluated within the suggested context. We then proposed the evaluation of these metrics through an observational study, executed considering SECO´s experts.

Finally, in order to provide better application of these metrics and evaluation effectiveness, an assessment process was proposed. This process tries to formalize the application and validation of the metrics through the observational study. This evaluation is important to encourage SECOS´ new collaborators, users and partners, providing a first step to ensure SECOS´s health.

This paper is structured as follows. Section two presents the systematic mapping execution and results. Section three describes a set of metrics for SECO quality and health, grouped in an architecture named HEAL ME. These metrics were extracted from the systematic mapping, and evaluated by specialists. Finally, section four presents the final considerations, threats to the validity, and future works.

2 SYSTEMATIC MAPPING

Basing the answers of research questions in evidences is an important approach to results effectiveness. For this reason, (Kitchenham 2004) presents the evidence-based Software Engineering paradigm. The principle of this paradigm is to answer research questions, based on evidences found in the literature.

Considering this approach (Kitchenham 2004), a systematic mapping of the literature was carried out to evaluate areas of interest related to SECO´s quality. The objective was to identify the main approaches present in the literature, trends and state of the art of SECO´s quality assurance. To perform the systematic mapping, three phases were defined: planning, conducting and reporting the study (Kitchenham 2004). For the execution of the entire mapping process, the Parsifal tool was used, available at: https://parsif.al.

2.1 Planning

The first step in the construction of the protocol was the definition of mapping and research questions, with the goal of finding SECO quality assurance approaches and its state of the art. As ecosystem health can be considered a sub-area of quality, the mapping was carried out under the theme of quality and later the study was specialized for the SECO health area.

Three mapping questions were presented: MQ1: What are the main publication venues in the area? MQ2: How are papers distributed over the years? MQ3: Which authors are outstanding in the area?

Four research questions were then proposed: RQ1: Which quality assurance approaches are used for SECO? RQ2: Which quality attributes are more often used to evaluate SECO? RQ3: Which model is the most used in the evaluation of SECO quality? RQ4: Which model or quality approach is more used in SECO health assessment?

The PICOC (Petticrew and Roberts 2008) was defined as follows: **Population**: solutions that address the quality assurance in SECO; **Intervention**: attributes and processes for quality or use of actors' perceptions or health and prosperity assessments; **Comparison**: no comparisons were defined; **Outputs**: methods, techniques, approaches, models, solutions, metamodels, dimensions and other solutions for quality; **Context**: Software Ecosystems.

Then, the inclusion criteria defined were: IC1: Publications from the year 2009 ahead, since SECO area has gained focus from the work published by (Bosch 2009); IC2: Open publications type, due to the need to evaluate their contents; IC3: Publications of the Computer Science area, because of its specificity; IC4: Publications which main theme is SECO quality assurance. The exclusion criteria were defined as follows: EC1: Publications before 2009; EC2: Publications that are not of the Computer Science area; EC3: Publications that are not open publications; EC4: Publications that do not focus on SECO quality assurance.

In the sequence, the research bases were selected. They were selected considering publications on the Computer Science area. Another criterion was the ability of using advanced searches to apply the mapping search string. Finally, all the selected bases should be compatible with the support tool. The selected bases were: ACM Digital Library (http://dl. acm.org/); IEEEXplorer (http://ieeexplore.ieee.org); ScienceDirect (http://www.sciencedirect.com/); Scopus (https://www.scopus.com); and Web of Science (http://apps.webofknowledge.com/).

With the bases defined, the next step is the definition of the search string. The PICOC items were used to identify the most relevant words and expressions. As a result, the following string was generated: (quality OR "quality assurance") AND (perception OR perceptions OR attribute OR attributes OR process OR health OR evolvability) AND ("software ecosystem" OR "software ecosystems" OR SECO OR "software digital ecosystem" OR "software digital ecosystems"). This is a generic string considering that each base has its own search syntax. In order to effectively do the searches, the string was adapted for each base, maintaining its basic structure.

An important parameter to evaluate the search effectiveness is the definition of control papers. They must be important papers in the area, and that is useful to evaluate if the search is correctly reflecting the proposed objectives. Five control papers were defined for this systematic mapping. They were also presented by (Manikas 2016) as important quality assurance papers in ECOS. The selected papers are: (Schugerl et al. 2009), (Hmood et al. 2012), (Jansen 2013), (Stefanuto et al. 2011), (Franco-Bedoya et al. 2014). The next phase is the conduction of the systematic mapping.

2.2 Conduction

In this phase, each database was accessed and the search string was executed. The searches were performed between August and September 2016 and updated in May 2017. The total number of studies founded was 109. Table 2 shows the distribution of these results by bases.

Table 1: Search results.

Database	Number of Papers
ACM	16
IEEEXplorer	12
ScienceDirect	9
Scopus	56
Web of Science	16
Total	109

Among these papers, 29 were duplicated and were automatically excluded by the Parsifal tool, resulting in 80 papers. Then the titles and summaries were read and the inclusion and exclusion criteria applied. In this process, 57 files were excluded, remaining 23 for text full analysis. After this stage, 11 papers were excluded, resulting in 12 papers classified as relevant for the area of SECO quality assurance. Reflecting the effectiveness of the search, among the relevant papers were the control papers, that the search string is consistent with the study objectives.

2.3 Study Report

Analyzing the distribution of publications we can answer the first question (MQ1): What are the main publication venues in the area? A widespread venue distribution is observed as only two papers were published in the same conference, the proceedings of the International Conference on Management of Emergent Digital EcoSystems - MEDES. Another important note is the fact that 10 papers were published in proceedings, and only two in journals. This situation denotes a lack of specific conferences and journals in the area.

In order to analyze the evolution of the area, we can observe the graph in Figure 1, where the number of publications per year since 2009 is presented. With this data, it is possible to answer the second question

(MQ2): How are papers distributed over the years? It is possible to visualize the growing importance of the area in the last four years. This is an expected outcome, since SECO approach is increasingly present in the context of current software development (Manikas 2016). However, between 2011 and 2012 there is a discontinuity growth, since the number of publications is lower in 2012 than in 2011. This situation may point out to the immaturity of the area. In this way, we may consider that perhaps the basic concepts of SECO are not fully established.

Finally, we can analyze the distribution of publications by author, answering the third question (MQ3): Which author or authors are most outstanding in the area? By observing the results, a dispersion can be detected. Among the twelve selected papers, only the ones published by (Alves and Pessôa 2010), (Stefanuto et al. 2011) and (Alves et al. 2015) have authors or co-authors in common. The remaining papers are from different authors.

Therefore, from this systematic mapping, there is evidence that the area is still emerging and is not fully explored, considering the small number of works about SECO quality assurance. In addition, we identified the importance of software quality assurance in the context of SECO research. These results are detailed reported in the following section.

2.4 Results

To answer the first research question (RQ1) - Which quality approaches are used for SECO? - Several different approaches can be mentioned. Among the papers are quality models, QuESo (Franco-Bedoya et al. 2014), CoCoADvISE (Lytra et al. 2015), SE-Advisor (Schugerl et al. 2009) and the meta-model SE-Equam in (Hmood et al. 2012). As quality frameworks, we can cite the BISA (Kajan et al. 2011). In (Alves and Pessôa 2010) the framework named 5CQualiBr is presented, and the PRO2PI-MFMOD framework is present in (Alves et al. 2015). The BPS Maturity Model is addressed in (Stefanuto et al. 2011) and (Alves and Pessôa 2010). Finally, (Mhamdia 2013) presents a literature review, listing several measurement processes applied to ECOS from a quality perspective, while (Frantz et al. 2015) present the application of Markov Decision Processes, with the same objective. The results reflect the area diversity, considering the identified approaches. Each proposal has its unique characteristics, ranging from maturity models to decision-making processes. However, one can observe the use of common techniques, such as semantic analysis.

Considering the second research question (RQ2) - Which quality attributes are more often used to evaluate SECO? - we can highlight the ones from (da Silva Amorim et al. 2014), i.e., communication, teamwork maturity, technology and integration. These attributes, which are linked to the SECO software platform, are also addressed by (Franco-Bedoya et al. 2014), (Jansen 2013) and (Jansen 2014). These three papers also share other attributes, such as sustainability and openness. Identifying these attributes is of great importance since they are the basis of the main quality models. In this way, it is evident that such attributes are of extreme importance for an evaluation and quality assurance in the context of a SECO.

The third research question (RQ3) - Which model is the most used in the evaluation of SECO quality assurance? - can be answered from the two-dimensional analysis. The first dimension is the recurrence of models in the papers. It is possible to highlight the maturity model presented by (Stefanuto et al. 2011), which is directly or indirectly addressed in three papers. The second dimension analyzed was the number of citations of the papers in the bases. As a result, we can present the (Franco-Bedoya et al. 2014) and (Schugerl et al. 2009) as the most cited quality models, and again (Stefanuto et al. 2011) as the most cited maturity model.

Finally, the fourth research question (RQ4) - Which model or quality approach is most used in SECO health assessment? – presented the models and

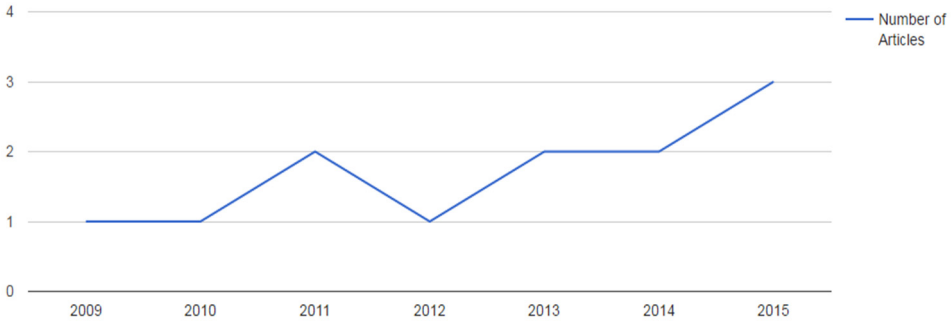

Figure 1: Publications evolution graph.

metrics proposed by (Franco-Bedoya et al. 2014) and (Jansen 2014), where SECO platform quality dimen-sions are directly addressed. Other models that treat health and prosperity in a less expressive way are found in (Schugerl et al. 2009) and (Hmood et al. 2012).

After analyzing the results, we can highlight some points. First, researches in the area follow the trend of creating quality models for SECO evaluation. (Franco-Bedoya et al. 2014) and (Jansen 2013) are concerned with evaluation of software characteristics and attributes through metrics. Another concern is the automation of processes and the use of semantic analysis to carry out the evaluations, due to the complexity of the processes and the environment to be analyzed (Schugerl et al. 2009). However, the papers do not address SECO in a generic way, only specific contexts are analyzed. In addition, process automation is still immature, and we believe that it can be substantially improved through the use of specific tools and intelligent analysis. Another drawback is the presentation of the evaluations results of the proposed models, whereas a more elaborate analysis with adequate visualization resources is not usual.

Considering these observations, HEAL ME architecture was proposed (Carvalho et al. 2017). It aims to evaluate the quality and health of a SECO in a generic and semi-automated way, analyzing data using metrics from the literature, ontological rules and visualization techniques to improve their understanding.

In order to present the HEAL ME metrics and also evidences of its usefulness, an observational study was carried. Specialists validated the set of metrics, with the aim of performing an initial validation of HEAL ME utility. In the next section, this process is detailed, focusing on SECO´s health characteristics.

3 QUALITY AND HEALTH METRICS

Based on the previous results, 58 quality and health evaluation metrics were defined and detailed in HEAL ME architecture (Carvalho et al. 2017) context. The complete list of metrics is available at: http://www.ufjf.br/nenc/files/2008/09/Metrics-HEAL-ME.pdf.

HEAL ME architecture aims to automate the health assessment process of a SECO. Based on the systematic mapping, the HEAL ME metrics were reviewed and evaluated by three SECO experts, based on an observational study. Each specialist individually assessed each metric to define its usefulness and importance. The conduction of the observational study is presented in the next section, showing the steps from the data collection to the reporting of results.

3.1 Observational Study

The study was conducted in two steps. At first, the data was organized, aiming to capture the specialists' perception about each metric. Then, a structured questionnaire with all 58 metrics was sent to specialists. Each of them individually analyzed the metrics. During the second step, specialists' answers were quantified assigning weights to their responses. Then, it was possible to formalize the metrics and define their components using the information obtained from the study results. This formalization will be presented in section 3.2.

The study was also organized considering five phases: Definition, Goals, Planning, Execution and Results. The study definition aims to outline the initial steps of the research. The goals phase defines the main objectives of the study. The planning phase aims to define the application of the study itself, as well as the required items for its execution and the selected data sources. The execution phase details the steps to reach the final results and, finally, at the results phase, the data analysis is detailed, emphasizing how the goals were reached (Perry et al, 1998).

Definition

The scope of the observational study was defined based on the GQM method (Basili et al. 1994): "to validate the metrics used by the HEAL ME architecture with the purpose of verifying the usefulness and importance of each metric from the point of view of specialists in the context of a SECO".

In order to define the scope, the following research question was proposed: Which metrics used by the HEAL architecture are useful for the evaluation of a SECO health?

Goals

The goal of the observational study was to evaluate the usefulness and adherence of each metric present in the HEAL ME architecture from the point of view of specialists in the context of SECO. To achieve this goal, the study was applied to the subjects using a questionnaire as the main instrument. Each subject evaluated the metrics presented within the defined scale.

Planning

To evaluate the proposed metrics, the study was performed considering SECOs experts and their background. The subjects were Software Engineering specialists, two from the industry and one from the academy. Data collection was based on online interviews with the subjects, supported by a structured questionnaire available at: https://drive.google.com/open?id=11moBFOXfE7CXVDNQVBJD_yZ8i0qCfpMKtv3NnZPOoKk. Each subject should evaluate each metric, considering its utility within the following scale: Essential, Desirable, and Dispensable. The use of a multiple-choice scale to answer the questionnaire reflects the precision needed in the metric assessment.

Execution

The application of the questionnaire was done online, without interviewer´s interference during the process. All subjects answered the entire questionnaire and did not report any doubts about its completion.

The subjects accessed the questionnaire and individually selected the responses, on different days and times. Each subject took, at average, about 20 minutes to complete the questionnaire. An important point to be emphasized is that all subjects have a good knowledge about SECO, and one of the subjects is currently working with SECO in the industry. After the study was carried out, the responses were collected, analyzed and the results are reported below.

Results

The results were analyzed to evaluate the adherence of each metric to the health and quality assessment process proposed by the HEAL ME architecture. Each response was distributed considering three scales: Essential, Desirable and Dispensable. To perform the analysis, each response received a weight, respectively, 2, 1 and 0, considering that essential is a mandatory metric, desirable is a metric that may be considered and dispensable are the ones that must be discarded. The weights demonstrate the relevance of each response set in a numeric way. These weights were totalized in each metric considering the response of each subject. The averages were calculated, and classified in the following scale: Essential (average greater than 1.66), Partially Essential (average less than 1.66 and higher than 1), Desirable (average equal to 1), Partially Dispensable (average less than 1 and above zero), and Dispensable (average equal to zero). The results are shown in Figure 2.

It can be noticed that 81.03% of the metrics were evaluated between Essential and Desirable, totalizing 46 metrics. This result shows evidences that the metrics are useful and adherent to the proposed context. On the other hand, it was detected that 18.97% of the metrics were evaluated between Partially Dispensable and Dispensable, totalizing 12 metrics. This demonstrates that new studies should be conducted in order to validate the evidence collected in this first evaluation. However, with these results, the research question could be answered, considering the 46-metrics positive evaluated. It should be noted, though, that this is a primary study. New experiments should be conducted in order to conclusively validate the research question.

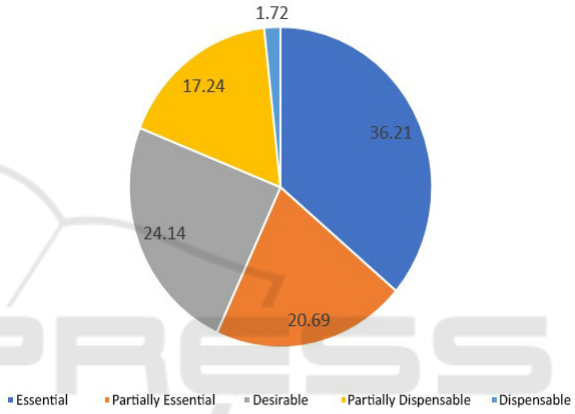

Figure 2: Study results.

3.2 Metrics Description

The list of formalized metrics is available at: http://www.ufjf.br/nenc/files/2008/09/Formalizadas HEAL-ME.pdf. There is also a need to define metrics´ components and evaluation procedures. Therefore, the metrics components are: Description, which shows the utility of the metric; Measure and Formula, that details the application of the metric using its data; Interpretation, which shows the meaning of metric result; Unit to quantify the result measure; and Actor, the individual related with the metric. With these components, the metrics evaluation precision is increased, and the results reflects the reality of the evaluated context. In addition, to facilitate this interpretation, the metrics were grouped in three SECO dimensions: Technical, Business and Social (Barbosa et. al. 2013).

3.3 Definition of Evaluation Process

Based on the metrics validation through the observational study, it was possible to improve the

health assessment process considering the HEAL ME architecture, evolving the architecture, as well as increasing its effectiveness in the evaluation of SECO´s health. Additionally, the metrics formalization improves the effectiveness and result precision. The metrics grouping in SECO dimensions have the potential to show the SECO environment, using a simple and realistic structure.

As stated before, the metrics used by the HEAL ME architecture were automated through semantic rules specified using an ontology together with the Semantic Web Rule Language (SWRL). Therefore, the SECO data are instantiated into the ontology to be evaluated. Some metrics are captured automatically by the HEAL ME architecture, through the interaction of the architecture with SECO as an application integrated to SECO´s core. this processes is described in (Carvalho et al. 2017). This evaluation process can be seen in Figure 4, using the BPMN model notation.

The evaluation process consists of five steps. The first is data collection. The data are collected considering several SECO parameters, which are related to development, users, relationships network, among others. This data is collected automatically through specific APIs that communicate with existing repositories and / or with relevant applications and with the platform. Each data collected is evaluated by a metric. The second step is the parametrization of the metric. These parameters are informed by experts and vary according to the characteristics of the SECO. The parameters are used to evaluate whether the collected data are in accordance to the metric. The third step is the instantiation of the data and parameters into the ontology. This step is necessary for the semi-automated execution of the evaluation, through the semantic rules. The fourth step is the execution of the rules. Using the parameters, the rules automatically evaluate if the data is in accordance or not to the metric. Finally, the last step is to visualize the results generated by the evaluation process. In this step, visualization techniques are used in order to facilitate user's understanding. Clustering techniques, filters, among others are used. It is important to point out that process-based automation is very important due to the large number of metrics and the complexity of executing quality and health assessment without an automatic support.

4 FINAL CONSIDERATIONS

Quality assurance is an important non-functional parameter in software production and development. It is also present in SECO context as the number of SECOs' users grows on a daily basis. This also causes a growth in the need for new functionalities and resources to be developed. In addition, the quality vision in this context goes beyond the traditional one of software development, for instance, addressing concepts such as SECO's health. This concept is stablished considering the reality of distributed development in the SECO's context. In order to know more about this panorama, a systematic mapping was conducted. This mapping made it possible to find specific papers presenting models, attributes and solutions for SECO quality assurance.

Through the systematic mapping, health metrics for SECO were found. These metrics were than inserted into the HEAL ME architecture, which aims to perform the SECO's health assessment automatically. However, assessing the applicability and usefulness of these metrics was necessary to allow better reliability on the results of its application. For these metrics' evaluation, an observational study was carried out with domain specialists. After the metrics were evaluated, they were formalized and their main attributes were described. The formalization of the metrics allowed the definition of the evaluation process. This allows the improvement of the accuracy of the evaluations, as well as facilitates the automation of the SECO's health evaluation process. As future work, we can mention the conduction of formal experiments to validate the use of the HEAL ME architecture in SECO specific contexts and the effectiveness of the metrics and the evaluation process.

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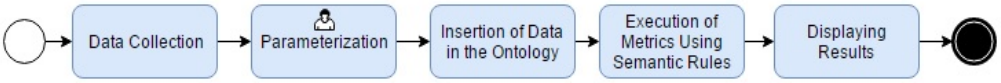

Figure 3: Evaluation flow of the metrics in the HEAL ME architecture.

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APPENDIX

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