Guest Editorial: Collaboration and Innovation Dynamics in Software Ecosystems

I. Introduction

OVER the past years, there has been an exponential growth in the number of articles mentioning "ecosystem" as their topic, and among them, ecosystems in the context of information and communication technologies have received particular attention [1]. Much of this research is motivated by the intuition that ecosystems facilitate innovation. Yet, despite this burgeoning research activity accompanied by a flourish of reviews, actual empirical investigations of the collaboration and innovation dynamics in an ecosystem in general and in software ecosystems specifically remain few and far between.

In our previous article [2], we proposed the following concept map (see Fig. 1) for collaboration and innovation in the field of software ecosystems, where we use the following notations.

1) Concepts that stem from an organization-centered view of software ecosystems are represented by nodes with a *rectangular* shape.
2) Concepts related to a project-centered view are represented as *rounded* blocks.
3) The *oval* shape is reserved for an innovation and its driver.
4) The proposed map introduces *new* concepts that have not been explicitly put forward by the two baseline/reference studies. These have a *white background* and an *italic* font.
5) Similarly, the links that have been added to the two existing frameworks are represented by *dashed lines*.
6) Links between software ecosystem concepts and innovation are in boldface, where they have been established in either study.

The left part of the map in Fig. 1 represents the long-term and organization-centric perspective, originally developed with regards to embedded software ecosystems (SECOs [3]). The right part of the map represents instead the medium-term and project-centric perspective, which was originally developed to describe open source software ecosystems (OSSECOs [4]).

Both perspectives contain concepts that are closely related. We have indicated some of these associations with dotted lines. Also, we have added additional concepts, which we feel are of particular use for explaining short-term variations in innovation dynamics.

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II. Papers Included in the Special Section

We received ten high-quality submissions, which were then rigorously peer-reviewed over three rounds. We finally accepted the following five papers that not only satisfied our reviewers, but also covered a broad spectrum of topics related to collaboration and innovation in software ecosystems.

1) In [A1], Spagnoletti et al. discussed a longitudinal case study of a large telecommunication equipment supplier, and how Agile practices, which are typical for small development teams, have helped it achieve agility at the organizational level. The case study presented was embedded in an ecosystem of 200 customers and hundreds of countries, and it was characterized by the emergence of disruptive technologies (e.g., cloud and 5G). Using a collection of primary and secondary data, the paper identified four "tensions" emerging in R&D operations as follows.
   a) Self-organizing versus control.
   b) Flexibility versus integrity.
   c) Product versus document delivery.
   d) Radical versus incremental change.

   These tensions must be managed by an organization by practices (and the authors reported ten of them) that enable four agile-driven organization-wide capabilities as follows.
   a) Management control.
   b) Organizational improvisation.
   c) Knowledge and communication.
   d) Organizational learning.

   The paper highlighted the importance of those capabilities, in the context of the practices of agile teams, as well as agile management, to resolve the tensions arising in R&D operations.
2) In [A2], Capilla et al. introduced for the first time the terminology around dynamic ecosystem (DECO), or autonomous dynamic ecosystem platforms, acknowledging the challenges that critical software applications face in being "continuously updated, reconfigured, and redeployed," especially when considering different domains. The vision of DECO platforms is to be grounded in a strong level of automation for data exchange and dynamic collaboration. The paper provided evidence that DECO systems exist and have attributes that set them apart from other SECO systems. In addition, they reported on four case studies and showed that dynamic operations handled by a DECO

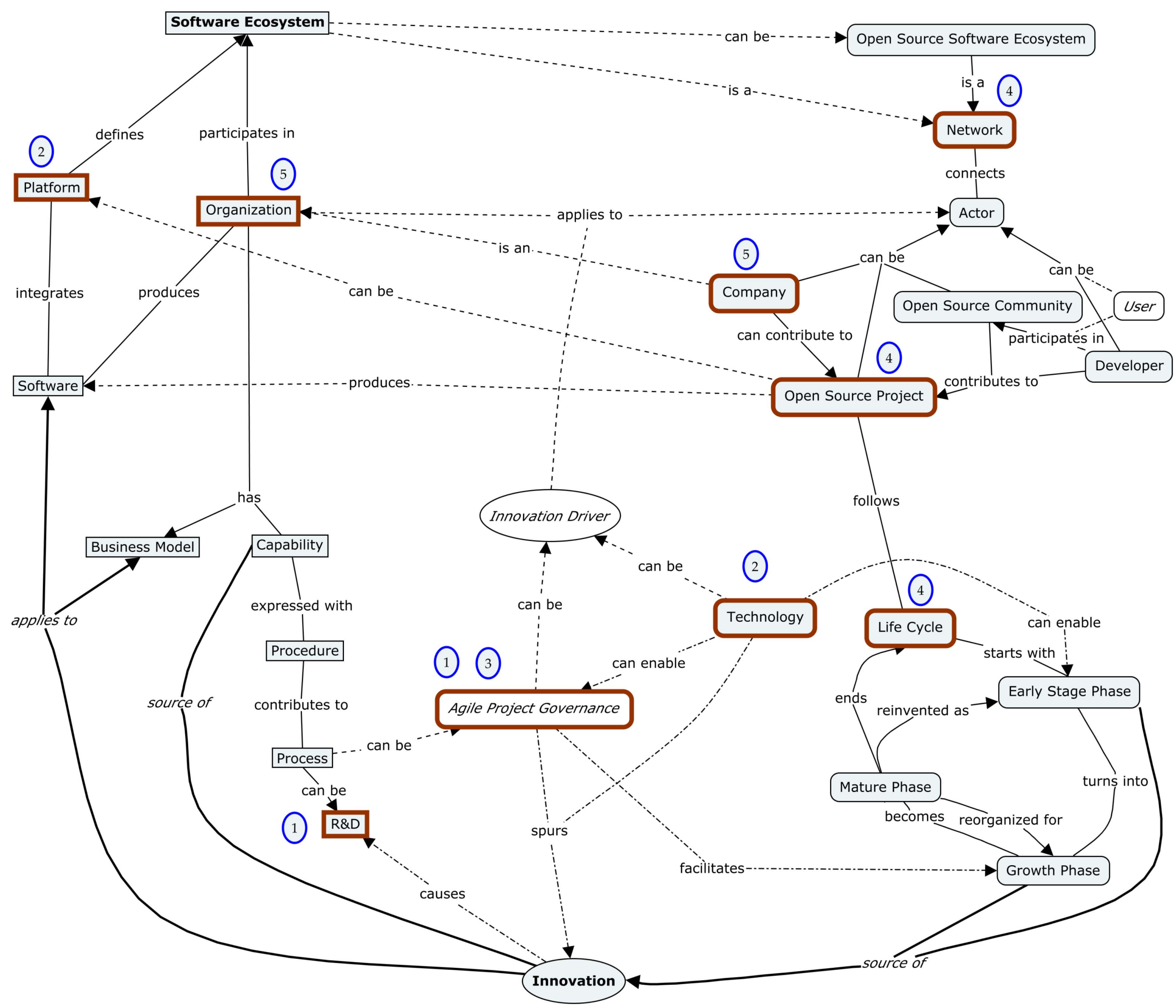

Fig. 1. Face of innovation: Concept map depicting how software ecosystems can bring about innovation (based on [2]). We have added numbers representing the papers accepted in the Special Issue, where the numbers 1–5 represent the articles [A1], [A2], [A3], [A4], and [A5], respectively, in that order. The highlighted concepts are those that are used in the article(s) referred to.

require both adequate software support and trustable data exchange information models.

3) In [A3], Costa et al. chose to focus on proprietary SECOs, that is, the focus on ecosystems in a closed environment. The following two activities that they reported on in their paper are as follows.
   a) A participative case study within a large international organization, which owns a proprietary SECO.
   b) An opinion survey (in the form of a questionnaire) to monitor which level of perception the participants have on the governance strategies of SECO's mechanisms.

The results of the first analysis showed that most of the governance strategies are aimed at obtaining competitive advantage over competitors, in the forms of knowledge management, software assets quality, and investment in innovative solutions. As part of the results of the second activity, they reported that, as an outcome of the survey, the interviewees felt encouraged to use new guidelines, standards, and processes as key factors to generate value for the organization.

4) In [A4], Mujahid et al. considered software projects and the ecosystems containing them, from the point of view of their interdependencies. Project-to-project or project-to-library links have the potential of breaking the functionalities of one or many projects at the same time, once one of the dependencies become obsolete and unreliable; in some cases, developers might not even be able to replace them with an alternative. The paper reported on an attempt to detect the state of obsolescence of a dependency, starting from its development traces. The challenge is to detect that a package has become unstable or obsolete "early enough" and to issue warnings regarding which packages appear in decline. The paper achieved relevant results, indicating the obsolescence of a package up to 18 months before its actual phase out. A tool has also been made available for extension, replication, and inspection.

5) Finally, in [A5], Wei et al. performed a qualitative analysis of complementors and types of exploitative and/or explorative innovation that might benefit an ecosystem of

software companies. The paper focused on five collaborative links (i.e., firm–academic institution collaboration, firm–firm collaboration, firm–user collaboration, firm–intermediary collaboration, and firm–government collaboration), as well as the exploitation and exploration factors as part of a model that produces higher or lower levels of innovation performance as an outcome. The combination of these factors produces four scenarios or configurations that are available to software firms regarding innovation paths and in order to achieve a high innovation performance in SECOs. Another important aspect of these configurations is that they might be dynamically adapted and adopted by a software firm (for example, shifting from "exploitation" to "ambidexterity" configuration). This allows a software company to dynamically collaborate with complementors, but also to flexibly perform innovation activities and later to adapt to another configuration when the market conditions change.

III. Discussion and Conclusion

We now revisit our previous map in Fig. 1 from [2] to see which concepts were covered by the abovementioned articles in our Special Section. The concepts used are in boldface, and next to the concepts, we see the article numbers (based on the abovementioned list numbers) that incorporated the concepts in their research. As is apparent from Fig. 1, the five articles published in this Special Session provide quite a good coverage of the mapped concepts.

To fully appreciate the contributions of the papers in this Special Section, it is important to distinguish the levels of analysis at which the research was carried out. Ecosystems are fractal by nature, in the sense that a software ecosystem is part of a larger business ecosystem while at the same time encompassing lower level ecosystems at the level of individual software projects [5]. A recent alternative attempt to represent the causal links between elements of the "digital platform ecosystems" identifies six units of analysis within two layers [6]. In the interest of parsimony, it may be sufficient to distinguish between studies, such as [A1], [A3], and [A5], which focus on actors as the unit of analysis, and studies, such as [A2] and [A4], which focus on the digital artifacts that facilitate the actors' activities within an ecosystem. Within these two groups, the studies address the following two types of research questions [5].

1) How does an innovation as a whole emerge from the interactions of the actors in the ecosystem [A2], [A3], [A5]?
2) How does an innovation in a higher level ecosystem emerge from the innovations in lower level ecosystems [A1], [A4]?

Thus, this Special Section provides insights into how the interactions and tasks for innovation can be supported in ecosystems of varying scales.

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Appendix
Related Works

[A1] P. Spagnoletti, N. Kazemargi, and A. Prencipe, "Agile practices and organizational agility in software ecosystems," *IEEE Trans. Eng. Manag.*, early access, Sep. 24, 2021, doi: 10.1109/TEM.2021.3110105.

[A2] R. Capilla, E. Cioroaica, B. Buhnova, and J. Bosch, "On autonomous dynamic software ecosystems," *IEEE Trans. Eng. Manag.*, early access, Oct. 27, 2021, doi: 10.1109/TEM.2021.3116873.

[A3] L. A. Costa, A. Fontão, and R. Santos, "Toward proprietary software ecosystem governance strategies based on health metrics," *IEEE Trans. Eng. Manag.*, early access, Oct. 21, 2021, doi: 10.1109/TEM.2021.3116531.

[A4] S. Mujahid, D. E. Costa, R. Abdalkareem, E. Shihab, M. A. Saied, and B. Adams, "Toward using package centrality trend to identify packages in decline," *IEEE Trans. Eng. Manag.*, early access, Dec. 1, 2021, doi: 10.1109/TEM.2021.3122012.

[A5] F. Wei, N. Feng, R. D. Evans, R. Zhao, and S. Yang, "How do innovation types and collaborative modes drive firm performance? An FsQCA analysis based on evidence from software ecosystems," *IEEE Trans. Eng. Manag.*, early access, Sep. 14, 2021, doi: 10.1109/TEM.2021.3102321.

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[3] E. Papatheocharous, J. Andersson, and J. Axelsson, "Ecosystems and open innovation for embedded systems: A systematic mapping study," in *Software Business*(ser. Lecture notes in business information processing), J. M. Fernandes, R. J. Machado, and K. Wnuk, Eds., Cham, Switzerland: Springer, 2015, pp. 81–95.

[4] N. Jullien, K.-J. Stol, and J. D. Herbsleb, "A preliminary theory for open-source ecosystem microeconomics," in *Towards Engineering Free/Libre Open Source Software (FLOSS) Ecosystems for Impact and Sustainability: Communications of NII Shonan Meetings*, B. Fitzgerald, A. Mockus, and M. Zhou, Eds. Singapore: Springer, 2019, pp. 49–68.

[5] P. Wang, "Connecting the parts with the whole: Toward an information ecology theory of digital innovation ecosystems," *Manage. Inf. Syst. Quart.*, vol. 45, no. 1, pp. 397–422, Mar. 2021.

[6] R. Floetgen, M. Novotny, F. Urmetzer, and M. Böhm, "Connecting the dots of digital platform ecosystem research: Constructs, causal links and future research," in *Proc. ECIS Res. Papers*, Jun. 2021. [Online]. Available: https://aisel.aisnet.org/ecis2021_rp/53

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