New Challenges in the Social Web: Towards Systems-of-Information Systems Ecosystems

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Abstract. Software vendors are currently concerned to the development of software-intensive Information Systems (IS) that interoperate among them, especially in the web and mobile platforms. This phenomenon has raised the concept of System-of-Information Systems (SoIS), which is a set of interoperable ISs that exchange data and services to achieve some major business goal. The scientific community has explored human interaction, interface design and system development through a growing theoretical and applied research, pointing out sociotechnical challenges in the social web. Since new types of sociotechnical relations can be established to increase gains and productivity in this context, considering technical, business and social dimensions, software ecosystems (SECO) emerge from those SoIS. We claim that the SECO perspective can foster the comprehension about SoIS by exploring the existing relations among constituent ISs within a SoIS as well as the nature of such relations and the human aspects of those systems. Thus, the aim of this paper is to introduce the concept of System-of-Information Systems Ecosystems (EcoSoIS) based on the existing background on IS, SoIS, and SECO, and how the Social Web and Interaction paradigms fit in this context.

Keywords: Systems-of-Information Systems, Systems-of-Systems, Software Ecosystems, Human Factors, Information Systems.

1 Introduction

Software vendors are currently concerned to the development of software-intensive Information Systems (IS), i.e., systems that can automate a set of business processes of their customers [10]. Recently, those ISs have been demanded to support a high-level of interoperability due to the dynamics of new open, collaborative business scenarios. One remarkable branch of IS software development is the Social Web, where social IS software such as Facebook and Instagram not only support social interaction, but also play the role of platforms for marketing and purchases, besides interoperability with several IS platforms. Therefore, this type of IS must be designed to support

interoperability, creating more complex business processes, and opening up new business chains [13] [16]. This phenomenon has raised the concept of System-of-Information Systems (SoIS), i.e., a set of interoperable ISs (termed in this context as constituent systems) that exchange data and services to achieve some major business goal [2] [3]. SoIS can be highly dynamic, enabling new constituents to join (or leave) the SoIS to contribute with their specific functionalities in order to achieve more complex behaviors.

As such, relations among interoperable IS are of utmost importance as novel businesses can be created and sustained, while other businesses can generate more value if those relations are better investigated and understood [6] [7]. New relations can also be established to increase gains and productivity considering technical, business and social dimensions. In turn, an entire business domain can be damaged or eliminated due to harmful business relations among ISs. This scenario requires new views on how to understand, describe and analyze the relations among such systems, bringing to light the vision of the new ecosystems that can surround them.

The concept of Software Ecosystem (SECO) has helped researchers and practitioners to model and analyze several existing relations among software elements that compose a technological platform, as well as their internal and external actors, such as Apple SECO or Eclipse SECO [14]. They are important as they enable to predict how to obtain value, return on investment, and how relations between distinct products can be beneficial or harmful for the business progress in IS development [15]. In this context, the platform of an ecosystem can be seen as a broker that supports a social web based on interaction among organizations, developers and users.

We claim that SECO can foster the comprehension about SoIS by exploring the existing relations among IS constituents within a SoIS as well as the nature of such relations. This concern may raise the concept of System-of-Information Systems Ecosystems (EcoSoIS), i.e., a SECO that involves the development and interoperable activity within a set of ISs working together to support business and social goals. This new scenario is worth to be investigated since new IS relations can benefit/harm an organization that delivers products and services, and whose clients can combine those assets to cooperatively work together to achieve a bigger business value [17].

In another perspective, the scientific community has explored human interaction, interface design and system development through a growing theoretical and applied research, pointing out sociotechnical challenges in the social web. However, these new arrangements of highly dynamic SoIS and interoperable IS playing roles in a SECO impose new challenges for interaction design, which must deal with functionalities that are available only while specific constituents are part of such SoIS. As such, they present all the information regarding SoIS constituents considering usability and accessibility principles, and other human-computer interaction issues.

In this paper, we introduce the concept of EcoSoIS based on the existing background on IS, SoIS, and SECO. We also present a discussion on the importance of such view as a research topic in the interdisciplinary research on IS development, human interaction and social web trends. Our main contribution is to explore how SECO perspective can help us to identify elements that affect SoIS as well as to come up with a research agenda, and to discuss interaction design under EcoSoIS perspective. This paper is organized as follows: Section 2 presents the foundations of IS, SoIS and SECO as the basis for proposing the concept of EcoSoIS in Section 3, in-

cluding a seminal discussion on how social and human interaction aspects fit EcoSoIS research topic; Section 4 summarizes a research agenda; finally, Section 5 concludes the paper with final remarks.

2 Background

This section introduces the main concepts that help us to define the object in which we are working on this paper.

2.1 Information Systems

According to the General Systems Theory (GTS) [11], systems are a set of elements dynamically interrelated to perform activities aiming at achieving a specific goal, while consuming energy, materials or data (input) and producing new forms of energy, materials or data (output). The concept of system has been useful to describe and understand the behavior of complex structures in many different knowledge domains - from Biology to Social Sciences, and particularly in IS area.

An Information System (IS) is a set of interrelated components that collect (or retrieve), process, store and distribute information [13]. The use of a mural on an organization wall, where different people share information, can be understood as an IS composed by humans and objects (the mural) from which information can be processed, published, retrieved and deleted to cope with the organizational goal of communicating relevant things. Especially in the web and mobile eras, IS research practice are facing challenges, e.g., how to establish and control ISs' borders and how to govern the software supply network formed over them considering the social web environment.

Conceptually, IS may also comprise software or other computer technology as one of its elements (computer-based or software-intensive IS). Therefore, the use of an organization's information portal – where people report and share news and information using their smartphones with the aim of establishing communication – is also an IS. Very often, the term 'information system' is used to specifically refer to software that processes information for a set of users. These IS are often known as computer-based or ***software-intensive IS***. This is correct if we consider that software is composed by interrelated parts (modules, functions etc.) with the aim of processing information. However, one should not restrict his understanding of IS to the software element. Henceforth, we consider software-intensive IS and IS as interchangeable terms.

Back to the GTS [11], systems exist inside other systems (they vary in hierarchy and complexity); they are usually open (they interact with the environment in which they are inserted in and learn with this interaction); their operation depends on their internal structure (the relationship performed by their elements); and they exhibit rules that help them to balance and regulate their operation (they try to avoid variations that will harm their operation or they are able to change and adapt to new balanced situations). Systems behavior can be predictable and descriptive (e.g., computers) or unpredictable, complex and difficult to be described (e.g., social or economic systems).

2.2 Systems-of-Information Systems

Systems can be combined to form what is termed Systems-of-Systems (SoS). SoS are alliances of independent systems (i.e., constituents) that are combined to interoperate and achieve some more complex behavior. Such behavior could not be obtained from those independent systems working separately [1]. SoS share a set of well-defined characteristics [1] [16]: (i) managerial independence of constituents, i.e., constituents are owned and managed by distinct organizations and stakeholders; (ii) operational independence of constituents, as constituents also perform their own activities, even when they are not contributing to the accomplishment of one of the SoS' functionalities; (iii) distribution, i.e., constituents require a network technology to communicate among themselves; (iv) evolutionary development, as SoS evolve due to the evolution of its constituents parts; and (v) emergent behavior, which corresponds to complex functionalities that arise from the interoperability among constituents.

Moreover, SoS should exhibit an opportunist nature, i.e., a system should be able to join other systems to form a SoS that accomplishes a mission, leaving the SoS when the mission finishes. Dynamic architecture has also been considered a remarkable SoS characteristic. In the context of the social web and human aspects research, SoS is still barely explored as methods, techniques and tools largely focus on the technical aspects. However, organizational aspects emerge, for example, how developers and users interact with those complex systems in order to accomplish their missions and how the social web environment can aid those stakeholders to communicate and collaborate in order to evolve such systems with new requirements [18].

Systems-of-Information Systems (SoIS) are a particular type of SoS composed by ISs [22]. SoIS have emerged due to the increasing trend of cooperation between distinct companies, combining efforts by offering more complex functionalities as a combination of their own IS [2] [3]. A SoIS is dynamically generated through the alliances among other software-intensive IS products, interoperating to create value to their owners and to new clients that benefit from their resulting partnership. Examples of this trend include Virtual Organizations, which comprise several distinct organizations that spontaneously get together over a social web environment, working cooperatively (including their software-intensive ISs) in the context of a specific project, leaving it in the next moment. Movements such as Clean Web[1], in which social network software and information technology are articulated to solve issues related to natural resources constraints, also represent trends in SoIS research and practice [16].

2.3 Software Ecosystems

Software vendors co-evolve their market capabilities around innovation: they work cooperatively and competitively to support and to develop new products, to satisfy customer needs and to innovate continuously [4]. These tight networks of suppliers, distributors, outsourcing companies, developers of related products or services, technology providers, and a plethora of other organizations affect and are affected by the creation and delivery of software vendor's products and services. Aligned to this

[1] http://goo.gl/5oZjss

viewpoint, researchers have coined a new perspective to analyze the software industry, known as Software Ecosystems (SECOs) [6] [7].

SECO is an effective way to construct software on top of a common technological platform (e.g., operating system, application, software asset base etc.), by composing applications and technologies developed by multiple actors (i.e., third-party developers, communities and organizations) [16]. Moreover, a SECO comprises a foundation technology or set of components used beyond a single firm which brings multiple parties together for a common business/development purpose or to solve a common problem. In this context, the ecosystem platform can be seen as a broker that supports a social web based on the interaction among organizations, developers and users.

Pragmatically speaking, we can conjecture that a SECO is formed by a *software platform* and a *community* [23]. Such platform is composed of many *artifacts*, which can be *products* or *services*. In turn, a community is formed by (1) *hubs*, i.e., main agents in a SECO (e.g., leading organizations that polarize a SECO), and (2) *niche players*, i.e., all stakeholders who collectively affect a SECO from individual actions onto the platform (e.g., each of them can influence, commit to, contribute to, promote, or extend the platform). Both types of central players in a SECO are associated to a role (e.g., keystone, developers, reseller, end-user etc.).

This common technological platform can originate software products that cooperate and/or compete in the market, or even other relations can be drawn among them. SECO is also characterized by both software production and consumption relations. These relations can be established with third-party developers, communities and/or other organizations to foster components development, supply and evolution in a large ecosystem created over the common technological platform. Examples of SECO include Microsoft SECO, iPhone SECO and Drupal SECO [5]. Additionally, a SECO can be part of another SECO, e.g., Microsoft CRM SECO is part of Microsoft SECO.

In the social and business perspectives, a SECO provides a complementary, organizational view to SoS development, which defines roles, rules of interaction, collaboration and synergistic capabilities for its constituent systems. There exist many similarities between SoS characteristics [9] and SECO technical challenges [15], e.g., how to ensure platform stability, simplicity, security, reliability, and evolution. In this sense, we can conjecture that SECO and SoIS may also hold intrinsic and synergistic relations that can be explored. We discuss this perspective in the next section.

3 Systems-of-Information Systems Ecosystems

Noticeably, SoIS has a strong business nature and its constituents' development becomes business-driven [2] [3]. One of the challenges is to cope with the complexity of describing, developing and operating SoIS as well as the ecosystem that emerge from it, considering its intrinsic attributes – structure, complexity, openness, need for balance and regulation, and different levels of behavior predictability – and achieving its desired business goals. Moreover, the diversity and amount of stakeholders' relationships mainly supported by a social web environment come up as a critical concern for both organizations and customers.

Due to its nature, a SoIS can hold an entire business, involving suppliers, clients, partners and technological platforms that act as an entire main 'technology' that sup-

ports that business. Then, we glimpse that the association among distinct software-intensive ISs creates a major/new SECO comprising the emergent behavior resulting from the association of their different business goals into a new and common one – a System-of-Information Systems Ecosystem (EcoSoIS[2]).

Figure 1 illustrates our understanding about EcoSoIS. Interoperability links among diverse ISs are established to create novel functionalities and to explore or create business opportunities. This happens due to inter-organizational alliances and cooperation. This joint set of ISs raises a SoIS at a technical level. We suppose that each organization that composes this 'consortium' owns a different IS platform. However, SoIS only deals with the technical aspects. Other remarkable elements, such as business goals, players, agents, value chains and production/consume relations – which are inherent elements in a SECO – are not covered by the SoIS technical dimension. As a result, business and social dimensions emerge, creating by definition a SECO that involves the interoperable ISs that are included in a SoIS context. As shown in Figure 1, a SECO can emerge (or not) from an IS that forms a SoIS, e.g., SECOs emerge from IS1 and IS3. However, the EcoSoIS is formed by the relations established with the SECOs and with the ISs themselves.

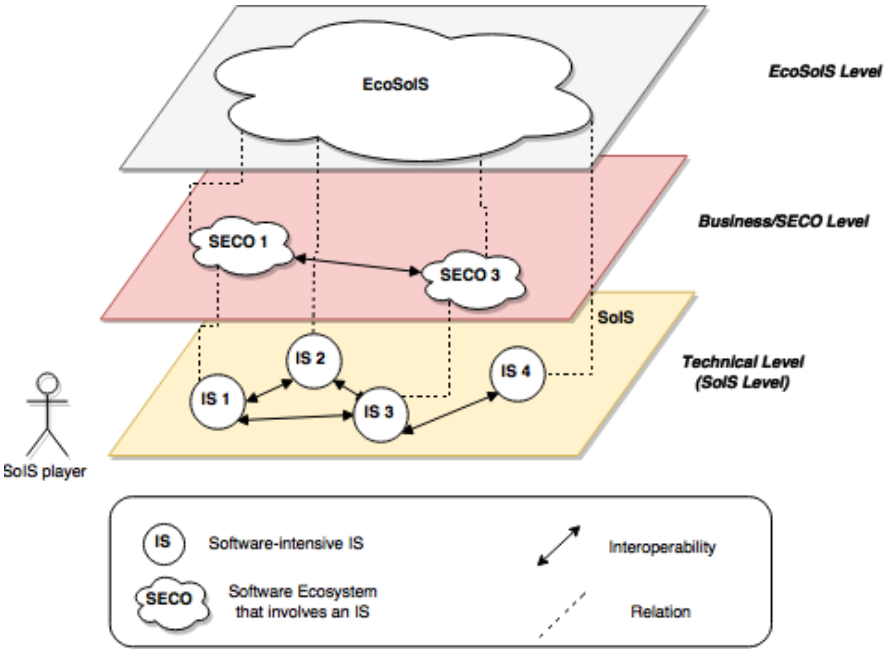

Fig 1. A conceptual illustration of an EcoSoIS.

Rewriting the view presented in Santos et al. [23], an EcoSoIS is formed by a *software platform* (the set of interoperable IS that form the underlying SoIS) and a *com-*

[2] Henceforth, EcoSoIS will be used interchangeably to express singular and plural forms, i.e., "System-of-Information Systems Ecosystems" and "Systems-of-Information Systems Ecosystems".

munity. Such platform is composed of many IS *constituents*, which can offer *products* or *services*, establishing new business links among the involved companies and enabling new functionalities to address new business opportunities. Such community is formed by (1) *hubs*, i.e., main agents in a SECO (e.g., leading organizations that polarize a SECO), and (2) *niche players*, i.e., all stakeholders who collectively affect a SECO from individual actions onto the platform (e.g., each of them can influence, commit to, contribute to, promote, or extend the platform). Both types of central players in a SECO are associated to a *role* (e.g., keystone, developers, reseller, end-user etc.). Under the perspective presented in Figure 1, for simplicity, we have a 1:1 relation, i.e., one SECO emerges from one and only one IS. However, we do not discard the possibilities that one SECO can be formed by multiple ISs.

This phenomenon creates an entire SECO that surrounds the entire SoIS and involves other inner SECOs that are inserted in that context. Thus, we have envisioned a EcoSoIS (or SoIS SECO), i.e., a SECO the surrounds the inner SECOs that can be associated with some of the constituent ISs that composes a SoIS, besides the value chains, players, business goals and agents that emerge from the interoperability between several ISs that compose a SoIS. Regarding the presence of the 'human element' within the EcoSoIS, an actor appears as a SoIS player (or even a customer) that interacts with the system through its constituents (i.e., SoIS interaction borders) or performs a role in the business process that supports the SoIS mission.

One example for exercising the EcoSoIS perspective lies on the domain of government and electronic democracy [12]. Public institutions have different IS and databases that need to be integrated so as to provide effective services to citizens (e.g., civil identification IS should be integrated with the police department IS and/or the public health system). Additionally, each distinct IS in this context may be maintained within a specific SECO involving vendors, developers, legislation, auditors, citizens etc. Their relationships vary depending on the diversity of business needs, i.e., new procedures or changes in legislation.

Demands for transparency and accountability put a different agent in this ecosystem: the citizen/society, particularly those able to develop their own applications using open data provided by public institutions by force of law. IS developed by individuals or group of individuals are a new SECO in this EcoSoIS, pushing the previous ecosystem to new behavior, results and innovation. Looking this scene from the perspective of EcoSoIS might help to develop a broader view of this ecosystem arrangements, business potential, emergent behavior, and innovation.

Another example of EcoSoIS in the domain of collaborative software engineering is the Brazilian Public Software Portal (BSP Portal) [19]. Public institutions and national organizations often acquire off-the-shelf and/or tailored ISs from international suppliers, sometimes making the satisfaction of stakeholders' needs harder. As a Brazilian initiative supported by the Ministry of Planning, BSP Portal serves as a public software catalog and a social web platform to help development communities to specify, build and evolve national software projects, mostly aiming at creating ISs.

Similarly to the previous example, such ISs should interoperate since different development communities are developing software that should communicate with public administration business processes and ISs, forming a SoIS. Each IS is supported by a community of developers and users, forming different ecosystems that sometimes share information, resources and artifacts. In the macro level (EcoSoIS), SPB Portal

adopts some strategies such as: stimulate self-managed communities, attract new actors, keep open for new partnerships, create behavior and technical patterns to sustain the ecosystem, and focus on collective intelligence for software development.

Finally, we can claim that **social and human interaction in EcoSoIS** is worth to be investigated [20]. Human aspects comprise a crosscutting concern in EcoSoIS as the 'human element' is a pivotal aspect to the interaction supported by the ecosystem network. In turn, the social web environment is a very important element to support coordination, collaboration and communication among all the stakeholders. A forthcoming work shall discuss other challenges in a more deep way. One social and human factor refers to the diversity of organizations and relations within a SECO. Such diversity requires special attention to the interaction means in order to sustain the EcoSoIS platform and keep stakeholders engaged and motivated. For example, how to identify stakeholders' capabilities and limitations in their relationships? How do stakeholders relate themselves based on the EcoSoIS's technologies? In the SECO research, such relationships have been investigated through the social network analysis [21]. The EcoSoIS manager (i.e., an organization that plays as a hub) should stimulate participation of external actors, SoISs' adoption by the community, and content/ experience sharing – other relevant factors for EcoSoIS. Global software reuse, hybrid business models (neither open nor closed), requirements engineering considering the crowd over the social web environment surrounding the EcoSoIS, transparency and modular design are also factors to be investigated and carefully taken into account.

4 Research Opportunities for EcoSoIS

The relations between SoS and SECO have been already proposed as a recent investigation topic [8] [9]. The association between SoIS and SECO raises a new research branch and opens new perspectives of investigation for a topic in the interdisciplinary research on IS development, human interaction and social web trends. Given that, we list some research challenges that we envisioned comprising EcoSoIS, as follows:

Human-Computer Interaction (HCI) in EcoSoIS. Human issues are crosscutting concerns in EcoSoIS. Social networks play a significant role in some types of EcoSoIS, since they can influence results achieved by becoming elements that influence the decisions of their users. On the other hand, social networks can also play the role of constituents in a SoIS. The phenomena derived from these new relations need to be investigated as future work branches. Furthermore, when dealing with EcoSoIS, interaction design must cope with (i) a larger amount of information related to the diversity of constituents to be displayed to users, (ii) presentation of constituents' functionalities as well as global behaviors offered by the entire SoIS, and (iii) accessibility and usability, considering the multitude of constituents that can be involved in such ecosystem – such issues are also worth of being investigated in EcoSoIS context.

Social Web and EcoSoIS. The Social Web is a prominent platform on which several businesses have been established. Indeed, social software has been employed to sustain marketing and purchases. We need to investigate how the Social Web can foster even more the establishment of new business chains among interoperable IS that form

a SoIS. As such, the SECO that surrounds such SoIS elements must also be investigated, culminating in a research opportunity that fills the gap between Social Web and EcoSoIS. Studies related to the basic types of relationship identified in the ecosystem (i.e., mutualism, competition/antagonism, neutralism, amensalism and parasitism) can aid researchers and practitioners to design and understand HCI applied to the platforms involved in an EcoSoIS.

Reference Architectures for EcoSoIS. Reference architectures comprise an abstract specification of a family of similar architectures, with documentation of their similarities, variabilities, and inherent properties [24] [25]. One single IS can occasionally originate a surrounding SECO. This can be born due to new commercial partners, business expansion, or market pressure. A single SECO has its own relations, such as competition or predation. A reference architecture can be established for such single SECO, modeling software/business properties and constraints, such as promised/ obtained advantages (e.g., access to private organizational databases whose data may be valuable to the business of a third party). However, when we think about EcoSoIS, we not only consider the inherent relations that exist inside a SECO that emerges from one or more IS, but we need to consider all the relations between the interoperable IS of such SoIS, as well as the possible competing ecological relations existing when we consider the entire SECO that emerge from the SoIS. Hence, we claim that modeling architectures and reference architectures for EcoSoIS is even more complex than for SECO, and comprises an important challenge.

Innovation with EcoSoIS. We claim that a single SECO, by itself, does not support innovation in the broad meaning of the word. A SECO that emerges from a single IS can exploit commercial relations, and from the variabilities eventually available in the single IS in which such SECO is based on. However, it is not possible, for example, to design novel functionalities as an arrangement of constituents' functionalities, as performed in the context of a SoIS at runtime. As such, the potential for innovation of a EcoSoIS seems to be more expressive than a single SECO. New businesses can come up from exploring existing relationships within a SoIS. Strategies should be drawn on how to recognize innovation opportunities within an EcoSoIS, as well as how to foster the emergence of innovation opportunities derived from a SoIS creation. Co-innovation is also an important issue to be handled in EcoSoIS, i.e., how to create new functionalities and tools upon the SECO platform aided by the community's members. Finally, open innovation should be directly considered in EcoSoIS, i.e., innovations no longer arise from an organization and depend on contributions from external actors (i.e., third-party developers, customers and users). Social web data mining and analysis could support ecosystem maintenance and evolution.

Emerging Requirements in EcoSoIS. In an EcoSoIS context, different requirements communication and management networks are produced and should be maintained over time by the different constituents that compose such SoIS (a context not present in a single SECO). New requirements can emerge from the interplay of a considerable number of stakeholders due to opportunities raised by combination of resources, and their commercial/technical products and platforms. As such, how to identify and man-

age emerging requirements from internal and external actors is a great challenge for EcoSoIS development.

EcoSoIS Governance. Information on software capabilities and market reports are not so useful when analyzed as the only support for SECO management decisions, without data from the organization's asset base (i.e., catalog of software and ISs) due to the lack of governance. Therefore, it is important to explore how to select the best strategies for survival in any ecosystem as a developer, a community, or an organization. An interesting question refers to how actors can achieve and maintain a healthy position in a EcoSoIS, i.e., how sustainable the EcoSoIS platform is over inherent changes, such as technology obsolescence or business evolution, not only pressured by politics and the need of one single SECO, but also from an entire set of multiple SECOs that impose different (and maybe conflicting or competing) interests. Governance must balance all these factors coming from EcoSoIS.

5 Final Remarks

We are living in a more and more open, connected world, uncovering new opportunities both to business innovation in organizations and to the empowerment of individuals, with more autonomy and satisfaction [13]. This brings challenges to the interdisciplinary research on IS development, human interaction and social web trends, since new types of ISs must be approached, such as how to understand, describe, model, build, and manage ISs to face the complexity of building new systems that are not closed artifacts anymore, but a set connected interoperable IS forming an entire new ecosystem, with emerging and unpredictable behavior. In this context, the ecosystem platform can be seen as a broker that supports a social web based on interaction among organizations, developers and users, so that human aspects are strongly relevant to the design and development of those systems.

In this paper, we introduced the concept of EcoSoIS based on the existing background on IS, SoIS, and SECO. Our main contribution is to explore how the SECO perspectives can help us to identify elements that affect SoIS as well as to come up with a research agenda and implications for human interaction and social web. We concluded that traditional approaches for IS development needs to consider not only the organizational contexts but also the broader ecosystems that includes organizations, individuals, and technologies. In other words, human, technical and organizational factors that affect SECOs from the perspective of social web, human interaction and computational system development affect the emerging EcoSoISs. As a research agenda, challenges related to HCI, social web, reference architectures, innovation, emerging requirements, and governance were pointed out. As future work, we intend to conduct a survey with experts on the related topics in order to refine the concept of EcoSoIS, as well as to expand the research agenda.

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References

1. Maier, M. W. Architecting principles for systems-of-systems. Systems Engineering 1(4):267-284 (1996).
2. Majd, S., Marie-Hélène, A., Alok, M. An Architectural Model for System of Information Systems. In Ciuciu I. et al. (eds.). On the Move to Meaningful Internet Systems: OTM 2015 Workshops. Lecture Notes in Computer Science, vol. 9416. Springer, Cham (2015).
3. Saleh, M., Abel, M. H. Information Systems: Towards a System of Information Systems. In Proceedings of the KMIS 2015 7th International Conference on Knowledge Management and Information Sharing, Lisbonne, Portugal, vol. 3, pp. 193-200 (2015).
4. Moore, J. F. The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems. Harper Business (1996).
5. Santos, R. P., Werner, C., Barbosa, O., Alves, C. Software Ecosystems: Trends and Impacts on Software Engineering. In Proceedings of the 26th Brazilian Symposium on Software Engineering, Natal, Brazil, pp. 206-210 (2012).
6. Jansen, S., Finkelstein, A., Brinkkemper, S. A Sense of Community: A Research Agenda for Software Ecosystems. In Proceedings of the 31st International Conference on Software Engineering, Vancouver, Canada, pp. 187-190 (2009).
7. Gawer, A., Cusumano, M. A. Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation. Harvard Business School Press (2002).
8. Jeronimo Junior, H., Werner, C. A Systematic Mapping on the Relations between Systems-of-Systems and Software Ecosystems. In Proceedings of the CBSoft 2015 – IX Workshop on Distributed Software Development, Software Ecosystems and Systems-of-Systems, Belo Horizonte, Brazil, pp. 65-72 (2015).
9. Santos, R. P., Gonçalves, M., Nakagawa, E. Y., Werner, C. On the Relations between Systems-of-Systems and Software Ecosystems. In Proceedings of the CBSoft 2014 – VIII Workshop on Distributed Software Development, Software Ecosystems and Systems-of-Systems, Maceió, Brazil, pp. 58-62 (2014).
10. Laudon, K. C., Laudon, J. P. Management Information Systems. Pearson Education (2016).
11. Bertalanffy, L. V. General System Theory: Foundations, Development, Applications. George Braziller Inc. (2015).
12. Araujo, R. M., Cappelli, C., Diirr, B., Engiel, P., Tavares, R. L. Democracia Eletrônica. In: Mariano Pimentel, Hugo Fuks. (Org.). Sistemas Colaborativos. 1ed. Rio de Janeiro: Campus/SBC, pp. 110-121 (2011). In Portuguese.
13. Tomicic-Pupek, K., Dobrovic, Z., Tomicic Furjan, M. Strategies for Information Systems Integration. In Proceedings of the ITI 2012 34th International Conference on Information Technology Interfaces, Cavtat/Dubrovnik, Croatia, pp. 311-316 (2012).
14. Manikas, K. Revisiting Software Ecosystems Research: A Longitudinal Literature Study. The Journal of Systems and Software 117(2016):84-103 (2016).
15. Bosch, J. From Software Product Lines to Software Ecosystem. In Proceedings of 13th International Software Product Line Conference, San Francisco, USA, pp. 1-10 (2009).
16. Araujo, R. M., Magalhães, A. Ecossistemas Digitais para o Apoio a Sistemas de Governo Abertos e Colaborativos. In Proceedings of the XI Brazilian Symposium on Information Systems, Goiânia, Brazil, pp. 647-650 (2015). In Portuguese.
17. Proctor, R., Zandt, T. Human Factors in Simple and Complex Systems. CRC Press, 2nd Ed. (2008).
18. Graciano Neto, V. V., Santos, R. P., Araujo, R. Sistemas de Sistemas de Informação e Ecossistemas de Software: Conceitos e Aplicações. In B. Zarpelão et al. (Org.) Tópicos em

Sistemas de Informação: Minicursos SBSI 2017. 1ed. Lavras: UFLA, v. 1, pp. 22-41 (2017). In Portuguese.
19. Lima, T; Santos, R. P., Oliveira, J. Werner, C. The Importance of Socio-technical Resources for Software Ecosystems Management. Journal of Innovation in Digital Ecosystems 3(2):98-113 (2016).
20. Santos, R. P., Viana, D., Maciel, C. Ecossistemas de Software: Uma Visão sobre Fatores Técnicos, Humanos e Organizacionais. In I. Gasparini, M. Mota (Org.) Livro dos Tutoriais do XV IHC. 15ed. Porto Alegre: SBC, v. C, pp. 70-90 (2016). In Portuguese.
21. Lima, T., Barbosa, G., Santos, R. P., Werner, C. Uma Abordagem Socio-técnica para Apoiar Ecossistemas de Software. iSys – Revista Brasileira de Sistemas de Informação 7(3):19-37 (2014). In Portuguese.
22. Graciano Neto, V. V., Cavalcante, El Hachem, E., Santos, D. S. On the Interplay of Business Process Modeling and Missions in Systems-of-Information Systems. In Proceedings of the 2017 IEEE/ACM Joint 5th International Workshop on Software Engineering for Systems-of-Systems and 11th Workshop on Distributed Software Development, Software Ecosystems and Systems-of-Systems (JSOS), Buenos Aires, Argentina, pp. 72-73 2017.
23. Santos, R. P. ReuseSEEM: An Approach to Support the Definition, Modeling, and Analysis of Software Ecosystems. In Proceedings of the 36th International Conference on Software Engineering, Hyderabad, India, pp. 650-653 (2014).
24. Nakagawa, E. Y., Oquendo, F., Becker, M. RAModel: A Reference Model for Reference Architectures. In Proceedings of the Joint 2012 Working IEEE/IFIP Conference on Software Architecture & European Conference on Software Architecture, Helsinki, Finland. pp. 297-301 (2012).
25. Graciano Neto, V. V., Garcés, L., Guessi, M., Oliveira, L. B. R., Oquendo, F. On the Equivalence between Reference Architectures and Metamodels. In Proceedings of the 1st International Workshop on Exploring Component-based Techniques for Constructing Reference Architectures, Montréal, Canada, pp.21-24 (2015).