Healthy until otherwise proven

Some Proposals for Renewing Research of Software Ecosystem Health

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ABSTRACT

The software ecosystem has become a central conceptualisation for characterising the contemporary software business world. To understand and evaluate ecosystems, the concept of 'ecosystem health' was borrowed from the field of biology. In a 'healthy' ecosystem, the participants will flourish and, *vice versa*, suffer in an unhealthy one. Yet, there is a lack of empirical validations for the current approach as well as certain limitations regarding the concept. This paper will present a critique on current ecosystem health measurement and evaluation approaches. In addition, there is discussion on three proposals that could help to refocus the academic research on software ecosystem health.

CCS CONCEPTS

• **Software and its engineering** → *Software organization and properties*; *Empirical software validation*;

KEYWORDS

Software ecosystem, ecosystem health, software business ecosystem, platform economy, position paper

ACM Reference Format:
Sami Hyrynsalmi, Jukka Ruohonen, and Marko Seppänen. 2018. Healthy until otherwise proven: Some Proposals for Renewing Research of Software Ecosystem Health. In *SoHeal'18: IEEE/ACM 1st International Workshop on Software Health , May 27-June 3 2018, Gothenburg, Sweden.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3194124.3194128

1 INTRODUCTION

Software ecosystems have emerged as an important concept to characterise and understand the modern networked software industry [39]. Companies build their products and services together, relying on the platforms, components, interfaces, and products offered by other companies. One example of the modern software business and ecosystems are the new smart devices with their application stores and publication channels. For instance, Apple was able to dethrone the old kings of the castle in the mobile phone markets with their paradigm-changing smart phone. While Nokia and RIM quickly adopted the new paradigm, containing touch screen phones, third-party applications, application stores and open programming interfaces, Apple was able to marginalise the old market leaders with the combined power of Apple and all software producers offering products for Apple's own smart phone platform.

While there are several explanations for the success of Apple and Google and the downfall of Nokia and RIM [e.g. 2, 7, 50, 57], the importance of the open platform, applications and their developers cannot be downplayed in the triumph of Apple and Google. Thus, it is no surprise that a similar approach has since started to spread to other areas also [14, 26].

The concept of 'ecosystem health' has become an indicator of the well-being, longevity and performance of an ecosystem [21]. In an ideal case, the ecosystem health can be used to evaluate the well-being of an ecosystem, pinpoint problematic areas, and target resources to improve these areas. Furthermore, in the case of competition, where two or more ecosystems offering similar services are competing against each other to gain the largest market share, ecosystem health metrics can be used by investors, governmental agencies and new companies to decide where to invest.

During the past few years, several literature studies have been published regarding ecosystem health in the context of software. For example, Hyrynsalmi et al. [21], Manikas and Hansen [36] and da Silva Amorim et al. [11] have addressed the state-of-the-art of software ecosystem health research. The latest study, da Silva Amorim et al. [11], found 23 studies and [21] identified 38 research papers.

However, the current approaches and discussions on software ecosystem health have certain problems. For example, there is no empirical evidence on the usefulness of the current tools and, in addition, there is a lack of clear understanding of what is a healthy ecosystem and what is not [21]. Thus, further work has been requested for understanding and developing usable tools for assessing the health of a software ecosystem.

This discussion acts as a position paper presenting criticism on the current approaches as well as proposing some new avenues for avoiding the known pitfalls. The view adopted in this paper follows the ecosystem definitions of Bosch [6], Jansen et al. [28] and the ecosystems considered could be classified as 'software (business) ecosystems'. However, the critique and ideas might also be valuable for 'software (technology) ecosystem researchers'.

The rest of this paper is structured as follows. Section 2 defines the central concepts — 'software ecosystem' and 'ecosystem health' — as well as the related work. Section 3 presents criticism of the current approach and some future avenues are discussed in Section 4.

SoHeal'18, May 27-June 3 2018, Gothenburg, Sweden

ACM ISBN 978-1-4503-5730-2/18/05…$15.00
https://doi.org/10.1145/3194124.3194128

2 CENTRAL CONCEPTS

In the following, the central concepts, i.e. software ecosystem and ecosystem health, will be defined. Furthermore, the most recent work on these two topics will be briefly discussed. For recent literature reviews on these topics, please refer to [21, 35], respectively.

2.1 Software ecosystem

The concept of a *'software ecosystem'* emerged from the book of the same name by Messerschmitt and Szyperski [40] in 2003. As later recounted by the authors, they saw that complementaries, as the opposite of competition, are an important part of the software industry and, thus, they decided to adapt the name for their book [27, p. xii]. Nevertheless, since the publication of the book, hundreds of studies concerning software ecosystems have been published [c.f. 35, 37, 49].

The concept of a 'software ecosystem' has inherited similarity with James F. Moore's [41] 'business ecosystem' concept. Therefore, it is important to understand the original model. According to Moore [42, p. 26], a business ecosystem is *"an economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they co-evolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles."*

Software ecosystem research has, roughly speaking, diverged into two — or even three — main groups: In the first group, the software ecosystem is seen as a special case of a more general 'business ecosystem' concept [21]. The studies belonging to this group often follow the definition by Jansen et al. [29, p. 187-188], according to which *"a software ecosystem is a set of businesses functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. These relationships are frequently underpinned by a common technological platform or market and operate through the exchange of information, resources and artefacts."*

The case examples of these kinds of software ecosystems are Apple's iOS / iPhone ecosystem and Google's Android operating system / Play store ecosystem [17]. However, studies have also been carried out on different ERP ecosystems, such as the SAP ecosystem, World of Warcraft markets as well as AutoCAD plug-ins [35].

In the second group, the (open-source) software projects and products, their decencies and developers are treated as an ecosystem. For example, Lungu [34, p. 29] defines the 'software ecosystem' as a *"collection of software projects which are developed and co-evolve in the same environment."* Studies following this kind of software ecosystem have addressed such ecosystems as Eclipse, Gnome, Linux and Ruby [35].

In addition, a third group is emerging: the (developer) software ecosystems, where the ecosystem consists of developers — both individuals as well as organisations — working on one or several development projects [53]. While this is still an emerging research area when compared to the previous two, it is a noteworthy theme that confuse the software ecosystem research field even more.

As it is clear from the two aforementioned definitions of software ecosystems, the research has diverged and there are such 'ecosystems' that fulfil the former definition but not the latter — and *vice versa*. For example, the Ruby ecosystem does fulfil the project-based definitions, yet it probably does not represent the business aspect of software ecosystems well [37]. However, it is worthy of note that there are also software ecosystems that fulfil both definitions.

As discussed by Hyrynsalmi et al. [21], this is one of the complicating issues in software ecosystem literature: the generalisation of results depends heavily on the ecosystem at hand as the results found from an open source project software ecosystem might not be applicable in mobile application ecosystems.

The authors have adopted the first view, what might be called as the 'software (business) ecosystem'. However, the critique presented towards software ecosystem health might also be applicable in the research of 'software (technology) ecosystems'.

2.2 Ecosystem health

For both the aforementioned ecosystem groups, 'ecosystem health' is an important conceptualisation. In the field of non-biological ecosystems, the concept can be traced to the seminal work done by Iansiti and Levien [22, 23]. They, however, adapted the term from previous work done in the context of biological ecosystems. Iansiti and Levien [23] expanded the work of Moore from business ecosystems and presented metrics to assess the health of an ecosystem.

According to Iansiti and Levien [23], the fate of a single company no longer depends on the strength of the company. Instead, its fate depends on the combined strengths of the participants of the network in which the company is involved and does business. According to this seminal paper, *"if the ecosystem is healthy, individual participants will thrive; if the ecosystem is unhealthy, individual participants will suffer"* [23, p. 5].

The authors presented three metrics for business ecosystem health, yet they pointed out that the same might also be applicable for biological ecosystems. The metrics are as follows [23]:

Productivity is a *"network's ability to consistently transform technology and other raw materials of innovation into lower costs and new products"* [23, p. 3]. An example metric for this is the return on invested capital.

Robustness refers to the ecosystem's ability tp absorb external shocks caused by e.g. new disruptive innovations and technologies. The survival rate is proposed as an example metric.

Niche creation is the ecosystem's ability to produce new niche products and services as they help to renew the ecosystem as well as absorb external shocks. An example metric is the amount of emerging technologies applied in the ecosystem.

The work by Iansiti and Levien [23] defined the baseline for all further work in the domain [e.g. 12, 13, 24, 32, 46], even in the context of software ecosystems [e.g. 1, 9, 10, 33, 38, 51, 54, 55]. While there are software ecosystem specific adaptations [see 4, 21, 37, 43], they still have their basis in the previously described work. For example, Ben Hadj Salem Mhamdia [4] studied the health of the Tunisian software industry, treated as an ecosystem in the study, by using robustness, productivity, interoperability, stakeholder satisfaction and creativity.

During recent years, several systematic literature studies have been done on the concept [11, 21, 36]. These studies have shown that there are only a handful of empirical studies aiming to either validate or disprove the current ecosystem health models. As pointed out in the most recent literature study, da Silva Amorim et al. [11] found six different concepts of 'software ecosystem health' as well as over 200 different metrics presented for evaluating ecosystem health.

3 DISCUSSION ON CURRENT CONCEPTS

There are a few major caveats in the current conceptual approach. In the following, we will present from our point of view the key caveats regarding metaphor, response, benefitting actors and the evolution perspective.

3.1 The metaphor

In science, metaphors are useful while also problematic [3, 48]. While the ecosystem analogy might widen managers' perspective [23], also the opposite is possible: the metaphor might move our focus to insignificant details [17].

Both 'ecosystem' and 'health' metaphors have problems. For example, Stallman [52] pointed out that the term 'ecosystem' hints at a lack of intention and ethics. Both of these, however, are an inseparable part of any artificial ecosystem built or constructed by humans. Furthermore, an ant, for instance, is unaware that it is a part of a bigger ecosystem and cannot, thus, intentionally alter the environment. In contrast, people, organisations and companies are self-aware and can even change the ecosystem to which they belong.

However, greater problems are related to the 'ecosystem health' concept. Firstly, while the concept has been adapted from the field of biology, even in its home field, there has been ongoing discussion on the suitability of the concept [c.f. 44, 45, 47]. That is, even in the original home of the concept, there are diverging views on whether the concept is usable or not.

Secondly, the concept of 'health' is derived from medicine and it is, unfortunately, extremely ambiguous [18]. Let us, consider the following simple, yet descriptive example: quite often a person, who has not visited a doctor for years, is considered to be as right as rain—i.e., perfectly fit and well. However, after receiving a diagnosis from the doctor, one can be transformed instantly from completely healthy to seriously ill. In other words, the modern medicine defines 'health' as absence of a disease [31]; that is, healthiness is defined just as the opposite of illness. Thus, healthiness does not represent well-being or longevity.

Therefore, we can ask what does 'software ecosystem health' actually measure or aim to measure? If we adopt the origins of the metaphor, we are looking for the absence of serious problems. This kind of view only aims to keep the ecosystem alive, not evaluate what is the most stable, vigorous and longest living alternative. However, the users of health metrics are likely to be more interested in these kinds of aspects. For example, the stakeholder responsible for operating or running the ecosystem should be interested, of course, in removing all 'diseases' from the ecosystem, but should also aim to improve the well-being and longevity of the ecosystem. Furthermore, the theoretical background of the concept does not give any support for defining metrics.

To summarise, the concept of 'ecosystem health' is questionable even in the original field of biology. Moreover, 'health' is an ambiguous term and the theoretical background of 'ecosystem health' is by no means clear.

3.2 Reactive or Proactive?

To the best of the authors' knowledge, all previous studies have been done as *post hoc* analyses. While this is a reasonable approach when noting the restrictions set by data collection and analysis; it leaves unanswered a significant question: are ecosystem health metrics able to predict or give hints on future development? In other words, do the metrics have proactive power to predict or only reactive power to explain past events.

Once again, let us consider the following simple example. Several times, simple metrics — such as the number of lines of code (LOC) — have been proposed for measuring the productivity of software ecosystem [21]. Let us consider the case of Nokia Ovi Store — the application store for Symbian devices — after the launch of Apple's AppStore. While practitioners, analysts and even the platform owner were aware of the probable forthcoming downfall, the absolute number of applications, installations as well as LOC were still likely to grow for a long time. Thus, would the health measured on the basis of the abovementioned three characteristics be able to forecast or give any indication of future development?

The metrics have a great *post mortem* explanatory power. For example, we can assume that the robustiness of the Symbian ecosystem was not top-grade and we could probably identify the point of time when the survival rate started to decrease. However, in that case, the metrics would only be reactive, explaining past incidents. To the best of the authors' knowledge, it has not been studied whether the proposed ecosystem health metrics do actually work in a proactive manner.

3.3 Healthy for whom?

The classic argument, by Iansiti and Levien [23], claims that participants in a healthy ecosystem will flourish while in an unhealthy one, they will suffer. However, as previously discussed, this simple metaphor is not easy to understand or use.

Once again, let us take the case of Apple's iOS / AppStore ecosystem. The ecosystem has produced an ever-growing number of new innovations, businesses and income for the platform owner and its participants. Yet, the question remains, for whom is the Apple's ecosystem healthy?

For example, the Apple ecosystem is clearly healthy from the point of view of Apple, the ecosystem orchestrator, as well as that of a small percentage of all developers who are doing profitable business in the domain [17]. However, for a newcomer in application development, it might be an unhealthy environment as there are hundreds of thousands of rival applications, developers and solutions competing for the same customers. Furthermore, all new innovation ideas are swiftly copied and adapted, usually at a lower price [19]. However, the ecosystem might be considered healthy for the consumers, as there are lots of different alternatives to choose from.

The question 'healthy for whom' adds more complexity to the ecosystem health concept. While Apple's ecosystem is good for a selected few, do all *"individual participants thrive"*, as emphasised in the definition of a healthy ecosystem by Iansiti and Levien [23]?

Furthermore, we could ask how many of the participants should thrive? Figure 1 illustrates two 'satisfaction' distribution. In the first distribution (a), only a few of the participants are highly satisfied and the rest are less satisfied. In the second distribution (b), all participants are less satisfied.

The figure aims to visualise the concept that both models can support healthy and long-living ecosystems. The first model is close to the current situation in Google Play when satisfaction is measured in terms of earnings [17]. The second model characterises, for example, an open-source technological ecosystem where all participants are treated democratically. Thus, presenting health metrics directly without noting for whom and for what the metrics are defined, is a problematic approach.

3.4 Evolution

Our fourth point can be motivated with a classic aphorism:

> *"Everything changes and nothing remains still."*
> – Heraclitus

In other words, another problematic issue with the concept of ecosystem health is a somewhat static view of an ecosystem. The inherent idea seems to be that an ecosystem could reach a stable, healthy level at which it could operate. On the contrary, in business life and even at a philosophical level it could be argued that change is the only constant. Thus, perhaps ecosystem health should be defined from this, emphasising the renewal perspective [e.g. 16, 56].

Furthermore, in Moore's [41, 42] original model of business ecosystems, there are four distinct phases in the ecosystem lifecycle; i) birth, ii) expansion, iii) leadership and iv) self-renewal ordDeath. Moore assumed that competition, the fight for a leadership position and changes are natural parts of the development and life of any business ecosystem.

Therefore, it could be argued that a single actor (a firm) can disappear from the ecosystem or it can be replaced with another actor without damaging the health of that ecosystem. Hence, an important factor for any participant in that ecosystem is the ability to preserve its flexibility and adaptability to changing requirements and needs. In addition, ecosystem health is not based on intelligent design but an emerging, self-constructing evolution. 'Resilience' [5] is the concept that reflects the capability of coping with change and re-organising.

4 PROPOSALS FOR FUTURE WORK

The critique presented above can be summarised in two main points: problems with *the concept* and problems with *the usage*. To overcome the current obstacles, we propose three different approaches to tackle them. The first one aims to either renew or redefine the concept, and the last two proposals focus on improving the usefulness of new metrics.

4.1 Reinventing terminology

Our first proposal for future work is to avoid using only the term 'health' and adopt more concrete, exact terms to explain what aspect or aspects of health — well-being, longevity *etc* — are measured. As discussed above, the term 'health' is complex and more details are needed as to which aspect the proposed metric addresses.

In addition, metaphors borrowed from other disciplines advance our thinking towards issues with the original content. For example, in some discussion, the 'ecosystem' concept has been over-applied, e.g. when searhing for the 'nutrients' of a business ecosystem. The same applies to 'health'. Thus, we should either be more careful in our wording and define our objectives clearly, or invent a new term to illustrate the issue better.

As a concrete step for the future, we propose further papers to discuss and answer the following three simple questions:

- *What* type of characteristic is measured from an ecosystem?
- *How* do the measured characteristics impact on the ecosystem?
- *Why* is it measured?

Finally, as the field of biology is still split on the concept of 'ecosystem health', there might be more fruitful areas to learn from. For example, in the field of geography, there are some proposals for *vitality* metrics of cities and municipalities [30]. These metrics aim to evaluate the well-being and quality of life in a certain geographical area.

While vitality should not be directly transferred from this context to measuring a software ecosystem, this is one of the possible, and hopefully fruitful, ways to renew the software ecosystem health literature.

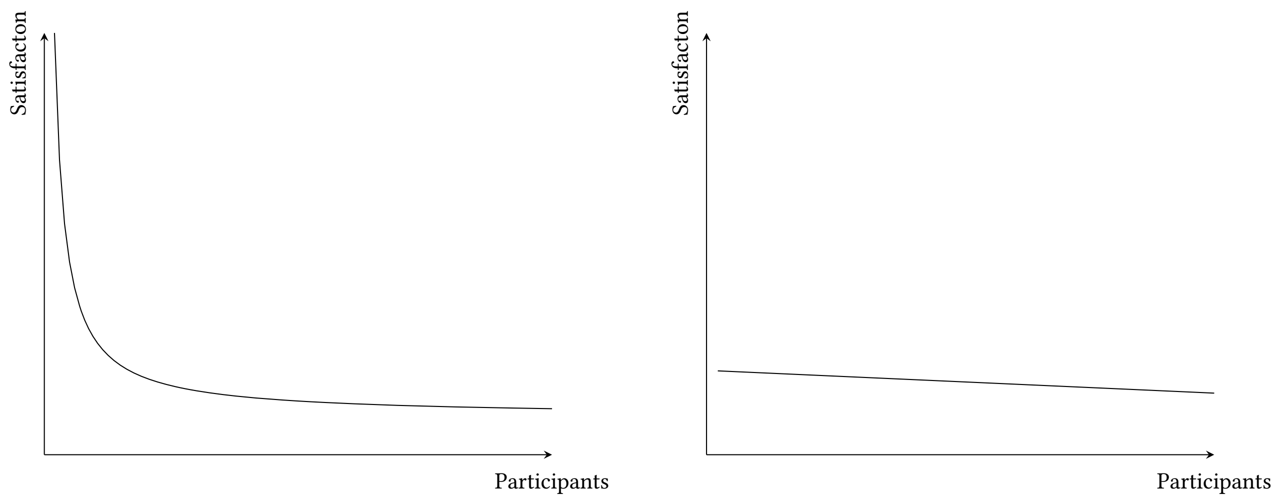
4.2 Focus on sub-types

Our second proposal is for researchers to focus on a certain type of ecosystem, instead of defining metrics for all kinds of software ecosystems. For example, Jansen [25] operationalises health metrics for open-source (technology) software ecosystems. Instead of aiming to create general ecosystem health models — e.g. [21] — case-specific health metrics for a well-defined ecosystem seems to be a more usable approach.

Firstly, the case-specific metrics can be tested and verified against a known case, without the need to raise the abstraction level to all kinds of software ecosystems. In other words, our advice is to bypass the current health measurement frameworks and focus closely on the ecosystem at hand. By identifying why and what aspects are being measured, researchers should focus on studying these aspects and how they reflect the well-being, longevity, activity, *etc.* of an ecosystem.

Secondly, case-specific metrics can be more easily tested against a known case and its competitors in order to see whether the metrics work in a proactive or reactive manner. As discussed previously, this is currently an issue of interest.

Thirdly, it is likely that different kinds of ecosystems have some inherited similarities. Therefore, working metrics for a single kind of ecosystem would, nevertheless, indirectly help to define metrics for other kinds of ecosystems.



(a) (b)

Figure 1: Two distribution of 'satisfaction', sorted from the most satisfied participant to the least satisfied, in ecosystems. [Modified from 17].

4.3 Granularity of analysis

Our last proposal considers the level of analysis. We would argue that, when measuring a system, we should use system-level metrics and characteristics, instead of individual-level measures. The previously discussed lines of code metric works as a simple example: LOC is a metric that focuses on the size of a single product (e.g., a mobile application). When using LOC as a metric at the ecosystem level, all values of different products are aggregated together into a single value. At the ecosystem level, LOC values — or even the size of change since the last timestamp — are simply measuring individual-level characteristics. At the ecosystem level, a more appropriate measure would be e.g. the number of applications or change in the number of applications. This is not a new approach even in the field of software ecosystem [c.f. 13]. Furthermore, similar development has already been seen in macro-level software evolution research [c.f. 8, 15].

The same problem of mixing granularity levels is visible in the discussion of ecosystem health. For example, a healthy ecosystem is rarely defined in the discussion of software ecosystems [21]. Besides, the healthy ecosystem is seen as a tautology for a healthy firm; however, as discussed above, there may be unhealthy and dying firms in an ecosystem whereas the ecosystem itself is still doing well.

Finally, special care should be taken when using metrics to compare two competing ecosystems. In that case, the system-level metrics should be reflecting the reality of the ecosystem rather than the performance of single firms. Furthermore, the metrics should predict some future development of the whole ecosystem, not the fate of single companies. As discussed previously [c.f. 20], participants in software ecosystems are an easily moving population that can quickly decide to abandon the old ecosystem or offer their products and services to all alternative ecosystems.

5 CONCLUSIONS

This discussion reviewed the recent advancements in software ecosystem health research and presented some criticism towards the current approach. The title of this paper refers to cases where a patient is supposed to be completely healthy until a recent incident reveals a serious illness. While this might be true for both human and software ecosystem patients, attention should be paid to developing more proactive tools and metrics to avoid these kinds of incidents with software ecosystems — as has been done in the field of medicine. Thus, this study suggested three proposals for refocusing the ecosystem health literature. Finally, this discussion points out that more work is needed to understand, evaluate and predict the well-being, longevity, activity and vitality of software ecosystems — for both those based on businesses and on those based on technological projects.

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