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A Proposed Technology Platform Framework to Support Technology Reuse

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Abstract

Managing a technology portfolio is one of the great challenges for sustained success, especially in high-technology industries where technologies can be a major selling point. For engineers, this portfolio is more of a toolbox for solving design problems, but in large organizations there can be so many technologies used in different business areas that even the engineers may not be aware of all of them. When the same technologies are used in different types of products, knowledge about them can also be generated by various groups within an organization. To improve the usefulness of a company's technology base, this paper proposes the use of a technology platform approach based on a framework featuring three different types of activities. The first approach is about adapting the technology base to future needs with the help of portfolio management techniques. The second approach serves to create awareness and shared understanding through an interactive technology catalogue, collecting information about how technologies work, where they are applied, and how they are used. The third approach is addressed at engineers who work with the technologies and includes practices for improving the reusability of knowledge recorded in documents and communicated to others who are using a particular technology for development. The framework is intended to support a systematic approach for technology reuse in order to stimulate organizational learning and reduce lead-time and cost of product development.

Keywords: technology, platform, portfolio, knowledge, capability

1. Introduction

Managing a technology portfolio is one of the great challenges for sustained success, especially in high-technology industries where technology can be a major selling point. Investments in technology development are both uncertain and long-term, which necessitates the use of supporting activities to aim technology resources in the

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proper direction. One such activity that is often overlooked is to deal with the multiplicity of applications that the technology can support. Instead, technologies are typically developed for a particular application for which existing technologies do not suffice to meet requirements. Provided that the organization is equipped with the right tools and recognizes the long-term usefulness of extending the technology base, there are a couple of opportunities of which to take advantage in those situations. This paper proposes a framework for identifying such opportunities and for realizing their potential. The framework is intended to provide an overall structure for the collection of management tools, processes, IT support and engineering practices that together make up the strategy for improving the reuse of technologies across products and over time. This systematic treatment of reuse opportunities will be referred to as a "technology platform approach".

2. Frame of reference

2.1. Technologies, capabilities and platforms

The term 'technology' is used by some researchers to refer to the product defining technologies that establish the rules for an entire industry, such as digital camera technology, while others refer to the broader concept of technological knowledge as types of competence used for development and manufacturing. The latter interpretation is used in this paper, which is in line with the definition provided by Burgelman et al. [1]: "Technology refers to the theoretical and practical knowledge, skills, and artifacts that can be used to develop products and services, as well as their production and delivery systems. Technology can be embodied in people, materials, cognitive and physical processes, plant, equipment and tools." Following that definition, technologies can be developed in many different settings, but the term 'technology development' will be used to refer to dedicated efforts to create new knowledge in order to prepare a particular technology for a certain field of application.

The collection of underlying knowledge about how to develop and produce products is an intangible asset that an organization can acquire and thrive on. The specific elements of knowledge that together create this competence can be described as "technological capabilities" [2], which differ from the definition of technology in the sense that a technological competency is more generic and can contribute to the realization of multiple technologies. When the collection of elements of technological competence are recognized as strategic assets and managed in a systematic way, our research group has chosen to label this collection a "technology platform". Our definition is intended to be compatible with the use of the term by Jolly and Nasiriyar [3] (Figure 1a) and analogous to how the term product platform is used to prescribe a systematic approach to reuse physical components and their interfaces[4]. This view is also found in the "Power Tower" framework in [5], in which a technological building block constitutes part of the foundation for developing product platforms and their derivative products (Figure 1b).

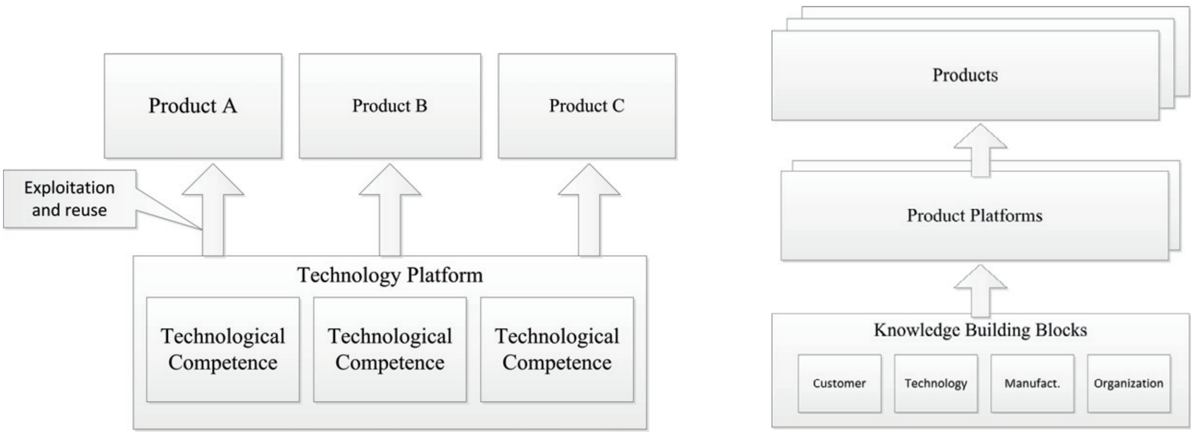

Fig. 1. a) The technology platform concept, adapted and redrawn from [3]. b) Technologies are leveraged in product platforms, which in turn are leveraged in products. Adapted and redrawn from the "Power Tower" in [5].

The technology platform concept may be viewed as technology-related aspects of core competency and dynamic capability [3]. Core competences are knowledge sets that may be leveraged in different products and that provide an organization with a competitive advantage [6]. Prahalad and Hamel [6] prescribe actions that put the concept into practice. One such action would be to identify and communicate the core competences that an organization possesses in order to create an awareness among employees and stimulate contributions to their development. Another action would be to strategically invest in promising competencies and a third action would be make sure technologies are leveraged across business units in products to which they can contribute. When applying these recommendations, it is important to keep in mind that there is a risk of becoming too focused on one's core capabilities. In order to keep the competencies aligned with the changing environment of a business organization, there is a need to let these competencies evolve and to challenge the current modes of developing products in order for them not to turn into core rigidities [7]. Hence, it calls for managerial capability to adequately apply and reconfigure resources, which is commonly referred to as possessing "dynamic capability" [8].

Researchers have proposed several different normative processes for technology development. The process that probably corresponds most closely to the ideas in this paper is the process framework developed by Schultz at al. [2]. As in this paper, this framework is an attempt to link practical techniques to business strategies and has also incorporated the ideas of generic technological capabilities. Their framework is composed of four phases: (1) Integrated Technology Strategy, (2) Concept Generation, Analysis and Enhancement, (3) Robustness Development and Analysis, a phase that is partly dedicated to exploring reusability aspects, and (4) Technology Selection, Transfer and Integration. Whereas the framework developed by Schultz et al. presents an overall process for technology development and integration, the approach suggested in this paper emphasizes the opportunities for improving reusability during different phases, ranging from strategic decision-making to information management solutions.

2.2. Portfolio management

Portfolio management can be applied to many different fields and for the benefit of technology managers, it supports decisions regarding which technologies to develop and phase out given current and anticipated future needs of an organization. In the literature, technology portfolio management is generally concerned with the core technologies of a firm, which would naturally be limited to around five to ten technologies (e.g. [9]). Some authors also advocate narrow technology portfolios, but other studies have shown a positive relationship between technology diversity and company performance [10]. Regardless of strategy, the techniques of portfolio management help visualizing the current state of a business organization to get an overview and help identify potential gaps that need to be filled using technology development or acquisition.

In a review of the metrics for assessing R&D portfolios, Linton et al. [11] categorize the metrics into two groups, management science techniques and graphic decision support, and go on to recommend combining them for best utility. They use a quantitative measure for screening a large number of R&D projects after which they resort to a qualitative visual support tool to increase the resolution of information for final decisions to be made. Schulz et al. [2] use technology portfolio assessments to analyze the technological contribution to the product portfolio using four metrics: (1) contribution to customer satisfaction, (2) technological strength, (3) technological maturity and (4) superiority. Based on these qualitative measures, each technology gets a profile used to map the composition of the technology portfolio on a bubble graph, using the two axes, bubble size, and bubble color to represent the four indicators. Arrows are drawn from the bubbles to illustrate forecasted trends – a key feature for addressing the reuse potential of future products.

2.3. Knowledge management

In product development, there are two types of knowledge management activities: knowledge creation and knowledge application or transfer [12]. In order to be effective, it is important for organizations to be able to reuse knowledge for solving recurring technical problems [13]. For the knowledge that can be codified, there are a host of opportunities to record and transfer it to others, while in the case of tacit knowledge, there is a need for personal interaction between the two parties of the knowledge transfer [12]. There are typically four different ways of documenting knowledge for future reuse; (1) unintentionally as a by-product of normal work, (2) as output of formal knowledge generation or knowledge transfer methods such as brainstorming, (3) through deliberate recording of structured formats for documentation, such as test reports, and finally, (4) by spearheading initiatives to gather and index old records into reusable knowledge packets [13].

Technological capabilities can be viewed as a special type of knowledge that supports the development and production of products. They possess some specific properties that are not shared with all other types of knowledge, including links to artifacts, possibilities to codify knowledge, and a clear practical purpose, all of which make it easier to record and organize that type of knowledge into a system [14]. When creating repositories of knowledge, there are a couple of critical challenges to making them useful; the willingness of employees to contribute, their accessibility and ease of use [15]. Employees who find such systems useful are more likely to make contributions to them and make sure that they contain updated and trustworthy information [15]. Knowledge repositories based on Web 2.0 solutions, such as blogs and wikis, have been proposed as means of facilitating knowledge sharing and even providing a channel for transferring tacit knowledge [16]. However, these repositories still require a culture of sharing and collaboration as well as ease of use in order to be effective. Some people voluntarily take on the role of “information shapers” who reorganize and edit content to improve readability and searchability for others [17]. However, there is often a lack of policies on how to manage the content of corporate wikis and who should be allowed to correct the information submitted by others [16].

3. Proposed technology platform framework

The intention of the technology platform framework proposed in this paper (Figure 2a) is to map the contexts where technology reuse activities support organizations in getting more value from their R&D investments. It differs from the framework presented by [3] in Figure 1a in that it goes further into the practical application of the technology platform concept to support the arrows linking capabilities and products.

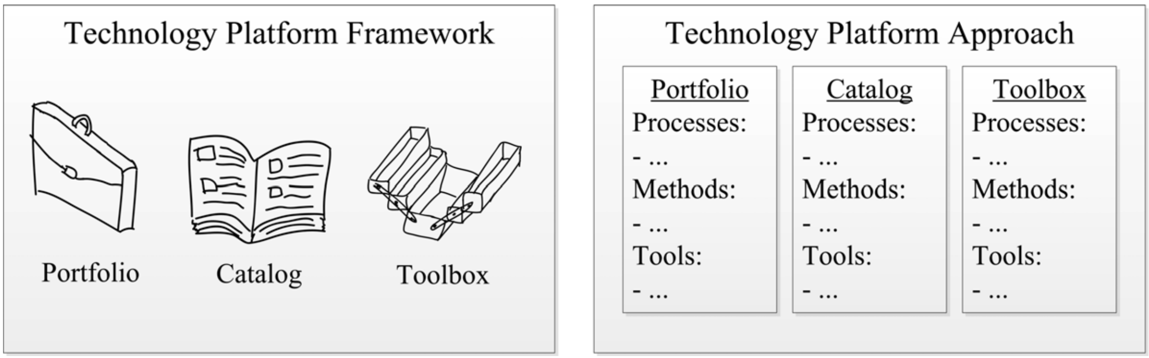

Fig. 2. a) Technology platform framework as a template for creating the b) technology platform approach.

Three different activity domains have been identified to facilitate reuse: strategic planning, an awareness of the technology base, and detailed information about technology reusability. To clarify the ways in which these types of activities can support the organization in practice, they are referred to as the “Portfolio”, the “Catalogue” and the “Toolbox”, respectively, of a technology platform. While all three views are intended to support technology reuse, they do so by serving different purposes. The portfolio view helps manage the overall content of the technology base, while the catalogue raises awareness about the existence of the technologies and how they work to encourage reuse and create access to that knowledge. Finally, the toolbox manages the details about how to apply the technologies to help experts and the employees working directly with them.

The ways in which these purposes are fulfilled are not prescribed by the framework itself, even though there might be a wealth of methods well suited for this purpose. Instead, the framework points to areas that deserve management attention and gives some notions on what can be accomplished. Organizations wishing to apply the framework, including researchers within the field, can use the framework to formulate an operational technology management approach by populating it with appropriate processes, methods and tools (Figure 2b).

3.1. Portfolio view

The technology portfolio is the strategic view of the collection of technological capabilities possessed by an organization, including portfolio management techniques and the visualization of reuse potential.

Technology management literature has been exploring the waxing and waning of technologies, how they replace each other and how they are applied to a range of everyday tasks. A corporate technology strategy takes these aspects into account and helps establishing the agenda for the R&D Department for a number of years to come. These strategies operate on a high level, focusing on perhaps no more than five different technologies perceived to be core to the business [18]. However, for operations to run efficiently, many more technologies come into play when developing new products. All those technologies are not core to the business but may rather be seen as tools to accomplish recurring design solutions that can either enable or be supplemental to the core technologies. This wider scope is the focus of the portfolio in the technology platform framework (Figure 3). It is a complement to top-level strategy activities and concerns the reuse potential of new technologies, the identification of redundancies and the detailed planning of technology development programs. The purpose is to visualize the big picture of the technology portfolio and create a stage for linking strategic planning and engineering efficiency.

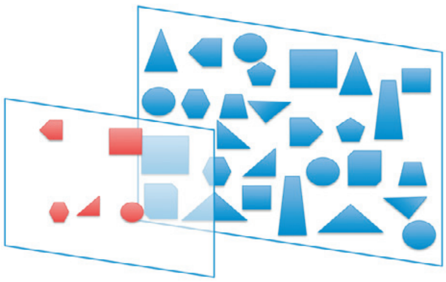

Fig. 3. Strategic technology portfolio (~5-6 technologies) and technology platform portfolio (>20 technologies).

A portfolio of technologies intended for reuse in future applications requires that the reusability of the various elements can be assessed. To visualize how much uncertainty there is in applying these elements [19], technology readiness levels (TRLs) can be determined; however, they require by definition a more or less specific application to be verified at levels above TRL 3. Even though it is not given by the metric, it is reasonable that a technology that has a high TRL for many different products is more likely to be quickly verified to the next level than a technology that has only been tested in a single case. From a reusability perspective, this information is most relevant and may be visualized in a variety of ways. If a new application should require the technology to be integrated into other technologies not heretofore used, Integration Readiness Levels (IRLs) [20] may be used to assess the difficulty of reusing the technology. IRL is a nine-level scale similar to TRLs that assesses the maturity of integration between any two technologies. By assessing all technology relationships in a system, IRLs can be combined into a metric for the System Readiness Level (SRL), which provides a summary of the technology readiness for a new application [20]. If the reuse situation should differ in aspects other than the integration into other technologies, such as product size or operational environment, other metrics or assessments could be developed for visualizing the contexts in which technologies have already been tested. The reuse situation is a trade-off between accuracy and simplicity of use, but regardless of where on this scale an organization chooses to implement this measure, its purpose is to provide a basis for discussions with the experts that can more accurately predict reusability over a range of applications. The uncertainties inherent in technology development should not be underestimated and however useful quantitative measures can be for reusability, when it comes to making important decisions, they need to be supported by qualitative assessments.

3.2. Catalogue view

An internal technology catalog is intended to create awareness and make it easier to access basic information, including links to more extensive reports or information leading to experts in the field.

One of the preconditions for reuse is the awareness of engineers and managers that there is in fact something to reuse. In small organizations, this is probably not an issue, since the personal network is sufficient to stay updated on the latest news and since one usually knows who to ask for expert advice. In large organizations, however, divisions and business units tend to be more isolated and advances in one area may not spread throughout the organization. There are a number of solutions, the most apparent being a functional organization in which experts in a certain field collaborate to share their knowledge. An engineer working on a certain design problem can then turn to this expert group for help and be quite certain that any relevant knowledge will be found through this channel. If there are multiple groups of experts in related fields, they can stay in contact through e.g. the rotation of personnel, collaboration on projects or organized meetings and workshops. For organizations where technological knowledge is even more widely disseminated, other solutions may be necessary. In many companies, design guidelines and handbooks serve this purpose, providing the best practices and inspiration from expertise logged and experiences shared within a company. To be able to locate and understand these documents, one usually needs to be acquainted with the technologies and how they work, since they tend to be more focused on micro-level information than on providing an overview of the technologies at hand for those who want to solve a design problem, as an example.

The purpose of the catalogue view is to bridge the gap between those who are not familiar with a technology area and the existing records of what there is to reuse. By providing a level of information that introduces knowledge-seekers to technology options and then guides them to further exploration into details and contacts within the company, there is a better chance that they find and reuse existing technological competence. The latter can be realized by creating repositories and document types for that kind of information, or by even putting posters up in the hallways of the office. The main limitations are the requirements of keeping them up-to-date and overcoming the unwillingness and lack of time of many engineers to document their knowledge and lessons learned for purposes other than the most urgent.

Internet sites and IT-tools for collaboration and knowledge sharing have been enabling many islands of expertise to create virtual communities around specific fields of interest. Such mutual sharing of experiences and information has also been inspiring researchers and practitioners to apply them internally within companies. The role model is Wikipedia, which has transformed a knowledge base into an encyclopedia that features both a high quality and a large quantity of information. A catalogue level of information could be realized in the same way, using a wiki (the website structure used for Wikipedia) containing articles on technologies and links to further reading and contact information (Figure 4). As previously mentioned, the system will not work without a culture of knowledge sharing, and needs to be supported by roles and processes to build and maintain it.

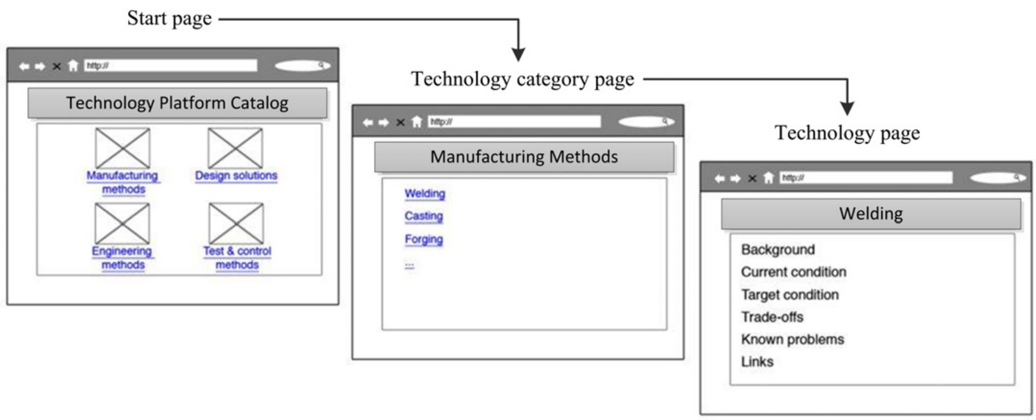

Fig. 4. Using a wiki as the repository for the technology platform catalogue information.

3.3. Toolbox view

The toolbox view consists of detailed reports and specifications about technologies, including information, hints and visualization about their reusability for different applications.

The third domain addressed in the technology platform framework is closest to the actual application of the technologies. The technology toolbox activities get technologies ready to be used – and reused – by engineers. In the optimal case, engineers can easily find the appropriate test reports and guidelines where the technology can be applied to serve their purposes. However, this requires technologies to have been previously verified to meet the same requirements, or that reports clarify what is yet to be tested in order to extend their use. For most organizations, a likely test scenario would be for engineers to ask a couple of colleagues to find a report on how the technology was applied to a previous case. They would then have to investigate the differences vis-à-vis the current application and contact the members of previous projects if they are still employed by the organization to recollect their previous work. Such investigations are time consuming and require a lot of redundant activities to catch up with the knowledge that was once at the top of the minds of an entire project group. As an alternative, one could leverage the momentum of knowledge built up when developing the technologies in the first place by preparing them for a broader range of requirements and applications upfront. Since software components are also used as tools or elements during development and often need to be modified in order to fit new applications, software reuse faces similar challenges to technology reuse. An example of how software reuse can be supported with toolbox activities is a technique called "design patterns". It has attained widespread use for standardizing architectures and describing software components on a higher level of abstraction in order to improve reusability even where details are not transferrable, e.g. across operating systems [21].

Instead of trying to make qualified guesses a couple of years later, the development team can also perform some additional tests and provide its best estimates to predict future uses. A precondition is that such investments pay off. Some of the uses forecast will probably never be realized and the cost-benefit structure becomes a betting game. There are a couple of different strategies that can be used to ensure that the cost-benefit balance is optimized. The easiest initial strategy is to "pick the low-hanging fruit". Some of the additional work can be performed quickly and at a low cost, including failure testing and conducting additional experiments when the equipment has been set up and adding a few suggestions to the reports for future readers about such topics as the probable challenges for those who might wish to extend the usable range of the technology. Another strategy would be to calculate the probability of future reuse and the costs, revenues or savings if they occur, i.e. calculating the value of buying the options for reusing the technology [22].

4. Preliminary results and future work

The proposed technology platform approach has its roots in the work performed at Volvo Aero Corporation (VAC), a Swedish subsystems supplier in the aerospace industry. To increase product quality and reduce development lead times, VAC identified an opportunity to coordinate knowledge and assets around macro-level functionalities [23]. Since then, interviews have been performed with VAC and a couple of Swedish companies in the automotive industry about knowledge and information management during technology development and early phases of product development [24]. Based on these interviews, a wiki-based solution was proposed for the catalogue view and a demonstrator was developed and discussed with VAC with positive results [25]. However, there are some major challenges in creating knowledge repositories, such as committing the resources to additional documentation, arriving at a critical mass of information for making them useful and keeping them up to date. Interview studies have confirmed that other companies also experience a need for improved coordination and knowledge sharing on technological competency, especially in large companies with a variety of business units at different sites.

4.1. Results of studies on technology information management

Our interview studies on information management for technology development have revealed few, if any, initiatives to collect reports and lessons around technologies. Instead, where the technology is mainly documented in the context of a project, product development projects have been in focus. Repositories for these reports and documents have been difficult to find without knowing exact titles or authors and in some cases, they have also been protected by permission rights. The major method for accessing information about technologies seems to be through personal contacts, and even with years of experience at a company, it can be difficult to locate the experts who possess knowledge of a certain topic.

4.2. Response on Wiki Demonstrator

As technologies are often developed by one group, applied to a product by another, produced by a third and maintained and repaired by a fourth group of employees, there are many possible sources of information about how a certain technology works in different settings. Furthermore, technologies are often used in different types and generations of products, thereby making the coordination of lessons learned even more complex. As a way of exposing stakeholders to these sources, a "Technology-Wiki Demonstrator" was developed intended to be used by a company as an internal catalogue of technologies. Compared to the global Wikipedia encyclopedia, this wiki would not be accessible to anyone outside a company and would include Yellow Pages information to relevant experts and users of each technology, with the pages moderated by an appointed technology expert for verification of the information. Like Wikipedia, its strengths would be the fact that many people can contribute, it can be updated quickly, and hyperlinks to more detailed information can be provided.

In one of the studies at the end of our interviews, the interviewees were shown the demonstrator and asked to comment. The reactions were highly positive, even enthusiastic, and many wanted it implemented at their company as soon as possible. Major strengths were perceived to be the access to top-notch information through which links to people and reports could be easily identified, as well as the possibility of learning the basics about technologies and staying updated on their progress. Others were worried about the fact that the core knowledge was displayed so openly and that it would be easy to steal, while yet others were hesitant regarding the format of the wiki in which anyone at a company could publish information that was not necessarily correct. Both concerns are relevant and need to be addressed in the design of such a technology catalogue.

4.3. Future work

The next step is to create the second generation of the demonstrator, including the visualization of the portfolio and toolbox, in addition to the wiki catalogue, and applying it to industry pilot tests and workshops. So far, the framework points out likely elements in a strategy document on technology reuse and identifies some practices that can be included. Future studies might also be able to test in what contexts these practices are relevant or inadequate to guide organizations towards realizing a technology platform approach for their business.

5. Conclusion

The concept of technology platforms has been suggested as a way of improving the reuse of technology development and exploiting present capabilities by turning them into new products. This paper has presented a framework for guiding the practical introduction and implementation of such a concept by drawing on literature findings on such topics as technology development, core capabilities, portfolio management and knowledge management. The framework is composed of three different categories of activity for technology reuse, strategic planning (portfolio view), knowledge accessibility (catalogue view) and the reusability of knowledge (toolbox view). When supplemented with adequate processes, methods and tools, the framework can be transformed into a systematic approach for technology reuse; examples of such elements have been presented. Two of the main challenges in successfully implementing such an approach include making the systems for recording and retrieving knowledge easy to use and keeping them updated with relevant and correct information. Future work might profitably focus on identifying methods for technology reuse and on mapping them to the framework in order to create guidelines on how to turn this framework into a practical technology platform.

Acknowledgements

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