Developing business technology and competitive intelligence in software science to business environments

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Abstract: Adding technology transfer to the mission statement of public research organisations (PRO’s) fundamentally influences the way research is managed as the capture and transfer of technology and competitive intelligence becomes more important. Software technology transfer isn’t a success. Recent research shows that cooperation with PRO’s slows down the development process of new software products. PRO’s active in software engineering produce a lot of software based assets like prototypes, tools... They need a development strategy that stresses the goal of easy-reusable and easy-transferable, high-quality research results and software assets. Software product lines (SPL’s) are a software platform development paradigm allowing companies to realize order-of-magnitude improvements of several business drivers due to high-reuse and quality strategies. The SPL-paradigm hasn’t yet been introduced in PRO’s because their mission isn’t to produce products. This paper explains how SPL’s enable PRO’s to collect research result, building easy-reusable, licensable business technology and starting-points for industries to develop new innovative products. The positive effects of the SPL research approach, together with the appropriate management techniques and new research culture are illustrated with an extensive technology transfer case-study that took place at the Information Technology Department at the Ghent University.

Keywords: software product line; software development; technology transfer; technology, business and competitive intelligence; software based research; science to business; technology planning; management.

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1 Introduction

This paper describes the experience of the INTEC Broadband Communication Networks Group (IBCN), a research group of the Department of Information Technology (INTEC) at the Ghent University that successfully introduced a product line approach to build complex software-intensive systems in support of their business technology and competitive intelligence development strategy. On the basis of a case-study is illustrated how public research organisations (PRO's) active in software engineering are able to anticipate successfully on new evolutions like the introduction of exogenous (market driven) research, next to endogenous (curiosity driven) activities. The paper starts with an overview of the current changes in the mission statement of PRO's and the implied challenges. As a reaction to these challenges, IBCN introduced software product lines (SPL's) in its research environment. All necessary processes and activities to support the new research strategy are explained in this paper, together with the benefits of this innovative SPL approach. A final conclusion is given, together with opportunities and challenges for future research.

2 Problem statement

The INTEC Broadband Communication Networks Group (IBCN) is involved in research on broadband communication networks, distributed software and advanced networking applications. The IBCN group is also part of IBBT (the Interdisciplinary institute for BroadBand Technology). This is a virtual public research organization that groups all the best-in-class research centers of the Flemish region in the ICT-domain. The mission of the IBBT is to develop highly competent human capital and to carry out multidisciplinary research projects on behalf of the Flemish business community and of the Flemish government. During this research, all necessary technological, legal and social aspects are addressed in order to facilitate the development and exploitation of broadband services. By investing in this multidisciplinary research, the Flemish government intends to ensure that Flanders becomes a leading and internationally recognized player in the future information society.

Figure 1 shows the current, recently changed, PRO's mission statement. Financial support comes from public funding, science infrastructure and research funding for collaboration with the industry (often project based, e.g. P6 research projects). The outcome of both endo- and exogenous research is publications and technology platforms. Technologies can be combined into proof of principles that create the basis for new products or services, licences or spin-offs. It has to be stressed that a PRO's mission is not to develop the products and services as such, only to construct the necessary innovative starting blocks like demonstrators, patents or other research software assets that can be integrated at minimum effort in industrial environments.
The introduction of project based research projects in collaboration with industries and the aim to construct competent technology platforms cause some specific problems for software based PRO’s like IBCN. A first major challenge is the management of all knowledge that arises during research project completion. A lot of this technology, business and competitive intelligence is tacit knowledge that exists in the heads of researchers but is never made explicit. When researchers move from project to project tacit knowledge often remains underutilized. Another risk of non-explicit intelligence is the loss of knowledge that occurs on the occasion employees permanently leave the organisations (e.g. to work somewhere else). When new researchers enter PRO’s they can’t consult available tacit knowledge because it’s never made tangible. This situation results in a lot of uncontrolled overhead every time new employees arrive. PRO’s need to find a way to capture all interesting knowledge in a reusable way, conform to their existing technology, business and competitive strategy.

A second problem is the protection of intellectual property (IP). Research groups active in domains like micro-electronics and biotechnology already have a history of capturing and protecting developed intelligence with patents. Software based research organisations do not have this tradition and are still struggling with the question on how to organise and protect IP that is translated into software programs. The management of Intellectual Property Rights (IPR) is a key success factor for technology transfer activities, for the mission statement of software engineering based PRO’s. Their research process requires the development of easy patentable software components and knowledge in a prescribed way.
Business drivers like competitiveness, reliability and timely development with respect of many quality requirements become an important issue of the research process, causing a third science to business transfer related challenge. These factors cause serious change management processes that can’t be introduced overnight with ad-hoc measures. PRO’s need careful designed research processes that put the entire organisation on the road to success for the implementation and the execution of the new mission.

Finding the balance between endo- and exogenous research is a last, hard to answer question that PRO’s are facing. Exogenous, market oriented technology research clearly results in more funding while endogenous research is the basis for new essential technology development. This situation creates a serious threat for opportunistic behaviour. Competence building for PRO’s becomes more complicated in an abundant knowledge landscape where research roadmaps are necessary. PRO’s should be able to construct processes that help to make road mapping a self-managing and self-steering activity.

3 Collaborative software based research project process

To be able to optimise the collaborative software based research project process, a clear insight in this process is needed. At start-up both PRO and other (industrial) partners are responsible for the embodiment of concrete deliverables. During the research PRO’s main input consists of technology knowledge, while companies provide consulting that is based on their product and service development strategy and business model. The concrete result of the project is a proof of concept or demonstrator (DEMO) like an alpha version that industrial partners might use for further product and service development.

The gain for PRO’s is funding and intellectual growth. During collaboration the PRO has a lot of opportunities to capture both business and market intelligence from the companies. Starting from the start-up of the project where companies provide their requirements based on market experience, over the development process where the industrial organisation provides a consulting role, concluding in the review and technology feedback phase of the demonstrator. Most of the received knowledge is tacit knowledge, only available in the heads of researchers. When the researcher can link his knowledge with future research or future projects it might be made explicit.

The results of the collaboration are explicit for the industrial partners. Most of the times they have clear technological deliverables, which can be evaluated once the project is finished. The outcome of this evaluation is merged into the product and service development strategy, directing the organisation to new opportunities. The problem for the industrial partners is that, in many cases, the collaboratively developed software assets can’t be integrated in their development process without a comprehensive re-engineering phase. The companies don’t receive easy-reusable software components from software based PRO’s. According to Heisman (2004) this slows down the time-to-market for these industrial partners, makes collaboration with PRO’s a less interesting and time-intensive challenge. In the context of this research several interviews with software companies have been carried out. All companies affirm that software PRO’s and software industry should become more attuned.
The technology feedback and market intelligence is far more difficult to capture for PRO’s. Saving this information has to happen in the technology platform of the PRO, influencing its endo- and exogenous research mission, influencing the PRO’s competence building process (e.g. user evaluation of a project based demonstrator might reveal unsatisfied security and usability requirements. This information can be used to start up PRO research on new technologies to meet these arising requirements). Today the received intelligence from industries is often tacit (because PRO’s have no process to make it tangible) and disappears once the project is finished, together with competence building opportunities.

4 The motivation for software product lines at public research organisations

Product lines are a widely applied production strategy within industries. The main idea is to reuse certain components within different products, hereby achieving economies of production. Also the software industry uses product lines, software product lines (SPL’s). According to Clements (2002) a SPL is a set of software-intensive systems sharing a common, managed set of features that satisfy the specific needs of a particular market segment or mission and that are developed from a common set of assets in a prescribed way. The different reusable components and knowledge of the SPL are stored in a central repository.

The benefits of SPL’s can be summarised in large-scale productivity gains, decreased time-to-market, increased product quality, increased customer satisfaction, more efficient use of human resources, ability to effect mass customization, ability to maintain market presence and ability to sustain unpredictable growth. Once the SPL management process is developed, there is a direct savings each time a product is built.
Introducing SPL’s in research environments implies an extension of current processes and a lot - apparent - overhead concerning management activities. Industrial environments have important differences with research environments (e.g. no products are developed during research). Before being able to introduce SPL’s, IBCN needed to perform a lot of SPL research, needed to look for the best strategy to introduce SPL’s in research environments. The still increasing projects that arise (and are great opportunities for PRO’s like IBCN), the faced problems for both companies and PRO’s concerning technology transfer, the augmenting number of researcher at IBCN and the need for structured processes together with competitive underlying strategies justify the motivation of IBCN to experiment with SPL’s at research environments.

5 The IBCN software product line

Applying the SPL strategy in research environments implies the adaptation of the software based research process, the creation of a SPL engineering process and some new management activities.

5.1 The software based research process

The outcome of software based research is new technology intelligence that is captured in one or more software assets like demonstrators or test applications. A ‘traditional’ software research process contains no prescribed procedures and can be abstracted as analysing the requirements, perform research and construct assets with respect of the requirements, publish about the gained knowledge and add the software assets to the technology platform as such. A serious re-engineering phase is often necessary in order to reuse embedded knowledge of software assets. Including this research process in a SPL lifecycle implies that the constructed assets consist of reusable software components that are saved together with all appropriate, surrounding knowledge in the SPL repository for future reuse. These software components and intelligence are building blocks for other derived software based research, licenses or start-IP for new spin-offs.

In an SPL environment the outcome of software based research is not only publications and software assets (like demonstrators in the context of collaborative research) but also reusable core asset development for the product line. This complicates the research process that now starts with an exhaustive domain engineering phase, an engineering activity for capturing and representing information about applications in a domain, specifically common characteristics and reasons for variability. During this development phase, researchers look for variation points. They try to gain insight in the expectations of all present and future users of the SPL assets (e.g. software components or knowledge like best practices) and aim to anticipate on future requirements, setting more generic requirements for the software based research when needed. The outcome is a commonality-variability analysis, a clear report of what features are reusable in the future (considering the current technology, business and competitive strategy of the PRO) and which properties are only valuable in the context of the research project as such.

While building architectures for software assets PRO’s employees explore how to maximise the reuse of available assets from their SPL repository. The repository contains all developed, generic and reusable software modules that were evaluated ‘highly common’ during former commonality-variability analyses and all valuable knowledge.
that is developed during former software based research. Reuse of technology, business and competitive intelligence (potentially captured in software assets) has a positive effect on the research effort and implies a decreased development time and an increased performance. If a component of the repository needs serious adaptation, a thorough investigation, that is comparable with the commonality-variability analysis for new modules, is executed. This activity takes into account the scope of the SPL (cf. technology, business and competitive strategy of the PRO) and helps to motivate the choice of making the available component more generic, or building a new one in the context of the research project as such. The outcome of the architecture development is a software design that contains a lot of reused modules, together with reusable new components in the perspective of future research and some less generic modules, only needed in the context of a specific research project.

The next activity is the transformation of the software architecture into a concrete program through software coding. The code has to be documented as good as possible in order to simplify future research. The better the code is documented, the easier it becomes to reuse it in other applications.

After a serious test phase, the developed software components and knowledge that have been evaluated as common are the input for the software product line engineering process. Important to notice is that before the software modules leave the software research process, they have been thoroughly tested and evaluated in their current application environment. This is an extra testing phase in a new application setting for components that are reused from the repository. Such an iterative lifecycle makes modules more reliable and bug-free.

A fundamental aspect during the whole process is the collection and reuse of important information in the context of the PRO's technology, business and competitive strategy. Not only software assets have to be saved, also all surrounding and relevant knowledge like best practices or technology feedback and market information (cf. the project based research process) needs to be captured. The SPL engineering process has to define the appropriate environment so intelligence is accurately saved and reused.

5.2 The software product line engineering process

The SPL engineering process' requirements are set by the PRO's technology, business and competitive strategies as SPL's are introduce to support these strategies. These requirements are used to define the SPL's scope, to concretise the problem domain or problem domains that will be covered by the SPL. In order to meet the recorded requirements, the SPL engineers need to set up a concrete planning. This step of the process includes determining the necessary time and resources for all SPL development activities. An important issue is to synchronise the SPL development process with the project based activities and other research of the PRO.

The SPL engineers are responsible for the distillation of all reusable software assets and related knowledge in the SPL repository. All SPL related software based research activities from domain analysis to testing and evaluation have to be designed and constantly improved in order to support the SPL. Capturing former tacit knowledge like technology feedback from collaborative research or saving developed best practices while working with new technologies is very important together with the reuse of the achieved technology, business and competitive intelligence. This why SPL engineers should introduce special activities like peer reviews in order to save this knowledge. Other
actions like meetings with all users of the research SPL might be appropriate in order to
evaluate the current performance and monitor the SPL development progress. SPL
engineers are as a matter of fact knowledge managers of the SPL based research process.
They take care all valuable knowledge is captured in the SPL and reused when
appropriate.

A next responsibility the SPL engineering process is to introduce the appropriate tools
and configuration management activities in order to support and maintain the SPL
deployment process. Examples of tools to capture knowledge are websites, spreadsheets
or reports. Software based assets can be captured with the aid of special software like
Subversion. Software based research activities need to be reorganised so all tools and
support are used accurately. The SPL repository has to be organised and maintained in an
easy to use database that provides all accurate information during every activity of the
software based research process. Improvement activities require serious metrics and
tracking action. The SPL engineers are responsible to provide the metrics and tracking
system (e.g. tell what information needs to be captured and how), integrate it in the
software based research process and analyse the results. SPL activities need some extra
resources (e.g. domain and architecture experts or extra software and hardware
equipment) and imply a new organisation structure and culture. SPL investments and
benefits are not always clearly measurable for PRO's because they do not have a tradition
of data collection, metrics and tracking. When these activities do not exist, SPL related
progress can only be measured by the number of successfully completed research
(projects), licenses and spin-offs. These are all long time measures. SPL’s provide the
opportunity to introduce short time evaluations and anticipate faster on new competence
building opportunities.

A lot of communication between software based researchers, SPL engineers and
managers is necessary. They all have different expectations. Software based researchers
expect shorter training times or contribution to more projects so they have a lot of
opportunities to test research results in concrete environments and get ideas for new
research. Managers want a more performing research organisation that leverages all
available technology, business and competitive intelligence. SPL engineers are the
intermediate persons who need to make sure all SPL stakeholders get what they expect
and make the right efforts in order to reach the planned goals.

5.3 The overall management process

A first step to introduce SPL’s at research environments is building a concrete research
case that can trigger the whole SPL start-up process. IBCN decided to start with a product
line about ICT service platforms and service discovery applications. Many applications
can be derived from the underlying technologies like home security systems and
multimedia applications. A nice example of a developed software asset is an application
that allows MMS-users to print a received MMS-message on a network printer. This
printer can be at home, in a business location like a factory, an airport, a hotel or other
place. The print-service is automatically discovered once a user enters a building with
network printer. One can imagine many services and applications derived from these
technologies like a doctor getting automatically all patient information on his PDA when
he enters a hospital room. Both examples share a lot of common features (e.g. service
discovery qualities) but also have unique properties. Consequently many variation points
can be introduced during domain engineering and commonality-variability development
activities. Clearly this application domain creates a lot of possible software related knowledge reuse opportunities. Moreover service platforms and service discovery related research fitted the research roadmap of IBCN.

A second responsibility is to provide the necessary resources like SPL engineers, repository configuration managers, extra time and funding for the researchers to execute software based research and evaluation in a SPL environment and a special architecture group (SPL's demand a more profound architecture study of developed software assets in order to make reuse possible). Also the training of employees in order to maximise the use and reuse of the SPL intelligence is an important organisational issue that needs some extra resources. The practical organisation and resource allocation need to take place in cooperation with the SPL engineer. If SPL repositories become too big, they might be split up based on domain characteristics (see also future research). Today IBCN has only one product line. This simplifies the situation, but the PRO needs to anticipate on future evolutions like more SPL's when appropriate.

As the SPL repository contains a lot of technology, business and competitive intelligence, the PRO’s management is now able to integrate this information in their activities. The repository provides a clear overview of the available knowledge of the PRO, making the strategic planning of collaboration in projects (cf. new funded research projects), licenses and spin-offs more transparent and providing a deeper insight in what the PRO can offer to external partners. As a matter of fact, SPL’s ease road mapping activities because PRO managers have a clear oversight of available competences and opportunities for competence building.

6 Research software product line lifecycle

An important aspect of organisational management activities is that they have to result in self-managing and self-steering processes. The PRO’s managers shouldn’t be concerned about the software based research processes or the SPL engineering processes. Their only concern is to take full advantage of these processes during their activities. This can be achieved by positioning every SPL related activity in a larger environment, a SPL lifecycle. Figure 3 gives an overview of this cycle.

The software based research process results in one or more software assets, constructed of reusable components if appropriate (cf. commonality-variability analyse). These generic components are passed on to the SPL engineering process together with all appropriate surrounding information and evaluation results (like feedback from collaborative research project companies). The requirements of the SPL engineering process are the PRO's technology, business and competitive strategies. The outcome of the SPL engineering process is reusable components that are stored together with all surrounding technology, business and competitive intelligence in the SPL repository. This repository the basis for new software based research, new licenses and new spin-offs.

When collaborative research takes place, companies help setting the requirements for the software based research and some of the software assets are passed on to the company when the project is finished (cf. dotted line in Figure 3). Due to the SPL software based research process that stresses the development of component based software architectures, these assets are easy-reusable building blocks for new services or products in industrial environments.
The SPL engineer, in cooperation with the PRO management, is responsible for defining appropriate metrics and introducing a correct tracking system. This results in a clear overview of current performance and provides information about possible optimizations. These activities offer opportunities to make all SPL related processes self-steering and self-improving.

Figure 3 The research SPL lifecycle

7 Benefits of research software product lines

7.1 Better technology, business and competitive intelligence management

During the SPL engineering process a SPL repository is created. This repository contains all reusable software assets and surrounding technology, business and competitive intelligence. It is an easy-to-consult knowledge base that is useful for both software based researchers and PRO management.

The reuse of the SPL repository intelligence results in much higher performance as a lot of knowledge is reused instead of reinvented. Managers can now consult short time metrics and tracking (like reuse statistics, number of corrected errors and development time for each software component per research project), instead of only long time measures like the number of projects, licenses or spin-offs.
The training time for persons who arrive in the PRO is shortened as the SPL engineering process makes important, former tacit, intelligence explicit. SPL engineers are responsible to inform all employees about available and reusable knowledge.

7.2 *Transparent intellectual property rights management*

The SPL repository contains easy-reusable software assets. The combination of these assets and surrounding knowledge is the technology, business and competitive intelligence basis of the PRO. The software assets have been extensively tested and are interesting building blocks for the development of new services and products in industrial environments. Licensing IP or use the IP as start-up intelligence for new spin-offs becomes less ad hoc and more structured.

7.3 *Business drivers that arise during collaborative research with industries are more easily respected*

A maximum reuse of available software assets and technology, business and competitive intelligence results in shorter development times for new research projects. Human research resources are used more efficiently as the capture of former tacit knowledge in the SPL repository leads to more time to invent instead of reinvent tacit knowledge. This evolution has a positive effect on the development time of new research based software assets.

The introduction of a concrete software based research process and SPL engineering process creates opportunities to introduce short time metrics. All executed activities during software based research and SPL engineering can be tracked and are subject of possible long time quality improvement. Every time a software component is reused, it is tested and evaluated in a new application environment. This improves the quality of new developed software assets that reuse existing components.

Due to the improvements on development time and quality, the overall performance of the PRO is leveraged to a higher level. Shorter development time, assured high quality, increased performance and the existence of prescribed, good managed processes make it more appealing for companies to collaborate with PRO’s.

7.4 *More accurate competence building process*

The SPL engineering process captures all important intelligence and makes it available in the SPL repository. This results in a clear overview of available competences. When a PRO joins collaborative projects with industries, they receive a lot of valuable knowledge like exhaustive feedback and market information. All this technology, business and competitive intelligence is captured in the repository and can be consulted while making roadmaps and defining the balance between endo- and exogenous research.

7.5 *New business culture and easier science to business marketing*

The SPL research environment is responsible for a new culture where everybody is motivated to share knowledge. When employees experience the benefits of easy available technology, business and competitive intelligence they become more actively concerned
in the SPL lifecycle processes. This creates more opportunities for the SPL engineer to leverage all processes to a higher level.

Marketing of technology and business competences becomes a lot easier when this activity is supported by SPL’s. As the technology, business and competitive intelligence is collected in the repository, the PRO has a clear overview of its competences. This makes science to business advertising a lot more transparent and manageable, resulting in a more appealing image for PRO’s when it comes to collaboration with companies.

8 Conclusions and future work

The introduction of research projects in collaboration with industries provides many new challenges for PRO’s. Exogenous research becomes at least as important as endogenous activities. This implies that PRO’s have to be vigilant to a lot more outside information and offer easy usable research results to outside (industrial) partners. SPL’s provide the processes to meet this new mission by introducing a new research culture through self-steering activities. The result is an improved development, management and marketing of technology, business and competitive intelligence within PRO’s in science to business environments.

SPL’s in research environments needs further investigation. Only the short time results have been explored. A thorough study of long time effects on the number of executed research projects in collaboration with companies, the amount of licenses and the augmentation of new spin-offs will provide even more evidence in favour of SPL’s in research environments.

Metrics and concrete tracking of activities need to be investigated on a long time basis in order to derive more general results. An important future challenge is the growth and future organisation of the SPL repository. As more and more information will be gathered, management will become less obvious. The SPL repository will have to be divided in several repositories, based on one or more problem domains. The concrete steps to guide this process need to be further deployed and tested in a real research environment.

Future research will be done in cooperation with the Vlerick Leuven Gent Management School and will also focus on the concrete business expectations concerning software assets transfer from PRO’s to the software industry and the effect of this technology transfer on the growth path of these companies. This information is necessary in order to improve the collaborative research project process. In this phase cooperation with IBBT will be of great importance as this innovation organization aims at the realization of collaborative demand driven research programs, focused on the development of generic knowledge. During these programs research SPL’s will play a significant role as they provide a repository for all developed knowledge and software assets.
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