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Patterns of Cooperative Technology Development and Transfer for Software-Engineering-in-the-Large

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***Abstract*—Technology can be regarded as scientific knowledge embodied in products or services. Particularly in the software domain, it has been recognized as a source of competitive advantage of corporations, industries and nations. Cooperative technology development and transfer happen in academic environments, but there is a wider context in which they can be performed. In this paper, we define patterns and report examples of cooperative technological activities that reflect best development and transfer practices of persons and institutions, taking advantage of our expertise in fostering the software industry in Brazil. We argue that such activities can benefit from the adoption of software patterns, determining what we regard as a Software-Engineering-In-The-Large approach to this subject. We show that our patterns are compositional, capture specific dialects, languages and theories, suggesting that they can be formalized in future works.**

Keywords — **Technology Transfer, Software Patterns, Software Development, Software Engineering.**

I. Introduction

Technology has long been recognized as one of the main sources of competitive advantage of corporations, industries and nations. This is particularly true nowadays, due to the current competitive pressures, which impose strict and growing focus on the generation of social and economic value [11]. Entire technology ecosystems are defined in order to ensure not only personal and institutional motivation and recognition, but also social and economic gains.

The life cycle of each technology begins with its development and proceeds with transference and exploitation activities, potentially involving not only persons, companies and research centers, but also other interested institutions, such as academic and government agencies, as well as investors. Due to the collective nature of technology development and transfer, it is not always possible to establish converging practices or interests. Sometimes what is perceived is in fact a gap (or divide) in these respects, particularly between industry and academic institutions. Unfortunately, there is no universal recipe to deal with these situations, but, due to the social and economic importance attributed to technology, plenty financial and non-financial instruments are available to foster cooperation on technology development and transfer.

Usually, the early stages of technology development and transfer happen in an academic environment [10], wherein they demand discussion and receive feedback, but there is a much wider context in which such activities can be performed. In fact, instead of considering the feasibility to transfer technology just from one context (academic research) and in one maturity level (transfer readiness), we believe that much greater benefit can be achieved if such practices are studied, analyzed and replicated taking into account the widest possible perspective.

In Software Engineering, this kind of approach is not new: in the 1970s, de Renner and Kron [2] proposed an In-the-Large approach to programming and that idea had inspiring influence in many other Software Engineering areas. In the context of technology transfer, this approach has already been explored: Finkelstein and others [5] studied how to transfer technology from instrument systems to the software domain and vice versa. This large scale approach to technology development and transfer activities is also in keeping with our work on the development of a nationwide software industry [3], [4].

In this paper, we report our experience and observational studies on this subject. We argue that Software-Engineering-In-The-Large can be most benefited from identifying and applying software patterns to cooperative technology development and transfer activities. We take advantage of our expertise in fostering the software industry in Brazil to identify and define patterns of cooperation and report corresponding examples of best practices of persons and institutions. Note that technology development and transfer also happens in business oriented places and through hostile movements (such as in private incubators and through mergers and acquisitions respectively), but these are not subject of study here, since the respective patterns are more connected to the strategies of the involved institutions than with technology itself.

The remainder of the paper is organized as follows: Section II describes our research universe, which consists in technology development and transfer activities (II-A) and software patterns (II-B); Section III presents definitions and examples from our database of technology development and transfer patterns. We conclude the paper discussing our findings and suggesting future research.

II. Research Universe

A. Technology Development and Transfer

Technology can be regarded as scientific knowledge embodied in products or services. This kind of embodiment is normally achieved by following (not necessarily all) the steps of a specific life cycle: scientific discovery, technology characterization and classification, intellectual and industrial rights property protection, marketing of technology, technology disclosure, negotiation and transfer.

Many stakeholders can be involved in the technology life cycle, such as academic and R&D institutions, technology transfer offices and brokers, private and governmental

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firms, investors, entrepreneurs and employers. Despite the fact that technology is developed by persons, it is in the institutional level that technology can be exploited in the form of products or services provided by companies or research institutions. The passage from the personal to the institutional level points out that there is at least one transference step in the life cycle of any technology.

In order to be transferred, technology should be mature [12] and transfer ready [9], avoiding great costs and risks. A mature technology should have been internally and externally enhanced and exploited, as well as popularized and propagated. The maturation period is distinct in each kind of technology, as well as the time required in each maturity stage. The transfer-readiness of a technology also takes into account commercial, market and management aspects. It is also possible to transfer disembodied scientific knowledge, the transference of know-how, for instance, but this is not the focus of our study here.

We believe that there is a great opportunity in studying technology development and transfer in the software domain, since software tends to be more intangible than other technologies (thus more difficult to understand and explore), on the one hand, but, on the other, the social and economic benefits of such activities are recognized to be sources of great competitive advantage (since corresponding social and economic benefits are transferred to those who use software technologies, a so called spillover effect).

B. Software Patterns

Software patterns capture best practices that can be replicated in similar contexts. They were initially formulated as a means of capturing software design activities [7], but many other applications have been reported – involving standard software artifacts, as well as personal and institutional behaviors – such as security patterns [17].

Patterns describe in a generic manner what to do in a certain situation, but not how something should be done. They favor the identification of actors and their roles, as well as established interactions with their occurrence environment. Due to their constructive nature, patterns make the learning curve smoother and cooperation less resource consuming, since the environment and expected interactions are explicit beforehand.

Patterns also capture the existing dialect and the language adopted in a certain domain. In fact, the same domain can be mapped from many distinct perspectives and have its inherent characteristics captured using different patterns. That is why patterns in general have a compositional nature: more than one pattern can be adopted simultaneously to deal with specific situations.

The distinctive characteristics of patterns make us believe that they are suitable for representing, analyzing and replicating technology development and transfer activities in the software domain. Moreover, the presentation of such activities according to a pattern framework appears to facilitate communication between partners and with funding agencies in convincing ways, leading to desirable support to such activities.

III. Software Technology Patterns

We adopt patterns to represent software technology development and transfer activities. Since we are concerned with changes in *status quo* concerning technology, we formulate each pattern so as to capture the main concerns and behaviors of the involved institutions and focus on the *locus* and ownership of technology creation and/or transference and/or usage.

Our patterns are organized into families according to the similarity of the involved actors. Apart from having a mnemonic name to remind us of its purpose, each pattern is stated using the following structure:

1) Purpose: Problem addressed by the pattern;
2) Actors: Stakeholders involved in the pattern;
3) Interactions: Interactions established among actors;
4) Environment: Actor assumptions and commitments;
5) Consequences: Point out the pattern pros and cons.

We illustrate each pattern by presenting a real world situation in which its concrete application is clearly identified. Due to space restrictions, some definitions and examples are omitted here.

A. Personal Patterns

Personal patterns capture high performance behaviors of individuals fulfilling their roles in technology development and transfer activities. We have already identified the following non-exhaustive list of personal patterns: Pairing, Supervisor, Mentor and Sabbatical (omitted).

1) Pairing Pattern:

- **Purpose**: Take advantage of an already existing technology which is owned by a trusted partner in order to develop a technology business;
- **Actors**: Two persons interested in the joint development of some technology business, playing the roles of technology provider and business owner;
- **Interactions**: They rely on a trust based partnership between the involved actors. The actors get together, negotiate the terms of the technology license or ownership transference and subsequently exploit the technology using the existing business as a channel;
- **Environment**:
  1) Both parties presume that the local regulatory and legal environment is stable and secure enough to provide the desired level of technology protection and litigation resolution if required;
  2) Since technology is generally intangible, provider ensures the effective transfer and usage by supplying any legal or operational support required;
  3) Business owner guarantees any requested compensation for the license or transference, such as cash payments, issue or transfer of shares etc;
- **Consequences**:
  1) **Pros**: Ensures that technology on the shelf is adopted in practice;
  2) **Cons**: The technology adoption or exploitation curve may be too smooth to satisfy existing financial requirements;

An example of this pattern appears in Figure 1.

Orbisat

In 2001, Rogério Camargo and João Moreira, two former students of the Aeronautics Institute of Technology (ITA) at São José dos Campos, Brazil, met again. After carrying out PhD studies at the University of Toulouse, France, Rogério had returned to Brazil in 1991 to found Orbisat, a manufacturing company of set-top boxes for satellite TV reception and other consumable electronic products. João, in turn, had remained in Munich, Germany, after finishing his PhD studies at the local technical university, working in his own company and for the German DLR. João wished to return to Brazil to further develop his patented technologies on software for airborne Synthetic Aperture Radars (SAR) [15] using local workforce. They wrote together a business plan so that the technology could be absorbed by Orbisat, defining a new business unit in this way. In doing so, it would be valuated and used by João to subscribe new equity issued by Orbisat, becoming a new company shareholder. In 2002, they submitted the plan to BNDES and obtained a loan of US$ 3 million so that the company could finish the software development and produce its first radar prototype with embedded software, turning their personal relationship into an operational business. The main commercial result of that investment was the production in 2003 of digital maps of 25% of the Venezuelan territory (southern part).

Fig. 1. Pairing Pattern Example

2) Supervisor Pattern:

- **Purpose**: Find a student to whom know-how on a specific subject can be transferred so as to define new technology by additional research or development;
- **Actors**: A researcher holding a position in an academic institution and a student interested in applied research, playing the roles of supervisor and student;
- **Interactions**: They vary according to the degree and complexity of required research/development and the program requirements that the actors have to follow. After supervisor accepts the student, they perform some meetings and exchange of research deliverables. In the end, the deliverables are transformed in a complete written work (thesis or dissertation) and a software product or service technology;
- **Environment**:
  1) Supervisor and student assume that the required infra-structure for research is provided by the academic institution to which they are affiliated;
  2) Supervisor provides stimuli, guidance, know-how and guarantees required additional resources so that the student can develop its work;
  3) Student provides dedication and commitment so as to complete the required research and technology development;
- **Consequences**:
  1) **Pros**: Consists in a low cost path to produce entry level innovative technologies, which generally require further refinement;
  2) **Cons**: Requires management in order to mitigate the risks related to the student behavior, such as completion failure and early corporate capture;

An example of this pattern appears in Figure 2.

2BuyNet

This example tells the story of the relationship between Luigi Fortunato and his supervisor Carlos José Lucena, respectively former undergraduate and full professor at the Pontifical Catholic University of Rio de Janeiro (PUC-Rio). Luigi had previous professional experience as a technician and programmer, acquired while he was an undergraduate student at PUC-Rio, as well as some research exposure, acquired in short stays in American research centers. After finishing his BSc course at PUC-Rio in 1996, he was accepted in the university for an MSc course. As a result of his research, he developed, with the guidance of prof. Lucena, the 2BuyNet e-commerce framework for designing, deploying and maintaining web stores [6], which later on became the subject of his dissertation and also a software product, commercialized by the Eduweb company.

Fig. 2. Supervisor Pattern Example

3) Mentor Pattern: This is a variation of the Supervisor pattern without the assumptions and commitments related to the academic programme to which the involved actors are connected. For examples of this pattern, the reader is referred to the IEEE Mentoring Program.

B. Enterprise Patterns

Enterprise patterns capture the internal structures and behaviors adopted by technological institutions in their attempts to fulfill their missions through cooperative technology development and transfer activities. We have already identified the following non-exhaustive list of enterprise patterns: Joint-Venture, R&D Laboratory, Spin-Off, Consulting and Outsourcing (both omitted).

1) Joint-Venture Pattern: This looks like the Pairing Pattern brought to the corporate world.

- **Purpose**: Take advantage of an already existing strategic partnership based on trust to develop or exploit new technology in the form of a new business;
- **Actors**: Institutions interested in the joint development of a new technology business;
- **Interactions**: They rely on a strategic partnership based on trust among the involved parties. The parties meet, negotiate the terms of their new venture and subsequently develop or exploit the new technology in the form of a new business, making available the required resources, particularly their teams;
- **Environment**:
  1) The parties presume that the local regulatory and legal environment is stable and secure enough to provide the desired level of technology protection and litigation resolution if required;
  2) Since technology is generally intangible, the involved parties should commit their best efforts to implement and enforce the negotiated terms related to their participation in technology development, ownership and access;
- **Consequences**:
  1) **Pros**: Ensures technology development or exploitation with reduced financial commitment and risk exposure from each party;

Von Braun Center + Semp Toshiba Informática

The Von Braun Center (VBC) is a non-profit institution located in Campinas, São Paulo State, Brazil, founded in 2001 by researchers based on that city. Since 2005, the center maintains an R&D contract with Semp-Toshiba Informática (STI) to perform on demand cooperative development of IT solutions. STI is a joint venture between the Brazilian Semp and the Japanese Toshiba groups. In 2009, VBC managed to sign an agreement with the Ministry of Cities of Brazil to develop solutions to manage not only goods transportation but also automated sales tax charging. The required R&D comprised the development of a secure communication protocol to be embedded in RFID chips and software to be embedded in standard hardware connected to specific antennas. In 2010, both institutions managed to obtain an approval for a cooperative project worth US$ 1,44 million of BNDES funds so that they could develop the RFID chip for that purpose. The development was finished in 2012, but, even before, both institutions had already decided to open a design house as a joint venture (STI having 60% of the equity, VBC with 30% and the Toshiba Group having the remaining 10% of the capital). The new company performs further developments and commercially explores the designed technologies.

Fig. 3. Joint-Venture Pattern Example

2) **Cons**: The difficulty to manage the partnership grows with the number of participants;

An example of this pattern appears in Figure 3.

2) R&D Laboratory: This is also known as the R&D Department pattern.

- **Purpose**: In order to create or further develop some technology, create an independent unit with separate operation and administration in relation to its parent;
- **Actors**: Parent and child units, departments in general, possibly having some hierarchical relationship between themselves;
- **Interactions**: Parent unit identifies the organizational structure related to technology creation or development, comprising personnel, infra-structure and others. Best practices suggest that the future evolution of the new unit be forecast using a specific business plan, in which future needs are mapped, particularly new funding requirements. The child unit is created based on this plan;
- **Environment**:
  1) Parent unit provides initial support for child development, such as personnel or advice, as well as agrees with the transference of part of its budget or assets to the new unit;
  2) Child unit provides best effort guarantees of technological maturity and business independence, such as by ensuring development continuity and finding pioneering customers;
- **Consequences**:
  1) **Pros**: Ensures that the parent unit focuses in its core business and takes limited risk exposure to the technology development, in particular that its resources are not exhausted;

Multifuel Engine Control System of Magneti Marelli [8]

Magneti Marelli is a subsidiary of the Italian Fiat Group. It has headquarters in Milan and keeps a subsidiary company in Brazil, called Magneti Marelli Controle Motor. This company had a fuel injector factory in Hortolândia, São Paulo State, but in 2001 a R&D laboratory was also created there. In the same year, the local engineers allocated in the lab began the development of a multifuel engine control system for vehicles, which was essentially different from the standard ones due to an embedded control software that automatically switches among different kinds of fuel available in vehicle tanks. The budget of the project was US$ 11,4 million, of which 23% were financed by BNDES. The sales of cars with multifuel engines begun in 2005 with a tax break incentive from the Federal Government and today they equip almost all the locally produced automotive vehicle fleet in Brazil.

Fig. 4. R&D Department Pattern Example

Orbinova (Orbisat example continued)

The set-top box and radar businesses of Orbisat continued to grow for some years, but eventually the need to obtain working capital and investment funds to buy an aircraft and produce a new radar prototype appeared. The company requested again funding from BNDES based on a new business plan. In 2005, the bank approved additional US$ 4,5 million, divided in a loan and an equity investment. Nearly at the same time, the company managed to obtain a US$ 10 million contract from the Brazilian Army to adapt the SAR technology to defense systems. In the next 5 years, the company growth was vigorous, doubling its revenues. However, it eventually became clear to the shareholders that the two business units were too different in their costs, margins and business models. A decision was taken in 2012 to spin-off the radar system business, which was sold to Embraer, the Brazilian aircraft manufacturer.

Fig. 5. Spin-Off Pattern Example

  2) **Cons**: The splitting process has costs and the new unit faces continuity threats, such as not finding customers, not proving maturity or becoming too independent;

An example of this pattern appears in Figure 4.

3) Spin-Off Pattern: This is analogous to the R&D Laboratory Pattern, but giving rise to a legally independent institution, rather than to a new organizational unit. To illustrate this pattern, we present the Orbinova example in Figure 5. In particular, the Orbisat related examples show that technology patterns are compositional: Pairing and Spin-Off were used in sequence, in subsequent moments.

C. Organizational Patterns

Organizational patterns capture the collective behaviors of persons and institutions in their attempts to achieve technological goals effectively. We have identified the following non-exhaustive list of such patterns: Incubator, Parking, Push-Out, Pull-Back, Mediator and Co-creator.

1) Incubator Pattern:

- **Purpose**: Find a physical location in which technology development and transfer can be performed with

Eduweb at Instituto Gênesis

Edu at Web is a company founded in 1998 by two graduating students at the Pontifical Catholic University of Rio de Janeiro (PUC-Rio). They wrote together a business plan aiming to develop technologies and exploit the learning and distance education market. The business plan was submitted to Instituto Gênesis, the incubator of PUC-Rio and was accepted for an initial stay period of 2 years, thereby becoming eligible to obtain tax incentives of the City of Rio de Janeiro and research grants of the State and Federal Governments. Soon afterward, two additional shareholders were admitted in the society, bringing with them an e-commerce technology (the 2BuyNet software) and management methods which the company included in its portfolio in the form of software products and services.

Fig. 6. Incubator Pattern Example

ideal access to academic and research advice and partnerships, services, funding and infra-structure;

- **Actors**: In general, a private company and an incubator located in a university or research center;
- **Interactions**: Company signs contract with incubator and creates or moves its entire structure or just the technology business unit to the incubator. Afterwards, it initiates or continues technology development, keeping interactions with the hosting environment;
- **Environment**:
  1) Incubator and Company assume that the Local, State or Federal Government provide appropriate tax or research incentives for incubated entities;
  2) Company performs technology development, fulfilling governance and financial requirements posed by the applicable laws and the incubator;
  3) Incubator provides infra-structure, as well as consulting and advising services, in exchange for regular payments or dividends distribution or equity participation in each company;
- **Consequences**:
  1) **Pros**: Ensures ideal infra-structure, research and tax incentives and also a friendly environment for technology development;
  2) **Cons**: May not be applicable to any kind of business nor to critical technologies;

An example of this pattern appears in Figure 6.

2) Parking Pattern: This corresponds to scaling up the Incubator Pattern to a larger ecosystem called a Technology Park, which also hosts mature companies rather than just start-ups. For an example of this pattern, the reader is referred to TecnoPUC, the technology park created in 2001 inside the Pontifical Catholic University of Rio Grande do Sul (PUC-RS), which hosts technology development and transfer activities of large global IT companies – such as Microsoft, Dell and HP – as well as Brazilian companies – such as Stefannini, GetNet, Lifemed and Parks.

3) Push-Out Pattern:

- **Purpose**: Find a partner with technical expertise or market access to which technology can be transferred, ensuring that it effectively reaches the market;

Aulanet at Eduweb

Soon after the incubation of Eduweb at Instituto Genesis, the company managed to sign a license contract with PUC-Rio so as to become exclusive developer, maintainer and distributor of AulaNet, a Learning Management System (LMS) developed by the Software Engineering Laboratory (LES) of the Informatics Department of that university [13]. In 2000, the company decided to leave Instituto Genesis, moving to offices in a district nearby. The technology and business development investments related to AulaNet required third party capital and then the company wrote a second business plan. Eduweb managed to obtain a loan of US$ 430.000,00 from BNDES in 2002 in order to implement that plan, which ensured the company growth for some additional years. With time, however, it became clear that scale matters in distance education businesses and thus Eduweb decided to merge in 2009 with two other firms, becoming part of a large group. Until 2013, more than 4.000 installations of the Aulanet platform had been performed.

Fig. 7. Push-Out Pattern Example

- **Actors**: A licensing institution and a licensee entity, usually a university and a private company, with eventual specialized support provided by another institution such as a foundation;
- **Interactions**: Licensing institution signs contract with licensee, possibly with third party participation, transferring technology ownership or commercial rights and establishing compensation forms. Licensee creates technology development, marketing and sales assistance structures. It approaches the market with the new offer, willing to perform required customizations;
- **Environment**:
  1) Licensing institution makes staff available for consulting, but refrains from performing the activities transferred to the licensee;
  2) Licensee obliges itself to perform additional investments, to offer the technology to the market and to share with the research institution part of the obtained results;
  3) Support Institution may have legal, operational and technical know-how, which should be made available to facilitate the main partnership;
- **Consequences**:
  1) **Pros**: Establishes a long term partnership between the licensing and licensee institutions, apart from ensuring that each actor better uses its own core competencies and resources;
  2) **Cons**: Should be carefully defined in order to avoid competition and disputes concerning rights and obligations of each party;

To illustrate this pattern, we present the Aulanet example in Figure 7. In particular, the 2BuyNet, Eduweb and Aulanet examples show that technology patterns are compositional: Supervisor, Incubator and Push-Out were used in parallel, in overlapping time periods.

4) Pull-Back Pattern:

- **Purpose**: Find a partner with technical expertise that accepts the challenge to develop new technology

From Banco Bamerindus to Visionnaire Pacto

In 1996, four lecturers of the Pontifical Catholic University of Paraná (PUC-PR) with expertise in distributed objects decided to found Visionnaire as a vehicle to provide to Banco Bamerindus a solution to a corporate service level agreement (SLA) problem specified to be solved using that technology. In the same year, the company launched the Distributed Objects series of workshops, which attracted more than 1.000 participants in its last editions. Later, in 1998, Visionnaire became the Object Management Group (OMG) representative for Latin America. Having additional growth plans, the company obtained in 2000 a loan of US$ 495.000,00 from BNDES to transform its know-how on SLA into the Pacto software. Next, in 2001, a venture capital investment of US$ 850.000,00 was received from shareholders of Pactual Bank. In 2003, Pacto was recognized by the Brazilian Ministry of Science and Technology as a product developed with local technology, ensuring a preference margin in public tenders. In the same year, Pacto was adopted by the Brazil Telecommunications carrier as its SLA platform.

Fig. 8. Pull-Back Pattern Example

(according to given specifications), which can be subsequently acquired, ensuring that the existing demand is effectively satisfied;

- **Actors**: A client institution and a technology supplier, in general a company and a R&D center;
- **Interactions**: Client studies technological routes, maps technological risks, specifies the demand and procures a supplier. A contract is signed between selected supplier and client, specifying rights and obligations, risk mitigation measures and financial terms. Supplier develops the technology and delivers the respective software product or service to the client;
- **Environment**:
  1) Client provides required payments while technology is under development and promises to adopt it if satisfying the specified requirements;
  2) Technology supplier adopts best suited technology and project management methods to produce the required technological solution;
- **Consequences**:
  1) **Pros**: Defines a commercial relationship between client and supplier since the beginning of technology development so as to satisfy the demand;
  2) **Cons**: The deliverables may not meet the requirements or nor be so innovative as if they were developed based on scientific research;

An example of this pattern appears in Figure 8.

5) Mediator Pattern:

- **Purpose**: Find a third party R&D institution that knows in detail the industrial and academic realities and can help, by using mediation, the client institution to solve some hard R&D problem relying on (perhaps state-of-the-art) technology research;
- **Actors**: In general, a client institution, some university(ies) and a R&D center;
- **Interactions**: Client specifies problem, signs contract with R&D institution and makes its team available for cooperation. R&D center also makes its team available, procures and selects academic institution(s), signs required contract(s) and coordinates the activities. Academic institution(s) perform(s) research. The cooperation result is put together by the R&D center and delivered as a finished technology to the client;
- **Environment**:
  1) Client provides clear problem statement and performs required payments to R&D institution;
  2) R&D institution guarantees non-disclosure and management capabilities to client;
  3) Academic institution(s) commit(s) with deliverables and expect(s) payment or recognition;
- **Consequences**:
  1) **Pros**: Ensures that each actor better uses its own core competencies and resources;
  2) **Cons**: May not have good cost-benefit relation for small projects and critical technologies may be exposed to inadmissible threats;

An example of this pattern appears in Figure 9.

SBDTV-T by CPqD

In 2003, the Brazilian Ministry of Communications launched a project aiming to develop a Digital TV System to support the migration from analog to digital terrestrial TV transmission and reception. The Federal Government had neither know-how nor specialists to develop the system, then deciding to contract the CPqD Foundation to coordinate the national efforts on that subject. CPqD structured a consortium of 75 local universities and research centers to perform R&D activities. At least US$ 25 million was invested in these activities from many sources. After 3 years, the consortium delivered a new technology based on the Japanese Digital TV System, mixing high-resolution MPEG4 transmission with fixed and mobile reception and interactivity based on a locally developed standardized middleware called Ginga (regarded as the main innovation of the project) [16]. The technology was made public by the local government, but today private companies explore the corresponding business, such as Totvs (software), LG (reception hardware) and Hitachi (transmission hardware). The system is in use in large cities and the transition will be concluded in 2018, when the entire country will be covered by digital signal.

Fig. 9. Mediator Pattern Example

6) Co-Creator Pattern:

- **Purpose**: Put together a group of knowledgeable institutions and persons with the common goal of developing a new technology;
- **Actors**: May be institutions, private individuals, or both, but the involved actors must be knowledgeable on the subject area of the technological development;
- **Interactions**: They vary according to the complexity of the required development, as well as the individual interests and applicable legal requirements. In general, the actors initially specify the required development, sign contract(s) to formalize the rights and obligations of each party and then perform the technology development in cooperation;

- **Environment**:
  1) Each actor must have willingness to cooperate and share development results;
  2) All the actors must keep strict observance of contract terms;
- **Consequences**:
  1) **Pros**: Makes it possible to develop technologies that are out of reach of individuals and small groups of actors;
  2) **Cons**: The complexity and management costs growth with the number of participants;

For an example of this pattern, the reader is referred to the MPS.BR model, a software process improvement model created by analogy with the CMMI model to be accessible to companies of all sizes [14]. It has been maintained by the Softex Society, a non-profit organization, and was developed together with local companies and academic institutions.

IV. Concluding Remarks

In this paper, we presented a collection of patterns that capture best practices of persons and institutions in their cooperative attempts to promote technology development and transfer activities. We illustrated these patterns by presenting the trajectories of some successful software technologies. We have argued that the adoption of technology development and transfer patterns is a key success factor for Software-Engineering-In-The-Large.

The literature recognizes that success in technology development and transfer activities depends on leadership and long term partnerships [1], [12]. Indeed, the pattern application examples presented here can be regarded as cases of success of cooperative efforts of some persons and institutions which sometimes date back to the 1990s (c.f. [3]). In these examples, we focused on the technologies themselves, as well as on the respective owners and exploitation locations. It seems to us that, in general, technology ownership is defined so as to maximize social or economic development, whereas location is defined so as to minimize technology development time and costs.

In our examples, we also presented instruments to foster technology creation, development, transfer and exploitation. Depending on maturity level and transfer readiness, distinct instruments seem to be best suited. We noticed a gradation of use of advice and consulting services, infra-structure provision, R&D grants, tax benefits, loans and venture capital instruments throughout the technology life cycle. The successful application of such instruments depends on the availability of resources, as well as (and perhaps most importantly) on their usage know-how. On the negative side, we noticed that lack of personnel, skill, advice, addition of value, scale and demand, as well as legal and environmental issues, have delayed technology development and transfer. In general, such difficulties have been overcome with suitable organization and management.

The details of the studied cases were abstracted away and their general concerns and behaviors were represented through software patterns, which capture particular dialects, languages and even theories in the domain of cooperative technology development and transfer. As in other mature scientific disciplines, particularly in Software Engineering, it seems to us that such theories can be formulated in a logical sense, but this should be addressed in our future research. The structure and composability of our patterns suggest that they can be treated as other standard software artifacts. Such a compositional and rigorous definition of software technology development and transfer activities may help funding agencies and technology intensive institutions to configure their business processes accordingly and consequently maximize their capability to generate social and economic value.

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